NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Phase 1 Geoscientific Desktop Preliminary Assessment, Terrain and Remote Sensing Study

TOWNSHIP OF SCHREIBER, ONTARIO

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Phase 1 Geoscientific Desktop Preliminary Assessment
Terrain and Remote Sensing Study
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Executive Summary

In December, 2011, the Township of Schreiber, Ontario, expressed interest in continuing to learn more about the Nuclear Waste Management Organization nine-step site selection process, and requested that a preliminary assessment be conducted to assess the potential suitability of the Schreiber area for safely hosting a deep geological repository (Step 3). This request followed the successful completion of an initial screening conducted during Step 2 of the site selection process.

The preliminary assessment is a multidisciplinary study integrating both technical and community well-being studies, including geoscientific suitability, engineering, transportation, environment and safety, as well as social, economic and cultural considerations. The findings of the overall preliminary assessment are reported in an integrated report (NWMO, 2013). The objective of the desktop geoscientific preliminary assessment is to determine whether the Township of Schreiber and its periphery, referred to as the “Schreiber area”, contains general areas that have the potential to meet NWMO’s geoscientific site evaluation factors.

This report presents the findings of a terrain and remote sensing assessment completed as part of the desktop geoscientific preliminary assessment of the Schreiber area (AECOM, 2013). The main information sources used include the Canadian Digital Elevation Data (CDED) elevation model, air photographs, and the maps and reports from the Northern Ontario Engineering Geology Terrain Study (NOEGTS). The assessment addresses the following seven objectives:

- Evaluate the nature, areal extent and depth of overburden materials;
- Delineate the areas of exposed bedrock or relatively thin overburden cover;
- Identify features that may preserve evidence of neotectonics;
- Establish the main site accessibility constraints;
- Determine and/or confirm watershed and sub-catchment boundaries;
- Infer groundwater recharge and discharge zones and divides; and
- Infer regional and local groundwater and surface flow directions.

Over the majority of the Schreiber area the Precambrian bedrock is thinly covered by a discontinuous veneer of glacial sediments. The largest accumulation of these sediments occurs in the Terrace Bay-Schreiber area where they achieve a thickness sufficient to hide the bedrock topography; this is the only location in the area where this occurs. The region is dominated by rugged terrain with substantial relief. Relief is slightly lower in the north-central portion of the area and notably lower in the area between the towns of Terrace Bay and Schreiber.

Drainage divides delineated in the provincial quaternary watershed file were reviewed to assess surface water flow patterns. The area’s drainage network is contained within four major quaternary level watersheds, all of which flow into Lake Superior. Groundwater flow within drift deposits and in shallow bedrock aquifers in the Schreiber area is expected to mimic the pattern of surface flow, with groundwater divides coinciding with drainage divides and discharge occurring into creeks, rivers, lakes and wetlands.

Conclusive identification of features indicative of paleo-seismic events and reactivation of ancient bedrock structures due to cycles of glacial loading and unloading cannot be identified using currently available sources of information. Field investigations would be required to identify such features.

The all weather road network in the Schreiber area is limited, especially in the interior of the area. Forestry and mineral exploration access trails locally augment the developed roads. Access routes could be developed to any part of the Schreiber area by following the numerous intersecting bedrock valleys.

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1. Introduction

In December, 2011, the Township of Schreiber, Ontario, expressed interest in continuing to learn more about the Nuclear Waste Management Organization nine-step site selection process (NWMO, 2010), and requested that a preliminary assessment be conducted to assess potential suitability of the Schreiber area for safely hosting a deep geological repository (Step 3). The preliminary assessment is a multidisciplinary study integrating both technical and community well-being studies, including: geoscientific suitability; engineering; transportation; environment and safety; as well as social, economic and cultural considerations (NWMO, 2013).

This report presents the findings of a terrain and remote sensing study completed as part of the desktop geoscientific preliminary assessment of the Schreiber area. The objective of the desktop geoscientific preliminary assessment is to determine whether the Township of Schreiber and its periphery, referred to as the “Schreiber area”, contains general areas that have the potential to meet NWMO’s geoscientific site evaluation factors (NWMO, 2010).

1.1 Objectives

A review and interpretation of remotely sensed data was conducted as part of the Phase 1 Desktop Preliminary Assessment of Potential Suitability for the Township of Schreiber (AECOM, 2013) to provide information on the surficial materials and terrain conditions present in the Schreiber area. The work completed as part of this project adds to and expands upon the knowledge base created by the Initial Screening report of the area (Golder, 2011).

This study makes use of remote sensing and geoscientific information sources to address the following seven objectives:

- Evaluate the nature, areal extent and depth of overburden materials;
- Delineate the areas of exposed bedrock or relatively thin overburden cover;
- Identify features that may preserve evidence of neotectonics;
- Establish the main site accessibility constraints;
- Determine and/or confirm watershed and sub-catchment boundaries;
- Infer groundwater recharge and discharge zones and divides; and
- Infer regional and local groundwater and surface flow directions.

1.2 Schreiber Area

The Schreiber area is located along the north shore of Lake Superior approximately 150 km east of Thunder Bay (Figure 1). The townships of Terrace Bay and Schreiber are located in the southeast corner and south-central portions of the area, respectively and contain population centres of the same names. The village of Rossport is located immediately beyond the western boundary. Access to the area is via Ontario King’s Highway 17 (the Trans Canada Highway) and a rail line operated by Canadian Pacific Railways; the routing of both systems generally follows the Lake Superior coastline. Primary access to the interior of the study area is provided by two north trending roads which connect with the Trans Canada Highway; one in Terrace Bay, and the second approximately 8 km west of Schreiber. A network of forestry roads and trails provides limited access to other parts of the area.

The Schreiber area used for the interpretation is approximately 1,100 square kilometres (km^2) and was provided by NWMO as a shape file (Figure 1).

1.3 Data and Methods

1.3.1 Source Data

Data for the Schreiber remote sensing study was collected from a variety of sources, including government organizations, such as Natural Resources Canada (NRCan) and the Ontario Geological Survey (OGS). Existing surficial and bedrock geology mapping, topographic mapping, and literature were all reviewed as part of the terrain mapping process in order to gain familiarity with the area, its Quaternary history, and the surficial materials present.

1.3.1.1 Topographic Mapping

Topographic mapping of the area, with a contour interval of 10 m, was obtained from the Ontario Ministry of Natural Resources (MNR, 2012). Digital topographic data in raster format, which are necessary for performing terrain mapping using the PurVIEW softcopy system, were obtained from Geobase (NRCan, 2009). This allowed terrain polygons drawn in PurVIEW to contain elevation information. These data also allowed the elevation of any given point to be displayed while mapping, providing confirmation of topographic interpretations made through stereo viewing. The digital topographic data had a grid resolution of between 8 and 23 m.

1.3.1.2 Canadian Digital Elevation Data (CDED)

The CDED topography data for the Schreiber area is available in six USGS DEM format individual tiles, each tile covering approximately 600 km^2, covering the entire area, including an area to the west of the Schreiber area. CDED data sets are provided in geographic coordinates, referenced horizontally using North American Datum 1983 (NAD83) and vertically based on the Canadian Geodetic Vertical Datum 1928 (CGVD28). Ground elevations are recorded in metres relative to mean sea level.

The tiles that cover the area have the following identifiers: 042e04_0100_deme; 042e03_0100_demw; 042e03_0100_deme; 042d13_0100_deme; 042d14_ 0100_demw; and 042d14_0100_deme. These files have an accuracy of less than five metres and a resolution of 0.75 arc seconds (Table 1), which is equivalent to approximately 16 to 23 m in the Schreiber area. The six individual tiles were merged, levelled, and a colour mosaic, shaded digital elevation model was created in ErMapper (SRK, 2013).

Table 1. Summary of 1:50,000 scale CDED tiles

NTS Tiles	East/West Coverage	Ground Resolution (arc sec.)
042d/ 14	Both	0.75
042d/ 13	East	0.75
042e/ 04	Both	0.75
042e/ 03	East	0.75

1.3.1.3 Satellite Imagery

Systeme Pour l'Observation de la Terre (SPOT) and Landsat Imagery

SPOT multispectral and panchromatic orthoimagery assisted in the identification of terrain types and areas of exposed bedrock in the Schreiber area. SPOT multispectral data consist of several bands, each band recording the reflected radiation within a particular spectral range, displayed with a radiometry of 8-bits (or a value ranging from 0 to 255). SPOT 5 images were acquired using the High Resolution Geometric (HRG) sensor. Each image covers an area of approximately 3,600 km^2.

For quality control, Natural Resources Canada (NRCan) provides images that have a maximum of 5% snow and ice cover, 5% cloud cover and a maximum viewing angle of 15°. NRCan orthorectified the SPOT images using three data sources: 1:50,000 scale Canadian Digital Elevation Data (CDED), National Road Network (NRN), and Landsat 7 orthoimagery. The orthoimages are provided in GeoTIFF format, projected using Universal Transverse Mercator (UTM) projection referenced to the North American Datum 1983 (NAD83).

The SPOT 4/5 Geobase OrthoImage for the Schreiber area is available as one individual tile (Table 2), containing four Geotiff images representing spectral bands B1, B2, B3, and MIR.

Table 2. Summary of SPOT imagery scenes

Scene ID	Image Center (Lat/Long)	Satellite	Date of Image
S5_08722_4857_20050706	48°57', -87°22'	SPOT 5	6-July-2005

The Landsat 7 Orthorectified Image for the Schreiber area is available as one individual tile from the Canadian Council of Geomatics (http://www.geobase.ca; Table 3), with bands 7, 4, and 3 combined; each tile covers approximately 33,400 km^2 in area. A false natural colour image (Landsat bands 4, 3 and 2) and short-wave infrared (SWIR; Landsat bands 7, 4 and 2) image were created for this tile (SRK, 2013) in ErMapper and saved as a compressed raster images. Higher resolution Landsat 7 imagery was obtained as Geotiff files from the Geogratis website (http://geogratis.cgdi.gc.ca/).

Table 3. Summary of Landsat 7 imagery scenes

Scene ID	Date of Image
024026_0100_000729_l7	29-Jul-2000

1.3.1.4 Aerial Photography

Complete aerial photographic coverage of the Schreiber area from 1983, at a scale of 1:50,000, was acquired in the form of high resolution (600 dpi) scans from the Archives of Ontario. The 47 images, part of the MNR's Ontario Base Mapping collection, were captured during seasons with limited vegetative cover thus permitting the identification of topographic features. All images were viewed in stereo prior to the commencement of mapping in order to gain familiarity with the landscape of the Schreiber area. The delineation of terrain polygons was subsequently completed through stereo observation of these photographs.

1.3.1.5 Geological Mapping

Surficial geology mapping from the OGS was acquired at a scale of 1:1,000,000 (OGS, 1997; OGS and MNR, 2005). Larger scale 1:100,000 surficial geology mapping from the Northern Ontario Engineering Geology Terrain Study (NOEGTS) covering the Schreiber area, contained in Studies 59 and 43 (Gartner, 1979a and 1979b), were closely referred to during terrain polygon delineation. Each NOEGTS map is accompanied by a report describing the landscape and surficial materials in the area, as well how the terrain may influence engineering decisions.

1.3.1.6 Drill Holes and Water Wells

There is limited information on groundwater resources in the Schreiber area with the Ontario Ministry of Environment Water Well Information System Database (2012) containing records of 30 wells. Concentrations of water wells occur in the vicinity of the towns of Schreiber and Terrace Bay with others located along the route of the Trans Canada Highway; two wells were drilled at the site of the past-producing Winston Lake Mine. One well, which plots in a remote location, is deemed to have erroneous co-ordinates. Several of the water well records in the MOE database are incomplete in terms of contained information. The wells were drilled between 1958 and 2010, with two-thirds being completed after 1990.

The diamond drill hole database maintained by the Ministry of Northern Development and Mines (2012) contains records of 351 drill holes in the Schreiber area. The holes were completed as part of mineral exploration programs, most commonly for precious and base metals. For this reason, the majority of the drill holes are located within the Schreiber-Hemlo greenstone belt or immediately adjacent to its boundaries. Concentrations of drill holes are located around Winston Lake, west of Big Duck Lake, south of Stingray Lake and east of Lower Ross Lake. Only a very limited number of drill holes are located in areas mapped as containing thicker surficial deposits.

Positional information for the majority drill holes in the database is generally good; however, the listed location for a small percentage of the drill holes must be considered as approximate. Caution must be exercised when viewing the overburden thickness as reported in the database; this is because the majority of the holes were advanced at an angle to vertical, thus artificially increasing the overburden thickness. When the angle is reported, a simple projection to vertical is required.

1.3.2 Terrain Mapping

All terrain interpretation and mapping was completed using a softcopy photogrammetric system, which allows for stereoscopic viewing of images and delineation of terrain polygons all within the digital environment. One of the main advantages to the softcopy approach, when compared to the traditional methods of terrain mapping using contact prints, is that of increased efficiency since digitization of hand-drawn polygons is no longer required, and polygon attributes are entered directly into a database as the polygon is drawn. Accuracy is also increased in this regard, since there is a level of uncertainty involved in digitizing a relatively wide hand-drawn line. Image resolution permitting, it is also possible to zoom in to certain features of interest in order to aid interpretations.

Mapping was completed using the PurVIEW software, which is a direct add-on to, and thus interfaces seamlessly with, ESRI's ArcGIS platform. Three sources of data provided the base for the softcopy mapping: digital aerial photograph images, their support files and an underlying digital elevation model (DEM). Forty-seven aerial photographs were obtained in TIF format, scanned at 600 dpi, to provide complete stereo coverage of the area. Each TIF image had its own support file, with a .sup extension, resulting in 47 .sup files associated with the Schreiber area. The support file contains the positional information (X, Y, Z coordinates) used to georeference each raster image. The support files are text-based, so they could be viewed in any text editor software. In order to assign elevation values to the vertices of each digitized polygon and facilitate ground level cursor tracking when interpreting the image, PurVIEW referred to a DEM of the area. Two DEM files corresponding to NTS map sheets 042D14 and 042E03 were obtained from Geobase (NRCan, 2009) to cover the area. The two files were merged and converted to TIF format which can be read by PurVIEW.

Terrain mapping of the Schreiber area divided the landscape into polygons according to surficial materials, landform characteristics, topography and drainage. Terrain units were delineated based on the Northern Ontario Engineering Geology Terrain Study (NOEGTS) classification (Gartner *et al.,* 1981) that is widely used in Ontario. Enhancements to the original NOEGTS mapping (Gartner, 1979a and 1979b) for the Schreiber area were made possible due to use of larger scale aerial photographs (scaled at 1:25,000) and technological advancements made in methods available for three-dimensional interpretation of aerial photographs (e.g., PurVIEW). Mapping detail is consistent with the scale of the air photos.

The aerial photography obtained from the Archives of Ontario at 1:50,000 scale was used for the terrain unit delineation and polygons were drawn through consideration of the above mentioned components and methods. Prior to mapping, all of the photographs were viewed stereoscopically to gain familiarity with the terrain patterns evident within the study area. Additional insight was drawn from existing surficial geology mapping (Gartner, 1979a and 1979b) and literature describing surficial materials and the general regional Quaternary history in the area (e.g., Prest, 1970; Zoltai,1967; Geddes, 1986; Sado and Carswell;1987; Barnett *et al.* 1991; Barnett, 1992; Morris, 2000).

Images were viewed at a scale of approximately 1:25,000 during terrain unit delineation. This allowed for an appropriate level of detail to be captured while maintaining consistent polygon size and ensuring smooth polygon line boundaries on the final map product. The objective of identifying areas where thicker overburden cover may obscure the surface expression of lineaments in the Schreiber area was considered throughout the mapping process and any areas of thicker overburden are identified. Attention was also paid to areas of glaciofluvial and glaciolacustrine deposits, outwash and poorly drained wetland areas as these offer insights into drainage conditions within the area.

Escarpments were identified through stereoscopic viewing of airphotos and confirmed by observation of existing topographic information. Significant escarpments were indicated on the map as linear features as these can represent barriers to linear corridors, such as roads or utility lines.

As described above, mapping was completed using the PurVIEW softcopy photograph interpretation program, an add-on to ArcGIS. Images were viewed stereoscopically on-screen, while the PurVIEW program allowed reference to the DEM of the study area (i.e., topographic data) in order to assist interpretations and mapping. Attributes, and any comments, were entered directly into the polygon database. A systematic quality check of all polygons was completed by a reviewer familiar with the area.

The system used to identify and describe the physical surficial geological terrain conditions for the Schreiber area follows that developed for NOEGTS (Gartner *et al.* 1981). Four characteristics of the Schreiber area terrain are noted during review of the airphotos:

- Material
  - Type and texture
- Landform type
  - Bedrock dominated, ground moraine, glaciofluvial, glaciolacustrine, organic
- Topography
  - Low relief, less than 15 m; Moderate relief, 15 to 60 m; and High relief, over 60 m (modified by varied conditions, such as knobby, plain and ridged). Values represent local relief changes; within a 500 m radius of a point.
- Drainage
  - Wet, mixed or dry.

These characteristics allow interpretation of resource potential (e.g., aggregate deposits), engineering opportunities and constraints (e.g., locating and construction of utilities and camps, road accessibility and construction, sewage disposal and water supply).

Polygon colours displayed on the map are consistent with the NOEGTS system (Gartner *et al.*, 1981). Any areas of thicker overburden are easily identified since they are represented with different colours depending on material type.

2. Summary of Geology

The Schreiber area is primarily located in the Archean Wawa Subprovince, Superior Province (Figure 2). The Wawa Subprovince comprises a volcano-sedimentary-plutonic terrane bounded to the east by the Kapuskasing structural zone (beyond the area of investigation) and to the north by the metasedimentary-dominated Quetico Subprovince (Santaguida, 2002; Johns *et al.*, 2003). The western end of the Wawa Subprovince is bordered by the Proterozoic Trans-Hudson orogen. To the south, the Schreiber area is flanked by the Early Proterozoic Southern Province.

The Wawa Subprovince is composed of two semi-linear zones of greenstone belts, the northern of which includes the Shebandowan, Schreiber-Hemlo, Manitouwadge-Hornepayne, White River, Dayohessarah, and Kabinakagami greenstone belts (only a portion of the Schreiber-Hemlo belt is shown on Figure 2). The Schreiber area is situated in the western portion of the Schreiber-Hemlo greenstone belt (sometimes referred to as the Terrace Bay-Schreiber greenstone belt). This greenstone belt is divided into western and eastern portions by the Proterozoic Coldwell alkalic complex. The Schreiber-Hemlo greenstone belt consists of a number of narrow, arcuate segments of supracrustal rocks that are bounded and enclosed by granitoid bodies, including the Crossman and Whitesand Lake batholiths. The Schreiber-Hemlo greenstone belt is divided into three lithotectonic assemblages by Williams *et al.* (1991); the Schreiber, Hemlo-Black River, and Heron Bay assemblages. The Schreiber and Hemlo-Black River assemblages are separated by the Proterozoic Coldwell alkalic complex (north of the town of Marathon). The Hemlo-Black River and Heron Bay assemblages are located to the north and south of the Lake Superior Hemlo fault zone (LSHFZ; Figure 2), respectively.

2.1 Bedrock Geology

The bedrock geology of the Schreiber area is shown in Figure 3. The main geological units in the Schreiber area include, several large granitoid intrusions (Terrace Bay, Crossman Lake and Whitesand Lake batholiths, and the Mount Gwynne pluton), the supracrustal rocks of the Schreiber assemblage of the Schreiber-Hemlo greenstone belt, and the several suites or swarms of mafic diabase dykes. Each of these sets of rock units is discussed in more detail below. In addition, the bedrock in the Schreiber area is overprinted by several orientations of brittle faults and the individual rock units have been subjected to varying amounts of metamorphism.

2.1.1 Granitoid Intrusive Rocks

Massive granite to granodiorite intrusions comprise a voluminous suite of rocks within and adjacent to the Schreiber-Hemlo greenstone belt (Figure 2). These are typically composite, ovoid intrusions that vary in size up to twenty-five kilometres in diameter. Their composite nature includes lithologies ranging from dominantly granite and granodiorite to quartz diorite, syenite and quartz monzonite (and their gneissic equivalents), as well as aplite and pegmatite dykes. These intrusions likely formed by partial melting of mafic to ultramafic sources (e.g., Polat, 1998; Polat *et al.*, 1998).

Granitoid intrusions in the Hemlo assemblage of the Schreiber-Hemlo greenstone belt returned ages between ca. 2.688 and 2.678 billion years (Ga) (Corfu and Muir 1989). Due to the similar character and emplacement style of granitoid intrusions in the Schreiber area compared to the Hemlo area, and an absence of more precise age dating, the granitoid intrusions in the Schreiber area are also considered to be emplaced between ca. 2.690 and 2.680 Ga (Smyk and Schnieders, 1995; Corfu and Muir, 1989).

The granitoid intrusions in the Schreiber area include the Terrace Bay, Crossman Lake and Whitesand Lake batholiths, and the Mount Gwynne pluton (Figure 2). These intrusions cover approximately 495 km^2 within the Schreiber area. The emplacement of these batholiths overlapped with regional metamorphism dated at ca. 2.688 to 2.675 Ga (Muir, 2003) and resulted in the development of amphibolite grade contact aureoles within the surrounding greenschist grade greenstone belt rocks (Marmont, 1984).

The Terrace Bay batholith is located in the southeastern part of the Schreiber area (Figure 2) and trends northeast, at an angle to the generally east-trending greenstone belt rocks. The bulk of the Terrace Bay batholith is a massive, homogeneous, equigranular and medium-grained granodiorite with common variations in texture, grain size and colour, with minor masses of quartz monzodiorite and quartz-monzonite (Marmont, 1984; Carter, 1988). Apophyses and dykes derived from the Terrace Bay batholith intrude the greenstone belt rocks (discussed in Section 2.2.2) within the vicinity of the batholith contact. These minor phases include: 1) aplite and pegmatite dykes; 2) quartz-feldspar, feldspar and hornblende porphyries; 3) carbonate-rich lamprophyre dykes; and 4) narrow, magnetic diabase dykes. The Terrace Bay batholith covers 67 km^2 within the Schreiber area.

The Crossman Lake batholith occupies the majority of the northern part of the Schreiber area (Figure 2). The batholith is predominantly massive and consists of a mixture of medium-grained quartz-monzonite and monzodiorite, (alkali-feldspar) granite, tonalite and granodiorite. Minor dykes and irregular masses of microgranite, quartz (-feldspar) porphyry and aplite occur along the margins of the batholith. The Crossman Lake batholith covers 300 km^2 within the Schreiber area.

The Whitesand Lake batholith occurs in the southwestern portion of the Schreiber area (Figure 2). This batholith is elongate in an east-west direction parallel to the structural trend within the surrounding greenstone belt rocks. The batholith consists of mostly massive (alkali-feldspar) granite with lesser porphyritic granite, monzodiorite, quartz monzonite and rare aplite. The Whitesand Lake batholith covers 123 km^2 within the Schreiber area.

The boundary between the Whitesand Lake and Crossman Lake batholiths is poorly defined. However, Carter (1988) places the boundary between the two batholiths along narrow septa of east-trending greenstone belt rocks along the western margin of the Schreiber area (Figure 2).

The Mount Gwynne pluton is located near the southern margin of the Schreiber area (Figure 2). It is located along the southern boundary of the supracrustal rocks of the Schreiber-Hemlo greenstone belt. The pluton comprises massive, medium-grained alkali-feldspar granite and biotite-hornblende granodiorite. The Mount Gwynne pluton covers 5 km^2 within the Schreiber area.

2.1.2 Schreiber-Hemlo Greenstone Belt

Supracrustal rocks in the Schreiber area occur in the western part of the Schreiber-Hemlo greenstone belt and are considered to be part of the Schreiber assemblage (Williams *et al*., 1991; Figure 2). Carter (1988) identified three major types of supracrustal rocks in the Schreiber assemblage: 1) tholeiitic, mafic metavolcanic rocks comprising mainly massive to pillow basalt, tuff and related breccias; 2) calc-alkalic, mafic to felsic metavolcanic rocks dominated by pyroclastic units; and 3) clastic and chemical metasedimentary rocks of turbiditic origin interbedded with minor banded iron formation. These three supracrustal rock types are described in further detail below.

Tholeiitic, mafic metavolcanic rocks are massive or schistose and variably metamorphosed ranging from dominantly greenschist facies to amphibolite facies and locally pyroxene hornfels facies. Greenschist facies mafic volcanic rocks are either massive or foliated and are aphanitic to medium-grained, whereas amphibolite facies mafic volcanic rocks are medium-grained and well foliated (Carter, 1988). The greenschist facies tholeiitic rocks comprise aphanitic, fine-grained massive and pillowed flows, as well as porphyritic, amygdaloidal and variolitic flows. Interbedded with these flows are minor autoclastic flow breccias and mafic to intermediate tuff horizons. The amphibolite facies tholeiitic rocks include fine- to medium-grained foliated amphibolite and garnet amphibolite. The minimum age of mafic volcanism is constrained by crosscutting pluton apophyses in the eastern half of the Schreiber-Hemlo greenstone belt at ca. 2.697 Ga (Muir, 2003).

Calc-alkalic mafic to felsic metavolcanic rocks are mainly greenschist facies massive, aphanitic to fine-grained andesite to porphyritic dacite flows. Minor amygdaloidal felsic interbeds occur with the massive flows. In addition, fine-grained to aphanitic tuff units with rare lapilli tuff and tuff breccia are interlayered with the mafic to felsic flows. Muir (2003) indicated that felsic calc-alkalic volcanism occurred from ca. 2.698 to 2.692 Ga, and intermediate volcanism occurred around 2.689 Ga in the eastern half of the Schreiber-Hemlo greenstone belt. This is compatible with U-Pb zircon age determinations for calc-alkaline volcanism that are generally within a narrow range between 2.698 and 2.688 Ga (Corfu and Muir, 1989).

Metasedimentary rocks are composed of greenschist facies wacke, silicified shale (including graphitic intervals), chert horizons and banded iron formation as well as minor amphibolite facies garnet- and sillimanite-bearing wacke. The wacke comprises foliated, fine- to medium-grained quartz-plagioclase-biotite rocks with minor epidote, apatite, muscovite and pyrite. Banded iron formations form thinly bedded units interlayered with the metavolcanic rocks comprising magnetite-chert or magnetite-only (oxide-facies) and pyrite-pyrrhotite-chert (sulphide-facies) horizons. Sedimentation of turbiditic wacke-mudstone in the Schreiber-Hemlo greenstone belt occurred after ca. 2.693 Ga for volcaniclastic deposits and possibly as late as ca. 2.685 Ga for wacke (Muir, 2003).

Rocks of the Quetico Subprovince consisting of metamorphosed turbiditic wacke with subordinate arenite-pegmatite migmatite and feldspar gneiss occupy the northern fringe of the Schreiber area (Carter, 1988). Deposition of these sedimentary rocks took place between 2.70 to 2.69 Ga, and amphibolite facies metamorphism occurred during the period 2.67 to 2.65 Ga (Williams *et al*., 1991).

Along the shore of Lake Superior in the Schreiber area, Mesoproterozoic sedimentary rocks of the ca. 2.200 Ga Animikie Group (Gunflint Formation, 24 in legend of Figure 2; Carter, 1988), the ca.1.500 Ga Sibley and ca. 1.100 Ga Osler Groups unconformably overlie Archean granitic and mafic metavolcanic rocks. These form discontinuous erosional remnants of an ancient fluvial-lacustrine system that comprises interbedded sandstone, conglomerate, ironstone, chert, shale, mudstone and limestone. These rocks are not metamorphosed and dip gently from 10 to 15 degrees to the southwest.

2.1.3 Mafic Dykes

Several suites of diabase dykes crosscut the Schreiber area (Figure 2), including:

- Northwest-trending Matachewan Suite dykes (ca. 2.473 Ga; Buchan and Ernst, 2004). This dyke swarm is one of the largest in the Canadian Shield. Individual dykes are generally up to 10 metres wide, and have vertical to subvertical dips. The Matachewan dykes comprise mainly quartz diabase dominated by plagioclase, augite and quartz (Osmani, 1991).
- North-trending Marathon Suite dykes (ca. 2.121 Ga; Buchan *et al*. (1996). These form a fan-shaped distribution pattern around the northern, eastern and western flanks of Lake Superior. The dykes vary in orientation from northwest to northeast, and occur as steep to subvertical sheets, typically a few metres to tens of metres thick, but occasionally up to 75 metres thick (Hamilton *et al.,* 2002). The Marathon dykes comprise quartz tholeiite dominated by equigranular to subophitic clinopyroxene and plagioclase.); and
- East-west–trending, reversely polarized Keweenawan Suite dykes related to ca. 1.100 Ga mid-continental rifting that was centred on proto-Lake Superior (Thurston, 1991a).

Potentially, a western extension of the ca. 2.167 Ga Biscotasing dyke swarm also occurs in the Schreiber area (Hamilton *et al*., 2002). These generally trend northeast; however, how these may be distinguished from northeast-trending Marathon dykes in the Schreiber area is undefined.

2.1.4 Faults

In the Schreiber area, several faults are indicated on public domain geological maps. These include the major (from west to east) Sox Creek, Ross Lake, and Cook Lake southeast-trending faults (Figure 2). Several northeast-trending faults are indicated on public domain maps including the Schreiber Point fault, the Worthington Bay fault (with the Syenite Lake fault along its extension), and the north-trending Ellis Lake fault. The timing and kinematics of these faults are not described in literature.

Carter (1988) conducted a field mapping program and developed a geological map for the Schreiber area, primarily on the basis of 1:15,840 scale aerial photographs and north-south trending traverse mapping at roughly quarter mile intervals. As a result of this mapping program, Carter (1988) attempted an interpretation of the fault movement along some of the faults shown on public domain geological maps. No supporting structural information was included in Carter (1988), so it is assumed that the fault movement interpretation was derived from aerial photographs. Carter's (1988) interpretation is only included here for historical reference. Carter (1988) interpreted the Sox Lake fault and the Schreiber Point fault as dextral strike-slip faults; the Cook Lake fault and Syenite Lake fault as dip-slip faults; and the Worthington Bay fault as a sinistral strike-slip fault. The current lineament study presents a different interpretation which is described below in Section 4.2.

2.2 Quaternary Geology

The Schreiber area is within the Abitibi Uplands physiographic region of Thurston (1991b) who subdivided the extensive James Region physiographic region of Bostock (1970). The region is characterized by abundant bedrock outcrop with shallow drift cover and a rugged surface.

The Quaternary sediments, commonly referred to as drift, soil or overburden, are glacial and post-glacial materials which overlie the bedrock in the Schreiber area. The distribution, thickness and physical characteristics of these deposits have an important influence on several aspects of the current investigation. Areas of thicker drift can hinder the interpretation of lineaments by masking their surface expression or muting the response obtained from geophysical surveys. Coarser-grained surficial sediments typically have a moderate to high transmissivity and can serve as local aquifers as well as being a potential source of mineral aggregates for use in building and road construction.

All glacial landforms and related materials within the Schreiber area are associated with the Wisconsinan glaciation which began approximately 115,000 years BP (Barnett 1992). The Quaternary (i.e., surficial) geology of the area has been mapped at a regional scale (>1:100,000) by several authors, including Zoltai (1965), Sado and Carswell (1987), and Barnett *et al.* (1991) and at a higher resolution by Gartner (1979a, 1979b) and Morris (2000, 2001). Quaternary deposits and landforms in the area are thought to have formed during the latter stages of ice cover (i.e., during the Late Wisconsinan, which began 30,000 years BP).

Morris (2000) reports bedrock erosional features (e.g., striae, roche moutonnée) and landforms that indicate a regional ice flow direction of 194° with a range of measured directions, due to local topographic conditions, of between 165° to 238°. For the majority of the Schreiber area drift thickness over bedrock is limited and the ground surface reflects the bedrock topography. Over the majority of the area bedrock outcrops are common and the terrain is classified, for surficial purposes, as a bedrock-drift complex; i.e., thin drift cover that only locally achieves thicknesses that mask or subdue the bedrock topography.

The remote sensing and terrain evaluation completed as part of the Phase 1 study provides the most detailed assessment of the type, distribution and thickness of surficial deposits in the Schreiber area (Figure 3). The most common glacial deposit in the Schreiber area is a thin, discontinuous till, generally less than two to three metres thick. Greater accumulations of till are found within bedrock depressions, large scale lineaments and on the down-ice (lee) side of bedrock highs. The till has a silty-sand matrix and contains abundant clasts in the pebble to cobble size range.

Two types of glaciofluvial deposits are present in the Schreiber area: ice-contact stratified drift deposits (ICSD) and outwash deposits. The ICSDs are associated with recessional moraines, dead-ice topography, eskers and valley fills (Morris, 2000). The largest ice-contact deposit forms the core of a 9 km long feature situated between Terrace Bay and Schreiber, south of Hays Lake. The ICSDs consist primarily of stratified, well to poorly sorted, sand and gravel that locally can achieve thicknesses of several tens of metres.

Glaciofluvial outwash deposits occur as relatively level areas within some narrow, bedrock controlled valleys (Figure 3). While valley controlled outwash deposits are found within the Schreiber area, significant deposits are also located along the Aguasabon, Whitesand and Pays Plat rivers, and Big Creek (which drains Clean and Deep lakes) and its tributaries. The thicknesses of these deposits are likely to be variable, and may be locally substantial. Outwash deposits are generally well-sorted and comprised of stratified sand, gravel and, locally, boulders.

Following retreat of the glacial ice approximately 9,500 years BP, the Lake Superior basin was occupied by a series of glacial lakes. It is likely that only the later of these lakes, Glacial Lake Minong and younger, affected the study area (Farrand and Drexler 1985; Barnett 1992). Lake inundation was limited to the area along the Lake Superior shoreline, to an elevation of ~305 m, and for a short distance inland within bedrock controlled valleys. Elevations of the various glacial lakes were controlled by the position of the ice mass and isostatic recovery of the land surface following deglaciation.

Fine-grained glaciolacustrine silts and clay deposits associated with the glacial lake have been encountered at depth in boreholes in the Terrace Bay area and other embayments further west along the Lake Superior shoreline (Gartner, 1979a). Overlaying these deposits are coarse-grained glaciolacustrine sediments that were deposited in a deltaic environment where bedrock valleys served as drainage channels discharging to the glacial lake. The largest glaciolacustrine delta is located in the Terrace Bay area where a sediment thickness of 48.3 m has been recorded. Another notable but smaller deltaic feature is found at Selim, at the mouth of the Whitesand River (Figure 3).

Bogs and organic-rich alluvial deposits are present along water courses in the area and in rock floored basins. These deposits tend to have a limited thickness, as determined by regional studies, and areal extent.

3. Topography

3.1 Elevation

The elevation difference within the Schreiber area is significant with a maximum range of approximately 402 m (Figure 4). The highest land within the area occurs just north of the Township of Schreiber, and the lowest point equals the elevation of Lake Superior (~183 masl). Localized variations in elevation caused by knobs and ridges are prevalent throughout the majority of the Schreiber area.

Across the area, the elevation of hills and ridges is commonly between 300 and 500 m. There is however, a general southward decrease in the elevation of hill tops from the 400 to 500 m range in the north to 300 to 400 m range in the south (Figure 4, inset map). A distinct area of consistently high elevation is located in the north-central portion of the area, with elevations reaching over 580 masl (Figure 4). This higher elevation area becomes fragmented towards the south and the west, with valleys and local areas of lower elevation separating blocks of higher topography.

The central portion of the Schreiber area, underlain by the Crossman Lake batholith, consists of a broad area of moderate elevation. South of this, the area underlain by the southern arm of the Schreiber-Hemlo greenstone belt contains local blocks of higher topography. The highest elevation in the area, approximately 590 masl, is located just north of the Township of Schreiber.

A broad, low elevation surface, corresponding to a large area of glaciofluvial outwash and glaciolacustrine deposits, occurs in the southeast corner of the area. This area, largely underlain by the Terrace Bay batholith, has surface elevations in the 200 to 300 m range.

Distinct valleys, corresponding to the Pays Plat River in the west and the Aguasabon River in the east, border the area of high elevation that dominates the north-central portion of the study area. These valleys are highlighted in blue on the inset map of Figure 4. Other significant valleys occur along the trends of the mapped bedrock faults (Figures 2 and 4). The principal orientations of these fault valleys are northwest and north-northeast.

3.2 Relief

The Schreiber area is characterized by moderate to high relief (greater than 80 m) over short distances, and very rugged topography consisting of knobby bedrock hills and steep escarpments. This is particularly noticeable in the southern two-thirds of the Schreiber area (excluding the southeastern corner). More moderate relief is present along the northern boundary of the area where it is generally less than 80 m.

Glaciofluvial deposits generally represent areas of local lower relief and near level topography, although some deposits are characterized by protrusions of bedrock knobs. The glaciofluvial and glaciolacustrine deposits in the southwestern corner of the study area also display lower relief (in the range of 20 to 40 m) over the majority of their surface area. Increased relief is present on these deposits in the Terrace Bay area due to the development of beach terraces by glacial lakes.

Relief in the Schreiber area was calculated using different approaches to highlight different aspects of the topography. These different representations of relief are presented in Figures 5 to 7. Figures 5 and 6 display relief calculated through subtracting the average elevation within a pre-defined radius (10 km and 2 km, respectively) from the elevation value in the processing cell, resulting in a value depicting the departure of a given point from the average surrounding elevation. The use of a 10 km averaging radius (Figure 5) highlights the presence of higher and lower ground within the area. The areas of greatest departure in Figure 5 are depicted as occurring along the shoreline of Lake Superior, and over the Whitesand Lake batholith and Gwynne Mountain pluton. The uniform, low elevation of Lake Superior south of this area weights the relief algorithm when the 10 km averaging radius is used, which results in an overestimation of the relief result when compared to the surrounding land surface alone. Nevertheless, the figure accurately reflects the relatively higher elevation areas and the steep Lake Superior shoreline in the southwestern portion of the study area. The broad, low-relief surface of the outwash deposits over the Terrace Bay batholith, and the more gently sloping shoreline in the southeastern portion of the study area are also evident.

Areas with elevation departures of 15 m or higher than the surrounding average are shown on the inset map of Figure 5. The 15 m value was used as it helped to better distinguish between regions of higher and lower elevations. The Pays Plat and Aguasabon river valleys on the northwest and eastern sides of the area, respectively, appear as distinct low areas. The higher ground in the north-central portion of the study area, as well as that immediately north of the Township of Schreiber is evident. The broad area of moderate elevation in the centre of the study area over the Crossman Lake batholith is also apparent.

The use of a 2 km averaging radius (Figure 6) for depicting the departure of a given point from the average surrounding elevation highlights the many knobs and ridges that characterize the Schreiber area. Somewhat more uniform local elevations are observed in the high-elevation, north-central portion of the area, over the Crossman

Lake batholiths, as well as over the outwash deposits in Terrace Bay area. The Pays Plat and Aguasabon river valleys appear as low features on Figure 6, as do other, smaller river systems in the study area; however, the high relief associated with the incision of the river valleys is emphasized. The weighting effect from the low, uniform elevation of Lake Superior is minimized when the 2 km averaging radius is used; however the steep shoreline and adjacent high relief areas are visible.

The inset map on Figure 6 displays areas that are at least 10 m higher than the surrounding average elevation, and further emphasizes the dominance of knob and ridge terrain within the study area. On the inset map, knobs (high ground) are displayed in red while valleys are displayed in blue. Knobby terrain is more prevalent in the southern and eastern portions of the study area (Figure 6).

Figure 7 displays the range in elevations within a 250 m radius of a given point in the area. Using this approach, the maximum amount of relief calculated over this short distance is approximately 200 m. Figure 7 emphasizes the presence of river valleys, as well as the high relief in the southern portion of the study area and along the Lake Superior shoreline. Lower relief is displayed in the north-central portion of the study area, and in the Terrace Bay-Hayes Lake region. The inset map differentiates between areas of high (>57m) local relief from those of moderate to low relief, approximately based on the NOEGTS topography categories.

3.3 Slope

Due to the predominantly high relief and knobby topography, slopes within the Schreiber area are steep and complex. Figure 8 illustrates the rugged nature of the topography, the widespread distribution of knobs and ridges, and the numerous steep-sided, incised river valleys. Forty-four percent of the area is represented by slopes greater than 6 degrees (Figure 8).

Near vertical escarpments are located across the area, including along the Lake Superior coast south and west of Schreiber. The orientation of escarpment faces and slopes in general, align with the trend of major faults and lineaments which transect the area. The steep slopes in the area are an indicator of minimal overburden cover. Areas with lower slopes, between the bedrock knobs, may represent pockets of locally thicker drift cover.

An area of low to moderate slopes occurs in the southeastern portion of the Schreiber area around Terrace Bay and the mouth of the Aguasabon River. Slopes on the glaciolacustrine and outwash plains only become steeper where bedrock knobs protrude or the deposits have been terraced by proglacial lakes.

Assuming that areas displaying gentler slopes may be indicative of somewhat thicker overburden, and areas with steep slopes are indicative of areas with no or very thin overburden, a map showing the density of slopes greater that 6 degrees was prepared (Figure 9). This figure highlights potential areas of thicker overburden that may obscure the surface expression of lineaments, or introduce uncertainty to the mapping and geologic interpretation of the area. Due to the fact that the knobs and ridges dominate the topography, overall high values of slope density are observed over the majority of the study area. Values show a general increase towards the south within the Schreiber area, with the exception of the low centred over the Terrace Bay batholith. This low represents the thick deposits of glaciolacustrine and glaciofluvial deposits in this area.

The highest slope densities are associated with mapped faults and deep river valleys, including the Pays Plat and Aguasabon river systems. Locally high density values correspond to fault locations, including those for the Sox Creek, Worthington Bay and Ellis Lake faults.

In the Schreiber area, the use of slope density mapping (Figure 9) as an indicator of potential thick drift is best done by interpreting the data in conjunction with the surficial geology (Figure 3). This provides a sense of perspective on the likelihood of increased drift thickness.

4. Drainage

The distribution of surface water and surface water drainage in the Schreiber area are important factors to consider in the preliminary assessment. The larger lakes can completely or partially conceal the surface expression of geological structures thus adding uncertainty to the results of a lineament interpretation comparing surficial and geophysical data sets (SRK, 2013). Surface water flow is also a useful surrogate for shallow groundwater flow. The Schreiber area is located within the Lake Superior watershed of the Atlantic Ocean watershed; the overall surface water drainage is shown on Figure 10. Drainage is southerly into Lake Superior from the height of land separating the Lake Superior drainage and that of the Hudson Bay system to the north.

4.1 Waterbodies and Wetlands

The numerous lakes within the Schreiber area occupy approximately 7.6 percent of the land surface (i.e., excluding Lake Superior) and occur with an even distribution, excluding the area near Terrace Bay. The lakes, many of which are elongate in shape, reflect the lineament pattern in the Schreiber area (SRK, 2013).

In general, the lakes are of a modest size with the majority having a surface area of less than 1.0 km^2. The larger water bodies (>1.5 km^2) in the Schreiber area are listed in Table 4.

Table 4. Size of lakes larger than or equal to 1.5 km^2 in the Schreiber area.

Lake	Area (km^2)	Perimeter (km)
Hays Lake	6.3	19.3
Aguasabon River	5.0	42.9
Whitesand Lake	2.8	23.6
Pays Plat Lake	2.5	13.3
Aguasabon Lake	2.3	23.1
Big Duck Lake	2.2	13.9
Lyne Lake	1.7	12.6
Carib Lake	1.5	20.0
Ellis Lake	1.5	12.8
Walker Lake	1.5	20.8

Bathometric surveys have been conducted by the MNR for 20 lakes in the Schreiber area (Figure 10). In addition to these detailed surveys, a lake sediment sampling survey conducted by the OGS recorded lake depths at approximately 630 locations in the Schreiber area (Dyer, 1997). In this survey, a limited number of the larger lakes in the area had multiple sampling sites. While it was the intent of this survey to sample the deepest part of the lakes, this cannot be confirmed. Nevertheless, the lake sediment survey data do, provide a general picture of average lake depths.

Table 5 indicates that approximately 60 percent of the sample sites (including lakes with multiple sites) measured by Dyer (1997) have a water depth of less than 5 m. Lakes deeper than 20 m account for only 6.8 percent of the sites sampled. The deepest lake measurement in the Schreiber area obtained by the OGS survey was 40 m from Big Duck Lake.

Table 5. Lake depth data in the Schreiber area (from Dyer, 1997).

Lake Depth (m)	Number of Lake Sites	Percentage
<5.0	375	59.8
5.1 – 10.0	110	17.5
10.1 – 15.0	75	11.9
15.1 – 20.0	27	4.3
20.1 – 25.0	18	2.9
25.1 – 30.0	11	1.7
>30.1	14	2.2

There is only a weak correlation between lake depth and lake size and no overall relationship between these parameters can be concluded. Bedrock geology does not appear to be a significant factor in controlling the depth, distribution or size of lakes in the area. Lakes occur with near equal consistency over both granitic and greenstone terrain, with the only exception being the Terrace Bay batholith.

An observation of note in the lake depth data is that a significant percentage of the deeper lakes are elongate in the north-south direction. Examples of these lakes include: Pays Plat (39 m); Walker (31 m); Lower Lake (34 m); Whitesand (29 m); Ellis (27 m); and Charlotte (23 m). It should be noted, however, that several other lakes with the same orientation had much shallower depths. It is possible, given the direction of the last ice advance, that glacial scouring may have contributed to the deepening of the lake basins with a north-south orientation.

Wetlands are developed at scattered locations along water courses in the area and in rock floored basins (Figure 3). Organic deposits associated with the wetlands are expected to have a limited thickness based on mapping conducted in the Hemlo area to the east and other areas of the Canadian Shield.

4.2 Watersheds

A watershed, also known as a catchment, includes all of the land that is drained by a watercourse and its tributaries. Watershed boundaries are defined by heights of land. Boundaries are set where a height of land causes water to flow away from the watercourse (MNR, 2012). The delineation of drainage divides are therefore useful for determining surface flow directions and also contribute to an initial understanding of the shallow groundwater flow system.

The Schreiber area is within the Little Pic tertiary watershed which drains via the Great Lakes water system and the St. Lawrence River. Approximately 6 km north of the Schreiber area, surface water drains to the north as part of the Hudson Bay primary watershed. The Schreiber area only begins to be sub-divided into different watersheds at the quaternary scale. The four quaternary-level watersheds that drain the area are shown in Figure 11. The quaternary watershed delineation was produced by the Ontario Ministry of Natural Resources (MNR, 2012) and represent sub-divisions of the larger tertiary watershed (02BA), which includes all of the Schreiber area and extends to Marathon in the east.

The boundaries of the quaternary watersheds for the Schreiber area were created based on the Provincial DEM and Enhanced Flow Direction products and as such the watershed boundaries are generally consistent with the regional hydrology available for Ontario (MNR, 2012). The horizontal positional accuracy of the quaternary watershed boundaries is variable depending on the nature and spatial distribution of the raw DEM information, and thus cannot be quantified without onsite investigation and verification. In general, positional accuracy in northern Ontario is within 400 m, but there is no statistical level of confidence available.

The terrain evaluation completed as part of this study confirmed the overall accuracy of the current mapping and delineated subareas of the watersheds which drain directly into Lake Superior. Additional subdivision of the quaternary watersheds is possible as each of the many lakes in the area represents a distinct catchment area. Given the scale of the area and the scope of the current study, such a detailed delineation was not completed.

The Pays Plat River is the principal drainage course in the western most watershed in the area. This watershed occupies the northwestern corner of the Schreiber area and drains into Lake Superior outside of the area through the Pays Plat First Nation Reserve 51, 6 km west of Rossport.

Adjacent to the east, land is drained by the Whitesand River watershed which extends as far inland as Little Duck Lake. Downstream of Whitesand Lake, the southern 1.5 km of the waterway is termed the Hewitson River. The Hewitson River enters Lake Superior at Selim, approximately 8 km west of Schreiber. Portions of this watershed are indicated in Figure 11 to drain directly into Lake Superior via a number of relatively short waterways, as opposed to a specific water course. These distinct areas are to the north and east of Rossport, and north, west and south of Schreiber.

The central portion of the Schreiber area is drained by the Big Duck Creek quaternary watershed, which extends from Big Duck Lake in the north to just east of Schreiber in the south where it enters Hays Lake. From this point water enters the Aguasabon River watershed, which drains the eastern portion of the area. Entering Lake Superior near Terrace Bay, the Aguasabon River watershed extends some distance to the north of the Schreiber area. The natural catchment area of this watershed has been enhanced by a diversion of a portion of the Kenogami River watershed north of Long Lac, which is north of the area boundary. Small areas east and west of the mouth of the Aguasabon River drain directly into Lake Superior via streams.

In the southeastern part of the Schreiber area northeast of Terrace Bay, a small area of a few hectares drains to the east. Flow from this area enters Lake Superior via Blackbird Creek outside of the area (Figure 11).

4.3 Surface Flow

The orientation of the drainage network within the Schreiber area is largely controlled by bedrock structural features (faults and lineaments) and the irregular topography of the terrain. Due to this control, the majority of waterways, including lakes, have a north, northwestward or northeastward orientation. While the overall drainage in the area is southward, the catchment areas of individual lakes within the watersheds result in short segments of northward flow (Figure 11).

The larger rivers draining the area’s watersheds are fed by numerous smaller creeks and rivers that effectively drain the vast majority of the Schreiber area. Creeks are lacking only in the region underlain by notable thicknesses of glaciolacustrine and glaciofluvial deposits in the area surrounding Terrace Bay where drainage is through groundwater recharge. Typically, segments of the waterways in the Schreiber area are short, on the order of less than 2 km, as they flow into and out of lakes occurring along the drainage paths. Gradients of the watercourses vary with those of smaller streams generally being higher; longer rivers, such as the Pays Plat and Aguasabon, have somewhat lower gradients. Rapids and small waterfalls are common in the area.

Periods of higher stream flow are related to the spring melt (March - May) and, to a lesser degree, increased autumn precipitation (October – November). While flows decrease in the summer months, data from Environment Canada (2012) indicate that significant precipitation events during this part of the year can dramatically increase flow for a short period of time. This is a reflection of rapid runoff from the bedrock terrain that dominates the area. There is a single gauging station in the area.

The majority of the Crossman Lake and Whitesand Lake batholiths in the area are drained by the Pays Plat River, Whitesand (Hewitson) River and Big Duck Creek watersheds. The easternmost portion of the Crossman Lake batholith is drained by the Aguasabon River watershed. Greenstone terrain is also drained by these watersheds with a significant portion also being drained by the Aguasabon River watershed. The Mount Gwynne pluton drains directly into Lake Superior, as does the majority of the Terrace Bay batholith.

5. Terrain Characteristics

An understanding of the distribution and thickness of overburden within the Schreiber area is essential for interpreting the distribution of lineaments mapped from satellite imagery and topographic surface data (AECOM, 2013; SRK Consulting , 2013), particularly with respect to lineament length and density. Thick drift deposits are able to mask the surface expression of lineaments. In areas of discontinuous drift deposits, the drift can conceal minor lineaments, producing low apparent lineament density and can censor the lengths of major structures. In areas of thick and extensive overburden, major structures can remain undetected using only satellite imagery and/or aerial photographs, particularly if these areas also contain large lakes.

Areas of exposed bedrock or thin drift are more readily amenable to site characterization for a deep geological repository, as such locations allow further investigation of potentially suitable bedrock units through outcrop mapping of bedrock structures and preliminary rock mass characterization.

The purpose of this section is to provide information to help enhance the understanding of overburden deposits in the Schreiber area. Sections 5.1 and 5.2 present reviews of the water well and drill hole data, respectively, on overburden thickness in the Schreiber area. Details on the expected composition, distribution and thickness of surficial deposits within the terrain units are presented in Section 5.3 and summarized specifically for the batholiths in Section 5.4.

5.1 Water Well Data

Data on overburden thickness from water well records held by the Ontario Ministry of the Environment (MOE) were reviewed to supplement the information on overburden deposits outlined by the terrain mapping component of this study. There is limited depth of overburden information for the Schreiber area in the Ontario Ministry of Environment Water Well Database (2012) as only 30 wells are in the database and records for several of these wells are incomplete (Table 6).

The majority of the water wells are located around the communities of Schreiber and Terrace Bay, and adjacent to Highway 17 (Figure 3). Two wells are located in the interior of the area east of Winston Lake, at the location of a former mining operation. A well reported in the northwest corner of the area is believed to have incorrect geographic co-ordinates and is not considered further herein.

Only eight water well records contain data on the depth to bedrock. In these wells the bedrock surface was encountered at depths ranging from 0 to 38.7 m, with seven of the wells reaching rock within 12 m of surface. Seven other wells, confirmed to end in overburden, had depths ranging from 4.3 to 47.2 m, indicating that bedrock would be found at a greater depth. The water wells penetrating thicker overburden (>5 m) are located in glaciolacustrine deposits or in bedrock controlled valleys.

Table 6. Ministry of Environment water well data for the Schreiber area.

WELL ID	Elevation (masl)	Depth of Well (mbgs)	Depth to Bedrock (mbgs)	Static Water Level (mbgs)	Water Well Type
6100544	186.6	33.5	9.4	0.9	Bedrock
6100727	322.0	47.2	NR		Overburden
6100894	278.7	42.4	38.7	7.6	Bedrock
6101984	349.5	21.9	NR		Overburden
6101997	332.7	17.4	NR	3.0	Overburden
6102420	285.9	94.5	11.0		Bedrock
6102787	345.7	31.1	0	9.1	Bedrock
6103335	339.9	6.1	NR	2.1	Overburden
6103496	351.9	53.9	5.8		Bedrock
6103558	209.1	51.8	11.3	9.1	Bedrock
6106047	384.4	76.8	10.7	4.3	Bedrock
6106258	302.2	82.6	2.4		Bedrock
6107275	275.0	16.2	NR		Overburden
6107320	450.4	4.3	NR		Overburden
6107509	347.9	5.0	NR		Overburden
7042962	321.7				
7051837	283.0	11.5			
7108895	186.1	20.7		5.6	
7108896	185.4	22.9		5.5	
7110366	203.3	7.5			
7110367	184.0	4.5			
7110374	185.7	15.1			
7111719	185.1	21.2		7.9	
7111720	185.4	21.6		7.9	
7114075	449.1	6.7			
7117260		3.0			

Table 6. Ministry of Environment water well data for the Schreiber area.

7120853	288.3	69.2			
7120854	286.1	76.8			
7122109	218.3	0.0			

NR – Bedrock not reached; Blank Fields – data not reported

5.2 Ontario Drill Hole Database

The diamond drill hole database maintained by the Ministry of Northern Development and Mines (2012) contains records of 351 drill holes in the Schreiber area (Appendix A). The majority of these are located within the Schreiber-Hemlo greenstone belt (Figure 2), in areas mapped as bedrock dominated terrain (Figure 3). Only a very limited number of drill holes are located in areas mapped as containing thicker surficial deposits.

The average depth of overburden in the drill holes is 3.1 m, with approximately a third of the holes having 1.0 m of drift cover. In viewing the overburden thickness data contained in this database it must be noted that a large number of the diamond drill holes were advanced at an angle. Given the relative shallow overburden in most of the drill holes the drill angle does not add appreciably to the indicated thickness of the surficial sediments (Table 7). However, a large majority of the drill holes reporting greater than 5.0 m of drift were advanced at an angle to vertical, thus artificially increasing the overburden thickness more significantly (Appendix A). The thickest sequence of overburden recorded from an angled drill hole was 63.1 m; when corrected to a vertical orientation the depth was reduced to 48.3 m

Table 7. Overburden depth in diamond drill holes in the Schreiber area (MNDM, 2012). Depth is corrected for drill angle.

Depth of Overburden (m)	Number of Drill Holes	Percentage
<1.1	114	32.5
1.1 – 3.0	151	43.0
3.1 – 5.0	48	13.7
5.1 – 10.0	30	8.5
>10.1	8	2.3

The diamond drill hole data indicate that variations in the thickness of the overburden of a few metres are common over short distances in bedrock dominated terrain in the Schreiber area. Exceptionally, the depth of overburden may vary by over 10 m within a similar distance. This is clearly demonstrated by a group of five drill holes located immediately east of Hayes Lake in an area of bedrock dominated terrain. Here, within a distance of 430 m, two holes have no overburden and the others have depths of 1.5, 7.3 and 12.2 m. A distance of approximately 100 m separates two adjacent drill holes, one is sited on outcrop and the other encountered 12.2 m of overburden.

5.3 Terrain Units

5.3.1 Morainal

The most common glacial deposit in the Schreiber area is a thin, discontinuous ground moraine (till) which has a silty-sand matrix and contains abundant clasts in the pebble to cobble size range. More extensive ground moraine deposits are located in the northwest, northeast and, to a lesser extent, the southeast corners of the area. Here the material forms a more continuous cover over the bedrock and the till thickness is estimated to be on the order of 2 to 3 m based on air photo interpretation. Bedrock outcrops are still common and bedrock structures are still easily discerned in these areas. The land typically has high level of relief and is generally dry (Figure 3).

Extensive but patchy deposits of till are common in the bedrock dominated areas across the Schreiber area. The thickness of the till in these areas, based on exploration borehole records and surficial mapping, is generally on the order of 1 to 3 m (Table 7). A typical terrain code for these areas indicates ground moraine (till) to be a subordinate landform to the bedrock. Greater accumulations of till are found within bedrock depressions, large-scale lineaments and on the down-ice (lee) side of bedrock highs.

5.3.2 Glaciofluvial

Glaciofluvial outwash deposits occur as relatively level areas within some narrow, bedrock controlled valleys (Figure 3). The outwash consists of generally well-sorted deposits comprised of stratified sand and gravel emplaced by the glacial melt waters during the retreat of the glacier from the area. While localized valley controlled outwash deposits are found in several locations within the Schreiber area, significant deposits are located along the Aguasabon, Whitesand and Pays Plat river valleys, and Big Creek and its tributaries (Figures 3). Thickness of the deposits is likely variable and, locally, may be substantial.

A large glaciofluvial deposit occurs south of Hays Lake between the towns of Terrace Bay and Schreiber. The extraction of gravel from this feature suggests that deeper material may have been deposited in an ice-contact environment that was subsequently modified by glaciolacustrine processes. The terrain mapping of this area characterizes it as containing sand, gravel and boulders in a sloping, low relief setting that is dry (Figure 3).

Other outwash deposits are found in the southern part of the Schreiber area and generally have a similar terrain classification, but do not contain large clasts beyond gravel size. In the northern part of the area, outwash dominated areas also frequently contain subordinate amounts of ground moraine, rock knobs and organic terrain; most have low to moderate relief and are well-drained.

5.3.3 Glaciolacustrine

Fine-grained glaciolacustrine silts and clay have been encountered at depth in boreholes in the Terrace Bay area and other embayments further west along the Lake Superior shoreline (Figure 3). The fine-grained nature of the sediment indicates their deposition in relatively deep water. A subsequent lowering of glacial lake levels combined with sediment input from the north, resulted in the burial of these materials by sandy coarser grained glaciolacustrine sediments. The upper sand-rich material was deposited in a deltaic environment where bedrock valleys, which served as drainage channels for the glacier, entered the glacial lake.

The largest glaciolacustrine delta is located in the Terrace Bay area where a sediment thickness of 48.3 m was documented in an exploration drill hole. This feature occurs as a low relief plain, lacking in wetlands. Other notable, but smaller deltaic features, are located southwest of Schreiber (Collingwood Bay) and near Selim at the mouth of the Whitesand River (Figure 3).

The presence of glacial lakes is also recorded by wave cut terraces, beaches and reworked glacial material. These are best developed on the deposit in the Terrace Bay-Schreiber area. Small glacial lakes of limited areal extent occur where glacial meltwater was trapped between the ice margin and higher ground (Morris, 2001).

5.3.4 Organic

Bogs and organic deposits are present along water courses in the area and in rock floored basins (Figure 3). These deposits tend to have a limited areal extent. Organic terrain typically has low relief and is wet; however, larger deposits contain areas of bedrock knobs and minor outwash.

5.3.5 Bedrock

The Schreiber area is dominated by large expanses of bedrock terrain with patchy overburden ground moraine, often less than 1 m thick, with an abundance of bare rock knobs (Figure 3). Locally, the overburden thickens on the flanks of, and between bedrock hills. Local relief ranges from about 40 m to over 100 m, and is characterized by rugged and cliffed topography with many escarpments producing steep and complex slopes. Talus accumulations are present along some of the high and steep escarpments. Bedrock terrain is generally well drained, but organic (wetland) pockets are scattered across the area.

In the north central portion of the Schreiber area the bedrock relief becomes slightly more subdued and less rugged, but has the same overburden cover as the bedrock area to the south.

5.4 Surficial Deposits and Terrain in Selected Areas

5.4.1 Crossman Lake Batholith

The Crossman Lake batholith is located in the western and north-central portions of the Schreiber area and has a surface area of over 300 km^2 (Figure 2). The batholith terrain is rugged with a maximum surface relief of approximately 300 m; local relief exceeds 100 m along fault escarpments and is commonly greater than 60 m over short distances. Low elevations occur along the Pays Plat River system while bedrock knobs consistently reach heights of 400 to 500 masl over much of the batholith’s distribution. Moderate to narrow width fault controlled valleys, with multiple orientations, dissect the rock mass.

The majority of the batholith has either limited or a thin, patchy covering of ground moraine (till). The till is more continuous and slightly thicker in the area north of Pays Plat Lake; however, this does not substantially diminish relief as bedrock frequently outcrops and steep slopes are common. The large outwash deposits over the batholith in the area south of Charlotte Lake and along the Pays Plat River system are pockets of low relief. The surface of these deposits varies from level to undulating, but become knobby when interrupted by bedrock outcrops. The outwash is believed to range from a few to several metres in thickness.

The area underlain by the batholith is well-drained by a network of waterways. Scattered organic deposits occur along reaches of some rivers and streams, and surrounding a number of lakes. The organic material in these wetlands typically accumulates to only limited depths.

5.4.2 Whitesand Lake Batholith

The Whitesand Lake batholith is exposed on surface west of the Township of Schreiber and north of Lake Superior, and has an area of approximately 123 km^2. Bedrock is found at or near surface over the great majority of the batholith; as is common in the region, surficial cover consists primarily of a discontinuous, thin till (Figure 3). Small sand-rich outwash deposits are located in the Whitesand Lake area and south of Sox Lake. Although these deposits create level surfaces, they are likely to be of limited depth. A coarse-grained glaciolacustrine deposit near Selim is similarly believed to be of modest thickness.

The surface of the Whitesand Lake batholith is rugged, dissected by faults and has a maximum relief of over 220 m. Highlands in the batholith typically reach elevations of over 400 masl. Lakes are common and drainage, via a number short streams and rivers, is good.

5.4.3 Terrace Bay Batholith

The Terrace Bay batholith, located in the southeastern part of the Schreiber area, covers an area of 67 km^2. From a terrain perspective, the batholith can be subdivided into two zones on the basis of drift cover. The majority of the batholith within the study area is covered by thick sand gravel-rich deposits that mask the bedrock (Figure 3). While maximum relief exceeds 120 m, relief over short distances is more commonly in the 20 m range. Drift thickness can achieve several tens of metres, but thins where bedrock knobs protrude. The coarse-grained nature of the surficial sediments facilitates good drainage and dry conditions. The southwest and eastern portions of the batholith areas of bedrock are dominated by terrain with discontinuous, thin ground moraine (till) (Figure 3). Over small areas the till thickens slightly and becomes more laterally extensive. Relief is high with rapid elevation changes over short distances.

5.4.4 Mount Gwynne Pluton

The Mount Gwynne pluton located in the southwest portion of the Township of Schreiber is small in comparison to the batholiths having a surface area of approximately 5 km^2. Relief across the pluton exceeds 220 m, including near sheer cliffs of over 100 m along the Lake Superior shoreline. Bedrock outcrops are common with the drift consisting of discontinuous ground moraine found between bedrock knobs (Figure 3).

6. Groundwater

6.1 Groundwater Flow, Recharge and Discharge

Water wells confirmed to be developed in overburden are restricted to the glaciolacustrine/glaciofluvial deposits in the southern part of the area, with one exception. These wells, terminating in sand and gravel, generally have low pumping rates; however, these yields are likely not reflective of aquifer capacity, as the wells supply residences with limited demand. Recorded well depths ranged from 4.3 to 47.2 m (MOE, 2012).

Within the Schreiber study area eight water wells are recorded as being developed in bedrock (MOE, 2012). These wells reach a maximum depth below ground surface of between 31.1 and 94.5 m and have reported yields ranging from 9 to 455 L/min. Two wells, which may be completed in bedrock in the vicinity of Terrace Bay, have recorded pumping rates of approximately 716 and 719 L/min from depths of 20.7 and 22.9 m, respectively.

The Schreiber area is characterized by the presence of bedrock at or near the surface. Groundwater recharge in these areas is through an interconnected fracture network present in the bedrock. Recharge can be rapid but is largely restricted to a near surface zone. Groundwater flow is to flanking valleys and depressions where the bulk of the groundwater discharges either directly to waterways or into surficial deposits occupying the lower ground. Surficial deposits on the highland bedrock areas, most commonly till, are usually thin and relatively coarse-grained allowing downward infiltration to the bedrock surface.

Coarse-grained outwash deposits found along the major bedrock valleys in the study area are recharged by ground and surface flow from the bedrock highlands and direct precipitation (rain and snow). Groundwater discharge from these deposits is as baseflow to streams and rivers which transect them. The presence of a shallow water table in many of the valley outwash deposits is suggested by the fact that the elevation of the dissecting waterway is often close to that of the surrounding ground surface.

The large elevated sand and gravel rich deposits located between Terrace Bay and Schreiber are also an area of significant groundwater recharge. Creeks and streams are generally lacking over the distribution of these glaciolacustrine/glaciofluvial sediments. Groundwater flow is likely southward to Lake Superior, and northward to Hays Lake and the Aguasabon River system. The influence of regional structures, such as the mapped faults in the area, on the rate and volume of flow is not known at present.

No information beyond what was presented in the initial screening study (Golder, 2011) on groundwater flow at typical repository depths (approximately 500 m) was found during this study.

7. Neotectonic Features

The geology of the Schreiber area is typical of many areas of the Canadian Shield, which has been subjected to numerous glacial cycles during the last million years, resulting in post-glacial isostatic rebound in the northern portion of the North America plate. During the maximum extent of the Wisconsinan glaciation, approximately 21,000 years ago (Barnett, 1992), the Earth's crust was depressed by more than 340 m in the Minnesota/North Dakota area (Brevic and Reid, 1999), due to the weight of glacial ice. The amount of crustal depression in the Schreiber area would be of a somewhat greater magnitude, due to its closer proximity to the main centre of glaciation located over Hudson's Bay.

Post-glacial isostatic rebound began with the waning of the continental ice sheets and is still occurring across most of Ontario. Vertical velocities show present-day uplift of about 10 mm/yr near Hudson Bay, the site of thickest ice at the last glacial maximum (Sella *et al*., 2007). The uplift rates generally decrease with distance from Hudson Bay and change to subsidence (1-2 mm/yr) south of the Great Lakes. The ''hinge line'' separating uplift from subsidence is consistent with data from water level gauges along the Great Lakes, showing uplift along the northern shores and subsidence along the southern ones (Mainville and Craymer, 2005). Current rates of isostatic uplift in the Schreiber area are not precisely known, although Lee and Southam (1994) estimate that the land is rising at a rate of 2.9 mm/yr at Michipicoten, Ontario, some 180 km to the southeast.

The movement and interaction of tectonic plates also creates horizontal stresses that result in the compression of crustal rocks. The mean of the current major horizontal principal stress orientation in central North America, based on the World Stress Map (Zoback, 1992) is NE (63° ± 28°). This orientation coincides roughly with both the absolute and relative plate motions of North America (Zoback, 1992; Baird and McKinnon, 2007), and is controlled by the present tectonic configuration of the North Atlantic spreading ridge (Sbar and Sykes, 1973) which has likely persisted since the most recent Paleocene-Eocene plate reorganization (Rona and Richardson, 1978; Gordon and Jurdy, 1986).

The study of neotectonic features in the Schreiber area may reveal the timing and magnitude of past seismic activity and deformations. Conclusive evidence of features indicative of reactivation of ancient bedrock structures could not be made using the information available in the current study. Field investigations would be required to identify such features since, under appropriate conditions, it may be possible to identify neotectonic features in bedrock and overburden, as discussed below.

7.1 Types of Bedrock Neo-tectonic Features

Under the appropriate conditions, glacial deposits may preserve neotectonic features indicative of paleo-seismic activity. Existence of such features can be used to extend the seismic record for a region well into the past. In the Schreiber area should any pop-up features be present, they may be recognized by their narrow, linear shape which could extend for hundreds of metres (White *et al.* 1973). Such features would likely only be found in areas of bedrock outcrop or thin overburden cover (<1 to 2 m). It is possible that tree cover, typical of that found in the boreal forest, would assist in making their identification difficult when interpreting air photo or other remotely sensed imagery. Faults resulting from neotectonic activity may be equally challenging to discern from ancient features. Recent faults (i.e., post-glacial faults) may show evidence of displacement, fresh brecciation or an unhealed character suggestive of recent formation.

7.2 Types of Overburden Neo-tectonic Features

The most common neotectonic feature in glaciated terrain is faulting caused by movement of the bedrock which is reflected in the overlaying surficial sediments. Displaced (faulted) post-glacial beach ridges in the lower Great Lakes have provided evidence of movement and allowed a determination as to the post-glacial timing of the feature's formation (McFall and Allam, 1990). Under the appropriate conditions, soft sediment deformation preserved in glacial sediments can also be an indication of post-depositional movement associated with paleo-seismic events.

In the Schreiber area neotectonic activity would best be recognized in stratified material such as fine-grained glaciolacustrine and glaciofluvial deposits. Disrupted or faulted bedding is more easily discerned in such materials as opposed to unsorted or coarse-grained deposits such as till and gravel. In the area, deposits most favourable for the preservation of neotectonic features are located in the Schreiber-Terrace Bay area and in the vicinity of Selim (Figures 3). The sand-rich segments of the glaciofluvial outwash deposits found in bedrock controlled valleys across the Schreiber area could also possibly display such features.

The examination of natural and man-made exposures, such as those found in stream/river sections and excavations would provide the best opportunity to locate any evidence of recent movement. Sedimentological studies of the material would be required to separate recent soft-sediment deformation from that caused by processes active at the time of deposition, such as dewatering, faulting resulting from the melting of buried ice blocks or glaciotectonic movement (Slattery, 2011).

8. Accessibility Constraints

Access along the southern edge of the Schreiber area is provided by the Trans Canada Highway (Highway 17) which closely follows the Lake Superior shoreline. Primary access to the interior of the area is provided by two north trending roads which connect with the Trans Canada Highway; one in Terrace Bay, and the second approximately 8 km west of Schreiber (Figure 12). Access to the east-central portion of the area and the northeastern corner of the area around Aguasabon Lake is via branching roads. Municipal and private roads provide good access to the relatively level area surrounding the Town of Terrace Bay as far west as Hayes Lake.

A network of forestry roads and trails provides limited access to other parts of the area. The largest forestry road network is located in the Robbie Lake area in the east-central part of the Schreiber area with less extensive area northeast of Big Duck Lake (Figure 12). This type of road network is traditionally not maintained following the completion of logging in the area. Trails developed for mineral exploration access are located over greenstone terrain, notably in those areas with a high concentration of mineral occurrences. Access is present north of Big Duck

Lake, which connects with the forest road network to the east; north and southeast of Winston Lake; and east of Lyne Lake, north of Schreiber (Figure 12). The condition and usability of these trails is highly variable. Excepting the trails, the roads access shown in Figure 12 is based on the Ministry of Natural Resources (MNR) road segment file obtained from Land Information Ontario. The MNR road segment file contains resource access roads constructed for and used by conventional (i.e., street legal) vehicles and it contains roads recorded in the Ontario Road Network. Recreation and mineral exploration access trails, and short-term forest operation roads or forest fire management roads are not included in the file.

Access to the eastern end of the Terrace Bay batholith is well developed, in contrast to the western portion southwest of Hayes Lake. The western part of the batholith is located immediately south of the Trans Canada Highway, so any newly constructed road would be of relatively short length. The Mount Gwynne pluton has no access, but it too is in close proximity to the Trans Canada Highway, south of the Town of Schreiber.

Limited access exists to most parts of the Crossman Lake batholith; the logging roads and associated trails in the eastern portion of the batholith, that part surrounded by the arms of the Schreiber-Hemlo greenstone belt, are of restricted extent. The western portion of the batholith within the Schreiber area has virtually no road access beyond the road leading to the closed Winston Mine. Trails do extend from this main road into areas of greenstone terrain, some of which approach the boundary of the batholith.

Road access to the Whitesand Lake batholith is provided by the Trans Canada Highway and the Winston Mine road. A limited number of short trails, most leading to lakes, are also present. Two power lines and a railway traverse the batholith.

The principal constraint on access to most parts of the batholiths in the Schreiber area, excepting the eastern part of the Terrace Bay batholith, is the notable relief. Significant relief commonly occurs over short distances creating steep slopes. As previously noted, the batholiths and most of the Schreiber area are characterized by rugged topography consisting of knobby bedrock hills and escarpments. The only exception to this is a level to undulating area of thick overburden between Terrace Bay and Schreiber. Access and development in this latter area is not unduly constrained other than by existing land use.

North of the Trans Canada Highway few natural constraints to development exist, other than topography and the position of lakes, typical of Canadian Shield terrain. As is the case for the two existing roads that enter the northern part of the study area, new roads can follow bedrock valleys as a means of reducing construction difficulties. The intersecting nature of the fault/lineament controlled valleys (which trend north, northwest, north-northwest and northeast) minimizes, but does not eliminate, the need to cross highland areas.

The development of access corridors will need to deal with several issues and obstacles, the most notable of which are:

- Unlevel ground over short distances;
- Numerous river and stream crossings; and
- The need to circumnavigate lakes.

Road and infrastructure development (e.g., power lines) could be developed using standard construction techniques commonly used in the Canadian Shield.

9. Summary

The terrain and remote sensing study conducted as part of the Phase 1 Desktop Geoscientific Preliminary Assessment for the Township of Schreiber demonstrated that the region is dominated by rugged terrain with substantial relief. Relief is slightly lower in the north-central portion of the area and notably lower in the area between the towns of Terrace Bay and Schreiber. Steep slopes are abundant in areas of rugged terrain with the highest density of slopes over six degrees occurring in an arc that trends across the southern portion of the area paralleling the Lake Superior shoreline. Structurally controlled bedrock valleys, frequently with steep sides, trend across the area in several directions (i.e., northwest, north-northwest, north and northeast).

Over the majority of the Schreiber area the Precambrian bedrock is thinly covered by a discontinuous veneer of glacial sediments. The most common surficial (Quaternary) deposit is ground moraine (till) which occurs throughout the area; slightly thicker till accumulations are found in the northeastern and northwestern corners of the area where the till becomes more continuous. Coarse-grained outwash deposits occur in some of the larger north trending valleys which drained the melting glacial ice mass as it withdrew to the north. Glaciofluvial and glaciolacustrine deposits occur in scattered locations along the Lake Superior coast. The largest accumulation of these sediments occurs in the Terrace Bay-Schreiber area where they achieve a thickness sufficient to hide the bedrock topography; this is the only location in the area where this occurs.

Two large batholiths, the Crossman Lake and the Whitesand Lake, form nearly half of the surface bedrock in the western and central portions of the Schreiber area. Surficial cover on these, and the very much smaller Mount Gwynne Pluton located in the Township of Schreiber, is typically a discontinuous, thin veneer of ground moraine (till) on the highlands with sporadic outwash deposits in the larger valleys. In contrast, the majority of the Terrace Bay batholith, located in the southeast corner of the study area, is buried beneath a thick cover of sand and gravel of glaciofluvial and glaciolacustrine origin.

The area’s drainage network is contained within four quaternary level watersheds, all of which discharge into Lake Superior. Watersheds (catchment areas) of the numerous lakes are typically small and have a relatively even distribution. Bedrock valleys and lowlands host an abundance of lakes, streams and rivers that provide good drainage of all parts of the area with shallow groundwater flow systems feeding the waterways. The majority of recharge to the waterways is through direct runoff or a shallow, fracture controlled groundwater system. Information on shallow aquifers in the region is cursory and completely lacking for deep flow systems.

The area is tectonically stable with no known neotectonic activity, although isostatic recovery associated with the last glaciation continues to affect the region, albeit at a very low rate.

The all weather road network in the Schreiber area is limited, especially in the interior of the area. Forestry and mineral exploration access trails locally augment the developed roads. Access routes could be developed to any part of the Schreiber area by following the numerous intersecting bedrock valleys.

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Appendix A

Depth of overburden obtained from diamond drill hole records

(MNDM Assessment File (AFRI) database)

AFRI File Number	Depth of Overburden (m)	Drill Angle From Horizontal (degrees)	Depth of Overburden Corrected to Vertical Orientation (m)
42E03SE0026	0.0		0.0
42D14SE2002	0.0		0.0
42D14SE2002	0.0		0.0
42D14SE0101	0.0		0.0
42D14NW0051	0.0	-90	0.0
42D14NW0050	0.0		0.0
42D14NW0050	0.0		0.0
42D14NW0043	0.0	-90	0.0
42D14NW0043	0.0	-90	0.0
42D14NW0043	0.0	-90	0.0
42D14NW0043	0.0	-90	0.0
42D14NW0043	0.0		0.0
42D14NW0043	0.0		0.0
42D14NW0018	0.0	-89	0.0
42D14NW0025	0.0	-86	0.0
42D14NW0045	0.0	-82	0.0
42D14NW8289	0.0	-70	0.0
42D14NW8289	0.0	-65	0.0
42D14NW8289	0.0	-65	0.0
42D13SE0001	0.0	-65	0.0
42E03SW0041	0.0	-60	0.0
42E03SE0005	0.0	-60	0.0
42D14SW0016	0.0	-60	0.0
42D14SW0016	0.0	-60	0.0
42D14SW0016	0.0	-60	0.0
42D14SE0477	0.0	-60	0.0
42D14NW8289	0.0	-60	0.0
42D13SE0001	0.0	-60	0.0
42D14NW0008	0.0	-57	0.0
42D13SE0001	0.0	-55	0.0
42D13SE0001	0.0	-55	0.0
42D14NW0045	0.0	-52	0.0
42D14NW0045	0.0	-52	0.0
42D14NW8289	0.0	-50	0.0
42D14NW8289	0.0	-50	0.0
42D14NW0048	0.0	-50	0.0
42D14NE0008	0.0	-50	0.0

AFRI File Number	Depth of Overburden (m)	Drill Angle From Horizontal (degrees)	Depth of Overburden Corrected to Vertical Orientation (m)
42D14NW0048	0.0	-48	0.0
42D14NW0048	0.0	-47	0.0
42E03SW0041	0.0	-45	0.0
42E03SE0005	0.0	-45	0.0
42E03SE0005	0.0	-45	0.0
42E03SE0005	0.0	-45	0.0
42D14SW0016	0.0	-45	0.0
42D14SE0477	0.0	-45	0.0
42D14SE0477	0.0	-45	0.0
42D14SE0086	0.0	-45	0.0
42D14SE0060	0.0	-45	0.0
42D14NW0051	0.0	-45	0.0
42D14NW0051	0.0	-45	0.0
42D14NW0050	0.0	-45	0.0
42D14NW0050	0.0	-45	0.0
42D14NW0050	0.0	-45	0.0
42D14NW0043	0.0	-45	0.0
42D14NW0041	0.0	-45	0.0
42D13SE0001	0.0	-45	0.0
42D13SE0001	0.0	-45	0.0
42D14SE0477	0.0	-40	0.0
42D14NW2005	0.3	-90	0.3
42D14NW0007	0.3	-88	0.3
42E03SE0022	0.3	-60	0.3
42E03SE0022	0.5	-70	0.4
42D14NW0043	0.5	-60	0.4
42E03SE0022	0.5	-45	0.3
42D14NW2005	0.5	-90	0.5
42D14NW0018	0.5	-86	0.5
42D14NW0034	0.5	-85	0.5
42D14SE2001	0.5	-50	0.4
42E03SE0005	0.5	-45	0.4
42D14SE2001	0.5	-45	0.4
42D14NW0018	0.6	-90	0.6
42D14NW0025	0.6	-89	0.6
42E03SW0005	0.6	-76	0.6
42D14NW2005	0.6	-70	0.6

AFRI File Number	Depth of Overburden (m)	Drill Angle From Horizontal (degrees)	Depth of Overburden Corrected to Vertical Orientation (m)
42D14NW0045	0.6	-90	0.6
42D14NW0045	0.6	-90	0.6
42D14NE0014	0.6	-70	0.6
42D14NW0043	0.6	-60	0.5
42E03SE0022	0.6	-45	0.4
42D14SW0016	0.6	-45	0.4
42D14SE0101	0.6	-45	0.4
42D14NW2005	0.7	-60	0.6
42E03SW0038	0.7	-45	0.5
42D14NW0020	0.8	-89	0.7
42D14NW0048	0.8	-90	0.8
42E03SE0022	0.8	-70	0.7
42D14NW2005	0.8	-60	0.7
42D14NW0048	0.8	-52	0.6
42D14SW0039	0.8	-45	0.5
42D14NW0048	0.8	-45	0.5
42D14NW0048	0.8	-45	0.5
42D14NW0007	0.8	-87	0.8
42D14NW0007	0.8	-83	0.8
42D14NW0001	0.9	-89	0.9
42E03SW0021	0.9	-50	0.7
42E03SE0005	0.9	-45	0.6
42D14NW0051	0.9	-90	0.9
42D14NW0043	0.9	-90	0.9
42D14NW0017	0.9	-70	0.9
42D14NE0014	0.9	-50	0.7
42D14SE0101	0.9	-45	0.6
42D14NW0041	0.9	-45	0.6
42D14NW0018	1.0	-89	1.0
42D14NW0011	1.0	-87	1.0
42D14NW0001	1.0	-76	1.0
42D14NW0043	1.0	-60	0.9
42D14NW2005	1.1	-90	1.1
42D14NW0018	1.1	-89	1.1
42D14SE2001	1.1	-45	0.8
42D14NW0039	1.2	-65	1.1
42E03SE0005	1.2	-45	0.8

AFRI File Number	Depth of Overburden (m)	Drill Angle From Horizontal (degrees)	Depth of Overburden Corrected to Vertical Orientation (m)
42E03SE0005	1.2	-45	0.8
42D14NW0002	1.2	-45	0.8
42D14NW0045	1.2	-90	1.2
42D14NW0045	1.2	-90	1.2
42D14NE0008	1.2	-50	0.9
42E03SW0038	1.2	-45	0.9
42E03SW0038	1.2	-45	0.9
42D14SE0101	1.2	-45	0.9
42D14NW0002	1.3	-55	1.1
42D14NW0020	1.4	-85	1.3
42D14NW0015	1.4	-86	1.4
42D14NW0015	1.4	-70	1.3
42D14NW0001	1.5	-89	1.5
42D14NW0018	1.5	-88	1.5
42D14NW0007	1.5	-83	1.5
42D14NW0001	1.5	-83	1.5
42E03SW0010	1.5	-70	1.4
42E03SW0010	1.5	-65	1.4
42E03SE0006	1.5	-45	1.1
42E03SE0005	1.5	-45	1.1
42E03SE0005	1.5	-45	1.1
42D14NW0045	1.5	-90	1.5
42D14NW0045	1.5	-90	1.5
42D14NW0045	1.5	-90	1.5
42D14NW0045	1.5	-90	1.5
42D14NW0045	1.5	-90	1.5
42D14NW0043	1.5	-90	1.5
42D14NW0045	1.5	-82	1.5
42E03SW0042	1.5	-50	1.2
42E03SW0042	1.5	-50	1.2
42D14NW0043	1.5	-50	1.2
42D14NE0008	1.5	-50	1.2
42E03SW0038	1.5	-45	1.1
42D14SW0038	1.5	-45	1.1
42D14SE0477	1.5	-45	1.1
42D14SE0086	1.5	-45	1.1
42D14NW0043	1.5	-45	1.1

AFRI File Number	Depth of Overburden (m)	Drill Angle From Horizontal (degrees)	Depth of Overburden Corrected to Vertical Orientation (m)
42D14NW0043	1.5	-45	1.1
42D14NW0043	1.5	-45	1.1
42D14NW0018	1.6	-75	1.5
42E03SW0010	1.6	-70	1.5
42D14NW8293	1.6	-65	1.5
42D14NW8293	1.6	-60	1.4
42E03SW0021	1.6	-45	1.1
42D14NW0043	1.7	-55	1.4
42D14NW0009	1.7	-83	1.7
42D14NW0009	1.7	-73	1.6
42E03SW0021	1.7	-65	1.5
42D14SW0028	1.7	-50	1.3
42D14NW8293	1.7	-50	1.3
42D14NW0002	1.8	-65	1.6
42D14NW0039	1.8	-55	1.5
42D14NW2005	1.8	-50	1.4
42D14NW0051	1.8	-90	1.8
42D14NW0051	1.8	-90	1.8
42D14NW0051	1.8	-90	1.8
42D14NW0043	1.8	-55	1.5
42D14SE0103	1.8	-50	1.4
42D14NE0008	1.8	-50	1.4
42E03SW0038	1.8	-45	1.3
42D14SE0103	1.8	-45	1.3
42D14SE0091	1.8	-45	1.3
42D15NW0086	1.8	-44	1.3
42D14NW0018	2.0	-84	2.0
42D14NW0008	2.0	-82	2.0
42D14NW0018	2.0	-80	2.0
42D14NW0018	2.0	-80	2.0
42D14NW0015	2.0	-71	1.9
42D14SW0027	2.0	-60	1.7
42E03SW0021	2.0	-50	1.5
42E03SE0005	2.0	-45	1.4
42E03SE0005	2.0	-45	1.4
42D14NW0003	2.0	-45	1.4
42D14NW0002	2.0	-45	1.4

AFRI File Number	Depth of Overburden (m)	Drill Angle From Horizontal (degrees)	Depth of Overburden Corrected to Vertical Orientation (m)
42D14NW0018	2.1	-84	2.0
42D14NW0010	2.1	-87	2.1
42D14NW0030	2.1	-85	2.1
42D14NW0018	2.1	-85	2.1
42E03SW0021	2.1	-45	1.5
42D14NW2005	2.1	-90	2.1
42D14NW0045	2.1	-90	2.1
42D14NW0045	2.1	-90	2.1
42D14NW0043	2.1	-60	1.8
42D14SE0103	2.1	-50	1.6
42D14NW0051	2.1	-45	1.5
42D14NW0051	2.1	-45	1.5
42D14NW0043	2.1	-45	1.5
42D14NW0040	2.1	-45	1.5
42D14NW2005	2.2	-70	2.1
42E03SW0010	2.2	-48	1.6
42E03SW0021	2.2	-45	1.6
42E03SW0010	2.2	-45	1.6
42E03SW0021	2.3	-45	1.6
42D14NW0013	2.4	-88	2.4
42D14NW0018	2.4	-86	2.4
42D14NW0051	2.4	-90	2.4
42E03SW0042	2.4	-50	1.9
42D14SW0016	2.4	-45	1.7
42E03SE0006	2.5	-45	1.8
42D14NE0014	2.5	-50	1.9
42D14NW0051	2.6	-45	1.8
42E03SW0010	2.6	-50	2.0
42E03SW0010	2.6	-42	1.7
42D14NW0007	2.7	-82	2.7
42D14NW0015	2.7	-60	2.3
42E03SW0021	2.7	-50	2.1
42E03SE0013	2.7	-50	2.1
42D14NW0051	2.7	-90	2.7
42D14NW2005	2.7	-50	2.1
42E03SW0042	2.7	-45	1.9
42D14NW0051	2.7	-45	1.9

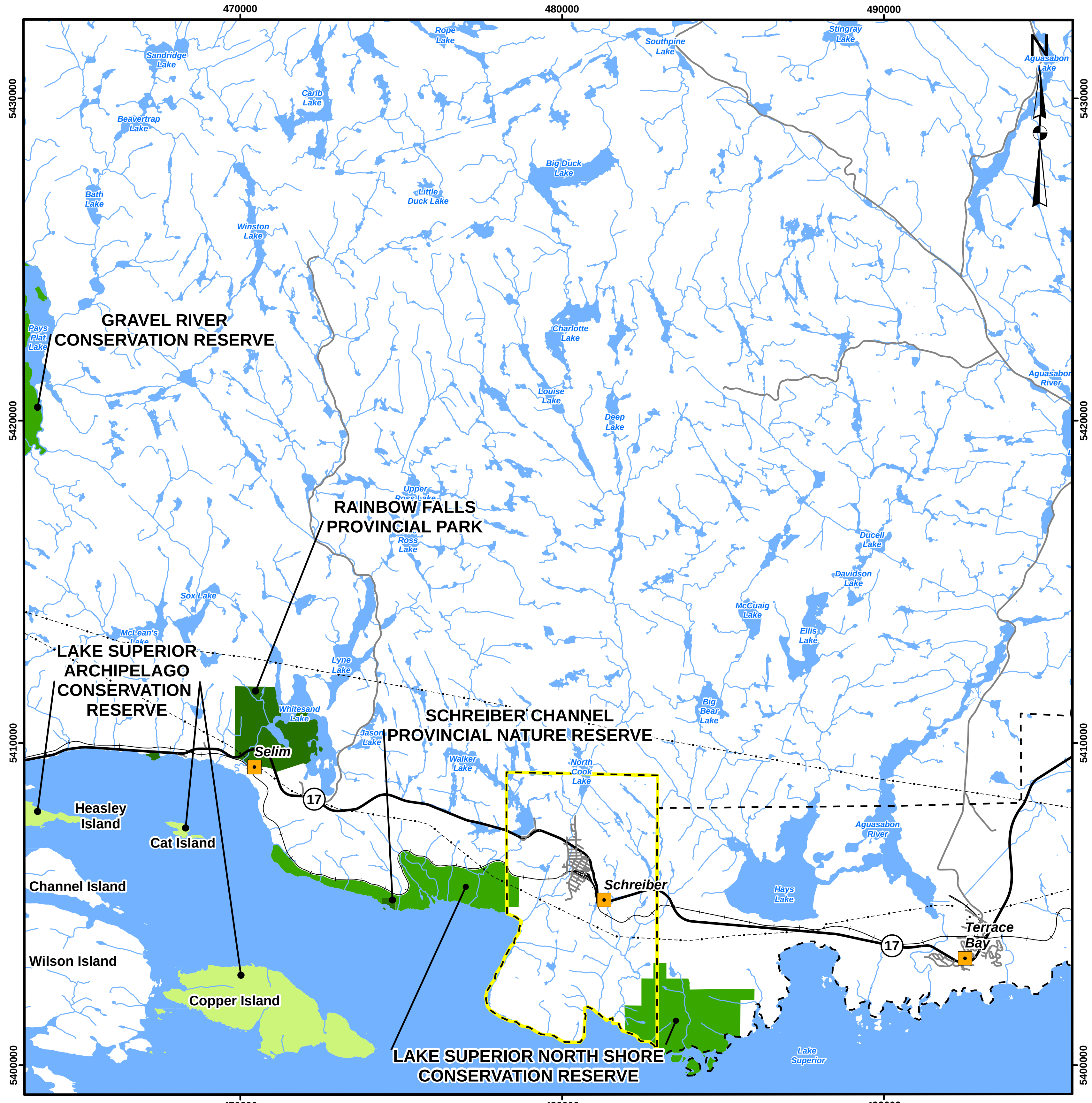
AFRI File Number	Depth of Overburden (m)	Drill Angle From Horizontal (degrees)	Depth of Overburden Corrected to Vertical Orientation (m)
42D14NW0051	2.7	-45	1.9
42D14NW0018	2.8	-89	2.8
42D14NW0008	2.8	-84	2.8
42E03SW0021	2.8	-70	2.6
42E03SW0021	2.8	-50	2.1
42E03SE0005	2.8	-45	2.0
42E03SE0005	2.8	-45	2.0
42D14SE2001	2.8	-45	2.0
42D14NW0015	3.0	-90	3.0
42D14NW0011	3.0	-89	3.0
42D14NW0015	3.0	-87	3.0
42D14SW0034	3.0	-70	2.8
42D14SW0027	3.0	-70	2.8
42D14NW8293	3.0	-70	2.8
42D14NW8293	3.0	-70	2.8
42D14NW8293	3.0	-70	2.8
42E03SW0021	3.0	-65	2.7
42D14SW8308	3.0	-65	2.7
42E03SW0010	3.0	-55	2.5
42E03SE0013	3.0	-50	2.3
42D14NW0015	3.0	-50	2.3
42D14NW0045	3.1	-90	3.1
42D14SE0477	3.1	-45	2.2
42D14SE0103	3.1	-45	2.2
42D14NW0051	3.1	-45	2.2
42D14NW0040	3.1	-45	2.2
42D14NW0040	3.1	-45	2.2
42D14NW0015	3.1	-90	3.1
42D14NW0039	3.1	-55	2.5
42D14NW0015	3.2	-90	3.2
42E03SE0013	3.2	-55	2.6
42D14NW0015	3.2	-40	2.1
42E03SW0036	3.3	-50	2.5
42D14SW0028	3.3	-50	2.5
42D14SE0101	3.4	-45	2.4
42D14NW0041	3.4	-37	2.0
42D14NW0013	3.4	-89	3.4

AFRI File Number	Depth of Overburden (m)	Drill Angle From Horizontal (degrees)	Depth of Overburden Corrected to Vertical Orientation (m)
42D14NW0015	3.5	-90	3.5
42D14NW0013	3.5	-90	3.5
42D14NW0013	3.5	-82	3.5
42D14NW0015	3.5	-69	3.3
42D14SE2001	3.5	-45	2.5
42E03SW0042	3.5	-45	2.5
42D14NE0008	3.7	-50	2.8
42E03SE0005	3.7	-45	2.6
42D14NW0043	3.7	-45	2.6
42D14NW0013	3.7	-71	3.5
42D14NW0015	3.8	-35	2.2
42D14NW0015	3.9	-72	3.7
42E03SW0010	3.9	-55	3.2
42D14NW2005	4.0	-60	3.4
42D14SE0091	4.0	-45	2.8
42D14NW0013	4.0	-90	4.0
42D14NW0013	4.0	-89	4.0
42D14NW0013	4.0	-89	4.0
42D14SW0033	4.0	-65	3.6
42D14NW0013	4.0	-61	3.5
42E03SW0021	4.0	-60	3.5
42D14NW0015	4.1	-87	4.1
42D14NW0011	4.2	-89	4.2
42D14NW0013	4.2	-59	3.6
42E03SW0010	4.2	-47	3.1
42D14SE0093	4.3	-48	3.2
42D14NW0041	4.3	-37	2.6
42D14NW0013	4.3	-60	3.7
42E03SW0021	4.3	-45	3.0
42D14SW0027	4.5	-70	4.2
42D14SW0008	4.6	-45	3.2
42D14SE0103	4.6	-45	3.2
42D14NW0013	4.8	-50	3.7
42E03SW0042	4.9	-50	3.7
42E03SW0042	4.9	-50	3.7
42D14NW0013	4.9	-88	4.9
42D14NW0015	5.0	-90	5.0

AFRI File Number	Depth of Overburden (m)	Drill Angle From Horizontal (degrees)	Depth of Overburden Corrected to Vertical Orientation (m)
42E03SW0021	5.0	-60	4.3
42D14NW0013	5.0	-44	3.5
42D14NW0015	5.0	-40	3.2
42D14NW0013	5.0	-35	2.9
42D14NW0013	5.1	-54	4.1
42E03SE0005	5.1	-45	3.6
42D14NW0040	5.2	-45	3.7
42D14NW0013	5.4	-36	3.2
42D14SW0008	5.5	-45	3.9
42D14NW0001	5.5	-90	5.5
42D14NW0015	5.6	-44	3.9
42D14NW0015	5.7	-44	4.0
42E03SW0042	5.8	-45	4.1
42D14NW0018	6.0	-89	6.0
42D14NW0045	6.1	-90	6.1
42D14NW0043	6.1	-60	5.3
42D14NE0014	6.1	-50	4.7
42D14SE0086	6.1	-45	4.3
42D14SE2001	6.2	-45	4.4
42D14SE2001	6.5	-45	4.6
42D14NW0015	6.5	-44	4.5
42E03SW0005	6.7	-83	6.7
42D14NW0039	6.7	-65	6.1
42D14NW0043	6.7	-90	6.7
42D13SE0002	7.3	-55	6.0
42D14SE0042	7.3	-45	5.2
42D14NW0013	7.5	-49	5.7
42E03SE0005	7.6	-45	5.4
42E03SW0042	7.6	-50	5.8
42D14NE0015	7.6	-50	5.8
42E03SW0043	7.6	-45	5.4
42D14NW0003	8.8	-45	6.2
42D14NW0043	8.8	-45	6.3
42D14SE0477	9.8	-45	6.9
42D14NW0043	9.8	-45	6.9
42E03SW0004	10.1	-61	8.8
42D14SW0008	10.4	-45	7.3

AFRI File Number	Depth of Overburden (m)	Drill Angle From Horizontal (degrees)	Depth of Overburden Corrected to Vertical Orientation (m)
42D14NW0043	10.4	-45	7.3
42D13SE0002	10.4	-45	7.3
42D14NW0043	10.7	-45	7.5
42D13SE0002	11.9	-52	9.4
42E03SE0005	11.9	-45	8.4
42D14SE0086	12.2	-45	8.6
42D14NW0043	12.2	-45	8.6
42D14SE0042	12.2	-35	7.0
42D14NW0015	12.7	-35	7.3
42D14NW8289	12.8	-70	12.0
42D14NW0043	13.4	-45	9.5
42E03SW0004	15.2	-62	13.5
42D13SE0002	17.4	-70	16.3
42E03SE0026	23.2	-50	17.7
42D14SW0008	26.8	-49	20.2
42D14SE0094	33.5	-45	23.7
42D14NW0051	40.2	-55	33.0
42D14SE0101	63.1	-50	48.3

Figures

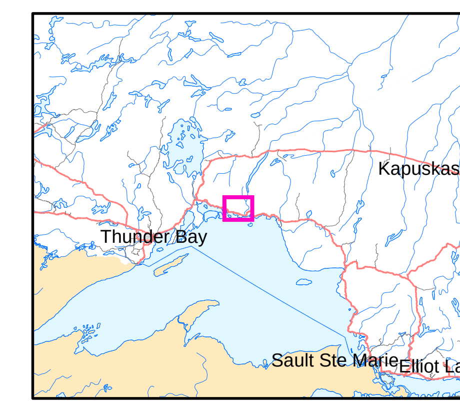


Legend

- City / Towns
- Township of Schreiber
- Township of Terrace Bay
- Main Road
- Local Road
- Railway
- Transmission Line
- Watercourse, Permanent
- Watercourse, Intermittent
- Waterbody, Permanent

Protected Areas

- Provincial Park
- Conservation Reserve
- Conservation Reserve (Recommended)



Data Sources:
Base Data: MNR LIO, obtained 2009-2013

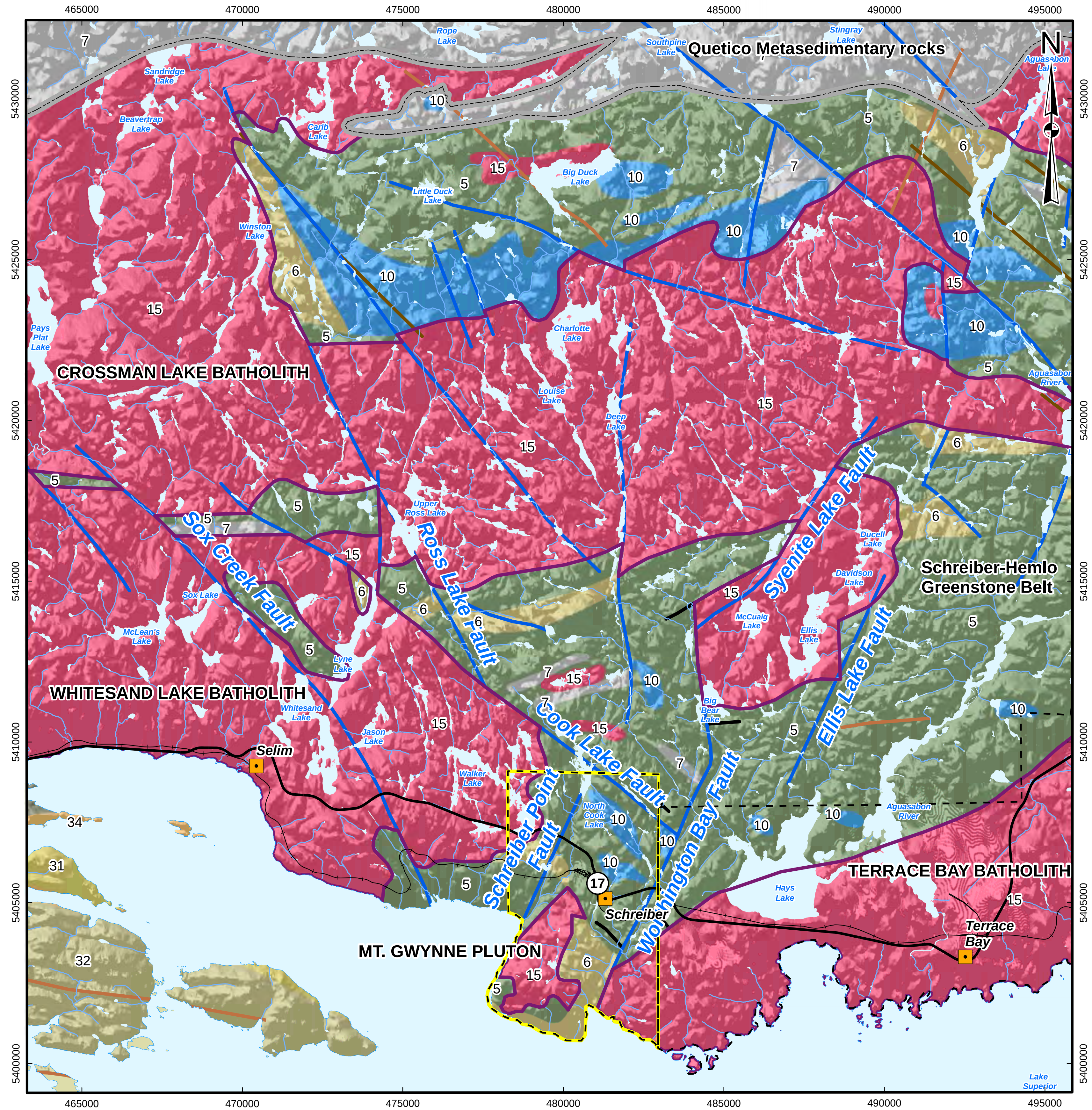
5 km

AECOM

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, SCHREIBER AREA, ONTARIO

TITLE
Township of Schreiber and Surrounding Area

DESIGN	GHF	14 Aug 2012	FIGURE 1	REVISION 5
GIS	GHF	23 Jan 2013		UTM ZONE 16
CHECK	CB	31 Jan 2013		NAD 1983
REVIEW	CB	31 Jan 2013		1:150,000



LEGEND

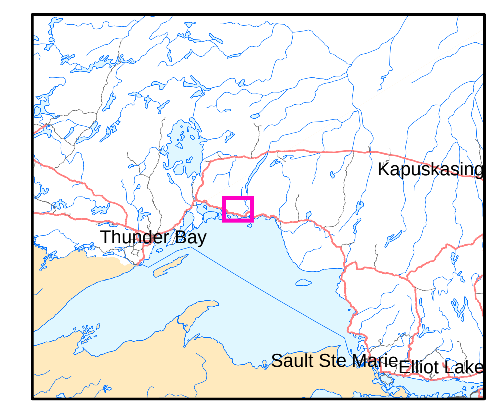
- City / Towns
- Township of Schreiber
- Township of Terrace Bay
- Main Road
- Railway
- Watercourse, Permanent
- Watercourse, Intermittent
- Waterbody, Permanent
- Mapped Fault
- Iron Formation
- Quetico-Wawa Subprovince Boundary
- Outline of batholith/pluton

Mapped Dyke

- Marathon, Kapuskasing or Biscotasing Mafic Dyke
- Matachewan Mafic Dyke
- Dyke (Other)

Bedrock Geology (Youngest to Oldest)

- 34. Mafic intrusive rocks (Keweenawan age)
- 32. Osler Gp., Mamainse Point Fm., Michipicoten Island Fm.
- 31. Sibley Gp.
- 24. Animikie Gp.
- 15. Massive granodiorite to granite
- 11. Gneissic tonalite suite
- 10. Mafic and ultramafic rocks
- 7. Metasedimentary rocks
- 6. Felsic to intermediate metavolcanic rocks
- 5. Mafic to intermediate metavolcanic rocks
- 2. Felsic to intermediate metavolcanic rocks



Data Sources:
Bedrock: OGS MRD 126-REV1 (1:250,000)
Faults: OGS MRD 126-REV1 (1:250,000)
Dykes: OGS MRD 126-REV1 (1:250,000)
Batholith: Generalized from OGS 2006
Base Data: MNR LIO, obtained 2009-2013
Underlay: Hillshade DEM, MNR Elevation and Slope

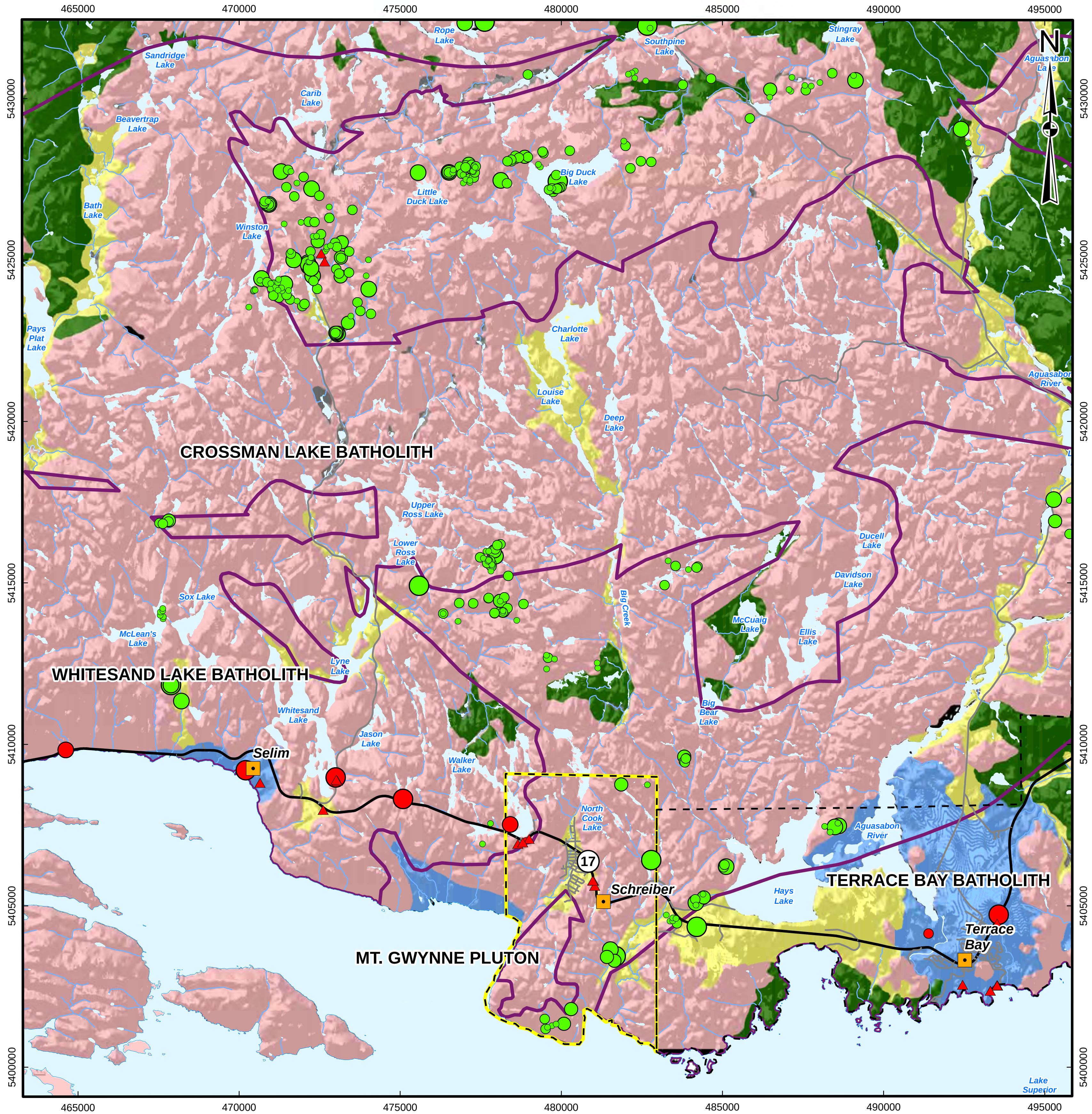
5 km

AECOM

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT
TERRAIN AND REMOTE SENSING STUDY, SCHREIBER AREA, ONTARIO

TITLE
Local Bedrock Geology of the Schreiber Area

DESIGN	GHF	14 Aug 2012	FIGURE 2	REVISION 4
GIS	GHF	25 Jan 2013		UTM ZONE 16
CHECK	CB	31 Jan 2013		NAD 1983
REVIEW	CB	31 Jan 2013		1:150,000



LEGEND

- Cities/Towns
- Township of Schreiber
- Township of Terrace Bay
- Main Road
- Local Road
- Watercourse, Permanent
- Watercourse, Intermittent
- Waterbody, Permanent
- Outline of batholith/pluton

Surficial Geology

- Morainal Terrain
- Glaciofluvial Terrain
- Glaciolacustrine Terrain
- Organic Terrain
- Bedrock Terrain

Water Well (MOE)

Depth to Bedrock (m)

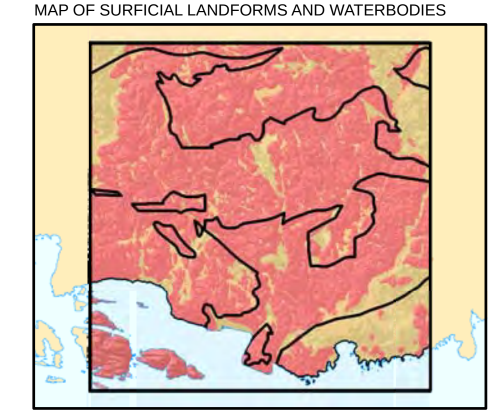
- Depth Unknown
- <1.0
- 1.1 - 3.0
- 3.1 - 5.0
- 5.1 - 10.1
- >10.1

Drill Hole (OGS)

Depth to Bedrock (m)

- <1.0
- 1.1 - 3.0
- 3.1 - 5.0
- 5.1 - 10.0
- >10.1

MAP OF SURFICIAL LANDFORMS AND WATERBODIES



Outline of batholith/pluton Surficial/water (24%) Bedrock Terrain (76%)

Data Sources:

Batholith: Generalized from OGS 2006
Overburden: OGS MRD-160 (1:100,000), AECOM, 2013
Base Data: MNR LIO, obtained 2009-2013
Water Well: MOE Water Well Information System
Drill Hole: OGS Drill Hole Database (Selected)

5 km

AECOM

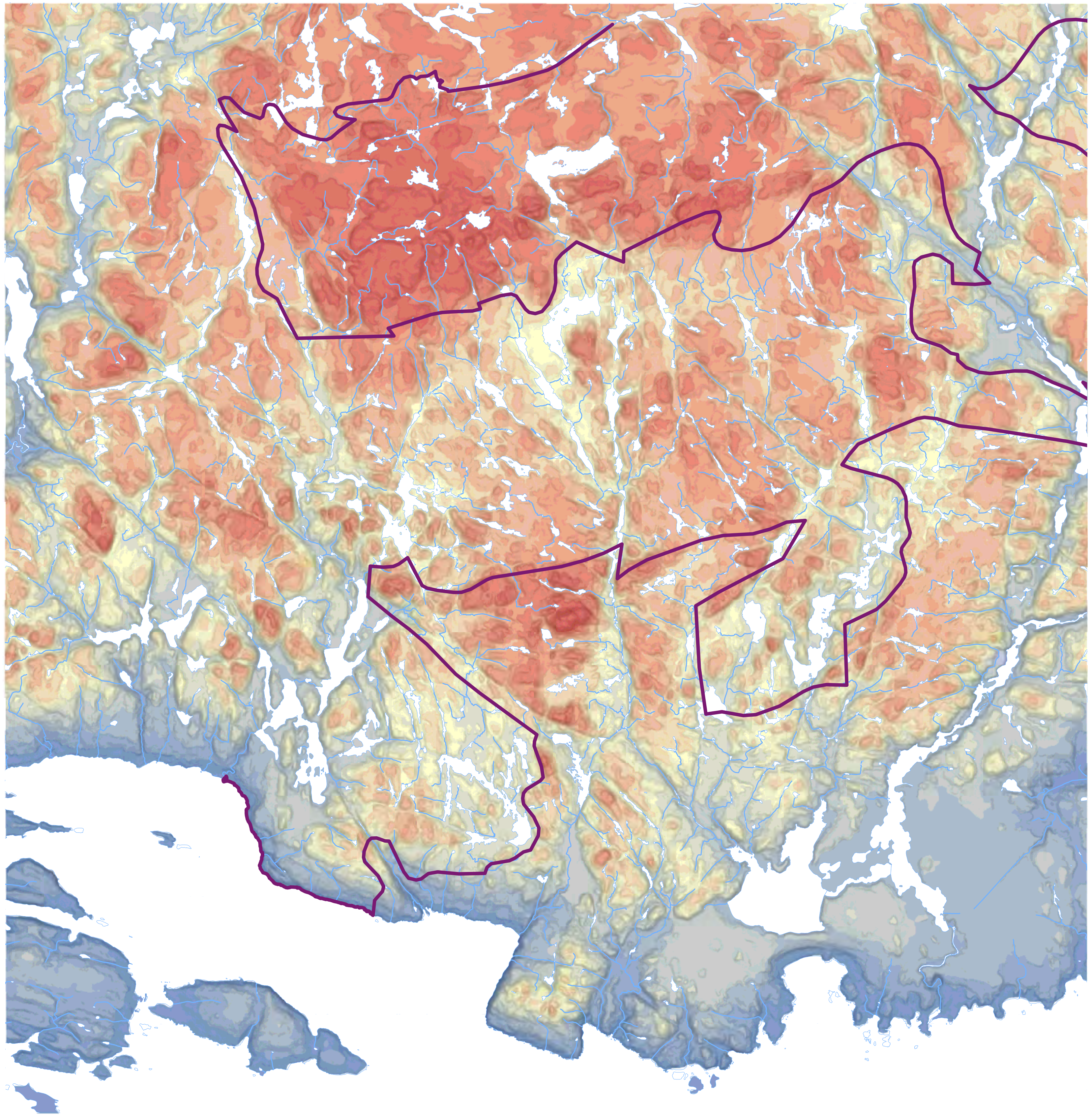
PROJECT

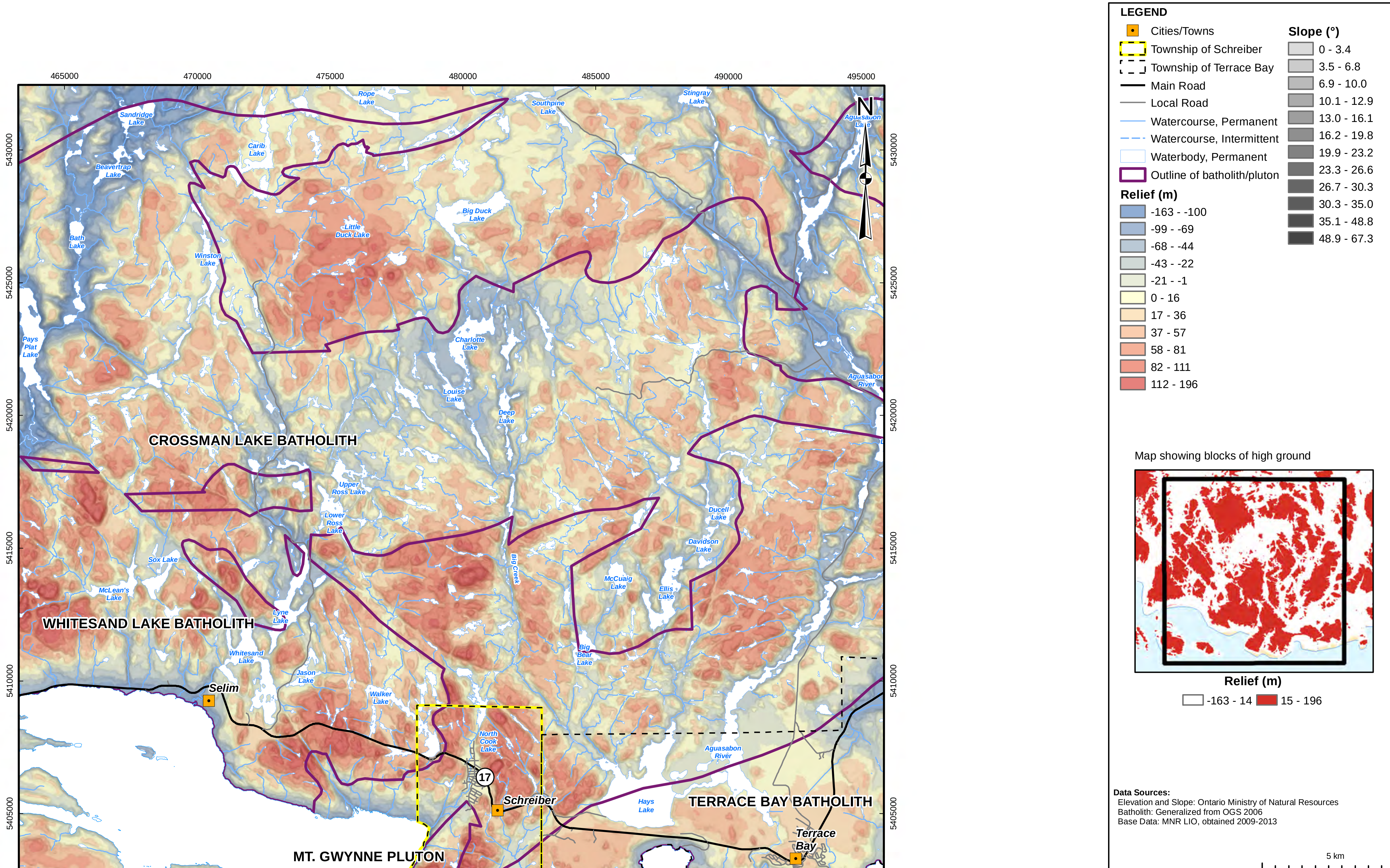
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT
TERRAIN AND REMOTE SENSING STUDY, SCHREIBER AREA, ONTARIO

TITLE

Surficial Geology of the Schreiber Area

DESIGN	GHF	14 Aug 2012	FIGURE 3	REVISION 4
GIS	GHF	4 Feb 2013		UTM ZONE 16
CHECK	CB	5 Feb 2013		NAD 1983
REVIEW	CB	5 Feb 2013		1:150,000





AECOM

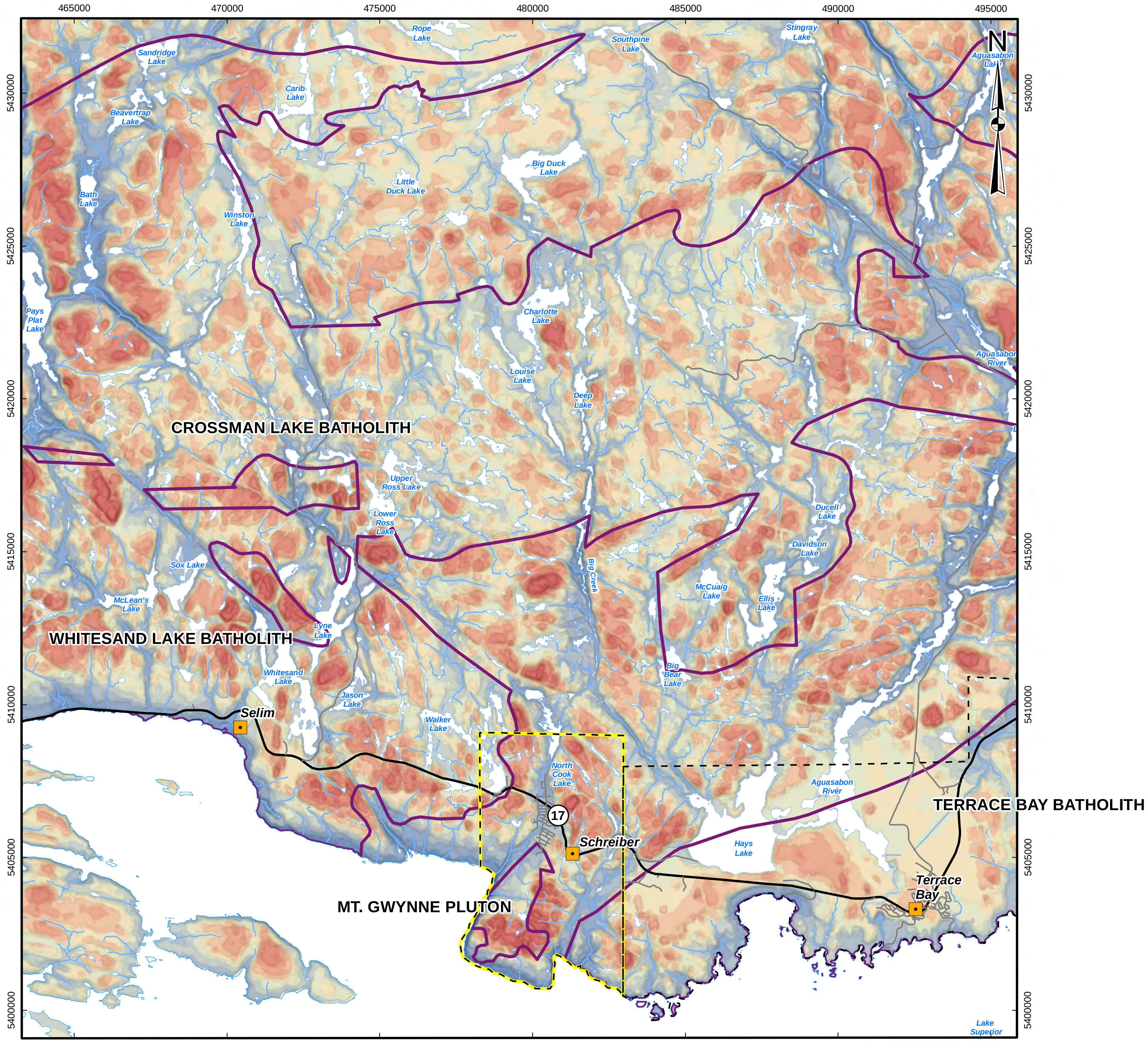
PROJECT

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT
TERRAIN AND REMOTE SENSING STUDY, SCHREIBER AREA, ONTARIO

TITLE

Departure from Average Elevation Within a 10 km Radius

DESIGN	GHF	14 Aug 2012	FIGURE 5	REVISION 4
GIS	GHF	4 Feb 2013		UTM ZONE 16
CHECK	CB	5 Feb 2013		NAD 1983
REVIEW	CB	5 Feb 2013		1:150,000



LEGEND

- Cities/Towns
- Township of Schreiber
- Township of Terrace Bay
- Main Road
- Local Road
- Watercourse, Permanent
- Watercourse, Intermittent
- Waterbody, Permanent
- Outline of batholith/pluton

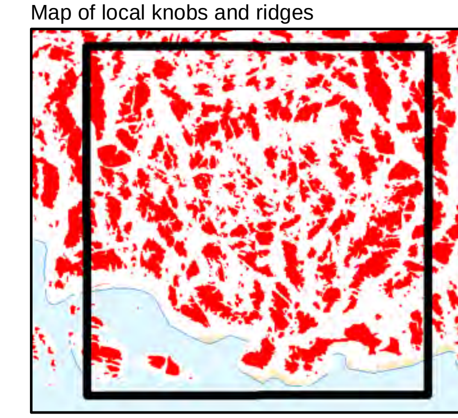
Relief (m)

- -129 - -66
- -65 - -44
- -43 - -27
- -26 - -12
- -11 - 1
- 2 - 14
- 15 - 28
- 29 - 46
- 47 - 69
- 70 - 135

Slope (°)

- 0 - 3.4
- 3.5 - 6.8
- 6.9 - 10.0
- 10.1 - 12.9
- 13.0 - 16.1
- 16.2 - 19.8
- 19.9 - 23.2
- 23.3 - 26.6
- 26.7 - 30.3
- 30.3 - 35.0
- 35.1 - 48.8
- 48.9 - 67.3

Map of local knobs and ridges



Relief (m)

-128 - 10 11 - 135

Data Sources:
Elevation and Slope: Ontario Ministry of Natural Resources
Batholith: Generalized from OGS 2006
Base Data: MNR LIO, obtained 2009-2013

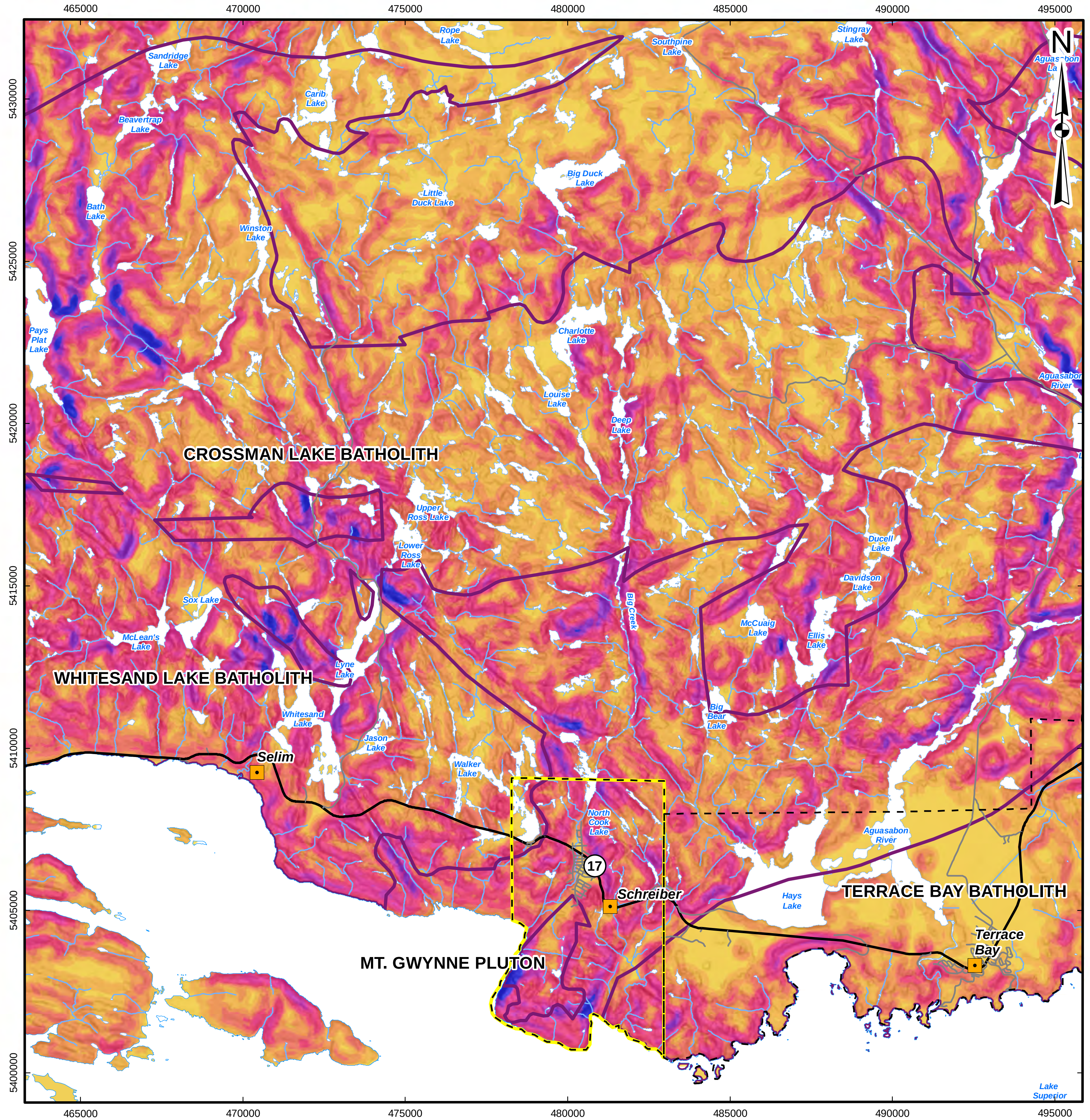
5 km

AECOM

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT
TERRAIN AND REMOTE SENSING STUDY, SCHREIBER AREA, ONTARIO

TITLE
Departure from Average Elevation Within a 2 km Radius

DESIGN	GHF	14 Aug 2012	FIGURE 6	REVISION 4
GIS	GHF	4 Feb 2013		UTM ZONE 16
CHECK	CB	5 Feb 2013		NAD 1983
REVIEW	CB	5 Feb 2013		1:150,000



LEGEND

- Cities/Towns
- Township of Schreiber
- Township of Terrace Bay
- Main Road
- Local Road
- Watercourse, Permanent
- Watercourse, Intermittent
- Waterbody, Permanent
- Outline of batholith/pluton

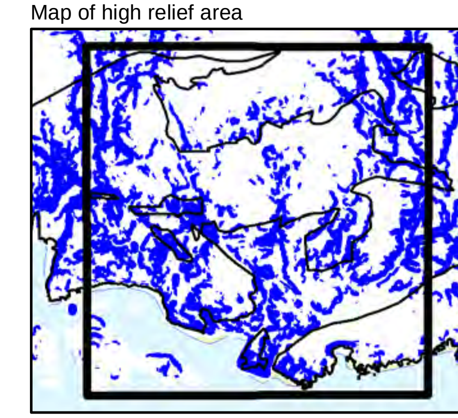
Relief (m)

- 0 - 20
- 21 - 34
- 35 - 47
- 48 - 60
- 61 - 73
- 74 - 87
- 88 - 102
- 103 - 120
- 121 - 144
- 145 - 206

Slope (°)

- 0 - 3.4
- 3.5 - 6.8
- 6.9 - 10.0
- 10.1 - 12.9
- 13.0 - 16.1
- 16.2 - 19.8
- 19.9 - 23.2
- 23.3 - 26.6
- 26.7 - 30.3
- 30.3 - 35.0
- 35.1 - 48.8
- 48.9 - 67.3

Map of high relief area



LEGEND

Relief (m)

- 0 - 57
- 58 - 206

Data Sources:
Elevation and Slope: Ontario Ministry of Natural Resources
Batholith: Generalized from OGS 2006
Base Data: MNR LIO, obtained 2009-2013

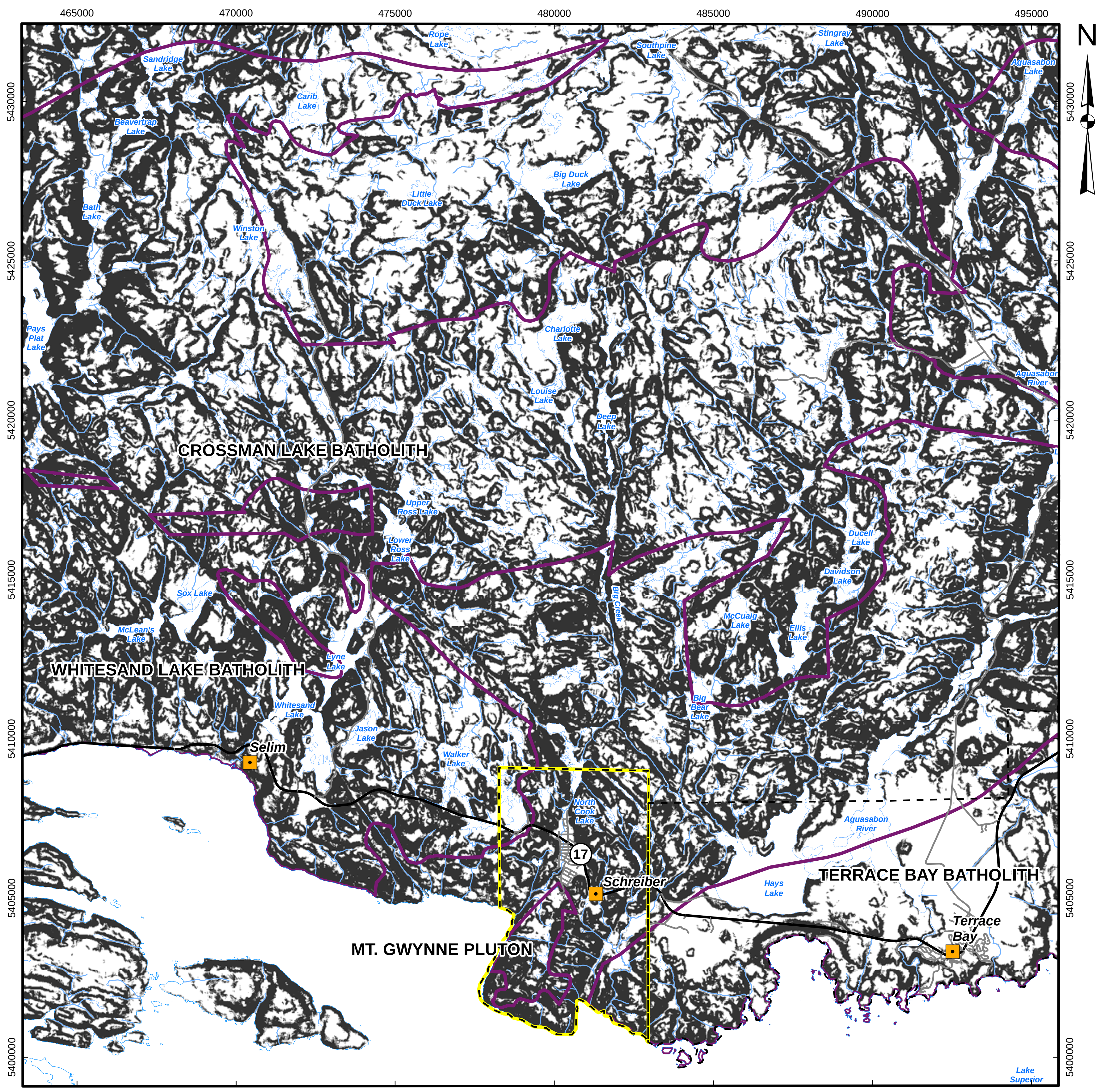
5 km

AECOM

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT
TERRAIN AND REMOTE SENSING STUDY, SCHREIBER AREA, ONTARIO

TITLE
Range in Elevation Within a 250 m Radius

DESIGN	GHF	14 Aug 2012	FIGURE 7	REVISION 4
GIS	GHF	4 Feb 2013		UTM ZONE 16
CHECK	CB	5 Feb 2013		NAD 1983
REVIEW	CB	5 Feb 2013		1:150,000



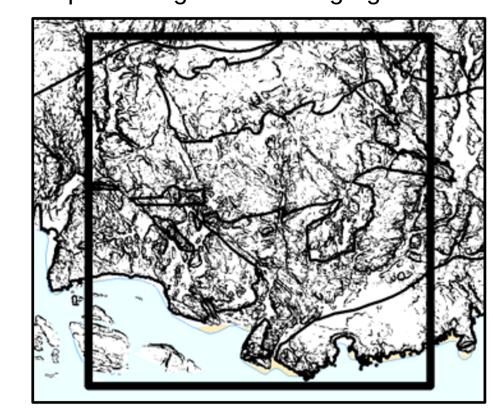
LEGEND

- Cities/Towns
- Township of Schreiber
- Township of Terrace Bay
- Main Road
- Local Road
- Watercourse, Permanent
- Watercourse, Intermittent
- Waterbody, Permanent
- Outline of batholith/pluton

Slope (°)

- 0 - 6
- 6.01 - 67

Map showing blocks of high ground



LEGEND

- 0 - 9.9
- 10 - 67

Data Sources:
Elevation and Slope: Ontario Ministry of Natural Resources
Batholith: Generalized from OGS 2006
Base Data: MNR LIO, obtained 2009-2013

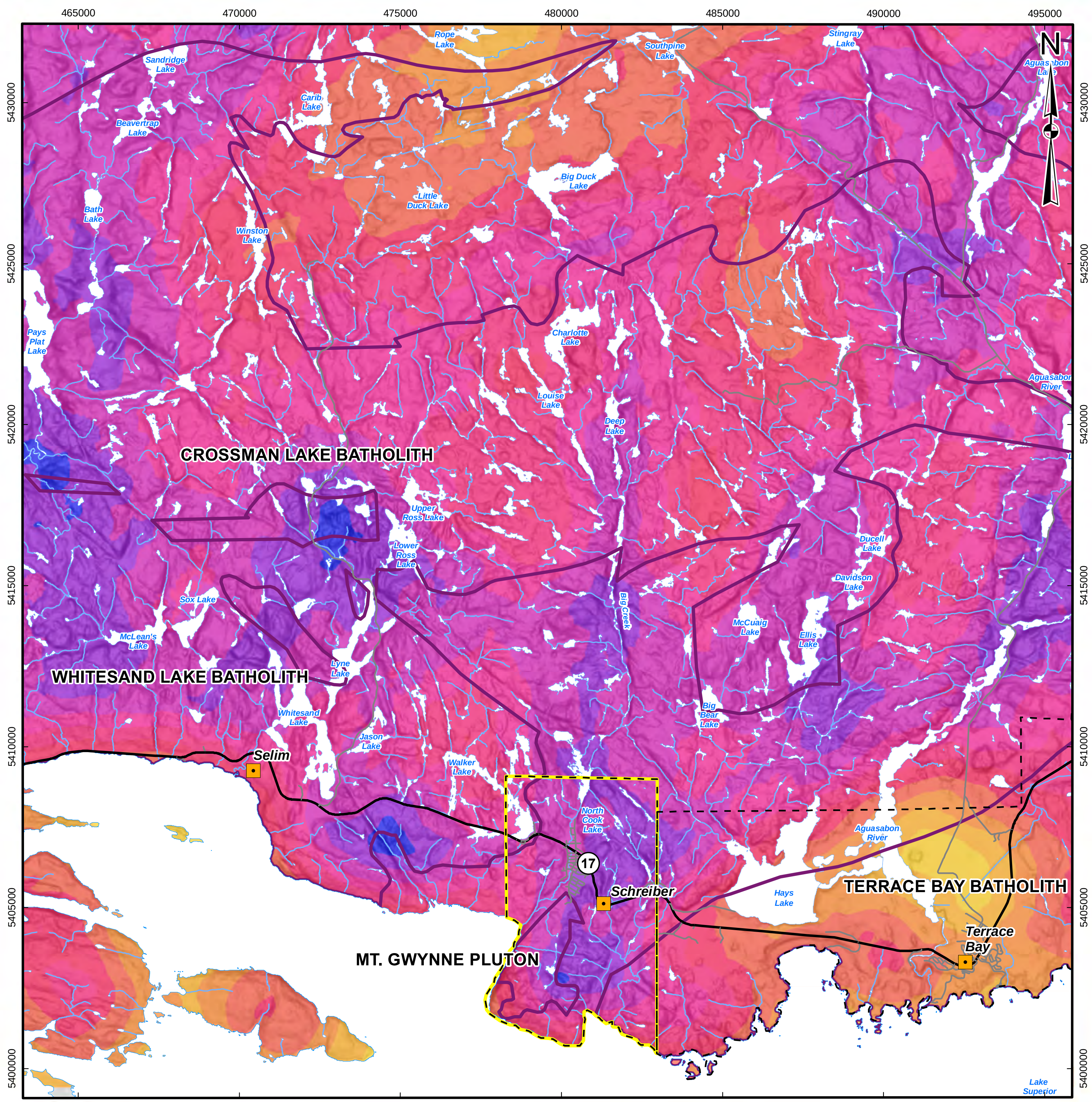
5 km

AECOM

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT
TERRAIN AND REMOTE SENSING STUDY, SCHREIBER AREA, ONTARIO

TITLE
Areas of 6° or Streeper Slope in the Schreiber Area

DESIGN	GHF	14 Aug 2012	FIGURE 8	REVISION 4
GIS	GHF	4 Feb 2013		UTM ZONE 16
CHECK	CB	5 Feb 2013		NAD 1983
REVIEW	CB	5 Feb 2013		1:150,000



LEGEND

- Cities/Towns
- Township of Schreiber
- Township of Terrace Bay
- Main Road
- Local Road
- Watercourse, Permanent
- Watercourse, Intermittent
- Waterbody, Permanent
- Outline of batholith/pluton

Slope Density

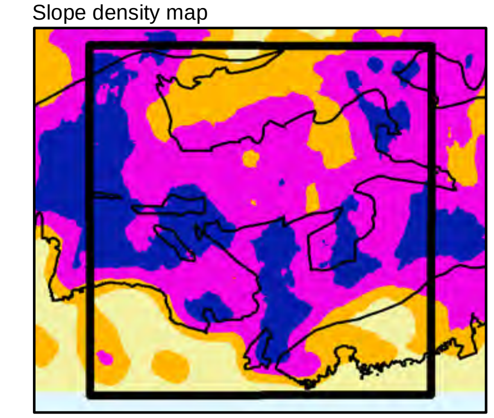
Points/km²

- 0 - 794
- 795 - 1,588
- 1,589 - 2,383
- 2,384 - 3,177
- 3,178 - 3,972
- 3,973 - 4,766
- 4,767 - 5,561
- 5,562 - 6,355
- 6,356 - 7,150
- 7,151 - 7,945

Slope (°)

- 0 - 3.4
- 3.5 - 6.8
- 6.9 - 10.0
- 10.1 - 12.9
- 13.0 - 16.1
- 16.2 - 19.8
- 19.9 - 23.2
- 23.3 - 26.6
- 26.7 - 30.3
- 30.3 - 35.0
- 35.1 - 48.8
- 48.9 - 67.3

Slope density map



LEGEND

Slope Density

Points/km²

- 0 - 1,986
- 1,987 - 3,972
- 3,973 - 5,958
- 5,959- 7,945

Data Sources:
Elevation and Slope: Ontario Ministry of Natural Resources
Batholith: Generalized from OGS 2006
Base Data: MNR LIO, obtained 2009-2013

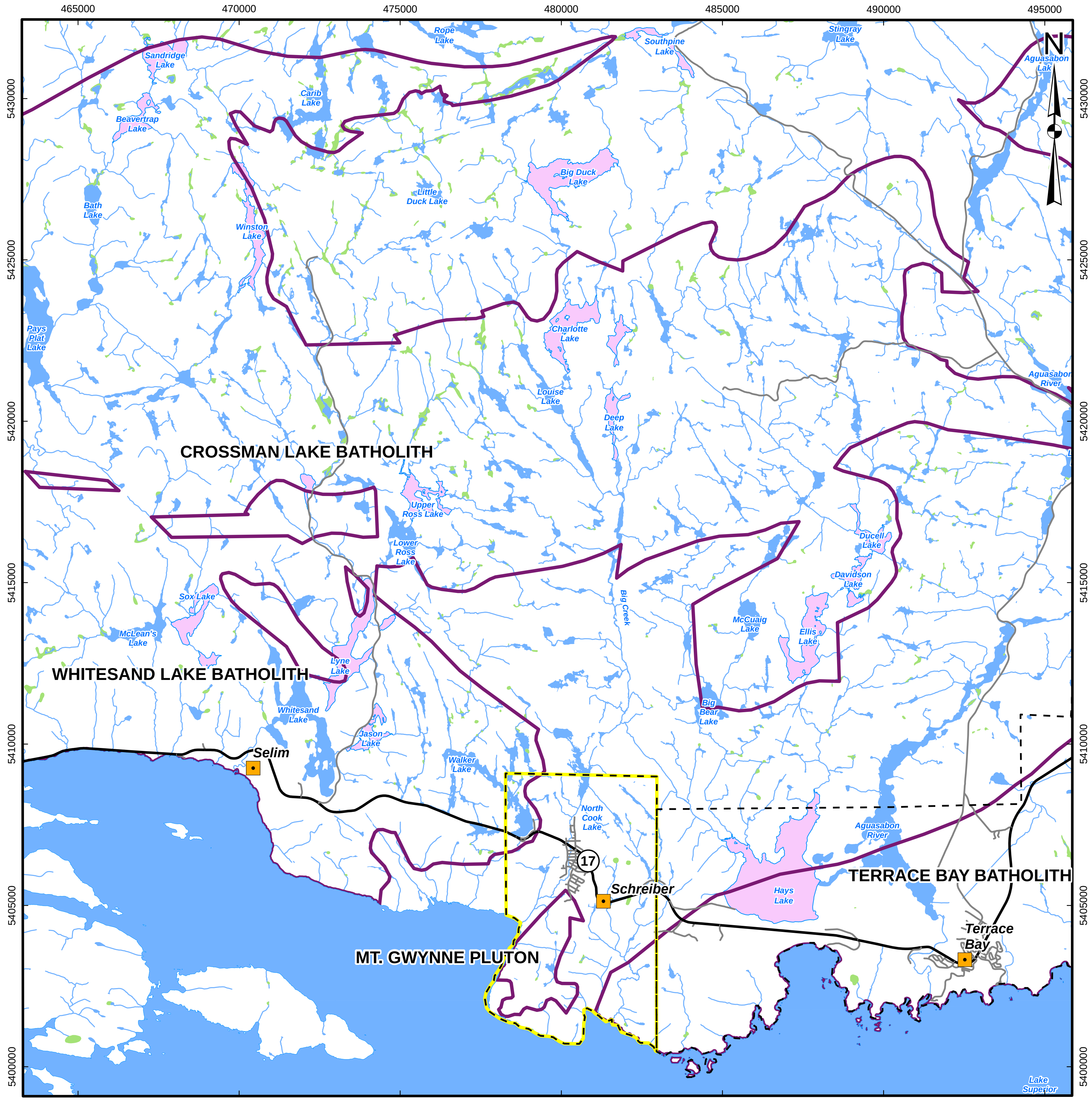
5 km

AECOM

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT
TERRAIN AND REMOTE SENSING STUDY, SCHREIBER AREA, ONTARIO

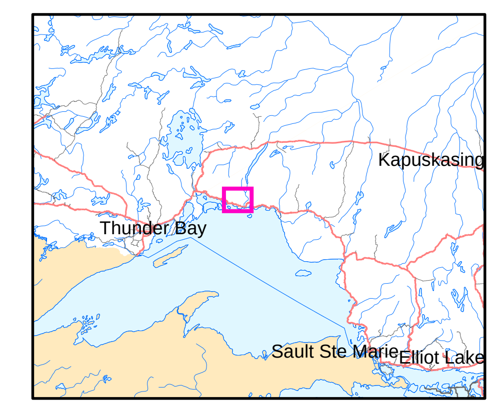
TITLE
Density of steep (≥6°) slopes within 2 km radius

DESIGN	GHF	14 Aug 2012	**FIGURE 9**	REVISION 4
GIS	GHF	4 Feb 2013		UTM ZONE 16
CHECK	CB	5 Feb 2013		NAD 1983
REVIEW	CB	5 Feb 2013		1:150,000



LEGEND

- Cities/Towns
- Township of Schreiber
- Township of Terrace Bay
- Main Road
- Local Road
- Watercourse, Permanent
- Watercourse, Intermittent
- Waterbody, Permanent
- Waterbody (depth survey)
- Wetlands
- Outline of batholith/pluton



Data Sources:
Batholith: Generalized from OGS 2006
Base Data: MNR LIO, obtained 2009-2013

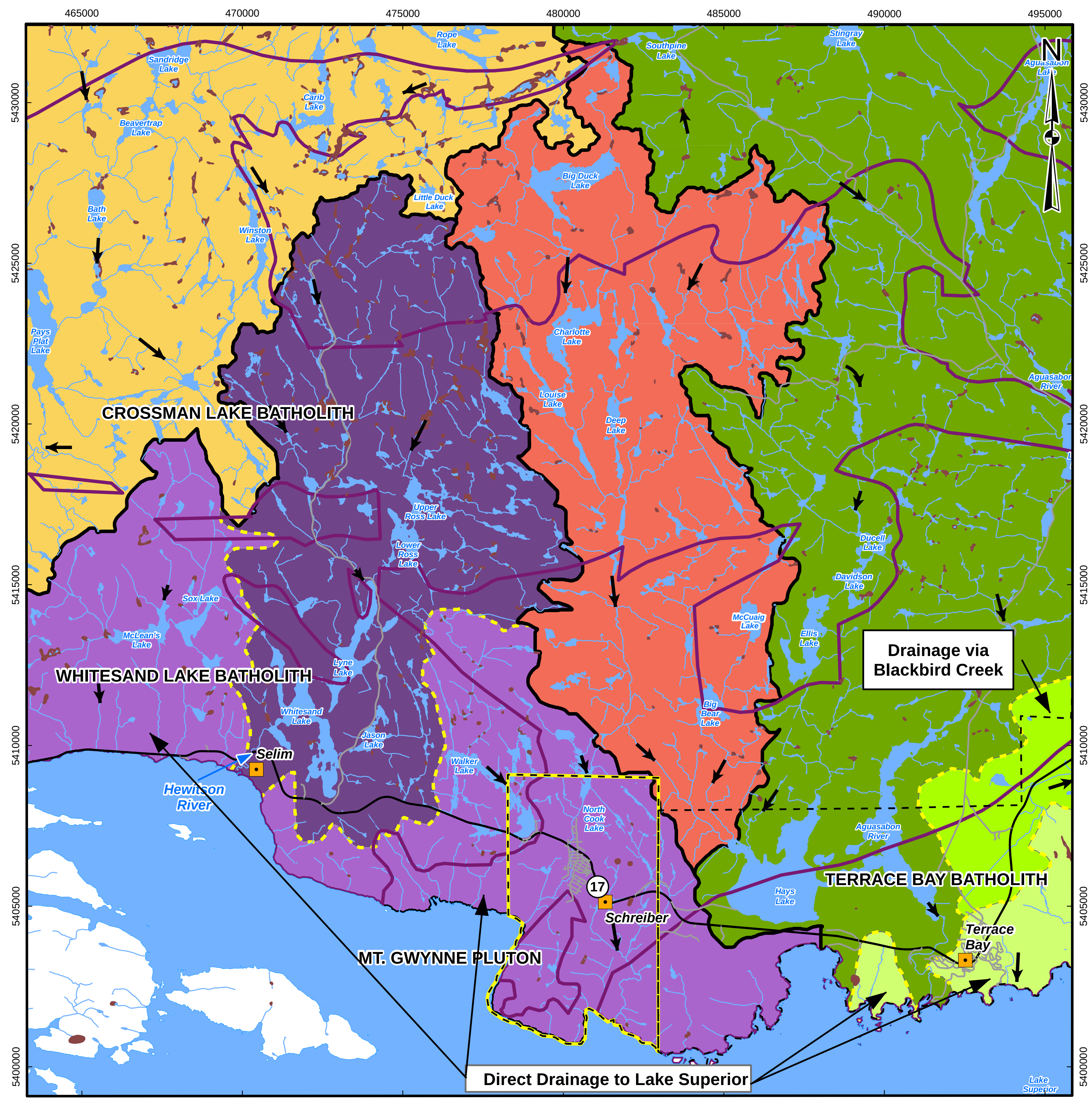
5 km

AECOM

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT
TERRAIN AND REMOTE SENSING STUDY, SCHREIBER AREA, ONTARIO

TITLE
Surface drainage features of the Schreiber Area

DESIGN	GHF	14 Aug 2012	FIGURE 10	REVISION 4
GIS	GHF	4 Feb 2013		UTM ZONE 16
CHECK	CB	5 Feb 2013		NAD 1983
REVIEW	CB	5 Feb 2013		1:150,000

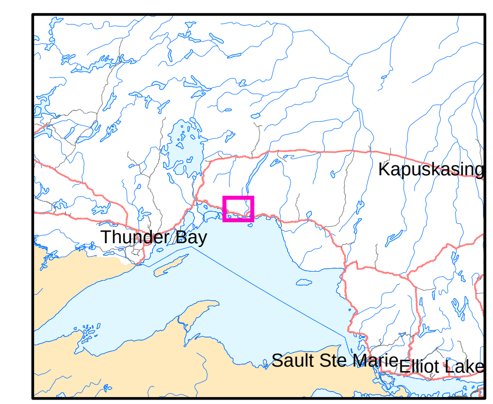


LEGEND

- City / Towns
- Township of Schreiber
- Township of Terrace Bay
- Main Road
- Local Road
- Surface Flow Direction
- Watercourse, Permanent
- Watercourse, Intermittent
- Waterbody, Permanent
- Wetlands
- Outline of batholith/pluton

Quaternary Watersheds

- Aguasabon River
  - Subwatershed Drainage Via Blackbird Creek
  - Subwatershed Direct Drainage to Lake Superior
- Big Duck Creek
- Pays Plat River
- Whitesand River
  - Subwatershed Direct Drainage to Lake Superior



Data Sources:
Batholith: Generalized from OGS 2006
Base Map: MNR LIO, obtained 2009-2013
Quaternary Watersheds: LIO Quaternary Watersheds

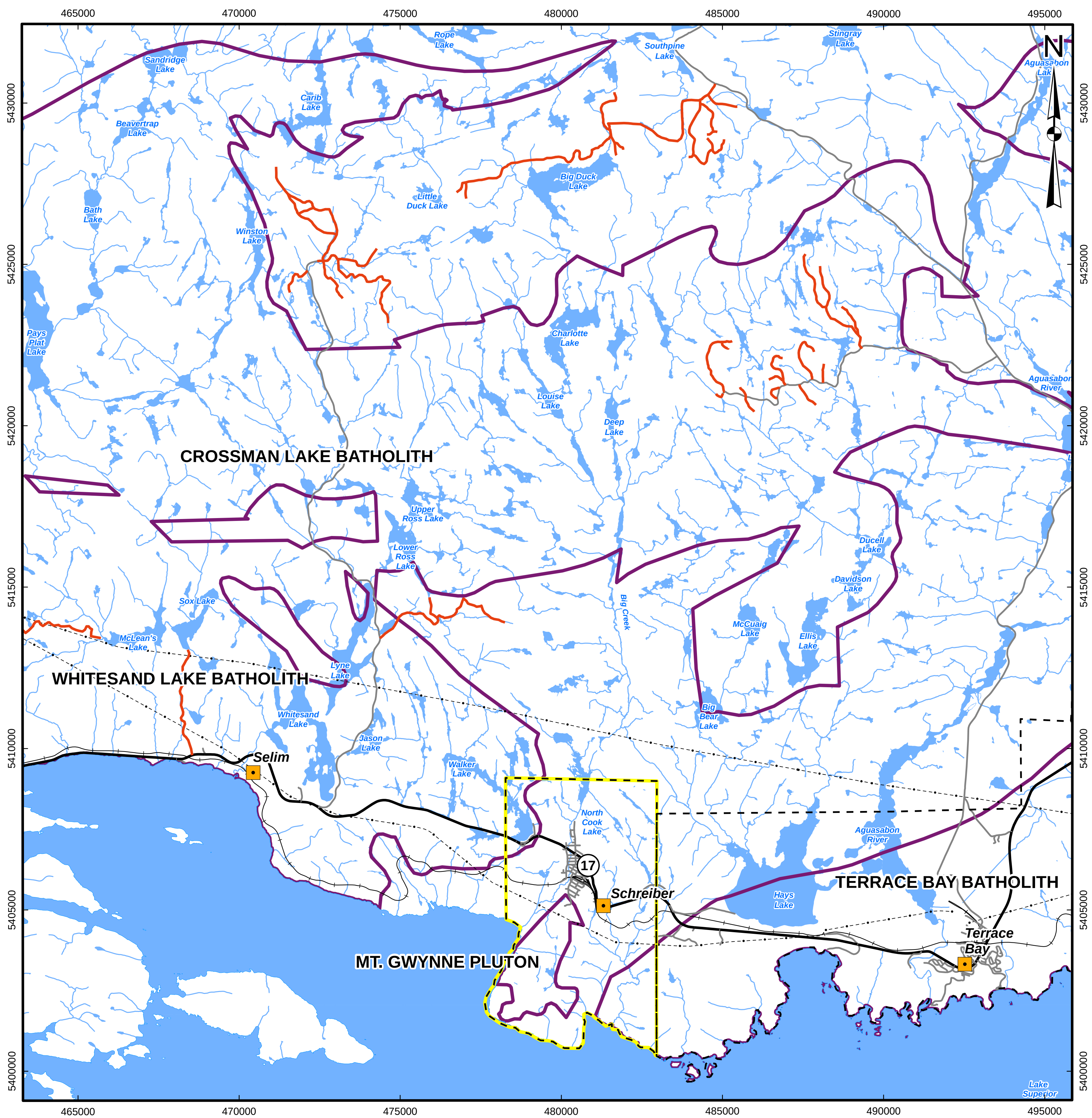
5 km

AECOM

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT
TERRAIN AND REMOTE SENSING STUDY, SCHREIBER AREA, ONTARIO

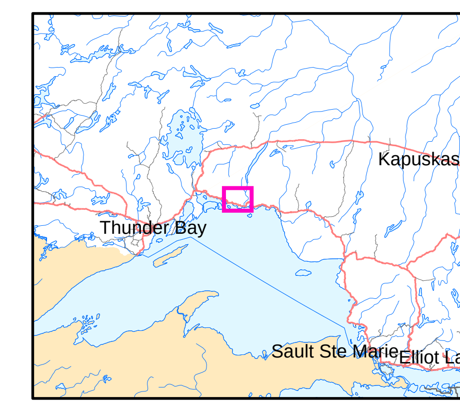
TITLE
Watersheds within the Schreiber Area

DESIGN	GHF	14 Aug 2012	FIGURE 11	REVISION 4
GIS	GHF	24 Jan 2013		UTM ZONE 16
CHECK	CB	31 Jan 2013		NAD 1983
REVIEW	CB	31 Jan 2013		1:150,000



LEGEND

- Cities/Towns
- Township of Schreiber
- Township of Terrace Bay
- Main Road
- Local Road
- Trails
- Railway
- Transmission Line
- Watercourse, Permanent
- Watercourse, Intermittent
- Waterbody, Permanent
- Outline of batholith/pluton



Data Sources:
Batholith: Generalized from OGS 2006
Base Data: MNR LIO, obtained 2009-2013

5 km

AECOM

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT
TERRAIN AND REMOTE SENSING STUDY, SCHREIBER AREA, ONTARIO

TITLE
Road network in the Schreiber Area

DESIGN	GHF	14 Aug 2012	FIGURE 12	REVISION 4
GIS	GHF	4 Feb 2013		UTM ZONE 16
CHECK	CB	5 Feb 2013		NAD 1983
REVIEW	CB	5 Feb 2013		1:150,000