nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

May 5, 2011

The Corporation of the Township of Ear Falls
P.O. Box 309
Ear Falls, ON P0V 1T0

Attn: Mayor and Members of Council

Re: Council Resolution 256 – Request for Information/Request for Screening

Dear Mayor Kahoot and Council,

Further to Council's request to Learn More about the Adaptive Phased Management program and request for an initial screening, I am pleased to attach a report outlining the findings from the initial screening, as described in the *Process for Selecting a Site for Canada's Deep Geological Repository for Used Nuclear Fuel* (May, 2010). As you know, the purpose of the initial screening in Step 2 of the process is to determine whether, based on readily-available information and five screening criteria, there are any obvious conditions that would exclude the Township of Ear Falls from further consideration in the site selection process.

As the report indicates, the review of readily-available information and the application of the five initial screening criteria did not identify any obvious conditions that would exclude the Township of Ear Falls from further consideration in the NWMO site selection process. The initial screening suggests that there are areas within the boundaries and at the periphery of the Township of Ear Falls that are potentially suitable for hosting a deep geological repository for Canada's used nuclear fuel. It is important to note that this initial screening has not confirmed the suitability of your community. Should your community choose to continue to explore its potential interest in the project, your area would be the subject of progressively more detailed assessments against both technical and social factors. Several years of studies would be required to confirm whether a site within your area could be demonstrated to safely contain and isolate used nuclear fuel.

The process for identifying an informed and willing host community for a deep geological repository for the long-term management of Canada's used nuclear fuel is designed to ensure, above all, that the site which is selected is safe and secure for people and the environment, now and in the future. The NWMO expects that the selection of a preferred site would take between seven to ten years. It is important that any community which decides to host this project base its decisions on an understanding of the best scientific and social research available and its own aspirations. Should the Township of Ear Falls continue to be interested in exploring the project, over this period there would be ongoing engagement of your community, surrounding communities and others who may be affected. By the end of this process, Ear Falls as a whole community would need to clearly demonstrate that it is willing to host the repository in order for this project to proceed.

Tel 416.934.9814
Fax 416.934.9526
Toll Free 1.866.249.6966
22 St.Clair Avenue East 6th Floor
Toronto Ontario Canada M4T 2S3
www.nwmo.ca

The next evaluation step would be to conduct a feasibility study as described in Step 3 of the site selection process. This feasibility study would focus on areas selected in collaboration with the community. As your community considers whether it is interested in advancing to the feasibility study phase, the NWMO encourages you to continue community discussion and further learning about the project. Support programs are available to assist your community to reflect on its long-term vision and whether this project is consistent with achieving that vision. Programs and resources are also available to engage your community residents in learning more about this project and becoming involved. We would be very pleased to provide further information about these programs.

Once again, I thank you for taking the time to learn about Canada's plan for the safe, secure management of Canada's used nuclear fuel.

Sincerely,

Kathryn Shaver

Kathryn Shaver,
Vice President, APM Public Engagement and Site Selection

REPORT

A world of capabilities delivered locally

April 2011

INITIAL SCREENING FOR SITING A DEEP GEOLOGICAL REPOSITORY FOR CANADA'S USED NUCLEAR FUEL

Township of Ear Falls, Ontario

Submitted to:
Nuclear Waste Management Organization
22 St. Clair Avenue East, 6th Floor
Toronto, Ontario
M4T 2S3

Report Number: 10-1152-0110 (1000)

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Executive Summary

On August 26, 2010, the Township of Ear Falls expressed interest in learning more about the Nuclear Waste Management Organization (NWMO) site selection process to find an informed and willing community to host a deep geological repository for Canada's used nuclear fuel (NWMO, 2010). This report summarizes the findings of an initial screening, conducted by Golder Associates Ltd., to evaluate the potential suitability of the Ear Falls area against five screening criteria using readily available information. The purpose of the initial screening is to identify whether there are any obvious conditions that would exclude the Township of Ear Falls from the site selection process. As per discussions between the NWMO and Township Council, the initial screening focused on the Township of Ear Falls and its periphery, which are referred to as the "Ear Falls area".

The review of readily available information and the application of the five initial screening criteria did not identify any obvious conditions that would exclude the Township of Ear Falls from being further considered in the NWMO site selection process. The initial screening indicates that there are areas within the Township and at the periphery of the Township of Ear Falls that are potentially suitable for hosting a deep geological repository. Potential suitability of these areas would need to be further assessed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

It is important to note that the intent of this initial screening is not to confirm the suitability of the Ear Falls area to host a deep geological repository, but rather to provide early feedback on whether there are known reasons to exclude it from further consideration. Should the community of Ear Falls remain interested in continuing with the site selection process, more detailed studies will be required to confirm and demonstrate whether the Ear Falls area contains sites that can safely contain and isolate used nuclear fuel. The process for identifying an informed and willing host community for a deep geological repository for Canada's used nuclear fuel is designed to ensure, above all, that the site which is selected is safe and secure for people and the environment, now and in the future.

The five initial screening criteria are defined in the site selection process document (NWMO, 2010) and relate to: having sufficient space to accommodate surface and underground facilities, being outside protected areas and heritage features, absence of known groundwater resources at repository depth, absence of known natural resources and avoiding known hydrogeologic and geologic conditions that would make an area or site unsuitable for hosting a deep geological repository.

A brief summary of the assessment against each of the initial screening criterion is provided below.

Availability of Land

Review of available mapping and satellite imagery indicates that the Ear Falls area contains sufficient land to accommodate the surface and underground facilities associated with the repository and that could be accessible for construction and field investigation activities.

Protected Areas, Heritage Sites, Provincial Parks and National Parks

The Ear Falls area contains sufficient land outside of protected areas, heritage sites, provincial parks and national parks to accommodate the repository's facilities. There are two conservation reserves and two provincial parks in the Ear Falls area, three of which partly lie within the Township boundaries. These protected areas occupy a small portion of land in the Ear Falls area. Limited heritage constraints were identified in the Ear Falls area. Known archaeological sites are small and generally concentrated on the shores and islands of Lac Seul and along the Chukuni River. There are no national historic sites in the Ear Falls area. The absence of other locally protected areas would need to be confirmed in discussion with the community and Aboriginal peoples in the area during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

Absence of Known Groundwater Resources at the Repository Depth

The review of readily available information did not identify any known groundwater resources at repository depth (typically 500 m) for the Ear Falls area. The Ontario Ministry of the Environment Water Well Records indicates that no potable water supply wells are known to exploit aquifers at typical repository depths in the Ear Falls area or anywhere else in northern Ontario. Water wells in the Ear Falls area obtain water from overburden or shallow bedrock sources at depths ranging from 4 to 134 m, with most water wells in the area between 30 to 40 m deep. Based on experience in similar crystalline rock settings in the Canadian Shield, the likelihood of the existence of exploitable aquifers at typical repository depth in the Ear Falls area is low. The absence of groundwater resources would need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

Absence of Economically Exploitable Natural Resources as Known Today

Based on the review of readily available information, the Ear Falls area contains sufficient land free of known economically exploitable natural resources, to accommodate the required repository facilities. The Ear Falls area has a generally low potential for oil and gas resources and economic minerals. Mining activity in the Ear Falls area to date has been limited to the extraction of iron ore from the former Griffith Mine in the northern sector of the Township. Metallic mineral occurrences have been identified only in few localized areas within the Township of Ear Falls and its periphery. There is ongoing gold exploration within the Township of Ear Falls, but the economical potential for gold in that area remains unproven.

No Known Geological and Hydrogeological Characteristics That Would Prevent the Site from Being Safe

The review of readily available geoscientific information did not identify any obvious geological or hydrogeological conditions that would clearly exclude the Township of Ear Falls from the site selection process. There are a number of geological units with geoscientific characteristics that are potentially suitable for a deep geological repository for used nuclear fuel within the Ear Falls area. Examples of these units include the Wenasaga Lake Batholith, Bruce Lake Pluton, Bluffy Lake Batholith and the extensive metasedimentary migmatites.

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1.0 INTRODUCTION

On August 26, 2010, the Township of Ear Falls expressed interest in learning more about the Nuclear Waste Management Organization (NWMO) nine-step site selection process to find an informed and willing community to host a deep geological repository for Canada's used nuclear fuel (NWMO, 2010). This report presents the results of an initial screening, conducted by Golder Associates Ltd., as part of Step 2 in the site selection process, to evaluate the potential suitability of the Ear Falls area against five screening criteria using readily available information. As per discussions between the NWMO and the Township Council, the initial screening focused on the Township of Ear Falls and its periphery, which are referred to as the "Ear Falls area" in this report.

1.1 Background

The ultimate objective of Adaptive Phased Management (APM) is long-term containment and isolation of used nuclear fuel in a deep geological repository in a suitable rock formation. The NWMO is committed to implementing the project in a manner that protects human health, safety, security and the environment, while fostering the long-term well-being of the community and region in which it is implemented (NWMO, 2005).

In May 2010, the NWMO published and initiated a nine-step site selection process to find an informed and willing community to host the repository (NWMO, 2010). The site selection process is designed to address a broad range of technical and social, economic and cultural factors as identified through dialogue with Canadians and Aboriginal peoples, and draws from experiences and lessons learned from past work and processes developed in Canada to site facilities for the management of other hazardous material. It also draws from similar projects in other countries pursuing the development of deep geological repositories for used nuclear fuel. The suitability of potential candidate sites will ultimately be assessed against a number of site evaluation factors, both technical and social in nature.

The geoscientific suitability of candidate sites will be assessed in three main phases over a period of several years, with each step designed to evaluate the site in progressively greater detail upon request of the community. The three site evaluation phases include: Initial Screenings to evaluate the potential suitability of the community against a list of initial screening criteria, using readily available information (Step 2); Feasibility Studies to determine if candidate sites within the proposed areas are potentially suitable for developing a safe deep geological repository for used nuclear fuel (Step 3); and Detailed Site Evaluations, at one or more selected sites, to confirm suitability based on detailed site evaluation criteria (Step 4). It is up to the communities to decide whether they wish to continue to participate in each step in the process.

1.2 Objectives and Approach for Conducting Initial Screenings

The overall objective of the initial screening is to evaluate proposed geographic areas against a list of screening criteria using readily available information. Initial screening criteria (NWMO, 2010) require that:

1) The site must have enough available land of sufficient size to accommodate the surface and underground facilities.

2) This available land must be outside of protected areas, heritage sites, provincial parks and national parks.

3) This available land must not contain known groundwater resources at the repository depth, so that the repository site is unlikely to be disturbed by future generations.

4) This available land must not contain economically exploitable natural resources as known today, so that the repository site is unlikely to be disturbed by future generations.

5) This available land must not be located in areas with known geological and hydrogeological characteristics that would prevent the site from being safe, considering the safety factors outlined in Section 6 of the Site Selection Document (NWMO, 2010).

The initial screening step involves the systematic consideration of each of the five initial screening criteria on a qualitative basis using readily available information from provincial, federal, municipal and other sources of information. It is not the intent of the initial screening study to conduct a detailed analysis of all available information, but rather to identify any obvious conditions that would exclude a community from the site selection process. For example, a site with known economically exploitable natural resources or geological or hydrogeological characteristics that are clearly unfavourable would be excluded from further consideration.

For cases where readily available information is limited and where assessment of some of the criteria is not possible at the screening stage, the area would be advanced to the feasibility study stage for more detailed evaluation provided the community remains interested in continuing to participate in the siting process.

The initial screening commences with an analysis of readily available information in order to develop an overall understanding of the geoscientific and other relevant characteristics of the site. The initial screening criteria are then applied in a systematic manner based on the understanding of the proposed area or site. The tasks involved include the following:

- Reviewing the regional and local physical geography, geology, seismicity, structural geology and Quaternary geology (surface geology);
- Reviewing the hydrogeology, including, regional groundwater flow, deep and shallow aquifers and hydrogeochemistry;
- Reviewing the economic geology, including petroleum resources, and metallic and non-metallic mineral resources;
- Applying the screening criteria; and
- Summarizing the findings with regards to potential suitability.

2.0 PHYSICAL GEOGRAPHY

2.1 Location

The Township of Ear Falls is situated in the District of Kenora in northwestern Ontario, at the northwestern end of Lac Seul, as shown on Figure 2.1. The Township of Ear Falls is located approximately 98 km northwest of Vermillion Bay, and approximately 65 km southeast of Red Lake and covers approximately 350 km^2 (Ear Falls Official Plan, 2004). Satellite imagery for the Ear Falls area (Landsat 7, taken in 2006) is shown on Figure 2.2.

2.2 Topography

The Township of Ear Falls is located in the Canadian Shield physiographic region, a low-relief, dome-like, gently undulating land surface with an elevation of about 150 masl (meters above sea level) in the north, increasing to about 450 masl towards the south. Figure 2.3 shows the general physiographic regions of Ontario (Thurston, 1991) including the subdivision of the Canadian Shield physiographic region into the Severn Upland, the Nipigon Plain, the Abitibi Upland and the Laurentian Highlands.

The Township of Ear Falls lies within the Severn Upland, a broadly rolling surface of Precambrian bedrock that occupies most of northwestern Ontario and which is either exposed at surface or shallowly covered with Quaternary glacial deposits. Terrains in the Severn Uplands contain numerous lakes (Thurston, 1991) and the terrain of the Ear Falls area is typical in that regard.

The land surface elevation in the Ear Falls area varies from approximately 350 to 400 masl, as shown on the digital elevation model, or DEM, (Figure 2.4) and drainage map (Figure 2.5) for the area. The northern part of the Township of Ear Falls is an area of low relief dominated by Bruce and Pakwash Lakes and their associated watercourses. In the central portion of the Township there is an area of high relief that trends roughly east-northeast to west-southwest. Further to the south, the topography is still moderately high, although the terrain has been eroded in places by tributaries of the Chukuni River. Surface Topography is also high at the southernmost end of the Township of Ear Falls, in the immediate vicinity of the settlement area of Ear Falls. The southwest boundary of the Township is dominated by the low topography of the Chukuni and English Rivers, which partially form the Township boundary itself. At the periphery of the Township of Ear Falls, higher elevations are identified mostly to the east.

The north-south trending Lac Seul Moraine, visible on the DEM (Figure 2.4) and the Quaternary geology map (Figure 3.9) is a dominant topographic feature in the Ear Falls area and represents the western extent of glacial ice during a re-advance of the Hudson Bay ice lobe, approximately 9,900 years ago (Teller, 1985). The moraine passes immediately to the east of the settlement area of Ear Falls in a north-south orientation and extends north and south of the Township.

2.3 Drainage

The Township of Ear Falls is located within the English River watershed, which is in turn part of the Winnipeg River sub-basin, which drains into the Nelson River basin, and eventually, Hudson Bay (Lake of the Woods Control Board, 2010). With reference to Figure 2.5, surface water generally flows through the Township of Ear Falls from the north and east, to the southwest. At the northeast corner of the Township, the Trout Lake River flows into Bruce Lake from the northeast and then into Pakwash Lake to the west. The outflow of Pakwash Lake is the Chukuni River, which flows to the south along the southwestern township boundary, where it joins the English River. The English River is the outflow from Lac Seul and it exits the lake at the southeast corner of the Township of Ear Falls. Water levels in Lac Seul are controlled by a hydroelectric dam operated by Ontario

Power Generation. The English River flows to the west, to where it joins the Chukuni River and then flows south into Camping Lake, and further to the southwest, where it is joined by the Wabigoon River, eventually joining the Winnipeg River.

2.4 Protected Areas

Parks and Reserves

There are two provincial parks and two conservation reserves in the Ear Falls area. Figure 2.1 shows the location of the Pakwash Provincial Park, Bruce Lake Conservation Reserve, Lac Seul Island Conservation Reserve and West English River Provincial Park.

The Pakwash Provincial Park is 40 km^2 in size, but only its easternmost portion (about 5 km^2) lies within the Township of Ear Falls on the eastern shores of Pakwash Lake. The remainder of the park extends to the west of the Township of Ear Falls, on the western shores of Pakwash Lake. It is co-managed by Ear Falls 2000 (a local community group) and the Provincial Government.

The Bruce Lake Conservation Reserve is now part of the Ontario Living Legacy program. This reserve is located east of Bruce Lake and encompasses 57 km^2 of peatlands and upland forests. Only the westernmost portion of the reserve, approximately 4 km^2, lies within the boundaries of the Township of Ear Falls. Two broad (up to 100 m wide) watercourses, Ten Mile Creek and Trout Lake River, flow roughly east to west through the northern portion of the reserve.

The Lac Seul Islands Conservation Reserve includes approximately 1,731 islands on Lac Seul. Some of these islands are within the Township of Ear Falls in the southeast.

The West English River Provincial Park is a waterway park that extends approximately 60 km along the English River from Barnston Lake, which is located approximately 15 km west of the Township of Ear Falls, to Tide Lake, which is located in the District of Kenora. The total area of the park is approximately 23 km^2, but only part of it lies within the Ear Falls area.

Heritage Sites

The cultural heritage screening examined known archaeological and historic sites in the Ear Falls area. Information on archaeological sites in Ontario is provided by the Ontario Ministry of Tourism and Culture, through their Ontario Archaeological Sites Database (Ontario Ministry of Tourism and Culture, undated).

There are 62 known archaeological sites in the Ear Falls area (Figure 2.1). For 53 of these sites, aside from their location, no information is contained in the database (e.g. time period or cultural affiliations are not provided). Of the remaining nine sites, five are identified as pre-contact (prior to European arrival) Aboriginal campsites, with three also having a later Euro-Canadian or historical Aboriginal occupation. Two sites have been identified as pre-contact Aboriginal activity sites: one being a Shield Archaic period fishing station and the other Woodland period chipping station. The remaining two sites are Euro-Canadian railway/marine sites. These latter four sites demonstrate the long duration of occupation by both Aboriginal and Euro-Canadian people in the area.

The archeological sites in the Ear Falls area are small, typically less than one hectare in size, and are mostly located on the shores and islands of Lac Seul. A few of the sites lie on the shores of Pakwash Lake and Wenasaga Lake and along the Chukuni River.

The potential for archaeological and historical sites along the English River and its associated tributaries is considered to be high as this watercourse was used as a major transportation route for both Aboriginal and Euro-Canadian people. There is also a high concentration of archaeological sites along Lac Seul, but no information, other than their location, is known. Archaeological potential is established by determining the likelihood that archaeological resources may be present on a subject property. In archaeological potential modeling, a distance to water criterion of 300 m is generally employed for primary water courses, including lakeshores, rivers and large creeks, while a criterion of 200 m is applied to secondary water sources, including swamps and small creeks (Government of Ontario, 1997).

There are no National Historic Sites in the Township.

3.0 GEOLOGY AND SEISMICITY

3.1 Regional Bedrock Geology

The geology of the Ear Falls area consists of unconsolidated Quaternary deposits overlying 2.5 to 3 billion year old bedrock of the Canadian Shield – a stable craton that forms the core of the North American continent. The Canadian Shield is a collage of Archean plates and accreted juvenile arc terranes and sedimentary basins of Proterozoic age that were progressively amalgamated. It was originally an area of very large mountains and intense volcanic activity, and was the first part of North America to be permanently elevated above sea level.

As shown on Figure 3.1, the Township of Ear Falls is situated within the Superior Province of the Canadian Shield. The Superior Province covers an area of approximately 1,500,000 km^2 stretching from the Ungava region of northern Québec through the northern part of Ontario and the eastern portion of Manitoba, and extending south through to Minnesota and the northeastern part of South Dakota.

The Superior Province has been divided into various subprovinces based on lithology, age, genesis, and metamorphism (Thurston, 1991). These subprovinces are also shown on Figure 3.1. The Township of Ear Falls lies largely within the English River Subprovince, which is an east-west trending, 30 to 100 km wide by 650 km long belt of metasedimentary and metamorphosed intrusive rocks extending from Manitoba to the Moose River Basin in the James Bay Lowlands. The English River Subprovince is bordered to the north by the Uchi Subprovince and to the south by the Bird River, Winnipeg River and Wabigoon Subprovinces. The northeastern corner of the Township of Ear Falls is part of the Uchi Subprovince.

Figure 3.2 shows the general bedrock geology and main structural features of the Western English River Subprovince and portions of its bounding subprovinces (Uchi, Winnipeg and Bird River). The English River Subprovince consists primarily of clastic metasedimentary rocks that have undergone regional migmatization and are intruded by 2.65 to 2.7 billion year old intrusive rocks (Breaks, 1991). The precursor sedimentary rocks have been interpreted as being mainly wackes and pellites that deposited in a fore-arc accretionary prism between at least 2.713 and 2.698 billion years ago (Percival and Easton, 2007), with much of the sediment content derived from a volcanic dominated source within the Uchi Subprovince (Breaks and Bond, 1993). Metavolcanic rocks account for only about 2% of the English River Subprovince. The Uchi Subprovince is a relatively narrow, east-trending region dominated by belts of metasedimentary and metavolcanic rocks that interweave intrusive complexes up to 3 billion years old (Stott and Corfu, 1991).

The closest regional faults to the Township of Ear Falls are the east-west trending Sydney Lake Fault and its related splay, the Long Legged Lake Fault (Figure 3.2). The Sydney Lake Fault transects the Township of Ear Falls about 7 km north of the settlement area and runs along the approximate boundary between the Uchi and English Subprovinces for a distance of about 450 km. The Wapesi Lake Fault is another fault in the region that lies approximately 30 km southeast of the Township of Ear Falls and runs in an east-northeast direction for about 140 km.

The English River Subprovince is generally composed of high metamorphic grade rocks with local granulite-grade zones. Metamorphic grades are generally lower in the Uchi Subprovince and the abrupt increase in metamorphic grade across the Uchi-English River Subprovince boundary may be the result of uplift of the English River Subprovince in relation to the adjacent metavolcanic complexes of the Uchi Subprovince (Breaks and Bond, 1993).

The northern boundary of the English River Subprovince with the volcanic-rich Uchi Subprovince is marked by the first appearance of metavolcanic rocks, a decrease in metamorphic grade, and the Sydney Lake Fault Zone.

The boundary between the English River Subprovince and the Winnipeg River and Wabigoon Subprovinces to the south is dominated by metamorphosed granitic intrusives and gneissic domes with no strong contrast in metamorphic facies.

On a regional scale, the English River Subprovince is dominated by an east-west striking mineral foliation with shallow to moderate plunges of 20° to 70° to the south. Typically, mineral foliation and compositional banding are coplanar in the predominant metasedimentary migmatite (Breaks and Bond 1993).

The geological history of the Ear Falls area can be summarized as follows (Breaks, 1991; Stott and Corfu, 1991):

- Until approximately 2.71 billion years ago major volcanic and igneous activity took place in the Uchi Subprovince. The final stages of volcanism in the Uchi Subprovince (2.72 to 2.71 billion years ago) involved intense and complex folding and faulting and coincided with sedimentation in a large sedimentary basin, the proto-English River Subprovince. Much of the sediment deposited in the English River Subprovince derived from a volcanic dominated source in the Uchi Subprovince.
- At about 2.71 billion years ago, the Kenoran compressional orogeny that affected the area caused the collision of the Wabigoon and Winnipeg River Subprovinces, involving complex folding, faulting and metamorphism in the boundary zone.
- An extensive intrusive magmatic event initiated approximately 2.7 billion years ago and led to the intrusion of mantle-derived melts into the interface between the English River Subprovince metasedimentary rocks and their basement.
- The magmatic activity continued and induced the emplacement of large volumes of magma underneath the 2.698 billion year old intrusions. The heat generated by this intrusion caused regional metamorphism that peaked 2.691 billion years ago and caused widespread, partial and total melting of the sedimentary rocks in the English River Subprovince. Coeval with this event was the intrusion of peraluminous granites (i.e. the Wenasaga Lake Batholith) and the shearing of the Sidney Lake and Long Legged Lake Faults.
- Two more episodes of metamorphism affected parts of the English River Subprovince approximately 2.68 and 2.67 billion years ago.

Gravity data for the region (Figure 3.3) shows a pronounced gravity high beneath the northern English River Subprovince, which has been the subject of considerable study (e.g. Gupta and Barlow, 1984; Nitescu et al., 2003). More recently, Nitescu et al. (2006) presented the most current interpretation of this gravity anomaly, which integrated gravity, magnetic and seismic geophysical data with surface geologic mapping. They hypothesized that the gravity anomaly is likely due to intrusions underlying the metasedimentary rocks in many places within the English River Subprovince. They infer that the metasedimentary rocks are on the order of less than 1 km thick where they are underlain by intrusives, and up to 4 km thick where they are not.

3.2 Local Bedrock Geology

3.2.1 Lithologies

The bedrock geology of the Ear Falls area is shown on Figure 3.4. Approximately 60% of the Township of Ear Falls is underlain by a belt of metasedimentary migmatites, which extends significantly beyond the township boundaries to the east, west and south. The metasedimentary migmatites are intruded by three plutonic masses within the Township of Ear Falls, the Bruce Lake and Pakwash Lake Plutons in the northeast corner of the Township and the Wenasaga Lake Batholith in the east-central portion of the Township. Both the Wenasaga

Lake Batholith and the Bruce Lake Pluton extend east of the Township boundary while the Pakwash Lake Pluton extends to the west. Smaller granitic/tonalitic intrusions are mapped within the metasedimentary migmatites in the south portion of the Ear Falls area. Airborne magnetic surveys (Figure 3.5) show several magnetic highs within the metasedimentary rocks, including an area immediately south of Pakwash Lake Provincial Park and a larger area immediately southwest of the Township limits, which may suggest the presence of additional unmapped intrusions in these areas.

Large intrusive bodies are also present at the periphery of the Township of Ear Falls (Figure 3.2). These include the 700 km^2 Bluffy Lake Batholith located some 12 km to the east of the Township boundary.

The metasedimentary migmatites that dominate the geology in the southern portion of the Township of Ear Falls formed as a result of high-grade metamorphism of the original sedimentary rocks. The low-pressure, high-temperature metamorphism that occurred in the area between 2.692 and 2.66 billion years ago produced partial melting of the precursor sedimentary rocks, resulting in the formation of migmatites comprised of two or more petrographically distinct components. Mapping of sedimentary relationships is difficult because primary structures have largely been obscured by high-grade regional metamorphism (Breaks, 1991). Nitescu et al. (2006) infer that the metasedimentary rocks are on the order of less than 1 km thick where they are underlain by intrusions, and up to 4 km thick, where they are not. These depth estimates are based on the integration of surface geologic mapping with gravity and magnetic data, and Lithoprobe seismic data from Line 2b, which runs through the Township of Ear Falls.

In the English River Subprovince, migmatites are classified according to their content of leucosome, which is the component of the rock that formed from segregated partial melting of the precursor sedimentary rock (Breaks, 1991). The most common migmatite in the Ear Falls area, as in most of the subprovince, is metatexite which is composed of gneiss with 10-70% of leucosome (Sanborn-Barrie et al., 2004). The leucosome is generally coarse grained and of granitic composition (Breaks, 1991).

In a small sector of the Township of Ear Falls, between the Bruce Lake and Pakwash Lake Plutons, the metasedimentary migmatites have been mapped as metamorphosed fine-grained clastic rocks and siliclastics with less that 10% of granitic leucosome. In this area, the metasedimentary rocks also comprise chert-magnetite ironstone (Sanborn-Barrie et al., 2004). Along the western shore of Bruce Lake the metasedimentary rocks contain an 80 m thick, interbedded banded iron formation (Griffith deposit) that was mined in the past (see Section 5.2).

Airborne radiometric data for the Ear Falls area (equivalent uranium) is provided on Figure 3.6. The gamma-ray spectrometry parameters (potassium, uranium and thorium) are often elevated in granitic rocks compared to volcanic or metasedimentary rocks. The changes in equivalent uranium response correlate well to the different lithologies mapped in the Ear Falls area; the metasediments generally have a low response, while the Wenesaga Lake Batholith has an elevated response. The Bruce Lake and Pakwash Lake Plutons have an attenuated response in places, possibly due to an increase in overburden thickness covering those areas or due to mineralogical heterogeneities across the intrusive bodies.

The main intrusive bodies occurring in the Ear Falls area are further described below and can be seen on Figures 3.2 and 3.4.

Wenasaga Lake Batholith

The Wenasaga Lake Batholith is a granite mass approximately 7 km wide by 26 km long that likely formed by the partial melting of the sedimentary host rock in conjunction with local injections of fresh magma (Breaks, 1991).

The batholith consists of a variety of peraluminous granite units ranging from massive to foliated with cataclastic units locally present. The granite units are well exposed in a blast cut along the former Griffith Iron Mine rail line near Detector Lake (Breaks et al., 2003). At this location, biotite-muscovite pegmatitic leucogranite grades into a biotite-rich granite containing inclusions of metasedimentary gneiss incorporated from the surrounding country rock.

The batholith is estimated to be of a similar age to the surrounding metasedimentary rocks, between 2.7 and 2.691 billion years old (Breaks, 1991; Nitescu, 2006), and has been deformed in a similar manner with two identified schistosities (Breaks et al., 2003). The first schistosity is coincident with the first period of metamorphism and generally parallels the metasedimentary structure. A second schistosity, relating to a second period of metamorphism, is superimposed over the first and is difficult to recognize except in mafic dikes which postdate folding.

The batholith has been examined for potential linkage with a metasedimentary-hosted rare-element pegmatite mineralization (the Sandy Creek beryl deposit) located adjacent to the southwestern flank of the batholith (Breaks et al., 2003). A gravity low associated with the Wenasaga Lake Batholith (see Figure 3.3) suggests that the batholith extends to substantial depth.

Bruce Lake Pluton

The Bruce Lake Pluton has been described by Shklanka (1970), and Breaks and Bond (1993). The approximately 200 km^2 pluton intrudes clastic metasedimentary rocks near the contact between the Uchi and English River Subprovinces.

The rock is medium-grained, light- to medium-grey and mainly massive with only localized and weak foliation (Shklanka, 1970). In composition, the rock varies from medium-grained biotite-hornblende diorite to quartz diorite to locally monzodiorite and gabbro with enclaves of sedimentary and volcanic rocks (Breaks and Bond, 1993; Sanborne-Barrie et al., 2004). Compositional variation is described as chaotic and gradational with few readily mappable contacts between the rock phases. Fragments or enclaves of mafic metavolcanic rocks and hornblendite are commonly incorporated within the pluton, whereas intermediate metavolcanic and trondhjemite to quartz diorite enclaves are rare.

Shklanka (1970) also describes contact breccias on the peninsula at the north end of the south half of Bruce Lake (Iron Bay) and interpreted the structural and lithological relationships at that location as indicative of granitic emplacement into an originally metamorphosed terrane.

The Bruce Lake Pluton appears to have intruded into the metasedimentary strata as evidenced by the presence of enclaves of metasedimentary rocks within the pluton (Shklanka, 1970; Breaks and Bond, 1993). This interpretation is supported by the apparent “wrapping” of the iron formation around the pluton as can be seen on the airborne magnetic survey for the area (see Figure 3.5). This is also supported by the presence of at least one schistosity, pre-dating the Bruce Lake Pluton in the metasedimentary rocks around the intrusion (Shklanka, 1970). This suggests an age of between 2.69 and 2.67 billion years based on the timing of the regional deformation described by Breaks (1991) and Stott and Corfu (1991). No information was found in readily available literature on the thickness of the Bruce Lake Pluton.

Pakwash Lake Pluton

The elliptical Pakwash Lake Pluton is located in the northwestern section of the Township of Ear Falls and is approximately 2 by 5 km in size. The intrusion is exposed on the western shore of Pakwash Lake. No information on the thickness of this intrusion was found in the readily available literature.

The pluton is structurally and mineralogically similar to the Bruce Lake Pluton, with weak foliation and composition ranging from quartz diorite to diorite. Relative to the Bruce Lake Pluton, the Pakwash Pluton has less quartz and more mafic minerals. Shklanka (1970) suggests a common parentage and contemporaneous age for the Bruce Lake and Pakwash Lake Plutons based on their mineralogical similarities.

In the Pakwash Lake Pluton, the rocks commonly possess a marked mineral lineation defined mainly by the alignment of amphibole grains. Contacts of the pluton with the host metasedimentary rocks are usually sharp (Shklanka, 1970).

Bluffy Lake Batholith

The Bluffy Lake Batholith is located approximately 12 km east of the Township of Ear Falls boundary and has a surface extension of more than 700 km^2. It is a heterogeneous batholith that comprises multiple phases of magmatic intrusion ranging in age from 3 to 2.7 billion years (Breaks, 1991). The Bluffy Lake Batholith is considered an intrusive complex composed of several units, with composition ranging from trondhjemite to quartz diorite and textures ranging from massive to foliated and gneissic. Contacts with the metasedimentary country rock are typically sharp (Breaks, 1991).

In contrast to the Wenasaga Lake Batholith, the Bluffy Lake Batholith shows little gravity response relative to the surrounding rocks (Figure 3.3). Gupta and Wadge (1986) suggest a sheet thickness of 1.5 to 3 km for the Bluffy Lake Batholith.

3.2.2 Metamorphism and Deformation

A comprehensive overview of metamorphism across the Superior Province of the Canadian Shield is provided by Easton (2000). The major periods of metamorphism in the English River Subprovince occurred between 2.71 and 2.68 billion years ago (Breaks, 1991).

Mapping by Breaks and Bond (1977; 1993) revealed that the English River Subprovince is generally composed of high metamorphic grade rocks with local granulite-grade zones. The metamorphic grade generally increases to the south with distance from the Uchi-English River boundary, although variable uplift of the English River assemblage and the extensive post-regional metamorphic fault systems between the two subprovinces frequently obscure this trend. The rocks in the Township of Ear Falls are of high metamorphic grade, except in the extreme north of the Township which falls within the Uchi Subprovince. Metamorphic grades in this area include amphibolites facies (Shklanka, 1970).

Rocks within the metasedimentary migmatite-dominated English River Subprovince have been subjected to multiple phases of folding, shearing, fracturing and faulting (Breaks et al., 1976; Breaks, 1991; Westerman, 1977). All the structures in the area have been traditionally recognized to have developed in four Archean deformation stages: three folding phases, followed by a phase of brittle deformation (Breaks, 1991). The second phase was by far the most important deformation event, extending at a regional scale and overprinting former deformation events. More recent revisions to the number of phases and processes undergone have been recently suggested (Hrabi and Cruden, 2006).

A large regional fault zone (the Sydney Lake-Lake St. Joseph Fault Zone) largely coincides with the boundary between the Uchi and English River Subprovinces (Figure 3.2). In the Ear Falls area, the Sydney Lake Fault Zone transects the central portion of the Township running east-west along the south margin of the Wenasaga Lake Batholith about 7 km north of the settlement area of Ear Falls (Figure 3.4). Nitescu et al. (2006), based on magnetic and seismic data, suggest that a splay (branch) of this fault may transect the Wenasaga Lake Batholith, but it has not been mapped or confirmed. The Long Legged Lake fault is related to the Sydney Lake Fault Zone and runs along the northeast margin of the Bruce Lake Pluton (Figure 3.4). The Sydney Lake Fault Zone has been interpreted by Stott and Corfu (1991) to have initiated as a north-verging thrust fault. This fault subsequently served as a dextral transcurrent shear zone in the late stage of Archean crustal history (post 2.702 billion years).

The fault zones that transect the Township of Ear Falls are approximately 1 to 2 km wide zones of ductile deformation composed of protomylonite and mylonite developed from metasedimentary migmatites, peraluminous granites, metamorphosed felsic to intermediate intrusive rocks, and metavolcanic units (Stott and Corfu, 1991). Smaller scale faults, displaying little or no offset in stratigraphy, are abundant throughout the Uchi Subprovince and Red Lake region outside of the boundaries of the Township (Gupta and Wadge, 1986). Several of these faults are shown on Figure 3.4 to the north of Pakwash Lake and along the northern border of the Bruce Lake Pluton.

The Sydney Lake and Long Legged Lake fault zones represent the final major Archean structural event in the Ear Falls area post 2.702 billion years (Breaks and Bond, 1993). No evidence of significant post-Archean activity along these fault zones has been reported in the available literature.

3.2.3 Neotectonic Activity

Neotectonics refers to deformations, stresses, and displacements in the earth's crust of recent age or which are still occurring. The geology of the Ear Falls area is typical of many areas of the Canadian Shield, which has been subjected to numerous glacial cycles during the last million years (Shackleton et al., 1990; Peltier, 2002). 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 near the Manitoba border with North Dakota (Brevic and Reid, 1999), due to the weight of glacial ice. The amount of crustal depression in the Ear Falls area would be of a similar magnitude but slightly greater due to its closer proximity to the main centre of glaciation.

Post-glacial isostatic rebound began with the waning of the continental ice sheets and is still occurring across most of Ontario. The greatest rates of crustal rebound (approximately 12 mm/a) are recorded in the Hudson Bay region, where the thickest glacial ice occurred (Sella et al., 2007). As a result of the glacial unloading, horizontal stresses are created locally in shallow bedrock in many areas of Ontario. Natural stress release features include elongated compressional ridges or pop-ups such as those described in White et al. (1973) and McFall (1993).

No detailed identification and interpretation of lineaments is available in the published literature for the Ear Falls area. It is therefore useful to review the findings of previous field studies involving fracture characterization and evolution as it may pertain to glacial unloading. McMurry et al. (2003) summarized several studies conducted in a number of plutons in the Canadian Shield and in the crystalline basement rocks in Western Ontario. These various studies found that fractures below a depth of several hundred metres in the plutonic rock were ancient features. Early-formed fractures have tended to act as stress domain boundaries. Subsequent stresses, such as those caused by plate movement or by continental glaciation, generally have been relieved by reactivation along the existing zones of weakness rather than by the formation of large, new fracture zones.

In summary, no neotectonic structural features are known to occur within the Ear Falls area.

3.3 Seismicity

The Township of Ear Falls lies in the Superior Province of the Canadian Shield, where large parts have remained tectonically stable for the last 2.5 billion years (Percival and Easton, 2007). Although Hayek et al. (2009) indicate that the general Western Superior Province has experienced a number of low magnitude, shallow seismic events, all recorded earthquakes in the Ear Falls area have a magnitude less than 4. Figure 3.7 presents the location of earthquakes with a magnitude greater than 3 that are known to have occurred in Canada from 1627 until 2007 and Figure 3.8 shows the locations and magnitudes of earthquakes recorded in the National Earthquake Database (NEDB) for the period between 1985 and 2010 in the Ear Falls area.

In summary, available literature and recorded seismic events indicate that the Ear Falls area is located within a region of very low seismicity: the tectonically stable northwest portion of the Superior Province of the Canadian Shield.

3.4 Quaternary Geology

Figure 3.9 illustrates the extent and type of Quaternary deposits in the Ear Falls area, and the location of the wells from which information on overburden thickness was obtained.

The Quaternary geology in the Township of Ear Falls is dominated at surface by deposits of glaciolacustrine silts and clays, which extend outside the Township boundaries to the north, east and south. At surface there are also minor amounts of glaciofluvial (sand and gravel) deposits as well as post-glacial deposits of peat, muck and organic-rich silts and clays found in bogs and swamps throughout the area (Figure 3.9). Recently deposited alluvial silts and clayey silts are also present along parts of the English River and some small streams.

The Quaternary glacial deposits in the Ear Falls area date back to the waning stages of the most recent glacial period known as the Wisconsinan. This period of glaciation began approximately 115,000 years ago and peaked about 21,000 years before present, at which time the glacial ice front extended south of Ontario into what is now Ohio and Indiana (Barnett, 1992). Any earlier soil deposits in the Ear Falls area were largely or entirely removed by glacial erosion which stripped away the pre-existing overburden and eroded the crystalline bedrock.

Ice from the Wisconsinan glaciation laid down the oldest known Quaternary deposit in the Ear Falls area: a stratum of sandy, stoney till mapped by Ford (1981), who described the unweathered till as massive to fissile with poor to moderate matrix cohesion. Unweathered till is usually olive-grey whereas the weathered till is brown to greyish brown. The extent of till over the Ear Falls area is unknown due to the extensive overlaying mantle of glaciolacustrine clays and silts at the surface. The till is not exposed at the surface within the Township limits except for a small area near the northeast corner of Bruce Lake.

Glaciofluvial deposits are exposed in several areas within the Township of Ear Falls and include a number of small eskers, portions of the Lac Seul Moraine and numerous sand bodies scattered about the area. The sands are typically fine to medium grained and are moderately well sorted and quartz rich (Ford, 1981).

During the waning of the Wisconsinan glaciation, northward drainage was blocked by the residual ice mass remaining over the Hudson Bay Basin. This created a large ice-dam lake, known as Lake Agassiz that covered much of northwestern Ontario and all of what is now the Ear Falls area. Clays and silts were laid down as Lake Agassiz gradually inundated the area circa 9,900 years ago and these fine-textured glaciolacustrine deposits cover much of the Ear Falls area to thicknesses exceeding 4 m, as indicated in water well records. Wave action in Lake Agassiz also produced a series of well-developed terraces on the Lac Seul Moraine and sandy aprons bordering the moraine (Shklanka, 1970).

Information on the thickness of Quaternary deposits in the Ear Falls area was obtained from a small number of water well records along the highways and from diamond drillholes in the former Griffith Mine and in the periphery of the Township to the north (see Figure 3.9). Recorded depths to bedrock in the Township of Ear Falls range from 0 to 30 m and are typically less than 10 m. The thickest overburden is inferred along the axis of the Lac Seul Moraine, a north-south trending glaciofluvial ice deposit and topographic high that runs along the easternmost portion of the Township of Ear Falls (Figure 3.9). The thickness of the Quaternary deposits immediately north of the Township is typically less than 20 m, although it locally increases up to approximately 50 m. Geological mapping (Breaks et al., 1976; Ford, 1981 and 1983; Thurston and Paktunc, 1985) indicates some bedrock outcrops of limited extent in the central portion of the Township of Ear Falls.

4.0 HYDROGEOLOGY

Information concerning groundwater in the Ear Falls area was obtained from the Ministry of the Environment Water Well Record (WWR) database. The locations of known water wells are shown on Figure 4.1. There are relatively few wells recorded in the Township of Ear Falls, since most of the approximately 1,170 residents obtain water from the municipal service that obtains its water from Lac Seul.

Water wells in the Ear Falls area obtain water from the overburden or the shallow bedrock. The shallow bedrock is the primary source of exploitable groundwater, while overburden basal sand and gravel deposits, where present, are also used as a groundwater source.

The MOE WWR database contained a total of 65 water well records for the Ear Falls area. A summary of these wells is provided below.

Table 4.1 - Water Well Record Details

Water Well Type	Number of Wells	Total Well Depth (m)	Static Water Level (m below surface)	Tested Well Yield (L/min)	Depth to Top of Bedrock (m)
Overburden	30	4 to 38	0 to 15	4.5 to 450	N/A
Bedrock	35	11 to 134	0 to 24	4.5 to 136	0 to 38

4.1 Overburden Aquifers

Water well records indicate that sand or sand/gravel overburden aquifers are present along the Lac Seul Moraine (see Figure 3.9) and along Highway 105 and Separation Lake Road. The Lac Seul Moraine is the most readily mapped overburden aquifer. Overburden sand and gravel aquifers can also occur at the contact between glacial tills and the underlying bedrock, and at the base of the glaciolacustrine deposits that form the most widespread surficial soil materials in the Ear Falls area. The overburden wells are 4 to 38 m deep.

Well yields are variable with recorded values of 4.5 to 450 L/min. These values reflect the purpose of the wells (private residential supply) and do not necessarily reflect the maximum sustained yield that might be available from the aquifer.

The limited number of well records and their concentration along the main roadways limits the available information regarding the extent and characteristics of the overburden aquifers in the Ear Falls area.

4.2 Bedrock Aquifers

No information was found on deep bedrock groundwater conditions at a typical repository depth of approximately 500 m. In the Township of Ear Falls there are 35 well records that can be confidently assigned to the shallow bedrock aquifer. These wells range from 11 to 134 m in depth, with most wells between 30 to 40 m deep. Measured pumping rates in these wells are variable and range from 4.5 L/min to 136 L/min with yields typically between 30 to 40 L/min. As previously discussed, these values reflect the purpose of the wells (private residential supply) and do not necessarily reflect the maximum sustained yield that might be available from the aquifers. Long-term groundwater yield in fractured bedrock will depend on the number and size of fractures, their connectivity, transmissivity, storage and on the recharge properties of the fracture network in the wider aquifer.

The Ministry of the Environment Water Well Records indicate that no potable water supply wells are known to exploit aquifers at typical repository depths in the Ear Falls area or anywhere else in northern Ontario. Experience from other areas in the Canadian Shield has shown that active groundwater flow is generally confined to shallow fractured localized systems. In these shallow regions, flow tends to be dependent on the secondary permeability created by fractures (Singer and Cheng, 2002). For example, in Manitoba's Lac du Bonnet Batholith, groundwater movement is largely controlled by a fractured zone down to about 200 m depth (Everitt et al., 1996). The low topographic relief of the Canadian Shield tends to result in low hydraulic gradients for groundwater movement in the shallow active region (McMurry et al., 2003). In deeper regions, hydraulic conductivity tends to decrease as fractures become less common and less interconnected (Stevenson et al., 1996; McMurry et al., 2003). Increased vertical and horizontal stresses at depth tend to close or prevent fractures, thereby reducing permeability and resulting in diffusion-dominated groundwater movement (Stevenson et al., 1996; McMurry et al., 2003).

4.3 Hydrogeochemistry

No information on groundwater hydrogeochemistry was found for the Ear Falls area. Existing literature, however, has shown that groundwater within the Canadian Shield can be subdivided into two main hydrogeochemical regimes: a shallow, generally fresh water flow system, and a deep, saline water flow system (Singer and Cheng, 2002).

Gascoyne et al. (1987) investigated the saline brines found within several Precambrian plutons and identified a chemical transition at around 300 m depth marked by a uniform, rapid rise in total dissolved solids and chloride. This was attributed to advective mixing above 300 m, with a shift to diffusion-controlled flow below that depth. It was noted that major fracture zones within the bedrock can, where present, extend the influence of advective processes to greater depths.

In the deeper regions, where groundwater transport in unfractured or sparsely fractured rock tends to be very slow, long residence times on the order of a million years or more have been reported (Gascoyne, 2000; 2004). Groundwater research carried out in AECL's Whiteshell Underground Rock Laboratory (URL) in Manitoba found that crystalline rocks from depths of 300 to 1,000 m have total dissolved solids (TDS) values ranging from 3 to 90 g/L (Gascoyne 2000; 2004). However, total dissolved solids exceeding 250 g/L have been reported in some regions of the Canadian Shield at depths below 500 m (Frape and McNutt, 1984).

5.0 ECONOMIC GEOLOGY

5.1 Petroleum Resources

The Township of Ear Falls is located in a high-metamorphic grade crystalline geological setting where the potential for petroleum resources is negligible. No hydrocarbon exploitation or exploration activity currently exists in the area.

5.2 Metallic Mineral Resources

There are currently no producing mines in the Ear Falls area, however approximately 75 million tonnes of iron ore were extracted from the past-producing Griffith Mine, located along the west side of Bruce Lake in the north part of the Township. No other mineral production is known to have occurred in the Township of Ear Falls to date. Several mineral occurrences have been identified in the Ear Falls area and exploration activities have taken place in the past and continue today. Figure 5.1 shows the areas of active exploration interest based on active mining claims and known mineral occurrences identified in the Ontario Geological Survey's Mineral Deposit Inventory Version 2 (OGS, 2004).

Metallic mineralization in the Ear Falls area includes: rare metal pegmatites and radioactive element-enriched pegmatites; iron formation deposits; cobalt-copper-nickel-platinum group metals; volcanogenic massive sulphide (nickel and copper) deposits; and gold.

Iron

Iron deposits exist within the metasedimentary rocks at the edge of the Bruce Lake Pluton in the northern portion of Township of Ear Falls. These deposits were in the past mined at the Griffith Iron Mine. The former open pit Griffith Iron Mine, located on the western shore of Bruce Lake, was first explored in the early 1920s. In 1965, a 75-year lease was taken on the property by the Steel Company of Canada Inc. (Stelco), now US Steel. Plant construction and development of the open pit mine began in January of 1966 and operation commenced by February of 1968. When in full production, the Griffith Mine produced about 1.5 million tonnes of pellets annually, with an iron content of 66.4%.

Between 1968 and 1986, approximately 75 million tonnes of iron ore were produced over the 18 year mine life. The mine closed because of deteriorating economics rather than exhaustion of ore and the remaining resources are reported to be in the order of 100 million tonnes. Northern Iron Corporation currently holds an option on the site and has planned diamond drilling to better define the remaining reserves (Northern Iron Corporation, 2010).

Airborne magnetic surveys indicate the presence of additional iron formation deposits bordering the south side of the Bruce Lake Pluton to the east of the Township of Ear Falls. The location of these iron formation deposits can be seen on the airborne magnetic survey data for the Ear Falls area (Figure 3.5). Exploratory diamond drilling was carried out in 1957 by Dome Exploration Limited at one of these locations, the Karas Lake occurrence, located approximately 12 km east of the Township of Ear Falls. The diamond drilling confirmed the presence of an iron formation (Dome Exploration (Canada) Limited, 1957) but the ore is not sufficient in grade and/or tonnage to warrant development.

Base Metals

No base metal deposits, prospects or occurrences are known within the Township of Ear Falls. The closest base metal occurrences to Ear Falls are limited to the metavolcanic rocks of the Birch-Uchi Greenstone Belt north of the Township, where volcanogenic massive sulphide deposits (VMS) were mined at the South Bay Mine about 55 km northeast of the Township of Ear Falls. Numerous base metal occurrences have been recognized in these metavolcanic rocks, the closest to the Township of Ear Falls being approximately 10 km north and northwest of its northernmost boundary (Figure 5.1). Exploration is currently ongoing at these locations (see active mining claims on Figure 5.1).

Gold

No gold deposits, prospects or occurrences are known within the Township of Ear Falls. Laurentian Goldfields Ltd., however, is currently actively exploring for gold in the metasedimentary rocks in the Township of Ear Falls. The company holds a large claim position in the Township of Ear Falls along the boundary between the Uchi and English River Subprovinces totalling 567 km^2. The land position was acquired to explore the source of a large gold-arsenic-antimony geochemical anomaly traced along the Sydney Lake Fault Zone and a small late tectonic granitic intrusion. The anomaly extends along an east-west trend over a distance of approximately 8 km (Laurentian Goldfields, 2010). The gold potential of these rocks is yet to be proven. A gold occurrence is also mapped within the metasedimentary rocks to the west of the Township of Ear Falls near the Chukuni River.

In the Ear Falls area, gold production and exploration is mostly restricted to the metavolcanic rocks of the Red lake and Birch-Uchi greenstone belts north of the Township. The Red Lake area of the Uchi Subprovince hosts one of the country's historic gold mining districts with more than 18 mines having produced nearly 25 million troy ounces of gold since the initial discovery of gold in the area in the 1920's. Most of the gold mining activity in this area is concentrated more than 30 km away from the Township of Ear Falls boundary, but a number of gold occurrences have been identified and are currently being explored in metavolcanic rocks about 10 km northwest of the Township, in the Dixie Lake area (Figure 5.1).

Uranium

No deposits, prospects or occurrences of uranium have been identified in the Ear Falls area. The closest uranium occurrence is approximately 35 km south of the Township of Ear Falls, in the Aerobus Lake area. Initial uranium exploration in this area dates back to 1955, when nine diamond drill holes intersected mineralized rock. Uranium in this area is associated with a quartz diorite hosted by migmatized metasedimentary rocks (Breaks et al., 1975). Currently, Delta Uranium Inc. holds exploration land claims over the prospective area and is performing exploration activities

Radioactive element-enriched pegmatites have been identified within the low- to medium-grade metamorphic rocks along the northern and southern boundary zones of the English River Subprovince (Breaks et al., 1976; Breaks and Bond, 1993). While pegmatite-hosted uranium deposits have been historically mined in the Bancroft area (Thurston, 1991), grades in such types of deposits are usually non-economic compared to the high-grade unconformity-hosted uranium deposits that currently account for all Canadian production.

Rare Metals

Despite some exploration activity has taken place over the years, no economic deposits of rare metals have been identified within the Township of Ear Falls or its periphery. Rare metals are discussed here under "metallic" mineral resources although they also include non-metals. Rare metal mineralization has been reported from the pegmatitic dykes cutting metasedimentary rocks near the southern margin of the Wenasaga Lake Batholith. The rare metal pegmatites have a diverse mineralogy and chemistry and correspond to beryl, albite spodumene, and complex spodumene types (Breaks, 1991). The English River Subprovince pegmatites are genetically related to small masses of less than 10 km^2 area of chemically fractionated, peraluminous granites (Breaks and Bond, 1993).

5.3 Non-Metallic Mineral Resources

Known non-metallic mineral resources in the Ear Falls area include sand and gravel, stone, peat, and the Sandy Creek beryl occurrence located in a metasedimentary hosted pegmatite south of the Wenasaga Lake Batholith.

Sand, Stone, and Gravel

A number of sand and gravel pits are located within the Township of Ear Falls. Most of these pits are located along the Lac Seul Moraine (Figure 3.9) which contains at least 15 sand and gravel workings (Ford, 1983). No rock quarrying operations are known to exist within the Township. Storey (1986) evaluated the Ear Falls area as part of a search for building and ornamental stone in the districts of Kenora and Rainy River, Ontario, but no suitable deposits were identified.

Peat

Peat exists in low-lying portions of the Ear Falls area. In 1986, Monenco Ontario Limited, on behalf of the Ontario Geological Survey (OGS), carried out an evaluation of a number of peatlands in the Ear Falls area. Some of the examined peatlands showed potential for supporting conventional peat operations, as indicated by high quality peat and thicknesses of 2 m and greater in some areas. One of these deposits is located within the Township of Ear Falls in the area south of the former Griffith Iron Mine between Pakwash and Bruce Lakes (Figure 5.1). Despite the commercial potential of some of these deposits in the area, no peat extraction has occurred in the Township or its periphery (Monenco Ontario Limited, 1986).

Diamonds

The potential for the Canadian Shield to host economic diamond deposits has been demonstrated by a number of mines in the Northwest Territories and Ontario. However, no kimberlites or lamproites that could be diamond bearing have been identified in the Ear Falls area.

Industrial Minerals

No industrial mineral deposits have been identified within the Ear Falls area apart from the Sandy Creek beryl occurrence located in a metasedimentary hosted pegmatite south of the Wenasaga Lake Batholith (Figure 5.1). This deposit includes small pegmatite dikes over an area of approximately 20 by 60 m in an area of generally poor exposure. The main pegmatite dike, which strikes 090° and dips from 65 to 85° to the north, is 1 to 2.5 m thick and bifurcates near its west end (Breaks et al., 2003). No information as to the depth extent of this occurrence is available.

6.0 INITIAL SCREENING EVALUATION

This section provides an evaluation of each of the five initial screening criteria (NWMO, 2010) for the Ear Falls area based on the readily available information presented in Sections 2 to 5. The intent of this evaluation is not to conduct a detailed analysis of all available information or identify specific potentially suitable sites, but rather to identify any obvious conditions that would exclude the Township of Ear Falls from the site evaluation process.

Initial screening criteria (NWMO, 2010) require that:

1) The site must have enough available land of sufficient size to accommodate the surface and underground facilities.

2) This available land must be outside of protected areas, heritage sites, provincial parks and national parks.

3) This available land must not contain known groundwater resources at the repository depth, so that the repository site is unlikely to be disturbed by future generations.

4) This available land must not contain economically exploitable natural resources as known today, so that the repository site is unlikely to be disturbed by future generations.

5) This available land must not be located in areas with known geological and hydrogeological characteristics that would prevent the site from being safe, considering the outlined safety factors in Section 6 of the site selection document (NWMO, 2010).

For cases where readily available information is limited and where the assessment of some of the criteria is not possible at the initial screening stage, the area would be advanced to the feasibility study stage for more detailed evaluation provided the community remains interested in continuing with the site selection process.

6.1 Screening Criterion 1: Land Availability

The site must have enough available land of sufficient size to accommodate the surface and underground facilities.

Surface facilities associated with the deep geological repository will require a surface land parcel of about 1 km by 1 km (100 ha) in size, although some additional space may be required to satisfy regulatory requirements. The underground footprint of the repository is about 1.5 km by 2.5 km (375 ha) at a typical depth of about 500 m.

This criterion was evaluated by assessing whether the Ear Falls area contains parcels of land that are large enough to accommodate the surface facilities and whether there is a sufficient volume of rock at depth to accommodate underground facilities. The available land areas should be accessible for the construction of surface facilities and for the various field investigations that are necessary to characterize the rock volume required to accommodate the footprint of the repository (e.g. drilling of boreholes).

Availability of land was assessed by identifying areas where surface facilities are unlikely to be built due to constraints such as the presence of natural features (e.g. large water bodies, topographic constraints), land use (e.g. developed areas, infrastructure), accessibility and construction challenges, based on the information presented in Section 2.

Review of available mapping and satellite imagery shows that the Township of Ear Falls contains limited constraints that would prevent the development of the repository's surface facilities (Figures 2.2 and 6.1). These would mainly include large permanent water bodies such as the Bruce Lake, Pakwash Lake, Detector Lake and Lac Seul, which account for about 20% of the Township area. Also, a very small portion of the Township of Ear Falls is covered by domestic and industrial infrastructure, with developments limited mainly to roadways and the settlement area itself (Figure 6.1). The areas at the periphery of the Township of Ear Falls are also largely undeveloped, with limited natural or physical constraints such as major infrastructure or permanent water bodies. Therefore, the Ear Falls area contains sufficient land to potentially accommodate the repository's surface facilities.

As discussed in Section 2, topography is variable in the Ear Falls area, but no obvious topographic features that would prevent construction and characterization activities have been identified. Most of the Ear Falls area could be accessed from the two main roads: Highway 105 and Separation Lake Road. Only the extreme northeast portion of the Township is considered to be poorly accessible, due to the extensive swampy terrain (see Figure 2.5).

As discussed in Section 6.5, readily available information suggests that the Ear Falls area has the potential of containing sufficient volumes of host rock to accommodate underground facilities associated with a deep geological repository. This would have to be confirmed in subsequent site evaluation stages.

Based on the review of readily available information, the Ear Falls area contains sufficient land to accommodate the repository's surface and underground facilities.

6.2 Screening Criterion 2: Protected Areas

Available land must be outside of protected areas, heritage sites, provincial parks and national parks.

The assessment of this criterion is needed to assure that the remaining available land, after excluding protected areas, is large enough to allow for the construction of the repository's facilities. For the purpose of this initial assessment, protected areas are considered to be ecologically sensitive or significant areas, as defined by provincial or federal authorities.

The Ear Falls area was screened for federal, provincial and municipal parks, conservation areas, nature reserves, national wildlife areas and archaeological and historic sites using available data from the Ontario Ministry of Natural Resources (Land Information Ontario) and the Ontario Ministry of Tourism and Culture.

With reference to Figure 2.1 and Figure 6.1, there are three known protected areas within the Township of Ear Falls: part of the Pakwash Provincial Park on the eastern shore of Pakwash Lake; part of the Bruce Lake Conservation Reserve west of Bruce Lake; and part of the Lac Seul Island Conservation reserve in Lac Seul. The Pakwash Provincial Park extends over most of the Pakwash Lake Pluton, and the Bruce Lake Conservation reserve extends over all of the Bruce Lake Pluton within the Township boundaries. Approximately 35% of the Bruce Lake Pluton in the area east of the Township of Ear Falls lies outside the limits of the Conservation Reserve. The Lac Seul Island Conservation Reserve covers only some of the islands in the southeast corner of the Township of Ear Falls. Apart from these three areas, the remaining lands within the Township are outside of protected areas, provincial parks and national parks. Most of the land at the periphery of the Township of Ear Falls is also outside of protected areas.

As discussed in Section 2.4, most of the land in the Ear Falls area is free of known heritage constraints. Known archaeological sites are small and generally concentrated on the shores and islands of Lac Seul and along the Chukuni River (Figure 2.1). There are no national historic sites in the Ear Falls area.

The absence of locally protected areas would need to be confirmed in discussion with the community and Aboriginal peoples in the area during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

Based on the review of readily available information, the Ear Falls area contains sufficient land outside of protected areas, heritage sites, provincial parks and national parks to accommodate the repository's facilities.

6.3 Screening Criterion 3: Known Groundwater Resources at Repository Depth

Available land must not contain known groundwater resources at repository depth, so that the repository site is unlikely to be disturbed by future generations.

In order to minimize the future risk of human intrusion during the long post-closure period, the repository should be sited in a host rock formation that does not contain significant groundwater resources at repository depth (typically 500 m) that may encourage future generations to access those resources and potentially compromise the long-term performance of the repository.

The review of available information did not identify any known groundwater resources at repository depth for the Ear Falls area. As discussed in Section 4.2, the Ontario Ministry of the Environment (MOE) Water Well Record (WWR) database shows that all water wells in the area obtain water from overburden or shallow bedrock sources at depths ranging from 4 to 134 m, with most wells between 30 to 40 m deep.

Experience from other areas in the Canadian Shield has shown that active groundwater flow is generally confined to shallow fractured localized systems (Singer and Cheng, 2002). For example, in Manitoba's Lac du Bonnet Batholith, groundwater movement is largely controlled by a fractured zone down to about 200 m depth (Everitt et al., 1996). In deeper regions, hydraulic conductivity tends to decrease as fractures become less common and interconnected (Stevenson et al. 1996; McMurry et al., 2003).

MOE Water Well Records indicate that no potable water supply wells are known to exploit aquifers at typical repository depths in the Ear Falls area or anywhere else in northern Ontario. Groundwater at such depths is generally saline and very low groundwater recharge at such depths limits the potential yield, even if suitable water quality were to be found. The absence of groundwater resources at repository depth in the Ear Falls area would, however, need to be confirmed during subsequent site evaluation stages if the community remains interested in continuing with the site selection process.

The review of available information did not identify any known groundwater resources at repository depth for the Ear Falls area. Experience in similar geological settings suggests that the potential for deep groundwater resources at repository depths is low throughout the Ear Falls area. The absence of groundwater resources at repository depth would, however, need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

6.4 Screening Criterion 4: Known Natural Resources

Available land must not contain economically exploitable natural resources as known today, so that the repository site is unlikely to be disturbed by future generations.

As with the assessment of groundwater resources, the need to minimize the risk of future human intrusion requires that the repository be sited in a host rock formation having a low potential for economically exploitable natural resources. Readily available information on past and potential future occurrence for natural resources such as oil and gas, metallic and non-metallic mineral resources was reviewed in Section 5.

The review indicates that there is no evidence of past or present exploration or development activities associated with petroleum hydrocarbon resources. Given the geological setting (i.e. crystalline rock), the potential for activities associated with these resources in the Ear Falls area is negligible.

There are currently no operating mines within the Township of Ear Falls. Mineral production to date within the Township has been limited to the former Griffith Iron Mine in the northern sector of the Township, which operated between 1968 and 1986 and produced a total of about 75 million tonnes of iron ore. Iron ore occurs as discontinuous bodies that are confined to the western margin of the Bruce Lake Pluton, with remaining reserves estimated at 100 million tonnes (Shklanka, 1970). The metasedimentary rocks along the southern margin of the Wenasaga Lake Batholith have shown potential for rare metal mineralization associated with pegmatitic dykes. An occurrence of beryl has been identified in this area (the Sandy Creek beryl occurrence), but no economically viable deposits have been identified. Laurentian Goldfields Ltd. is currently exploring for gold in the metasedimentary rocks in the Township of Ear Falls along the Sydney Lake Fault Zone. The gold potential of this area, however, remains unproven.

It is important to note that metallic mineral potential in the Township of Ear Falls is associated with specific geological settings and localities. As shown on Figure 5.1, which overlays the location of mining activities and occurrences on the bedrock geology, the potential for metallic minerals is associated with the contact margins between adjacent rock types (such as the contact between intrusions and metasediments) and the Sydney Lake Fault Zone. No metallic mineralization has been identified within the Wenasaga Lake Batholith or the Bruce Lake and Pakwash Lake Plutons.

Mining activities, primarily for gold and base metals, at the periphery of the Township of Ear Falls are mainly concentrated north of the Township in the Red Lake and Birch-Uchi Greenstone Belts. Iron formations have also been identified in other places in the metasedimentary rocks of the Ear Falls area, but their economic viability has not been proven. No mineral potential has been identified within the Bluffy Lake Batholith.

No record of non-metallic mineral resources exploitation was found within the Ear Falls area. The area was assessed in the 1980's for its building and ornamental stone potential, but no economically suitable deposits were identified. Commercial potential for peat exists in some low-lying areas, but no peat extraction has occurred in the Township of Ear Falls or its periphery (Figure 5.1).

In summary, in the Ear Falls area the potential for mineral resources is low and mostly associated to the greenstone belts north of the Township of Ear Falls. Deposits of economically exploitable natural resources are not known within the Township except for the well-defined iron deposits described above.

Based on the review of readily available information, the Ear Falls area contains sufficient land, free of known economically exploitable natural resources, to accommodate the required repository facilities. The absence of natural resources would need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

6.5 Screening Criterion 5: Unsafe Geological or Hydrogeological Features

Available land must not be located in areas with known geological and hydrogeological characteristics that would prevent the site from being safe, considering the outlined safety factors in Section 6 of the site selection document (NWMO, 2010).

The site should not be located in an area of known geological or hydrogeological features that would make the site unsafe, as per the following five geoscientific safety-related factors identified in the site selection process (NWMO, 2010):

1) Safe containment and isolation of used nuclear fuel. Are the characteristics of the rock at the site appropriate to ensuring the long-term containment and isolation of used nuclear fuel from humans, the environment and surface disturbances?

2) Long-term resilience to future geological processes and climate change. Is the rock formation at the site geologically stable and likely to remain stable over the very long-term in a manner that will ensure the repository will not be substantially affected by natural disturbances and events such as earthquakes and climate change?

3) Safe construction, operation and closure of the repository. Are conditions at the site suitable for the safe construction, operation and closure of the repository?

4) Isolation of used fuel from future human activities. Is human intrusion at the site unlikely, for instance, through future exploration or mining?

5) Amenable to site characterization and data interpretation activities. Can the geologic conditions at the site be practically studied and described on dimensions that are important for demonstrating long-term safety?

At this early stage of the site evaluation process, where limited data at repository depth exist, the five safety-related geoscientific factors are assessed using readily available information, with the objective of identifying any obvious unfavourable hydrogeological and geological conditions that would exclude the Township of Ear Falls from further consideration. These factors would be gradually assessed in more detail as the site evaluation process progresses and more site specific data is collected during subsequent site evaluation stages, provided the community remains interested in continuing with the site selection process.

As discussed below, the review of available geoscientific information did not identify any obvious geological or hydrogeological characteristics that would exclude the Township of Ear Falls from further consideration in the site selection process at this stage.

Safe Containment and Isolation

The geological and hydrogeological conditions of a suitable site should promote long-term containment and isolation of used nuclear fuel and retard the movement of any potentially released radioactive material. This requires that the repository be located at a sufficient depth, typically around 500 m, in a sufficient rock volume with characteristics that limit groundwater movement.

Readily available information on the local and regional geology and hydrogeology was reviewed in Sections 3 and 4, respectively. The Township of Ear Falls is underlain by a belt of metasedimentary migmatites intruded by three plutonic masses, the Bruce Lake and Pakwash Lake Plutons in the northeast and northwest corners of the Township and the Wenasaga Lake Batholith in the east-central portion of the Township (Figure 3.4). The Township of Ear Falls is transected by the regional Sydney Lake Fault Zone and its splays (the Long Legged Lake Fault Zones). These fault zones have a width of about 1 to 2 km and affect a small portion of the Township. The areas along these faults zones are likely not suitable for hosting a repository. No information on smaller scale faults was found for the area. Given the deformation history in the region, further assessment would be required during subsequent site evaluation phases to investigate the presence of smaller scale faults within the Ear Falls area.

The metasedimentary rocks extend significantly beyond the township boundaries to the east, west and south. Their thickness has been estimated to be from less than 1 km to 5 km based on geophysical data sources. While there is no information on the degree of homogeneity of these metasedimentary rocks at repository depth, the high degree of metamorphism and partial melting they have experienced in the past would suggest that their physical characteristics could mimic those of granitic rock. Therefore, the metasedimentary rocks may be potentially suitable for hosting a deep geological repository, except in the vicinity of the Sydney Lake and Long Legged Lake Fault Zones.

The Pakwash Lake and Bruce Lake Plutons and the Wenasaga Lake Batholith occupy approximately 20% of the Township area. The Pakwash Lake and Bruce Lake Plutons are potentially suitable for hosting a repository. However, within the township, they would not be able to accommodate the repository's surface facilities as they are both either covered by water or by protected areas (i.e. the Pakwash Provincial Park and the Bruce Lake Conservation Reserve) as noted in Section 6.1. The Wenasaga Lake Batholith appears to have sufficient surface area to potentially host a repository within the Township (Figure 3.4). Available geophysical information suggests that this batholith may extend to substantial depth (Figure 3.3). Therefore, most of the Wenasaga Lake Batholith warrants further consideration as a potential repository host rock.

Both the Wenasaga Lake Batholith and the Bruce Lake Pluton extend beyond the Township boundaries (see Figure 3.2) and have sufficient lateral extent at surface to accommodate a deep geological repository at the periphery of the Township of Ear Falls. Further studies are needed to assess whether the Bruce Lake Pluton has sufficient thickness to accommodate the repository. The Bluffy Lake Batholith also appears to have sufficient lateral area and thickness to potentially host a repository.

From a hydrogeologic point of view, the review of readily available information did not reveal the existence of known deep fracture systems or deep aquifers in the Ear Falls area (see Section 4.2). The presence of active deep groundwater flow systems in crystalline formations is controlled by the frequency and interconnectivity of fractures at depth. Experience from other areas in the Canadian Shield, particularly for granitic intrusions (plutons), indicate that active groundwater flow tends to be generally limited to shallow fractured systems, typically less than 300 m. In deeper rock, fractures are less common and less likely to be interconnected, leading to very slow groundwater movement with residence times that could reach a million years or more (McMurray et al. 2003; Gascoyne 2004, 2000).

In summary, the review indicates that the Ear Falls area contains areas with no obvious geological and hydrogeological conditions that would fail the containment and isolation requirements. This would need to be confirmed through subsequent evaluation phases. Other geoscientific characteristics that may have an impact on the containment and isolation functions of a deep geological repository such as the mineralogy of the rock, the geochemical composition of the groundwater and rock porewater, the thermal and geomechanical properties of the rock will also need to be assessed during subsequent site evaluation stages, provided the community remains interested in continuing with the site selection process.

Long-term Stability

A suitable site for hosting a repository is a site that would remain stable over the very long-term in a manner that will ensure that the performance of the repository will not be substantially altered by future geological and climate change processes, such as earthquakes or glaciation. A full assessment of this geoscientific factor requires detailed site specific data that would be typically collected and analyzed through detailed field investigations. The assessment would include understanding how the site has responded to past glaciations and geological processes and would entail a wide range of studies involving disciplines such as seismology, hydrogeology, hydrogeochemistry, paleohydrogeology and climate change.

At this early stage of the site evaluation process, the long-term stability is evaluated by assessing whether there is any evidence that would raise concerns about the long-term hydrogeological and geological stability of the Ear Falls area. As discussed below, the review of readily available information did not reveal any obvious characteristics that would raise such concerns.

The Township of Ear Falls is located in the Superior Province of the Canadian Shield, where large portions of land have remained tectonically stable for the last 2.5 billion years (Percival and Easton, 2007). As discussed in Sections 3.1 and 3.2, there is no evidence that the two regional fault zones observed in the Ear Falls area (i.e. Sydney Lake - St. Joseph Fault and the Long Legged Lake - Pakwash Lake Fault, Figure 3.4) have been significantly active in the last 2 billion years.

The geology of the Ear Falls area is typical of many areas of the Canadian Shield, which has been subjected to numerous glacial cycles during the last million years. Glaciation is a significant past perturbation that could occur in the future. However, findings from studies conducted in other areas of the Canadian Shield suggest that deep crystalline formations, particularly the plutonic intrusions, have remained largely unaffected by past perturbations such as glaciation. Findings of a comprehensive paleohydrogeological study of the fractured crystalline rock at the Whiteshell Research Area, located within the Manitoba portion of the Canadian Shield (Gascoyne, 2004), indicated that the evolution of the groundwater flow system was characterized by periods of long-term hydrogeological and hydrogeochemical stability. Furthermore, there is evidence that only the upper 300 m have been affected by glaciation within the last million years. McMurry et al. (2003) summarized several studies conducted in a number of plutons in the Canadian Shield and in the crystalline basement rocks of Western Ontario. These various studies found that fractures below a depth of several hundred metres in the plutonic rock were ancient features. Subsequent geological processes such as plate movement and continental glaciation have caused reactivation of existing zones of weakness rather than the formation of large, new zones of fractures.

In summary, the review did not identify any obvious geological or hydrogeological conditions that would clearly fail to meet the long-term stability requirement for a potential repository within the Township of Ear Falls and its periphery. As mentioned above, long-term stability would need to be further assessed through detailed multidisciplinary geoscientific and climate change site investigations, if the community remains interested in continuing with the site selection process.

Potential for Human Intrusion

The site should not be located in areas where the containment and isolation functions of the repository are likely to be disrupted by future human activities such as exploration or mining. Therefore, the repository should not be located within rock formations containing exploitable groundwater resources (aquifers) at repository depth or economically exploitable natural resources as known today.

This factor has already been addressed in Sections 6.3 and 6.4, which concluded that the potential for groundwater resources at repository depths and known economically exploitable natural resources is low throughout the Ear Falls area.

Amenability to Construction and Site Characterization

The characteristics of a suitable site should be favourable for the safe construction, operation, closure and long-term performance of the repository. Beside the requirement for space discussed in Section 6.1, this requires that the strength of the host rock and in-situ stress at repository depth are such that the repository could be safely excavated, operated and closed without unacceptable rock instabilities; and that the soil cover depth over the host rock should not adversely impact repository construction and site investigation activities. Similarly, the host rock geometry and structure should be predictable and amenable to site characterization and interpretation activities.

From a constructability perspective, limited site specific information is available on the local rock strength characteristics and in-situ stresses for the Ear Falls area. However, there is abundant information at other locations of the Canadian Shield that could provide insight into what should be expected for the Ear Falls area in general. Available information suggests that crystalline rock formations within the Canadian Shield, particularly within plutonic intrusions, generally possess geomechanical characteristics that are good to very good and amenable to the type of excavation activities involved in the development of deep geological repository for used nuclear fuel (McMurry et al. 2003; Chandler et al. 2004; Arjang and Herget, 1997; Everitt, 1999).

In terms of predictability of the geologic formations and amenability to site characterization activities, the review of readily available information on the bedrock geology and Quaternary geology for the Ear Falls area (Sections 3.2 and 3.4) indicates that conditions which could make the rock mass more difficult to characterize and predict may be present in localized areas. For example, available information on overburden thickness shows that Quaternary deposits are typically less than 20 m, but could exceed 40 m in some areas. The degree to which these factors might affect the characterization and data interpretation activities would require further assessment during subsequent site evaluation stages provided the community remains interested in continuing in the site selection process.

Based on the review of available geological and hydrogeological information, the Ear Falls area comprises land that does not contain obvious known geological and hydrogeological conditions that would make the area unsuitable for hosting a deep geological repository.

7.0 INITIAL SCREENING FINDINGS

This report presents the results of an initial screening to assess the potential suitability of the Ear Falls area against five initial screening criteria using readily available information. As per discussions between the NWMO and the Township Council, the initial screening focused on the Township of Ear Falls and its periphery, which are referred to as the "Ear Falls area". As outlined in NWMO's site selection process (NWMO, 2010), the five initial screening criteria relate to: having sufficient space to accommodate surface facilities, being outside protected areas and heritage features, absence of known groundwater resources at repository depth, absence of known natural resources and avoiding known hydrogeologic and geologic conditions that would make an area or site unsuitable for hosting a deep geological repository.

The review of available information and the application of the five initial screening criteria did not identify any obvious conditions that would exclude the Township of Ear Falls from further consideration in the NWMO site selection process. The initial screening indicates that there are areas within the boundaries of the Township of Ear Falls that are potentially suitable for hosting a deep geological repository. Examples of these areas include portions of the Wenasaga Lake Batholith and the metasedimentary migmatites that dominate the bedrock geology of the Township. The review has also revealed that there are areas at the periphery of the Township of Ear Falls that are potentially suitable. These include the metasedimentary migmatites, the Wenasaga Lake Batholith, the Bruce Lake Pluton and the Bluffy Lake Batholith. Potential suitability of these areas would need to be further assessed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

It is important to note that at this early stage of the site evaluation process, the intent of the initial screening is not to confirm the suitability of the Ear Falls area, but rather to identify whether there are any obvious conditions that would exclude it from the site selection process. Should the community of Ear Falls remain interested in continuing with the site selection process, several years of progressively more detailed studies would be required to confirm and demonstrate whether the Ear Falls area contains sites that can safely contain and isolate used nuclear fuel.

The process for identifying an informed and willing host community for a deep geological repository for Canada's used nuclear fuel is designed to ensure, above all, that the site which is selected is safe and secure for people and the environment, now and in the future.

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9.0 REPORT SIGNATURE PAGE

GOLDER ASSOCIATES LTD.

Charles Mitz, M.Eng., P.Geo. Senior Geoscientist	George Schneider, M.Sc., P.Geo. Principal

CM/GWS/wlm

n:\active\2010\1152\10-1152-0110 nwmo-initial screenings-on\1000 ear falls screening\reports\9th final for nwmo internal approval april 2011\10-1152-0110 1000 screening rpt ear falls 12apr11.docx

FIGURES

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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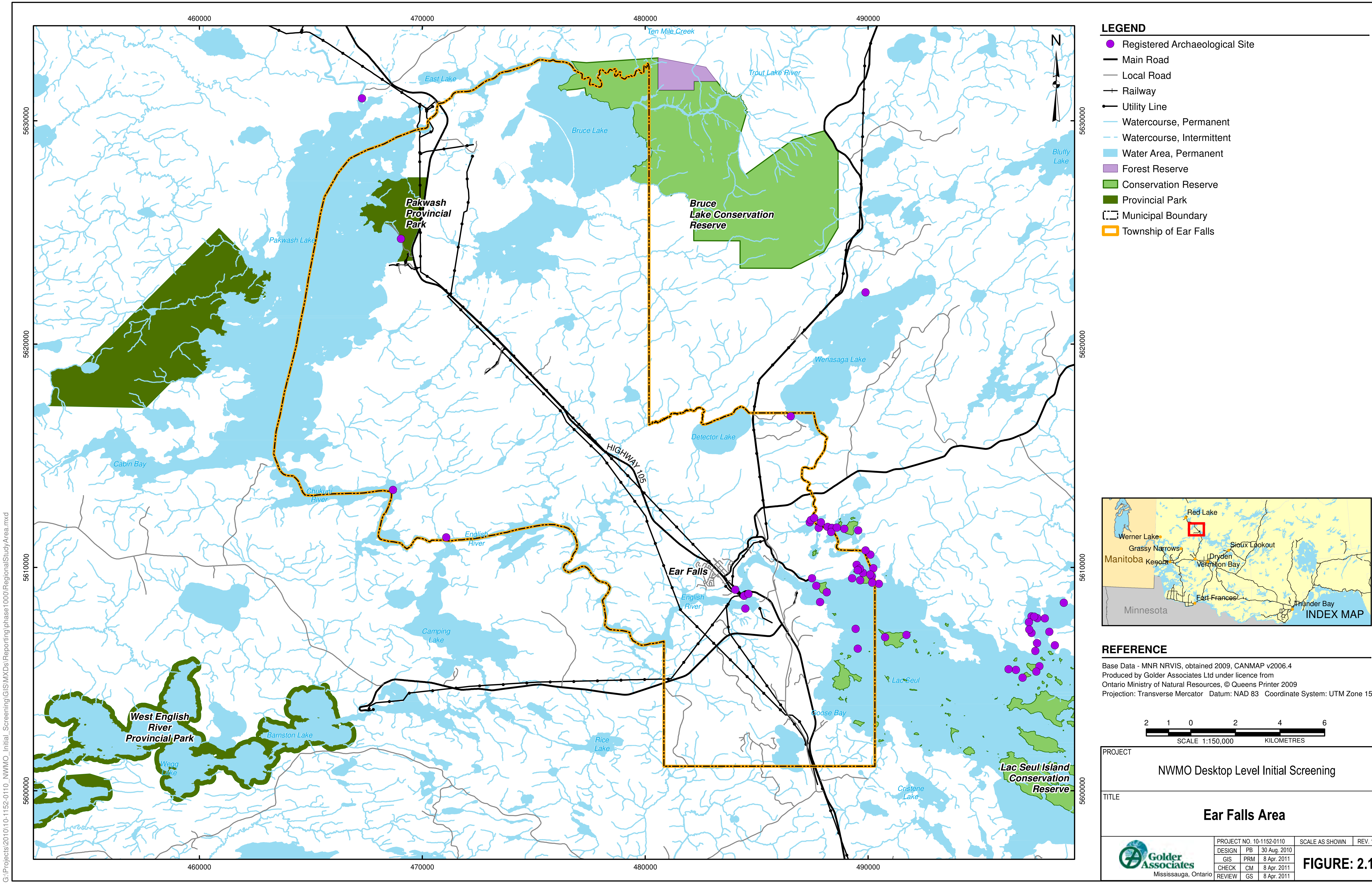
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Ltd.
2390 Argentia Road
Mississauga, Ontario, L5N 5Z7
Canada
T: +1 (905) 567 4444

Golder Associates



LEGEND
Registered Archaeological Site
Main Road
Local Road
Railway
Utility Line
Watercourse, Permanent
Watercourse, Intermittent
Water Area, Permanent
Forest Reserve
Conservation Reserve
Provincial Park
Municipal Boundary
Township of Ear Falls
Ten Mile Creek
East Lake
Trout Lake River
Bruce Lake
Bluffy Lake
Pakwash Provincial Park
Pakwash Lake
Bruce Lake Conservation Reserve
Wenasaga Lake
Detector Lake
HIGHWAY 105
Cabin Bay
Chukuni River
English River
Ear Falls
Camping Lake
Lac Seul
Goose Bay
West English River Provincial Park
Barnston Lake
Wegg Lake
Rice Lake
Cristene Lake
Lac Seul Island Conservation Reserve
460000
470000
480000
490000
5630000
5620000
5610000
5600000
N
Red Lake
Werner Lake
Grassy Narrows
Sioux Lookout
Kenora
Dryden
Vermilion Bay
Manitoba
Fort Frances
Thunder Bay
Minnesota
INDEX MAP
REFERENCE
Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15
2 1 0 2 4 6
SCALE 1:150,000 KILOMETRES
PROJECT
NWMO Desktop Level Initial Screening
TITLE
Ear Falls Area
PROJECT NO. 10-1152-0110
SCALE AS SHOWN
REV. 1.0
DESIGN PB 30 Aug. 2010
GIS PRM 8 Apr. 2011
CHECK CM 8 Apr. 2011
REVIEW GS 8 Apr. 2011
Golder Associates
Mississauga, Ontario
FIGURE: 2.1
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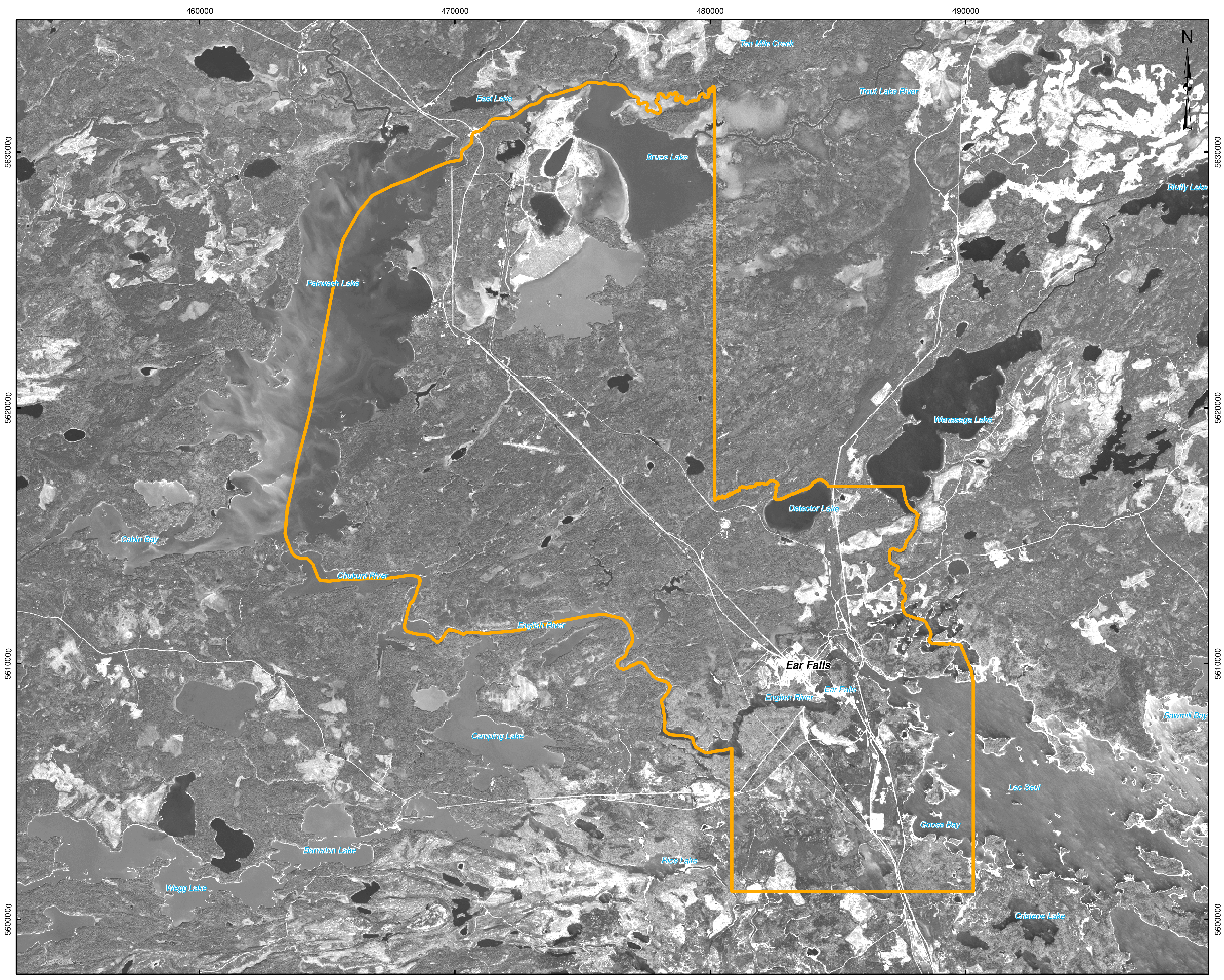
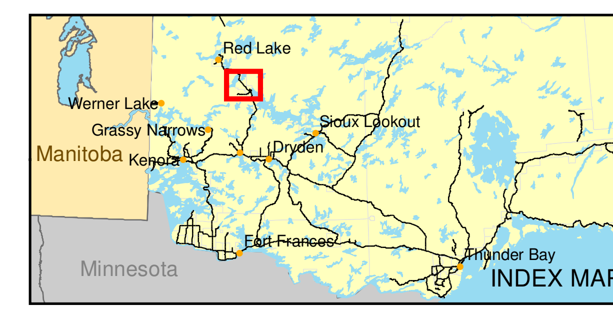


LEGEND

Township of Ear Falls



REFERENCE

Imagery: Spot 5 , Obtained from Geobase (2006, 10m resolution)
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15

2 1 0 2 4 6
SCALE 1:150,000 KILOMETRES

PROJECT

NWMO Desktop Level Initial Screening

TITLE

Satellite Imagery of the Ear Falls Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1152-0110			SCALE AS SHOWN	REV. 1.0
DESIGN	PB	30 Aug. 2010	FIGURE: 2.2	
GIS	PRM	8 Apr. 2011		
CHECK	CM	8 Apr. 2011		
REVIEW	GS	8 Apr. 2011		

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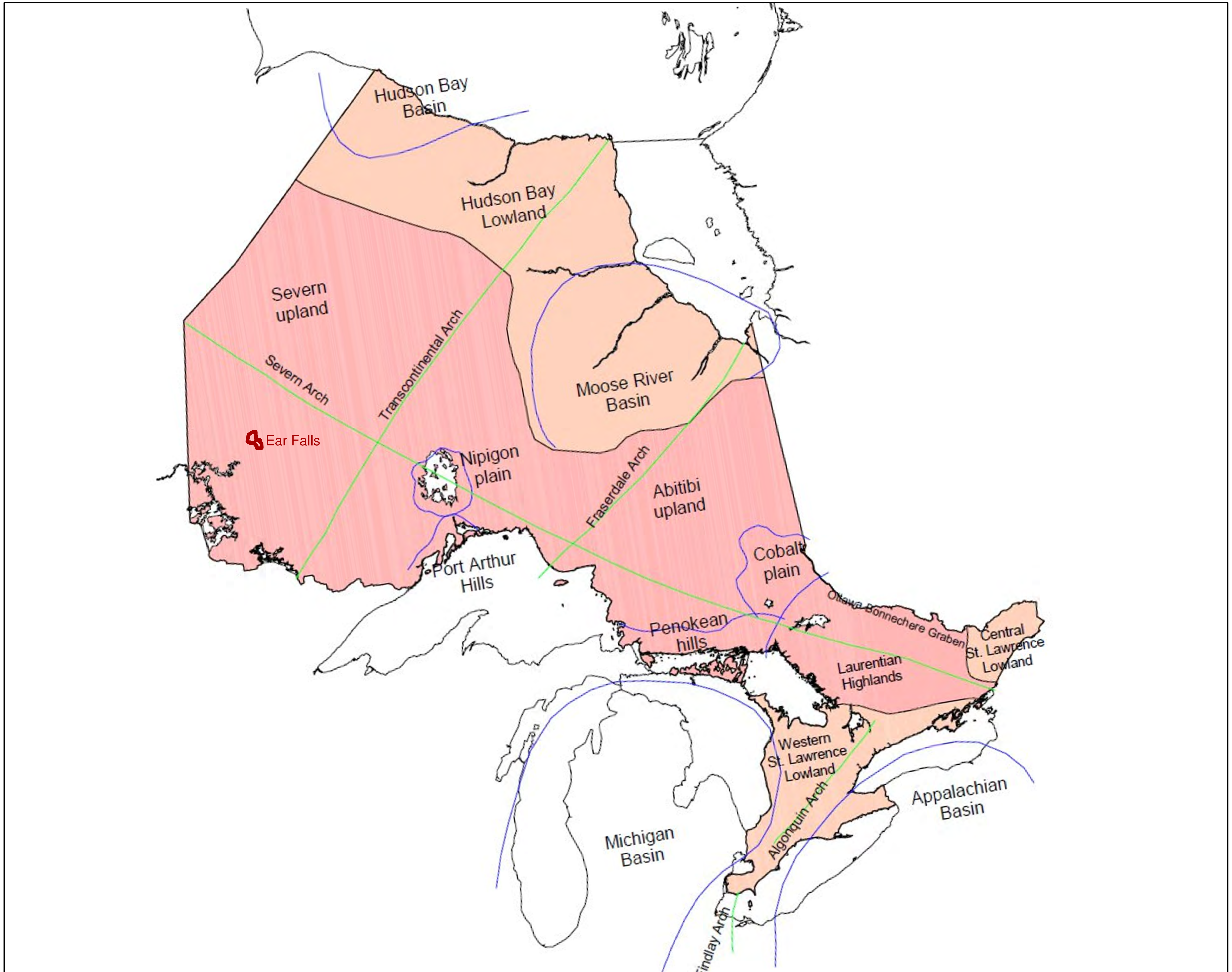

LEGEND

- Phanerozic Borderlands
- Precambrian Canadian Shield
- Township of Ear Falls

REFERENCE

Base Data - ESRI Digital Chart of the World, 2010
Physiography: Physiographic regions in Ontario based on Bostock (1970)
(from Thurston et al. 1991)
Projection:NA

PROJECT

NWMO Desktop Level Initial Screening

TITLE

Physiographic Regions of Ontario

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1152-0110			SCALE AS SHOWN	REV. 1.0
DESIGN	PB	30 Aug. 2010	**FIGURE: 2.3**	
GIS	PRM	8 Apr. 2011		
CHECK	JF	8 Apr. 2011		
REVIEW	GS	8 Apr. 2011		

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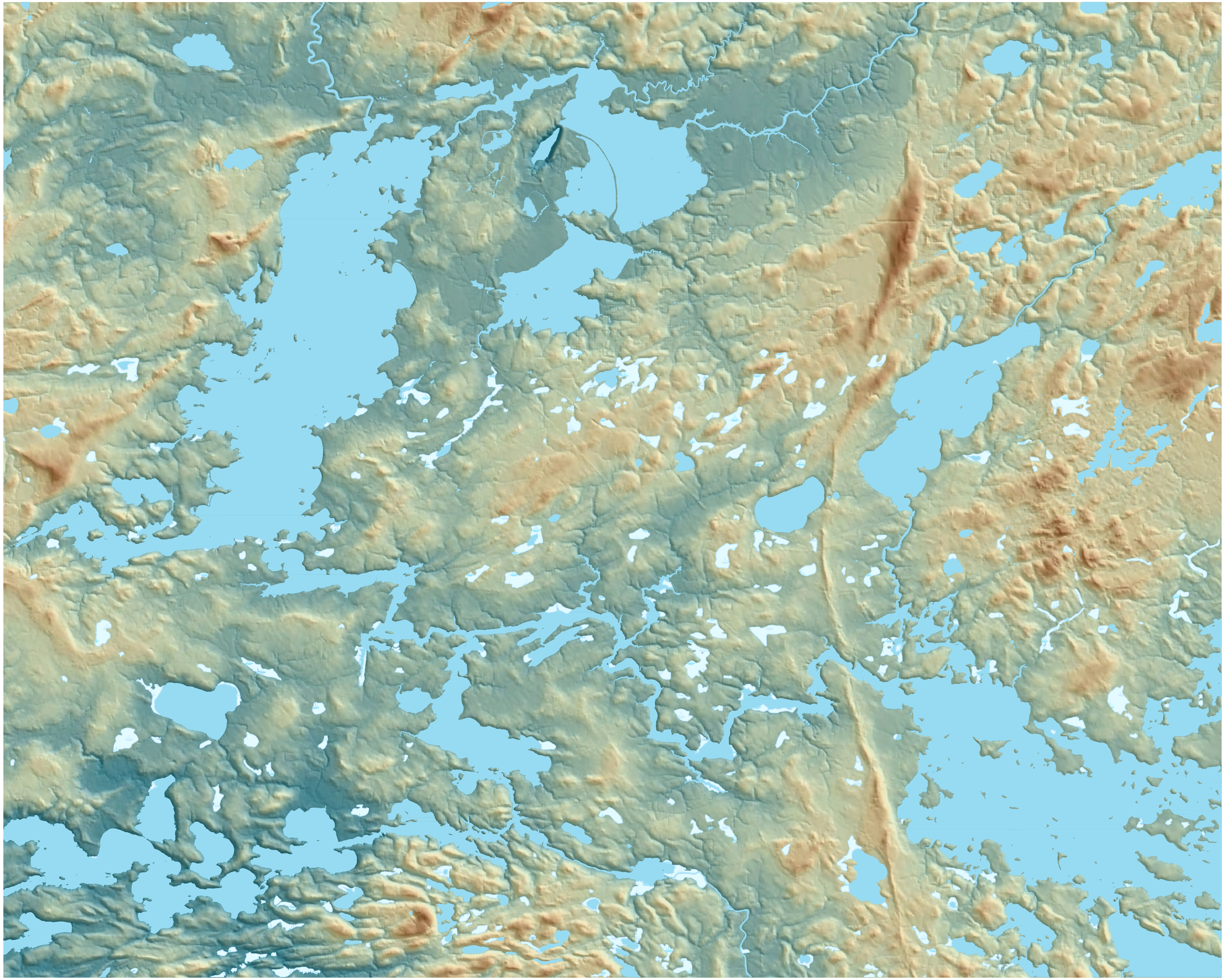

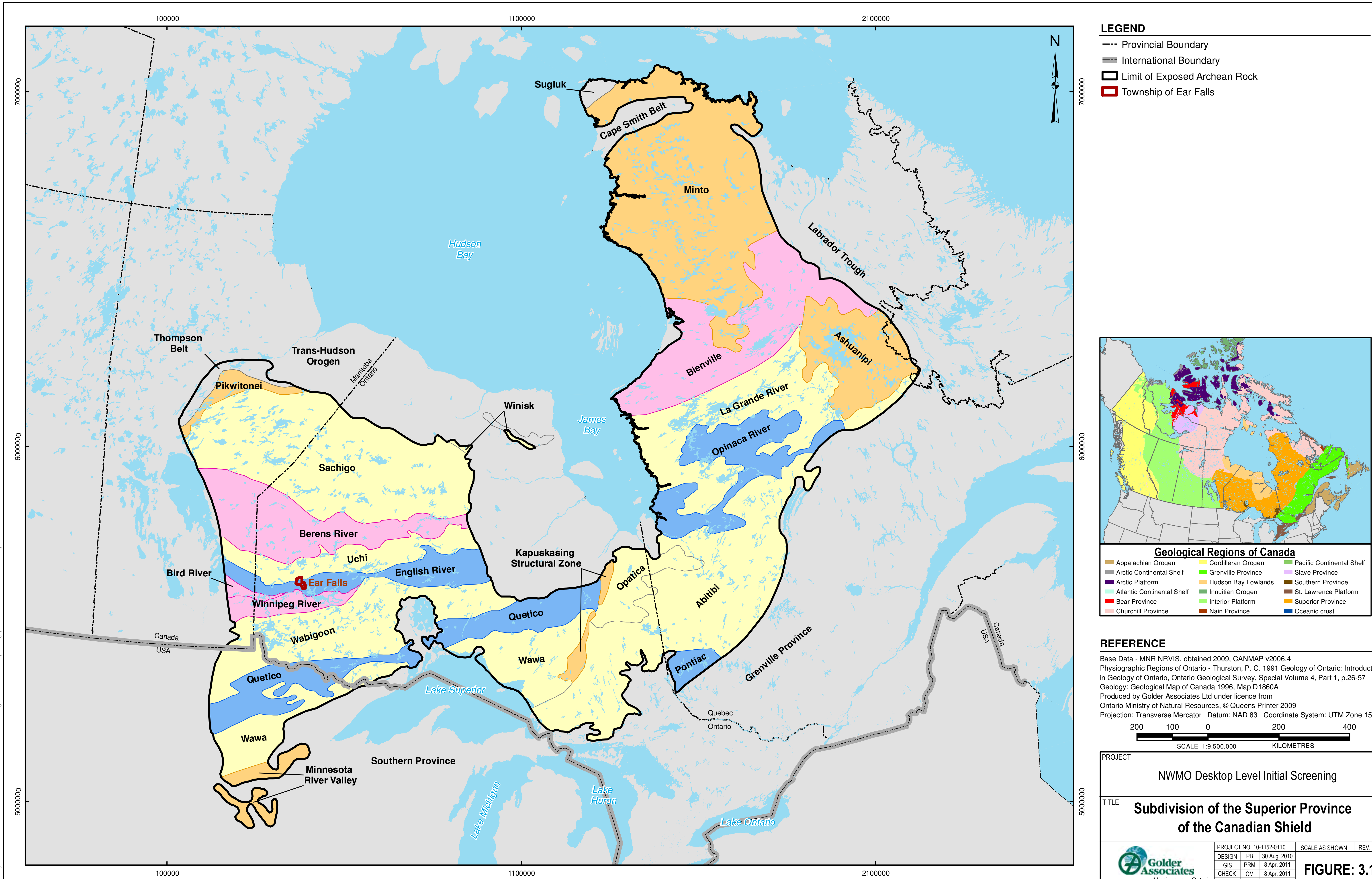

LEGEND
Provincial Boundary
International Boundary
Limit of Exposed Archean Rock
Township of Ear Falls
Geological Regions of Canada
Appalachian Orogen
Cordilleran Orogen
Pacific Continental Shelf
Arctic Continental Shelf
Grenville Province
Slave Province
Arctic Platform
Hudson Bay Lowlands
Southern Province
Atlantic Continental Shelf
Innuitian Orogen
St. Lawrence Platform
Bear Province
Interior Platform
Superior Province
Churchill Province
Nain Province
Oceanic crust
REFERENCE
Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Physiographic Regions of Ontario - Thurston, P. C. 1991 Geology of Ontario: Introduction in Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, p.26-57
Geology: Geological Map of Canada 1996, Map D1860A
Produced by Golder Associates Ltd under licence from Ontario Ministry of Natural Resources, © Queens Printer 2009
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15
200 100 0 200 400
SCALE 1:9,500,000 KILOMETRES
PROJECT
NWMO Desktop Level Initial Screening
TITLE
Subdivision of the Superior Province of the Canadian Shield
PROJECT NO. 10-1152-0110 SCALE AS SHOWN REV. 1.0
DESIGN PB 30 Aug. 2010
GIS PRM 8 Apr. 2011
CHECK CM 8 Apr. 2011
REVIEW GS 8 Apr. 2011
Golder Associates
Mississauga, Ontario
FIGURE: 3.1
N
Sugluk
Cape Smith Belt
Minto
Labrador Trough
Hudson Bay
Bienville
Ashuanipi
La Grande River
Opinaca River
James Bay
Winisk
Thompson Belt
Trans-Hudson Orogen
Manitoba
Ontario
Pikwitonei
Sachigo
Berens River
Uchi
English River
Bird River
Ear Falls
Winnipeg River
Wabigoon
Quetico
Wawa
Kapuskasing Structural Zone
Opatica
Abitibi
Pontiac
Grenville Province
Quebec
Ontario
Canada
USA
Lake Superior
Southern Province
Minnesota River Valley
Lake Michigan
Lake Huron
Lake Ontario
100000
1100000
2100000
7000000
6000000
5000000
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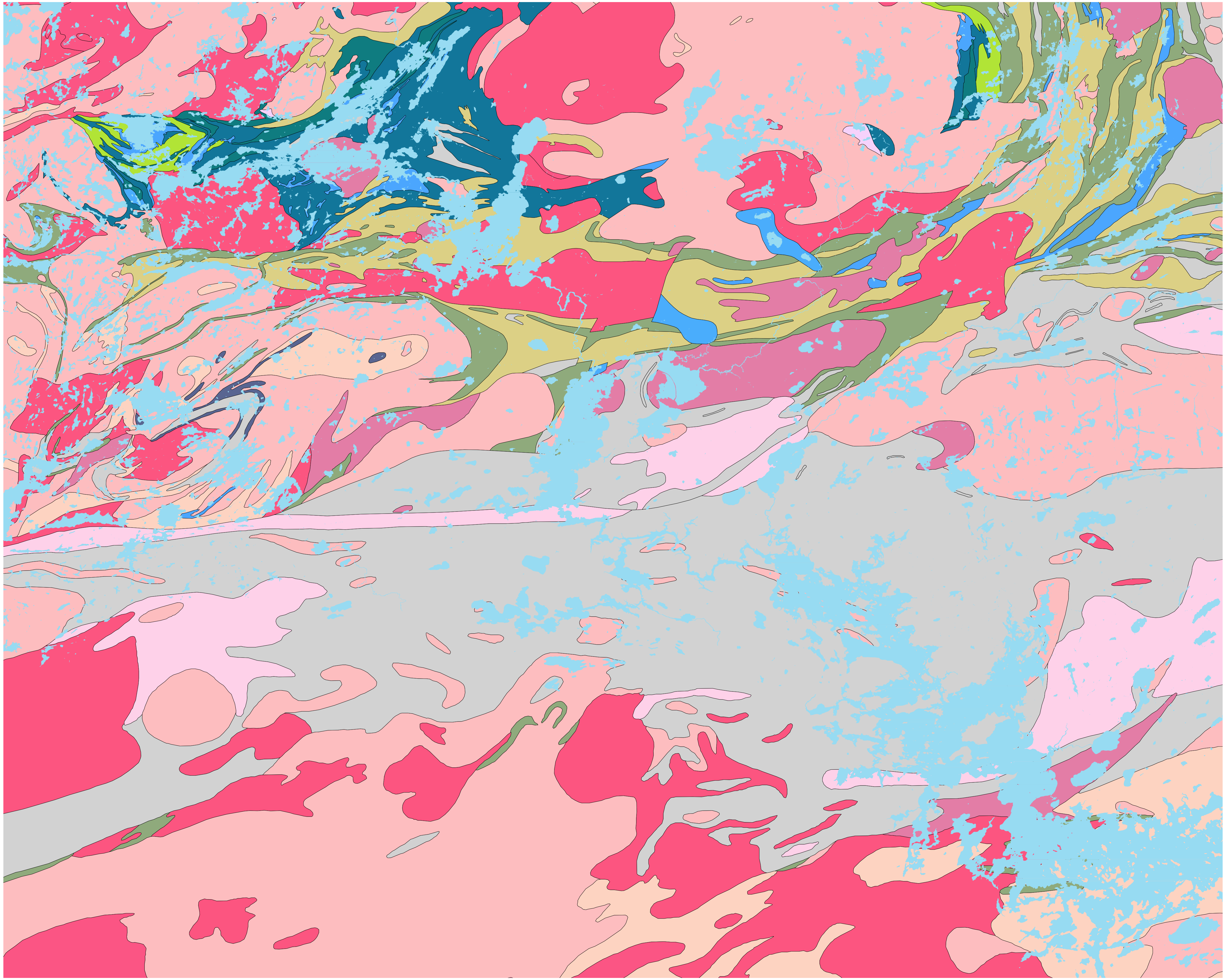
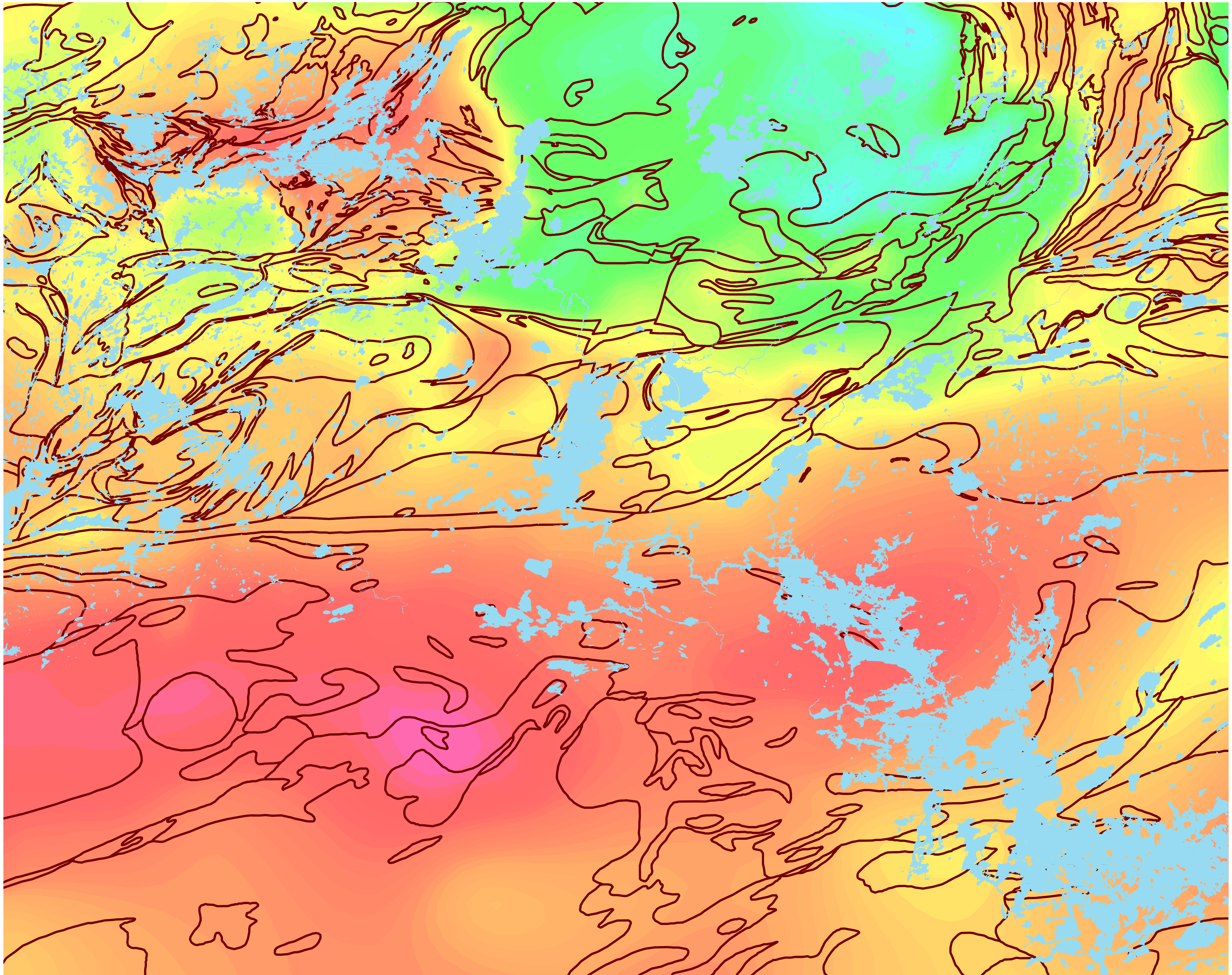
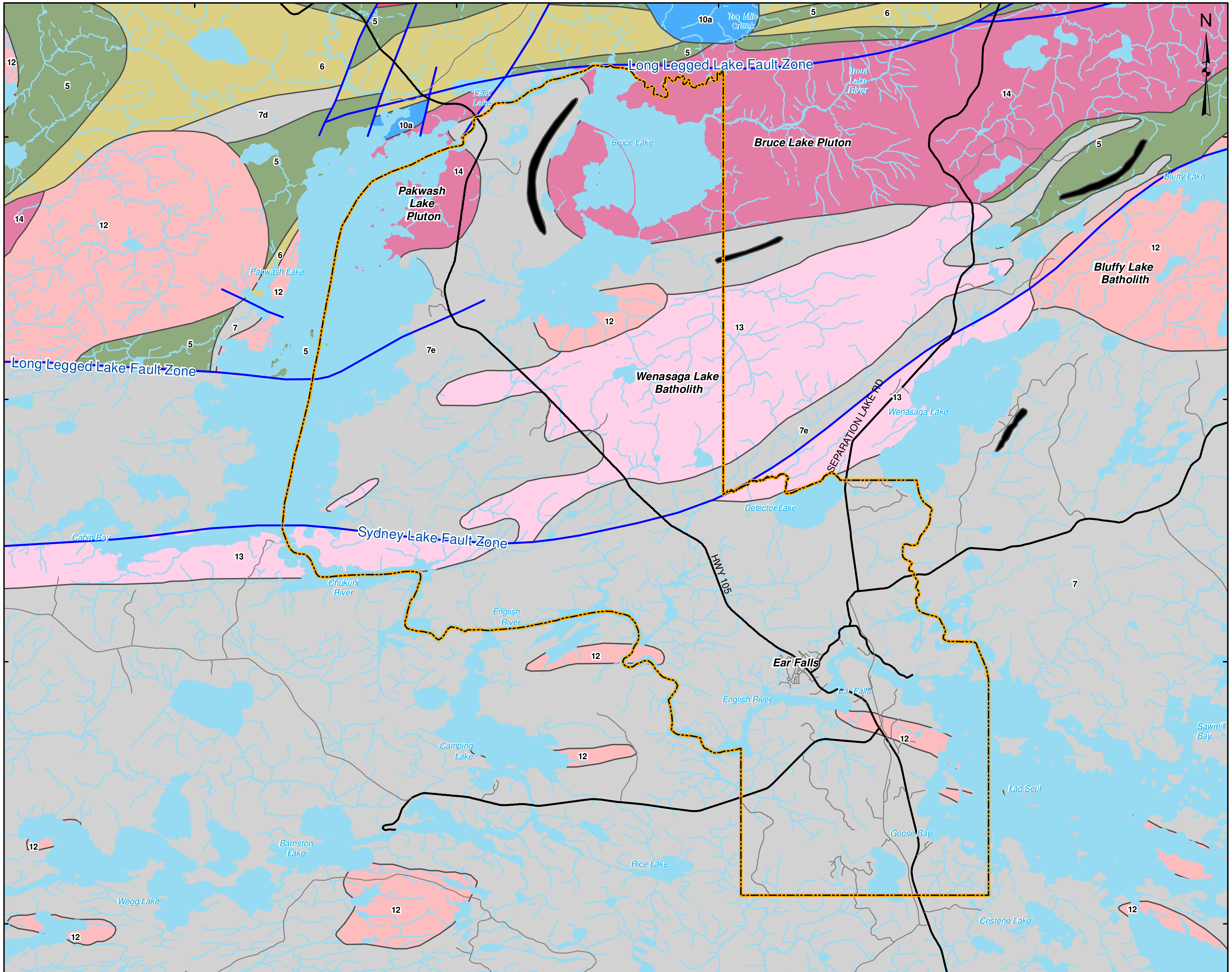
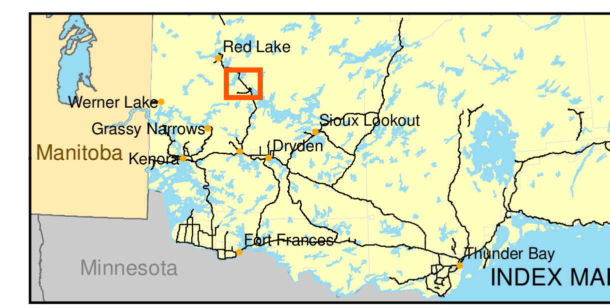






LEGEND

- Main Road
- Local Road
- Railway
- Watercourse, Permanent
- Watercourse, Intermittent
- Water Area, Permanent
- Geological Fault
- Geological Contact
- Iron Formation
- 15 Massive granodiorite to granite
- 14-Diorite-monzodiorite-granodiorite suite
- 13 Muscovite-bearing granitic rock
- 12 Foliated tonalite suite
- 10 Mafic and ultramafic rocks
  - 10a Gabbro
- 7 Metasedimentary rocks
  - 7c Marble, chert, iron formation, minor metavolcanic rocks
  - 7d Conglomerate and arenite
  - 7e Paragneiss and migmatites
- 6 Felsic to intermediate metavolcanic rocks
- 5 Mafic to intermediate metavolcanic rocks
- Township of Ear Falls



REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Geology: MRD126-Bedrock Geology of Ontario, 2007
Produced by Golder Associates Ltd under licence from Ontario Ministry of Natural Resources, © Queens Printer 2009
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15

2 1 0 2 4 6
SCALE 1:150,000 KILOMETRES

PROJECT
NWMO Desktop Level Initial Screening

TITLE
Bedrock Geology of the Ear Falls Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1152-0110			SCALE AS SHOWN	REV. 1.0
DESIGN	PB	30 Aug. 2010	FIGURE: 3.4	
GIS	PRM	8 Apr. 2011		
CHECK	CM	8 Apr. 2011		
REVIEW	GS	8 Apr. 2011		

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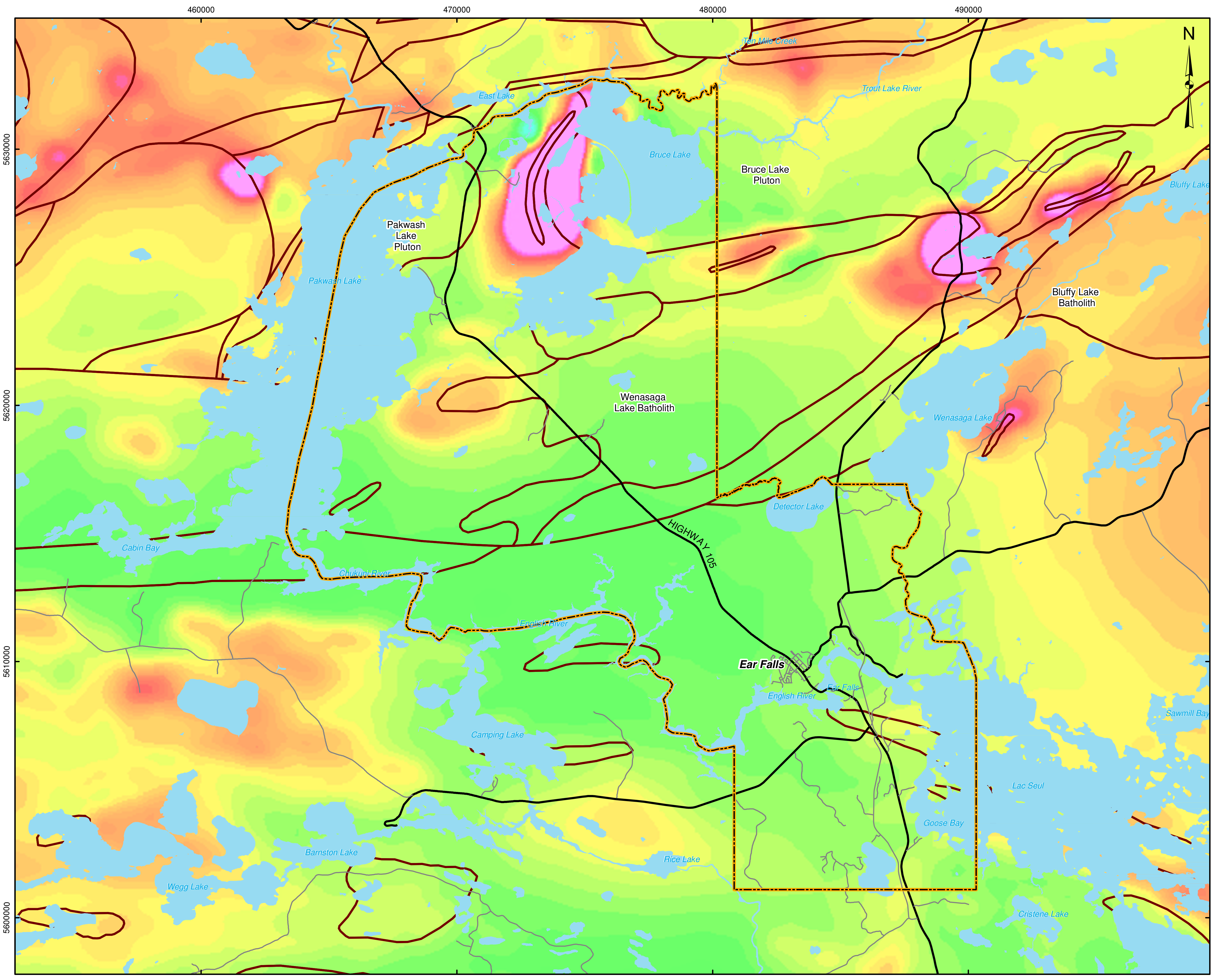
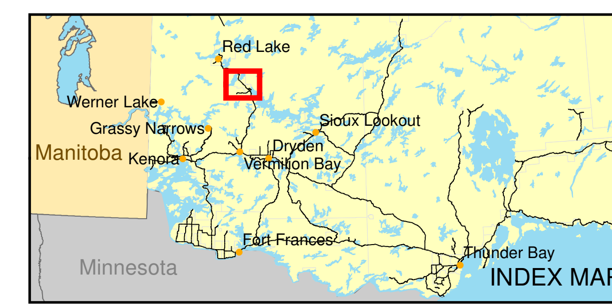


LEGEND

- Main Road
- Local Road
- Railway
- Water Area, Permanent
- Municipal Boundary
- Township of Ear Falls
- Geological Contact

Residual Total Magnetic Field (nT)

1000, 900, 800, 700, 600, 500, 400, 300, 200, 100, 0, -100, -200, -300, -400, -500, -600, -700, -800, -900, -1000



REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Geophysics: GSC Canada - 200m - Magnetic - Residual Total Field, 2008;
Canadian Aeromagnetic Data Base,Airborne Geophysics Section, GSC - Central Canada
Division,Geological Survey of Canada,Earth Sciences Sector,Natural Resources Canada
Geology: MRD126-Bedrock Geology of Ontario, 2007
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15

2 1 0 2 4 6

SCALE 1:150,000 KILOMETRES

PROJECT

NWMO Desktop Level Initial Screening

TITLE

Residual Magnetic Total Field of the Ear Falls Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1152-0110			SCALE AS SHOWN	REV. 1.0
DESIGN	PB	30 Aug. 2010	FIGURE: 3.5	
GIS	PRM	8 Apr. 2011		
CHECK	JF	8 Apr. 2011		
REVIEW	GS	8 Apr. 2011		

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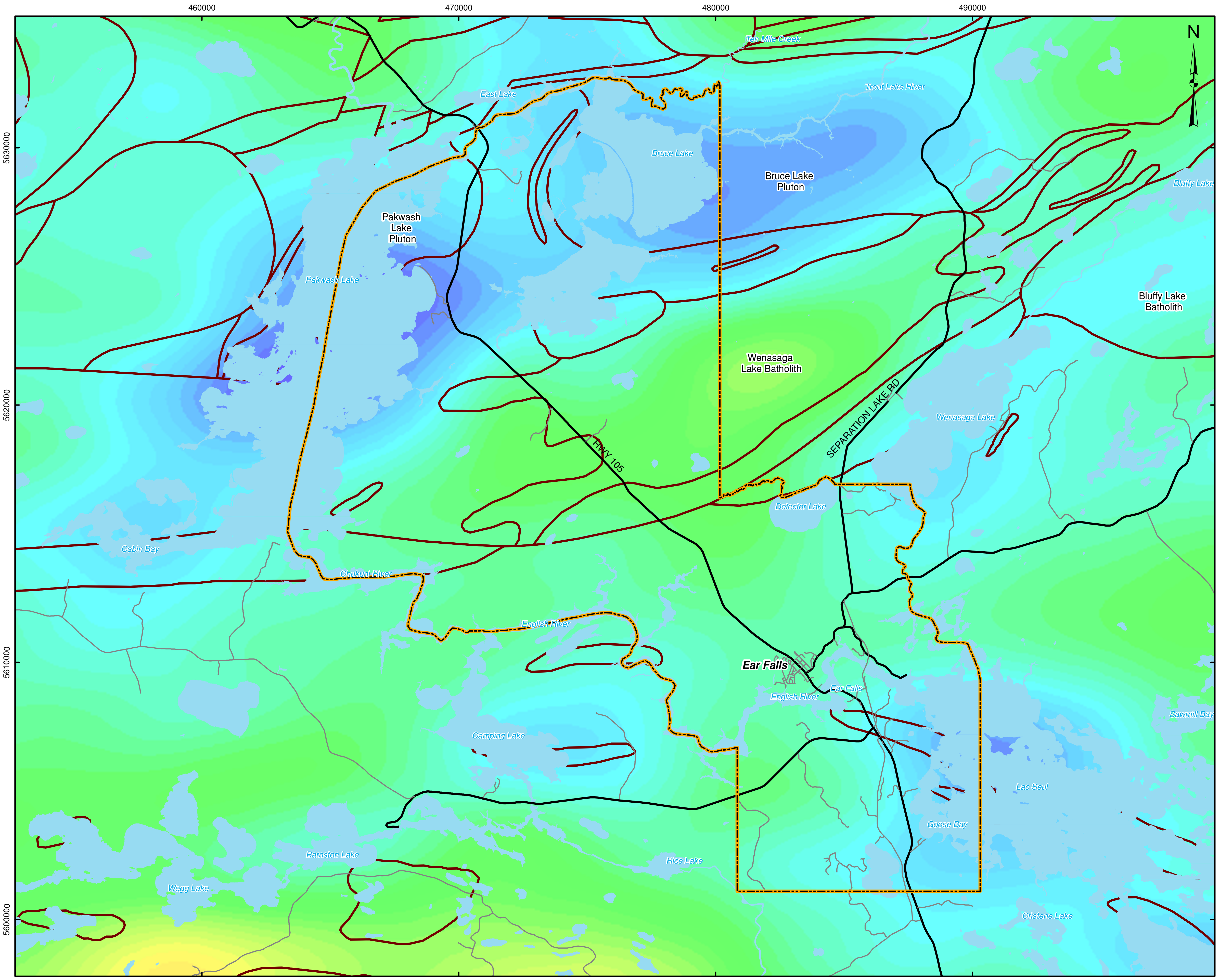
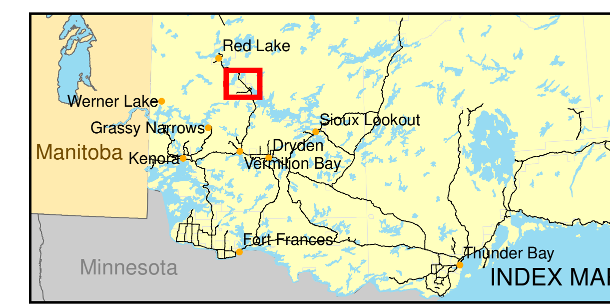


LEGEND

- Main Road
- Local Road
- Railway
- Water Area, Permanent
- Municipal Boundary
- Township of Ear Falls
- Geological Contact

Equivalent Uranium (ppm)

3, 2.8, 2.6, 2.4, 2.2, 2, 1.8, 1.6, 1.4, 1.2, 1, 0.8, 0.6, 0.4, 0.2, 0



REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Radiometrics: GSC Canada - 250m -Equivalent Uranium, 2010;
National Gamma-Ray Spectrometry Program Data Base, Airborne Geophysics Section,GSC -
Central Canada Division, Geological Survey of Canada, Earth Sciences Sector,Natural Resources Canada
Geology: MRD126-Bedrock Geology of Ontario, 2007
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15

2 1 0 2 4 6

SCALE 1:150,000 KILOMETRES

PROJECT

NWMO Desktop Level Initial Screening

TITLE

Equivalent Uranium of the Ear Falls Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1152-0110			SCALE AS SHOWN	REV. 1.0
DESIGN	PB	30 Aug. 2010		
GIS	PRM	8 Apr. 2011		
CHECK	JF	8 Apr. 2011		
REVIEW	GS	8 Apr. 2011		

FIGURE: 3.6

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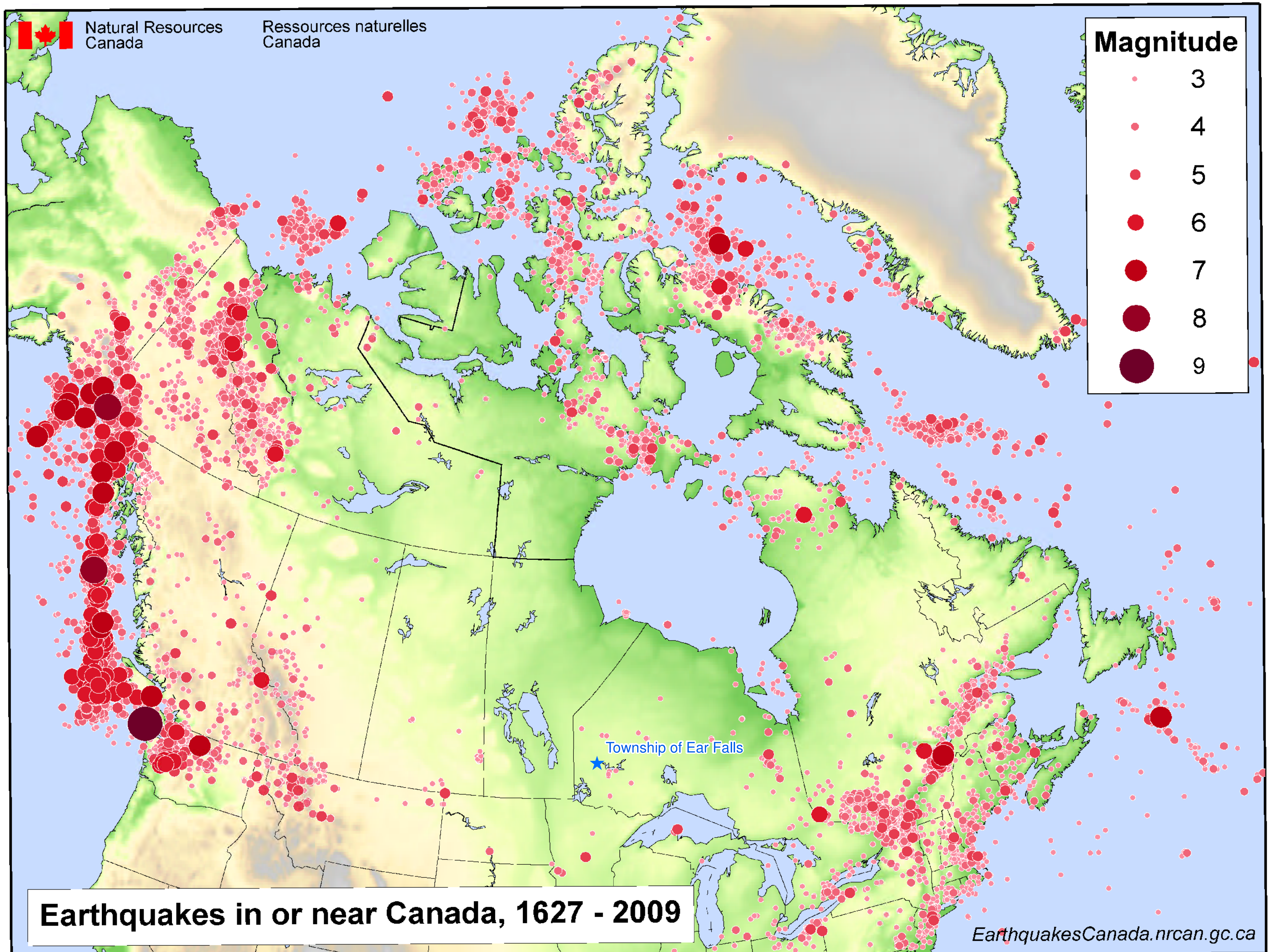

LEGEND

★ Township of Ear Falls

REFERENCE

Base Data - ESRI Digital Chart of the World,2010
Seismic: NRCAN, Earthquake Map of Canada 1627-2009
Projection:NA

PROJECT

NWMO Desktop Level Initial Screening

TITLE

Earthquakes Map of Canada 1627-2009

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1152-0110			SCALE AS SHOWN	REV. 1.0
DESIGN	PB	30 Aug. 2010	**FIGURE: 3.7**	
GIS	PRM	8 Apr. 2011		
CHECK	JF	8 Apr. 2011		
REVIEW	GS	8 Apr. 2011		

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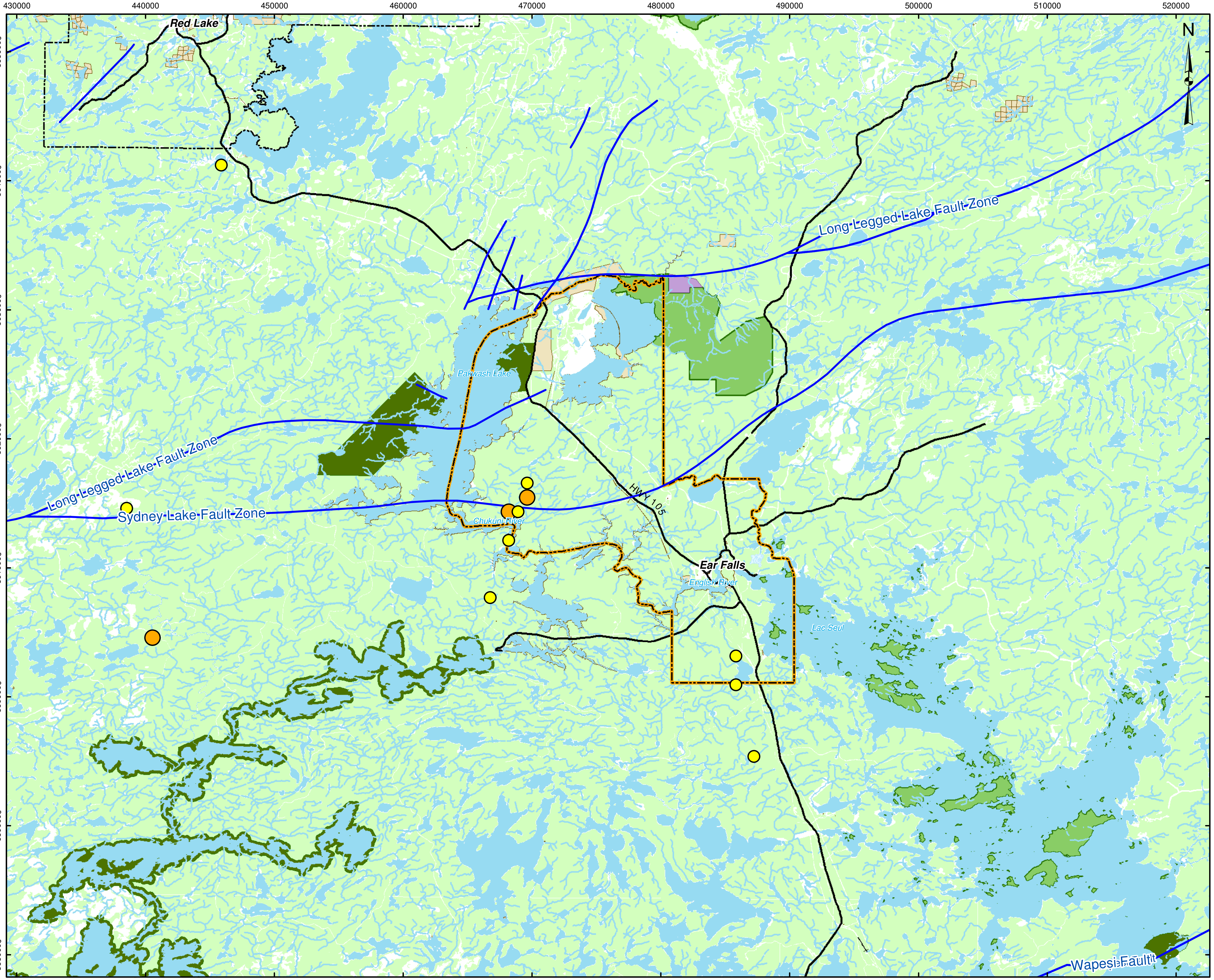
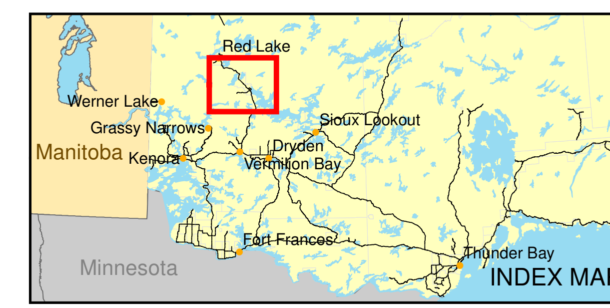


LEGEND

Seismic Events (Magnitude)
- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- > 3.0

- Geological Fault
- Main Road
- Railway
- Watercourse, Permanent
- Watercourse, Intermittent
- Water Area, Permanent
- Wooded Area
- Forest Reserve
- Conservation Reserve
- Provincial Park
- Crown Leased Land
- Crown Disposition Land
- Municipal Boundary
- Township of Ear Falls



REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Seismic:Earthquakes Canada, GSC, Earthquake Search (On-line Bulletin), Sept 2010
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15

5 2.5 0 5 10 15
SCALE 1:300,000 KILOMETRES

PROJECT

NWMO Desktop Level Initial Screening

TITLE

Historical Earthquake Records for the Ear Falls Area and Surrounding 1985-2010

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1152-0110			SCALE AS SHOWN	REV. 1.0
DESIGN	PB	30 Aug. 2010		
GIS	PRM	8 Apr. 2011		
CHECK	JF	8 Apr. 2011		
REVIEW	GS	8 Apr. 2011		

FIGURE: 3.8

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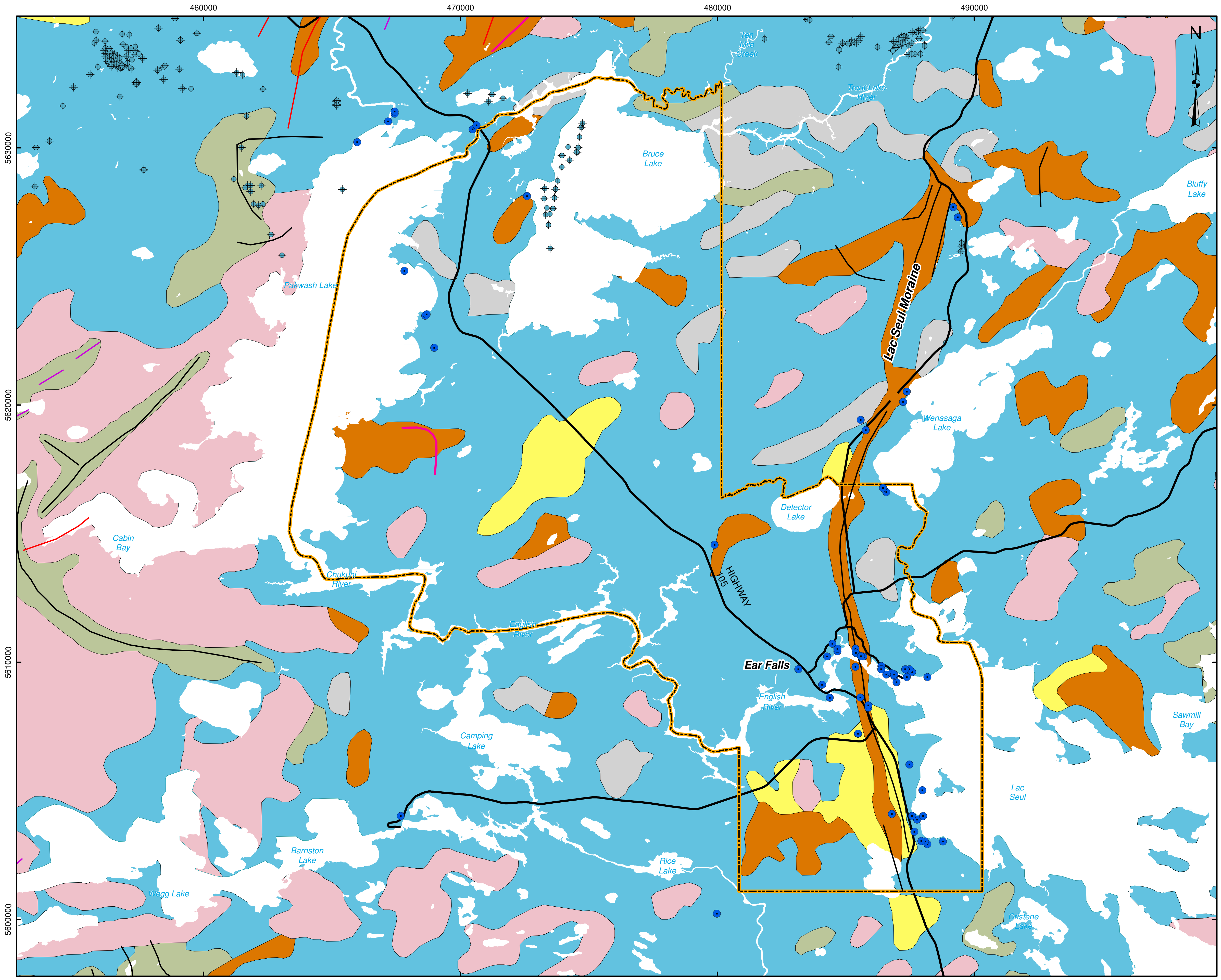
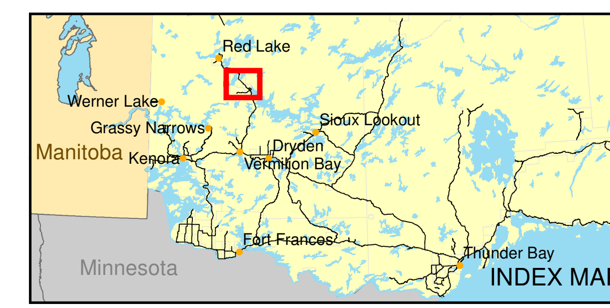


LEGEND

- MOE Well Location
- Diamond Drillhole
- Dunes
- Beach, Bar or Spit
- Drumlin or Area of Drumlins
- Esker or Area of Eskers; Direction of Flow Know or Assumed
- Terrace Escarpment (abandoned shore bluff)
- Terrace Escarpment; Fluvial
- Trend of End Moraine Crest
- Main Road
- Railway
- Municipal Boundary
- Township of Ear Falls
- 1: Bedrock
- 18: Till
- 22: Glaciofluvial Ice
- 23: Glaciofluvial Outwash Deposit
- 24: Glaciolacustrine Deposit
- 25: Glaciolacustrine Deposit
- 28: Fluvial Deposit
- 32: Organic Deposit
- 33: Lake



REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Geology: EDS014-Surficial Geology of Ontario 1:1,000,000, 2000
Wells: Ministry of the Environment, 2010
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15

2 1 0 2 4 6
SCALE 1:150,000 KILOMETRES

PROJECT

NWMO Desktop Level Initial Screening

TITLE

Quaternary Geology of the Ear Falls Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1152-0110			SCALE AS SHOWN	REV. 1.0
DESIGN	PB	30 Aug. 2010	FIGURE: 3.9	
GIS	PRM	8 Apr. 2011		
CHECK	CM	8 Apr. 2011		
REVIEW	GS	8 Apr. 2011		

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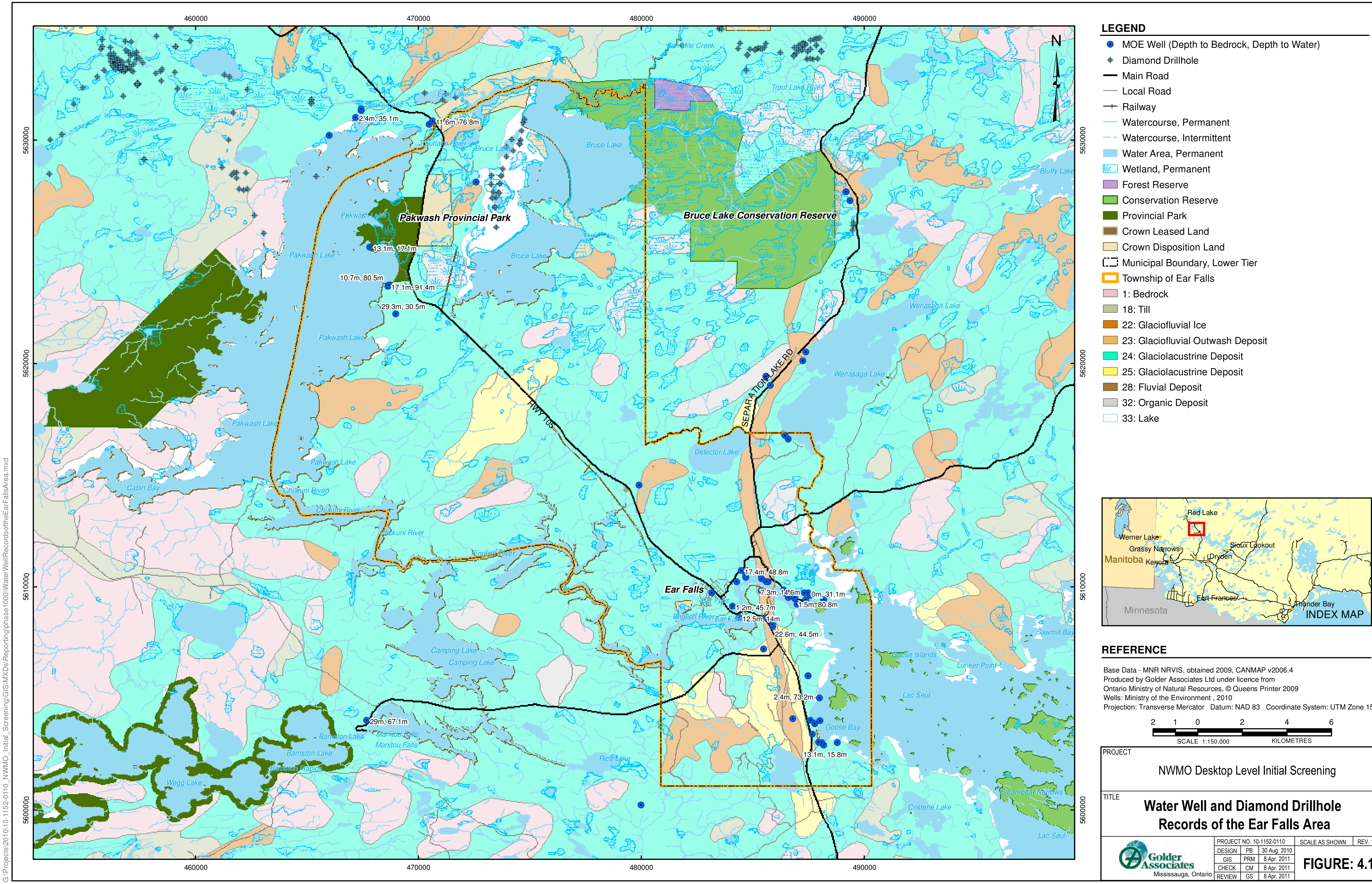
LEGEND
MOE Well (Depth to Bedrock, Depth to Water)
Diamond Drillhole
Main Road
Local Road
Railway
Watercourse, Permanent
Watercourse, Intermittent
Water Area, Permanent
Wetland, Permanent
Forest Reserve
Conservation Reserve
Provincial Park
Crown Leased Land
Crown Disposition Land
Municipal Boundary, Lower Tier
Township of Ear Falls
1: Bedrock
18: Till
22: Glaciofluvial Ice
23: Glaciofluvial Outwash Deposit
24: Glaciolacustrine Deposit
25: Glaciolacustrine Deposit
28: Fluvial Deposit
32: Organic Deposit
33: Lake
Pakwash Provincial Park
Bruce Lake Conservation Reserve
Ear Falls
HWY 105
SEPARATION LAKE RD
Pakwash Lake
Bruce Lake
Wenasaga Lake
Detector Lake
Cabin Bay
Chukuni River
English River
Camping Lake
Barnston Lake
Wegg Lake
Goose Bay
Lac Seul
Rice Lake
Cristene Lake
Lunker Point
Sawmill Bay
Bluffy Lake
Trout Lake River
Manitou Falls
2.4m, 35.1m
11.6m, 76.8m
13.1m, 17.1m
10.7m, 80.5m
17.1m, 91.4m
29.3m, 30.5m
17.4m, 48.8m
7.3m, 14.6m
0m, 31.1m
1.5m, 80.8m
1.2m, 45.7m
12.5m, 14m
22.6m, 44.5m
2.4m, 73.2m
13.1m, 15.8m
29m, 67.1m
460000
470000
480000
490000
5600000
5610000
5620000
5630000
N
Red Lake
Werner Lake
Grassy Narrows
Sioux Lookout
Dryden
Kenora
Manitoba
Fort Frances
Thunder Bay
Minnesota
INDEX MAP
REFERENCE
Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Wells: Ministry of the Environment , 2010
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15
2 1 0 2 4 6
SCALE 1:150,000 KILOMETRES
PROJECT
NWMO Desktop Level Initial Screening
TITLE
Water Well and Diamond Drillhole Records of the Ear Falls Area
PROJECT NO. 10-1152-0110
SCALE AS SHOWN
REV. 1.0
DESIGN PB 30 Aug. 2010
GIS PRM 8 Apr. 2011
CHECK CM 8 Apr. 2011
REVIEW GS 8 Apr. 2011
Golder Associates
Mississauga, Ontario
FIGURE: 4.1
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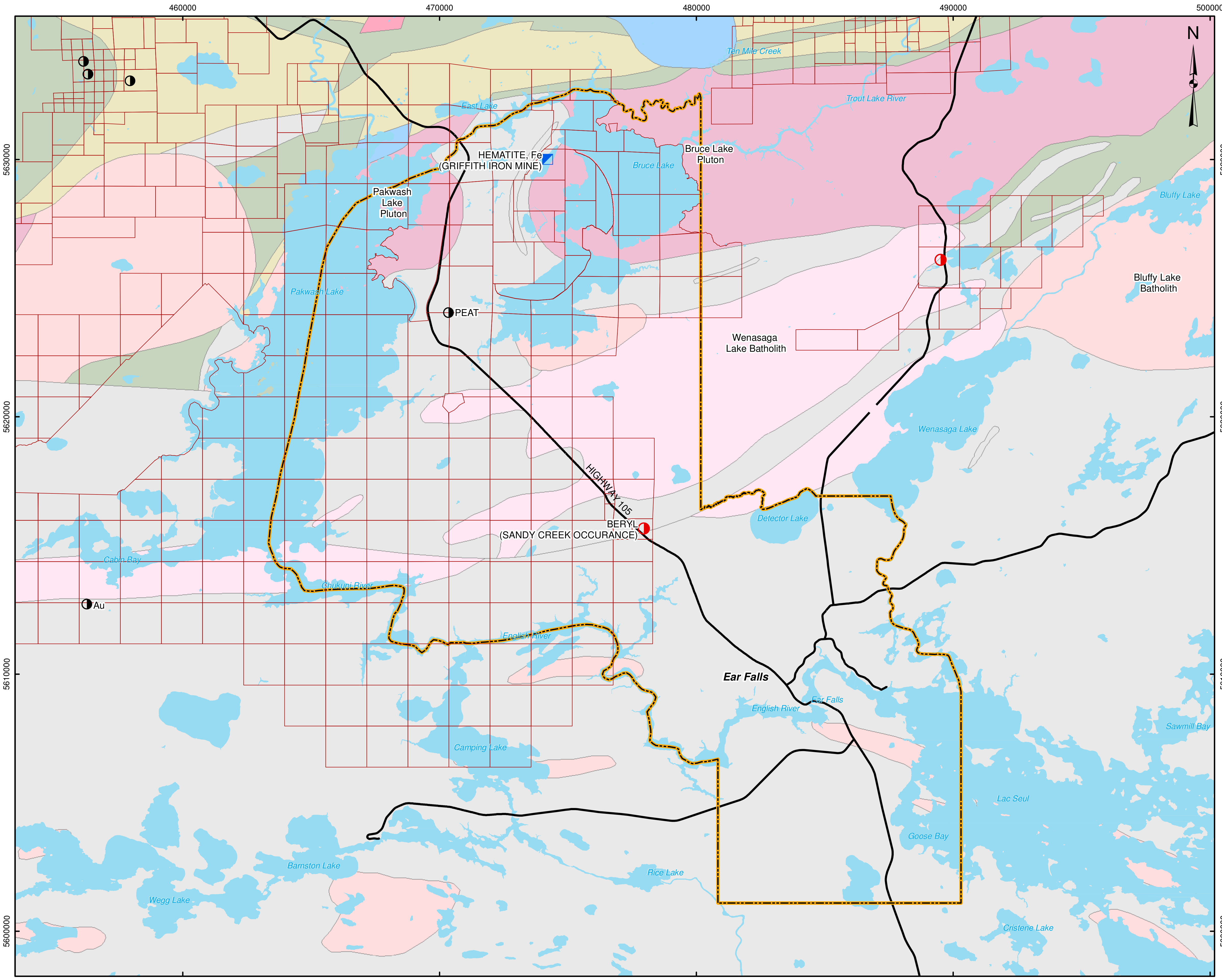
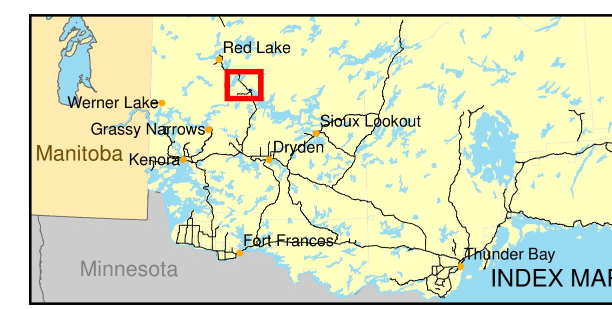


LEGEND

- Discretionary Occurrence
- Occurrence
- Past Producing Mine with Reserves
- Main Road
- Railway
- Water Area, Permanent
- Active Mining Claims
- Municipal Boundary
- Township of Ear Falls
- 15 Massive granodiorite to granite
- 15a Potassium feldspar megacrystic units
- 14-Diorite-monzodiorite-granodiorite suite
- 13 Muscovite-bearing granitic rock
- 12 Foliated tonalite suite
- 10 Mafic and ultramafic rocks
- 10a Gabbro
- 7 Metasedimentary rocks
- 7c Marble, chert, iron formation, minor metavolcanic rocks
- 7d Conglomerate and arenite
- 7e Paragneiss and migmatites
- 6 Felsic to intermediate metavolcanic rocks
- 5 Mafic to intermediate metavolcanic rocks



REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Claims: Ministry of Northern Mines and Development July 2010
Mineral Inventory: Mineral Deposit Inventory of Ontario v2, 2004
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15

2 1 0 2 4 6

SCALE 1:150,000 KILOMETRES

PROJECT

NWMO Desktop Level Initial Screening

TITLE

Mining Claims and Mineral Potential in the Ear Falls Area

PROJECT NO. 10-1152-0110			SCALE AS SHOWN	REV. 1.0
DESIGN	PB	30 Aug. 2010		
GIS	PB	30 Aug. 2010		
CHECK	JF	30 Aug. 2010		
REVIEW	GS	30 Aug. 2010		

Golder Associates
Mississauga, Ontario

FIGURE: 5.1

G:\Projects\2010\10-1152-0110_NWMO_Initial_Screening\GIS\MXDs\Reporting\phase1000\MiningClaimsandMineralPotentialintheEarFallsArea.mxd