nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

October 7, 2011

Municipality of Wawa
40 Broadway Avenue
P.O. Box 500
Wawa, ON P0S 1K0

Attn: Mr. Chris Wray, CAO/Clerk-Treasurer

Re: **Adaptive Phased Management Initial Screening – The Municipality of Wawa**

Dear Mr. Wray,

Further to the Municipality of Wawa'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 Municipality of Wawa 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 Municipality of Wawa from further consideration in the NWMO site selection process. The initial screening suggests that the Wawa area contains portions of lands 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 Municipality of Wawa 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, Wawa 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

c. Mayor Linda Nowicki

Initial Screening for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel

Municipality of Wawa, Ontario

Revision: 0 (Final)

Prepared for:
Nuclear Waste Management Organization
22 ST. Clair Avenue East, 6th Floor
Toronto, Ontario M4T 2S3

Prepared by:

Geofirma
Engineering Ltd
1 Raymond St., Suite 200
Ottawa, Ontario K1R 1A2
Tel: (613) 232-2525
Fax: (613) 232-7149
www.geofirma.com

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October, 2011

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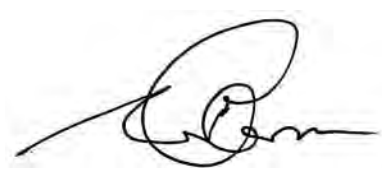
Prepared by:	Anthony West, Nattawadee Panikom	
Reviewed by:	Kenneth Raven	
Approved by:	 Kenneth Raven	

EXECUTIVE SUMMARY

On May 3, 2011, the Municipality of Wawa 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 Geofirma Engineering Ltd., to evaluate the potential suitability of the Wawa 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 Municipality of Wawa from further consideration in the site selection process. The initial screening focused on the Municipality of Wawa and its periphery, which are referred to as the "Wawa area" in this report.

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 Municipality of Wawa from further consideration in the NWMO site selection process. The initial screening indicates that the Wawa area contains portions of lands with geological formations that are potentially suitable for hosting a deep geological repository. Examples of these formations include the Whitefish Lake-Brule Bay Batholith and the Western Batholith that are present in the southern and northwestern parts of the Municipality respectively, and extend well beyond its boundaries. The Wawa Gneiss Domain, outside the southern boundary of the Municipality, is also potentially suitable. The rocks of the Michipicoten Greenstone Belt within and outside of the Municipality are likely unsuitable for hosting a deep geological repository due to their compositional heterogeneity, spatial variability and potential for natural resources.

It is important to note that at this early stage of the site selection process, the intent of this initial screening was not to confirm the suitability of the Wawa area to host a deep geological repository, but rather to identify whether there are any obvious conditions that would exclude it from the site selection process. Should the community of Wawa remain interested in continuing with the site selection process, more detailed studies would be required to confirm and demonstrate whether the Wawa 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

The review of available mapping and satellite imagery shows that the Wawa area contains limited constraints that would prevent the development of the repository's surface facilities. The developed areas and large water bodies occupy only a small portion of the Municipality and its periphery. While most of the Municipality and its periphery are unconstrained by topography, there may be areas where the topography may locally be unfavourable for the development of the repository's facilities and a more detailed assessment would be required.

Protected Areas, Heritage Sites, Provincial Parks and National Parks

The Wawa area contains sufficient land outside of protected areas, heritage sites, provincial parks and national parks to accommodate the repository's facilities. Seven protected areas were identified in the Wawa area, including provincial parks, conservation reserves and forest reserves. One of the reserves (Magpie River Terraces Conservation Reserve) lies entirely within the Municipality of Wawa. Overall these protected areas occupy only a small part of the Wawa area. Known archaeological sites are small and generally concentrated around the Lake Superior shoreline and within protected areas. There are no National Historic Sites in the Wawa area. The presence of 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 available information did not identify any known groundwater resources at repository depth (approximately 500 m) for the Wawa area. The Ontario Ministry of the Environment Water Well Information System database does not identify any potable water supply wells exploiting aquifers at typical repository depths in the Wawa area or anywhere else in Northern Ontario. Water wells in the Wawa area source water from overburden or shallow bedrock aquifers at depths of 117 m or less. Based on experience in similar crystalline rock settings in the Canadian Shield, the likelihood that exploitable aquifers are present at typical repository depth is low throughout the Wawa area. The absence of groundwater resources at repository depth 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 Wawa area contains sufficient areas, free of known economically exploitable natural resources, to accommodate the required repository's facilities. The potential for economically exploitable natural resources in the Municipality of Wawa and its periphery is associated with specific geological units such as the rocks of greenstone belts. The natural resource potential of the granitoid terrane external to the greenstone belts is limited, and mostly associated with its margin. There are currently no operating mines within the Municipality of Wawa or within the Wawa area that was screened.

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

Based on the review of readily available geological and hydrogeological characteristics and available experience from other similar rocks in the Canadian Shield, the Wawa area contains portions of land that do not contain known unsafe geological and hydrogeological conditions. There are a number of geological units with geoscientific characteristics that are potentially suitable for hosting a deep geological repository within the Wawa area. Examples of these formations include the Whitefish Lake-

Brule Bay Batholith and the Western Batholith that are present in the southern and northwestern parts of the Municipality respectively, and extend well beyond its boundaries. The Wawa Gneiss Domain, outside the southern boundary of the Municipality, is also potentially suitable. The rocks of the Michipicoten Greenstone Belt within and outside of the Municipality are likely unsuitable for hosting a deep geological repository due to their compositional heterogeneity, spatial variability and potential for natural resources.

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1 INTRODUCTION

On May 3, 2011, the Municipality of Wawa 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 Geofirma Engineering Ltd., as part of Step 2 in the site selection process to evaluate the potential suitability of the Wawa area against five screening criteria using readily available information. The initial screening focused on the Municipality of Wawa and its periphery, which are referred to as the "Wawa 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, such 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, such 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 further consideration in 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 initial 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, bedrock 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 PHYSICAL GEOGRAPHY

2.1 Location

The Municipality of Wawa is located along the northeast shore of Lake Superior at Michipicoten Bay approximately 170 km north of Sault Ste. Marie, as shown in Figure 2.1. The Municipality of Wawa is approximately 422 km^2 in size. The settlement area of Wawa is situated at the south end of Wawa Lake, approximately 7 km northeast of the Lake Superior shoreline. The Municipality also includes the settlement areas of Michipicoten River Village, and Michipicoten Harbour, both on the shore of Lake Superior.

The Municipality of Wawa is bordered on the west by the Gros Cap Indian Reserve, on the south by protected areas, and on the east, north and southeast by unorganized territory. The closest settlements to the settlement area of Wawa are Hawk Junction which is 20 km to the northeast, Dubreuilville which is 40 km to the north-northeast, and White River which is 80 km to the northwest. The settlement area of Wawa is accessed by the Trans Canada Highway (Highway 17) from the north and south, by Highway 101 from the east, by secondary roads, and by air. The Wawa area is accessible by the Algoma Central Railway, which connects Sault Ste. Marie in the south to Hearst in the North. Satellite imagery for the Wawa area (Spot 5, taken between 2005 and 2010) is presented in Figure 2.2.

2.2 Topography

The Municipality of Wawa is located in the Canadian Shield physiographic region, a low-relief, dome-like, gently undulating land surface. 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 Municipality of Wawa lies in the Abitibi Uplands, a broadly rolling surface of Canadian Shield bedrock that occupies most of north-central Ontario (Natural Resources Canada, 2011). Within this area, bedrock is typically either exposed at surface or shallowly covered with Quaternary glacial deposits or post-glacial organic soils (Thurston, 1991).

The topography of the Wawa area is presented on Figure 2.4. The land surface ranges from around 600 masl on the northern limit of the Municipality to 183 masl along the shore of the Lake Superior. The lowest ground surface elevations occur in the river valleys, notably the Michipicoten, Magpie, and Old Woman Rivers, which empty into Lake Superior. The settlement area of Wawa is located within the Magpie River valley at approximately 290 masl elevation. The highest elevations exist in upland areas surrounding the Municipality, typically in association with exposed granitic rocks. Very steep slopes are common in the area, including near vertical 200 m high cliffs at Old Woman Bay.

2.3 Drainage

The Municipality of Wawa is located within the Lake Superior drainage basin of the Atlantic Ocean watershed. The overall surface water drainage in the Wawa area is shown on Figure 2.5. Drainage is generally southerly into Lake Superior from the height of land between the Lake Superior drainage basin and that of the Hudson Bay system located approximately 50 km to the northeast (see index map in Figure 2.5) .

The main drainage is carried by the Michipicoten River, which flows approximately 110 km from Dog Lake just northeast of the Wawa area into Manitowik Lake, Whitefish Lake, and finally into Lake Superior. Tributaries of the Michipicoten River include the Shikwamka River which drains the east-central part of the study area, the Anjigami River which drains Anjigami Lake and the south-central part of the study area, and the Magpie River which drains the north-central part of the study area including the northern half of the Municipality.

The western part of the study area is drained by smaller south-flowing rivers, the largest of which are the Doré River and the Dog River. The south-central part of the Wawa area including Mishewawa Lake is drained by the Old Woman River which discharges to Lake Superior at Old Woman Bay. The south-east part of the Wawa area including Gould Lake is drained by the Agawa River which flows south through the Agawa Canyon (Agawa River Fault) prior to discharging into Lake Superior at Agawa Bay, 70 km south of the settlement area of Wawa.

2.4 Protected Areas

2.4.1 Parks and Reserves

There are seven protected areas in the Wawa area, as shown in Figure 2.1, including four Ontario provincial parks, two conservation reserves, and a forest reserve. The largest provincial park in the Wawa area is Lake Superior Provincial Park, which covers approximately 55,000 ha and 120 km of Lake Superior shoreline south of the Municipality of Wawa. Potholes Provincial Park is located on Highway 101 approximately 40 km west of the settlement area of Wawa, and is 347 ha in size. Michipicoten Post Provincial Park occupies 289 ha of land on the south shore of the Michipicoten River at its outlet into Lake Superior, approximately 7 km southwest of the settlement area of Wawa. Nimoosh Provincial Park, located approximately 30 km west of the settlement area of Wawa, is approximately 3,500 ha in size and contains reaches of the Dog River and Jimmy Kash River. None of the provincial parks lie within the boundaries of the Municipality of Wawa.

The two conservation reserves in the Wawa are the Magpie River Terraces Conservation Reserve and the South Michipicoten River-Superior Shoreline Conservation Reserve. The Magpie River Terraces Conservation Reserve protects approximately 2,088 ha of land centred approximately 7 km north of the settlement area of Wawa, entirely within the Municipality boundary. The Michipicoten River-Superior Shoreline Conservation Reserve protects approximately 2,219 ha of land between the south bank of the Michipicoten River and the northern boundary of Lake Superior Provincial Park, approximately 10 km south of the settlement area of Wawa. A few hectares of this conservation reserve lie within the Municipality boundaries. A 390 ha forest reserve, is located between the south bank of the Michipicoten River and the northern boundary of Lake Superior Provincial Park, straddling Highway 17.

2.4.2 Heritage Sites

The cultural heritage screening examined known archaeological and historic sites in the Wawa area. Information on archaeological sites in Ontario is provided by the Ontario Ministry of Tourism and Culture, through their Archaeological Sites Database (Ontario Ministry of Tourism and Culture, 2011).

The background research indicates that the Ojibway (Anishinabe) have inhabited the Lake Superior shoreline in the Wawa area for many thousands of years. The Michipicoten Post was an important summer settlement at the confluence of the Michipicoten and Magpie Rivers that was operated between 1821 and 1904 by the Hudson's Bay Company (Douglas, 1995). There are 11 known archaeological sites in this location (Figure 2.1), including Michipicoten Bay and Harbour. Other Lake Superior shoreline archaeological sites in the Wawa area include 11 in Lake Superior Provincial Park, particularly around Old Woman Bay, and 2 in Nimoosh Provincial Park. There are 4 known archaeological sites within and surrounding the Magpie River Terraces Conservation Reserve within the Municipality of Wawa. East of the Municipality of Wawa there five sites whose locations relative the settlement area of Wawa are as follows: 1 on Anjigami Lake approximately 20 km to the southeast, 1 on the upper reaches of the Michipicoten River approximately 20 km to the east-southeast, 1 on Manitowik Lake approximately 40 km to the northeast, and 2 approximately 50 km to the east. There are no National Historic Sites in the Wawa area (Parks Canada, 2011).

The potential for archaeological and historical sites within the Wawa area is considered to be high given the sites already documented, the proximity to the Lake Superior shoreline, and the importance of the area in the historic fur trade. The presence of local heritage sites would need to be further confirmed in discussion with the community and Aboriginal peoples in the area, if the community remains interested in continuing with the site selection process.

3 GEOLOGY AND SEISMICITY

3.1 Regional Bedrock Geology

The geology of the Wawa area consists of unconsolidated Quaternary deposits overlying 3 to 2.5 billion year old (3 to 2.5 Ga) bedrock of the Canadian Shield – a stable craton that forms the core of the North American continent. The Canadian Shield is an assemblage of Archean-age plates and accreted juvenile arc terranes and sedimentary basins of Proterozoic age that were progressively amalgamated over geologic time scales.

As shown on Figure 3.1, the Municipality of Wawa 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 extends 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 Municipality of Wawa is located in the southeastern portion of the Wawa Subprovince; a belt of rocks about 900 km long and 150 km wide, extending from central Minnesota in the United States to the Kapuskasing area in northeastern Ontario. The Wawa Subprovince is bounded on the north by the metasedimentary rocks of the Quetico Subprovince, and to the south by Proterozoic aged (1.9 to 1.1 billion-year old) rocks of both the Southern Province and rocks associated with the Midcontinent Rift system. To the east, the Wawa Subprovince is truncated by the Kapuskasing Structural Zone that separates the Wawa Subprovince from the Abitibi Subprovince (and is sometimes referred to as the Abitibi-Wawa Belt). The Wawa Subprovince is composed primarily of Archean greenstone belts and granitic intrusions, with smaller mafic intrusive rocks locally present. Diabase dikes, largely of Proterozoic age, occur in “swarms” in the entire Superior Province.

Figure 3.2 shows the general bedrock geology and main structural features of the southeastern part of the Wawa Subprovince, where the Municipality of Wawa is located. The main geological features of the area are groups of rocks known as the Michipicoten, Gamitagama, and Mishibishu Greenstone Belts, and granitoid terranes (Williams et al., 1991) surrounding them. The Michipicoten Greenstone Belt makes a regional reference point, and the surrounding granitoid terranes are named differently on its southern and northern flanks. To the south, between the Michipicoten Greenstone Belt and the Kapuskasing Structural Zone, the granitoid terrane is referred to as the Wawa Gneiss Domain (Thurston et al. 1977; Moser, 1994). The granitoid terrane to the west of the Michipicoten Greenstone Belt is generally referred to as the Western Batholith (Card and Poulsen, 1998).

The greenstone belts are supracrustal assemblages formed by mafic to felsic volcanic cycles between 2.9 and 2.7 billion years ago, including associated metasedimentary rocks and intrusions of granitoid rocks. The surrounding granitoid rocks are a mosaic of felsic plutons including the Whitefish Lake Batholith, the Renabie Pluton, the Dubreuilville Pluton, the Western Batholith, and slivers of supracrustal rocks. While some of the granitoid intrusions and supracrustal rocks in the granitoid terrane are dated as old as 2.9 billion years, the mosaic of granitoid plutons are generally younger than the supracrustal rocks of the greenstone belts, and are dated around 2.7 billion years old (Turek et al. 1990; Turek et al. 1992; Moser, 1994). The plutons are thought to be mid-crustal intrusions developed during or after the production of the greenstone belts (Percival, 1990). The precise relationship between the external granitoid rocks and greenstone belts is uncertain, although the granitoid intrusions in the greenstone belts and the surrounding granitoid rocks are of similar age (Sage, 1994).

Faulting is common in the southeastern part of the Wawa Subprovince, with most faults being oriented northwest and less commonly northeast (McGill and Shrady, 1986; Sage, 1994). The largest of the northwest trending faults are the Trembley, Mildred Lake and Marsden Faults, which cross the Wawa area. These faults are aligned with the Matachewan swarm diabase dikes which were emplaced 2.454 billion years (Ontario Geological Survey, 1991), and were likely tectonically active in the late Archean and early Proterozoic eras (Sage, 1994). The largest of the northeast trending faults are the Wawa-Hawk-Manitowik Lake and Old Woman River Faults, which cross-cut the Municipality of Wawa and are commonly associated with the Kapuskasing Structural Zone (Sage, 1994). While these faults may be associated with late Archean tectonism (Sage, 1994; Manson and Halls, 1997), they are much more commonly associated with Paleoproterozoic tectonism associated with the Kapuskasing Structural Zone which bounds the Wawa Gneiss Domain approximately 60 km to the southeast (Figure 3.1). The Kapuskasing Structural Zone is interpreted by Percival and West (1994) as a tilted block which was uplifted during the Paleoproterozoic era, approximately 1.9 billion years ago (Sage, 1994; Manson and Halls, 1997). The uplift resulted in exposure of the upper 30 km of the crust, with increasing deeper structural levels below the Michipicoten Greenstone Belt being exposed to the east. In this interpretation, the Michipicoten Greenstone Belt has been subject to less than 10 km of erosion, while the Wawa Gneiss Domain has been subject to between 10 and 20 km of erosion.

A major fault in the southeastern part of the Wawa Subprovince is the Agawa Canyon Fault, occurring approximately 10 km to the east of the Municipality of Wawa, which is sometimes referred to as the McVeigh Creek Fault. This fault can be traced many kilometres south of the Michipicoten Greenstone Belt, and its northerly orientation is unique in the area. The fault is considered to be post-Keweenawan in age (i.e. younger than 1.1 billion years), and associated with the Midcontinent Rift (Manson and Halls, 1997).

3.2 Local Bedrock Geology

3.2.1 Lithologies

The bedrock geology of the Wawa area is shown on Figure 3.3. Approximately 75% of the Municipality of Wawa is underlain by the supracrustal rocks of the Michipicoten Greenstone Belt, which extends beyond the Municipality boundaries to the north, northwest, and southwest (see Figure 3.2). The southern part and the northwestern part of the Municipality are underlain by granitoid rocks that are external to the greenstone belt, specifically the Wawa Gneiss Domain and the Western Batholith, respectively. The Wawa Gneiss Domain is composed of gneissic tonalite, the granite to granodiorite Whitefish Lake Batholith, migmatized supracrustal rocks and diabase dikes (Williams et al. 1991). The Western Batholith extends between the Michipicoten and the Mishibishu Greenstone Belts and is composed of three different granitic suites. These batholiths extend well beyond the boundaries of the Municipality.

Geophysical surveys for the Wawa area support the mapped lithologies. Gravity data for the Wawa area is shown in Figure 3.4, which indicates the relative densities of the basement rocks. Since mafic rocks (e.g., basalt and gabbro) are rich in heavier elements (e.g., magnesium and iron), they generally exhibit positive gravity response. In contrast, felsic rocks such as granite are rich in lighter elements (e.g., silicon, oxygen) and exhibit negative gravity response. Figure 3.4 indicates a pronounced positive gravity response for the Michipicoten and Gamitagama Greenstone Belts, and to a lesser extent for the Mishibishu Greenstone Belt, relative to the surrounding granitoid rocks. This is expected given the occurrence of mafic rocks in the greenstone belts, and the presence of iron formation among the metasedimentary rock types of the greenstone belts (Card and Poulsen, 1998).

Gravity data in Figure 3.4 show negative gravity anomalies that generally correspond with lower density plagioclase- and quartz-rich tonalitic and granodioritic rocks that comprise the intrusive plutonic and granitic gneiss terranes external to the greenstone belts.

Airborne magnetic surveys can detect variations in magnetism caused by the presence of magnetic minerals (mainly magnetite and pyrrhotite). Airborne magnetic surveys are useful tools for ore body detection, and enhanced lithological and structural mapping of bedrock geology (Ontario Geological Survey, 2003). The airborne magnetic data for the Wawa area is shown in Figure 3.5. In this figure, there is a clear correlation between the mafic rocks of the greenstone belts (Figure 3.3) and the magnetic highs. The largest magnetic anomaly is located northwest of the settlement area of Wawa, coincident with the presence of iron formation and the historic iron ore mining of the Michipicoten district (e.g., the Helen Mine north of Wawa and the Josephine Mine near Hawk Junction). The Wawa Gneiss Domain, including the Whitefish Lake Batholith, and the Western Batholith exhibit low magnetism, with subdued linear anomalies corresponding to the mapped diabase dikes. Similar linear anomalies suggest the presence of diabase dikes, where none are currently mapped.

Airborne radiometric data for the Wawa 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. Figure 3.6 indicates that the highest equivalent uranium response is coincident with the plutonic granitoid rocks (e.g., the Whitefish Lake Batholith and the Western Batholith), while the lowest equivalent uranium response is coincident with the largest areas of mafic metavolcanic rock of the greenstone belts (e.g. immediately north of the northeasterly corner of the Municipality). It is noted that the equivalent uranium signature is not consistent across the Whitefish Lake Batholith and across the Western Batholith (compare the southwest to the northeast end of the Whitefish Lake Batholith, or the Whitefish Lake area to the area immediately to the east of it). This may reflect compositional heterogeneity found in these plutonic rocks not reflected in the mapping as undivided granodiorite to granite (Massey 1985; Williams et al. 1991). There is elevated equivalent uranium present in association with felsic metavolcanic rocks (specifically unit 6b: rhyolitic, rhyodacitic flows, tuffs, and breccias), centred approximately 7 km west-northwest of the settlement area of Wawa. Rhyolitic breccias are known hosts for uranium deposits (Dahlkamp, 2009), which may explain the elevated equivalent uranium.

The main greenstone belts and intrusive bodies in the Wawa area are further described below.

Michipicoten Greenstone Belt

The central part of the Municipality of Wawa is occupied by part of the Michipicoten Greenstone Belt which extends 140 km northeast from Michipicoten Bay, with a typical width of 30 km. The Michipicoten Greenstone Belt is a structurally and stratigraphically complex assemblage of volcanic, sedimentary and intrusive rocks, metamorphosed to greenschist facies and localized amphibolite facies (Williams et al. 1991; Sage, 1994). The Michipicoten Greenstone Belt consists of three cycles of volcanic rocks approximately 2.90, 2.75 and 2.70 billion years old (Turek et al. 1992). Chemical sedimentation led to iron formation, including the 100-150 m thick Michipicoten iron formation that caps the middle volcanic cycle (Sage, 1994). Stratigraphic correlation between different units is complicated by shearing and later folding deformations (Arias and Helmstaedt, 1990), while geochronological studies indicate overlapping events of volcanism, sedimentation, and granitic intrusion (e.g., Turek et al. 1992).

The three cycles of metavolcanic rocks of the Michipicoten Greenstone Belt each consist of similar massive and pillowed magnesium- and iron-rich tholeiitic flows (i.e., mafic volcanism) overlain by intermediate to felsic rocks consisting of tuff, lapilli tuff, coarse to very coarse breccias and quartz-feldspar crystal tuff (i.e., felsic volcanism). The lens of supracrustal rocks is up to several kilometres thick (Percival, 1990; Arias and Helmstaedt, 1990), supported by and intruded by the granitoid terrane. About 12 km northeast of the Municipality of Wawa, the thickness of the metavolcanic rocks exceeds approximately 1,000 m (Sage, 1994).

Coarse clastic and finer-grained metasedimentary rocks occupy areas several kilometres across within the northern part of the Municipality, and north of Michipicoten Bay (Figure 3.3). The metasedimentary rocks are the youngest rocks of the greenstone belt. These rocks interfinger with and are derived from the intermediate to felsic volcanic rocks of the 2.7 billion year old cycle; they are immature, thin-bedded to massive wackes, siltstones, argillites, subarkoses, and conglomerates, and increase in volume and clast size towards Lake Superior (Sage, 1994). The term Doré conglomerates is often used to describe the granite boulder-containing rocks, whose type location is at Michipicoten harbour, where the conglomerate horizon is up to 1400 m thick (Sage, 1994).

Intrusive rocks are common in the Michipicoten Greenstone Belt, resulting from a minimum of four intrusive periods generally occurring during or following the three periods of volcanism. It is suggested that some of the intrusions occurred during the formation of the external plutons (i.e., the granitoid terrane surrounding the greenstone belt), much of which occurred toward the end of and following the volcanic activity (Turek et al. 1992). The intrusive rocks within the Michipicoten Greenstone Belt can be classified either as 1) intermediate to mafic or 2) intermediate to felsic as described below.

Intermediate to Mafic Intrusions

The intermediate to mafic intrusive rocks can be broadly categorized as conformable sill-like intrusions, small stocks and plutons, and mafic to ultramafic plugs and stocks (Sage, 1994). The conformable sill-like intrusions form wide (up to 500 m) and long bodies that are easily distinguishable on the bedrock geology map (Figure 3.3) near the Helen Mine on the northern shore of Wawa Lake and 5 km north of Wawa Lake. These intrusions vary from quartz diorite to gabbro. The only small intermediate to mafic stock in the Wawa area is the Reed Lake Stock, approximately 5 km southeast of Wawa Lake. The Reed Lake Stock is approximately circular in shape and is less than 2 km across. Mafic to ultramafic plugs and stocks are located predominantly west of Hawk Junction, and in the northeastern corner of the Municipality. They are typically up to several kilometres long, and less than 1 km across. The thickness of these intermediate to mafic intrusions is unknown.

Intermediate to Felsic Intrusions (Hawk Complex and Jubilee Stock)

The two main intermediate to felsic intrusions within the Michipicoten Greenstone Belt in the Wawa area are the Hawk Lake Granitic Complex and the Jubilee Stock which lie about 15 km northeast and 2 km east of the settlement area of Wawa, respectively, adjacent to the Wawa-Hawk-Manitowik Lake Fault (Figure 3.4). These intrusions are synvolcanic, being of similar age to the metavolcanic rocks of the greenstone belt (Sage, 1994; Turek et al. 1992).

The Hawk Lake Granitic Complex lies immediately north of Hawk Lake near Hawk Junction, and includes several plutons, the largest of which is approximately 5 km long and 5 km wide. This intrusion is fault-bounded on its southern boundary by the Wawa-Hawk-Manitowik Lake Fault and on its eastern boundary by the Marsden Fault. These rocks vary from trondhjemite to granodiorite in composition, and, in the centre of the complex, are medium to coarse-grained in texture, changing to quartz-feldspar porphyry toward the margins (Sage, 1994; Sage et al., 1996). They are similar in age to the oldest volcanic cycle (i.e., 2.9 billion year old) and are potentially the source of the oldest volcanic rocks (Williams et al. 1991). The thickness of this complex is unknown. The Hawk Lake Granitic Complex may be associated with a caldera collapse (Turek et al. 1992).

The Jubilee Stock is located on the shores of Wawa Lake and to the south. It is an elongated body approximately 6 km long and 1.3 km wide, with the long axis oriented at approximately 20°, composed dominantly of fine- to medium-grained diorite, quartz-diorite and granodiorite (Sage, 1979; Sage et al., 1996). Its thickness is not known. It contains a relatively large volume of metavolcanic rock fragments and blocks (Sage, 1994), and is dated as equivalent to the rocks of the middle (2.75 billion years old) volcanic cycle (Turek et al. 1992). The Jubilee Fault cuts across the western portion of the stock. Based on stratigraphic and structural relationships, the Jubilee stock may represent a caldera (Sage, 1979; 1994).

Wawa Gneiss Domain

The Wawa Gneiss Domain, sometimes referred to as the Wawa Gneiss Terrane, the Wawa Tonalitic Gneiss Complex or the Anjigami Gneiss Domain, lies south of the Michipicoten Greenstone Belt and underlies the eastern and southern half of the Wawa area. The Wawa Gneiss Domain is a 10-15 km thick array of tonalitic and granodioritic orthogneisses and plutons surrounding extensive bodies of amphibolites- to granulite-grade mafic gneiss and paragneiss (Jackson and Sutcliffe, 1990; Percival, 1990; Moser, 1994). More than 60% of the lithology of the Wawa Gneiss Domain in the Wawa area is biotite- and amphibolites-bearing tonalitic gneiss (2.71 billion year old), while the rest is divided into gneissic tonalite-granodiorite and massive granite-tonalite (2.68 billion year old) (Jackson and Sutcliffe, 1990; Moser, 1994).

In the area adjacent to the Agawa Canyon Fault, toward which the southeastern portion of the Michipicoten Greenstone Belt extends, the Wawa Gneiss Domain is composed of tonalite and granodiorite, but diorite, quartz diorite and granite can also be found. There is a general gneissic fabric and a moderately to strongly developed foliation (Massey, 1985).

A portion of the Wawa Gneiss Domain bounds the Gamitagama Greenstone Belt on its northern flank. It is of trondhjemitic composition, massive to foliated, and has an abrupt, near vertical contact against rocks of the greenstone belt (Krogh and Turek, 1982). Using stratigraphic relationships, Krogh and Turek (1982) constrained its age as older than 2.668 billion years.

Whitefish Lake Batholith

The Whitefish Lake Batholith (Williams et al. 1991) is a massive granodiorite to granite intrusion within the Wawa Gneiss Domain, making up much of the central portion of the Wawa area (see Figure 3.3). South of the extension of the Michipicoten Greenstone Belt which bisects the batholith, the batholith has previously been referred to as the Brule Bay Batholith (McCrank et al. 1981). The Whitefish Lake-Brule Bay Batholith covers an approximate elongated area with northeast and southwest axes of approximately 62 km x 15 km, respectively. No specific information was found on the thickness of these two granitic bodies, though as part of the regional granitoid terrane, they would exceed 10 km in thickness (Percival, 1990). The massive granodiorite to granite intrusion has been dated at 2.694 billion years old (Turek et al. 1984). The batholith is composed of medium-grained, massive, equigranular granodiorite to quartz monzonite (Wilson, 1990). Diorite to granodiorite displays a weak to moderate foliation and in some parts a gneissic structure, and texture is generally equigranular with minor porphyritic phases. Away from the margins, the batholith becomes more massive granodiorite and granite (Massey, 1985). Massey (1985) posed a magmatic origin for the foliation in the granodiorite, acknowledging that a tectonic component may have enhanced its development. There is little other information available on the batholith or indeed on the granitoid rocks in general, although studies indicate greater inhomogeneity than is evident from the un-subdivided mapping of these rocks (Williams et al. 1991). Mapping (e.g., Ontario Geological Survey, 2007) indicates the Whitefish Lake Batholith to be cut by diabase dikes of Proterozoic age (described below).

There is an unnamed migmatitic terrane within the Whitefish Lake Batholith and adjacent to the Michipicoten Greenstone Belt about 10 km southeast of the settlement of Wawa. The migmatitic terrane lacks precise boundaries and is not shown on Figures 3.2 and 3.3. Nevertheless, it runs for at least 3 km adjacent to the Michipicoten Greenstone Belt (Sage, 1979; Sage et al. 1982a). This terrane is heterogeneous and consists of several phases, the most prominent being diorite and tonalite. One of the phases has been formerly dated at 2.86 billion years (Sage, 1994).

Migmatized Supracrustal Rocks and Massive Granodiorite to Granite Intrusion, SE Corner of Wawa Area

Migmatized supracrustal rocks are mapped in the southeast part of the Wawa area, which at larger scale appear as "slivers" (see Figure 3.2). These slivers are up to 40 km long and between 2 and 10 km wide. Between the slivers of migmatized supracrustal rocks is an oblong-shaped massive granodiorite to granite intrusion, approximately 20 km in length and 10 km in width. There is no detailed geological mapping for this area, although the available regional-scale mapping shows the migmatized supracrustal rocks and the massive granodiorite intrusion to be intruded by the regional "swarm" of diabase dikes. The thickness and absolute age of these rocks are unknown.

<u>Western Batholith</u>

The Western Batholith (Card and Poulsen, 1998), in the northwest portion of the Wawa area, separates the Michipicoten Greenstone Belt from the Mishibishu Greenstone Belt, and consists of three granitic suites (see Figure 3.4): The most southerly suite is massive to foliated tonalite to granodiorite (Foliated Tonalite Suite). The next unit to the north is a foliated to gneissic tonalite to granodiorite (Gneissic Tonalite Suite). The most northerly unit is a massive to foliated granodiorite to granite (Granodiorite to Granite Suite). All the suites are approximately 20 to 30 km long and 10 to 15 km wide. There is no information available on the thickness of these units. Turek et al. (1984) dated the Gneissic Tonalite Suite at 2.698 billion years old.

Diabase and Lamprophyre Dikes

There are two main sets of diabase dikes that intrude all rock types in the Wawa area. The first set consists of northwest trending dikes having a 330-340° strike and subvertical dip. The northwest trending dikes belong to the Matachewan Swarm (Bates and Halls, 1991; West and Ernst, 1991; Phinney and Halls, 2001). The Matachewan dikes were emplaced around 2.47-2.45 billion years ago in the area between Lake Superior and James Bay, with subvertical dip and north-northwest to northwest strike, reaching up to 40 m in width (Phinney and Halls, 2001). The second set consists of subvertical, northeast trending dikes striking 30-50°. A potential origin of the northeast trending diabase dikes related to the Kapuskasing Structural Zone uplift has been posed by Halls and Davis (2004), while some of them are related to the Marathon Swarm (2126-2101 million years) (Halls et al. 2006). Both northwest and northeast trending sets of dikes are compositionally indistinguishable.

Sage (1994) also reported a younger set of dikes identical to the older ones, which occupy the same system of fractures, with northwest and northeast trends, and of presumed Proterozoic age. In the Naveau Township area, or south of the Michipicoten Greenstone Belt, Massey (1985) reported the presence of diabase dikes varying in thickness from a few cm to 30 m, which cut across all other lithologies and exhibit predominant northwest to north-northwest direction with a possible east-northeast conjugate set. He estimated a probable Keweenawan age (~1.1 billion year old) (Massey, 1985).

Lamprophyre dikes in the Wawa area crosscut all Archean lithologies and diabase dikes. Sage (1994) constrained the presence of these dikes to both the Hawk Lake area and the iron mines area to its north and east (Figure 3.3). The second generation of these dikes is also presumed Proterozoic in age, and Sage (1994) reported their presence majorly along the shoreline of Lake Superior, where they are generally thin, varying up to a metre in width, subvertical, and trend dominantly northeast, consistent with the structures related to the Kapuskasing Structural Zone.

3.2.2 Metamorphism and Deformation

The structural geology of the Wawa area is complex, reflecting the overlapping events of volcanism, sedimentation and granitic intrusion, all related to the formation of the Canadian Shield between 3.1 and 2.6 billion years ago (Card and Poulsen, 1998). The supracrustal rocks of the Michipicoten Greenstone Belt were subjected to repeated deformation during the 240 million year period of their formation (Sage, 1994). The surrounding granitoid terrane is variably deformed, depending on age.

The Michipicoten Greenstone Belt underwent multiple stages of deformation from approximately <2.72 to 2.66 billion years ago (Moser, 1994). Key structures resulting from the deformation events during this period in the greenstone belt include early major recumbent folds and thrusts, with later superimposed upright folds (Arias and Helmstaedt, 1990). Geological boundaries within the supracrustal rocks of the Michipicoten Greenstone Belt are commonly interpreted to be coincident with strike-slip faulting, although the lack of marker horizons complicates interpretation.

In the Wawa Gneiss Domain, detailed structural studies east of the Wawa area, have recognized at least five deformational events characterized by discrete deformation styles and timing. Structures from earlier than 2.7 billion years to approximately 2.58 billion years include gneissosity in tonalities, tight folds, ductile subhorizontal shear zones, and ductile extensional faults. In the Wawa Gneiss

Domain, composite deformation fabrics trend generally east-west, with northerly dips varying from steep in the west to gentle farther east (Moser, 1994). For the Western Batholith, no information was found on deformation structures for the pre-2.6 billion year period.

In addition to the pre-2.6 billion year old structures described above, both the supracrustal rocks of the Michipicoten Greenstone Belt and the granitoid rocks of the Wawa Gneiss Domain and the Western Batholith are cut by a series of younger (< 2.6 billion years), sub-parallel northwest and northeast trending faults, with a spacing of approximately 5 to 15 km, that are commonly filled by diabase dikes (McGill and Shrady, 1986; Sage, 1994). Regional scale faults traced over many tens of kilometres in the Wawa area include the northwest trending Trembley, Black Trout Lake and Mildred Lake Faults, and the northeast trending Wawa-Hawk-Manitowik Lake and Old Woman River Faults, (Figure 3.3). East of the Municipality, the north-trending Agawa Canyon Fault can be traced many kilometres north and south of the Michipicoten Greenstone Belt. As noted in Section 3.1, the different fault orientations are associated with distinct tectonic events approximately 2.5, 1.9, and 1.1 billion years ago. These regional scale faults are rooted in the mantle, and are associated with offsets in the several kilometre range. The Wawa area has remained largely tectonically stable over the last 1.1 billion years.

In addition to the regional scale faults, numerous smaller scale faults and lineaments have been mapped in the Wawa area. Examples of these smaller scale faults mapped in the Michipicoten Greenstone Belt are the Magpie River Fault, the Firesand River Fault, and the Loonskin Lake Fault, shown on Figure 3.3. These are faults or zones of closely spaced faults, typically spaced from a few hundred metres to several kilometres apart (Sage et al. 1982a). In the Wawa Gneiss Domain information on smaller scale faults and lineaments is obtained from local scale geological mapping in the Whitefish Lake – Brule Bay Batholith, in the southern part and east of the Municipality of Wawa (Sage et al., 1982b; Massey et al., 1983; Massey, 1985). Lineaments identified in these areas are subparallel to regional faults and trend northeast and northwest. For the northeast-trending lineaments spacing ranges from approximately 250 m to 3 km, and for the northwest-trending lineaments from about 500 m to 1.5 km. No detailed mapping of the Wawa Gneiss Domain bounding the Gamitagama Greenstone Belt was found, but the gneiss in this area it is partially cut by three main faults spaced 4-5 km apart. There is no detailed map of the migmatized supracrustal intrusions or the large massive granodiorite to granite intrusion between them (southeast part of the Wawa area).

On the eastern part of the Western Batholith, Mandziuk and Studemeister (1981) noted the presence of well defined lineaments in the Molybdenite Lake area parallel to the regional Trembley and Black Trout Lake Faults. These northwest trending features have an approximate spacing of 5 km, while northeast trending lineaments of the same approximate spacing were also mapped. Intrusive doming and possible folding is present in the area, along with a system of northeast trending fracture zones transecting the lake in several places (Mandziuk and Studemeister, 1981).

Minor offset of diabase dikes has been seen, indicating only minor tectonic activity has occurred since diabase dike emplacement in the Archean and Proterozoic eras. The age of this deformation is unknown (Sage, 1994). Like all other rocks in the area, the diabase dikes have been affected by greenschist grade regional metamorphism. They usually display a well developed chilled margin and an aureole of contact metamorphism.

The greenstone belt rocks of the Wawa area have been metamorphosed to the greenschist grade of regional metamorphism, with an aureole of contact metamorphism of amphibolite grade marginal to large internal and external plutons (Ayres, 1969; Easton, 2000). Relative to smaller greenstone belts (e.g., Hemlo) the grade of metamorphism in the Michipicoten Greenstone Belt is low. Within the Wawa Gneiss Domain, the grade of metamorphism increases eastward toward the Kapuskasing Structural Zone, reflecting the deeper structural level (Easton, 2000).

3.2.3 Summary

In summary, the bedrock geology of the Wawa area is comprised of the supracrustal rocks of the Michipicoten Greenstone Belt, surrounded by granitoid terrane. The Michipicoten Greenstone Belt is comprised of Archean volcanic rocks which have been subjected to repeated folding and faulting, sedimentation, granitic intrusion, and regional metamorphism. The rocks of the Michipicoten Greenstone Belt are highly heterogeneous and fractured. South of the Michipicoten Greenstone Belt lies the Wawa Gneiss Domain, which is a mosaic of granitoid plutons with slivers of metavolcanic rocks, all of Archean age. The Wawa Gneiss Domain is predominantly tonalitic gneiss, with intrusions of massive granodiorite to granite, including the 60 km long Whitefish Lake-Brule Bay Batholith, and another unnamed 20 km long intrusion. Relative to the greenstone belts, the Wawa Gneiss Domain is less heterogeneous in structure, and is cut by a sparse network of faults associated with discrete tectonic events in the Late Archean/Early Proterozoic, Paleoproterozoic and Mesoproterozoic eras. West of the Michipicoten Greenstone Belt is the Western Batholith, with properties similar to the Wawa Gneiss Domain. There is no evidence that the region has been tectonically active within the past one billion years.

3.3 Quaternary Geology

Most of the Wawa area has exposed bedrock, and Quaternary deposits are predominantly located in bedrock controlled valleys. Figure 3.7 illustrates the extent and type of Quaternary deposits in the Wawa area and the location of the wells from which information on overburden thickness was obtained. The Quaternary geology of the Wawa area is fully described in Morris (2001), upon which this section is based.

All Quaternary deposits within the Wawa area were deposited during the Late Wisconsin by the Labrador sector of the Laurentide Ice Sheet. Bedrock striae indicate that there were two prominent ice flow directions. The oldest and most pervasive ice flow was south to southwest (159° - 240°). A later, weaker ice flow was to the southwest and west (220° - 290°). The younger set of striae was formed during the latter stages of glaciation as the ice sheet began to thin and bedrock topography began to influence the direction of ice flow.

During ice retreat, ice-contact stratified drift was deposited as recessional moraine, eskers and dead ice topography, leaving a thin (less than 1 m thick) till veneer that drapes the bedrock surface. This till veneer, when present, is the uppermost deposit across most of the Wawa area (labelled “Bedrock” on Figure 3.7). Glaciofluvial outwash was deposited primarily within bedrock-controlled valleys directly from the ice margin or from wasting ice detached from the ice sheet. Also during retreat, the ice sheet was fronted by glacial meltwaters associated with the Lake Superior basin or by glacial meltwater impounded by the ice sheet and topographically higher ground. Glaciolacustrine materials were deposited in these waters, filling the deeper bedrock valleys.

According to the water well records (Ontario Ministry of the Environment, 2010) and the diamond drillhole database (Ontario Geological Survey, 2005) overburden thicknesses of up to 86 m exist in the bedrock valleys of the Michipicoten and Magpie Rivers, as they approach Lake Superior. Materials encountered during drilling include thick sequences of clay, sand, and gravel. Other valleys containing significant thicknesses of overburden include the Doré and Shikwamka.

3.4 Neotectonic Activity

Neotectonics refers to deformations, stresses, and displacements in the earth's crust of recent age or which are still occurring. Neotectonics of the Wawa area is typical of many areas of the stable craton of the Canadian Shield (Adams and Clague, 1993), which has been subjected to numerous glacial cycles during the last million years (Shackleton et al., 1990; Peltier, 2002). The neotectonic activity of the Wawa area appears to be principally due to post-glacial isostatic rebound resulting from melting of the Laurentide Ice Sheet (Adams and Clague, 1993).

Post-glacial isostatic rebound began with the melting and retreat 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) in Paleozoic rock of southern Ontario.

Herget (1972), Herget and Arjang (1990) and Arjang (1991), based on stress testing and analyses completed at the G.W. MacLeod iron mine in Wawa, indicate pre-mining, major horizontal compressional stress direction of northeast-southwest. These local horizontal stress results are similar to directions for other parts of the Superior Province in eastern North America, and have been interpreted by Herget (1972) as stable and preserved in relative magnitude for close to a billion years.

Other than those mentioned above, no identification and interpretation of neotectonic structures was found in the readily-available literature for the Wawa 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.

3.5 Seismicity

The Municipality of Wawa 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). Hayek et al. (2009) indicated that the Superior Province has experienced a number of low magnitude shallow seismic events; however, there have not been any recorded earthquakes in the Wawa area over the period 1982-2009. Figure 3.8 presents the location of earthquakes with a magnitude 3 or greater that are known to have occurred in Canada from 1627 until 2009 and Figure 3.9 shows the locations and magnitudes of earthquakes recorded in the National Earthquake Database (NEDB) for the period between 1985 and 2011 in the northeastern Lake Superior area. These two figures show that there have not been any recorded earthquakes in the Wawa area over these periods. The closest recorded earthquake was a 2.2 magnitude event recorded in 2011, northwest of White River, approximately 87 km northwest of the settlement area of Wawa.

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

4 HYDROGEOLOGY

The Municipality of Wawa obtains its municipal water supply from Wawa Lake. The water is treated at the municipally-owned and operated water treatment plant, and distributed to the settlement area of Wawa including the Michipicoten River Village (The Corporation of the Municipality of Wawa, 2010).

Information concerning groundwater in the Wawa area was obtained from the Ministry of the Environment (2010) Water Well Information System (WWIS) database. The locations of known water wells are shown on Figure 4.1. The WWIS database contains a total of 50 water well records for the Wawa area. Of these there are 32 records which provided useful information on lithology, well yield, and static water level, as indicated in the table below.

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	24	5-100	0.9-28	9-227	NA
Bedrock	8	38-117	9-113	4-68	0-86

4.1 Overburden Aquifers

There are 24 water well records in the Wawa area that can be confidently assigned to overburden aquifers. These wells are all completed in overburden materials within the bedrock valleys of the Magpie, Michipicoten and Doré Rivers, as they approach Lake Superior and range in depth from 5 to 100 m deep (Figure 4.1). The thickest overburden encountered in water wells was 86 m. The well yields for these wells range from 9 to 227 L/min, with the range being explained by the diversity of materials encountered during drilling: from clay to gravel. These well yields reflect the purpose of the wells (private residential supply) and do not necessarily reflect the maximum sustained yield that might be available from overburden aquifers. The static water levels in the overburden wells range from less than 1 m to 28 m, with the largest depth-to-water being associated with thick deposits of coarse grained materials.

The review of the water well information indicates that where thick overburden deposits exist, within bedrock valleys and particularly as they approach Lake Superior (Morris, 2001), competent overburden aquifers also exist. It is notable, however, that overburden is thin to non-existent over much of the Wawa area.

4.2 Bedrock Aquifers

The review of available information did not identify any known groundwater resources at repository depth (approximately 500 m) in the Wawa area. There are 8 well records that can be confidently assigned to the shallow bedrock aquifer in the Wawa area, ranging in depth from 38 to 117 m.

Measured pumping rates in these wells are variable and range from 4 L/min to 68 L/min, with an average yield of 34 L/min. These well yields reflect the purpose of the wells (in many cases private residential supply with limited water demand) and do not necessarily reflect the maximum sustained yield that might be available from the shallow bedrock 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 (2010) WWIS shows no potable water supply wells which exploit aquifers at typical repository depths in the Wawa 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 (Herget and Arjang, 1990) 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 Wawa area. Existing literature, however, has shown that groundwater within the Canadian Shield can be subdivided into two main hydrogeochemical regimes: a shallow, generally fresh groundwater flow system, and a deep, saline to brine groundwater flow system (Singer and Cheng, 2002).

Gascoyne et al. (1987) investigated the saline groundwater to 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; Frape and Fritz, 1987).

5 ECONOMIC GEOLOGY

5.1 Petroleum Resources

The Municipality of Wawa is located in a crystalline geological setting where the potential for petroleum resources is negligible. No hydrocarbon exploitation or exploration activities are known to occur in the Wawa area.

5.2 Metallic Mineral Resources

There has been a long history of iron and gold mining in the Wawa area, starting in approximately 1897. For over 100 years, iron was extracted at three principal mine sites in the Michipicoten Greenstone Belt (Sault Ste. Marie Public Library, 2008). Gold exploration and mining has similarly been ongoing in the Wawa area, from both the Michipicoten and Mishibishu Greenstone Belts, but there are currently no operating gold mines in the Wawa area. Although the geological conditions in the greenstone belts are such that base metal massive sulphide deposits are expected, exploration for such deposits has not been successful, and base metal mining in the Wawa area has not occurred. In comparison to the greenstone belts, exploration and mining for metals within the external granitoid terrane (e.g., of the Wawa Gneiss Domain) has been limited to non-existent.

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 (Ontario Geological Survey, 2010). The historical and ongoing interest in the Michipicoten and Mishibishu Greenstone Belts, and the lack of interest in the external granitoid terrane, is evident from the relative densities of mineral occurrences and active mining claims.

Metallic mineralization occurrences in the Wawa area include: iron, copper-zinc base metals, molybdenum, gold and silver.

5.2.1 <u>Iron</u>

Deposits of iron formation are common in the Michipicoten Greenstone Belt (Figure 5.1). The iron formation, as hematite and siderite, resulted from chemical sedimentation during quiescent periods among the three cycles of volcanism between 2.9 and 2.7 billion years ago. Over 140 million tonnes of iron ore were recovered over the period from 1897 to 1997 from the Helen, MacLeod, and Sir James Dunn Mines just north of the settlement area of Wawa; the Lucy, Ruth, and Josephine Mines west and northwest of Hawk Junction; and the Magpie Mine, approximately 20 km north of the Wawa.

There is no current production of iron ore in the Wawa area, although there are still identified reserves. For example, the Ontario Ministry of Northern Development and Mines estimates that approximately 44 million tonnes of iron ore exists that is not currently being mined in Michipicoten Greenstone Belt (Ontario Ministry of Northern Development and Mines, 2010). Dianor Resources Inc. announced in 2011 that it would undertake a preliminary review of the iron ore potential of its Leadbetter (diamond) property which contains the Lucy Iron Range (Dianor, 2011); whereas Canada Iron Inc. holds the iron rights to the Josephine Mine (Canada Iron Inc., 2011).

5.2.2 Base Metals and Molybdenum/Tungsten

Base metal showings with subordinate precious metal content are rare in the Michipicoten Greenstone Belt, despite the fact that the rocks appear very favourable for such deposits (Sage, 1994). As evident in Figure 5.1, there have been occurrences of copper and zinc, although the precious metals in association with these showing are of most economic interest (Sage, 1994). No record of past or current base metal mining in the Wawa area was found.

There is an active mining claim and occurrence of molybdenum within the Western Batholith, west of the Michipicoten Greenstone Belt (see Figure 5.1). The molybdenum occurs in association with a fault and zone of quartz veins. There is also an occurrence of the transition metal tungsten (as wolframite) in the Western Batholith on the shore of Lake Superior. The economic viability of these occurrences has not been proven.

5.2.3 Gold

In as much as the Michipicoten was famous for its iron ore mines, the area also had a long history of gold mining. Starting with the gold rush of 1897 to 1906, and followed by periods of activity tied to the price of gold and the international economy. The most productive gold mines in the immediate Wawa area were the Grace-Darwin, Jubilee, Minto, and Parkhill Mines. Between 1902 and 1939, these mines produced approximately 110,000 oz of gold, while from 1968 to 1991 the Surlaga Mine produced a further 8,600 oz. All these mines occur within the rocks of the Michipicoten Greenstone Belt. These mines are all part of the Michipicoten Camp, which is one of four "Wawa Gold Camps" defined by Heather (1991). The other three camps, being the Mishibishu Lake, the Goudreau-Lochalsh, and Missanabie-Renabie, lie within or adjacent to the Mishibishu and Michipicoten Greenstone Belts, but are outside the Wawa area, as defined by Figure 3.4.

Gold mineralization in the Michipicoten Camp occurs within the margins and hornsfelded supracrustal rocks enveloping the Hawk Lake Granitic Complex and the Jubilee Stock (Sage, 1994). Here the gold occurs primarily in shear zones (Delisle, 1991). Gold is also present in the external granitoid terrain or in felsic intrusions and occurs in veins within marginal zones in close contact with the metavolcanics (Studemeister, 1985; Heather and Arias, 1987) including the former Renabie Gold mine, which is within the Wawa Gneiss Domain, adjacent to the eastern end of the Michipicoten Greenstone Belt, approximately 80 km northeast of the settlement area of Wawa.

Gold exploration continues in the region, but at present there are no active mines in the screened area. The mining claims in the vicinity of the Jubilee stock, southeast of the settlement area of Wawa, are predominantly held by the Citadel Gold Mines Inc., and there has been a historical resource estimate of 525,000 ounces of gold (Delta Uranium Inc., 2009). The closest operating gold mines are the Island Gold mine located approximately 40 km northeast of Wawa on the northern margins of the Michipicoten Greenstone Belt, and the Eagle River mine located approximately 50 km west of Wawa in the Mishibishu Greenstone Belt. These mines are outside the area considered in the screening.

In summary, gold occurs predominantly within the greenstone belts and along sheared margins of some intrusive rocks. There are no economic occurrences of gold and there have been no gold mining activities in the main bodies of the granitoid terrane surrounding the Michipicoten Greenstone Belt in the Wawa area.

5.2.4 Uranium

The Firesand River Carbonatite Complex, located approximately 10 km southeast of the settlement area of Wawa, was identified in an inventory of Ontario uranium and thorium deposits (Robertson and Gould, 1983), and is known to contain low concentrations of uranium and thorium (Wilson, 1990). Radioactive carbonate-rich dikes occur in numerous road cuts along highway 101 but they appear too small to be of economic interest (Sage et al. 1982c). Also, the radiometric survey (Figure 3.6) indicates radioactivity predominantly, but not uniformly, within the external granitoid terrane (e.g., the Whitefish Lake Batholith). However, no economic deposits of uranium have been identified in the Wawa area. The closest known economic uranium mineralization is approximately 100 km south, in the Montreal River area.

5.2.5 Rare Metals

There is no known past or current mining for rare metals in the Wawa area. According to Wilson (1990) rare earth metals have some potential for discovery and development in the Wawa area. Pegmatites within the external granitoid terrane and the Firesand Creek Carbonatite complex have been identified as targets for rare earth element exploration.

5.3 Non-Metallic Mineral Resources

5.3.1 Sand, Stone and Gravel

Sand and gravel resources are coincident with the glaciofluvial outwash deposits as mapped on Figure 3.9 (Municipality of Wawa, 2011), and sand and gravel extraction occurs from a pit near the mouth of the Michipicoten River. Such extraction is limited to unconsolidated overburden deposits of shallow depth.

Superior Aggregates holds a license for below water table extraction of trap rock in the Michipicoten Harbour area, on Lake Superior at the west end of Michipicoten Bay (The Sault Star, 2011). Other aggregate quarries are likely present within the Wawa area.

According to Wilson (1990), the potential for an economically viable building stone industry in the Wawa area is poor to fair, with the internal plutons of the Michipicoten Greenstone Belt being the best sites for quarry development. External plutons, while having potentially suitable rock, were considered too difficult to access (i.e., too remote) to make them economically viable.

5.3.2 Diamonds

In 1991, industrial grade diamonds were discovered in the Michipicoten River. In 1995, gem quality diamonds were found in a bedrock occurrence on the Trans Canada Highway, approximately 20 km north of the settlement area of Wawa. Since then, more than 50 occurrences of diamondiferous bedrock have been reported in an area of approximately 30 km^2 in size, centred approximately 20 km north of the settlement area of Wawa (see the diamond occurrences north of the Municipality boundary in Figure 5.1) (Wilson, 2006). These occurrences are hosted within 2.6-2.7 billion year old calc-alkaline lamprophyres and volcaniclastic breccias, formed contemporaneously with the metavolcanic rock of the greenstone belt (Kopylova et al. 2010), and are unusual in that they are not associated with kimberlites (Wilson, 2006). A second set of occurrences approximately 12 km northeast of the settlement area of Wawa (in the vicinity of the Lucy iron range) is hosted in metasedimentary conglomerate, although the primary volcanic rock of the conglomerate diamonds may be a kimberlite (Kopylova et al, 2010).

Active exploration for diamonds in the Wawa area currently exists (Wilson, 2006). A joint venture between Spider Resources and KWG Resources Inc. is the principal developer of the breccia-hosted diamonds north of the Municipality, while Dianor Resources Inc. is the developer of the conglomerate-hosted Leadbetter diamond project (Dianor, 2011). Dianor (2011) estimates 566 million tonnes of diamond-bearing conglomerate.

In 1997, two kimberlite intrusions (possibly associated with a narrow subvertical dike striking north-northwest) were discovered in the eastern part of the Whitefish Lake Batholith, approximately 5 km east of the northern tip of Whitefish Lake (Kaminsky et al. 2002). The economic viability of these kimberlite diamond deposits has yet to be proven.

5.3.3 Industrial Minerals

According to Wilson (1990), there was a minimal potential for the development of industrial mineral deposits at 1990 market prices. Wilson (1990) described eleven known occurrences of minor importance.

6 INITIAL SCREENING EVALUATION

This section provides an evaluation of each of the five initial screening criteria (NWMO, 2010) for the Wawa 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 Municipality of Wawa from further consideration in the site selection 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 Wawa 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 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.

The review of available mapping and satellite imagery shows that the developed areas and large water bodies occupy only a small portion of the Municipality of Wawa (Figures 2.1 and 2.2). Although the Municipality has a large range in topographic elevations, ranging between approximately 183 and 600 masl, most of the Municipality is unconstrained by topography (Figure 2.4). Locally, there may be areas where topography may be unfavourable for the development of the repository's facilities and a more detailed assessment would be required. Lands at the periphery of the Municipality of Wawa contain limited constraints that would prevent the development of the repository's surface facilities. The lands are largely undeveloped, accessible and contain areas with favourable topography.

As discussed in Section 6.5, readily-available information suggests that the Wawa area has the potential to contain 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, if the community remains interested in participating in the siting process.

Based on the review of readily-available information, the Wawa 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 Wawa 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 Ministries of Natural Resources (Land Information Ontario) and Tourism and Culture.

There are seven protected areas are found in the Wawa area (Figure 2.1), including four Ontario provincial parks, two conservation reserves, and a 390 ha area of forest reserve. From largest to smallest, the Provincial Parks in the Wawa area are Lake Superior (55,000 ha), Nimoosh (3,500 ha), Potholes (347 ha), and Michipicoten Post (289 ha) Provincial Parks. The two Conservation Reserves are South Michipicoten River-Superior Shoreline (2,219 ha) and Magpie River Terraces (2,088 ha) Conservation Reserves. With the exception of the Magpie River Terraces Conservation Reserve, these protected areas border Lake Superior (Figure 2.1), and are outside the Municipality boundaries. The Magpie River Terraces Conservation Reserve is inland from Lake Ontario, and is entirely contained within the Municipality. These protected areas occupy a small portion of land within the Wawa area.

As discussed in Section 2.4, almost of the land in the Wawa area is free of known heritage constraints. Known archaeological sites are small and generally concentrated around the shoreline of Lake Superior. The majority of the known archaeological sites are contained within the protected areas discussed above. There are no National Historic Sites in the Wawa area.

The presence of 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 Wawa 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 Wawa area. As discussed in Sections 4.1 and 4.2, the Ontario Ministry of the Environment (MOE) Water Well Information System database shows that all water wells known in the Wawa area obtain water from overburden or shallow bedrock sources at depths of up to 117 m.

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).

The MOE Water Well Information System database indicates no potable water supply wells are known to exploit aquifers at typical repository depths in the Wawa 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 Wawa 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 Wawa area. Experience in similar geological settings suggests that the potential for deep groundwater resources at repository depth is low throughout the Wawa area. The absence of groundwater resources at repository depth would 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 Wawa area is negligible.

There are currently no operating mines within the Municipality of Wawa or its periphery although the area has a long history of mineral exploration and mining. For approximately 100 years, starting in 1897, iron ore was mined from bands of iron formation within the Michipicoten Greenstone Belt at the Helen, MacLeod, Sir James Dunn, Lucy, Ruth, and Josephine Mines. Over approximately the same time frame, gold mining was active in the area, notably from the Grace-Darwin, Jubilee, Minto, Parkhill and Surlaga Mines. These mines exploited gold mineralization within the margins and hornfels supracrustal rocks enveloping the Hawk Lake Granitic Complex and the Jubilee Stock, granitic intrusions within the Michipicoten Greenstone Belts. The closest operating gold mines are the Island Gold mine located approximately 40 km northeast of Wawa on the northern margins of the Michipicoten Greenstone Belt, and the Eagle River mine located approximately 50 km west of Wawa in the Mishibishu Greenstone Belt. These mines are outside of the area considered in the screening.

Mineral exploration in the Wawa area is concentrated primarily within the Michipicoten Greenstone Belt. Limited mineralization has been identified in the granitic intrusions in the area. These include occurrences of gold and molybdenum mineralization, mostly concentrated at the contact with the rocks of the greenstone belts. The economical potential of these occurrences has not been proved to date.

Since 1995, many occurrences of diamondiferous bedrock have been reported within the Michipicoten Greenstone Belt (Figure 5.1) of the Wawa area and active exploration continues. Two diamond-bearing kimberlite intrusions were discovered in the eastern part of the Whitefish Lake Batholith. The economic viability of these kimberlite diamond deposits has yet to be proven.

Extraction of sand and gravel and quarrying of stone has occurred in the Wawa area in the past and continues today. However, the risk that these resources pose for future human intrusion is negligible, as quarrying operations are typically limited to very shallow depths. No potential for commercial peat extraction has been identified.

In summary, the potential for economically exploitable natural resources in the Municipality of Wawa and its periphery is associated with specific geological units, mostly rocks of the Michipicoten Greenstone Belt. The natural resource potential of the granitoid terrane external to the greenstone belts is limited, and mostly associated with its margin.

Based on the review of readily-available information, the Wawa area contains sufficient lands, 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 selection 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 geological and hydrogeological conditions that would exclude the Municipality of Wawa from further consideration. These factors would be gradually assessed in more detail as the site selection 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 readily-available geoscientific information did not identify any obvious geological or hydrogeological characteristics that would exclude the Municipality of Wawa from further consideration in the site selection process at this stage.

6.5.1 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.

As shown on Figure 3.3, the geology of the Municipality of Wawa is dominated by metavolcanic rocks and associated metasedimentary rocks of the Michipicoten Greenstone Belt, which extends beyond the Municipality boundaries to the north, northwest, and southwest. As discussed in Sections 3.2.1 and 3.2.2, these rocks are heterogeneous, fractured and variable in composition. They are arranged in layers of varying thickness. Past tectonic events have deformed these layers, making them difficult to characterize from a stratigraphic point of view. These events created numerous regional folds, faults and smaller scale shear zones within the metavolcanic rocks in the Wawa area. Although these metavolcanics rocks may have sufficient thickness and lateral extent, they are unlikely to be suitable for hosting a deep geological repository due to their structural complexity and heterogeneity. Within the Michipicoten Greenstone Belt are the Hawk Lake Granitic Complex and the Jubilee Stock. While these intermediate to felsic granitic intrusions may contain sufficient volume to host a repository, their suitability for this purpose may be affected by proximity to faults and the potential for mineral resources at their margins.

About 25% of the Municipality of Wawa is underlain by granitoid (gneissic) terrane, including the Wawa Gneiss Domain in the south, and the Western Batholith in the northwest. Both the Wawa Gneiss Domain and the Western Batholith extend well beyond the Municipality boundaries to the south, east and northwest, respectively. The Wawa Gneiss Domain is predominantly tonalitic gneiss, with intrusions of massive granodiorite to granite, including the 60 km long, 2.7 billion year old Whitefish Lake-Brule Bay Batholith, and another unnamed 20 km long intrusion. The Western Batholith has lithological properties similar to the Wawa Gneiss Domain. The thickness of the various plutons which make up the granitoid terrane is uncertain, although their likely origin as mid-crustal intrusions suggests a thickness of at least 10 km (see Section 3.2.1). Relative to the greenstone belts, the Wawa Gneiss Domain (including the Whitefish Lake-Brule Bay Batholith) and the Western Batholith are less heterogeneous in compositional structure, and are cut by a sparse network of faults associated with discrete tectonic events in the Late Archean/Early Proterozoic, Paleoproterozoic and Mesoproterozoic eras. Mapped regional faults occur with a spacing of 5 to 15 km so there are potentially sufficient volumes of rock between regional faults to host a deep geological repository. Faults have been mapped at a local scale with spacing between 250 m and 3 km. The extent to which these minor faults extend to depth and their potential impact on siting the repository would need to be evaluated during subsequent site evaluation stages. The region has been largely tectonically stable for approximately one billion years.

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 Wawa 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 and batholiths), indicates 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 (McMurry et al., 2003; Gascoyne, 2000; 2004).

Based on the geological and hydrogeological characteristics described above and on available experience from other similar rocks in the Canadian Shield, the granitoid terrane in the Wawa area warrants further consideration as potentially suitable host rock. The various granitic units in the area seem to occur in sufficient volumes to host a deep geological repository within or at the periphery of the Municipality. These include the Whitefish Lake-Brule Bay Batholith and the Western Batholith that are respectively present in the in the southern and northwestern parts of the Municipality and extend well beyond its boundaries. The Wawa Gneiss Domain, outside of the southern boundary of the Municipality, is also potentially suitable.

In summary, the review indicates that the Municipality of Wawa and its periphery contain areas with no obvious geological and hydrogeological conditions that would preclude safe containment and isolation at repository depth. This would need to be assessed during subsequent site evaluation stages. 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 would also need to be assessed during subsequent site evaluation stages, provided the community remains interested in continuing in the site selection process.

6.5.2 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 selection process, the long-term stability factor is evaluated by assessing whether there is any evidence that would raise concerns about the long-term hydrogeological and geological stability of the Wawa area. As discussed below, the review of readily available information did not reveal any obvious characteristics that would raise such concerns.

The Municipality of Wawa 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). As discussed in Sections 3.1 and 3.2, faults and shear zones have been identified in the Wawa area; however, there is no evidence to suggest these fault zones have been tectonically active within the past billion years.

The geology of the Wawa 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 in the Wawa area. As mentioned above, the long-term stability factor would need to be further assessed through detailed multidisciplinary geoscientific and climate change site investigations, if the community remains interested in continuing in the site selection process.

6.5.3 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 deep groundwater resources at repository depths and known economically exploitable natural resources is low throughout the granitoid terrane in the Wawa area. It is therefore unlikely that the granitoid terranes in the Wawa area would be disrupted by future human activities.

6.5.4 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 Wawa area. However, there is abundant information at other locations of the Canadian Shield that could provide insight into what should be expected for the Wawa 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).

The review of readily-available information on the bedrock geology and Quaternary geology for the Wawa area (Sections 3.2 and 3.3) did not indicate any obvious conditions which could make the granitoid terrane difficult to characterize, although conditions such as thick overburden cover may exist in localized areas. Because of their compositional variability and high degree of deformation, the rocks of the greenstone belts are not amenable to characterization.

The degree to which factors such as geologic variability and overburden thickness might affect the characterization and data interpretation of the granitoid intrusions is unknown at this stage and would require further assessment during subsequent site evaluation stages of the site selection process, provided the community remains interested in continuing in the site selection process.

Based on the review of available geological and hydrogeological information, the Wawa area contains portions of land that do not contain obvious known geological and hydrogeological conditions that would make the area unsuitable for hosting a deep geological repository.

7 INITIAL SCREENING FINDINGS

This report presents the results of an initial screening to assess the potential suitability of the Wawa area against five initial screening criteria using readily available information. The initial screening focused on the Municipality of Wawa and its periphery, which are referred to as the "Wawa area" in this report. As outlined in NWMO's site selection process (NWMO, 2010), the five initial screening criteria relate to: having sufficient space to accommodate surface and underground facilities, being outside protected areas and heritage sites, 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 readily available information and the application of the five initial screening criteria did not identify any obvious conditions that would exclude the Municipality of Wawa from further consideration in the NWMO site selection process. The initial screening indicates that the Wawa area contains portions of lands with geological formations that are potentially suitable for hosting a deep geological repository. Examples of these formations include the Whitefish Lake-Brule Bay Batholith and the Western Batholith that are present in the southern and northwestern parts of the Municipality respectively, and extend well beyond its boundaries. The Wawa Gneiss Domain, outside the southern boundary of the Municipality, is also potentially suitable. The rocks of the Michipicoten Greenstone Belt within and outside of the Municipality are likely unsuitable for hosting a deep geological repository due to their compositional heterogeneity, spatial variability and potential for natural resources.

It is important to note that at this early stage of the site selection process, the intent of the initial screening is not to confirm the suitability of the Wawa area, but rather to identify whether there are any obvious conditions that would exclude it from further consideration in the site selection process. Should the community of Wawa 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 Wawa 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 REPORT SIGNATURE PAGE

Respectfully submitted,

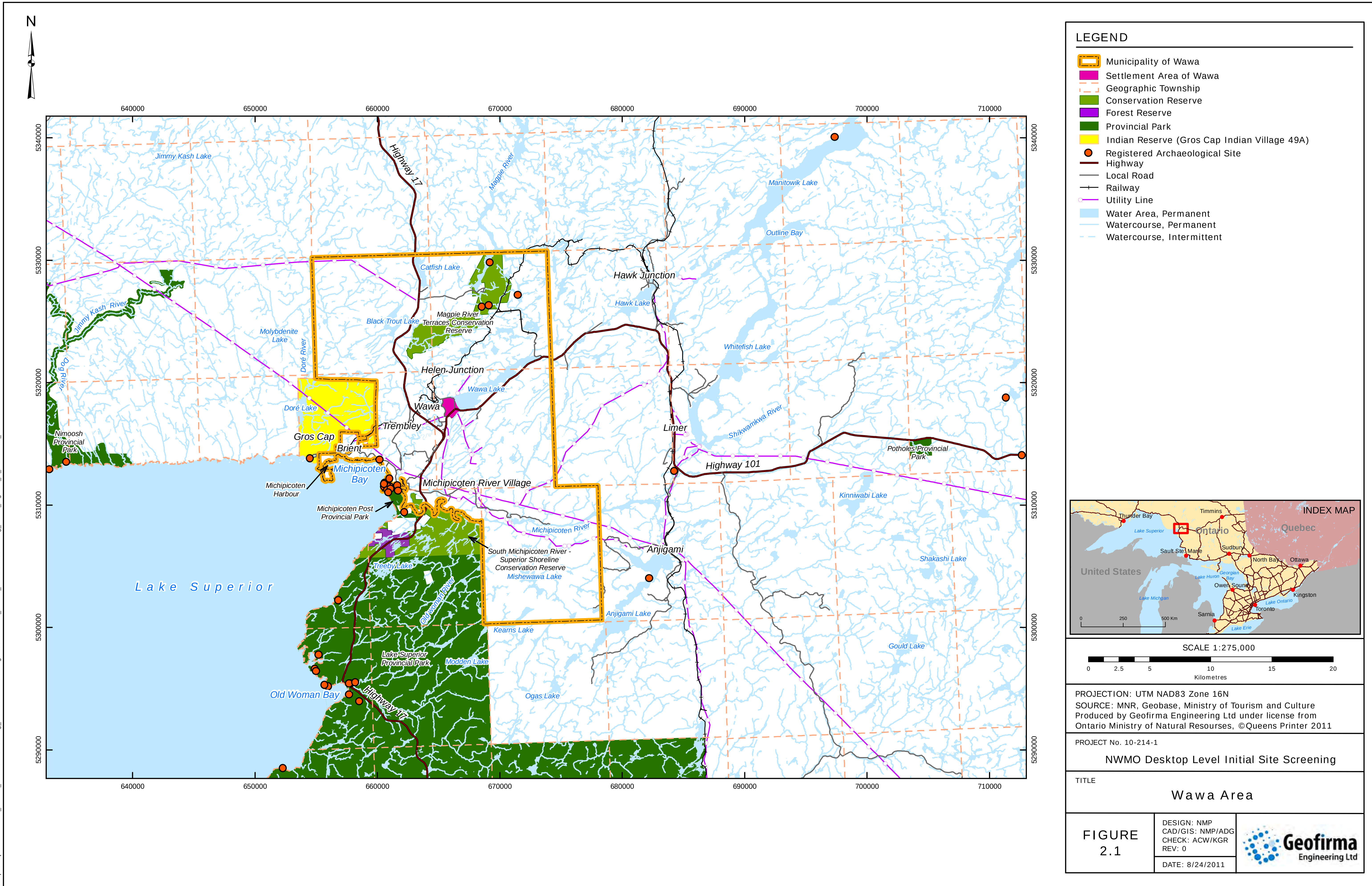
Geofirma Engineering Ltd.

Anthony West, Ph.D., P.Eng.
Senior Engineer

Kenneth Raven, P. Eng., P.Geo.
Principal

APPENDIX A

Report Figures



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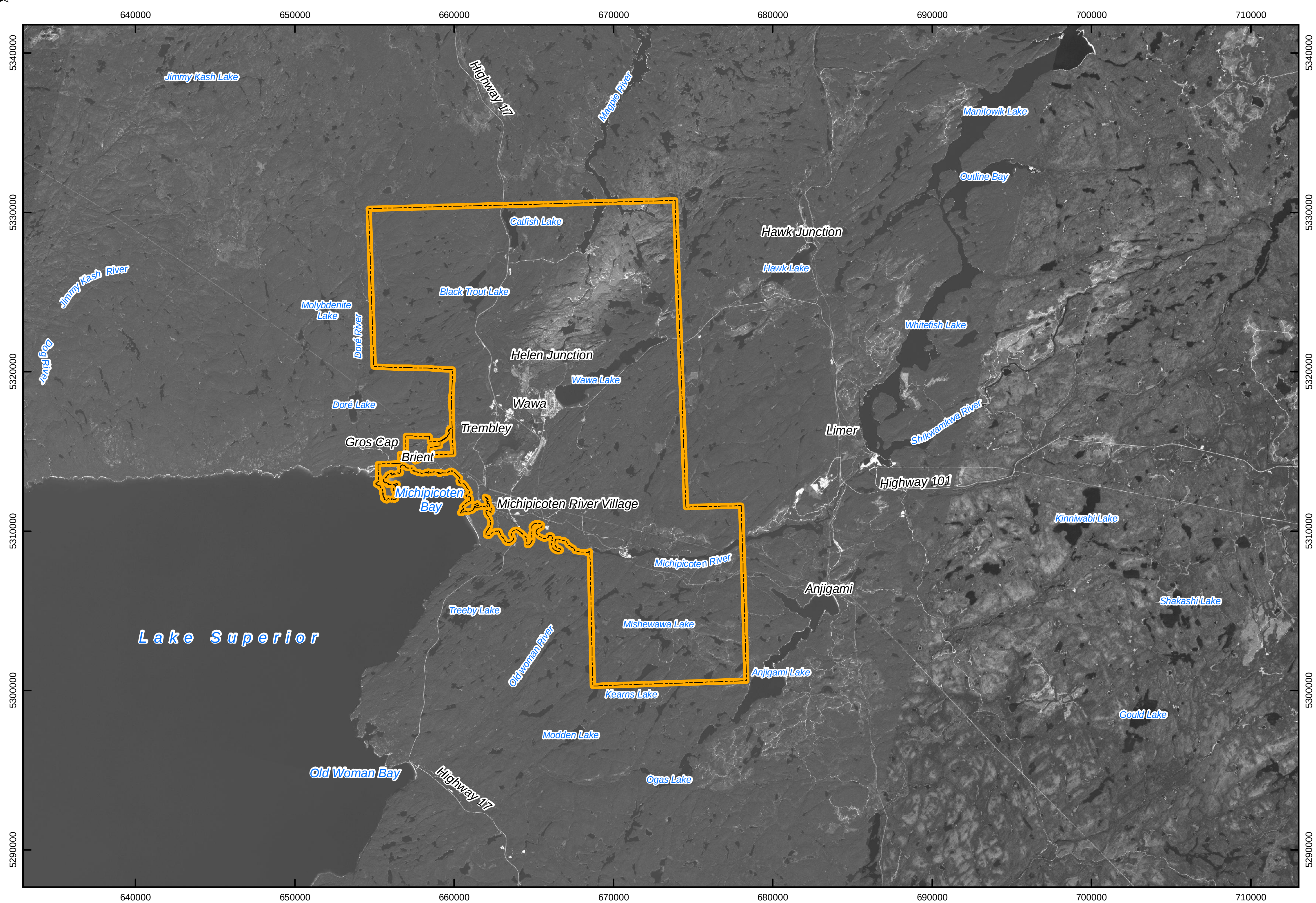

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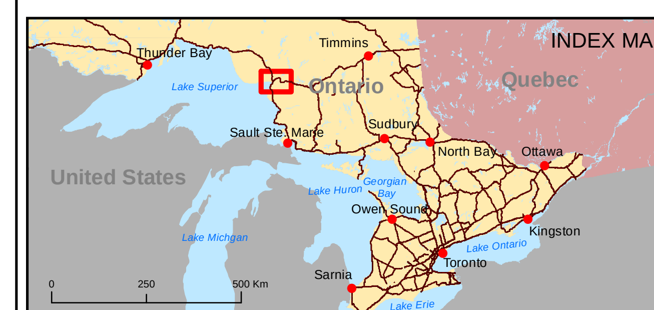
Municipality of Wawa



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PROJECT No. 10-214-1

NWMO Desktop Level Initial Site Screening

TITLE

Satellite Imagery of the Wawa Area

FIGURE 2.2

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

Geofirma Engineering Ltd

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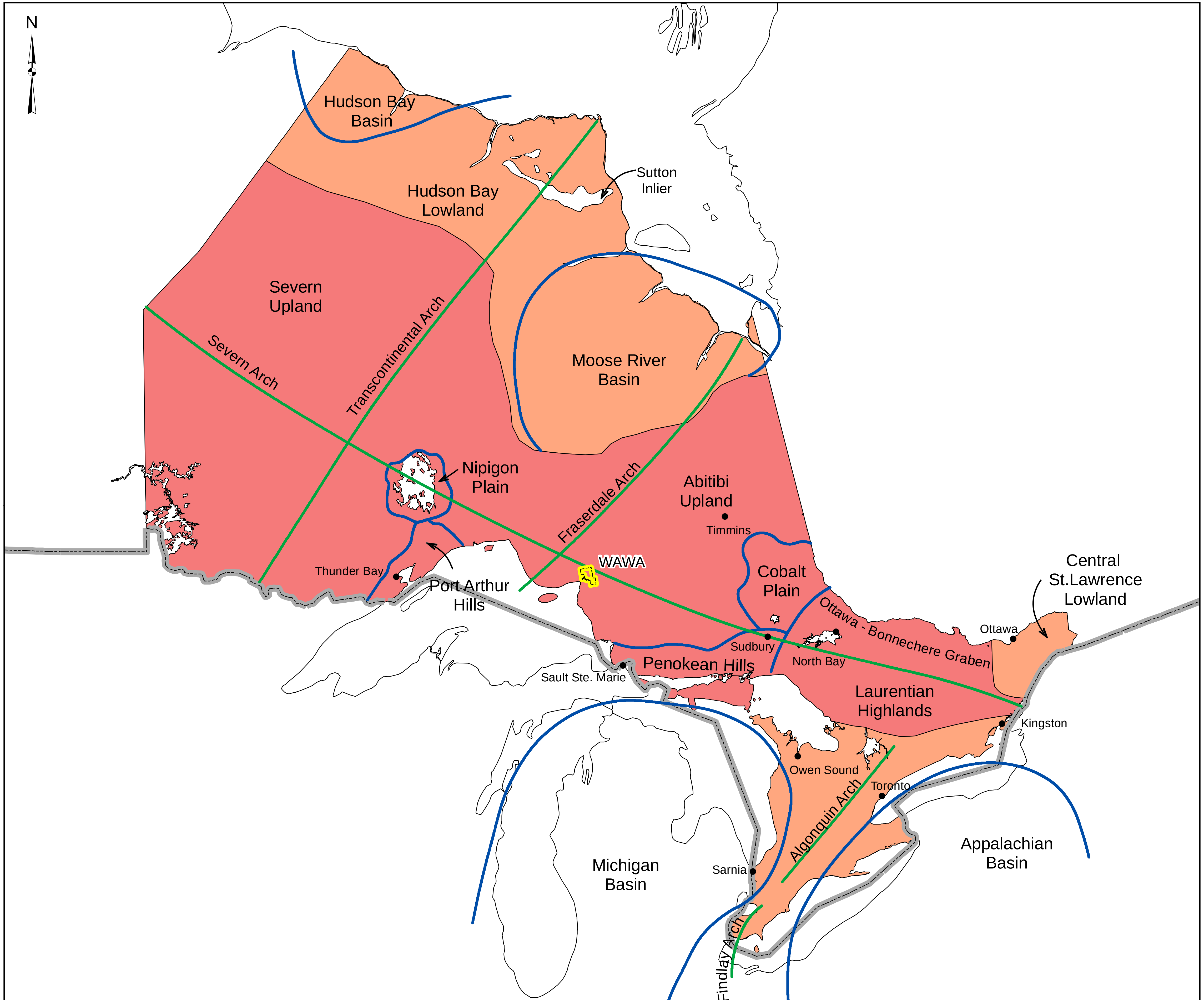

LEGEND

- Municipality of Wawa
- International Boundary
- Phanerozoic Borderlands
- Precambrian Canadian Shield
- Limits of Basins

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Kilometres

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SOURCE: NRCAN, ESRI Canada
Physiography: Physiographic regions in Ontario based on Bostock (1970) (from Thurston et al. 1991)

PROJECT No. 10-214-1

NWMO Desktop Level Initial Site Screening

TITLE

Physiographic Regions of Ontario

FIGURE 2.3

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

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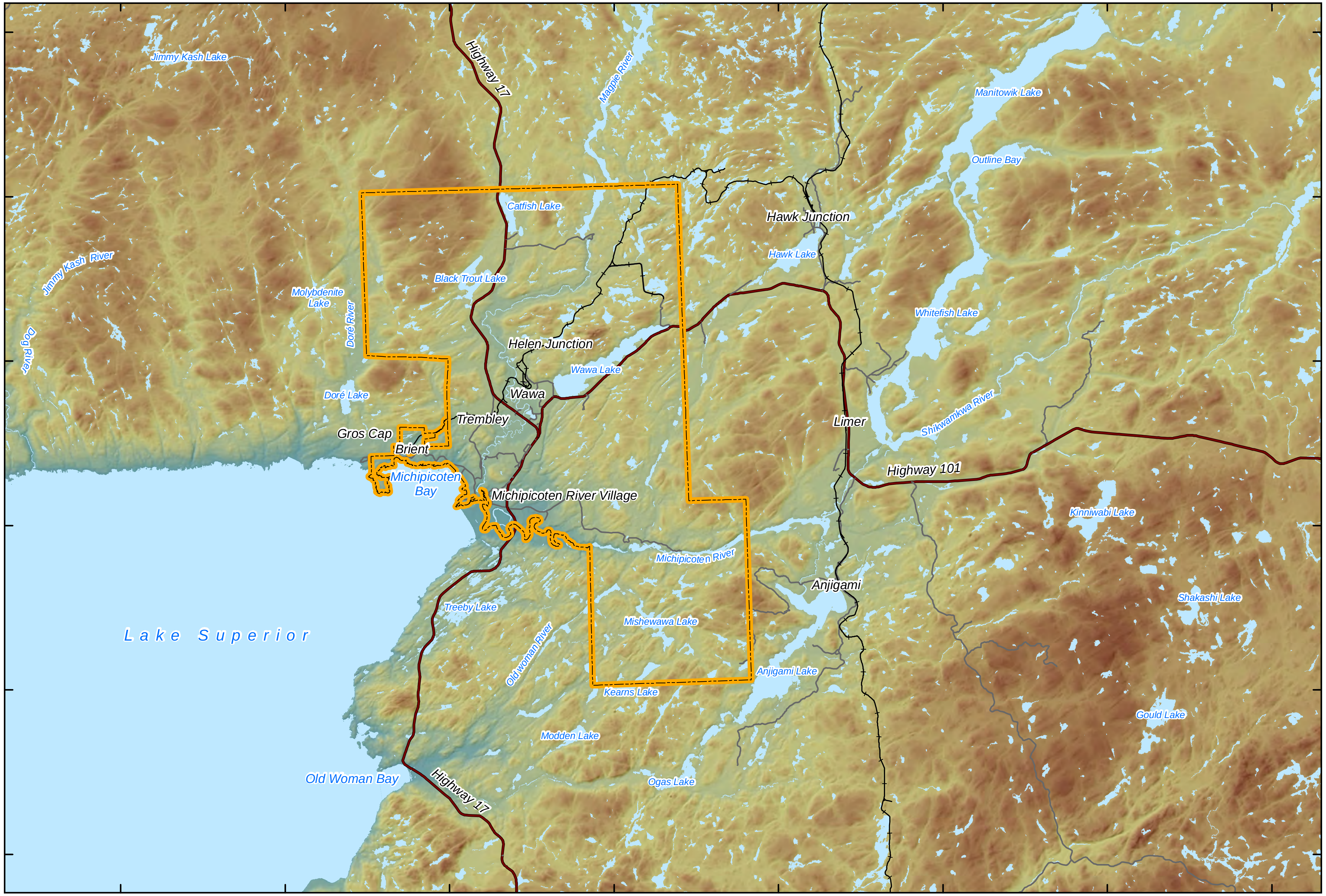

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LEGEND

- Municipality of Wawa
- Highway
- Local Road
- Railway
- Water Area, Permanent

Elevation Model (mASL)

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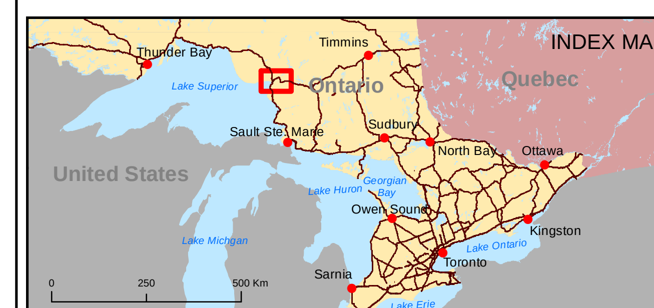

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SOURCE: MNR, Geobase
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PROJECT No. 10-214-1

NWMO Desktop Level Initial Site Screening

TITLE

Digital Elevation Model (DEM) of the Wawa Area

FIGURE 2.4

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

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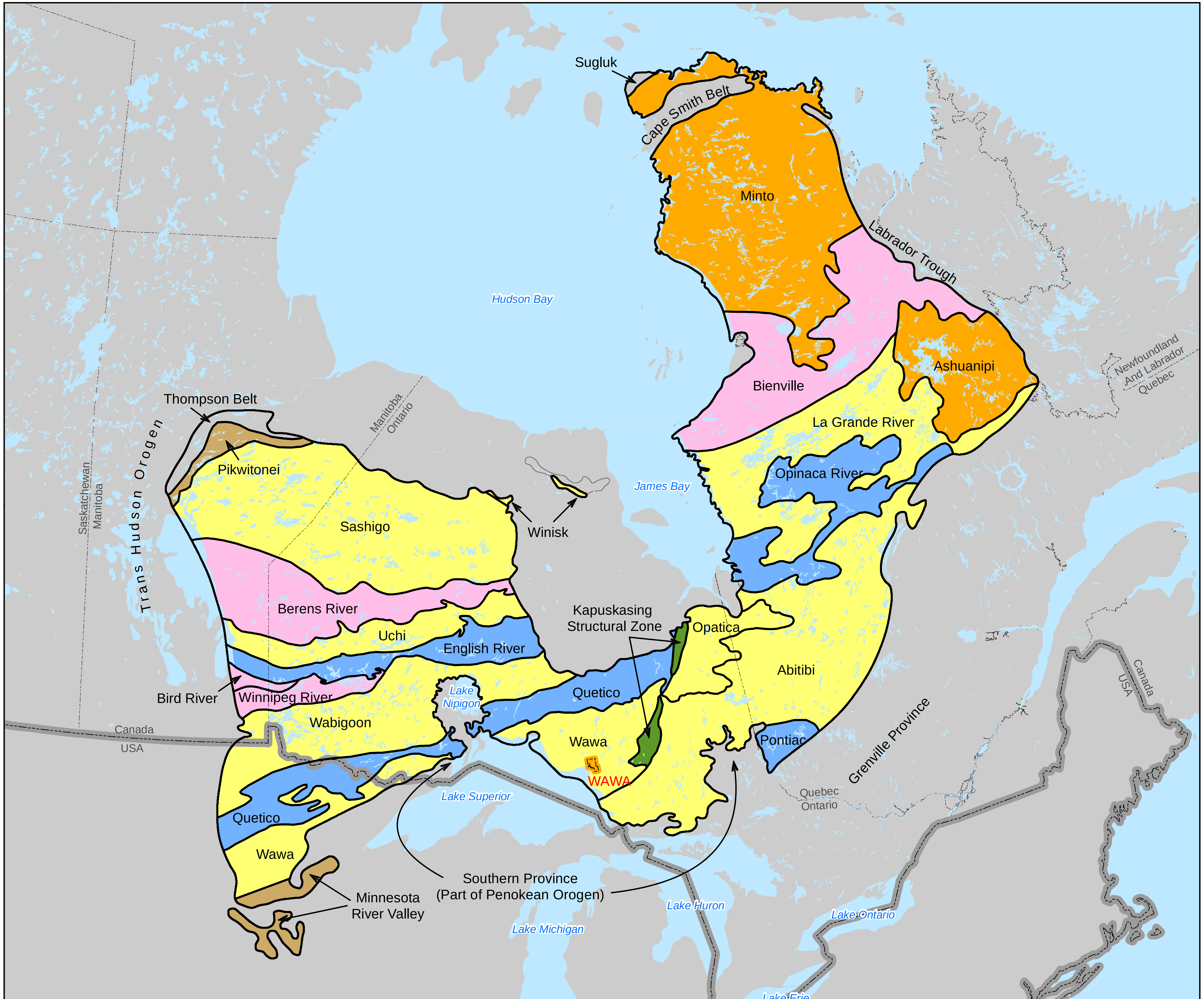

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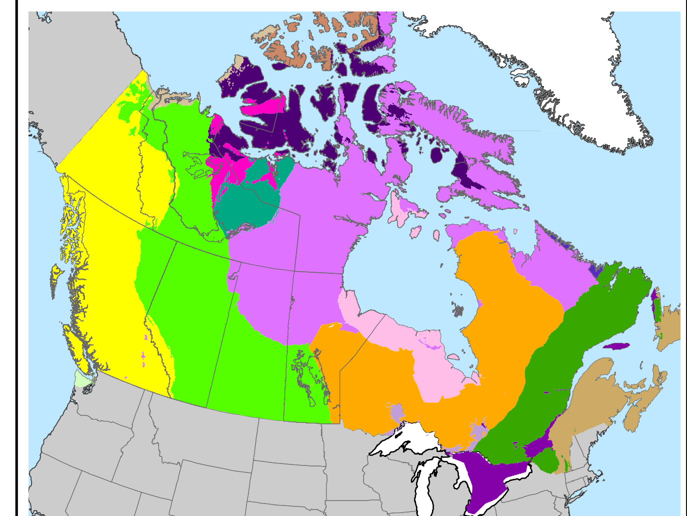

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Canadian Shield, Modified from Card and Ciesieski, 1986
Geology: Geological Map of Canada 1996, Map D1860A
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NWMO Desktop Level Initial Site Screening

TITLE
Subdivision of the Superior Province of the Canadian Shield

FIGURE 3.1

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

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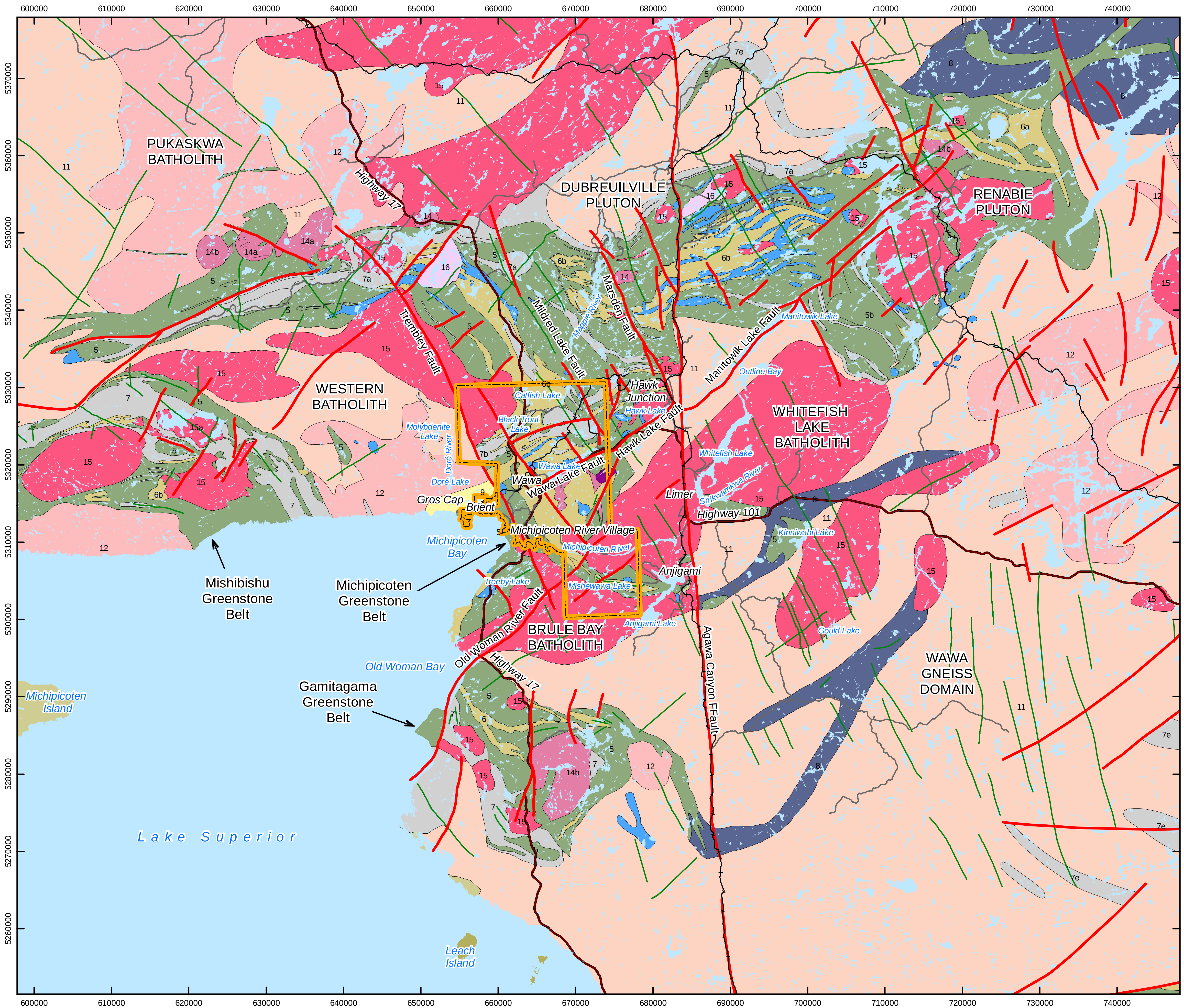

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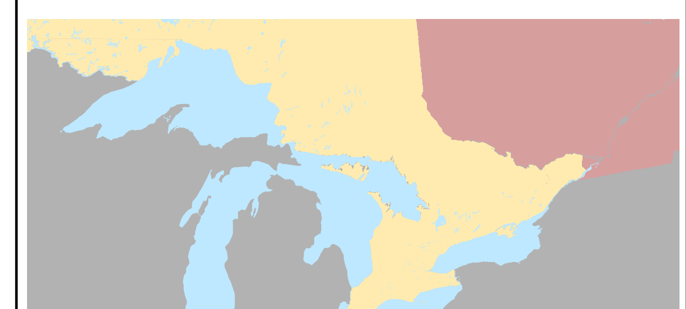

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Geology: MRD126-Bedrock Geology of Ontario, 2007
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PROJECT No. 10-214-1

NWMO Desktop Level Initial Site Screening

TITLE Geology of the Southeastern Part of the Wawa Subprovince

FIGURE 3.2

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

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G:\Maps\Projects\10-214-1_NWMO_InitialSiteScreening_Wawa\RO Version Figures\10-214-1_NWMO_InitialSiteScreening_Wawa_Figure3_2_GeologyoftheWawaArea_R0.mxd

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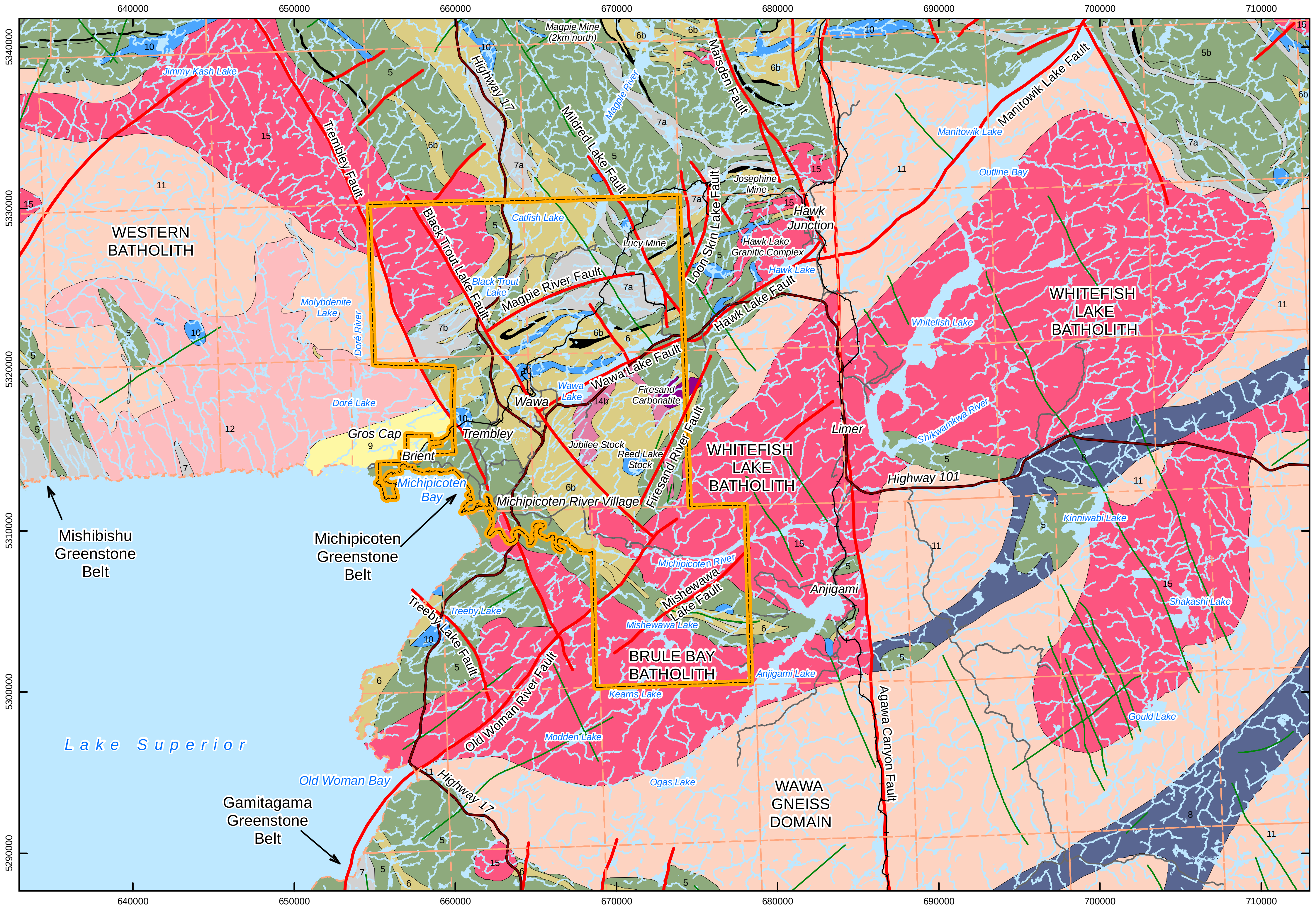

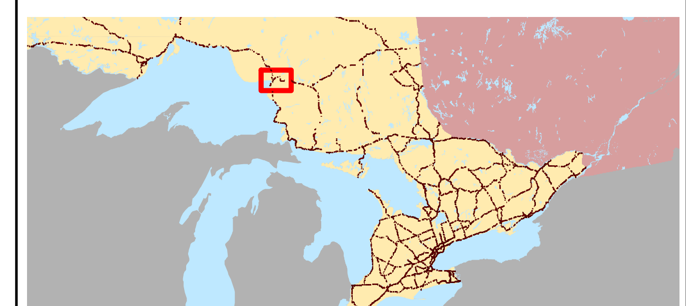

SCALE 1:275,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geology: MRD126-Bedrock Geology of Ontario, 2007
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PROJECT No. 10-214-1

NWMO Desktop Level Initial Site Screening

TITLE

Bedrock Geology of the Wawa Area

FIGURE 3.3

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

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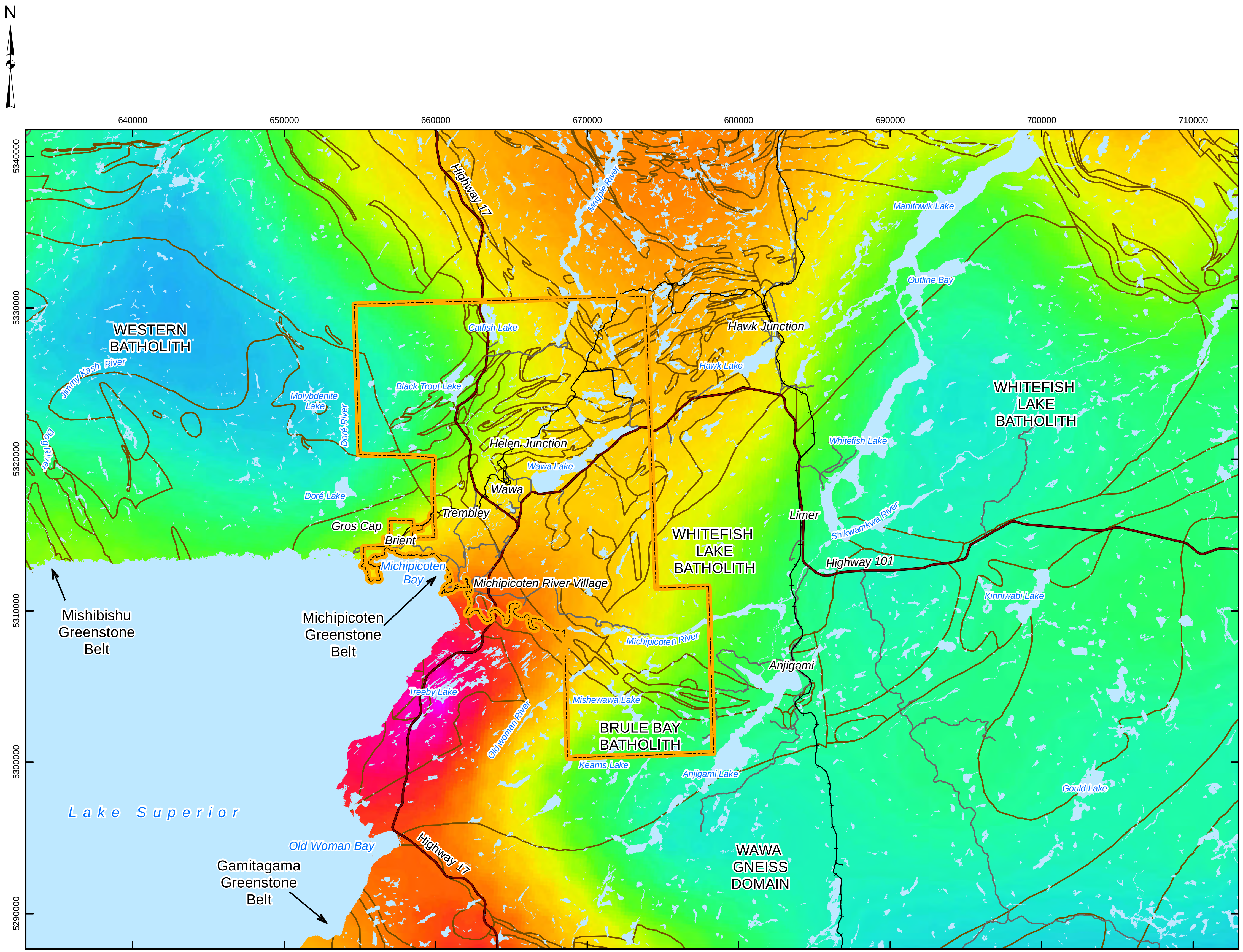

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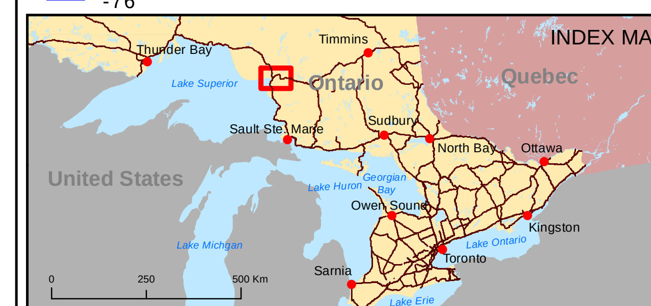
LEGEND

- Municipality of Wawa
- Highway
- Local Road
- Railway
- Water Area, Permanent
- Geological Contact

Gravity Anomaly (mGal)

4, 0, -4, -8, -12, -16, -20, -24, -28, -32, -36, -40, -44, -48, -52, -56, -60, -64, -68, -72, -76



SCALE 1:275,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geophysics: GSC Canada - 2km resolution - Bouguer Gravity Anomalies, obtained 2011;
Canadian Gravity Anomaly Data Base, Canadian Geodetic Information System, Gravity & Geodetic Networks Section, Geodetic Survey Division, Geomatics Canada, Earth Sciences Sector, Natural Resources Canada
Geology: MRD126-Bedrock Geology of Ontario, 2007
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PROJECT No. 10-214-1

NWMO Desktop Level Initial Site Screening

TITLE

Gravity Map of the Wawa Area

FIGURE 3.4

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

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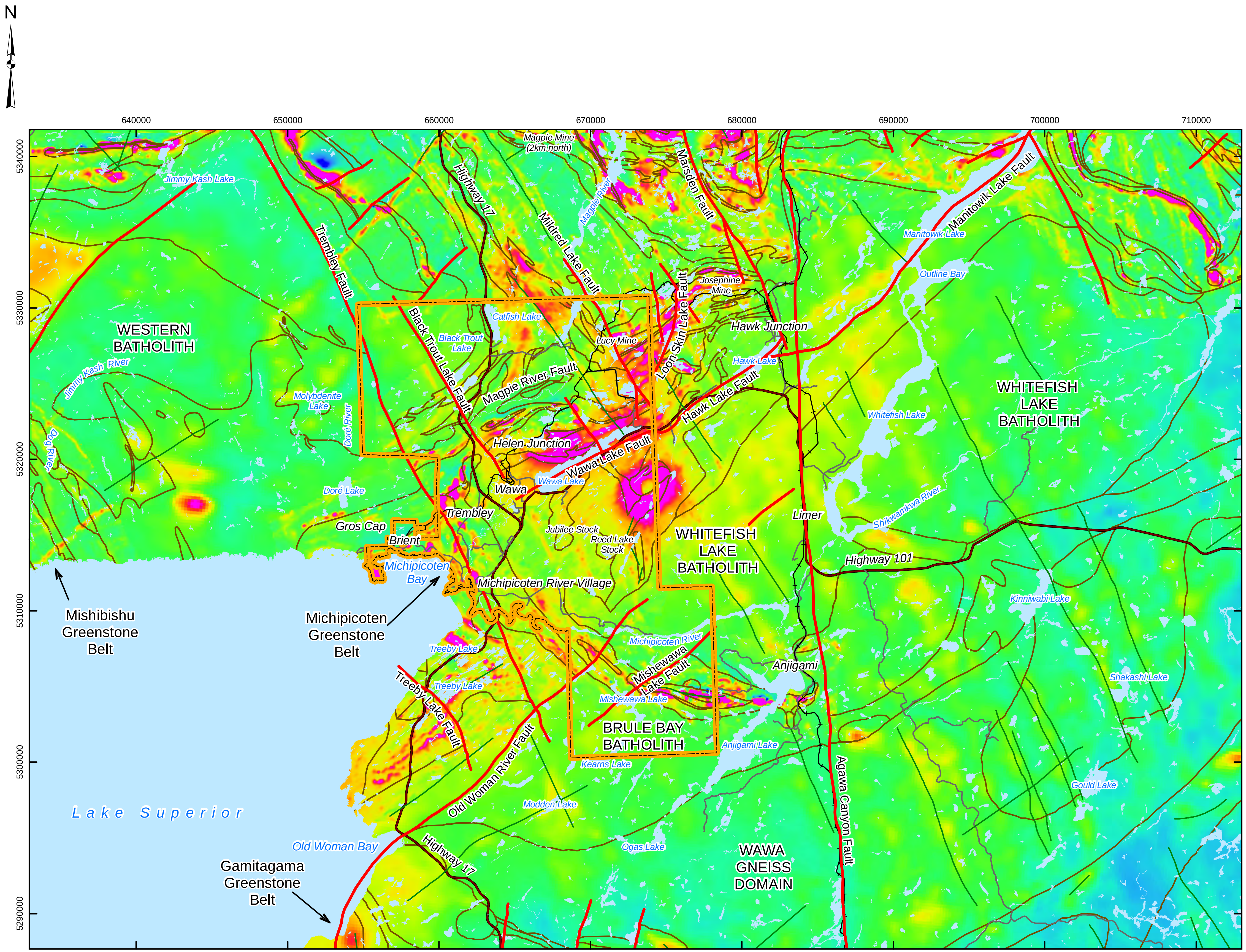
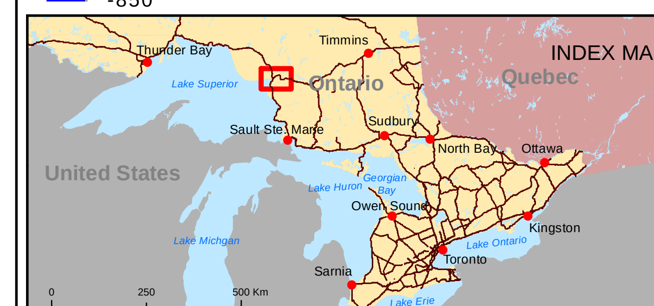


LEGEND

- Municipality of Wawa
- Highway
- Local Road
- Railway
- Water Area, Permanent
- Geological Fault
- Dike
- Geological Contact

Residual Total Magnetic Field (nT)

10400
9650
8900
8150
7400
6650
5900
5150
4400
3650
2900
2150
1400
650
-100
-850



SCALE 1:275,000

0 2.5 5 10 15 20
Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geophysics: Geophysical Data Set 1009 and 1010;
Total Magnetic Field - 40m, 2003; Ontario Geological Survey, Ministry of Northern Development and Mines,
Magnetic - Residual Total Field, - 200m, obtained 2011;
GSC Canada, 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
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NWMO Desktop Level Initial Site Screening

TITLE

Residual Total Magnetic Field of the Wawa Area

FIGURE 3.5

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

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G:\Maps\Projects\10-214-1_NWMO_InitialSiteScreening_Wawa\RO Version Figures\10-214-1_NWMO_InitialSiteScreening_Wawa_Figure3_5_ResidualMagneticTotalFieldoftheWawaArea_R0.mxd

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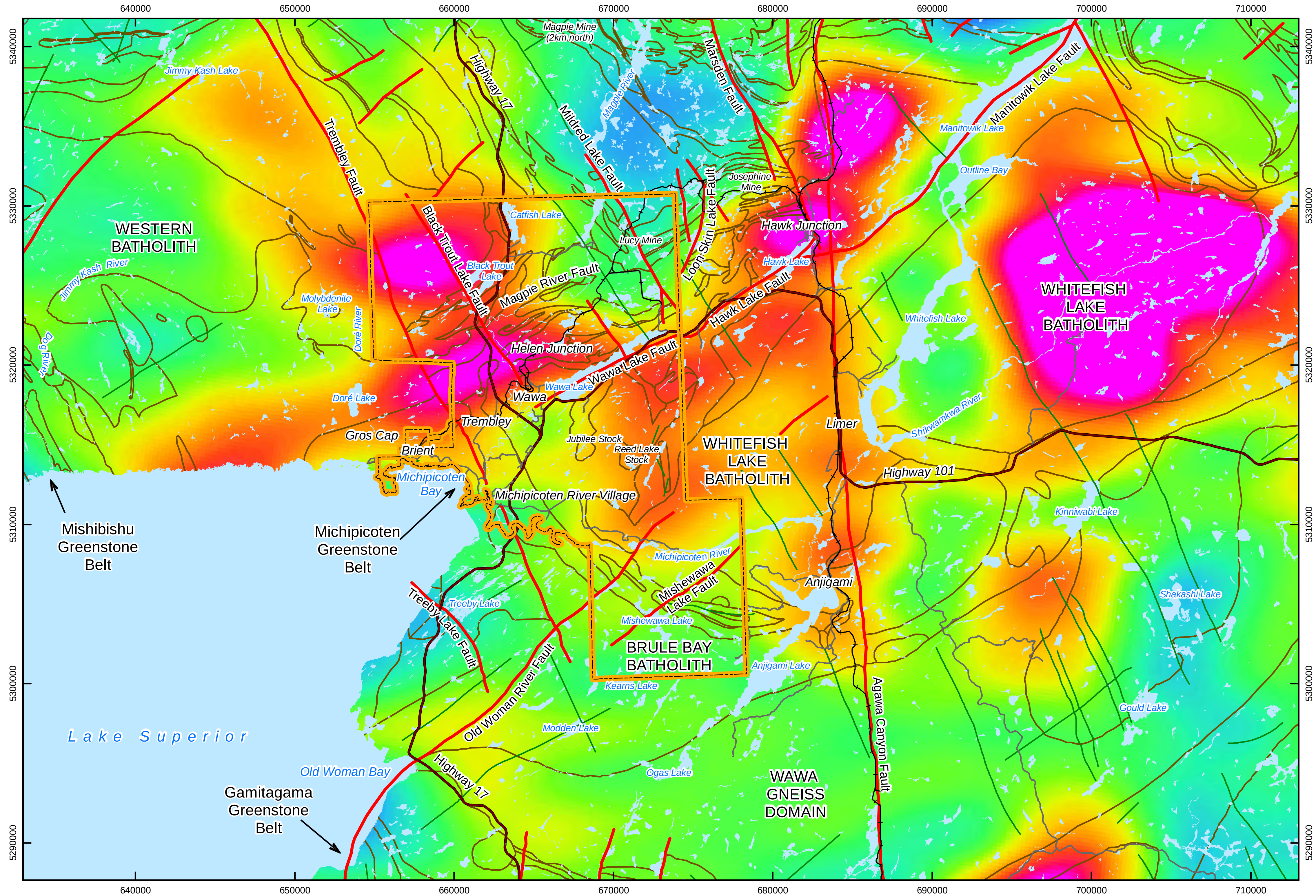

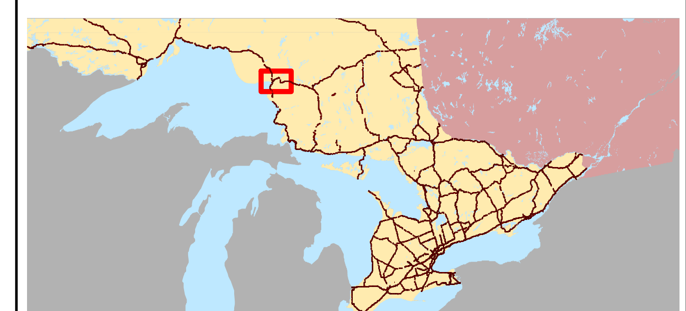

SCALE 1:275,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Radiometrics: GSC Canada - 250m -Equivalent Uranium, obtained 2011; 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
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NWMO Desktop Level Initial Site Screening

TITLE

Equivalent Uranium of the Wawa Area

FIGURE 3.6

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

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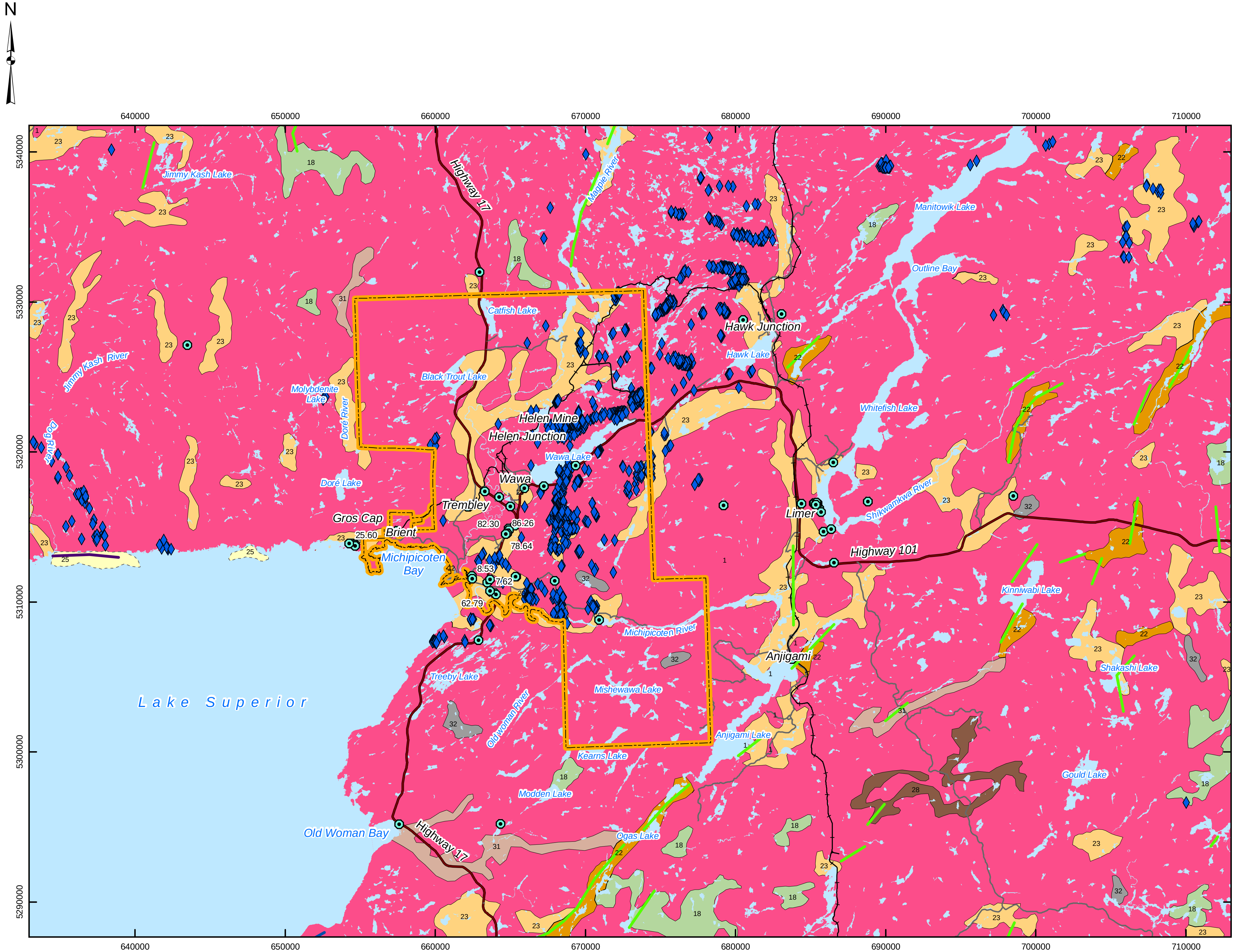
G:\Maps\Projects\10-214-1_NWMO_InitialSiteScreening_Wawa\RO Version Figures\10-214-1_NWMO_InitialSiteScreening_Wawa_Figure3_6_EquivalentUraniumoftheWawaArea_R0.mxd

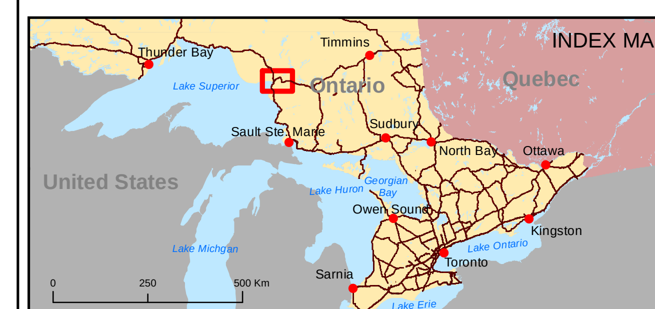


LEGEND

- Municipality of Wawa
- Highway
- Local Road
- Railway
- Water Area, Permanent
- MOE Well (Depth to Bedrock - m, blank = no data)
- Diamond Drillhole
- Beach, Bar or Spit
- Esker or Area of Eskers; Direction of Flow Known or Assumed
- Terrace Escarpment (abandoned shore bluff)

Geology

- 1: Bedrock
- 18: Till
- 22: Glaciofluvial Ice-contact Deposits
- 23: Glaciofluvial Outwash Deposits
- 25: Glaciolacustrine Deposits
- 28: Fluvial Deposits on Abandoned Flood Plains, Terrace Remnants
- 31: Fluvial Deposits on Modern Flood Plains
- 32: Organic Deposits



SCALE 1:275,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geology: EDS014-Surficial Geology of Ontario 1:1,000,000, 1988
Wells: Ministry of the Environment, 2010
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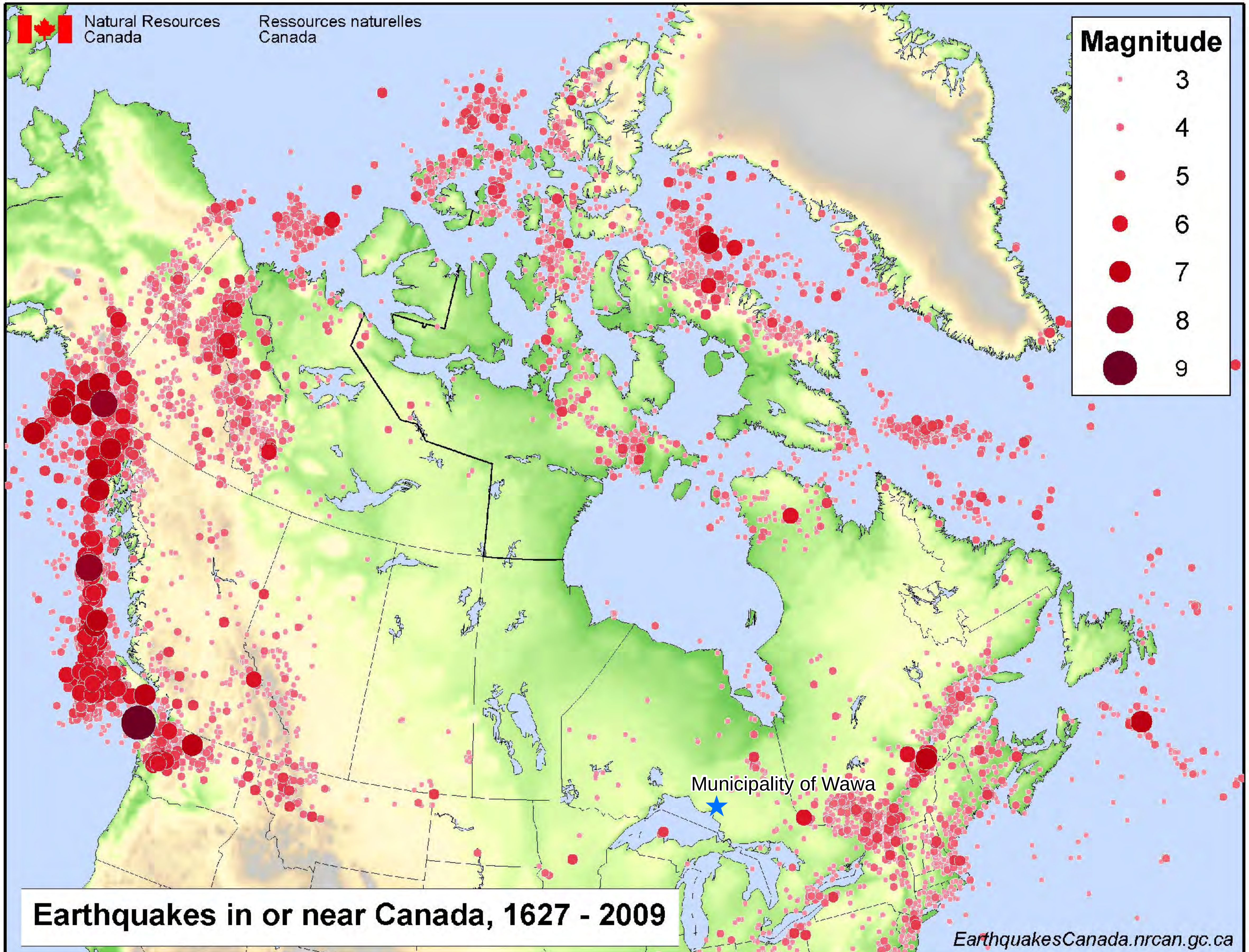
NWMO Desktop Level Initial Site Screening

TITLE

Quaternary Geology of the Wawa Area

FIGURE 3.7	DESIGN: NMP CAD/GIS: NMP/ADG CHECK: ACW/KGR REV: 0 DATE: 8/24/2011	Geofirma Engineering Ltd

G:\Maps\Projects\10-214-1_NWMO_InitialSiteScreening_Wawa\RO Version Figures\10-214-1_NWMO_InitialSiteScreening_Wawa_Figure3_7_QuaternaryGeologyoftheWawaArea_R0.mxd



LEGEND

★ Municipality of Wawa

Not to Scale

PROJECTION: NA
SOURCE: Seismic: NRCAN, Earthquake Map of Canada 1627-2009

PROJECT No. 10-214-1

NWMO Desktop Level Initial Site Screening

TITLE

Earthquake Map of Canada 1627-2009

FIGURE 3.8

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

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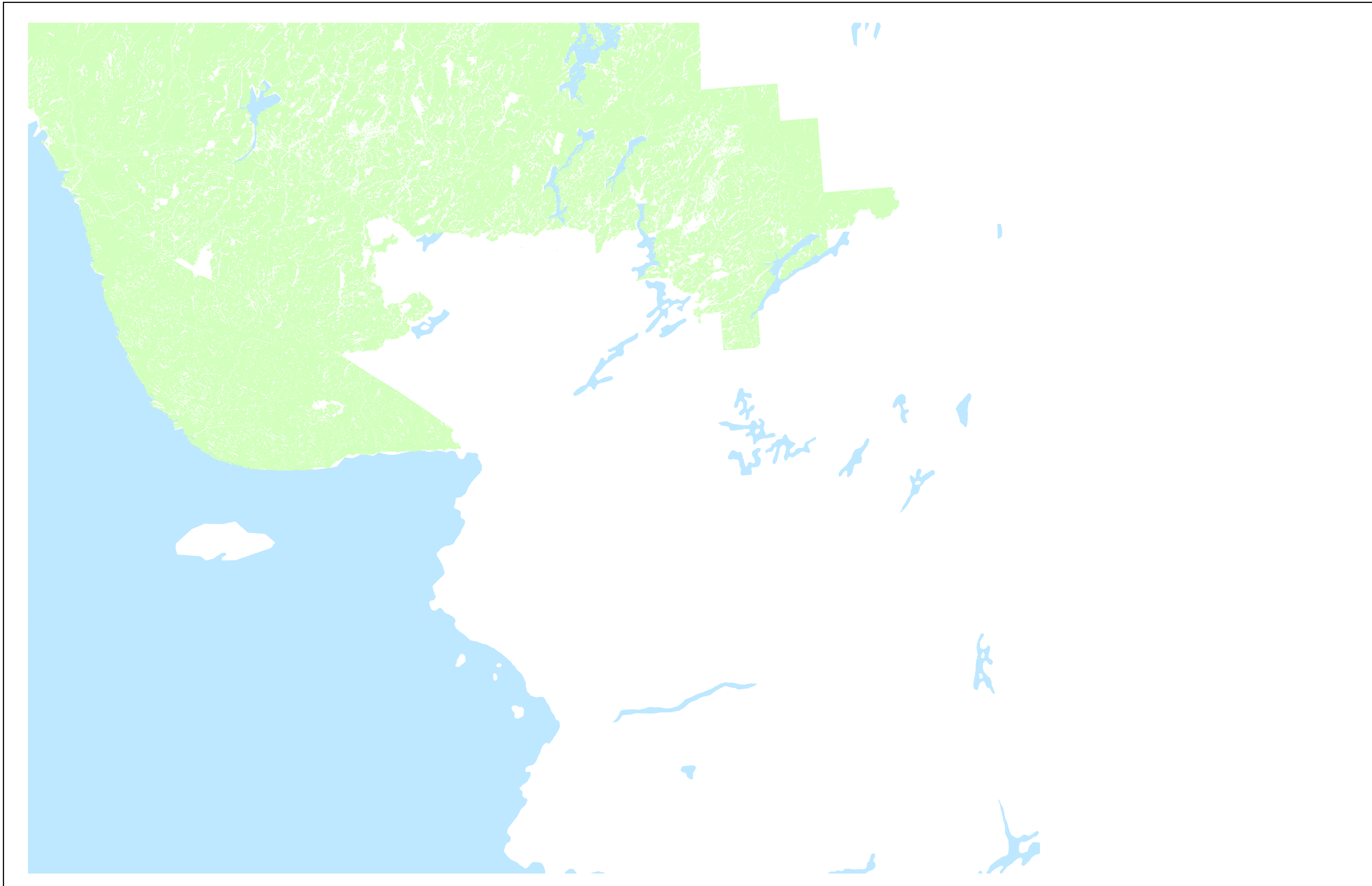
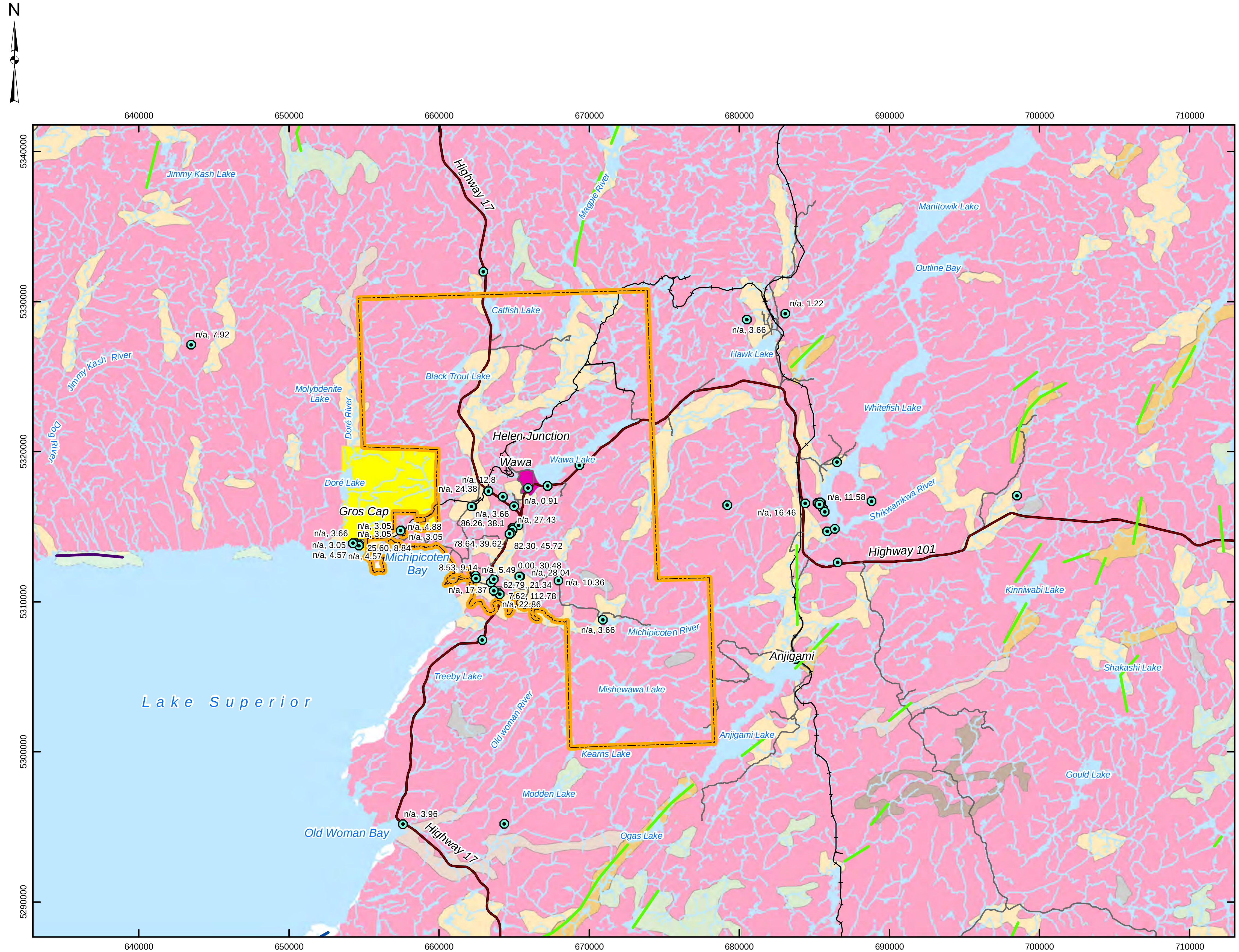
G:\Maps\Projects\10-214-1_NWMO_InitialSiteScreening_Wawa\RO Version Figures\10-214-1_NWMO_InitialSiteScreening_Wawa_Figure3_8_EarthquakeMapofCanada1627-2009_R0.mxd





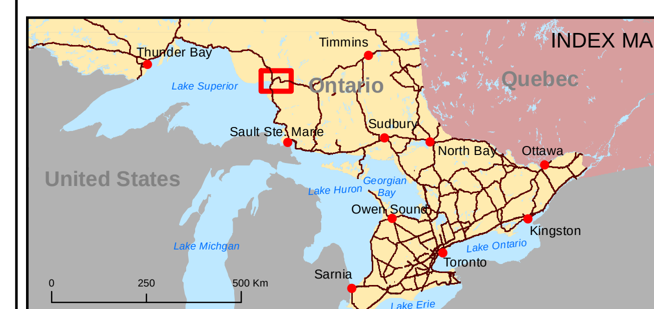
LEGEND

- Municipality of Wawa
- Settlement Area of Wawa
- Indian Reserve (Gros Cap Indian Village 49A)
- Highway
- Local Road
- Railway
- Water Area, Permanent
- Watercourse, Permanent
- Watercourse, Intermittent
- MOE Well (Depth to Bedrock, Depth to Water - m)
- Beach, Bar or Spit
- Esker or Area of Eskers; Direction of Flow Known or Assumed
- Terrace Escarpment (abandoned shore bluff)

Geology

- 1: Bedrock
- 18: Till
- 22: Glaciofluvial Ice-contact Deposits
- 23: Glaciofluvial Outwash Deposits
- 25: Glaciolacustrine Deposits
- 28: Fluvial Deposits on Abandoned Flood Plains, Terrace Remnants
- 31: Fluvial Deposits on Modern Flood Plains
- 32: Organic Deposits

INDEX MAP



SCALE 1:275,000

0 2.5 5 10 15 20
Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geology: EDS014-Surficial Geology of Ontario 1:1,000,000, 1988
Wells: Ministry of the Environment, 2010
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NWMO Desktop Level Initial Site Screening

TITLE

Water Well Records of the Wawa Area

FIGURE 4.1

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

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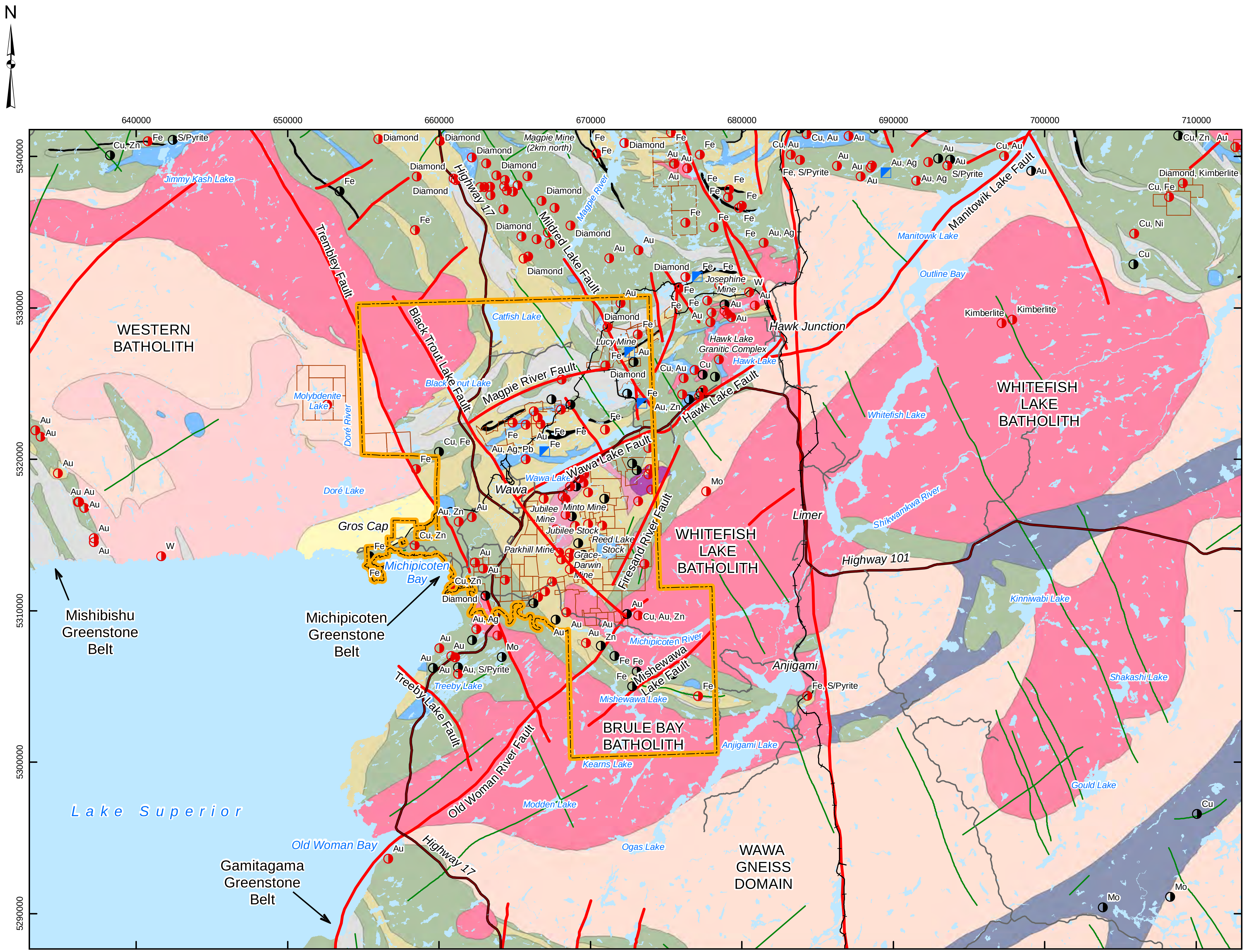
G:\Maps\Projects\10-214-1_NWMO_InitialSiteScreening_Wawa\RO Version Figures\10-214-1_NWMO_InitialSiteScreening_Wawa_Figure4_1_WaterWellRecordsoftheWawaArea_R0.mxd

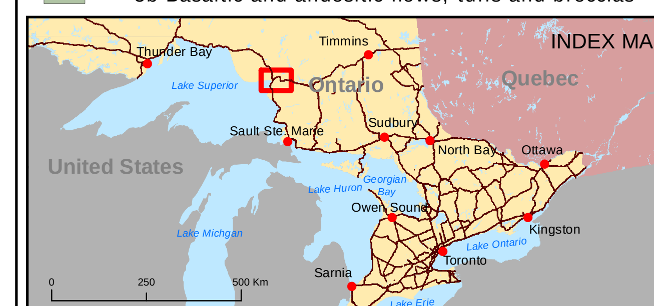


LEGEND

- Municipality of Wawa
- Highway
- Local Road
- Railway
- Water Area, Permanent
- Geological Fault
- Dike
- Active Mining Claims
- Discretionary Occurrence
- Occurrence
- Past Producing Mine With Reserves

Bedrock Geology

- Iron Formation
- 35 Carbonatite-alkalic intrusive suite (1.0 to 1.2 Ga)
- 15 Massive granodiorite to granite
  - 15a Potassium feldspar megacrystic units
- 14-Diorite-monzodiorite-granodiorite suite
  - 14b Granodiorite, granite
- 12 Foliated tonalite suite
- 11 Gneissic tonalite suite
- 10 Mafic and ultramafic rocks
  - 10c Ultramafic rocks
- 9 Coarse clastic metasedimentary rocks
- 8 Migmatized supracrustal rocks
- 7 Metasedimentary rocks
  - 7a Paragneisses and migmatites
  - 7b Conglomerate and arenite
  - 7e Paragneiss and migmatites
- 6 Felsic to intermediate metavolcanic rocks
  - 6b Rhyolitc, rhyodacitic flows,tuffs and breccias
- 5 Mafic to intermediate metavolcanic rocks
  - 5b Basaltic and andesitic flows, tuffs and breccias



SCALE 1:275,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Claims: Ministry of Northern Mines and Development June 2011
Mineral Inventory: Mineral Deposit Inventory, 2010
Geology: MRD126-Bedrock Geology of Ontario, 2007
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NWMO Desktop Level Initial Site Screening

TITLE Mining Claims and Mineral Potential in the Wawa Area

FIGURE 5.1

DESIGN: NMP
CAD/GIS: NMP/ADG
CHECK: ACW/KGR
REV: 0

DATE: 8/24/2011

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G:\Maps\Projects\10-214-1_NWMO_InitialSiteScreening_Wawa\RO Version Figures\10-214-1_NWMO_InitialSiteScreening_Wawa_Figure5_1_MiningClaimsandMineralPotentialintheWawaArea_R0.mxd