nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

September 21, 2012

The Municipality of Arran-Elderslie
P.O. Box 70, 1925 Bruce Road 10
Chesley, ON N0G 1L0

Attn: Ms. Peggy Rouse

Re: **Adaptive Phased Management Initial Screening – The Municipality of Arran-Elderslie**

Dear Ms. Rouse,

Further to the Municipality of Arran-Elderslie'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 Arran-Elderslie 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 Arran-Elderslie from further consideration in the NWMO site selection process. The initial screening suggests that the Municipality comprises geological formations 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 Arran-Elderslie 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, Arran-Elderslie as a whole community would need to clearly demonstrate that it is willing to host the repository in order for this project to proceed.

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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

Cc: Mayor Paul Eagleson

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

The Corporation of the Municipality of Arran-Elderslie

Report

AECOM

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

The Corporation of the Municipality of Arran-Elderslie

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Executive Summary

On June 25, 2012 the Corporation of the Municipality of Arran-Elderslie 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 AECOM, to evaluate the potential suitability of the Municipality of Arran-Elderslie 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 Arran-Elderslie from further consideration in the site selection process. The initial screening focused on the areas within the boundaries of the Municipality of Arran-Elderslie. Areas within neighbouring municipalities were not included in the initial screening.

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 Arran-Elderslie from being further considered in the NWMO site selection process. The initial screening indicates that there are geological formations within the boundaries of the Municipality that are potentially suitable for safely hosting a deep geological repository. Potentially suitable host formations include the Upper Ordovician shale and limestone units that comprise the geology of the Municipality at typical repository depths.

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

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

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

Availability of Land

Review of available mapping and satellite imagery indicates that the Municipality of Arran-Elderslie contains sufficient land to accommodate the surface and underground facilities associated with the repository and could be accessible for construction and field investigation activities. The Municipality contains limited constraints that would prevent the development of the repository's surface facilities. The main land constraints comprise the wetland complexes that exist within the Municipality, and the industrial/commercial infrastructure associated to the settlements of Tara, Chesley and Paisley. The remainder of the Municipality of Arran-Elderslie is largely agricultural land.

Protected Areas, Heritage Sites, Provincial Parks and National Parks

The Municipality of Arran-Elderslie contains sufficient land outside of protected areas, heritage sites, provincial parks and national parks to accommodate the repository's facilities. There are no provincial or national parks within the Municipality. There are five conservation areas, four designated Provincially Significant Wetlands and four Earth Science Areas of Natural and Scientific interest (ANSI) within the Municipality of Arran-Elderlie, representing about 10% of the available land. Limited heritage constraints were identified in the Municipality. There are 14 archaeological sites within the Municipality. These are sites are localized and small in size. There are no National Historic Sites within the Municipality of Arran-Elderslie.

The absence of locally protected areas and heritage sites 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 Municipality of Arran-Elderslie. The Ontario Ministry of Environment Water Well Records indicate that no potable water supply wells are known to exploit aquifers at typical repository depths in the Municipality of Arran-Elderslie. Water wells in the Municipality obtain water from overburden or shallow bedrock aquifers at depths ranging from 5 to 133 m. Experience in similar geological settings across southern Ontario suggests that the potential for deep groundwater resources at repository depths is low throughout the Municipality of Arran-Elderslie. 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 Municipality of Arran-Elderslie contains sufficient land, free of known economically exploitable natural resources, to accommodate the required repository facilities. The Municipality of Arran-Elderslie has no documented oil and gas pools. There is no record of metallic mineral production in the past, and no exploration potential for metallic minerals has been identified within the Municipality. Known non-metallic mineral resources in Southern Ontario include bedrock-derived crushed stone, natural surficial sand and gravel resources, salt and building stone. Current licensed non-metallic mineral extraction in the Municipality of Arran-Elderslie is limited to sand and gravel resources. However, the risk that these resources pose for future human intrusion is negligible, as quarrying operations would be limited to very shallow depths.

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

Based on the review of available geological and hydrogeological information, the Municipality of Arran-Elderslie comprises areas of land that do not contain obvious known geological and hydrogeological conditions that would make the area unsuitable for hosting a deep geological repository. The initial screening indicates that the sedimentary rock sequence beneath the Municipality of Arran-Elderslie is potentially suitable for hosting a deep geological repository. Potentially suitable host formations include the deep Upper Ordovician shale and limestone units.

Table of Contents

page

1. Introduction 1
1.1 Background 1
1.2 Objectives and Approach for Conducting Initial Screenings 1

2. Physical Geography 3
2.1 Location 3
2.2 Topography 3
2.3 Drainage 3
2.4 Protected Areas 4
2.4.1 Parks and Reserves 4
2.5 Heritage Sites 4

3. Geology and Seismicity 6
3.1 Regional Geology 6
3.1.1 Regional Geological Setting 6
3.1.2 Precambrian Crystalline Basement Geology 6
3.1.3 Regional Sedimentary Bedrock Stratigraphy 7
3.2 Local Sedimentary Bedrock Geology of the Municipality of Arran-Elderslie 10
3.2.1 Stratigraphy 10
3.3 Deformation and Metamorphism 13
3.3.1 Tectonic History 13
3.3.2 Fault History 14
3.3.3 Diagenesis 15
3.3.4 Karst 15
3.4 Geomechanical Properties 16
3.5 Quaternary Geology 17
3.5.1 Quaternary Overburden Thickness 17
3.5.2 Glacial Erosion 17
3.6 Neotectonic Activity 18
3.7 Seismicity 18

4. Hydrogeology 19
4.1 Groundwater Wells 19
4.2 Deep Groundwater System 19
4.3 Hydrogeochemistry 20

5. Economic Geology 21
5.1 Hydrocarbon Resources 21
5.2 Metallic Mineral Resources 21
5.3 Non-Metallic Mineral Resources 21
5.3.1 Sand and Gravel 22
5.3.2 Bedrock Resources 22

6. Initial Screening Evaluation 23
6.1 Screening Criterion 1: Land Availability 23
6.2 Screening Criterion 2: Protected Areas 24

6.3 Screening Criterion 3: Known Groundwater Resources at Repository Depth 25
6.4 Screening Criterion 4: Known Natural Resources 26
6.5 Screening Criterion 5: Unsafe Geological or Hydrogeological Features 26

7. Initial Screening Findings 31

8. References...32

List of Figures

Figure 2.1 Municipality of Arran-Elderslie and Surrounding Area
Figure 2.2 Satellite Imagery of the Municipality of Arran-Elderslie
Figure 2.3 Physiographic Regions of the Municipality of Arran-Elderslie and the Surrounding Area
Figure 2.4 Digital Elevation Model (DEM) of the Municipality of Arran-Elderslie and the Surrounding Area
Figure 2.5 Drainage Features of the Municipality of Arran-Elderslie
Figure 3.1 Geological Features of Southern Ontario
Figure 3.2 Geology of Southern Ontario
Figure 3.3 Geological Cross-Section
Figure 3.4 Gravity Map of Southern Ontario
Figure 3.5 Residual Total Magnetic Field of Southern Ontario
Figure 3.6 Bedrock Geology and Oil and Gas Wells of the Municipality of Arran-Elderslie and the Surrounding Area
Figure 3.7 Karst Mapping of Southern Ontario
Figure 3.8 Quaternary Geology of the Municipality of Arran-Elderslie and the Surrounding Area
Figure 3.9 Overburden Thickness in the Municipality of Arran-Elderslie and the Surrounding Area
Figure 3.10 Earthquake Map of Canada 1627-2010
Figure 3.11 Earthquake Map of Southern Ontario 1985-2012
Figure 4.1 Water Well Records of the Municipality of Arran-Elderslie
Figure 5.1 Non-Metallic Bedrock Resources of the Municipality of Arran-Elderslie and the Surrounding Area

List of Tables

Table 3.1 Stratigraphy of Southern Ontario (Armstrong and Carter, 2010) 8
Table 3.2 Subcrop Geological Unit and Final Well Completion Unit for Oil and Gas Wells Intersecting the Precambrian Crystalilne Basement Surrounding the Municipality of Arran-Elderslie 11
Table 3.3 Stratigraphy Derived from Oil and Gas Exploration Wells #F012117 (1958), #T001720A (1964), and #T001877 (1964) in Municipality of Arran-Elderslie (Itasca and AECOM, 2011 after OGSRL, 2006) 12
Table 3.4 Timetable of Major Tectonic Events in Southern Ontario 13
Table 4.1 MOE Water Well Record Details.. 19

1. Introduction

On June 25, 2012, the Corporation of the Municipality of Arran-Elderslie 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 AECOM, as part of Step 2 in the site selection process to evaluate the potential suitability of the Municipality of Arran-Elderslie against five screening criteria using readily available information. The initial screening focused on the areas within the boundaries of the Municipality of Arran-Elderslie. Areas within neighbouring municipalities were not included in the initial screening.

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, social, economic and cultural factors as identified through dialogue with Canadians including 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 of the process.

1.2 Objectives and Approach for Conducting Initial Screenings

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

1. The site must have enough available land of sufficient size to accommodate the surface and underground facilities.
2. This available land must be outside of protected areas, heritage sites, provincial parks and national parks.
3. This available land must not contain known groundwater resources at the repository depth, so that the repository site is unlikely to be disturbed by future generations.
4. This available land must not contain economically exploitable natural resources as known today, so that the repository site is unlikely to be disturbed by future generations.

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

The initial screening step involves the systematic consideration of each of the five initial screening criteria on a qualitative basis using readily available information from provincial, federal, municipal and other sources of information. It is not the intent of the initial screening study to conduct a detailed analysis of all available information, but rather to identify any obvious conditions that would exclude a community from 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 screening stage, the area would be advanced to the feasibility study stage for more detailed evaluation, provided the community remains interested in continuing to participate in the siting process.

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

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

2. Physical Geography

2.1 Location

The Municipality of Arran-Elderslie is situated within Bruce County in southern Ontario, approximately 15 km southwest of Owen Sound (see index map of Figure 2.1). The Municipality is approximately 466 km^2 in size. The largest settlement areas within the Municipality are those of Paisley, located along the southwestern boundary; Chesley, in the southeast corner; and Tara, in the northeast corner of the Municipality (Figure 2.1). Municipal offices are located in the settlement of Chesley. Satellite imagery for the Municipality of Arran-Elderslie (Spot 5, taken in 2006) is presented on Figure 2.2.

2.2 Topography

The Municipality of Arran-Elderslie is located in the Western St. Lawrence Lowlands physiographic region, a low-relief, gently undulating land surface (see index map of Figure 2.3). Figure 2.3 shows the detailed physiographic regions of the Municipality of Arran-Elderslie and surrounding areas.

The southern half of the Municipality of Arran-Elderslie lies in the Saugeen Clay Plain physiographic region, while the majority of the northern half of the Municipality lies in the Arran Drumlin Field physiographic region. The northwestern corner of the Municipality extends into the Huron Fringe physiographic region. The Municipality is covered with Quaternary glacial deposits, and numerous small lakes, streams, and swampy areas are found throughout (Figure 2.1).

The Digital Elevation Model (DEM) for the Municipality of Arran-Elderslie is presented on Figure 2.4. Topography ranges from gently undulating to rolling, with land surface elevations from 185 to 300 metres above sea level (mASL). The northern half of the Municipality, within the Arran Drumlin Field physiographic region, is characterized by southwest-oriented linear ridges resulting in a moderate relief, hummocky landscape. The southern half of the Municipality is predominantly low relief, however two distinct moraine ridges run east-west across the Municipality. The highest elevations (approximately 395 mASL)) are found along the moraine ridges in the south, as well as in the drumlinized plain in the northern portion of the Municipality. The lowest elevations are associated with the low-relief, low-elevation topography in the northwestern corner of the Municipality in the Huron Fringe physiographic region. Low elevations also occur along the Saugeen River, which runs through the southwestern corner of the Municipality, and has cut a deep valley through the clay plain (Figure 2.4).

2.3 Drainage

Surface water drainage for the Municipality of Arran-Elderslie is shown in Figure 2.5. The Municipality of Arran-Elderslie occupies part of two sub-watersheds within the Western Georgian Bay and Eastern Lake Huron sub-basin. The southwestern half of the Municipality is situated within the Saugeen sub-watershed, while the northeastern half of the Municipality is located within the Bruce Peninsula sub-watershed.

Within the Saugeen sub-watershed, drainage is generally west to northwesterly towards the Saugeen River, which discharges into Lake Huron. The main branch of the Saugeen River flows northwest through the southwestern corner of the Municipality through the community of Paisley. The southern portion of the Municipality is characterized by a dense network of small tributaries. A major tributary of the Saugeen River, the North Saugeen River, flows to the west-northwest through Chesley and across the southern portion of the Municipality, and discharges into the main branch of the Saugeen River just north of Paisley.

Within the Bruce Peninsula sub-watershed, the Sauble River flows in a north-northwesterly direction through Tara and the northeastern portion of the Municipality, ultimately discharging into Lake Huron at Sauble Beach about 20 km north of the Municipality. Tributaries feeding the Sauble River flow in a north-northeasterly direction, their orientation governed by the drumlins of the Arran Drumlin Field (Figure 2.5).

Wetland areas are present throughout the Municipality of Arran-Elderslie (Figure 2.5). The Sangs Creek and Allenford Station Wetland Complexes lie along the northern border of the Municipality, and the Tara Floodplain Wetland Complex is located along the eastern boundary. The Arran Lake Wetland Complex, located in the northeastern portion of the Municipality, is the largest wetland area, covering approximately 12 km^2, and includes Arran Lake. The locally significant Elderslie Swamp Wetland Complex, lies in the south-central portion of the Municipality, within the Saugeen sub-watershed. Numerous other low-lying, poorly drained swampy areas exist within the region (Figure 2.5).

2.4 Protected Areas

2.4.1 Parks and Reserves

There are no provincial or national parks within the Municipality of Arran-Elderslie. The nearest parks are MacGregor Point Provincial Park, located approximately 13 km west of the Municipality, and Inverhuron Provincial Park, located about 25 km southwest of the Municipality. Both of these parks are situated along the shore of Lake Huron. There are five conservation areas within the Municipality of Arran-Elderslie (Figure 2.1): the McBeath and Lockerby Conservation Areas located in the southwestern corner of the Municipality; the Tara Conservation Area on the eastern boundary of the settlement area of Tara; the Arran Management Conservation Area within the northeastern portion of the Arran Lake Wetland Complex; and an unnamed conservation area maintained by the Saugeen Valley Conservation Authority present within the Elderslie Swamp Wetland Complex (Figure 2.1). These conservation areas have a combined area of approximately 3 km^2 (about 1% of the Municipality).

There are four designated Provincially Significant Wetlands within the Municipality of Arran-Elderslie comprising the Sangs Creek Wetland Complex, the Allenford Station Wetland Complex, the Tara Floodplain Wetland Complex and the Arran Lake Wetland Complex (Figure 2.1). These wetlands have a combined area of approximately 19 km^2, comprising 4% of the Municipality. Several Earth Science Areas of Natural Scientific Interest (ANSI) are present within the Municipality and include the Tara Moraine and Arkwright Drumlins, located just outside of Tara; the Tara and Dobbinton Eskers, located in the east-central portion of the Municipality; and the Williscroft Moraine in the south-central portion of the Municipality (Figure 2.5). These features cover approximately another 5% of the Municipality with a combined area of approximately 23 km^2. The ANSI's represent prominent glacial geological features that support unique habitats and protect groundwater infiltration and recharge function. Known protected areas occupy approximately 10% of the Municipality of Arran-Elderslie.

The presence and function of other natural features and areas, such as significant woodlands, significant valleylands or significant wildlife habitats (Provincial Policy Statement, 2005; Bruce County Official Plan, 2011) would be addressed during subsequent site evaluation stages, if the community remains interested in continuing to participate in the site selection process.

2.5 Heritage Sites

The cultural heritage screening examined known archaeological and historic sites in the Municipality of Arran-Elderslie and surrounding areas, using the Ontario Archaeological Sites Database maintained by the Ontario Ministry of Tourism, Culture and Sport (Ontario Ministry of Tourism and Culture, undated).

There are 141 registered archaeological sites in the area examined, which is an approximately 40 km radius around the Municipality of Arran-Elderslie. The majority are of Aboriginal cultural affiliation; lithic scatters, fishing/hunting camps, burial sites, and many camp sites. Several are of Euro-Canadian affiliation, which include domestic, residential, and homestead sites. There are no National Historic Sites in the area. Locations of known archaeological sites are not shown in maps within this report to comply with Ministry of Tourism and Culture publication guidelines.

There are 14 known archaeological sites documented in the Municipality of Arran-Elderslie. These sites are of Aboriginal cultural affiliation: two of these are of undetermined cultural affiliation or function; one is of undetermined cultural affiliation but are distinguished as a campsite; two are pre-contact findspots; three Archaic (Laurentian) campsites; two are Archaic/Late-Middle Woodland cultural affiliation which includes a campsite and an undetermined function; three are Woodland (Saugeen) campsites which includes two campsites and a village. One is of a Euro-Canadian homestead dating to the mid to late 19th century located at Grey Bruce Line.

The potential for archaeological sites within the Municipality of Arran-Elderslie is high for both Aboriginal and Euro-Canadian finds. Archaeological potential is established by determining the likelihood that archaeological resources may be present on a subject property. In archaeological potential modelling, a distance to water criterion of 300 m is generally employed for primary water courses, including lakeshores, rivers and large creeks, while a criterion of 200 m is applied to secondary water sources, including swamps and small creeks (Government of Ontario, 1997).

3. Geology and Seismicity

This section provides a general overview of the geology and seismicity of southern Ontario, including the Municipality of Arran-Elderslie and surrounding areas, focusing on information that is most relevant to this initial screening.

3.1 Regional Geology

3.1.1 Regional Geological Setting

The bedrock geology of southern Ontario consists of a thick Paleozoic sedimentary sequence from Cambrian to Mississippian in age, deposited approximately 542 million to 318 million years ago (Johnson et al., 1992; Walker and Geissman, 2009). This sedimentary sequence unconformably overlies the Precambrian crystalline basement of the Grenville Province, the south-easternmost subdivision of the Canadian Shield (Figure 3.1; Figure 3.2). The Grenville Province comprises 2,690 million to 990 million year old rocks deformed during orogenic events 1,100 to 970 million years ago (Percival and Easton, 2007; Carr et al., 2000; White et al., 2000). The Precambrian Grenville Province, which extends from Labrador to Mexico, is generally considered to have been relatively tectonically stable since approximately 970 million years ago (Percival and Easton, 2007, see Section 3.3).

Southern Ontario is underlain by two main paleo-depositional centres, the Appalachian and Michigan Basins, which are separated by a Precambrian crystalline basement high referred to as the Algonquin Arch (Figure 3.1). The Paleozoic succession underlying the Municipality of Arran-Elderslie and surrounding area was deposited in the Michigan Basin, a broadly circular intracratonic basin centred in Michigan. The Paleozoic succession thins from a maximum of approximately 4,800 m at the centre of the Michigan Basin to approximately 850 m on the flank of the Algonquin Arch east of the Municipality of Arran-Elderslie (Figure 3.1). The Paleozoic strata dip gently (3.5 to 12 m/km) to the west or southwest throughout the Ontario portion of the Michigan Basin (Figure 3.1; Armstrong and Carter, 2010).

Figure 3.2 presents the bedrock geology of southern Ontario. Figure 3.3 shows a geological cross-section (location shown on Figure 3.2), which highlights the west-southwesterly dip of the Paleozoic succession from the Niagara Escarpment in the east, to Lake Huron in the west, passing through the Municipality of Arran-Elderslie (note approximately 45x vertical exaggeration). Also note that on Figure 3.3, due to differences in outcrop versus subsurface stratigraphic nomenclature, the colour-shaded bedrock units in the cross-section do not correspond directly to the colour shades shown in the bedrock map and accompanying legend on Figure 3.2.

3.1.2 Precambrian Crystalline Basement Geology

The Precambrian crystalline basement beneath much of southern Ontario is characterized by gneisses and metamorphic rocks of the Grenville Province of the Canadian Shield (Figure 3.1; Carter and Easton, 1990). Geophysical investigations provide useful information regarding the character of these basement rocks. Seismic profiles of the crystalline basement have been interpreted as representing the penetrative ductile Grenville-aged deformation fabric beneath the undeformed Paleozoic sedimentary rocks (e.g., Milkereit et al., 1992). Similarly, the gravity and residual total magnetic field maps of Southern Ontario, shown in Figures 3.4 and 3.5, reflect the distribution of rock units within the Precambrian crystalline basement, rather than features of the overlying Paleozoic sedimentary rock succession.

The Municipality of Arran-Elderslie is underlain by a moderately low gravity signal. The lowest intensities occur along the western boundary and increase towards the east (Figure 3.4). Moderate aeromagnetic field values are present along the western boundary of the Municipality of Arran-Elderslie, representing the outer edge of a high aeromagnetic anomaly located along the Lake Huron Shoreline to the west. Low magnetic field values are present throughout the remainder of the Municipality, and are part of an irregularly shaped series of lows that extend in a northeasterly direction from Goderich to Owen Sound (Figure 3.5). The observed variations of both gravity and magnetic intensity in southern Ontario may be in part the result of mineralogical and structural variation within and between recognized lithotectonic terranes of the Precambrian crystalline basement (Easton, 1992; Boyce and Morris, 2002).

3.1.3 Regional Sedimentary Bedrock Stratigraphy

Table 3.1 illustrates the Paleozoic bedrock stratigraphy for three different geographic regions in southern Ontario (Armstrong and Carter, 2010). The Municipality of Arran-Elderslie and surrounding areas are within the region described by the centre column of Table 3.1. The Paleozoic sedimentary stratigraphy includes shale, carbonate and evaporate units formed predominantly from marine sediments that were deposited when this portion of eastern North America was located at tropical latitudes and intermittently covered by shallow seas (Johnson et al., 1992; Armstrong and Carter, 2010).

The sedimentary bedrock stratigraphy shown in Table 3.1 and in Figure 3.3 adopts a subsurface nomenclature, while geological mapping as shown in Figures 3.2 and 3.6 uses an outcrop nomenclature (e.g., Armstrong and Carter, 2010). This distinction primarily applies to the Trenton and Black River groups where the Bobcaygeon Formation (outcrop) is equivalent to the Coboconk and Kirkfield formations (subsurface), and the Verulam and Lindsay formations (outcrop) are approximately equivalent to the Sherman Fall and Cobourg formations (subsurface), respectively.

The cross-section shown in Figure 3.3 bisects the southern portion of the Municipality and illustrates the high degree of lateral continuity of individual units within the Paleozoic sedimentary bedrock succession of southern Ontario. This cross-section also shows the uniformity of thicknesses and bedding dip magnitudes for the Upper Ordovician shale and limestone sedimentary rocks across the area. These geological units within southern Ontario display a high level of lateral consistency, and the geological cross-section is considered representative of the stratigraphy within the Municipality of Arran-Elderslie.

The following descriptions of the Paleozoic bedrock stratigraphy in southern Ontario utilize the subsurface nomenclature as defined in Table 3.1. The descriptions are primarily adapted from Johnson et al. (1992) and Armstrong and Carter (2010), the latter of which is an update of the stratigraphy presented by Armstrong and Carter (2006). The Paleozoic bedrock stratigraphy is described according to the main sedimentary sequences presented in the central column of Table 3.1.

Table 3.1 Stratigraphy of Southern Ontario (Armstrong and Carter, 2010)

Standard Reference		Elgin, Essex, Huron, Kent, Lambton, Middlesex, Perth Counties and Western Lake Erie	Manitoulin Island, Bruce, Grey, Durham, Halton, Waterloo, and Wellington Counties	Brant, Haldimand, Lincoln, Norfolk, Oxford, Welland, Wentworth Counties and Eastern and Central Lake Erie
Mississippian		PORT LAMBTON: Sunbury		
Devonian	Upper	PORT LAMBTON: Berea		
Devonian	Upper	PORT LAMBTON: Bedford		
Devonian	Upper	Kettle Point		Kettle Point
Devonian	Middle	HAMILTON: Ipperwash		
Devonian	Middle	HAMILTON: Widder		
Devonian	Middle	HAMILTON: Hungry Hollow		HAMILTON: Hungry Hollow
Devonian	Middle	HAMILTON: Arkona		HAMILTON: Arkona
Devonian	Middle	HAMILTON: Rockport Quarry		
Devonian	Middle	HAMILTON: Bell		
Devonian	Middle	Marcellus		Marcellus
Devonian	Middle	Dundee (gas) (oil)		Dundee
Devonian	Middle	DETROIT RIVER: Lucas (oil)	DETROIT RIVER: Lucas	
Devonian	Middle	DETROIT RIVER: Sylvania; Amherstburg	DETROIT RIVER: Amherstburg	DET. R: Amherstburg; Onondaga
Devonian	Lower	Bois Blanc	Bois Blanc	Bois Blanc; *Springvale*
Devonian	Lower			Oriskany
Silurian	Upper	Bass Islands	Bass Islands	Bass Islands; Bertie
Silurian	Upper	SALINA: G Unit	SALINA: G Unit	SALINA: G Unit
Silurian	Upper	SALINA: F Unit	SALINA: F Unit	SALINA: F Unit
Silurian	Upper	SALINA: E Unit	SALINA: E Unit	SALINA: E Unit
Silurian	Upper	SALINA: D Unit		
Silurian	Upper	SALINA: C Unit	SALINA: C Unit	SALINA: C Unit
Silurian	Upper	SALINA: B Unit	SALINA: B	SALINA: B
Silurian	Upper	SALINA: A-2 Unit (gas)	SALINA: A-2 Unit; A Unit	SALINA: A-2 Unit; A Unit (gas)
Silurian	Upper	SALINA: A-1 Unit (gas) (oil)	SALINA: A-1 Unit	SALINA: A-1 Unit
Silurian	Upper	Guelph; *Eramosa* (gas) (oil)	Guelph; *Eramosa*	Guelph; *Eramosa* (gas)
Silurian	Lower	Lockport: *Goat Island*	Amabel: *Wiarton*	Lockport: *Goat Island*
Silurian	Lower	Lockport: *Gasport*		Lockport: *Gasport*
Silurian	Lower			CLINTON: Decew
Silurian	Lower	CLINTON: Rochester	Amabel: *Lions Head*	CLINTON: Rochester
Silurian	Lower			CLINTON: Irondequoit (gas)
Silurian	Lower	CLINTON: Reynales	CLINTON: Fossil Hill	CLINTON: Reynales; Thorold (gas); Neahga
Silurian	Lower		CATARACT: St. Edmund	
Silurian	Lower		CATARACT: Wingfield	
Silurian	Lower		CATARACT: Dyer Bay; Grimsby	CAT-ARACT: Grimsby (gas)
Silurian	Lower	CATARACT: Cabot Head	CATARACT: Cabot Head	CAT-ARACT: Cabot Head
Silurian	Lower	CATARACT: Manitoulin	CATARACT: Manitoulin; Whirlpool	CAT-ARACT: Man.; Whirlpool (gas) (oil)
Ordovician	Upper	Queenston	Queenston	Queenston
Ordovician	Upper	Georgian Bay - Blue Mountain	Georgian Bay - Blue Mountain; *Collingwood*	Georgian Bay - Blue Mountain
Ordovician	Upper	TRENTON: Cobourg (gas) (oil)	TRENTON: Cobourg	TRENTON: Cobourg
Ordovician	Upper	TRENTON: Sherman Fall (gas) (oil)	TRENTON: Sherman Fall	TRENTON: Sherman Fall
Ordovician	Upper	TRENTON: Kirkfield (gas) (oil)	TRENTON: Kirkfield	TRENTON: Kirkfield
Ordovician	Upper	BLACK RIVER: Coboconk (gas) (oil)	BLACK RIVER: Coboconk	BLACK RIVER: Coboconk
Ordovician	Upper	BLACK RIVER: Gull River	BLACK RIVER: Gull River (gas)	BLACK RIVER: Gull River (gas)
Ordovician	Upper	BLACK RIVER: Shadow Lake	BLACK RIVER: Shadow Lake	BLACK RIVER: Shadow Lake
Cambrian	Upper	Trempealeau		Little Falls
Cambrian	Upper	Eau Claire (gas) (oil)		Theresa (gas) (oil)
Cambrian	Upper	Mt. Simon		Potsdam
Precambrian		crystalline basement	crystalline basement	crystalline basement

Legend: ☼ gas; ● oil

Cambrian

The Cambrian bedrock geology in southern Ontario is dominated by white to grey quartzose sandstone with regional lithological variations that include fine to medium crystalline dolostone, sandy dolostone, and argillaceous dolostone to fine to coarse quartzose sandstone (Hamblin, 1999). Cambrian deposits are generally characterized as a succession of clastic and carbonate rocks resulting from transgressive Cambrian seas that flooded across the broad platform of the Algonquin Arch and into the subsiding Michigan and Appalachian basins (Hamblin, 1999). The Cambrian units are largely absent over the Algonquin Arch as the result of a pre-Ordovician regional-scale unconformity (Bailey Geological Services and Cochrane, 1984). Based on the regional stratigraphic framework, the Cambrian unit is interpreted to pinch out near the western boundary of the Municipality of Arran-Elderslie (Itasca Canada and AECOM, 2011), and thus is expected to be absent beneath most of the Municipality. There are no surface exposures of the Cambrian unit in southwestern Ontario.

Upper Ordovician

Unconformably overlying the Cambrian unit is a thick sequence of Ordovician sedimentary units with a distinctly bimodal composition; a carbonate-rich lower unit and a shale-rich upper unit. The lower unit was deposited during a major marine transgression (Coniglio et al., 1990) prior to the westward inundation of the carbonate platform by the upper unit shale-dominated sediments (Hamblin, 1999). The Upper Ordovician carbonates subcrop in the northeastern part of southern Ontario around the Lake Ontario and Lake Simcoe regions and the Upper Ordovician shales subcrop east of the Niagara Escarpment between Owen Sound and Niagara Falls (Figure 3.2).

The lower carbonate unit of the Upper Ordovician succession is a thick sequence of predominantly limestone formations (carbonate and argillaceous carbonate sedimentary rocks), which include, from bottom to top, the Shadow Lake, Gull River and Coboconk formations of the Black River Group, and the Kirkfield, Sherman Fall, Cobourg (including the Collingwood Member), formations of the Trenton Group (Table 3.1). These rocks range in character from coarse-grained bioclastic carbonates to carbonate mudstone with interbedded calcareous and non-calcareous shales. The Shadow Lake Formation, at the base of the Black River Group, is characterized by poorly sorted, red and green sandy shales, argillaceous and arkosic sandstones, minor sandy argillaceous dolostones and rare basal arkosic conglomerate. The lower part of the overlying Gull River Formation consists mainly of light grey to dark brown limestones and the upper part of the formation is very fine grained with thin shale beds and partings. The Coboconk Formation, at the top of the Black River Group, is composed of light grey-tan to brown-grey, medium to very thick bedded, fine to medium grained bioclastic limestones (Armstrong and Carter, 2010).

The lowest interval of the Trenton Group is the Kirkfield Formation which is characterized by fossiliferous limestones with shaley partings and locally significant thin shale interbeds. The overlying Sherman Fall Formation ranges in lithology from dark grey argillaceous limestones interbedded with calcareous shales, found lower in the formation, to grey to tan bioclastic, fossiliferous limestones that characterize the upper portions of the unit. The overlying Cobourg Formation is described regionally as a grey, fine-grained limestone to argillaceous limestone with coarse-grained fossiliferous beds and a nodular texture. The Cobourg Formation is also subdivided to include an upper Collingwood Member that consists of dark grey to black, calcareous shales with increased organic content and distinctive fossiliferous limestone interbeds (Hamblin, 2003; Armstrong and Carter, 2010).

The upper unit of the Upper Ordovician succession is characterized by a thick sequence of predominantly shale sedimentary rocks, which comprise the Blue Mountain, Georgian Bay and Queenston formations. The Blue Mountain Formation is characterized by uniform soft and laminated grey non-calcareous shale with minor siltstone and minor impure carbonate (Johnson et al., 1992; Hamblin, 1999). The overlying Georgian Bay Formation is composed of blue-grey shale with intermittent centimetre-scale siltstone and limestone interbeds. The Queenston Formation is characterized by maroon, with lesser green, shale and siltstone with varying amounts of carbonate. The top of the Queenston Formation is marked by a regional erosional unconformity (Table 3.1; Armstrong and Carter, 2010).

Lower Silurian

The Lower Silurian units, including the Cataract and Clinton groups and the Amabel and Guelph formations, unconformably overlie the Upper Ordovician shale (Table 3.1). A major marine transgression at the boundary of the Clinton and Cataract groups, and isolation of the Michigan Basin from the Appalachian Basin as a result of tectonic activity, was responsible for deposition of the extensive carbonate-dominated Amabel and Guelph formations. These Lower Silurian units form the cap-rock of the Niagara Escarpment in outcrop. The Lower to Upper Silurian boundary occurs within the Guelph Formation (Table 3.1; Brunton and Dodge, 2008).

The Cataract Group unconformably overlies the Upper Ordovician Queenston Formation and includes a lower unit of grey argillaceous dolostone and minor grey-green shale, and an upper clastic unit which consists of grey to green to maroon noncalcareous shales with minor sandstone and carbonate interbeds. The Clinton Group is composed of thin- to medium-bedded, very fine- to coarse-grained fossiliferous dolostone. The Amabel Formation includes a lower unit of light grey to grey-brown, finely crystalline, thin- to medium-bedded, sparingly fossiliferous dolostone with minor chert nodules. It also includes an upper unit of blue-grey, fine- to coarse-grained, thick bedded to massive dolostone, which locally contains minor dolomitic limestone. The upper unit is lithologically very similar to the lower unit but is more argillaceous and locally contains vugs filled with gypsum, calcite, halite, or fluorite. The Guelph Formation lithology varies from reefal to inter-reefal dolostones and dolo-mudstones (Armstrong and Goodman, 1990).

Upper Silurian

The Upper Silurian units include the evaporite and evaporite-related Salina Group and overlying dolostones and minor evaporites of the Bass Islands Formation (Table 3.1). The Upper Silurian units subcrop in a northwest trending belt that extends from south of Niagara Falls to west of Owen Sound (Figure 3.2). The Salina Group is characterized by repeated, cyclical deposition of carbonate, evaporite and argillaceous sedimentary rocks. A change to normal marine carbonate conditions away from the cyclic carbonate and evaporate setting was responsible for deposition of the Bass Islands Formation, which is a microcrystalline, commonly bituminous dolostone containing evaporite mineral clasts. The contact with the overlying Devonian carbonates marks a major unconformity characterized by subaerial exposure (Uyeno et al., 1982).

Lower and Middle Devonian

The Lower and Middle Devonian units unconformably overlie the Upper Silurian Bass Islands Formation and are dominated by carbonate sedimentary rocks of the Bois Blanc Formation and the Detroit River Group (Table 3.1). Devonian rocks are not present beneath the Municipality of Arran-Elderlsie (Figure 3.2). The Devonian carbonates are found southwest of the Municipality and outcrop along the shoreline of Lake Huron and north shoreline of Lake Erie (Figure 3.2).

3.2 Local Sedimentary Bedrock Geology of the Municipality of Arran-Elderslie

3.2.1 Stratigraphy

The bedrock geology of the Municipality of Arran-Elderslie and surrounding area is shown in Figure 3.6. The figure also shows the location of oil and gas boreholes from the Oil, Gas and Salt Resources Library Petroleum Wells Subsurface Database (OGSRL, 2006) located around the periphery of the Municipality of Arran-Elderslie. Review of readily available information indicates that the subsurface Paleozoic bedrock geology of the Municipality of Arran-Elderslie is consistent with the regional geological framework described in Section 3.1.3. The Municipality is underlain by an Ordovician to Silurian Paleozoic sedimentary sequence that was deposited approximately 488 to 415 million years ago (Walker and Geissman, 2009; Armstrong and Carter, 2010). Additional information on the local sedimentary bedrock geology is available from the recently completed site characterization program at the nearby Bruce nuclear site for OPG's proposed DGR for low and intermediate level radioactive waste (OPG-DGR) described in detail by NWMO (2011) and Intera (2011). Key available borehole data include:

- Well #F012117 (1958), located approximately 5 km north of the Municipality, Well #T001720A (1964), located approximately 4 km west of the Municipality and Well #T001877 (1964), found approximately 15 km east of the Municipality (Figure 3.6). These wells were specifically selected because they are in close proximity to the Municipality and extend through the entire Paleozoic sedimentary sequence to the top of the Precambrian crystalline basement at depths of approximately 520 to 720 metres below ground surface (mBGS).
- Oil and gas boreholes surrounding the Municipality as shown in Figure 3.6 (OGSRL, 2006, Itasca and AECOM, 2011).
- Six boreholes (DGR-1 to DGR-6) at the Bruce nuclear site (Figure 3.6) with depths ranging from 463 to 869 mBGS, including one borehole (DGR-2), which intersects the top of the Precambrian crystalline basement at a depth of 861 mBGS (Intera, 2011).

The wells in the OGSRL database, including DGR-1 and DGR-2 at the Bruce nuclear site, were used to develop a geological framework model for the OPG-DGR project (Itasca Canada and AECOM, 2011). The model allows for interpretation and simple 2-D and 3-D visualization of the stratigraphy over a portion of southern Ontario such as the cross-section shown in Figure 3.3.

There are no exploration boreholes drilled within the Municipality of Arran-Elderslie. Information on the stratigraphy beneath the Municipality was interpreted from OGSRL wells #F012117, #T001720A, and #T001877 located in close proximity to the Municipality, and is presented in Table 3.3.

Well #F012117 and Well #T001877 are located within the Guelph Formation Subcrop area, while Well #T001720A is located in the Salina Formation subcrop (Figure 3.6, Table 3.2). The Goat Island and Gasport Formation (Amabel Formation Equivalent) are interpreted from the well logs to be absent. This is likely the result of geological interpretation as these units may have been grouped within the overlying Guelph Formation. Guelph formation thicknesses are known to vary based on the presence or absence of reefal facies. The variation in stratigraphy within the Upper Ordovician units (Collingwood, Kirkfield and Coboconk formations) is also likely related to geological interpretation. The Collingwood formation, for example, may be grouped with the Cobourg or overlying shales. The Cambrian unit, as predicted from regional studies, is absent east of the Municipality (Well #T001877; Table 3.3), but is found west of the Municipality (Well #T001720A; Table 3.3). The Cambrian pinch-out is therefore interpreted to occur near the western boundary of the Municipality of Arran-Elderslie (Bailey and Cochrane, 1984). Overall, the major stratigraphic sequences predicted from regional studies (Armstrong and Carter, 2010) are represented in these three deep wells (Table 3.3).

Table 3.2 Subcrop Geological Unit and Final Well Completion Unit for Oil and Gas Wells Intersecting the Precambrian Crystalilne Basement Surrounding the Municipality of Arran-Elderslie

Well License #	Total Depth (mBGS)	Top Geological Unit (Subcrop)	Bottom Geological Unit
F012117	525.5	Guelph Formation	Precambrian
T001720A	719.9	Salina Formation – G Unit	Precambrian
T001877	556.3	Guelph Formation	Precambrian

Table 3.3 Stratigraphy Derived from Oil and Gas Exploration Wells #F012117 (1958), #T001720A (1964), and #T001877 (1964) in Municipality of Arran-Elderslie (Itasca and AECOM, 2011 after OGSRL, 2006)

Standard Reference		Geological Unit*	#F012117		#T001720A		#T001877	
			Unit Top (mBGS)	*Unit Thickness (m)*	*Unit Top (mBGS)*	*Unit Thickness (m)*	*Unit Top (mBGS)*	*Unit Thickness (m)*
Quaternary		Drift	-	-	3.7	61.2	0.9	15.9
Silurian	**Upper**	Bass Islands / Bertie Formation	-	-	-	-	-	-
		Salina G Unit	-	-	64.9	6.7	-	-
		Salina E Unit	-	-	71.6	15.2	-	-
		Salina C Unit	-	-	86.9	30.2	-	-
		Salina A-2 Unit	-	-	117.0	24.4	-	-
		Salina A-1 Unit	-	-	141.4	3.0	-	-
		Guelph Formation	9.1	71.7	144.5	128.6	16.8	83.8
	Lower	Goat Island Formation	-	-	-	-	-	-
		Gasport Formation	-	-	-	-	-	-
		Reynales / Fossil Hill Formation	80.8	7.6	273.1	11.0	100.6	1.5
		Cabot Head Formation	88.4	36.6	284.1	9.8	102.1	13.7
		Manitoulin Formation	125.0	12.2	293.8	17.1	115.8	16.8
Ordovician	**Upper**	Queenston Formation	137.2	54.8	310.9	54.3	132.6	68.6
		Georgian Bay / Blue Mountain Formation	192.0	131.1	365.2	157.6	201.2	162.1
		Collingwood Formation	323.1	18.3	-	-	-	-
		Cobourg Formation	341.4	46.6	522.7	46.7	363.3	45.1
		Sherman Fall Formation	388.0	21.3	569.4	74.3	408.4	83.9
		Kirkfield Formation	409.3	47.9	-	-	-	-
		Coboconk Formation	-	-	643.7	5.5	492.3	3.0
		Gull River Formation	457.2	61.0	649.2	64.3	495.3	48.8
		Shadow Lake Formation	518.2	6.4	713.5	1.3	544.1	12.2
Cambrian		Cambrian	-	-	714.8	5.1	-	-
Precambrian		Precambrian	524.6		719.9		556.3	

*Note: * Nomenclature at the Formation level in this table is slightly different than the recently updated nomenclature used in Table 3.1 (Armstrong and Carter, 2010).*

The Paleozoic sequences interpreted to exist below the Municipality of Arran-Elderslie were also encountered in the deep boreholes beneath the Bruce nuclear site (Intera, 2011). Based on the information from OGSRL Well #F012117 (Table 3.3), the total thickness of the Paleozoic strata near the northeastern boundary of the Municipality of Arran-Elderslie is 516 m. The Paleozoic thickness near the southwestern boundary is 655 m, based on information from Well #T001720A.

Based on the information shown on Table 3.3 and Figure 3.6, and given the regional shallow southwest-dipping geometry of the Paleozoic sedimentary rocks (3.5 to 12 m/km to the west or southwest throughout the Ontario portion of the Michigan Basin (Armstrong and Carter, 2010)), the geology of the Municipality of Arran-Elderslie at typical repository depths (approximately 500 m) is interpreted to comprise Upper Ordovician shale and limestone units as well as interbedded shales, sandstones, and conglomerates of the Upper Ordovician Shadow Lake Formation. The Upper Ordovician limestone units beneath the Municipality are expected to comprise the Gull River, Coboconk, Kirkfield, Sherman Fall, and Cobourg formations. They are interpreted to be approximately 190 m thick, at depths of about 500 to 700 m in the southwestern part, and depths of approximately 350 to 550 mBGS towards the northeast part of the Municipality (Table 3.3). The overlying Upper Ordovician shale units, which include the Collingwood, Georgian Bay/Blue Mountain, and Queenston formations are expected to be approximately 200 m thick, and found at depths of approximately 300 to 500 mBGS in the southwest and depths of approximately 150 to 350 mBGS in the northeast parts of the Municipality. The individual Ordovician formation thicknesses are expected to remain relatively uniform (Section 3.1.3) across the Municipality.

There is limited readily available information on the geoscientific characteristics of the Upper Ordovician shale and limestone units beneath the Municipality of Arran-Elderslie. However, it is expected that they are similar to the characteristics of the Upper Ordovician units beneath the nearby Bruce nuclear site, which are described as comprising relatively undeformed, near horizontally layered low porosity and low hydraulic conductivity sequences. These sequences are correlative over large lateral extents as a result of their simple geometry and uniform thicknesses (NWMO, 2011). The consistency of the thickness of the Upper Ordovician sequence (approximately 176 m to 190 m) between Well #F012117, Well #T001720A, and Well #T001877 located north, west and of the Municipality of Arran-Elderslie (Table 3.3), respectively, and the deep boreholes at the Bruce nuclear site suggests lateral continuity and predictability of the Ordovician stratigraphic units across this part of southern Ontario. This interpretation would have to be confirmed during subsequent stages of site evaluation, if the community remains interested in continuing with the site selection process.

3.3 Deformation and Metamorphism

3.3.1 Tectonic History

The geologic evolution of southern Ontario is characterized by a series of tectonic events, structural uplift, erosion, burial and faulting, which have occurred over the past 1210 million years. Readily available information indicates that the Paleozoic sedimentary sequence in southern Ontario has not undergone regional-scale metamorphism (Armstrong and Carter, 2010). Table 3.4 summarizes the timing of major tectonic events that have influenced the Precambrian and Paleozoic rocks beneath southern Ontario.

Table 3.4 Timetable of Major Tectonic Events in Southern Ontario

Time Interval Before Present (millions of years)	Tectonic Activity	Reference
1210 – 1180	Regional metamorphism (proto-Grenville)	Lumbers et al., 1990; Easton, 1992; Hanmer and McEachern, 1992
1109 – 1087	Magmatism and formation of Midcontinent Rift	Van Schmus, 1992
1030 – 970	Main phase of Grenville Orogeny	Carr et al., 2000; White et al., 2000
970 – 530	Extensional rifting and opening of the Iapetus Ocean	Thomas, 2006
530 – 320	Subsidence of Michigan Basin and Uplift of southern Ontario basement arches (episodic)	Sanford et al., 1985; Howell and van der Pluijm, 1999; Kesler and Carrigan, 2002
470 – 440	Taconic Orogeny • E-W to NW-SE compression, uplift (southern Ontario arches)	Sloss, 1982; Quinlan and Beaumont, 1984; McWilliams et al., 2007
410 – 320	Caledonian/Acadian Orogeny • E-W to NW-SE compression, uplift (southern Ontario arches)	Sutter et al., 1985; Marshak and Tabor, 1989; Gross et al., 1992; Kesler and Carrigan, 2002
300 – 250	Alleghenian Orogeny • E-W to NW-SE compression	Engelder and Geiser, 1980; Gross et al., 1992
200 – 50	• Opening of the Atlantic Ocean • St. Lawrence rift system created • reactivated Ottawa-Bonnechere Graben • NE-SW extension • uplift	Kumarapeli, 1976; Kumarapeli, 1985
50 – Present	• NE-SW compression (from ridge push) • post-glacial uplift	Barnett, 1992

Precambrian Tectonic History

After a phase of regional metamorphism of the Precambrian crystalline basement rocks during the Grenville Orogeny, a continent-scale rifting event occurred, which generated magmatism in the form of intrusive mafic dykes and sills and extrusive basaltic flows (Easton, 1992; Van Schmus, 1992). This phase was followed by crustal shortening and the main phase of the Grenville Orogeny (Carr et al., 2000; White et al., 2000).

The end of the Grenville Orogeny is marked by the transition to a passive tectonic phase of extension and rifting during the opening of the Iapetus Ocean (Table 3.4; Thomas, 2006).

Paleozoic Tectonic History

Deposition of the Paleozoic rocks in southern Ontario began with a large rifting event and subsequent subsidence and deposition within the Michigan Basin (Sanford et al., 1985). The Middle Ordovician to Devonian-Mississippian sedimentary rocks reflect the complex interaction between regional-scale tectonic forces, sedimentation, and eustatic sea level fluctuations associated with the Taconic, Caledonian/Acadian, and Alleghenian orogenic events (Table 3.4). Uplift of the Precambrian crystalline basement arches in southern Ontario, and episodic subsidence within the Michigan Basin during these three main tectonic events are largely responsible for the regional variations in depositional setting and rock types.

Mesozoic-Cenozoic Tectonic History

The Atlantic Ocean began to open approximately 200 million years ago during the Triassic Period and associated tectonic activity was focused at the margin of the continent. A transition from northwesterly to west-southwesterly North American plate motion and initiation of spreading in the North Atlantic approximately 50 million years ago controls the current east-northeast-oriented compressional stress field of eastern North America that characterizes the most recent tectonic phase (Barnett, 1992).

3.3.2 Fault History

Documented basement-seated faults that displace the Paleozoic strata in southern Ontario are shown on Figure 3.2 (compiled by Armstrong and Carter, 2010). The faults are organized into three categories based on the youngest geological unit that is offset: i) Shadow Lake/Precambrian, ii) the Trenton Group (Ordovician-aged) and iii) the Rochester Formation (Silurian-aged). These faults have been interpreted using borehole data obtained from oil and gas wells (structural contour maps) and geophysical analysis (e.g., Brigham, 1971). The faulting is interpreted to be caused by re-activation of pre-existing faults in the Precambrian crystalline basement during the evolution of the Paleozoic Michigan and Appalachian Basins (Sanford et al., 1985; Marshak and Paulsen, 1996).

Mapped faults within southern Ontario are shown as segments measuring from a few metres to about 40 km in length, with one exception that is almost 100 km in length (Figure 3.2). The faults are generally interpreted to be nearly vertical in dip, exhibit normal and/or strike-slip motion, and cluster into two main orientations; east-northeast to southeast and north to north-northeast (Figure 3.2). Displacements on all faults range from a few metres up to a maximum of 100 m (Brigham, 1971; Carter et al., 1996). Where faults strike easterly, the predominant offset is south-side-down. This fault orientation is most common near the Chatham Sag in southwestern Ontario where a marked concentration of faults occur along, and southeast of, the trace of the Algonquin Arch (Figures 3.1 and 3.2).

Sanford et al. (1985) introduced a conceptual fracture framework for southern Ontario, based on hand contouring of isopachs of selected Silurian units and structure contours on the top of the Silurian Rochester Formation (outcrop nomenclature, equivalent to the Fossil Hill Formation). Some similarity exists between this conceptual fault model and the distribution of known faults located southeast of the Algonquin Arch and in particular proximal to the Chatham Sag. However, such a systematic fault pattern is not observed in structural contours on the top of the Precambrian basement surface to the northwest of the Algonquin Arch in the southern Ontario portion of the Michigan Basin, nor is it consistent with known or interpreted mapped faults in this area (Bailey Geological Services and Cochrane, 1984; Carter et al., 1996; Armstrong and Carter, 2010). Johnson et al. (1992) also noted that although fractures may exist, the extensive fracture framework conceptualized by Sanford et al. (1985), which includes an ordered and approximately 10 km-spaced set of faults offsetting Silurian strata, is not recognized.

No Paleozoic faults are mapped within the Municipality of Arran-Elderslie (Figure 3.6). Two faults, exhibiting an east-northeast strike orientation, have been reported within an area of approximately 30 km surrounding the Municipality. These faults are located approximately 8 km northeast and 18 km southwest of the Municipality (Figure 3.6). Both faults are in interpreted to predate the deposition of the Ordovician Trenton Group carbonates and are reported as offsets in the Shadow Lake Formation, Cambrian unit or Precambrian Basement. The age of these faults would therefore be approximately 480 million years ago.

In summary, 2 basement-seated faults are recognized within approximately 30 km of the Municipality of Arran-Elderslie (Figure 3.2). These faults have an ancient history, which predates deposition of the Upper Ordovician limestone and shale formations. There is no evidence from the regional stratigraphic framework that anomalous structural complexity due to tectonic faulting occurs within the Paleozoic sedimentary succession beneath the Municipality of Arran-Elderslie. This would have to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

3.3.3 Diagenesis

Diagenesis includes changes (chemical, physical, biological) undergone by sediments after their initial deposition, not including metamorphism or surface weathering. The Paleozoic rocks of southern Ontario have been altered through their depositional and post-depositional lifecycle by diagenetic processes. The primary diagenetic process in the Michigan Basin is dolomitization of limestone, which is interpreted to have occurred in response to tectonically driven fluid migration associated with Paleozoic orogenic events (e.g., Coniglio and Williams-Jones, 1992). Other diagenetic processes that have occurred in the Paleozoic sedimentary sequence in southern Ontario include clay alteration (Ziegler and Longstaffe, 2000), and hydrocarbon formation, migration and emplacement (e.g., Armstrong and Carter, 2010).

Diagenesis through salt dissolution in the Salina Formation and creation of subsequent collapse features (Upper Silurian and Devonian stratigraphy) has also altered the Paleozoic rocks. The process of salt dissolution and the creation of collapse features in the rock occurred in response to tectonic events that pushed large volumes of fluid through the stratigraphy dissolving the salt. This process occurred more than 300 million years ago during the Silurian to Devonian Caledonian Orogeny and the Devonian to Mississippian Acadian Orogeny (Sanford et al., 1985).

In summary, significant diagenetic events affecting the Paleozoic rocks of southern Ontario correspond to major tectonic events, which have not been active since approximately 200 million years ago (Table 3.4). There is limited readily available information regarding the diagenetic character of the Paleozoic sedimentary rocks beneath the Municipality of Arran-Elderslie. This information would need to be assessed further during subsequent stages of site evaluation, if the community remains interested in continuing with the site selection process.

3.3.4 Karst

Karst is created by the dissolution of carbonate and evaporite rocks as groundwater migrates through the sedimentary strata. Karst processes are most active in the shallow subsurface (less than 200 mBGS) while deeply buried rocks beneath southern Ontario are unlikely or not affected by modern karst processes (Worthington, 2011). These deeper formations could have been affected by karst processes during or after their deposition, referred to as paleokarst. In southern Ontario, these paleokarst zones are most likely to be observed at large breaks in the sedimentary record marked by regional unconformities (Table 3.1). In most cases, including at the Bruce nuclear site, the paleokarst porosity has been infilled with younger sediments, such as evaporites, that destroy the porosity and permeability of the original karst (NWMO, 2011).

A map showing the distribution of areas with known, inferred or potential karst in southern Ontario is presented in Figure 3.7 (Brunton and Dodge, 2008). There is no known karst mapped within the Municipality of Arran-Elderslie.

Within the Municipality, areas of potential karst are identified in the Lockport, Amabel, and Guelph formations, present along the northeastern side of the Municipality (Figure 3.7; Brunton and Dodge, 2008).

Figure 3.7 shows that in southern Ontario, mapped karst is found in the Ordovician carbonates that outcrop along the boundary with the Canadian Shield between Georgian Bay and eastern Ontario, Silurian Formation carbonates exposed along the escarpment (Lockport, Amabel, and Guelph formations, and the Bass Islands and Bertie formations) and Devonian carbonates in southern Ontario (Dundee Formation and Detroit River Group). Inferred and potential karst incorporates the outcrop and subcrop areas of the known karst geological units as outlined above. Brunton and Dodge (2008) noted that large-scale karstification is found both proximal to significant escarpments or cuesta margins and/or laterally within a few hundred metres of incised river systems. Modern karstification of carbonates is likely to occur almost exclusively in shallow freshwater zones.

In summary, karst features in southern Ontario are unlikely to affect the deep subsurface geological or hydrogeological conditions at typical repository depth (approximately 500 m). The influence that paleokarst may have on the deep carbonate rock formations beneath the Municipality of Arran-Elderslie would need to be assessed further during subsequent stages of site evaluation, if the community remains interested in continuing with the site selection process.

3.4 Geomechanical Properties

No readily available information on rock geomechanical properties at typical repository depth was found for the Municipality of Arran-Elderslie. However, a detailed assessment of the geomechanical properties of the Paleozoic sequence underlying the nearby Bruce nuclear site was conducted as part of detailed site characterization for the OPG-DGR project (Golder, 2003; NWMO, 2011; NWMO and AECOM, 2011). The assessment was based on the understanding of the regional geomechanics of southern Ontario, as well as on a suite of field and laboratory observations and measurements conducted at the Bruce nuclear site. A wide range of geomechanical properties of the sedimentary sequence was assessed, including short- and long-term behaviour of underground openings at typical repository depths. A brief summary of the relevant properties is given below, focusing on the Upper Ordovician shale and limestone units, the latter of which are interpreted to exist at typical repository depths beneath the Municipality of Arran-Elderslie.

Previous construction experience with the excavation of underground openings in southern Ontario indicates that excavated openings in either the Upper Ordovician shale or limestone units are likely to be dry and stable (Golder, 2003). These include the 925 m long Darlington cooling water intake tunnel and the 470 m long storage cavern access tunnel at the Wesleyville Generating Station. The Darlington tunnel was completed within the Cobourg Formation beneath Lake Ontario. The Wesleyville tunnel intersects both the Cobourg Formation and the underlying Sherman Fall Formation.

Available information on strength and in situ stresses suggest that the Upper Ordovician shale and limestone units have a high strength and favourable geomechanical characteristics, which makes them amenable to the excavation of stable underground openings. For example, estimated mean uniaxial compressive strengths for Upper Ordovician limestone (Cobourg Formation) and shale (Georgian Bay Formation) units were 113 MPa and 32 MPa, respectively at the Bruce nuclear site (Intera, 2011). These values compare favourably with other sedimentary formations considered internationally for the long-term management of radioactive waste (NWMO, 2011).

Numerical simulations of the behaviour of underground openings in the limestone of the Cobourg Formation for the OPG-DGR project suggest that the openings will remain stable during construction and operation, requiring only standard support. The simulations also suggest that, in the long-term, the barrier integrity of the enclosing Ordovician bedrock formations will not be affected under various loading scenarios associated with glacial ice sheet, seismic ground motions and repository gas pressure (NWMO, 2011).

In summary, available information on geomechanical properties of the Upper Ordovician shale and limestone units in southern Ontario suggests these units have a high strength, and favourable geomechanical characteristics, which makes them amenable to the excavation of stable underground openings.

3.5 Quaternary Geology

The extent and type of Quaternary deposits in the Municipality of Arran-Elderslie and surrounding areas are illustrated in Figure 3.8. The Quaternary cover in the area mostly comprises glacial deposits including tills, glaciofluvial and glaciolacustrine sediments deposited during the late Pleistocene Wisconsinan glaciations, as well as more recent fluvial, lacustrine and organic deposits. The Quaternary sediments were deposited during fluctuations of the Huron and Georgian Bay Lobes of the Laurentide Ice Sheet that occurred between approximately 23,000 and 10,000 years ago during the Wisconsinan glaciation, prior to final retreat of glacial ice (Karrow, 1974).

Mapping of the Quaternary deposits in the Municipality of Arran-Elderslie shows that glacial till, forming moraines and drumlins, is found throughout the Municipality (Figure 3.8). Well-formed drumlins are found in the northern half of the Municipality with axes trending northeast-southwest. The southern portion of the study area is dominated by glaciolacustrine clay and silt. Glaciolacustrine deposits can also be found in the low-lying areas between the drumlin ridges in the northern portion of the Municipality. East-west oriented moraine ridges of the Williscroft moraine and the Banks moraine associated with the St. Joseph Till cross the Municipality in the southern half and mark the boundary between the drumlinized area to the north and the clay plain to the south. Thinner ridges of ice-contact stratified drift of the Tara moraines are present in the northeast corner of the Municipality. The northwestern corner of the Municipality is characterized by glaciolacustrine beach deposits that contain boulder pavements, and evidence of wave-cut and previously eroded drumlins (Chapman and Putnam, 1984). Localized organic deposits are present in the areas characterized by the Arran Lake and Allenford Station wetland complexes (Figure 2.5 and Figure 3.8).

3.5.1 Quaternary Overburden Thickness

The thickness of the Quaternary deposits in the Municipality of Arran-Elderslie and surrounding areas is shown in Figure 3.9 (Gao et al., 2006). The Municipality of Arran-Elderslie is covered by Quaternary deposits with overburden thicknesses ranging from approximately less than 1 m to 102 m (Derived from MOE Water Well Records), with the majority of the Municipality covered by greater than 10 m. Overburden thickness is greatest on the western side of the Municipality and decreases towards the east. The thickest areas of overburden are associated with the glaciolacustrine beach deposits and drumlin ridges on the western side, and thicker deposits are also found along the crest of the Banks Moraine in the southern portion of the Municipality. Moraine and drumlin ridges appear in Figure 3.9 as areas of locally thicker overburden. Overburden cover is thinnest along the northeastern side of the Municipality towards the Niagara Escarpment and associated bedrock outcrop areas.

3.5.2 Glacial Erosion

Southern Ontario is expected to be affected by major glaciations recurring approximately every 100,000 years (Peltier, 2011). Hallet (2011) studied glacial erosion of the Bruce Peninsula caused by the Laurentide Ice Sheet, and concluded that significant glacial erosion likely did not occur, based on observations of striated surfaces with multiple episodes preserved, the relative absence of friction cracks, and the pervasive low relief of striated surfaces. Hallet (2011) also concluded that although uncertainties remain in ice sheet reconstructions and estimates of erosion by ice and melt water, all lines of study indicate that, at the nearby Bruce nuclear site, glacial erosion would conservatively be 100 m per 1 million years.

3.6 Neotectonic Activity

Neotectonics refers to deformations, stresses and displacements in the earth's crust of recent age or which are still occurring. The Late Pleistocene Laurentide Ice Sheet that advanced over most of Canada into the United States began approximately 120,000 years ago (Peltier, 2011). At last glacial maximum 25,000 years ago the Laurentide Ice Sheet surpassed 2,800 m in thickness over the most glaciated regions of the continent (Peltier, 2002). The weight of the ice sheet depressed the surface of the earth by approximately 600 m (Peltier, 2011). After the ice retreated some 14,000 years ago, the earth's surface has rebounded through a process known as glacio-isostatic adjustment which continues today. In southern Ontario and the Great Lakes region, the magnitude of glacio-isostatic adjustment is about 1.5 mm/year (Peltier, 2011). This glacial unloading results in a stress regime in shallow bedrock areas that can lead to the development of stress release features such as elongated compressional ridges or pop-ups that are documented in southern Ontario (McFall, 1993).

A neotectonic study was conducted as part of detailed site characterization for OPG's proposed DGR at the Bruce nuclear site to analyse Quaternary landforms for the presence of seismically-induced soft-sediment deformation (Slattery, 2011). The study was conducted within a radius of up to 50 km away from the Bruce nuclear site, which includes parts of the Municipality of Arran-Elderslie. The study found no evidence for neotectonic activity associated with the most recent glacial cycle approximately 25,000 years ago (Slattery, 2011).

3.7 Seismicity

The Municipality of Arran-Elderslie is located in the Grenville Province of the Canadian Shield, where much of southern Ontario has remained tectonically stable since approximately 970 million years ago (Percival and Easton, 2007; Table 3.4). All recorded earthquakes in southern Ontario have a magnitude of less than 5 (Figure 3.10; Natural Resources Canada, 2012). Figure 3.10 shows the location of all earthquakes with a magnitude greater than 3 that are known to have occurred in Canada from 1627 until 2010 (Natural Resources Canada, 2012) and Figure 3.11 shows the locations and magnitudes of all earthquakes recorded in southern Ontario between 1985 and 2012 (Natural Resources Canada, 2012). Most of the earthquakes in the region around the Municipality of Arran-Elderslie are concentrated in the area located southeast of the Algonquin Arch and, to a lesser extent, offshore in Lake Huron and Georgian Bay (Figure 3.11).

In summary, available literature and recorded seismic events indicate that the Municipality of Arran-Elderslie is located within a region of low seismic hazard.

4. Hydrogeology

4.1 Groundwater Wells

Information on groundwater in the Municipality of Arran-Elderslie was obtained from the Ontario Ministry of the Environment (MOE) Water Well Record Database. The location of known water wells is shown on Figure 4.1. The Municipality of Arran-Elderslie relies on shallow overburden and bedrock aquifers for its domestic, industrial and municipal water supply. In addition to being used for potable supply, shallow groundwater also supports baseflow to numerous streams and wetlands within the area. There are two active municipal water supply well fields in the Municipality of Arran-Elderslie; these include the Chesley Well Supply and the Tara Well Supply. The reported wellhead protection areas are 4.23 km^2 and 4.10 km^2, in the areas around the towns of Chesley and Tara, respectively (Saugeen, Grey Sauble, Northern Bruce Peninsula, 2011a, 2011b). The well head protection areas would need to be considered during subsequent site evaluation stages, if the community decides to continue in the site selection process.

The MOE Water Well Record Database contains a total of 696 water well records for the Municipality of Arran-Elderslie (Figure 4.1). Of these 696 well records, 3 records contained information only on location and provided no data on well type, depth, or hydrogeological conditions while 22 wells had duplicate well records for the same well number. A summary of the 693 well records with hydrogeological data is provided in Table 4.1.

Table 4.1 MOE Water Well Record Details

Well Type	Number of Well Records	Depth Range (m)		Static Level Range (mBGS)		Well Yield (L/min)		
		Min	Max	Min	Max	Min	Max	Mean
Overburden	88	4.6	101.8	-0.3	36.3	0.3	9.1	2.9
Bedrock	605	6.1	132.6	-1.2	36.3	0.8	45.7	4.0

The MOE Water Well Records indicate that no potable water supply wells are known to exploit aquifers at typical repository depths (approximately 500 m) within the Municipality of Arran-Elderslie. Of the 696 well records found for the Municipality of Arran-Elderslie, 88 well records show completion in overburden aquifers, 605 well records indicate completion in bedrock aquifers and 3 contained no stratigraphic completion records (Table 4.1). Wells completed within overburden range in depths from approximately 5 to 102 m. Overburden well yields range from 0.3 to 9.1 L/min, with mean values of 2.9 L/min. Wells completed in the bedrock range in depth from approximately 6 to 133 m. Bedrock well yields range from 0.8 to 45.7 L/min, with mean values of 4.0 L/min. These yields reflect the purpose of the wells, and do not necessarily reflect the maximum sustained yield that might be available from the aquifer. Note that a negative value in Table 4.1 for Static Level Range indicates an artesian well with the estimated head above the ground surface.

4.2 Deep Groundwater System

There is no direct hydrogeological information available on the deep groundwater system beneath the Municipality of Arran-Elderslie. However, as described in Section 3.2.1., there is an interpreted high degree of lateral continuity and predictability of the Upper Ordovician shale and limestone units across this part of southern Ontario. It is interpreted that the hydrogeological setting at depth beneath the Municipality of Arran-Elderslie is likely to be similar to that interpreted from regional hydrogeological information and the detailed site characterization work completed at the nearby Bruce nuclear site for OPG's proposed DGR project (Hobbs et al., 2011; Intera, 2011; NWMO, 2011).

These studies indicate that the active groundwater system is shallow, and limited to the upper approximately 200 mBGS. Below this depth, an intermediate to deep groundwater system has been recognized, both regionally and at the Bruce nuclear site (Intera, 2011; NWMO, 2011). Field data from the Bruce nuclear site indicates that the deep groundwater system has low groundwater yields due to the very low hydraulic conductivities (approximately 10^{-15} to 10^{-10} m/s) of the sedimentary formations encountered at depth. The deep groundwater system at typical repository depth beneath the Bruce nuclear site is interpreted as diffusion-dominated and isolated from the shallow groundwater system by multiple near horizontally layered, laterally extensive, low permeability shale, dolostone and anhydrite formations (NWMO, 2011).

In summary, there are no known exploitable groundwater resources at typical repository depths in the Municipality of Arran-Elderslie. In addition, at typical repository depths the Upper Ordovician shale and limestone units are expected to exhibit very low hydraulic conductivities making them unsuitable for groundwater resources. Also, as discussed in Section 4.3, available regional information indicates a transition from fresh to non-potable, saline groundwater below approximately 200 mBGS (Hobbs et al., 2011; NWMO, 2011).

4.3 Hydrogeochemistry

There is no direct readily available information on groundwater hydrogeochemistry at typical repository depth for the Municipality of Arran-Elderslie. However, the regional hydrogeochemistry for southern Ontario has been described as part of site characterization activities for OPG's proposed DGR at the Bruce nuclear site (Hobbs et al., 2011; NWMO, 2011).

Two geochemical systems are recognized at the regional scale in southern Ontario: 1) a shallow system (less than 200 mBGS) containing fresh through brackish waters. Waters in this system have stable isotopic compositions ($\delta^{18}O$ and $\delta^{2}H$) consistent with mixing of dilute meteoric or cold-climate (glacial) waters with more saline waters; and 2) an intermediate to deep system (more than 200 mBGS) containing predominately which have elevated total dissolved solids (TDS) values (200,000 to 400,000 mg/L) and distinct stable oxygen and hydrogen isotopic signatures (Hobbs et al., 2011; NWMO, 2011).

Within the regional geochemical database, the maximum depth at which glacial waters are observed is 130 mBGS (Hobbs et al., 2011). The major ion composition of waters from the intermediate to deep system, in particular Cl and Br concentrations, support the interpretation that these waters evolved from ancient seawater by evaporation past halite saturation, with limited evidence for recent dilution by meteoric or glacial waters. The redox conditions are believed to be reducing, due to the presence of methane gas in hydrocarbon reservoirs (Hobbs et al., 2011). The nature of the brines, in particular the high salinities and enriched $\delta^{18}O$ values of the porewaters, indicate that the deep system is isolated from the shallow groundwater system and that the porewaters have resided in the system for a very long time (NWMO, 2011).

5. Economic Geology

5.1 Hydrocarbon Resources

The Paleozoic rocks of southern Ontario are known to include regions of commercial hydrocarbon accumulation; however, there are no known oil and gas pools within the Municipality of Arran-Elderslie (Figure 3.6). The nearest known oil and gas pool to the Municipality is the Ordovician aged Hepworth Gas Pool located approximately 10 km north of the Municipality. There are no other pools located within 30 km of the Municipality of Arran-Elderslie (Figure 3.6).

Historic exploration in the region around the Municipality of Arran-Elderslie focused on Upper Ordovician and Upper Silurian units as potential hydrocarbon plays (e.g., Sanford, 1993; Hamblin, 2008; Lazorek and Carter, 2008). The cluster of exploration wells and the Hepworth gas Pool located north of Arran-Elderslie are primarily targeting Upper Ordovician natural gas plays. Exploration wells located west of the Municipality target primarily Silurian or Cambrian aged units for natural gas (OGSRL, 2006). No exploration wells have been documented in the Municipality of Arran-Elderslie in the Oil, Gas and Salt Resources Library (OGSRL) Petroleum Wells Subsurface Database (OGSRL, 2006). The absence of oil and gas pools in the Municipality of Arran-Elderslie would need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

New conceptual hydrocarbon plays are identified for southern Ontario by Hamblin (2008). Potential plays include Cambrian gas deposits at the eastern edge of the Michigan Basin, Upper Ordovician Shadow Lake Formation where it overlies the Cambrian, and Upper Ordovician shale gas. With respect to potential Cambrian and Shadow Lake plays, Cambrian units are interpreted to be absent beneath most of the Municipality of Arran-Elderslie. An analysis of the shale gas potential for the Bruce nuclear site, located 24 km to the west of the Municipality of Arran-Elderslie, found that insufficient total organic content of the Ordovician shales, as well as insufficient thermal maturity, would preclude any likelihood of commercial shale gas accumulations (Engelder, 2011).

In summary, no hydrocarbon pools have been identified within the Municipality of Arran-Elderslie. The potential for existing and new conceptual hydrocarbon plays would have to be examined during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

5.2 Metallic Mineral Resources

There is no record of current or past metallic mineral production, and no exploration potential for metallic minerals has been identified within the Municipality of Arran-Elderslie. The sole documented metallic mineral occurrence in southern Ontario is sphalerite associated with Mississippi Valley Type (MVT) lead/zinc deposits within Silurian dolomite on the Bruce Peninsula (e.g., Sangster and Liberty, 1971). No commercial MVT deposits or other metallic resources have been found within southern Ontario.

5.3 Non-Metallic Mineral Resources

Known non-metallic mineral resources in the region include bedrock-derived crushed stone, natural surficial sand and gravel resources, salt and building stone. Current licensed non-metallic mineral extraction in the Municipality of Arran-Elderslie is limited to sand and gravel resources (Figure 5.1).

5.3.1 Sand and Gravel

Sand and gravel pits in the Municipality of Arran-Elderslie generally correspond to glaciofluvial outwash or ice-contact deposits found at surface (Figures 3.8 and 5.1). The Ontario Geological Survey Aggregate Resources Inventory for Bruce County (Rowell, 2012) indicates that 2010 aggregate production from the Municipality of Arran-Elderslie was 159,394 tonnes or approximately 7% of Bruce County's total sand and gravel resource extraction. Rowell (2012) designated primary, secondary and tertiary significance for sand and gravel resources based on quality and potential volume. One area within the Municipality of Arran-Elderslie was assigned a primary significance; and comprises the currently operating pits that are located in the southern half of the Municipality north of Paisley (Figure 2.1 and Figure 5.1). Areas of secondary significance correspond to glaciofluvial ice-contact deposits in the north-east portion of the Municipality associated with the Tara Moraines, as well as in the southern portion of the Municipality associated with the moraine ridges (Figure 3.8, Figure 3.9).

5.3.2 Bedrock Resources

There are no known licensed bedrock quarries or commercial mining operations within the Municipality of Arran-Elderslie (Figure 5.1). Three licensed quarries are present within approximately 20 km northeast of the Municipality towards the Niagara Escarpment along Georgian Bay.

Economic bedrock resources are typically close to the surface, covered by less than 8 m of overburden, and must be of mineable thickness. Most bedrock extraction operations are located in areas where the overburden thickness is 3 m or less. The majority of the Municipality of Arran-Elderslie is covered by greater than 8 m of Quaternary sediments (Section 3.5.1 and Figure 3.9). Those areas with thin overburden or outcrop contain no unique bedrock resources with respect to aggregate, cement or building stone.

There are no known commercial salt resources located in the Municipality of Arran-Elderslie. The Salina B salt, which is the primary salt source in southern Ontario, has been largely dissolved and removed over most of the area (Sanford et al., 1985).

6. Initial Screening Evaluation

This section provides an evaluation of each of the five initial screening criteria (NWMO, 2010) for the Municipality of Arran-Elderslie 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 Arran-Elderslie from further consideration in the site evaluation process. The initial screening focused on the areas within the boundaries of the Municipality of Arran-Elderslie. Areas within neighbouring municipalities were not included in the initial screening.

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 to participate in the siting 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 (1 km^2; 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 (3.75 km^2; 375 ha) at a typical depth of about 500 m.

This criterion was evaluated by assessing whether the Municipality of Arran-Elderslie 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 the underground facilities. The available land areas should be accessible for the construction of surface facilities, and for the various field investigations that are necessary to characterize the rock volume required to accommodate the footprint of the repository (e.g., drilling of boreholes).

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

Review of available mapping and satellite imagery shows that the Municipality of Arran-Elderslie contains sufficient area for the repository's surface facilities (Figures 2.1, 2.2 and 2.5). The main land constraints include the wetland complexes which account for approximately 4% of the land area within the Municipality, and the Sauble and Saugeen River valleys. In addition, a small portion of the Municipality is covered by localized residential and industrial/commercial infrastructure, primarily located within the settlement areas of Tara, Chesley, and Paisley in the northeast, southeast, and southwest areas of the Municipality, respectively (Figure 2.1). The remainder of the Municipality of Arran-Elderslie is largely agricultural land with development limited primarily to roadways and settlement areas.

As discussed in Section 2, topography is variable across the Municipality of Arran-Elderslie (Figure 2.4). However, no obvious topographic features that would prevent construction and characterization activities over large areas have been identified. Most of the Municipality of Arran-Elderslie could be accessed from Highway 21 and the numerous subsidiary county and rural roads that cross the area (Figure 2.1).

As discussed in Section 6.5, readily available information suggests that the Municipality of Arran-Elderslie has the potential of containing sufficient volumes of host rock at depth 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 continuing to participate in the site selection process.

Based on the review of readily available information, the Municipality of Arran-Elderslie 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 Municipality of Arran-Elderslie was screened for federal, provincial and municipal parks, conservation areas, nature reserves, national wildlife areas and archaeological and historic sites using available data from the Ontario Ministry of Natural Resources (Land Information Ontario) and the Ontario Ministry of Tourism and Culture.

As discussed in Section 2.4, there are no provincial or national parks within the Municipality of Arran-Elderslie (Figure 2.1). The nearest provincial park is MacGregor Point Provincial Park, located approximately 13 km southwest of the Municipality along the shore of Lake Huron. Five small conservation areas are present in the Municipality and have a combined area of approximately 3 km^2, representing about 1% of the Municipality. These include the McBeath, Lockerby and Tara Conservation Areas, the Arran Management Area and an unnamed Conservation Area maintained by the Saugeen Valley Conservation Authority located within the Elderslie Swamp Wetland Complex. There are also four Provincially Significant Wetlands and four Earth Science Areas of Natural and Scientific Interest (ANSI) within the Municipality of Arran-Elderslie. Known protected areas represent about 10% of the Municipality.

As discussed in Section 2.4, most of the land in the Municipality of Arran-Elderslie is free of known heritage constraints. There are 14 known archeological sites within the Municipality. These sites are localized and small in size. There are no National Historic Sites in the Municipality of Arran-Elderslie.

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

Based on the review of readily available information, the Municipality of Arran-Elderslie contains sufficient land outside 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 the 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 hydrogeological information did not identify any known groundwater resources at repository depth beneath the Municipality of Arran-Elderslie. The Ministry of the Environment Water Well Records indicate that no potable water supply wells are known to exploit aquifers at typical repository depths (approximately 500 m) within the Municipality of Arran-Elderslie or the surrounding areas (Section 4.1). All water wells known in the Municipality of Arran-Elderslie obtain water from overburden or shallow bedrock sources at depths ranging from 5 to 133 m.

As discussed in Section 4.2, the potential for groundwater resources at the typical repository depth beneath the Municipality of Arran-Elderslie is very low. Experience from other areas in southern Ontario and the detailed site characterization work recently completed at the nearby Bruce nuclear site for OPG's proposed DGR for low and intermediate level radioactive waste has shown that there is no active deep groundwater system at typical repository depths due to the very low hydraulic conductivities of the Upper Ordovician shale and limestone units (approximately 10^{-15} to 10^{-10} m/s). The active groundwater system is shallow and limited to the upper approximately 200 m. Available hydrogeological data from OPG's proposed DGR project indicates that the deep groundwater regime at typical repository depth is diffusion-dominated and isolated from the shallow groundwater system. In addition, as discussed in Section 4.3, a transition from fresh to non-potable and highly saline groundwater has been recognized below approximately 200 mBGS.

The review of available information did not identify any known groundwater resources at repository depth beneath the Municipality of Arran-Elderslie. Experience in similar geological settings in the region suggests that the potential for deep groundwater resources at repository depths is extremely low beneath the Municipality of Arran-Elderslie. This would, however, need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

6.4 Screening Criterion 4: Known Natural Resources

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

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

The review of available information indicates that there are no known oil and gas pools within the Municipality of Arran-Elderslie and no historic hydrocarbon exploration wells exist within the Municipality of Arran-Elderslie. New conceptual hydrocarbon plays are identified for southern Ontario by Hamblin (2008), including Upper Ordovician shale gas and Cambrian gas. An assessment of the shale gas potential at the Bruce nuclear site (25 km north of the Municipality) found that the likelihood of commercial gas accumulation in the Ordovician shale is low because of their low organic content and insufficient thermal maturity, while Cambrian deposits are interpreted to be largely absent beneath the Municipality. The absence of historical (i.e. Silurian plays and Ordovician hydrothermal dolomite plays) or new conceptual oil and gas plays would need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

There are currently no operating mines within the Municipality of Arran-Elderslie. There is no record of metallic mineral production in the past. No exploration potential for metallic minerals has been identified within the Municipality.

Current licensed non-metallic mineral extraction in the Municipality of Arran-Elderslie is limited to sand and gravel resources (Section 5.3). The risk that these resources pose for future human intrusion is negligible, as quarrying operations would be limited to very shallow depths.

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

6.5 Screening Criterion 5: Unsafe Geological or Hydrogeological Features

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

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

1. Safe containment and isolation of used nuclear fuel. Are the characteristics of the rock at the site appropriate to ensuring the long-term containment and isolation of used nuclear fuel from humans, the environment and surface disturbances?
2. Long-term resilience to future geological processes and climate change. Is the rock formation at the site geologically stable and likely to remain stable over the very long-term in a manner that will ensure the repository will not be substantially affected by natural disturbances and events such as earthquakes and climate change?
3. Safe construction, operation and closure of the repository. Are conditions at the site suitable for the safe construction, operation and closure of the repository?
4. Isolation of used fuel from future human activities. Is human intrusion at the site unlikely, for instance, through future exploration or mining?
5. Amenable to site characterization and data interpretation activities. Can the geologic conditions at the site be practically studied and described on dimensions that are important for demonstrating long-term safety?

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

Safe Containment and Isolation

The geological and hydrogeological conditions of a suitable site should promote long-term containment and isolation of used nuclear fuel and retard the movement of any potentially released radioactive material. This requires that the repository be located at a sufficient depth, typically around 500 m, in a sufficient rock volume with characteristics that limit groundwater movement. Readily available information on the local and regional geology and hydrogeology was reviewed in Sections 3 and 4.

As discussed in section 3.2.1, the geology of the Municipality of Arran-Elderslie is consistent with the regional geological framework. The Municipality is entirely underlain by a predictable and laterally extensive Ordovician Paleozoic sedimentary sequence.

Based on information from historic oil and gas deep exploration wells in the immediate vicinity of the Municipality (Well #F012117, #T001720A, and #T001877, Table 3.3), the total thickness of the Paleozoic strata in the Municipality of Arran-Elderslie is interpreted to range between approximately 516 m near the northeastern boundary of the Municipality to approximately 655 m near the southwestern boundary.

Near the southwestern boundary of the Municipality of Arran Elderslie both Upper Ordovician shale and limestone units are interpreted to be at sufficient depth to potentially accommodate a repository for used nuclear fuel. Upper Ordovician limestone units in this area of the Municipality are expected to be encountered from approximately 500 to 700 mBGS and are overlain by Upper Ordovician shale units ranging in depth from approximately 300 to 500 mBGS. The depth of these units is interpreted to decrease towards the northeastern boundary of the Municipality, where only the Upper Ordovician limestone units are expected to be at sufficient depth, ranging from approximately 350 to 500 mBGS.

While there is limited information on the geoscientific characteristics of the Upper Ordovician shale and limestone units beneath the Municipality of Arran-Elderslie, it is expected that they are similar to the Upper Ordovician units beneath the nearby Bruce nuclear site (Section 3.2.1). The latter are described as comprising relatively undeformed, low porosity and low hydraulic conductivity sequences that are correlative over large lateral extents as a result of their simple near horizontal geometry and uniform thicknesses. The Upper Ordovician limestone units appear to have favourable geological characteristics and sufficient depth and rock volume to potentially host a deep geological repository. Upper Ordovician shale units also appear to have favourable geological characteristics and sufficient rock volume in the southwestern part of the Municipality of Arran-Elderslie.

Given the regional consistency of the geological setting, the hydrogeological and hydrogeochemical conditions at typical repository depth beneath the Municipality of Arran-Elderslie are expected to be similar to those beneath the Bruce nuclear site (section 4.2). The deep groundwater regime within the Upper Ordovician limestone and overlying shale units beneath the Bruce nuclear site is described as diffusion dominated and isolated from the shallow groundwater system which is limited to the upper 200 mBGS. No mapped faults are documented beneath the Municipality of Arran-Elderslie. It should be noted that documented faults in the region are generally described based on borehole logs, and there are no documented oil and gas exploration wells within the Municipality (Figure 3.2).

The interpreted isolated nature of the deep groundwater systems at typical repository depths is supported by the regional hydrogeochemical setting (Section 4.3). Regional chemistries of the deep brines indicate that they were formed by evaporation of seawater, which was subsequently modified by fluid-rock interaction processes. Limited evidence for recent dilution by meteoric or glacial waters was found within the regional geochemical database. The nature of the deep brines, in particular their high salinities and distinct isotopic signatures, suggests long residence times and indicates that the deep system has remained isolated from the shallow groundwater system.

In summary, the review of available information indicates that the Municipality of Arran-Elderslie contains areas with no known obvious geological or hydrogeological conditions that would fail the containment and isolation requirements. The Upper Ordovician shale and limestone units that are found at typical repository depth beneath the Municipality of Arran-Elderslie are potentially suitable for hosting a deep geological repository for used nuclear fuel. These formations exist at a sufficient depth and in sufficient volumes to potentially host a deep geological repository. They are also expected to have hydrogeological characteristics that would limit groundwater movement. Similar conclusions were previously reached by Mazurek (2004) in a regional analysis of the sedimentary formations within southern Ontario, which identified the Upper Ordovician shale and limestone units as potentially suitable environments to host a deep geological repository for used nuclear fuel. Additional geoscientific characteristics that may have an impact on the containment and isolation functions of a deep geological repository for used nuclear fuel beneath the Municipality of Arran-Elderslie, such as the mineralogy of the rock, the geochemical composition of the groundwater and rock porewater, and the thermal and geomechanical properties of the rock would need to be further assessed during subsequent site evaluation stages, provided the community remains interested in continuing with the site selection process.

Long-Term Stability

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

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

The Municipality of Arran-Elderslie is underlain by Precambrian crystalline basement of the Grenville Province, the south-easternmost subdivision of the Canadian Shield. The Precambrian Grenville Province, which extends from Labrador to Mexico, is generally considered to have been relatively tectonically stable since approximately 970 million years ago (Section 3). Two faults have been reported within an area of approximately 30 km surrounding the Municipality, both of which predate the deposition of the Ordovician Trenton Group Carbonates. There is no evidence from regional studies suggesting that these types of faults have been tectonically active within the past approximately 450 million years.

The geology of the Municipality of Arran-Elderslie is typical of many areas of southern Ontario, 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 southern Ontario suggest that the deep subsurface Paleozoic sedimentary formations have remained largely unaffected by past perturbations such as glaciations (Sections 3 and 4).

A neotectonic study was conducted as part of detailed site characterization for OPG's proposed DGR at the Bruce nuclear site to analyse Quaternary landforms for the presence of seismically-induced soft-sediment deformation (Section 3.3.3). The study was conducted within a radius of up to 50 km away from the Bruce nuclear site, which includes most of the Municipality of Arran-Elderslie. The study concluded that the area has not likely experienced any post-glacial neotectonic activity. A study of the glacial erosion of the Bruce Peninsula caused by the Laurentide Ice Sheet concluded that significant glacial erosion likely did not occur, based on observations of striated surfaces with multiple episodes preserved, the relative absence of friction cracks, and the pervasive low relief of striated surfaces (Section 3.6.2). The study also concluded that potential future glacial erosion in the area would be limited with a conservative site-specific estimate of erosion of 100 m per 1 million years, which is much less than the typical depth of a used nuclear fuel repository (approximately 500 m).

In summary, the review did not identify any obvious geological or hydrogeological conditions that would fail to meet the long-term stability requirement for a potential repository within the Municipality of Arran-Elderslie. The long-term stability factor would need to be further assessed through detailed multi-disciplinary geoscientific and climate change site investigations, if the community remains interested in continuing with the site selection process.

Potential for Human Intrusion

The site should not be located in areas where the containment and isolation functions of the repository are likely to be disrupted by future human activities such as exploration or mining. Therefore, the repository should not be located within rock formations containing exploitable groundwater resources (aquifers) at repository depth and economically exploitable natural resources and other valuable commodities 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 is low and that there are no known economically exploitable natural resources at typical repository depth within the Municipality of Arran-Elderslie. No exploration wells for oil and gas have been drilled in the Municipality.

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. Besides 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, although no readily available site specific information on rock strength characteristics and in-situ stresses was found for the Municipality of Arran-Elderslie, there is abundant information at other locations of southern Ontario that could provide insight into what would be expected for the Municipality of Arran-Elderslie. Available information on strength and in-situ stresses suggests that the Upper Ordovician shale and limestone units have favorable geomechanical characteristics and are amenable to the excavation of stable underground openings. For example, estimated mean uniaxial compressive strengths for Upper Ordovician limestone (Cobourg Formation) was 113 MPa at the Bruce nuclear site. This value compare favourably with other sedimentary formations considered internationally for the long-term management of radioactive waste (Section 3.4). Numerical simulation of the behaviour of underground openings in the limestone Cobourg Formation for the OPG-DGR project indicated that the openings will remain stable during construction and operation, requiring only standard support. The simulations also show that, in the long-term, the barrier integrity of the enclosing Ordovician bedrock formations will not be affected under various loading scenarios associated with glacial ice sheet, seismic ground motions and repository gas pressure (Section 3.5).

In terms of predictability of the geologic formations and amenability to site characterization activities, the review of available information on the bedrock geology for the Municipality of Arran-Elderslie did not reveal any conditions that would make the rock mass difficult to characterize. As discussed in Section 3, the sedimentary sequences beneath the Municipality of Arran-Elderslie are consistent with the regional geological framework for southern Ontario. The Paleozoic bedrock stratigraphy is characterized by minimal structural complexity and a simple geometry, providing a basis for the subsurface predictability of stratigraphic formations.

The Paleozoic sedimentary sequence beneath the Municipality of Arran-Elderslie is covered by Quaternary overburden deposits. As described in Section 3, overburden thickness in the Municipality range from less than 1 m to approximately 102 m. The regional geological framework, the geometry and the interpreted predictability of the subsurface stratigraphic formations suggests that the thickness of the overburden cover is not likely to affect the ability to characterize the subsurface bedrock formations beneath the Municipality of Arran-Elderslie.

In summary, the review of readily available geological and geomechanical information for the Municipality of Arran-Elderslie (Section 3) did not indicate any obvious conditions which would make the rock mass unusually difficult to characterize.

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

7. Initial Screening Findings

This report presents the results of an initial screening to assess the potential suitability of the Municipality of Arran-Elderslie against five initial screening criteria using readily available information. The initial screening focused on the areas within the boundaries of the Municipality of Arran-Elderslie. Areas within neighbouring municipalities were not included in the initial screening.

As outlined in NWMO's site selection process (NWMO, 2010), the five initial screening criteria relate to: having sufficient space to accommodate surface facilities, being outside protected areas and heritage 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 Arran-Elderslie from being further considered in the NWMO site selection process. The initial screening indicates that there are geological formations within the boundaries of the Municipality that are potentially suitable for safely hosting a deep geological repository. Potentially suitable host formations include the Upper Ordovician shale and limestone units that comprise the geology of the Municipality at typical repository depths.

It is important to note that at this early stage of the site evaluation process, the intent of the initial screening was not to confirm the suitability of the Municipality of Arran-Elderslie, but rather to identify whether there are any obvious conditions that would exclude it from the site selection process. Should the community of Arran-Elderslie 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 Municipality of Arran-Elderslie 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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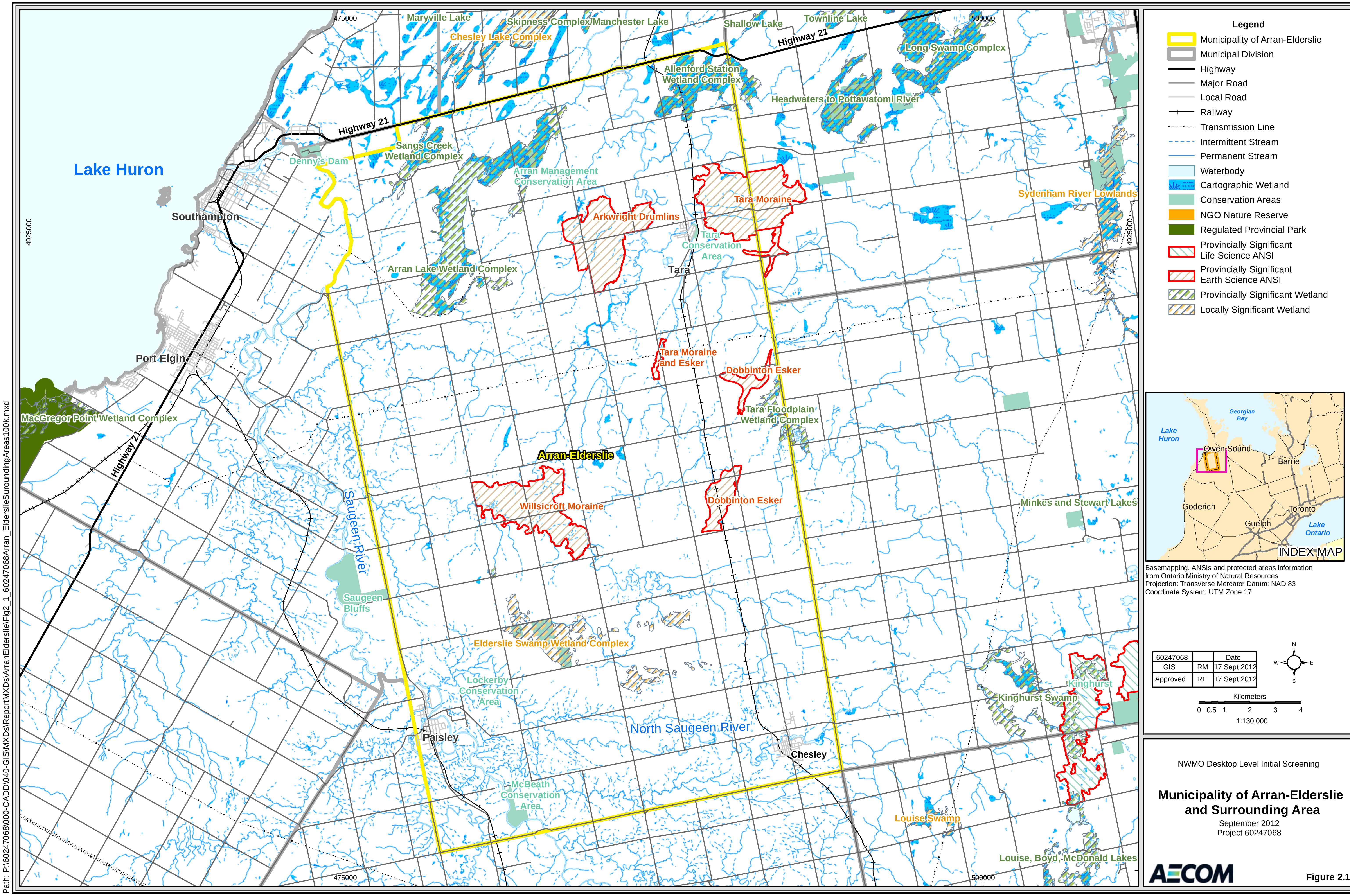
Figures



Lake Huron
Southampton
Port Elgin
Paisley
Tara
Chesley
Arran-Elderslie
Highway 21
Maryville Lake
Skipness Complex/Manchester Lake
Chesley Lake Complex
Shallow Lake
Townline Lake
Long Swamp Complex
Allenford Station Wetland Complex
Headwaters to Pottawatomi River
Sangs Creek Wetland Complex
Denny's Dam
Arran Management Conservation Area
Sydenham River Lowlands
Arkwright Drumlins
Tara Moraine
Tara Conservation Area
Arran Lake Wetland Complex
Tara Moraine and Esker
Dobbinton Esker
Tara Floodplain Wetland Complex
MacGregor Point Wetland Complex
Willsicroft Moraine
Minkes and Stewart Lakes
Saugeen River
Saugeen Bluffs
Elderslie Swamp Wetland Complex
Lockerby Conservation Area
Kinghurst
Kinghurst Swamp
North Saugeen River
McBeath Conservation Area
Louise Swamp
Louise, Boyd, McDonald Lakes
475000
500000
4925000
Legend
Municipality of Arran-Elderslie
Municipal Division
Highway
Major Road
Local Road
Railway
Transmission Line
Intermittent Stream
Permanent Stream
Waterbody
Cartographic Wetland
Conservation Areas
NGO Nature Reserve
Regulated Provincial Park
Provincially Significant Life Science ANSI
Provincially Significant Earth Science ANSI
Provincially Significant Wetland
Locally Significant Wetland
Georgian Bay
Lake Huron
Owen Sound
Barrie
Goderich
Guelph
Toronto
Lake Ontario
INDEX MAP
Basemapping, ANSIs and protected areas information from Ontario Ministry of Natural Resources
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17
60247068
Date
GIS
RM
17 Sept 2012
Approved
RF
17 Sept 2012
N
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Kilometers
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NWMO Desktop Level Initial Screening
Municipality of Arran-Elderslie and Surrounding Area
September 2012
Project 60247068
AECOM
Figure 2.1
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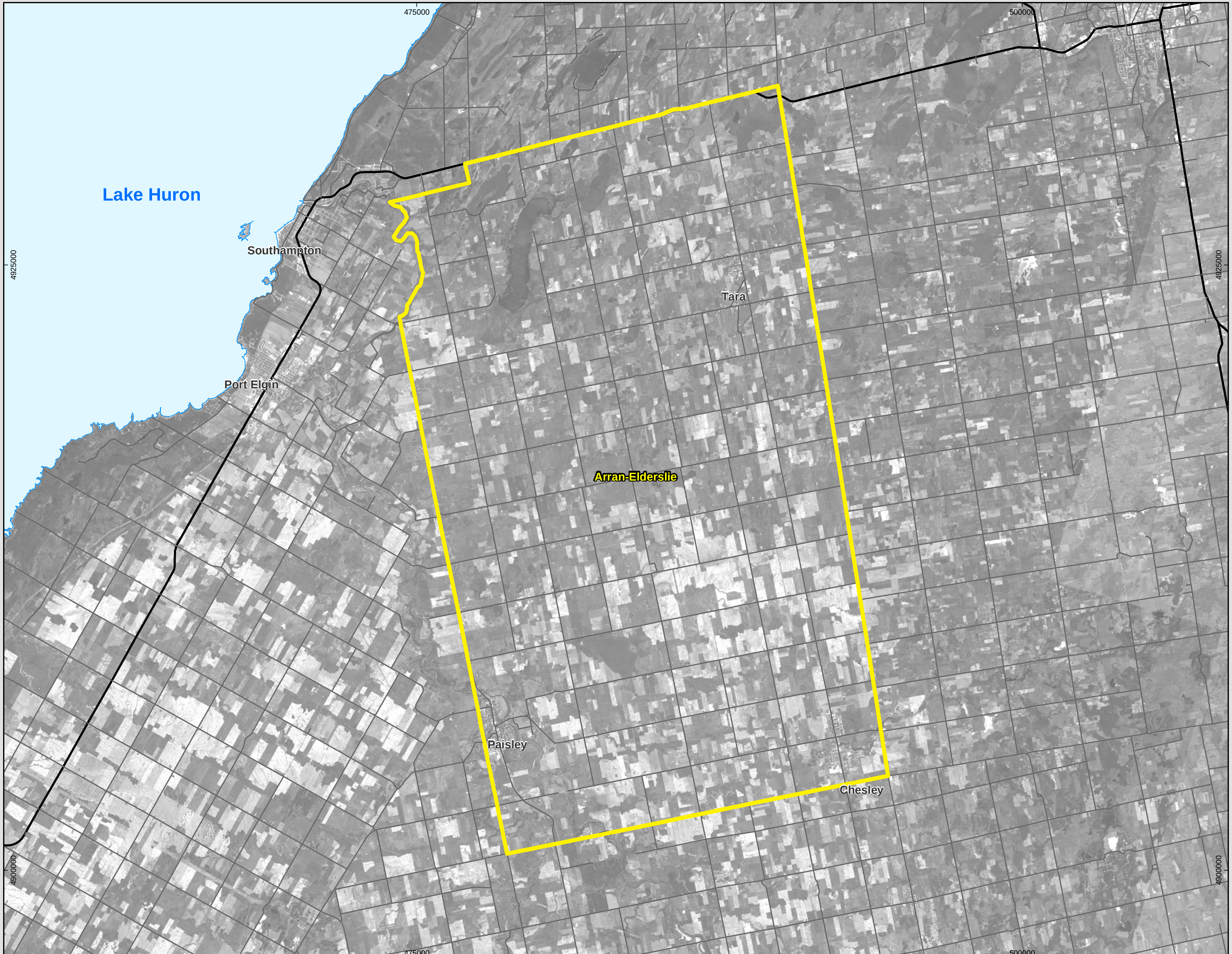
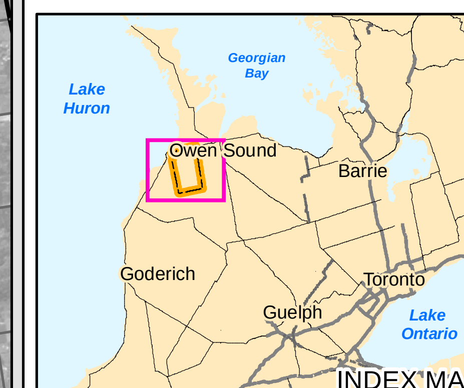


Legend

- Municipality of Arran-Elderslie
- Highway
- Major Road
- Waterbody



Basemapping from Ontario Ministry of Natural Resources
Imagery: Spot 5, Obtained from Geobase (2006, 10 m resolution)
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	13 Sep 2012
Approved	RF	13 Sep 2012

N W E S

Kilometers
0 1 2 4 6 8
1:150,000

NWMO Desktop Level Initial Screening

Satellite Imagery of the Municipality of Arran-Elderslie

September 2012
Project 60247068

AECOM

Figure 2.2

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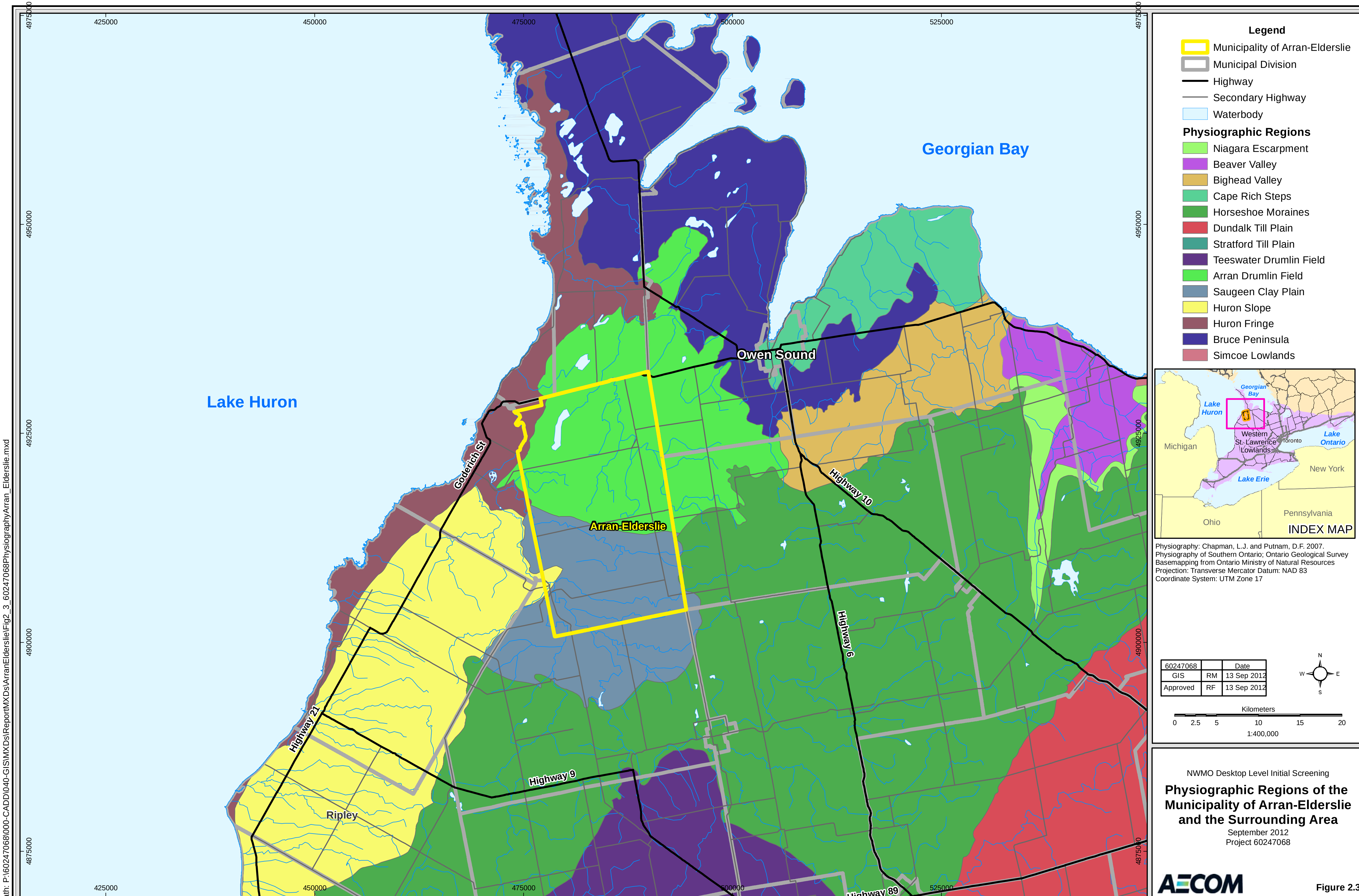


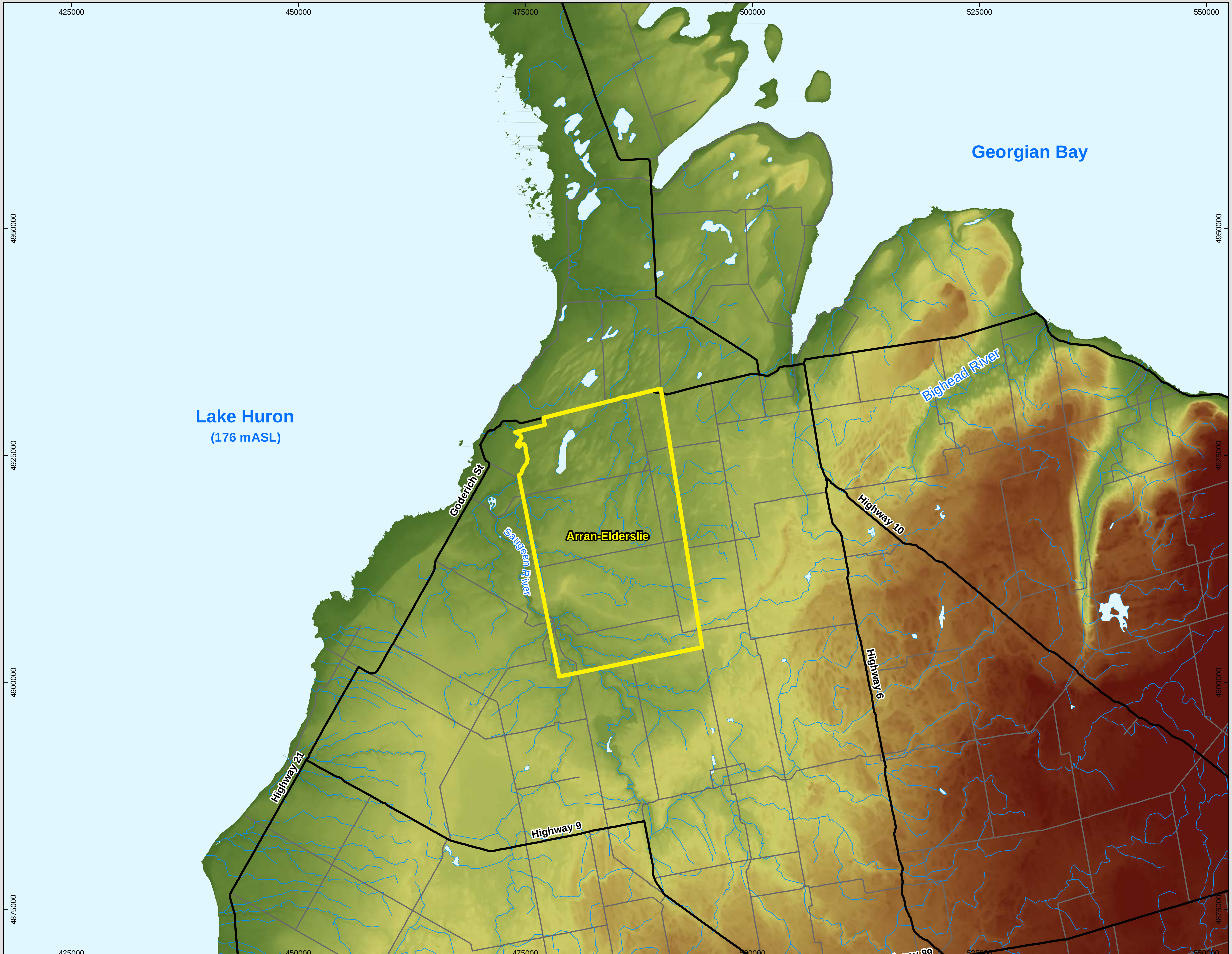
NWMO Desktop Level Initial Screening

Physiographic Regions of the Municipality of Arran-Elderslie and the Surrounding Area

September 2012

Project 60247068

Figure 2.3



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Legend

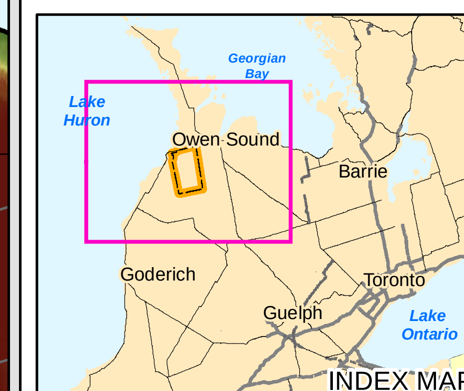
- Municipality of Arran-Elderslie
- Highway
- Secondary Highway
- Watercourses
- Waterbodies

Elevation (mASL)

522

350

176



Basemapping from Ontario Ministry of Natural Resources
DEM: Land Information Ontario
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	13 Sep 2012
Approved	RF	13 Sep 2012

N W E S

Kilometers
0 2.5 5 10 15 20
1:400,000

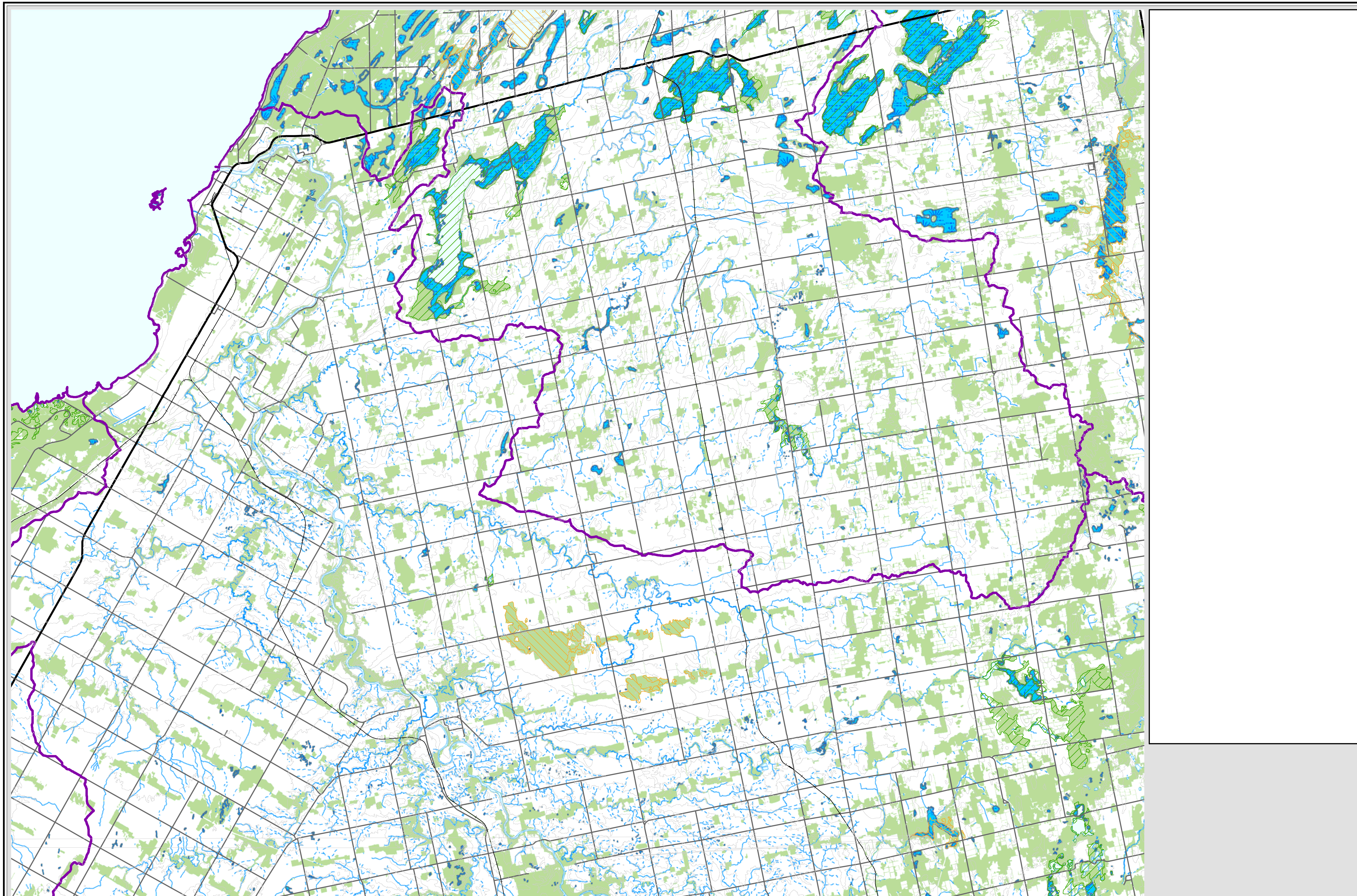
NWMO Desktop Level Initial Screening

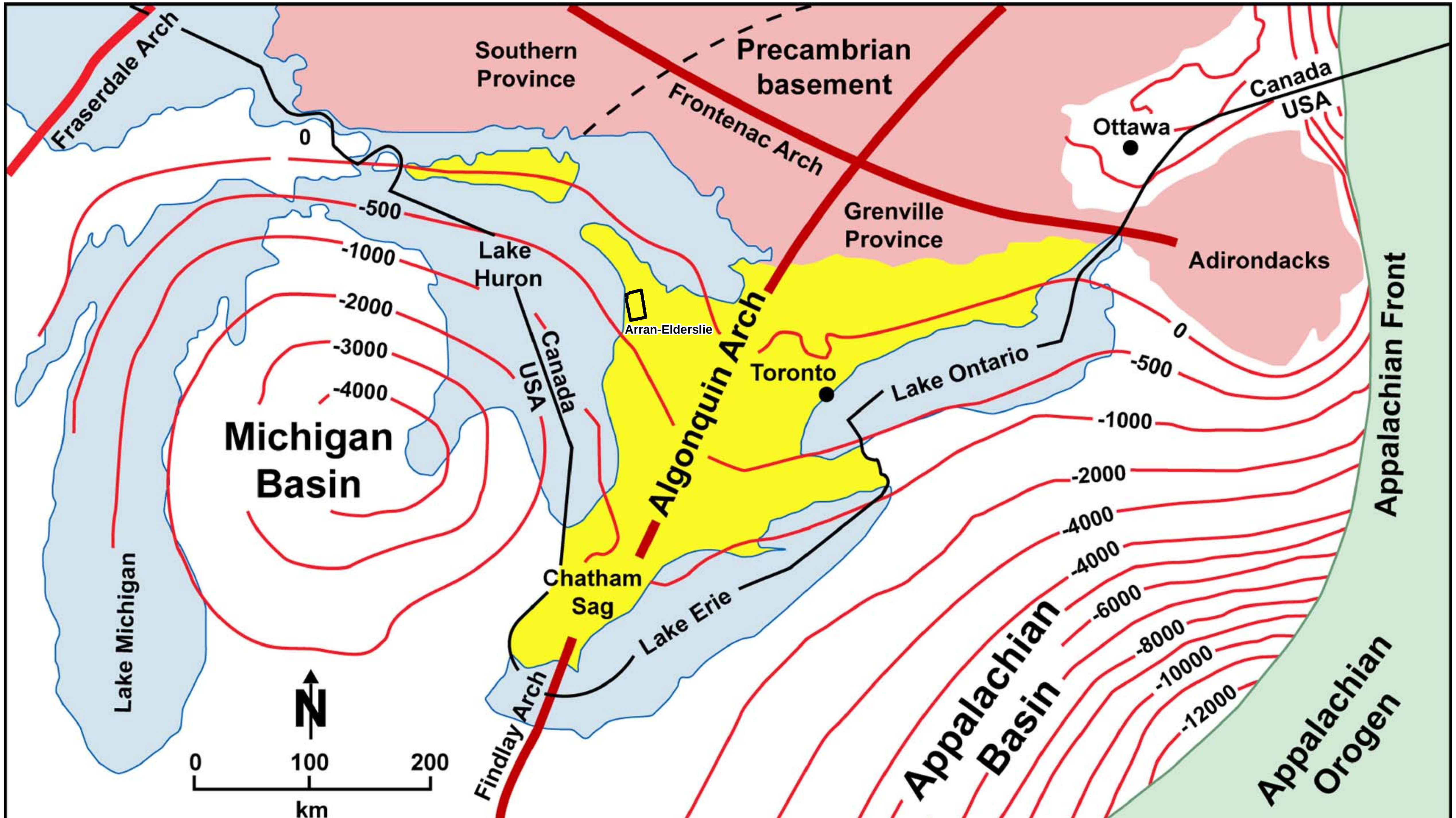
Digital Elevation Model (DEM) of the Municipality of Arran-Elderslie and the Surrounding Area

September 2012
Project 60247068

AECOM

Figure 2.4





Legend

- Municipality of Arran-Elderslie
- Precambrian Basement
- Appalachian Orogen
- Paleozoic Sedimentary Rock of Southern Ontario
- Contours of Precambrian Basement (mASL)
- Axes of Arches
- Precambrian Basement Boundary

60247068		Date
GIS	RM	23 Jul 2012
Approved	RF	23 Jul 2012

Modified after Johnson et al., 1992

NWMO Desktop Level Initial Screening

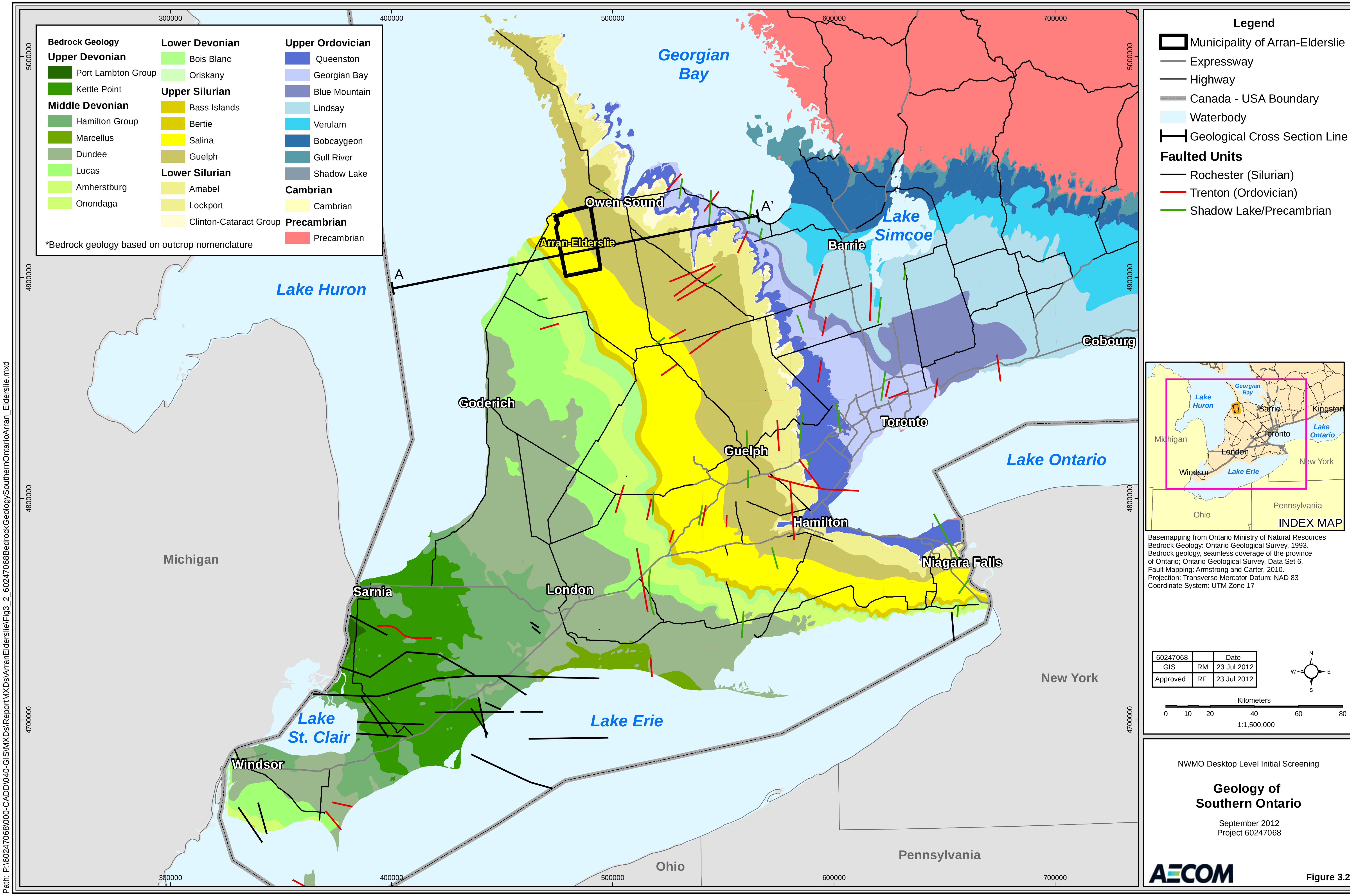
Geological Features of Southern Ontario

September 2012
Project 60247068

AECOM

Figure 3.1

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\ArranElderslie\Fig3_1_60247068GeologicFeaturesofSouthernOntArran_Elderslie.mxd



Bedrock Geology
Upper Devonian
Port Lambton Group
Kettle Point
Middle Devonian
Hamilton Group
Marcellus
Dundee
Lucas
Amherstburg
Onondaga
Lower Devonian
Bois Blanc
Oriskany
Upper Silurian
Bass Islands
Bertie
Salina
Guelph
Lower Silurian
Amabel
Lockport
Clinton-Cataract Group
Upper Ordovician
Queenston
Georgian Bay
Blue Mountain
Lindsay
Verulam
Bobcaygeon
Gull River
Shadow Lake
Cambrian
Cambrian
Precambrian
Precambrian
*Bedrock geology based on outcrop nomenclature
Legend
Municipality of Arran-Elderslie
Expressway
Highway
Canada - USA Boundary
Waterbody
Geological Cross Section Line
Faulted Units
Rochester (Silurian)
Trenton (Ordovician)
Shadow Lake/Precambrian
Georgian Bay
Lake Huron
Lake Simcoe
Lake Ontario
Lake Erie
Lake St. Clair
Owen Sound
Arran-Elderslie
Barrie
Cobourg
Goderich
Toronto
Guelph
Hamilton
Niagara Falls
Sarnia
London
Windsor
Michigan
New York
Pennsylvania
Ohio
A
A'
300000
400000
500000
600000
700000
5000000
4900000
4800000
4700000
INDEX MAP
Georgian Bay
Lake Huron
Barrie
Kingston
Toronto
Lake Ontario
Michigan
London
Windsor
Lake Erie
New York
Pennsylvania
Ohio
Basemapping from Ontario Ministry of Natural Resources
Bedrock Geology: Ontario Geological Survey, 1993.
Bedrock geology, seamless coverage of the province
of Ontario; Ontario Geological Survey, Data Set 6.
Fault Mapping: Armstrong and Carter, 2010.
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17
60247068 | | Date
GIS | RM | 23 Jul 2012
Approved | RF | 23 Jul 2012
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Kilometers
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NWMO Desktop Level Initial Screening
Geology of Southern Ontario
September 2012
Project 60247068
AECOM
Figure 3.2
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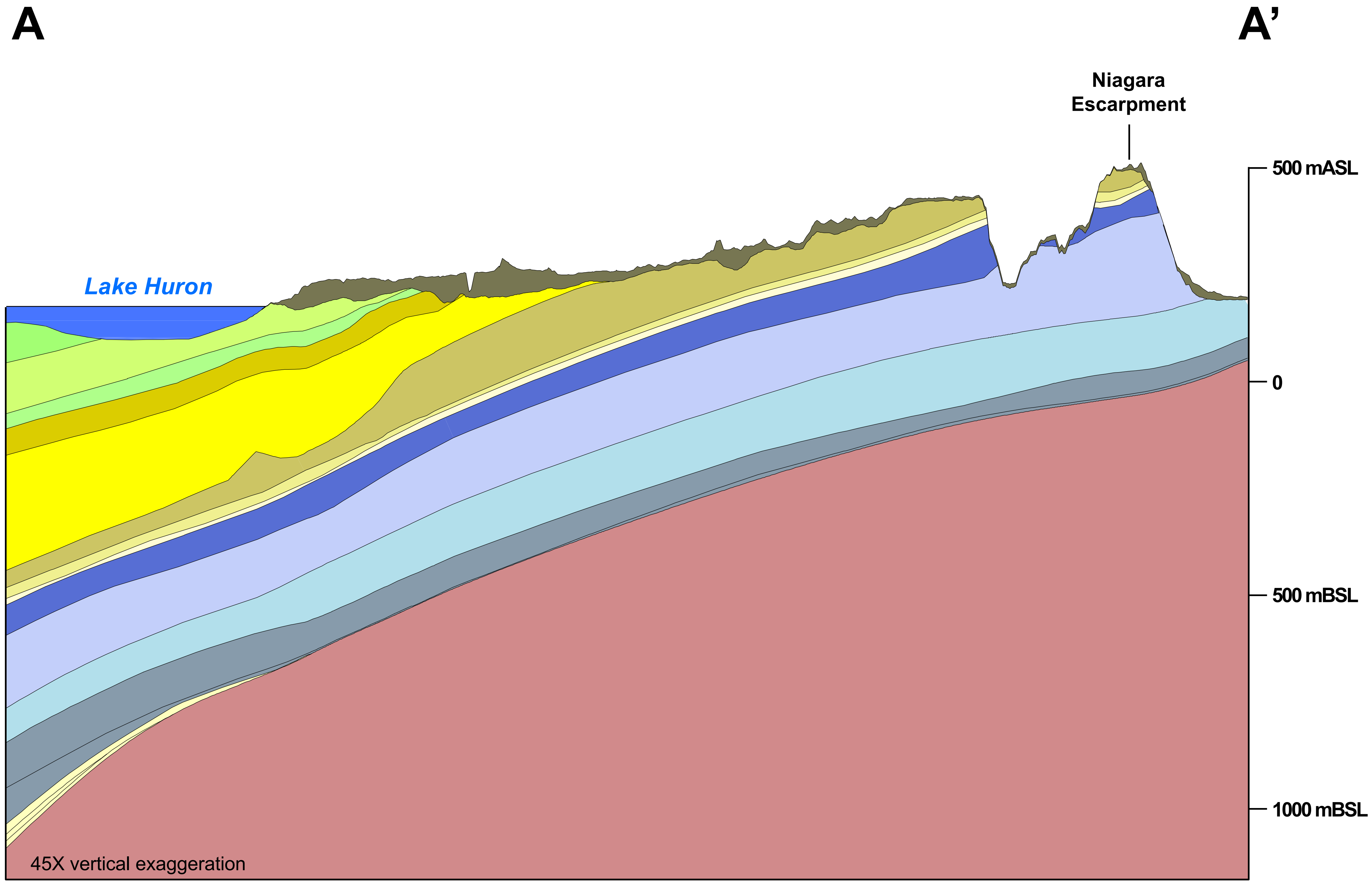


Legend

Overburden

Bedrock Geology

Middle Devonian
- Lucas
- Amherstburg

Lower Devonian
- Bois Blanc

Upper Silurian
- Bass Islands
- Salina
- Guelph

Lower Silurian
- Lockport (Goat Island, Gasport)
- Clinton-Cataract Group (Fossil Hill, Cabot Head, Manitoulin)

Upper Ordovician
- Queenston
- Georgian Bay/Blue Mountain
- Trenton (Cobourg, Sherman Fall, Kirkfield)
- Black River (Coboconk, Gull River, Shadow Lake)

Cambrian
- Cambrian

Precambrian
- Precambrian

Modified after NWMO (2011)

60247068		Date
Approved	SB	13 Sep 2012
Approved	RF	13 Sep 2012

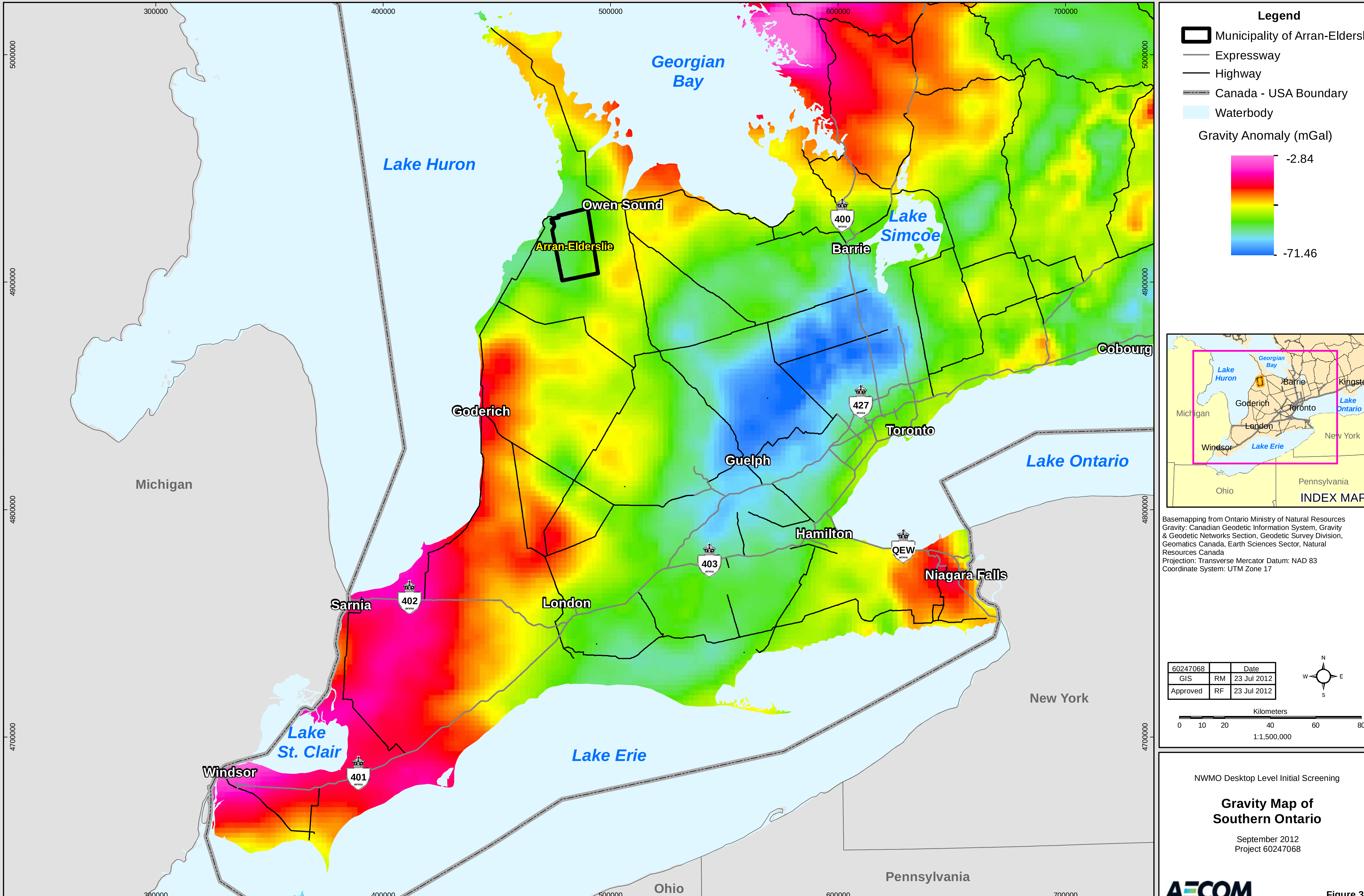
NWMO Desktop Level Initial Screening

Geological Cross-Section
(Location Shown in Figure 3.2)

September 2012
Project 60247068

AECOM

Figure 3.3



NWMO Desktop Level Initial Screening

Gravity Map of Southern Ontario

September 2012
Project 60247068

AECOM

Figure 3.4

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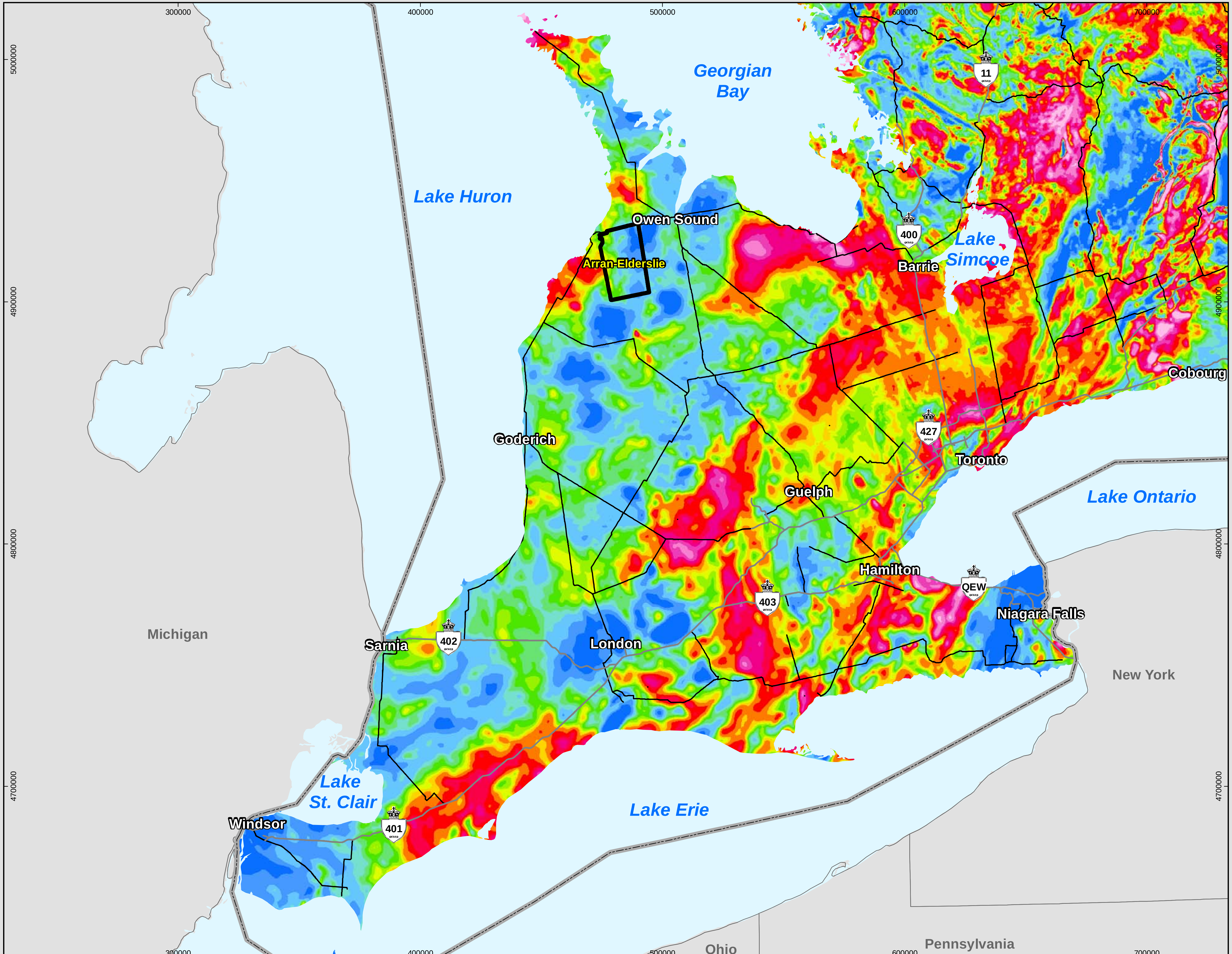

Legend

- Municipality of Arran-Elderslie
- Expressway
- Highway
- Canada - USA Boundary
- Waterbody

Residual Total Magnetic Field (nT)

1235

250

-543

Basemapping from Ontario Ministry of Natural Resources
Aeromagnetic Data: 2011 Canadian Aeromagnetic Data Base, Airborne Geophysics Section, GSC - Central Canada Division, Geological Survey of Canada, Earth Sciences Sector, Natural Resources Canada, 2011
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	23 Jul 2012
Approved	RF	23 Jul 2012

N W E S

Kilometers
0 10 20 40 60 80
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NWMO Desktop Level Initial Screening

Residual Total Magnetic Field of Southern Ontario

September 2012
Project 60247068

AECOM

Figure 3.5

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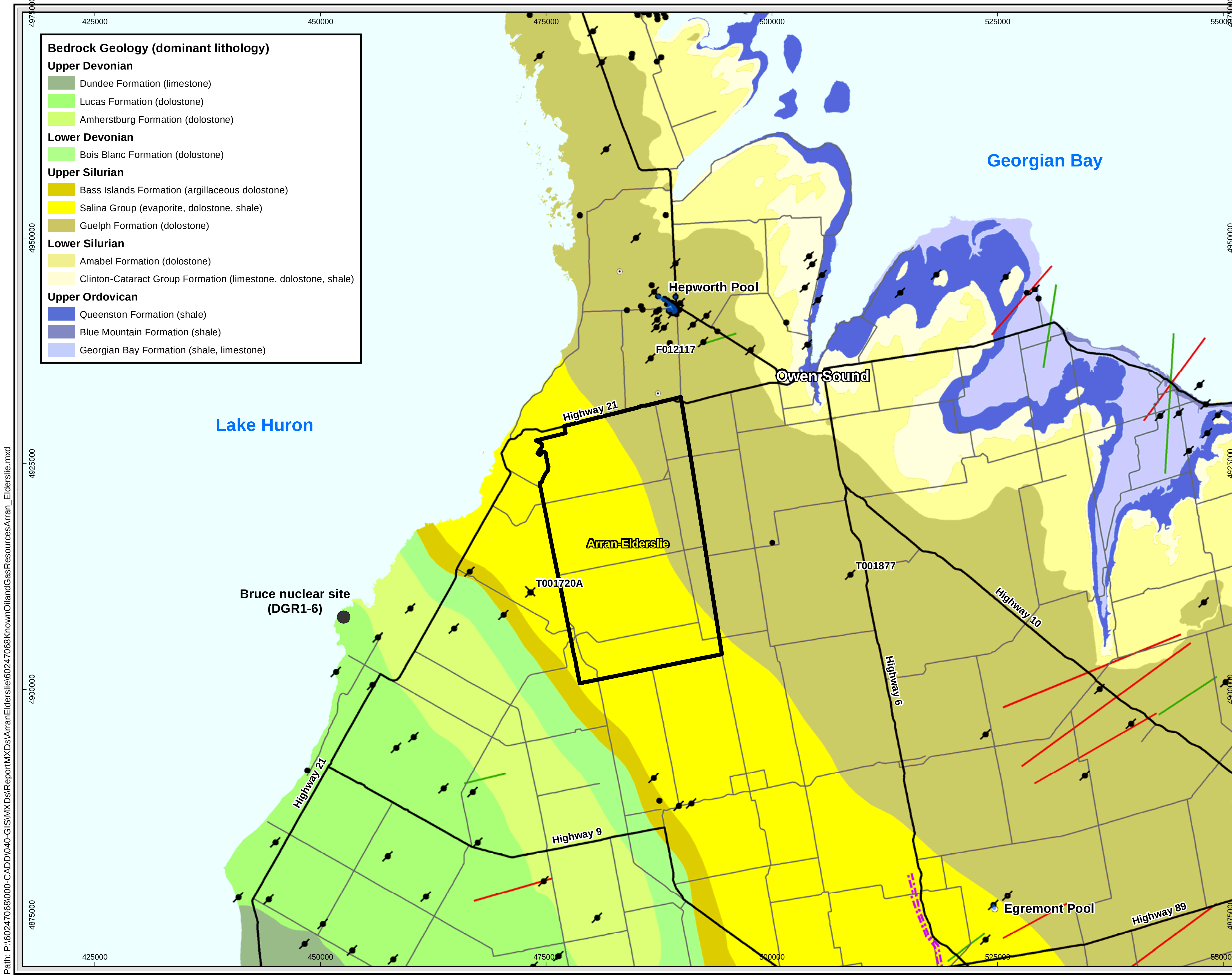

Legend

- Municipality of Arran-Elderslie
- Highway
- Secondary Highway
- Waterbody

Petroleum Wells

- Abandoned Well
- Abandoned and Junked (Lost)
- Active Well
- Observation Well
- Unknown

Oil and Gas Pool

- Ordovician
- Natural Gas Pipeline (1999)

Faulted Units

- Rochester (Silurian)
- Trenton (Ordovician)
- Shadow Lake/Precambrian

Basemapping from Ontario Ministry of Natural Resources
Bedrock Geology: Ontario Geological Survey, 1993.
Bedrock geology, seamless coverage of the province of Ontario; Ontario Geological Survey, Data Set 6.
Oil and Gas Pools and Pipelines: Oil and Gas Pools and Pipelines. 2006. Map of Southwestern Ontario. Oil, Gas & Salt Resources Library. London, Ontario.
Petroleum Wells: Ontario Oil, Gas & Salt Resources Library, 2005.
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	20 Sep 2012
Approved	RF	20 Sep 2012

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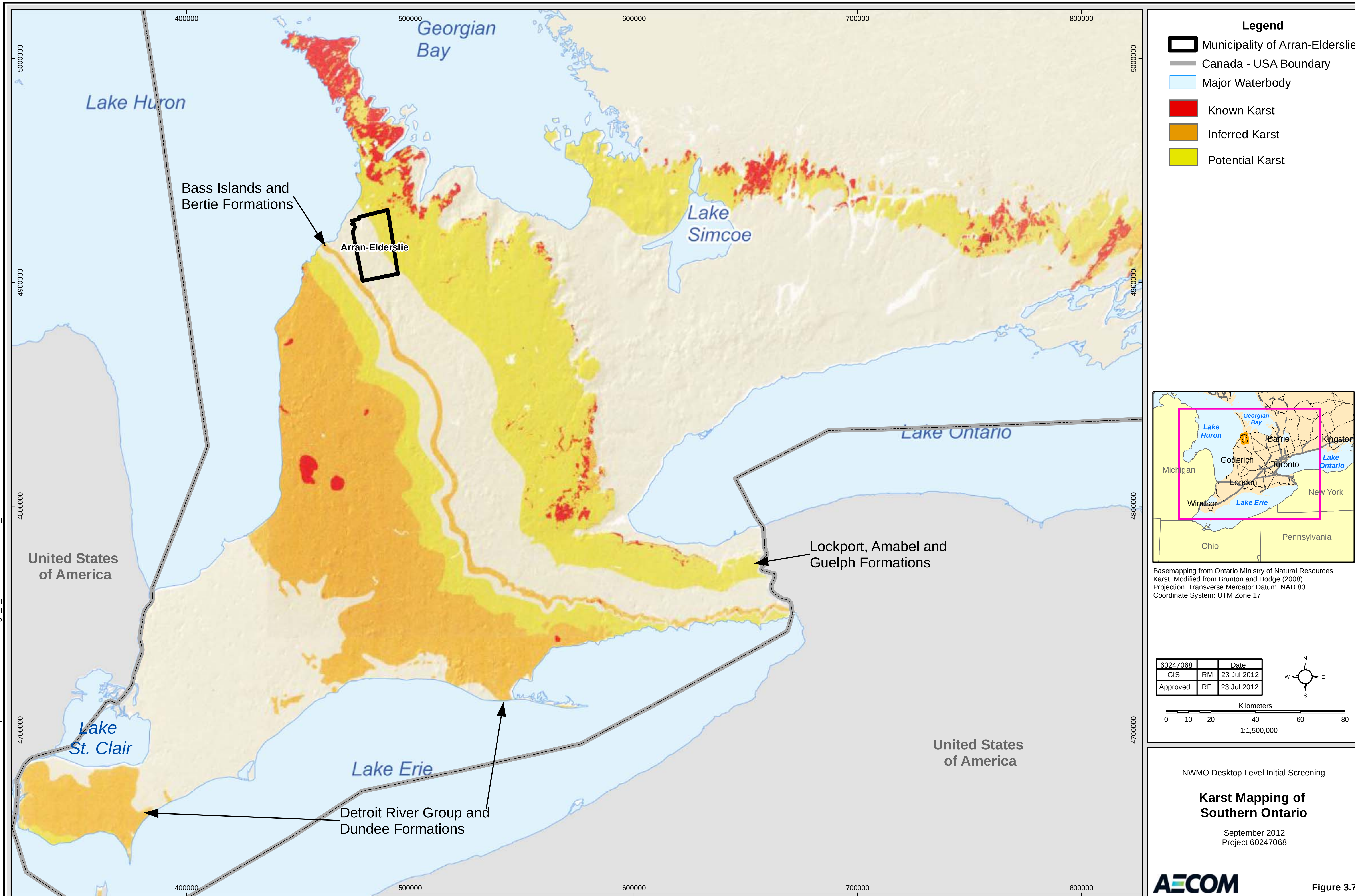
NWMO Desktop Level Initial Screening

Bedrock Geology and Oil & Gas Wells of the Municipality of Arran-Elderslie and the Surrounding Area

September 2012
Project 60247068

AECOM

Figure 3.6

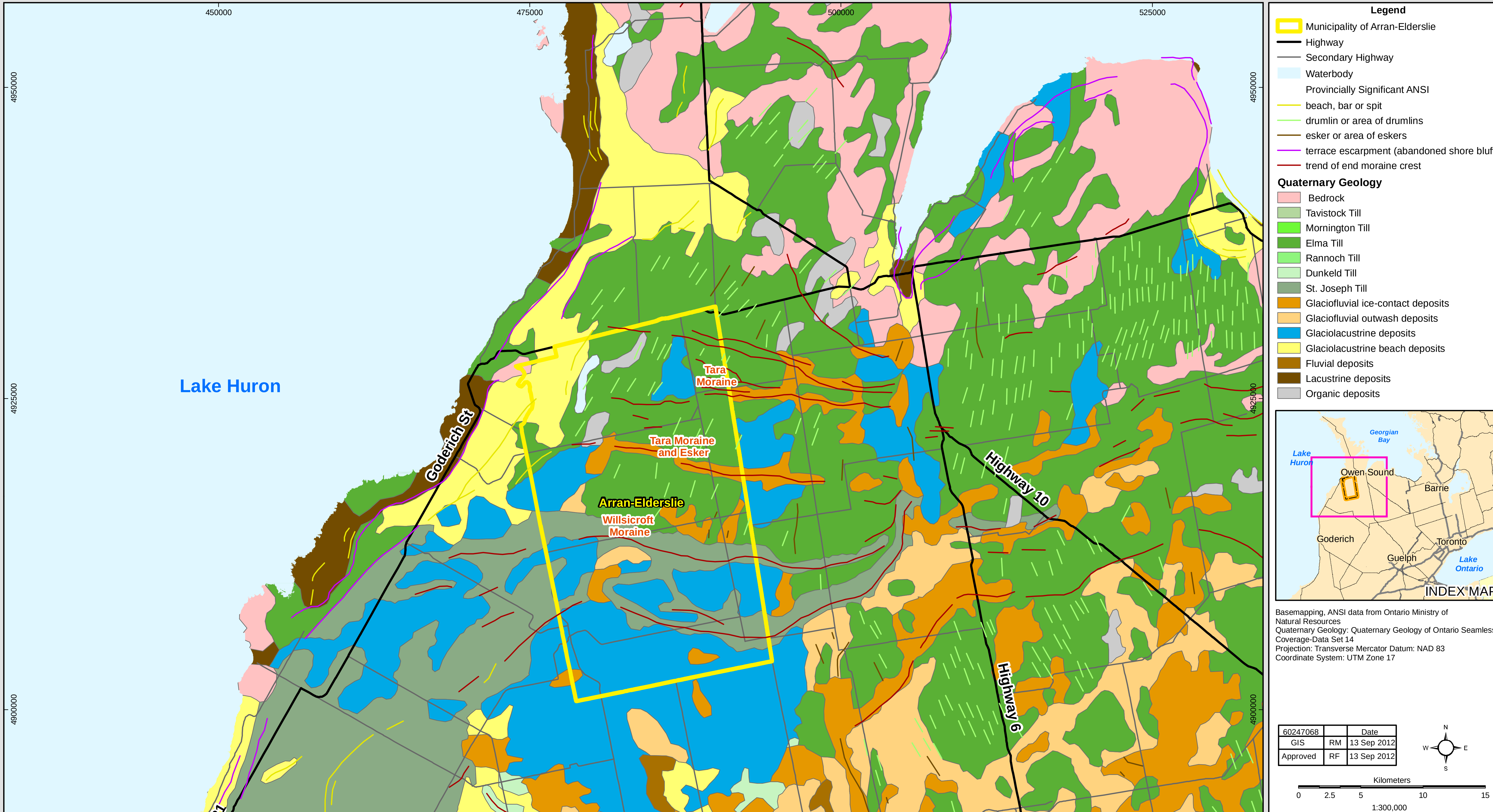


NWMO Desktop Level Initial Screening

Karst Mapping of Southern Ontario

September 2012
Project 60247068

Figure 3.7



NWMO Desktop Level Initial Screening

Quaternary Geology of the Municipality of Arran-Elderslie and the Surrounding Area

September 2012
Project 60247068

AECOM

Figure 3.8

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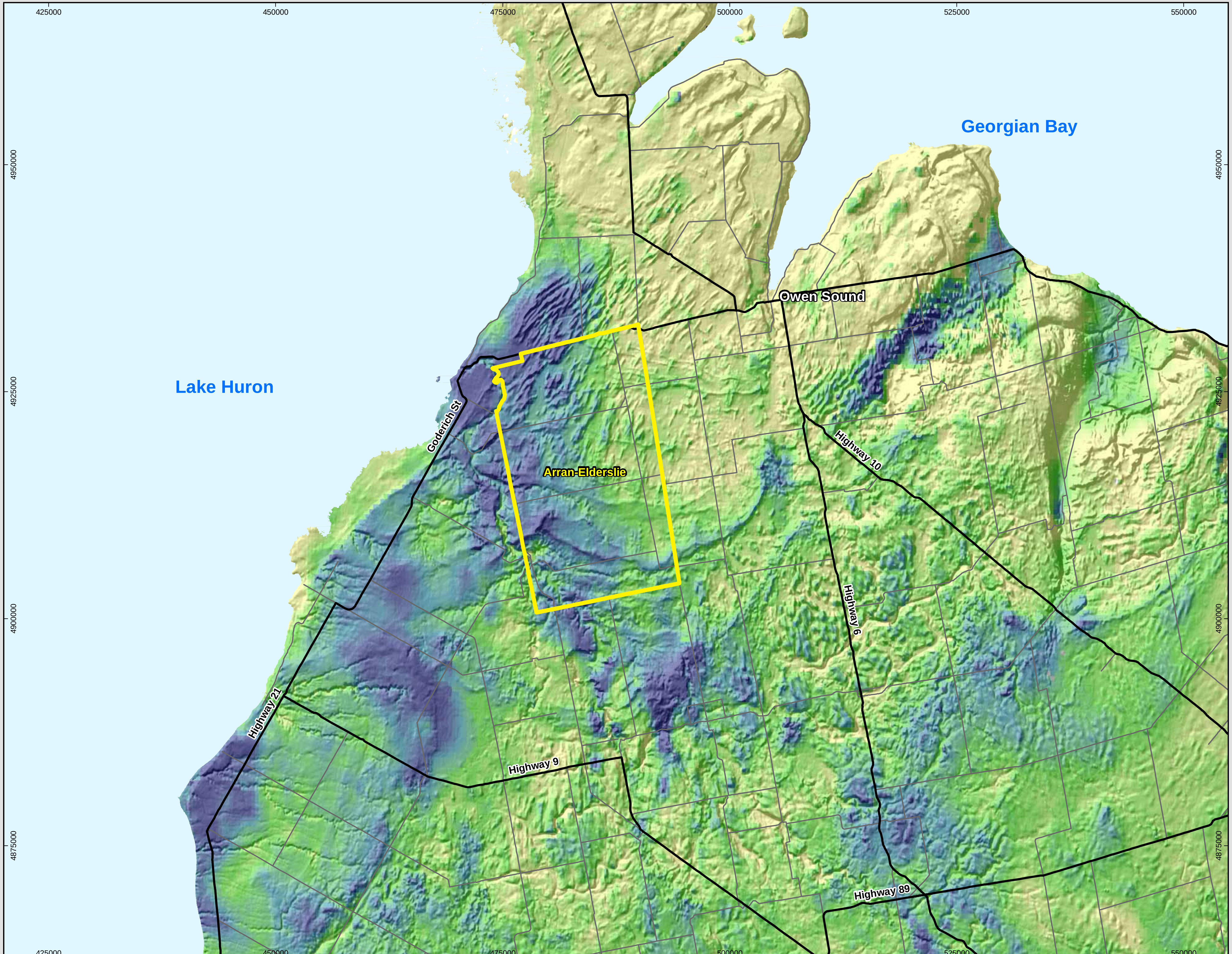

Legend

- Municipality of Arran-Elderslie
- Highway
- Secondary Highway
- Waterbody

Overburden Thickness (m)

120

60

0

Basemapping from Ontario Ministry of Natural Resources
Overburden Thickness: Gao, C., Shirota, J., Kelly, R. I., Brunton, F.R., van Haaften, S. 2006. Bedrock topography and overburden thickness mapping, southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 207. ISBN 1-4249-2550-9
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60247068		Date
GIS	RM	21 Aug 2012
Approved	RF	21 Aug 2012

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NWMO Desktop Level Initial Screening

Overburden Thickness in the Municipality of Arran-Elderslie and the Surrounding Area

September 2012
Project 60247068

AECOM

Figure 3.9

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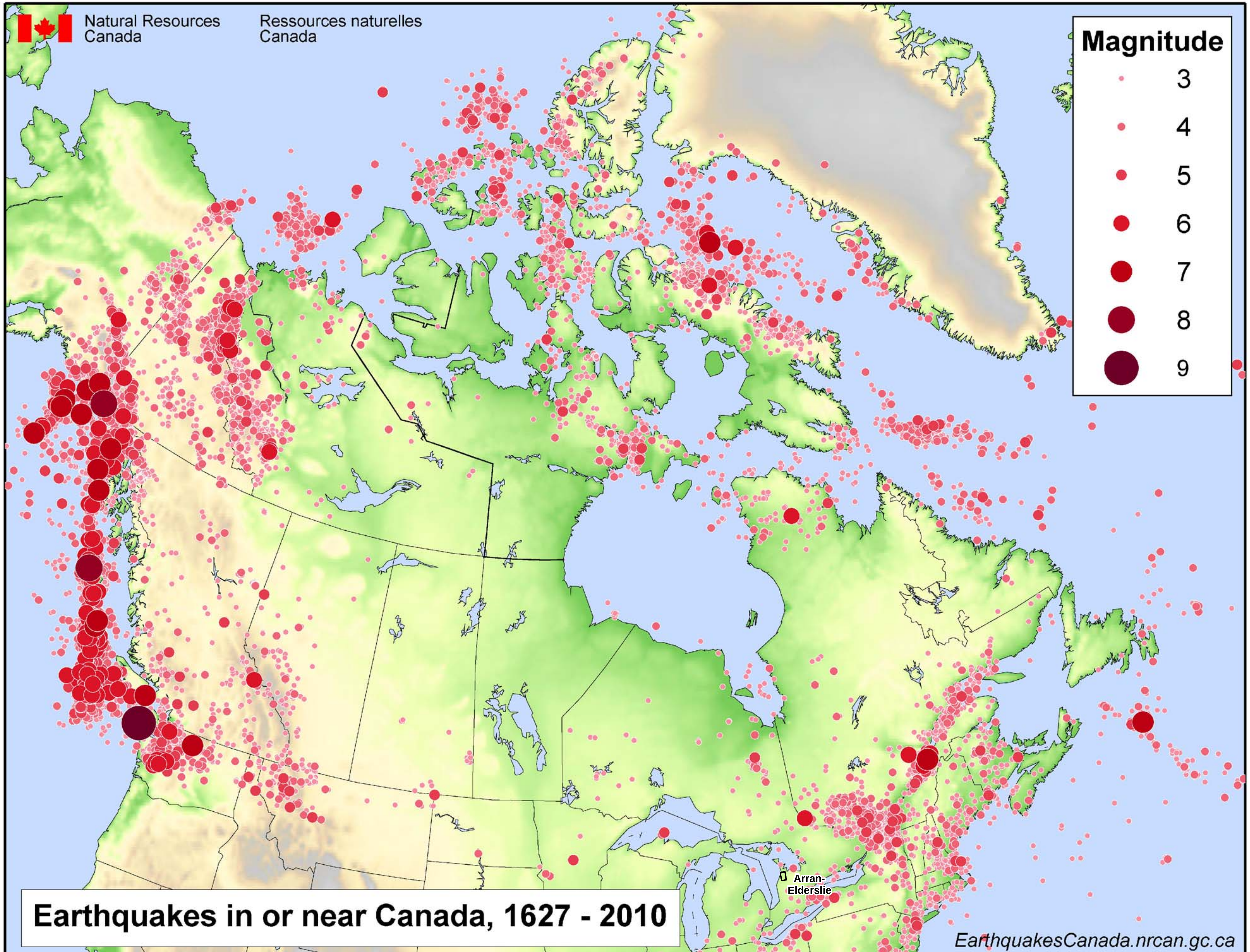

Legend

Municipality of Arran-Elderslie

60247068		Date
GIS	RM	23 Jul 2012
Approved	RF	23 Jul 2012

Basemapping from Ontario Ministry of Natural Resources
Seismic: NRCAN. Earthquake Map of Canada 1627 -2010
Projection: NA

NWMO Desktop Level Initial Screening

Earthquake Map of Canada 1627 - 2010

September 2012
Project 60247068

AECOM

Figure 3.10

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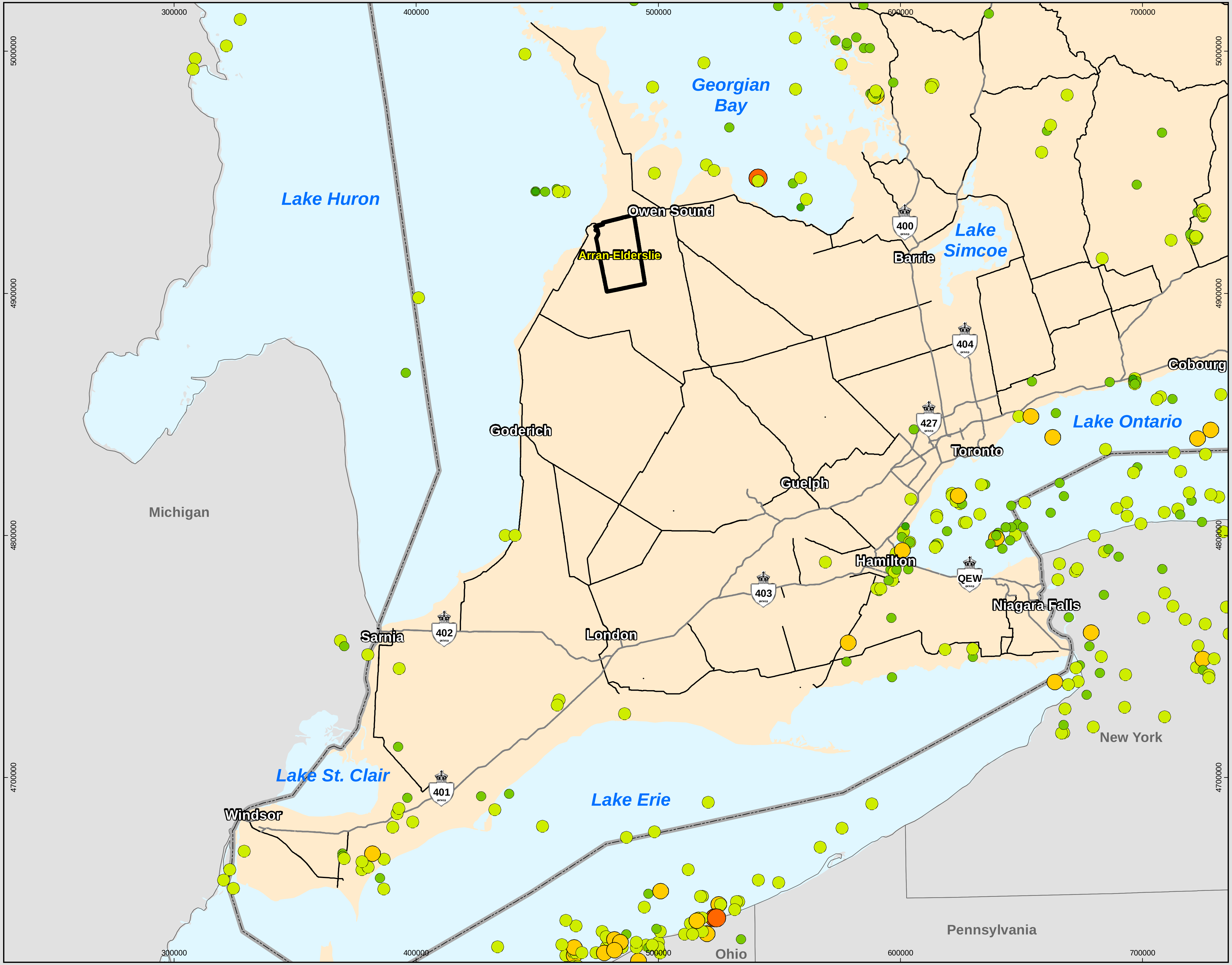
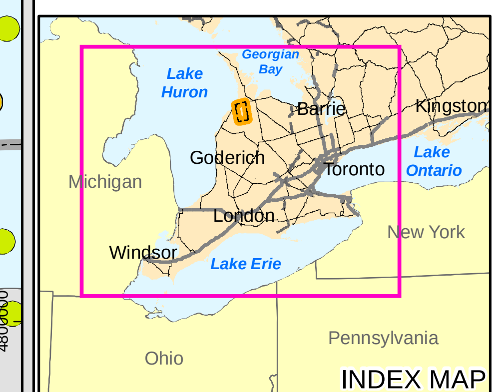


Legend

- Municipality of Arran-Elderslie
- Canada - USA Boundary
- Expressway
- Highway
- Waterbody

Seismic Events (Magnitude)

- <1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0
- 5.1 - 6.0



Basemapping from Ontario Ministry of Natural Resources
Seismic: Earthquakes Canada, GSC, Earthquake Search (On-line Bulletin) Feb. 2012.
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GIS	RM	23 Jul 2012
Approved	RF	23 Jul 2012

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Kilometers
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NWMO Desktop Level Initial Screening

Earthquake Map of Southern Ontario 1985 - 2012

September 2012
Project 60247068

AECOM

Figure 3.11

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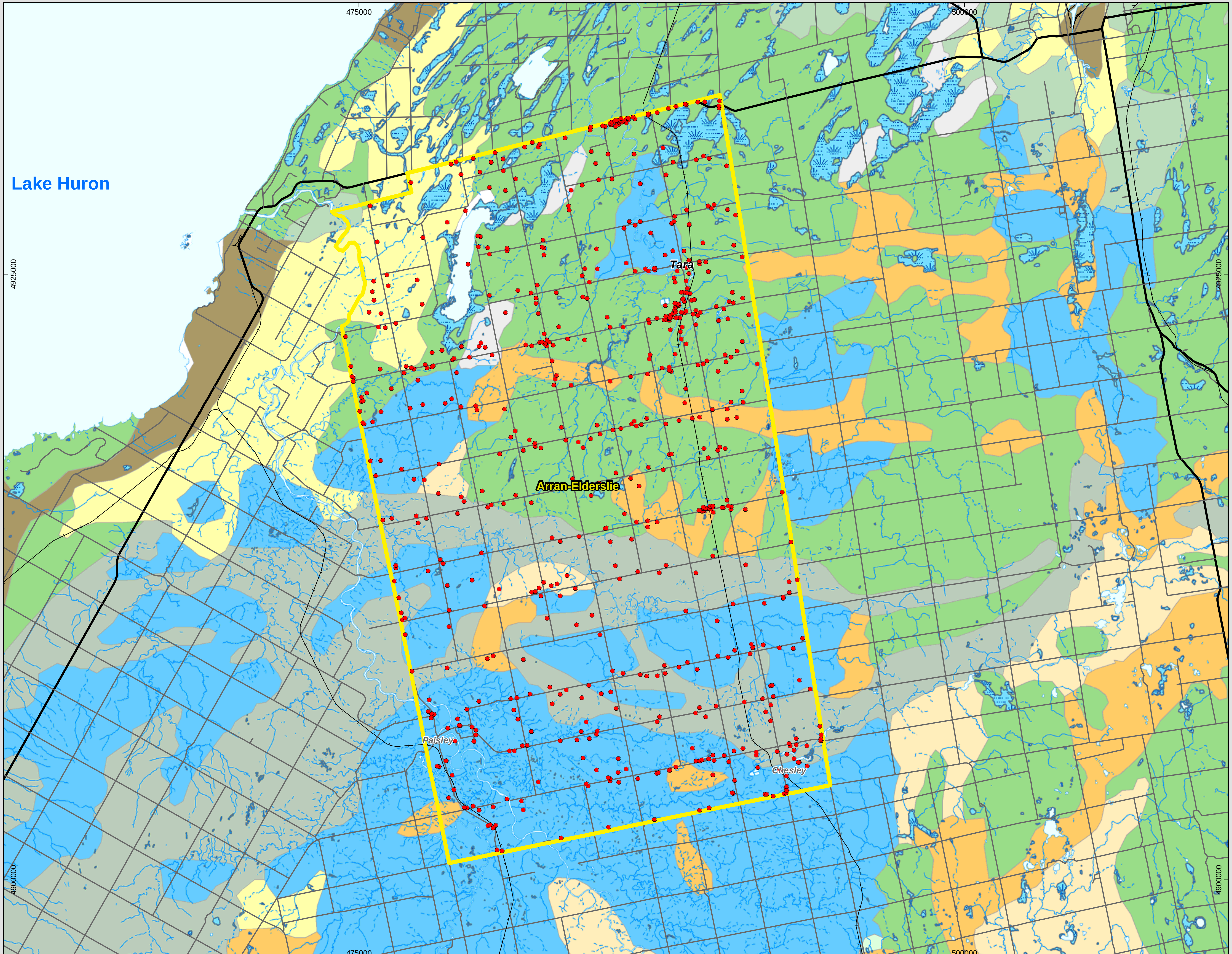
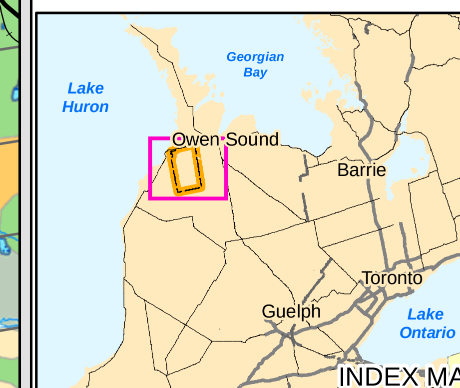


Legend

- Municipality of Arran-Elderslie
- MOE Water Well Record
- Highway
- Major Road
- Railway
- Intermittent Stream
- Permanent Stream
- Waterbody
- Wetland

Quaternary Overburden

- Bedrock
- Elma Till
- Rannoch Till
- Dunkeld Till
- St. Joseph Till
- Glaciofluvial ice-contact deposits
- Glaciofluvial outwash deposits
- Glaciolacustrine deposits
- Glaciolacustrine beach deposits
- Lacustrine deposits
- Organic deposits



Basemapping from Ontario Ministry of Natural Resources
Quaternary Geology: Quaternary Geology of Ontario Seamless Coverage-Data Set 14
Wells: Ministry of Environment, 2012
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	13 Sep 2012
Approved	RF	13 Sep 2012

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Kilometers
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1:150,000

NWMO Desktop Level Initial Screening

Water Well Records of the Municipality of Arran-Elderslie

September 2012
Project 60247068

AECOM

Figure 4.1

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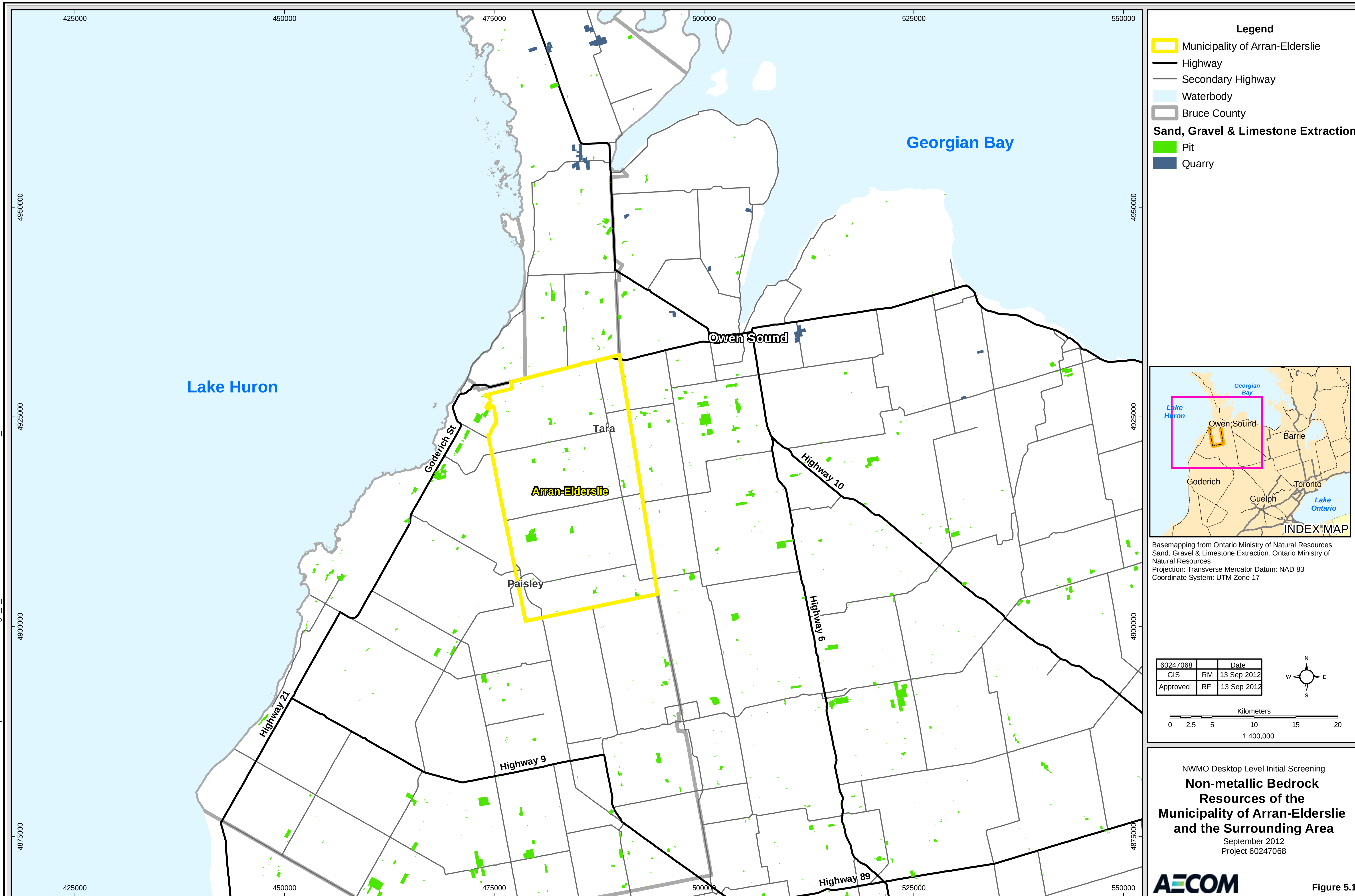

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