nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

September 19, 2012

The Town of Saugeen Shores
P.O. Box 820, 600 Tomlinson Drive
Port Elgin, ON N0H 2C0

Attn: Mr. Larry Allison

Re: **Adaptive Phased Management Initial Screening – The Town of Saugeen Shores**

Dear Mr. Allison,

Further to the Town of Saugeen Shores' 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 Town of Saugeen Shores 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 Town of Saugeen Shores from further consideration in the NWMO site selection process. The initial screening suggests that the Town 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 Town of Saugeen Shores 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, Saugeen Shores 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

Enc.

c. Mayor Mike Smith

AECOM

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

The Corporation of the Town of Saugeen Shores

Report

AECOM

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

The Corporation of the Town of Saugeen Shores

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Executive Summary

On May 14, 2012, the Corporation of the Town of Saugeen Shores expressed interest in learning more about the Nuclear Waste Management Organization's (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 Town of Saugeen Shores 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 Town of Saugeen Shores from further consideration in the site selection process. The initial screening focused on the areas within the boundaries of the Town of Saugeen Shores. At the request of the Town, the areas west of Highway 21 were not included in the initial screening. The Council wishes to preserve those areas for future expansion. Other areas which Council may identify for future expansion would be considered during subsequent site evaluation stages if the Town of Saugeen Shores remains interested in the site selection process. 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 Town of Saugeen Shores from being further considered in the NWMO site selection process. The initial screening indicates that there are geological formations within the boundaries of the Town 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 Town at typical repository depths.

It is important to note that the intent of this initial screening is not to confirm the suitability of the Town of Saugeen Shores 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 Saugeen Shores remain interested in continuing with the site selection process, more detailed studies would be required to confirm and demonstrate whether the Town of Saugeen Shores 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 economically exploitable 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

At this early stage the review of available mapping and satellite imagery indicates that, despite the relatively small size of the screened area (east of Highway 21) and the presence of some land constraints, the Town of Saugeen Shores appears to contain sufficient land to potentially accommodate the repository's surface and underground facilities. These lands could be accessible for construction and field investigation activities. Availability of land and the feasibility of locating a repository within the Town would be further assessed during subsequent stages of the evaluation process if the Town of Saugeen Shores continues to be interested in the site selection process.

Protected Areas, Heritage Sites, Provincial Parks and National Parks

The Town of Saugeen Shores contains sufficient land outside of protected areas, heritage sites, provincial parks and national parks to accommodate the repository's facilities.

The area of the Town east of Highway 21 considered for the initial screening contains one designated protected area, the Saugeen Bluffs Conservation Area. This conservation area is located in the southeastern corner of the Town and covers a fairly small surface area of about 2 km^2. The MacGregor Point Provincial Park and the MacGregor Point Wetland Complex are situated in the southwestern corner of the Town, west of Highway 21. There are 10 known archeological sites documented within the Town of Saugeen Shores. These are small localized sites that are generally concentrated around water features such as lakes and rivers and the present-day settlements of Port Elgin and Southampton. There are no National Historic Sites within the Town of Saugeen Shores.

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 Town of Saugeen Shores. 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 Town of Saugeen Shores. Water wells in the Town obtain water from overburden or shallow bedrock aquifers at depths ranging from approximately 5 to 183 m. Experience in similar geological settings across southern Ontario suggests that the potential for deep groundwater resources at repository depths is low throughout the Town of Saugeen Shores. 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 Town of Saugeen Shores contains sufficient land, free of known economically exploitable natural resources, to accommodate the required repository facilities. The Town of Saugeen Shores has no documented oil and gas resources or economic minerals. Two historic exploration wells drilled within the Town of Saugeen Shores for hydrocarbon exploration resulted in dry holes with no production potential. 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. There is no record of metallic mineral production in the past, and no exploration potential for metallic minerals has been identified within the Town of Saugeen Shores. 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 Town of Saugeen Shores 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 Town of Saugeen Shores 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 Town of Saugeen Shores is potentially suitable for hosting a deep geological repository. Potentially suitable host formations include the Upper Ordovician shale and limestone units.

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1. Introduction

On May 14, 2012, the Corporation of the Town of Saugeen Shores 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 Town of Saugeen Shores against five screening criteria using readily available information. The initial screening focused on the areas within the boundaries of the Town of Saugeen Shores. At the request of the Town, the areas west of Highway 21 were not included in the initial screening. The Council wishes to preserve those areas for future expansion. Other areas which Council may identify for future expansion would be considered during subsequent site evaluation stages if the Town of Saugeen Shores remains interested in the site selection process. 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.

1.1 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 Town of Saugeen Shores is situated within Bruce County in southern Ontario, approximately 40 km southwest of Owen Sound, along the shoreline of Lake Huron (Figure 2.1). The Town of Saugeen Shores is approximately 174 km^2 in size (Town of Saugeen Shores Official Plan, 2006). The total land area east of Highway 21 is approximately 131 km^2. The largest communities in the Town of Saugeen Shores are Port Elgin and Southampton, located along Highway 21 near Lake Huron (Figure 2.1). The combined settlement areas for these communities is around 26 km^2, with 10 km^2 located east of Highway 21. The Town of Saugeen Shores also includes parts of the hamlets of Burgoyne and North Bruce, which each occupy less than 1 km^2 within the Town, east of Highway 21. Municipal offices are located in Port Elgin. Satellite imagery for the Town of Saugeen Shores (Spot 5, taken in 2006) is presented on Figure 2.2. Most of the lands adjacent to and west of Highway 21 are settlement areas likely comprised of residential and commercial development while land use east of Highway 21 is primarily rural/agricultural (Figure 2.2).

2.2 Topography

The Town of Saugeen Shores 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 Town of Saugeen Shores and surrounding area.

The northern part of the Town of Saugeen Shores lies in the Huron Fringe physiographic region, while the southern part of the Town lies in the Huron Slope physiographic region. The Saugeen Clay Plain and the Arran Drumlin Field physiographic regions occupy small areas along the eastern municipal boundary. The Town of Saugeen Shores is covered primarily with Quaternary glacial deposits, although modern lacustrine beach sediments occupy the majority of the Lake Huron shoreline along the western boundary of the Town.

The Digital Elevation Model (DEM) for the Town of Saugeen Shores and surrounding area is presented on Figure 2.4. The terrain is dominantly low relief and slopes down gradually towards Lake Huron, from a maximum of around 261 metres above sea level (mASL) in the southeast corner of the Town to a minimum of approximately 176 mASL along the western shoreline. An abrupt drop in land surface elevation, or bluff, occurs in the southwestern corner of the Town within the McGregor Point Provincial Park. A flat, low-lying area along the Lake Huron shoreline lies below the bluffs and characterizes the MacGregor Point Wetland Complex. The Saugeen River has cut a broad, deep valley through the overburden as it meanders from the southeast corner of the Town towards the river mouth in the northwest corner (Figure 2.4). Long, linear northeast-southwest trending drumlin ridges are present within the Arran Drumlin Field physiographic region along the west-central boundary of the Town.

2.3 Drainage

Surface water drainage for the Town of Saugeen Shores is shown in Figure 2.5. Drainage is generally from south to north into Lake Huron. The Town of Saugeen Shores is located within the Saugeen sub-watershed of the Western Georgian Bay and Eastern Lake Huron sub-basins.

The Town of Saugeen Shores is drained by the Saugeen River which flows from the southeastern corner of the Town northward to the river mouth where it discharges into Lake Huron at the settlement of Southampton (5 km north of Port Elgin). Numerous small tributaries feed the Saugeen River as it approaches the mouth, with the largest of these tributaries being Mill Creek, which drains lands south of the Saugeen River (Figure 2.5). The southwestern corner of the Town of Saugeen Shores is occupied by the MacGregor Point Wetland Complex, adjacent to Lake Huron (Figure 2.5).

2.4 Protected Areas

2.4.1 Parks and Reserves

Figure 2.1 shows the location of parks, reserves and provincially significant areas in the Town of Saugeen Shores and surrounding area. There is one provincial park, which includes a provincially significant wetland, and one conservation area within the Town of Saugeen Shores.

The MacGregor Point Provincial Park is situated west of Highway 21 in the southwestern corner of the Town of Saugeen Shores, along the shoreline of Lake Huron. The park is approximately 14 km^2 in size and occupies approximately 6% of the area of the Town (Figure 2.1). The park is used year-round for activities such as camping, hiking, fishing, boating, canoeing, swimming, cycling, and winter sports. It provides habitat to many species of migratory birds and contains many species of rare native plants.

The MacGregor Point Wetland Complex is a Provincially Significant Wetland located within MacGregor Point Provincial Park. Several additional Provincially Significant Wetlands, the Arran Lake, Arran, and Sangs Creek Wetland Complexes, are located beyond the northeastern boundary of the Town. Numerous other wetlands are present further north, in the area around Owen Sound and on the Bruce Peninsula as well as south of the Saugeen Shores near the Brucedale Conservation Area (Figure 2.1).

A single conservation area, the Saugeen Bluffs Conservation Area, exists within the Town of Saugeen Shores, and is located in the southeastern portion of the Town with an approximate size of 2 km^2 (Figure 2.1).

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.

2.4.2 Heritage Sites

The cultural heritage screening examined known archaeological and historic sites in the Town of Saugeen Shores 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 117 registered archaeological sites in the area examined, which is an approximately 40 km radius around the Town of Saugeen Shores. The sites are of First Nations, Métis, and Euro-Canadian cultural affiliation. The majority are of Aboriginal cultural affiliation; including one lodge, several lithic scatters, fishing/hunting camps, burial sites, and many camp sites. Twenty-six sites 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 ten known archaeological sites documented in the Town of Saugeen Shores. These ten sites are of Aboriginal cultural affiliation: two of these are of undetermined cultural affiliation or function; three are of undetermined cultural affiliation but are distinguished as burials and campsites; two are pre-contact findspots; three are Woodland (including Petun and Saugeen) campsites, which include burials. These archeological sites are generally located near the settlements of Southampton and Port Elgin, are small in size, and occupy a small portion of the Town area. A fur trading post established near the mouth of the Saugeen River in 1826 by the Hudson's Bay Company represents a centre of Métis trading and culture which was active until the mid-nineteenth century.

The potential for archaeological sites within the Town of Saugeen Shores 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).

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.

3. Geology and Seismicity

This section provides a general overview of the geology and seismicity of southern Ontario, including the Town of Saugeen Shores and surrounding area, 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 (Table 3.4; 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 (Table 3.4; Percival and Easton, 2007).

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 Town of Saugeen Shores and surrounding areas 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 Town of Saugeen Shores (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 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 southern portion of the Town of Saugeen Shores (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 Town of Saugeen Shores is underlain by a moderately low gravity signal. The gravity signal increases radially outwards from the Town, reaching moderately high-intensity values at Owen Sound and at Goderich (Figure 3.4). The southern half of the Town of Saugeen Shores is located over a high aeromagnetic anomaly on the shore of

Lake Huron. The aeromagnetic signal decreases in strength towards the northern boundary of the Town (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 Town of Saugeen Shores and surrounding area are within the region described by the centre column of Table 3.1. The Paleozoic sedimentary stratigraphy includes shale, carbonate and evaporite 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 adopts a subsurface nomenclature, while geological mapping as shown in Figures 3.2 and 3.6 use 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.

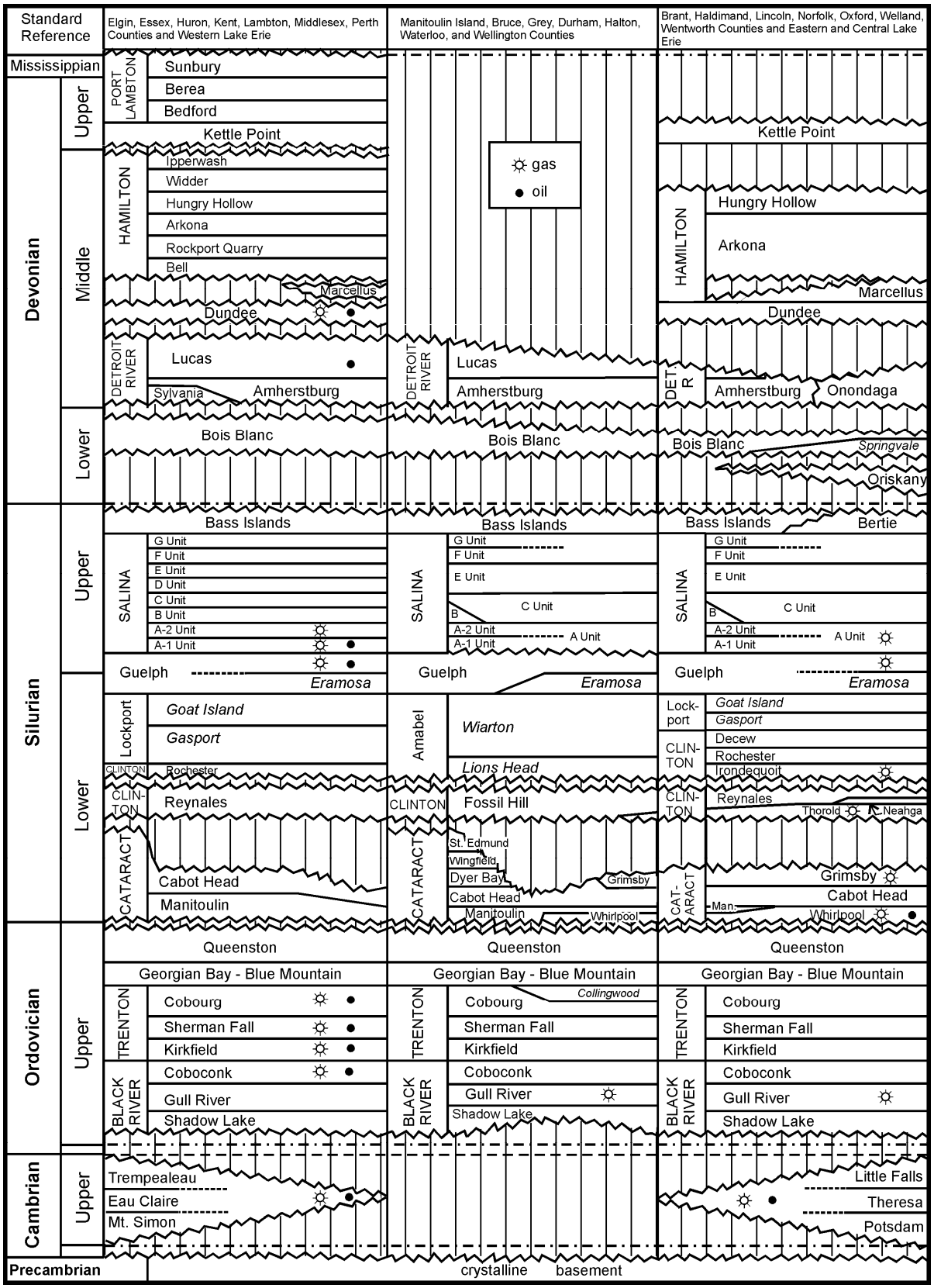
The cross-section shown in Figure 3.3 illustrates the high degree of lateral continuity of individual units within the Paleozoic sedimentary bedrock succession of southern Ontario. This cross-section also shows the uniformity of thicknesses and bedding dip magnitudes for the Upper Ordovician shale and limestone sedimentary rocks across the area.

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.

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). The Cambrian unit is present beneath the Town of Saugeen Shores based on borehole records (see Section 3.2.1) and is known to pinch out to the west of the Town (Itasca Canada and AECOM, 2011). There are no surface exposures of the Cambrian unit in southwestern Ontario.

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



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 and Cobourg 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.

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 evaporite 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). The Bois Blanc Formation is primarily a cherty dolostone unit overlain by mixed limestones and dolostones of the Detroit River Group (Amherstburg and Lucas formations). The Amherstburg Formation is a grey-brown to dark brown, fine- to coarse-grained, bituminous, bioclastic, fossiliferous, commonly cherty limestone and dolostone. Local reef development within the Amherstburg Formation is commonly also known as the Formosa Limestone. The Lucas Formation consists of brownish-grey, brown and cream, thin- to thick-bedded, fine crystalline dolostone. The Devonian carbonates crop out along the shoreline of Lake Huron and north shoreline of Lake Erie (Figure 3.2).

3.2 Local Sedimentary Bedrock Geology of the Town of Saugeen Shores

3.2.1 Stratigraphy

The bedrock geology of the Town of Saugeen Shores and surrounding area is shown in Figure 3.6. The figure also shows the location of oil and gas boreholes within the Town of Saugeen Shores and surrounding areas from the Oil, Gas and Salt Resources Library Petroleum Wells Subsurface Database (OGSRL, 2006). Review of readily available information indicates that the subsurface Paleozoic bedrock geology of the Town of Saugeen Shores is consistent with the regional geological framework described in Section 3.1.3. The Town is underlain by an Ordovician to Silurian Paleozoic sedimentary sequence that was deposited approximately 488 to 416 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:

- Two oil and gas wells within the Town (Table 3.2), (Wells #T001720A and #T001892) drilled in 1964 and 1965, respectively, that extend through the entire Paleozoic sedimentary sequence to the top of the Precambrian crystalline basement at depths of approximately 720 and 770 metres below ground surface (mBGS) (Figure 3.6).

- Oil and gas boreholes surrounding the Town of Saugeen Shores, as shown in Figure 3.6 (OGSRL, 2006).
- Six boreholes (DGR-1 to DGR-6) at the Bruce nuclear site about 12 km southwest of the Town with depths ranging from 463 to 869 mBGS (Figure 3.6), including one borehole (DGR-2) that 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.

The stratigraphy beneath the Town of Saugeen Shores, as interpreted from OGSRL Well #T001720A and Well #T001892, is shown in Table 3.3. These wells are located in close proximity, approximately 7 km apart, along the southern boundary of the Town (Figure 3.6). The type and number of individual stratigraphic units identified and described in Table 3.3 are consistent with the regional stratigraphic framework summarized in Section 3.1.3 and Table 3.1 (Armstrong and Carter, 2010). The main difference in the individual logged units between Well #T001720A and Well #T001892 is the absence of the Goat Island and Gasport formations in the log records from Well# T001720A. This may be the result of differences in geological interpretation between individual well loggers or may represent lithological variability between the two wells. The Guelph Formation is known to contain potential thick reef-type deposits in southern Ontario, which causes variations of the Silurian unit thicknesses. Variability in the well logs within the Ordovician units (Table 3.3) are likely the result of well logging interpretation differences between the Coboconk and Gull River formations. The major stratigraphic sequences are represented in both deep wells and are consistent in depth and thickness (Table 3.3).

The same Paleozoic succession encountered in the Town of Saugeen Shores was also encountered in the deep boreholes beneath the Bruce nuclear site (Intera, 2011). Based on the information from OGSRL Well #T001720A and #T001892 (Table 3.3), the total thickness of the Paleozoic strata near the southern boundary of the Town of Saugeen Shores is 655 m and 714 m, respectively. At typical repository depths (approximately 500 m), the geology of the southern limit of the Town of Saugeen Shores comprises Upper Ordovician shale and limestone units. The Upper Ordovician limestone units beneath the southern area of the Town are nearly 200 m thick, extending from 523 mBGS to 714 mBGS in Well #T001720A, and from 573 mBGS to 758 mBGS in Well #T001892. The limestone units include the Gull River, Coboconk, Sherman Fall, and Cobourg formations (Table 3.3). The Upper Ordovician shale units are cumulatively more than 200 m thick, extending from 311 mBGS to 523 mBGS in Well #T001720A, and from 358 mBGS to 573 m BGS in Well #T001892, and include the Georgian Bay/Blue Mountain, and Queenston formations. 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 depth of the Upper Ordovician shale and limestone units is expected to decrease towards the northeast corner of the Town by up to approximately 190 m. The individual Ordovician formation thicknesses are expected to remain relatively uniform across the Town (Section 3.1.3).

There is limited readily available information on the geoscientific characteristics of the Upper Ordovician shale and limestone units beneath the Town of Saugeen Shores. However, it is expected that they are very 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 that are correlative over large lateral extents as a result of their simple geometry and uniform thicknesses (NWMO, 2011). The interpreted consistency of the Ordovician sequence between Well #T001720A and #T001892 located within the Town of Saugeen Shores and the 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.

Table 3.2 Subcrop Geological Unit and Final Well Completion Unit for Oil and Gas Wells within the Town of Saugeen Shores

Well License #	Total Depth (mBGS)	Top Geological Unit (Subcrop)	Bottom Geological Unit
T001720A	719.9	Salina Formation – G Unit	Precambrian
T001892	769.0	Bass Islands Formation	Precambrian

Table 3.3 Stratigraphy Derived from Oil and Gas Exploration Wells OGSRL #T001720A (1964) and #T001892 (1965) in the Town of Saugeen Shores (Itasca and AECOM, 2011, after OGSRL, 2006)

Standard Reference		Geological Unit*	#T001720A		#T001892	
			Unit Top (mBGS)	*Unit Thickness (m)*	*Unit Top (mBGS)*	*Unit Thickness (m)*
Quaternary		Drift	3.7	61.2	0.9	44.5
Silurian	**Upper**	Bass Islands	-	-	45.4	35.1
		Salina G Unit	64.9	6.7	80.5	39.9
		Salina E Unit	71.6	15.2	120.4	32.0
		Salina C Unit	86.9	30.2	152.4	25.9
		Salina A-2 Unit	117.0	24.4	178.3	27.1
		Salina A-1 Unit	141.4	3.0	205.4	5.5
		Guelph Formation	144.5	128.6	210.9	55.8
	Lower	Goat Island Formation	-	-	266.7	20.4
		Gasport Formation	-	-	287.1	28.0
		Reynales / Fossil Hill Formation	273.1	11.0	315.2	11.0
		Cabot Head Formation	284.1	9.8	326.1	12.2
		Manitoulin Formation	293.8	17.1	338.3	20.1
Ordovician	**Upper**	Queenston Formation	310.9	54.3	358.4	59.1
		Georgian Bay / Blue Mountain Formation	365.2	157.6	417.6	155.4
		Cobourg Formation	522.7	46.7	573.0	40.3
		Sherman Fall Formation	569.4	74.3	613.3	76.2
		Coboconk Formation	643.7	5.5	689.5	68.2
		Gull River Formation	649.2	64.3	-	-
		Shadow Lake Formation	713.5	1.3	757.7	1.3
Cambrian		Cambrian	714.8	5.1	759.0	10.0
Precambrian		Precambrian	719.9		769.0	

*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).*

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 1,210 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.

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).

Table 3.4 Timetable of Major Tectonic Events in Southern Ontario

Time Interval Before Present (millions of years)	Tectonic Activity	Reference
1,210 – 1,180	Regional metamorphism (proto-Grenville)	Lumbers et al., 1990; Easton, 1992; Hanmer and McEachern, 1992
1,109 – 1,087	Magmatism and formation of Midcontinent Rift	Van Schmus, 1992
1,030 – 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

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 Town of Saugeen Shores (Figures 3.2 and 3.6). Three faults, exhibiting an east-northeast strike orientation, have been reported within an area of approximately 30 km surrounding the Town. One of these, located approximately 30 km south of the Town of Saugeen Shores, is interpreted to postdate the deposition of the Ordovician Trenton Group carbonates that occurred approximately 450 million years ago (e.g., Sutter *et al*., 1985), but predate the deposition of the overlying Upper Ordovician shales. The other two faults are interpreted to predate the deposition of the Ordovician Trenton Group carbonates. One of these lies approximately 22 km south of the municipal boundary, and the other is found approximately 24 km northeast of the Town.

In summary, three basement-seated faults are recognized within approximately 30 km of the Town of Saugeen Shores (Figure 3.2). These faults have an ancient history, which predates deposition of the Upper Ordovician 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 Town of Saugeen Shores. 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 Town of Saugeen Shores. 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 infiltrates 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). 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 Town of Saugeen Shores. Within the Town, areas of inferred karst are identified in the Bass Islands and Bertie Formations (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 deeper carbonate rock formations beneath the Town of Saugeen Shores 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 Town of Saugeen Shores. 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, which are found at typical repository depths beneath the Town of Saugeen Shores.

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 the 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 Town of Saugeen Shores and surrounding areas are illustrated in Figure 3.8. Geology mapping (Figure 3.8) shows a small area in the northern corner of the Town as exposed bedrock; however, Surficial Geology mapping from the Ontario Geological Survey (not included in this report) suggests a cover of lacustrine sand deposits in the area. Differences in mapping for Quaternary sediments may be the result, for example, of mapping scales or the use of different data sources. 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). Overlying the mapped Quaternary deposits in many areas, including the Saugeen River valley, are recent alluvial and lacustrine sediments (not mapped in Figure 3.8).

Mapping of the Quaternary deposits in the Town of Saugeen Shores shows that glacial till, forming east-west to northeast-southwest trending moraine ridges, is present in the southern third of the Town (Figure 3.8). Patchy glaciolacustrine silt and clay deposits up to 5 m thick fill depressions in the moraine surface. Glaciolacustrine sands deposited within Glacial Lake Algonquin run through the centre of the Town, parallel to the Lake Huron Shoreline. Wave-cut beach deposits up to 10 m thick are present in this area, and are described by Sharpe and Edwards (1979) as being well-sorted, stratified, pebbly beach-face gravels. Closer to the shoreline, coarser, more poorly sorted gravels are exposed in the Lake Nipissing aged bluffs. Modern lacustrine deposits characterize the narrow strip of land that runs along the shoreline of Lake Huron. Local patches of till are also mapped along the shoreline in the southwestern and northwestern corners of the Town of Saugeen Shores, in addition to a small, drumlinized area along the eastern boundary.

3.5.1 Overburden Thickness

The thickness of the Quaternary deposits in the Town of Saugeen Shores and surrounding areas is shown in Figure 3.9 (Gao et al., 2006) overburden thickness mapping. The Town of Saugeen Shores is covered by Quaternary deposits with overburden thicknesses ranging from around 2 m to approximately 157 m (derived from MOE Water Records) with the majority of the Town covered by greater than 10 m thick overburden. The thickest overburden deposits are found within the eastern half, as well as in the northern part of the Town at the mouth of the Saugeen River. Much of this area is characterized by a thick sequence of glaciolacustrine sands and beach deposits from Glacial Lake Algonquin (Sharpe and Edwards, 1979). Locally thicker areas associated with the moraine and drumlin ridges are found in the east and southeastern portions of the Town. The thinnest overburden deposits in the area, as mapped in Figure 3.9, are found in the southwestern corner of the Town of Saugeen Shores in the area of MacGregor Point Provincial Park. Wave action has eroded much of the overburden in this area and exposed till is present. An area of locally thin coverage is also found where the Saugeen River has cut a deep valley through the overlying till (Figure 3.9).

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 approximately 10 km south of Saugeen Shores, 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, which 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 the Town of Saugeen Shores. The study found no evidence for neotectonic activity associated with the most recent glacial cycle approximately 25,000 years ago (Slattery, 2011).

In summary, no neotectonic structural features are known to occur in the Town of Saugeen Shores. This would need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

3.7 Seismicity

The Town of Saugeen Shores 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). Earthquakes in the region around the Town of Saugeen Shores are concentrated in the area offshore in Georgian Bay and to a lesser extent offshore Lake Huron approximately 20 km northeast for the Town of Saugeen Shores (Figure 3.11).

In summary, available literature and recorded seismic events indicate that the Town of Saugeen Shores is located within a region of low seismic hazard. Low magnitude earthquakes have been recorded at distance of 20 km and greater away from the Town.

4. Hydrogeology

4.1 Groundwater Wells

Information on groundwater in the Town of Saugeen Shores was obtained from the Ontario Ministry of the Environment (MOE) Water Well Record Database. The location of known water wells are shown on Figure 4.1. The Town of Saugeen Shores is supplied by the Saugeen Shores Water System (Saugeen, Grey Sauble, Northern Bruce Peninsula, 2011). This system is supplied by two Lake Huron water intakes (one serves as a backup for emergencies) and a water treatment plant (WTP) located in Southampton. No municipal drinking water systems that use groundwater are reported in the Town; however groundwater wells are used for individual potable supply in rural areas. The WTP intake protection zone has an onshore area of 6.8 km^2, which 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 342 water well records for the Town of Saugeen Shores (Figure 4.1). Of these 342 well records, 8 records contained information only on well location and provided no data on well type, depth, or hydrogeological conditions. A summary of the 334 wells 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	116	4.6	157.0	0.30	49.1	0.2	12.2	3.8
Bedrock	218	6.7	182.9	-9.1	48.8	0.9	30.5	4.1

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 Town of Saugeen Shores. Of the 342 well records found for the Town of Saugeen Shores, 116 wells were completed in overburden aquifers and 218 wells were completed in bedrock aquifers (Table 4.1). Wells completed within the overburden range in depths from approximately 5 to 157 m. Overburden well yields range from 0 to 12 L/min, with mean values of 3.8 L/min. Wells completed in the bedrock range in depth from approximately 7 to 183 m. Bedrock well yields range from 1 to 31 L/min, with mean values of 4.1 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 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 Town of Saugeen Shores. However, as described in Section 3.2.1, there is a high degree of lateral continuity and predictability of the Upper Ordovician shale and limestone units across this part of southern Ontario. This suggests that the hydrogeological setting at depth beneath the Town of Saugeen Shores 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 of the Upper Ordovician

shale and limestone units (approximately 10^{-15} to 10^{-10} m/s). 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 Town of Saugeen Shores. In addition, at typical repository depths the Upper Ordovician shale and limestone units exhibit very low hydraulic conductivites, 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 Town of Saugeen Shores. 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 brines 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 Town of Saugeen Shores. Oil and gas exploration wells, known pools and mapped oil and gas pipelines are shown in Figure 3.6. There are three known oil and gas pools in the area surrounding the Town, hosted within Ordovician and Silurian aged formations (Figure 3.6). The Hepworth Pool, hosted in Ordovician aged formations, is located approximately 20 km northeast of Saugeen Shores. The Ashfield 5-IX WD Silurian pool and the Egremont Ordovician pool are both located greater than 50 km from the Town of Saugeen Shores to the south and south east (Figure 3.6).

Historic exploration in the region around the Town of Saugeen Shores typically focused on Upper Ordovician and Silurian units as potential hydrocarbon plays (e.g., Sanford, 1993; Hamblin, 2008; Lazorek and Carter, 2008). Two exploration wells have been documented in the Town of Saugeen Shores in the Oil, Gas and Salt Resources Library (OGSRL) Petroleum Wells Subsurface Database (OGSRL, 2006). These wells resulted in dry holes with no production potential and have been abandoned. The absence of oil and gas plays in the Town of Saugeen Shores 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 gas plays, Wells #T001720A and #T001892 within the Town of Saugeen Shores did intersect Cambrian (5.1 m and 10.0 m thick) and Shadow Lake (1.3 m thick) deposits (Table 3.3), but no commercial or active hydrocarbon plays were reported and the wells were abandoned. The absence of such types of plays would need to be confirmed during subsequent site evaluation stages. An analysis of the shale gas potential for the Bruce nuclear site, located 12 km to the southwest of the Town of Saugeen Shores, found that insufficient total organic content of the Ordovician shales, as well as insufficient thermal maturity, would preclude any likelihood of commercial gas accumulations in these units (Engelder, 2011).

In summary, no hydrocarbon pools have been identified within the Town of Saugeen Shores. The potential for historical and new conceptual hydrocarbon plays in the Town of Saugeen Shores 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 Town of Saugeen Shores. 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 Town of Saugeen Shores is limited to sand and gravel resources (Figure 5.1).

5.3.1 Sand and Gravel

Sand and gravel pits in the Town of Saugeen Shores generally correspond to glaciolacustrine plain and beach 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 Town of Saugeen Shores was 364,529 tonnes or approximately 16% 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 Town of Saugeen Shores was assigned a primary significance; this comprises the currently operating pits that are located in the west-central portion of the town, through the community of Port Elgin, extending along the Glacial Lake Algonquin beach complex (Figure 5.1). Roswell (2012) estimates that 23.7 million tonnes of aggregate may still be available for extraction in this area. No areas of secondary significance are found within the Town. The possibility of several areas of tertiary significance existing within the Town of Saugeen Shores, consisting of aggregate resources buried by younger sediments, is mentioned in Roswell, 2012.

5.3.2 Bedrock Resources

There are no known licensed bedrock quarries or commercial mining operations within the Town of Saugeen Shores (Figure 5.1). Figure 5.1 shows the licensed quarries located north of the Town of Saugeen Shores towards Owen Sound and the Bruce Peninsula.

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 Town of Saugeen Shores is covered by greater than 8 m of Quaternary sediments (Figure 3.9). Those areas with thin overburden or outcrop are associated with river valleys and contain no unique bedrock resources with respect to aggregate, cement or building stone.

There are no known commercial salt resources located in the Town of Saugeen Shores. The Salina 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 Town of Saugeen Shores 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 Town of Saugeen Shores from further consideration in the site evaluation process. The initial screening focused on the areas within the boundaries of the Town of Saugeen Shores. At the request of the Town, the areas west of Highway 21 were not included in the initial screening. The Council wishes to preserve those areas for future expansion. Other areas which Council may identify for future expansion would be considered during subsequent site evaluation stages if the Town of Saugeen Shores remains interested in the site selection process. 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 Town of Saugeen Shores 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. It is important to note that the purpose of this assessment is not to identify specific siting areas. It is rather to identify whether there are obvious space constraints that would prevent the development of a repository within the Town.

The Town of Saugeen Shores is a relatively small municipality approximately 174 km^2 in size. As mentioned earlier in the report, the initial screening focussed on the area east of Highway 21 (Figure 2.1), which has a surface area of approximately 131 km^2. The area west of Highway 21 was not included in the initial screening at the request of the Town. The Council wishes to preserve those areas for future expansion.

The main land constraints and protected areas located east of Highway 21 are shown in Figures 2.1 and 2.2. They include parts of the settlement areas of Port Elgin and Southampton (approximately 10 km^2), parts of the hamlets of Burgoyne and North Bruce (less than 1 km^2), the Saugeen Bluffs Conservation Area (approximately 2 km^2), and the Saugeen River. There remains sufficient land area outside of these constraints to potentially accommodate the surface and underground footprints of the repository (approximately 1 km^2 and 3.75 km^2, respectively). Most of the Town of Saugeen Shores could be accessed from Highway 21 and the numerous subsidiary county and rural roads which cross the area (Figure 2.1).

As discussed in Section 6.5, readily available information suggests that the Town of Saugeen Shores 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.

At this early stage of the site evaluation process, despite its relatively small size, the Town of Saugeen Shores appears to contain sufficient areas to accommodate the repository's surface and underground facilities. Land availability and the feasibility of locating a repository within the Town would be further assessed during subsequent stages of the evaluation process if the Town of Saugeen Shores continues to be interested in the site selection process.

Based on the review of readily available information, the Town of Saugeen Shores 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 Town of Saugeen Shores 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.

There is one provincial park, one conservation area, and one provincially significant wetland within the Town of Saugeen Shores (Figure 2.1). The Saugeen Bluffs Conservation Area is located in the southeastern corner of the Town and is approximately 2 km^2 in size. The MacGregor Point Provincial Park and the MacGregor Point Wetland Complex are situated in the southwestern corner of the Town, along the shoreline of Lake Huron, in the area west of Highway 21 not included in this initial screening.

As discussed in Section 2.4, there are 10 documented archeological sites within the Town of Saugeen Shores. These sites are small in size and generally concentrated around water features such as lakes and rivers and the settlement areas of Port Elgin and Southampton (Figure 2.1). There are no National Historic Sites in the Town of Saugeen Shores.

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 Town of Saugeen Shores 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 Town of Saugeen Shores. 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 Town of Saugeen Shores or the surrounding areas (Section 4.1). All water wells known in the Town of Saugeen Shores obtain water from overburden or shallow bedrock sources at depths ranging from 5 to 183 m.

As discussed in section 4.2, the potential for groundwater resources at the typical repository depth beneath the Town of Saugeen Shores 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 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 Town of Saugeen Shores. Experience in similar geological settings in the region suggests that the potential for deep groundwater resources at repository depths is extremely low beneath the Town of Saugeen Shores. 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, and 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 Town of Saugeen Shores. Two historic exploration wells drilled within the Town of Saugeen Shores for hydrocarbon exploration resulted in dry holes with no production. New conceptual hydrocarbon plays are identified for southern Ontario by Hamblin (2008), including Upper Ordovician shale gas. An assessment of the shale gas potential at the Bruce nuclear site (located 12 km to the southwest of the Town of Saugeen Shores) found that the likelihood of commercial gas accumulation in the Ordovician shale is very low because of their low organic content and insufficient thermal maturity. Given the proximity of the Bruce nuclear site and the consistency of the regional geological setting, the presence of commercial gas accumulations in the Ordovician shales beneath the Town of Saugeen Shores is also unlikely. The presence or absence of historical 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 Town of Saugeen Shores. There is no record of metallic mineral production in the past. No exploration potential for metallic minerals has been identified within the Town.

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 Town of Saugeen Shores is limited to sand and gravel resources (Section 5.3). However, 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 Town of Saugeen Shores 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 Town of Saugeen Shores, 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 Town 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 Town of Saugeen Shores 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 bedrock geology of the Town of Saugeen Shores is consistent with the regional geological framework. The Town is entirely underlain by a predictable and laterally extensive Paleozoic sedimentary sequence that was deposited approximately 488 to 416 million years ago.

Based on information from historic oil and gas exploration wells within the Town (Wells #T001720A and #T001892, Table 3.3), the total thickness of the Paleozoic strata near the southern boundary of the Town of Saugeen Shores is 655 m and 714 m, respectively. The well data show that at depths that are typically considered for deep geological repositories (approximately 500 m), the geology near the southern boundary of the Town of Saugeen shores comprises Upper Ordovician shale and limestone units. In the northeastern portion of the Town of Saugeen Shores, the geology at repository depths is expected to comprise Upper Ordovician limestones. The Ordovician limestone units are cumulatively more than 200 m thick and are overlain by nearly 200 m of Upper Ordovician shale (Section 3.2). Formation thicknesses are expected to remain uniform within the Town.

While there is limited information on the geoscientific characteristics of the Upper Ordovician shale and limestone units beneath the Town of Saugeen Shores, it is expected that they are very 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. Given their depth, thickness and lateral extent, the Upper Ordovician shale and limestone units would potentially provide a sufficient volume of potentially suitable rock to physically host a deep geological repository for used nuclear fuel.

Given the regional consistency of the geological setting, the hydrogeological and hydrogeochemical conditions at typical repository depth beneath the Town of Saugeen Shores are expected to be similar to those beneath the Bruce nuclear site (Section 4.2). The deep groundwater regime within the Upper Ordovician shale and limestone 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 (Section 4.2). No faults are mapped in the Paleozoic sedimentary sequence beneath the Town of Saugeen Shores (Figure 3.2).

The isolated nature of the deep groundwater system is further 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 Town of Saugeen Shores 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 at typical repository depths beneath the Town of Saugeen Shores 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 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 Town of Saugeen Shores, such as the mineralogy of the rock, the geochemical composition of the groundwater and rock porewater, the potential for paleokarst, 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 Town of Saugeen Shores. As discussed below, the review of readily available information did not reveal any obvious characteristics that would raise such concerns.

The Town of Saugeen Shores 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). No mapped basement faults have been identified in the Town of Saugeen Shores.

The geology of the Town of Saugeen Shores 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 unaltered 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 the Town of Saugeen Shores. 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). 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).

As discussed in Section 4.3, an analysis of the regional geochemical database found no geochemical evidence for the infiltration of glacial or recent meteoric recharge water into the Upper Ordovician shale or limestone formations beneath the Bruce nuclear site.

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 Town of Saugeen Shores. 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 very low, and that there are no known economically exploitable natural resources in the Town of Saugeen Shores. The potential for hydrocarbon plays would have to be further examined during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

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 Town of Saugeen Shores, there is abundant information at other locations of southern Ontario that could provide insight into what could be expected for the Town of Saugeen Shores. Available information on strength and in-situ stresses suggests that the Upper Ordovician shale and limestone units have favourable 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) and shale (Georgian Bay Formation) units were 113 MPa and 32 MPa, respectively at the Bruce nuclear site. These values 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 Town of Saugeen Shores did not reveal any conditions that would make the rock mass difficult to characterize. As discussed in Section 3, the sedimentary sequence beneath the Town of Saugeen Shores is 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 Town of Saugeen Shores is covered by Quaternary overburden deposits. As described in Section 3.5, overburden thickness in the Town ranges up to approximately 157 m. The regional geological framework, the simple geometry and the predictability of the subsurface stratigraphic formations indicates that the thickness of the overburden cover is not likely to affect the ability to characterize the subsurface bedrock formations beneath the Town of Saugeen Shores.

In summary, the review of readily available geological and geomechanical information for the Town of Saugeen Shores (Section 3) did not indicate any obvious conditions which would make construction or characterization activities unusually difficult.

Based on the review of available geological and hydrogeological information, the Town of Saugeen Shores 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 Town of Saugeen Shores against five initial screening criteria using readily available information. The initial screening focused on the areas within the boundaries of the Town of Saugeen Shores. At the request of the Town, the areas west of Highway 21 were not included in the initial screening. The Council wishes to preserve those areas for future expansion. Other areas which Council may identify for future expansion would be considered during subsequent site evaluation stages if the Town of Saugeen Shores remains interested in the site selection process. Areas within neighbouring municipalities were not included in the initial screening.

As outlined in the 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 economically exploitable 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 Town of Saugeen Shores from being further considered in the NWMO site selection process. The initial screening indicates that there are geological formations within the boundaries of the Town 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 Town 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 Town of Saugeen Shores, but rather to identify whether there are any obvious conditions that would exclude it from the site selection process. Should the community of Saugeen Shores 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 Town of Saugeen Shores 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.

8. References

Armstrong, D.K. and T.R. Carter, 2006:
An Updated Guide to the Subsurface Paleozoic Stratigraphy of Southern Ontario. Ontario Geological Survey, Open File Report 6191.

Armstrong, D.K. and T.R. Carter, 2010:
The Subsurface Paleozoic Stratigraphy of Southern Ontario. Ontario Geological Survey, Special Volume 7.

Armstrong, D.K. and W.R. Goodman, 1990:
Stratigraphy and depositional environments of Niagaran carbonates, Bruce Peninsula, Ontario. Field Trip No. 4 Guidebook. American Association of Petroleum Geologists, 1990 Eastern Section Meeting, hosted by the Ontario Petroleum Institute. London, Ontario.

Bailey Geological Services Ltd. and R.O. Cochrane, 1984:
Evaluation of the conventional and potential oil and gas reserves of the Cambrian of Ontario. Ontario Geological Survey, Open File Report 5499.

Barnett, P.J., 1992:
Quaternary geology of Ontario. In: Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, 1008-1088.

Boyce, J.J. and W.A. Morris, 2002:
Basement-controlled faulting of Paleozoic strata in southern Ontario, Canada. New evidence from geophysical lineament mapping. Tectonophysics, 353, 151-171.

Brigham, R.J., 1971:
Structural geology of southwestern Ontario and southeastern Michigan. Ontario Department of Mines and Northern Affairs Paper 71-2.

Bruce County Official Plan, 2011:
County of Bruce Official Plan. Printed August 26, 2011. http://www.brucecounty.on.ca/assets/departments/planning/files/County%20Documents/County%20Plan_Consolidated_Public_Aug%202011.pdf.

Brunton, F.R. and J.E.P. Dodge, 2008:
Karst of southern Ontario and Manitoulin Island. Ontario Geological Survey, Groundwater Resources Study 5.

Canadian Aeromagnetic Data Base, 2011:
Aeromagnetic Data Base, Airborne Geophysics Section, GSC – Central Canada Division, Geological Survey of Canada, Earth Sciences Sector, Natural Resources Canada. (http://gdcinfo.agg.nrcan.gc.ca/contact_e.html#DataCentre)

Canadian Geodetic Information System, 2011:
Gravity and Geodetic Networks Section, Geodetic Survey Division, Geomatics Canada, Earth Sciences Sector, Natural Resources Canada. (http://gdcinfo.agg.nrcan.gc.ca/contact_e.html#DataCentre)

Carr, S.D., R.M. Easton, R.A. Jamieson and N.G. Culshaw, 2000:
Geologic transect across the Grenville Orogen of Ontario and New York. Canadian Journal of Earth Sciences 37(2-3), 193–216.

Carter T.R., R.A. Treveil and R.M. Easton, 1996:
Basement controls on some hydrocarbon traps in southern Ontario, Canada. In: B.A. van der Pluijm and P.A. Catacosinos (eds.), Basement and Basins of Eastern North America. Geological Society of America Special Paper 308, 95-107.

Carter, T.R. and R.M. Easton, 1990:
Extension of Grenville basement beneath southwestern Ontario: lithology and tectonic subdivisions. In: Carter, T.R. (ed.), Subsurface Geology of Southwestern, a Core Workshop, America Association of Petroleum Geologists, 1990 Eastern Section Meeting. Ontario Petroleum Institute, London, Ontario.

Chapman, L.J. and D.F. Putnam, 1984 (2007 Digitized):
The Physiography of Southern Ontario. Ontario Geological Survey, Special Volume 2, 270 pp. Accompanied by Map P.2715 (coloured), scale 1:600 000.

Coniglio M. and A.E. William-Jones, 1992:
Diagenesis of Ordovician carbonates from the north-east Michigan Basin, Manitoulin Island area, Ontario: Evidence from petrography, stable isotopes and fluid inclusions. Sedimentology 39, 813-836.

Coniglio, M., M.J. Melchin and M.E. Brookfield, 1990:
Stratigraphy, sedimentology and biostratigraphy of Ordovician rocks of the Peterborough–Lake Simcoe area of southern Ontario; American Association of Petroleum Geologists, 1990 Eastern Section Meeting, hosted by Ontario Petroleum Institute, Field Trip Guidebook no.3. London, Canada.

Earthquakes Canada:
GSC, Earthquake Search (On-line Bulletin), http://earthquakescanada.nrcan.gc.ca/stndon/NEDB-BNDS/bull-eng.php, Nat. Res. Can., Feb. 2012.

Easton, R.M., 1992:
The Grenville Province and the Proterozoic history of central and southern Ontario. In: The Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, 714-904.

Engelder, T. and P. Geiser, 1980:
On the use of regional joint sets as trajectories of paleostress fields during the development of the Appalachian plateau, New York. Journal of Geophysical Research 85(B11), 6319-6341.

Engelder, T., 2011:
Analogue Study of Shale Cap Rock Barrier Integrity. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-23 R000. Toronto, Canada.

Gao, C., J. Shirota, R.I. Kelly, F.R. Brunton and S. van Haaften, 2006:
Project Unit 05-013; bedrock topography and overburden thickness mapping, southern Ontario. Ontario Geological Survey, Miscellaneous Release—Data 207. ISBN 1-4249-2550-9.

Golder, 2003:
LLW Geotechnical Feasibility Study, Western Waste Management Facility, Bruce Site, Tiverton, Ontario. Report to Municipality of Kincardine and Ontario Power Generation. Golder Associates Ltd, Technical Report 021-1570.

Gross, M.R., T. Engelder and S.R. Poulson, 1992:
Veins in the Lockport dolostone: evidence for an Acadian fluid circulation system. Geology 20, 971-974.

Government of Ontario, 1997:
Conserving a Future for Our Past: Archaeology, Land Use Planning & Development in Ontario. Toronto: Ministry of Citizenship, Culture and Recreation, Archaeology and Heritage Planning Unit.

Hallet, B., 2011:
Glacial Erosion Assessment. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-18 R000. Toronto, Canada.

Hamblin, A., 1999:
Upper Ordovician strata of southwestern Ontario: Synthesis of literature and concepts. Geological Survey of Canada, Open File 3729.

Hamblin, A., 2003:
Detailed outcrop and core measured sections of the Upper Ordovician/Lower Silurian succession of southern Ontario. Geological Survey of Canada, Open File 1525.

Hamblin, A., 2008:
Hydrocarbon potential of the Paleozoic succession of southwestern Ontario. Preliminary conceptual synthesis of background data. Geological Survey of Canada, Open File 5730.

Hanmer, S. and S.J. McEachern, 1992:
Kinematical and rheological evolution of a crustal-scale ductile thrust zone, Central Metasedimentary Belt, Grenville Orogen, Ontario. Canadian Journal of Earth Sciences 29, 1779-1790.

Hobbs, M.Y., A. deHaller, M. Koroleva, M. Mazurek, J. Spangenberg, U. Mäder and D. Meier, 2011:
Regional Hydrogeochemistry – Southern Ontario. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-12 R000. Toronto, Canada.

Howell, P.D. and B.A. van der Pluijm, 1999:
Structural sequences and styles of subsidence in the Michigan basin. Geological Society of America Bulletin 111, 974-991

Intera, 2011:
Descriptive Geosphere Site Model. Intera Engineering Ltd. report for the Nuclear Waste Management Organization NWMO DGR-TR-2011-24 R000. Toronto, Canada.

Itasca Canada and AECOM, 2011:
Three-Dimensional Geological Framework Model. Itasca Consulting Canada, Inc. and AECOM Canada Ltd. report for the Nuclear Waste Management Organization NWMO DGR-TR-2011-42 R000. Toronto, Canada.

Johnson, M.D., D.K. Armstrong, B.V. Sanford, P.G. Telford and M.A. Rutka, 1992:
Paleozoic and Mesozoic geology of Ontario. In: The Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, 907-1008.

Karrow, P.F., 1974:
Till Stratigraphy in parts of Southwestern Ontario. Geological Society of America Bulletin 85, 761-768.

Kesler, S.E. and C.W. Carrigan, 2002:
Discussion on "Mississippi Valley-type lead-zinc deposits through geological time: implications from recent age-dating research" by D.L. Leach, D. Bradley, M.T. Lewchuk, D.T.A. Symons, G. de Marsily, and J. Brannon (2001). Mineralium Deposita 36, 711-740.

Kumarapeli, P.S., 1976:
The St. Lawrence rift system, related metallogeny, and plate tectonic models of Appalachian evolution, 301 - 320. In D.F. Strong (Ed.), Metallogeny and Plate Tectonics. Geological Association of Canada, Special Paper 14.

Kumarapeli, P.S., 1985:
Vestiges of lapetan Rifting in the Craton West of the Northern Appalachians Geoscience Canada, 12, Number 2.

Lazorek, M. and T. Carter, 2008:
The Oil and Gas Plays of Ontario. Ontario Oil and Gas 2008 Edition. Ontario Petroleum Institute. London, Canada.

Lumbers, S.B., L.M. Heaman, V.M. Vertolli and T.W. Wu, 1990:
Nature and timing of middle Proterozoic magmatism in the Central Metasedimentary Belt, Grenville Province, Ontario. Special Paper- Geological Association of Canada 38, 243-276.

Marshak, S. and J.R. Tabor, 1989:
Structure of the Kingston Orocline in the Appalachian fold-thrust belt, New York, Geological Society of America Bulletin 101, 683-701.

Marshak, S. and T. Paulsen, 1996:
Mid-continent U.S. fault and fold zones: A legacy of Proterozoic intracratonic extensional tectonism? Geology 24, 151–154.

Mazurek, M., 2004:
Long-term Used Nuclear Fuel Waste Management - Geoscientific Review of the Sedimentary Sequence in Southern Ontario. Institute of Geological Sciences University of Bern Technical Report TR 04-01, Switzerland.

McFall, G.H., 1993:
Structural Elements and Neotectonics of Prince Edward County, Southern Ontario. Géographie physique et Quaternaire 47, 303-312.

McWilliams, C.K., R.P. Wintsch and M.J. Kunk, 2007:
Scales of equilibrium and disequilibrium during cleavage formation in chlorite and biotite-grade phyllites, SE Vermont. Journal of Metamorphic Geology 25, 895-913.

Milkereit B., D.A. Forsyth, A.G. Green, A. Davidson, S. Hanmer, D.R. Hutchinson, W. Hinze and R.F. Mereu, 1992:
Seismic images of a Grenvillian terrane boundary. Geology 20, 1027-1030

Natural Resources Canada, 2012:
Earthquake Map of Canada, 1627-2010. http://www.earthquakescanada.nrcan.gc.ca/historic-historique/caneqmap-eng.php

Natural Resources Canada Centre for Topographic Information – Sherbrooke (CTI-S):
Geobase Orthoimage 2005-2010. Spot 5, Obtained from Geobase (2006, 10 m resolution.

NWMO, 2005:
Choosing a way forward: The future management of Canada's used nuclear fuel. Nuclear Waste Management Organization. (Available at www.nwmo.ca)

NWMO, 2010:
Moving Forward Together: Process for Selecting a Site for Canada's Deep Geological Repository for Used Nuclear Fuel, Nuclear Waste Management Organization, May 2010. (Available at www.nwmo.ca)

NWMO, 2011:
OPG's Deep Geological Repository for Low and Intermediate Level Waste: Geosynthesis. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-11 R000. Toronto, Canada.

NWMO and AECOM, 2011:
Regional Geomechanics – Southern Ontario. AECOM Canada Ltd. and Nuclear Waste Management Organization Report NWMO DGR-TR-2011-13 R000. Toronto, Canada.

Ontario Geological Survey, 1993:
Bedrock geology, seamless coverage of the province of Ontario; Ontario Geological Survey, Data Set 6.

Ontario Geological Survey, 1997:
Quaternary geology, seamless coverage of the province of Ontario: Ontario Geological Survey, Data Set 14.

Ontario Ministry of the Environment, 2012:
Well Records. http://ww.ene.gov.on.ca/environment/en/subject/wells/STDPROD_075977.html. 2012.

Ontario Ministry of Natural Resources, 2009:
Land Information Ontario Data Warehouse (LIO). Available from: http://www.mnr.gov.on.ca/en/Business/LIO. June 2009.

Ontario Ministry of Tourism, Culture and Sport, undated:
Ministry Cultural Services Unit, Ontario Archaeological Sites Database, Accessed: March 2012.

Ontario Oil, Gas and Salt Resources Library (OGSRL), 2006:
Oil and Gas Pools and Pipelines of Southern Ontario, revised October 2006. Petroleum Resources Centre, Ministry of Natural Resources Oil, Gas & Salt Resources Library UTM NAD83. Ontario Digital Base Data.

Peltier, W.R., 2002:
A design basis glacier scenario. Ontario Power Generation Report 06819-REP-01200-10069-R00. Toronto, Canada.

Peltier, W.R., 2011:
Long-Term Climate Change. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-14 R000. Toronto, Canada.

Percival, J.A. and R.M. Easton, 2007:
Geology of the Canadian Shield in Ontario. An Update. OPG Report No. 06819-REP-01200-10158-R00, OGS Open File Report 6196, GSC Open File Report 5511.

Provincial Policy Statement, 2005:
Provincial Policy Statement. Approved by the Lieutenant Governor in Council, Order in Council No. 140/2005. Issued under Section 3 of the *Planning Act*.
http://www.brucecounty.on.ca/assets/departments/planning/files/County%20Documents/PPS-2005.pdf.

Quinlan, G. and C. Beaumont, 1984:
Appalachian thrusting, lithospheric flexure and the Paleozoic stratigraphy of the Eastern Interior of North America. Canadian Journal of Earth Sciences 21, 973-996.

Rowell, D.J., 2012:
Aggregate Resources Inventory of the County of Bruce, Southern Ontario. Ontario Geological Survey Aggregate Resources Inventory Paper 190, 112 pages.

Sanford, B.V., 1993:
St. Lawrence Platform: economic geology. In: Stott, D.F. and J.D. Aitken (Eds.), Sedimentary Cover of the Craton in Canada, Geological Survey of Canada, Geology of Canada Series, no.5, 787-798.

Sanford, B.V., F.J. Thompson and G.H. McFall, 1985:
Plate tectonics – A possible controlling mechanism in the development of hydrocarbon traps in southwestern Ontario. Bulletin of Canadian Petroleum Geology 33, 52-71.

Sangster, D.F. and B.A. Liberty, 1971:
Sphalerite concretions from Bruce Peninsula, Southern Ontario, Canada. Economic Geology 66, 1145-1152.

Saugeen, Grey Sauble, Northern Bruce Peninsula, 2011:
Assessment Report - Saugeen Valley Source Protection Area. Approved November 28, 2011. http://www.waterprotection.ca/AR/SVSPA/SVSPA_Approved_AR_Complete_Text.pdf.

Sharpe, D.R. and Edwards, W.A.D, 1979:
Quaternary Geology of the Chesley-Tiverton Area, Southern Ontario. Ontario Geological Survey Preliminary Map P.2314, Geological Series. 1:50,000.

Slattery, S., 2011:
Neotectonic Features and Landforms Assessment. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-19 R000. Toronto, Canada.

Sloss, L.L., 1982:
The Michigan Basin: Selected structural basins of the Midcontinent, USA. UMR Journal 3, 25-29.

Sutter, J.F., N.M. Ratcliffe and S.B. Mukasa, 1985:
40Ar/39Ar and K-Ar data bearing on the metamorphic and tectonic history of western New England. Geological Society of America Bulletin 96, 123-136.

Thomas, W.A., 2006:
Tectonic inheritance at a continental margin. GSA Today 16(2), 4-11.

Town of Saugeen Shores, 2006:
Local Official Plan. http://www.saugeenshores.ca/downloads/municipal/OP_2007_Full.pdf

Uyeno, T.T., P.G. Telford and B.V. Sanford, 1982:
Devonian conodonts and stratigraphy of southwestern Ontario. Geological Survey of Canada, Bulletin 332.

Van Schmus, W.R., 1992:
Tectonic setting of the Midcontinent Rift system. Tectonophysics 213, 1-15.

Walker, J.D. and J.W. Geissman, compilers, 2009:
Geologic Time Scale: Geological Society of America, doi: 10.1130/2009.CTS004R2C.

White, D.J., D.A. Forsyth, I. Asudeh, S.D. Carr, H. Wu, R.M. Easton and R.F. Mereu, 2000:
A seismic-based cross-section of the Grenville Orogen in southern Ontario and western Quebec. Canadian Journal of Earth Sciences 37, 183–192.

Worthington, 2011:
Karst Assessment. Worthington Groundwater report for the Nuclear Waste Management Organization NWMO DGR-TR-2011-22 R000. Toronto, Canada.

Ziegler, K. and F.J. Longstaffe, 2000:
Clay mineral authigenesis along a mid-continent scale fluid conduit in Palaeozoic sedimentary rocks from southern Ontario, Canada. Clay Minerals 35, 239-260.

Figures

Lake Huron

Saugeen First Nation

Chesley Lake Complex

Denny's Dam

Sangs Creek

Arran

Arran Lake

Arran Lake Wetland Complex

Arkwright Drumlins

Southampton

Highway 21

Burgoyne

Port Elgin

Saugeen Shores

MacGregor Point Provincial Park

MacGregor Point Wetland Complex

Mill Creek

North Bruce

Brucedale

Scott Point

Dunblane

Saugeen River

Willsicroft Moraine

Saugeen Bluffs Conservation Area

Elderslie Swamp Wetland Complex

Lockerby

475000

4925000

4926000

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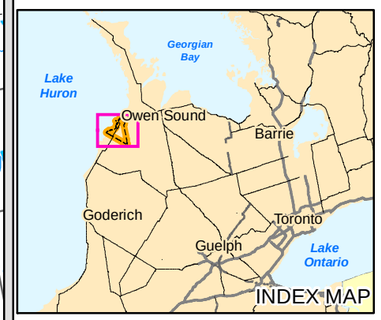
Legend

- Town of Saugeen Shores
- Municipal Division
- Highway
- Major Road
- Local Road
- Railway
- Intermittent Stream
- Permanent Stream
- Waterbody
- Cartographic Wetland
- Conservation Areas
- NGO Nature Reserve
- Regulated Provincial Park
- First Nations Land
- Provincially Significant Life Science ANSI
- Provincially Significant Earth Science ANSI
- Provincially Significant Wetland
- Locally Significant Wetland

2.5 km × 1.5 km — Repository Underground Footprint



Cultural Resource Data: Ontario Archaeological Sites Database
Basemapping, ANSIs and Parks data from Ontario Ministry of Natural Resources
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	12 Sept 2012
Approved	RF	12 Sept 2012

N, W, E, S

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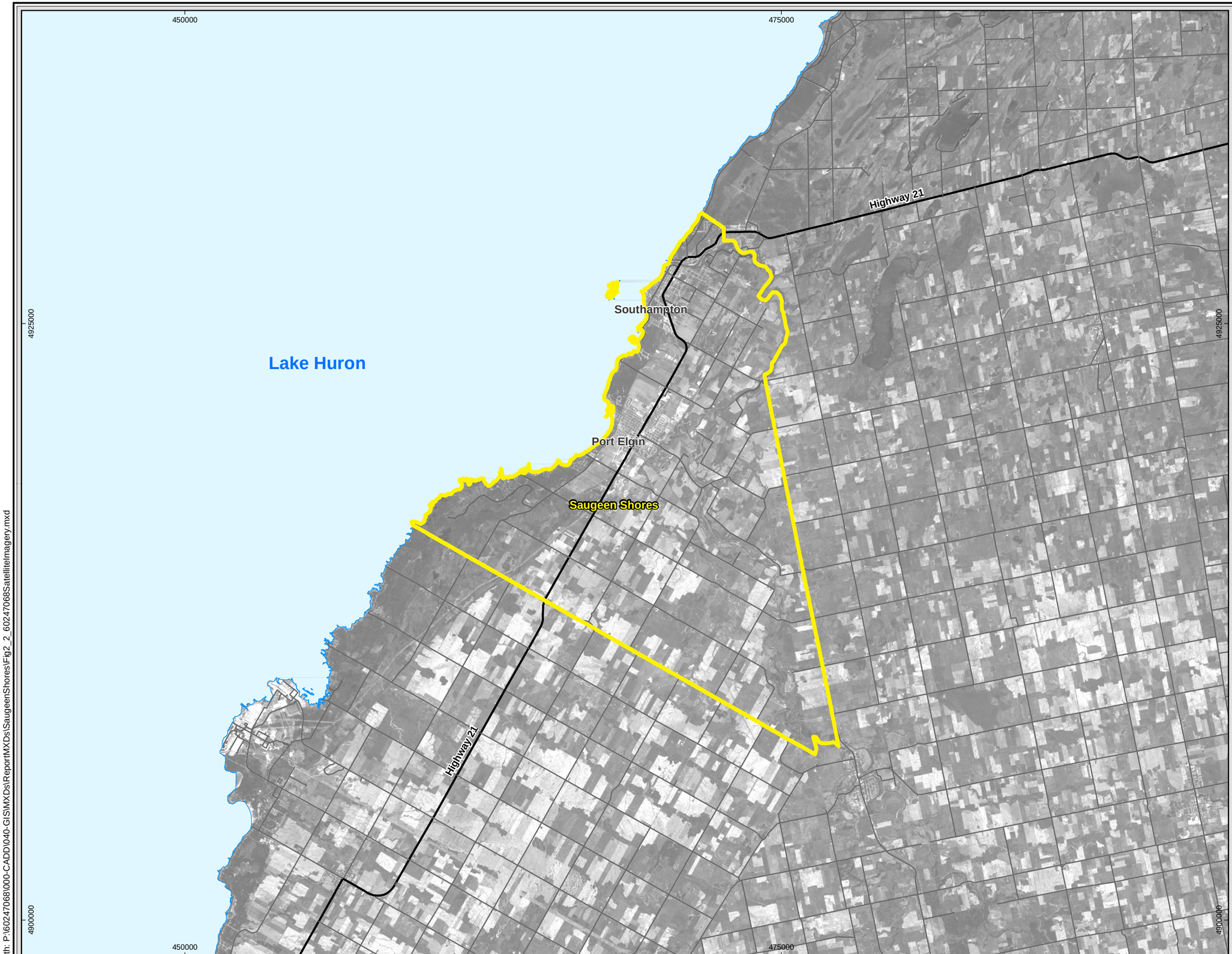
NWMO Desktop Level Initial Screening

Town of Saugeen Shores and Surrounding Area

September 2012
Project 60247068

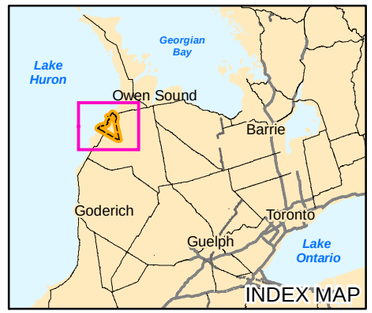
AECOM

Figure 2.1



Legend

- Town of Saugeen Shores
- 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	14 Aug 2012
Approved	RF	14 Aug 2012

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S

Kilometers
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NWMO Desktop Level Initial Screening

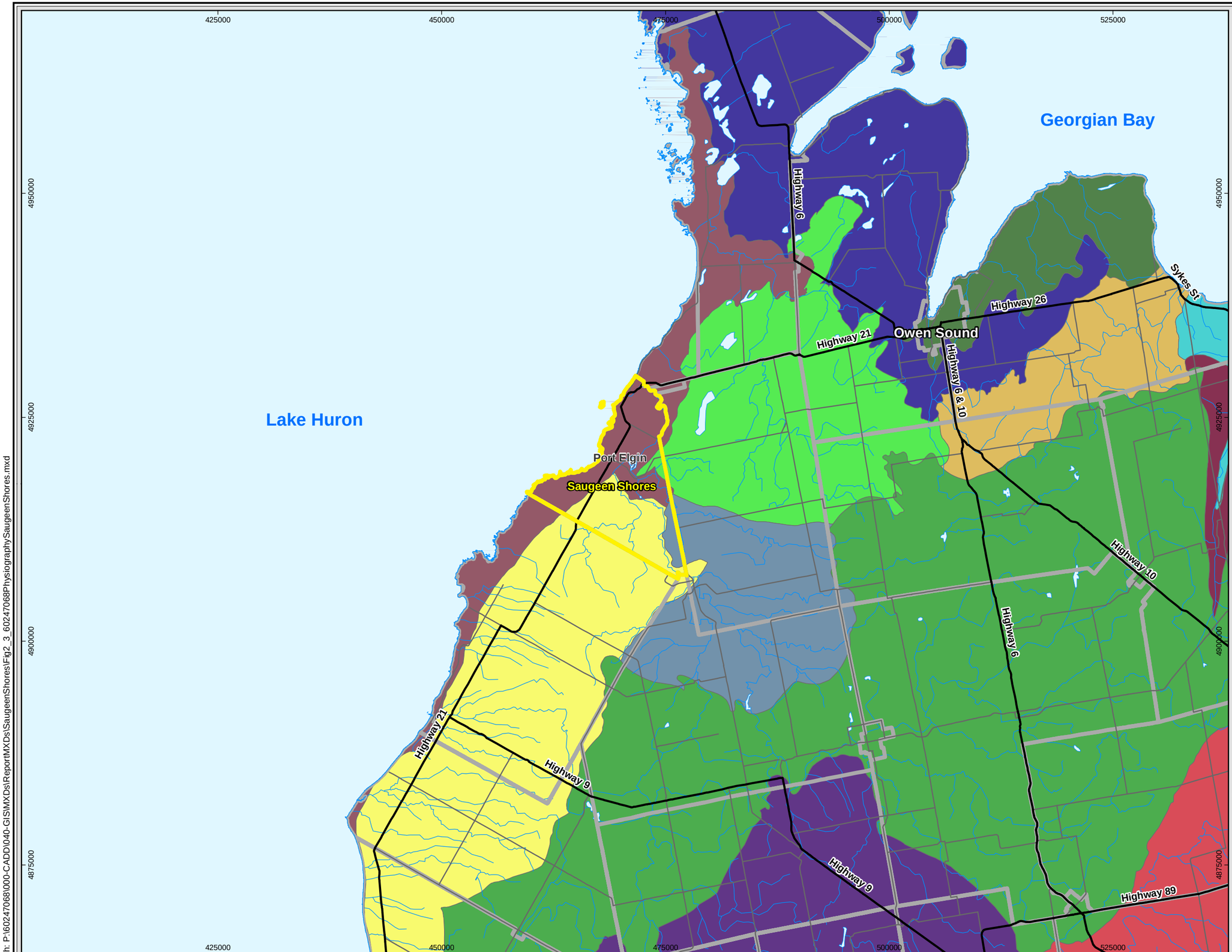
Satellite Imagery of the Town of Saugeen Shores

September 2012
Project 60247068

AECOM

Figure 2.2

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig2_2_60247068SatelliteImagery.mxd

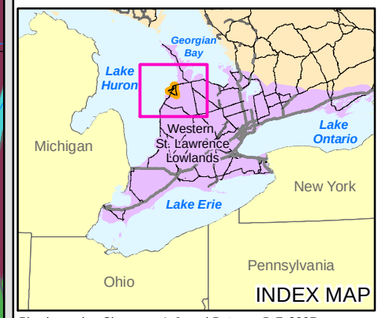


Legend

- Town of Saugeen Shores
- Municipal Division
- Highway
- Secondary Highway
- Waterbody

Physiographic Regions

- Niagara Escarpment
- Beaver Valley
- Bighead Valley
- Cape Rich Steps
- Horseshoe Moraines
- Dundalk Till Plain
- Teeswater Drumlin Field
- Arran Drumlin Field
- Saugeen Clay Plain
- Huron Slope
- Huron Fringe
- Bruce Peninsula



Physiography: Chapman, L.J. and Putnam, D.F. 2007.
Physiography of Southern Ontario; Ontario Geological Survey
Basemapping from Ontario Ministry of Natural Resources
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	14 Aug 2012
Approved	RF	14 Aug 2012

N W E S

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

NWMO Desktop Level Initial Screening

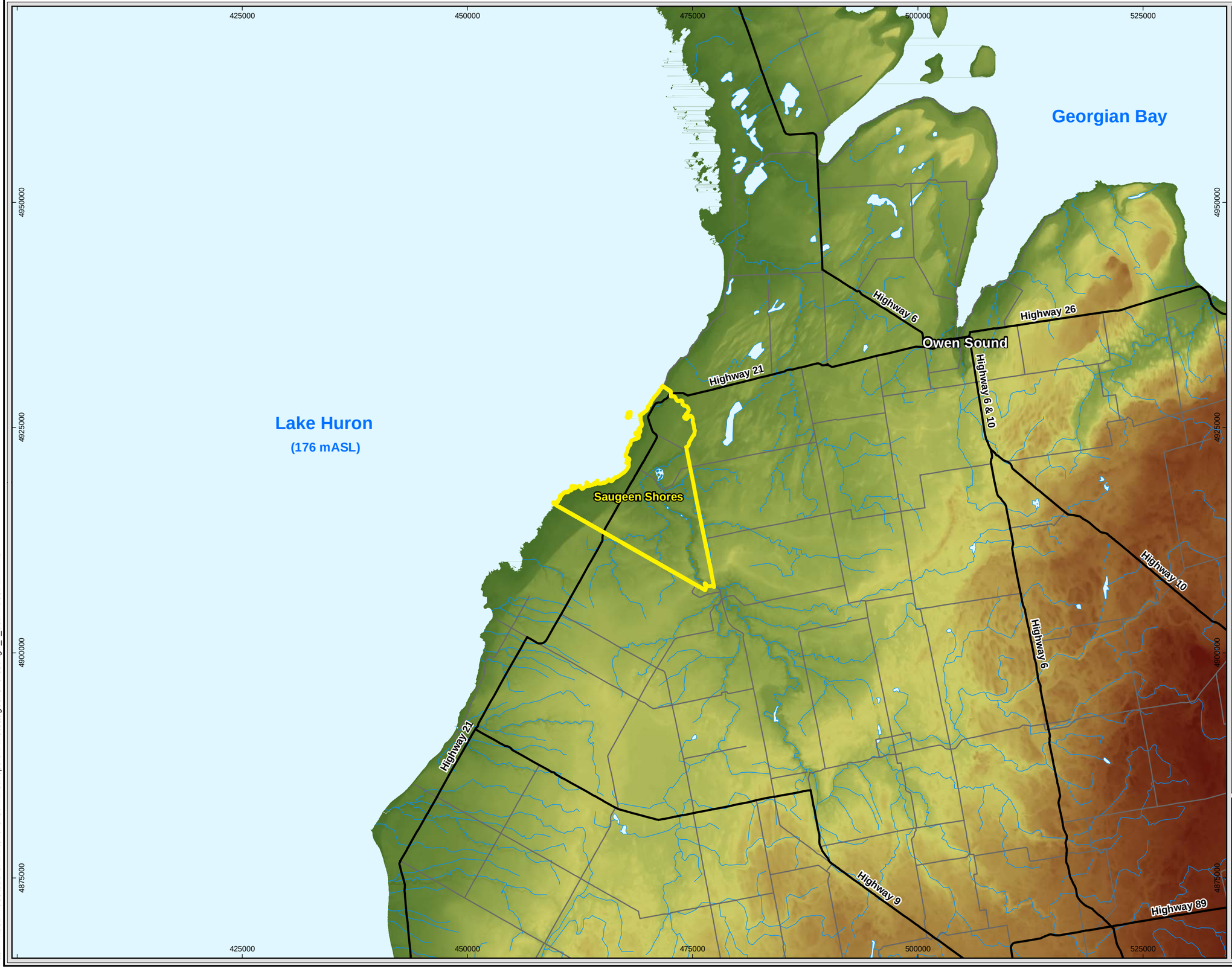
Physiographic Regions of the Town of Saugeen Shores and the Surrounding Area

September 2012
Project 60247068

AECOM

Figure 2.3

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShoresFig2_3_60247068PhysiographySaugeenShores.mxd

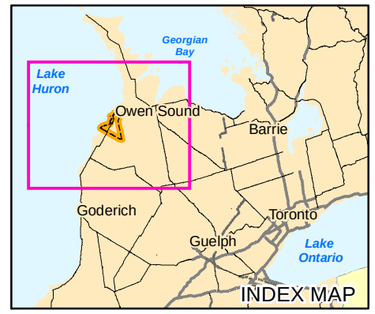


Legend

- Town of Saugeen Shores
- Highway
- Secondary Highway
- Watercourse
- Waterbody

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	14 Aug 2012
Approved	RF	14 Aug 2012

N W E S

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

NWMO Desktop Level Initial Screening

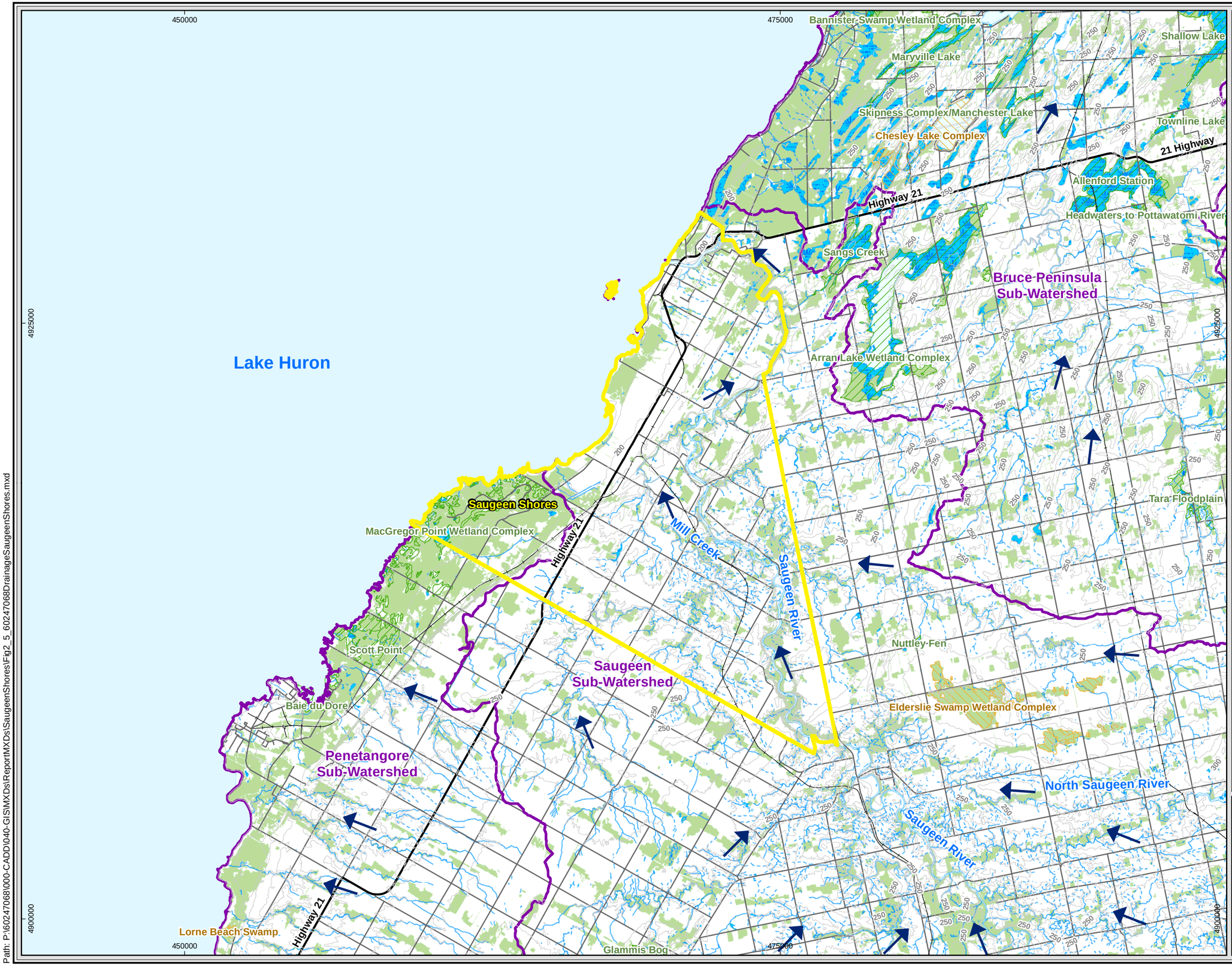
Digital Elevation Model (DEM) of the Town of Saugeen Shores and the Surrounding Area

September 2012
Project 60247068

AECOM

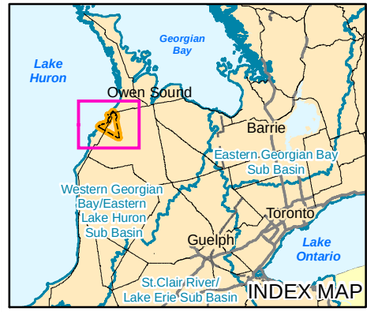
Figure 2.4

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig2_4_60247068DEM.mxd



Legend

- Town of Saugeen Shores
- Topographic Contour (10 m)
- Highway
- Major Road
- Railway
- Waterbody
- Cartographic Wetland
- Provincially Significant Wetland
- Locally Significant Wetland
- Wooded Area
- Subwatershed Boundary
- Direction of Surface Water Flow



Basemapping, ANSIs and Watersheds from Ontario Ministry of Natural Resources
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	14 Aug 2012
Approved	RF	14 Aug 2012

N W E S

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

NWMO Desktop Level Initial Screening

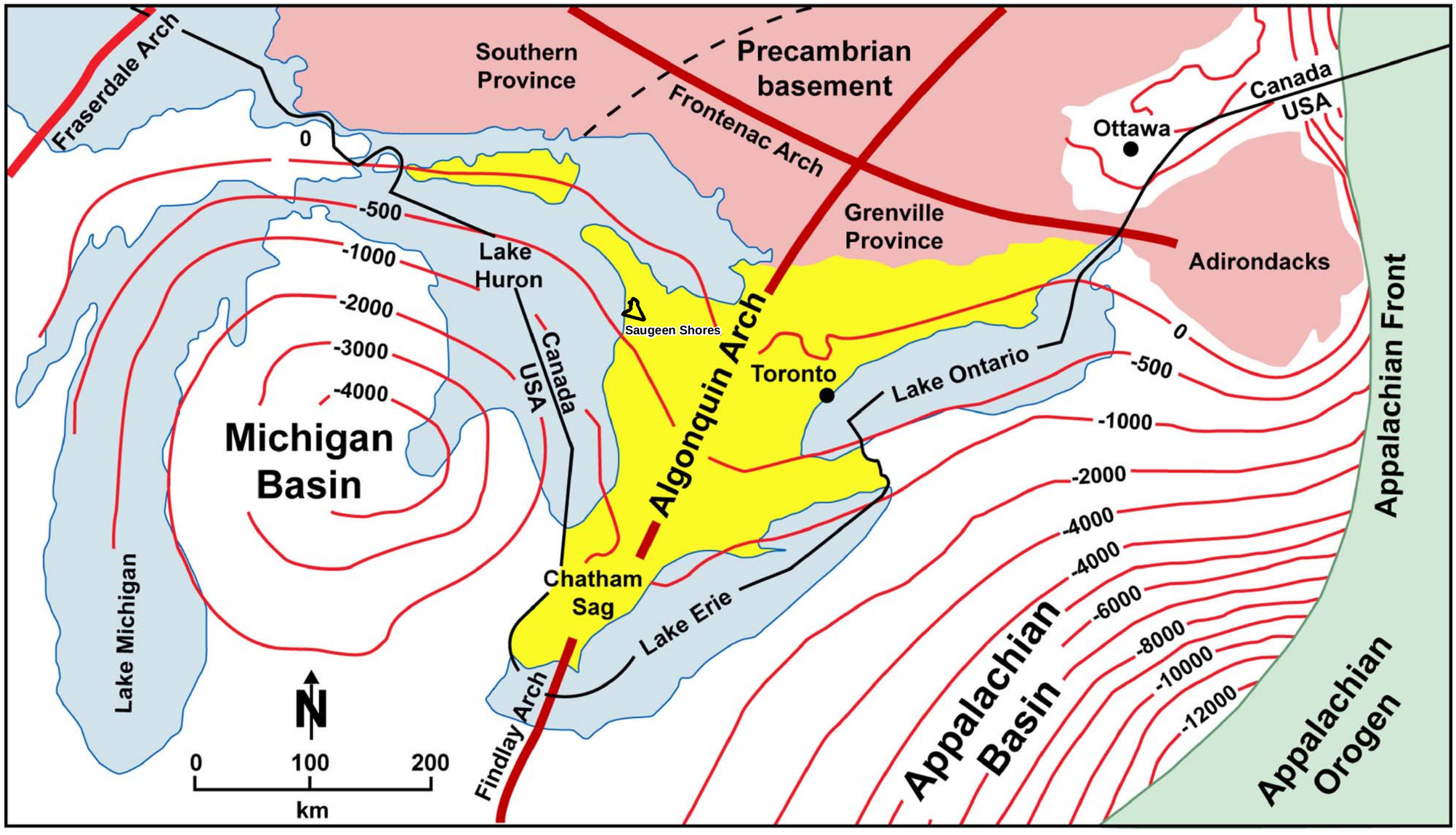
Drainage Features of the Town of Saugeen Shores

September 2012
Project 60247068

AECOM

Figure 2.5

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig2_5_60247068DrainageSaugeenShores.mxd



Legend

- Town of Saugeen Shores
- 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	18 Jul 2012
Approved	RF	18 Jul 2012

Modified after Johnson et al., 1992

NWMO Desktop Level Initial Screening

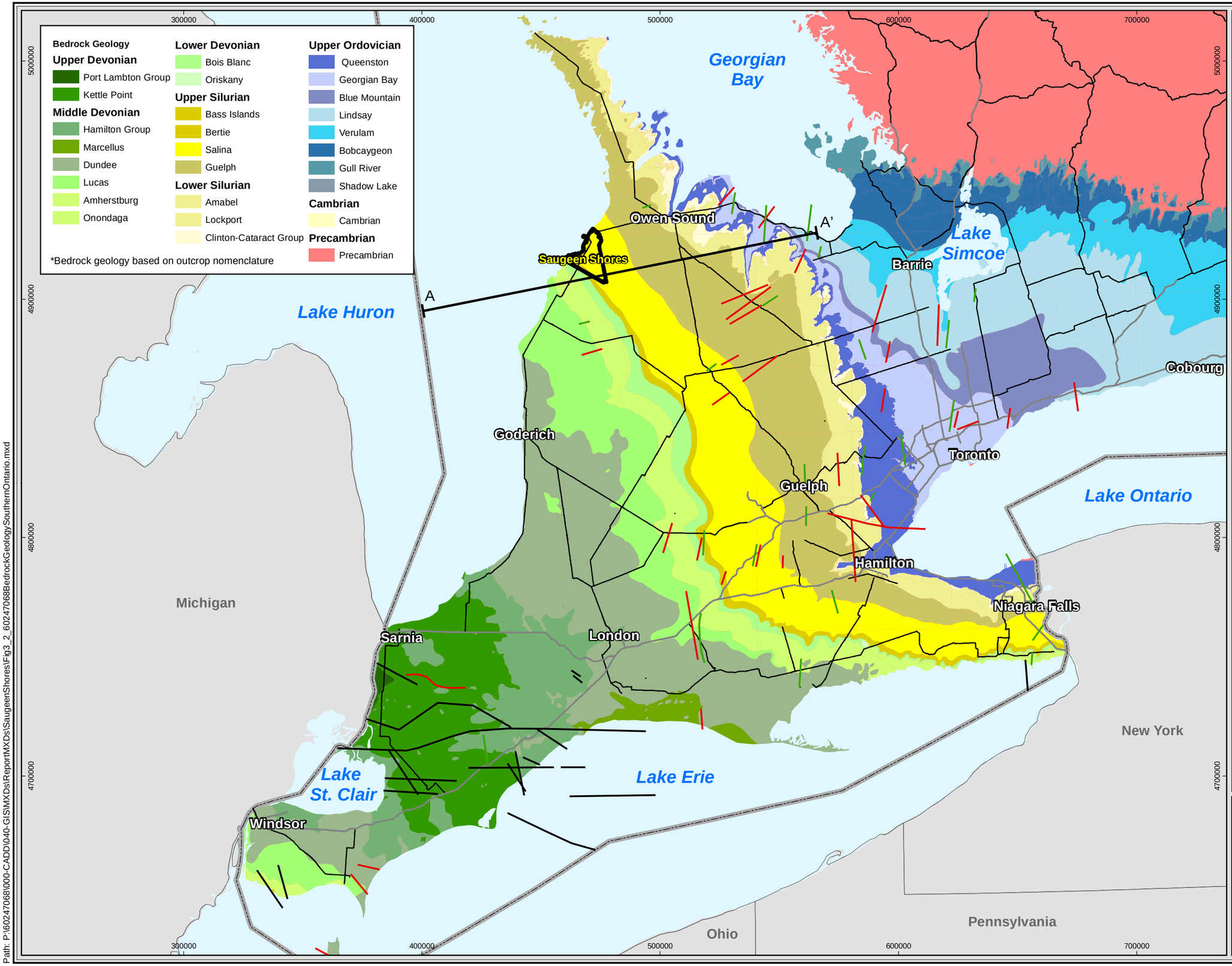
Geological Features of Southern Ontario

September 2012
Project 60247068

AECOM

Figure 3.1

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig3_1_60247068GeologicFeaturesofSouthernOnt.mxd



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	18 Jul 2012
Approved	RF	18 Jul 2012

N W E S

Kilometers
0 10 20 40 60 80
1:1,500,000

NWMO Desktop Level Initial Screening

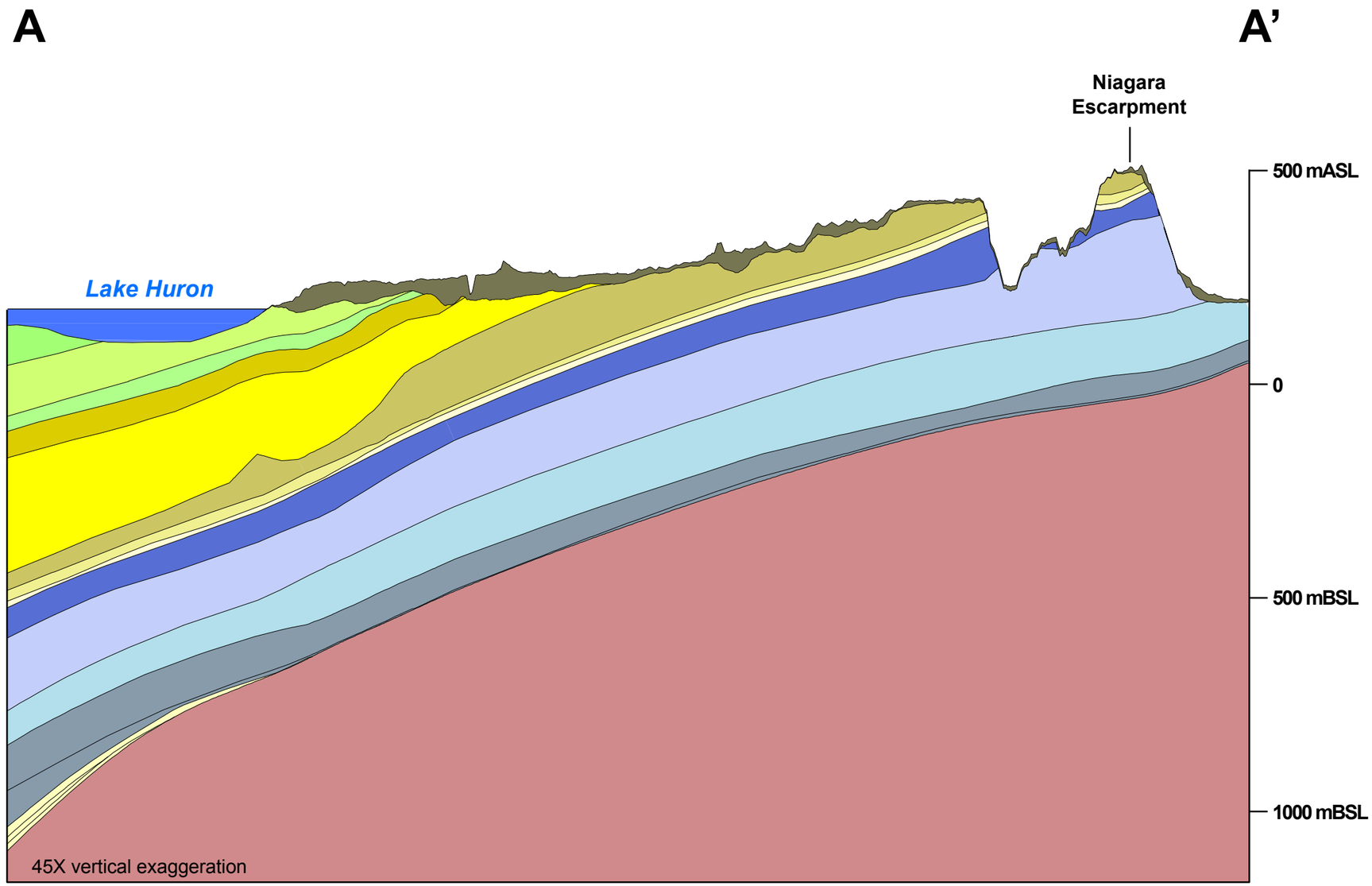
Geology of Southern Ontario

September 2012
Project 60247068

AECOM

Figure 3.2

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShoresIFig3_2_60247068BedrockGeologySouthernOntario.mxd



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

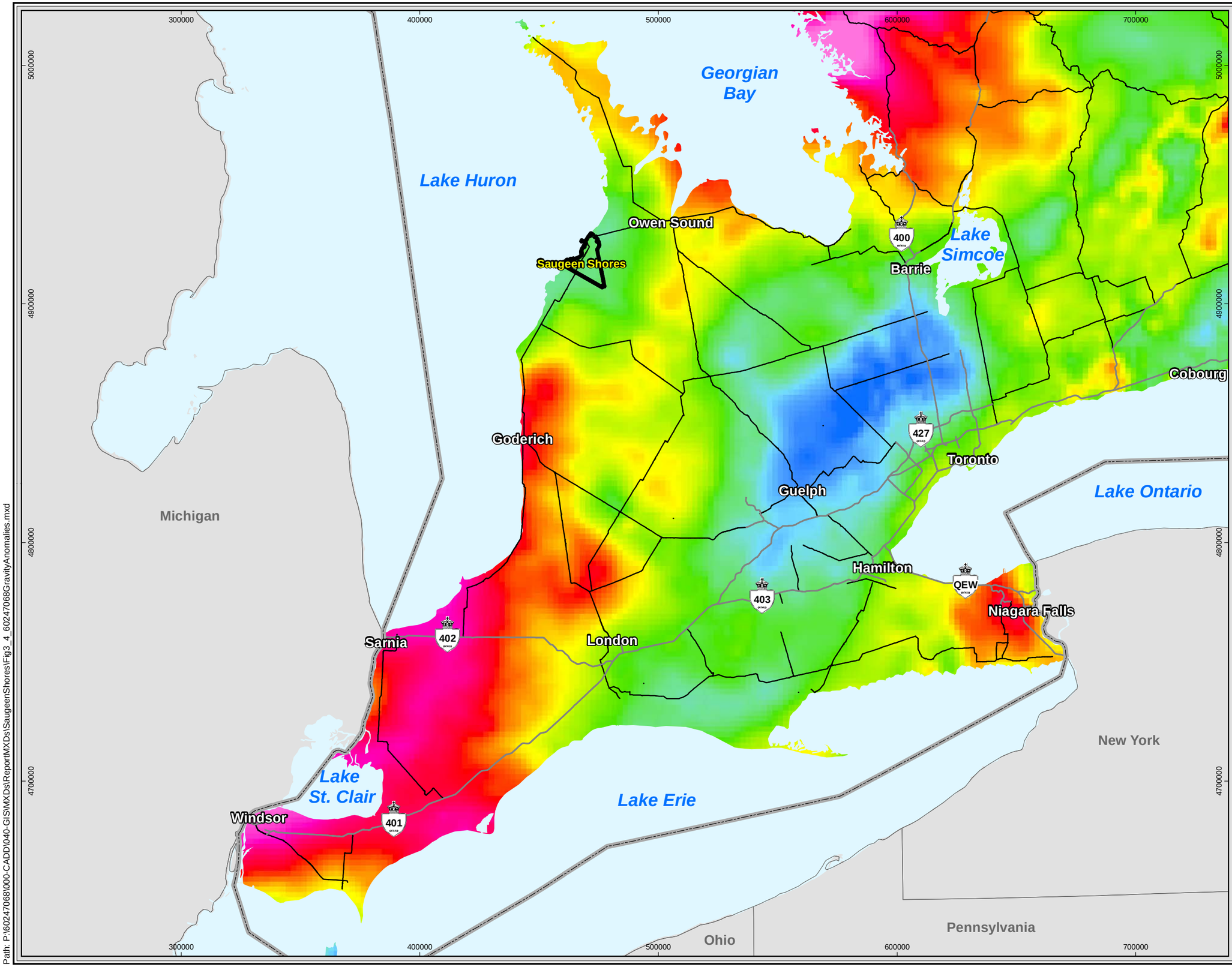
Geological Cross-Section

(Location Shown in Figure 3.2)

September 2012
Project 60247068

AECOM

Figure 3.3



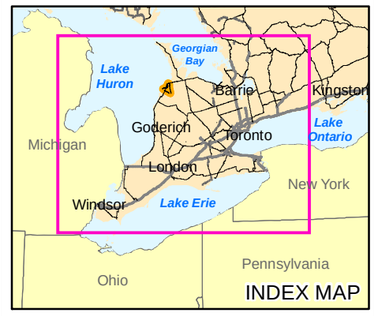
Legend

- Town of Saugeen Shores
- Expressway
- Highway
- Canada - USA Boundary
- Waterbody

Gravity Anomaly (mGal)

-2.84

-71.46



Basemapping from Ontario Ministry of Natural Resources
Gravity: Canadian Geodetic Information System, Gravity & Geodetic Networks Section, Geodetic Survey Division, Geomatics Canada, Earth Sciences Sector, Natural Resources Canada
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	18 Jul 2012
Approved	RF	18 Jul 2012

N W E S

Kilometers
0 10 20 40 60 80
1:1,500,000

NWMO Desktop Level Initial Screening

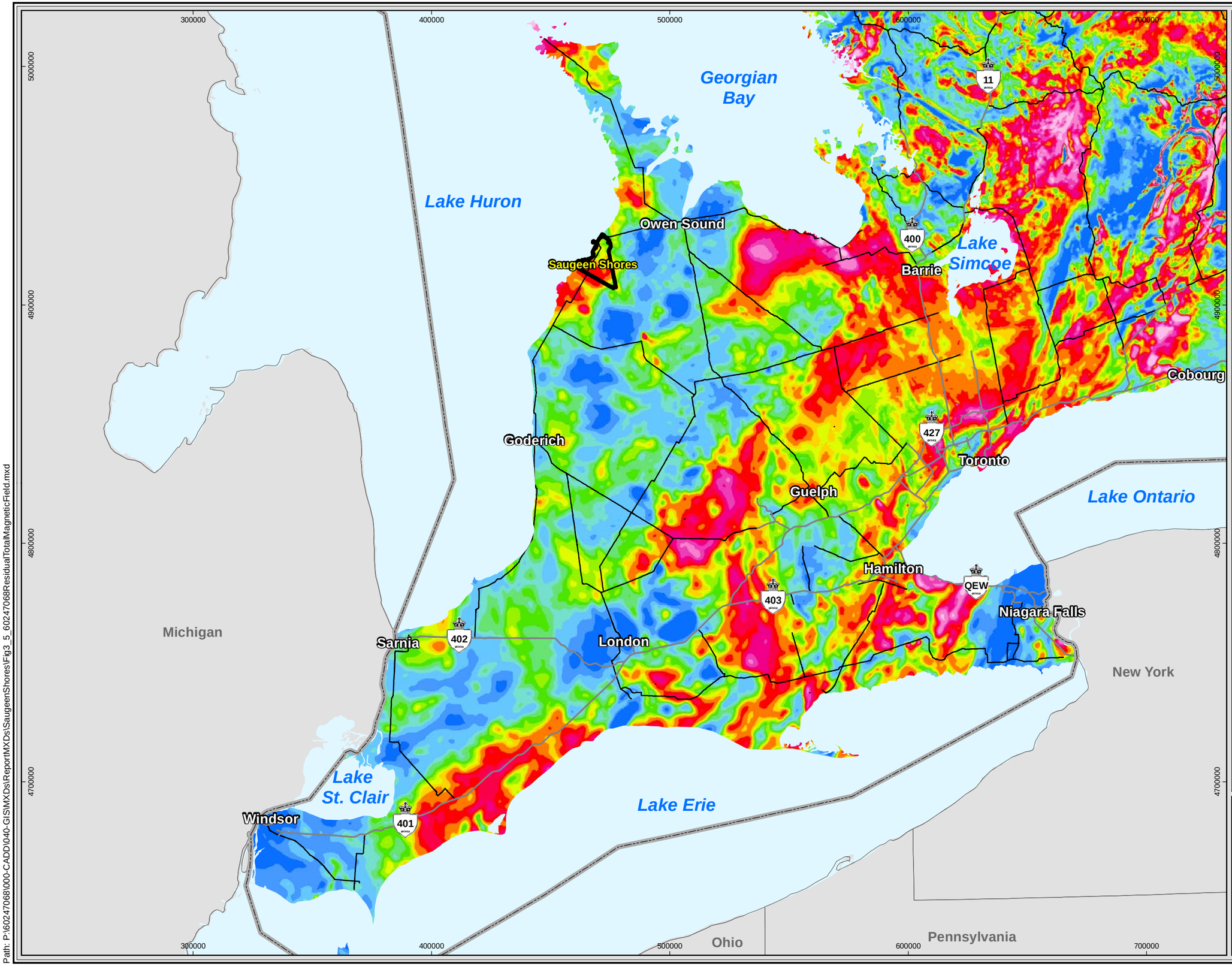
Gravity Map of Southern Ontario

September 2012
Project 60247068

AECOM

Figure 3.4

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig3_4_60247068GravityAnomalies.mxd



Legend

- Town of Saugeen Shores
- 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	18 Jul 2012
Approved	RF	18 Jul 2012

N
W E
S

Kilometers
0 10 20 40 60 80
1:1,500,000

NWMO Desktop Level Initial Screening

Residual Total Magnetic Field of Southern Ontario

September 2012
Project 60247068

AECOM

Figure 3.5

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig3_5_60247068ResidualTotalMagneticField.mxd

Bedrock Geology (dominant lithology)

Upper Devonian
- Dundee Formation (limestone)
- Lucas Formation (dolostone)
- Amherstburg Formation (dolostone)

Lower Devonian
- Bois Blanc Formation (dolostone)

Upper Silurian
- Bass Islands Formation (argillaceous dolostone)
- Salina Group (evaporite, dolostone, shale)
- Guelph Formation (dolostone)

Lower Silurian
- Amabel Formation (dolostone)
- Clinton-Cataract Group Formation (limestone, dolostone, shale)

Upper Ordovician
- Queenston Formation (shale)
- Georgian Bay Formation (shale)
- Blue Mountain Formation (shale)

425000 450000 475000 500000 525000

4950000 4925000 4900000 4875000

Georgian Bay

Lake Huron

Hepworth Pool

Owen Sound

Saugeen Shores

T001892

T001720A

Bruce nuclear site
(DGR1-6)

Ashfield 5-IX WD Pool

Egremont Pool

Highway 6

Highway 21

Highway 26

Highway 6 & 10

Highway 10

Highway 9

Highway 89

Sykes St

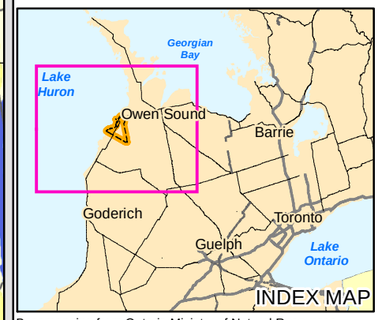
Legend

- Town of Saugeen Shores
- Highway
- Secondary Highway
- Waterbody

Petroleum Wells
- Abandoned Well
- Abandoned and Junked (Lost)
- Active Well
- Suspended Well
- Unknown

Oil and Gas Pool
- Ordovician
- Silurian
- 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	18 Jul 2012
Approved	RF	18 Jul 2012

N W E S

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

NWMO Desktop Level Initial Screening

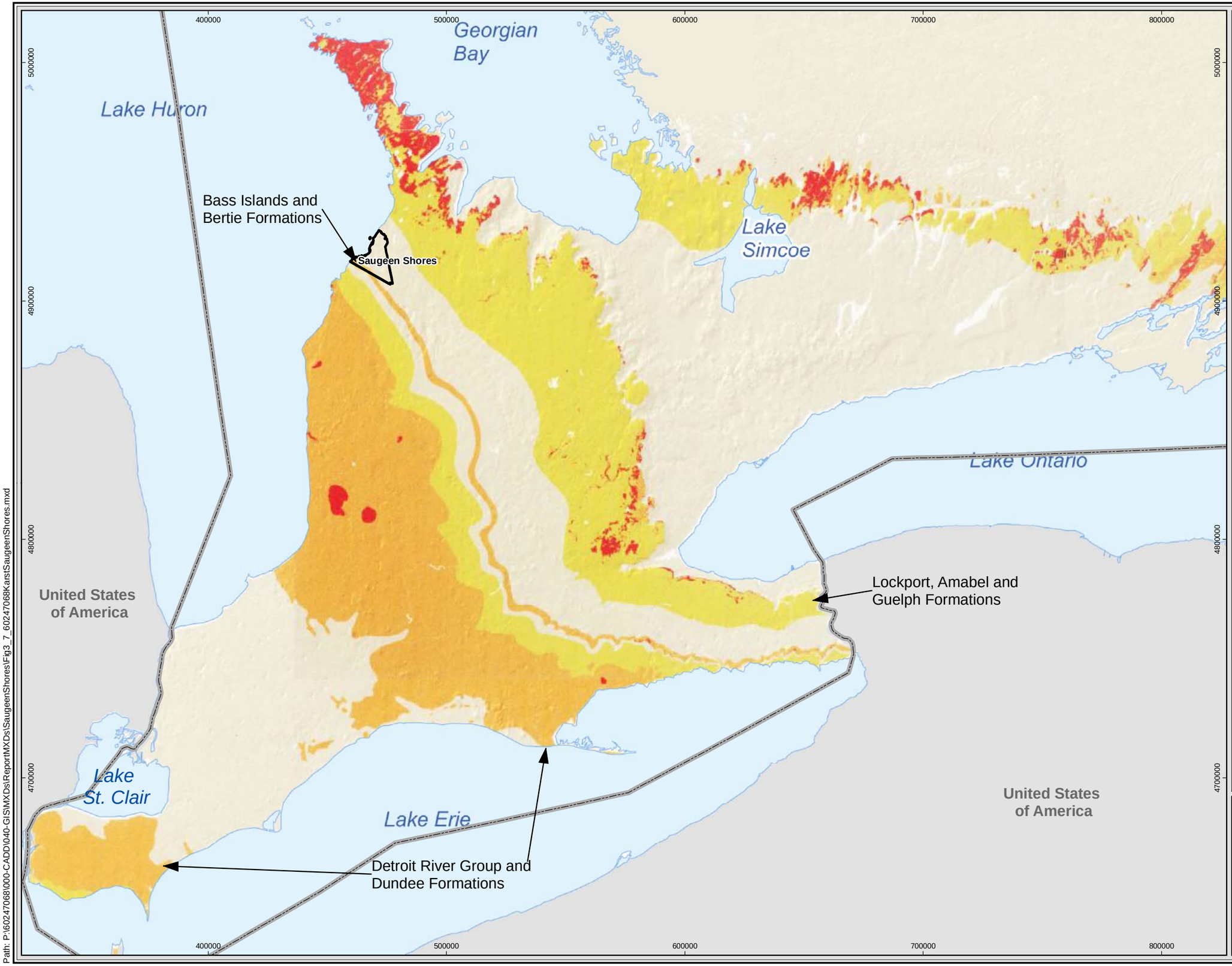
Bedrock Geology and Oil & Gas Wells of the Town of Saugeen Shores and the Surrounding Area

September 2012
Project 60247068

AECOM

Figure 3.6

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig3_6_60247068KnownOilandGasResourcesSaugeenShores.mxd



Legend

- Town of Saugeen Shores
- Canada - USA Boundary
- Major Waterbody
- Known Karst
- Inferred Karst
- Potential Karst

Basemapping from Ontario Ministry of Natural Resources
Karst: Modified from Brunton and Dodge (2008)
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	18 Jul 2012
Approved	RF	18 Jul 2012

N W E S

Kilometers
0 10 20 40 60 80
1:1,500,000

NWMO Desktop Level Initial Screening

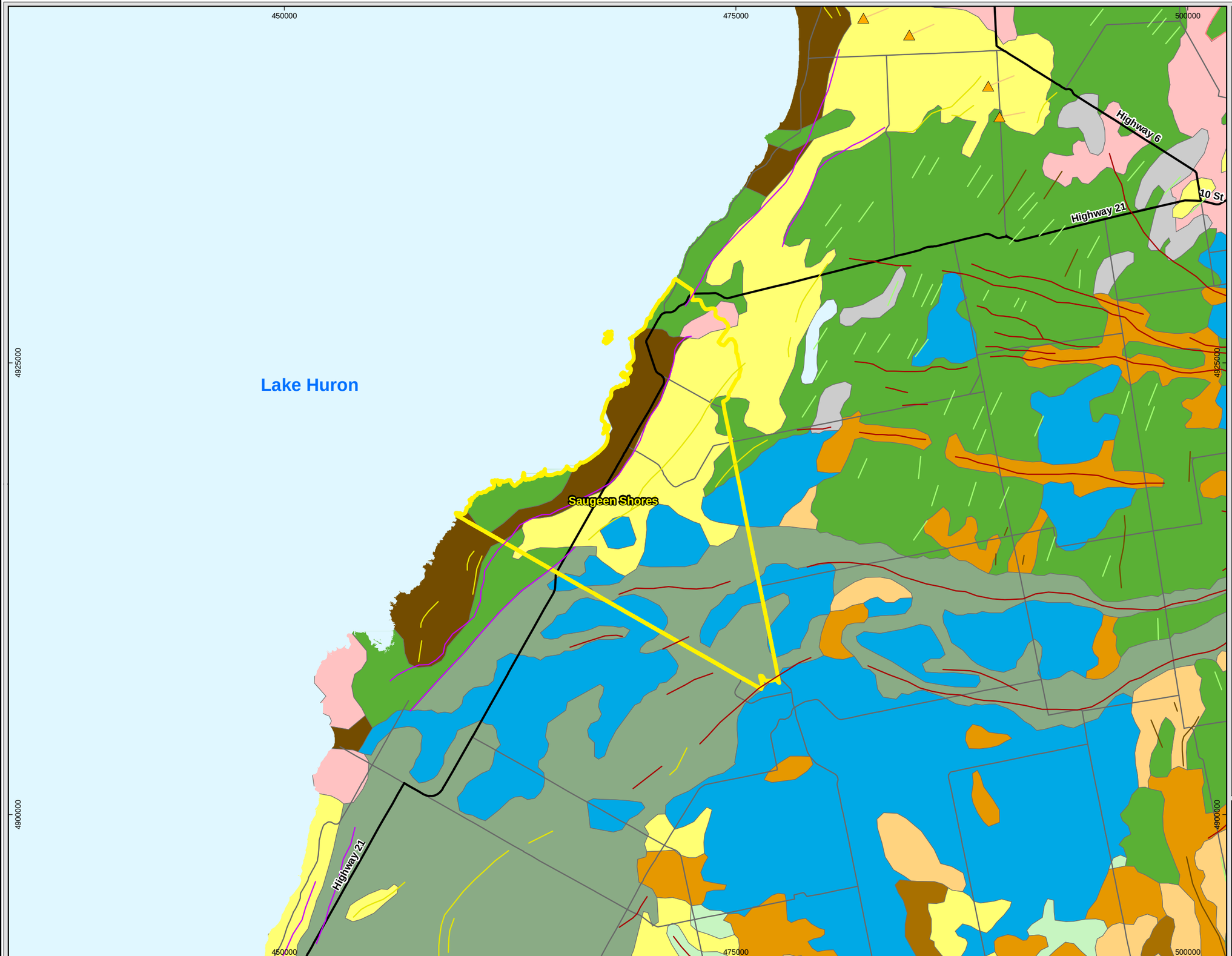
Karst Mapping of Southern Ontario

September 2012
Project 60247068

AECOM

Figure 3.7

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig3_7_60247068KarstSaugeenShores.mxd



Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig3_8_60247068QuaternaryGeologySaugeenShores.mxd

Georgian Bay

Lake Huron
176 mASL

Saugeen Shores

Owen Sound

Highway 6
Highway 21
Highway 26
Sykes St
Highway 6 & 10
Highway 10
Highway 9
Highway 89

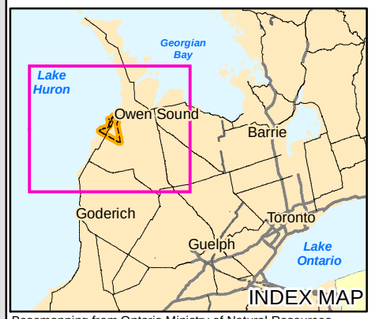
425000
450000
475000
500000
525000
4950000
4925000
4900000
4875000

Legend

- Town of Saugeen Shores
- 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
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	18 Jul 2012
Approved	RF	18 Jul 2012

N
W
E
S

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

NWMO Desktop Level Initial Screening

Overburden Thickness in the Town of Saugeen Shores and the Surrounding Area

September 2012
Project 60247068

AECOM

Figure 3.9

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig3_9_60247068OverburdenThicknessSaugeenShores.mxd

Natural Resources Canada

Ressources naturelles Canada

Magnitude

3

4

5

6

7

8

9

Saugeen Shores

Earthquakes in or near Canada, 1627 - 2010

EarthquakesCanada.nrcan.gc.ca

Legend

Town of Saugeen Shores

60247068		Date
GIS	RM	18 Jul 2012
Approved	RF	18 Jul 2012

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

NWMO Desktop Level Initial Screening

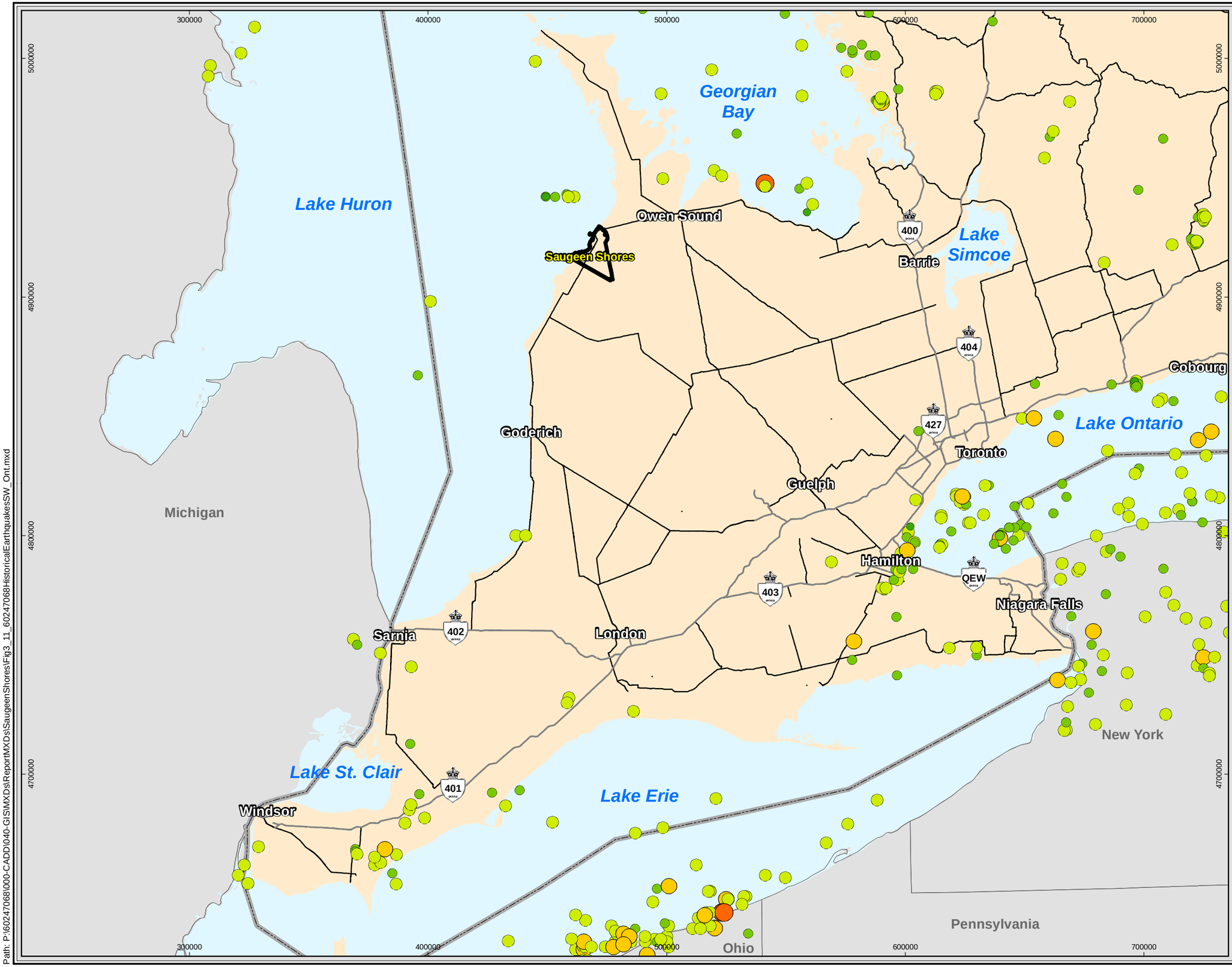
Earthquake Map of Canada 1627 - 2010

September 2012
Project 60247068

AECOM

Figure 3.10

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig3_10_60247068HistoricalEarthquakesCanada.mxd

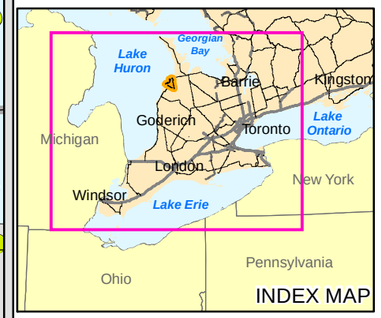


Legend

- Town of Saugeen Shores
- 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.
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	18 Jul 2012
Approved	RF	18 Jul 2012

N W E S

Kilometers
0 10 20 40 60 80
1:1,500,000

NWMO Desktop Level Initial Screening

Earthquake Map of Southern Ontario 1985 - 2012

September 2012
Project 60247068

AECOM

Figure 3.11

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig3_11_60247068HistoricalEarthquakesSW_Ont.mxd

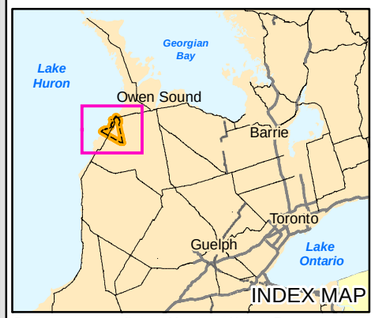
450000
475000
4925000
4900000
Lake Huron
Highway 21
Saugeen Shores
Main Street

Legend

- Town of Saugeen Shores
- MOE Water Well Record
- Highway
- Major Road
- Railway
- Intermittent Stream
- Permanent Stream
- Waterbody
- Cartographic Wetland

Quaternary Overburden

- Bedrock
- Elma 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	14 Sep 2012
Approved	RF	14 Sep 2012

N
W E
S

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

NWMO Desktop Level Initial Screening

Water Well Records of the Town of Saugeen Shores

September 2012
Project 60247068

AECOM

Figure 4.1

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig4_1_60247068WaterWellsSaugeenShores.mxd

Path: P:\60247068\000-CADD\040-GIS\MXDs\ReportMXDs\SaugeenShores\Fig5_1_60247068EconomicBedrockResources.mxd

425000 450000 475000 500000 525000

4950000 4925000 4900000 4875000

Lake Huron

Georgian Bay

Saugeen Shores

Owen Sound

Highway 6

Highway 21

Highway 26

Sykes St

Highway 6 & 10

Highway 10

Highway 9

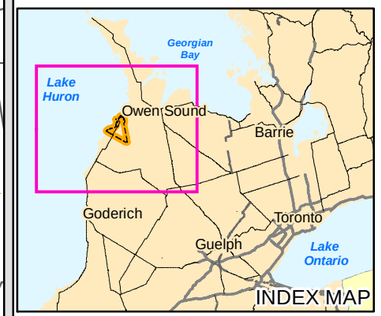
Highway 89

Legend

- Town of Saugeen Shores
- Highway
- Secondary Highway
- Waterbody
- Bruce County

Sand, Gravel & Limestone Extraction

- Pit
- Quarry



Basemapping from Ontario Ministry of Natural Resources
Sand, Gravel & Limestone Extraction: Ontario Ministry of Natural Resources
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	15 Jun 2012
Approved	RF	15 Jun 2012

N W E S

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

NWMO Desktop Level Initial Screening

Non-metallic Bedrock Resources of the Town of Saugeen Shores and the Surrounding Area

September 2012
Project 60247068

AECOM

Figure 5.1