NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Preliminary Assessment for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel

THE CORPORATION OF THE MUNICIPALITY OF ARRAN-ELDERSLIE, ONTARIO

FINDINGS FROM PHASE ONE STUDIES

APM-REP-06144-0106

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About the NWMO and its work

The Nuclear Waste Management Organization (NWMO) was created by Canada's nuclear energy generators in 2002 as a requirement of the *Nuclear Fuel Waste Act*. The Act requires the NWMO to study, recommend and then implement a plan for the long-term management of used nuclear fuel in Canada.

The NWMO approaches its work with the following vision: the long-term management of Canada's nuclear waste in a manner that safeguards people and respects the environment, now and in the future.

The NWMO is guided by five fundamental values:

Integrity: We will conduct ourselves with openness, honesty and respect for all persons and organizations with whom we deal.

Excellence: We will pursue the best knowledge, understanding and innovative thinking in our analysis, engagement processes and decision-making.

Engagement: We will seek the participation of all communities of interest and be responsive to a diversity of views and perspectives. We will communicate and consult actively, promoting thoughtful reflection and facilitating a constructive dialogue.

Accountability: We will be fully responsible for the wise, prudent and efficient management of resources, and be accountable for all our actions.

Transparency: We will be open and transparent in our process, communications and decision-making, so that the approach is clear to all Canadians.

The work of the NWMO is subject to federal regulatory oversight and is regulated under the *Nuclear Safety and Control Act*. The NWMO's work is required to meet all applicable regulatory standards and requirements for protecting the health and safety of persons, the environment and national security, and to respect Canada's international commitments on the peaceful use of nuclear energy. For financial surety, its work is also required to be fully funded by the waste-producing organizations through independently managed trust funds.

Preface

Since initiating the siting process in May 2010, the Nuclear Waste Management Organization (NWMO) has worked collaboratively with interested communities to implement Adaptive Phased Management (APM), Canada's plan for the safe, long-term care of used nuclear fuel. At this early point in the multi-year site selection process, the focus of work is on exploring potential to meet specific requirements to safely host a deep geological repository and Centre of Expertise, the core components of Canada's plan.

Findings summarized in this document have emerged from studies conducted as part of Phase 1 of the Preliminary Assessment, the initial phase of study in Step 3 of the nine-step process for selecting a site. This document reviews the outcome of desktop studies that explored the potential to find a site that can safely and securely contain and isolate used nuclear fuel from people and the environment for the long time period required.

Findings from the Phase 1 Preliminary Assessment are intended to support the Municipality and the NWMO in taking stock of the community's potential to meet the requirements for hosting APM facilities. These assessments also provide the basis upon which the NWMO will identify a smaller number of communities to be the focus of the next phase of more detailed studies. This document provides a synthesis of geoscientific studies. The early findings indicated the Municipality of Arran-Elderslie does not contain sufficient land areas that have the potential to meet the geoscientific site evaluation factors required for hosting the deep geological repository for used nuclear fuel. In light of these findings, the NWMO concluded its assessment studies in the Municipality of Arran-Elderslie in January 2014.

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The journey of the Municipality of Arran-Elderslie in the APM process began in February 2012 when the Municipality approached the NWMO to learn more about the program. This request came to the NWMO in response to an open invitation to communities to learn more about Canada's plan with the understanding the community could end its involvement at any time.

The Municipality's Council participated in a Learn More session in June 2012, and later that month passed a resolution to request an initial screening of the community's potential suitability for the project. In July 2012, the NWMO delivered a presentation to community officials in Arran-Elderslie to review the plan for conducting this initial screening and to confirm details of the work.

Upon completing the initial screening in September 2012, the NWMO and the contractor that conducted the work presented findings to Council. Copies of the final report (summary version, as well as detailed report) were also provided. The report's findings indicated that "*the review of readily available information and application of the five initial screening criteria did not identify obvious conditions that would exclude the Municipality of Arran-Elderslie from further consideration in the site selection process.*" Open houses were also held in the community in October 2012.

In December 2012, Council expressed an interest in learning more about preliminary assessments, the next step in the site selection process. The NWMO provided a briefing to Council that outlined what would be involved should the Council wish to proceed to this step.
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Council passed a resolution expressing its interest in continuing to learn more about APM and to initiate feasibility studies by proceeding to Step 3 for the first phase of preliminary assessment activities.

In January 2014, the NWMO concluded its siting studies in the Municipality of Arran-Elderslie. Early findings indicated the Municipality of Arran-Elderslie does not contain sufficient land areas that have the potential to meet the geoscientific site evaluation factors required for hosting the deep geological repository for used nuclear fuel, as outlined in the site selection process document.

Safety, security and protection of people and the environment are central to the NWMO siting process. NWMO worked with the Municipality of Arran-Elderslie to assist the community's transition out of the siting process.

The discussion which follows in this document provides an outline of the siting process and the approach to the current phase of work – Preliminary Assessments. It also provides an overview of the learning from the geoscientific studies which were conducted as part of the community's participation in this phase of the site selection process. It concludes with the NWMO's reflections on this learning, which lead to the conclusion of further studies in the community. Preliminary Assessment studies were concluded based on early findings of geoscientific studies. Preliminary Assessments of the potential to meet engineering requirements, environment and safety requirements, and transportation-related requirements, as well as the potential to foster the well-being of the community through the implementation of the project, were not completed.

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The objective of the site selection process, through several phases of progressively more detailed assessments, is to arrive at a single location for both the deep geological repository for Canada's used nuclear fuel and the Centre of Expertise. The preferred site will need to ensure safety and security for people and the environment and contribute to the well-being of the area. Selecting a site will require many more years of detailed technical, scientific and social study and assessments, and much more engagement with interested communities, potentially affected First Nation and Métis communities, and surrounding communities.

With a number of communities engaged in exploring their interest and suitability for hosting the APM Project, the site selection process must provide a basis for progressively identifying a smaller number of communities for more detailed assessment. Through increasingly more detailed studies, communities with strong potential to meet the project's specific requirements will be identified to become the focus of further assessment.

This process of stepwise reflection and decision-making will be supported by a sequence of assessments and engagement that will enable the NWMO and communities to learn more about the suitability of each potential siting area and make decisions about where to focus more detailed work. Communities may choose to end their involvement at any point during the site evaluation process until a final agreement is signed, subject to all regulatory requirements being met and regulatory approvals received.
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1. INTRODUCTION

1.1 The Purpose of This Document

Since May 2010, the Nuclear Waste Management Organization (NWMO) has worked with interested communities to implement Adaptive Phased Management (APM), Canada's plan for the long-term care of used nuclear fuel. The NWMO has worked collaboratively with interested communities to begin to explore their potential to meet site selection requirements for locating the deep geological repository and Centre of Expertise, the core components of Canada's plan.

Following a road map for decision-making that was developed collaboratively through two years of public engagement, the site selection process is now advancing through a multi-year series of steps and engagement to ensure, above all, that the site which is selected is safe and secure, and meets the highest scientific, professional and ethical standards.

Findings summarized in this document have emerged from studies conducted as part of Phase 1 of the Preliminary Assessment – the initial phase of study in Step 3 of the nine-step site selection process. The document reviews the outcome of desktop studies that explored the potential to find a site which can safely and securely contain and isolate used nuclear fuel from people and the environment for the long time period required.

As communicated to the Municipality in January 2014, the work undertaken as part of the Phase 1 geoscientific assessment determined the Municipality of Arran-Elderslie does not contain sufficient land areas that have the potential to meet the geoscientific site evaluation factors outlined in the site selection process document (NWMO, 2010). In light of these findings, the NWMO concluded studies in the community (Geofirma, 2014; NWMO, 2014). This document provides a synthesis of work undertaken, and is based on a series of supporting geoscientific technical documents.

1.2 Towards Partnership

Through working with communities involved in the site selection process in Phase 1 activities, and initial outreach with potentially affected First Nation and Métis communities and surrounding communities, the nature and shape of the partnerships required to implement the APM Project is beginning to emerge. This project will only proceed with the involvement of the interested community, potentially affected First Nation and Métis communities, and surrounding communities working in partnership to implement it.

Although the focus of this assessment is the Municipality of Arran-Elderslie, it is understood that a broader partnership involving potentially affected First Nation and Métis communities and other communities in the surrounding area would be needed in order for the project to proceed in this or any other area. Should any of Arran-Elderslie's neighbouring communities be found to have overall strong potential to be suitable and proceed to Phase 2 for further study, Arran-Elderslie would be involved in that future phase of work.

1.3 A Matter of Responsibility

For decades, Canadians have been using electricity generated by nuclear power reactors in Ontario, Quebec and New Brunswick. Over 2.5 million used fuel bundles have been produced.

When used nuclear fuel is removed from a reactor, it is considered a waste product, is radioactive and requires careful management. Although its radioactivity decreases with time, chemical toxicity persists and the used fuel will remain a potential health risk to people and the environment for many hundreds of thousands of years. Canada's used nuclear fuel is now safely stored on an interim basis at licensed facilities located where it is produced. Putting in place a plan for the long-term, safe and secure management of used nuclear fuel for the protection of people and the environment is an important responsibility that Canadians share. Through dialogues with citizens and Aboriginal peoples across Canada, the NWMO has heard that this generation wants to move forward in dealing with our used nuclear fuel, believing it to be imprudent and unfair to future generations to wait any longer.

1.4 The Foundation of Canada's Plan

The Government of Canada selected Canada's plan for the long-term management of used nuclear fuel in 2007. The plan, called Adaptive Phased Management, involves the development of a large national infrastructure project in an informed and willing host community. The project involves the long-term containment and isolation of used nuclear fuel from people and the environment in a deep geological repository in a suitable rock formation. It also involves the development of a Centre of Expertise and transportation plan.

As required by the *Nuclear Fuel Waste Act*, 2002, the NWMO is responsible for implementing Canada's Plan. The NWMO is committed to carrying out its work collaboratively with interested and affected citizens and organizations in a manner that is socially acceptable, technically sound, environmentally responsible and economically feasible.

Adaptive Phased Management (APM) – At a Glance:

- Was developed through a nationwide dialogue between 2002 and 2005
- Was selected as Canada's plan by the Government of Canada in 2007, consistent with the *Nuclear Fuel Waste Act*
- Key features include:
  - Safe and secure centralized containment and isolation of used nuclear fuel in a repository deep underground in a suitable rock formation
  - A series of steps and clear decision points that can be adapted over time
  - An open, inclusive and fair siting process to identify an informed and willing host community
  - Opportunities for people and communities to be involved throughout the implementation process
  - Optional temporary shallow storage at the central site, if needed
  - Long-term stewardship through the continuous monitoring of used fuel
  - Ability to retrieve the used fuel over an extended period should there be a need to access the waste or take advantage of new technologies
  - Financial surety and long-term program funding to ensure the necessary money will be available for the long-term care of used nuclear fuel

1.5 The Site Selection Process

Through a collaborative process in 2008 and 2009, the NWMO worked with interested Canadians to develop the decision-making framework for selecting a site for the project. The site selection process is laid out in the NWMO's document: "*Moving Forward Together: Process for Selecting a Site for Canada's Deep Geological Repository for Used Nuclear Fuel*" (NWMO, 2010).

The site selection process is designed to ensure safety, security and protection of people and the environment. Reflecting the guidance provided by Canadians, the site selection process is built on a set of principles that reflects the values and priorities of Canadians on this issue. The process also contains a number of steps that these Canadians told us need to be part of the decision-making process to ensure it is an appropriate one for Canada, as set out in the table on the next pages.

Phase 1 Preliminary Assessments are conducted as part of Step 3 activities early in the site selection process. Several additional steps must be completed over the course of the next several years before a preferred site will be identified and environmental assessment and regulatory review will be sought. Interested communities may leave the site selection process at any time during this process until a final agreement is signed, subject to all regulatory requirements being met and regulatory approval received.

It is fundamental to the siting process that only an informed and willing community be selected to host the project as evidenced by a compelling demonstration of willingness involving community residents. The project will only be implemented in an area in which robust safety requirements can be met and well-being will be fostered.

Table 1-1: Steps in the Site Selection Process – At a Glance

Getting Ready	**The NWMO publishes the finalized siting process, having briefed provincial governments, the Government of Canada, national and provincial Aboriginal organizations, and regulatory agencies on the NWMO's activities**. The NWMO will continue briefings throughout the siting process to ensure new information is made available and requirements which might emerge are addressed.
Step 1	**The NWMO initiates the siting process with a broad program to provide information, answer questions and build awareness among Canadians about the project and siting process.** Awareness-building activities will continue throughout the full duration of the siting process.
Step 2	**Communities identify their interest in learning more, and the NWMO provides detailed briefing. An initial screening is conducted.** At the request of the community, the NWMO will evaluate the potential suitability of the community against a list of initial screening criteria.
Step 3	**For interested communities, a preliminary assessment of potential suitability is conducted.** At the request of the community, the NWMO will conduct a feasibility study collaboratively with the community to determine whether a site has the potential to meet the detailed requirements for the project. Regional engagement will be initiated, and an initial review of transportation considerations will be conducted. Interested communities will be encouraged to inform surrounding communities, including potentially affected Aboriginal communities and governments, as early as possible to facilitate their involvement.
	Phase 1: For interested communities passing the Initial Screening, a preliminary desktop assessment is conducted. Some communities may be screened out based on these assessments.
	Phase 2: Field investigations and expanded regional engagement proceed with smaller number of communities.
Step 4	**For interested communities, potentially affected surrounding communities are engaged if they have not been already, and detailed site evaluations are completed.** In this step, the NWMO will select one or more suitable sites from communities expressing formal interest for regional study and/or detailed multi-year site evaluations. The NWMO will work collaboratively with these communities to engage potentially affected surrounding communities, Aboriginal governments and the provincial government in a study of health, safety, environment, social, economic and cultural effects of the project at a broader regional level (Regional Study), including effects that may be associated with transportation. Involvement will continue throughout the siting process as decisions are made about how the project will be implemented.

Step 5	**Communities with confirmed suitable sites decide whether they are willing to accept the project and propose the terms and conditions on which they would have the project proceed.**
Step 6	**The NWMO and the community with the preferred site enter into a formal agreement to host the project.** The NWMO selects the preferred site, and the NWMO and community ratify a formal agreement.
Step 7	**Regulatory authorities review the safety of the project through an independent, formal and public process, and if all requirements are satisfied, give their approvals to proceed.** The implementation of the deep geological repository will be regulated under the *Nuclear Safety and Control Act* and its associated regulations to protect the health, safety and security of Canadians and the environment, and to respect Canada's international commitments on the peaceful use of nuclear energy. Regulatory requirements will be observed throughout all previous steps in the siting process. The documentation produced through previous steps, as well as other documentation that will be required for a licence application, will be formally reviewed by regulatory authorities at this step through an Environmental Assessment, and if this assessment is successful, then licensing hearings related to site preparation (and possible construction) of facilities associated with the project. Various aspects of transportation of used nuclear fuel will also need to be approved by regulatory authorities.
Step 8	**Construction and operation of an underground demonstration facility proceeds.**
Step 9	**Construction and operation of the facility**.

1.6 Initial Community Involvement

Communities involved in this stage of work entered the site selection process by expressing interest in learning more about Canada's plan for the long-term management of used nuclear fuel and the APM Project (Step 2) as part of an open invitation process.

With this expression of interest, the NWMO undertook an Initial Screening as part of Step 2 studies and began working with the community as they learned about the project and reflected upon their interest in it. The purpose of the Initial Screening was to determine whether, based on readily available information and five screening criteria, there were any obvious conditions that would exclude the community from further consideration in the site selection process.

For communities that successfully completed an Initial Screening and decided to enter Step 3 of the site selection process (Preliminary Assessments), the NWMO began working with the community to conduct a Preliminary Assessment. The purpose of Preliminary Assessments is to continue the learning and reflection process within the community, begin to involve First Nation and Métis communities in the vicinity and surrounding communities in the process, and further explore the potential for the community to meet the detailed requirements for the project with more detailed scientific and technical studies.

Twenty-two communities have entered the site selection process since it began in 2010. There are 14 communities involved in the site selection process (four are in Phase 2 of Step 3; 10 are in Phase 1 of Step 3). Figure 1-1 maps the locations of these communities in Saskatchewan and Ontario.

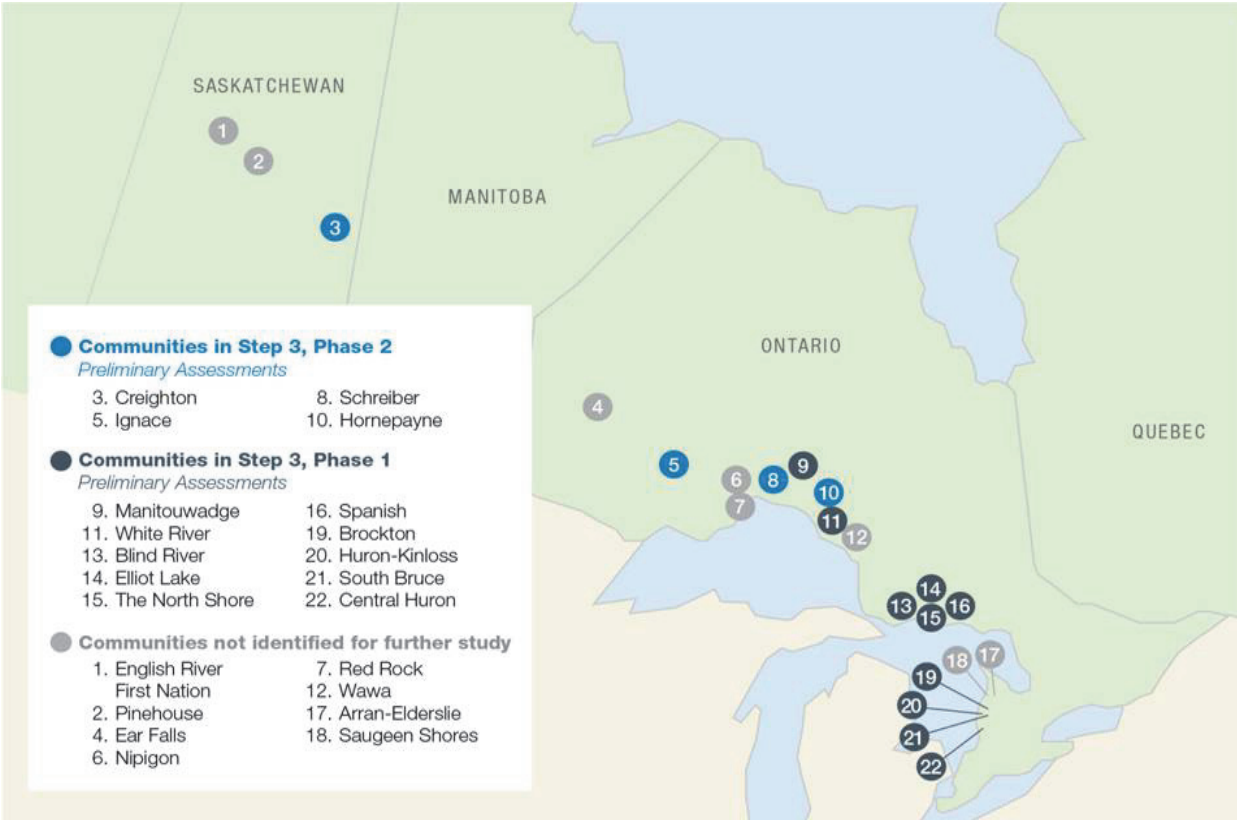


Figure 1-1: Communities Involved in the Site Selection Process

1.7 Approach to Preliminary Assessments

Preliminary Assessments address siting factors and criteria as described in the NWMO's document: "*Moving Forward Together: Process for Selecting a Site for Canada's Deep Geological Repository for Used Nuclear Fuel*" (NWMO, 2010). Preliminary Assessment studies in Step 3 of the siting process are conducted in two phases, with the opportunity for stock-taking by both the community and the NWMO throughout. The Municipality of Arran-Elderslie had requested the initiation of the first phase of preliminary assessment activities. As described in Section 1.1, preliminary geoscientific studies determined Arran-Elderslie does not contain sufficient land areas that have the potential to meet the geoscientific site evaluation factors outlined in the site selection process, and assessment studies were concluded in the community (Geofirma, 2014; NWMO, 2014). Additional information on the geoscientific assessment is provided in Chapter 3 of this report.

For general context, the remainder of this section outlines the overall approach the NWMO is following to conduct both Phase 1 and Phase 2 of Preliminary Assessment studies.

- ***Phase 1:*** Assessments are conducted with all communities that successfully completed an Initial Screening and asked to be the focus of a Preliminary Assessment. This phase involves desktop studies to explore the potential to meet safety requirements, and includes studies of engineering, geoscientific suitability, environment and safety, and transportation. This phase also involves community-learning about the project, and engagement and reflection on the potential for the project to foster the well-being of the community and fit with its long-term vision. Working with communities, this phase also explores early indications as to whether it would be possible to sustain interest in learning through subsequent phases of work required to support informed decision-making and a compelling demonstration of willingness at a future stage. This phase begins to involve First Nation and Métis communities in the vicinity and surrounding communities in a dialogue about the project that would continue in future phases. This phase of work is completed in a year or more.

- ***Phase 2:*** Assessments are conducted with a smaller number of interested communities selected by the NWMO based on the outcome of Phase 1 studies. Phase 2 work will further assess potentially suitable areas through detailed technical studies and field investigations. This phase also involves more detailed exploration of the potential to foster the well-being of the community. Learning and engagement are expanded to involve potentially affected First Nation and Métis communities and surrounding communities in exploring the potential to foster the well-being of the larger area, interest in the project, and the foundation to work together in partnership to implement the project. Together, the NWMO, potentially suitable communities, First Nation and Métis communities in the vicinity, and surrounding communities will reflect upon the suitability of the community and area to host the APM Project. Phase 2 Preliminary Assessments are expected to require a number of years to complete.

The focus of the Preliminary Assessments to date has been on Phase 1. The two-phased approach to assessments is discussed in "*Preliminary Assessment of Potential Suitability – Feasibility Studies*" (NWMO, 2011).

The NWMO has adopted an integrated approach to Preliminary Assessments, with assessments focused on safety and community well-being through study of many technical, scientific and social requirements for the project.

In assessing the siting factors and criteria, four overarching research questions guide this early phase of Preliminary Assessment, and are a focus of reflection by both the NWMO and the community. These questions are discussed in more detail in "*Preliminary Assessment of Potential Suitability – Feasibility Studies*" (NWMO, 2011).

1. Safety, security and protection of people and the environment are central to the siting process. ***Is there potential to find a safe site?***

   Safety was examined through several perspectives:
   - **Potential to find a site with suitable geology.**
   - **Potential to safely construct the facility at the potential site.**
   - **Potential for safe and secure transportation to the potential site.**
   - **Potential to manage any environmental effects and to ensure safety of people and the environment.**

2. The project will be implemented in a way that will foster long-term well-being of the community. ***Is there potential to foster the well-being of the community through the implementation of the project, and what might need to be put in place (e.g., infrastructure, resources, planning initiatives) to ensure this outcome?***

3. At a later step in the process, the community must demonstrate it is informed and willing to host the project. ***Is there potential for citizens in the community to continue to be interested in exploring this project through subsequent steps in the site selection process?***

4. The project will be implemented in a way that will foster the long-term well-being of the surrounding area. ***Is there potential to foster the well-being of the surrounding area and to establish the foundation to move forward with the project?***

These broad questions are addressed through a series of studies as outlined in Figure 1-2.

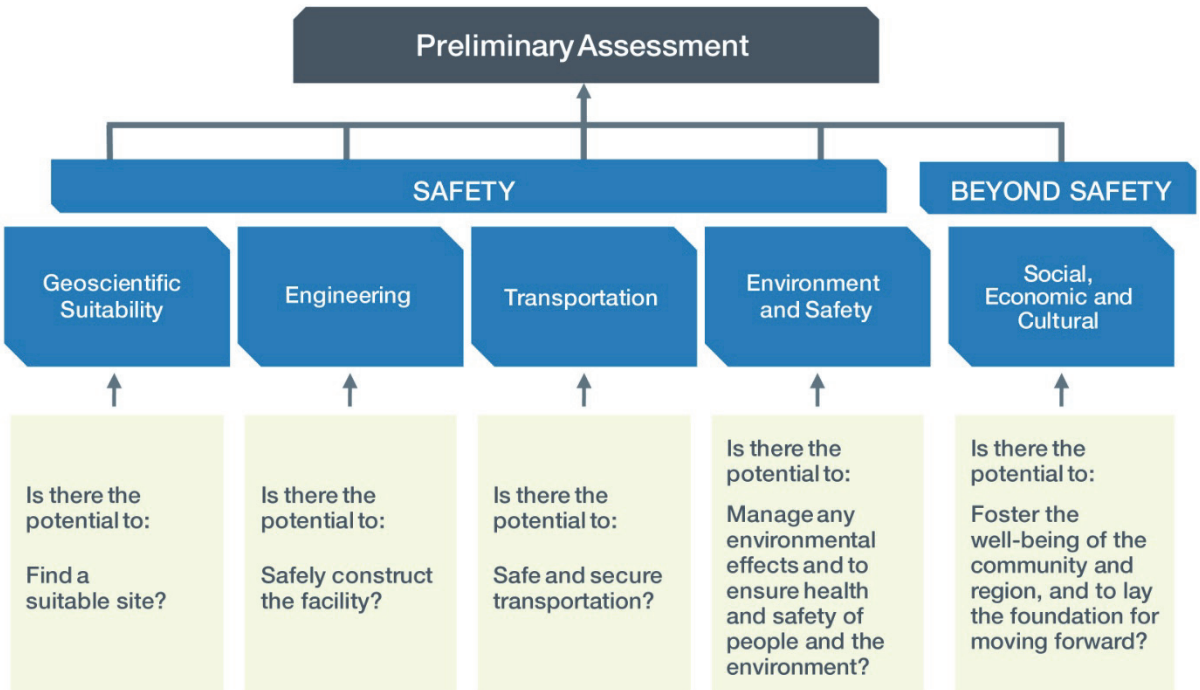


Figure 1-2: The Phase 1 Preliminary Assessment Studies

In Phase 1, studies involve a range of activities. Some activities are undertaken by expert consultants, such as the assessment of the geological characteristics of the area, which is one of several studies focused on assessing the potential to find a safe site. Other activities are undertaken in partnership with the community; for instance, exploring the potential for the project to be implemented in a way that contributes to the long-term well-being of the community.

As discussed in the NWMO site selection process, the suitability of potential sites is assessed against a number of site evaluation factors, organized under six safety functions a site would need to satisfy to be considered suitable (NWMO, 2010). Phase 1 safety assessment studies initiate exploration of a subset of these factors using a desktop study approach. Phase 2 assessments will include field studies and borehole investigation, which will allow for a broadening of the assessment to more comprehensively address the evaluation factors. The six safety evaluation factors are:

- ***Safe containment and isolation of used nuclear fuel:*** Are the characteristics of the rock at the site appropriate to ensuring long-term containment and isolation of used nuclear fuel from humans, the environment and surface disturbances caused by human activities and natural events?
- ***Long-term resilience to future geological processes and climate change:*** Is the rock formation at the siting area 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 geological and climate change processes such as earthquakes and glacial cycles?
- ***Safe construction, operation and closure of the repository:*** Are conditions at the site suitable for the safe construction, operation and closure of the repository?
- ***Isolation of used fuel from future human activities:*** Is human intrusion at the site unlikely, for instance through future exploration or mining?
- ***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?
- ***Safe transportation:*** Does the site have a route that exists or is amenable to being created that enables the safe and secure transportation of used fuel from storage sites to the repository site?

A number of factors beyond safety were identified for assessment of the potential for the project to foster the well-being of the interested community (NWMO, 2010). Phase 1 community well-being studies are focused on each community that expressed interest in learning about the project. For this reason, the studies address the subset of factors pertaining to the community. Phase 2 studies are designed to expand the assessment to consider factors related to the surrounding area, including potentially affected First Nation and Métis communities and surrounding communities. The factors beyond safety are:

- **Potential social, economic and cultural effects during the implementation phase of the project, including factors identified by Aboriginal Traditional Knowledge.**
- **Potential for enhancement of the community's and the region's long-term sustainability through implementation of the project, including factors identified by Aboriginal Traditional Knowledge.**
- **Potential to avoid ecologically sensitive areas and locally significant features, including factors identified by Aboriginal Traditional Knowledge.**
- **Potential for physical and social infrastructure to adapt to changes resulting from the project.**
- **Potential to avoid or minimize effects of the transportation of used nuclear fuel from existing storage facilities to the repository site.**

In order to ensure a broad, inclusive and holistic approach to assessment in these areas, a community well-being framework was identified to help understand and assess the potential effects of the APM Project.

1.8 Organization of Report

Findings from the siting studies for the Municipality of Arran-Elderslie are outlined in this report. The findings are based on a series of supporting geoscientific technical documents, each of which is identified in Chapter 3. The reflection on suitability is found in Chapter 4.

Report Overview

- ***Chapter 2*** – Brief introduction to the community.
- ***Chapter 3*** – Geoscientific preliminary assessment, which explores the potential to find a suitable site within the community.
- ***Chapter 4*** – Taking into account the siting studies, this chapter concludes with reflections on potential suitability of the community.

2. INTRODUCTION TO THE MUNICIPALITY OF ARRAN-ELDERSLIE

The Municipality of Arran-Elderslie is located in the centre of Bruce County, along the eastern boundary separating Grey County and Bruce County. The Municipality is comprised of a large rural area and smaller settlement areas. Figure 2-1 shows Arran-Elderslie in its regional context.

According to 2011 Census data, the total population of the Municipality is 6,810. Arran-Elderslie's main economic drivers are agriculture and industries that service the agricultural sector. Additionally, it is home to some light manufacturing.

The Sauble River flows across Arran-Elderslie's northern boundary with the Town of South Bruce Peninsula and runs through Tara. The Saugeen River forms the northwestern boundary of the Municipality and from there runs through Paisley and Chesley. Arran Lake is situated in the northern portion of the Municipality.

There are a number of First Nation and Métis communities and organizations in the vicinity of Arran-Elderslie, including the Saugeen Ojibway Nations (Saugeen First Nation and Chippewas of Nawash Unceded First Nation). Métis Nation of Ontario community councils in the vicinity include Moon River Métis, Georgian Bay Métis, and Great Lakes Métis. The Historic Saugeen Métis are also located in the vicinity.

Figure 2-1: Arran-Elderslie and Surrounding Lands

3. ASSESSMENT OF GEOSCIENTIFIC SUITABILITY

3.1 Geoscientific Preliminary Assessment Approach

The Phase 1 geoscientific desktop preliminary assessment for the communities of Arran-Elderslie, Brockton, Huron-Kinloss, Saugeen Shores, and South Bruce, was conducted in an integrated manner considering the geoscientific characteristics of the five Bruce County communities that entered the site selection process. This chapter summarizes the geoscientific assessment of the Municipality of Arran-Elderslie as part of the overall assessment of these five communities. Findings specific to Arran-Elderslie are summarized in Section 3.4.1.1. The geoscientific assessment was conducted by Geofirma Engineering Ltd. (Geofirma, 2014a).

The objective of the Phase 1 geoscientific desktop preliminary assessment was to assess whether the communities contain general areas that have the potential to satisfy the geoscientific evaluation factors outlined in the site selection process document (NWMO, 2010). The identification of potentially suitable areas focused on the area within the boundaries of the five communities [Municipalities of Arran-Elderslie, Brockton and South Bruce, Township of Huron-Kinloss, and Town of Saugeen Shores (shown in orange in Figure 3.1)]. Areas beyond the municipal boundaries of these five communities were not considered. However, for the purpose of the assessment, geoscientific information was collected and interpreted over a larger area comprising the five communities and their surroundings. The larger area is referred to in this chapter as the “Area of the Five Communities”, which is the entire area shown in Figure 3-1.

The geoscientific desktop preliminary assessment built on the work previously conducted for the initial screenings (AECOM, 2012a; 2012b; 2012c; 2012d; 2012e) and included the following activities:

- Assembly and detailed review of available geoscientific information such as geology, structural geology, natural resources, hydrogeology and overburden deposits (surficial deposits);
- Interpretation of available geophysical surveys;
- Interpretation of available borehole geophysical data and selected 2-D seismic reflection surveys to provide information on the geometry and potential structural features of the subsurface bedrock geology;
- Terrain analysis studies to help assess overburden (surficial deposits) type and distribution, bedrock exposures, accessibility constraints, watershed and subwatershed boundaries, and groundwater discharge and recharge zones;
- Assessment of land use and protected areas including parks, conservation reserves, heritage sites and source water protection areas; and
- The identification and evaluation of general potentially suitable areas based on systematic assessment of key geoscientific characteristics and constraints that can be realistically assessed at this stage of the assessment.

The details of these various studies are documented in a main Geoscientific Suitability Report (Geofirma, 2014a) and three supporting documents: Terrain Analysis (JDMA, 2014); Geophysical Interpretation (PGW, 2014); and Borehole Geophysical Well Log and 2D Seismic Data Interpretation (Geofirma, 2014b).

3.2 Geoscientific Site Evaluation Factors

As discussed in the NWMO site selection process, the suitability of potential sites is evaluated in a staged manner through a series of progressively more detailed scientific and technical assessments using a number of geoscientific site evaluation factors, organized under five safety functions that a site would need to ultimately satisfy in order to be considered suitable (NWMO, 2010).

- ***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 caused by human activities and natural events?
- ***Long-term resilience to future geological processes and climate change:*** Is the rock formation at the siting area 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 geological and climate change processes such as earthquakes and glacial cycles?
- ***Safe construction, operation and closure of the repository:*** Are conditions at the site suitable for the safe construction, operation and closure of the repository?
- ***Isolation of used fuel from future human activities:*** Is human intrusion at the site unlikely, for instance through future exploration or mining?
- ***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?

The assessment was conducted in two steps. The first step assessed the potential to find general potentially suitable areas within the communities using key geoscientific characteristics that can realistically be assessed at this stage of the assessment (Section 3.4.1). The second step assessed whether identified general potentially suitable areas have the potential to ultimately meet all the safety functions outlined above (Geofirma, 2014a).

The remainder of this chapter provides an overview of the geoscientific characteristics of the Area of the Five Communities (Section 3.3), followed by a summary of the geoscientific assessment of suitability (Section 3.4).

3.3 Geoscientific Characteristics of the Communities

The following sections provide a summary of available geoscientific information for the Area of the Five Communities as they relate to physical geography, bedrock geology, Quaternary (surficial) geology, seismicity, structural geology, hydrogeology and natural resources.

3.3.1 Physical Geography

A detailed discussion of the physical geography of the Area of the Five Communities is provided in the terrain analysis report (JDMA, 2014). There are six physiographic regions within the Area of the Five Communities: Arran drumlin field, Horseshoe moraines, Huron fringe, Huron slope, Saugeen clay plain, and Teeswater drumlin field.

The large-scale topography in the Area of the Five Communities is controlled by bedrock topography, whereas the detailed topography is often controlled by surficial deposits and erosional landforms cut into the surficial sediments. The pattern of elevation across the Area of the Five Communities (Figure 3-2) controls the overall pattern of drainage and is itself largely controlled by the bedrock topography. The elevation gradient in the Area of the Five Communities from southeast to northwest is from about 400 metres to 176 metres, with this elevation drop occurring over an approximate 70 kilometre lateral distance (Figure 3-2).

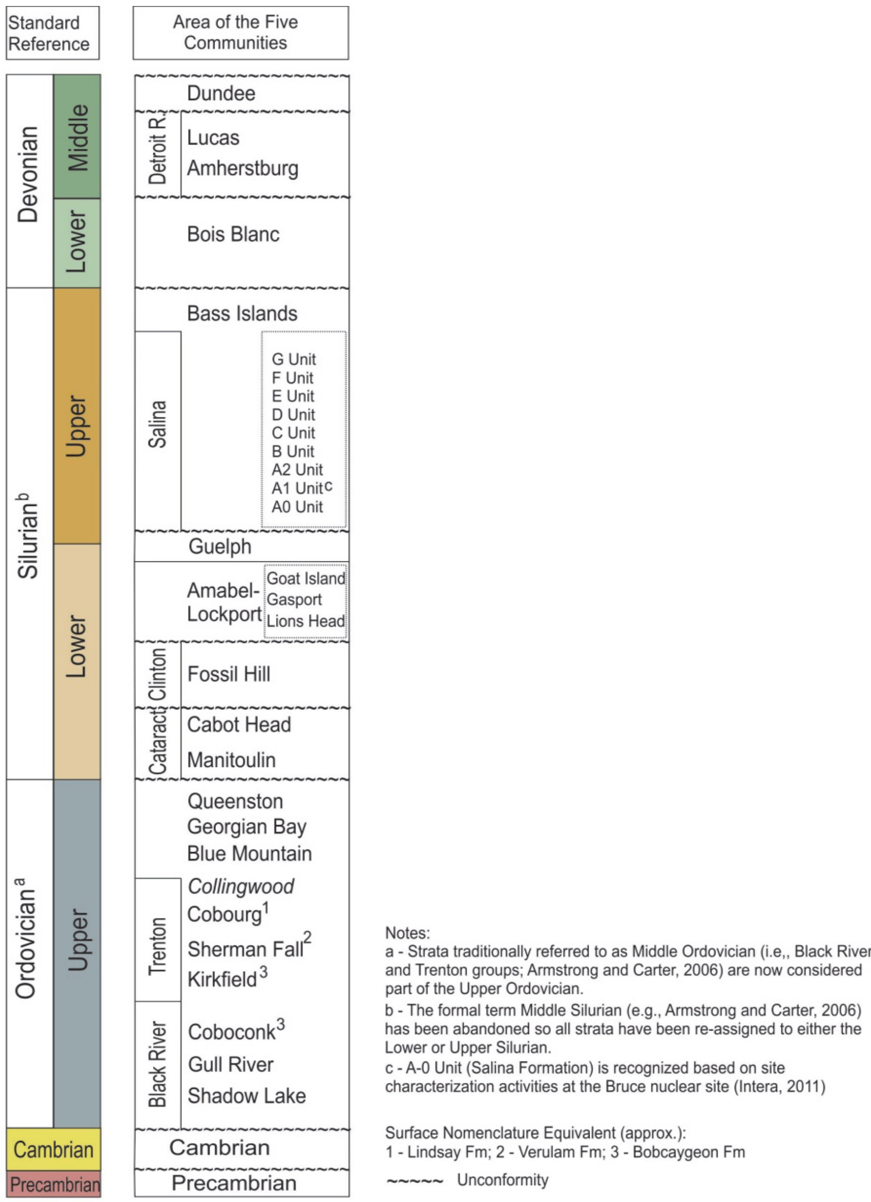
Overburden covers the bedrock surface throughout almost the entire area of the communities, with overburden thicknesses ranging from zero up to about 104 metres, with the thickest overburden in the area associated with buried bedrock valleys (JDMA, 2014). Less than one per cent of the Area of the Five Communities is occupied by water bodies of various sizes. The nine largest lakes in the area, aside from Lake Huron, cover from 0.4 to 3.9 square kilometres of the Area of the Five communities.

3.3.2 Bedrock Geology

Information on the bedrock geology in the Area of the Five Communities was obtained from publically available reports and geologic maps, as well as from interpretation of existing 2D seismic and borehole geophysical data (Geofirma, 2014b) and from the interpretation of existing airborne geophysical data (PGW, 2014). The main geoscientific desktop preliminary assessment report (Geofirma, 2014a) provides a detailed description of the regional and local geology of the Area of the Five Communities. The bedrock geology and Quaternary geology are based on 1:250,000 scale geological maps from the Ontario Geological Survey (OGS, 2011) and 1:50,000 scale surficial Quaternary maps (OGS, 1997; 2010). 2D seismic interpretations were conducted by reinterpreting four historical 2D seismic reflection data lines (725937, 825938, A002800018, A003900020) that are available within the Area of the Five Communities (Figure 3-3). Detailed lithological and mineralogical information on the Paleozoic bedrock formations in the Area of the Five Communities is available from Armstrong and Carter (2010) and from studies completed as part of the work undertaken at the Bruce nuclear site for the proposed Low and Intermediate Level Waste Deep Geological Repository (AECOM Canada Ltd. and Itasca Consulting Canada Inc., 2011; Intera Engineering Ltd., 2011).

As shown on Figure 3-4, the Paleozoic sedimentary sequence of southern Ontario overlies the Precambrian crystalline basement of the Grenville Province of the Canadian Shield. In southern Ontario the lithology of the Paleozoic formations is generally similar over large distances, and therefore descriptions provided in Armstrong and Carter (2010) are indicative of what can be expected for the Area of the Five Communities. Table 3-1 illustrates the Paleozoic bedrock stratigraphy, which is 500 to 1000 metres thick, for the Area of the Five Communities.

Table 3-1: Stratigraphy of the Area of the five Communities (after Armstrong and Carter, 2010)



The initial screenings (AECOM, 2012a; 2012b; 2012c; 2012d; 2012e) identified the Paleozoic Upper Ordovician shale and limestone sedimentary rock units as potentially suitable for hosting a deep geological repository for used nuclear fuel. These Upper Ordovician rocks comprise a thick sequence with a distinctly bimodal composition: a carbonate-rich lower unit and a shale-rich upper unit.

The lower carbonate-rich unit of the Upper Ordovician overlies the Cambrian unit, where present, or the Precambrian basement (Figure 3-4). It is a thick sequence (approximately 200 metres thick) predominated by limestone and argillaceous limestone formations, 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 (including the Collingwood Member) formations of the Trenton Group (Table 3-1). The Shadow Lake Formation, at the base of the Black River Group, is characterized by poorly sorted, red and green sandy shales, argillaceous and arkosic sandstones, minor sandy argillaceous dolostones and rare basal arkosic conglomerate. The lower part of the overlying Gull River Formation consists mainly of light grey to dark brown limestones and the upper part of the formation is very fine grained with thin shale beds and partings. The Coboconk Formation, at the top of the Black River Group, is composed of light grey-tan to brown-grey, medium to very thick bedded, fine to medium grained bioclastic limestones (Armstrong and Carter, 2010).

The Kirkfield Formation, at the base of the Trenton Group, is characterized by fossiliferous limestones with shaley partings and local, 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 formation. The overlying Cobourg Formation is 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 (approximately 200 metres) of predominantly shale sedimentary rocks, which comprise from base to top: 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). In the lower part of the Blue Mountain Formation there is downward gradation from grey to greenish-grey shales to a very dark grey to black shale (Armstrong and Carter, 2010). 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, and lesser green, shale and siltstone with varying minor amounts of carbonate. The top of the Queenston Formation is marked by a regional erosional unconformity (Table 3-1; Armstrong and Carter, 2010).

The Upper Ordovician shale and limestone packages exhibit relatively uniform thicknesses (i.e., about 200 metres each), and are known to dip uniformly to the southwest at between 0.23 degrees and one degree in the Area of the Five Communities (e.g., Watts et al., 2009; Intera Engineering Ltd., 2011). The depth to the top of the Cobourg Formation ranges from about 350 metres below ground surface in the northern corner of the Municipality of Arran-Elderslie to approximately 800 metres below ground surface at the southwestern boundary of the Township of Huron-Kinloss (Geofirma, 2014a). Erosion, pinnacle reef formation and salt bed dissolution introduce a certain degree of non-uniformity into the Paleozoic sequence in the Area of the Five Communities, mostly in relation to the thickness and presence/absence of certain Silurian formations (Geofirma, 2014a).

There are two mapped subsurface basement-seated faults within the Area of the Five Communities, one in the Municipality of Brockton and one that extends from the Municipality of South Bruce into the Township of Huron-Kinloss. Both are interpreted to be about 5 to 10 kilometres in length and strike east-northeast (Figure 3-3). The fault in the Municipality of Brockton is located at the west end of the Municipality, and it is interpreted to offset up to the Shadow Lake Formation/Precambrian units. The other mapped subsurface fault is in the northwest corner of the Municipality of South Bruce, extending west into the Township of Huron-Kinloss, and is interpreted to extend upwards as shallow as the Trenton Group limestones. Given the sparse borehole data used to interpret these two faults, there is some uncertainty associated to their location, orientation and existence.

In addition, two sub-vertical faults were interpreted as part of the 2D seismic interpretation study conducted as part of this preliminary assessment (Geofirma, 2014b). One of these interpreted faults is in the Municipality of South Bruce, and is interpreted as a near vertical reverse fault extending from the Precambrian basement up to the base of the Silurian formations. This interpreted fault is in the same general location as the mapped subsurface fault identified in the Municipality of South Bruce (Figure 3-3). The second interpreted fault is located in the Township of Huron-Kinloss, and is thought to be a near vertical reverse fault that extends upwards from the Precambrian basement and into the Silurian Cabot Head Formation. The confidence in location, orientation and existence of these interpreted faults in the Municipality of South Bruce and the Township of Huron-Kinloss remains low.

3.3.3 Quaternary Geology

The terrain analysis report (JDMA, 2014) provides a detailed description of the Quaternary geology of the Area of the Five Communities. Glacial landforms and associated sediments within the Area of the Five Communities were deposited by the Huron and Georgian Bay lobes of the Laurentide Ice Sheet during the Late Wisconsinan 23,000 to 10,000 years ago (Karrow, 1993).

As shown on Figure 3-5, the Quaternary cover in the Area of the Five Communities comprises different types of glacial deposits. Overburden covers over 99 per cent of the area, with thicknesses ranging from zero up to about 104 metres, with the thickest overburden in the area associated with buried bedrock valleys (Gao, 2011a; 2011b).

3.3.4 Erosion

Geofirma (2014a) summarizes the currently available information on glacial erosion in southern Ontario. The depth of glacial erosion depends on several regionally specific factors, such as the ice-sheet geometry, topography, and history, as well as local geological conditions, such as overburden thickness, rock type and pre-existing weathering. Various recent studies were aimed at assessing the impact of glaciations on erosion over sedimentary rocks. A recent literature review conducted by Hallet (2011) concluded that although uncertainties remain in ice sheet reconstructions and estimates of erosion by ice and melt water, all lines of evidence indicate that, in southern Ontario, glacial erosion would not exceed a few tens of metres in 100,000 years with a conservative estimate of 100 metres per one million years for the Bruce nuclear site (location of the Bruce nuclear site is shown on Figure 3-1).

3.3.5 Seismicity and Neotectonics

3.3.5.1 Seismicity

The Area of the Five Communities overlies the Grenville Province of the Canadian Shield and the interior of the North American continent, where large parts have remained tectonically stable for the last 970 million years (Percival and Easton, 2007). Figure 3-6 shows the location and magnitudes of seismic events recorded in the National Earthquake Database (NEDB) for the period between1985 to 2013 in southern Ontario (NRC, 2013a). Earthquake magnitude resolution in Figure 3-6 was improved to less than 1.0 for the Area of the Five Communities and environs based on the 2007 installation of the microseismic monitoring network for the site characterization work at the Bruce nuclear site, and to magnitude 2.0 for the remainder of southern Ontario based on an expanded POLARIS (Portable Observatories for Lithospheric Analysis and Research Investigation Seismicity) network established in 2002. Over this time period, there are no recorded earthquakes located within any of the five Communities, with the closest recorded earthquakes located offshore in Lake Huron about 25-30 kilometres northwest of the Town of Saugeen Shores, and north of Owen Sound. The maximum magnitude of these events was of 2.5 Nuttli Magnitude. A 4.3 Nuttli Magnitude earthquake was recorded in 2005 northeast of Owen Sound within Georgian Bay at distances of 80 to 110 kilometres of the centres of the communities (Hayek et al., 2011).

3.3.5.2 Neotectonic Activity

Neotectonics refers to deformations, stresses and displacements in the earth's crust of recent age or which are still occurring. These processes are related to tectonic forces acting in the North American plate as well as those associated with the numerous glacial cycles that have affected the northern portion of the plate during the last million years, including all of the Canadian Shield (Shackleton et al., 1990; Peltier, 2002).

The geology of the Area of the Five Communities is typical of many areas of southern Ontario, which have been subjected to nine glacial cycles during the last million years (Peltier, 2002). Post-glacial isostatic rebound is still occurring across most of Ontario. Vertical velocities show present-day uplift of about 10 millimetres per year near Hudson Bay, the site of thickest ice at the last glacial maximum (Sella et al., 2007). The uplift rates generally decrease with distance from Hudson Bay and change to subsidence (one to two millimetres per year) south of the Great Lakes. The present day rebound rate in the Area of the Five Communities is about 1.5 millimetres per year (Peltier, 2011).

No neotectonic structural features are known to occur within the Area of the Five Communities. Slattery (2011) completed a remote-sensing and field-based study that analysed Quaternary landforms for the presence of seismically-induced soft-sediment deformation within five to 50 kilometres of the Bruce nuclear site. The investigation involved reviewing existing information sources (e.g., papers, reports, and maps), interpreting air photos and a LiDAR (Light Detection and Ranging) digital elevation model, and searching for liquefaction structures displayed in sediment exposures in the field. The review of existing information and interpretation of air photos was done for the entire area within 50 kilometres of the Bruce nuclear site, providing coverage of the entire Area of the Five Communities. No conclusive geomorphological or sedimentological evidence of post-glacial neotectonic activity was identified within the study area (Slattery, 2011).

3.3.6 Hydrogeology and Hydrogeochemistry

Information concerning groundwater use in the Communities was obtained principally from the Ontario Ministry of the Environment (MOE) Water Well Information System (WWIS) database (Ontario Ministry of the Environment, 2013a), as well as from regional groundwater studies and source water protection studies based on interpretation of these data. Water wells in the Area of the Five Communities obtain water from the overburden or the shallow bedrock.

The WWIS database contains a total of 12,442 water well records for the Area of the Five Communities. Not all of these water well records are complete and not all of these records provide useful hydrogeological information. A total of 10,374 water wells for the Area of the Five

Communities that have been reliably identified as overburden wells (1,337) and bedrock wells (9,037), and were plotted on Figure 3-5. The well type was uncertain for the remaining 2,068 wells which were not plotted. Most of the water well records (10,194) provide useful information on well depth, lithology, well yield, and static water level. Table 3-2 summarizes the number and type of these water well records within the communities (3,785). The remaining 6,409 water wells that provide useful hydrogeological information are located outside of the municipal boundaries of the five communities.

Table 3-2: Water Well Record Summary for the Communities

Well Type	No. of Well Records	Well Depth Range (metres below ground surface)		Static Water Level Range (metres below ground surface)		Well Yield (Litres/minute)		
		Min	Max	Min	Max	Min	Max	Mean
Municipality of Arran-Elderslie (Total 723 Well Records)								
Overburden	98	4.6	101.8	-0.3	36.3	4.5	450	47
Bedrock	625	6.1	218	-1.2	36.3	9.0	495	42
Municipality of Brockton (Total 1,154 Well Records)								
Overburden	244	2.7	114.6	-1.8	50	4.5	360	52
Bedrock	910	5.0	134.1	-2.1	54.3	9.0	1,230	57
Municipality of South Bruce (Total 845 Well Records)								
Overburden	53	2.7	96.9	0.6	20.7	13.5	1,350	95
Bedrock	792	3.7	163.1	-12.2	48.8	9.0	1,125	60
Township of Huron-Kinloss (Total 861 Well Records)								
Overburden	78	2.5	93.3	1.5	27.4	9.0	1,125	88
Bedrock	603	15.2	111.3	-6.1	45.1	18.0	1,125	81
Town of Saugeen Shores (Total 382 Well Records)								
Overburden	156	2.6	157	-0.6	49.1	4.5	200	42
Bedrock	226	6.7	182.9	-9.1	48.8	9.0	1,350	29
Note: This table lists the 3,785 wells within the municipal boundaries of the five communities that can confidently be assigned to overburden or bedrock aquifers. There are an additional 6,409 wells in the Area of the Five Communities, beyond the boundaries of the five communities.								

3.3.6.1 Overburden Aquifers

There are 1,337 water well records in the Area of the Five Communities that can be confidently assigned to overburden aquifers. These wells are generally 10 to 100 metres deep and have mean well yields of 40 to 90 litres per minute. These well yields reflect the purpose of the wells (i.e. primarily residential use) and do not necessarily reflect the maximum sustained yield that might be available from the aquifers intersected by the wells.

Noteworthy overburden aquifers within the communities include (Saugeen, Grey Sauble, Northern Bruce Peninsula Source Water Protection Region, 2011a; 2011b; Ausable Bayfield Maitland Valley Source Protection Region, 2011):

- The confined sand and gravel Chesley Aquifer found in proximity to and north of Chesley, Municipality of Arran-Elderslie;
- The partially confined sand and gravel Port Elgin-Southampton Aquifer found near and within the lower part of the Saugeen River, Town of Saugeen Shores;
- The confined sand and gravel Hanover Aquifer in the Municipality of Brockton which provides municipal water supply for Hanover;
- The partially confined sand and gravel Walkerton Aquifer situated in the vicinity of Walkerton, Municipality of Brockton;
- The unconfined sand Lake Warren Shoreline Aquifer located as a narrow north-south band of glaciolacustrine deposits within the Township of Huron-Kinloss;
- The unconfined sandy beach deposits of the Lake Huron Beach Aquifer found along the present day shoreline of Lake Huron in the Township of Huron-Kinloss and the Town of Saugeen Shores; and
- The unconfined sand and gravel Wawanosh Kame Moraine Aquifer located in the southeast part of the Township of Huron-Kinloss and the southwest part of the Municipality of South Bruce.

Source water protection assessment reports (Saugeen, Grey Sauble, Northern Bruce Peninsula Source Water Protection Region, 2011a; 2011b; Ausable Bayfield Maitland Valley Source Protection Region, 2011) provide the locations of significant groundwater recharge areas within the Area of the Five Communities, indicating areas where greater than average groundwater recharge likely occurs. These areas were mapped based on consideration of surficial geology, soils, land cover and topography. Significant groundwater recharge occurs in flat-lying/hummocky areas with sands and gravels at surface and limited land cover (Geofirma, 2014a).

3.3.6.2 Bedrock Aquifers

No water wells in the Area of the Five Communities were drilled to typical repository depths of approximately 500 metres below ground surface. There are 9,037 water well records in the Area of the Five Communities that can be confidently assigned to shallow bedrock aquifers. Shallow bedrock hydrogeological information is available primarily from surface to depths of 100 to 150 metres from the MOE well records (MOE, 2013a) based on regional use of this shallow bedrock aquifer as a source of drinking water. Shallow bedrock is the most important source of drinking water in the communities, and is the primary source of most of the municipal water supplies located inland from Lake Huron. Shallow bedrock aquifers within the communities are composed of an aggregate of the upper few metres to over 100 metres of the different shallow bedrock formations present, which range from Middle Devonian Lucas Formation dolostone in the southwest (Township of Huron-Kinloss) to Upper Silurian Guelph Formation dolostone in the northeast (Municipality of Arran-Elderslie) (Figure 3-6). The municipalities of Brockton and South Bruce are underlain at shallow depths by Lucas Formation dolostones through to Salina Group dolostones, shales and evaporites. The Town of Saugeen Shores is underlain by the Salina Group and a thin band of Upper Silurian Bass Islands Formation dolostone along its southern boundary. Water quantity and quality within the shallow bedrock aquifer can vary dramatically across the communities as a consequence of the different chemical and physical characteristics of the individual bedrock formations.

In many parts of the Area of the Five Communities, an overlying layer of clay and silt till confines the shallow bedrock aquifer. In these areas the low permeability silt and clay till is considered to represent an aquitard that protects the shallow bedrock aquifer.

3.3.6.3 Shallow Groundwater Regime

The shallow groundwater regime includes the overburden aquifers and aquitards, and shallow bedrock aquifers that provide drinking water supplies to both municipalities and residences. Within eastern parts of the municipalities of Brockton and South Bruce and within most of the Municipality of Arran-Elderslie and the Town of Saugeen Shores, the shallow groundwater regime will likely extend to depths of 150 metres or more within the Guelph Formation. Within the Township of Huron-Kinloss the shallow groundwater regime likely extends to somewhat shallower depths of about 100 metres.

Groundwater flow directions within shallow systems often mimic surface water flow directions with the groundwater table generally present as a subdued reflection of topography. Shallow groundwater flow will be directed from areas of higher hydraulic head, such as highlands and drainage divides to areas of lower hydraulic head such as low-lying areas of valleys, depressions, and surface waters. The extent of such shallow flow systems will be defined by local, topography-controlled, drainage divides across which groundwater flow will not readily occur. Generally, for such shallow systems, groundwater divides will coincide with surface water drainage divides.

3.3.6.4 Formation Hydraulic Pressures

There is limited readily available information on formation hydraulic pressures at typical repository depths in the communities; however, there is detailed information on hydraulic pressures within the Paleozoic bedrock sequence in the Area of the Five Communities from studies at the Bruce nuclear site.

Formation hydraulic pressures in bedrock to depths of about 850 metres below ground surface have been measured in-situ and reported for the entire Paleozoic bedrock sequence at the Bruce nuclear site using special multiple-port pressure monitoring instrumentation consisting of numerous packer-isolated test intervals installed in several deep boreholes (Intera Engineering Ltd., 2011). These ongoing hydraulic pressure measurements allow for determination of the presence of normally-pressured, overpressured or underpressured conditions within individual deep formations and estimation of groundwater flow directions within shallow and deep bedrock aquifers.

There is significant underpressuring of the deep aquiclude of the Ordovician shales and Trenton Group limestones of up to 250 to 300 metres below ground surface expressed as environmental water head at the Bruce nuclear site (Intera Engineering Ltd., 2011). These underpressures are an important hydrogeological characteristic of the Ordovician shales and Trenton Group limestones which indicate that these formations would act as barriers to groundwater migration. Possible explanations for the observed underpressures include: poroelastic response to glacial unloading and flexure; poroelastic response to Cenozoic erosional unburdening; capillary pressure effects due to the presence of a separate gas phase; and/or chemical osmosis (Intera Engineering Ltd., 2011). The occurrence and persistence of these underpressures are clearly indicative of very low formation permeability and provide confidence in the very low permeabilities reported from hydraulic testing at the Bruce nuclear site (NWMO, 2011). These hydrogeological properties indicate aquiclude conditions with no advection of brine, and a system in which gas flow would also be diffusion controlled.

There is also significant overpressuring of up to 165 metres above ground surface expressed as environmental water head within the permeable Cambrian sandstone that propagates into some of the overlying Black River Group limestones and siltstones. There are also some moderate overpressures occurring within the Salina A1 and A0 Units, Goat Island, Gasport, Lions Head and Fossil Hill formations and within the middle of the Blue Mountain Formation. Possible explanations for the cause of these overpressures include: hydraulic connection to a remote elevated regional recharge area (e.g., Niagara Escarpment, Canadian Shield); remnant overpressure from deep basin glacial meltwater recharge and post-glacial basin isostatic rebound; and/or up-basin regional fluid (brine or gas) migration and pressurization (Intera Engineering Ltd., 2011).

Current pressure measurements within the Salina Upper A1 Unit aquifer at the Bruce nuclear site indicate groundwater flow directions to the northwest toward Lake Huron (Intera Engineering Ltd., 2011) consistent with groundwater flow directions in the overlying shallow groundwater regime at the Bruce nuclear site and in the Area of the Five Communities. Current pressure measurements for the slightly deeper Guelph Formation aquifer indicate that groundwater flows in an up-dip direction to the east-northeast towards the Guelph Formation subcrop (Geofirma, 2014a). The data from the Bruce nuclear site, along with the regional-scale understanding, suggests that similar formation hydraulic pressures are present in the Paleozoic bedrock sequence beneath the communities.

3.3.6.5 Hydrogeochemistry

Information on shallow overburden and bedrock groundwater geochemistry in southwestern Ontario, including the Area of the Five Communities, is presented by the Ontario Geological Survey (Hamilton, 2011) and by the Ontario Ministry of the Environment (2013b). Within the Area of the Five Communities, Hamilton (2011) summarizes the groundwater geochemistry of 101 wells (43 overburden, 58 bedrock) to a maximum depth of 148 metres sampled from 2007 to 2010. The Ontario Ministry of the Environment (2013b) presents water quality information for the 17 wells that are part of the Provincial Groundwater Monitoring Network.

There is no direct readily available information on hydrogeochemistry at typical repository depths in the communities. Geofirma (2014a) summarizes the expected hydrogeochemical conditions of the shallow to deep Paleozoic and underlying Precambrian bedrock within the Area of the Five Communities based on a number of sources, including detailed porewater and groundwater testing completed at the Bruce nuclear site (Intera Engineering Ltd., 2011); regional compilations of oil, gas and salt well data completed as proposed Low and Intermediate Level Waste Deep Geological Repository Geosynthesis (NWMO, 2011; Hobbs et al., 2011); and data from the Ontario Petroleum Institute (Carter and Fortner, 2011). Because the extremely low permeability of most of the Silurian and Ordovician formations precludes conventional groundwater sampling, significant reliance was placed on extraction and testing of porewaters for determination of bedrock hydrogeochemical parameters.

Based on information from the Bruce nuclear site, hydrogeochemical data shows highly saline, non-potable brines (salinities of approximately 200,000 to 300,000 milligrams per litre total dissolved solids in the Ordovician formations) exist at typical repository depths within the area. The current understanding of the origin of brines within the Michigan Basin indicates that they were formed by evaporation of sea water that was subsequently modified by: dilution of brines by lower salinity water; dissolution of halite by lower salinity water; and diagenetic water-rock interactions, particularly dolomitization. The data from the Bruce nuclear site is consistent with the regional scale understanding, and suggests that similar brines are present in the Ordovician rocks beneath the communities.

3.3.7 Natural Resources

The potential for natural resources in the Area of the Five Communities is shown on Figure 3-7 and discussed in detail in Geofirma (2014a). Natural resources assessed for the area include: petroleum resources (conventional and unconventional oil and gas), metallic mineral resources, non-metallic mineral resources (sand and gravel, bedrock resources and salt) and potable groundwater resources associated with the Guelph Formation.

Although the potential for petroleum resources is recognized in southern Ontario, most delineated oil and gas pools are located far to the south of the Area of the Five Communities. As shown on Figure 3-7, there are only three oil and gas pools, all of them located immediately south of the Township of Huron-Kinloss. There are no known oil and gas pools within the communities and all the exploration wells drilled within the communities resulted in dry holes.

Discretionary mineral occurrences of limestone, dolostone, and marl are present within the communities, but the occurrences are associated with shallow depths (typically less than 20 metres) within the Area of the Five Communities. Sand and gravel pits are operating throughout the Area of the Five Communities. Most of these pits are shallow (less than eight metres depth) and located within esker, glaciofluvial outwash, ice contact or glaciolacustrine beach deposits.

Salt beds of the Silurian Salina Group are known to be present beneath the Township of Huron-Kinloss, and the southwestern-most corner of the Municipality of South Bruce; however, these deposits are relatively thin and shallow compared to the depth of the Cobourg Formation in that area. The salt beds of the Silurian Salina Group are not present beneath the Municipality of Arran-Elderslie, the Municipality of Brockton, or the Town of Saugeen Shores.

The Guelph Formation dolostone is a regionally important water supply aquifer, and is present over most of the Area of the Five Communities. Within the communities, the top of the Guelph Formation is found at depths ranging from about five metres in the Municipality of Arran-Elderslie to a maximum of over 500 metres in the Township of Huron-Kinloss. Given the recognized potential of the Guelph Formation as a water supply aquifer, there is potential for its development as a fresh water source below depths typically assumed for shallow bedrock water supplies in the Area of the Five Communities (Geofirma, 2014a). However, in order for the Guelph Formation to be accessed as a water supply aquifer the groundwater must be potable. Figure 3-7 shows the inferred extent of the occurrence of fresh water within the Guelph Formation in the Area of the Five Communities. The northeastern extent of fresh water in the Guelph Formation shown in Figure 3-7 is the mapped outcrop limit of the Guelph Formation. The southwestern limit of fresh water occurrence within the Guelph Formation shown in Figure 3-7 is about 200 to 250 metres below ground surface. Potable water is likely to occur to the northeast above this depth horizon.

The communities are located in a sedimentary rock setting in southern Ontario, where the potential for metallic mineral resources is considered to be low.

3.3.8 Geomechanical and Thermal Properties

There are no data on geomechanical and thermal properties of the Paleozoic bedrock formations at typical repository depths within the communities. However, geomechanical property data are available from detailed drilling and testing investigations at the nearby Bruce nuclear site (Intera Engineering Ltd., 2011, Golder Associates Ltd., 2013), and from regional compilations of geomechanical data (NWMO and AECOM Canada Ltd., 2011; Golder Associates Ltd., 2003a). Thermal property data are also available from additional detailed drilling and testing investigations at the nearby Bruce nuclear site (Atomic Energy of Canada Ltd., 2011), and from compilations of data available in the published literature (Clauser and Huenges, 1995; Sass et al., 1984; Cermak and Rybach, 1982). Based on the lateral traceability and predictability of the Paleozoic sequence in southern Ontario, geomechanical and thermal properties of the Paleozoic sequence in the communities can be expected to be similar to those measured at the Bruce nuclear site and elsewhere in southern Ontario.

Argillaceous limestone of the Cobourg Formation has high strength, with an average Uniaxial Compressive Strength (UCS) value of 113 megapascals, thus indicating a high degree of stability for deep underground excavations (Intera Engineering Ltd., 2011; NMWO, 2011). The Upper Ordovician shale and limestone units at the Bruce nuclear site are very sparsely fractured and of excellent quality, with the Cobourg Formation having a rock mass designation of excellent and a rock quality designation generally ranging between 90 and 100 per cent at the Bruce nuclear site (Intera Engineering Ltd., 2011). The measured fracture frequency is similar in all of the Ordovician formations and ranges from approximately 0 to 1.7 fractures per metre, with an average value of generally less than 0.3 fractures per metre. The mean measured thermal conductivity, thermal diffusivity and specific heat for Paleozoic formations measured on core samples collected at the Bruce nuclear site are generally consistent with thermal property data reported in the literature for sedimentary rocks. The Cobourg Formation has slightly higher thermal conductivity that the overlying Ordovician shales, and underlying Sherman Fall Formation.

Site-specific geomechanical and thermal data would need to be obtained during later stages of the site evaluation process.

3.4 Potential Geoscientific Suitability of the Communities

This section provides a summary of how key geoscientific characteristics and constraints were applied to the five Bruce County communities involved in the site selection process to assess whether they contain general areas that have the potential to satisfy the NWMO's geoscientific site evaluation factors (Section 3.4.1). The potential of identified areas to ultimately satisfy all geoscientific evaluation factors and safety functions outlined in the NWMO's site selection process is described in Geofirma (2014a).

3.4.1 Potential for Finding General Potentially Suitable Areas

The potential for finding general areas that are potentially suitable for hosting a deep geological repository was assessed using the key geoscientific characteristics and constraints briefly described below.

- ***Geological Setting:*** The initial screenings of the five Bruce County communities involved in the site selection process (AECOM Canada Ltd., 2012a; 2012b; 2012c; 2012d; 2012e) identified the Upper Ordovician shale and limestone units as potentially suitable host rock formations. As described in Section 3.3.2, the 500 to 1000 metre thick Paleozoic bedrock sequence within the five Communities typically includes Devonian dolostones overlying Silurian dolostones, shales and evaporites, overlying Upper Ordovician shales and limestones, and occasionally Cambrian sandstone, overlying Precambrian basement. The Upper Ordovician Cobourg Formation argillaceous limestone is overlain by about 200 metres of Upper Ordovician shales and underlain by about 150 metres of deeper Upper Ordovician limestones (Figure 3-4).

Based on available information on the geoscientific characteristics of the sedimentary sequence beneath the Five Communities, the Ordovician Cobourg Formation (argillaceous limestone) would be the preferred host rock for a used nuclear fuel deep geological repository. The natural geological setting in this formation would provide the most favourable geoscientific characteristics for ensuring safety. As described in Section 3.3, the Cobourg Formation underlies the Bruce County area in sufficient thickness and volume, and has favourable geoscientific characteristics such as very low hydraulic conductivity and high geomechanical strength (Geofirma, 2014a).

While the other Trenton Group limestone formations (i.e. Sherman Fall and Kirkfield formations) and the Upper Ordovician shales (i.e. Queenston, Georgian Bay and Blue Mountain formations) also have very low hydraulic conductivities, they are less preferred than the Cobourg Formation from a geomechanical perspective (i.e. lower rock strength). The limestone formations of the Black River Group are also less preferred as they have uniformly higher hydraulic conductivity values than the Cobourg Formation. The favourable characteristics of the Cobourg Formation are complemented by the presence of approximately 200 metres of overlying very low permeability Ordovician shale formations, which act as an additional hydraulic barrier.

There are only two mapped subsurface faults within the communities, in the municipalities of Brockton and South Bruce and the Township of Huron-Kinloss. Two faults were also interpreted from the analysis of available 2D seismic data within the communities (Section 3.3). For the purpose of this preliminary assessment, these faults were not considered as key constraints in the identification of general potentially suitable areas as the possible faults are very localized and there is uncertainty at this stage regarding their location, orientation and existence. The potential for faults in the Paleozoic sequence within the communities would need to be further assessed during subsequent stages of the site selection process.

- ***Minimum Depth of Top of the Cobourg Formation:*** For the sedimentary sequence in the Area of the Five Communities, it was determined that a minimum depth of 500 metres below ground surface would be preferred in order to maintain the integrity of a repository within the Cobourg Formation. This preferred depth would also protect the 200 metre thick Ordovician shale barrier under the most conservative assumptions of future bedrock removal rates due to glacial erosion (Section 3.3.4; Hallet, 2011; Figure 3-8).

- ***Protected Areas:*** All known protected areas within the communities were excluded from further consideration (Figure 3-8). These include exclusion areas identified by the communities for future development, Conservation Areas and Reserves, First Nation Reserves, provincial parks, provincially significant wetlands, and built-up areas.

- ***Source Water Protection Areas:*** Land-based water protection zones (IPZs, Intake Protection Zones) 1 and 2, and groundwater protection areas (WHPAs, Well Head Protection Areas) A, B and C were excluded from further consideration (Figure 3-8), given that they provide the highest level of protection for municipal groundwater supplies through land use planning and controls. The consideration of WHPAs D and E would need to be further assessed in collaboration with the communities in future studies.

- ***Natural Resources:*** The potential for natural resources in the Area of the Five Communities is shown on Figure 3-7. Discretionary mineral occurrences of limestone, dolostone, and marl present within the communities are not considered as siting constraints due to the shallow depth associated with these occurrences (typically less than 20 metres). While oil and gas pools exist immediately south of the Township of Huron-Kinloss, and potential for petroleum resources is recognized in southern Ontario, there are no known oil and gas pools within the communities and all the exploration wells drilled within them resulted in dry holes. Salt beds of the Silurian Salina Group are known to be present beneath the Township of Huron-Kinloss; these are also not considered as a siting constraint at this stage given the relatively thin nature of the deposits and their relatively shallow occurrence underneath the Township of Huron-Kinloss (approximately 350 to 400 metres below ground surface) compared to the depth of the Cobourg Formation (approximately 700 to 800 metres below ground surface).

- ***Surface Constraints:*** Surface features such as overburden, the limited extents of wetlands outside protected areas, the relatively flat topography and the ease of accessibility within the communities were not found to be significant siting constraints. Overburden cover is extensive and locally thick within the communities, and wetlands cover from 10 to 20 per cent of each of the communities (Figure 3-5). However, these features were not considered as significant constraints to siting at this stage. Water bodies cover a relatively small area.

The consideration of the above key geoscientific characteristics and constraints revealed the Area of the Five Communities has a number of favourable geoscientific characteristics for hosting a deep geological repository for used nuclear fuel. However, there are areas that have more potential than others.

Figure 3-8 illustrates the key geoscientific characteristics and constraints used to identify general potentially suitable areas. The application of these key characteristics and constraints revealed that the municipalities of Brockton and South Bruce, and the Township of Huron-Kinloss contain large areas that have the potential to satisfy NWMO's geoscientific evaluation factors. The assessment also revealed that the Municipality of Arran-Elderslie, the subject of this report, and the Town of Saugeen Shores have limited potential to satisfy the geoscientific evaluation factors outlined in the NWMO's site selection process when the above geoscientific characteristics and constraints are coupled with land use constraints. The following sub-sections provide additional detail on general potentially suitable areas for each of the Bruce County communities involved in the site selection process.

At this early stage of the assessment, the boundaries of the identified general potentially suitable areas in the Municipalities of Brockton and South Bruce, and the Township of Huron-Kinloss are not yet defined in detail. Their location and extent would be further refined during subsequent site evaluation stages, should any of these three communities continue in the site selection process.

3.4.1.1 Municipality of Arran-Elderslie

There are six conservation reserves, four provincially significant wetlands and several earth science Areas of Natural Scientific Interest (ANSIs) within the Municipality, which combined account for approximately nine per cent of the area of the Municipality (Figure 3-8). In addition there are also two wellhead protection areas; one associated with the Tara well supply, and one associated with part of the wellhead protection area for the Chesley well supply. Other surface constraints within the Municipality include the built-up areas of the settlement areas of Paisley, Chesley and Tara.

There are no oil and gas pools or mineral occurrences recorded within the Municipality of Arran-Elderslie, so there are no known natural resource constraints at this stage for identifying general potentially suitable areas within the Municipality. There are no faults mapped within the Municipality.

There are no boreholes drilled within the Municipality of Arran-Elderslie to provide direct information on the subsurface bedrock geology. However, information on the bedrock geology beneath the Municipality can be obtained from wells surrounding the Municipality and from the regional understanding of the Paleozoic geology. The Municipality of Arran-Elderslie is underlain by a laterally extensive and uniform Paleozoic sequence, which is interpreted to have a cumulative thickness on the order of 700 metres. Contour mapping (Geofirma, 2014a) shows that the preferred Cobourg Formation is expected to be found at depths ranging from approximately 343 metres below ground surface in the northeastern portion of the Municipality to approximately 545 metres below ground surface towards its southwestern portion. The area within the Municipality where the top of the Cobourg Formation is at preferred depth of greater than 500 metres below ground surface represents only about five per cent of the area of the Municipality, which is insufficient for hosting a deep geological repository. This area contains a number of surface constraints that further reduce land availability. These include: the McBeath Conservation Area, built-up areas associated with the settlement area of Paisley, railway infrastructure and the Teeswater River.

In summary, the Municipality of Arran-Elderslie does not contain sufficient land areas that have the potential to meet the geoscientific site evaluation factors discussed above.

3.4.1.2 Town of Saugeen Shores

The Town of Saugeen Shores contains several protected areas that occupy about 25 per cent of the Town. These include the Saugeen Bluffs Conservation Area, MacGregor Point Provincial Park, provincially significant wetlands, water intake protection zones at Southampton, and built-up areas at Port Elgin and Southampton. The land west of Highway 21 was excluded as it is preserved for future expansion.

There are no oil and gas pools or mineral occurrences recorded within the Town of Saugeen Shores. Two pinnacle reefs of the Guelph Formation are known to exist in the southern portion of the Town (Geofirma, 2014a). While pinnacle reefs of the Guelph Formation are known to host economically exploitable petroleum resources elsewhere in southern Ontario (e.g., approximately 50 kilometres south of the Town), exploration wells drilled through the pinnacle reefs in the Town of Saugeen Shores resulted in dry holes and did not encounter commercial hydrocarbon accumulations.

As described in Section 3.3.2, the bedrock geology in the Area of the Five Communities, including the Town of Saugeen Shores, is characterized by a laterally extensive and predictable sequence of Paleozoic formations. Based on borehole data, the cumulative thickness of the sedimentary sequence is estimated to be more than 700 metres in the southern portion of the Town. Contour mapping (Geofirma, 2014a) indicates that the depth to the top of the preferred Cobourg Formation decreases from approximately 584 metres below ground surface near the southern boundary of the Town to about 400 metres below ground surface in the northern part. The area where the depth to the top of the Cobourg Formation is greater than the preferred 500 metres below ground surface represents roughly 40 per cent of the Town area, and is located in the southern portion of the Town (Figure 3-8). There are no faults mapped within the Paleozoic sequence beneath the Town of Saugeen Shores.

Although the Cobourg Formation is present at depths greater than the preferred 500 metres below ground surface over an area representing roughly 40 per cent of the Town, this area contains a number of constraints that greatly reduce the prospect of finding areas that are large enough for hosting the repository's surface and underground facilities. These constraints include: the MacGregor Point Provincial Park along the shore of Lake Huron, the Saugeen Bluffs Conservation Area, a Surface Water Intake Protection Zone in Southampton, built-up areas at Port Elgin and Southampton, and the Saugeen River and its tributaries (Figure 3-8). In addition, the land west of Highway 21 was excluded from further consideration at the request of the community, as it is preserved for future expansion. When all these constraints are considered, limited area remains available for potentially hosting a deep geological repository.

In summary, the Town of Saugeen Shores has very limited potential to contain areas that would meet the geoscientific siting factors discussed above.

3.4.1.3 Municipality of Brockton

The Municipality of Brockton is underlain by a predictable and laterally extensive Paleozoic sedimentary sequence. Based on information from well T004854 located near the western edge of the Municipality (Geofirma, 2014a), the thickness of the Paleozoic sequence in this area is approximately 890 metres.

Depth contour mapping (Geofirma, 2014a) shows that a large portion (about 70 per cent) of the Municipality has the preferred Cobourg Formation at depths greater than the preferred depth (500 metres below ground surface). The top of the Cobourg Formation varies from about 404 metres below ground surface in the northeastern portion of the Municipality to approximately 691 metres below ground surface towards the western margin of the Municipality. The thickness of the overlying Upper Ordovician shale formations is estimated to be relatively uniform and more than 200 metres thick within the Municipality. There is one mapped subsurface fault within the Paleozoic sedimentary sequence in the Municipality, located at the west end of the Municipality and extending to the west beyond the municipal boundaries (Figure 3-3). The mapped subsurface fault is interpreted to offset the Shadow Lake Formation/Precambrian units.

Known potential for economically exploitable natural resources in the Municipality of Brockton is limited to a few shallow discretionary limestone and marl occurrences located mostly in the vicinity of Walkerton (Figure 3-7). There are no known oil and gas pools identified within the

Municipality, and all six exploration wells drilled within the Municipality resulted in dry holes with no petroleum potential.

The only significant built-up area in the Municipality is that associated with the settlement area of Walkerton (Figure 3-8). The western portion of the Municipality of Brockton is covered by the Greenock Swamp Wetland Complex (68 square kilometres), which is designated as a Provincially Significant wetland complex. Part of this wetland complex is also designated as a conservation area. The wellhead protection area, zones A to C, associated with the Walkerton well supply system cover approximately six square kilometres on the southern portion of the Municipality, just west of the settlement area of Walkerton (Figure 3-8). A wellhead protection area and a surface water protection zone are also present on the eastern edge of the Municipality, associated with water supply to the settlement area of Hanover. There are two very small earth science ANSIs located in the central and south-central parts of the Municipality.

The consideration of the above geoscientific characteristics and constraints indicates that the central portion of the Municipality of Brockton appears to have favourable geoscientific characteristics for hosting a deep geological repository. This general potentially suitable area is located north of the settlement area of Walkerton and east and north of the Greenock Swamp Wetland Complex (Figure 3-8). The top of the preferred Cobourg Formation beneath this area occurs at depth ranging from about 500 to 650 metres below ground surface, which is greater than the preferred minimum depth. This general potentially suitable area is mostly free of surface constraints and protected areas, with just a few localized provincially significant wetlands located along the banks of the Saugeen River, two small rectangular localized conservation areas/reserves (i.e., that are part of the Saugeen Conservation Area and Lands), a small earth science ANSI (Saugeen River Section), and a small well head protection area for the Chepstow Powers Subdivision well supply. The area is easily accessible via the existing road network (Figure 3-8).

Topography in the general potentially suitable area is relatively flat, although distinct topographic features are identified associated with the Saugeen and Teeswater rivers (Figure 3-2). The area also contains non-designated wetlands and extensive overburden deposits with thicknesses of up to approximately 100 metres locally. As discussed in Section 3.4.1, at this early stage of the assessment, topographic features, wetlands and overburden thickness are not considered as key constraints for the identification of general potentially suitable areas.

3.4.1.4 Municipality of South Bruce

The bedrock geology of the Municipality of South Bruce comprises a thick Paleozoic sequence that is laterally extensive and predictable. Data from two boreholes (F012062 and T004881) drilled through the entire Paleozoic sequence within the Municipality indicate that the estimated total thickness of the Paleozoic package is approximately 870 metres. Available borehole data within the Municipality confirm the presence of the preferred Cobourg Formation at depths ranging from about 433 metres below ground surface in the northeast corner of the Municipality to 717 metres below ground surface towards its southwestern portion (Geofirma, 2014a). The Cobourg Formation is overlain by a more than 200 metre thick shale package (i.e. Upper Ordovician shale units). There is only one subsurface fault mapped within the Paleozoic sequence in the northwest corner of the Municipality of South Bruce (Figure 4-3). This fault is interpreted to displace the Trenton Group limestones and deeper formations only, including the Precambrian basement. The reinterpretation of seismic line 725937, which crosses the mapped subsurface fault in the Municipality of South Bruce, identified a potential fault that extends upwards from the Precambrian basement into the base of the Silurian Cabot Head Formation.

The coincidence between this interpreted seismic anomaly and the mapped subsurface fault provides a certain amount of confidence in the existence of a fault in the area crossed by the seismic line.

There are no known oil and gas pools within the Municipality of South Bruce, and the three exploration boreholes drilled within the Municipality resulted in dry holes with no petroleum potential. There are a number of discretionary limestone occurrences in the central portion of the Municipality (Figure 3-7); the potential for limestone, however, is limited to very shallow depths and was not considered as a siting constraint.

Protected areas include the Provincially Significant Greenock Swamp and Teeswater wetland complexes in the western portion of the Municipality, and the Otter Creek Wetland Complex north of Mildmay. There is also the Saugeen Conservation Reserve south of Mildmay, and small parts of the wetland complexes are designated as conservation areas (Figure 3-8). Other potential siting constraints within the Municipality include built-up areas in Teeswater, Mildmay and Formosa and well head protection areas associated with the water supply systems in Teeswater and Mildmay, and the southern extension of the Walkerton well head protection area (Figure 3-8).

The consideration of the above geoscientific characteristics and constraints indicates that the Municipality of South Bruce contains large areas that have the potential to meet NWMO’s geoscientific site evaluation factors. The potentially suitable area covers most of the Municipality with the exception of the westernmost portion and the northeast corner of the Municipality, as well as localized areas around Mildmay, Teeswater and Formosa (Figure 3-8). The top of the Cobourg Formation is interpreted to be at depths greater than the preferred 500 metres below ground surface beneath the entire the Municipality, except in small area in the northeastern corner. The potentially suitable area in the Municipality is easily accessible via the existing road network (Figure 3-8).

Non-designated wetlands are uniformly mapped throughout the potentially suitable area and overburden deposits are widespread, with mean thicknesses of about 20 metres. Topography in the identified general potentially suitable area is relatively flat. As discussed in Section 3.4.1, at this early stage of the assessment, topographic features, wetlands and overburden thickness are not considered as key constraints for the identification of potentially suitable areas.

3.4.1.5 Township of Huron-Kinloss

The bedrock geology beneath the Township of Huron-Kinloss consists of a laterally extensive and predictable Paleozoic sequence. Based on data from one well (F012061) drilled through to the Precambrian basement in the southern portion of the Township, the total thickness of the Paleozoic sequence in that area is approximately 1,000 metres. Based on contour mapping, the depth to the top of the preferred Cobourg Formation is interpreted to range from approximately 683 metres below ground surface in the northeastern portion of the Township to about 809 metres below ground surface towards its southern portion. Data from well F012061 confirms that the Cobourg Formation within the Township is overlain by about 200 metres of Upper Ordovician shale formations. One mapped subsurface fault extends into the eastern part of the Township of Huron-Kinloss (Figure 3-3). In addition, a possible fault was interpreted in a seismic line in the Township of Huron-Kinloss (Section 3.3.2).

While there are a number of pools that produce gas from pinnacle reefs of the Guelph Formation immediately south of the Township of Huron-Kinloss (Figure 3-7), there are no known oil and gas pools within the Township. All seven wells drilled within the Township resulted in dry holes and did not encounter economical accumulations of hydrocarbons, including wells drilled through three known pinnacle reefs. As described in Geofirma (2014a), salt beds of the Silurian Salina Group exist beneath the Township of Huron-Kinloss; the Salina B-Salt is interpreted to be approximately 75 metres thick towards the southwestern portion of the Township, thinning out towards its eastern part. Salt beds of the Salina Group extend beyond the Township boundaries to the south and are currently being exploited approximately 30 kilometres south of the Township, at Goderich. Given that the Salina salt beds are relatively thin within the Township and occur approximately 400 metres above the Cobourg Formation, they are not considered a constraint from a siting perspective at this stage of the assessment. There are no other mineral occurrences within this community.

Protected areas within the Township of Huron-Kinloss include seven designated Provincially Significant Wetlands located in the eastern portion of the Township (Figure 3-8). The area west of Highway 21 was excluded from consideration at the request of the community. There is also one earth science ANSI northwest of Lucknow, seven well head protection areas, and one surface water protection zone. Built-up areas are associated with the settlement areas west of Highway 21, and with the settlement areas of Ripley and Lucknow (Figure 3-8).

The consideration of the above geoscientific characteristics and constraints indicates that the Township of Huron-Kinloss contains large areas that have the potential to meet NWMO's geoscientific site evaluation factors. These include most of the area between the wetland complexes in the eastern portion of the Township and Highway 21, outside of protected areas and surface constraints discussed above. As discussed above, the top of the preferred Cobourg Formation is interpreted to be at depths greater than the preferred 500 metres below ground surface beneath the entire Township.

Topography in the general potentially suitable area is relatively flat, gradually decreasing from east to west (Figure 3-2). There are no significant topographic constraints and only a few non-designated wetlands are mapped within the central portion of the Township. Access to the general potentially suitable area is easy with the existing road network (Figure 3-8).

3.5 Geoscientific Preliminary Assessment Findings

The objective of the Phase 1 geoscientific preliminary assessment was to assess whether the Bruce County communities involved in the site selection process contain general areas that have the potential to satisfy the geoscientific site evaluation factors outlined in the NWMO's site selection document (NWMO, 2010)

The preliminary geoscientific assessment built on the work previously conducted for the initial screenings (AECOM, 2012a; 2012b; 2012c; 2012d; 2012e) and focused on the the Area of the Five Communities (Figure 3-1). The assessment was conducted using available geoscientific information and key geoscientific characteristics that can be realistically assessed at this early stage of the site evaluation process. These include: geology; structural geology; surface conditions; protected areas; and the potential for economically exploitable natural resources. Where information for the Area of the Five Communities was limited or not available, the assessment drew on information and experience from other areas with similar geological settings in southern Ontario.

The geoscientific desktop preliminary assessment included the following review and interpretation activities:

- Assembly and detailed review of available geoscientific information such as geology, structural geology, natural resources, hydrogeology and overburden deposits (surficial deposits);
- Interpretation of available geophysical surveys;
- Interpretation of available borehole geophysical data and selected 2-D seismic reflection surveys to provide information on the geometry and potential structural features of the subsurface bedrock geology;
- Terrain analysis studies to help assess overburden (surficial deposits) type and distribution, bedrock exposures, accessibility constraints, watershed and subwatershed boundaries, and groundwater discharge and recharge zones;
- Assessment of land use and protected areas including parks, conservation reserves, heritage sites and source water protection areas; and
- The identification and evaluation of general potentially suitable areas based on systematic assessment of key geoscientific characteristics and constraints that can be realistically assessed at this stage of the assessment.

Based on this preliminary evaluation, the Municipality of Arran-Elderslie does not contain sufficient land areas that have the potential to meet the geoscientific site evaluation factors outlined in the site selection process document (NWMO, 2010).

4. REFLECTION ON POTENTIAL SUITABILITY

4.1 Findings

This report has assessed the potential for the Municipality of Arran-Elderslie to meet the geoscientific site evaluation factors set for the project.

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 selected is safe and secure for the protection of people and the environment, now and in the future. The geoscientific evaluations are an important foundation for Phase 1 studies into the potential to find a safe site.

Phase 1 geoscientific evaluations in the area of the five Bruce County communities involved in the site selection process have built upon results from the initial screenings through a more detailed desktop review of available information. This work has focused on assessing whether it is possible to identify areas that have the potential to satisfy geoscientific site evaluation factors published in the NWMO's site selection process document (NWMO, 2010).

Preliminary assessment studies suggest that there is very limited potential for the Municipality of Arran-Elderslie to be suitable for the APM Project. Preliminary geoscientific assessments indicate that the Municipality of Arran-Elderslie does not contain sufficient land areas that have the potential to meet the geoscientific site evaluation factors outlined in the site selection process document. Based on the geology of the area, the NWMO has identified a preferred rock formation (Ordovician Cobourg Formation) and a preferred minimum depth (500 metres) for hosting a repository in the Bruce County area. The Municipality of Arran-Elderslie does not contain sufficient land areas with this rock formation at the preferred minimum depth to host the repository. In light of these findings, the NWMO has concluded studies in the community.

Safety, security and protection of people and the environment are central to the siting process. The NWMO's decision to conclude studies in Arran-Elderslie is guided by these findings on geoscientific suitability.

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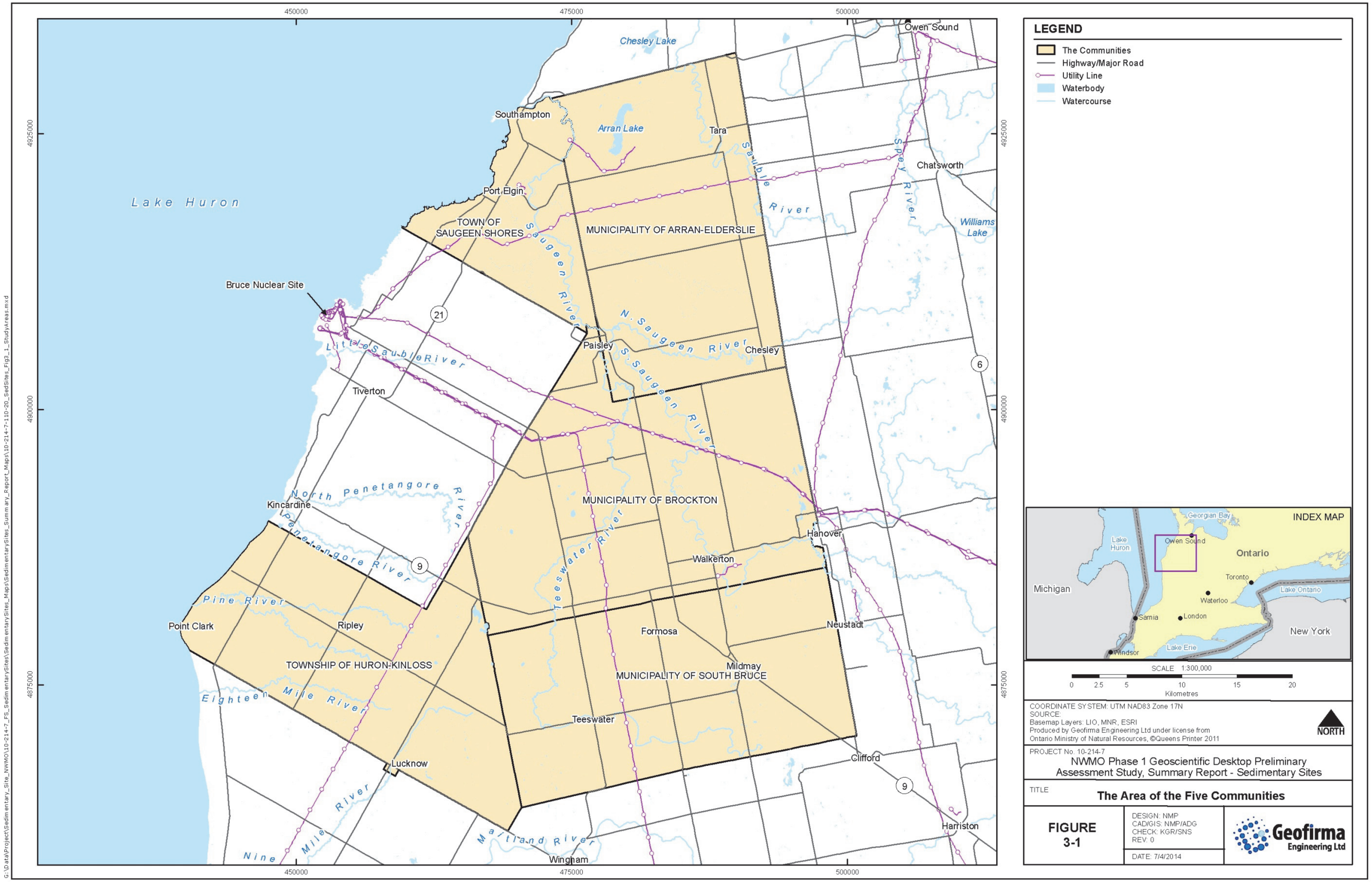


Figure 3-1: The Area of the Five Communities

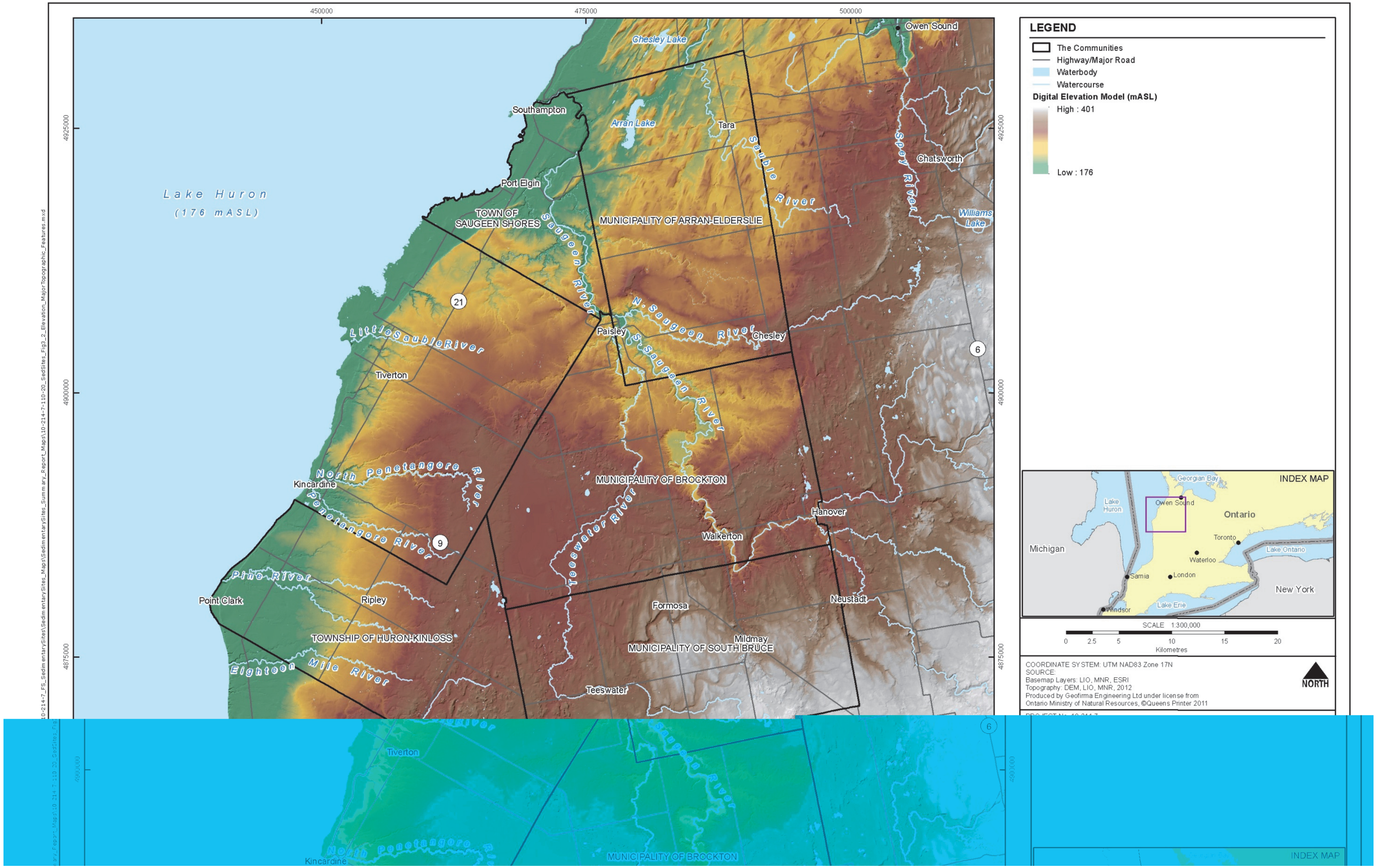


Figure 3-2: Ground Surface Elevation of the Area of the Five Communities

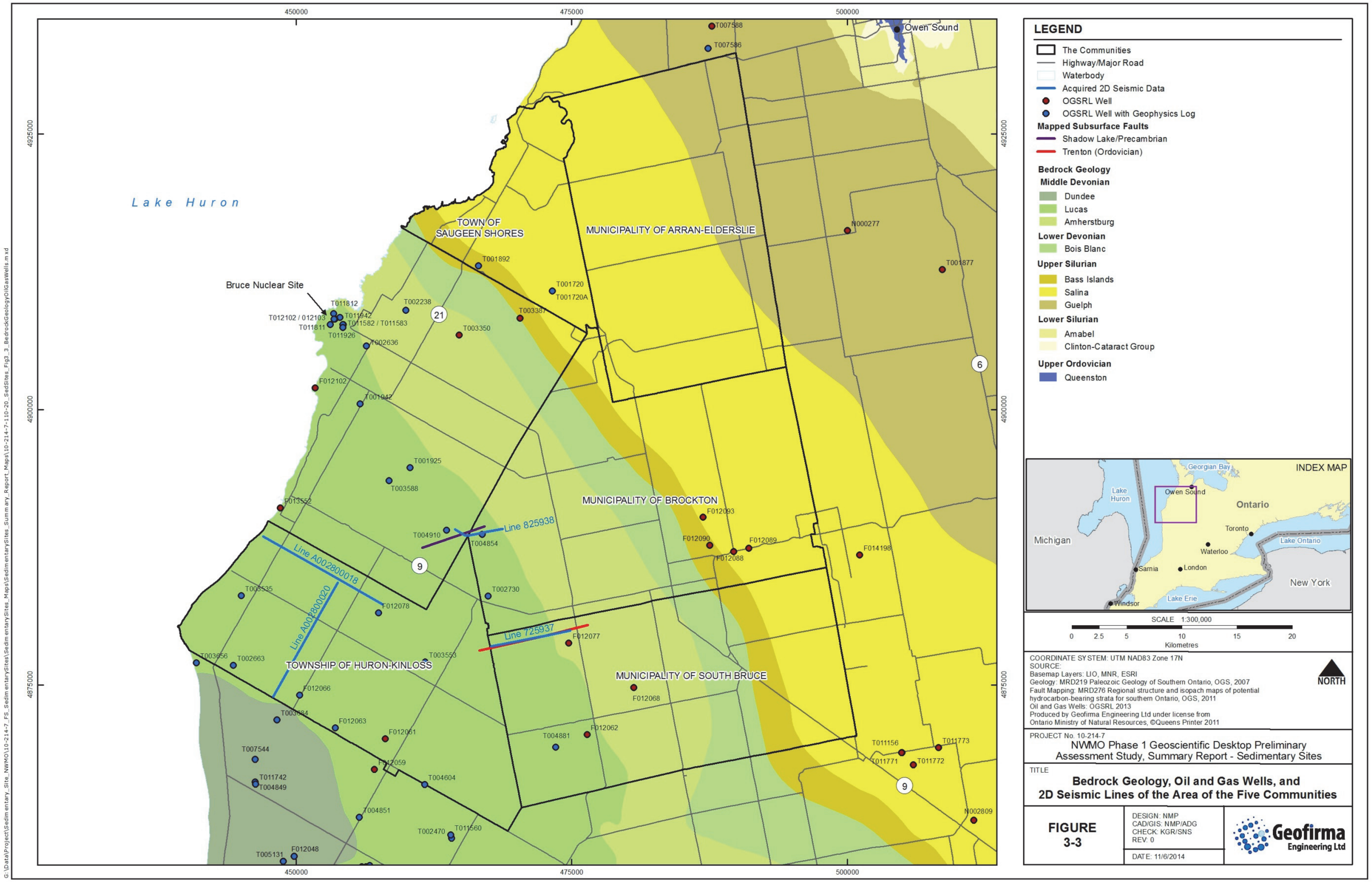
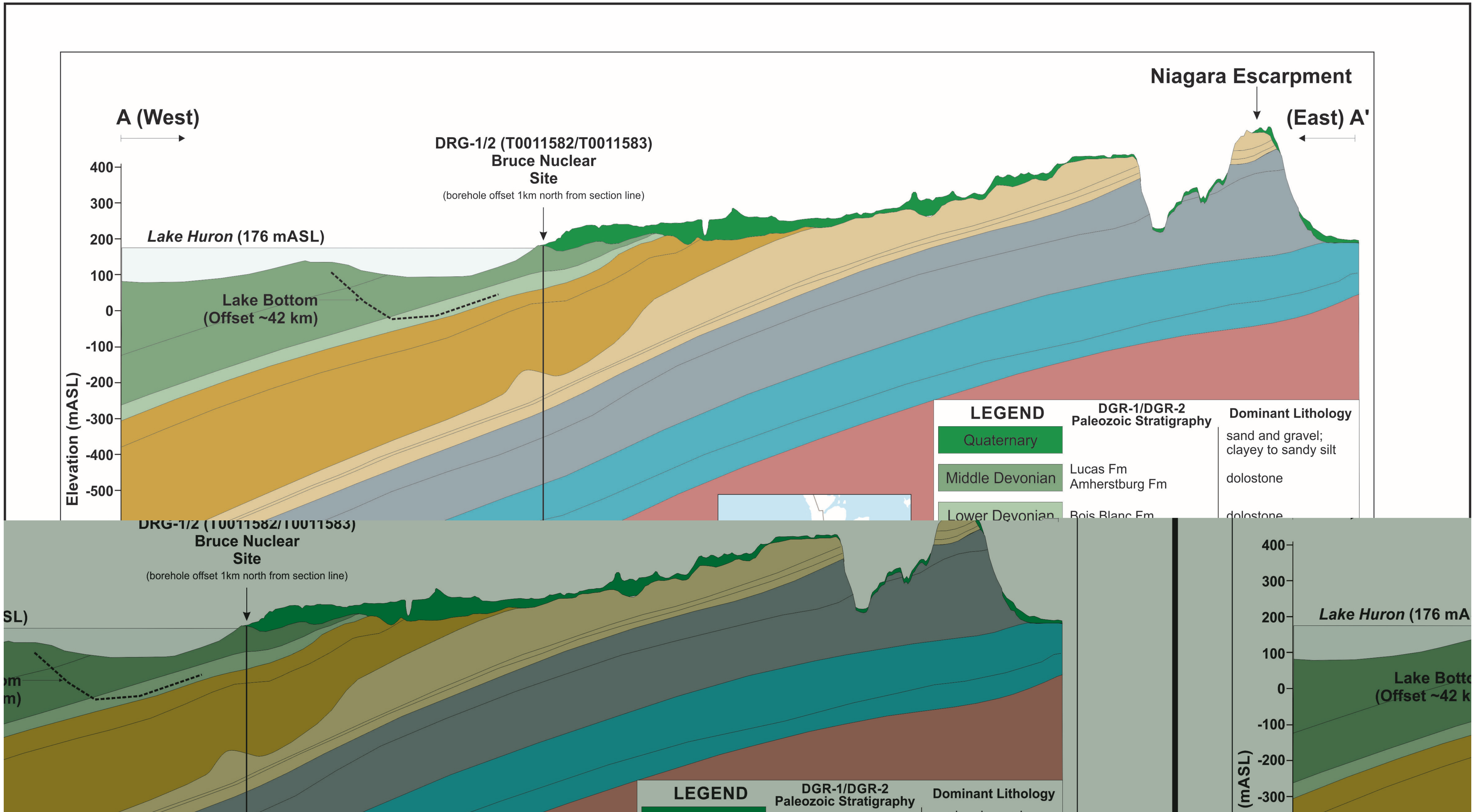


Figure 3-3: Bedrock Geology, Oil and Gas Wells, and 2D Seismic Lines of the Area of the Five Communities



Data Source: after NWMO, 2011

FIGURE 3-4 - Regional Geological Cross-Section of the Eastern Flank of the Michigan Basin

PROJECT No: 10-214-7
NWMO Phase 1 Geoscientific Desktop Preliminary Assessment Study, Summary Report - Sedimentary Sites

Prepared by: NMP/ADG
Reviewed by: KGR/SNS
Date: 03/07/2014

Geofirma Engineering Ltd

"P:\Projects\2010\10-214 NWMO APM Site Screening\10-214-7 Sedimentary Sites FS\110 Reporting\110.20 Summary Report\Working files\10-214-7-110-20_SedSites_Fig3_4_Cross_Section_EasternFlankMichiganBasin.cdr"

Figure 3-4: Regional Geological Cross Section of the Eastern Flank of the Michigan Basin

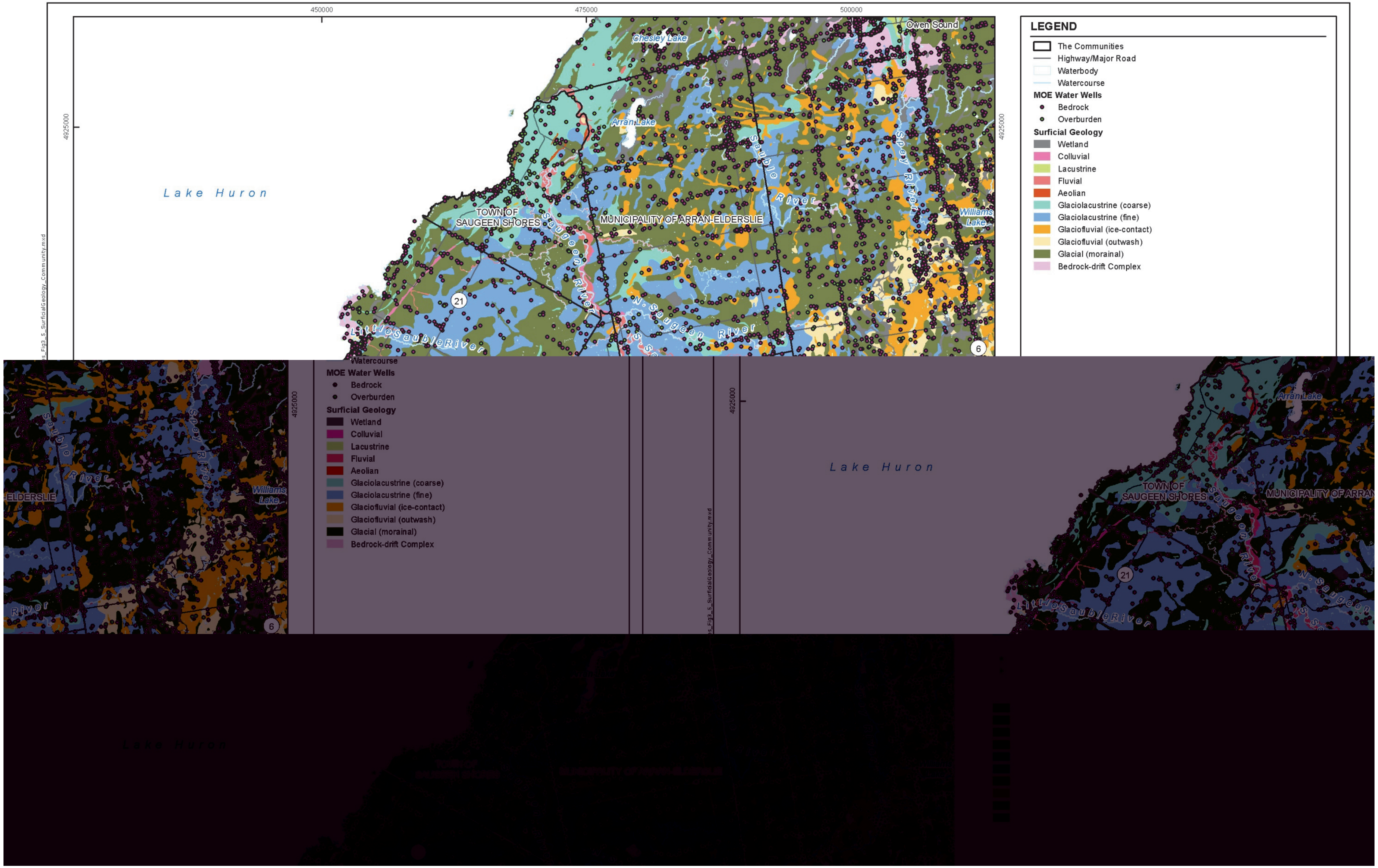


Figure 3-5: Surficial Geology and Groundwater Wells within the Area of the Five Communities

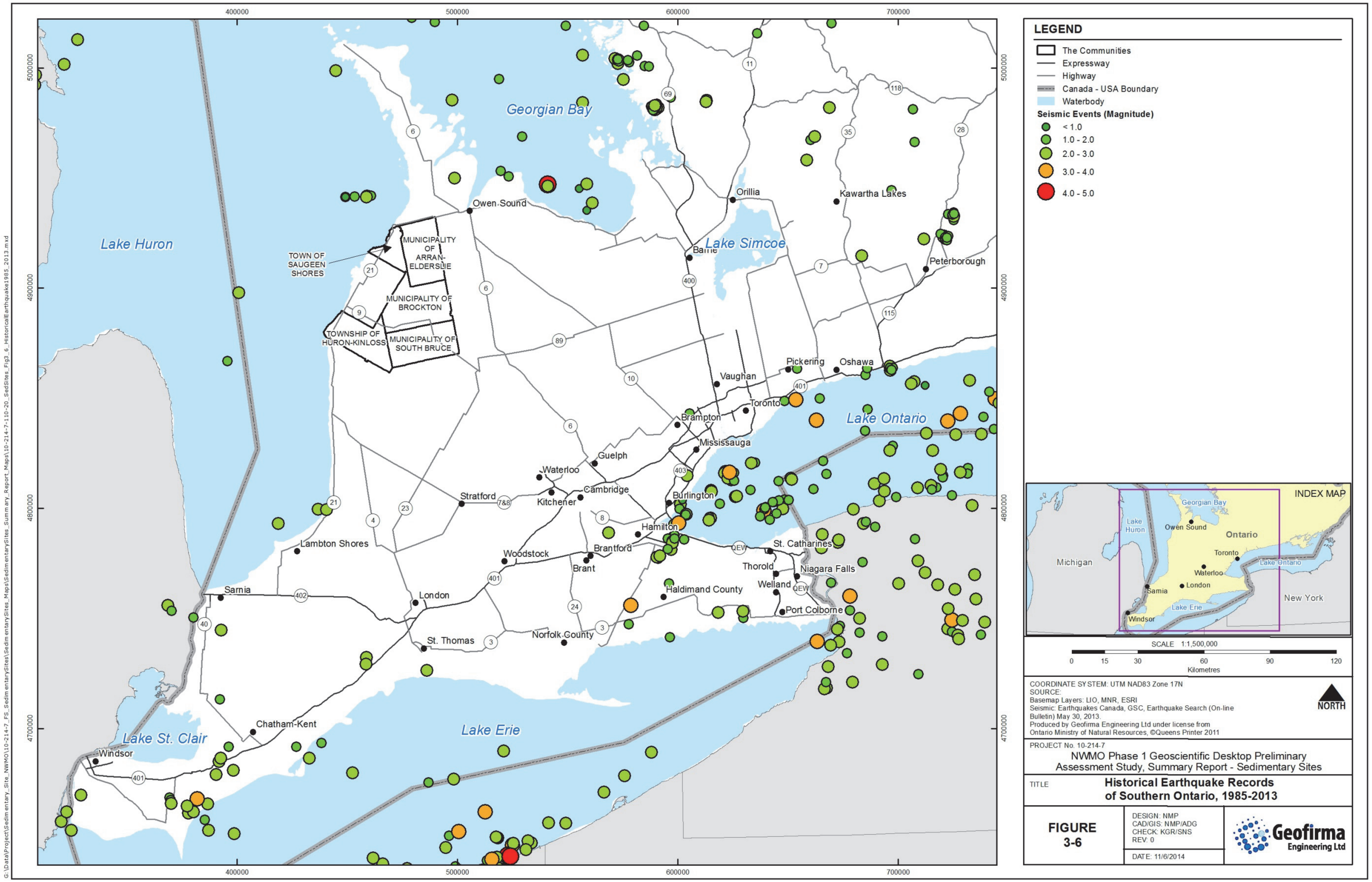


Figure 3-6: Historical Earthquake Records of Southern Ontario, 1985-2013

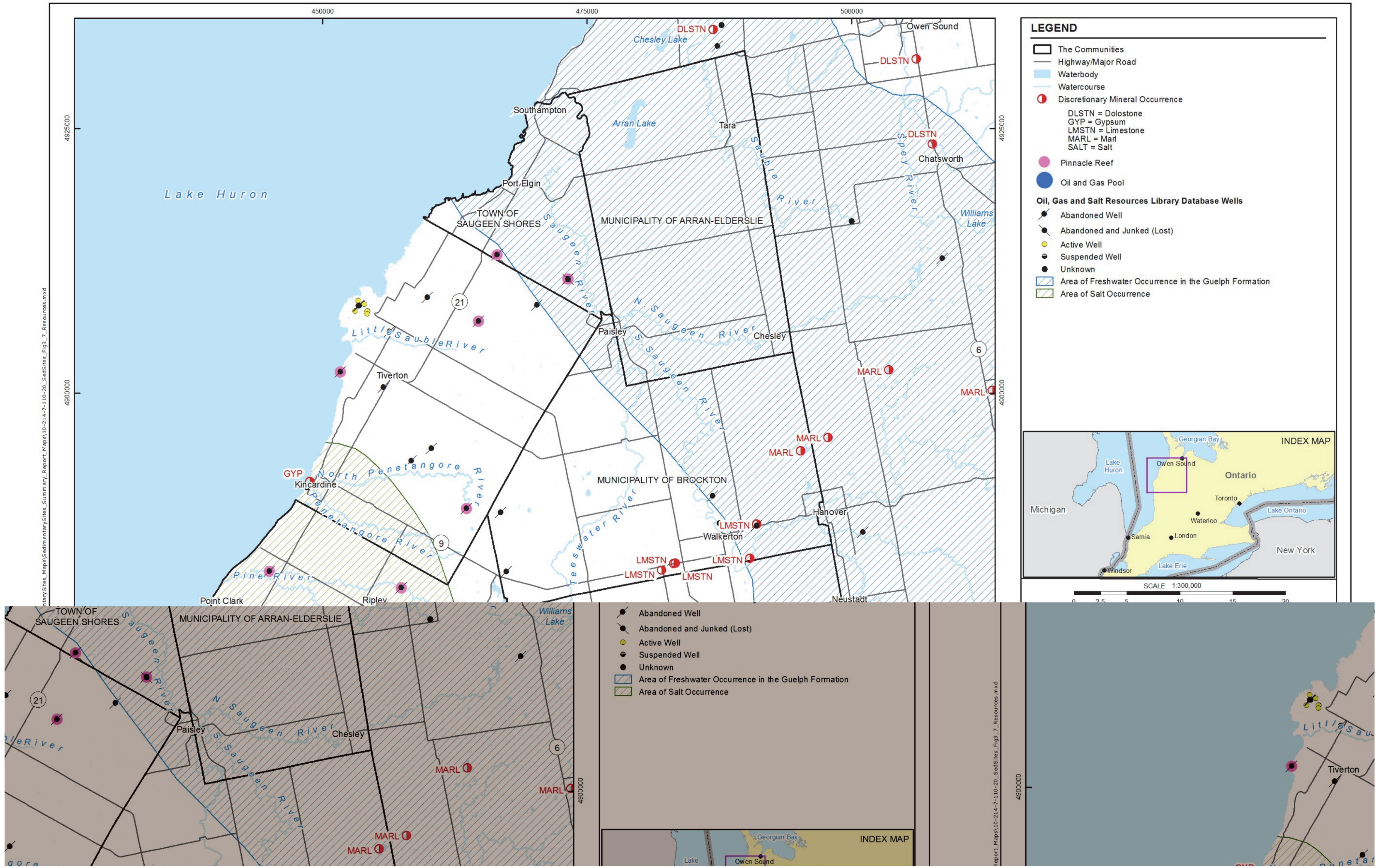


Figure 3-7: Petroleum, Mineral, and Deep Groundwater Resources in the Area of the Five Communities

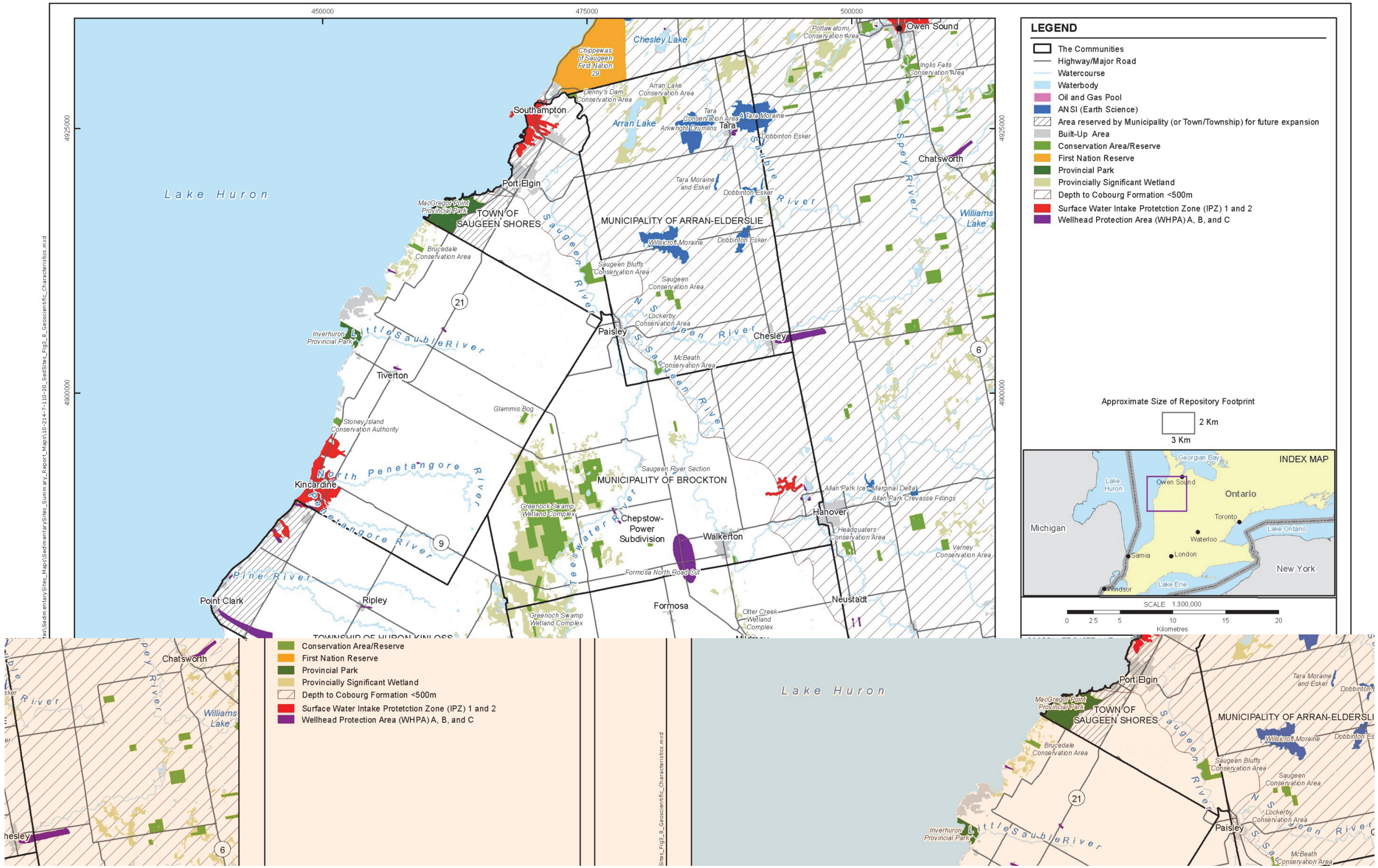


Figure 3-8: Key Geoscientific Characteristics and Constraints in the Area of the Five Communities

5. REFERENCES

References for Chapter 1

Geofirma Engineering Ltd (Geofirma). 2014. Interim Results of Geoscientific Preliminary Assessment, Sedimentary Sites, Southern Ontario. Technical Memorandum dated January 9, 2014. Ottawa, Canada.

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

Nuclear Waste Management Organization (NWMO). 2011. Preliminary Assessment of Potential Suitability – Feasibility Studies. Toronto, Canada.

Nuclear Waste Management Organization (NWMO). 2014. Letter from K. Shaver to Mayor P. Eagleson and Mayor M. Smith Re: Adaptive Phased Management Site Selection Process – Interim Findings from Step 3, Phase 1 Preliminary Assessments. Dated January 16, 2014. Toronto, Canada.

References for Chapter 3

AECOM (AECOM Canada Ltd). 2012a. Initial Screening for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, The Corporation of the Municipality of Arran-Elderslie, Prepared for the Nuclear Waste Management Organization (NWMO). AECOM Report 60247068-5. Toronto, Canada.

AECOM (AECOM Canada Ltd). 2012b. Initial Screening for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, Municipality of Brockton, Prepared for the Nuclear Waste Management Organization (NWMO). AECOM Report 60247068-1. Toronto, Canada.

AECOM (AECOM Canada Ltd). 2012c. Initial Screening for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, The Corporation of the Municipality of South Bruce, Ontario, Prepared for the Nuclear Waste Management Organization (NWMO). AECOM Report Number 60247068-2. Toronto, Canada.

AECOM (AECOM Canada Ltd). 2012d. Initial Screening for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, The Corporation of the Township of Huron-Kinloss, Prepared for the Nuclear Waste Management Organization (NWMO). AECOM Report 60247068-3. Toronto, Canada.

AECOM (AECOM Canada Ltd). 2012e. Initial Screening for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, The Corporation of the Town of Saugeen Shores, Prepared for the Nuclear Waste Management Organization (NWMO). AECOM Report 60247068-4. Toronto, Canada.

AECOM Canada Ltd. and Itasca Consulting Canada, Inc. 2011. Regional Geology – Southern Ontario. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report DGR-TR-2011-15 R000. Toronto, Canada.

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

Atomic Energy of Canada Limited (AECL). 2011. Summary of Thermal Properties Tests on DGR4 Rock Samples, Memorandum GSEB-11-040 from David Dixon to Tom Lam. November 10. Whiteshell Laboratories.

Ausable Bayfield Maitland Valley Source Protection Region. 2011. Assessment Report – Amended May 2011. Maitland Valley Source Protection Area. May 30.

Bailey Geological Services Ltd. and R.O. Cochrane. 1984a. Evaluation of the Conventional and Potential Oil and Gas Reserves of the Cambrian of Ontario. Ontario Geological Survey. Open File Report 5498.

Bailey Geological Services Ltd. and R.O. Cochrane. 1984b. Evaluation of the Conventional and Potential Oil and Gas Reserves of the Ordovician of Ontario. Ontario Geological Survey. Open File Report 5499.

Carter, T.R. and L. Fortner. 2011. Regional bedrock aquifers and a conceptual groundwater flow model for southern Ontario. Presentation to the 50th Annual Ontario Petroleum Institute Conference. http://www.ogsrlibrary.com/downloads/Carter_OPI_2011_Bedrock_Aquifers.pdf. October 21. London, Ontario.

Cermak, V. and L. Rybach. 1982. Thermal conductivity of minerals and rocks, 305-343. *In* G. Angenheister (Ed). Landolt-Bornstein: Numerical Data and Functional Relationships in Science and Technology. New Series. Group V, V.1a. Springer. Berlin.

Gao, C. 2011a. Origin of regional buried bedrock valleys in the Great Lakes region: a case study of southern Ontario. Proceedings of the Geohydro 2011 - Joint Mtg of the Quaternary Association and the Canadian Chapter of the International Association of Hydrogeologists. Quebec City. August 28-31.

Gao, C. 2011b. Buried bedrock valleys and glacial and subglacial meltwater erosion in southern Ontario, Canada. Canadian Journal of Earth Sciences. 48, 801-818.

Geofirma (Geofirma Engineering Ltd.). 2014a. Phase 1 Geoscientific Desktop Preliminary Assessment of Potential Suitability for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, Municipalities of Arran-Elderslie, Brockton and South Bruce, Township of Huron-Kinloss and Town of Saugeen Shores. Prepared for the Nuclear Waste Management Organization (NWMO). NWMO Report APM-REP-061440-0108. Toronto, Canada.

Geofirma (Geofirma Engineering Ltd). 2014b. Phase 1 Geoscientific Desktop Preliminary Assessment, Processing and Interpretation of Borehole Geophysical Log and 2D Seismic Data, Municipalities of Arran-Elderslie, Brockton and South Bruce, Township of Huron-Kinloss and Town of Saugeen Shores. Prepared for the Nuclear Waste Management Organization (NWMO). NWMO Report APM-REP-06144-0110. Toronto, Canada.

Golder Associates Ltd. (Golder). 2013. OPG's Deep Geological Repository for L&IL Waste – Factual Report – Boreholes DGR-7 and DGR-8 Geotechnical Logging, Report 1011170042-REP-G2040-004-01 prepared for the Nuclear Waste Management Organization, March.

Golder Associates Ltd. (Golder). 2003. LLW Geotechnical Feasibility Study, Western Waste Management Facility, Bruce Site, Tiverton, Ontario. Final Report to Municipality of Kincardine and Ontario Power Generation. Toronto, Canada.

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

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. 1999. Upper Ordovician Strata of Southwestern Ontario: Synthesis of Literature and Concepts. Geological Survey of Canada. Open File 3729.

Hamilton, S.M. 2011. Ambient Groundwater Geochemistry Data for Southwestern Ontario, 2007-2010, Ontario Geological Survey. Miscellaneous Release – Data 283.

Hayek, S.J., J.A. Drysdale, J. Adams, V. Peci, S. Halchuk and P. Street. 2011. Seismic Monitoring Annual Report 2010. Prepared for the Nuclear Waste Management Organization (NWMO). NWMO Report DGR-TR-2011-44 R0. Toronto, Canada.

Hobbs, M.Y., S.K Frape, O. Shouakar-Stash and L.R. Kennell. 2011. Regional Hydrogeochemistry – Southern Ontario. NWMO Report 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 Engineering Ltd. 2011. Descriptive Geosphere Site Model. Prepared for the Nuclear Waste Management Organization (NWMO). NWMO Report DGR-TR-2011-24 R000. Toronto, Canada.

JDMA (J.D. Mollard and Associates (2010) Limited). 2014. Phase 1 Geoscientific Desktop Preliminary Assessment, Terrain and Remote Sensing Study, Municipalities of Arran-Elderslie, Brockton and South Bruce, Township of Huron-Kinloss and Town of Saugeen Shores, Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report APM-REP-06144-0109. 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:* Geology of Ontario. Ontario Geological Survey. Special Volume 4, Part 2, 907-1008.

Karrow, P.F. 1993. Quaternary Geology, Conestogo Area. Ontario Geological Survey. Map M2558.Scale 1:50,000.

NRC (Natural Resources Canada). 2013a. National Earthquake Database. http://www.earthquakescanada. nrcan.gc.ca/stndon/NEDB-BNDS/bull-eng.php. Downloaded May 30, 2013.

NWMO (Nuclear Waste Management Organization). 2011. Geosynthesis. NWMO Report DGR-TR-2011-11 R000. Toronto, Canada.

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

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

OGS (Ontario Geological Survey). 2011. 1:250 000 scale bedrock geology of Ontario. Ontario Geological Survey. Miscellaneous Release–Data 126 - Revision 1.

OGS (Ontario Geological Survey). 2010. Surficial Geology of Southern Ontario. Miscellaneous Release-Data 128-REV.

OGS (Ontario Geological Survey). 1997. Quaternary Geology, Seamless Coverage of the Province of Ontario: Ontario Geological Survey. Data Set 14.

Ontario Ministry of the Environment. 2013a. Water Well Information System (WWIS) – Well Record Data. Accessed October, 2013.

Ontario Ministry of the Environment. 2013b. Provincial Groundwater Monitoring Network Program, http://www.ene.gov.on.ca/environment/en/mapping/groundwater/index.htm . Accessed October, 2013.

PGW (Paterson, Grant & Watson Limited). 2014. Phase 1 Geoscientific Desktop Preliminary Assessment, Processing and Interpretation of Geophysical Data, Municipalities of Arran-Elderslie, Brockton and South Bruce, Township of Huron-Kinloss and Town of Saugeen Shores. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report APM-REP-06144-0111.Toronto, Canada.

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

Peltier, W.,R. 2002. On eustatic sea level history: last glacial maximum to Holocene. Quaternary Science Reviews. 21, 377–396.

Percival, J.A., and R.M. Easton. 2007. Geology of the Canadian Shield in Ontario: an Update. Ontario Power Generation. Report 06819-REP-01200-10158-R00. OGS Open File Report 6196. GSC Open File Report 5511.

Sass, J.H., J.P. Kennedy, E.P. Smith and W.E. Wendt. 1984. Laboratory Line-Source Methods for the Measurement of Thermal Conductivity of Rocks near Room Temperature. U.S. Geological Survey Open File Report 84-91,1-21.

Saugeen, Grey Sauble, Northern Bruce Peninsula Source Water Protection Region. 2011a. Assessment Report. Saugeen Valley Source Protection Area. November 28.

Saugeen, Grey Sauble, Northern Bruce Peninsula Source Water Protection Region. 2011b. Assessment Report. Grey Sauble Source Protection Area. November 30.

Sella, G.F., S. Stein, T.H. Dixon, M. Craymer, T.S. James, S. Mazzotti and R.K. Dokka. 2007. Observation of glacial isostatic adjustment in “stable” North America with GPS. Geophysical Research Letters. 34, L02306.

Shackleton, N.J., A. Berger and W.R. Peltier. 1990. An alternative astronomical calibration of the lower Pleistocene timescale based on ODP Site 677. Transactions of the Royal Society of Edinburgh. Earth Sciences. 81, 251-261.

Slattery, S. 2011. Neotectonic Features and Landforms Assessment. Prepared for the Nuclear Waste Management Organization (NWMO). NWMO Report DGR-TR-2011-19 R000. Toronto, Canada.

Watts, M., D. Schieck and M. Conigli., 2009. 2D Seismic Survey of the Bruce Site. Prepared for the Nuclear Waste Management Organization (NWMO). NWMO Technical Report TR-07-15 Revision 0. Intera Engineering Ltd. Ottawa, Canada.

References for Chapter 4

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

6. GLOSSARY

PRELIMINARY ASSESSMENT OF GEOSCIENTIFIC SUITABILITY

Aeromagnetic data – Data gathered by measuring the Earth's magnetic field using an airborne magnetometer.

Aquiclude – A medium with very low values of hydraulic conductivity (permeability) which, although it may be saturated with groundwater, is almost impermeable with respect to groundwater flow. Such geologic media will act as boundaries to aquifers and may form confining strata.

Aquifer – A geological unit or structure that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells and springs. A confined aquifer is bound by low permeability formations such that it is under pressure. An unconfined aquifer is one whose upper groundwater surface (water table) is at atmospheric pressure.

Aquitard – A confining bed and/or formation composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs, but stores groundwater.

Argillaceous – Largely composed of, or containing, clay-size particles (less than 4 microns) or clay minerals.

Basement (rock) – The crust of the Earth (Precambrian igneous and metamorphic complex) underlying the sedimentary deposits.

Bedrock – Consolidated rock that underlies soil or other unconsolidated material.

Brine – Water with a salinity greater than 100,000 milligrams per litre (greater than 100 grams per litre) total dissolved solids.

Canadian Shield – A large plateau that occupies most of eastern and central Canada and consists of exposed Precambrian basement rocks in a stable craton. It is surrounded by younger sedimentary rocks.

Craton – A large portion of a continental plate that has remained relatively tectonically stable since the Precambrian Era.

Crystalline rock – A rock of igneous or metamorphic origin consisting wholly of mineral crystals.

Deformation – Any process of folding, faulting, shearing, or fabric development undergone by a rock as a result of Earth stresses; or the change in geometry of a body of rock as a consequence of Earth stresses.

Diffusion – Random movement of both ions and molecules in water from areas of higher concentration to areas of lower concentration.

Discretionary occurrence – An occurrence that does not meet any of the defined criteria of an occurrence as established by Ontario Mineral Deposit Inventory (MDI) database.

Dolostone – Also named dolomite, it is a sedimentary rock of which more than 50 per cent by weight consists of the mineral dolomite (magnesium carbonate). Dolostone is generally thought to form when magnesium ions replace some of the calcium ions in limestone by the process of dolomitization. Warm migrating fluids along some faults and fractures may locally dolomitize limestone, and the resulting rock, being more porous, may become a host for oil and gas deposits in an appropriate sedimentary setting and physical/chemical environment.

Erosion – The process by which the surface of the Earth is worn away by the action of water, wind, or ice movement. The erosive process operates by the combined action of weathering and transportation, where first rocks are broken down (weathering), and then the smaller pieces are carried away (transportation).

Fault – A fracture or a zone of fractures that occurs as a result of brittle deformation and within which there is relative displacement of the fracture surfaces.

Fracture – A break in the rock mass, including cracks, joints, faults, and bedding partings.

Geomechanics – A branch of Geology that embraces the fundamentals of structural geology and knowledge of the response of natural materials to deformation.

Gravity data – Data gathered by measuring variations in the Earth's gravitational field caused by differences in the density of subsurface rocks.

Homogenous – A volume of rock that exhibits spatial uniformity of its physical properties (e.g., lithology, porosity).

Hydraulic conductivity – Ease with which water can move through a volume of rock, and is measured in unit length (e.g., metres) per unit time (e.g., seconds).

Hydraulic Head – Fluid mechanical energy per unit weight of fluid, which correlates to the elevation that water will rise to in a well.

Hydrogeochemistry – Branch of Geochemistry that studies the chemical characteristics of ground and surface waters and their interaction with the rock environment of an area.

Hydrogeology – Branch of Geology that studies the movement and characteristics of subsurface waters.

Igneous rock – A rock that solidified from molten or partly molten material (i.e., from magma).

In-situ stress – The current state of stresses in a rock mass/region, representing the magnitude of, and direction in which, the rock is being compressed due to crustal movement.

Isostatic rebound – Rise of land masses that were depressed by the huge weight of ice sheets.

Karst – A type of topography that is formed in limestone, gypsum or other soluble rocks primarily by dissolution. It is typically characterized by the formation of sinkholes, caves and underground drainage.

Limestone – A sedimentary rock composed of the mineral calcite (calcium carbonate). Where it contains appreciable magnesium carbonate, it is called dolomitic limestone. Typically, the primary sources of this calcite are the shells of marine organisms.

Lithology – Set of physical characteristics of a rock, including colour, grain size, and mineralogy.

Metamorphic rock – *A rock derived from pre-existing rocks by mineralogical, chemical or structural changes in response to marked changes in temperature, pressure, shearing stress, or chemical environment.*

Metasedimentary (rock) – Sedimentary rock that has been subjected to metamorphic processes, which resulted in alterations to the original mineral composition of the rock.

Neotectonics – Neotectonics refers to deformations, stresses and displacements in the Earth's crust of recent age or which are still occurring.

Nuttli Magnitude – Magnitude is a measure of the amount of energy released at the source of an earthquake. It is commonly described using the Richter scale (ML). However, this scale does not apply to Eastern North America where the seismic waves attenuate differently. As a result, a different scale, namely the Nuttli magnitude scale (Mn or mN), was adapted to better measure the seismic events in Eastern North America.

Occurrence – Evidence of mineralization present within a surface rock sample (channel or grab) and/or isolated diamond-drill intersection(s) that may or may not have the potential to be exploited. At least one sample must meet the minimum requirements for a mineral occurrence. This definition forms the basis of an occurrence used in the Mineral Deposit Inventory database maintained by the Ontario Geological Survey (OGS).

Overburden – The silt, sand, gravel, or other unconsolidated material overlying the bedrock surface, either by having been transported or formed in place.

Paleo – Prefix used when referring to something "ancient" or "old."

Paleohydrogeology – Branch of Hydrogeology concerned with the study of ancient hydrologic processes, regimes and associated hydrologic features preserved in the rock.

Permeability – Is a measure of the relative ease of fluid flow under a hydraulic gradient, and is a function only of the medium through which the fluid is moving.

Quaternary – Period of time of the Earth extending from approximately 2.6 million years ago until present time.

Sandstone – A medium-grained clastic sedimentary rock that may be deposited by water or wind, and is composed of abundant sand size particles, with or without a fine-grained matrix (clay or silt), and cemented (commonly silica, iron oxide or calcium carbonate); i.e., the consolidated equivalent of sand.

Sedimentary rock – Rock formed by the accumulation of layers of clastic and organic material or precipitated salts.

Seismology – The study of seismic waves from earthquakes to investigate the structure and processes within the Earth.

Shale – A fine-grained detrital sedimentary rock, formed by the compaction and cementation of clay, silt, or mud. It may have a fine laminated structure which gives it fissility; i.e., preferred plane(s) along which the rock splits readily.

Stratigraphy – The study of the age relation of rock strata, including the original succession (order of placement), form, distribution, composition, fossil content, geophysical and geochemical properties, and the environment of origin and geologic history of a rock mass. The science primarily involves the description of rock bodies, and their organization into distinctive, mappable units based on their properties and features.

Tectonics – The study of the interplay between the plates that make up the outer part of the Earth, which usually results in earthquakes, creation of mountains, and fault movement, among others.

Terrain – An area of ground with a particular physical character.

Thermal conductivity – Ease with which heat can move through a volume of rock, and is measured in unit energy (e.g., Watt) per unit distance (metre) and unit temperature (Kelvin).

Total Dissolved Solids – The quantity of dissolved material in a sample of water.