

2017 Report of the
NWMO Adaptive Phased Management
Geoscientific Review Group (GRG)

- Preliminary Geoscientific Assessments -

December 2017



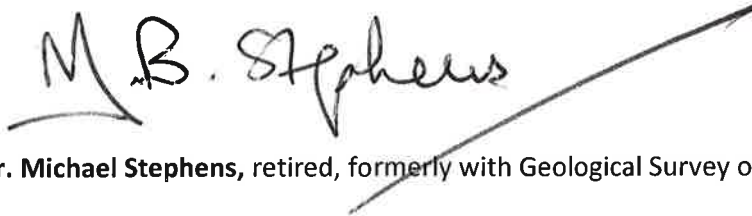
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2017 Report of the NWMO Adaptive Phased Management Geoscientific Review Group (GRG) December 2017

Table of contents

Executive summary	3
1 Introduction	5
2 Objectives of NWMO’s geoscientific preliminary assessments.....	5
3 GRG review activities in 2017	6
3.1 Meetings between GRG and NWMO	6
3.2 Specific studies reviewed by the GRG.....	7
4 Overall assessment of progress during 2017	8
5 GRG review comments	8
5.1 Airborne Geophysical Surveys in Elliot Lake and Blind River Area	8
5.1.1 Airborne survey plan (2017)	9
5.1.2 Interpretation of airborne surveys (2017)	9
5.2 Lineament Interpretation in Elliot Lake and Blind River Area	9
5.3 Geological mapping in Ignace, Hornepayne, Manitouwadge, White River, Elliot Lake and Blind River Areas	10
5.3.1 Key findings from geological mapping (2014-2017)	10
5.4 Identification of Potential Repository Areas in Ignace, Hornepayne, Manitouwadge, White River, Elliot Lake and Blind River Areas (2016-2017).....	11
5.5 Review of geoscience relative suitability assessment for the communities Hornepayne, Manitouwadge and White River.....	11
5.6 Test Plans for initial borehole drilling in Ignace area.....	11
5.7 Location, objectives and approach for drilling Ignace initial three boreholes	13
6 Concluding remarks	13
7 Acknowledgement	13
8 References	13
9 Attachment - Brief biographies of the APM-GRG members	15

Executive summary

This report provides a summary of the work completed in 2017 by the Adaptive Phased Management Geoscientific Review Group (APM-GRG; abbreviated to GRG). This year the GRG met twice by teleconference call and once during a field visit to the Ignace area. In addition, due to other commitments of the Chair, Dr. M. Stephens summarized the GRG's activities and findings to the NWMO's Advisory Council and Board of Directors.

The GRG reviewed approaches, methods, criteria and findings related to broad geoscientific issues addressed by the NWMO in candidate areas underlain by crystalline rock. This included a review of findings regarding the location and geoscientific relative suitability of the identified potential repository areas, test plans for the first borehole in the Ignace area, and the plans and approaches for the next two boreholes at this site.

Specific activities included reviews of:

- Phase 2 high-resolution airborne geophysical survey interpretation report for Elliot Lake and Blind River.
- Phase 2 lineament interpretation report for Elliot Lake and Blind River.
- Phase 2 geological mapping reports for Ignace, Hornepayne, Manitouwadge, White River, Elliot Lake and Blind River.
- Approach and rationale for identification of potential repository areas and evaluation of uncertainties for Ignace, Hornepayne, Manitouwadge, White River, Elliot Lake and Blind River.
- Geoscience relative suitability assessment for Hornepayne, Manitouwadge and White River.
- Test Plans for Ignace Borehole 1:
 - WP 2 – Borehole Drilling and Coring
 - WP 3 – Geological and Geotechnical Core Logging, Photography and Sampling
 - WP4a – Petrophysical Testing of Core
 - WP4b – Geomechanical Testing of Core
 - WP4c – Porewater Extraction and Analysis and Petrographic Analysis
 - WP5 – Geophysical Logging and Interpretation
 - WP6 – Hydraulic Testing
 - WP7 – Opportunistic Groundwater Sampling
 - WP8 – Temporary Well Sealing
- Location, objectives and approach for Ignace Boreholes 2 and 3.

As in previous years, the GRG made various contributions to many geoscientific aspects and these are briefly described in this report. NWMO documented all suggestions, questions, comments in disposition tables and subsequently addressed them. The NWMO provided high quality responses to all issues in a timely, transparent and professional manner. In the GRG members' opinion, the adopted approach follows or exceeds international practices in this phase of assessment.

The GRG's overall judgement of the progress during 2017 is again very positive. A systematic approach was adopted and executed by the NWMO, and the GRG feels that good progress was made in geoscientific site assessments. The NWMO team and its consultants have undertaken an extraordinary amount of field work this year and this work was completed on time and documented in high quality

reports. This allowed the GRG to fulfil its mandate and carefully assess approaches, interpretations and conclusions.

Technical and scientific aspects are described in the main body of this report. A few high-level aspects are highlighted here:

- The GRG agrees that the interpretation of the airborne geophysical surveys for the Elliot Lake and Blind River area provided a sound basis for lineament interpretations and field geological mapping.
- The GRG is pleased to see that comments made on previous communities to improve the interpretation of lineaments, and on planning and collecting field geological mapping data were applied to the Elliot Lake and Blind River area.
- The GRG welcomes how the geological mapping work in the communities sited on crystalline rock has improved the understanding of the geological significance of lineaments, both dykes and brittle structures, and the fracture characteristics inside and adjacent to dykes.
- With respect to the rationale for identification of potential repository areas and associated uncertainties in the Ignace, White River, Hornepayne, Manitouwadge, Elliot Lake and Blind River areas, the GRG is satisfied with the adopted approach and with the consistent and sound use of geoscientific data collected to date.
- The GRG provided comment and advice on specific Test Plans for initial borehole drilling in the Ignace area, resulting in the sharpening of nomenclature and processes for the consistent interpretation of the compositional, structural, petrophysical, geomechanical and hydrogeological attributes of rock masses encountered during drilling activities. As a consequence, the initial borehole program was well planned to produce quality and useful data.
- The GRC visited the area of the first Ignace Borehole and was able to explore how the site characterization efforts documented in the various reports related to the in situ conditions. It was evident to the GRG that NMWO's team executed an extensive and very detailed field mapping effort. The GRG is looking forward to the findings from the first underground exploration as a first subsurface element in developing an integrated 3D geoscience model for this potential site.

1 Introduction

The Adaptive Phased Management Geoscientific Review Group (APM-GRG; abbreviated to GRG) was established by NWMO in 2012. It aims to provide independent review comments and advice on the preliminary geoscientific assessments being conducted as part of NWMO's evaluations to identify a suitable deep geological repository site in an informed and willing host community for Canada's used nuclear fuel. More specifically, the GRG provides comments on the approach, methods and criteria used, the data interpretation, and the adequacy of proposed preliminary field investigation and drilling programs to advance the understanding of the geology and increase confidence in the potential suitability of the various siting areas being considered by NWMO.

This report covers GRG activities during 2017. Previous GRG reports were issued in December 2013, 2014 and 2016, and are publically available on NWMO's website (APM-GRG 2013, 2014, 2016 www.nwmo.ca). Brief biographies of the GRG members for the 2017 term are attached to this report.

2 Objectives of NWMO's geoscientific preliminary assessments

The suitability of communities is assessed using a staged approach including 'Initial Screenings', 'Preliminary Assessments' and 'Detailed Site Characterization', and considers both technical and community well-being factors (NWMO 2010).

The overall preliminary assessment is conducted through a series of technical, socio-economic and cultural studies conducted in two phases over several years. Technical studies involve geoscience, engineering, transportation, environment and safety. The objective of the geoscientific suitability preliminary assessment is to assess whether candidate areas have the potential to meet NWMO's site evaluation factors (geoscientific suitability). It is conducted in two phases:

- **Phase 1 - Desktop Study:** Undertaken for all communities electing to be the focus of a preliminary assessment. This phase involves desktop studies using available geoscientific information, and a set of key geoscientific characteristics and factors that can be realistically assessed at the desktop phase of the preliminary assessment. Desktop studies for all 21 communities are completed.
- **Phase 2 - Preliminary Field Investigations:** Undertaken to further assess the potential suitability of a subset of communities selected by the NWMO. Depending on the geological setting, Phase 2 field investigations can include high resolution airborne surveys, geological mapping and initial borehole drilling.

The subset of communities advanced to Phase 2 preliminary assessment are selected based on the findings from the desktop study during Phase 1, considering technical, socio-economic and cultural considerations. It is important to note that the mandate of the GRG is entirely focussed on the approach, methods, criteria and findings associated with the geoscientific suitability assessments. The GRG is not involved in matters pertaining to transportation and environment, and is not consulted when narrowing down the number of communities.

The status of communities' involvement in NWMO's site selection process as of November 2017 is illustrated in Figure 1. There are currently seven communities remaining in the site selection process. They are all in Phase 2 of the preliminary assessment and include Ignace, Manitouswadge, Hornepayne, Elliot Lake and Blind River on crystalline rock, and Huron-Kinloss and South Bruce on sedimentary rock. During 2017, the GRG reviewed geoscience reports related to the five communities situated on crystalline rock. The GRG also reviewed similar reports related to the White River area and comments on those reviews are included in this report even though this area is no longer included in the site selection process. No review activities bearing on the two sedimentary rock sites were assigned to the GRG this year.

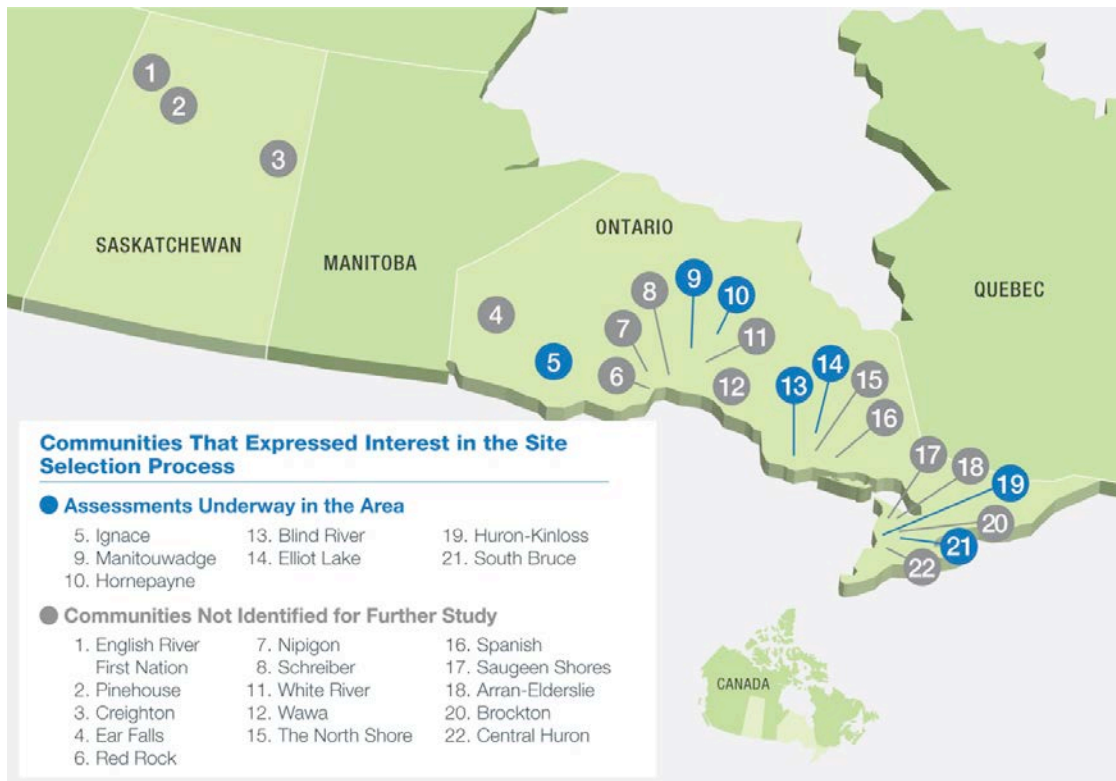


Figure 1 – Communities that expressed interest in the site selection process (as of November 2017).

3 GRG review activities in 2017

As the following list of activities illustrates, 2017 was a very active period for the GRG with a site visit and more than twenty documents being reviewed by the GRG members.

3.1 Meetings between GRG and NWMO

In 2017, the GRG has been involved in reviewing NWMO’s geoscientific activities in the communities remaining in Phase 2 of the preliminary assessments. Meetings with NWMO and its consultants included two teleconference calls and one in-person meeting. Specifically,

- Teleconference call on May 17, 2017;
- In-Person meeting during a field visit to the Ignace/Wabigoon Lake Ojibway Nation area between August 27th and 30th, 2017 (Figure 2); and
- Teleconference call on November 22, 2017.

As in previous years, an in-person presentation summarizing the GRG’s activities and findings to the NWMO’s Advisory Council and Board of Directors was made. This year Dr. M. Stephens reported on November 28 and 29, 2017.

As in previous years, GRG member Dr. A. Gautschi attended the NWMO Annual Geoscience Seminar in Toronto on June 7 and 8, 2017. These seminars are focused on NWMO's geoscientific R&D program and often include presentations from international guests.

The GRG valued the field visit in August, 2017 as it provided an opportunity to interact with the local communities. The GRG encourages NWMO to organize similar visits in the future as it ensures a sound understanding of the actual situation at potential sites. It greatly enhanced the GRG’s ability to appreciate the complexity of the field studies and the challenges for the field crews. It also helped to ground truth the adopted approaches and methods, and to experience the enthusiasm of the associated communities. Feedback from the GRG for consideration by the NWMO was shared

following the discussions during the visit. Besides some general observations, the feedback included considerations relating to scheduling of site selection fieldwork, work packages for this program (see also Section 5.6), data reporting and integration including forthcoming 3D geosphere modelling.



Figure 2. GRG members and two colleagues from NWMO examining initial borehole site 1 (to the left) and an outcrop along a prominent surface lineament (to the right) in the Ignace area.

3.2 Specific studies reviewed by the GRG

The GRG has systematically reviewed approaches, methods, criteria and findings related to the following broad geoscientific issues and comments on them in the later sections of this report.

- Findings regarding the location and suitability of potential siting areas identified in each candidate area;
- Adequacy of the proposed preliminary field investigation programs to further assess and increase confidence in potential suitability;
- Assessments of uncertainties of candidate areas; and
- Studies to be carried out in connection with Ignace Borehole 1.

More specifically, these activities included:

- Review of work plan, data, interpretation and report for Phase 2 high-resolution airborne geophysical surveys in the communities of Elliot Lake and Blind River (Section 5.1).
- Review of work plan, interpretation and report for Phase 2 lineament studies in the communities of Elliot Lake and Blind River (Section 5.2).
- Review of work plans, interpretation and reports for the geological mapping in each of the communities Ignace, Hornepayne, Manitowadge and White River, and in the combined communities Elliot Lake and Blind River (Section 5.3).
- Review of approach, rationale and identification of potential repository areas in each of the communities Ignace, Hornepayne, Manitowadge and White River, and in the combined communities Elliot Lake and Blind River (Section 5.4).
- Review of geoscience relative suitability assessment for the potential repository areas in the communities Hornepayne, Manitowadge and White River (Section 5.5).
- Review of Test Plans for Ignace Borehole 1 (Section 5.6).

- Review of the approach and rationale used to identify the location of Ignace Boreholes 2 and 3 (Section 5.7).

4 Overall assessment of progress during 2017

The GRG's review process followed the same approach as in previous years:

- Prior to meetings, NWMO shared draft work plans, initial findings and reports, as they became available, in order to solicit review comments;
- Meetings, teleconferences and email exchanges with NWMO and its consultants were held to discuss the GRG's review comments;
- GRG comments were documented and tracked in disposition tables, which were sent to the GRG to ensure that the approach to address the review comments was appropriate; and
- Draft versions of final reports were reviewed by the GRG to ensure that review comments were addressed by NWMO and its consultants to the satisfaction of the GRG.

As in previous years, the GRG is satisfied with the assessment approach adopted by the NWMO and is impressed by the progress made in the geoscientific site evaluations. In particular, the GRG notes that NWMO has now started the initial borehole drilling program of the Phase 2 Preliminary Field Investigations. This follows completion of detailed geophysical and geological studies, and the identification and relative suitability assessment of potential repository areas in the five remaining communities underlain by crystalline rock. The systematic, iterative process developed and adopted by NWMO together with a site visit allowed the GRG to review findings and progress in great detail.

The NWMO team and its consultants have again undertaken high quality work that facilitated a carefully reviewed approach. Despite the much higher work volume this year, the GRG was able to provide timely input for consideration by NWMO. On this basis, the GRG supports the overall outcomes from these studies. Suggestions by the GRG for process improvements were considered and implemented by NWMO in a timely, highly transparent and professional manner. As a consequence, NWMO continues to maintain a high standard of quality work and is making steady progress in the site evaluation process. In the GRG members' opinion, the adopted approach continues to follow or exceed international practices.

The GRG's overall contributions in 2017 included:

- Advice on specific work plans, data interpretations and reports to ensure proper identification of data sources and quality, to improve a characterization approach, and to sharpen nomenclature and processes for the consistent interpretation of the compositional, structural, petrophysical, geomechanical and hydrogeological attributes of rock masses encountered during field mapping and borehole drilling activities;
- Systematic review and quality assurance of draft final reports to assist in achieving and ensuring high international standards; and
- Advice on specific Work Packages (WP) and Test Plans related to the execution of the first site characterization borehole.

5 GRG review comments

5.1 *Airborne Geophysical Surveys in Elliot Lake and Blind River Area*

The NWMO completed high-resolution airborne geophysical surveys for the Elliot Lake and Blind River area. The GRG reviewed the community specific work plan for the surveys, as well as the interpretation of the acquired aeromagnetic and airborne gravity data including draft final report. The planning, acquisition and interpretation of this survey followed the same approach and methods previously

reviewed by the GRG for Ignace, Schreiber, Creighton, Hornepayne, Manitouwadge and White River (APM-GRG 2014, 2016).

5.1.1 Airborne survey plan (2017)

In previous years, the GRG was involved in setting the survey specifications and procedures to ensure that the acquired data exceed the industry standard in terms of data quality control and quality assurance. The same specifications and procedures were used for the surveys in 2017, and the same contractor (Sander Geophysics Ltd.) was involved. Hence, the approach and goals of the new surveys are consistent with those of the surveys previously flown in other communities.

Due to the planning and diligence of the NWMO and the continuous interaction with the contractor, the newly acquired data are of the highest quality and will serve the needs of the site evaluation process.

5.1.2 Interpretation of airborne surveys (2017)

The GRG reviewed a draft final report of the geophysical interpretation report for the Blind River and Elliot Lake area. The report was found to be well structured, well written and of high quality. The GRG made a number of comments to improve the clarity of the interpretations.

It is the opinion of the GRG that the interpretation of the airborne geophysical surveys for the Blind River and Elliot Lake area provided a sound basis for lineament interpretation and field geological mapping, including gaining a better insight into the occurrence of dykes, rock heterogeneity and the extent of the need for refining existing geological maps.

The modelling in the geophysical interpretations undertaken and reported in previous years had to assume densities (and magnetic susceptibilities) that were based on limited evidence. After those reports were completed, geological mapping has been undertaken that involves collecting rock samples and magnetic susceptibility data. The measured density and magnetic susceptibility data can be used to better constrain the 2.5D inversion models. The GRG recommends that these densities be measured and analyzed. If the density data are significantly different from those used in the previous models, it is recommended that the modelling be revisited. This could provide better estimates of the thicknesses of the geological units, particularly where NWMO plans to place boreholes.

5.2 Lineament Interpretation in Elliot Lake and Blind River Area

The GRG conducted an initial review of a draft interpretation of lineaments in the form of preliminary interpretation figures and key findings, and later reviewed the final draft lineament report for the Elliot Lake and Blind River area. The same methodology was used to interpret lineaments as in the other communities, and the final draft lineament report follows the structure of equivalent reports. The report is well written and of high quality. The GRG recommended some changes to achieve consistency and to improve clarity.

The GRG appreciates that lineament characteristics and the methodology to establish the final integrated lineament model were described in more detail and that attention was paid to the judgement of the expert person carrying out the lineament interpretation. In this manner, the subjectivity of this process could be minimized. Terminology issues noted by the GRG in earlier review work have largely been resolved.

In summary, the GRG considers the lineament interpretation conducted by the NWMO for the Blind River and Elliot Lake area to be of very high quality and to have achieved an exceptionally high scientific level for lineament interpretation compared to international practices.

5.3 Geological mapping in Ignace, Hornepayne, Manitouwadge, White River, Elliot Lake and Blind River Areas

NWMO completed detailed geological mapping activities in the Elliot Lake and Blind River area in 2017. The approach was to conduct field observations at as many outcrops as possible in the study areas. This geological mapping included an initial phase of mapping in the form of Observing General Geological Features using existing road and trails to visit rock outcrops, similar to what was done for Ignace, Hornepayne, Creighton and Schreiber in 2014, and Manitouwadge and White River in 2016. The work in the Elliot Lake and Blind River area thereby completed this phase of geological mapping in the communities sited on crystalline rock.

The objective of the detailed geological mapping program was to advance the understanding of the lithological character and structure of the bedrock, to ground truth interpretations from airborne geophysical surveys and lineament interpretations, and to characterize the fracture characteristics inside and immediately adjacent to dykes. Findings from the geological mapping along with geophysical and lineament interpretation were designed to inform the selection of potential repository areas in each community.

5.3.1 Key findings from geological mapping (2014-2017)

Reviews of work plans for the initial and more detailed geological mapping in communities located on crystalline rock, as well as a review of a layout for the reporting of the geological mapping were completed during 2016 (APM-GRG 2014, 2016). During 2017, the GRG reviewed the draft final reports for the detailed geological mapping activities in Ignace, and the combined initial and detailed mapping activities in Hornepayne, Manitouwadge, White River, Elliot Lake and Blind River areas.

Overall the GRG considered the mapping work to be very detailed and of high quality. The reports are well structured, well written and very well illustrated. The GRG noted that the reports follow the reporting structure established in earlier review work (GRG 2016) and, as a consequence, are fully consistent with previous reports. The new field data and the previous Phase 2 lineament interpretation work were incorporated in the reports summarizing the Phase 2 initial findings and the identification of potential repository areas (see Section 5.4).

The GRG's primary comments on the mapping reports were related to ensuring consistency in terminology, the plotting and analysis of structural data, the fractures inside dykes, and the character of contacts to dykes. The GRG noted that the field studies confirmed that lineaments inferred from magnetic data are effective for the identification of dykes and, together with surficial data, for the identification of possible fracture zones. GRG was pleased to see that the NWMO had used a highly experienced field geologist to oversee geological mapping activities and to conduct Quality Assurance audits and compliance verification activities in the field. Overall the GRG found that the geological mapping program was well planned, consistently executed, and produced good quality and very useful data.

Some specific comments made by the GRG include:

- Terminologies were cleaned-up to be consistent with the APM glossary and with other mapping reports. This is important as many of the terminologies will be used for the first borehole in Ignace.
 - The main issue was the term 'brittle-ductile'. This matter was resolved after discussion between the NWMO, Contractors and the GRG about how to classify various lineaments observed using the surface and airborne magnetic data, e.g. as ductile, brittle-ductile or brittle. This also applied to structures observed in the field.
 - Another issue concerned terminology of veins versus dykes. Veins and dykes can be differentiated on the basis of length scale, regularity and width. The GRG advised NWMO to adopt this distinction in their glossary of terms. Any time the terms are used, they will be qualified by the width and nature of the infilling material.

- A further issue concerned the statistical treatment of structural orientation data; specifically, the use of stereographic projections and circular histograms to represent data and the number of measurements required to apply statistical methods such as contouring, and for assessing the statistical meaning of peak trends.
- The GRG feels that the field observations around the frequency and character of fractures in and close to diabase dykes, as well as the contact relationships between the dykes and the host rock, have provided key insight into the uncertainty in the significance of the dykes for groundwater flow. GRG recommends that close attention be maintained on these features. To further reduce uncertainties, the GRG repeats its recommendation that information bearing on the character of groundwater flow along dyke contacts should be acquired using experience from underground mines in Canada (GRG 2016).
- The GRG recommends that NWMO generates updated versions of the 2D geological maps at the ground surface in each area where further work with drilling is planned. This work should make use of older and new field data. The updated geological maps should show the latest 2D model for the spatial distribution of major lithological units, inferred dykes from the lineament interpretation work and field data, inferred fracture zones mainly from the lineament interpretation work, and representative point data. This information is a valuable input to future 3D modelling work, which will make use of data from drilling and modelling of geophysical data.

5.4 Identification of Potential Repository Areas in Ignace, Hornepayne, Manitouwadge, White River, Elliot Lake and Blind River Areas (2016-2017)

The GRG reviewed the approach, rationale and identification of potential repository areas in the Ignace, Hornepayne, Manitouwadge, White River, Elliot Lake and Blind River communities, including an assessment of associated uncertainties. Repository areas at this stage of investigation are defined as smaller areas that have the potential to meet NWMO's geoscientific site evaluation criteria and have a sufficient volume of rock to host one or more repository footprints.

GRG members were satisfied with the rationale applied in the identification of preliminary repository areas and the evaluation of associated uncertainties, and are satisfied with the consistent and sound use of geoscientific data collected to date. The GRG agrees with the consistent adoption of this approach in all the crystalline rock communities.

The GRG suggested some reorganization of the parts of the reports concerned with the approach to identifying potential repository areas and recommended clarifying some terminology, particularly around the term "brittle-ductile shear zones". Geological mapping observations can now be used to support interpreted lineaments, including fracture zones and diabase dykes. The GRG noted that the lineament analyses from the new high-resolution geophysical data and imagery is well utilized in the selection of potential repository areas. However, the GRG requested a more detailed assessment concerning the interplay between the recently acquired observational mapping data and the earlier desktop interpretation work using remote geophysical and topographic data.

5.5 Review of geoscience relative suitability assessment for the communities Hornepayne, Manitouwadge and White River

The GRG reviewed the geoscience relative suitability assessment for Manitouwadge, Hornepayne, and White River and was satisfied that the approach has been consistent in all communities located on crystalline rock. The GRG emphasized that the NWMO can reduce the risk of finding a geologically suitable area if a diversity of lithological areas are selected for further study.

5.6 Test Plans for initial borehole drilling in Ignace area

The GRG reviewed the Test Plans for the initial borehole drilling program in the Ignace area, and made comments and recommendations to improve the clarity of various plans and, most importantly, to

improve the consistency between plans. The GRG recommended a second round of reviews for the second drafts of two of the Test Plans. Some examples of the recommendations made by GRG to NWMO as well as the outcome of the recommendations are listed below:

- Ignace BH1 WP2 Test Plan: Borehole Drilling and Coring
 - The GRG agreed with the planned maximum casing depth for this first borehole. Discussions on drilling fluid tracer concentrations led to the selection of an agreed level of fluorescein for tracing the drilling fluid.
- Ignace BH1 WP3 Test Plan: Core Logging, Photography and Sampling
 - The GRG made extensive suggestions on clarifying and improving the terminology used in the various geological tables in the acQuire database. This specifically involved improvements in the correct use of terminology for rock types and textures (classification), geological structures, and alteration types.
 - The GRG recommended the use of a portable gamma-ray spectrometer to distinguish between tonalite and granodiorite, the two major lithological components at Ignace.
 - Following a rapid response by NWMO to the comments of the GRG on the initial version of the initial borehole WP3 Test Plan and the delivery of a revised Test Plan, the GRG was satisfied with the planned procedures.
- Ignace BH1 WP4a Test Plan: Petrophysical Testing of Core
 - The GRG recommended significant revisions to the WP4a Test Plan, and recommended submittal of a revised text plan for a second review by the GRG. Following this second review round, the GRG was satisfied with the revisions but suggested that further refinements may be advisable for future boreholes. For example, it was suggested that future plans address effects of stress relaxation on samples and suggested a literature survey concerning the relationship between diffusion coefficients and porosity in crystalline rocks.
- Ignace BH1 WP4b Test Plan: Geomechanical Testing of Core
 - Upon the GRG's recommendation indirect (Brazilian) tensile strength testing was added.
- Ignace BH1 WP4c Test Plan: Porewater Extraction and Analysis
 - The GRG noted that the Test Plan is mature and takes into account more than ten years of experience in Sweden, Finland, Canada and Switzerland.
 - The GRG made recommendations to improve the integration of 'Opportunistic Groundwater Sampling' and porewater characterisation to ensure consistency between the two (see also comments on WP 6 and 7).
- Ignace BH1 WP5 Test Plan: Geophysical Logging and Interpretation
 - The GRG made recommendations on a suite of logging types that should be included in this Test Plan. For example, the GRG recommended to carry out an active Fluid-Temperature-Resistivity Log (i.e., by activation of inflow zone by pumping).
- Ignace BH1 WP6 Test Plan: Hydraulic Testing
 - The GRG agreed with the hydraulic testing plan, including the option of potentially sampling water during hydraulic testing, if opportunistic water samples are not collected. The GRG emphasized the need for integration between WP6 and WP7.
- Ignace BH1 WP7 Test Plan: Opportunistic Groundwater Sampling
 - The GRG agreed with the approach to collect opportunistic samples, and noted that alternates (including those listed in WP6 and planned for a future work package (WP9)) provide other mechanisms for collecting samples. The GRG recommended to take time series of samples in zones with low water productivity in order to be able to extrapolate the composition of the groundwater. The GRG also recommended to take backup samples for later complementary analyses.
- Ignace BH1 WP8 Test Plan: Temporary Wellbore Sealing

- The GRG agreed with having a Test Plan for temporary wellbore sealing that includes planned and unplanned needs for sealing.

5.7 Location, objectives and approach for drilling Ignace initial three boreholes

The GRG reviewed the location, objectives and approach for the initial three boreholes in the Ignace area. Overall, the GRG felt that the timelines set for the drilling program, in general, were very tight, and that the evaluation of the results from earlier drilling and modification of procedures for the later drilling may not be completed in time before a drill site is selected and the later drilling starts.

6 Concluding remarks

The GRG is satisfied with the progress made during 2017, and continues to be impressed by the systematic and consistent approach adopted by NWMO to conduct early geoscientific site evaluations. NWMO has developed sound workflows for the various field and interpretation studies to ensure consistency between the many consultants involved and between many communities, which allowed the GRG to carefully assess approaches, interpretations and conclusions. On this basis, the GRG supports the overall outcomes from these studies at this stage of investigation.

The GRG is particularly pleased to see how the geological mapping work has improved the understanding of the geological significance of lineaments, both dykes and brittle structures, and the fracture characteristics inside and adjacent to dykes.

The GRG notes that the NWMO has now entered a new stage in the Phase 2 preliminary field investigations with the initiation of drilling at the Ignace site and welcomes the level of detail in the work Test Plans for the drilling. The GRG has made many suggestions for process improvements and is pleased to report that the NWMO at all times is responding to all identified issues in a timely, highly transparent, technically sound and professional manner.

Based on the experience of its members, the GRG feels that the adopted approach and the quality of the studies by the NWMO team and its consultants continue to follow or exceed international practices at this phase of site evaluation.

7 Acknowledgement

This year, NWMO completed the high-resolution airborne geophysical survey program and decided to add additional expertise to the GRG. NWMO has therefore started the search for a replacement for Dr. Richard Smith, expert in geophysics. Dr. Smith will continue to advise NWMO as a discipline expert consultant. On behalf of NWMO, the GRG members wish to acknowledge the many and most valuable contributions of Dr. Smith during Phases 1 and 2 and the excellent collaboration with him. Dr. Smith was a most dedicated member of the GRG.

8 References

- NWMO, 2010. Moving Forward Together: Process for Selecting a Site for Canada's Deep Geological Repository for Used Nuclear Fuel, Nuclear Waste Management Organization. Available at www.nwmo.ca
- APM-GRG, 2013. 2012-2013 Report of the NWMO Adaptive Phased Management Geoscientific Review Group (GRG). Available at www.nwmo.ca
- APM-GRG, 2014. 2014 Report of the NWMO Adaptive Phased Management Geoscientific Review Group (GRG). Available at www.nwmo.ca

Geoscientific Review Group Report 2017

APM-GRG, 2016. 2015-2016 Report of the NWMO Adaptive Phased Management Geoscientific Review Group (GRG). Available at www.nwmo.ca

9 Attachment - Brief biographies of the APM-GRG members

The APM-GRG is composed of five internationally recognized experts from Canada, Sweden, Switzerland, and Australia. They combine extensive multidisciplinary experience in areas relevant to the siting of deep geological repositories in both crystalline and sedimentary rock formations.



Dr. Alexander Cruden is a Professor and Head of the School of Earth, Atmosphere & Environment at Monash University (Australia). Dr. Cruden has more than 25 years of geoscience experience related to structural geology, analysis and characterization in both crystalline and sedimentary rock settings. Dr. Cruden completed a fault reactivation analysis and structural characterization of southwestern Ontario as part of site characterization activities for Ontario Power Generation's proposed Low and Intermediate Level Waste Deep Geologic Repository at the Bruce site.



Dr. Andreas Gautschi is Chief Geoscientific Advisor at the Swiss National Cooperative for the Disposal of Radioactive Waste. Dr. Gautschi has more than 30 years of geoscience experience related to the planning, co-ordination and implementation of site evaluation programs for deep geological repositories in both crystalline and sedimentary rocks. He coordinated successful geoscience activities that contributed to the selection of the Opalinus Clay formation as the preferred geologic setting for the long-term management of high-level waste in Switzerland. He also has a lectureship at ETH Zurich.



Dr. Peter Kaiser is Chairman of the APM-GRG, Professor Emeritus of Bharti School of Engineering at Laurentian University and former Chair for Rock Engineering and Ground Control, Founding Director of the Center for Excellence in Mining Innovation and Director of the Rio Tinto Centre for Underground Mine Construction. His interests and expertise lie in geomechanics, underground excavation stability, mine design, mechanized excavation and the applications of emerging technologies that increase mining safety and productivity. Dr. Kaiser is a Fellow of the Canadian Academy of Engineers and a Fellow of the Engineering Institute of Canada. He is the author of over 350 technical and scientific publications.



Dr. Richard Smith is a Professor in the Department of Earth Sciences at Laurentian University, where he is the Industrial Research Chair of Exploration Geophysics. He has expertise in the application of geophysical methods generally and airborne methods specifically to investigate the geosphere at depth. Dr. Smith brings over 20 years of experience working in the exploration business. In 2015, he was asked by the Geological Society of London and the UK Department of Energy and Climate Change to be a member of the National Geological Screening Independent Review Panel.



Dr. Michael Stephens retired in 2015 as Senior State Geologist with the Geological Survey of Sweden. Dr. Stephens has been actively involved in the Swedish site evaluation process, including country-wide reconnaissance studies conducted in Sweden to identify potentially suitable regions for hosting a deep geological repository, geoscientific feasibility studies, and the detailed site characterization of the Forsmark site which was selected by the Swedish Nuclear Fuel and Waste Management Company as the site for that country's deep geological repository for used nuclear fuel.