2022 Report of the NWMO Adaptive Phased Management Geoscientific Review Group (GRG)

December 2022

By NWMO Adaptive Phased Management Geoscientific Review Group

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Remarks by GRG Chair

As in previous years, the Adaptive Phased Management Geoscientific Review Group (APM-GRG) was able to follow many of NWMO's geoscientific initiatives and to undertake a thorough review of work or test plans and technical documents. Fortunately, the GRG was this year able to undertake a field trip to the South Bruce Site to view some of the potential host rock units before attending an in-person review meeting in Toronto. This greatly helped the GRG to reconnect with the Geoscience team and to discuss matters in more detail than has been possible during virtual meetings between 2020 and 2022.

The expertise on the GRG was enhanced by the addition of one new member (Dr. Sven Follin) in late 2021. With four members from Sweden and Switzerland, the review team brings relevant scientific and practical experience from countries that have investigated the suitability of repository sites for decades and are in advanced stages of site characterization and selection for repository construction. These members are also aware of or involved in the most advanced stages of repository construction in Finland where an operating license application for a repository was given in late 2021. The remaining two members bring advance knowledge of the geology of the Canadian Shield and Bruce Peninsula, rock mass characteristics of potential host rocks, and experience with underground construction and mining.

The primary focus of the GRG's review and advisory work dealt with site characterization studies and several work or test plans at the Revell Site, and the first site characterization report and some test plans at the South Bruce Site. The GRG was informed about the interface between geoscience and safety assessment and reviewed 'Confidence in Safety' reports for both sites.

The GRG was again informed by high-quality presentations at monthly virtual meetings about progress at drill sites, data processing and interpretation. This report presents a summary of the GRG's findings and conclusions for the 2022 calendar year. Overall, the GRG is satisfied with the progress made this year and the quality of work produced by the Geoscience team despite the negative impact of the pandemic on the delivery schedule of important reports. Specifically, the GRG is pleased to see good progress in the further development of the 3D geological models at both sites and the initial implementation of a first site-scale Discrete Fracture Network (DFN) model in the hydrogeological model for the Revell Site. Nevertheless, the GRG remains concerned about tight timelines to produce the 'Descriptive Geoscientific Site Model' (DGSM) and 'Geosynthesis' reports, and the handover of data to the Engineering and Safety Assessment teams. The GRG reiterated concerns about issues related to concept development and data integration as described in more detail in this report.

The GRG shares the opinion of NWMO, expressed in their 'Confidence in Safety' reports for the Revell and South Bruce sites summarizing the results as of early 2022, indicating that both sites would be suitable from a technical perspective for hosting a repository. These reports were intended to serve public discussion around site selection. The GRG understands NWMO's plan for future years including ongoing site characterization and engineering design work, designed to further increase confidence and demonstrate the suitability of the selected site.

On behalf of all GRG members, I wish to express our appreciation for the professional work by the NWMO team and for the diligent response to review feedback provided by the GRG.

Peter K. Kaiser, Ph.D, P.Eng., F.EIC, F.CAE

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1 Introduction

The Adaptive Phased Management Geoscientific Review Group (APM-GRG; abbreviated to GRG) was established by NWMO in 2012. It was formed to provide independent review comments and advice on the geoscientific assessments being conducted as part of NWMO's evaluations to identify a single suitable deep geological repository site for Canada's used nuclear fuel in an informed and willing host community. More specifically, the GRG reviews all site characterization work and provides critical comments on the approach, methods and criteria used, the data interpretation, and reporting of findings. It assesses and advises on 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. Increasingly, the GRG is providing feedback on draft data interpretation reports resulting from this site characterization program and related modelling of the potential repository sites.

This report covers the activities of the GRG during 2022. Previous annual reports are publicly available on NWMO's website (www.nwmo.ca) and are listed in the list of references. Brief biographies of the six current GRG members are attached to this report.

2 Geoscience site characterization activities in 2022

The NWMO continues to assess the suitability of the remaining potential sites for a deep geological repository, following a staged approach that includes 'Initial Screenings', 'Preliminary Assessments' and 'Detailed Site Characterization', and considers both technical and community well-being factors (NWMO 2010).

In 2022, the assessment focussed on the potential suitability of siting areas within two regions in Ontario: the Wabigoon Lake Ojibway Nation (WLON)-Ignace area in northwestern Ontario, and the Saugeen Ojibway Nation (SON)-South Bruce area in southern Ontario (Figure 1).

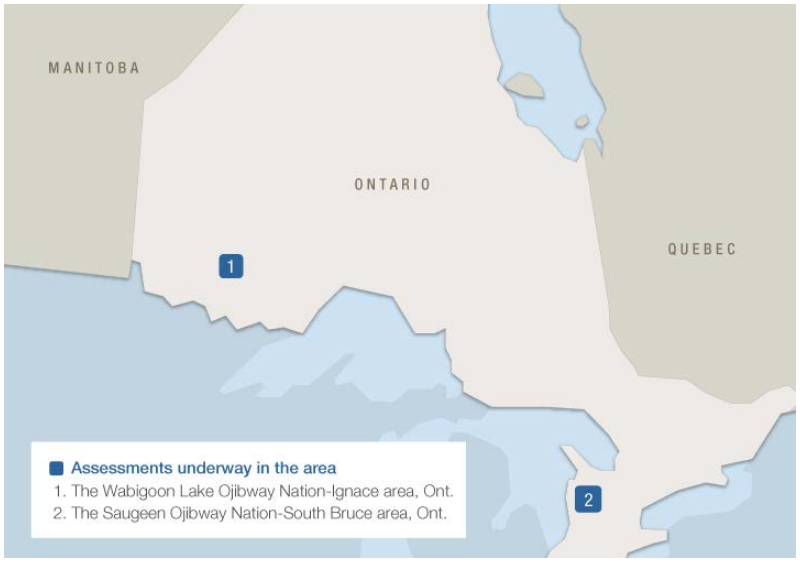

Figure 1: Two areas of ongoing NWMO site suitability assessments

The WLON-Ignace area is underlain by Archean crystalline rocks and, by the end of 2022, the Geoscience Site Assessment team and their contractors had completed the drilling and testing of six deep boreholes in the Revell Batholith. The primary geoscientific field activities in this area included ongoing purging, profiling, and sampling of the instrumented deep and shallow groundwater monitoring wells, as well as maintenance and monitoring of the installed nine-

station microseismic monitoring network. Data from fieldwork activities was received, reviewed, and then used to publish a first “Confidence in Safety – Revell Site” report based on the results available in early 2022 (NWMO 2022a). The report indicates that this site, pending further planned investigations, should be suitable from a technical perspective for hosting a repository. This report is intended to support public discussion around site selection. In addition, a partial draft ‘Descriptive Geoscientific Site Model’ (DGSM) has been produced at the end of 2022 for review by the GRG in early 2023. This model constitutes a significant milestone in understanding the Revell Site.

The SON-South Bruce area is underlain by Paleozoic sedimentary rocks and, by the end of 2022, the Geoscience Site Assessment team and their contractors completed the drilling and testing of two deep boreholes at the site. The primary geoscientific activities in this area included completing the installation and initiation of ongoing profiling and sampling of a shallow groundwater well network, as well as maintenance and monitoring of an installed microseismic monitoring network. Data from fieldwork activities is being received, processed, and reviewed, and a draft 3D geological site model has been produced and is currently under review by the GRG. A “Confidence in Safety – South Bruce Site” report was published, summarizing the results as of early 2022 (NWMO 2022b). This report is also intended to support public discussion around site selection and indicate that this site, pending further planned investigations, should be suitable from a technical perspective for hosting a repository.

3 GRG review activities in 2022

Review activities this year were conducted by six GRG members described in brief biographies at the end of this report and shown below in Figure 2. The review process followed the same approach as in previous years, involving virtual and in-person meetings, formal reviews of technical documents, and direct correspondence between GRG and the NWMO Geoscience team. The GRG is satisfied with the adopted mode of communication, which allows the GRG to operate effectively.

Figure 2. APM-GRG members from left to right, back and front:
Peter Kaiser (Chairman), Alexander (Sandy) Cruden and Anders Ström, and
Sven Follin, Michael Stephens and Andreas Gautschi

3.1 Meetings between the GRG and the NWMO Geoscience team

The GRG completed ten virtual meetings in 2022 to discuss specific technical/scientific issues, and to address questions and recommendations emerging from the reviews of technical documents. In addition, a 2-day in-person meeting was held after a visit to the South Bruce Site on November 2, 2022. A meeting with NWMO's Senior Management was held during this in-person meeting to inform the GRG of the overall program goals and approaches, and to discuss areas that the GRG considers requiring further attention. In this manner, the GRG continued to fulfill its advisory function on forthcoming work tasks. The schedule and primary focus of the meetings are summarized in Table 1.

Table 1: GRG meeting schedule for 2022

Meeting	Topic of Focus
January 11, 2022 (W) (W for web-meeting)	Special meeting to discuss hydrogeological issues, review of methodology for flow and transport in sparsely fractured rock.
January 13, 2022 (W)	Discrete Fracture Network (DFN) report with overview of planned approach to analyze DFN data from the Revell Site, and how to model the results in the hydrogeological model using HydroGeoSphere.
February 15, 2022 (W)	Overview of NWMO's indigenous relations activities; New geochronology at the Revell Site with implications for genetic models of amphibolite.
March 24, 2022 (W)	South Bruce Site hydraulic testing, and 3D seismic acquisition and processing.
May 5, 2022 (W)	Overview of NWMO's regulatory project and geoscience's role; *in situ* engineered module experiment.
May 13, 2022 (W)	In-depth discussion about subordinate rock types at the Revell Site.
June 30, 2022 (W)	Overview of seismic programs; correlating transmissivity data with DFN sets at the Revell Site.
September 2, 2022 (W)	Overview of 'Confidence in Safety'; particularly aspects of site selection; timing of Geoscience documents and safety case/regulatory aspects including repository engineering.
October 5, 2022 (W)	Long-term geomechanical stability analysis and Rock Mass Rating (RMR) approach.
November 2-4, 2022 (IP) (IP for in- person meeting)	Visit of fractured rock exposed at Inverhuron Provincial Park, borehole sites SB_BH01 and SB_BH02, and drill core archive at South Bruce Site; R&D initiatives in geomechanics and hydro-geochemistry; South Bruce Site 3D geological model; Revell Site DFN and 3D geological models; thermal models at both sites; and glacial modeling.
November 4, 2022 (IP)	Meeting with Senior Management to discuss means to support and strengthen the Geoscience team for timely delivery of quality documents required for licensing.
December 7, 2022 (W)	DGSM Version 0 overview, summary and conclusions.

NWMO shared draft work or test plans and initial findings in technical documents as they became available to solicit review comments. Feedback from the GRG for consideration by the NWMO was shared during and after each virtual meeting and, more importantly, individual GRG members communicated directly by e-mail or during additional focused virtual meetings. These meetings and e-mail exchanges with the NWMO Geoscience team served to discuss the GRG's review comments and impressions on progress made. In particular, the in-person meeting in November provided an excellent opportunity to discuss various broader issues identified by the GRG earlier during the year for action by the Geoscience team (see Section 4).

3.2 Specific studies reviewed by the GRG

In 2022, the GRG systematically reviewed approaches, methods and findings reported in 13 technical documents. Only documents that were received and reviewed prior to November 30, 2022, are addressed here. Some key aspects arising from the review work are summarized below.

The GRG appreciates the diligent use of disposition tables linked to the reviewed documents that facilitates tracking and, if necessary, a response to actions planned by the NWMO. Disposition tables and modified final reports were also reviewed by the GRG.

3.2.1 Revell Site in the WLON-Ignace area

The technical documents addressing activities close to and around the Revell Site (WLON-Ignace area) involved the acquisition of noble gas borehole data, the monitoring of groundwater and microseismic data, and data analysis, data integration and modelling work in various disciplines (Table 2). A draft 'Descriptive Geoscientific Site Model' (DGSM) report, constituting a significant milestone for site understanding, has been received and will be reviewed by the GRG in early 2023.

Table 2: Technical documents reviewed or to be reviewed by the GRG from the Revell crystalline rock site in the WLON-Ignace area

Timing of receipt	Title of technical document
March 2022	Confidence in Safety – Revell Site.
March 2022	Work Plan for Sub-Regional Scale Integrated Hydrogeological Model for the Revell Batholith and Surrounding Area.
May 2022	WP10 - Rock Mass Classification for IG_BH01, IG_BH02 and IG_BH03 (three separate documents).
May 2022	Groundwater Monitoring of Shallow Well Networks - Ignace Test Plan.
June 2022	2D Seismic Investigations, Ignace Area, Report.
June 2022	Ignace Area Microseismic Monitoring Project Annual Event Summary Report (November 2020 - December 2021).
September 2022	WP10 – Geological Integration Report for Borehole IG_BH04 (awaiting disposition table and final report).
October 2022	Site-scale Discrete Fracture Network Model for the Revell Batholith (awaiting disposition table and final report).
October 2022	Groundwater Noble Gas Data Quality and Utility (Memo. Awaiting disposition table and final report).
December 2022	Descriptive Geoscientific Site Model of the Revell Site, Version 0

The GRG also reviewed, during the early part of 2022, a 'Confidence in Safety' report for the Revell Site (Table 2) intended to support public discussion around site selection. Even though the report did not contain details in geoscience and was beyond the mandate of the GRG, the GRG reviewed and discussed the report after a request from NWMO as there is tight link between findings in geoscience, and repository design, construction, and safety.

Bearing in mind the relationship between the subordinate rock amphibolite and gently to moderately dipping, higher-frequency fracture intervals with groundwater flow close to or along contacts, the GRG recognized that the results of the 2D seismic reflection investigations will provide important information to the 3D geological model and therefore the hydrogeological modelling work at the Revell Site. At the in-person meeting in November, the GRG noted good progress with respect to the use of the seismic reflection data in this context. Key issues identified during the review of the geological data analysis and integration along borehole IG_BH04 concerned the interpretation of the rock composition in the lower c. 100 m along the borehole. Too much emphasis seems to have been placed on a single semi-quantitative mineralogical analysis. The presence of weathering at c. 600 m and 900 m along the borehole was also questioned.

The GRG expressed concern on how hydrogeological aspects in crystalline rock are treated in the 'Confidence in Safety' and in the hydrogeological modelling work plan documents. In their review of these documents, the GRG considered that too much emphasis was placed on the equivalent porous medium (EPM) approach covering large volumes of the bedrock, bearing in mind that it is connectivity and heterogeneity of discrete fractures that govern the flow groundwater paths and solute transport through sparsely fractured rocks. The GRG was pleased to subsequently review a document dedicated to the first site-scale Discrete Fracture Network (DFN) modelling approach as input to the hydrogeological modelling workflow. This DFN model addresses fractures and fracture zones in the equivalent trace length range 100 to 500 m and complements the 3D geological model (DesRoches *et al*. 2021) in which zones with trace length more than 500 m are addressed.

The GRG identified a significant number of technical and conceptual issues during the review of the first site-scale DFN modelling report and the adopted approach. The GRG anticipates that many of the issues raised in the review can be addressed in a revised document but consider that some of the more conceptual aspects around, for example, fracture size distribution and the spatial arrangement of fractures, require an elaborated assessment of alternative approaches in a revised version of the DFN model. The GRG also requested information on the hydrogeological modelling work plan concerning how variability in transmissivity along fractures and fracture zones will be tackled in the groundwater flow and solute transport modelling work using the adopted software (HydroGeoSphere). In response, the NWMO indicated that specific values will be provided in an input file for each DFN element in the model mesh.

The GRG, in their review of the geomechanics reports for IG_BH01, IG_BH02 and IG_BH03, pointed out that Rock Mass Rating (RMR), as commonly used in underground construction, contains two parameters that cannot be obtained from boreholes (orientation of potential underground excavations and water inflow into the excavations). For this reason, the GRG recommended adoption of an RMR-index that depends only on measurable quantities. This approach will be adopted by the NWMO Geoscience team.

The GRG was pleased to review a first document dedicated to the He (helium) age dating of deep groundwater samples from the Revell Site. These first samples show negligible drilling fluid contamination, and the data provide evidence for very long mean underground residence

times in the order of millions of years. The relationship between flowing groundwater and porewater from the rock matrix will be evaluated when He data from porewaters are available.

The GRG considered that the style of the 'Confidence in Safety' report adopted for a broader public is adequate. The GRG pointed out a need for modification of the conceptual underground repository layout as adopted in the report. The orientation of tunnels, canisters and access tunnels should not be randomly allocated, and it should be emphasized that the layout needs to take account of the orientation of regional stress field at the site. The GRG notes that these modifications were completed in the final report and shares the opinion of NWMO that this site should be suitable from a technical perspective for hosting a repository.

3.2.2 South Bruce Site in the SON-South Bruce area

The technical documents addressing activities close to and around the South Bruce Site (SON-South Bruce area) involved the monitoring of shallow groundwater data in the same manner as that adopted at the Revell Site, a test plan for groundwater monitoring along borehole SB_BH01, and geological data analysis and integration for borehole SB_BH01 (Table 3). A draft 3D geological model for the South Bruce Site and surrounding region is currently under review by the GRG. The GRG also reviewed during the early part of 2022 a 'Confidence in Safety' report for the site, with the same purpose as that for the Revell Site (Table 3).

Table 3: Titles of technical documents reviewed or being reviewed by the GRG from the South Bruce sedimentary rock site in the SON-South Bruce area

Timing of receipt (site)	Title of technical document
December 2021	WP09 Test Plan: Westbay MP55 Multi-Level Groundwater Monitoring System Installation for SB_BH01.
March 2022	Confidence in Safety – South Bruce Site.
June 2022	Groundwater Monitoring of Shallow Well Networks – South Bruce Test Plan.
September 2022	WP10 – Geological Integration Report for Borehole SB_BH01 (awaiting disposition table and final report).
December 2022	3D Geological Model for South Bruce and Surrounding Region: Model Version 1.0

The GRG were pleased to see in the geological integration report for borehole SB_BH01 how well the core logging results agree with the predictions made in a recently published regional geological 3D model for the Paleozoic bedrock of southern Ontario (Carter *et al*. 2021). Furthermore, the frequency of fractures in the Upper Ordovician potential repository rock and the surrounding units along the borehole is very low, similar to that observed at the Bruce nuclear site. Preliminary data from hydraulic testing in borehole SB_BH01, reported to the GRG at the March virtual meeting, indicate strong similarities with the hydrogeology of the Bruce nuclear site (very low hydraulic conductivities, and hydraulic under-pressures in the Cobourg Formation and surrounding lithostratigraphic units). There is clearly a high level of structural-hydraulic predictability in the sedimentary rock succession at and close to the South Bruce Site.

As for the 'Confidence in Safety' report for the Revell Site, the GRG is satisfied with the style of presentation of the similar report for the South Bruce Site, bearing in mind the aim to reach

a broader public audience. Although the geological information and, even more significantly, the key geomechanical, hydrogeological and geochemical (including hydrogeochemical) data presented in the 'Confidence in Safety' report rely on the findings from the Bruce nuclear site, the high level of predictability in the sedimentary succession supports this methodology. The GRG shares, based on currently available geoscientific information, the opinion of the NWMO that the South Bruce Site should also be suitable from a technical perspective for hosting a repository.

4 Broader issues identified by the GRG for further action

The GRG is satisfied with the systematic approach and the methods adopted by the NWMO and is impressed by the progress made despite the continued disruptions by the Covid-19 pandemic. Nevertheless, throughout the year, the GRG identified various broader issues for action by the Geoscience team. Many of these issues have been resolved to the satisfaction of the GRG and a few are being addressed by pending actions. This section provides a brief summary.

The GRG is pleased that the NWMO Geoscience team is now paying closer attention on gently to moderately dipping, higher-frequency fracture intervals close to or along the contacts of subordinate rock types at the Revell Site, including amphibolite. The GRG also notes improvements in the conceptual thinking around heterogeneity of transmissivity along fractures and the level of site understanding for hydrogeochemistry at the same site. Questions raised by the GRG around use of the term 'Rock Mass Rating (RMR)', about what is included in the term 'conceptual hydrogeological modelling', and around choice of the software for both site-scale groundwater flow and solute transport modelling have also all been clarified. Following revision of the plan for site selection from end 2023 to Q4 2024, the NWMO has informed the GRG about a revised timeline for the DGSM and Geosynthesis reports for both the Revell and South Bruce sites.

The GRG was well informed about changes to and restructuring of the NWMO Geoscience team but is still concerned that the team will not be able to complete the required work at the two potential sites at a standard that meets or exceeds international standards of geoscience characterization for construction. While the quality and consistency of discipline-specific reporting is at a high standard, the GRG is concerned that integration across sub-disciplines will not keep pace with individual work packages, because the team members are expected to simultaneously work on two fundamentally different potential repository sites. For this reason, the GRG has recommended to management to find and implement ways to strengthen the team, not just by adding critical resources for data analysis but by providing clear mandates for certain key roles and by limiting the scope to provide focus to meet the timelines. The GRG also suggested that providing expertise in data integration from individuals that are or have been involved in similar studies in the Finnish, Swedish or Swiss programs might assist the Geoscience team. In particular, the GRG suggested that such external support could guide in developing necessary conceptual models that are essential for the handover of site models to the Engineering and Safety Assessment teams, as well as for eventual communication to the public.

At this point in the site characterization process, data integration at various levels of modelling is at a critical stage. At the geoscience level and in the context of the DGSM report, linkages between sub-disciplines (e.g., geology, geomechanics, hydrogeology, hydrogeochemistry, etc.) need to be made, explained and quantified. Groundwater flow and transport models are not the ultimate representation of data integration but are rather tools to support and verify linkages between data sub-sets. At the safety assessment level, data integration is a data management issue. Hence, it is important to ensure that data flows between the Geoscience team, the R&D

group and the Safety Assessment group that facilitates its proper and accurate use. The GRG remains interested in the interaction between the Geoscience and Safety Assessment teams.

In this context, the GRG advises the NWMO to undertake concrete activities with respect to modelling solute (radionuclide) transport based on a close collaboration between the Geoscience and Safety Assessment teams. This will require the development of conceptual or schematic models (summarised as diagrams or sketches) based on core logging and field mapping of potentially water-conducting features, and compilation of quantitative input data for solute transport models. Issues to be addressed in these models are advective flow in fractures and fracture zones with variable transmissivity, diffusion of solutes into the rock matrix and into stagnant water in fracture systems, sorption in fractures and in the rock matrix, and anion exclusion effects.

Many assumptions must be made in any geoscience program and the applicability of preliminary findings are often limited. Furthermore, many uncertainties will remain during all stages of site investigation and will only be eliminated when underground access is available. For this reason, the GRG requested that assumptions and limitations be clearly identified together with findings from different studies, in order to guide further work that is required to eliminate assumptions and uncertainties, and to build confidence. In mineral exploration, the process of building confidence is formalized by the requirement to identify inferred, probable, and proven quantities during the valuation of orebodies. In this process, data collection and integration are used to systematically replace assumptions by facts (Figure 3). In this process, a registry of assumptions is used to formally record assumptions, dispose of those that have been eliminated, and identify others that will be addressed in the future. The GRG recommends that a similar approach be developed and adopted by the Geoscience team to track assumptions, uncertainties and limitations of the findings from different studies.

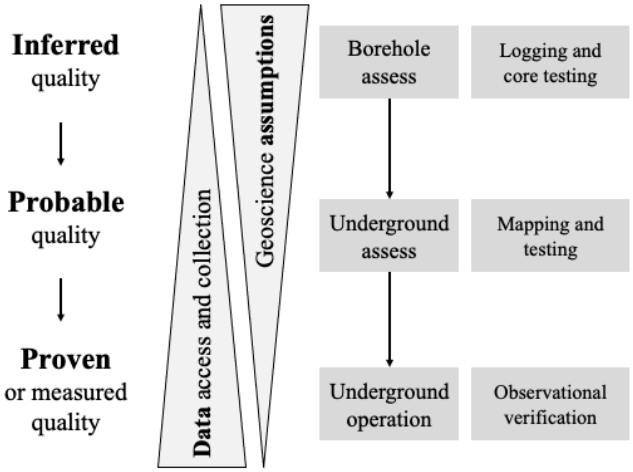

Figure 3. Building confidence in site characterization (modified after Kaiser 2019).

With respect to specific technical matters, during the in-person meeting in November the GRG was pleased to observe good progress in further development of the 3D geological model of the Revell Site and welcomed the plan to implement the DFN modelling approach for smaller-scale fractures and fracture zones at the site in the groundwater modelling workflow. However, bearing in mind the results of the review of the first site-scale DFN modelling report (see Section 3), a revision of the conceptual thinking in this modelling approach needs to be addressed before an acceptable DFN model is implemented in the groundwater modelling workflow. The GRG would also welcome in the work ahead an assessment of the DFN approach to fractures with an equivalent trace length less than 100 m. As noted above in Section 4, groundwater modelling should include a clear identification of all assumptions and limitations plus a better

integration of important geological findings at the Revell Site (e.g., gently dipping zones of higher-frequency fracturing and subordinate lithologies, with known hydraulic transmissivity).

The GRG also welcomes the first site characterization report at the South Bruce Site containing integrated geological and geophysical data from borehole SB_BH01 but awaits a more detailed analysis of the fractures along it. Although very few fractures were observed in the Upper Ordovician rocks along SB_BH01, the GRG advises the NWMO to bear in mind the difficulties in detecting steeply dipping fractures in sub-vertical boreholes.

The GRG has repeatedly pointed out that the *in-situ* stress state in the Canadian Shield must be considered and respected during the analysis of various data sets, even if the specific conditions at the potential repository sites have not yet been confirmed by stress measurements. The existence of three stress domains (shallow typically at <300 m, intermediate, and deep typically at >600 m) must be considered in the interpretation of consequential data (e.g., geomechanics, hydrogeochemistry) and in groundwater flow models. The GRG notes that the issue around *in-situ* stress state in the Canadian Shield has been addressed as a part of the DGSM Version 0 report recently delivered to the GRG for review.

5 Concluding remarks

This report summarizes the most important findings and conclusions of the GRG in connection with their work during 2022.

Significant progress was made this year in data processing in the various disciplines, and high-quality reports were obtained and reviewed by the GRG. The current understanding of the Revell Site (WLON-Ignace area) has benefitted particularly from the completion of 2D seismic investigations, completion of the WP10 Geological Integration Report for the fourth borehole (IG_ BH04), development of a first site-scale DFN model, and acquisition of the first noble gas analyses from a sample below 500 m depth, showing very long groundwater residence times on the order of millions of years.

Good progress was also made at the South Bruce Site (SON-South Bruce area) with respect to the documentation of the WP10 Geological Integration Report for the first South Bruce borehole (SB_BH01), which has considered the latest stratigraphic classification and findings by the Canadian and Ontario Geological Surveys up to 2022. Preliminary hydrogeological data from SB_BH01, showing strong similarities with earlier findings from investigations at the Bruce nuclear site, have also improved the current understanding of the sedimentary rock site.

The development of a first site-scale DFN model at the Revell Site is an important step but improvements are expected in future versions before confidence can be attained in the DFN modelling of the hydrogeological system. It needs to be kept in mind that groundwater flow and transport models are not the ultimate representation of discipline integration but are rather tools to support and verify linkages between discipline-specific data sub-sets. The GRG emphasizes again that the *in situ* stress state in the Canadian Shield must be considered and respected during an integrated analysis of various data sets as long as direct stress measurements are lacking.

The GRG recommends that the Geoscience team applies increased attention to careful tracking of assumptions, uncertainties and limitations of the findings from different studies. The GRG also remains interested in the interaction between the Geoscience and Safety Assessment teams, in particular with respect to issues arising when modelling groundwater flow and solute (radionuclide) transport at each site.

The GRG is pleased to see that the schedule for site selection has been expanded by one year but is still concerned that the Geoscience team will not be able to continue to process the necessary data and develop site description models that meet or exceed international standards of geoscience characterization by the planned construction timeframe.

In summary, the GRG was again impressed by the professional work undertaken by the Geoscience team and is looking forward to contributing to a successful resolution of outstanding challenges.

6 References

Documents available from www.nwmo.ca including annual reports by the GRG

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Brief biographies of the APM-GRG members

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

Dr. Peter Kaiser

Dr. Peter Kaiser, Chairman of the APM-GRG, is Professor Emeritus of Mining Engineering at Laurentian University, former Chair for Rock Engineering and Ground Control, Director of the Rio Tinto Centre for Underground Mine Construction, Founding Director of the Centre for Excellence in Mining Innovation, and geomechanics consultant. His interests 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.

Dr. Sandy (Alexander) Cruden

Dr. Sandy (Alexander) Cruden is Professor of Tectonics and Geodynamics in the School of Earth, Atmosphere and 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. Sven Follin

Dr. Sven Follin is a retired geoscience consultant who has been actively involved in the Swedish site evaluation process for hosting a deep geological repository, including geoscientific feasibility studies and the detailed site characterization of the Forsmark site, which was selected by SKB (the Swedish Nuclear Fuel and Waste Management Company) as the site for the deep geological repository for spent nuclear fuel in Sweden. Focus has been on hydrogeological aspects using the discrete fracture network (DFN) approach. He was also involved in SKB's subsequent safety assessment. In addition to working with site descriptive hydraulic DFN modelling for SKB, Dr. Follin has been actively involved in the hydraulic investigations and the structural-hydraulic DFN modelling of excavated damage zones (EDZ) around deposition tunnels at the Olkiluoto site, which was selected by Posiva (the Finnish Nuclear Fuel and Waste Management Company) as the site for the deep geological repository for spent nuclear fuel in Finland.

Dr. Andreas Gautschi

Dr. Andreas Gautschi was Chief Geoscientific Advisor at the Swiss National Cooperative for the Disposal of Radioactive Waste (Nagra). Since his retirement he works as an international geoscientific consultant. 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, in close collaboration with Nagra's safety assessment group. For many years he had lectureships at Tübingen University and ETH Zurich on Deep Geological Disposal of Radioactive Waste.

Dr. Michael Stephens

Dr. Michael Stephens is a retired Senior State Geologist with the Geological Survey of Sweden in Uppsala. 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 SKB as the site for the deep geological repository in Sweden. Focus has been on base geological aspects.

Mr. Anders Ström

Mr. Anders Ström is Senior Program Manager of final disposal solutions for spent fuel at SKB (the Swedish Nuclear Fuel and Waste Management Company). Mr. Ström has been actively involved in SKB's siting program since the early 1990s, among other things, in charge of the development of requirements on the crystalline rock for the spent fuel repository and criteria for site evaluation. During the site characterization project, he was Chief Project Manager for the multidisciplinary site descriptive modelling conducted for the two candidate sites at Forsmark and Laxemar-Simpevarp (Oskarshamn). He is now in charge of the close co-operation between SKB and Posiva, in Finland, for implementing robust disposal solutions according to the KBS-3 concept.