Joint Review Panel

Environmental Assessment Report

CEAA Reference No. 17520

Deep Geologic Repository for Low and Intermediate Level Radioactive Waste Project

May 6, 2015

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Acknowledgements

An environmental assessment of this magnitude requires the dedication and commitment of an outstanding team. The Joint Review Panel expresses its sincere gratitude to the co-managers of the Panel Secretariat, Debra Myles (CEAA) and Kelly McGee (CNSC), for their unwavering support and guidance throughout this assessment. Special thanks are also due to Michael Young (CNSC), David Haddon (CEAA), and Robyn-Lynne Virtue (CEAA) for their research, advice, and assistance. Denis Saumure (CNSC) and Pierre-Daniel Bourgeau (CNSC) provided valuable legal advice throughout the process. Sincere thanks also to Marie-Claude Valade (CNSC) for looking after the general welfare of the Panel.

The Panel wishes to acknowledge with gratitude the contributions of the proponent, the federal, provincial and municipal entities, Aboriginal groups, and the organizations and citizens who participated in the review. Their patience, civility, and respect for the process are greatly appreciated.

Published under the authority of the Minister of Environment, Government of Canada

Joint Review Panel Environmental Assessment Report - Deep Geologic Repository for Low and Intermediate-level Radioactive Waste Project (May 6, 2015)

Print: Cat. No.: En106-139/2015E
ISBN: 978-0-662-03911-2

PDF.

Cat. No.: En106-139/2015E-PDF
ISBN: 978-0-662-03910-5

www.ceaa-acee.gc.ca
www.nuclearsafety.gc.ca

May 6, 2015

The Honourable Leona Aglukkaq
Minister of the Environment
Les Terrasses de la Chaudière
10 Wellington St, 28th Floor
Gatineau QC
K1A 0H3

Dear Minister Aglukkaq:

The Joint Review Panel for the Deep Geologic Repository Project for Low and Intermediate Level Radioactive Waste has completed its environmental assessment of the project in accordance with the *Agreement to Establish a Joint Review Panel for the Deep Geologic Repository Project by Ontario Power Generation Inc. within the Municipality of Kincardine, Ontario* issued on January 26, 2009, and the Amendment to the Agreement issued on August 3, 2012. The Panel is pleased to submit its report for your consideration.

Sincerely,

Stella Swanson
Joint Review Panel Chair

James F. Archibald
Joint Review Panel Member

Gunter Muecke
Joint Review Panel Member

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EXECUTIVE SUMMARY

The executive summary presents a brief description of the review process, the proposed project and the main conclusions of the Joint Review Panel (the Panel). The Panel's recommendations are presented in Chapter 16 of this report.

THE PROPOSED PROJECT AND THE JOINT REVIEW PANEL PROCESS

Low and intermediate-level radioactive waste (L&ILW) is produced as a by-product of the operation of nuclear generating stations owned by Ontario Power Generation (OPG) at the Bruce, Pickering and Darlington sites in Ontario. This waste is currently stored at the Western Waste Management Facility (WWMF), a surface facility on the Bruce nuclear site. The Deep Geologic Repository Project (DGR) is a proposal by OPG to build and operate an underground disposal facility for 200,000 cubic metres of L&ILW on the Bruce nuclear site, in the Municipality of Kincardine.

The Minister of the Environment and the President of the Canadian Nuclear Safety Commission (CNSC) established the Panel on January 24, 2012 to undertake the review of the project under the *Canadian Environmental Assessment Act* and the *Nuclear Safety and Control Act*. The Panel Members are Dr. Stella Swanson (Chair), Dr. James F. Archibald and Dr. Gunter Muecke.

The Panel's mandate was to: assess the proposed project in accordance with the requirements of the *Canadian Environmental Assessment Act, 2012*; consider the OPG application for a Licence to Prepare Site and Construct under the *Nuclear Safety and Control Act*; and obtain information about potential adverse effects that the project may have on potential or established Aboriginal rights, title or Treaty rights.

OPG proposed to construct the DGR approximately 1.2 kilometres from the shore of Lake Huron, near the existing WWMF. The DGR would be constructed in limestone in the Cobourg Formation, at a depth of approximately 680 metres below ground surface. The underground facilities would include two shafts, tunnels, emplacement rooms and various underground service areas and installations. The surface facilities would include underground access and ventilation buildings, a waste package receiving building and related infrastructure. The total surface footprint of the DGR would be approximately 30 hectares and the underground facilities would encompass approximately 40 hectares.

The purpose of the DGR would be to safely manage L&ILW in the very long term, so that the radioactivity in the waste will not pose a concern to the health and safety of persons and the environment. Low-level waste has low levels of radioactivity and can be handled without special radiation protection measures. It includes materials such as protective clothing, floor sweepings, mops, and rags. Intermediate-level waste consists of non-fuel waste that cannot be handled without radiation protection measures. It includes materials such as used reactor core components, refurbishment waste, and resins and filters from nuclear reactor operations.

The project is divided into preclosure and postclosure periods. The preclosure period would last about 60 years and would include site preparation and construction, operations and decommissioning. The postclosure period would include a period of institutional control followed by abandonment forever.

All project activities would be undertaken under the regulatory oversight of the CNSC and other government agencies. The project would be constructed using conventional mining techniques, operated using established radioactive waste management practices, decommissioned using conventional practices and natural processes, and would include mitigation and follow-up as required.

The proposed DGR is an important, unique, precedent-setting project. It would be the first of its kind in North America, and it is the first of its kind in the world to propose using limestone as the host rock formation. It is likely that the knowledge and experience gained through the project will assist the Canadian government in its separate Adaptive Phased Management process for the long-term management of used fuel.

SUMMARY OF CONCLUSIONS OF THE JOINT REVIEW PANEL

The Proposed DGR is Not for the Disposal of Used Fuel

The Panel heard several claims that the project might ultimately be expanded to include high-level radioactive waste (used fuel). The Panel emphasizes that the project would be for L&ILW only. OPG repeatedly and categorically stated that used fuel would not be placed in the DGR. The Panel notes that the Municipality of Kincardine passed a resolution stipulating that no used fuel would be placed in the DGR. The federal-mandated Adaptive Phased Management process for the management of used fuel is a distinctly different process than the Panel review process for L&ILW. The Adaptive Phased Management process is in the early stages of finding appropriate sites. A used fuel repository would have distinctive design requirements different than the DGR and would require a separate environmental assessment and licence application to the CNSC.

The Panel Obtained Information Regarding Project Effects on Aboriginal Interests

Obtaining Input from Aboriginal Groups

The Panel based its assessment of effects the project may have on Aboriginal interests upon: information provided directly to the Panel by Aboriginal groups through written and oral submissions; information obtained by OPG through its consultation with Aboriginal groups; and information provided by the Crown Consultation Coordinator (in this case CNSC staff).

Aboriginal groups were provided with opportunities to express their views. These opportunities were provided by OPG, the Crown Consultation Coordinator, and the Panel. Further, the Participant Funding Program administered by the Canadian Environmental Assessment Agency, together with the individual, private agreements entered into between OPG and the participating Aboriginal groups provided those groups with important capacity to participate. The Panel is of the view that Aboriginal groups were well informed and understood how to participate in the Panel process.

The Agreement to Establish a Joint Review Panel specifically identified the Saugeen Ojibway Nation. The Saugeen Ojibway Nation were provided with the opportunity to present their views throughout the review. The Panel allocated specific times for the Saugeen Ojibway Nation to present their views at the public hearing. The Panel obtained information and evidence about the adverse effects the project may have on potential or established Aboriginal rights, title or Treaty rights, as identified to the Panel by the Saugeen Ojibway Nation.

The Panel acknowledges and encourages the communication and relationship-building with OPG that has been described by Aboriginal groups over the course of this review. The Panel expects that discussions of potential effects on traditional uses and resources will continue as part of the individual agreements entered into between OPG, the Saugeen Ojibway Nation, Métis Nation of Ontario and Historic Saugeen Métis. The Panel also notes CNSC's commitment to ongoing consultation with Aboriginal groups associated with this project.

Effects on Aboriginal Interests

The Panel concludes that the changes in the natural environment that may be caused by the project, such as changes in dust and noise levels during site preparation and construction, and changes in radioactivity levels during operation, are not likely to cause significant adverse effects on Aboriginal interests, including health and socio-economic conditions, physical and cultural heritage, the current use of lands and resources for traditional purposes, or any structure, site or thing that is of historical, archaeological, paleontological or architectural significance, provided all relevant mitigation measures are successfully implemented. These mitigation measures are not limited to those related to the Jiibegmegoong burial site, but also include the mitigation measures committed to by OPG or those recommended by the Panel relating to effects on air quality, noise, water quality, water quantity, radiation and radioactivity, plants and animals.

The Panel received information on the unique spiritual and cultural perspectives that Aboriginal groups brought to the assessment of this project. Aboriginal groups articulated concerns that such unique worldviews might not align with the technical analysis and measured evaluations of the project carried out to meet prescribed legal requirements. The Panel acknowledges and respects the information regarding the cultural and spiritual connections to the land, waters and all creation. The Panel believes that important bridges have been built between the scientific information for this environmental assessment and the cultural and spiritual worldviews of the Aboriginal people who participated in this review. Building community confidence and trust, demonstrating certainties and sharing information that will address anxieties is no doubt an ongoing responsibility resting on the shoulders of the Crown, OPG and the participating Aboriginal groups.

The DGR is the Solution for the Long-Term Management of Low and Intermediate-Level Radioactive Waste

The Panel agrees with OPG that the DGR is the preferred solution for the long-term management of L&ILW. OPG was of the view that permanent emplacement of the waste in a DGR, where it is separated from the biosphere by multiple geological barriers, would be a safer solution over the long term than the current method of storage at the WWMF. The Panel presents it observations regarding this conclusion below.

Underground Disposal Has Lower Risks than Surface Storage

The Panel agrees with the current international consensus that deep geologic disposal of radioactive waste is the preferred option for containing and isolating radioactive waste from humans and the biosphere. The Panel concludes that placing the L&ILW in an appropriately located underground repository would pose a lower risk to human health and the environment than surface storage. Compared to a surface facility, the additional protection of hundreds of metres of rock in a difficult-to-access location with limited or no exposure to natural surface phenomena reduces the likelihood as well as the consequences of both natural and human-related hazards. Natural hazards such as flooding, tornadoes, and earthquakes would have a higher probability of causing effects to humans and the environment when the waste is on the surface. Malfunctions, accidents, and malevolent acts would also be more likely to result in environmental effects if waste is at the surface.

The DGR Should be Built Now Rather than Later

The Panel is of the view that the sooner the waste is isolated from the surface environment the better. The Panel notes the importance of reducing and, if appropriate, reusing and recycling the waste. However, it recognizes that current technologies to alter the waste to render it no longer hazardous are limited, particularly for intermediate level waste that contains radionuclides with longer half-lives. The Panel concludes that the likelihood and consequences of an event resulting in the release of radionuclides from surface storage are greater than they would be for a DGR. The Panel is of the view that the risk of waiting until technologies are available to eliminate the hazards associated with longer-lived radionuclides outweighs the benefits.

There is a Strong Safety Case for the DGR

OPG presented a safety case for the DGR. The Panel is of the view that the safety case for the project is strong because of:

- the highly suitable geology;
- the nature of the waste;
- robust engineering design;
- built-in, long-term safety features;
- good long-term performance under normal conditions, including glaciation;
- acceptable risks under unlikely, ‘what if’ scenarios; and

- the demonstration of passive containment provided by natural geology in other settings (natural analogues).

Highly Suitable Geology

OPG proposed to build the DGR at a depth of 680 metres below the surface in the thick, stable and solid limestone rock of the Cobourg Formation. The Cobourg Formation has very low permeability, which means that liquids and gases cannot pass easily through this rock because it has very few cracks and very few and tiny pores. The Cobourg Formation is underneath 200 metres of shale-rich bedrock (called the cap rock) which also has very low permeability. Because of the very low permeability of the Cobourg Formation and the cap rock, the movement of water and gas from the repository will be dominated by diffusion. Diffusion in rocks is a very slow process. For example, it would take a water particle at the repository depth in undisturbed rock approximately 10,000,000 years to move one metre.

The host rocks of the Cobourg Formation are very old and have remained stable under nine glaciations over the past one million years. The formation extends far enough laterally to provide room for the repository. The limestone of the Cobourg Formation has not been subject to the formation of cavities caused by percolation of water down from the surface (called karst formation). There is no evidence that glacial meltwater and water from precipitation has been able to reach the Cobourg Formation for at least 2.5 million years; this is because of the low permeability of the cap rock above it. The groundwater at the repository level is ancient and has not moved for millions of years, demonstrating the low permeability of the rocks. The area is not prone to frequent and/or large earthquakes. The repository is expected to have very low oxygen levels in the postclosure period, leading to low rates of microbial activity and producing chemical conditions that favour the formation of insoluble forms of some contaminants such as metals. The rock formation at the repository level has lower fluid pressure than the surrounding rock formations, meaning that the tendency would be for movement of water or gas to occur towards the repository rather than away from it.

The Nature of the Waste

Eighty percent of the waste volume will be low-level waste. Over half of the total radioactivity of the L&ILW would decay between the start of the project and the closure of the repository. About three-quarters of the radioactivity would be gone 100 years after closure. Most of the very long-lived radionuclides are within corrosion-resistant Zircaloy; therefore, even though they would still be present, their release from the Zircaloy would be very slow.

Robust Engineering

The proposed DGR would be built in strong rock that is not associated with major failures such as roof collapse. After waste emplacement, individual waste panels would be separated from the shafts by distance and concrete barriers, thus limiting the opportunity for radionuclides to migrate to the surface via the shafts during operation. The proposed repository would be designed for stability, with thick pillars and rooms aligned with the natural rock stress direction. OPG determined that backfilling the repository rooms to increase stability would not improve the safety case; rather, it would be better to leave space for gas generated from waste degradation. The Panel is satisfied that OPG would conservatively design the structural features of the DGR using best mining technology and practice to ensure the integrity and effectiveness of the repository.

Built-in, Long-Term Safety Features

OPG proposed to limit the design of the DGR to two shafts in order to limit the number of potential direct pathways to the surface. The Panel agrees with this assessment. The principal engineered barrier for restricting potential contaminant release to the surface will be the shaft seal structures. It is therefore important that OPG minimize the development of the excavation damaged zones about each shaft surface, and maximize the effectiveness of the shaft seal elements within each shaft.

As described by OPG, when the repository is closed, the shafts would be sealed with a bentonite/sand mixture and an asphalt mixture. These seals would limit any migration of contaminants via groundwater and gas flow in the shafts. A concrete monolith would be built at the base of the shafts to provide long-term support to the shaft seals and the repository tunnels in the vicinity of the shafts. Concrete bulkheads would be placed in the shafts at the levels of two more permeable rock layers (the Guelph and Salina A formations), in order to prevent groundwater flow in these layers from affecting the shaft seals. These bulkheads would also provide structural support for the overlying shaft seals. The Panel is satisfied that the proposed approach is reasonable.

Good Long-term Performance under Normal Conditions

The Panel is confident that the DGR will perform well in the long-term under normal conditions, which would include the degradation of waste containers and seals over time, gas generation, earthquakes and glaciation. The modelling of the repository performance showed that none of these likely events would result in unacceptable doses to humans or non-human biota. This was true even when it was assumed that rockfalls from the roof of the repository occurred shortly after closure, all organics and metals fully degraded into gases, the radionuclide inventory was 10 times higher than in the 2010 inventory, radionuclides were released instantly on contact with water, all radionuclides were soluble in water, and there was very little retardation of radionuclide movement due to being adsorbed to rock surfaces. Even with all of these (and more) conservative assumptions, the maximum calculated dose rate to humans was 100,000 times lower than the limit for exposure to the public, and would occur thousands of years in the future to a family assumed to be living right on the DGR site. The maximum dose rate to a person living farther away and consuming fish and water from Lake Huron was orders of magnitude lower than for the people living at the DGR site – virtually zero.

The Panel is confident that the modelled doses have not been underestimated. This confidence is based upon the multiple conservative assumptions used in the model. OPG used these assumptions to account for uncertainty about what might happen in the future. In other words, no matter how wrong the model might have been about exactly what, when and where certain things might happen, it would be extremely difficult to produce a combination of features, events and processes that would result in doses any higher than what was estimated without deliberately assuming basic natural laws (such as gravity) are no longer applicable. Furthermore, OPG's models were calibrated to minimize differences between calculated and measured variables and verified to confirm the proper functioning of the computer codes. OPG's confidence in its models was enhanced through participation in international co-operative projects in which the same problems were solved using different computer codes and the results compared to establish that equivalent results were obtained.

Acceptable Risks Under "What If" Scenarios

The Panel assessed the "what if" scenarios evaluated by OPG and concludes that even if these unlikely events were to occur, risks to humans and the environment would be acceptable. The inadvertent human intrusion and severe shaft failure scenarios resulted in the highest projected doses. The projected doses from these scenarios exceeded the dose limit for protection of the public; however, because they were so unlikely, the risk was deemed to fall within the definition of acceptable risk (1 in 100,000 risk of additional cancer).

The presence of economic quantities of gas or oil resources would be a potential feature contributing to human intrusion into the DGR. Therefore, the Panel recommends that the level of confidence in the absence of economic oil and gas deposits in the vicinity of the DGR be increased through further investigation.

The Panel also recommends that OPG continue to research the performance of shaft seal materials such as bentonite and asphalt. Confidence in the very low likelihood of severe shaft seal failure will be increased by following the Panel's recommendation.

Natural Analogues

The Panel heard a lot of concern regarding the requirement for very long-term performance of the DGR. The DGR will largely rely on passive barriers to contaminant movement provided by the natural geology. Natural analogues provide examples of such passive barriers. OPG cited examples such as Appalachian basin shale cap rocks which have contained hydrocarbon gases for millions of years at high pressures. Another example of a natural analogue is in Saskatchewan, where the world's richest deposits of uranium have existed for millions of years without contaminant movement and with no radioactive signature by uranium or its daughter products evident at the earth's surface.

The Bruce Nuclear Site is Appropriate

The Panel concludes that locating the DGR on the Bruce nuclear site is appropriate relative to other alternative sites because of the highly suitable geology (as described above) and because additional transportation of the waste to a site distant from the WWMF would not be required. The Panel notes that a comparison of the proposed DGR in the Cobourg Formation to a hypothetical repository in granite showed that the main difference between the two was the additional risk of transporting the waste from the Bruce nuclear site to the granite site. The relative performance of the two rock types (Cobourg limestone and high-quality granite) was not different enough to distinguish either one as having better performance over the long-term; both would perform well within regulatory requirements for safety and environmental protection.

The Panel agrees with OPG that a DGR at the Bruce nuclear site is more sustainable than if it were built on an undeveloped offsite location. The relative environmental effects of constructing a DGR on an undeveloped site would be higher than on the already-disturbed Bruce nuclear site. There would be socio-economic challenges at an undeveloped site, notably, the requirement to obtain, train and retain skilled staff, provide infrastructure such as roads, and obtain services specific to the nuclear industry. In addition, the Bruce nuclear site is highly secure; thus, the risk of malevolent acts is already managed and low.

The Project is Not Likely to Cause Significant Adverse Effects

The Panel concludes that OPG provided adequate information for the Panel to conduct its environmental assessment of the project, and that OPG incorporated the guiding principles outlined in the Environmental Impact Statement (EIS) Guidelines. OPG committed to mitigation measures designed to: reduce the magnitude, spatial extent, frequency, and/or duration of effects; or to create or enhance the reversibility of effects. None of the residual adverse effects remaining after application of mitigation measures were judged by OPG to be significant.

The Panel concludes that the project is not likely to cause significant adverse environmental effects. The prevention of significant residual adverse effects depends upon the complete and timely implementation of mitigation measures committed to by OPG plus additional mitigation measures recommended by the Panel. Comprehensive follow-up monitoring to verify the predictions in the environmental assessment will also be required. The Panel has made a number of recommendations regarding follow-up monitoring. The Panel places particular emphasis on the importance of additional mitigation measures to prevent residual adverse effects on water quality and fish, especially lake whitefish, caused by the discharge of conventional contaminants from the stormwater management system to MacPherson Bay of Lake Huron.

The Panel evaluated OPG's assessment of both non-radiological and radiological malfunctions and accidents and is satisfied that these events would not be likely to cause significant residual adverse effects. OPG's malfunction and accident scenarios incorporated a range of events, including fire; explosion/detonation; electrical accidents; spills of fuel, chemicals, lubricants or oils; and vehicle accidents. The Panel's conclusion relies upon OPG's application of its fire protection measures and emergency and spill response procedures.

The Panel is of the view that, with the implementation of OPG's proposed operating procedures, conventional worker safety would be maintained at levels similar to or better than those of comparable commercial mining operations in the Province of Ontario. To achieve these goals, OPG's safety management systems must prioritize measures to mitigate malfunction and accident events that possess the highest likelihood of occurrence. The Panel has made a recommendation regarding underground vehicular traffic accidents and rockfall accidents.

The Panel is satisfied that credible malevolent acts are not likely to result in significant adverse effects, both on and off the DGR site. The Panel concurs that the effects of OPG's credible malevolent act scenarios would be bounded by those of non-radiological malfunction and accident scenarios. The Panel is satisfied that malevolent acts are not likely to occur, given the security and mitigation measures described by OPG.

Learning from experience will be a fundamental component of OPG's preparedness for malfunctions and accidents. In addition to its own operational experience, OPG can call upon the experience of the nuclear and mining industries world-wide. Of note, OPG's review of incidents at the Waste Isolation Pilot Plant (WIPP) in the United States revealed the importance of a strong safety culture including: the maintenance of high quality management systems; effective oversight by managers and regulators; continued development of the safety case for the lifetime of the project; and maintenance of effective worker training and safety cultures during all project phases.

The Panel is of the view that it will be important for OPG and the CNSC to be prepared for any malfunction or accident, not only in order to protect the health and safety of workers, the public and the environment, but also because no matter how small the consequences may be from a science point-of-view, such an event could negatively affect the public perception of the project.

As part of its cumulative effects assessment, OPG provided information regarding the potential future inclusion of reactor decommissioning waste in the DGR. These activities would require separate review processes by the CNSC, and were not included as part of the proposed project. The Panel is satisfied that the cumulative effects of the potential inclusion of decommissioning waste in the DGR have been adequately addressed and concludes that no significant adverse effects to the environment are likely to occur, provided that mitigation measures are effective. The Panel notes that adaptive management may be required for OPG to adjust to new information that becomes available over the next two to four decades.

The Panel concludes that it is not likely that there would be significant residual adverse cumulative effects from the project. The Panel notes the importance of a consistent, long-term commitment to mitigation for surface water quality, and also notes the importance of mitigation for air quality and noise. The Panel emphasizes the importance of follow-up monitoring to confirm the absence of significant residual adverse cumulative effects. Specific details of the monitoring program will be further defined should the project be approved and proceed to licensing.

The Panel notes that cumulative effects at an ecosystem scale were not addressed by OPG in its EIS, nor was this explicitly required under the EIS Guidelines. However, the concerns expressed by participants about the ecological integrity of Lake Huron and the potential for cumulative effects on the lake, and the Great Lakes in general, illustrates the need for a societal discussion regarding how such concerns can be addressed – if not by individual proponents, then by provincial and federal regulatory agencies.

Worker and Public Health and Safety Will be Protected

The Panel concludes that the project is not likely to cause significant adverse effects on the health and safety of the public and workers taking into consideration the commitments made by OPG, the proposed mitigation measures, and the additional recommendations from the Panel. The Panel is of the view that OPG adequately described the likely residual effects of the project, as well as their significance, for workers, local residents, seasonal users and members of Aboriginal communities. The Panel emphasizes that it is important that OPG, and the CNSC, continue to engage with persons who have an interest in the project and its effects on human health.

Worker Health and Safety

The Panel is satisfied that OPG's review of activities and the scope of conventional and radiological hazards was reasonable, extensive and credible. The Panel is of the view that these hazards will be managed by OPG, with regulatory oversight by the CNSC and provincial agencies, in order that worker and public health and safety are protected. The principal activities that would be undertaken by workers during each stage of DGR development and operation were clearly defined, and appropriately described. The Panel is also satisfied that OPG committed to appropriate mitigation and control measures for each conventional safety hazard. Plans for mitigation and monitoring to ensure radiation protection were described in sufficient detail that the Panel is confident that regulatory dose limits for nuclear energy workers will be met.

The Panel notes that while OPG has developed an excellent conventional and radiological health and safety record for its workers at its nuclear facilities in Ontario, diligence will be required to ensure worker protection during activities for which OPG has less experience, particularly those associated with mining.

The Panel stresses the importance of OPG maintaining a strong safety culture over the long life of the project. OPG management systems must continue to incorporate systems and measures that encourage continuous improvement in all aspects of occupational safety to mitigate hazards and ensure worker safety. These systems must be upheld throughout site preparation, construction, operations and decommissioning.

Public Health and Safety

The Panel is satisfied that the project is not likely to cause adverse effects on public safety, considering OPG's Emergency Management System and its commitment to coordination with local emergency response service providers. The effectiveness of safety programs at the DGR is essential for maintaining public safety.

The Panel concludes that the project is not likely to cause significant adverse effects to the overall health of members of the public. Overall health encompasses the effects of changes in physical, socio-economic, cultural and emotional determinants of health caused by the project. The Panel concludes that it is not likely that changes in air quality, noise or radioactivity levels caused by the project would result in significant adverse effects on the health of the general public, including people living near the project site, provided mitigation measures are implemented and are effective. This conclusion is based upon the Panel's confidence that effects have not been underestimated, due to the highly conservative nature of the modelling. The Panel suggests that there be public input into follow-up monitoring of air quality, noise and radiation in order to increase trust in the monitoring information among concerned community members.

The Panel heard from both permanent and seasonal residents with concerns regarding emotional determinants of health; these concerns require acknowledgement and specific action (to be determined through dialogue). Anxiety is a key emotional determinant of health, regardless of whether physical determinants have been affected or not. The Panel suggests that participation of personnel from the Grey-Bruce Health Unit could be beneficial, particularly with respect to addressing concerns related to emotional determinants of health.

Aboriginal Health and Safety

The Panel concludes that changes in the environment as a result of the project are not likely to cause significant adverse environmental effects on Aboriginal health and safety.

The Panel notes that some concerns were raised that the project could result in the perception that the quality of traditional resources may change. This view would be associated with emotional determinants of health. The Panel expects that explicit discussion of effects on traditional uses, and thus potential effects on emotional determinants of health, will be part of the dialogue associated with agreements between OPG and the Saugeen Ojibway Nation, the Historic Saugeen Métis and the Métis Nation of Ontario.

RIGOROUS AND RELIABLE ADAPTIVE MANAGEMENT SYSTEMS WILL BE REQUIRED

The Panel is of the view that OPG’s management systems for worker and public health and safety and protection of the environment are central to the prevention of significant adverse effects. The project management systems must be particularly rigorous and reliable because of the longevity of the project and the lack of prior experience with this specific type of project. Over the preclosure phases of the project, the extent of knowledge and understanding of key environmental indicators and the appropriate action levels will increase and evolve. It is likely that advances in scientific knowledge and technology will enable additional, alternative, or enhanced mitigation measures. There will be many opportunities to learn from the results of follow-up monitoring.

The Panel emphasizes that it is important that OPG maintain the capacity for the development and implementation of an adaptive management system that: identifies appropriate key indicators of performance; predetermines action levels used to identify the requirement for corrective management measures; identifies testable predictions about the performance of the DGR mitigation measures; and develops a range of available options in response to action levels.

The Panel emphasizes that a rigorous application of the Geoscientific Verification Plan coupled with an adaptive management system is required to further confirm and enhance the safety case and further verify the postclosure assessment. The Geoscientific Verification Plan can provide confidence in the models used to predict long-term repository performance by systematic and diligent data acquisition during the construction and operational phases of the project. Data obtained from the Geoscientific Verification Plan must be used within OPG’s adaptive management system in a timely and efficient manner. As noted above, this will require that a clear and defensible set of action levels be established to identify when the difference between actual and expected conditions differs sufficiently that action must be taken. This action could range from additional, more detailed monitoring to cessation of the development of the DGR until the safety case can be re-confirmed through design change or the DGR is permanently halted.

THE DGR PROJECT WILL NOT AFFECT LAKE HURON

The protection of Lake Huron and the Great Lakes was a dominant theme in written and oral submissions to the Panel. The location of the proposed DGR 1.2 km from the shoreline of Lake Huron was a catalyst for concerns and comments from Canadian and American citizens about drinking water quality, recreational use, aquatic ecology, and the economic, cultural and spiritual value of the lake.

The Panel concludes that the project is not likely to cause significant adverse effects on the water quality or aquatic ecosystems of Lake Huron or the other Great Lakes, provided that mitigation measures, including the Panel's recommendations, are implemented. This conclusion also applies to MacPherson Bay of Lake Huron.

The Panel is confident that there will be no significant adverse effects on Lake Huron or the other Great Lakes because:

- radiation releases from the project during preclosure and postclosure phases would be extremely low relative to current radiation levels in Lake Huron and negligible relative to dose limits for the protection of the public;
- malfunctions, accidents, and malevolent acts during the preclosure phase would not have the potential to release sufficient radiation to exceed dose limits for the protection of the public via use of Lake Huron;
- natural processes, barriers and physical laws present and active during the normal evolution of the postclosure phase could not produce the conditions that would result in exceedances of regulatory limits for the protection of the public;
- disruptive, "what if" scenarios would not result in exceedances of dose limits related to human uses of water from Lake Huron;
- the project will not contribute significantly to any of the current primary risks to Lake Huron and the other Great Lakes, such as invasive species;
- the project will not contribute to cumulative effects to Lake Huron, provided all discharges comply with applicable statutes and regulations, notably the *Fisheries Act*; and
- there would be no significant adverse effect on the use by Aboriginal peoples of drinking water, fish or other species in Lake Huron due to radionuclides or chemicals of concern.

Environment Canada informed the Panel that Canada had met its obligations under the *Great Lakes Water Quality Agreement* with respect to the project. Canada, through the Great Lakes Executive Committee Co-chair, notified the U.S. and the Great Lakes Executive Committee of the DGR public hearing and the process for participating in the hearing on June 21, 2013.

The Panel notes that some people, particularly Aboriginal people, may have concerns about effects on Lake Huron that are based upon their worldview and accompanying spiritual requirements regarding showing respect for the earth. This would include asking permission of the earth to construct the DGR. The Panel expects that such concerns will be part of the ongoing dialogue between OPG and Aboriginal peoples under the terms of various agreements.

The Panel fully agrees that Lake Huron and the other Great Lakes are precious resources that demand society's highest level of protection and regard. To that end, the Panel applauds the efforts of Canadian and American federal, state, provincial, and municipal agencies as well as First Nation, tribal, Métis, and private groups, as they address the primary risks to the lakes. The Panel notes that the future sustainability of the Great Lakes depends upon society's collective ability to reduce the significant stressors on the lake, notably invasive species, habitat disruption or destruction, non-point source pollution, and climate change. The Panel is of the view that the relative position of the proposed project within the spectrum of risks to the Great Lakes is a minor one, albeit one that demands strict attention and regulation.

ENGAGEMENT WITH ABORIGINAL GROUPS AND THE PUBLIC IS VERY IMPORTANT

The Panel emphasizes that OPG must continue to engage with members of the public and Aboriginal groups. The Panel expects that future licensing requirements related to public engagement will include the respectful attention to all concerns from Aboriginal and non-Aboriginal people.

The Panel is of the view that engagement is an interactive and iterative process of discussion among citizens that contributes meaningfully to specific decisions in a transparent and accountable way. It includes the free exchange of ideas, with acceptance of different values.

The Panel encourages OPG and the CNSC to continue to develop their public consultation programs in such a way that the programs move beyond the provision of information to dialogue and, ultimately, to engagement. The Panel believes that the resolution of public concerns and anxiety regarding the project will rely not only on science, but on true engagement with citizens.

OVERALL CONCLUSION

The Panel concludes that the project is not likely to cause significant adverse environmental effects, taking into account the implementation of the mitigation measures committed to by OPG together with the mitigation measures recommended by the Panel.

CHAPTER 1 INTRODUCTION

The Deep Geologic Repository Project for Low and Intermediate Level Radioactive Waste (DGR) is a proposal by Ontario Power Generation (OPG) for the site preparation, construction, operation, decommissioning and abandonment of a deep geologic radioactive waste disposal facility on the Bruce nuclear site, within the municipality of Kincardine, Ontario. The DGR would be designed to safely manage low and intermediate level radioactive waste (L&ILW) produced from the continued operation of OPG-owned nuclear generating stations at the Bruce, Pickering and Darlington nuclear sites in Ontario.

The Minister of the Environment and the President of the Canadian Nuclear Safety Commission (CNSC) established the Joint Review Panel (The Panel) to undertake the review of the project under the *Canadian Environmental Assessment Act* (S.C. 1992, c. 37 - since repealed and replaced by the *Canadian Environmental Assessment Act, 2012* -S.C. 2012, c. 19, s. 52) and the *Nuclear Safety and Control Act* (S.C. 1997, c. 9) on January 24, 2012. The Panel Members are Dr. Stella Swanson (Chair), Dr. James F. Archibald and Dr. Gunter Muecke.

The Panel was directed to conduct a review, in accordance with its established mandate, as amended August 27, 2013, to meet the requirements of the *Canadian Environmental Assessment Act, 2012* and that allows it to consider the OPG application for a Licence to Prepare Site and Construct under the *Nuclear Safety and Control Act*. Further, the review was to allow information to be obtained about the adverse effects that the project may have on potential or established Aboriginal rights, title or Treaty rights.

This report presents the Panel's rationale, conclusions and recommendations regarding the examination of environmental effects under the *Canadian Environmental Assessment Act, 2012* including mitigation measures and follow-up. This chapter contains background to the project, an overview of the project, and a description of the purpose and organization of the report.

1.1 HISTORY OF THE DECISION TO CONTINUE WITH A PROPOSED DGR

For close to 40 years, the operation of OPG-owned nuclear generating stations at the Bruce, Pickering and Darlington nuclear sites in Ontario has resulted in the production of thousands of cubic metres of radioactive waste. To date, this waste, which is classified in three categories - low-level, intermediate-level, and high-level - has been managed in a number of on-site storage facilities operated by OPG. Since 1974, the L&ILW from all three sites has been consolidated and stored at the Western Waste Management Facility (WWMF), located at the Bruce nuclear site within the Municipality of Kincardine, Ontario, on the shore of Lake Huron.

In April 2001, the federal government introduced an Act respecting the long-term management of nuclear fuel waste. The *Nuclear Fuel Waste Act* (S.C. 2002, c. 23), came into force on November 15, 2002, and dealt only with the long-term management of used nuclear fuel (high-level waste), not L&ILW.

OPG stated that the introduction of the *Nuclear Fuel Waste Act*, prompted the Municipality of Kincardine to initiate discussions with OPG regarding the long-term management of the low-and intermediate-level waste stored at the WWMF, considered by OPG to be an interim waste management solution. In accordance with the Government of Canada's *Radioactive Waste Policy Framework* (1996), OPG was responsible for implementing a long-term solution for managing its L&ILW.

OPG explained that, in 2002, the Municipality of Kincardine and OPG signed a Memorandum of Understanding setting out terms for an Independent Assessment Study of three long-term waste management options: enhanced processing and surface storage; surface concrete vaults; and deep rock vaults. The assessment, conducted by Golder Associates and published in 2004, included technical feasibility and socio-economic impacts, as well as a review of international practices. The assessment found that all three long-term management options were technically feasible and could safely be constructed and operated at the WWMF, and that no clear preference for any of the options had been identified in public attitude and tourism research. OPG reported that it also held preliminary discussions regarding waste management options with the Chippewas of Saugeen First Nation and the Chippewas of Nawash Unceded First Nation, collectively referred to as the Saugeen Ojibway Nation, beginning in August 2003.

Ultimately, the Municipality of Kincardine identified a deep geologic repository as its preferred option for the long-term management of L&ILW. Visits to several international waste repository sites by members of Kincardine council were reportedly instrumental in the Municipality identifying its preference for this option. The Municipality of Kincardine also passed a resolution stipulating that no used fuel would be placed in the repository.

OPG explained that its decision to proceed with the DGR at the Bruce nuclear site was based upon several factors. According to OPG, the preference of the Municipality of Kincardine was one of those factors. Other factors included the international consensus that appropriate deep geologic sites offer the best disposal option for long-lived radioactive waste, and the proximity of the waste at the WWMF to the proposed DGR site. Additionally, OPG expressed that the present generation, which produced the waste and has benefited from the electricity generated by OPG's nuclear generating stations, is responsible for its ultimate disposal, rather than leaving it as a legacy to be dealt with by future generations.

1.2 BRIEF DESCRIPTION OF THE PROPOSED DGR

The DGR would be constructed at the Bruce nuclear site, approximately 1.2 kilometres from the shore of Lake Huron, near the WWMF (Figure 1). The DGR would be constructed in limestone, beneath 680 metres of sedimentary bedrock. The underground facilities would include access-ways (shafts and tunnels), emplacement rooms, and various underground service areas and installations. The surface facilities would include underground access and ventilation buildings, a waste package receiving building, and related infrastructure (Figure 2). The total surface footprint of the DGR would be approximately 30 hectares and the underground facilities would encompass approximately 40 hectares.

OPG intends for the DGR to safely manage L&ILW in the very long term, covering an extended period of time so that the radioactivity in the waste will not pose a concern to the health and

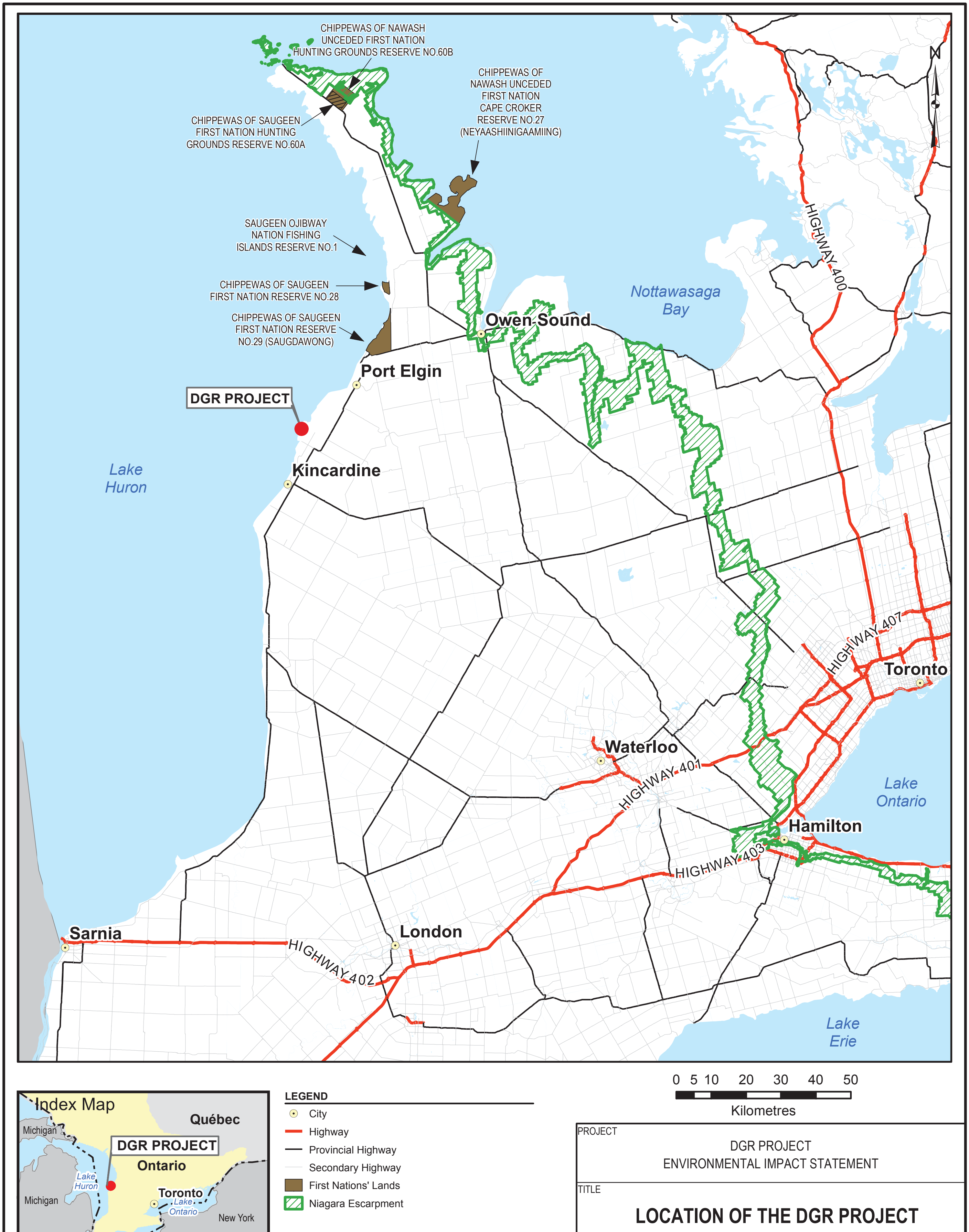


Figure 1: The Project Location (reproduced from DGR EIS Figure1.1.1-1)

safety of persons and the environment. Low-level waste has low levels of radioactivity and can be handled without special radiation protection measures. It includes materials such as protective clothing, floor sweepings, mops, and rags. Intermediate-level waste consists of non-fuel waste containing significant quantities of long-lived radionuclides. It cannot be handled without radiation protection measures. It includes materials such as used reactor core components, refurbishment wastes, and resins and filters from nuclear reactor operations.

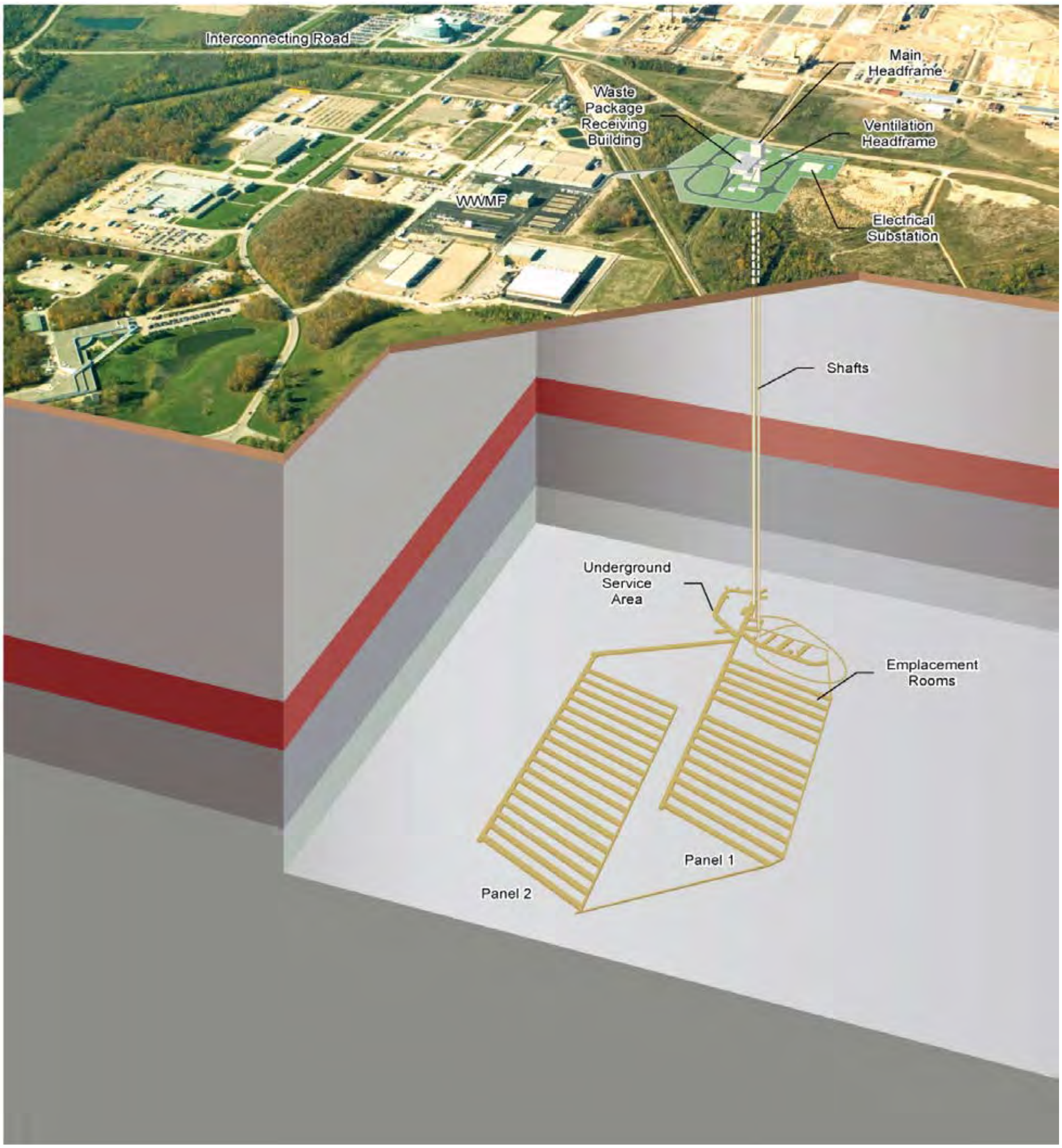


Figure 2: Schematic of the Proposed Project (reproduced from DGR EIS Figure 1.1.1-3)

The DGR, if approved, will not accept used nuclear fuel. OPG repeatedly and categorically committed to the use of the DGR for L&ILW only.

The proposed DGR is an important, unique, precedent-setting project. It would be the first of its kind in North America, and it is the first of its kind in the world to propose using limestone as the host rock formation. It is likely that the knowledge and experience gained through the project will assist the Canadian government in its separate Adaptive Phased Management process for the long-term management of used fuel.

1.3 THEMATIC APPROACH TO THE REVIEW

The Panel structured its approach to the review around nine major areas in order to capture all of the topics and aspects that it needed to consider for the review in the most logical way. These areas arose out of a detailed analysis of written and oral submissions. The use of these areas

A Brief Explanation of Radiation

Radiation refers to energy that emanates, or radiates, from a source. Radioactive materials, called radioisotopes or radionuclides, occur naturally in soil, water, air, food, and building materials. They are also generated through the production of nuclear power and nuclear weapons.

Familiar types of radiation include radio waves, microwaves and visible light waves. These types of radiation belong to the category known as nonionizing radiation because they have too little energy to strip electrons from other atoms.

Ionizing radiation, on the other hand, is capable of stripping electrons and breaking chemical bonds, creating atoms or molecules that have an electric charge. Ionizing radiation can damage cells and DNA. The most common types of ionizing radiation are alpha particles, beta particles, gamma rays, and x-rays.

Radioactivity is a measure of how quickly a radioisotope decays to a stable state by emitting ionizing radiation. Radioisotopes with long half-lives (the amount of time required to decay to half its original value) emit less radiation per unit of time than those with short half-lives. Therefore, although long-lived radioactive waste requires long-term management, those radioisotopes are much less radioactive. As an example, cobalt-60, with a half-life of 5.3 years is much more radioactive than plutonium-239, with a half-life of 24,110 years.

Radioactivity is expressed in Becquerels (Bq). One Becquerel is the quantity of a radioactive material that will have 1 transformation in one second. Often radioactivity is expressed in larger units like thousands (kBq), millions (MBq) or billions (GBq) of Becquerels.

Another important basic measure of radiation is the Sievert (Sv), which is a measure of equivalent dose. Equivalent dose relates the absorbed dose of radiation in human tissue to the effective biological damage. Equivalent dose is often expressed in terms of thousandths of a Sievert, or millisievert (mSv); or millionths of a Sievert, or microsievert (µSv). Annual doses of radiation are expressed in units of millisieverts per year (mSv/yr) or microsieverts per year (µSv/yr).

Both short and long-lived radioactive waste can be hazardous, but for different reasons. Radioisotopes with short half-lives are hazardous because they can produce a high radiation exposure in a short time. Long-lived radioisotopes produce much lower exposure per unit of time, but as they decay, they can generate additional radioisotopes with shorter half-lives. Furthermore, many long-lived radioisotopes have high chemical toxicity. Uranium-238, for example, has such a long half-life (4.46 billion years) that its radiation hazard is close to zero. The hazard from uranium-238 is due to its properties as a toxic heavy metal.

did not mean that the Panel ignored other topics. The Panel determined that it was necessary to use these areas as lenses through which the Panel could view the wide array of topics that must be considered in its review and recommendations. These major areas are:

- justification for the proposed project
  - purpose and need
  - alternatives
- reliability of the pre-closure and post-closure safety cases
  - pre-closure normal operations
  - pre-closure accidents, malfunctions and malevolent acts
  - post-closure normal evolution
  - post-closure disruptive scenarios
- environmental assessment methodology
  - determination of significance of adverse effects
  - cumulative effects
- management of the DGR site
  - radioactive waste management
  - environmental management
  - occupational health and safety
- protection of Lake Huron and the Great Lakes in general
- social and economic aspects
  - public consultation and engagement
  - effects on socio-economic factors resulting from project-related changes in the environment
- direct effects of the project on socio-economic factors Aboriginal interests, rights and title
  - consultation and engagement
  - traditional knowledge
- human health and safety
  - radiation
  - air quality, water quality, noise
  - emergency preparedness
- mitigation and follow-up
  - OPG commitments to mitigation and monitoring
  - timelines and period of institutional control
  - design of monitoring programs in support of decision-making
  - baselines and thresholds
  - triggers for action

Although not presented in this sequence, these topics are addressed throughout the report.

1.4 JOINT REVIEW PANEL REPORT

This report presents the Panel's rationale, conclusions and recommendations regarding the examination of environmental effects under the *Canadian Environmental Assessment Act, 2012*, as well as mitigation and follow-up. It includes information relating to the Panel process, OPG's environmental assessment methodology and the project description, as well as a summary of the information received by the Panel, including comments from participants, and the Panel's conclusions relating to:

- purpose, need and alternatives;
- design features and project development;
- waste management;
- effects on the natural environment;
- effects on human health and safety;
- malfunctions, accidents, and malevolent acts;
- social and economic aspects;
- Aboriginal interests, rights and title;
- postclosure safety case;
- Lake Huron and the Great Lakes; and
- cumulative effects

The Panel's review of the primary components of the safety case for the project under the *Nuclear Safety and Control Act* is presented in several chapters as follows:

- geology of the DGR site – Chapter 13;
- engineering design and built-in long-term safety features – Chapter 6;
- nature of the wastes – Chapter 7; and
- postclosure performance assessment – Chapter 13

The report also includes the Panel's views on matters raised throughout the review. The report concludes with a summary of recommendations, including requirements for mitigation and follow-up.

CHAPTER 2 THE REVIEW PROCESS

This chapter summarizes the period prior to the establishment of the Panel, outlines the establishment of the Panel, including the terms of reference for its review, and describes the period following the establishment of the Panel. The activities undertaken by the Panel in gathering information for its review, as well as the opportunities provided for participation by members of the public, Aboriginal groups and government departments are also summarized.

2.1 PROCESS LEADING TO THE ESTABLISHMENT OF THE JOINT REVIEW PANEL

The process leading up to the establishment of the Panel spanned the period from January 2006 to January 2012. This process was initiated following the OPG submission of a proposal to prepare a site and construct a DGR, in December, 2005. The process is summarized in Table 1.

The CNSC determined that it was the only responsible authority under the *Canadian Environmental Assessment Act* in relation to the project. Environment Canada, Health Canada, Natural Resources Canada and Fisheries and Oceans Canada were federal authorities with expert information or knowledge to offer in relation to the project. Additional federal departments participated in the review process by providing information and advice at the request of the Panel.

The Ontario Ministry of the Environment and Climate Change indicated on March 8, 2006 that the Government of Ontario had no environmental assessment responsibilities in relation to the project. Relevant provincial ministries did participate in the review process, however, by providing information and advice at the request of the Panel.

The project was initially considered of the type prescribed in the *Comprehensive Study List Regulations* (SOR/94-638). Following a public hearing on the scope of the environmental assessment in October 2006, the CNSC recommended that the Minister of the Environment refer the environmental assessment to a review panel. On June 29, 2007, the Minister of the Environment announced that the project would be referred to a Panel.

Following a 75-day public comment period, the Government of Canada issued Guidelines for the Preparation of the Environmental Impact Statement for the Deep Geologic Repository for Low- and Intermediate-Level Radioactive Wastes (EIS Guidelines) and the Agreement to Establish a Joint Review Panel for the Deep Geologic Repository Project by Ontario Power Generation Inc. within the Municipality of Kincardine, Ontario (Panel Agreement) on January 26, 2009. The EIS Guidelines outlined the minimum information requirements for the EIS to be prepared by OPG to allow the detailed analysis of the potential environmental effects of the project. The EIS Guidelines also listed the requirements for the Licence to Prepare Site and Construct. The Panel Agreement outlined how the Panel would function and included the Panel Terms of Reference for the environmental assessment and the consideration of the licence application.

Table 1: Chronology of the Pre-Panel Process

Date	Milestone
December 2, 2005	OPG submitted its proposal to prepare a site and construct a DGR for L&ILW on the existing Bruce nuclear site within the Municipality of Kincardine to the CNSC
January 30, 2006	environmental assessment for the project initiated
February 16, 2006	notice of commencement of a federal environmental assessment issued
October 23, 2006	public hearing held by the CNSC to consider the Environmental Assessment Track Report regarding OPG's proposal
December 21, 2006	the CNSC recommended to the federal Minister of the Environment that the project be referred to a federal environmental assessment review panel
June 29, 2007	the Minister of the Environment announced that the project would be referred to a joint review panel
April 4 - June 18, 2008	draft EIS Guidelines and Panel Agreement made available for a 75-day public comment period
January 26, 2009	final EIS Guidelines and Panel Agreement released
April 14, 2011	OPG submitted its EIS, Preliminary Safety Report, and other documents in support of the environmental assessment and application for a site preparation and construction licence for the DGR
January 24, 2012	the Minister of the Environment and President of the CNSC established the Panel to undertake the review of the project under the *Canadian Environmental Assessment Act* and the *Nuclear Safety and Control Act*
July 6, 2012	*Canadian Environmental Assessment Act, 2012* came into force

2.2 ESTABLISHMENT OF THE JOINT REVIEW PANEL

The Minister of the Environment and the President of the CNSC established the Panel to undertake the review of the project under the *Canadian Environmental Assessment Act* and the *Nuclear Safety and Control Act* on January 24, 2012. The Panel is both a Review Panel pursuant to the *Canadian Environmental Assessment Act* for the purposes of carrying out an environmental assessment of the project; and a Panel of the Commission, created pursuant to section 22 of the *Nuclear Safety and Control Act*, for the purposes of the review of the licence application under section 24 of the *Nuclear Safety Control Act*. The framework for the environmental assessment and the consideration of the Licence to Prepare Site and Construct, collectively referred to as the review, was outlined in the legislation, the Panel Agreement and the EIS Guidelines.

On July 6, 2012, the *Canadian Environmental Assessment Act, 2012* came into force, which necessitated adjustments to the Panel Agreement. The federal Minister of the Environment and the President of the CNSC amended the Panel Agreement on August 27, 2012, confirming that the project review was to continue under the provisions of the *Canadian Environmental Assessment Act, 2012*. The Amendment to the Panel Agreement stipulated that the Panel shall conduct the review in accordance with the Terms of Reference and in a manner that:

- discharges the requirements set out in the *Canadian Environmental Assessment Act, 2012*;
- permits it to obtain the information and evidence required for it to consider the licence application under the *Nuclear Safety and Control Act*; and
- permits it to obtain information and evidence about the adverse effects the project may have on potential or established Aboriginal rights, title or Treaty rights as identified to the Panel by the Saugeen Ojibway Nation and other Aboriginal groups, and enables it to bring any such information and evidence to the attention of the Minister of the Environment and the Responsible Authority for the project in support of consultation between the Crown and the Saugeen Ojibway Nation and other Aboriginal groups.

2.3 CHRONOLOGY OF THE REVIEW PROCESS FOLLOWING THE APPOINTMENT OF THE PANEL

As per its Terms of Reference, the Panel's goal was to obtain all of the information it required to prepare its report to the Minister of the Environment. The information was considered through a single process. As such, the Panel encouraged and facilitated the participation of government agencies, members of the public and Aboriginal groups in this process. A summary of the Panel review process is outlined in Table 2. The review and comment period on the EIS, Preliminary Safety Report, licence application and supporting documents, which OPG had submitted as a combined submission on April 14, 2011, began on February 3, 2012.

2.3.1 Review and Comment Period on the EIS

The review and comment period was an opportunity for all persons and organizations to provide their views to the Panel on whether the EIS and licence application documents adequately addressed the requirements set out in the EIS Guidelines issued to OPG by the federal government. The public and Aboriginal groups were also invited to make recommendations to the Panel on additional information that should be provided by OPG.

The Panel announced on April 25, 2013 that the review and comment period would end on May 24, 2013, at which point the Panel would have 30 days to determine whether it had sufficient information to proceed to the public hearing phase of the review. The review and comment period comprised a total of 487 days. As provided for in the timelines for the environmental assessment, the end date of the comment period was extended as a result of the time required by OPG to address the information requests by the Panel. A list of organizations and individuals that participated in the review is presented in Appendix 1.

Table 2: Timeline for the Review Process

Phase	Date	Milestone
Review & Comment Period	January 24, 2012	Panel established by the Minister of the Environment and the President of the CNSC
	February 3, 2012	commencement of comment period on the EIS, Preliminary Safety Report, other documents in support of the environmental assessment and application for a site preparation and construction licence
	February 21, 2012	Panel Orientation Session held to receive presentations from OPG on the organization of the EIS and licence application documents, as well as presentations by the CNSC and federal authorities, Environment Canada, Fisheries and Oceans Canada, Health Canada and Natural Resources Canada.
	June 5-7, 2012	Panel visit to proposed project site
	July 18, 2012	Technical Information Session #1: Proposed design, construction and operational details relating to the DGR
	August 27, 2012	Amendment to the Panel Agreement for the *Canadian Environmental Assessment Act, 2012*
	October 11, 2012	Technical Information Session #2: Modelling
	October 22-23, 2012	Panel visit to the Konrad Repository site, Salzgitter, Germany
	October 25, 2012	Panel visit to the Final Repository for Radioactive Waste (SFR), Forsmark, Sweden
	November 14-15, 2012	Panel visit to the Waste Isolation Pilot Plant (WIPP), Carlsbad, New Mexico, USA
	March 20, 2013	Technical Information Session #3: Socio-Economic
	April 25, 2013	end of comment period announced
	May 24, 2013	end of comment period

Public Hearing	June 18, 2013	public hearing announced
	September 16 - October 11, 2013	public hearing held in Kincardine and Saugeen Shores, Ontario
	October 28-30, 2013	public hearing continued in Saugeen Shores, Ontario
	November 2013 - April 2014	requests for additional information and follow-up requests sent to OPG and the CNSC
	June 3, 2014	additional public hearing days announced
	September 9 - 18, 2014	public hearing continued in Kincardine, Ontario
	October 9, 2014	deadline for closing comments from registered hearing participants
	October 19, 2014	deadline for closing comments from OPG
Close of the Record	November 18, 2014	close of the record for the review

2.3.2 Information Requests

Over the course of the review and comment period, the Panel issued 509 requests for additional information from OPG in order to obtain information required to meet the requirements of the EIS Guidelines. These requests were based on input from the federal review team, Ontario ministries, Aboriginal groups, non-government organizations, members of the public, and the Panel's own review. Following the public hearing in 2013, the Panel issued an additional six information requests to OPG, bringing the total number to 515.

The information requests covered a wide range of subject areas, including the following:

- geology;
- hydrogeology;
- safety case;
- postclosure assessment;
- modelling;

- DGR design;
- radioactive waste inventory;
- waste packaging;
- accidents and malfunctions;
- radiation and radioactivity;
- human health;
- surface water;
- aquatic environment;
- effects on Lake Huron;
- site preparation and construction;
- noise;
- air quality;
- waste rock;
- EIS methodology;
- alternative means of carrying out the project;
- follow-up monitoring and mitigation;
- cumulative effects;
- Aboriginal and public consultation;
- Aboriginal rights, interests and title; and
- socio-economic issues.

2.3.3 Comments on the Project

In addition to the information requests, members of the public also submitted comments on the project. These comments were posted on the Canadian Environmental Assessment Registry (the public registry). The Panel received comments from individuals, including US citizens, non-government organizations, municipal government representatives, and politicians. The comments received were varied, and included both expressions of support and opposition to the project. Examples of comments included:

- suggested procedural matters for the review;
- requests for clarification regarding project details;
- expressions of concern regarding the potential effects of the project on the Great Lakes, human health and socio-economic conditions; and
- comments regarding the project in conjunction with the separate ongoing Nuclear Waste Management Organization Adaptive Phase Management process.

2.3.4 Site Visits

During the review and comment period, the Panel conducted several site visits in order to become more familiar with the project site, as well as international practices for long-term waste management. The Panel produced reports for each site visit and made them available on the public registry for the project. The Panel conducted the following site visits in 2012:

- project site, Kincardine, Ontario

- Konrad Repository site, Salzgitter, Germany
- Final Repository for Radioactive Waste (SFR), Forsmark, Sweden
- Waste Isolation Pilot Plant (WIPP), Carlsbad, New Mexico, USA

2.3.5 Orientation and Technical Information Sessions

The Panel also held orientation and technical information sessions during the review. The sessions were open to the public and video webcast over the Internet. Transcripts of the information sessions were posted on the public registry and webcasts were archived on the CNSC website. The Panel held the following sessions in 2012 and 2013:

- Panel Orientation Session
- Technical Information Session #1: Design, Construction and Operational Details
- Technical Information Session #2: Modelling
- Technical Information Session #3: Socio-Economic

2.3.6 Experts Contracted on the Panel's Behalf

Pursuant to Part II, section 10 of the Terms of Reference for the Review, the Panel directed the CNSC and the Canadian Environmental Assessment Agency to issue contracts to two experts on its behalf. The Panel engaged independent experts to provide their evaluation of certain technical and scientific issues in relation to the review, through the provision of written and oral submissions to the Panel.

Dr. Peter Duinker was contracted for a submission relating to the prediction of the significance of adverse environmental effects and the assessment of cumulative environmental effects. Dr. William Leiss was contracted to prepare a research paper that addressed the identification of stigma around nuclear facilities, including international waste repositories, and a description of the impact of these facilities on valued social components. The reports by Dr. Duinker and Dr. Leiss were posted on the public registry for the project, and they both appeared at the public hearing. The Panel encouraged and allowed all parties sufficient opportunity to consider the reports and to provide comments to the Panel on their contents.

2.3.7 The Public Registry

The online public registry for the project included all of the information associated with the review, including submissions from OPG, the federal review team, Aboriginal groups, and the public. The public registry also included news releases and Panel records, as well as all hearing documents. The public registry was available on the Canadian Environmental Assessment Agency website at www.ceaa.gc.ca, reference number 06-05-17520.

2.3.8 Participant Funding

The Canadian Environmental Assessment Agency made funding for participants available through its Participant Funding Program. An independent Funding Review Committee evaluated applications for funding and recommended funding levels to the Canadian Environmental Assessment Agency, which administered the program.

Phase I Funding

In 2007, a total of $50,000 was awarded to the following applicants to support their review of and comment on the draft Panel Agreement and draft EIS Guidelines:

- the Northwatch Coalition for Environmental Protection
- Citizens for Renewable Energy
- Greenpeace Canada
- Saugeen Ojibway Nation
- Citizens for Alternatives to Chemical Contamination
- the Canadian Coalition for Nuclear Responsibility

Phase II Funding

In 2011, a total of $175,000 was awarded to the following applicants to support their review of and comment on the EIS and their preparation for and participation in the public hearing:

- the Sierra Club of Canada
- the Northwatch Coalition for Environmental Protection
- the Power Workers' Union
- the Canadian Environmental Law Association
- the Huron-Grey-Bruce Citizens Committee on Nuclear Waste
- Great Lakes United
- the International Institute of Concern for Public Health

In 2011, Phase II funding was also made available to support Aboriginal participation and related consultation activities in the environmental assessment. A total of $151,025 was awarded to the Historic Saugeen Métis, the Métis Nation of Ontario Secretariat and the United Chiefs and Councils of Mnidoo Mnising.

Additional Funding

After the Panel announced that additional hearing days would be held regarding the subjects of information requests that were issued by the Panel in November 2013 and March 2014, the Agency made additional participant funding available to support registered participants at the additional public hearing days. A total of $27,538.80 was awarded to the following applicants for this purpose:

- Historic Saugeen Métis;
- Frank Greening;
- ZeroWaste4ZeroBurning;
- Ontario Clean Air Alliance;
- Northwatch Coalition for Environmental Protection;
- United Church of Canada (The Maritime Conference of the);
- The Inverhuron Committee;
- Canadian Environmental Law Association;
- Power Workers’ Union;

- Dr. Sandy Greer;
- Save Our Saugeen Shores, INC; and
- Algonquin Eco Watch.

2.3.9 Confidentiality Requests

All information obtained by the Panel during its review was made available to the public. In exceptional circumstances, a person could request that information submitted be kept confidential by providing a written request to the Panel. The Panel had the responsibility to determine if the confidentiality request should be granted and to what extent it will apply. Following requests, the Panel determined the Traditional Knowledge Study submitted by the Métis Nation of Ontario would be kept confidential; and the information submitted by OPG pertaining to the security of nuclear facilities would be dealt with during an in-camera session to be held during the public hearing.

2.3.10 Public Hearing

Following the close of the public comment period on May 24, 2013, the Panel had 30 days to determine whether it had sufficient information to proceed to the public hearing phase of the review. The Panel made this determination and announced the public hearing on June 18, 2013. The Panel issued Public Hearing Procedures (June 18, 2013), which outlined the submission deadlines and options for participation in the hearing. The Panel held hearing sessions in 2013 and 2014, which are outlined below.

2013 Hearing Days

The Panel held public hearing days from September 16 to October 5, 2013 in Kincardine, Ontario, and from October 7 to October 11, 2013 and October 28 to 30, 2013 in Saugeen Shores, Ontario. The Panel made an effort to accommodate participants by holding some hearing sessions on evenings and Saturdays, and receiving presentations by telephone. Each hearing session was video webcast and archived on the CNSC website, and transcripts were prepared and posted to the public registry for the project as soon as they were available, which was most often the following day.

Over the course of the 2013 hearing days, the Panel considered submissions from 227 participants, including:

- 62 oral presentations that were accompanied by written submissions;
- 90 oral-only statements; and
- 75 written-only submissions.

Hearing participants included federal departments, provincial ministries, municipal governments, Aboriginal groups and individuals, American elected officials and government agencies, non-government organizations, and individuals.

The hearing sessions were organized such that specific subjects could be addressed in particular hearing sessions and included the following:

- project justification;
- site characterization;
- geology – long-term performance;
- geology - safety case;
- management of L&ILW;
- accidents, malfunctions & malevolent acts;
- security (in-camera session);
- air quality;
- noise;
- terrestrial environment, including wildlife and species at risk;
- human health;
- aquatic environment – groundwater;
- aquatic environment – surface water, habitat & aquatic biota;
- aquatic environment - Lake Huron;
- environmental assessment issues;
- follow-up & monitoring;
- communication & consultation;
- Aboriginal interests;
- licensing, permits & authorizations; and
- socio-economic issues.

Throughout the hearing, as directed by the Panel, OPG gave presentations addressing the subject matter of each hearing session. Relevant government participants also gave presentations related to the given subject matter. Registered participants made oral presentations or oral statements in accordance with the hearing agenda.

Following the presentations, the Panel asked questions of OPG, CNSC staff and other presenters. Once the Panel had completed its questioning, participants were allowed to ask questions, through the chair, to OPG, CNSC staff, and other presenters, time-permitting. The Panel issued an undertaking in situations where the response to a question was not immediately available. An ongoing Public Hearing List of Undertakings was maintained and made available by the Panel.

In addition, at the discretion of the Panel, members of the public who had not been scheduled to make a presentation at the hearing were given the opportunity to make a brief oral statement.

2014 Hearing Days

At the end of the 2013 hearing days, the Panel announced that it required further information from OPG. The Panel issued a total of six additional information requests to OPG in November 2013 and March 2014, focused on the subjects of:

- methodology used by OPG to determine the significance of adverse environmental effects;
- updates to the Geoscientific Verification Plan;
- expansion plans for the project;
- relative risk analysis of alternative means of carrying out the project;

- implications of revisions to the reference waste inventory; and
- applicability of incidents at the Waste Isolation Pilot Plant to the safety case for the project.

The Panel decided to hold additional hearing days to facilitate the review of the six information requests. The Panel announced the additional hearing days on June 3, 2014. Participants from the 2013 hearing days, as well as new participants, were invited to request the opportunity to make an oral presentation or were invited to make a written submission. Submissions were to be only in relation to one or more of the six post-2013 hearing information requests.

Over the course of the eight hearing days between September 9 and 18, 2014, the Panel considered oral submissions from 69 participants. This was in addition to the presentations by OPG and staff of the CNSC and the written-only hearing submissions. Hearing participants included federal departments, provincial ministries, municipal governments, Aboriginal groups and individuals, American elected officials and government agencies, non-government organizations and individuals.

Similar to the 2013 hearing days, as directed by the Panel, OPG gave presentations addressing the subject matter of each hearing session, as did relevant government participants. Registered participants made oral presentations in accordance with the hearing agenda. Following the presentations, the Panel asked questions of OPG, CNSC staff and other participants. At the end of each day, once the Panel had heard from all presenters and completed its questioning, participants were allowed to ask questions, through the Chair, to OPG, CNSC staff, and other presenters, time-permitting. In addition, at the discretion of the Panel, members of the public who had not been scheduled to make a presentation at the hearing were given the opportunity to make a brief oral statement.

The Panel issued three additional undertakings during the 2014 hearing days, continuing the Public Hearing List of Undertakings from 2013. In total, the Panel issued 74 undertakings.

2.3.11 Closing Remarks

The Panel issued a Procedure for Closing Remarks by Proponent and Registered Hearing Participants on October 18, 2013. On September 19, 2014, the Panel announced that closing written remarks from participants, including Aboriginal groups and government participants, were due October 9, 2014, and closing remarks from OPG were due October 19, 2014.

Closing remarks were optional and were not required from any party. In total, the Panel received 39 submissions of written closing remarks, including those from OPG, CNSC staff and other federal departments, Aboriginal groups, individuals and organizations.

2.3.12 Close of the Record

Upon receipt of the closing remarks, the Panel conferred regarding the information it had received. On November 18, 2014, the Panel announced that it was ready to proceed with the writing of its report to be submitted to the Minister of the Environment. The Panel affirmed that it had obtained the information that it required to complete its mandate and that this information was available on the public registry for the project. As such, no additional comments or information were accepted by the Panel. The Panel stated that it would complete its report within the timeline set out in the amended Panel Agreement (August 2012), and deliver its report to the Minister of the Environment on or before May 6, 2015.

2.4 INVOLVEMENT OF REVIEW PARTICIPANTS

The Panel recognizes the importance of including the views of members of the public and Aboriginal persons in a review process. The Panel attempted to make the process accessible to participants by providing several different ways to participate and be heard, and to ensure that everyone had the opportunity to make their views known. The Panel gave careful consideration to all submissions and perspectives.

Throughout the review, participants, including Aboriginal groups, government representatives and members of the public, provided information, expressed their views, and proposed questions and information requests regarding the project.

The Panel received several Requests for Rulings on procedural and administrative matters related to the ability or appropriateness of the Panel to fulfill its responsibilities, process length, the time allotted for hearing presentations, cross examination of hearing participants, definition of the project, definition of waste types, and the assessment of cumulative effects. The Panel duly considered all the requests and provided its decisions which were posted on the public registry. The Panel considered the hearing to be an essential part of the review process. The Panel conducted the public hearing in a fair and open manner that ensured a thorough examination of the relevant subjects, while providing for timely and meaningful public participation.

The Public Hearing Procedures specifically addressed participation by Aboriginal groups. The Public Hearing Procedures strongly encouraged their participation during the hearing and allowed for the hearing procedures to be amended, as required, to facilitate participation by Aboriginal peoples.

The presentations and comments offered by participants during the course of the review covered the diverse aspects of the project. Their content and bearing on the deliberations of the Panel are included in the appropriate subject sections of this report. Aboriginal participation is described in further detail in Chapter 12 of this report.

CHAPTER 3 OPG ENVIRONMENTAL ASSESSMENT METHODOLOGY

As explained in the EIS Guidelines, an environmental assessment is a planning tool used to ensure that projects are considered in a careful and precautionary manner in order to avoid or mitigate the possible adverse effects of development on the environment and to encourage decision makers to take actions that promote sustainable development and thereby achieve or maintain a healthy environment and a healthy economy. In carrying out its assessment of the project, OPG was required to:

- identify all environmental effects that were likely to arise from the project;
- propose measures to mitigate adverse effects; and
- predict whether there would be likely significant adverse environmental effects after the implementation of mitigation measures, i.e., determine the significance of any residual effects (residual adverse effects are those effects that would remain after the implementation of mitigation).

This chapter is a summary of the information presented by OPG explaining the methodology it used in preparing the EIS and presenting the Panel's evaluation of this methodology. First, the framework for OPG's environmental assessment, which consisted of spatial and temporal boundaries and the selection of valued ecosystem components is summarized and reviewed. Second, the steps used to focus the assessment and assess effects is described and reviewed. Third, OPG's determination of the significance of residual adverse effects is discussed and evaluated. The final section in the chapter examines the means by which OPG applied the seven guiding principles for environmental assessment identified in the EIS guidelines.

3.1 FRAMEWORK FOR THE ENVIRONMENTAL ASSESSMENT

OPG completed its assessment of environmental effects within a framework, based on the EIS Guidelines, which included spatial boundaries, temporal boundaries and valued ecosystem components.

3.1.1 Spatial Boundaries

Spatial boundaries are the geographic study areas for an environmental assessment. They must encompass the areas of the environment that can reasonably be expected to be affected by the project, or which may be relevant to the assessment of cumulative environmental effects.

OPG adopted, with some refinements, the three generic study areas outlined in the EIS Guidelines: the Site Study Area, the Local Study Area and the Regional Study Area. OPG also added a fourth study area, the Project Area, which was the area where project-related effects would be most likely to occur and was the area of focus for the environmental assessment.

The four study areas are shown in Figure 3 and Figure 4.

Figure 3: Environmental Assessment Study Areas (reproduced from DGR EIS Summary p17)

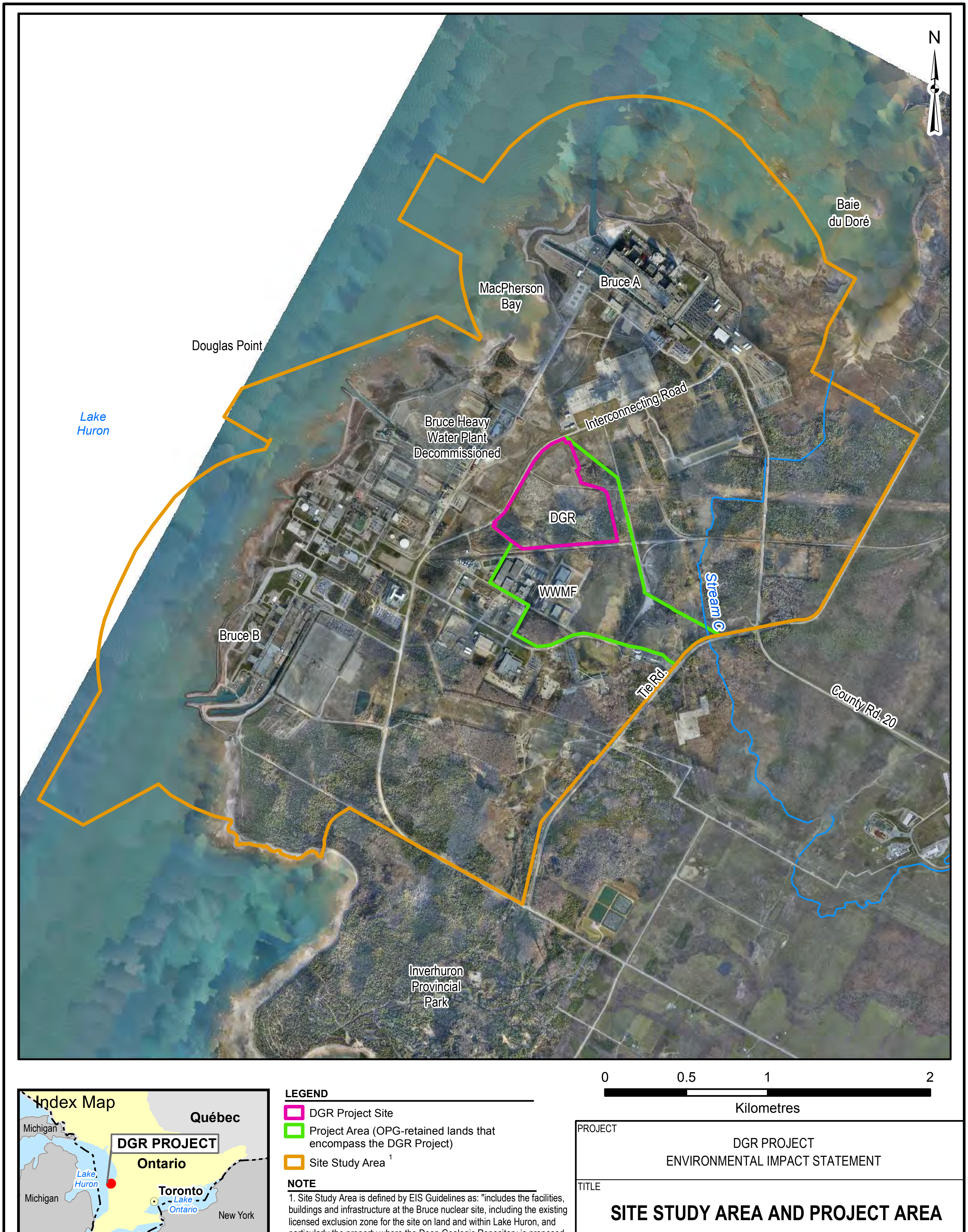


Figure 4: Environmental Assessment Site Study Area and Project Area (reproduced from DGR EIS Figure 5.1.3-1)

The four study areas are:

- the **Project Area**, which corresponds to the boundary of the OPG-retained lands at the centre of the Bruce nuclear site where the project was proposed;
- the **Site Study Area**, which corresponds to the property boundary of the Bruce nuclear site, including the existing licensed exclusion zone on land and in Lake Huron;
- the **Local Study Area**, which corresponds to the 10 km emergency planning zone centred on the Bruce nuclear site, as identified by Emergency Management Ontario; and
- the **Regional Study Area**, which encompasses Bruce County with the exception of the peninsula communities of the Town of South Bruce Peninsula and the Municipality of Northern Bruce Peninsula.

OPG noted that the study area boundaries were generally common for all components of the environment, with some modification for specific environmental components, such as watersheds rather than property boundaries.

3.1.2 Temporal Boundaries

The temporal boundaries for the environmental assessment establish the timeframes for which the direct, indirect and cumulative effects are assessed. OPG identified the following four temporal phases for the project:

- site preparation and construction phase, which includes site preparation and all activities associated with the construction of the project, up until operations commence with the placement of waste;
- operations phase, which covers the period during which waste is emplaced in the project, as well as a period of monitoring prior to the start of decommissioning;
- decommissioning phase, which would begin immediately after the operations phase for the DGR, and would include dismantling surface facilities and sealing the shafts; and
- abandonment and long-term performance phase, which would begin once the decommissioning activities have been completed.

OPG explained that all of the construction activities at the project would occur during the site preparation and construction phase, which OPG expected to last approximately five to seven years. Activities during the operations phase would include receipt and on-site handling of waste packages, transfer underground and emplacement of L&ILW in rooms in the repository, and activities necessary to support and monitor operations. OPG expected the operations phase to last approximately 40 to 45 years with waste being emplaced for the first 35 to 40 years. OPG noted that the length of the monitoring period would be decided at some future time in consultation with the regulator.

Activities during the decommissioning phase would include preparation for decommissioning and decommissioning, and may include monitoring following decommissioning. OPG expected the decommissioning activities to take five to six years. The abandonment and long-term performance phase would include institutional controls for a period up to three hundred years.

OPG stated that these timeframes were intended to be sufficiently flexible to capture the effects of the project. OPG noted that its assessment generally focused on the first three phases as no project activities would be occurring during the abandonment and long-term performance phase. OPG explained that the abandonment and long-term performance phase would continue for over 1,000,000 years, well beyond when the peak radiological effects may occur, taking into account the hazardous lifetime of the L&ILW and the design life of the engineered barriers. This period would include many climatic cycles, such as glaciation.

The Panel considers the spatial and temporal boundaries selected by OPG to be appropriate. OPG's addition of the Project Area to the three study areas specified in the EIS Guidelines was justifiable given the likely spatial scale of many of the measurable effects. The Panel agrees with OPG's adjustments to study area boundaries to account for differences among environmental components. OPG's division of temporal boundaries according to the four pre-closure project phases provided the appropriate timeframes for assessment of specific stressor/valued ecosystem component combinations. For example, exposure of non-human biota to radionuclides would not occur during the site preparation and construction phase, but could occur during the operation and decommissioning phases.

3.1.3 Valued Ecosystem Components

A valued ecosystem component is an environmental element of an ecosystem that is identified as having scientific, social, cultural, economic, historical, archaeological or aesthetic importance. The EIS Guidelines required that OPG identify the criteria it used to identify valued ecosystem components, and included a preliminary list of valued ecosystem components for each environmental component of the assessment.

OPG's approach to valued ecosystem component selection was to have technical specialists identify a preliminary list and then provide the lists to interested parties for confirmation and suggestion of other valued ecosystem components. OPG considered the following questions in its selection of valued ecosystem components:

1. What major or special ecological features of the site or surrounding area should be protected from adverse effects of the project?
2. What aspects of the physical environment could be sensitive to the effects of the project?
3. What individual species or range of species of wildlife and plants could be sensitive to the effects of the project?
4. What aspects of the socio-economic environment should be considered in assessing the effects of the project?

In response to a Draft Scoping Document for the project issued by the CNSC in 2006, OPG produced a draft list of valued ecosystem components. The draft list was largely based on past environmental assessments at the Bruce nuclear site to produce consistency. Modifications were made based on:

- presence of the valued ecosystem component in the Site Study Area
- potential effects
- appropriate surrogate for effects to other similar species
- ecological importance (position in the food web, relative contribution to productivity)
- baseline data availability (sufficient information to allow a reasonable evaluation of effects)

- native species
- socio-economic importance
- historical Aboriginal importance
- species of conservation status
- sensitivity to the stressors produced by the project

The EIS Guidelines instructed OPG to modify the list as appropriate following consultations with Aboriginal people, the public, and federal and provincial government departments, including the CNSC and the Canadian Environmental Assessment Agency. OPG pointed out that the draft list of valued ecosystem components was made widely available to the general public through a number of open houses in the Regional Study Area and beyond, and input obtained at these open houses did not produce any changes to the list. OPG also presented a summary of public comments regarding valued ecosystem component selection.

OPG provided specific opportunities for Aboriginal groups to comment on the selection of valued ecosystem components from 2007 to 2010, including an opportunity for Saugeen Ojibway Nation representatives to observe field studies completed in 2009. OPG noted that it did not receive any specific written comments or concerns regarding the list of valued ecosystem components from Aboriginal groups prior to the release of the EIS in 2011.

OPG modified the list of valued ecosystem components specified in the EIS Guidelines based upon technical considerations and knowledge of the study areas. For example, the groundwater valued ecosystem component was subdivided according to depth intervals in order to represent direct and indirect effects on groundwater. OPG also used the confirmed presence of species in the study areas. For example, the suggestion of the meadow vole as a small mammal representative was modified to the short-tailed shrew because meadow voles were not found in the study area during small mammal trapping surveys. Spottail shiner was added as an aquatic valued ecosystem component because it is an important forage fish species. Twelve valued ecosystem components were identified for radiation and radioactivity to represent different levels in the food chain and thus different exposure pathways to radionuclides. Modifications to the socio-economic valued ecosystem components were based upon the “community asset” framework. Human health valued ecosystem components were subdivided into overall health of local residents, members of Aboriginal communities, seasonal users and workers.

The list of valued ecosystem components provided by OPG in its EIS is reproduced in Table 3. OPG stated that it selected valued ecosystem components according to value, sensitivity, and likelihood of being affected by the project. Value included legal, scientific, ecological, cultural, social, economic and aesthetic considerations. Sets of valued ecosystem components were selected for each aspect of the environment, e.g., air, surface water, and terrestrial environments. Each valued ecosystem component was represented by measurable indicators, i.e., aspects of the valued ecosystem component that could be affected by the project. For example, indicators of water quality would include measures of total suspended sediment because site preparation and construction activities could produce an increased amount of suspended sediment in runoff from the site.

Table 3: List of Valued Ecosystem Components for the Project (information reproduced from DGR EIS Table 5.3.2-1)

Grouping	Valued Ecosystem Component	Environmental Component
Physical	Air Quality	Atmospheric Environment
	Noise Levels	
	Surface Water Quantity and Flow	Hydrology and Surface Water Quality
	Surface Water Quality	
	Soil Quality	Geology
	Overburden Groundwater Quality	
	Overburden Groundwater Transport	
	Shallow Bedrock Groundwater Quality	
	Shallow Bedrock Groundwater and Solute Transport	
	Intermediate Bedrock Water Quality	
	Intermediate Bedrock Solute Transport	
	Deep Bedrock Water Quality	
	Deep Bedrock Solute Transport	
Biological	Eastern White Cedar	Terrestrial Environment
	Heal-all	
	Common Cattail	
	Muskrat	
	White-tailed Deer	
	Northern Short-tailed Shrew	
	Midland Painted Turtle	
	Northern Leopard Frog	
	Mallard	
	Red-eyed Vireo	
	Wild Turkey	
	Yellow Warbler	
	Bald Eagle	
	Redbelly Dace	Aquatic Environment
	Variable Leaf Pondweed	
	Creek Chub	
	Lake Whitefish	
	Benthic Invertebrates	
	Burrowing Crayfish	
	Smallmouth Bass	
	Brook Trout	
	Spottail Shiner	
Radiological	Terrestrial Invertebrates	Radiation and Radioactivity
	Benthic Invertebrates	
	Aquatic Vegetation	
	Benthic Fish	
	Pelagic Fish	
	Aquatic Birds	
	Aquatic Mammals	
	Terrestrial Vegetation	
	Terrestrial Birds	
	Terrestrial Mammals	
	Amphibians and Reptiles	
	Humans	

Socio-economic Environment	Population and Demographics	Socio-economic Environment
	Other Human Assets	
	Employment	
	Business Activity	
	Tourism	
	Residential Property Values	
	Municipal Finance and Administration	
	Other Financial Assets	
	Housing	
	Municipal Infrastructure and Services	
	Other Physical Assets	
	Inverhuron Provincial Park	
	Other Social Assets	
Aboriginal Interests	Aboriginal Heritage Resources	Aboriginal Interests
	Traditional Use of Lands and Resources	
	Aboriginal Communities	
Human Health	Overall Health of Local Residents	Human Health
	Overall Health of Members of Aboriginal Communities	
	Overall Health of Seasonal Users	
	Health of Workers	
Multi-feature Physical	Lake Huron	Various components
	Stream C	
	South Railway Ditch	
	Wetland within the Project Area	

OPG stated that the selected valued ecosystem components represented features or elements of the natural environment, e.g., a local wetland, considered to be culturally or scientifically important. OPG noted that these features are complex, comprising several ecological aspects, and affected by a range of pathways of exposure to (or effects from) stressors produced by the project. OPG considered the selected valued ecosystem components to be appropriate for both project-specific and cumulative effects.

The Métis Nation of Ontario expressed concerns regarding the selection of valued ecosystem components. The Métis Nation of Ontario expressed the view that the valued ecosystem components chosen by OPG were not appropriate for identifying effects to Métis people because Métis rights are different than First Nations rights. The Métis Nation of Ontario suggested specific valued ecosystem components that reflected their traditional use study, which they had provided to the Panel. The Métis Nation of Ontario expected that the results of the environmental assessment would be re-visited in light of their suggested valued ecosystem components.

OPG responded to these concerns by stating that potential effects of the project on the selected valued ecosystem components could also be used to describe the potential effects on valued ecosystem components that had not been selected, but share biological and habitat characteristics with the selected valued ecosystem components. OPG explained that the project valued ecosystem components were strategically chosen such that the results of the effects assessment could be extended to individual species not explicitly evaluated. For example, burbot has similar lake habitat preferences for spawning and rearing as lake whitefish, and catfish share the same reproductive behaviour as smallmouth bass. OPG also noted that some of the species suggested by the Métis Nation of Ontario would not be present in the study area, such as moose and crane.

The Panel is satisfied that the valued ecosystem components selected for the project adequately represented important and valued features of the ecosystems within the Project Area, and the Site, Local and Regional Study Areas, and that OPG determined valued ecosystem components not only by their ecological importance but also by their inherent cultural, economic, and/or spiritual value.

The Panel notes that it received notification from the Métis Nation of Ontario that an agreement between OPG and Métis Nation of Ontario was reached in the summer of 2014. At that time, the Métis Nation of Ontario stated that it did not intend to attend the public hearing scheduled in September 2014. The Panel was not provided with any details regarding the possible nature of future discussions between OPG and the Métis Nation of Ontario; however, the Panel considers it logical to assume that discussions regarding the concerns about valued ecosystem components, including follow-up monitoring, might occur as part of this agreement.

3.2 STEPS USED IN OPG'S ENVIRONMENTAL ASSESSMENT

OPG stated that it followed a series of general steps in its environmental assessment for the project (Figure 5):

- describe the project for planning purposes;
- characterize the existing baseline environment conditions;
- identify potential interactions between the project and the environment;
- assess the possible project-environment interactions to determine if there are measurable changes to the environment – a measurable change is a change in the environment that is real, observable or detectable compared with existing conditions;
- advance measurable changes to determine whether there is a likely environmental effect. (Effects are assessed as either beneficial or adverse. An adverse effect is defined as a "non-trivial change." Adverse effects were advanced for consideration of possible mitigation measures to eliminate or reduce the effects. Beneficial effects are not considered further. The remaining effects are residual adverse effects. Residual effects are also assessed to determine if they combine with other projects to produce cumulative effects);
- assess whether the residual adverse effects present after mitigation are significant; and
- propose follow-up programs to verify the predictions made in the assessment, to confirm whether mitigation measures are effective and to allow provisions for change.

OPG noted that its environmental assessment studies were conducted by a team of internal and contracted experts. Contractors included the Nuclear Waste Management Organization, consultant organizations, and universities. The environmental assessment results were supported by a large framework of technical and scientific documentation presented in the EIS and supporting documents, which form part of the record for the review. OPG noted that international peer review groups provided oversight and guidance for the work conducted for the DGR, including geoscience, safety assessment, and engineering and design work programs.

OPG's project description is reviewed and evaluated in Chapters 4, 5 and 6 of this report. OPG's description of the existing environment is reviewed and evaluated according to specific chapters and subsections within those chapters in this report. For example, surface water, terrestrial and aquatic valued ecosystem components are covered in Chapter 8.

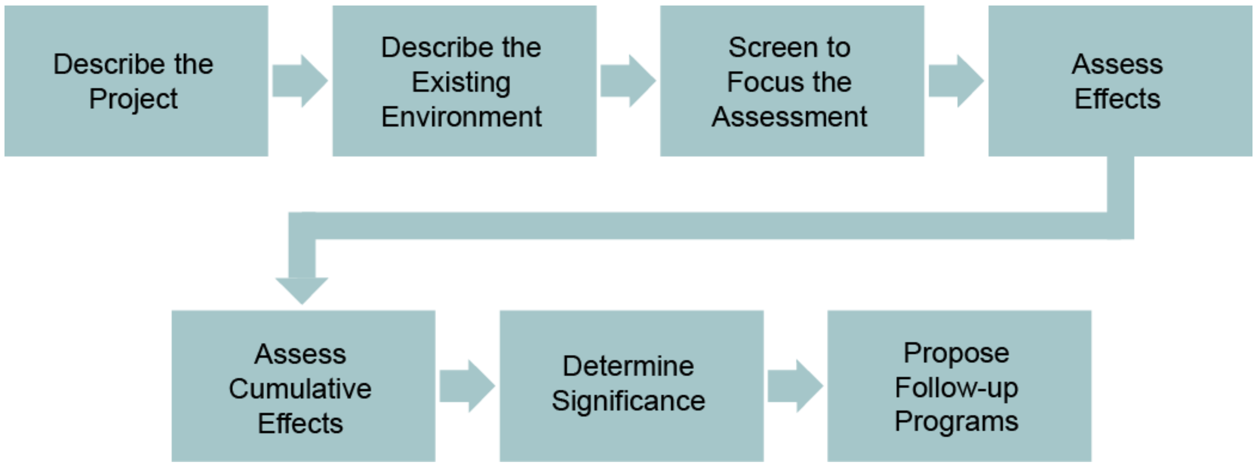


Figure 5: The OPG Environmental Assessment Process (PMD 13-P1.1B, OPG Presentation Overview, Slide 16)

3.2.1 Screening to Focus the Assessment

OPG conducted screening in order to focus its assessment. The screening included determining the interactions between valued ecosystem components and project activities, identifying measurable changes, identifying potential adverse effects, and identifying mitigation.

Interactions between Valued Ecosystem Components and Project Activities

OPG examined whether direct or indirect interactions would occur between each valued ecosystem component and the project, for each phase of the project. A direct interaction would be one that occurs when a valued ecosystem component is affected by a change that results from a work and activity, and an indirect interaction would be one that occurs when a valued ecosystem component is affected by a change in another valued ecosystem component. As an example of an indirect interaction, changes in air quality could affect valued ecosystem components in the terrestrial environment and human health. OPG noted that, for conservatism, in cases where there was doubt as to whether there would be an interaction, OPG assumed that there would be and carried it forward to further assessment.

OPG stated that activities that could result in direct interactions included:

- site preparation – grading, clearing, installation of impervious surfaces;
- construction – excavation and construction of surface facilities, shaft construction, dewatering, construction of waste rock piles, construction and operation of the stormwater management system;

- operation – above-ground transport of waste, underground transport of waste, operation of the stormwater management system ; and
- decommissioning – shaft sealing, demolition of surface facilities, re-grading and reclamation of the project site.

Examples of indirect interactions considered by OPG included changes in:

- groundwater flow that could affect surface water quantity;
- air quality that could affect soil quality, water quality, plants, animals, human health or Aboriginal interests;
- noise levels that could affect plants, animals, human health, Aboriginal interests or socio-economic valued ecosystem components;
- surface water quantity and flow that could affect habitat for plants and animals; and
- surface water quality that could affect plants, animals, human health or Aboriginal interests.

The Panel concludes that OPG's identification of direct and indirect interactions between project activities was thorough, traceable and transparent. OPG applied an appropriate level of conservatism in its approach.

Identification of Measurable Changes

OPG's application of professional judgement regarding whether interactions between the project activities and valued ecosystem components would result in measurable changes varied with the particular environmental component. In some cases, a narrative was presented explaining the logic for whether or not measurable change would occur, such as for soil quality, aquatic valued ecosystem components, and air quality. In other cases, OPG used quantitative estimates and benchmarks to distinguish among effects likely to be measurable or distinguishable from existing conditions, such as for surface water quantity and flow. OPG used a combination of qualitative and quantitative information for terrestrial valued ecosystem components, where criteria for measurable changes were presented for each valued ecosystem component and then a narrative was used to explain whether or not those criteria would be exceeded.

The Panel concludes that OPG's identification of measurable change for each project/valued ecosystem component interaction was sufficiently transparent such that other professionals would be able to perform their own evaluations.

Identification of Adverse Effects

OPG assumed that any measurable change would be adverse, which would therefore require the identification of mitigation measures to address all measurable changes. This assumption inserted a substantial layer of conservatism into the entire environmental assessment.

The Panel concludes that the assumption that any measurable change would be adverse addresses many of the uncertainties associated with the understanding of the nature and extent of effects associated with the project. The Panel notes that this broad approach may have limited, to some extent, OPG's ability to distinguish mitigation measures that would be absolutely required from those that would be of a lower priority.

Identification of Mitigation Measures

OPG identified and described mitigation measures for each measurable change in valued ecosystem component indicators. Indicators are the metrics used to measure and report on the condition and trend of a valued ecosystem component. In some cases, even when measurable changes were not identified, OPG committed to mitigation measures in order to ensure protection of valued ecosystem component in accordance with legislation, such as for the *Migratory Birds Convention Act* (S.C. 1994, c. 22).

The Panel notes that mitigation measures committed to by OPG in the EIS were sometimes superseded or supplemented by other mitigation measures identified during the review, such as through responses to information requests or during the public hearing. As such, the Panel makes the following recommendation.

Recommendation 3.1: Before a Licence to Prepare Site and Construct is granted, OPG shall submit to the CNSC an updated list of mitigation commitments for each identified adverse effect. OPG shall remove out-dated or redundant commitments from this list.

3.2.2 Determination of Significance of Residual Adverse Effects

This section includes an overview of three separate methodologies used to identify adverse effects and determine the significance of residual adverse effects in relation to the project; two performed by OPG, and a third by CNSC staff. This section is intended to cover the methodologies and not the results. The Panel's evaluation of the likelihood of the project to result in significant adverse environmental effects follows later in this report.

The determination of likelihood that the project will cause significant adverse environmental effects is at the core of the Panel's responsibility under the *Canadian Environmental Assessment Act, 2012*. Significance is determined for the residual adverse effects that would remain after the implementation of mitigation. The determination of significance must be done in a transparent, systematic and defensible manner based upon an appropriate combination of scientific data, regulatory thresholds, standards and criteria, social values, cultural knowledge and professional judgment. If significant adverse effects are identified, then it must be determined whether these effects are likely.

The EIS Guidelines outlined the requirements for OPG to evaluate the significance of residual effects. Any residual effects that persisted, despite mitigation, were to be assessed for significance. OPG was expected to take all reasonable precautions to protect the environment, and use all reasonable means, such as best available technologies or industry best practices, to eliminate or mitigate adverse environmental effects.

Reliance on mitigation to reduce or eliminate residual adverse effects and, thus, screen them out prior to the determination of significance was a common aspect of OPG's methodology. This reliance created an important onus on OPG to use proven, reliable, and sustainable mitigation methods. It also required that monitoring be designed to provide timely confirmation of the effectiveness of mitigation in order to allow for adjustment and adaptation if the effectiveness is not what was expected.

OPG noted that while the *Canadian Environmental Assessment Act, 2012* contains no legislative direction on what constitutes a significant adverse environmental effect, section 11.3 of the EIS Guidelines required that each residual adverse effect be considered in the categories of:

- the magnitude of the effect;
- the geographic extent of the effect;
- the timing and duration of conditions causing the effect;
- the frequency of the effect;
- the degree to which the effect is reversible;
- the social and ecological context; and
- the probability of occurrence.

The Panel notes that significance determination is highly sensitive to context. The ecological setting, including the presence of highly valued landscape features or species, forms part of the context. The Panel received extensive information about valued features and species from Aboriginal and non-Aboriginal participants. The Panel understood that effects of the project on ecosystem features identified as highly vulnerable and irreplaceable were considered to be unacceptable. This was particularly true for the water quality and aquatic life of Lake Huron.

Context also includes societal values. The determination of significance incorporates, either explicitly or implicitly, the values and judgements of the proponent, the public and decision-makers. Therefore, the more explicit the inclusion of values in the evaluation of significance, the more transparent the results will be. There may be disagreement with the results, but at least the reasoning, including the value judgements, leading to those results will be clear. Transparency regarding the values context helps address the point made by some participants that science is not value-neutral; rather, it incorporates the cultural worldviews of the scientists performing the assessment. Thus, the determination of significance must include adequate substantiation of the subjectivity of the experts involved in the assessment.

The use of valued ecosystem components is one of the primary methods for the explicit incorporation of values in significance determination. The valued ecosystem components should represent an appropriate and representative range of socio-economic and cultural, including Aboriginal, values and should include vulnerable and irreplaceable species. As discussed above, the Panel has concluded that the biophysical valued ecosystem components selected for the assessment sufficiently represented ecological, social and cultural values. The Aboriginal Interests valued ecosystem components are evaluated and discussed in Chapter 12 of this report.

Methodologies Used to Determine the Significance of Residual Adverse Effects

Three methods were used to determine significance of residual adverse effects of the project. In its EIS, OPG used a decision tree method. Following an information request from the Panel, OPG also presented a narrative approach. CNSC staff conducted its own evaluation of significance using a weight-of-evidence approach. The relative merits of each of these methods are presented below.

Overall, the Panel found the narratives provided by OPG to be the most useful of the three methods applied to the determination of significance. The combination of the three different methods provided additional confidence to the Panel regarding the determination of significance.

The OPG Decision Tree Method

OPG applied six criteria to its evaluation of the significance of residual adverse effects: magnitude; geographic extent; timing and duration of conditions causing the effect; frequency; degree of irreversibility; and, social/ecological context. The likelihood of effects was not included; this was not required because no significant adverse effects were identified. Both direct and indirect effects were included in the assessment.

If no residual adverse effects were identified, no assessment of significance was conducted. This placed a strong onus on OPG to propose effective mitigation. Panel recommendations regarding mitigation are presented for specific biophysical components in subsequent subsections of this report.

If residual adverse effects remained after mitigation, significance was evaluated for each effect. First, the magnitude of the effect was rated as low, medium or high according to each criterion. Then, the level of environmental consequence was determined by using a decision tree. Finally, the social and/or ecological importance of the valued ecosystem component being affected was considered to determine significance.

OPG used three categories of significance: not significant; may not be significant; and, significant. An effect that “may not be significant” was one that, in the professional judgement of the OPG specialists, would not be significant; however, follow-up monitoring was required to confirm that significant adverse effects would not occur. The decision trees used for each environmental component were accompanied by tables presenting the ratings for each criterion and the overall assessment of significance. The decision trees were meant to assist in the explanation of how OPG arrived at the overall assessment. For example, a combination of high magnitude, medium geographic extent, low timing and duration, low frequency and low irreversibility for residual effects on air quality resulted in either a “not significant” or “may not be significant” overall assessment depending upon social/ecological importance.

A considerable amount of professional judgement was required for OPG to apply the decision tree methodology. The overall assessment results were not always easy to understand because the reasoning was sometimes difficult to follow. Several participants commented on OPG’s methodology. Some participants expressed the view that the methodology was reasonable and appropriate, and that OPG had adequately assessed and determined the significance of adverse effects. Others noted that OPG had relied on professional judgement and the use of models, and suggested that the results were not transparent or credible due to uncertainties or a lack of sufficient empirical evidence. As previously described in Chapter 2, the Panel commissioned Dr. Peter Duinker to evaluate OPG's decision-tree based significance determination method.

Dr. Duinker had several criticisms of the approach and method OPG used to determine the significance of residual effects as presented in the EIS. The primary issues were:

1. the use of apparently arbitrary professional judgements;
2. the lack of a clear scientific basis in setting limits for the significance criteria; and
3. complicated and non-transparent decision trees used for the ultimate determination of significance of each residual adverse effect.

Dr. Duinker suggested that other expert assessors using OPG's decision tree method could have come to different conclusions because of the lack of transparency and clear rationale for the route taken through the decision trees to the final significance determination. Dr. Duinker provided additional information and context for his review during his oral presentation at the hearing in 2013. He pointed out that environmental assessments should provide decision-makers with useful and defensible information in support of confident decision making. Therefore, the determination of significance of residual adverse effects must be reliable and transparent. Dr. Duinker recommended that significance should be determined with strong quantitative and qualitative reasoning with respect to the application of the six criteria, magnitude, spatial extent, timing/duration, frequency, degree of irreversibility, and likelihood. Dr. Duinker emphasized, however, that, notwithstanding his criticisms of OPG's methods, he could not conclude that OPG's findings regarding significance were wrong.

On the basis of Dr. Duinker's review as well as information presented at the hearing, the Panel decided to issue an information request requiring OPG to provide a detailed narrative to explain how the significance of each residual adverse effect on the biophysical environment and on Aboriginal interests were determined. Given Dr. Duinker's criticism of the logic used in the EIS, the Panel further required that the narrative must explain the logic behind the significance determinations using context-based reasoning.

OPG Narrative-Based Methodology

In its response to information request EIS-12-510, OPG outlined a narrative-based methodology used to determine the significance of residual adverse effects. OPG explained that it identified residual adverse effects for air quality, noise, hydrology, the aquatic and terrestrial environments, and Aboriginal interests, and provided reasoned argument narratives that described the significance assessments for each identified residual adverse effect. A reasoned narrative involves making reasoned judgements, based on scientific literature and applicable government standards or guidelines, of each residual adverse effect in comparison to an established hypothesis.

OPG explained that, in general terms, an adverse effect may be considered significant if it is major or catastrophic, widespread, long-term and/or frequent, or irreversible. Conversely, adverse effects that are inconsequential or minor, localized, infrequent or of short duration, or reversible, may be considered not significant.

Participants also commented on the narrative-based approach used by OPG. Some expressed the view that the narrative approach provided additional confidence in the OPG determination that the project would not cause significant adverse effects. Other participants disagreed with the OPG hypotheses of what would constitute a significant adverse effect, and thus disagreed with the OPG significance determination.

OPG formulated a hypothesis statement for each residual adverse effect, identifying conditions that would make the residual adverse effect significant. For example, “to have a significant effect on the air quality valued ecosystem component, the project would need to result in ambient air concentrations beyond the Site Study Area that exceed relevant established ambient air quality criteria more than 10% of the time.” Following a reasoned narrative, OPG judged the predicted effect against these hypotheses, summarizing the evidentiary bases for the detailed narratives from the EIS and corresponding Technical Support Documents. OPG stated that both the EIS and the reasoned argument narratives reached the same conclusion that the project would not result in any significant adverse environmental effects.

The Panel reviewed the strength of the evidence and the clarity of the narrative, as well as whether the narrative implicitly or explicitly recognized and incorporated values as part of the context. For example, interpretation of what constitutes a “low magnitude” change requires an explicit consideration of whether that definition requires adjustment for a valued ecosystem component that is highly vulnerable, irreplaceable, or of high cultural or spiritual significance.

The Panel found that the narratives in support of the significance determinations for the biophysical valued ecosystem components increased the transparency, credibility and defensibility of OPG’s conclusions. The narratives also increased the likelihood that other expert assessors could come to the same or similar conclusions, or, alternatively, would be able to clearly articulate how and why they disagreed with the OPG conclusions.

CNSC “Weight-of-Evidence” Approach

CNSC staff independently determined significance, using the information in the EIS and considering each of the significance criteria collectively, using what was referred to as a “weight-of-evidence” approach. CNSC staff used the same significance criteria as used by OPG, i.e., magnitude, extent, timing and duration, frequency, irreversibility and ecological context. The Panel understands that the individual lines of evidence that were combined to produce an overall weight-of-evidence were the assessments of each of the significance criteria.

CNSC staff explained that the magnitude line of evidence was based upon what was referred to as a “risk analysis,” where predicted effects were compared to benchmarks. Benchmarks were determined using specified variances from baseline values (for water flows), environmental quality guidelines, objectives or criteria (for water quality), or qualitative factors for judging the degree of measurable change (size and shape of lost habitat, presence of unique features and ecological function).

The only complete risk analysis conducted by CNSC staff was for surface water quality. CNSC staff derived risk indices comparing predicted concentrations of constituents of potential concern, such as chloride, ammonia, and copper, with provincial water quality objectives. Risk quotients greater than 1 were interpreted by CNSC staff as indicating a risk to aquatic biota in the receiving environment, i.e., MacPherson Bay in Lake Huron, and the need for mitigation to reduce the risk.

Magnitude was the only line of evidence explicitly considered and presented by CNSC staff across all of the biophysical components. The other significance criteria were not discussed at all for hydrology and surface water quality. Geographic extent was referred to very briefly and cryptically in the discussion of habitat loss for aquatic valued ecosystem components, where CNSC staff stated that the estimated area of habitat alteration was in a localized area because it was less than 1.6% of similar habitat of the drainage ditch. The only valued ecosystem component where all criteria appeared to have been applied was the eastern white cedar.

The assessment of significance by CNSC staff differed from OPG's primarily in the use of risk indices for water quality, and a somewhat different narrative in support of the assessment for eastern white cedar.

It is the Panel's view that the CNSC staff approach was not a true weight-of-evidence approach. Weight-of-evidence requires the standardized, transparent evaluation of the same lines of evidence for each component in order to arrive at an overall result that reflects the combined "weight" of the individual lines of evidence. The OPG tables in the EIS which summarize the rating of each significance criterion were closer to a weight-of-evidence approach than what was used by CNSC staff. Therefore, CNSC staff conclusions were evaluated by the Panel on the basis of CNSC's narrative explaining the basis for each conclusion.

3.3 GUIDING PRINCIPLES FOR THE ENVIRONMENTAL ASSESSMENT

The Panel used the guiding principles outlined in the EIS Guidelines. The guiding principles are:

- use of environmental assessment as a planning tool;
- transparent and effective use of existing information;
- public participation and Aboriginal engagement;
- traditional knowledge;
- sustainable development;
- the Precautionary Principle; and
- consideration of ecosystems in the environmental assessment methodology.

Each guiding principle is explained below, as well as a description of how OPG incorporated it in its environmental assessment.

3.3.1 Use of the Environmental Assessment as a Planning Tool

Environmental assessment is a planning tool used to ensure that projects are considered in a careful and precautionary manner in order to achieve or maintain a healthy environment and a healthy economy. OPG stated that the approach it used in the EIS for assessment of the project fulfilled this principle via the use of a thorough, traceable and step-wise procedure to characterize and assess the environmental effects of the project, propose measures to mitigate adverse effects, and predict whether there will be likely significant adverse effects after mitigation measures are implemented.

The Panel is satisfied that the approach used by OPG to assess the project was consistent with the guiding principle of the use of an environmental assessment as a planning tool. In particular, the Panel observed that OPG used a precautionary approach, described in more detail later in this chapter; incorporated in-design mitigation measures to reduce adverse effects; and committed to adaptive management in response to information received through follow-up monitoring.

3.3.2 Use of Existing Information

The EIS Guidelines encouraged OPG to make use of existing information relevant to the project and either include the information directly in the EIS or provide clear references to this information. In addition, OPG was to comment on how representative the data were, clearly separate factual lines of evidence from inference, and state any limitations on the inferences or conclusions that can be drawn from them.

OPG provided lists of references for the existing sources of information used for each chapter in the EIS in section 14 of the EIS. OPG also included extensive lists of references in its Technical Supporting Documents, as well as new data collected in support of the EIS and supporting documents.

One participant expressed concerns regarding OPG's use of existing information for the reference waste inventory that OPG used in its safety case calculations. The participant noted that the EIS Guidelines stated that the studies for existing information should be prepared using best available information and methods, to the highest standards in the relevant subject area, and pointed out that, in some cases, rather than use direct measurements from existing waste, OPG used calculated values, which led to certain radionuclide concentrations being underestimated. This subject is addressed in Chapter 7 of this report.

The Panel is satisfied that OPG used existing information and referenced it appropriately in the EIS. Regarding the collection of data in support of the EIS and supporting documents, the Panel notes that OPG committed to conducting further baseline studies if additional data were needed. The Panel has included recommendations for additional baseline data collection for biophysical components discussed elsewhere in this report. For example, CNSC staff, Environment Canada, and the Saugeen Ojibway Nation identified the need for some additional baseline information with respect to water and sediment quality, surface hydrology, near-surface groundwater, and fish habitat and the fish community of MacPherson Bay.

3.3.3 Public Participation and Aboriginal Engagement

The EIS Guidelines stated that public participation is a central objective of the overall review process. Meaningful public participation requires the proponent to address concerns of the general public regarding the anticipated or potential environmental effects of the project. Another objective of the overall review process is to involve potentially affected Aboriginal people in order that the environmental assessment can identify and address concerns regarding any changes that the project may cause in the environment and the resulting effects of any such changes on the use of lands and resources for traditional purposes by Aboriginal persons.

OPG reported on its public participation activities throughout the environmental assessment process as required under the *Canadian Environmental Assessment Act, 2012*. OPG's project team provided local communities and interested stakeholders with opportunities to become informed on the status of the studies, as well as to provide input to the environmental assessment and obtain answers to their questions. OPG implemented public participation programs in the host Municipality of Kincardine and the adjacent municipalities of Brockton, Saugeen Shores, Huron-Kinloss, South Bruce, Arran-Elderslie, South Bruce Peninsula and Northern Bruce Peninsula. OPG also provided briefings to selected groups in Michigan. OPG also reported on its notification about key development in the project and the environmental assessment provided via website postings, newsletters, and placement of information in local libraries and print and radio advertising. In the EIS, OPG addressed questions and concerns expressed by the public regarding the project during the public engagement activities.

Many participants expressed views regarding public participation in the review. Several supported OPG's engagement of the public, noting the many community consultation activities that had taken place since 2003. Other participants expressed dissatisfaction with OPG's engagement, suggesting that it could have been improved through the use of "town hall" meetings, as opposed to "open house" meetings. Some participants noted that they had not been aware of the project until more recently, and suggested that OPG could have included more seasonal and US residents, as well as populations throughout the Great Lakes Basin. More information regarding these views is discussed in Chapter 11.

OPG stated that its engagement with the Saugeen Ojibway Nation began in 2003, well before the formal initiation of the environmental assessment process. Communications included meetings to identify and understand the local Aboriginal communities' interests in the project as well as to provide information about the project and the regulatory process. OPG provided funding to the Saugeen Ojibway Nation to assist in accessing resources for participating in the review process.

OPG's engagement with Métis groups began in 2008. An agreement with the Historic Saugeen Métis Community was finalized in 2010 which provided capacity for involvement in the review of the project. Engagement with the Métis Nation of Ontario included a participation agreement finalized in 2011. More information concerning OPG's engagement with Aboriginal groups is discussed in Chapter 12.

The Panel placed emphasis on providing interested parties with fair and ample opportunity to participate in the review, and the public hearing in particular. The Panel received information regarding the adequacy and effectiveness of OPG's public engagement. The Panel also focused on information provided by the Crown Consultation Coordinator as well as information obtained from the direct interaction with Aboriginal groups at the hearing. The Panel's detailed review and conclusions regarding public consultation are presented in Chapter 11 and regarding Aboriginal engagement in Chapter 12.

3.3.4 Traditional Knowledge

Traditional knowledge refers to the broad base of knowledge held by individuals and collectively by communities that may be based on spiritual teachings, personal observation and experience or passed on from one generation to another through oral and/or written traditions. Traditional knowledge is knowledge held by, and unique to, Aboriginal peoples. It includes, but is not limited to, traditional ecological knowledge.

OPG reported that it incorporated specific traditional knowledge, where available, through the characterization of the existing environment and assessment of effects. OPG examined issues of importance to Aboriginal communities, including:

- interests raised by Aboriginal communities in relation to previous studies;
- interests raised by Aboriginal communities in the context of dialogue for the current project; and
- insight into traditional knowledge, and interests of general importance to Ojibway and Métis peoples.

The Panel evaluated the nature and extent of traditional knowledge that was presented to OPG for inclusion in its assessment, and to the Panel for consideration in its review. The Panel is satisfied that OPG incorporated traditional knowledge to the extent practicable. The application of traditional knowledge in the environmental assessment is discussed in Chapter 12 and elsewhere in this report.

3.3.5 Ecosystem-Based Approach

The EIS Guidelines stipulated that an ecosystem-based approach would require OPG to identify and justify the indicators and measures of ecosystem health using both scientific and traditional knowledge and perspectives. The EIS Guidelines stipulated that an ecosystem-based approach would also include:

- consideration of the resilience of species, communities and their habitats;
- size, geographical extent and density of animal populations;
- habitat at regional and local scales via ecological mapping;
- interrelations among valued ecosystem components and the relation of the valued ecosystem component to the entire ecosystem and communities of which they are a part;
- nutrient and chemical cycles;
- food chains;
- productivity; and
- range and probability of natural variation over time.

The primary mechanisms employed by OPG to achieve an ecosystem–based approach were: (1) its selection and use of valued ecosystem components and associated indicators; and (2) its application of the criteria for significance of residual adverse effects using the professional ecological judgment of the EIS team. This professional judgement included, for some valued ecosystem components but not all, explicit consideration of resilience. Nutrient and chemical cycles and food chains were considered qualitatively via narratives within the EIS as well as via assumptions used in models of radiation exposure of non-human biota. OPG conducted habitat mapping for the terrestrial ecosystems in the study areas, including wetlands. OPG modified the definitions of Regional, Local and Site Study Areas and the Project Area stipulated in the EIS Guidelines to reflect ecologically relevant boundaries for potential effects. OPG considered the range and probability of natural variation over time through its assessment of existing conditions, which included examination of past data collected by others, such as Bruce Power and federal or provincial agencies, as well as collection of baseline data from the Site, Local and Regional Study Areas.

The Panel determined that, in general, OPG applied an ecosystem-based approach. The Panel came to this conclusion by comparing the description of an ecosystem-based approach in the EIS Guidelines and the methods used by OPG. In the Panel's view, using an ecosystem-based approach poses a substantial challenge. Scientific knowledge about the specific ecosystems of concern, or the role of valued ecosystem components within those ecosystems, is often limited or completely lacking. It is the view of the Panel that proponents cannot be expected to fill fundamental gaps or substantial uncertainties in scientific understanding. The challenge then becomes how to best address the scientific gaps and uncertainties via environmental assessment methodology. The application of the Precautionary Principle is the standard approach in these cases. OPG applied the Precautionary Principle in its assessment, as described in a subsection below.

3.3.6 Sustainable Development

According to the EIS Guidelines, sustainable development seeks to meet the needs of present generations without compromising the ability of future generations to meet their own needs. OPG was to strive to integrate the objective of net ecological, economic and social benefits to society in the project, with specific consideration of:

- the extent to which biological diversity may be affected by the project; and
- the capacity of renewable resources that are likely to be significantly affected by the project to meet the needs of present and future generations.

OPG's incorporation of sustainable development in the environmental assessment was based on the objective of meeting the needs of present generations without compromising the ability of future generations to meet their own needs. According to OPG, specific instances where it incorporated sustainability included the consideration of alternative means of carrying out the project, the extent to which biological diversity would be affected, and the potential effects of the project on the capacity of renewable resources. OPG added to its consideration of sustainable development in its response to information requests from the Panel regarding the incorporation of sustainability in the evaluation of the significance of adverse effects.

Overall Contribution of the Project to Sustainability

OPG stated that the primary contribution to sustainable development of the project was that it would address the management of L&ILW in this generation rather than delaying it to the future, providing flexibility for future generations. Contributions to sustainability on a local scale were listed as:

- avoidance of transport of the waste with its attendant higher cost, emissions and consumption of resources;
- reducing the surface footprint for waste management;

- avoidance of sensitive lands such as the northeast marsh;
- decreasing contact opportunities for terrestrial and aquatic species; and
- providing continued employment and revenue opportunities in the Regional Study Area.

CNSC staff stated that OPG's consideration of sustainable development met the requirements of the EIS Guidelines. Environment Canada commented that its technical review of the project did not specifically address whether OPG had met the sustainability criteria of biological diversity and the capacity of renewable resources; however, the criteria were encompassed in the scope of the technical review. For example, Environment Canada assessed how the project would affect species at risk, migratory birds, and fisheries.

The Canadian Environmental Law Association commented on OPG's consideration of sustainable development for the project, including in the areas of the assessment of alternative means of carrying out the project, cumulative effects assessment, the availability of resources for the long-term management of the project, and socio-economic outcomes. It was suggested that OPG should have considered sustainability as an overarching concept that encompasses critical, context-specific engineering matters, important social, economic and ecological considerations, and all stages of the project.

Sustainability as a Criterion for Determination of Significance of Adverse Effects

In response to an information request requiring a more detailed explanation of how sustainability principles were used to determine the significance of effects, OPG explained that sustainability was part of the basis for the "degree of irreversibility" assessment criterion. Only those effects that were "readily reversible" were given a low rating for this criterion because OPG assumed that such effects would have no impact beyond the life of the project and that the environment would return to existing conditions. Effects that were reversible with time, presumably time beyond the decades encompassing the life of the project, were assigned a medium rating. OPG explained that sustainable development does not readily lend itself to incorporation into the other criteria used for the determination of significance, e.g., magnitude, spatial extent, or duration.

Incorporation of sustainable mitigation design to increase the likelihood of long-term effectiveness without the requirement for costly interventions was an important issue for the Panel. OPG provided information regarding sustainable mitigation design in its responses to several information requests. OPG presented design features that were well-known standard methods and approaches. For example, OPG committed to minimizing the amount of impervious surfaces as well as the footprint of the project areas, including equipment staging and laydown areas. OPG committed to revegetation of the waste rock pile, drainage ditches, and unpaved surfaces using native, non-invasive species consistent with local conditions and which would be capable of providing vigorous, plentiful cover with minimal care. OPG also committed to mitigation measures best suited to protect listed species such as snapping turtles, including measures to avoid destruction, injury or interference with the species, its residence or its habitat.

Monitoring of the effectiveness of mitigation is essential to ensuring sustainable practices. The Canadian Environmental Law Association commented that OPG should have adequate resources in place to ensure that follow-up monitoring can continue into the foreseeable future without being a burden on future generations. Although OPG committed to a number of specific follow-up monitoring measures during the review, the Panel has determined more are required, as stated in the Panel's recommendations for modifications and additions to the monitoring program. These recommendations are presented later in this report.

The Panel is satisfied that OPG's assessment of effects on the natural environment during the pre-closure phase of the proposed project adequately addressed sustainable development within the specifications provided in the EIS Guidelines. The Panel acknowledges the challenges involved in the incorporation of sustainability principles into traditional effects assessment. The Panel is of the view that future environmental assessments under the *Canadian Environmental Assessment Act, 2012* could benefit from more explicit guidance on the application of sustainable development principles. As such, the Panel makes the following recommendation:

Recommendation 3.A: Future guidance for the conduct of environmental assessments under the *Canadian Environmental Assessment Act, 2012* should include an explicit list of sustainability indicators for use in each category of project, such as mining, oil and gas, linear development, and ports and harbours. The guidance should include examples of how sustainability can better be incorporated into the evaluation of significance of adverse effects.

Capacity of Renewable Resources

OPG stated that the project would not adversely affect the sustainable use of renewable resources such as surface water, groundwater, soil quality, aquatic resources, or terrestrial resources. For context, OPG also assessed the project's effects on the sustainable use of non-renewable resources, such as aggregate resources and petroleum resources. The Panel's review of OPG's assessment of effects on surface and near-surface groundwater resources and aquatic and terrestrial biota is presented in Chapter 8, and summarized below.

OPG did not predict any effects on the supply or quality of surface water, as discussed in Chapter 8. OPG did not predict adverse effects on near-surface or shallow bedrock groundwater quality. As discussed in Chapter 8, OPG pointed out that potable groundwater only occurs in the upper-most groundwater system. At depths below 170 metres, groundwater becomes too saline to be used as potable water. This would prevent or discourage deep drilling for potable groundwater. Further, OPG predicted no effects on the use or enjoyment of Lake Huron. Effects on Lake Huron are discussed in more detail in Chapter 14.

OPG assumed that any effects on soils and soil quality caused by the project would be reversible through remediation. Residual adverse effects on aquatic biota were predicted for the Project Area only. Because of the localized effects, OPG did not predict effects on the sustainability of these resources, including fisheries in Lake Huron.

OPG predicted that a residual adverse effect on eastern white cedar, and by implication other tree and shrub species subject to removal during site preparation and construction, would occur on the project site. However, since the forest resource on the DGR site is not a harvestable resource, OPG determined that there would be no effect on renewable timber resources. OPG stated that since the removal of 8.9 hectares of mixed woods forest represents only about 11% of this type of habitat for sheltering and foraging within the Site Study Area, white-tailed deer, and, by inference, other species using this habitat, would not likely relocate. This subject is addressed in more detail in Chapter 8.

OPG stated that the project would not affect the availability of aggregate resources because its use of these resources, such as sand, gravel, and quarried rock would be small relative to locally available aggregate. Although aggregate resources would be created via excavation and blasting during site preparation and construction phases of the project, OPG did not present any plans for releasing the waste rock into the local aggregate market.

OPG stated that there was low potential for the occurrence of base metals, salt deposits, commercial hydrocarbon accumulation, shale gas and potable groundwater resources in the Project Area. OPG's petroleum assessment stated that there was a low probability of economic oil or shale gas within 40 km of the project. The Panel presents its review of the potential for petroleum resources in Chapter 13 as it relates to human intrusion scenarios.

OPG noted that fuels for on-site vehicle and equipment operation would be required through all phases of the project but that consumption of fuels would not be expected to deplete the existing supply. OPG did not present a corporate policy regarding current and future use of fossil fuels either with respect to conservation of non-renewable resources or reduction of the production of greenhouse gases. This subject is further discussed in Chapter 8.

CNSC staff concurred with OPG that project effects were not likely to affect the sustainability of renewable resources. CNSC staff stated that OPG's characterization of the existing conditions and effects to the capacity for renewable resources and sustainability met the requirements of the EIS Guidelines.

The Panel is satisfied that OPG adequately addressed the project's effects on the capacity of renewable resources and concludes that the project is not likely to cause significant adverse effects to the capacity of renewable resources. As discussed in Chapter 8, specific mitigation measures will be required to ensure that the discharge from the stormwater management pond complies with section 36 of the *Fisheries Act*, thus preventing significant adverse effects on aquatic biota in MacPherson Bay of Lake Huron. The Panel notes that future conditions may create different economic drivers for resource exploration and extraction. The Panel has recommendations on this subject, which is addressed in more detail in Chapter 13.

Biodiversity

OPG's assessment of effects on biodiversity during the preclosure period depended upon the logic that if there was no effect on biodiversity within the Site Study Area, there would be no effects within the Local or Regional Study Areas. OPG stated that while there would be losses of habitat or individuals of species as part of the project, the effects were either not considered measurable or, if measurable and adverse after mitigation, they were not judged to be significant.

OPG stated that its corporate Biodiversity Policy would form part of the basis for the Environmental Protection Program of the project. In a response to an information request, OPG stated that, since the spring of 2000, it had planted approximately 5 million native trees and shrubs on more than 2,400 hectares of ecologically significant lands in southern Ontario. OPG noted that this initiative was part of OPG's Biodiversity Program and would contribute to climate change adaptation and mitigation.

CNSC staff concurred with OPG that there was no expected effect on biodiversity in the Site Study Area, the Local Study Area, or the Regional Study Area. CNSC staff stated that OPG's characterization of the existing conditions and effects to biodiversity met the requirements of the EIS Guidelines.

The Panel is satisfied that OPG adequately addressed the project's effects on biodiversity. The Panel expects that OPG will actively seek out opportunities to apply its corporate Biodiversity Policy during the preclosure phases of the project.

3.3.7 The Precautionary Approach

As explained in the EIS Guidelines, one purpose of environmental assessments is to ensure that projects are considered in a careful and precautionary manner before authorities take action in connection with them, in order to ensure that such projects do not cause significant adverse environmental effects. The Precautionary Principle informs the decision-maker to take a cautionary approach, or to err on the side of caution, especially where there is a large degree of uncertainty or high risk.

The EIS Guidelines outlined a variety of ways in which OPG was to indicate its consideration of the Precautionary Principle, under the guiding principles set out in the 2003 Canadian Privy Council Office document *Framework for the Application of Precaution in Science-based Decision Making About Risk*. This document sets out guiding principles for the application of precaution to science-based decision making in areas of federal regulatory activity for the protection of health and safety and the environment, and the conservation of natural resources.

OPG's primary tool for ensuring the incorporation of a precautionary approach was to use conservative assumptions in the assessment. OPG explained that at each of the screening stages of the assessment, potential project-related effects were advanced if they could not systematically be removed from consideration through application of scientific evidence. Additionally, OPG assumed that all identified residual adverse effects would occur and were therefore assessed for significance, rather than eliminating some residual adverse effects from consideration due to low likelihood of occurrence. The exception to this practice was in the assessment of malfunctions, accidents and malevolent acts.

The Panel has determined that OPG's environmental assessment generally included a sufficient level of precaution. However, in some cases, the Panel has recommended additional mitigation to ensure that uncertainty associated with the significance of residual adverse effects is further reduced.

The Panel's evaluation of the application of the Precautionary Principle was guided by the document *A Framework for the Application of Precaution in Science-based Decision Making* *about Risk* published by the Canadian Privy Council Office, as well as by the specific requirements regarding the use of precaution set out in the EIS Guidelines. In the Panel's opinion, the application of the Precautionary Principle includes:

- a project design that will not cause serious or irreversible damage to the environment or human health of current or future generations within an acceptable level of uncertainty;
- the management of uncertainty through the consistent application of conservative assumptions and provision for adaptive management;
- transparent and rigorous justification of assumptions used in the design of the project as well as in support of modelling used to demonstrate the Safety Case;
- evaluation of alternative means by comparing the level of risk avoidance, adaptive management capacity and preparation for surprise;
- priority placed on avoiding adverse effects;
- acceptable risk from accidents, malfunctions and malevolent acts, including acceptable uncertainty regarding the risk;
- effective and adaptive follow-up and monitoring activities; and
- public input on the acceptability of risk and uncertainty associated with the project.

The primary source of uncertainty associated with the project is the requirement to evaluate performance and risk extending to the far future. This uncertainty is so substantial that precaution must prevail through all aspects of the postclosure assessment. Assessment for the shorter-term, preclosure period is subject to lower uncertainty and has the benefit of experience gained with other, similar projects, including mining projects and other nuclear waste repositories. However, even with the benefit of experience, the application of precaution is an imperative in order to ensure that there are no significant adverse effects associated with the project.

As stated in the Privy Council document, sound scientific information and its evaluation must be the basis for applying precaution. Scientific data relevant to the risk must be evaluated through a sound, credible, transparent and inclusive mechanism leading to a conclusion that expresses the possibility of occurrence of harm and the magnitude of that harm, including the extent of possible damage, persistency, reversibility and delayed effect. Peer review represents a concrete test of the practical application of precaution to decision making. Scientific advice should be drawn from a variety of sources and experts, and should reflect the full diversity of scientific interpretations consistent with the evidence available. This does not preclude contributions of traditional knowledge.

According to the Privy Council document, precaution is guided by judgment, based on values and priorities; thus it is legitimate that decisions be guided by society's chosen level of protection against risk. However, the document goes on to state that while societal values and public willingness to accept risk are key in determining the level of protection, in all cases sound scientific evidence is a fundamental prerequisite to applying the precautionary approach.

The Panel accepts and has applied the above fundamental prerequisite of sound scientific evidence. Therefore, the Panel's review of OPG's application of the Precautionary Principle starts with a science-based review of the application of conservative assumptions within the assessment methodology. The Panel's review of the role of values in the application of the Precautionary Principle follows the science-based review.

Science-Based Review of OPG's Use of the Precautionary Principle

OPG used five primary methods to insert precaution into the environmental assessment. First, any predicted measurable change from existing conditions, no matter how small, was considered to be adverse. Second, all adverse effects were assumed to have a 100% likelihood of occurring. Third, conservative assumptions were used within predictive air, noise, water quantity and water quality models to ensure that effects were not underestimated. Fourth, the evaluation of significance of adverse effects was based upon maximum predicted effects, no matter how infrequent or over how small an area, for example, maximum predicted air quality concentrations. Fifth, the magnitude criterion used within the process to determine significance was often, although not always, based upon established criteria that are protective of the environment and include a level of conservatism, such as for air and water.

Since professional judgment played an essential role in OPG's application of the precautionary approach, it was important the Panel that OPG establish the qualifications and experience of its assessment team. In response to an information request, OPG provided the qualifications of the technical specialists and reviewers for each discipline. Senior reviewers had years of experience ranging from 16 to 40, with the majority ranging between 20 and 30 years. All members of the team had advanced degrees and/or accreditation such as Professional Engineers or Professional Geologists. OPG explained that when technical specialists or reviewers differed in their professional judgement, the most conservative was used.

In its 2013 hearing submission, CNSC staff specifically evaluated the application of the Precautionary Principle to the preclosure assessment and made reference to the use of adequately conservative assumptions as they pertained to specific topics. CNSC staff described the conservative assumptions used by OPG in the preclosure assessment as being adequate or acceptable for the following topics:

- the behaviour of non-radiological contaminants;
- surface water quality;
- air quality;
- radiological effects on humans and non-human biota from normal operations; and
- the application of the As Low As Reasonably Achievable (ALARA) principle.

CNSC staff had comments or recommendations related to uncertainties associated with the properties and extent of the excavation damage zone, waste characterization, and generated gas pressures in the repository. CNSC staff stated that the reasoning and context provided by OPG on its environmental assessment methods were valid and conservative. CNSC staff further stated that OPG had adequately demonstrated a reasonable assurance, through conservative assessment, that public and environmental protection would be provided in the very long term.

The Panel concludes that OPG's science-based approach was precautionary. The Panel notes that OPG made use of third-party peer review, including review by international experts, in many aspects of its assessment. The Panel is satisfied that OPG applied an appropriate level of conservatism in its approach.

Review of the Role of Values in the Application of the Precautionary Principle

The Panel acknowledges the important role that values play in decision-making. Values, in turn, lead to bias. Awareness and acknowledgment of values and bias is fundamental to transparent decision-making. The interpretation of scientific evidence will always be subject to bias. This cannot be avoided. However, scientists can be transparent about their biases and the effect those biases may have on their interpretation.

The Panel believes in the role of sound science in decision-making. However, values also influence decisions. The Privy Council document on the use of the Precautionary Principle reflects this via its principle requiring a high degree of transparency, clear accountability and meaningful public involvement. Application of this principle includes the "inclusion of a range of perspectives in the decision-making process." Not all of these perspectives will be science-based.

In the Panel's opinion, transparency regarding the combination of science and values in decision-making is required in the case of the DGR. To that end, the Panel provides the following discussion of three topics that must be addressed and placed in context.

1. Requirement for zero risk

Several participants stated that there must be zero risk associated with the management of L&ILW. The statement made by some participants that there is "no safe dose" from radiation is part of the zero risk argument.

The Panel notes that there is no such thing as zero risk - just different balances between risk and benefit which, in turn, require different levels of risk management. The definition of the appropriate balance of risk and benefit will be affected by values. Thus, the societal requirement for management of nuclear waste is particularly rigorous relative to other sources of risk. This is not necessarily because there is scientific evidence of high risk; rather, it is because there are strong values associated with involuntary exposure to radiation.

As stated in the Privy Council document on the Precautionary Principle, governments cannot guarantee zero risk, even if zero risk is a stated requirement of some participants. Precaution does not equate with zero risk; rather, it reflects an appropriate societal balance between caution and sustainability. The most appropriate decision may not even be the lowest risk scenario if all of the alternatives produce low risk relative to benefits. The status quo storage of L&ILW on the surface at the Bruce nuclear site is not a zero-risk alternative.

2. Familiar uncertainty of the status quo versus unfamiliar uncertainty with proposed DGR

The status quo storage of L&ILW at the surface is familiar; the WWMF has been in operation for over 40 years. However, the Panel emphasizes that familiarity and lower uncertainty do not equate with lower risk. Risks from severe weather events and malevolent acts are substantially higher for surface storage than for underground storage of nuclear waste. The Panel did not receive any submissions that stated that the WWMF could or should be operated under a zero risk requirement; rather, the status quo was often presented as the preferred alternative until uncertainty about deep geologic disposal was reduced. This preference illustrates the well-known phenomenon where there is a lower tolerance for risk from unfamiliar, higher-uncertainty alternatives.

The Precautionary Principle can be used in the context of low tolerance for unfamiliar and highly uncertain alternatives. In the case of the proposed DGR, because the evaluation of risks far into the future includes uncertainties, the use of extremely conservative assumptions, sometimes to the point of implausibility, is appropriate. OPG used extremely conservative assumptions in its postclosure assessment, such as assuming a complete and simultaneous failure of all barriers in the shaft. Assumptions used for the preclosure assessment were also highly conservative, as outlined above.

Another application of the Precautionary Principle to unfamiliar or uncertain risks is to manage both the likelihood and consequences components of the risk equation. The likelihood of radionuclide release to the surface environment can be reduced through the use of multiple barriers, including natural barriers that do not require human intervention or management. The severity of consequences can be managed through the rigorous application of the As Low As Reasonably Achievable principle, i.e., the design and operation of a facility includes all reasonable features to keep radiation doses well below dose limits.

Submissions from some participants indicated that no matter how conservative the assumptions were, how many barriers there would be, or how low the probability of the risk was, there was no confidence that the risk from the DGR could ever be tolerable. The Precautionary Principle cannot sufficiently address the concerns of these participants because there is an underlying issue of lack of trust in the models, the decision-making process, and/or the proponent and decision-makers. The building of trust requires long-term, meaningful engagement. The subject of engagement is discussed elsewhere in this report.

3. The role of values in the evaluation of risk

The Panel heard a lot about values. Aboriginal values associated with the land and the immutable connection between the land and Aboriginal people were highlighted in written and oral submissions. The value of Lake Huron and the Great Lakes in general was a dominant theme for many participants.

The use of language by some participants invoking “moral imperatives” to protect the Great Lakes is explicitly values-based. On the one hand, there is evidence of very broadly-based and strong agreement with the high value of the Great Lakes as a source of services to humans, including drinking water and recreation, as well as their inherent ecological and spiritual value. However, does high value equate with high risk? The scientific evidence says no, but is scientific evidence enough? There was a wide-spread opinion that highly-valued components of the natural world, particularly Lake Huron, would be exposed to severe and wide-ranging consequences from the project. The more highly valued the component, the more severe and wide-ranging the consequences were assumed to be. There was a missing link in this discussion – likelihood. The prevailing opinion among participants who had concerns about the project was that no matter how low the likelihood and how low the actual radionuclide concentrations, any release to Lake Huron would be unacceptable over any time frame.

One other aspect of this discussion was the plausible consequences. Thousands of people signed a petition and dozens of municipal and regional councils passed resolutions with language that presented high consequences to drinking water and the ecology of the entire Great Lakes as almost a given. The origin of this opinion appeared to be the combination of a highly valued environment with an unfamiliar and uncertain concept, notwithstanding any and all applications of the Precautionary Principle in assessing the concept.

Reconciling the science-based and values-based points of view through the use of the Precautionary Principle may not be possible for some participants; however the probability of this increases if trust increases. Engagement with stakeholders across the Great Lakes Basin will be required to build this trust and to initiate discussions about the broader risk context for the Great Lakes, including widespread habitat destruction, invasive species and nutrient enrichment.

With these views regarding values in mind, and in the context of an environmental assessment review, the Panel makes the following recommendation:

Recommendation 3.B: Future guidelines for the conduct of environmental assessment under the *Canadian Environmental Assessment Act, 2012* should include explicit recognition of the role of values in establishing the appropriate level of precaution, and, further, should provide guidance regarding the methods and approaches for use in incorporating values into the application of the Precautionary Principle. Explicit consideration of the values inherent in Aboriginal world views should be included. Applicable case studies illustrating the role of values in establishing the level of precaution should be described.

The Panel suggests that it would be useful for future assessments of the project to have plain language explanations of how the precautionary approach would apply to those assessments. The Panel is also of the view that OPG should include this information in its public information program. As such, the Panel makes the following recommendation:

Recommendation 3.2: As part of its public information program, OPG shall prepare succinct, plain language explanations of the application of the Precautionary Principle to any future studies or assessments regarding the DGR. These explanations should be included in any future public proceedings regarding the DGR.

3.4 PANEL CONCLUSION REGARDING OPG'S ENVIRONMENTAL ASSESSMENT METHODOLOGY

The Panel concludes that OPG has met the requirements of the EIS Guidelines in carrying out its assessment of the project. The Panel is satisfied that OPG incorporated the guiding principles outlined in the EIS Guidelines, and that OPG's determination of the significance of residual adverse effects was acceptable. The Panel notes that the combination of the three different methodologies used by OPG and CNSC staff provided the Panel with additional confidence regarding the determination of significance.

The Panel is satisfied that OPG adequately:

- identified all environmental effects that were likely to arise from the project;
- proposed measures to mitigate adverse effects; and
- predicted whether there would be likely significant adverse environmental effects after the implementation of mitigation measures.

The Panel identified some additional baseline data needs which can be addressed by OPG prior to site preparation. The Panel emphasizes that the challenges inherent in the application of sustainability and the Precautionary Principle can, at least in part, be addressed through continuing engagement by OPG with Aboriginal groups and community stakeholders.

The Panel reiterates the important onus on OPG to use proven, reliable, and sustainable mitigation methods. Further, the Panel emphasizes the importance of the design of the follow-up monitoring program such that timely confirmation of the effectiveness of mitigation can be provided.

The project timeframe is expected to span decades, during which time the project would undergo continuous evaluation and re-evaluation, particularly through the CNSC licence phases and associated licence applications. The Panel strongly recommends that the complete public registry for the project remain fully available for the duration of the project, as far into the future as possible. This would allow the public, Aboriginal groups, regulators and government agencies to continue to access and make use of the information.

Recommendation 3.C: To allow convenient public and Government Agency access to all records related to the review of the project, the complete Canadian Environmental Assessment Registry for the project should remain available for the duration of the project and as far into the future as possible.

CHAPTER 4 THE PROPOSED PROJECT

Over the course of the review, OPG made several adjustments to the project description to reflect the new information produced since the completion of the EIS. The Panel notes that the fundamental aspects of the project, including waste types and volume, did not change. On October 17, 2014, at the request of the Panel, OPG submitted a consolidated project description to include the revised aspects of the project that were included in the review. OPG noted that the environmental assessment was based on a preliminary design for the DGR, and that it would develop a detailed design should the project be approved.

This chapter is based on the consolidated project description and includes a description of the proposed project site, the waste types and volumes expected to be placed in the DGR, a description of the project's physical works and phases, and financial aspects. The review of the proposed project included any modifications that were developed over the course of the review.

Figure 6: Key Features of the Bruce Nuclear Site (reproduced from DGR EIS Figure 6.3.3-1)

4.1 PROJECT LOCATION

OPG has proposed to construct the DGR on the 932-hectare Bruce nuclear site located within the Municipality of Kincardine (Figure 6). The Bruce nuclear site encompasses two operating nuclear generation stations with four reactors each, Bruce A and Bruce B, as well as the Douglas Point nuclear generating station, which is no longer in operation. In addition, the site includes the former Bruce Heavy Water Plant and the WWMF. Although OPG is the owner of the Bruce nuclear site, the majority of the site is controlled under a long-term leasing agreement with the current operator, Bruce Power. Bruce Power also controls all access to the site. Under the leasing agreement between OPG and Bruce Power, OPG has retained control of a portion of the Bruce nuclear site, including the WWMF and adjacent lands.

The Douglas Point generating station was constructed by the former Ontario Hydro and Atomic Energy of Canada Ltd., and operated until 1984. This facility remains in place with the reactor shut down and in a safe storage state. The used fuel from the reactor is stored in concrete canisters at the Douglas Point facility.

The Bruce A nuclear generating station began operation in 1977 but was taken out of service in the late 1990s. The Bruce B nuclear generating station reactor units went into service between 1984 and 1987. In 2001, OPG leased the Bruce A and Bruce B nuclear generating stations to (now) Bruce Power, which has since returned the Bruce A reactor units to service.

The Bruce Heavy Water Plant began operation in 1973 and provided heavy water for use in CANDU reactors until 1997. OPG received a decommissioning licence from the CNSC for the facility in 2004.

The WWMF has been developed in stages since 1974, and began operation in 1976. It has been operated by OPG (previously Ontario Hydro), since it was originally constructed. The WWMF was developed to provide interim storage for L&ILW generated by the operation of OPG's 20 nuclear reactors at the Bruce, Pickering and Darlington nuclear generating stations until the development of a long-term management facility. The WWMF includes accommodation for the storage of L&ILW, as well as a dry storage facility, which began operating in 2002, for used fuel from the Bruce A and Bruce B nuclear generating stations.

OPG proposed to locate the project on the OPG-retained lands at the centre of the Bruce nuclear site, located in the area immediately north of the WWMF, approximately one kilometre from the Lake Huron shoreline. The project site would be situated to the south of the Bruce A nuclear generating station and to the northeast of the Bruce B nuclear generating station. The project surface facilities would cover approximately 30 hectares, including the construction laydown areas and the area designated for waste rock management. The areal extent of the underground facilities would be approximately 40 hectares.

In 1966, the proposed site was in a natural “green field” state, which was then cleared and used as a construction laydown area for the Bruce Heavy Water Plant from 1971 to 1980. Some areas on the site contain mature trees that likely existed prior to the development of the Bruce nuclear site. OPG noted that Aerial photos from 2007 and 2009 depict what appears to be a remnant concrete pad of a structure that had been located near the proposed location of the two DGR shafts. During the period 2007 to 2009, the project site was used for the disposal of clean soil, which has since been placed in areas that were formerly used for construction laydown. From 1971 to 2009, a railway was present at the southern end of the project site but this railway is no longer in service.

4.2 WASTE TO BE MANAGED IN THE DGR

OPG's project description included a description of the types of waste that would be managed in the DGR, as well as the expected volumes of each waste type. OPG also provided information about waste types that were excluded from the project.

4.2.1 Waste Types

OPG stated that the DGR would contain L&ILW produced by the operating nuclear generating stations at Pickering, Darlington, and Bruce, and refurbishment waste generated from activities such as the replacement of motors, valves, instrumentation, fuel channels and steam generators in existing reactors. Formal definitions of low-level and intermediate-level radioactive waste are provided below, including Canadian Standards Association definitions. A more detailed description of waste types is provided in Chapter 7. As previously explained, these wastes are currently being processed and stored at the WWMF.

Low-level Radioactive Waste

Low-level waste consists of common industrial items that have become contaminated with low levels of radioactivity during routine clean-up and maintenance at the nuclear generating stations. It consists of mops, rags, paper towels, temporary floor coverings, floor sweepings, protective clothing, and hardware items such as tools. The majority of these wastes are processed through incineration or compaction for volume reduction.

Canadian Standards Association Waste Categorization Definitions

CSA Standard N292.3-08 Management of Low- and Intermediate-Level Radioactive Waste (CSA 2008) provides the following definitions of low-level waste, intermediate-level waste and high-level waste:

a) Low-level radioactive waste contains material with radionuclide content above established clearance levels and exemption quantities, but generally has limited amounts of long-lived activity. Low-level waste requires isolation and containment for periods of up to a few hundred years. Low-level waste does not generally require significant shielding during handling and interim storage.

b) Intermediate-level radioactive waste typically exhibits levels of penetrating radiation sufficient to require shielding during handling and interim storage. Intermediate-level waste generally requires little or no heat dissipation during its handling, transportation, and long-term management. However, because of its total radioactivity level, intermediate-level waste might require consideration of the implications of short-term heat generation. Because of its long-lived radionuclides, intermediate-level waste generally requires a higher level of containment and isolation than can be provided in near-surface repositories.

c) High-level radioactive waste is used (i.e., irradiated) nuclear fuel that has been declared as radioactive waste and/or is waste that generates significant heat (typically more than 2 kW/m3) via radioactive decay. Used nuclear fuel is associated with penetrating radiation; thus, shielding is required. Used nuclear fuel also contains significant quantities of long-lived radionuclides, necessitating long-term isolation. Waste forms derived from used nuclear fuel (e.g., nuclear fuel reprocessing wastes) can also exhibit similar characteristics and thus are considered high-level. Placement in deep, stable geological formations is recommended for the long-term management of high-level waste.

Intermediate-level Radioactive Waste

Intermediate-level waste consists of ion exchange resins, filters and irradiated reactor core components. Because of its physical condition and greater levels of radioactivity, it is not processed for volume reduction. Intermediate-level waste is stored in concrete- and steel-lined structures constructed in boreholes, in concrete-lined and covered trenches, and in concrete above-ground structures.

4.2.2 Waste Volumes

OPG stated that, based on the existing and projected inventory, the DGR was expected to receive approximately 50,000 waste packages representing a total emplaced volume of approximately 200,000 m^3. The total projected inventory was based on a scenario where each of the current reactors at the Bruce, Pickering and Darlington nuclear generating stations operates to the end of its planned life, including a mid-life refurbishment of most of the reactors. They annually generate approximately 5,000 m^3 to 7,000 m^3 of waste, which, after processing, results in 2,000 m^3 to 3,000 m^3 of additional stored waste at the WWMF.

Figure 7 shows the expected relative distribution of waste planned for emplacement in the DGR, by emplaced volume. About 75% is operational low-level waste, about 15% is operational intermediate-level waste, and about 10% is refurbishment L&ILW.

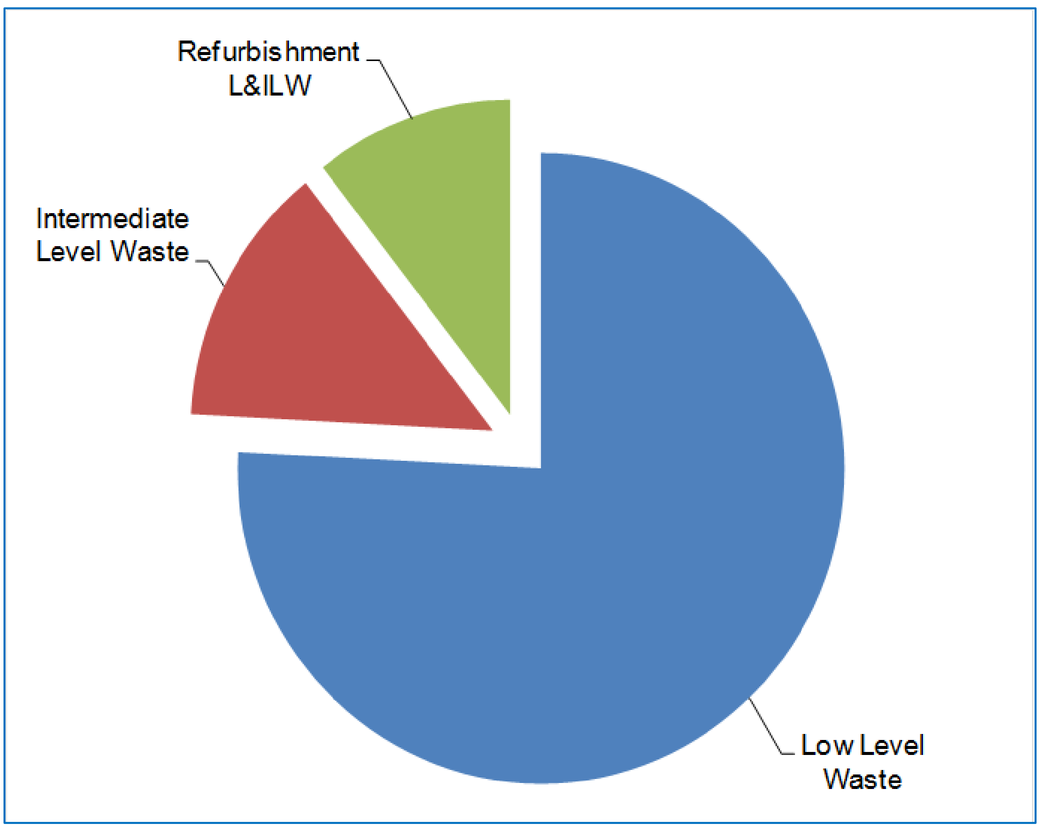


Figure 7: Relative Waste Volumes planned for Emplacement in the DGR (reproduced from EIS Figure 4.5.1-1)

4.2.3 Waste Types Excluded from the Project

OPG's DGR application was for the emplacement of L&ILW currently in storage at the WWMF, as well as that produced from the continued operation of OPG-owned generating stations at Darlington, Pickering and Bruce. The project specifically excludes:

- Decommissioning waste from OPG-owned nuclear generating stations;
- High level waste, i.e., used nuclear fuel and recognizable fuel fragments;
- Waste from other nuclear power plant owners;
- High thermal cobalt-60 sources;
- Corrosives, explosives or compressed gases;
- Waste packages that contain more than 1% by weight of chelating agents or monodentate organic liquids; and
- Waste packages with more than 1% by weight of trace or unintentional petroleum oils.

OPG's initial assessment of L&ILW waste volume from the decommissioning of the Pickering, Darlington and Bruce nuclear generating stations was approximately 135,000 m^3. OPG noted that detailed waste volumes and characteristics are not currently available as decommissioning is not expected to occur for several decades. OPG stated that the decommissioning of each generating station would require a separate, new environmental assessment, which would address the management of the decommissioning waste at that time.

As previously stated, used fuel, otherwise known as high-level waste, would not be accommodated in the DGR. OPG stated that its regulatory application for the project was only for L&ILW, and the DGR Hosting Agreement between OPG and the Municipality of Kincardine was only for L&ILW. The federal government has mandated a completely separate and distinct approach, Adaptive Phased Management, for all of Canada's used fuel. OPG noted that a repository for high-level waste, as well as liquid, highly reactive or gaseous wastes, would necessitate different design requirements than the proposed DGR.

OPG's cumulative effects assessment included the potential management of decommissioning waste in the DGR, as well as the transport of used fuel off the Bruce nuclear site to a hypothetical used fuel repository. These subjects, as well as Panel rulings regarding their consideration in the review, are addressed in Chapter 15.

4.3 PHYSICAL STRUCTURES OF THE DGR

The physical structures of the DGR include surface facilities and underground facilities.

4.3.1 Surface Facilities

OPG stated that the various permanent surface structures and facilities to be constructed as part of the project included, but were not limited to, the main shaft headframe, the ventilation shaft headframe and hoist house, the waste package receiving building, intake and exhaust fans and heater house, the waste rock management area, and the stormwater management pond (Figure 8). The permanent facilities are outlined below. Temporary structures and facilities usedduring construction would be removed following the completion of construction activities.

Figure 8:DGR Surface Infrastructure Layout (reproduced from DGR EIS Figure 4.4.1-2)

Main shaft headframe building: The main shaft would provide primary access to the repository. The main shaft headframe would house hoisting equipment to lower and raise cages for transporting personnel, equipment and waste packages.

Waste package receiving building: The waste package receiving building would receive the waste packages from the WWMF and stage them for transfer onto the main shaft cage. The building would be connected to the main shaft headframe, and include a maintenance and storage area.

Compressor building: This building, located nearby the main shaft, would house two compressors to provide compressed air for surface and underground use. One compressor would normally operate with the other on stand-by. The compressors would also provide air to the underground refuge stations in the event of an emergency.

Intake fans and heater house: The function of the surface intake fans would be to provide the required airflow for the DGR. Heaters would be used during the winter to raise air temperature before delivery underground.

Offices, main control room and amenities building: The offices and main control room are part of the amenities building that would be attached to the north side of the main shaft headframe and waste package receiving building. Lockers, change room and showering facilities, lunch room and training/visitor’s area would be located in this complex. The main control room, forming a part of the amenities area, would be equipped with computing, control, and monitoring equipment to marshal all signals and data transmitted from underground. Other facilities include a lamp room, mechanical equipment rooms and storage.

Ventilation shaft headframe and collar house: The ventilation shaft would exhaust the repository ventilating air and be used as a second egress and for hoisting rock to surface during the construction phase. The collar house would be used for general maintenance and storage of shaft hardware and equipment spares.

Ventilation shaft hoist house: The hoist house would house the double drum hoist for the ventilation shaft, which would operate a two-compartment conveyance. The hoisting equipment would be for shaft sinking, waste rock removal during repository development, and egress during operations. The ventilation shaft would include a single skip – counterweight configuration to be utilized for waste rock removal during construction, guided by rope guides. Arresting gear would not be required for a double drum arrangement. The ventilation shaft drum hoist with the single skip – counterweight configuration would be removed after construction. During the construction phase, the ventilation shaft would also be fitted with an auxiliary Blair hoist (double-rope), outfitted with a double deck cage capable of transporting 12 persons, to operate as a service hoist. After construction, the auxiliary Blair hoist would remain in operation for shaft inspections and emergency egress.

Exhaust fan building: Exhaust fans would be located at the exit of the ventilation shaft plenum. Although the main exhaust ventilation fans would be located near the ventilation shaft on the repository level, the surface fans would assist in directing the exhaust through the plenum and not up through the ventilation headframe. The building would be equipped with acoustic baffled silencers to reduce noise.

Waste rock management area: Waste rock generated as a result of excavation of the shafts and underground openings at the repository level would be managed on the project site in the waste rock management area. Approximately 1,000,000 m^3 of rock would be managed over the long-term in the waste rock management area. The overall footprint of the waste rock management area, including its stormwater management system, would be approximately 17 hectares. Separate temporary waste rock piles for dolostone and shale would also be accommodated on the project site.

Stormwater management pond: All stormwater runoff from the project site, as well as any groundwater pumped to surface from underground sumps, would be directed via ditches to the stormwater management pond for treatment to remove suspended solids. The stormwater management pond would be sized to provide a retention area for the settling of particles and the ability to retain a 6 hour, 25 millimetre rain event. The entire stormwater management system would be sized to safely pass run-off from a large storm event with no damage to the system. The stormwater management pond would be constructed with a low permeability base and would discharge into the existing Bruce nuclear site drainage ditch network for release to MacPherson Bay in Lake Huron. A network of drainage ditches would be constructed around the project site, including the perimeter of the waste rock management area, to confine run-off to the site area.

Road connections to WWMF: A two-lane road situated on a fill embankment over the abandoned rail bed and existing ditches crossing over the abandoned rail bed (i.e., the North Railway Ditch and the South Railway Ditch) would provide direct access between the WWMF and the project site. Culverts would be used to provide for water flow in the two existing ditches. The road would allow for vehicle and personnel passage and be fenced along both sides, connecting with the fencing around the WWMF and the DGR surface facilities. OPG has assumed that this crossing would remain in place after operations have ceased.

OPG stated that after the completion of shaft sinking, the temporary structures associated with sinking activities, such as the temporary main shaft sinking hoist house, main shaft and ventilation shaft winch houses, would be removed. The main shaft headframe would be furnished for the permanent operations including installation of the main and auxiliary hoists. All temporary structures, including temporary offices, fuel storage, storage structures and a concrete batch plant, would be removed from the site following completion of construction activities.

4.3.2 Underground Facilities

OPG stated that the underground layout of the repository would have two vertical shafts in an islanded arrangement that would include an underground services area for the provision of offices, a workshop, a wash bay, a permanent refuge station, lunch room and a geotechnical laboratory. This arrangement would enable most of the underground infrastructure to be kept close to the shafts, while keeping the waste emplacement areas away from areas that would normally be occupied by workers. Portable refuge stations would be placed within access tunnels adjacent to each panel of emplacement rooms.

The underground atmosphere would be maintained in a reasonably steady and dry state to limit corrosion of structures and waste packages. There would be two panels of emplacement rooms, with Panel 2 being filled first with the majority of the waste packages in storage at the WWMF at the time that emplacement operations commence. Both panels would contain low-level waste and intermediate-level waste storage rooms. OPG stated that, in general, low-level waste and intermediate-level waste packages would not be stored in the same room. Three rooms in Panel 1 would be equipped with rail tracks that would be used to move some of the heavier intermediate-level waste packages. OPG further stated that the underground arrangement would enable the underground infrastructure to be kept in close proximity to the shaft, while keeping the emplacement areas away from areas normally occupied by workers. Each of the underground structures and facilities is outlined below.

Shafts: As previously noted, two shafts would provide access to the repository: the main shaft and the ventilation shaft. The main shaft would provide access to the repository for personnel and waste, provide a secondary conduit for services and fresh air to the repository, and be an alternative route for the transport of any collected water from underground to the surface. The ventilation shaft would provide the primary conduit for services to the repository, provide emergency access for staff to and from the repository, provide a route for exhaust air from the repository, and be used for the removal of excavated rock from the repository. A ramp down from the repository level would provide access to the bottom of both shafts for the construction and operations phases, and provide access to the loading pocket, used only during construction for loading waste rock into a conveyance for delivery to surface.

Underground services area: The underground services area would include the amenity and equipment maintenance areas, as well as the electrical substation, geoscience area and sanitary facility. The amenities would include a permanent refuge station combined with a lunch room and an office, sized and designed for 50 people, and with radiological protection controls at the entrance. The refuge station would be equipped with emergency supplies of fresh water, compressed air, a fire-rated door with sealing materials, and a communications link with the surface. Portable refuge stations, positioned close to the emplacement rooms as they are developed and being filled during operations, would also be included. The maintenance shop, service bay and diesel fuel bay would be used for servicing underground equipment.

Access tunnels: The main access-ways would consist of the access tunnel from the main shaft, south access tunnel, and two panel access tunnels. Access to the emplacement rooms from the main shaft and ventilation shaft stations would be via two panel access tunnels designed for single vehicle passage with poured concrete floors. A portion of the Panel 1 access tunnel would have rail embedded in the concrete floors to allow movement of rail carts loaded with large and heavy packages. Exhaust ventilation (or return air) tunnels would provide a continuous path to the ventilation shaft for spent air. The exhaust ventilation tunnels would not typically be occupied other than for inspection and maintenance, however, they could provide a means of secondary egress.

Waste emplacement rooms: There would be two panels of emplacement rooms for storage of the waste. Panel 1 would have 14 rooms and Panel 2 would have 17 rooms. The room dimensions would be generally sized at 8.6 m wide by 7.1 m high, and all would be nominally 250 m in length. The waste packages in the emplacement rooms would be systematically arranged based on the waste type and the physical characteristics of the packages. The floors of the emplacement rooms would be poured concrete to facilitate packing efficiencies and forklift movement. Some emplacement rooms would have rail embedded in the concrete floors to facilitate the movement of heavy intermediate-level waste packages. The ends of the rooms would be interconnected with the exhaust ventilation tunnel and use a bulkhead to regulate ventilation from the room. The entrance of the emplacement rooms would allow sufficient space for end walls to be constructed, once the rooms have been filled, to restrict access and provide shielding, as required.

4.3.3 Common Services

OPG described the common services for the DGR, which would include:

- the ventilation system;
- dust control measures;
- the electrical supply, including the emergency power system;
- the communication system;
- control and monitoring systems, including fire detection and suppression;
- fuel storage facilities;
- potable, industrial and fire water delivery;
- the sewage system; and
- fire protection, including surface and underground facilities.

All of the above systems are required to ensure occupational health and safety as well as environmental performance.

4.4 PROJECT PHASES

The project would include the following phases:

- site preparation and construction;
- operations;
- decommissioning; and
- abandonment (long-term performance).

Activities under these phases require different licences from the CNSC under the *Nuclear Safety and Control Act*, and have to conform to regulatory requirements. For any CNSC licence application, a proponent must file the required material to be reviewed by the Commission prior to the application being considered. When issuing a licence under subsection 24(2) of the *Nuclear Safety and Control Act*, the Commission must be satisfied that the proponent is qualified to carry out the authorized activities and that the proponent will make adequate provision for the protection of the environment, the health and safety of persons, and the maintenance of national security and international obligations. The DGR would be considered a Class IB nuclear facility under the *Class I Nuclear Facilities Regulations*.

OPG's application for a Licence to Prepare Site and Construct was the first in a series of licences that would be required for the project. Over the life of the project, the following licences would be required:

- Licence to Prepare Site and Construct;
- Licence to Operate;
- Licence to Decommission; and
- Licence to Abandon.

4.4.1 Site Preparation and Construction

OPG stated that, should a site preparation and construction licence be granted, its first activity would be to complete the detailed design for the project. OPG explained that site preparation would involve the preparation of the site infrastructure for construction activities, and include clearing approximately 30 hectares of the project site and preparing the construction laydown areas. Infrastructure, such as waste rock and stormwater management areas and roads, would also be constructed as part of site preparation activities.

As described by OPG, specific activities associated with site preparation would include:

- site fencing;
- removing brush and trees and transferring them for storage or use as mulch on OPG-retained lands;
- excavating, removing and stockpiling topsoil for later use elsewhere on the project site or on other OPG-retained lands on the Bruce nuclear site;
- grading the project site, including grading of construction access roads, construction laydown areas, the waste rock management area and various building locations;
- constructing the site drainage system, including excavating all ditches and constructing the stormwater management pond;
- implementing a ground improvement program (grouting), if required, for the main shaft and ventilation shaft in advance of shaft sinking to control potential groundwater inflows; and
- installation of services and potential tie-ins.

Specific activities associated with construction would include:

- construction of permanent buildings, including two headframe buildings;
- set-up of shaft-sinking equipment, and sinking of main and ventilation shafts;
- development of access tunnels and emplacement rooms;
- placement of excavated rock in the waste rock management area and temporary piles; and
- commissioning of the DGR facility.

OPG stated that the site preparation and construction phase was expected to last about 10 years.

4.4.2 Operations

OPG stated that waste emplacement operations would commence following construction and after OPG obtains a licence to operate the DGR from the CNSC. As described by OPG, specific activities associated with operations would include the following:

- receipt of disposal-ready waste packages;
- movement of waste packages from surface to below ground;
- placement of waste packages in emplacement rooms;
- installation of end walls on full emplacement rooms;
- installation of closure walls in tunnels;
- maintenance of various systems including hoists, fire protection systems, waste handling equipment and underground rock support; and
- monitoring, such as additional geomechanical testing and measurement, to ensure the facility is performing as expected.

OPG stated that the operations phase was expected to last about 40 years.

4.4.3 Decommissioning

OPG stated that decommissioning would begin following a period of monitoring after all of the waste has been emplaced and after OPG obtains a licence to decommission the DGR from the CNSC. The objective of decommissioning would be to permanently retire the DGR facility from service in a manner that ensures the health and safety of the public and the workers, and protection of the environment. OPG explained that decommissioning would involve closing the DGR and restoring it to an agreed end-state; upon completion of decommissioning and obtaining a licence to abandon the site, the site would be in a condition that would make it available for other uses while under institutional controls.

OPG noted that planning for decommissioning would be an on-going process, with planning assumptions expected to change over time. As such, OPG would periodically review and revise the Preliminary Decommissioning Plan to incorporate changes in the planning assumptions. Specific activities associated with decommissioning would include:

- installation of concrete monolith at base of shafts;
- sealing the shafts;
- removal of surface buildings; and
- recycling of materials and disposal of waste.

OPG stated that the decommissioning phase was expected to last about five to six years.

4.4.4 Abandonment

Abandonment refers to the period following the decommissioning and closure of the DGR. There are no specific works and activities during this phase. The abandonment and long-term performance phase would require a licence to abandon the facility from the CNSC, and would also include a period of institutional controls to ensure the protection of human health and the environment. For safety assessment purposes, and consistent with national guidance and international practice, OPG assumed that the institutional controls for the DGR would remain in place for up to 300 years.

OPG explained that institutional controls would help prevent or reduce the likelihood of human actions inadvertently interfering with the waste or causing degradation of the safety features of the repository. Institutional controls could include passive controls and active controls. Passive controls could include local land use controls, preservation of knowledge and memory through public records/archives, and use of durable surface and/or subsurface markers. Active controls could include activities requiring action by some authority to conduct monitoring, surveillance, maintenance of the monitoring equipment, remedial work, and maintenance of some aspects of the site features.

4.5 FINANCIAL ASPECTS

Financial aspects include OPG's long-term planning, as well as the financial guarantee for decommissioning following site preparation and construction.

4.5.1 Project Funding

OPG stated that, in the early 1990s, it developed financial plans for long-term waste management on the basis that future generations should not bear the cost of today's operations. OPG explained that it makes financial contributions to segregated funds dedicated solely for the long-term management of waste and for the decommissioning of its generating stations. These funds would pay the costs associated with developing and operating a facility for the long-term management of L&ILW, a facility for long-term management of used fuel, and the decommissioning of generating facilities. OPG reported that, as of end of 2009, the fund was valued at approximately $10 billion. According to OPG, the expected cost of the project was approximately $1 billion.

OPG stated that it was committed to maintaining the required financial, technical and administrative capabilities to ensure the safe construction and operation of the DGR. From a financial perspective, funding for the project would be derived from OPG's segregated Decommissioning Fund, the adequacy of which is routinely reviewed as part of the financial guarantee requirements of the CNSC.

4.5.2 Early Decommissioning

OPG stated that, in the event that the project was cancelled, for any reason, during the site preparation and construction phase or prior to waste emplacement, OPG would decommission the project site. OPG's application for a site preparation and construction licence included a proposed financial guarantee, in the form of a Letter of Credit through a third-party financial institution, as well as a plan for a decommissioning financial guarantee associated with the licensed activities of site preparation and for construction of the DGR facility. The financial guarantee was for the decommissioning of a constructed DGR prior to placing the facility in operation, and return of the site to a pre-licence state. This financial guarantee would need to be approved by the CNSC at the time of licensing.

CNSC staff stated that the proposed financial guarantee for the site preparation and construction phase was acceptable and met the requirements of CNSC Regulatory Guide G-206, *Financial Guarantees for the Decommissioning of Licensed Activities*. CNSC staff noted that the Letter of Credit would be on a sliding scale basis that escalates as the financial guarantee obligation increases during site preparation and construction.

CHAPTER 5 PURPOSE, NEED AND ALTERNATIVES

This chapter summarizes the information presented by OPG to fulfill the requirements of the EIS Guidelines with respect to the purpose of and need for the project, alternatives to the project, and alternate means of carrying out the project. It also includes the views of CNSC staff and participants, as well as the Panel's assessment of this information.

5.1 PURPOSE OF AND NEED FOR THE PROJECT

The EIS Guidelines stipulated that OPG must clearly describe the need for the proposed DGR. The description was to define the problem or opportunity the project is intending to solve or satisfy, and was to establish the fundamental rationale for the project. OPG was to describe the purpose of the project by defining what is to be achieved by carrying it out, and include a description of how the site location was selected. The need for and purpose of the project were to be established from the perspective of the project proponent and provide the context for the consideration of alternatives.

5.1.1 Purpose of the DGR

According to OPG, the purpose of the DGR is to provide for the safe, long-term management of the existing and forecasted inventory of L&ILW produced by OPG-owned or -operated nuclear generating stations, up to an emplaced volume of approximately 200,000 m^3. OPG, as the owner of this waste, has the legal responsibility to manage it in a safe and environmentally responsible manner. OPG stated that the long timeframe requires a solution that would:

- protect humans and the environment;
- be passive; and
- not require long-term institutional control.

5.1.2 Need for the DGR

OPG stated that the project is needed because it would protect people and the environment from the hazards of L&ILW in both the short- and long-term. OPG plans to manage the DGR inventory in the very long term, covering the extended period of time that the radioactivity in the waste might pose a concern to the health and safety of persons and the environment. Some forms of L&ILW contain long-lived radionuclides, which can be hazardous for hundreds, and in some cases, thousands of years. OPG was of the view that permanent emplacement of the waste in a DGR, where it would be separated from the biosphere by multiple geological barriers, would be a safer solution over the long term than the current method of storage at the WWMF. OPG currently stores about 100,000 m^3 of L&ILW from operations and refurbishment at the WWMF.

OPG noted that, even if all future wastes were reduced to zero, the need for the project would not be eliminated due to the existing volume of stored wastes. OPG further noted that, while near-surface disposal facilities can provide the required protection for shorter-lived radionuclides, deep geologic disposal in suitable rock formations is the safest solution, and consistent with international guidance and practice, for long-lived radionuclides.

The need for the project is driven by OPG's intention of providing a long-term solution for its L&ILW and not leaving this task and cost for future generations. OPG explained that the WWMF was developed to provide interim storage for L&ILW until a long-term management facility had been established. OPG stated that, although the WWMF structures were designed for a minimum life of 50 years and could continue to safely store the waste much longer than 50 years with proper maintenance, it would be better to implement a long-term solution now.

According to OPG, Canadians have indicated that they do not want to wait another generation for substantial progress to be made in developing long-term solutions for radioactive waste management. This view was shared by the Municipality of Kincardine, which believed that it was important for OPG to plan and take responsibility for the long-term management of this waste now.

5.1.3 Regulatory Responsibility

The federal government is responsible for oversight and regulation of nuclear waste in Canada. Under the federal *Radioactive Waste Policy Framework*, the responsibility for managing L&ILW lies with the waste producer. OPG is therefore responsible for the short and long-term management of L&ILW waste from the Pickering and Darlington nuclear generating stations. Under the terms of its lease agreement with Bruce Power, OPG is also responsible for managing the L&ILW from the Bruce generating stations.

Every aspect of the management of L&ILW by OPG is regulated by the CNSC. The CNSC issues operating licences and inspects all nuclear facilities and related activities to ensure that operations meet all applicable federal regulatory criteria and do not pose undue risks to people or the environment. OPG stated that it has operated, and continues to operate, in compliance with federal regulatory requirements.

Used Nuclear Fuel

In accordance with the EIS Guidelines, the long-term management of used nuclear fuel is not within the scope of the project. Therefore it is not and has not been considered as part of this environmental assessment. The long-term management of used nuclear fuel is under the mandate of the Nuclear Waste Management Organization, which was established pursuant to the *Nuclear Fuel Waste Act*. The Nuclear Waste Management Organization has the statutory mandate to implement Adaptive Phased Management, the approach for the long-term management of used nuclear fuel that was approved by the federal government in 2007. Adaptive Phased Management is entirely separate and distinct from the project.

Some participants expressed the view that OPG should not proceed with the project until the Adaptive Phased Management process has been carried out. Views were also expressed that the Adaptive Phased Management process should have included the L&ILW produced by OPG owned and -operated nuclear generating stations. OPG noted that this would not be consistent with the Radioactive Waste Policy Framework.

OPG explained that its application to the CNSC for a site preparation and construction licence was for a DGR for the OPG L&ILW, and that the submitted safety case was specifically for L&ILW. Correspondingly, the licence, if granted, would be to prepare the site and construct a DGR as described in the documents submitted in support of the licence application. The subsequent operating licence would limit OPG to the emplacement of wastes in the DGR consistent with those described in documents submitted in support of that licence.

OPG further stated that neither OPG nor the Nuclear Waste Management Organization had evaluated the technical potential for the proposed DGR to be transformed into a repository for used nuclear fuel, nor were there any plans to conduct such an evaluation. In addition, the Municipality of Kincardine passed a resolution indicating that no used fuel is to be placed in the DGR.

Why Used Fuel Could Not be Placed in the DGR

Some participants expressed concerns that the proposed DGR might eventually be used for the disposal of used nuclear fuel. OPG stated that it could not transform the DGR into a facility for high-level waste, i.e., used nuclear fuel, disposal for three primary reasons:

1. OPG has no legal ability to establish a DGR for used fuel;
2. The regulatory process would not allow OPG to put used nuclear fuel into a DGR licensed for L&ILW; and
3. OPG has made a public commitment that used fuel would not be placed in the L&ILW DGR.

5.1.4 Selection of the Project Location

OPG outlined its reasons for selecting the Bruce nuclear site as its preferred location for the proposed project. The OPG decision was based on several factors including:

- the likelihood of highly suitable geology at the Bruce nuclear site;
- the request by and support of the community for the establishment of a long-term solution for radioactive waste management; and
- the additional disruption and cost associated with transportation to another location

OPG described the process leading to its decision to proceed with the DGR. This process is summarized in Table 4. In 2001, the Municipality of Kincardine approached OPG regarding its long-term plans for the management of L&ILW, and expressed an interest in being the host Municipality for such a project. In April 2002, a Memorandum of Understanding was signed setting out the terms under which OPG, in consultation with the Municipality of Kincardine, would develop a plan for the long-term management of L&ILW at the WWMF. Under the terms of the Memorandum of Understanding, Kincardine and OPG undertook a fact-based assessment of possible long-term management options for low-level waste at the Bruce nuclear site. The ability of the repository concepts to accept intermediate-level waste was also assessed qualitatively.

Table 4: Background Timeline for the Project - Involvement of the Municipality of Kincardine

Date	Milestone
April 25, 2001	The Federal government introduced Bill C-27, a proposed *Nuclear Fuel Waste Act*, which prompted the Municipality of Kincardine to approach OPG regarding long-term plans for L&ILW
March 19, 2002	Municipality of Kincardine council passed a motion to support WWMF licence renewal only if OPG agreed to sign a Memorandum of Understanding for long-term plans for waste management.
April 16, 2002	Memorandum of Understanding between Municipality of Kincardine and OPG, setting out the terms under which OPG, in consultation with the Municipality of Kincardine, would develop a plan for the long-term management of L&ILW at the WWMF, signed
November 15, 2002	The *Nuclear Fuel Waste Act* (S.C. 2002, c. 23) came into force
February 2004	Independent Assessment Study of possible long-term management options for L&ILW completed by Golder Associates
April 21, 2004	Municipality of Kincardine council endorsed "Deep Rock Vault" option in Resolution 2004-232
August 2004	OPG decided that it would proceed with a DGR
Fall 2004	Councils of adjacent municipalities expressed support for the project 1. Town of Saugeen Shores: September 28, 2004 2. Township of Huron-Kinloss: October 13, 2004 3. Municipality of Arran-Elderslie: September 27, 2004 4. Municipality of Brockton: September 22, 2004
September 29, 2004	Kincardine council agreed to a municipal poll as means to assess support for the project
October 2004	Memorandum of Understanding between OPG and the Saugeen Ojibway Nation signed, outlining terms and a process for OPG and the SON to communicate on the Independent Assessment Study
October 13, 2004	Host Agreement between Municipality of Kincardine and OPG signed (Kincardine By-law No. 2004 -157)
January - February 2005	Strategic Council poll for the Municipality of Kincardine conducted
December 2, 2005	OPG submitted its proposal to prepare a site, construct and operate a Deep Geologic Repository (DGR) for low and intermediate level radioactive waste on the existing Bruce nuclear site within the Municipality of Kincardine to the Canadian Nuclear Safety Commission

OPG stated that, based on the results of the assessment, including an Independent Assessment Study performed by Golder Associates and tours of international nuclear waste management facilities, the Municipality of Kincardine passed a resolution in April 2004 selecting the Deep Rock Vault option as the preferred course of study in regards to the management of

L&ILW. OPG supported the Kincardine Council resolution and entered into a Hosting Agreement with the Municipality of Kincardine. OPG noted that the DGR Hosting Agreement would provide benefits to Kincardine and four surrounding municipalities for the licensing and construction of a DGR for L&ILW. OPG also decided to include long-lived intermediate-level waste in the waste inventory to be placed in the DGR once a DGR was selected as the preferred alternative.

OPG stated that, in accordance with the DGR Hosting Agreement, a period of public consultation was held from October 2004 to January 2005, followed by a telephone poll, which was conducted in January and February 2005 by a third-party firm, Strategic Council, on behalf of the Municipality of Kincardine. OPG further stated that the results of the poll demonstrated that a majority of Kincardine residents supported the project.The Panel considered additional information concerning the establishment of community support for the project as context for its review. The Panel received submissions from the Municipality of Kincardine, as well as from the Town of Saugeen Shores, the Township of Huron-Kinloss, the Municipality of Arran-Elderslie, and the Municipality of Brockton. All of these submissions expressed support for the project. The Municipality of Kincardine presented an overview of the Independent Assessment Study process and explained the rationale of the Municipality for selecting its preference for the DGR option, noting that visits to international waste repositories were instrumental in coming to this decision. The Panel also received an expression of support for the project from the County of Bruce and from elected municipal representatives who reiterated their councils' support for the project.

The Panel heard from some individuals and community groups, including seasonal residents of the Regional Study Area, that they did not support the official views of their municipal councils. Some participants criticized the Independent Assessment Study and 2005 telephone poll, and suggested that a municipal referendum should have been held instead. Some participants expressed the view that the DGR Hosting Agreement was a means by which OPG could influence the municipalities for their support, or felt that the terms of the agreement were not lucrative enough. Some residents expressed concerns regarding the conduct of their elected officials, members of Bruce County Council, in participating in alleged closed meetings with members of OPG, Nuclear Waste Management Organization and CNSC staff.

Other participants, including individuals and former elected officials, expressed support for the conduct of the Municipality of Kincardine in deciding to proceed with the DGR. They noted that the Independent Assessment Study was a public process that included public consultation, and that the DGR process had been discussed in open council meetings. Some agreed with the decision of the Municipality of Kincardine to conduct the Strategic Council poll rather than a referendum, as it resulted in a greater level of participation than a referendum likely would have had. They also supported the financial compensation in the DGR Hosting Agreement, noting that it was not unusual for facilities of this nature to have such arrangements with host communities. The Municipality of Kincardine noted that some facilities under the control of the Government of Ontario have agreements to establish payments to municipalities in lieu of property taxes.

Throughout the review, and particularly during the public hearing, the Panel requested and received additional information on these subjects, including the conduct of the Independent

Assessment Study, public consultation prior to the environmental assessment, the DGR Hosting Agreement, and the Strategic Council poll. The Panel is satisfied with the information it received. The issue of public acceptance of the project is discussed in Chapter 11 of this report.

5.1.5 Panel Conclusion Regarding Purpose and Need

The Panel is satisfied that OPG provided sufficient rationale to substantiate the purpose of and need for the proposed project. The Panel understands that OPG is responsible for the management of its L&ILW and that the proposed project offers a long-term solution to deal with this waste. The Panel agrees that it is not an issue that should be left unresolved for future generations, and that there are good reasons for OPG to put forward a project that will deal with the waste at this time. The Panel accepts OPG's rationale for selecting the Bruce nuclear site as its preferred location for the project. Analysis pertaining to OPG's preference for a DGR at the Bruce nuclear site is presented and discussed in the following sections on alternatives to the project and alternative means of carrying out the project.

The Panel emphasizes that its review did not include the issue of used fuel waste as this waste is not part of the proposed project. The Adaptive Phase Management process being undertaken by the Nuclear Waste Management Organization is a completely separate process to address Canada's used fuel waste, and the proposed DGR is not to be used for the management of this waste.

5.2 ALTERNATIVES TO THE PROJECT

The EIS Guidelines required that OPG present an analysis of alternatives to the project that describes functionally different ways to meet the project need and achieve the project purpose, from the perspective of the proponent. OPG was to:

- identify any alternatives to the DGR that were within the control and/or interests of OPG;
- explain how OPG developed the criteria to identify the major environmental, economic and technical costs and benefits of those alternatives;
- provide reasons for rejection of these alternatives; and
- identify the preferred alternative for the project based on the consideration of relative environmental, economic and technical benefits and costs.

5.2.1 Assessment of Alternatives to the Project

OPG described the assessment of alternatives to the project. OPG explained that the Independent Assessment Study, undertaken as part of the OPG Memorandum of Understanding with the Municipality of Kincardine, was done concurrent with engineering and geotechnical feasibility studies of concepts for low-level waste management at the WWMF. The concepts considered were:

- enhanced processing and storage;
- covered above-grade concrete vaults;
- shallow concrete vaults;
- deep concrete vaults;

- shallow rock cavern vaults in near-surface dolostone (less than 100 m below surface);
- deep rock cavern vaults in a thick salt bed (200 to 400 m below surface);
- deep rock cavern vaults in a tight shale formation (400 to 600 m below surface);
- deep rock cavern vaults in a tight limestone formation (600 to 800 m below surface); and
- ongoing management at the WWMF (status quo).

The results of a primary screening analysis eliminated deep concrete vaults and deep rock cavern vaults in a thick salt bed from further evaluation because suitable host formations are absent at the WWMF site. A secondary geotechnical feasibility screening showed that the shallow concrete vaults and shallow rock cavern vaults were not technically feasible at the WWMF site. The two final deep rock cavern vault concepts were combined and considered together as deep rock vaults (now referred to as the DGR). The four feasible concepts were compared considering relative technical, environmental and economic factors.

OPG stated that the Independent Assessment Study found that each of the four long-term management concepts was technically feasible and could be safely constructed at the WWMF site. OPG noted that there was considerable international experience using each of the concepts for the long-term management of L&ILW, and that each option was capable of meeting and exceeding Canadian and international safety standards.

OPG stated that, based on this assessment, the deep rock vault option was most preferred by the host community, considering technical/safety factors and environment/social factors. OPG agreed with this preference. OPG explained that the low permeability of the host rock for the deep repository concepts would meet radiological protection criteria, whereas surface repository concepts would require additional analysis to ascertain the degree to which intermediate-level waste could be managed. An examination of the environmental protection feasibility of the four options showed that all potential adverse effects could be mitigated or managed using known and proven methods. The status quo option was the most favourable for economic factors (i.e., lowest cost).

OPG presented Canadian and international research and experience that demonstrated that deep geologic disposal of long-lived radioactive waste is the most practical option. During the hearing, OPG explained that there are three ways to deal with any type of hazardous waste: to contain it and separate it from the biosphere, to dilute it to the point that the hazard is removed, or to alter it so that it is no longer hazardous. OPG stated that dilution would not be an acceptable option for the disposal of L&ILW. Further, OPG stated that, even if it were possible to alter L&ILW to the point that the radioactive hazard is removed, it would not be practical to do so, given the state of existing technology. As such, OPG was of the view that the only option would be containment and separation, with a DGR expected to provide the greatest margin of safety. OPG noted that this view was supported by a strong international consensus regarding long-term waste management.

Several participants questioned OPG’s preference for a DGR. Some participants expressed a preference for alternatives such as the status quo, hardened on-site storage or rolling stewardship. The Panel sought additional information from participants regarding these views. Participants explained that these alternatives would allow for continuous monitoring and response to any accidental releases, and could allow future generations to develop and use new technologies to eliminate the hazards associated with long-lived radioactive waste. The Panel heard from many participants that placing the waste in the DGR would result in the waste being out of sight, out of mind. Some participants expressed the view that the Independent Assessment Study, which had been conducted prior to the initiation of the OPG environmental assessment, did not meet the requirements of the EIS Guidelines.

Other participants supported the OPG preference for a DGR. These participants concurred with OPG's conclusion that a DGR would be the safest option for the long-term.

CNSC staff stated that OPG had adequately assessed alternatives to the project, as described by the EIS Guidelines. CNSC staff noted examples of international repositories that were considered to be acceptable facilities for the long-term management of radioactive waste.

Following the public hearing days in 2013, the Panel determined that it required more information about alternatives and alternative means, including alternative locations, and issued information request EIS-12-513 to OPG. In response to this information request, OPG presented the results of a study conducted by an Independent Expert Group (OPG IEG) regarding the relative risk of four alternatives, these being:

1. the as-is facility at the WWMF (the status quo);
2. enhanced surface storage at the WWMF (hardened storage);
3. the proposed DGR in the Cobourg Formation at the Bruce Power site; and
4. a conceptual DGR in granitic bedrock of the Precambrian Canadian Shield.

The OPG IEG evaluated the relative risks of the four options but was not directed to rank them. With respect to the relative risks of indefinite, long-term surface storage versus geologic disposal, the OPG IEG found that one issue of significant difference was the degree of confidence in the very long- term availability and operation of the active management required for both surface storage options. The OPG IEG stated that the risk associated with an eventual loss of institutional control would be greater for the surface storage options than for the DGR options.

Ultimately, surface or near-surface options would require a continued presence of institutional control onsite to ensure that the surface sites would be maintained and secured. Furthermore, surface storage sites would be more vulnerable to natural hazards, such as extreme weather events, earthquakes, and glaciation. OPG noted that one of the reasons for selecting a DGR was that, once closed, it would not require additional human intervention to continue to serve its purpose of safely isolating the waste from the environment, even under glacial cycling conditions.

5.2.2 Panel Conclusion Regarding Alternatives to the Project

The Panel is satisfied that OPG has met the requirements of the EIS Guidelines and has effectively assessed and substantially considered alternatives to the project. OPG has provided sufficient information to allow the Panel to make its conclusions and recommendations. The Panel accepts OPG's selection of a DGR as the preferred alternative for the management of its L&ILW. The Panel accepts that there is a strong international consensus for deep geologic disposal of long-lived radioactive waste, particularly in comparison to above-ground storage.

5.3 ALTERNATIVE MEANS OF CARRYING OUT THE PROJECT

The EIS Guidelines required that OPG identify and describe the alternative means to carry out the project that are, from the perspective of the proponent, technically and economically feasible, as well as the environmental effects of each alternative means. In describing the preferred means, OPG was to identify the relative consideration of environmental effects, the technical and economic feasibility, the criteria used to identify alternative means as unacceptable, and how the criteria were applied to identify a preferred alternative.

5.3.1 Assessment of Alternative Means of Carrying Out the Project

Based on the EIS Guidelines, OPG's consideration of alternative means included:

- radioactive waste reduction at source;
- siting of the DGR in a location outside the OPG-retained lands adjacent to the WWMF;
- siting of the DGR in a different location within the retained lands adjacent to the WWMF;
- layout and design of the DGR;
- construction methods;
- timing options for various components and phases of the project;
- alternative storage systems (applies only to tile-hole equivalents and resin liners); and
- alternatives to natural containment (i.e., engineered barriers).

The EIS Guidelines explicitly noted that the alternative "reduction at source" did not represent consideration of abandoning nuclear power, and consideration of provincial energy policy was not within the Terms of Reference of the review. In addition, the EIS Guidelines noted that, while the need for and purpose of the project was to include a description of how the site location was selected, other potential sites, if considered, were to be assessed under the context of alternative means.

OPG described its assessment of alternative means of carrying out the project. As reported in the EIS, for each aspect of the project for which alternative means were identified and evaluated, OPG established criteria of economic feasibility, worker health and safety, public health and safety, technical feasibility, physical/biophysical environmental effects, and socioeconomic environmental effects. OPG adjusted the description of the individual criterion for each aspect of the project to make it relevant to that aspect, ranked each option relative to the other options according to the criteria, and then assessed whether it was acceptable and achievable. OPG noted that the criteria and assessments were based on the professional judgement of the project team, which included OPG and contracted personnel, members of independent review groups, engineering consultants, and environmental assessment professionals.

OPG provided a list of the alternative means considered and the preferences selected, and noted that its approach was to determine if safer, more reliable and more cost-effective methods and designs could be used. OPG also presented a comparison of siting alternatives on and off the Bruce nuclear site as well as within the Bruce nuclear site. OPG's preferred alternatives were those that OPG found to be the most acceptable and achievable means to carry out the project based on technical, environmental and social criteria, in accordance with the EIS Guidelines.

As a result of this analysis, OPG selected the lands adjacent to the WWMF on the Bruce nuclear site as the preferred site for the project because the lands were vacant, were part of the land retained by OPG in its lease agreement with Bruce Power, and would provide the closest connection to the existing waste facilities. OPG selected the argillaceous limestone Cobourg Formation, located at a nominal depth of 680 metres below ground surface, as the preferred host rock for the DGR.

CNSC staff stated that OPG had adequately assessed elements of alternative means of carrying out the project, as required by the EIS Guidelines. CNSC staff further noted that OPG's approach for evaluating alternative means for carrying out the project was acceptable and followed the Canadian Environmental Assessment Agency Operational Policy Statement – *Addressing Purpose of and Alternative Means under the Canadian Environmental Assessment Act, 2012*.

Consideration of Sites Other Than the Bruce Nuclear Site

In its analysis of alternative sites for the project, OPG compared a conceptual DGR site off the Bruce nuclear site to a DGR on the Bruce nuclear site. OPG assumed that a DGR facility could be constructed and operated safely either on-site or off-site, with the technical feasibility and worker health and safety conditions being the same for each. OPG outlined the factors that identified the Bruce nuclear site as the preferred alternative means of carrying out the project, including the following:

- the cost of a DGR off the Bruce nuclear site would be greater due to the need to conduct a lengthy site selection process and to transport the L&ILW from the WWMF to an off-site DGR;
- the potential for environmental effects would be greater for an off-site location if the off-site location was undeveloped, versus the existing industrial development at the Bruce nuclear site;
- the compatibility with land uses at another site would be unknown, versus the known compatibility of the DGR with facilities at the Bruce nuclear site; and
- the availability of sufficient lands off-site with host rock suitable for a DGR, within the control of OPG, would be unknown.

As a result of this review, and given that the Municipality of Kincardine was a willing host community, OPG did not actively solicit other potential host communities or undertake geoscientific studies at other sites. No other municipalities approached OPG seeking to be considered as a potential host for the facility. OPG noted that, without a willing host municipality, the siting of a deep geologic repository for nuclear waste would not be feasible. Given its confidence that disposal of L&ILW in the DGR on the Bruce nuclear site would provide for long-term public safety and would not contaminate Lake Huron or any other part of the Great Lakes and St. Lawrence River system, OPG believed that it was not necessary to further pursue the selection of an alternative site.

Many participants expressed concerns regarding the siting of the proposed project adjacent to Lake Huron and the Great Lakes watershed, as well as the agricultural lands of Bruce County, and were of the view that OPG should have undertaken a more exhaustive site selection process, including geoscientific studies of specific off-site locations. Many participants suggested that a more remote site, located in the granite formations of the Canadian Shield or elsewhere, away from the Great Lakes watershed, would have been more appropriate than one in the Cobourg Formation at the Bruce nuclear site. These participants were of the view that OPG's analysis regarding the alternative options of siting of the DGR in a location outside the OPG-retained lands adjacent to the WWMF was insufficient and did not meet the requirements of the EIS Guidelines.

Other participants agreed with OPG's preference for the proposed project site. These participants were of the view that a DGR would be protective of Lake Huron and the environment. Some participants noted that the Municipality of Kincardine was a willing host community, and, since the waste was already stored at the WWMF, there existed a local workforce with nuclear expertise.

There have been studies regarding the potential for the granite formations in the Canadian Shield to house radioactive waste in the long term, such as the Underground Research Laboratory in Pinawa, Manitoba. As such, the Panel directed OPG to have its IEG draw from this information to supplement OPG's high-level comparison of the proposed DGR and a conceptual DGR located off-site. The OPG IEG reported that both the proposed DGR and a repository within a suitable granite formation would be expected to perform well within regulatory requirements for long-term safety and environmental protection. The most significant difference between sites was that an off-site repository would require the additional step of moving the waste off the Bruce nuclear site, necessitating substantially more handling and transportation, which would result in an increased risk of conventional transportation accidents. The OPG IEG judged the potential risk consequences of this additional handling and transportation, particularly the potential for radiologic exposure, to be quite low, due to the regulatory requirements in place for these activities.

Rather than comparing specific known sites, the OPG IEG used available information to develop a set of generic characteristics for a high-quality unaltered body of granite and based the relative risk analysis upon those generic characteristics. The OPG IEG explained that all granite bodies in the Canadian Shield are known to be naturally fractured, and that there was a high probability that a natural fracture system at a granite DGR in the Canadian Shield would have a greater potential for the transport of radionuclides than the rocks that host and enclose the repository horizon at the Bruce DGR site. As such, a DGR in a granite formation could require the use of more engineered barriers.

CNSC staff, in its review of the information presented by the OPG IEG, noted that there were exceptions to the OPG IEG generic assumption regarding nature of fractures in granite in the Canadian Shield, and commented that the OPG IEG statements about the suitability of granite for a DGR in comparison to the sedimentary rock of the Cobourg Formation could be misleading. The OPG IEG acknowledged this, and stated that the one representative hypothetical site that it developed was not an ideal site but rather a high-quality, better-than-average site. CNSC staff agreed that while the hypothetical granite formation was not ideal, it was a realistic scenario. CNSC staff noted that any site selected for a DGR would have to undergo a detailed site characterization to ensure that it would meet regulatory requirements. The OPG IEG was of the view the site characterization for a granite site would be more difficult than for the Bruce nuclear site.

The Panel is of the opinion that the characteristics of the granite body that was subject to the OPG IEG analysis were not as favourable as those found at the Underground Research Laboratory in Manitoba. At the hearing, the Panel questioned why the OPG IEG had not made its comparison based on the specific data referred to by the Panel, particularly that of the Underground Research Laboratory. The OPG IEG was of the view that the comparison it had made was reasonable given that a site in Manitoba would not be in consideration for an OPG DGR, and given that no specific sites within the province of Ontario with accompanying community acceptance had been identified.

Further, regarding the relative risk analysis of surface water receiving environments, the Panel had requested that the analysis of the conceptual DGR in granite include distinctly different surface water receiving environments, including a boreal wetland, a stream system with several stream orders, and a large lake system, analogous to a great lake. In its analysis, the OPG IEG assumed that the surface water conditions would be the same as those at the Bruce nuclear site which is a combination of the different systems. The OPG IEG did not compare the relative risk of a site that was not located adjacent to a great lake. For this reason, some participants were of the view that the OPG IEG risk analysis was flawed.

The Panel sought clarification from the OPG IEG regarding this comparison. The OPG IEG explained that in order for its relative risk comparison to be meaningful, the settings and circumstances had to be similar. The OPG IEG noted, however, that in its analysis, the risk associated with either DGR located next to a great lake was very low and well below regulatory criteria. As such, the distance to a body of water would not affect the overall relative risk ranking. The Panel agrees with this assessment.

The Panel also asked the OPG IEG to compare the perception of risk for the different alternatives. The OPG IEG presented its observations for public and Aboriginal views regarding the project but determined that insufficient information was available for it to provide a ranking for the risk perception for the four options. Some participants expressed the view that the perception of risk for a DGR located away from the Great Lakes system would be less than one located adjacent to the Great Lakes. The OPG IEG declined to comment on this view, and noted the differences between the perception of risk and its assessment of relative risk.

Some participants expressed the view that the OPG IEG had inadequately assessed the relative risks associated with the handling and transportation of waste. The Panel does not share this view and is satisfied that these activities and their associated risks were sufficiently described for the purpose of the relative risk assessment. The Panel notes that while its Terms of Reference did not include consideration of the existing practice of the transport of waste from the Pickering and Darlington nuclear generating stations to the WWMF, as these activities are separately regulated and licenced by the CNSC, they did include the transport of waste from the WWMF to the proposed DGR, or, in this case, a DGR located off the Bruce nuclear site.

Some participants did not agree with the approach taken by the OPG IEG, or felt that, despite this information, OPG's alternative means analysis still did not meet the requirements of the EIS Guidelines. Furthermore, some participants felt that the OPG IEG had not explicitly fulfilled the requirements of the Panel's request in several ways, particularly regarding the comparison of the proposed DGR to a granite site, community acceptance, and the perceived risk of a DGR next to large body of water such as a great lake. Other participants felt that the OPG IEG report validated their views about the expected performance of the proposed DGR.

CNSC staff and Natural Resources Canada agreed with the overall conclusions of the OPG IEG regarding the relative risks of the proposed DGR scenarios. CNSC staff commented that the relative risk analyses of the four options by the OPG IEG satisfied the requirements of the EIS Guidelines.

Notwithstanding the lack of a direct comparison of data for an off-site DGR in a granite formation to the proposed DGR, the Panel concludes that the proposed DGR in limestone at the Bruce nuclear site is suitable, and would be expected to perform well within regulatory requirements for long-term safety and environmental protection. The Panel accepts that a granite formation can be equally suitable, but agrees with the OPG IEG conclusion that the most significant difference between the proposed DGR and an off-site DGR would be the greater risks involved in the handling and transportation of waste to an off-site repository. Given the level of protection provided by a DGR, the risks to the surface environment are low, and the proximity to a great lake does not change this conclusion.

The Panel is satisfied that OPG's preference for a DGR in the Cobourg Formation on the lands adjacent to the WWMF at the Bruce nuclear site has been sufficiently justified. The Panel is satisfied with the reasons for which OPG identified the preferred project location - that the proposed site is within the control of OPG, and that OPG was to select its preference based on its perspective.

Consideration of Sustainability in the Evaluation of Alternative Means

The EIS Guidelines stated that the project, including its alternative means, must take into account the relations and interactions among the various components of the ecosystems, and meeting the needs of the population. In the EIS, OPG was required to include a consideration of the extent to which the project would contribute to sustainable development.

In response to an information request from the Panel, OPG outlined its evaluation of alternative means using sustainability considerations. OPG explained that the primary contribution of the project to sustainable development was that it would address the management of L&ILW in this generation rather than delaying it to the future, thus providing flexibility for future generations. The project would contribute to sustainability through avoidance of transport of the waste, reduction of the surface footprint for waste management, avoidance of sensitive lands such as the northeast marsh, decrease contact opportunities for terrestrial and aquatic species, and through the provision of continued employment and revenue opportunities in the Regional Study Area.

The Panel is satisfied that OPG adequately considered sustainability in its evaluation of alternative means. The Panel is of the view that a DGR would be more sustainable than surface storage, and more sustainable than a DGR at an undeveloped offsite location.

Consideration of the Precautionary Principle in the Evaluation of Alternative Means

The EIS Guidelines required that OPG indicate how the Precautionary Principle was considered in the design of the project. OPG was to indicate how alternative means of carrying out the project were evaluated and compared in light of risk avoidance, adaptive management capacity and preparation for surprise.

In response to an information request from the Panel, OPG outlined its evaluation of alternative means taking into consideration the Precautionary Principle. For each alternative means category, OPG provided its rationale for its preferred alternative, taking risk avoidance, adaptive management capacity, and preparation for surprise into consideration.

OPG explained that, since the criteria it used for evaluating alternative means were based on economics (cost), worker health and safety, public health and safety, technical feasibility, effects on the physical and biophysical environment, and the social and economic environment, the concepts of risk avoidance, adaptive management capacity and preparation for surprise were incorporated into the evaluation of the alternative means relative to these considerations. As an example, alternative means that avoided public or worker health and safety risks were considered to be more favourable.

Regarding the alternative DGR in granite in the Canadian Shield, OPG noted that for risk avoidance, an off-site would have more risk associated with the transportation of waste. For adaptive management capacity, it would require the development of knowledgeable and experienced staff, and for preparation for surprise, emergency response plans would have to be implemented once the site has been chosen. In addition, the additional transport risk would have to be managed.

In a discussion at the hearing, the OPG IEG explained its views regarding risk management and the application of the Precautionary Principle. The OPG IEG stated that risk management would require that measures be in place to manage risks and uncertainties associated with a given project so that there would be a sufficient margin of safety to account for those uncertainties. The OPG IEG noted that in this way, risk management would inherently reflect the Precautionary Principle.

The Panel is satisfied that OPG has adequately considered the Precautionary Principle in its assessment of alternatives. The Panel notes the important role that management systems would have in addressing risk avoidance, adaptive management and preparation for surprise. The Panel would expect the OPG management system to continue to evolve and focus on adaptive management over time.

5.3.2 Panel Conclusion Regarding Alternatives Means of Carrying out the Project

The Panel accepts the preferred alternative means of carrying out the project selected by OPG. After reviewing all of the information regarding alternatives, the Panel is satisfied that the Cobourg Formation in the lands adjacent to the WWMF at the Bruce nuclear site is the preferred location for the project. This selection represents a sufficiently sustainable and precautionary alternative.

5.4 PANEL CONCLUSION REGARDING PURPOSE, NEED AND ALTERNATIVES

The Panel concludes that OPG has met the requirements of the *Canadian Environmental Assessment Act, 2012* regarding purpose, need and alternatives. The Panel accepts OPG’s selection of the proposed DGR at the proposed location as its preference for the project. The Panel is satisfied that OPG adequately considered sustainability criteria and the Precautionary Principle in its assessment.

CHAPTER 6 DGR SITE DESIGN AND GEOTECHNICAL CHARACTERIZATION

This chapter presents the Panel's evaluation and conclusions on the range and scope of OPG's geotechnical characterization, monitoring, design and construction activities for DGR development during the preclosure and postclosure operational phases. The Panel also considered specific issues raised by CNSC staff, Environment Canada and Natural Resources Canada with respect to site design and geotechnical characterization.

6.1 DEVELOPMENT OF THE DGR SITE

OPG stated that the primary purpose of the DGR was to provide for the safe long-term management of L&ILW in a geologic setting that would contain and isolate the waste from the biosphere. In order to fulfill this objective, OPG applied specific safety criteria to the DGR design, based on CNSC regulations, including Regulatory Guide G-320, *Assessing the Long Term Safety of Radioactive Waste Management*, and federal, provincial and International Atomic Energy Agency guidance.

OPG implemented a Geoscientific Site Characterization Plan that utilized surface drilling of deep boreholes for the preliminary characterization of the geosphere and to verify that the geosphere would be suitable for the safe, long-term containment and isolation of L&ILW. On the basis of its surface-based geoscientific investigations, OPG determined that the bedrock would be capable of providing multiple effective barriers for containment and isolation of L&ILW at a depth of approximately 680 meters below the surface, in the Cobourg Formation.

As part of its DGR design process, OPG developed a Geoscientific Verification Plan that would be used to gather additional geotechnical and geomechanical information in the underground repository during the construction phase. Geotechnical deals with the engineering behaviour of rock materials in which physical properties of rock materials are used to assess how these materials will interact with various site conditions. Geomechanical deals with the geologic study of the behaviour of rock, including determination of rock mass characteristics and rock mechanical properties such as fracture frequency and strength. OPG identified Geoscientific Verification Plan activities that would occur during shaft sinking and during lateral development within the Cobourg Formation.

6.1.1 DGR Geotechnical Setting

OPG presented analyses of the subsurface geomechanical conditions of the proposed DGR project site that were determined from multiple drilling and sampling campaigns. OPG conducted rock characterization using samples recovered from eight boreholes, DGR-1 through DGR-8, located within the proposed DGR site boundary, at depths up to approximately 860 meters below the surface. OPG's drill sampling program was designed to minimize potential connectivity between the surface and deep geosphere environments. Exploration boreholes were spatially distant from each other and located either external to the planned repository footprint or through one of the proposed shaft locations. During geosphere site investigation, OPG drilled deep boreholes to sample rock formations about, but not within or through, the planned repository site to avoid increasing permeability between the repository level, shallow groundwater zones and the surface. The exception was the deep borehole located at the site of the main shaft (DGR-8), which went to a depth of 724 meters.

OPG used the information from the borehole tests to define a geomechanical site model that described rock material and rock mass characteristics for the five stratigraphic units that would constitute the host and cap rock of the DGR. OPG evaluated the geomechanical properties, such as strength, of recovered core specimens from various stratigraphic horizons using certified laboratories and recognized international standards. OPG also had third-party experts evaluate these properties.

OPG used quantitative measurements of characteristic rock properties, as illustrated in Figure 9, to evaluate the geomechanical behaviour of the rock mass that would occur during and after DGR construction. OPG stated that data from borehole samples indicated consistent distributions and magnitudes versus depth for important material properties that were used for structural design purposes. OPG noted that rock formations at depths below 200 meters exhibited “excellent” rock quality within all stratigraphic formations down to and below the Cobourg Formation. These rock strata exhibited a high degree of intactness and very low fracture frequency. OPG indicated that the limestone at the depth of the proposed repository had statistically consistent and high strength character between sites from which samples were recovered. For conservatism in its geomechanical modelling assessment of repository stability performance, OPG used a strength estimate for Cobourg Formation rock that was considerably lower than the average measured strength.

6.1.2 DGR Geomechanical Design Features

OPG’s proposed DGR design included a 100-year excavation life that would accommodate both a 40-year operational life for waste emplacement in Panels 1 and 2, as well as time to allow for possible expansion of the DGR to accommodate decommissioning waste (if such an expansion were needed and approved). OPG proposed a robust DGR geomechanical design that would provide long-term structural stability. The features of OPG’s preclosure stability design included:

- orienting emplacement rooms to minimize mining-induced stress concentrations and improve excavation stability (mining-induced stresses develop in rock adjacent to mine excavations due to construction activities, and the shape and orientation of excavations);
- shaping of excavation perimeter walls to mitigate mining-induced stresses;
- creating large pillar dimensions to maintain low pillar stress conditions; and
- applying both systematic and timely wall and roof support to both stabilize fractured rock zones and enhance the existing rock structure.

Rock stabilization measures and rock reinforcement are conventional procedures in underground mining and civil excavation operations that are used to effectively mitigate worker hazards associated with ground falls. OPG modelled the stability of various design features of the proposed DGR in the short- and long-term using geomechanical information obtained from

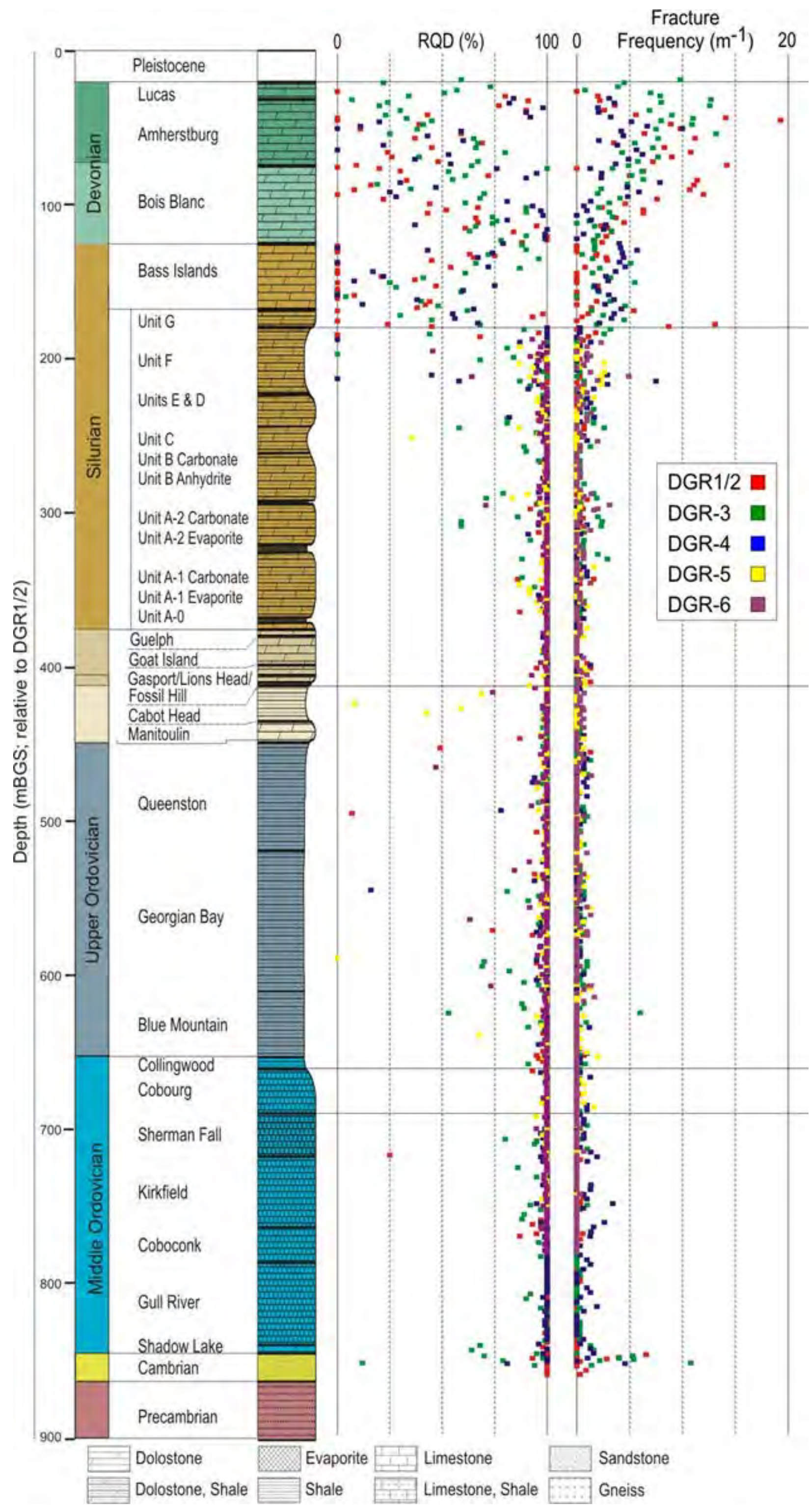


Figure 9: Stratigraphic Column Showing RQDs and Fracture Frequency from DGR-1 and DGR-6 (reproduced from DGR EIS Figure 6.2.9-2)

limited field and borehole sampling in rock formations through and within which the shafts and repository would be constructed. OPG documented the structural behaviour of repository excavations by modelling various scenarios and sites that included a repository-wide layout of panels, rooms and tunnels, individual repository rooms within intact and/or bedded formation layers, and excavation openings at intersections between rooms and access tunnels.

OPG predicted that localized zones of high stress would not cause adverse effects on excavation stability. OPG assessed mining-induced stress conditions in rooms and access areas of proposed excavations based on inferred *in situ* stress conditions at the proposed repository site. *In situ* stress is the pre-existing, natural stress condition in rock created by effects such as gravity loading. Stress conditions were shown to be well below the strength of repository level rock. OPG anticipated that localized high stress zones would develop in limited areas within the rock. OPG indicated that, at high stress zones, excavation walls and roofs might be subject to shallow fracturing that could be controlled by the installation of conventional support media.

OPG noted that shallow fracturing effects similar to those predicted for the DGR have occurred at other mine sites, such as the Norton Mine in Ohio, which operated at the same depth within the Cobourg Formation and over the same periods of time to those expected for the DGR construction and operation phases. OPG stated that localized excavation damaged zones created by shallow fracturing would pose the principal hazards to workers from localized falls of loose rock in the preclosure phase of the project. OPG indicated that effective repository operation would require that the repository design be carefully managed, that the formation of excavation damaged zone be reduced, and that repository walls be reinforced to prevent or restrict rockfall events.

OPG used the existing *in situ* stress level at the proposed site to assess both the short- and long-term geomechanical stability of the proposed DGR. OPG assessed site stress conditions using published regional data and qualitative observations of borehole deformation conditions. The Panel notes that OPG's *in situ* stress measurements during its preliminary site investigation program were limited in number and qualitative. OPG used data from a single site, the Norton Mine, as an analogue for predicting DGR stress conditions. Measurements from OPG's preliminary borehole examination program indicated a low density of fractures, many of which were sealed by mineral infill, in the borehole walls. From these results OPG determined that high magnitude horizontal *in situ* stress conditions do not exist at the proposed DGR site. However, OPG reported that for sedimentary rock formations of the Great Lakes Basin, the horizontal stress magnitudes were higher than the vertical stress magnitude.

6.1.3 Panel Conclusion Regarding Geomechanical Design Features

The Panel concludes that OPG has credibly demonstrated the effectiveness of the proposed support techniques, their associated spacing, layout and depths of installation for the predicted geosphere conditions.

It is important to accurately determine the magnitude and orientation of *in situ* stress conditions in order to assess the geomechanical response and structural performance of the DGR. OPG submitted reasonable assessments of pre-existing rock stress conditions at the proposed DGR site based on published research and limited borehole measurements from its Geoscientific Site Characterization Plan. However, the Panel is of the view that OPG should consider additional site stress assessment in order to reduce uncertainties in the preliminary geosphere characterization and to verify that geosphere stress conditions would not adversely affect the safe, long-term containment and isolation of L&ILW. This topic will be further discussed by the Panel in following sections of this chapter.

6.2 PRECLOSURE DGR DESIGN FEATURES

OPG described the project in two temporal stages: preclosure and postclosure. The preclosure stage includes the entire time period until closure of the DGR, including site preparation and construction, operations, and decommissioning. The postclosure phase begins at closure of the DGR, and includes up to 300 years of institutional control, followed by abandonment forever.

6.2.1 DGR Construction Methods

OPG proposed to construct the DGR using proven conventional mining methods to develop shafts and underground excavations, using drilling and blasting to fracture intact rock and to create excavations of the desired shape, size and orientation. OPG stated that it would make use of special blasting techniques, such as sequenced detonation of explosives within controlled layouts, to achieve the planned structural geometries of excavations and to minimize the extent of blast-induced fracturing about these excavations, referred to as the highly damaged zone and the excavation damaged zone. OPG's choice of the proposed mining excavation method was based on proven experience in mining and civil engineering operations, and upon its own experience in the underground construction of its nuclear facilities. OPG determined that alternative construction methods, such as mechanical excavation, were not suitable for the project due to the excavation size and orientation, the rock strength conditions of the Cobourg Formation host rock, and other operational constraints.

OPG stated that the transport, storage and use of explosives for surface and underground construction activities would be managed in accordance with the federal *Explosives Act* (R.S.C., 1985, c. E-17), as administered by Natural Resources Canada, and Regulation 854 of the Ontario *Occupational Health and Safety Act*, as administered by the Ontario Ministry of Labour. OPG proposed to use limited quantities of commercial explosives in its daily excavation activities, typical of the amounts used by mining operations for developing underground excavations of similar size to those that would exist within the DGR. Limited quantities of explosives will be used for each blasting cycle to control the generation of ground vibrations. Explosives would be transported to and stored on site in purpose-built, secure magazines in accordance with Natural Resources Canada's *Blasting Explosives and Initiation Systems – Storage, Possession, Transportation, Destruction and Sale* (NRCan 2008). OPG confirmed that all explosives for DGR operations would be supplied by external contractors and that no explosives manufacturing facilities would exist on site.

CNSC staff noted that the controlled drilling and blasting technique proposed by OPG for underground construction is a proven technique, and could be used effectively to develop the

DGR excavations while minimizing excessive creation of excavation damaged zone. Compared to other techniques, this excavation method would improve both short- and long-term safety of the project by reducing risks for groundwater flow and contaminant migration along the highly permeable excavation damaged zone. CNSC staff was satisfied with the information provided by OPG regarding the planned use of explosives during construction, and stated that that there were no unacceptable risks to workers or the environment relating to the use of explosives.

Panel Conclusion Regarding DGR Construction Methods

The Panel concludes that the drilling and blasting construction methods proposed by OPG are appropriate for construction of the DGR. The use of a controlled drilling and blasting excavation technique can reduce rock damage while maintaining stable rock structure in sedimentary rock formations. In the view of the Panel, the daily and annual quantities of explosives to be used for the proposed project are not excessive. Alternative construction techniques assessed by OPG, such as mechanical excavation, are currently unsuitable for use in both shaft and horizontal excavation environments due to operational limitations. The Panel accepts OPG's proposed excavation technique and agrees that OPG can effectively limit excavation damaged zone development during underground construction operations. The Panel agrees with OPG's assessment that in both the short- and long-term, reduction of the excavation damaged zone within the shaft and the repository workings will reduce the potential for contaminant migration to the surface environment and enhance worker safety within the DGR.

6.2.2 DGR Shaft Design

OPG proposed to develop two vertical shafts between the surface and the horizontal repository excavations within the Cobourg Formation. The main shaft would be used for the transport of personnel, supplies and waste containers between the surface and the repository, and to provide fresh air from the surface to the underground sites. The second shaft would be used for the transport of excavated waste rock to surface and to exhaust ventilating air to the surface from the repository level. OPG planned the two shafts to provide redundant access and egress between surface and the proposed repository, as well as to provide capacity for single-pass airflow ventilation to sustain the operation of equipment and meet the needs of underground personnel during DGR operations.

OPG stated that the shaft collars, as with all other DGR surface and underground facilities, would be designed and constructed according to the *National Building Code of Canada*. This Code includes a requirement to evaluate the impact of seismic activity on structures. OPG indicated that the DGR shaft collars would be developed through the surficial overburden and constructed to a depth of approximately 20 metres into the underlying bedrock. In OPG's design, the shaft collar would exist partially as a surface structure, extending above the ground surface, and partially as an underground structure that would be firmly embedded into the bedrock foundation.

OPG stated that its assessment demonstrated that there would be no significant adverse effects on the stability of surface or underground DGR facilities due to seismic activity. The potential long-term impacts to the DGR from seismic activity and site stability conditions are further discussed in Chapter 13.

OPG stated that the DGR shaft collars are an important aspect of the design of the DGR surface facilities. The top of the shaft collar would be located at an elevation of 188 m above sea level; above maximum potential flood elevations that were predicted to result from probable maximum flood and probable maximum precipitation events. Probable maximum precipitation is a calculation of the greatest depth of precipitation for a given duration that is meteorologically possible for an area of given size. OPG stated that the probability of DGR flooding from Lake Huron would be low due to the distance from, and the difference in elevation between, the Lake and the DGR shaft collar site. OPG stated that the elevation difference between the static elevation of Lake Huron and the planned elevation of the shaft collar for extreme flooding events would be a minimum of seven meters. CNSC staff suggested that the probable maximum precipitation for the DGR site should be updated in order to consider the effects of climate change.

OPG stated that ground treatment by grouting would take place prior to the development of the shaft collar to reduce any flows of groundwater into the shaft collar site. This feature of the shaft collar design would reduce the potential for shaft flooding through the collar. OPG predicted that potential flooding of the DGR facilities and shaft due to effects of climate change during the site preparation, construction and operations phases would be unlikely. OPG determined that flooding impacts caused by severe rainfall events would be controlled and mitigated through the use of proper engineering design.

OPG proposed to use a controlled drilling and blasting excavation method for all shaft development (sinking) operations. As part of its design process, OPG used geomechanical models that made use of measured site rock characteristics to assess the stability of the proposed shaft openings. OPG proposed multiple methods of conditioning and supporting the shaft walls to maintain the structural stability of the rock within the various geologic formations that the shaft would intersect. OPG proposed to grout the upper 180 meter thick dolostone-dominated layer before shaft advance in order to mitigate excessive water inflows into shafts. OPG stated that the grouting process would be done through surface drilling to the full 180 meter depth, through progressive grouting of short shaft sections as construction occurs through this upper section, or through the use of both methods. Within and below the dolostone-dominated layer, cast concrete shaft liners would be used to restrict water inflow into the shafts and to collect and re-direct flows to the surface. OPG stated that, as part of the Geoscientific Verification Plan, modelling and design predictions of the geomechanical response of excavation rock, in particular development of the shaft excavation damaged zone, would be further assessed and verified during and after construction.

Panel Conclusion Regarding Shaft Design

The Panel is satisfied that OPG’s proposed methods for shaft development, including excavation and support measures, are appropriate and will ensure safe operating conditions for workers and mechanized equipment during the planned construction and operations phases of the DGR. The Panel concludes that OPG’s DGR shaft design components have been adequately considered and are appropriate for the safe, long-term development and use of the underground facility.

The Panel concurs with OPG's assessment of the effects of seismic events on the shafts and concludes that adherence to applicable building standards and the provision of robust shaft design features, such as the concrete shaft collar at surface, are necessary features for the mitigation of adverse effects associated with potential seismic activity. The Panel understands that, should the project be approved, the detailed design of the shaft collar would be based upon seismic analysis and adherence to the most current *National Building Code of Canada*.

Recommendation 6.1: Prior to construction, OPG shall provide, to the satisfaction of the CNSC, detailed designs for all above-ground and underground structures to demonstrate compliance with the *National Building Code of Canada*.

The Panel concurs with CNSC staff that the probable maximum precipitation for the DGR site should be updated in order to consider the effects of climate change. The detailed design of the shaft collar elevation should take the updated probable maximum precipitation into consideration to prevent flooding of the shaft collar.

Recommendation 6.2: In order to verify predictions in the environmental assessment and avoid effects of the environment on the project, OPG shall, prior to construction, conduct and prepare an updated assessment of the probable maximum precipitation event. The updated probable maximum precipitation event shall incorporate the potential effect of climate change and a rigorous sensitivity analysis shall be performed. The shaft collar height shall be increased to an appropriate elevation based on the updated probable maximum precipitation event, to the satisfaction of the CNSC.

6.2.3 Lateral (Repository) Development Design

OPG's proposed repository layout consisted of a shaft island service area and two panels containing a total of thirty-one waste emplacement rooms. OPG planned the development of a shaft island layout to maintain a reduced surface footprint for DGR facilities. Additionally, OPG's proposed underground island configuration, as illustrated in Figure 10, includes the main shaft and ventilation shaft, a service area for workers and equipment and storage facilities that would permit maximum separation of occupied work zones in these facilities from the emplacement rooms where waste containers would be stored. This separation would minimize worker exposure to radiation during the operations phase of the repository. During the construction phase, this configuration would also minimize worker exposure to conventional accident hazards by restricting underground worker access to areas where only essential construction personnel would be working.

OPG explained that initial development on the repository level would connect the two shafts to sustain increased ventilation capacity between them and to permit construction of the underground services area. Sequential development of the entire repository would be undertaken to prepare the two waste emplacement panels of rooms prior to initiating any waste

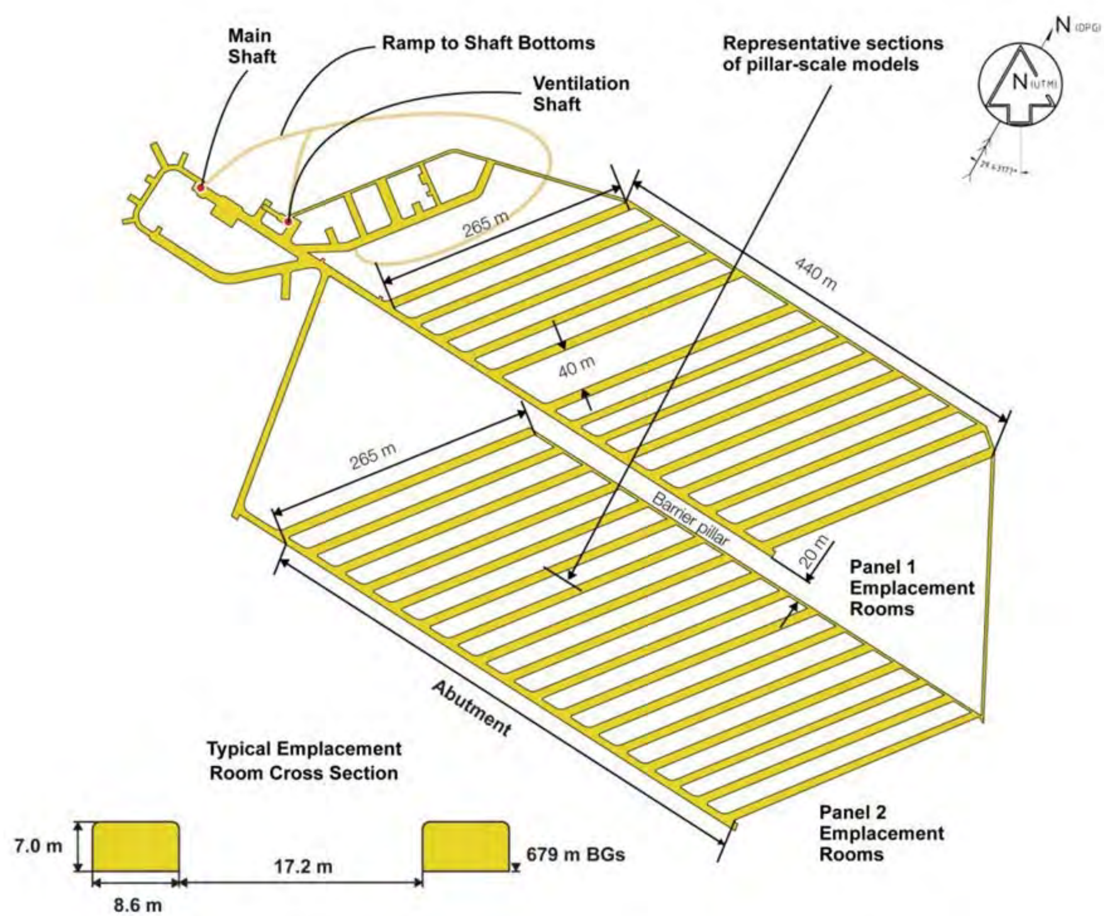


Figure 10: Repository Layout and Emplacement Room/Panel Features (reproduced from DGR Geosynthesis TSD, Figure 6.11)

emplacement operations. OPG considered this process to offer greatest benefit in terms of public and worker safety, cost, ease of construction and operation, and the lowest environmental effect.

OPG also considered the development of a ramp from surface to the repository level as an alternative to shaft access. Some participants commented on OPG's selection of a hoist rather than a ramp, suggesting that a ramp would be safer. OPG determined that the development of a ramp for waste container movement from surface to the repository level would pose a greater risk to workers than a vertical shaft, due to the extended ramp distance and time of travel associated with construction and operational activities. A ramp would have an exposed length approximately one order of magnitude larger than that of each vertical shaft and would result in larger waste rock storage requirements on the surface. For the preclosure waste emplacement phase, ramp access would create longer travel times and greater risk to workers due to exposure during waste container movement operations. The additional ramp exposure length would also create a significantly larger excavation damaged zone surface area and enhanced pathways for contaminant travel to surface compared to a vertical shaft layout.

OPG stated that the spacing of waste emplacement rooms, the spacing of pillars within panels, and the spacing of pillars between panels, would generate pillar stresses that would be far less than the existing repository level rock strength, thus maintaining pillar stability. The orientation and sizing of the waste emplacement rooms were designed to minimize excavation boundary stress development. OPG predicted that localized zones of high stress and rock fracturing would develop around waste emplacement rooms, and that these zones would be stabilized by installation of planned rock support measures. OPG expected only minor and limited surface damage to occur around excavations during the preclosure construction and operations phases. On the basis of these design features, OPG determined that risks to workers from conventional accidents and malfunctions would be typical of those encountered by underground mine workers.

CNSC staff expressed no concerns regarding the number and layout of shafts that OPG proposed to use. CNSC staff noted that OPG would be required to provide technical detail concerning shaft excavation, shaft rock initial and final support features, and shaft service area support design prior to the commencement of construction activities.

Panel Conclusion Regarding Lateral (Repository) Development Design

The Panel considers OPG's proposed lateral development design and construction methods to be appropriate for the project. The Panel does not consider the proposed DGR to be large in size when compared to typical underground mining operations.

The Panel concludes that, given the implementation of OPG's proposed planning procedures and design measures, the stability of underground structures, the effectiveness of underground support measures and worker safety can be effectively maintained throughout the construction and operations phases. The Panel also concludes that the use of two shafts, common in most underground mines where ramps are not used, would be appropriate for the project.

6.2.4 Ventilation system

OPG designed the ventilation system to collect only fresh, uncontaminated surface air for use in the underground repository. The surface ventilation air intake and fans would be located upstream of the waste package receiving building and the exhaust vent for underground air. OPG designed features of the ventilation system to prevent contaminants from reaching work sites and workers in the underground repository in the event of an incident on the surface involving a release of harmful materials.

OPG's proposed design incorporated single pass, flow-through ventilation through each room between access and exhaust tunnels. Ventilation would be maintained for the duration of emplacement operations. OPG explained that, as waste emplacement rooms are completely filled, OPG would construct end closure walls at the room entrance to seal each room and prevent contaminated air from leaking into the access tunnel where operations would continue. Upon completion of full or partial panel filling, permanent concrete closure walls would be constructed in access and exhaust tunnels to isolate each group of rooms.

OPG stated that, during shaft construction, ventilation for workers and other operational needs would be provided by dedicated fan networks located within each of the two shafts. Once construction at the repository level has begun, OPG would connect the ventilation networks between the two shafts. OPG indicated that, as emplacement rooms are excavated, fresh ventilation air would flow into the repository from the main shaft, through access tunnels extending into each waste emplacement panel, and into and through open waste emplacement rooms.

OPG’s ventilation design included provisions for remote and continuous monitoring of various underground atmospheric conditions that would be necessary to maintain safe repository operation, such as airflow quantity, temperature, relative humidity, and contaminant gas and dust concentrations. Under normal operating conditions, workers would be exposed to fresh air sources located upstream from waste emplacement areas. Exhaust air from open emplacement rooms would then travel into a return air tunnel that would exit to the surface through the ventilation shaft. Airflow through access tunnels and emplacement rooms would occur in single-pass fashion to avoid recirculation of potentially contaminated air within the repository where workers will be present.

OPG stated that during the operations phase, the potential would exist that radiologic contaminant releases may occur from waste containers through various normal operating processes, such as container venting, or unanticipated releases such as container breaching. OPG explained that container venting may release limited quantities of radiological contaminants during the short intervals when container transport through repository tunnels and room emplacement operation occur. OPG noted that during these intervals, only limited exposures for workers would occur. OPG further noted that the ventilation measures proposed for the DGR would effectively limit worker exposure to the site where a release occurs and ensure that contaminants are transported away from the site of the source.

Panel Conclusion Regarding Ventilation System

The Panel is satisfied that the proposed ventilation design would ensure safe operational conditions for workers and mechanized equipment during the planned construction and operations phases of the DGR. In the Panel’s opinion, the single-pass ventilation design would be suitable and effective for capturing and removing radiological releases resulting from typical container venting during normal operations. It would also effectively control releases from unanticipated breaching events. Breaching events are discussed in more detail in Chapter 10.

6.2.5 DGR Backfill

Backfilling is a mining procedure that uses engineered materials to re-fill openings during or after their excavation to structurally support wall and roof sections. OPG proposed using backfill within the DGR in the form of: (i) concrete room closure walls for isolation of waste-filled emplacement rooms; (ii) a concrete monolith structure at the base of each shaft to enhance the stability of shaft foundations; and (iii) layered concrete, bentonite/sand, asphalt and crushed waste rock engineered seals within the shafts as barriers to radionuclide transport from the repository level to the surface. OPG stated that the use of backfill in waste emplacement rooms, which would lead to higher repository gas pressures resulting from waste degradation in the long-term, would not enhance the postclosure safety case. With the exception of the concrete monolith, the backfill forms considered by OPG for use in the proposed DGR were designed solely to be barriers to worker access or contaminant release. Only the concrete monolith was considered by OPG to be a structural support.

OPG indicated that, during the preclosure period, repository emplacement rooms would be expected to remain stable without the use of room backfilling. OPG predicted that the absence of backfill in repository rooms would not detrimentally affect excavation integrity or increase the release of gas during this phase. Room closure and panel isolation walls were the only forms of backfill proposed by OPG for use in the DGR during this period.

As illustrated in Figure 11, OPG proposed to install a concrete monolith structure within the service area tunnels and at the base of the two shafts prior to closure, and during decommissioning operations at the repository level.

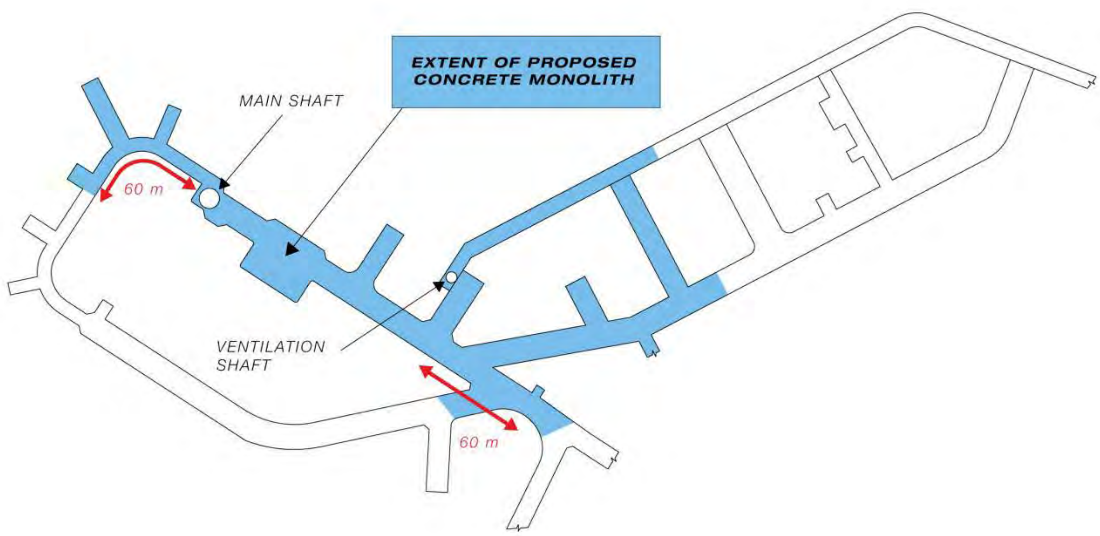


Figure 11: Proposed Concrete Monolith Structure at the Base of the DGR Shafts (reproduced from DGR EIS Figure 4.11.4-1)

OPG explained that the monolith structure, which would provide support for the rock formation immediately above service area excavations and act as a stable foundation for overlying shaft seal materials, would not function as a barrier to contaminants. This assessment was based upon OPG's assumption that the excavation damaged zone and transmissive bedding planes existing about the tunnels, within which the concrete monolith would be placed, would be key contaminant pathways to the shaft. As part of its safety case, OPG stated that no remediation of the repository level excavation damaged zone or bedding plane zones would be planned in areas where the concrete monolith would be developed in order to prevent worker safety hazards associated with site remediation efforts. A bedding plane is a planar combination of rock layers, usually horizontal or near-horizontal, at the repository site.

Panel Conclusion Regarding Backfill

The Panel accepts that backfill closure walls would offer little structural benefit to the proposed repository because of the strategic siting and small size of the emplacement rooms. The principal operational benefit of backfill closure walls would derive from their function as barriers that would restrict potential radionuclide release to ventilated sections of the repository and restrict worker access to filled rooms, thereby enhancing worker safety. The Panel agrees that backfill would reduce the volume available to accommodate gas generated by degradation of the waste.

The Panel is of the view that contaminant release around and through the concrete monolith structure could be potentially reduced if the monolith, and the horizontal transmissive zones within the monolith area, were to be developed as enhanced engineered barriers and designed in a similar fashion to shaft seal barriers. Enhancement of the monolith zone as a second engineered barrier, in addition to the primary shaft seal barrier, for restricting contaminant release to the biosphere would add additional engineering-in-depth to the postclosure safety case.

Methods by which OPG could enhance the monolith barrier zone were the subject of limited discussions by OPG during the review. Potential methods included facilitating excavation damaged zone mitigation through fracture grouting and partial removal of the excavation damaged zone and highly transmissive zones within the monolith area tunnels. The Panel recognizes that remediation of the excavation damaged zone about the tunnels in which the monolith will be placed may be feasible. The Panel is of the view that remediation efforts such as this are not unique within the mining industry, where fractured rock zones are encountered, and can be implemented through effective management and design. Additional engineering measures, such as installation of keyed cast concrete bulkheads within the monolith structure or the use of other fracture sealing techniques, could also reduce potential contaminant flow through or around the concrete monolith. The use of concrete bulkheads at strategic locations within the shafts is a current feature of OPG's shaft seal design and therefore not a unique design element for contaminant flow mitigation. The application of similar measures within the horizontal concrete monolith structure would not be substantially different from those of the existing shaft design.

Recommendation 6.3: In order to enhance post-closure containment of radionuclides and other contaminants OPG should, prior to decommissioning, and to the satisfaction of the CNSC, identify materials and procedures that could be used to enhance the effectiveness of the monolith and surrounding transmissive zone as a barrier against contaminant transport to the shaft.

6.2.6 DGR Shaft Seal System

OPG predicted that the shaft excavation damaged zone would be a primary pathway for the migration of radionuclides from the DGR during the postclosure period. The majority of the excavation damaged zone was predicted to develop soon after shaft excavation and would slowly increase in size over time. OPG used the measured properties of rock cores recovered from the geosphere to model the effectiveness of different types of shaft seals as barriers against contaminant release.

OPG stated that it would not install shaft seals until after the completion of closure activities in the repository. OPG predicted that seals would be durable for at least 60,000 years, and that the use of shaft seals would effectively prevent the release of radiologic contaminants from the proposed repository. OPG stated that, post decommissioning, the engineered shaft seals would be the principal barriers for restricting the release of contaminants into groundwater.

OPG stated that the shaft seals would consist primarily of a bentonite/sand mixture, concrete, asphalt and engineered fill layers. These materials would be used to fill the full length of shafts between the repository level and ground surface, as illustrated in Figure 12. OPG noted that the concrete bulkhead seal would be constructed as part of the shaft seal system to provide structural support for bentonite/sand shaft seal materials.

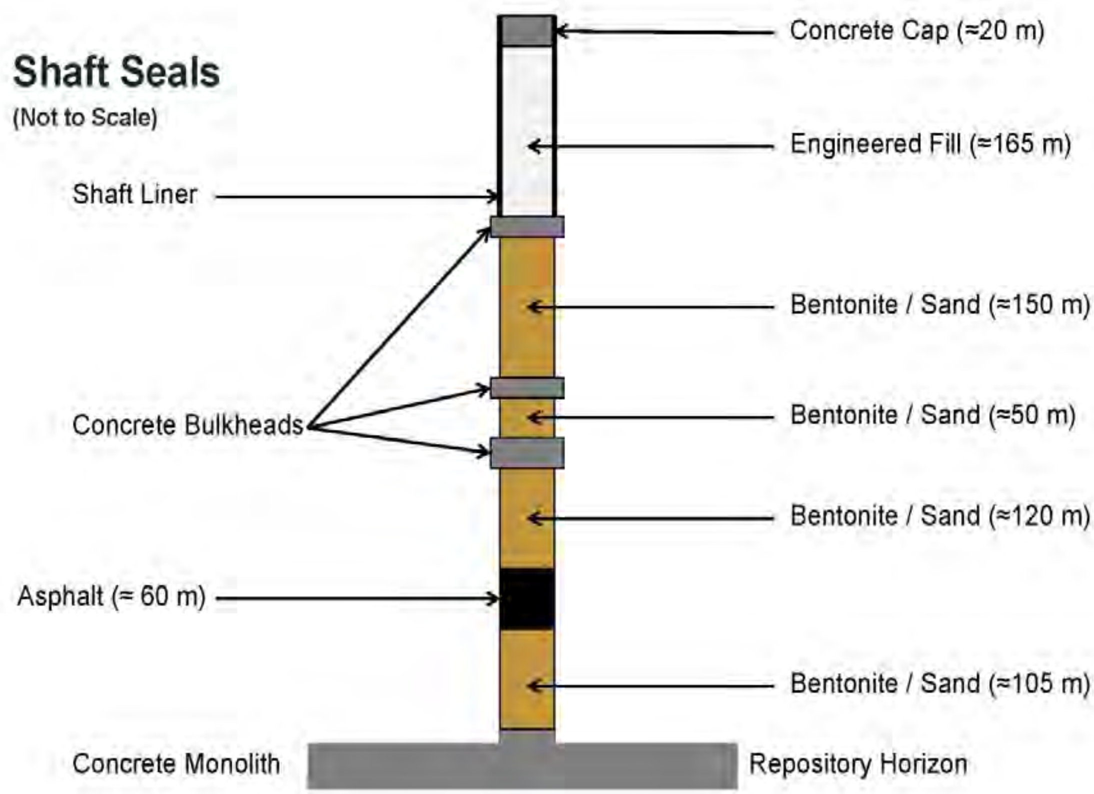


Figure 12: OPG Planned Layout of Shaft Barriers (reproduced from OPG submission for TIS #1; Slide 76)

OPG stated that research on seal performance of bentonite/sand mixtures having different mix ratios had been conducted by other parties, but that its preferred seal composition mixture ratio of bentonite to sand was 70/30. OPG did not provide any rationale or explanation for the selection of this specific mixture ratio for one of its primary shaft seal elements other than to state that this mixture type would not liquefy as a result of seismic shaking.

For future design planning, OPG stated that the characteristics of shaft seal materials would be determined through laboratory testing, collaboration with international research organizations, and long-term site testing. This testing would be part of the activities undertaken during the operations phase of the DGR as part of the Geoscientific Verification Plan. OPG noted that additional testing would be needed to confirm the behaviour of seal materials, particularly within the more porous shale formations. OPG planned to validate the effectiveness of seal materials by installing and monitoring the materials within various borehole sites located in shale formations. OPG indicated that it had not made any measurements of seal behaviour at the proposed DGR site, and that its modelling of conceptual seal performance as a radiologic barrier was based solely upon international research experience in varying rock formation types.

OPG acknowledged that there was little available information related to the stability of bentonite seal mixtures when exposed to the saline waters that would be present within the proposed DGR shafts. OPG noted that there was limited international research regarding the effects of sea water on bentonite. In addition, OPG did not identify differences in mixture compositions and salinity conditions between those of existing international research efforts and those to be used in the proposed DGR environment. The Panel notes that no direct comparison between existing international research on shaft seal performance and the planned DGR site research can be made at this time.

CNSC staff noted that the primary proposed seal materials, mainly bentonite, are geochemically stable, which would reduce the likelihood of their long-term degradation. CNSC staff reviewed OPG’s assessment of short-and long-term seismicity effects on the safety of the DGR and concurred that no significant damage would result to the lowest concrete bulkhead shaft seal. CNSC staff identified that there were uncertainties associated with the long-term performance of shaft seals and recommended that OPG develop and conduct a research and development program on the longevity of shaft seals to be initiated during the site preparation and construction phase. CNSC staff stated that it was satisfied with the evaluation of shaft seal materials for the purpose of the environmental assessment.

Panel Conclusion Regarding the Shaft Seal System

The Panel concludes that the proposed shaft seal materials were adequately characterized for the purpose of the environmental assessment. The Panel is of the view that OPG should initiate the investigation and selection of optimal shaft seal materials as soon as possible, and prior to site preparation and construction phases, to permit the longest possible interval of research study into shaft seal behaviour prior to closure of the repository. Shaft seals are a primary engineered barrier for inhibiting contaminant release to the natural environment in the long term. The Panel makes the following recommendations:

Recommendation 6.4: In order to confirm the predictions in the environmental assessment regarding post-closure containment of radionuclides and other contaminants, OPG shall initiate long-term testing of seal material behaviour under similar conditions and depths to those that each seal material will experience at the proposed DGR site. The testing program shall include experimental and theoretical demonstrations of the long-term performance of the seals. OPG shall consider the chemical, hydraulic and physical interaction of the seals with specific rock formations and the associated excavation damage. The rock formations to be considered shall include the host and cap formations, and other formations that influence the long-term safety case. The test program shall commence as soon as possible prior to site preparation and construction, and be conducted to the satisfaction of the CNSC. The safety case should be updated taking the results of this work into consideration.

Recommendation 6.5: In order to enhance post-closure containment of radionuclides and other contaminants, OPG shall research comparative seal behaviour of bentonite/sand mixtures having composition ratios other than 70/30. The test program should commence prior to site preparation and construction and be conducted to the satisfaction of the CNSC.

Recommendation 6.6: In order to enhance post-closure containment of radionuclides and other contaminants, prior to construction, OPG shall initiate research on a range of potential candidate seal materials to assess the influence of DGR in-situ saline groundwaters on the effectiveness of these materials as a barrier. At the time of decommissioning, OPG should select the seal materials with the best observed performance for use in the DGR, in conjunction with CNSC and based on the results of the research.

6.2.7 Geoscientific Verification Plan

OPG's Geoscientific Verification Plan included a framework for verification activities that would be undertaken to assess the geomechanical attributes of the DGR site that contributed to the DGR preclosure safety case. OPG divided its updated Geoscientific Verification Plan into two sections: geotechnical verification activities (studies of *in situ* rock mass properties and an assessment as to whether such properties fall within design limits of the safety case) and geoscience verification activities (studies to provide data for verifying the conservative assumptions and geoscience data used in support of the DGR postclosure safety case). OPG stated that the data from the Geoscientific Verification Plan would be used to: confirm site conditions predicted by the results of the surface drilling program; support engineering design decisions; and support the DGR safety case conclusions. Chapter 13 includes additional discussion of the Geoscientific Verification Plan in relation to the postclosure safety case. This chapter focusses on the use of the Geoscientific Verification Plan to verify and support engineering design decisions

OPG noted that the Geoscientific Verification Plan would verify the geologic, hydrogeologic and geochemical conditions described during its Geoscientific Site Characterization Program. Data from the Geoscientific Verification Plan would be used to verify sub-surface geologic and geotechnical conditions within the cap and host rock formations through and within which the DGR would be developed and operated. OPG outlined the Geoscientific Verification Plan verification activities that would be undertaken to assess site geomechanical attributes that contribute to the DGR Safety Case. Geoscientific Verification Plan activities would include, but not be limited to: geologic mapping; geophysical inspection; analysis of retrieved core samples; *in situ* large-scale rock sample analysis; hydraulic property determination; excavation deformation analysis; and *in situ* stress determination. OPG stated that adjustments and revisions to the Geoscientific Verification Plan would occur as additional experience and information becomes available through the construction phases.

For preclosure planning purposes and on the basis of information obtained from the proposed Geoscientific Verification Plan studies, OPG committed to the identification of specific action levels (called trigger criteria by OPG) for geologic and geotechnical measurements. OPG indicated that it would apply mitigation measures to reduce or eliminate short-term preclosure safety effects of the DGR as part of its adaptive management system, including, but not limited to, pauses in construction or operational activities.

In its adaptive design assessment, OPG stated that it would initiate additional shaft grouting and/or sump pumping capacity should excess seepage water flow into the shaft beyond anticipated volumes. OPG stated that it would apply seepage inflow mitigation within the shafts if inflow rates exceed 3 litres per second, 0.33 litres per second and 0.5 litres per second in the upper 200 meters shaft section, at the Salina A1 Formation contact and at the Guelph Formation contact, respectively.

Within the Cobourg Formation, OPG planned to assess large, undisturbed volumes of the rock mass for geomechanical parameters, such as rock strength, at a larger scale than was conducted during preliminary characterization studies. Rock core testing would be conducted to verify the up-scaling of parameters for the detailed repository design. As part of its Geoscientific Verification Plan, OPG proposed to conduct *in situ* overcore stress measurements, a test procedure conducted within boreholes to determine the three-dimensional state of rock stress, at the depth of the repository within the shaft and at one other repository-level site.

OPG stated that, should the up-scaled parameters be found to be lower than the previously predicted values, changes to the repository design, such as enlargement of pillar structures between panels, modification of opening geometries and alteration of support designs, would be considered to ensure long-term stability. For example, adaptive repository design during construction and operations would be considered if: a threshold rock strength of less than 80 MegaPascals is measured; the magnitude of the major horizontal principal *in situ* stress exceeds 34 MegaPascals; or if the orientation of the major horizontal principal *in situ* stress falls outside an OPG-defined sector bounded by N40°E and N100°E at the repository horizon.

In its revised Geoscientific Verification Plan, OPG presented several geotechnical verification activities, associated preliminary action levels, and mitigation responses, including design change or remediation. OPG proposed preliminary action levels for revisiting the DGR design to ensure safety for: *in situ* stress; rock mass rating value (used for rock support design and concrete liner design); groundwater inflow rate; post-excavation seepage from the shaft wall;

shaft wall deformation; rock loading on the concrete liner at shale horizons; and geomechanical properties used to ensure prevention of liner cracking and eliminate ingress of groundwater.

The Panel notes that preliminary action levels and mitigation responses for some stated shaft and lateral development activities have not been expressly defined or uniformly described by OPG. OPG stated that further action levels and response measures would be developed should the project be approved. OPG stated that action levels would be re-evaluated as future monitoring information is obtained and assessed.

CNSC Review of the Geoscientific Verification Plan

CNSC staff stated that there were four objectives for OPG's Geoscientific Verification Plan:

1. confirm that sub-surface conditions fall within the DGR safety envelope;
2. reduce uncertainties related to long-term performance of natural and engineered barriers;
3. optimize the DGR design and reduce construction and operational risks; and
4. support future license applications.

This chapter deals with the third and fourth objectives.

CNSC staff indicated that the proposed geotechnical verification activities would function adequately to provide:

- confirmation of DGR excavation and shaft liner design;
- optimization of ground support;
- verification of geomechanical properties and *in situ* stress;
- large-scale verification of pillar integrity;
- additional information regarding the longevity of shaft seals; and
- calibration of the geomechanical and hydraulic models.

CNSC staff stated that the preliminary action levels identified by OPG for preclosure design updates and the implementation of mitigation measures were acceptable for adaptive management procedures. CNSC staff related that similar adaptive management methods have been successfully applied by uranium mines in Saskatchewan under more challenging operating conditions than would be expected to exist at the proposed DGR. CNSC staff also stated that OPG's updated Geoscientific Verification Plan conformed to international best practice in terms of the adequacy of verification activities, and would be acceptable for permitting design adaptation during construction and operations to maintain the DGR safety case.

CNSC staff stated that, should a license to prepare the site and construct the project be issued, it would verify OPG's compliance with the Geoscientific Verification Plan. CNSC explained that it would: review Geoscientific Verification Plan test plans and procedures; monitor OPG's response to Geoscientific Verification Plan data; confirm that, where the results are materially different than expected, OPG has assessed the implications on safety in both the near and long term; and verify that OPG responds appropriately to the results in order to maintain worker safety and to protect the public and the environment.

CNSC staff stated that it would continue to conduct research and examine the results of international studies associated with geologic repository performance, including the use of geophysical methods that may be used to reduce uncertainties associated with the geosphere. This would provide the CNSC with information to use in discussions with OPG on geoscientific verification activities.

Panel Conclusion Regarding the Geoscientific Verification Plan

The Panel concludes that the proposed Geoscientific Verification Plan will provide additional information to confirm the predictions of the environmental assessment. The Panel notes that there are areas where the Geoscientific Verification Plan can be further improved. The Panel is of the view that OPG's adaptive management system must ensure effective and proactive implementation of responses to information obtained from its Geoscientific Verification Plan. Therefore, a complete set of action levels for all geotechnical indicator measurements will be required. The Panel is also of the view that a range of mitigation options should be developed in advance, in order that action triggered by Geoscientific Verification Plan information occurs in a timely manner.

Recommendation 6.7: OPG shall include in its adaptive management system a complete and clearly defined set of action levels, which would trigger a safety review process and, if necessary, mitigation. The management system shall be completed to the satisfaction of the CNSC prior to construction.

The Panel affirms that the geosphere is a critical barrier to contaminant release, and requires protection against excessive localized damage during and after the construction phase. The excavation damaged zone in proximity to all underground excavations will be strongly influenced by the pre-existing state of ground stress and its interaction with excavated structures. Accurate determination of the *in situ* state of ground stress is an important aspect of the safety case of the DGR. OPG stated that the horizontal stress components in the sedimentary rock of the proposed DGR site would have a considerable effect on the safety of the repository design.

The Panel notes that OPG's proposed *in situ* overcore stress measurements would provide limited or single site determinations of Cobourg Formation stress magnitude and orientation conditions that may not be representative of horizontal stress conditions existing over the larger spatial area of the proposed repository. Changes in geologic structure within underground sites can induce significant variation of *in situ* stress conditions over short distances.

The Panel expects that the Geoscientific Verification Plan will include a focus on discontinuity patterns and fracture conditions over a larger horizontal scale in order to increase confidence in the predicted geomechanical behaviour at the repository scale. The Panel is of the view that for proper geomechanical property characterization, data for larger scale representation of the DGR site would require more extensive sampling and testing. The Panel notes that, due to limited drilling accessibility and sampling of all geosphere layers, sparse geomechanical information existed for some formations. As the majority of drill holes were oriented vertical or near-vertical, OPG conducted little examination of the directional variation of the geomechanical character of rock formations at the DGR site.

The Panel is of the view that additional geotechnical information will be needed to provide relevant geomechanical assessment of short- and long-term repository structural performance. As such, the Panel recommends:

Recommendation 6.8: OPG shall perform additional geomechanical characterization work at sites located throughout the repository footprint to increase the quantity and the spatial distribution of site data collected during the preliminary site investigation phases. This work shall commence during site preparation and construction and should continue during operations, and be completed to the satisfaction of the CNSC.

Tests identified in OPG's Geoscientific Verification Plan were only designed to measure vertical stress change conditions within waste emplacement panel pillars. OPG's proposed tests may not corroborate *in situ* orientation or pre-existing magnitude conditions of site stresses or pillar stress conditions between rooms. The Panel is of the view that OPG should undertake additional stress verification measures in its Geoscientific Verification Plan to enhance confidence in its repository safety case design.

The Panel recommends that additional revisions be made to OPG's Geoscientific Verification Plan. These revisions should be designed to permit collection of additional *in situ* stress information (through overcoring stress measurement) to improve the reliability of data for this major design component of the repository, and provide additional validation of bounding conditions in defense of OPG's room orientation and structural design plans for mitigation of stress concentrations about proposed repository structures. Consequently, the Panel makes the following recommendation:

Recommendation 6.9: OPG shall, during construction, undertake additional *in situ* stress magnitude and orientation testing at the depth of the repository within the Cobourg Formation. *In situ* stress measurement tests shall be conducted at sites located apart from the two planned Geoscientific Verification Plan shaft sites and be completed prior to emplacement room construction activities. OPG should consider third-party review of *in situ* testing and stress data information. All testing shall be done to the satisfaction of the CNSC.

6.3 POSTCLOSURE DGR DESIGN FEATURES

The key design features of the DGR that are pertinent to postclosure safety, and that are described in this chapter as well as in Chapter 13, include elements of site characterization, facility design, and repository evolution modelling. CNSC staff have identified essential components of the long-term safety case for the management of radioactive waste, including:

- site characterization (stability of the rock formation from geochemical, hydrological and geological points of view, for very long periods of time);
- facility design;
- waste characterization; and

- modelling the evolution of the repository for a period up to one million years.

The specific elements evaluated in this chapter will focus on postclosure design features of the components listed above, such as:

- long-term changes to the physical stability of the repository;
- effectiveness of backfill for structural stabilization;
- impacts of the shaft excavation damaged zone on DGR performance; and
- shaft seal performance.

6.3.1 Anticipated Physical Changes to the DGR During Normal Evolution Postclosure Conditions

OPG assessed the long-term stability of the repository for periods beyond 100 years and up to 1,000,000 years after construction. OPG stated that the integrity of the geosphere and the effectiveness of the repository monolith and shaft seals were key to preventing the release of contaminants from the DGR after decommissioning. Structural stability analyses were undertaken that incorporated the use of conservative site conditions, including the effects of time dependent rock strength degradation, repeated glacial loading and unloading for up to ten cycles, and increased gas pressurization. OPG conducted structural modelling for repository-wide, individual repository room, and tunnel-to-emplacement room intersection site conditions. Additionally, OPG’s modelling analyses considered the damage effects that would result if no internal barrier pillars were to be developed between separate repository panels and from the presence of weak bedding plane fracturing above and below repository rooms. Stability analyses that were reported by OPG are described in the following sections.

OPG expected that, during the initial 100,000 year period after decommissioning, the repository rooms would experience localized damage to all exposed surfaces (walls, roof and floor). OPG noted that pillars between individual waste emplacement rooms were expected to remain structurally intact during this interval. OPG indicated that changes in ground stress, induced by surface glacial loads through the earliest two glacial ice ages during the initial 150,000 year period following decommissioning, would not affect pillar stability. Beyond 300,000 years after decommissioning, OPG expected that the effects of several ice ages would cause significant rock failure and roof collapse within repository rooms.

OPG expected that, by 1,000,000 years following repository decommissioning, full pillar degradation between individual emplacement rooms, as well as localized roof collapse, would occur. OPG’s modelling analyses indicated that the effectiveness of barrier pillars between waste emplacement panels would not be reduced during this period. OPG stated that the loss of structural integrity of Cobourg Formation rock surrounding each emplacement room and the gradual filling of rooms by collapsing rock beyond the initial 100,000 year period after decommissioning would prevent any subsequent collapse or fracturing of over- and under-lying limestone formation rock. OPG’s analysis indicated that possible delamination, the minor separation of layered or bedded rock strata, in the order of fractions of millimeters, and movement of bedding planes could develop if no engineered support measures were to be applied across them.

Modelling of the entire repository and Cobourg Formation layer by OPG indicated that the influence of localized rock failure and room filling would result in minor settlement effects on the overlying rock horizons. OPG expected that only small vertical displacements of the overlying rock layers would occur that could result in fracturing of the overlying cap rock shale formations. This was based upon the fact that collapsed rock material would have a greater volume than the original intact rock, thus creating less potential for movement of fractured portions of the overlying cap rock into emplacement room voids. OPG's studies indicated that, depending on the barrier pillar conditions, the maximum vertical settlements above the repository and within the overlying Georgian Bay cap rock shale formation would vary between 30 to 45 cm. OPG stated that it did not anticipate that damage would occur within the overlying Blue Mountain cap rock shale formation as a result of these settlement levels.

Panel Conclusion Regarding Anticipated Physical Changes to the DGR During Normal Evolution Postclosure Conditions

The Panel is satisfied that OPG has adequately assessed and characterized geomechanical changes to long-term stability that will result from normal evolution case conditions arising within and about the DGR facility during the postclosure period.

6.3.2 Effectiveness of Backfilling on DGR Emplacement Room Stability during Postclosure Conditions

OPG predicted that without the use of backfill in repository rooms, stable gas pressure conditions would develop and the potential for wall fracturing would be reduced. OPG's modelling of repository gas pressure generation scenarios illustrated that the use of backfill would generate increased long term pressure conditions in low permeability rock formations that could result in additional excavation wall fracturing and expansion of emplacement room excavation damaged zone features. Therefore, OPG determined that backfill would not be used.

Some participants expressed the opinion that backfilling the repository rooms would be an appropriate method to enhance waste containment. OPG stated that the containment provided by the impermeable rock formations of the geosphere and the engineered shaft seal barriers was adequate, and that in-room backfilling would provide little benefit in terms of cost or safety. OPG was of the view that the use of backfill would lead to increased costs for repository development, impose higher worker doses due to the need to undertake backfill placement in close proximity to waste containers within waste emplacement rooms, and would detrimentally affect the structural conditions of emplacement rooms through an increased excavation damaged zone resulting from generation of higher long term gas pressures.

Panel Conclusion Regarding Backfilling Emplacement Rooms

The Panel agrees with OPG's backfill modelling assessments that the use of backfill in emplacement rooms would not enhance the postclosure safety case; however, the Panel notes that cost should not be a determining criterion.

6.3.3 Impacts of the Shaft Excavation Damaged Zone on DGR Performance during Postclosure Conditions

The shaft excavation damaged zone is one of the primary pathways for the potential movement of contaminants to the surface. OPG's Postclosure Safety Assessment and Preliminary Safety Reports identified and modelled that contaminant transport through the shaft excavation damaged zone would have the potential to contribute to the dose to humans and the natural environment. OPG noted that the typical excavation damaged zone thicknesses would be approximately 0.5 times the opening radius of each of the shafts that would be constructed for the DGR. OPG stated that the excavation damaged zone would be influenced by construction activities, the stress interaction of repository structures with the existing *in situ* stress field, and the physical degradation of repository features such as rock pillars and support media, all of which are engineering design components.

OPG examined the effectiveness of excavation damaged zone and shaft seal performance as barriers to radionuclide transport for normal evolution and disruptive scenario cases. OPG stated that the shaft excavation damaged zone would not be a dominant contaminant transport pathway to the surface environment because of favourable rock formations and hydrologic characteristics, the effectiveness of shaft seals and the adoption of controlled drilling and blasting excavation techniques.

OPG expected that additional stress relaxation may also take place during closure operations when removal of shaft concrete support and existing reinforcement media will occur prior to placement of shaft seal materials. Stress relaxation may result in increased width of the excavation damaged zone, increased fracture density, or enlarged fracture apertures. The Panel notes that *in situ* stresses will act on DGR structures during all stages of repository activity and throughout the postclosure period.

OPG stated that, following the closure of the proposed DGR emplacement rooms and panels, and the development of the concrete monolith, OPG would progressively remove shaft infrastructure, remove and condition a depth of the excavation damaged zone around each shaft perimeter, and install various shaft seal structures. OPG proposed that shaft seal installation would take place from the repository level working upwards to the ground surface. OPG explained that shaft decommissioning would require progressive removal of small sections of concrete lining and wall support media such as rock bolts, plus the installation of new rock bolts, in order to provide temporary shaft bottom liner support during these activities. OPG noted that the process of installing new rock bolt supports could itself result in additional excavation damaged zone and the extension of fracture zones. OPG also stated that the shaft seal materials would provide lateral support to shaft walls during and after the shaft decommissioning process. OPG determined that shaft seal support would prevent further excavation damaged zone development with time.

Panel Conclusion Regarding the Excavation Damage Zone

The Panel concludes that OPG has adequately described the excavation damage zone for the purpose of the long-term performance of the DGR. The Panel acknowledges that removal of the concrete liner and a proposed 500 mm annulus of the excavation damaged zone, dependent upon timing of these activities, may subject zones of newly-exposed, intact rock about the shaft surface to mining-induced stress concentrations that could potentially create additional fracture development. The Panel notes that the continuing presence of *in situ* stresses, and the exposure of relatively intact rock structure about the shafts to these stresses, may jeopardize the purpose of damaged rock removal for reducing the shaft excavation damaged zone during decommissioning.

The Panel is of the view that OPG must take all possible steps to maintain the integrity of the shaft excavation damaged zone, as this is one of the primary potential routes of contaminate release between the DGR and biosphere. Accordingly, the Panel makes the following recommendation:

Recommendation 6.10: Prior to decommissioning, in order to enhance post-closure containment of radionuclides and other contaminants, OPG should develop measures, acceptable to the CNSC, to monitor and mitigate stress-induced fracturing of shaft walls prior to placement of shaft seal materials.

6.3.4 Assessment of Shaft Seal Performance during Postclosure Conditions

OPG predicted that only limited degradation of the concrete materials, and no significant alteration/degradation of the bentonite/sand or asphalt materials, would occur over the long term. OPG noted that anthropogenic and natural analogues of similar sealing materials are capable of remaining stable and isolating groundwater access for periods of tens of thousands to millions of years.

A discussion of shaft seal design aspects of the DGR was presented earlier in this chapter. In this previous section, the Panel noted that shaft seals would exist as primary engineered barriers within the DGR for inhibiting contaminant release to the natural environment in the long term. Accordingly, three recommendations were made by the Panel concerning shaft seal research that will be required to optimize shaft seal performance.

Panel Conclusion Regarding Shaft Seal Performance During Postclosure Conditions

The Panel is satisfied that OPG has adequately assessed the shaft seal performance under an acceptable range of normal evolution case conditions during the postclosure period. In order to meet the long-term design expectations for its safety case, OPG is encouraged to demonstrate its capability to design, test and validate the effectiveness of its proposed shaft seal materials under an extensive range of site conditions.

6.4 PANEL CONCLUSION REGARDING DGR DESIGN AND GEOTECHNICAL CHARACTERIZATION

The Panel concludes that OPG has adequately characterized the proposed DGR design, identified appropriate mitigation measures to address geotechnical hazards, and designed effective monitoring programs through its Geoscientific Verification Plan. The Panel understands that OPG would develop the detailed design for the DGR should the project be approved and should OPG obtain a site preparation and construction licence for the DGR, and that activities associated with the Geoscientific Verification Plan would continue during construction and operations.

The Panel considers the overall structure of the Geoscientific Verification Plan to be acceptable, and appropriate for the verification of the engineering design features of the DGR. The Panel notes that it made several recommendations in order to improve the Geoscientific Verification Plan.

The Panel further concludes that OPG adequately characterized the expected performance and behaviour of aspects of the DGR design for the postclosure period. The postclosure safety assessment is reviewed in Chapter 13.

CHAPTER 7 WASTE MANAGEMENT

This chapter presents a review of the management of the L&ILW to be placed in the DGR. The chapter begins with definitions of L&ILW and descriptions of the waste materials, including their physical and chemical characteristics. The inventory of radioactive and other constituents within L&ILW is then reviewed, with specific discussion of the implications of changes to the waste inventory to the safety case for the DGR. Waste quantities and opportunities for waste reduction are discussed. Criteria for acceptance of waste for disposal in the DGR are then reviewed. Waste packaging is described, including package modification, should such modification be required. The Panel also reviews waste package transfer into the DGR and concludes the chapter with a comparison of the proposed management of L&ILW with international practice.

Waste characteristics and waste management are important components of the long-term safety case that need to be included in the safety assessment. CNSC Regulatory Guide *G-320,* states that the long term safety case consists of “providing reasonable assurance that waste management will be conducted in a manner that protects human health and the environment.” Key aspects of this subject include the types and quantities of nuclear waste that would be deposited in the DGR, the packaging and handling of the waste, and the associated risks and hazards.

7.1 CATEGORIZATION OF WASTE

This section includes the definitions of L&ILW, OPG’s categorization of the waste streams, and a discussion regarding the physical and chemical hazards of the waste.

7.1.1 Definitions of Low-level and Intermediate-level Nuclear Waste

According to OPG, the classification of waste as low-level waste or intermediate-level waste is the primary determinant of how OPG’s nuclear waste is processed and managed. The handling, packaging, transport, storage, and eventual placement of waste in the DGR would depend on this characterization. OPG categorizes its low-level radioactive waste and intermediate-level radioactive waste in accordance with CSA Standard N292.3-08 *Management of Low- and Intermediate-Level Radioactive Waste* (CSA 2008) (see text box in Chapter 4). OPG stated that all of its radioactive waste that is not used fuel is either low-level waste or intermediate-level waste.

CNSC staff also provided information regarding the regulatory requirements for waste management. Low-level waste is material in which the concentration or quantity of radionuclides is above the clearance levels and exemption quantities established by the *Nuclear Substances and Radiation Devices Regulations* (SOR/2000-207), and that contain primarily short-lived radionuclides, i.e., have half-lives up to 30 years. Low-level waste does not require significant shielding during handling and interim storage, and requires isolation and containment for periods up to a few hundred years. Intermediate-level waste contains quantities of long-lived radionuclides and requires containment and isolation for more than several hundred years.

Both CNSC staff and OPG use dose limits for waste packages to categorize waste. Waste is classified as low-level waste if the waste package has a dose rate of less than 10 mSv/h at an offset distance of 30 cm, which corresponds to one-fifth of the annual radiation dose limit for nuclear energy workers. Waste is classified as intermediate-level waste if the dose rate is greater than or equal to 10 mSv/h at 30 cm, or if the package is known to contain a significant amount of long-lived radionuclides. OPG made no distinction between short-lived and long-lived intermediate-level waste.

A participant, the International Institute of Concern for Public Health, expressed concern that OPG had not provided an upper boundary for radioactivity in waste considered to be intermediate-level waste, and questioned whether there was a defined level of activity at which intermediate-level waste could be considered to be high-level waste. OPG did not provide an upper dose rate for intermediate-level waste packages, but noted that this would be determined by dose rate restrictions of the Waste Acceptance Criteria. The Waste Acceptance Criteria are discussed later in this chapter.

All of the waste destined for the DGR has been and will be generated from the operation and refurbishment of OPG-owned or -operated nuclear facilities. The low-level waste and intermediate-level waste are separated and categorized at their source as part of a Waste Management Program approved by the CNSC. OPG emphasized that used reactor fuel would not be placed into the DGR.

7.1.2 Categorization of Waste Streams

The physical and chemical properties of the L&ILW cover a wide spectrum of compositions and forms. OPG noted that the contaminated materials are often complex compounds and composites that do not lend themselves to ready separation. For the purpose of safety assessment and engineering, OPG distinguished two waste streams:

- operational L&ILW - waste generated during the normal operations of a nuclear reactor; and
- refurbishment L&ILW- the unique waste streams that can be generated during the refurbishment process of CANDU reactors.

OPG stated that it currently tracks about 70 different waste types. Many of these are small volume items, or have similar properties to other waste types. For the purpose of describing the DGR waste inventory, OPG grouped these waste types into 21 waste categories.

According to OPG, the major categories of materials in the operational low-level waste were:

- different types of ash from waste incineration;
- compacted waste (in bales or boxes) including such items as rubber hoses, metal cans, insulation, metal mop buckets and presses;
- non-processible waste that cannot be incinerated or compacted (in boxes, drums, or as large and irregularly shaped objects) such as heavy gauge metal, metal filings, wire cables, and heat exchangers;
- spent resins from light water and/or active liquid treatment systems; and
- sludge from the Bruce two-stage active liquid treatment system.

The major categories of materials in the operational intermediate-level waste were:

- spent ion-exchange resins from the reactor primary heat transport systems and moderator water cleanup systems;
- ion exchange columns;
- irradiated reactor core components; and
- filters and filter elements.

OPG stated that it does not process intermediate-level waste for volume reduction because of its physical characteristics and greater levels of radioactivity. Intermediate-level waste is stored at the WWMF in concrete- and steel-lined structures constructed in boreholes, in concrete-lined and covered trenches, and in concrete above-ground structures.

Refurbishment waste consists of waste generated from activities such as the replacement of motors, valves, instrumentation, fuel channels and steam generators in existing reactors. OPG noted that the refurbishment of a reactor would be expected to result in the production of about 21,700 m^3 of L&ILW (8,400 m^3 of low-level waste and 13,300 m^3 of intermediate-level waste). For planning purposes, OPG assumed that all of OPG's reactor units would be refurbished at or near their mid-life.

7.1.3 Physical and Chemical Characteristics of Low-level and Intermediate-level Waste

OPG stated that the physical composition of the waste would typically consist of industrial materials, including steel, plastics, other metals and inorganics which are contaminated with radioactivity. OPG noted that the total radionuclide inventory of the DGR would increase as wastes is added to the DGR but also decrease over time due to radioactive decay.

OPG stated that low-level waste normally does not require significant shielding for worker protection during handling and storage, and that the total radiotoxicity of this waste would largely decay in a few hundred years, resulting in low radiotoxicity similar to that of rock excavated from the DGR. Radiotoxicity is an alternative measure of radiological hazard to radioactivity. It takes into account the difference in hazard from exposure to the different radionuclides, due to differences in how they interact with the human body.

OPG further stated that intermediate-level waste often requires shielding for worker protection during handling. About 10% of the waste volume would be operational intermediate-level waste, which would decay significantly during the initial 10,000 year period after emplacement in the DGR. OPG noted that although the short-lived radionuclides in this waste would decay to negligible levels by 2062, the estimated closure date for the DGR, the 10% of the waste volume in the refurbishment intermediate-level waste would contain most of the long-lived radioactivity and constitute a long-term hazard.

OPG explained that, after a few hundred years, the waste radioactivity would be dominated by carbon-14 in the intermediate-level waste. In the very long term, residual radioactivity would be dominated by zirconium-93 in the retube waste, which represents about one percent of the radioactivity that would be present at the time of repository closure. A fuller discussion of waste degradation and the long-term safety assessment can be found in the Chapter 13.

Based on the projected 2062 inventory, OPG stated that the radioactivity in the DGR would be dominated by tritium (H-3), carbon-14 (C-14), nickel-63 (Ni-63) and niobium-94 (Nb-94). OPG explained that three of these (H-3, C-14 and Ni-63) are pure beta emitters, and that Nb-94 is a strong gamma emitter and a weak beta emitter. OPG noted that none of the dominant radionuclides is a strong alpha emitter. OPG further noted that the alpha emitters in the waste would be the actinides. Actinides are a series of chemical elements that encompasses the 15 metallic chemical elements with atomic numbers from 89 to 103, including natural uranium and thorium. Other actinides are produced by transmutation reactions from uranium in nuclear reactors.

Of interest to the Panel was the potential presence of a number of uranium and transuranic radionuclides (fission products, including plutonium) in the waste streams designated to be placed within the DGR. Uranium in the reactor fuel and the actinide fission products generated from it while in the reactor pose hazards both due to their radioactivity and their toxicity as heavy metals. OPG noted that such fission products are normally restricted to the fuel bundle assemblies and removed as used fuel to be stored in the station's irradiated fuel bay for future disposal. Damage to the cladding of fuel bundles in the reactor and consequent radionuclide releases can provide pathways for these elements to migrate into the waste stream via small fragments of fuel bundles and release products too small to be visible.

OPG stated that the DGR Waste Acceptance Criteria, further discussed in a later section of this chapter, specifically excluded the acceptance of "used nuclear fuel and recognizable fuel fragments", which OPG defined as visually recognizable pieces of fuel, such as a pellet, fuel element or partial fuel bundle, from the DGR. OPG noted that such wastes are not routinely produced at OPG or Bruce Power nuclear generating stations but are the result of rare, discrete incidents involving severe physical damage to a fuel bundle. The fragments of fissile materials would normally be isolated during clean-up operations and stored in the fuel bays at the stations as "failed fuel." OPG stated that recognizable fuel fragments would be recognized by measurable dose rates that are significantly higher than those for normal wastes and are thus easily detectable. OPG further noted that WWMF personnel verify the actual dose rates of waste containers received at the WWMF.

OPG stated that fuel damage is more likely to lead to the release of fission products that are too small to be visible. Since they have a low solubility, the fission products released into the primary heat transport system would generally deposit in the feeder piping or the steam generators, and most likely be captured in the filters or ion exchange columns used in the cleanup of the primary heat transport system cooling water. The used filters and ion-exchange resins are considered to be intermediate-level waste and would have to meet dose requirements of the Waste Acceptance Criteria. OPG provided no dose threshold for actinides in the L&ILW that would initiate further inspection for fuel fragments since it considered the presence of fuel fragments in L&ILW to be highly unlikely. The accumulation of fission products in resins and filters was considered to be acceptable, provided that they are classified as intermediate-level waste if the dose rate is greater than or equal to 10 mSv/h at 30 cm.

CNSC staff recommended that OPG should develop a waste characterization program that would be reviewed and revised as appropriate to conform to international guidance. The Panel is of the view that this waste characterization program should include thresholds for actinides.

OPG stated that, in addition to radioisotopes, the L&ILW may contain varying amounts of substances, chemicals or elements that can be hazardous to humans and the environment. These include asbestos (originally used as insulating material in some stations); heavy metals such as uranium, cadmium, mercury, chromium, and lead; and certain organic materials such as polycyclic aromatic hydrocarbons, chlorinated benzenes and phenols, and dioxins and furans produced in the incinerator and trapped in the ash. Metals like chromium, nickel, and lead are present in container materials, i.e., stainless steel and lead shielding. OPG stated that, over time, the radioactive decay of radioisotopes would produce stable progenies, such as heavy metals, that pose hazards to human health and the environment when their concentrations exceed effects thresholds. OPG noted that, as with the radiological waste, all of these materials are confined to appropriate containers that are intended to be effective barriers until the waste has been isolated in closed repository chambers.

OPG noted that the management of non-radiogenic constituents in the waste would be governed by Regulation 347 (*General – Waste Management*, R.R.O. 1990) under the Ontario *Environmental Protection Act*, which addresses leachate toxic wastes. Leachate toxic waste in the DGR would consist mainly of heavy metals, notably cadmium, chromium, lead and mercury, and some organic compounds in the incinerator ash. The Waste Acceptance Criteria for the DGR specifically excluded other classes of hazardous waste.

7.1.4 Panel Conclusion Regarding Categorization of Waste

The Panel is satisfied that OPG adequately described the waste categories and waste streams for the DGR, as well as the associated physical and chemical hazards. OPG provided the Panel with a full categorization of the types of materials that would be placed into the DGR and their classification as low-level waste or intermediate-level waste. The Panel is satisfied that both the categorization and classification conform to CSA Standard N292.3-08 and the *Nuclear Substances and Radiation Devices Regulations*.

The Panel recommends that OPG design and implement additional precautions to ensure the protection of workers, the public and the environment from potential exposure to actinides. These precautions should include explicit thresholds for actinide activity that would trigger the implementation of a contingency plan to ensure protection of workers, the public and the environment.

Recommendation 7.1: In order to avoid significant adverse effects to human health and the environment due to potential actinide exposure, OPG shall develop and establish thresholds and appropriate screening methods for actinides, to the satisfaction of CNSC, for all waste packages to be emplaced in the DGR. OPG shall also develop a contingency plan for managing waste packages that exceed these thresholds. The thresholds, screening methods and contingency plans should be in place before an operating licence is issued.

7.2 WASTE INVENTORY

OPG presented its 2010 DGR Reference Inventory Report, which was a detailed summary of all existing and predicted future production of L&ILW designated for storage in the DGR. The Reference Inventory was a key component in the physical planning for the DGR and for the analysis of the postclosure evolution of the repository.

The DGR Reference Inventory included:

- all L&ILW types;
- radionuclide inventories in the wastes;
- chemical, physical, and radiological characteristics of wastes and containers; and
- inventory as a function of time considering receipt of wastes and radioactive decay.

OPG explained that the reference inventory was based on measurements, calculations and estimates of waste quantities. The estimates focused on the radionuclides of most importance to the DGR safety case. Almost half of the inventory intended for the DGR is already stored at the WWMF while the remaining amounts were based on projections that included future reactor refurbishments and waste management initiatives. OPG had to use assumptions to calculate the inventory for both the existing and future waste packages.

OPG noted that the radionuclide activity concentrations in L&ILW as-received at the WWMF were based on direct measurements, scaling factors, used fuel ratios, and neutron activation analysis. OPG adopted the use of scaling factors to calculate the concentrations of difficult-to-measure radionuclides, such as pure beta emitters, which cannot be measured by non-intrusive methods in waste packages. OPG noted that scaling factors are widely used internationally and were obtained by a variety of methods.

CNSC staff commented on OPG's methods to determine the waste inventory, noting that, in addition to certain direct measurements, OPG used scaling factors, used fuel ratios, and neutron activation calculations for intermediate-level waste from irradiated core components to estimate the activity in all containers produced from the different waste streams. CNSC staff stated that OPG's characterization was sufficient for the purposes of the environmental assessment, but suggested that OPG could further enhance the waste characterization program and align it with international standards.

Some participants questioned aspects of the accuracy and veracity of the 2010 Reference Waste Inventory. Specific questions concerned radionuclide concentrations in CANDU reactor components, such as pressure tubes and garter springs, for which the concentrations of some radioisotopes appeared to have been significantly underestimated or not estimated at all. The underestimates appeared to be due to the use of calculated values and scaling factors, rather than measured values where such measurements would have been available. The radioisotopes of concern included tritium, curium-244, cesium-137, antimony-125, cobalt-60, nickel-63 and nickel-59.

OPG acknowledged that some of the assumptions in its calculations were no longer appropriate. OPG subsequently revised the estimates and evaluated the impact of the revisions to the Reference Waste Inventory on both the preclosure and postclosure safety cases. OPG determined that, since all of the waste packages would be required to meet the DGR Waste Acceptance Criteria, they would have to be sufficiently shielded and/or allowed sufficient decay time to ensure that they meet dose rate Waste Acceptance Criteria before they could be handled and placed into the DGR. OPG stated that the revisions to the inventory would not affect the ability of the waste to meet the Waste Acceptance Criteria.

OPG re-evaluated the post-closure safety assessment models with the revised inventories using a similar level of detail as used in the initial assessment models. OPG noted that some of the radioisotopes that had been underestimated, such as H-3, Cs-137, and Cm-244, have short half-lives and thus would not affect the long-term safety case.

The only change in OPG's modelling was the inclusion of the conservative assumption that the revised radionuclide inventories were primarily the result of surface deposits from reactor coolant on the pressure tubes, which would be quickly released on contact with water. The results of the re-run models showed that the inventory changes had no significant effect on the long-term safety case since the DGR design and site would provide a large safety margin.

Some participants expressed concerns regarding the waste inventory. Participants noted that chemical, radiological and biological processes would occur in the waste containers and stated that, while some of these may be predictable, others may not be. As such, participants stressed the importance of having the contents of each waste container adequately characterized. Some participants suggested that it would not be possible to completely and accurately determine the waste inventory. OPG reiterated that the safety case took into account the implications of uncertainties through conservatism in the analysis and through sensitivity studies, in order to ensure a large margin of safety.

7.2.1 Waste Inventory Verification Plan

Since the DGR Reference Waste Inventory is a work in progress that would require updating until the closure of the DGR, the Panel requested that OPG provide a Waste Inventory Verification Plan. This plan was to provide clear objectives, activities, and time-lines of future endeavours to improve the accuracy of the Reference Waste Inventory. OPG was also to include any plans for an independent third-party evaluation of the methodology and verification procedures.

OPG provided a Waste Inventory Verification Plan that would be implemented by more specific work programs and plans within the OPG management system. The plan summarized the activities underway and planned by OPG. OPG committed to continue to measure and verify the properties of the L&ILW arising from operations and refurbishment of OPG-owned or -operated nuclear generating facilities that are intended for disposal in the proposed DGR. The plan included an external third-party review of the waste characterization program.

CNSC staff had initially determined that the results of OPG's waste characterization efforts appeared low compared to those from other countries such as the US, Japan and Korea, which manage similar types of waste in shallower repositories. Despite the predicted doses in the normal evolution scenario being orders of magnitude below background, there remained uncertainties associated with the waste inventory. As a result of these uncertainties, CNSC staff recommended that OPG enhance its waste characterization program and align it with the expectations of international standards, such as ISO 21238 *The Scaling Factor Method to Determine the Radioactivity of Low- and Intermediate-Level Radioactive Waste Packages Generated at Nuclear Power Plants*. The submission of the Waste Inventory Verification Plan by OPG and the commitment to complete it in time for an application for a licence to operate the DGR satisfied the CNSC. CNSC staff determined that the Waste Inventory Verification Plan would provide reasonably conservative predictions when the long-term postclosure safety assessment is re-visited, should a licence to operate be sought by OPG.

7.2.2 Panel Conclusion Regarding the Waste Inventory

The Panel recognizes that the Reference Waste Inventory has to be a living document that may be modified up to the decommissioning of the DGR. Deficiencies in the 2010 Reference Waste Inventory, presented with the EIS, emerged during the review process, as noted by CNSC staff and some participants. The Waste Inventory Verification Plan presented by OPG addressed the Panel's concerns regarding the potential uncertainties associated with the 2010 inventory, and provided confidence that the adaptive management inherent in the plan is the most appropriate approach. The Panel accepts the information presented by OPG and CNSC staff, and concludes that recent and future revisions of the inventory are not likely to affect the long-term safety assessment of the proposed DGR. In order to ensure that the Waste Inventory Verification Plan continues to be revised and updated at appropriate intervals, the Panel makes the following recommendation:

Recommendation 7.2: In order to ensure that the Waste Inventory Verification Plan continues to be revised and updated at appropriate intervals, prior to and throughout the Operations phase, OPG should subject the Waste Inventory Verification Plan to periodic review by an external third party, acceptable to the CNSC, at intervals determined by, but not limited to, the addition of new waste streams.

7.3 WASTE QUANTITIES

The amounts of each waste category to be stored in the DGR may be expressed in terms of volume, weight, waste radioactivity, or number of containers. As shown in Figure 13, in the context of the long-term safety case, the projected total waste activity and its change over time would be the most significant. OPG determined the amount of radioactive waste and number of packages over the duration of OPG’s nuclear program by using the existing inventory in its Integrated Waste Tracking System, and by projecting the receipt of future waste.

OPG’s forecasted volume of the total emplaced waste in the DGR was estimated to be about 200,000 m^3. Approximately 75% of the emplaced volume would be operational low-level waste, and 14% would contain intermediate-level waste. Refurbishment waste had a planned emplaced volume of 21,700 m^3, or 11% of the total, of which 61% would be intermediate-level waste and 39% would be low-level waste. The anticipated number of containers that would

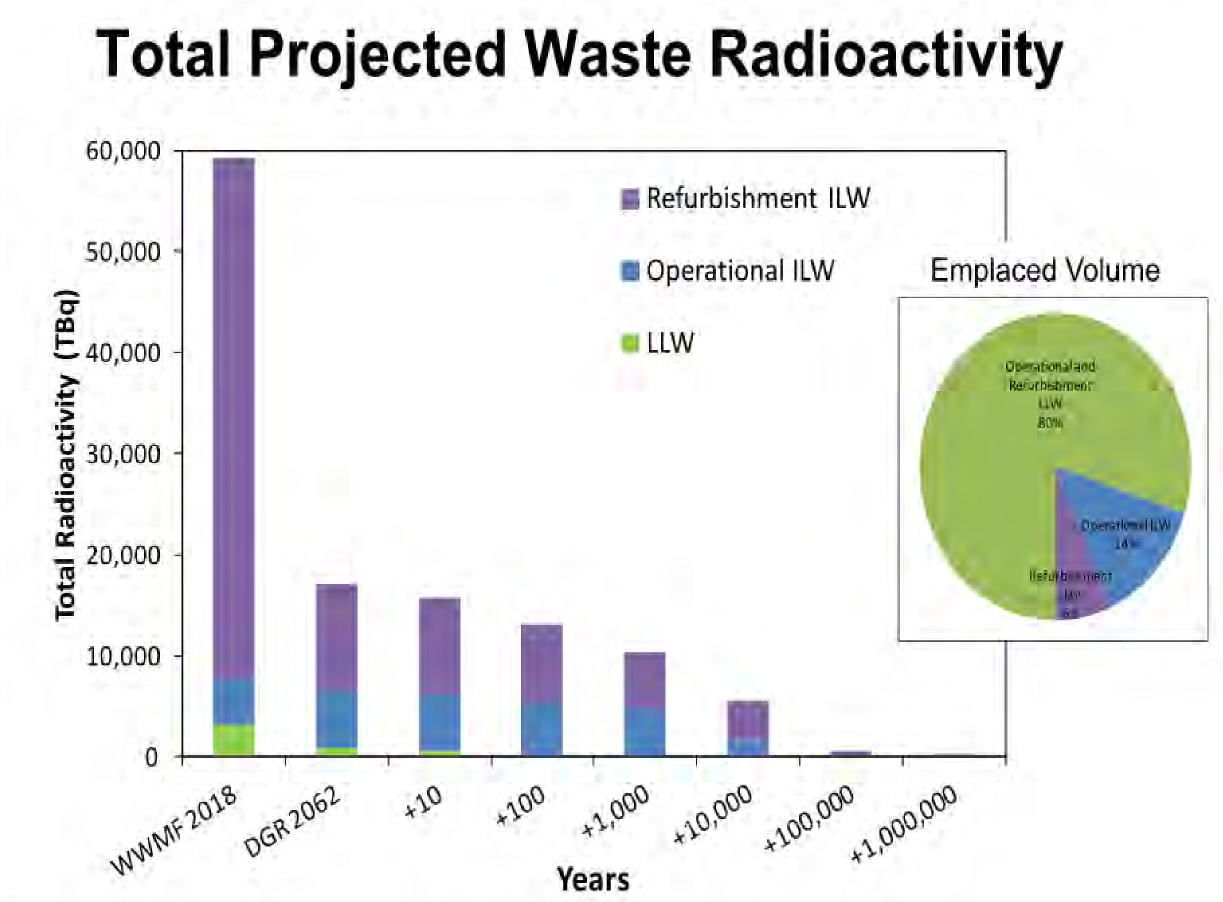


Figure 13: Relative contributions of intermediate-level waste and low-level waste in the DGR to total radioactivity over the next million years. Pie chart shows the relative waste volumes planned for emplacement in the DGR (reproduced from OPG PMD 13-P1.1F)

be stored in the DGR at 2062, the earliest projected time of closure, was 45,200 low-level waste containers and 7,400 intermediate-level waste containers for a total of 52,600.

Approximately 90,000 m^3 of L&ILW is currently stored at the WWMF. OPG explained that OPG-owned or -operated nuclear generating stations produce approximately 5,000 m^3 to 7,000 m^3 of new L&ILW each year, which is transported to the WWMF for processing and interim storage. After volume reduction, this results in 2,000 m^3 to 3,000 m^3 of additional stored waste annually. OPG noted that if each of the current 20 reactors operates to the end of its planned life (includes a mid-life refurbishment of most of the reactors), this would result in a total of approximately 170,200 m^3 (as stored) of operational and refurbishment L&ILW. When placed into DGR-ready packages, the total volume of waste packages would be about 200,000 m^3 as indicated in Table 5.

Table 5: Waste Volumes in Reference Forecast (information reproduced from DGR EIS Table 4.5.1-1)

Volume	Operations LLW	Operations ILW	Refurbishment L&ILW	Total
Net waste volume (m^3)	95,100	9,300	11,200	115,600
As-stored volume (m^3)	135,000	13,500	21,700	170,200
Emplaced volume (m^3)	154,700	27,600	21,700	204,000

For total radioactivity, OPG provided an estimate of the amounts of short-lived intermediate-level waste and long-lived intermediate-level waste destined for the DGR. OPG CANDECON resin intermediate-level waste, irradiated core component intermediate-level waste, and retube end fittings intermediate-level waste would be (generally) classed as short-lived intermediate-level waste. These were estimated to have a total radioactivity of about 4,000 TBq in 2062 and an emplaced waste volume of about 16,000 m^3, approximately 40% of the total intermediate-level waste volume, with most of the activity and volume in the end fitting waste stream. The other intermediate-level waste, classed as long-lived intermediate-level waste by this criterion, would have a total radioactivity of about 12,000 TBq in 2062 and an emplaced waste volume of about 25,000 m^3, approximately 60% of the total intermediate-level waste volume.

7.3.1 Waste Reduction

OPG reported that all of its nuclear facilities have implemented waste minimization strategies, and that this ongoing process would continue to be applied to wastes prior to emplacement in the DGR. OPG did not include any additional waste treatment or conditioning for the proposed project. All treatment, including conditioning and packaging, would continue to be performed at the WWMF under its existing operating licence and/or at other specialized facilities licensed for this purpose. CNSC staff stated that it requires that best practices be used to minimize the amount of waste that is generated at these facilities.

OPG described its practices for waste minimization and volume reduction. Most of the waste volume is low-level waste and contains much of the cellulosic and other organic material of the waste streams. Approximately half of the original low-level waste is incinerated at the WWMF. This would reduce waste volume and gas generation in the repository, as only the ash would be placed into the DGR. Some participants expressed concerns regarding the incineration of low-level waste. OPG stated that the incinerator is part of the existing operations at the WWMF under a CNSC licence, and has regulated limits in accordance with a Certificate of Approval issued by the Ontario Ministry of the Environment and Climate Change.

Some of the waste is compacted; OPG stated that approximately 22% of the waste was categorized as compacted waste. Further volume reduction could be achieved through supercompaction, which would have a compaction ratio up to 10:1, and would be able to handle a wider range of wastes than conventional compaction. OPG rejected the general use of supercompaction, because it would result in higher worker doses and generally increase long-term hazards due to increased gas production as a result of more metal being added to the repository in the form of sacrificial drums (emptied containers) and overpacks.

At the hearing, OPG outlined its current plans to further decrease the volume of waste generated at its facilities by, for example, initiating new recycling initiatives, surface cleaning procedures and decontamination methods. The Power Workers' Union emphasized its involvement in the initiation of a pilot program to find ways to reduce the amount of waste that would need to be emplaced in the DGR.

Several participants commented on the potential opportunities for recycling certain types of waste, particularly those that contain valuable metals. One participant expressed particular concern that OPG had not provided for the recycling of nickel, zirconium and neutron reflector carbon. In a response to an information request, OPG explained that, although an elemental inventory of the bulk waste did contain substantial amounts of some metals, this did not mean that the materials were in a pure or accessible form that could be easily separated. For example, most of the copper would be present in the form of corrosion resistant alloys, such as heat exchanger tubes, while most of the lead would be in the form of shielding integral to waste packages. OPG noted that it would continue to explore recycling opportunities, such as the reprocessing of steam generators and heat exchangers at licensed commercial facilities. OPG further noted that if recycling removed 90% of the carbon steel in steam generators, then the total mass of waste handled by the DGR would be about 91% of current plans, and the total remaining gas generation would be about 93% of current projections. CNSC staff commented that metal refining and processing are industries with significant amounts of environmental emissions and that it was not aware of any country where this was an acceptable practice for highly contaminated metals. The Panel is satisfied with the response from OPG and CNSC staff.

7.3.2 Panel Conclusion Regarding Waste Quantities

The Panel concludes that OPG adequately described the waste quantities that would be emplaced in the DGR. The Panel notes that approximately 80% of the emplaced waste volume in the DGR would be low-level waste (Figure 13), which, by the time of decommissioning in 2062, would contribute only a small fraction to the total radioactivity in the DGR. Over the 300-year period of proposed institutional control, the radioactivity in the bulk of the waste volume (the low-level waste) would have largely decayed, including that of H-3, Co-60 and Cs-137. Only C-14 would remain an important radionuclide in the low-level waste. Advances in waste treatment (possibly including physical radioisotope separation) and changing priorities for the use of the storage space may lead to a future re-evaluation of the necessity to retain such low-activity materials in a DGR. Some European countries have adopted options for low-level waste disposal that do not involve a DGR.

The Panel is of the view that OPG should develop and adopt adaptive management procedures that would address and facilitate a scenario involving the future diversion of low-level waste away from the DGR. For example, the enclosures of the low-level waste emplacement chambers, the spatial organization of the waste, the integrity of the waste packages, the record keeping and package labelling should allow for future decision makers to revisit and revise the current and proposed practices and priorities. While the Panel accepts the need for the DGR, it notes that it would be prudent for OPG to retain the flexibility to accommodate potential future disposal options for low-level waste.

Recommendation 7.3: In order to retain flexibility to reduce the volume of waste stored in the DGR, OPG should prepare, to the satisfaction of CNSC and before a licence to operate the DGR is issued, an adaptive management plan that includes management actions to exploit potential future options for the disposal of low-level waste.

Regarding waste reduction, the Panel notes that the DGR would receive a substantial amount of combustible waste via the compacted waste stream, which consists of approximately 75% combustible material. The Panel concurs with OPG that surface reduction by compaction and emplacement into fully enclosed metal and/or concrete containers would greatly reduce the risk of accidental fire. Precaution dictates that fire prevention, detection, suppression, and emergency procedures and protocols must be given the highest priority during the operations phase of the project.

The Panel recognizes that OPG has made substantial efforts to implement waste reduction and recycling in its waste management. The Panel is of the view that the current waste reduction and recycling efforts are adequate, progressive, and generally in line with international practice, as discussed later in this chapter. The Panel notes, however, that due to the associated decrease in gas generation, any further waste reduction and recycling efforts would be beneficial. As such, the Panel encourages OPG to continue to actively pursue waste reduction and recycling initiatives in all its nuclear installations. In order to further the goal of waste reduction, the Panel also makes the following recommendations:

Recommendation 7.A: In order to further the goal of waste reduction, as required by CNSC Regulatory Policy P-290, the CNSC should develop guidance for waste reduction, setting goals and timelines relevant to the project.

Recommendation 7.4: OPG should minimize the volume of waste stored in the DGR to the extent practicable through waste reduction and recycling initiatives.

7.4 WASTE ACCEPTANCE CRITERIA

OPG presented preliminary Waste Acceptance Criteria for the DGR, noting that they had not yet been finalized. OPG anticipated that the final criteria would closely reflect the Waste Acceptance Criteria used at the WWMF. The aim of the Waste Acceptance Criteria would be to avert any harmful releases of container contents prior to their emplacement in and the closure of the repository panels. In addition, the criteria included provisions that would limit the dose rate of waste packages to protect workers during waste handling activities. Notable among the numerous acceptance criteria were:

- containers must be adequately labelled, stackable up to 6 meters, fire resistant, and their contents must be well documented;
- waste that contains more than 1% free liquid by volume, reactive wastes, polychlorinated biphenyl (PCB) wastes, pathological wastes, ignitable wastes, explosives, corrosives, compressed gases, and high thermal cobalt-60 sources;
- dose rate limits specify 2 mSv/h on contact with external surfaces of waste packages or shielding and 0.1 mSv/h at 1 m from transportation package; and
- sludges must have a slump of less than 150 mm.

In a submission to the Panel, the US EPA raised concerns about the presence of residual liquids in the Active Liquid Waste sludges designated for the DGR. The Panel issued an information request on this matter. OPG responded that the waste category Active Liquid Waste sludge referred to the original source of the waste, not its final state. OPG explained that, prior to delivery to the WWMF, this waste is treated with clay-based or polymer binding agents to produce a solid cake which is then packaged into steel containers. OPG stated that no additional measures would be necessary to control condensation and leakage of sludges following packaging.

The Panel raised questions about the applicability and compliance of the Waste Acceptance Criteria to older waste, as the waste from OPG's operation and refurbishment of heavy-water-moderated CANDU power reactors dates back to at least 1971 when Pickering A went into service. OPG noted that while the waste characterization documentation of older waste was not as detailed as its current practice, the waste characteristics were expected to be similar since they originate from similar reactor operations and waste conditioning methods. OPG emphasized that the number of waste streams from its reactors, which have been in place for a long time period and have remained consistent, was limited. OPG explained that when it has re-examined older waste packages, they have been found to consistently conform to the present Waste Acceptance Criteria. As part of its continuing waste characterization program, OPG proposed to improve the documentation of older waste streams as required to support the assumptions in DGR safety assessments.

During the hearing, OPG described the Waste Acceptance Criteria as a ‘dynamic, active document’ as the criteria undergo periodic reviews, usually limited to such items as packaging modifications. OPG stated that although quantitative inspection criteria for container damage had not yet been developed for containers designated for the DGR, they would be developed in the future as the Waste Acceptance Criteria are finalized.

CNSC staff pointed out that CNSC site staff at nuclear generating stations conduct periodic reviews and inspections that include adherence to the current WWMF Waste Acceptance Criteria. OPG stated that it visually inspects waste intended for incineration or compaction at the WWMF prior to processing to ensure that there has not been a lack of waste segregation at the nuclear generating stations.

Some participants commented about the Waste Acceptance Criteria. They noted the importance of the Waste Acceptance Criteria, suggesting that the failure to adhere to them could result in accident or malfunction scenarios.

7.4.1 Panel Conclusion Regarding Waste Acceptance Criteria

The Panel concludes that the wide range of requirements and exclusions included in the Waste Acceptance Criteria for the DGR will ensure the protection of workers, the public and the environment. The Panel accepts that the current Waste Acceptance Criteria presented in the EIS may change, in detail, over time. The Panel is of the view that the Waste Acceptance Criteria, particularly with respect to waste containers, should be finalized as soon as possible to provide additional confidence in the safe transfer of the waste from its current storage into the repository. In addition, the Panel suggests that, as a precautionary measure, the long-term stability of solidified sludges be verified in order to confirm the control of condensation and leakage. The Panel makes the following recommendation regarding waste acceptance criteria:

Recommendation 7.5: In order to confirm the predictions in the environmental assessment that there will be no significant adverse effects to human health and the environment due to releases of container contents prior to their emplacement in, and the closure of, the repository panels, OPG's Waste Acceptance Criteria shall be finalized and approved by the CNSC before a licence to operate the DGR is issued. The Waste Acceptance Criteria should be reviewed by both the CNSC and an independent third-party, acceptable to the CNSC.

Recommendation 7.6: Before a licence to operate the DGR is issued, to confirm the prediction in the environmental assessment that no further measures are required to control condensation from, and leakage of, sludges following packaging, OPG shall perform research, and report on, the predicted long-term stability (up to decommissioning) of the solidified active liquid waste sludges and the potential release of liquids when exposed to conditions applicable to the DGR, to the satisfaction of CNSC.

7.5 WASTE PACKAGING AND PACKAGE MODIFICATION

This section includes a description of the packages used by OPG to store L&ILW, as well as measures to modify the packages in order to ensure their continued safe function over the operations phase.

7.5.1 Waste Packaging

OPG stated that all forms of radioactive waste intended for storage in the DGR would be packaged in containers designed to safely hold the waste during handling, transportation, and storage. The containers, constructed of steel and/or concrete, may also provide some shielding from ionizing radiation and provide enhanced opportunities for stacking to improve storage efficiency. The containers were not intended to provide long-term containment and there are no specific CNSC regulatory requirements for radioactive waste containers to be placed in a repository. CNSC staff explained that waste package design and testing was the responsibility of OPG and that CNSC staff would evaluate packaging and containers as part of a licensing application for a waste management facility.

OPG explained that waste containers are designed according to specific requirements and procured from qualified vendors under OPG's nuclear procurement procedures, which include requirements for manufacturing, inspection and test plans, to ensure that they meet OPG's specified design requirements and technical specifications. The vendors undergo periodic quality management audits by OPG to ensure that they are maintaining their quality management systems.

OPG noted that the DGR would be designed to accept the majority of the waste packages currently in storage at the WWMF without requiring further processing or packaging. There are currently in excess of 100 different waste containers used for storage of L&ILW at the WWMF, several of which are illustrated in Figure 14. Information on each waste package is, and would continue to be, maintained in an electronic database.

OPG noted that the Waste Acceptance Criteria for waste containers would require that they be of sound structural integrity, show no significant rusting, no leakage, and no wobbling or tilting in their storage site. OPG stated that each package would be visually inspected prior to transfer to the DGR to ensure that it meets the DGR Waste Acceptance Criteria. Containers that do not meet all the applicable Waste Acceptance Criteria conditions would be remediated prior to transfer and acceptance in the DGR. Most low-level waste would be placed in closed but not sealed low-level waste containers, as container venting was considered as part of the DGR design basis. OPG noted that some of the low-level waste is stored in steel boxes that are welded shut. Where there is potential for gas build-up in containers that are not designed to withstand the pressure, the Waste Acceptance Criteria would require that the containers be vented. Gas generation would also be expected from intermediate-level waste ion exchange resins that are contained in older carbon steel containers (the current containers are stainless steel). During transfer from the WWMF to the DGR, these packages would be inspected and vented if appropriate. OPG stated that it had no evidence that the venting mechanism or path of containers could be blocked, and that it was unlikely that gas pressure could build up in a container leading to container failure during DGR handling and operations.

As a conservative assumption, OPG stated that waste containers were not credited with any function in the postclosure safety assessment. They were not considered to provide any barrier that would prevent the transport of radioactive or chemical constituents to the surface environment. OPG determined that the geology and hydrogeology of the site would provide adequate multiple barriers. OPG expected, however, that waste containers would maintain their integrity to the degree necessary to facilitate easy retrieval (if required) for a decade or more after emplacement in the DGR, and that many containers would provide effective containment for considerably longer periods. In particular, the robust steel and concrete containers used for intermediate-level waste have a 50 year design life. As repository panels are sequentially filled, over approximately 10 to 15 year time spans, closure walls would be installed that effectively isolate the waste packages emplaced within that panel.

B25 Compacted Waste Box

DBIN Drum Bin

BINOPK LLW Container Overpack

NPB47 Non-Processible Waste Container

RLSS 3 m³ Resin Liner

SPC Shield Plug Container

RWC-EF Retube Waste Container – Endfittings

ETH Encapsulated RWOS 1 Tilehole

Figure 14: Examples of Waste Containers for Emplacement in the DGR (reproduced from DGR EIS Figure 4.5.1)

7.5.2 Waste package modification

OPG explained its plans to overpack certain containers for added worker protection prior to transfer to the DGR. For some classes of higher dose-rate wastes, such as some ion exchange resins, shielding overpacks would be used in order to meet the waste package dose rate restrictions of the Waste Acceptance Criteria. For added worker protection, any potentially dispersible wastes, such as incinerator ash, or containers that do not pass inspection or are otherwise considered to be at-risk, would be overpacked in new containers prior to transfer.

OPG provided overpacking and shielding assumptions for each waste type in the DGR Reference Inventory report. These would be developed in conjunction with the finalization of the DGR design, safety assessment and Waste Acceptance Criteria to ensure that they meet all applicable requirements and be fully integrated into the design and safety assessment. OPG noted that some of the overpacks had not yet been designed.

7.5.3 Panel Conclusion Regarding Waste Packaging

The Panel accepts that, prior to emplacement into the DGR, OPG would ensure that all waste containers would be remediated if they do not meet the Waste Acceptance Criteria. However, the Panel believes that a standardized inspection protocol should be in place to ensure that all containers will perform safely throughout the preclosure period of the DGR. A release of radioactive or non-radioactive contaminants from their containers prior to closure of the repository could pose a potential risk to workers and have a negative effect on the public perception of the safety of the facility. The Panel concurs that overpacking would be an effective mitigation measure for waste containers that could pose a risk to workers or the environment. As an additional level of precaution OPG should ensure that the integrity of waste packages will be maintained over the entire preclosure period of the DGR. The Panel recommends that:

Recommendation 7.7: Before a licence to operate the DGR is issued, and in order to reduce the likelihood of significant adverse environmental effects due to a container breach before closure of the DGR, OPG shall provide, to the satisfaction of the CNSC, an inspection protocol for waste containers, beyond visual inspection, that must be followed before their placement in the DGR. The protocol shall include procedures that ensure that container venting mechanisms will remain functional following emplacement in the DGR.

Recommendation 7.8: In order to protect human health and the environment during operations, OPG should take all steps necessary to ensure the integrity of waste packages over the entire preclosure period of the DGR, to the satisfaction of the CNSC.

7.6 WASTE TRANSFER INTO THE DGR

OPG outlined how the waste packages retrieved from the WWMF would be transported to the Waste Package Receiving Building in a DGR-ready state on flat-bed transporters, covered transporters, or forklifts. The packages would be visually inspected to ensure that damage has not occurred in the transfer and to confirm that Waste Acceptance Criteria have been met.

OPG presented information concerning the numerous measures that would be taken to ensure the safe movement of waste packages to, into and at the DGR, including during surface handling, shaft handling, underground transfer and placement into the emplacement rooms. All operations would be conducted in a physically stable configuration utilizing practices that ensure secure and safe handling of the packages. All procedures would have to meet applicable regulatory requirements.

All waste packages would be transferred into the main shaft cage by means of a rail-based transfer cart, which would be mechanically secured for transport from the surface level to the repository level. The safety features of the cage and hoist, which includes a chairing mechanism and cart locking device, would be based on existing proven mining industry designs for similar cage types and loads. The rate of travel of the main cage would be limited to 5.0 m/s. At the underground shaft station, most waste packages would be removed from the cart by forklift and moved to either a temporary staging area near the shaft station or directly to an emplacement room. Alternatively, the rail cart would proceed via the embedded rail network directly into a gantry crane-equipped emplacement room.

For the rail carts, OPG performed stability calculations for the major waste package types under conservative sudden stops from full speed conditions. The results showed that the rail cart would have to be travelling at a speed of three to five times its maximum velocity of 0.5 m/s before the package stability would be compromised by tipping during a sudden stop situation.

At their final destinations in the DGR, similar types of waste packages would be emplaced in the same rooms, as this would be efficient for handling and stacking. Some rooms would be intended for low-level waste, others for unshielded intermediate-level waste or for shielded intermediate-level waste. Since the higher dose rate packages of intermediate-level waste are shielded and generally also contain a higher concentration of long-lived radionuclides, their separate placements from short-lived intermediate-level waste would effectively segregate short-lived intermediate-level waste from long-lived intermediate-level waste in the DGR. Waste packages would be stacked according to the specifications for each type using approved procedures, similar to those currently used by OPG at the WWMF. Emplacement rooms would be completely filled prior to the installation of end walls.

7.6.1 Panel Conclusion Regarding Waste Transfer into the DGR

The Panel concludes that, in the preclosure phase of the project, both the radiological and non-radiological hazards associated with the waste will be well managed, and that any possible effects on workers, the public, or the environment will be as low as reasonably achievable. Accidental container breaches, resulting in the release of radiological or non-radiological toxins are discussed elsewhere in this report.

The extensive experience of OPG in the safe handling and transport of waste containers in surface storage facilities, such as the WWMF, provides the Panel with confidence that these activities can be safely carried out in the DGR. The Panel is satisfied that any potential problems associated with these activities in the underground repository can be effectively managed and appropriately addressed. The Panel notes that the primary risks to workers during waste transfer would, in most instances, be equivalent to those encountered in conventional underground mining operations. These risks, and their management, are considered in Chapters 9 and 10.

The Panel emphasizes that the underground environment imposes limitations that should be addressed fully before proceeding with the emplacement of the waste packages. By completely filling chambers without planned access routes, OPG forestalls remedial actions in the case of unanticipated container failures and radionuclide releases during the operations phase of the project. OPG maintained that retrievability would always be possible, even after the installation of closure walls, although the effort of and radiological effects on the workforce of such actions were not evaluated. Consequently, the Panel makes the following recommendation:

Recommendation 7.9: In order to avoid significant adverse effects to human health, before a licence to operate the DGR is issued, OPG shall develop and implement, to the satisfaction of the CNSC, a detailed plan on how it would mitigate a scenario where intermediate-level waste containers fail in filled chambers at a time when the DGR was still in operation. The plan should evaluate the anticipated exposures to the workforce if the rooms were completely filled, as well as during the period when the retrieval of containers would still be possible via planned access routes.

7.7 INTERNATIONAL WASTE MANAGEMENT PRACTICE

The nuclear waste management approaches for L&ILW taken by other countries vary considerably depending on such criteria as waste sources, legislative responsibilities, land use restrictions and host geology. The Panel received information regarding the international experience with long-term nuclear waste management from OPG, CNSC staff and review participants. In addition, the Panel conducted site visits and received information at the following existing international facilities:

- Forsmark, Sweden (operational);
- Schacht Konrad, Germany (under construction); and
- Waste Isolation Pilot Plant, USA (operational).

Countries with surface or near-surface repositories usually make a distinction between short-lived waste and long-lived waste, the objective of which is to exclude long-lived waste from these repositories. Countries with only deep repositories (or plans for such) may or may not make such a distinction. One participant provided information on the waste management approaches of EURATOM, which is an international organization, with the same membership as the European Union, that deals with nuclear issues. The member countries consider deep geologic repositories to be unnecessary for short-lived low-level waste and short-lived intermediate-level waste, and have determined that long-lived intermediate-level waste should be separated from short-lived intermediate-level waste. Under this approach, long-lived intermediate-level waste would be designated to be co-located with high-level waste for permanent storage.

In several of their submissions, the Saugeen Ojibway Nation emphasized that the separation of long-lived intermediate-level waste and its co-location with high-level waste had not been adequately assessed by OPG. CNSC staff clarified that, in the Canadian context, the nuclear installation licensees, in this case OPG, are responsible for low-level waste and intermediate-level waste generated by their operations, but that high-level waste is the responsibility of the federal government, which is engaged in the Nuclear Waste Management Organization Adaptive Phased Management process. CNSC staff further noted that it was not in the purview of CNSC staff to make policy decisions that would alter the existing framework. The Panel acknowledges the legislated division of responsibility and notes that OPG's approach is consistent with the Canadian waste management framework.

Deep geologic repositories most closely resembling the proposed DGR are operating or under development in Germany, Sweden, Finland and the USA. Each facility will only accept waste in solid or solidified form. The Waste Acceptance Criteria for each facility tend to differ in response to national requirements arising from specific waste sources:

- **Konrad (Germany)**: repository most closely resembles OPG's DGR in that it will be accepting non-heat generating L&ILW. The waste will include short-lived and long-lived wastes originating from the operation and decommissioning of nuclear power plants, as well as research, industrial, and medical applications. Exposure limits are set at less than a mean dose rate of 2 mSv/h at the surface of waste packages and a local maximum of 10 mSv/h. For drum packages the dose limit is 0.1 mSv/h at a distance of 1 metre, and the same at 2 metre away from containers.
- **Forsmark (Sweden)**: repository accepts L&ILW from operations and eventual decommissioning of nuclear power plants in Sweden. The maximum dose rate on waste packages depends on the waste type and disposal location in the repository: 500 mSv/h in the disposal silo for intermediate-level waste, 100 mSv/h for the concrete molds and drums in the disposal vault for intermediate-level waste, 10 mSv/h for the concrete tanks for low-level waste in the rock vault, and 2 mSv/h for short-lived low-level waste inside the concrete tanks. The total amount of long-lived radionuclides is limited by safety assessment.
- **Loviisa and Olkiluoto (Finland)**: repositories differ from OPG's DGR in that they are dedicated to specific nuclear power plants operating in their vicinity. In both cases they only accept short-lived L&ILW from operations and the eventual decommissioning of their respective power plants.
- **Waste Isolation Pilot Plant (USA)**: repository acceptance criteria are not comparable to OPG's DGR since the facility was specifically designed to deal with transuranic waste from defence related activities. By US regulations this is waste that has been contaminated with alpha-emitting transuranic radionuclides possessing half-lives greater than 20 years and in concentrations greater than 3.7 MBq/kg.

Most international waste management organizations implement waste volume reduction. Waste is compacted in Finland, Sweden, and Germany, while incineration is practised in Sweden and Germany. Supercompaction is used in several countries, including Germany, France, Japan, Spain, the UK and the USA.

International nuclear repositories generally consider the waste containers and the waste form to be integral components of the multiple barriers that would inhibit the release and transport of the radionuclides. In Germany, the waste form is considered to be the first barrier and the container, with specified tightness, is the second barrier. The emplacement rooms and backfill are a third barrier. Waste forms used to immobilize the waste are cement or bitumen in steel or cement containers, and are implemented in Germany, Sweden and Finland. Commonly, smaller containers, usually drums, are encased in larger outer disposal containers, such as in Finland and Germany. For the Konrad repository a total of 11 standardized container types are accepted for emplacement. The containers are grouped into those without increased requirements on the barrier properties and those with increased requirements.

At the Konrad repository, containers of legacy waste delivered for storage would undergo random checking using proven non-destructive and destructive test methods. Non-destructive testing would be through use of a segmented gamma-scanner, a neutron counter (both passive and active), and a tomography system using simultaneous transmission and emission measurements using a cobalt-60 source. Destructive testing would involve obtaining drill core samples of selected waste packages. Data determined under independent control would not be checked again.

In France, reversibility and planned waste container retrievability, over a 100 to 300 year period, is considered desirable and necessary for both high-level waste and long-lived intermediate-level waste. ANDRA, the French organization responsible for nuclear waste disposal, is engaged in research into how retrieval could be achieved without compromising the long-term safety of a geologic repository. OPG's planning for the DGR did not include provisions to facilitate the retrieval of waste containers once the waste has been deposited in the emplacement rooms. OPG explained that materials placed in the DGR would be considered to be waste and the need for retrieval was not anticipated. During the hearing, OPG stated that, although the waste containers would potentially remain retrievable, the amount of effort required to do so would increase as the emplacement rooms are filled, the closure walls are installed, and the shaft seals are emplaced. Several participants were of the view that reversibility and planned retrievability should be integral parts of the DGR design. Their reasons included the need for response to unforeseen events, including natural disasters, malfunctions, accidents and malevolent acts; potential future improvements in waste disposal technology; possible changes in policy and regulatory frameworks; and for the recovery of valuable materials.

7.7.1 Panel Conclusion Regarding International Waste Management Practice

The Panel recognizes that the diversity of circumstances and requirements for low- and intermediate-level nuclear waste management of other countries have led to practices that may not be applicable to OPG's proposed DGR. The Panel heard from OPG, and the CNSC as Canada's nuclear regulator, that they are well connected to international networks and research projects involving nuclear waste management. These strong contacts reassure the Panel that both organizations will continue to incorporate and benefit from appropriate best practices as they evolve on an international scale.

However, the Panel has recommendations and suggestions regarding waste characterization and waste containers that have been adopted by other countries and that it believes should be considered and implemented by OPG and the CNSC.

International practice suggests to the Panel that OPG could explore enhanced standardization of waste container types leading to a future reduction of configurations. Possible benefits of such a reduction and simplification could include decreased complexity in handling equipment and procedures, greater operator familiarity, and more efficient stackability.

The Panel has concerns that OPG has proposed to limit the inspection of waste containers, prior to emplacement into the DGR, to visual examination of the exterior of the containers. OPG considered waste-to-container interactions to be very unlikely, provided that the current Waste Acceptance Criteria were followed at the time of packaging. Ion-exchange resins stored in carbon steel liners were considered by OPG to be most vulnerable to waste-to-container interactions. OPG noted that during overpacking into corrosion resistant stainless steel containers, all retrieved liners were observed to be still intact. OPG presented this experience as evidence of the sufficiency of external waste container inspection. OPG investigated a number of methods of testing for internal container corrosion and rejected the use of ultrasonic testing methods and real-time radiography/x-ray tomography for the inspection of waste packages as not being practical or effective.

The Panel considers corrosive degradation of containers due to container material-waste interactions to be a plausible scenario. Such interactions may not be detectable by visual inspection until containment is breached. Since the containers have not been tested for periods that span their current age plus the operational phase of the DGR, the Panel questions whether past performance is a good indicator of future performance. As mentioned previously, the consequences of a container breach may affect worker health and safety, and could negatively affect public perception of DGR operations. Consequently, the Panel recommends that:

Recommendation 7.10: In order to prevent significant adverse effects to human health, due to container breaches, OPG shall investigate and report to the CNSC, on a regular basis starting prior to construction and until the end of the Operations phase, on the effectiveness of existing and emerging imaging technologies which could be used to detect waste-to-container interactions that may lead to container breaches. If effective non-destructive testing methods become available they should be promptly instituted to supplement visual inspections of waste packages.

The Panel recognizes that, internationally, there are variations on how waste is categorized and managed, and believes that the CNSC should take this experience into consideration in its planning for the management of future waste streams. For example, short-lived intermediate-level waste (half-life < 30 years) could be considered as a distinct category from long-lived intermediate-level waste (half-life > 30 years), with possible implications for segregation of waste streams and a reduction in the volume of waste destined for placement in a DGR. As such, the Panel makes the following recommendation to the CNSC:

Recommendation 7.B: In anticipation of future decommissioning waste streams, the CNSC should review its classification and management criteria for intermediate-level waste and compare them with international practice.

7.8 PANEL CONCLUSION REGARDING WASTE MANAGEMENT

The Panel reviewed a comprehensive body of submissions and information on OPG's planned waste management practices for the proposed DGR, as well as on OPG's nuclear waste management practices at the WWMF over the past 40+ years. The exemplary safety record over this period provides the Panel with considerable confidence that future waste management for the DGR can be carried out with the same diligence for the safety of the OPG workforce, the public and the environment. The Panel concludes that OPG has adequately characterized the hazards associated with the nuclear waste destined to be stored in the DGR. While improvements in procedures are ongoing and expected to continue, this does not detract from the Panel's conclusion that OPG's waste management practices are consistent with international standards and that they will continue to be so for the duration of the project.

CHAPTER 8 EFFECTS ON THE NATURAL ENVIRONMENT

This chapter presents the Panel's evaluation and conclusions regarding whether there will be significant residual effects of the project on the natural environment, including soil quality, air quality, noise and vibration, surface and near-surface groundwater, and terrestrial and aquatic biota. The Panel's evaluation considered OPG's assessment methodology, commitments to mitigation of adverse effects, and follow-up monitoring. This chapter also includes an assessment of the effects of the environment on the project.

8.1 SOIL QUALITY

OPG examined the potential for direct and indirect effects of the project on soil quality and determined that there would be no measurable, adverse effects. Direct effects could occur via soil removal, seepage from the Waste Rock Management Area, or operation of the stormwater management system. OPG stated that while soils would be removed during site preparation, non-native materials would not be brought onto the site and site grading activities would not measurably change soil quality.

OPG examined the potential for effects of seepage from the Waste Rock Management Area on subsurface soil and determined that seepage was more likely to flow from the base of the rock pile to the stormwater management system than it was to infiltrate to the subsurface because of the prevailing native till soil, which has a very low potential for infiltration. OPG acknowledged that a component of stormwater runoff in the drainage ditch system would infiltrate subsurface soils. However, OPG explained that most of the precipitation that reaches the native soil in the drainage ditches or from sheet runoff towards the stormwater management pond would migrate along the till surface rather than infiltrate into the till. OPG further reasoned that the surface area of the drainage ditch and stormwater pond would be a small percentage of the total Project Area. Therefore, OPG determined that the operation of the stormwater management system would not cause a direct measurable change to soil quality. Finally, OPG stated that, during the decommissioning phase of the project, any parameters of concern associated with sealing of the shafts, such as salts, would largely occur in porewater trapped within the rock and would not readily be released to groundwater migrating through the upper seal materials. Furthermore, the volume of seal materials would be small compared to the volume of soil and bedrock down-gradient from the shafts.

OPG stated that there would be no indirect effects on soil quality from changes in air quality or near-surface groundwater quality. OPG did not expect that dust deposited on the surface would persist long enough to affect soils. OPG did not predict any measurable changes in near-surface groundwater quality; therefore, no measurable changes in soil quality from interactions with groundwater were predicted. The potential for effects on near-surface groundwater is discussed in more detail in a later section of this chapter.

OPG did not predict that disturbance of soils affected by past contamination would produce a measureable change to soil quality during site preparation and construction. OPG reported historic contaminated areas within the Site Study Area identified during Phase I and Phase II environmental site assessments. Six of the contaminated locations identified in the Phase II assessment were close to the Project Area. Copper, nickel and zinc were the most common contaminants found to exceed Ontario Ministry of the Environment and Climate Change guidelines. Historical soil contamination was not identified on the project site and therefore was not carried forward in OPG's assessment.

8.1.1 Panel Conclusion Regarding Effects on Soil Quality

The Panel concludes that the project would not cause measureable changes in soil quality and that there would be no significant adverse effects on soil quality. Specific mitigation measures with respect to soil quality are not required; however, the Panel has recommendations regarding the waste rock management area and stormwater management system, with respect to seepage, which are presented in a later section of this chapter.

8.2 AIR QUALITY

OPG modelled maximum concentrations for several air quality indicator compounds, including sulphur dioxide, nitrogen dioxide, carbon monoxide and particulates, as well as carcinogenic and non-carcinogenic compounds. OPG applied a model called AERMOD, which is the standard model used for regulatory purposes in Ontario. Five years of local meteorological data were used as input to the model. OPG also used conservative assumptions regarding the amounts emitted by the various sources on the project site. For example, OPG assumed that all vehicle exhaust, dust and noise sources were operating continuously and simultaneously, and modelled the highest construction emissions.

OPG committed to mitigation to ensure compliance with air quality criteria. Mitigation measures included:

- the use of construction equipment that will meet Tier 2 emission standards (at a minimum);
- maintenance of equipment in good working order;
- watering of roadways for dust suppression;
- minimization of drop heights of rock and other material; and
- the use of vehicles meeting the newest emission standards.

OPG determined that there would be no significant adverse effects on air quality. OPG's hypothesis was that the project would need to result in ambient concentrations of air quality indicators beyond the Site Study Area that exceeded established ambient air quality criteria more than 10% of the time. During site preparation and construction as well as decommissioning phases, OPG's predicted maximum ambient concentrations of sulphur dioxide, nitrogen oxide and carbon monoxide would not exceed the relevant ambient air quality criteria beyond the Site Study Area, i.e., the Bruce nuclear site fenceline. OPG predicted that the maximum 24-hour ambient concentrations of $PM_{2.5}$. PM_{10} and suspended particulate matters would exceed relevant criteria, but that this would occur less than 0.5% of the time, in a relatively small area immediately adjacent to, but beyond the Site Study Area. The maximum concentrations were nearly double the 99.9th percentile predictions. During the operations phase, OPG predicted that none of the predicted maximum ambient concentrations would exceed the relevant ambient air quality criteria.

OPG stated that its follow-up monitoring of air quality indicators would be designed to verify that emission rates and predicted concentrations used in the environmental assessment were reasonable but conservative. Monitoring data would also verify that the mitigation measures are being incorporated as planned and are effective in ensuring no significant adverse effects. OPG stated that it would measure the air quality indicators predicted to have a residual adverse effect - two forms of particulate matter (PM_{10}, $PM_{2.5}$), as well as nitrogen dioxide. These measurements would be continuous during site preparation and construction, with a re-evaluation of measurement frequency at the end of each following year

CNSC staff stated that the project was not likely to result in significant adverse environmental effects to air quality, taking into account mitigation measures. CNSC staff explained that OPG's assessment of air quality was sufficient, including the use of the AERMOD dispersion model for predicting maximum concentrations of air quality indicators. CNSC staff concurred with OPG that the first stage of site preparation and construction would produce the upper bound air emissions. OPG predicted that the project would produce low emissions of volatile organic compounds, such as benzene and formaldehyde, and polycyclic aromatic hydrocarbons. As such, these were not considered to be useful air quality indicators. CNSC staff agreed with this assessment.

Environment Canada stated that OPG's modelling approach and emission estimates were appropriate, and that the air quality predictions were credible and suitably conservative. Environment Canada pointed out that the conservative nature of the estimates likely over-predicted the effects.

The Ontario Ministry of the Environment and Climate Change stated that an Environmental Compliance Approval for air would be required should the project proceed to site preparation and construction. The Ontario Ministry of the Environment and Climate Change noted that the air dispersion modelling in the EIS was not sufficient to allow for a complete review under Ontario regulations, and that, should the project proceed, OPG would have to demonstrate compliance with Ontario regulation *O.Reg. 419/05-Air Pollution-Local Air Quality* through the preparation of an Emission Summary and Dispersion Modelling Report produced using Ontario Ministry of the Environment and Climate Change procedures.

Some participants expressed concerns about exposure to particulates at locations close to the Bruce nuclear site fenceline. There were particular concerns raised regarding the increased susceptibility of the elderly or people with chronic respiratory conditions. The Panel's review of the implications of changes in air quality to human health is presented in Chapter 9.

8.2.1 Panel Conclusion Regarding Effects on Air Quality

The Panel concludes that significant adverse effects on the air quality indicators assessed by OPG are not likely, given the inherent conservatism in the air quality modelling, the use of the predicted maximum values in the assessment, the infrequency of predicted exceedances of air quality criteria even when maximums were used, and the limitation of these exceedances to a small area adjacent to the project site.

The Panel is satisfied that OPG adequately assessed and characterized effects on air quality resulting from project activities. The Panel notes that the AERMOD model used by OPG has been extensively calibrated and validated. The Panel is satisfied that OPG addressed uncertainty associated with model inputs in a conservative manner, such as by assuming that all emissions sources during any one stage were operating concurrently and continuously. The Panel notes OPG's selection of the best local data sources and the best available data.

The Panel's conclusion relies upon the timely and effective implementation of mitigation measures. The Panel's specific conclusions related to the effects of changes in air quality indicators on human health are presented in Chapter 9 and on plants and animals in a later section of this chapter.

Recommendation 8.1: In order to confirm the prediction in the environmental assessment of no significant adverse effects on air quality, and to address specific concerns of individuals living at or near the critical receptor locations used in the EIS models, OPG shall, to the satisfaction of the CNSC, conduct a monitoring program for NOx and particulates, including PM_{10} and $PM_{2.5}$, during site preparation and construction.

Recommendation 8.2: Prior to site preparation, OPG shall finalize and submit a detailed plan to manage air emissions, to the satisfaction of CNSC. The management plan should be reviewed by Environment Canada, Health Canada and the Ontario Ministry of the Environment and Climate Change. The plan should include details of the mitigation measures, including thresholds for corrective management actions; frequency of site inspections; and record keeping.

8.3 NOISE AND VIBRATION

OPG modelled noise levels at three receptor locations near the project site using the CadnaA noise model, which uses the noise prediction algorithms from *ISO 9613 Standard - Acoustics -- Attenuation of sound during propagation outdoors*. The three locations assessed by OPG were: Albert Road adjacent to Inverhuron Provincial Park (R1); across Baie du Doré from the Bruce A nuclear generating station (R2); and, within Inverhuron Park at an existing camp site (R3). Existing (baseline) noise levels were described using a combination of monitoring and short-duration measurements. Noise predictions were based on worst-case noise emissions from all sources. OPG assumed that all receptors were downwind of noise sources, i.e., there was no reduction in noise level for upwind receptors. OPG estimated the maximum change in noise by comparing its predictions to the quietest hour under existing conditions. An adverse effect was considered to be likely if the predicted noise levels exceeded the quietest existing hourly noise levels by more than 3 dB.

OPG noted that the sources of noise would vary depending on the project phase. During site preparation and construction, sources would include trucks, bulldozers, compactors, excavators, graders, pavers, and blowers. During the operations phase, the above-ground transfer of waste would produce noise emissions from flat-bed transporters/tracks, forklifts, and back-up diesel generators. Underground transfer of waste would produce noise emissions from forklifts, the hoist house, and headframe equipment. Other noise sources associated with support and subject to monitoring throughout the DGR life cycle included intake and exhaust fans, the air compressor plant, the electrical sub-station, and back-up diesel generators. Sound contributions associated with worker traffic to and from the site were also included. Noise emissions during decommissioning were expected to be less than the measurable changes identified in the site preparation and construction phase.

In determining the noise emissions, OPG considered in-design mitigation measures that would be integral to the design and implementation of works and activities. In-design noise mitigation measures considered in the modelling were:

- the use of appropriate silencers for on-site vehicles and equipment;
- the maintenance of a tight project footprint to limit vehicle travel routes; and
- the maintenance of fans in good working order.

OPG also committed to the planting of trees on the waste rock pile. OPG acknowledged that trees would provide marginal, if any, noise attenuation; furthermore, this planting would not occur until after the waste rock pile was completed. OPG stated that, with respect to the Kincardine Noise Control Bylaw (2008-076), construction activities are permitted during evening and night-time hours provided they are not clearly audible at the points of reception, i.e., the three assessed receptor locations that would be monitored during site preparation and construction. The Panel interprets this statement as meaning that site preparation and construction activities will occur during night-time hours provided that monitoring confirms that construction noise is not clearly audible at the monitoring locations. The Panel comments on this issue further in Chapter 9. OPG stated that, during the operations phase, exhaust fans would be maintained in accordance with manufacturer's specification and maintenance records would be verified annually. OPG did not provide any specific information regarding additional mitigation in response to issues with exhaust fan noise.

OPG stated that the follow-up noise monitoring program would take place at the three receptor locations identified in the EIS. Timing of monitoring would be tailored to specific site activities, that is, during representative stages within construction that best represent peak noise or specific noise scenarios, such as when OPG starts sinking the shafts or moving waste rock. Monitoring would be continuous over 48 hours, and the monitoring program would be re-evaluated annually. OPG explained that there were no plans to increase the number of noise monitoring stations because the primary purpose of monitoring was to confirm predicted noise levels at the three receptor locations modelled in the EIS.

OPG stated that additional mitigation is required mitigation measures could include alternatives to back-up alarms and altering configuration of the waste rock management area to achieve greater noise attenuation. OPG also stated that it would consider the effect of noise on Aboriginal uses of the lands within the Local Study Area by examining the results of monitoring data from representative time periods (summer, fall); however, there was no intention of targeted monitoring to address Aboriginal use of the Local Study Area.

OPG predicted that the noise levels caused by the project activities would be from 2 to 5 dBA above existing noise levels at the three receptor locations R1, R2 and R3. A-weighted decibels (dBA) are an expression of the relative loudness of sounds in air as perceived by the human ear, which is less sensitive to low audio frequencies. The largest incremental increase of 5 dBA would occur at the Baie du Doré location, affecting four residences, during site preparation and construction. A similar increase was predicted for the decommissioning phase (Figure 15).

OPG assessed the effects of blasting via airborne and ground vibration separately using an Ontario Ministry of the Environment and Climate Change method (NPC 119). The receptor locations assessed were all within the Project Area, where it was assumed the highest ground vibration levels would occur. Therefore, the locations for estimation of human exposure to ground and air vibration from blasting were much closer to the source than the locations used for the noise assessment. OPG reported that all predictions of ground vibration met applicable regulatory limits. All predicted air vibrations were less than the maximum limit of 128 dBL. Un-weighted noise levels (dBL) represent the actual acoustic energy in the atmosphere The assessment of blasting conservatively assumed no attenuation due to shielding by rock. OPG pointed out that although blasting for shaft development would last for about 1.5 years, the depth of the shaft after the first year would be about 450 metres below grade. At this depth, it was expected that the blasting noise, i.e., air vibrations, would not be audible at the noise receptor locations.

8.3.1 Panel Conclusion Regarding Effects on Noise and Vibration

The Panel concludes that the project is not likely to result in significant adverse effects on noise and vibration. The Panel is satisfied that OPG has adequately assessed and characterized effects on noise and vibration resulting from project activities. The CadnaA model is widely accepted by various jurisdictions, including the Ontario Ministry of the Environment and Climate Change. The Panel notes that there have been numerous studies which have verified the CandaA model results. The Panel is satisfied that OPG used appropriate conservative assumptions to manage uncertainty in model inputs, including worst-case noise emissions from noise sources and all receptors assumed to be downwind of all noise sources at the same time.

The Panel’s conclusions regarding the effects of changes in noise and vibration on animals are presented later in this chapter. Effects related to human health are presented in Chapter 9. Noise effects on livestock are discussed in Chapter 11.

8.4 SURFACE WATER AND NEAR-SURFACE GROUNDWATER

Surface water and near-surface groundwater provide the most significant pathways for the migration of both non-radiological and radiological contaminants in the surface environment during all phases of the DGR lifecycle. Near-surface groundwater includes the surficial groundwater zone and the shallow bedrock groundwater zone defined by OPG. Primary sources of contaminant release to these pathways would be: groundwater pumped to the surface during

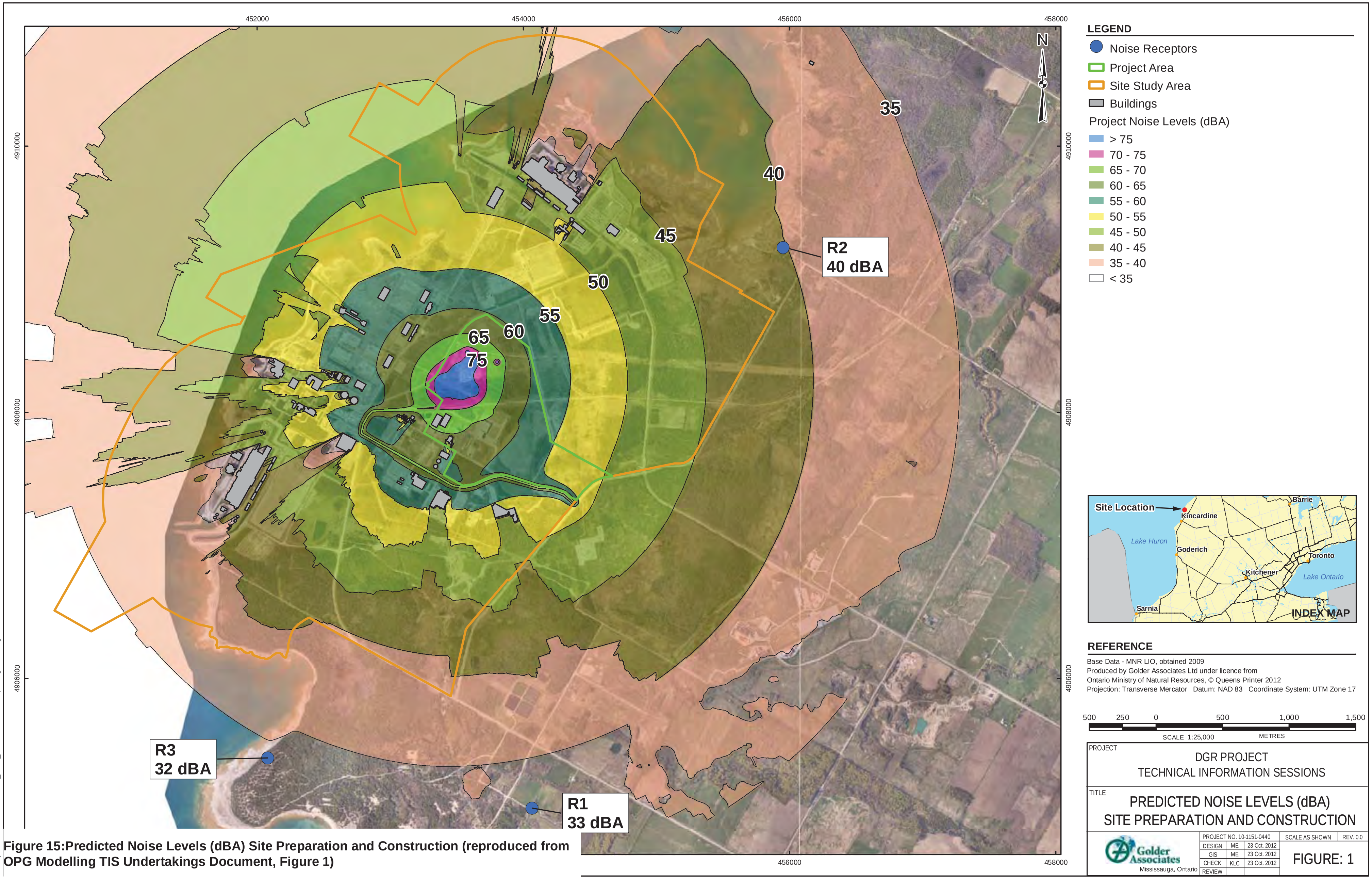


Figure 15:Predicted Noise Levels (dBA) Site Preparation and Construction (reproduced from OPG Modelling TIS Undertakings Document, Figure 1)

repository construction (referred to as “mine water” in this report); surface runoff from areas under construction as well as during operation and decommissioning; and runoff from the waste rock management areas during all phases of the project. Accidental spills are another potential source.

8.4.1 Surface Water Features on the DGR Site

The Site Study Area, which includes the Bruce nuclear site, has an extensive existing drainage system consisting of catch basins, manholes, constructed ditches and culverts. All of the drainage is directed to Lake Huron via several outfalls and natural drainage features. OPG divided the Site Study Area into several drainage areas. Natural drainage enters the Site Study Area via Stream C, a former tributary of the Little Sauble River that was diverted to Baie du Doré during initial development of the Bruce nuclear site. The project site is largely located within a single drainage area, and its runoff drains into MacPherson Bay via the drainage ditch at Interconnecting Road. The remaining small portion of the project site is currently drained by the North Railway Ditch and Stream C, which briefly transect the southeast corner of the Project Area.

OPG designed its water management system for the Project Area such that all water produced or captured on the Project Area would be directed into the existing ditch system. The flow would be centralized and discharged from a stormwater management pond into Lake Huron at MacPherson Bay. As shown in Figure 16, the existing main elements of the ditch system are:

- a drainage ditch at Interconnecting Road (also referred to as Un-named Ditch) that discharges into MacPherson Bay;
- North and South Railway ditches draining toward Stream C; and
- ditches along the boundaries and internal to the DGR site that drain towards the drainage ditch at Interconnecting Road.

A small productive wetland (marsh) borders the Project Area to the northeast and a seasonal wetland (swamp) is located in the southeast corner of the Site Study Area. OPG determined that the northeast marsh was likely the result of precipitation being retained in a shallow depression. OPG explained that there are no inflows to the marsh other than surface runoff from a small catchment of approximately 3 hectares, and that the only outflow of the marsh is intermittent discharge over a sill located in the northwestern area. OPG suggested that the wetland exists because of the underlying low-permeability till. OPG noted that it is expected that marsh drainage only occurs when the water levels in the marsh exceed the sill elevation. This outfall connects to the drainage ditch at Interconnecting Road.

8.4.2 Distribution and Nature of Near-surface Groundwater at the DGR Site

OPG determined that, within the Site Study Area, bedrock is overlain by unconsolidated surficial deposits of stony, sandy or silty till (deposits originating from continental glaciers of the last ice age). Interlayered in the surficial deposits are also thin sand and gravel beach deposits and minor gravel dominated glaciofluvial outwash deposits. Glaciofluvial deposits are those resulting

Figure 16: Site Drainage System and Surface Water Features (reproduced from CNSC PMD 13.P1-3l, Slide 15)

from the action of glacial meltwater streams. OPG stated that overburden thickness varied from 0 to 20 m with location. In the south-central portion of the Project Area, largely beneath the WWMF, is a Middle Sand unit, i.e., a permeable groundwater bearing horizon that constitutes an aquifer. Where overlying till is thin, the Middle Sand unit can recharge by surface water infiltration, and where underlying till is absent it can directly recharge the underlying bedrock aquifer.OPG further stated that, beneath the surficial deposits, the Site Study Area is characterized by highly permeable limestone and dolostone formations of the Lucas, Amherstburg, and Bois Blanc formations, which constitute the shallow bedrock groundwater system that provides potable groundwater for the Local Study Area. Flow directions for the Lucas Formation aquifer within the DGR site boundary are to the northwest into Lake Huron.

OPG's deep boreholes provided evidence that the stratification of the groundwater system at the site effectively isolates the surficial and shallow bedrock (0-169 m) groundwater system from the deeper regions. Potable groundwater is restricted to the shallow groundwater system within glacial deposits and the confined upper Lucas Formation, the bedrock formation closest to the surface in the Project Area. Groundwater sampling by OPG showed that the groundwater in the deeper strata becomes progressively brackish, saline, and hypersaline (surpassing the salinity of ocean water) and much older.

The key feature protecting the shallow bedrock aquifer (Lucas Formation) in the Project Area is the presence of a continuous, thick, and dense clay/silt till with very low hydraulic conductivities. Hydraulic conductivity is a coefficient that reflects the permeability of the rock, i.e., a measure of the rock's ability to transmit water when submitted to a hydraulic gradient. OPG asserted that this layer would form an effective barrier (aquitard) that would prevent both downward and lateral movement at depth of water and dissolved contaminants. OPG stated that site geotechnical investigations showed that this layer exists over the entire site area to a depth of approximately 10 meters above bedrock. The low hydraulic conductivities would limit infiltration of surface waters to a conservatively estimated rate of 5 to 10 cm/yr. There are more porous layers in the glacial till cover (Middle Sand unit) in the Site Study Area; however, OPG stated that these more porous layers were thought to be absent in the smaller and more localized Project Area, where sources of contamination such as the waste rock management area would be located.

OPG used existing shallow groundwater monitoring wells to examine the movement of contaminants from the WWMF along the south-eastern margin of the DGR site boundary. In 2012, OPG installed a new set of shallow groundwater monitoring wells along the western margin of the DGR site boundary and down-gradient of the proposed waste rock management area.

OPG assessed the potential effects on the near-surface geology and hydrogeology and predicted that there would be no residual adverse effects as a result of the project. OPG stated that for an effect on near-surface groundwater to be considered a significant adverse effect, migration of contaminants of potential concern in excess of established criteria or guidelines would have to occur on a frequent or continuous basis or an alteration of the shallow groundwater flow regime would have to occur such that it would alter sensitive or critical habitats on a frequent or continuous basis. OPG determined that the project would not affect the overall site groundwater regime or sensitive ecological features near the site. Since no residual adverse effects were identified, OPG did not conduct a significance assessment.

The Panel concludes that it is not likely that the project would cause significant adverse effects on near-surface groundwater or sensitive ecological features including the northeast marsh. The Panel notes that even infrequent or periodic effects on near-surface groundwater may have the potential to cause adverse effects on significant species during critical life stages. To provide additional support regarding the conclusions of no significant adverse effects, the Panel recommends confirmation of surficial (overburden) stratigraphy prior to construction.

Recommendation 8.3: In order to avoid significant adverse effects on near-surface hydrology, prior to beginning construction of the stormwater management system, OPG shall verify that the overburden stratigraphy at the site is the same as predicted in the EIS. If unexpected, higher permeability, stratigraphy is encountered, OPG must assess the potential effect on water levels in the northeast marsh and evaluate and implement mitigation options.

8.4.3 Possible Connections between Surface Water and Near-surface Groundwater at the DGR site

As explained in the previous section, OPG stated that the till layer covering the shallow bedrock aquifer would efectively prevent any connection between surface water and the shallow-bedrock aquifer. This would include connections beneath the waste rock management area and the stormwater management pond.

Government agency reviewers recommended that OPG verify the characteristics of the surface layers overlaying the bedrock aquifer, i.e., the overburden stratigraphy. The Ontario Ministry of Northern Development and Mines reviewed the overburden geology of the site and noted complexities, including sedimentation associated with the margins of ice as ice sheets retreated and a possible buried moraine. These complexities could include units with infiltration rates greater than the predicted 5-10 centimetres per year. If such units occur, they would provide an effective vertical connection and faster flow-path for surface waters downwards to the top of the bedrock. However, the Ministry did not provide data specific to the Project Area. Environment Canada also noted that the overburden stratigraphy should be verified during construction.

The Canadian Environmental Law Association commented that the primary near-surface aquifers at the DGR site are in carbonate formations that have been eroded by water (karst) and heterogeneous glacial sediments from different sources. Both karstic carbonates and heterogeneous glacial sediment can exhibit substantial uneven and often rapid movement of water, such that a small fraction of these media can contribute to most of the water flow. This makes the characterization of contaminant distribution and migration challenging.

The Panel notes that the spacing of OPG's sampling stations in the surficial till cover over the Project Area, and the survey methods employed, do not preclude the presence of features that could provide pathways for the flow of surface water within the surficial deposits or into the underlying shallow bedrock aquifer. Permeable sandy glacial outwash channels tens of metres wide that could provide hydraulic connections to the shallow bedrock aquifer may have been missed by the surveys. Fracturing in both weathered and fresh tills is a well-documented phenomenon. The presence of fractures would substantially increase both the vertical and horizontal hydraulic conductivities of the tills. Detection of such fractures in clay-rich tills is obscured by conventional sampling methods and requires special methods which target their detection.

Recommendation 8.4: In order to verify predictions in the environmental assessment regarding the shallow bedrock aquifer, OPG shall, prior to site preparation, update the hydrogeologic properties of the till cover in the water balance and surface water/groundwater interaction numerical models. The models should be updated to the satisfaction of the CNSC, as more data become available.

8.4.4 Effects on Surface Water Quality

OPG described the sources and pathways for contaminants to reach surface water. The main sources and compositions of potential contaminants would be:

- mine waters pumped to the surface during repository construction containing:
    - highly saline groundwater from formations at depths greater than 170 m;
    - nitrate residues from explosives used in the excavation of the shafts and repository chambers; and
    - oils/greases from equipment emissions and fuel spills.
- leachate generated by the waste rock piles during all phases of the project containing:
    - acid drainage from sulphide mineral decomposition in the waste rock;
    - metals and metalloids released by the interaction of waste rock with meteoric water;
    - salinity released from the waste rock originating from formations with highly saline porewaters;
    - hydrocarbon releases from rocks excavated from oil-bearing strata; and
    - nitrogen compounds from blasting residues adsorbed unto rock fragments.
- surface runoff from areas under construction as well as during operation and decommissioning; and
- accidental spills.

These sources and pathways are discussed below. Accidental spills are discussed in Chapter 10.

Mine Water

OPG explained that mine water would consist of water used for drilling and dust suppression, process water, groundwater flowing into the shaft and repository and possible condensation in the ventilation shaft. OPG conservatively estimated that the maximum total flow that could be experienced during construction would be 21 L/s. For the purposes of the assessment, OPG assumed that the maximum design dewatering flow rates would occur continuously. The water discharged during excavation would be directed into the drainage ditches of the stormwater management system. During the operational phase, groundwater inflows from shafts and the repository would be directed to underground sumps and from there the water would be pumped to the surface for discharge to the stormwater management system. OPG stated that the maximum sump pumping design flows would be 2.3 L/s during operations.

OPG committed to several mitigation measures with respect to mine water. Prior to pump-out to the surface, the mine water would be collected in an underground sump with settling features that would reduce the amount of total suspended solids. The underground water would be monitored prior to being released into the surface drainage system. A second monitoring location, at a location to be determined based on the final design of the stormwater system, would also be in place.

Waste Rock Management Area Leachate

The storage of waste rock generated during shaft sinking and repository development on the surface would expose a range of rock types of variable composition to the atmosphere, precipitation, and weathering processes. Chemical interactions of precipitation with minerals in the waste rocks would potentially release metals, metalloids, adsorbed nitrogen compounds, chloride and hydrocarbons into the percolating water in the form of leachate.

OPG planned to store waste rock in three separate waste rock storage areas, depending on rock composition. Shale and dolostone generated during shaft sinking would be stored in two separate temporary stock piles. The limestone produced during repository development would be stored in a permanent stock pile (Figure 17). OPG stated that it may use the material in the temporary shale and dolostone piles for berm construction and site preparation. Any remaining material would be covered shortly after shaft sinking has been completed. Environment Canada agreed that such a use of waste rock on site would be appropriate as long as any potential leachate from these materials would flow into the stormwater management pond.

OPG stated that, during site preparation, the waste rock management area would be prepared and graded. The grading would require the removal of portions of the upper weathered till, as well as the potential for placement of compacted till in other areas to establish appropriate grades to ensure that the water does not pond underneath the pile. Silt curtains would be installed during the preparation of the waste rock management area and the initial phases of waste rock deposition to mitigate release of suspended sediments.

OPG performed static short-term leachate tests of rock samples from the different rock layers intercepted by the exploratory deep drill holes. OPG determined that the runoff from the waste rock piles would not have a significant effect on the surface water or near-surface groundwater. OPG noted that the leachate tests on core samples would not be able to predict elevated nitrogen compound concentrations due to explosive residues present in the waste rock piles.

OPG stated that the presence of the low permeability clay/silt till over the entire Project Area would eliminate the need for liners under the waste rock management areas. OPG acknowledged that a quantity of leachate from the waste rock management area would ultimately enter the shallow groundwater regime below the site. OPG determined that the chemical characteristics of the leachate, combined with leachate generating capacity, would not lead to an effect on the groundwater quality, in part due to the natural attenuation by the glacial till overlying the bedrock interface. OPG stated that any surface runoff from the waste rock management area would be intercepted by the ditch system and directed to the stormwater management pond. During the hearing, OPG committed to drill and continuously core additional shallow boreholes at the waste rock management area site to a depth of approximately five metres to verify the hydrogeological properties of the till cover.

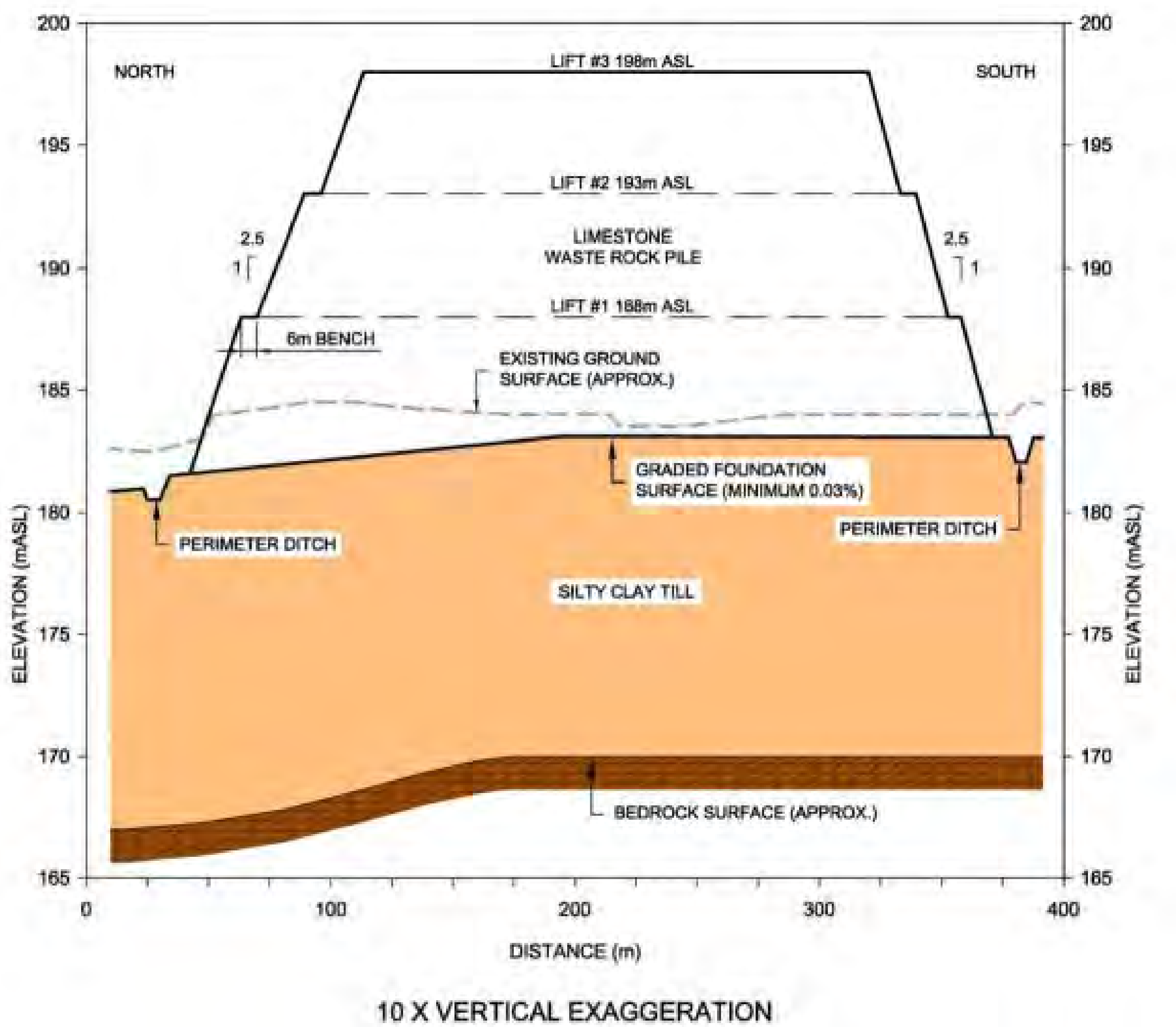


Figure 17: Proposed Configuration of the Waste Rock Management Area for the Permanent Storage of Cobourg Limestone (reproduced from OPG TIS Submission, Slide 39)

OPG stated that sampling at three locations, to be determined, would be sufficient to characterize the surface water runoff from the waste rock piles and other areas of the project site. Environment Canada recommended that full-strength leachate should be monitored since diluted leachate from a limited number of locations would complicate the understanding of the evolution of the leachate.

Environment Canada stated that OPG's responses to information requests regarding leachate quality indicated a degree of certainty that did not seem justified based on the available information, and were not conclusive. Environment Canada noted that the composition of the leachate would likely be variable and that it may take some time before significant changes in the chemistry develop and reach its maximum effect. Environment Canada identified additional contaminants that could be of primary concern and possibly problematic: various metals and metalloids, including arsenic, copper, zinc, iron, aluminum, boron, cobalt, thallium, vanadium, chromium, lead, and nickel; oil and grease; and petroleum hydrocarbons. Environment Canada supported the general conclusion that there should be sufficient neutralization potential to counteract any acidity generated in the waste rock piles. However, this was based on the assumption that the small sample size of the test material adequately captured the actual compositional variability of the waste rock. Environment Canada recommended that conclusions about the acid generating potential of the rocks be verified as part of a rigorous waste rock characterization program.

Environment Canada also recommended that OPG undertake kinetic tests on additional core samples and/or conduct field cell studies. The data obtained by such tests would give better predictions of the potential future leachate chemistry before the full waste rock pile was developed, and would allow for the design and early implementation of any treatment system. Environment Canada also identified the waste rock storage piles as an additional potential source of salinity. Environment Canada suggested that the waste rock should not be used or disposed of outside the boundaries of the stormwater management pond collection system.

The County of Bruce requested that OPG monitor runoff from the waste rock pile during construction and operations to confirm the prediction/assumption that leachate quality would improve over time.

The Panel shares Environment Canada's concerns about the adequacy of leachate characterization presented by OPG. Prior to and during shaft sinking, additional kinetic tests and field cell studies should be undertaken to provide predictions that more closely replicate the behaviour of the mass and mixture of rocks in the waste rock piles. Such information will be essential for the design and timely implementation of treatment systems involving surface runoff and shallow groundwater contaminants. Also, leachate compositions are likely to evolve with time, making predictions of its composition less certain.

The Panel recommends that a liner be installed under the waste rock management area to prevent penetration of leachate to the shallow groundwater system. A liner would address the uncertainty associated with the characterization of the surficial materials underlying the waste rock management area. Liners also represent best practice, in the Panel's opinion. With a liner in place, leachate would be directed to a treatment facility or directly into the stormwater management pond before having the opportunity to penetrate into the shallow groundwater regime. In the Panel's view, once the waste rock management areas are in place, the mitigation of any groundwater contamination that might occur would become challenging. The installation of interception wells for treatment of any identified contaminated groundwater would not offer a permanent and sustainable solution. Placing a liner beneath the waste rock management area represents the Panel's preferred mitigation measure.

The Panel recommends that OPG establish a follow-up program that includes monitoring of the amount and quality of leachate and surface runoff from the waste rock piles to the stormwater management system. The monitoring program would provide data for adaptive management should the quantity and quality of leachate or surface runoff become problematic in terms of OPG compliance with discharge criteria at the exit from the stormwater management pond.

Recommendation 8.5: In order to verify predictions in the environmental assessment regarding leachate quality, prior to construction OPG shall improve the characterization of the leachate that will be generated by the waste rock piles, by performing kinetic leach tests on existing core samples. During shaft excavation OPG shall conduct field cell studies on the material being deposited in the dolostone, shale, and limestone waste rock piles to verify leachate compositions and the acid generation potential under prevailing conditions.

Recommendation 8.6: In order to verify predictions in the environmental assessment regarding leachate quality, prior to construction OPG shall submit to the CNSC a waste rock characterization program for contaminants of concern other than those linked to acid generating potential (including, but not limited to metals and metalloids released under alkaline conditions, total dissolved solids and hydrocarbons). The OPG waste rock characterization program shall be based on sampling full-strength leachates and be valid for the duration of construction.

Recommendation 8.7: In order to verify the predictions in the environmental assessment that there will be no significant adverse effects to aquatic life from the waste rock pile runoff, OPG shall, to the satisfaction of the CNSC, develop a waste rock follow-up program. The follow-up program shall occur through all preclosure phases of the project and shall address the quantity and quality of leachate and surface runoff directed to the stormwater management system, and shall include sampling of full strength leachates.

Recommendation 8.8: In order to avoid significant adverse effects to near-surface groundwater, OPG shall place a liner, acceptable to CNSC, under the waste rock management areas to direct leachate to a treatment facility or the stormwater management pond. The liner shall be placed during site preparation and construction, and be developed in consultation with Environment Canada.

Recommendation 8.9: In order to avoid significant adverse environmental effects to near-surface groundwater, OPG shall not dispose of waste rock outside the boundaries of the stormwater management pond collection system, during any phase of the project, without the permission of the CNSC.

Recommendation 8.10: In order to verify the predictions in the environmental assessment regarding the effectiveness of the design of the stormwater management system, OPG shall calibrate and verify hydrological and water quality models over the life of the project with new information as it becomes available, including but not limited to, leachate geochemistry and flow rates. The models should be calibrated and verified prior to site preparation, at the end of construction, and periodically during operations, to the satisfaction of the CNSC.

Surface Water Runoff

OPG designed its surface water management system to capture and direct all site storm and underground water to a stormwater management pond for eventual discharge via a controlled outlet and the drainage ditch at Interconnecting Road into MacPherson Bay (Figure 18). A ditch and berm system would surround all active areas of the project site. OPG emphasized that source reduction and elimination of contaminants was one of the priorities of its water management plans.

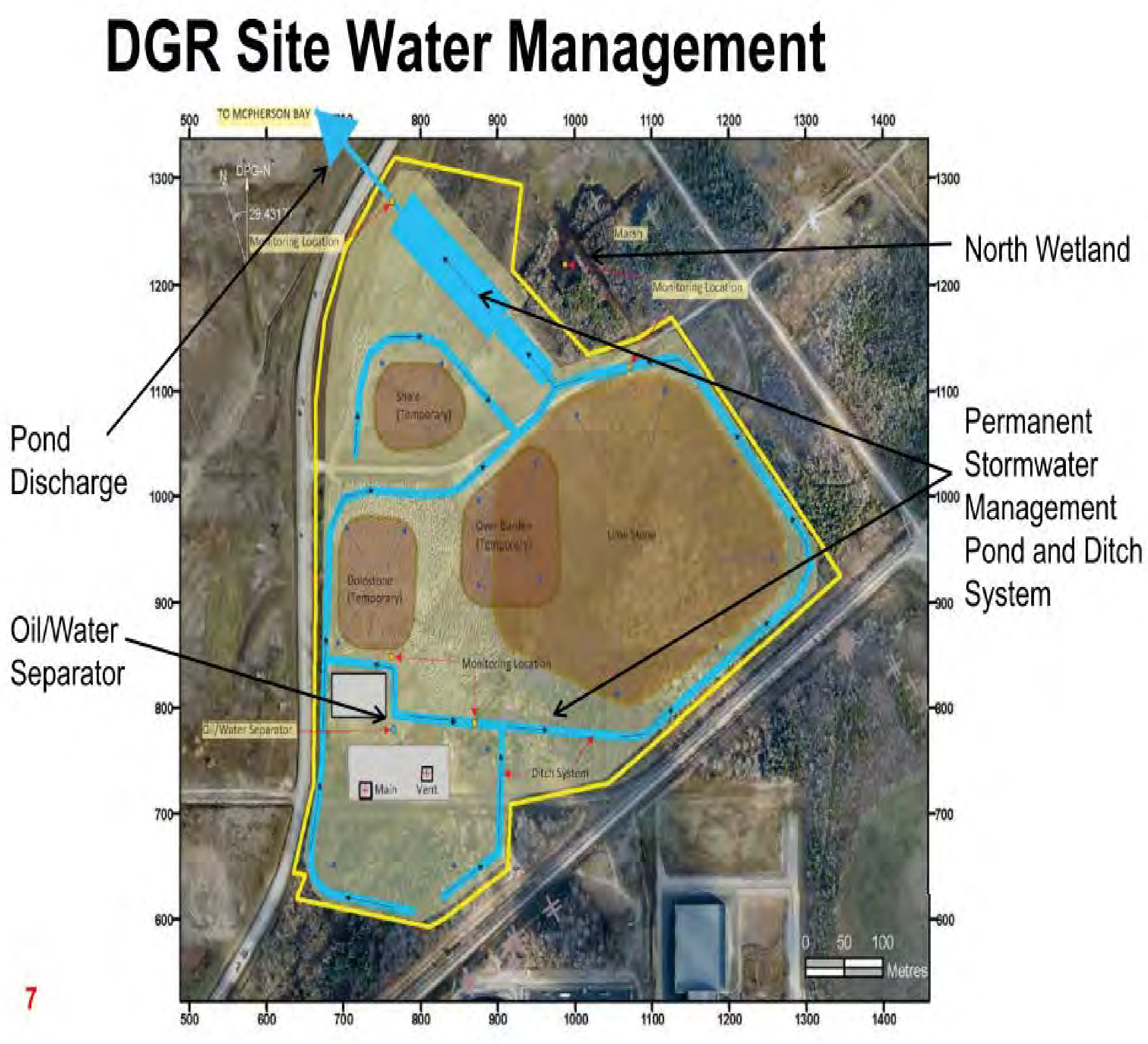


Figure 18: Proposed Water Management System including drainage ditches, stormwater management pond, drainage ditch at Interconnecting Road (pond discharge) and oil/water separator (reproduced from OPG PMD 13-P1.1M, Slide 7)

OPG stated that all water collected from the underground (process water and groundwater inflows), general site runoff, and leachate from the waste rock management areas would be collected in the stormwater management pond (Figure 19). The stormwater management pond would be designed to retain runoff during storm events, as the runoff would contain higher-than-normal levels of total suspended solids as a result of soil erosion. The design would provide a minimum retention period of 24 hours for the six-hour, 25 millimeter storm event and ensure that, under normal operating conditions, the total suspended solid effluent discharge will not exceed 40 milligrams per liter. Mobilization of sediment by surface runoff would be most intense during the site preparation phase, due to the site clearing, stripping, grubbing and grading, as well as the excavation of the stormwater management pond. OPG planned a temporary settling pond for the construction phase. Once the stormwater management pond has been constructed, water collected from the site would be routed first into a sediment forebay, and from there over a submerged weir into the main pond. OPG noted that the stormwater management pond would operate passively in normal conditions and halt discharges when required. In between precipitation events, the stormwater management pond would be used to

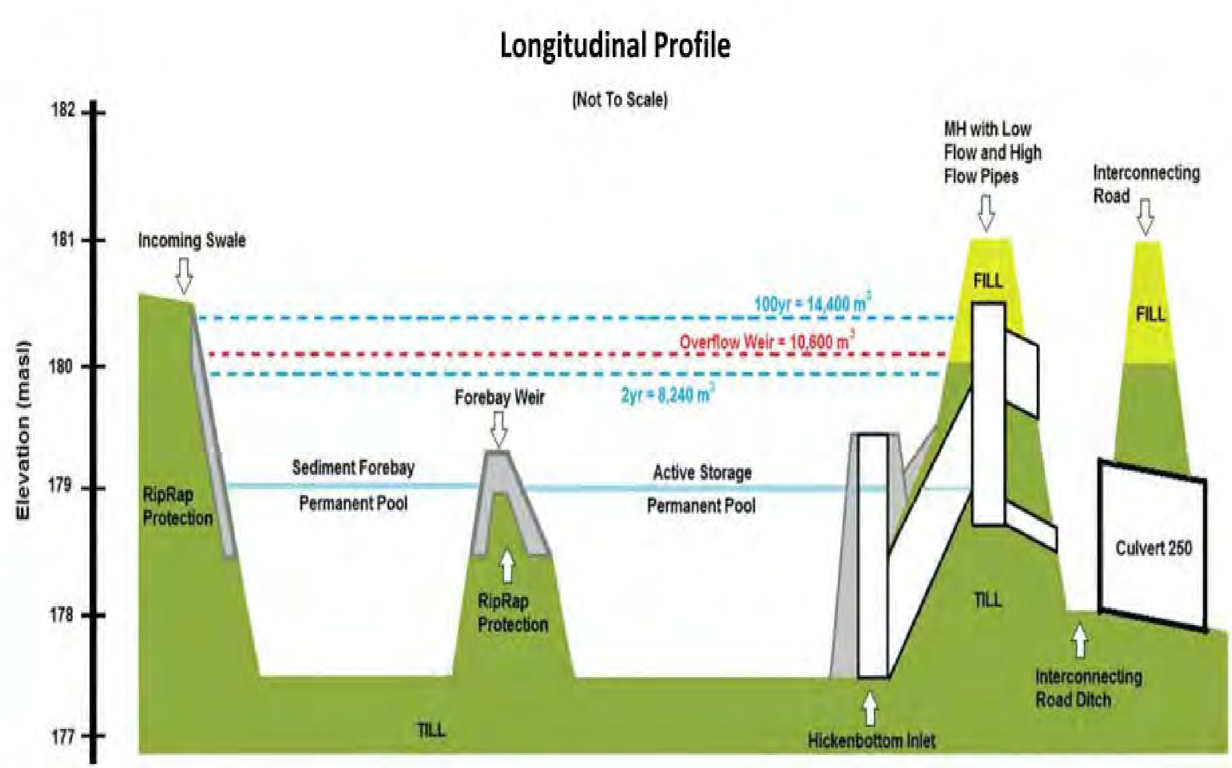


Figure 19: Longitudinal section of the proposed stormwater management pond showing the sediment forebay and active storage areas. Effluent levels (broken blue lines) are shown for 2 year and 100 year storm events. (reproduced from OPG TIS Submission, Slide #54)

control concentrations of total suspended solids, primarily from underground sources. During construction, a temporary settling pond would be used to gravitationally settle out any excess solids in water pumped from underground before discharge into the ditch system leading to the stormwater management pond. OPG did not specify the location of this temporary pond, but noted that it would be decommissioned at the end of construction.

OPG stated that the presence of low permeability clay/silt till would eliminate the need for liners under the stormwater management pond. The Panel notes that the till cover under the stormwater management pond would be thinned by approximately 2.5 meters during excavation. Therefore, there may be an increased potential for movement of water from the stormwater management pond to near-surface groundwater. The groundwater flowpath may not be intercepted by the drainage system, thus creating a possible pathway to receiving environments such as the on-site wetlands, Baie du Doré and Stream C.

Water Treatment

OPG committed to a number of water quality mitigation measures, including:

- removing oils and greases via oil/water separators prior to discharge to the stormwater management system;
- using best blasting practices for source reduction of ammonia and nitrates; and
- grouting to control inflow of highly saline groundwater into the two shafts of the DGR.

OPG stated that source reduction or elimination would be sufficient in terms of meeting regulatory criteria for discharge from the stormwater management pond, and thus, protection of MacPherson Bay. OPG committed that the contractor(s) carrying out shaft sinking and lateral development would be required to have a portable water treatment plant available on site. This treatment would be available for rapid deployment in the event that oil, grease or suspended solids in process water had elevated concentrations and could not be effectively treated by the installed systems.

OPG stated that if, during shaft sinking, it became apparent that treatment for salinity was required, treatment would be done at the surface. During development of the repository, if saline inflows continued to be an issue, OPG stated that it would install mitigation such as a desalination plant underground. The discharge from the desalination plant would be directed to the main underground sump and from there to the surface. OPG described the mitigation as readily available units that could handle the small volumes expected, about 39 cubic metres per day.

OPG stated that it would identify whether there would be a need for water treatment of the stormwater management pond discharge through the results of a monitoring program that would ensure that there will be no significant adverse effects to the environment. OPG noted that it would install a temporary water treatment plant, should high concentrations of contaminants or total suspended solids become a concern.

Environment Canada presented an evaluation of the proposed stormwater management system. Environment Canada noted that the stormwater management system would not be a conventional urban stormwater management system; rather, it would be similar to an industrial wastewater treatment system. Environment Canada emphasized that meeting discharge criteria would almost certainly require treatment, particularly with respect to chloride but also with respect to un-ionized ammonia, nitrate, and oils and greases. Environment Canada stated that OPG should use the best available technology economically achievable to ensure that contaminant concentrations in the stormwater management pond discharge are protective of aquatic life. Environment Canada noted that if the pre-treatment of salinity in the water pumped during shaft sinking and repository excavation was to be through the use of an evaporator, and if volumes were large, then the discharge of heated effluent into the storm water management pond (rather than being released as steam) may produce thermal effects on the aquatic environment. Environment Canada suggested that these possible thermal effects should be taken into consideration when OPG designs the treatment components of the storm water storage system. Environment Canada recommended that OPG should also consider other potential treatment options for salinity.

CNSC staff conducted a preliminary quantitative risk assessment to determine if an environmental risk to aquatic life would remain after the implementation of the following mitigation measures: best blasting practices to minimize ammonia remaining on waste rock; collection of saline groundwater at the bottom of the shafts followed by treatment with an evaporator; and treatment of stormwater pond water in order to ensure that concentrations of all chemicals of concern are in compliance with OPG's proposed discharge criteria. Except for chloride, these criteria corresponded to Provincial Water Quality Objectives. OPG's proposed chloride discharge criterion was 200 mg/L, compared with the Canadian water quality guideline of 120 mg/L for the protection of aquatic life. CNSC staff pointed out that the fingernail clam, a food source for lake whitefish, could be affected by chloride concentrations; however, the effluent plume created by the discharge was expected to disperse and be diluted quickly by wind and wave actions in MacPherson Bay, leading to highly localized and short-term exposures of clams to elevated chloride. Thus, CNSC staff determined that the discharge from the stormwater management pond to MacPherson Bay would comply with section 36 of the *Fisheries Act* and there would be no deleterious effects on aquatic life in the bay. Environment Canada concurred with this determination.

Environment Canada stated that monitoring of key indicators in MacPherson Bay would be required to ensure the protection of aquatic life. These indicators would include water quality indicators, such as indicators of nutrient enrichment caused by nitrogen in the stormwater management pond discharge. Nitrogen would be produced by blasting activities on the DGR site during construction. Other indicators would include the benthic invertebrate community. Environment Canada pointed out that adequate baseline data for key indicators would be fundamentally important in order that any potential effect from the project could be detected. Thus, Environment Canada recommended a follow-up monitoring program that would include water quality, sediment quality and benthic invertebrate community abundance and species composition. Environment Canada also recommended a caged bivalve study to determine whether the discharge was causing an unanticipated effect. The Panel agrees with these recommendations.

The County of Bruce requested that OPG commit to operating the stormwater management pond with the discharge closed until OPG can substantiate the quality of stormwater management pond source terms and discharge water. The Saugeen Ojibway Nation expressed concerns regarding the project effects on MacPherson Bay. These views are discussed in further detail in Chapter 14.

OPG stated that prior to discharge into MacPherson Bay, surface water discharge must meet regulatory requirements; this would provide assurance of no adverse effects on aquatic habitat. OPG committed to comply with final water quality criteria for the discharge from the storm water management pond. The discharge criteria would be developed as part of an Ontario Environmental Compliance Approval. The criteria would be established taking into consideration the Provincial Water Quality Objectives, the acute toxicity thresholds for sensitive species that are present in the receiving environment, and the existing water quality in the receiving water at MacPherson Bay. Environment Canada noted that the stormwater management pond discharge must, at a minimum, be non-acutely lethal to aquatic life. OPG would be required to provide the toxicity testing criteria (acute lethality as well as sublethal tests), test methods and frequency of testing intended to be used to demonstrate compliance with the *Fisheries Act*.

OPG stated that it would confirm the effectiveness of the stormwater management system via monitoring during site preparation, construction and operations phases. OPG's proposed surface water quality follow-up monitoring program focused on verification of the prediction of no effect on surface water quality. OPG stated that it would monitor underground water prior to discharge to surface runoff, and from there to the stormwater management pond, as well as waste rock characteristics, in order to confirm the effectiveness of mitigation measures underground and to confirm the predicted absence of acid rock drainage from the waste rock. The discharge from the stormwater management pond would be monitored to confirm compliance with the established discharge criteria. OPG committed to collecting additional pre-licensing baseline data for surface water quality to supplement the data provided in the EIS.

Capacity of the Stormwater Management System

The Panel notes that the stormwater management pond must be of sufficient size to contain the volume of water produced by large storm events and prevent uncontrolled release of untreated water to Lake Huron over the lifetime of the surface facilities, which would be several decades. As stated above, OPG sized the stormwater management pond to meet Ontario stormwater criteria, using a design storm of a six-hour, 25 millimetre storm event and the ability to safely pass, without over-topping, a one in 100-year storm, which would be a 74 millimetre rain event. To place these amounts into perspective, OPG noted that Hurricane Hazel was 280 millimetres of rain over 48 hours, and a storm event in Toronto in 2013 was 125 millimetres in five hours. OPG expected that the stormwater management pond would perform and maintain its integrity through large storm events; however, it was not intended to withhold and retain a storm event on site beyond the existing design criteria.

Environment Canada pointed out that larger storms would likely result in the stormwater management pond being unable to meet the *Fisheries Act* due to the inability to retain and treat larger storm flows. In addition, Environment Canada noted that the frequency and intensity of extreme precipitation events under climate change should be taken into account. Environment Canada cited a recent study which found that return values of annual maximum 3-day accumulated rainfall totals in the region were projected to increase by 25-60% for the period 2051-2100.

Some participants expressed concerns about the capacity of the stormwater management pond. They expressed the view that OPG had not adequately taken into account severe weather events and climate change scenarios, and suggested that this could lead to adverse effects on water quality.

OPG stated that there would be ample opportunity for adaptive management and modification of the stormwater management pond design should there be evidence that a change in design is required (including effects of climate change on frequency of severe storms). OPG further explained that there would be ample area in close proximity to the stormwater management pond to expand should there be a need to do so.

OPG noted that the derivation of probable maximum precipitation for the DGR site formed part of the basis for the design of the height of the shaft collar, but would not be a reasonable basis for design of the stormwater management pond. probable maximum precipitation is the greatest depth of precipitation for a given duration meteorologically possible for a given size area. The Panel agrees that probable maximum precipitation should not be the basis for the stormwater system design. The Panel presented a recommendation regarding the need for an updated probable maximum precipitation and an analysis of any effect of the updated probable maximum precipitation on the design of the shaft collar in Chapter 6.

CNSC staff explained that the design capacity of retention ponds would be based upon the risk to the environment if the pond were to be over-topped. The consequences of an unplanned and uncontrolled release of water plus suspended sediment to MacPherson Bay (and potentially Baie du Doré and Stream C) caused by inundation of the stormwater management pond and/or drainage ditches during a severe storm event would depend upon the amount and chemical composition of the water and sediments. CNSC staff indicated that until there was a characterization of the sediments that would accumulate in the pond, the consequences of a release of those sediments could not be assessed. CNSC staff indicated that required care and maintenance of the stormwater management pond would include measures to ensure there would not be an excessive accumulation of sediment in the pond. CNSC staff confirmed that once there was knowledge of the characteristics of the sediments that would collect in the stormwater management pond, OPG could conduct a risk assessment of a large-scale release of water and sediment due to a severe storm. The risk assessment results would then be evaluated by CNSC staff to determine whether changes in pond design would be necessary.

OPG Determination of Significance of Residual Adverse Effects on Surface Water Quality

OPG stated that there would be no significant adverse effects on surface water quality. OPG explained that for an effect on surface water quality to be considered a significant adverse effect, releases of water quality indicators would have to be in excess of relevant water quality objectives or guidelines, or the surface water quality regime would have to be altered sufficiently to affect sensitive or critical habitat on a long-term or continuous basis. OPG maintained that its commitments regarding water treatment to meet applicable water quality criteria would ensure that there would be no residual adverse effects on surface water quality; therefore, no significance assessment was performed.

Panel Conclusion Regarding Effects on Surface Water Quality

The Panel concludes that there will be no significant adverse effects on surface water quality during site preparation, construction, operations and decommissioning provided that water treatment facilities are designed and implemented to ensure that the discharge from the storm water management pond fully complies with section 36 of the *Fisheries Act*. The Panel concurs with Environment Canada that the storm water management pond should be operated as an industrial wastewater treatment system. As such, all water treatment facilities required to achieve full compliance should be in place during site preparation and construction, operations, and decommissioning. Unexpected and unpredicted contaminant releases at the site will require a prompt response; e.g., unexpected high volumes of highly saline water during shaft construction. The Panel notes that periodic monitoring may not be adequate to detect water quality issues in time to implement appropriate water treatment options if those options are not already in place.

The Panel agrees with Environment Canada and CNSC staff that the design capacity of the stormwater management system should be re-examined in light of the risk of large-scale releases of water and sediment due to a severe storm event. This re-examination should address explicitly the effect of climate change on the return period of severe storms.

The Panel notes that adaptive management of the stormwater management system must be rigorous and timely. The Panel considers that the highest priority failure modes associated with the design of the system relate to severe storm events. Therefore, reasonable contingency measures must be pre-designed and approved in the event that other water flow conditions occur. There must also be a robust monitoring system that will detect problems in time to allow the contingency measures to be implemented, and an audit system to ensure that the approach is being followed.

The Panel concludes that a liner should be installed under the stormwater management pond to prevent release to the shallow groundwater system, and from that system, to surface water receiving environments such as on-site wetlands, Baie du Doré or Stream C. A liner would address the uncertainty associated with the characterization of the surficial materials underlying the stormwater management system and the associated uncertainty regarding the direction and flow of groundwater on the project site. The liner would also address the removal of a substantial amount of surficial material prior to construction of the stormwater management pond. As noted previously by the Panel, liners also represent best practice. The Panel notes its Recommendation 8.11.

The Panel concludes that the follow-up monitoring program must include a comprehensive monitoring program in MacPherson Bay in order that EIS predictions regarding no significant adverse effects on aquatic biota are verified. The Panel agrees with Environment Canada's recommended components of the follow-up monitoring program: water quality; sediment quality; benthic invertebrate community abundance and species composition; and a caged bivalve study. The Panel is of the view that the follow-up monitoring program must be statistically defensible; therefore, additional baseline data for key indicators will be required in support of the follow-up program under the *Canadian Environmental Assessment Act, 2012*.

The Panel also notes that a dispersion study of the discharge into MacPherson Bay would provide support for the CNSC determination in its preliminary quantitative risk assessment that the discharge would be rapidly dispersed and diluted. Furthermore, the dispersion study would provide information useful for identification of sampling locations.

Recommendation 8.11: In order to avoid significant adverse effects to surficial and shallow bedrock groundwater, OPG shall place a liner under the stormwater management pond. The liner shall be placed during site preparation and construction. The specifications of the liner should be developed in consultation with Environment Canada.

Recommendation 8.12: In order to avoid significant adverse effects to surface water quality, OPG shall, prior to construction, submit to the CNSC a plan for treatment of all water destined for discharge from the stormwater management pond. OPG shall treat stormwater management pond releases, to the satisfaction of the CNSC, such that they comply with section 36 of the *Fisheries Act* throughout construction, operations and decommissioning.

Recommendation 8.13: In order to prevent significant adverse environmental effects due to over-topping of the stormwater management system, OPG shall review and, if necessary, revise the design of the stormwater management system, to the satisfaction of the CNSC, based upon an assessment of the likelihood of significant changes in the return period and magnitude of major storm events.

Recommendation 8.14: In order to prevent significant adverse effects to surface water, OPG shall, to the satisfaction of the CNSC, prepare a contingency plan to mitigate effects of severe storm-related uncontrolled overland flow to Stream C, Baie de Doré, and MacPherson Bay during the period of site preparation before the stormwater management system is fully functional.

Recommendation 8.15: In order to confirm the predictions in the environmental assessment and ensure compliance with the *Fisheries Act*, OPG shall, to the satisfaction of the CNSC and in consultation with Environment Canada, monitor concentrations of relevant contaminants of concern and conduct acute and chronic toxicity tests on the contents of the stormwater management pond prior to discharge.

Recommendation 8.16: In order to confirm the predictions in the environmental assessment, and to ensure compliance with the *Fisheries Act*, OPG shall implement a follow-up program, to the satisfaction of the CNSC, to monitor a broad spectrum of parameters (e.g., other metals, phosphate, total petroleum hydrocarbons) at the point of discharge of the storm water management pond quarterly, during site preparation and construction, and later during operations.

Recommendation 8.17: In order to verify predictions in the environmental assessment and the effectiveness of the mitigation of water quality by the stormwater management system, and as support for the design of the follow-up monitoring program in MacPherson Bay, OPG shall, in consultation with Environment Canada and to the satisfaction of the CNSC, conduct an effluent dispersion study in MacPherson Bay after commissioning of the stormwater management pond.

Recommendation 8.18: In order to verify predictions in the environmental assessment and the effectiveness of the mitigation of water quality by the stormwater management system, OPG shall, in consultation with Environment Canada and to the satisfaction of the CNSC, conduct follow-up monitoring in MacPherson Bay during site preparation and construction, and later during operations. The follow-up monitoring program shall include water quality, sediment quality, benthic invertebrate community indicators, and caged bivalve studies at sampling locations and frequencies determined in consultation with Environment Canada and to the satisfaction of the CNSC. OPG shall ensure that there are adequate baseline data for all follow-up monitoring indicators prior to site preparation.

8.4.5 Effects on the Quantity and Timing of Surface Water Flow

OPG indicated that its construction activities would affect surface water quantity and flow as a result of an eight-hectare drainage area diversion from the Stream C watershed to MacPherson Bay. During site preparation and construction, diversion, as well as shaft excavation and sump pumping, would increase the annual flow to the existing drainage ditch at Interconnecting Road by an estimated 114%. Flow in the North Railway Ditch at Stream C would decrease by 31%. During operations, the increased flow to the drainage ditch would be 61% while reduced flow in the North Railway Ditch at Stream C would remain the same. There would be no changes in flow in the South Railway Ditch from the project. OPG calculated the decrease in the drainage area of Stream C to be 0.8%, decreasing the average annual flow at point of discharge from the Bruce nuclear site to 143.4 L/s or 0.8% (assuming a 1:1 relationship between drainage area and stream flow).

OPG determined that any predicted change in annual flow of more than ±15% would be considered to be an adverse effect. OPG stated that the flow increase in the drainage ditch at Interconnecting Road during site preparation and construction, as well as operations, would be an adverse effect because the total increases in flow would range from 61% to 114% (based on annual average flows). The predicted 31% decrease in flow in the North Railway Ditch at Stream C was also designated an adverse effect.

OPG hypothesized that for an effect on an existing engineered channel, e.g., a ditch, to be assessed as a significant adverse effect, a decrease in flow must be sufficient to alter the capacity of the engineered channel through excessive sediment deposition. Alternatively, an increase in flow must exceed the design capacity of the channel sufficiently to cause flooding and/or erosion.

OPG stated that, at present, the annual flow in the North Railway Ditch was low and the predicted decrease would not be expected to increase the amount of sediment deposition such that it would affect the design capacity enough to cause flooding. Any sediment deposition would be addressed through maintenance. As such, OPG considered the residual adverse effect on flow in the North Railway Ditch to be not significant. OPG planned to monitor flows in the North Railway Ditch prior to the start of construction and during construction in order to verify predicted changes to flows to Stream C as part of its follow-up monitoring program.

OPG Determination of Significance of Residual Adverse Effects on Surface Water Flow

OPG considered the residual adverse effect on flow increase in the drainage ditch at Interconnecting Road to be not significant. OPG explained that while the predicted increase in flow exiting the drainage ditch at Interconnecting Road had the potential to exceed the existing design capacity of the ditch, the flow capacity would be assessed and the ditch re-sized during the final design process, if necessary, to ensure that increases in flow will not cause flooding and/or erosion. OPG stated that the ditch would be modified in accordance with accepted practices, such as the Ontario Ministry of Transportation *Drainage Management Manual* (1997), and undergo regular maintenance if the ditch conditions cannot convey the predicted flows.

CNSC staff agreed with OPG's general conclusions regarding the effects of the project on surface water flow; however, CNSC staff stated that additional information would be required to support the development of a statistically defensible follow-up monitoring program under the *Canadian Environmental Assessment Act, 2012*. CNSC staff expected that uncertainties regarding baseline and effects on surface water flow would be resolved prior to construction of the project.

Panel Conclusion Regarding Effects on Surface Water Flow

Based on the above information, the Panel concludes that the project will not cause significant adverse effects to surface water flow. The Panel notes that the predicted increase in flow of the existing drainage ditch at Interconnecting Road has the potential to exceed the existing design capacity. The Panel emphasizes the importance of OPG's incorporation of contingency planning for response to large water flows caused by severe storm events as part of its adaptive management program.

Recommendation 8.19: In order to verify predictions in the environmental assessment, OPG shall develop, to the satisfaction of the CNSC, a follow-up program for flow reduction rates in the North Railway Ditch and Stream C, during site preparation and construction. If monitoring results indicate differences from predictions, OPG shall, to the satisfaction of the CNSC, determine whether mitigation measures are required to ensure there are no significant adverse effects on surface water quantity.

Recommendation 8.20: In order to avoid significant adverse effects to nearshore habitat in MacPherson Bay, OPG shall submit, prior to construction and to the satisfaction of the CNSC, a management plan that provides a detailed description of the options available to increase the capacity of the drainage ditch at Interconnecting Road in the event the flow exceeds the capacity of the ditch. The plan shall identify the relative potential effects of each of the options on the ecology of MacPherson Bay, and consider the relative effects when selecting and implementing the preferred option.

8.4.6 Effects on Wetlands

OPG stated that the proximity of the northeast wetland (marsh) to the perimeter ditch, stormwater management pond, and permanent waste rock management area, may result in effects on the water level of the wetland during the site preparation and construction period. As discussed in more detail in a later section of this chapter, OPG modelled the zone of influence from dewatering the shallow bedrock groundwater during shaft sinking and determined that the zone would not approach the northeast wetland.

OPG designed the site drainage system to avoid any measurable effects on the wetland habitat. In addition to a commitment to maintain a 30 m setback from adjacent wetlands, the construction and operation of the stormwater management pond was not expected to change water levels or discharge water to the northeast marsh. OPG stated that the site drainage system design would not allow for water to overtop ditches or the stormwater management pond to the adjacent wetland, and would safely convey the peak outflow rate from a 24-hour, 100-year rainfall event. Runoff from the waste rock piles would be directed to the perimeter ditches through grading, preventing runoff from the waste rock piles reaching the wetland.

Although weathered/fractured tills were not expected to occur beneath the stormwater management pond or the waste rock management area, OPG had an allowance for the lining of both as a mitigation measure should such conditions or intervening till deposits be encountered during site preparation and construction.

The County of Bruce requested that OPG provide a more detailed method to determine baseline fluctuations in wetland water tables in the study area by, for example, tying on-site measurements into longer term data sets in the region. The request from the County of Bruce was based upon the fact that variations outside the seasonal norm cannot be determined with a one year baseline.

Environment Canada determined that changes in shallow groundwater levels at the site would be unlikely or minimal, and that minor changes to the site watershed would not have effects on adjacent wetlands. Nevertheless, Environment Canada recommended that OPG provide verification of the overburden stratigraphy at the time when the storm water management pond is constructed. Environment Canada stated that, should more permeable layers be encountered, OPG must assess the potential for effects on water levels in the marsh and evaluate and implement mitigation options. Environment Canada also recommended monthly monitoring of water levels in the northeast marsh, prior to site preparation and construction, to establish baseline conditions. This monitoring would need to continue for three years after the construction of the stormwater management pond, coupled with an analysis of precipitation inputs, to establish whether there is any reduction in water levels in the wetland attributable to the project.

In the Panel's opinion, the proximity of the northeast marsh to the site boundary makes it vulnerable to negative changes in water level. Because of its depositional environment, the till cover composition can show spatial variability that will be difficult to detect. The presence of vertical fractures in the till or the presence of interlayered sandy lenses could provide pathways by which water from the marsh could drain towards the base of the storm water management pond, which is located at a lower elevation.

The Panel considered Environment Canada's recommendations involving multi-season monitoring of precipitation and the water levels of the marsh. The timeline for OPG to obtain definitive monitoring results would postpone any mitigation until repository construction is well underway. The implementation of effective mitigation measures would be difficult and disruptive at such time. The Panel is of the view that the inclusion of a liner in the construction of the stormwater management pond, as recommended, would be a more effective strategy to not only prevent effects on the wetland, but also to stop leakage of contaminants from the stormwater management pond, through a thinned till cover, into the shallow bedrock groundwater regime.

Panel Conclusion Regarding Effects on Wetlands

The Panel concludes that the project is not likely to cause significant adverse effects to the northeast wetland provided that OPG installs liners beneath both the storm water management pond and the waste rock management area. Recommendations 8.8 and 8.11 reflect this Panel conclusion. The Panel notes that the geometry (including the height) of the waste rock management area may change as construction proceeds. Therefore, monitoring of wetland water levels should continue throughout the construction phase.

Recommendation 8.21: In order to confirm predictions in the environmental assessment regarding effects on wetland water levels, OPG shall conduct monthly monitoring of water levels in the northeast marsh, beginning prior to site preparation and construction in order to establish a baseline. A follow-up program shall then be established, in consultation with Environment Canada and to the satisfaction of the CNSC.

8.4.7 Effects on Sediment

The chemical compositions of sediments from both standing and flowing bodies of water reflect natural environmental conditions as well as historical inputs from human activities. Baseline sediment quality data provide the means for evaluating any additional inputs by hydrologic or atmospheric pathways that may be attributable to project activities. The disturbance of contaminated sediments could remobilize contaminants into the water column.

OPG stated that the baseline sediment samples it collected within the Site Study Area in 2009 showed some concentrations of metals and petroleum hydrocarbons that exceeded Canadian Council of Ministers of the Environment and Ontario Ministry of the Environment and Climate

Change criteria. OPG noted that these concentrations were consistent with elevated values at the Bruce nuclear site due to historical industrial activities.

OPG explained that sediment quality data had been collected between 1997 and 2001 in a three-phase environmental assessment monitoring program for the Used Fuel Dry Storage Facility at the WWMF. The results of this program showed relatively higher radiological activities in sediment during the construction of the facility. OPG added that the ongoing Bruce Power Radiological Environmental Monitoring Program is used to assess the effects of all operations at the Bruce nuclear site, including radionuclide concentrations in sediments. None of the sampling sites in these surveys fell within the Site Study Area.

Since radionuclide and chemical contaminant data of sediments in the Local Study Area had showed little change in concentration over time, OPG did not believe that additional sediment sampling was warranted. CNSC staff disagreed with OPG and recommended that OPG collect additional baseline sediment quality data. CNSC staff determined that there was uncertainty in the sediment quality data in MacPherson Bay because the design of the sampling program did not take into consideration seasonal and year-to-year variability.

Environment Canada noted the possibility that site preparation and construction activities could cause sediment discharges into the railway ditches that would then convey suspended solids to Stream C. Environment Canada was satisfied, however, that as long as sediment is controlled b silt curtains in accordance with OPG’s commitments, and as long as OPG employs best management practices during construction, no effects would be expected on Stream C.

Panel Conclusion Regarding Effects on Sediment

The Panel agrees with CNSC staff that additional baseline data on sediments is required to provide information on seasonal and year-to-year variability. This information could then be used in the follow-up program to verify OPG’s effect predictions.

Recommendation 8.22: In order to confirm the predictions in the environmental assessment, OPG shall conduct a sediment quality follow-up program in MacPherson Bay during construction and operations. Prior to construction, OPG shall collect additional baseline sediment quality data at the ditch at Interconnecting Road and MacPherson Bay. All sampling shall be conducted to the satisfaction of the CNSC.

8.4.8 Effects on Near-surface Groundwater

The near-surface groundwater regime includes the surficial groundwater zone and shallow bedrock groundwater zone defined by OPG. OPG explained that the potential effects on near-surface groundwater by project activities were:

- groundwater withdrawal during sinking of two shafts through the upper bedrock sequence;
- diversion and migration of the existing tritium plume originating from the WWMF;
- continued leakage after installation of casing/grouting in the upper bedrock sequence of the shafts;

- effects related to construction of the waste rock management area and stormwater management pond; and
- any infiltration of contaminated surface water through the surficial till cover.

Each of these is discussed in more detail below.

Effects of Shaft Sinking on the Near-surface Groundwater Flow Pattern

OPG stated that the dewatering of the overburden and near-surface groundwater regimes during shaft sinking could potentially affect the groundwater flow patterns and seepage rates into the shafts. This, in turn, could affect the waste rock piles, the storm water management pond, the northeast wetland adjacent to the main waste rock pile, and the existing tritium plume originating from the WWMF.

OPG's modelling determined that the zone of groundwater withdrawal during construction of the upper 170 m of the shafts would not have a radius of influence that would exceed an estimated tens of meters (predicted to be 54 m) from each shaft. This would place the stormwater management pond, waste rock pile, and wetlands beyond the reach of the zones affected by the withdrawal from the shallow aquifer. The dominant groundwater inflows into the shafts would occur through fractured carbonate rock of the Lucas Formation, not the overburden. As such, drawdown would not approach any surface water courses or wetland features. OPG stated that once the hydrostatic shaft liners have been installed and sealed, the shafts would be hydraulically isolated and no longer influence the groundwater system.

CNSC staff recommended that OPG provide verification of assessment results for the zone of influence from dewatering during excavation and construction through groundwater and shaft discharge monitoring programs. OPG committed to monitoring the shallow groundwater network during the construction phase.

Natural Resources Canada pointed out that, in addition to the Lucas Formation, the permeable upper 20 m of the Bass Islands Formation could be the source of major inflow of groundwater during shaft excavation. Natural Resources Canada suggested that proper grouting may be required to prevent groundwater inflows at this level.

Environment Canada stated that, due to a limited hydraulic connection, the shaft development was unlikely to cause the drawdown of water levels in the northeast marsh. Environment Canada explained that the marsh is formed by a perched water table that sits upon a thick low permeability glacial till layer that limits downward infiltration of water, and therefore has limited hydraulic connection with the more rapidly dewatering carbonate bedrock. The modelled zone of influence from the shafts was 54 m, as compared to the 500 m distance of the marsh from the shafts.

The Panel concludes that shaft excavation will have only a temporary effect on local shallow groundwater volumes and flow directions provided the hydrostatic shaft liners effectively seal groundwater inflow from the Lucas and Bass Islands formations. No surface water courses or wetland features should be affected. It will be important that OPG verify its predictions regarding the amount of drawdown and zone of influence through a shaft discharge monitoring program.

Effects of Shaft Construction on the Existing Tritium Plume in Near-surface Groundwater

The response of the existing groundwater tritium plume from the WWMF to groundwater withdrawal is a matter of concern during, and possibly after, shaft excavation through the surficial and shallow bedrock groundwater zone. OPG stated that existing groundwater monitoring wells detected elevated tritium levels in the high hydraulic conductivity Middle Sand unit of the surficial glacial deposits. OPG noted that the Middle Sand unit does not extend under the project site, and that dewatering during shaft construction would be temporary until the installation of hydrostatic shaft liners. Although OPG conducted numerical modelling on the effects of the construction of shafts on the shallow groundwater system, it did not do the same for the tritium plume migration and interaction.

OPG installed an additional eight down-gradient and two background shallow groundwater wells in 2012, which became part of the monitoring network to provide baseline information. These wells would continue to be monitored throughout the construction phase. OPG's data suggested existing background tritium levels of 10 Bq/L at the project site. OPG's conservative estimates of tritium for shaft discharge would not exceed 250 Bq/L. As explained above, the zone of influence affected by the withdrawal would not extend more than several tens of meters from the shaft locations.

OPG stated that tritium concentrations in monitoring wells around the DGR boundary would be monitored to detect any changes to groundwater concentrations in the Project Area. Tritium would also be measured in the stormwater management system, and there would be periodic analysis of tritium in the ventilation sump water.

CNSC staff expressed the view that the current network of monitoring wells would be inadequate to provide early detection. CNSC staff explained that all of the new monitoring wells for shallow groundwater were clustered around the northern side of the DGR footprint (down-gradient), and stated that early detection of potential migration of the tritium plume would require additional monitoring wells, including wells up-gradient of the DGR footprint, to provide reference data.

Some participants expressed concern that whatever workplace management and operating conditions that resulted in the spread of tritiated water through the area of the WWMF may also prevail at the DGR site and result in significant contamination of groundwater and/or surface water in the DGR area. The Panel does not share these concerns; however, as described below, the Panel is of the view that the tritium plume requires additional characterization prior to shaft sinking.

The Panel concludes that it is unlikely that the existing tritium plume originating from the WWMF will reach the area of the shafts; however, there is uncertainty associated with OPG’s assessment that must be addressed. The plume's movement towards the shafts would need to be clearly defined in order to enable OPG to identify and implement necessary mitigation measures if tritium levels are observed to be higher and occur earlier than expected.

Recommendation 8.23: Prior to site preparation and construction, OPG shall use information from existing and planned groundwater monitoring wells for verification of the environmental assessment predictions regarding the zone of influence from dewatering during excavation and construction. The verified predictions regarding the zone of influence shall be used for the final design of shaft excavation procedures and infrastructure, including mitigation of groundwater inflow from surficial and shallow bedrock groundwater zones

Recommendation 8.24: During construction, in order to confirm predictions in the environmental assessment, OPG shall implement a follow-up program for groundwater quality and groundwater inflow rates into the shafts and repository, to the satisfaction of the CNSC. If groundwater inflows exceed predicted values or if the zone of influence is larger than expected, OPG shall implement mitigation measures to either reduce groundwater inflow or the zone of influence. If groundwater loadings and/or concentrations of contaminants of concern exceed environmental assessment predictions, OPG shall implement mitigation measures to avoid adverse effects to surface water quality, to the satisfaction of the CNSC.

Recommendation 8.25: In order to verify the predictions in the environmental assessment, OPG shall, prior to shaft sinking, enhance its capability to detect and monitor the movement of the tritium plume originating from the WWMF by adding an adequate number of monitoring wells up-gradient of the DGR shafts, to the satisfaction of the CNSC.

Recommendation 8.26: In order to verify the predictions in the environmental assessment, prior to shaft sinking, OPG shall conduct a comprehensive assessment of the migration of the tritium plume originating from the WWMF site, to the satisfaction of the CNSC. The assessment shall include updated modelling of the tritium plume migration. If groundwater modelling or monitoring indicates that the tritium plume may reach the shaft before the shaft collars are installed, OPG shall prepare a contingency plan, to the satisfaction of the CNSC.

Effects of Construction of the Waste Rock Management Area and Stormwater Management Pond on Near-surface Groundwater

OPG conducted a series of numerical groundwater simulations designed to assess the influence of the waste rock management area and stormwater management pond on the underlying shallow groundwater system. Under all anticipated conditions, mounding of the potentiometric surface was not predicted beneath the waste rock management area or the stormwater management pond and their presence were not expected to materially influence the local shallow groundwater flow directions. A potentiometric surface is an imaginary surface that defines the level to which water in a confined aquifer would rise were it completely pierced with wells. OPG stated that routine quarterly groundwater monitoring within the shallow bedrock at the Project Area perimeter would provide future evidence to verify the numerical predictions.

The Panel agrees that construction of the waste rock management area and stormwater management pond are not likely to cause significant adverse effects on the local shallow groundwater flow directions or groundwater levels.

Effects on Potable Water Sources in the Local Study Area

OPG determined that shallow groundwater migration directly beneath the Site Study Area is oriented vertically downward within the till cover. Groundwater discharge from the till may enter an underlying confined permeable carbonate aquifer in which groundwater migration is horizontal and directed to Lake Huron. OPG stated that there are no potable groundwater supply wells between the Project Area and Lake Huron. As previously explained in this chapter, deep boreholes at the Project Area have shown that potable groundwater is restricted to the shallow groundwater system, within glacial deposits and the confined upper Lucas Formation. However, potable water and wells extend down to the Amherstburg and Bois Blanc formations in the Local Study Area.

CNSC staff confirmed the absence of any potable groundwater supply wells in the Site Study Area and noted that potential future potable groundwater supplies would be upgradient of the project. Therefore, CNSC stated that no potable groundwater resource was expected to be affected by the project.

Health Canada evaluated possible effects of the project on drinking water beyond the site boundaries. Health Canada determined that there would not be any changes to the water sources and well water quality of persons living near the Bruce nuclear site, and that the project would not result in any exceedance of applicable water quality guidelines or standards at the point of human consumption or exposure.

Participants expressed concerns about effects of migration of the tritium plume in groundwater originating at the WWMF into potable water supplies. This issue is discussed in Chapter 9.

Panel Conclusion Regarding Effects on Near-surface Groundwater

The Panel concludes that the project is not likely to result in significant adverse effects to near-surface groundwater, provided mitigation measures commited to by OPG, and those recommended by the Panel, are implemented. The project is not likely to cause significant advers effects to surface water courses, wetland features or potable groundwater.

8.4.9 Panel Conclusion Regarding Effects on Surface Water and Near-surface Groundwater

The Panel concludes that the project is not likely to result in significant adverse environmental effects on surface water or near-surface groundwater, provided that OPG implements the mitigation measures that it has committed to and those recommended by the Panel. The Panel stresses the importance of ensuring that the discharge from the stormwater management system meets applicable water quality criteria and that the design capacity of the system reflects adjustments for the potential effects of climate change on the severity and frequency of storm events.

8.5 PLANTS, ANIMALS AND THEIR HABITATS

OPG assessed pre-closure activities related to site preparation, construction, and operation to determine whether they would result in any residual significant adverse effects. This assessment included effects on plants, animals and their habitats.

8.5.1 Effects on Plants

OPG evaluated effects on the following plant valued ecosystem components:

- eastern white cedar;
- heal-all; and
- common cattail.

OPG assessed both direct effects, such as vegetation removal, and indirect effects, which result from changes in air quality, water quality, and water flow. OPG also proposed mitigation measures to ensure that the effects would not be significant.

OPG stated that the vegetation types in the project Area consist of industrial barren, where existing surface facilities - notably the WWMF- are located, and mixed forest (Figure 20). The Site Study Area includes a wider variety of ecological communities; however, OPG determined that all of the direct effects would occur within the Project Area.

OPG stated that site preparation and construction would result in the removal of 77% of the total 11.6 hectares of mixed forest and 72% of the total 30.1 hectares of the industrial barren vegetation in the Project Area (Figure 21). Eastern white cedar and heal-all would be the plant valued ecosystem components affected. OPG did not consider the removal of heal-all in the industrial barren to be an adverse effect because the growing conditions in this specific area of the site were limited to begin with. OPG also predicted a minor disturbance of cattail in the North and South Railway Ditches as a result of the installation of a crossing and culvert. However, OPG assumed that “naturalization” of the plant community in the ditches, back to baseline conditions, would occur. OPG determined that the removal of mixed forest areas would result in an adverse effect to eastern white cedar. Only eastern white cedar was carried forward in the assessment because OPG assumed that heal-all, cattail and the plant species represented by these valued ecosystem components would regrow after disturbance.

The Panel notes that OPG did not estimate the length of time required for regrowth of vegetation such as heal-all and cattail, nor did it discuss what other plants, including invasive species and noxious weeds, may colonize the disturbed areas. The Panel expects that OPG would monitor vegetation regrowth over the lengthy time period represented by the site preparation and construction, operations, and decommissioning phases. The Panel also expects that OPG would implement measures to control invasive plant species and noxious weeds.

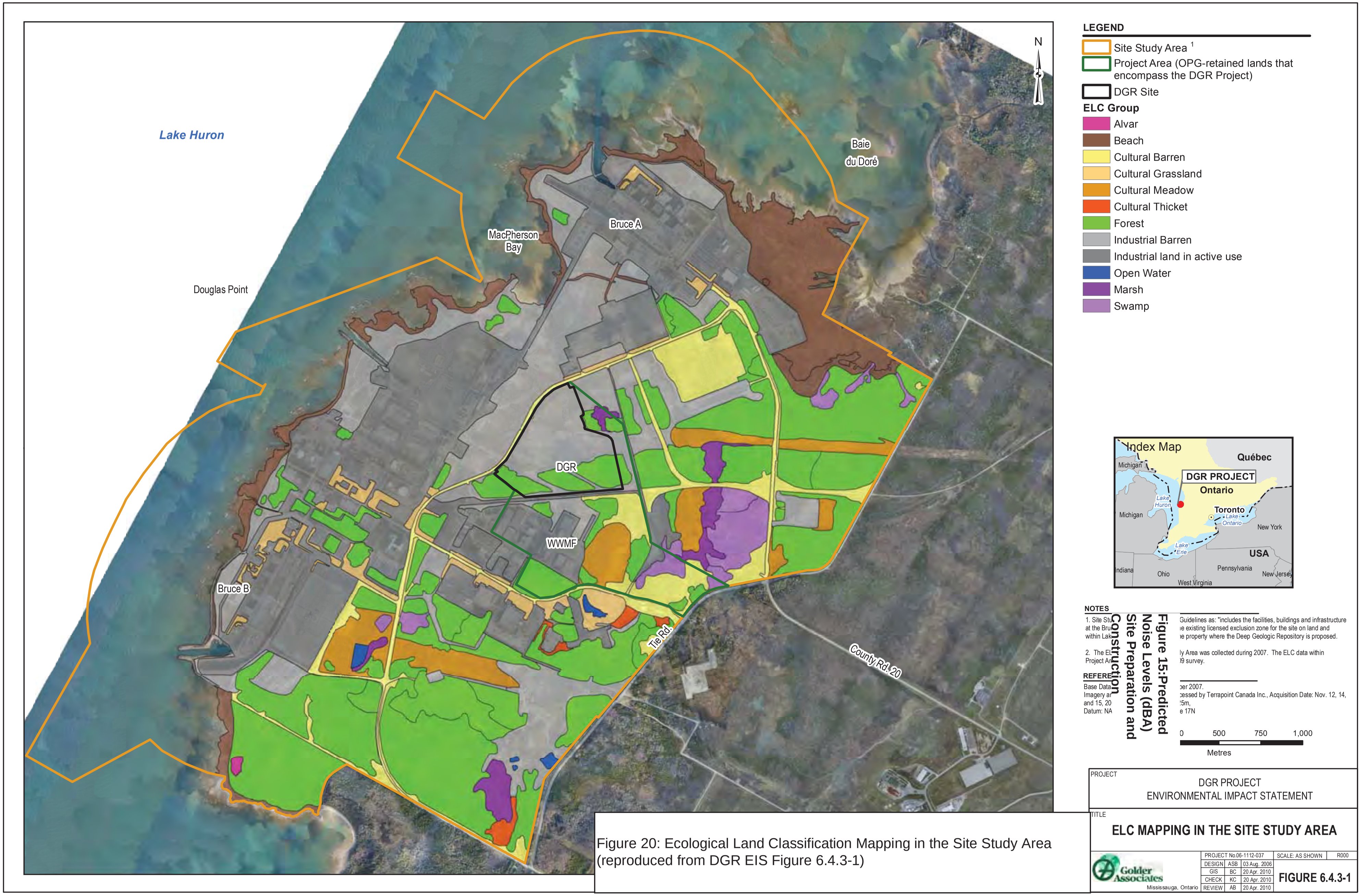


Figure 20: Ecological Land Classification Mapping in the Site Study Area (reproduced from DGR EIS Figure 6.4.3-1)

Figure 21: Example of Mixed Wood in the Project Area (reproduced from the DGR Joint Review Panel Project Site Visit (June 7, 2012) Report)

OPG stated that there would be no additional removal or alteration of habitat following site preparation and construction, including during decommissioning and abandonment. The Panel notes that after several decades, regrowth or reclamation of plant communities in the Project Area and Site Study Area would have occurred prior to decommissioning. Decommissioning activities such as the removal of surface facilities, the removal of hardened surfaces, re-grading, and the restoration of natural drainage would all have the potential to disturb both industrial and adjacent natural areas. Therefore, the Panel suggests that future licensing for the decommissioning phase should consider mitigation of the disturbance caused by decommissioning activities on re-established plant communities.

OPG predicted that, during site preparation and construction, changes in air quality indicators such as nitrogen dioxide, sulphur dioxide and particulate concentrations, would either be below criteria or occur infrequently enough that plants would not be noticeably affected. However, OPG noted that some plants, such as eastern white cedar, may be sensitive to fumigations from combustion engine exhaust, e.g., nitrogen dioxide.

OPG predicted that there would not be any adverse effects on cattails from changes in water flow. This was because cattails are adapted to periodic dry or low flow conditions, as well as periodic high flow conditions.

Because OPG's surface water quality assessment did not predict adverse effects on surface water quality, OPG predicted that there would be no effects on common cattail or eastern white cedar. This assessment included consideration of the use of road safety salt at the site, but did not include consideration of elevated salinity in the stormwater drainage system leading to and including the stormwater management pond. Although OPG committed to mitigation to ensure that water quality criteria would be met prior to discharge to MacPherson Bay, this does not necessarily mean that the water quality in the stormwater management system would have no potential for causing adverse effects to plants that colonize the stormwater system. The Panel notes that since the stormwater system, including the stormwater management pond, would become habitat due to the plant community in the ditches reverting to baseline conditions, monitoring of the effects of elevated salinity on aquatic or semi-aquatic plant species such as cattails would be required (Figure 22)

Figure 22: Example of Drainage Ditch Habitat in the Project Area (reproduced from the DGR Joint Review Panel Project Site Visit (June 7, 2012) Report)

Mitigation Measures for Plants

OPG made several commitments regarding minimizing the loss of plant species and habitat associated with the clearing of the mixed forest during site preparation and construction. These commitments included investigating opportunities to retain tree cover, and deploying fencing to prevent additional loss of specimens and habitat. Fencing would protect vegetation and would help prevent incidental damage and soil compaction caused by equipment and workers encroaching into areas proposed for protection within the Site Study Area. OPG also committed to using best management practices to minimize the transfer of soils from the project site area to natural features within the Project Area and Site Study Area. The Panel assumes that OPG will ensure that contractors are informed and, where necessary, trained to ensure that best practices are used for soil and vegetation protection.

OPG committed to several measures to reclaim plant habitat. These included planting trees on berms, embankments, and areas not used for laydown of equipment. Architectural trees would be planted near amenities buildings. All unpaved surfaces, including laydown areas, would be cleared, cleaned and revegetated with native, non-invasive species after the completion of construction. Drainage ditches would be inspected and maintained to prevent excess sedimentation.

Environment Canada noted that OPG had provided a conceptual revegetation plan for the waste rock pile and suggested that this revegetation would provide an opportunity to create habitat for some bird species. As such, Environment Canada suggested that it should be consulted at the time that OPG develops its detailed revegetation plan in order to help identify the most beneficial habitat type that could be supported in light of site conditions. The Panel supports this position.

The Panel understands that the Project Area will be an industrial site for decades; therefore, there will be an inevitable shift in habitat. However, the Panel expects that OPG will take every opportunity to maintain or enhance habitat within the Project Area and the Site Study Area, in accordance with its Biodiversity Policy. The Panel also expects that OPG will include the minimization of the loss of species and habitat during site preparation and construction in the OPG Environmental Management System, including training of contractors in order to ensure adherence to specific mitigation practices.

Significance of Residual Adverse Effects on Plants

OPG identified a residual adverse effect on eastern white cedar because mitigation measures would not reduce or eliminate the loss of trees caused by site preparation and construction of the project facilities and amenities. However, this residual adverse effect was judged to be not significant because the removal of 8.9 hectares of mixed woods was not considered to be large enough to affect the sustainability or productivity of eastern white cedar in the Local Study Area, and would be reversible with time following closure of the DGR. OPG noted that the three small fragmented stands that would be removed were made up of common species with no notable age or size characteristics, did not support any sensitive species, and did not provide unique ecological functions that would be lost. OPG stated that adjacent woodland populations and communities would not be compromised by the removal, that there would be no measurable effect on regional connectivity of habitat, and that this removal would not cause or contribute to fragmentation in the Local Study Area.

CNSC staff concurred with OPG that the residual effect on eastern white cedar would not be significant because of the limited spatial extent of vegetation removal. CNSC staff noted that this did not mean that there would be no loss of species or habitat caused by project works and activities; rather, that these losses were not considered to be measurable nor would they warrant mitigation measures. CNSC staff noted that the OPG Biodiversity Policy would be used in the development of environmental protection policies to ensure that biodiversity is maintained during operations.

Panel Conclusion Regarding Effects on Plants

The Panel concludes that the project is not likely to cause significant adverse effects on plants and plant communities relative to the local and regional baseline plant communities and the habitat that these communities provide. The Panel expects that OPG will actively apply its Biodiversity Policy to ongoing revegetation and maintenance of habitat on the project site, and not wait for the decommissioning phase to implement restoration programs, as noted by CNSC staff. The Panel agrees with the recommendation from Environment Canada that native plants should be used in revegetation.

The Panel notes that some plants may be sensitive to changes in air quality during site preparation and construction. As part of the air quality follow-up monitoring program, OPG should monitor indicators of effects of changes in air quality on plants, such as yellowing of leaves, premature leaf drop, and spotting or browning of leaves. OPG could then interpret these indicators in light of air quality data collected over the same time period and apply mitigation should air quality events correspond with changes in plant indicators.

The Panel has several recommendations regarding plants:

Recommendation 8.27: In order to confirm the absence of significant adverse effects on plants and plant communities, OPG shall monitor the presence of cattails and other aquatic plants important as habitat within the stormwater drainage system, including the stormwater management pond. Baseline conditions should be established prior to habitat disturbance, and follow-up monitoring should take place after the disturbance of habitat during site preparation, construction and operations phases. This monitoring program should be conducted to the satisfaction of the CNSC and be included in the OPG environmental management system for the project. OPG shall address any significant adverse change in these plant communities that, in turn, would have the potential to affect significant species, such as amphibians and reptiles, in accordance with the *Species at Risk Act*.

Recommendation 8.28: In order to confirm the absence of significant adverse effects on plants and plant communities as predicted in the environmental assessment, OPG shall implement a follow-up program to monitor the naturalization of disturbed areas, during construction and operations, to the satisfaction of the CNSC. If monitoring indicates the presence of invasive plant species and noxious weeds, OPG shall implement appropriate mitigation measures.

Recommendation 8.29: In order to verify the prediction in the environmental assessment that there will be no significant adverse effects on plants due to changes in air quality, OPG shall monitor indicators of effects of changes in air quality on plants, both on the Project Area and in the Site Study Area. This monitoring shall occur during site preparation and construction and be conducted to the satisfaction of the CNSC.

Recommendation 8.30: In order to enhance the potential of the Project Area as future habitat, OPG shall, prior to decommissioning, submit a detailed revegetation plan for the waste rock pile to the CNSC. OPG should consult with Environment Canada when developing the plan.

8.5.2 Effects on Terrestrial Animals

OPG evaluated effects on the following terrestrial animal valued ecosystem components:

- Northern short-tailed shrew;
- Muskrat;
- White-tailed deer;
- Red-eyed vireo;
- Wild turkey;
- Yellow warbler;
- Mallard;
- Bald eagle;
- Midland painted turtle; and
- Northern leopard frog.

OPG assessed direct effects on terrestrial animals, such as habitat removal and vehicle strikes, as well as indirect effects, including changes in air quality, noise, water quality, and water flow. OPG proposed mitigation measures to ensure that the effects would not be significant.

OPG predicted that the removal of vegetation on the project site would not cause a measurable change in the utilization of habitat for northern short-tailed shrew, muskrat or white-tailed deer. The habitat for shrews and muskrats would not be disturbed during site preparation. Although 8.9 hectares of mixed forest would be removed, this amount was deemed to be too small to cause measureable changes in sheltering or foraging of white-tailed deer.

OPG stated that it would not remove vegetation communities that are important for supporting the midland painted turtle and northern leopard frog, including marsh, open water, and grassy fields, during site preparation. As such, there would be no direct effects from habitat removal on these species.

OPG predicted that the project would result in increased vehicle strikes; however, the incremental increase in shrew, muskrat, white-tailed deer and bird mortality would be negligible relative to the existing traffic volume on the Bruce nuclear site. OPG did not predict collisions with buildings due to confusion with lighting or glass reflection to cause measurable, incremental effects on bird populations relative to mortality associated with the current Bruce nuclear site. Increased vehicle strikes were predicted to have a negligible incremental effect on reptile and amphibian populations because the planned access route to the project site would not cross the two wetland areas assumed to be primary reptile and amphibian habitat.

OPG stated that key vegetation communities providing food, shelter or breeding habitat for mallard, yellow warbler and bald eagle would not be removed during site preparation. OPG noted that the removal of 77% of the mixed forest within the Project Area and 11.4% of the total mixed forest area within the Site Study Area could result in the loss of individuals or breeding pairs of red-eyed vireo and wild turkey. However, OPG assumed that it was more likely that individuals would be displaced to other suitable habitat located within the Site Study Area. OPG determined that the loss of mixed wood forest within the Site Study Area was not likely to result in local extinction or measurable reductions in the populations of these two bird species.

OPG predicted that there was no potential for groundwater-related effects on wetland plants or animals. OPG explained that the wetland communities within the Project Area appeared to be maintained by seasonal and surface water flow and that there would be no changes in the groundwater flow regimes. As noted earlier in this chapter, the Panel has recommended that this be confirmed through monitoring of wetland water levels and groundwater in the immediate vicinity of the wetlands.

OPG stated that there would be no effects on midland painted turtle and northern leopard frog from changes in surface water quality because the surface water quality assessment had determined that there would be no adverse effects on water quality. As discussed above for plants, OPG did not consider the potential for increased salinity in the drainage system, which would be habitat for some species. The concentrations of dissolved salts such as chloride may exceed the tolerance limit for certain aquatic species, resulting in a change in community composition, and potentially, a change in the availability of preferred food species for reptiles and amphibians. The low-consequence effects predicted for aquatic species in the South Railway Ditch, including food species for turtles and frogs, were assumed by OPG to be too low to produce measurable changes in frog or turtle populations.

OPG predicted that there would be no effects on mammals or birds from changes in air quality because peak concentrations during site preparation, construction and operation would be below the lowest observed effect levels recorded in toxicology studies. The majority of suspended particles would be too large to be inhaled.

OPG acknowledged that noise from site preparation and construction could disturb individuals; however, it was assumed that mammals and birds could habituate and resume current behaviours at the affected locations or relocate to adjacent habitats. OPG further argued that the number of individuals subjected to project-related increases in noise levels would be limited compared to populations elsewhere in the Site Study Area, and that the wildlife would already be exposed to industrial noise disturbances on the Bruce nuclear site.

Environment Canada stated that noise would have the greatest potential effects on birds and that these effects would be concentrated around the area where the repository shafts would be developed. Environment Canada identified individuals of two priority bird species within the area of the repository shafts: four eastern meadowlarks and two eastern wood pewees. Environment Canada noted that these numbers represented 0.0001% of the provincial population of these species, and stated that noise effects would not be significant at a population level.

OPG predicted that changes to existing light levels during the site preparation and construction, and operations phases would not adversely affect wildlife. Increases in ambient light would occur in industrial barren areas with very limited habitat or were predicted to be below published thresholds for adverse effects on wildlife. While nighttime roosting could be interrupted, OPG reasoned that the wildlife at the Bruce nuclear site were already habituated to the increased light within the Project Area and the Site Study Area, and that other darker nighttime roosting areas would not be affected by the project.

OPG determined that changes in water quantity and flow in the drainage ditch system on the project site would not cause an adverse indirect effect on wildlife. OPG stated that muskrat and northern leopard frog should be able to tolerate the predicted 31% decrease in flow in the North Railway Ditch and the predicted increase in flow to the drainage ditch discharging to MacPherson Bay. The ditch habitats were judged as being unsuitable for mallard and midland painted turtle.

OPG did not assess the potential for adverse effects on mallards, other waterfowl, and shorebirds using the stormwater management pond and drainage system as habitat. Although OPG committed to mitigation to ensure that water quality criteria would be met prior to discharge to MacPherson Bay, this does not necessarily mean that the water quality in the drainage system itself would have no potential for causing adverse effects. The Panel acknowledges that the potential constituents of concern in the drainage system would, for the most part, be unlikely to be toxic to birds at predicted concentrations; however, the Panel expects that OPG will carefully monitor the use of the drainage system as habitat by birds and address any potential hazards in an appropriate manner.

Mitigation Measures for Terrestrial Animals

Notwithstanding the lack of predicted adverse effects on bird populations, OPG committed to avoid vegetation clearing during the breeding bird season (May 1 to July 31) wherever possible, and, where not possible, to conduct a nest survey to ensure there are no active nests in the trees to be felled.

Environment Canada pointed out that project works or activities, such as construction access, site grubbing, vegetation clearing, and construction activities, were potentially destructive or disruptive activities to birds, their nests, or eggs, and stated that they should be avoided at key locations or during key periods, including the breeding periods and periods of high usage such as migration and/or feeding. These locations and periods would vary by region and by species. Environment Canada stated that, while avoidance would be the best approach, appropriate preventive and mitigative measures should be developed and implemented in order to minimize the risk of detrimental effects to migratory birds and to help maintain sustainable populations of migratory birds. Environment Canada suggested that OPG should make provisions so that if nests are found in open areas, these nests can be flagged and marked, and have buffers placed around them so that no work within the buffer areas can occur until the nesting cycle is complete. The Panel concurs with this suggestion.

The Panel expects that OPG will apply its Biodiversity Policy to the maintenance of a healthy, self-sustaining community in the drainage ditch system, including monitoring of key functional and structural features such as plant cover and diversity, invertebrate diversity and abundance, and abundance of indicator species such as frogs, turtles and birds which may nest and feed in these habitats.

Significance of Residual Adverse Effects on Terrestrial Animals

Based on its assessment, OPG did not predict any residual adverse effects on birds, mammals, reptiles or amphibians. Therefore, OPG did not evaluate the significance of effects.

Panel Conclusion Regarding Effects on Terrestrial Animals

The Panel concludes that the project is not likely to cause adverse effects on bird, mammal, reptile or amphibian populations due to either direct or indirect effects of the project; therefore, a determination of significance was not necessary. The Panel agrees with Environment Canada that, as a precaution, mitigation for the prevention of effects on breeding birds is required. The Panel has made a recommendation regarding the protection of migratory birds.

The Panel has determined that other precautionary mitigation measures may be required to address the potential effects of elevated salinity in the drainage ditch system and the stormwater management pond on plants and wildlife. The Panel is of the view that effects of salinity on the re-established plant community in the drainage system may, in turn, affect habitat quantity or quality for amphibians, reptiles, birds, invertebrates and small-bodied fish. Therefore, it may be necessary for OPG to plant species with a higher tolerance for salinity than those species currently present.

Recommendation 8.31: In order to confirm predictions in the environmental assessment regarding effects on aquatic and semi-aquatic species, prior to construction OPG shall submit a follow-up program to the satisfaction of the CNSC. The program shall contain mitigation measures to be taken, should concentrations of total dissolved solids in the storm water management system be observed at levels with the potential to affect sensitive plant or animal species. The plan shall include provisions for the establishment of a self-sustaining plant community that will provide habitat for amphibians, birds, invertebrates and small-bodied fish

Recommendation 8.32: In order to confirm the predictions in the environmental assessment regarding effects to migratory birds and migratory bird habitat, OPG shall develop and implement a follow-up program, prior to site preparation and to the satisfaction of the CNSC. The program shall include management measures to effectively avoid or minimize the risk of detrimental effects to migratory birds, their nests and eggs, if adverse effects are observed. The plan shall include the provision that if nests are found in open areas, these nests be flagged, marked and buffers placed around them so that no work within the buffer areas occurs until the nesting cycle is complete.

8.5.3 Effects on Aquatic Life

OPG evaluated effects on the following aquatic life valued ecosystem components:

- Redbelly dace;
- Variable leaf pondweed;
- Creek chub;
- Lake whitefish;
- Benthic invertebrates;
- Smallmouth bass;
- Brook trout; and
- Spottail shiner.

OPG assessed direct effects on aquatic life, such as habitat disturbance, and indirect effects, such as changes in ground vibration, water quality, and water flow. OPG also proposed mitigation measures to ensure that the effects would not be significant.

OPG identified the aquatic features of the project site (Figure 23) and noted that there would be some direct effects on aquatic habitat. Removal of some riparian vegetation and alteration of the banks of the South Railway Ditch, considered to be habitat by the Saugeen Valley Conservation Authority, would occur during construction of the rail crossing. Drainage ditch maintenance activities would occur during the operations phase, resulting in disturbance of habitat. OPG identified adverse effects for the valued ecosystem component species redbelly dace, creek chub, benthic invertebrates, variable leaf pondweed and burrowing crayfish. OPG did not identify any direct effects on habitat or aquatic life in Stream C or MacPherson Bay of Lake Huron.

OPG noted that while it is not subject to a Saugeen Valley Conservation Authority permit under Ontario regulation *O. Reg. 169/06 (Development, Interference with Wetlands, and Alterations to Shorelines and Watercourses Regulation)* for construction of the crossing of the South Railway Ditch, it has been its past practice to proceed through the Saugeen Valley Conservation Authority permitting process. The Saugeen Valley Conservation Authority suggested that OPG should proceed with this process for any works at or near the South Railway Ditch. The Panel supports this suggestion.

OPG indicated that the construction of the crossing over the abandoned rail bed and other surface infrastructure would result in the loss of a small portion of burrowing crayfish habitat, about 100 m^2, along the North Railway Ditch, as well as other ditches and the abandoned railway spur in the western portion of the Project Area. OPG estimated that this loss would represent about 0.01% of the burrowing crayfish habitat within the Project Area. OPG did not predict any direct crayfish mortality caused by construction because crayfish were not found to be using the habitat within the project site during OPG's baseline investigations in 2006 and 2009. Decommissioning activities were predicted to cause a measurable change to burrowing crayfish habitat; however, OPG did not provide any details regarding the relative size of the change. The Panel assumes that this measurable change would be further quantified and evaluated during licensing for the decommissioning phase, should the project be approved.

Figure 23:Aquatic Features of the Site (reproduced from DGR EIS Figure 6.5.3-1)

OPG considered the effects of blasting activities during construction on aquatic life in the South Railway Ditch and Stream C. OPG determined that the predicted maximum ground vibration reaching the South Railway Ditch during shaft sinking would be less than the Fisheries and Oceans Canada *Guidelines for the use of explosives in or near Canadian fisheries waters* for the protection of spawning beds during egg incubation. Stream C would be located 1.2 kilometres or more from the ventilation and main shafts, which would be main areas for blasting; as such, OPG determined that the setback distance between blasting and the aquatic habitat within Stream C would be far enough to protect aquatic life. Therefore, no measurable change to aquatic habitat was predicted due to blasting. Fisheries and Oceans Canada agreed with this assessment.

OPG did not predict any changes in surface water quality in the South Railway Ditch or Stream C during site preparation, construction, operations or decommissioning because site drainage would be diverted to the stormwater management system. Atmospheric deposition of particles and nitrates via rain or snowfall or dust deposition was not judged to be sufficient to produce measurable changes in water quality in Stream C.

The predicted 31% decrease in water quantity and flow in the North Railway Ditch due to the construction of the stormwater management system was considered to be an adverse effect by OPG. OPG found that the North Railway Ditch did not support a fish population and was dry most of the time during baseline investigations; however a residual adverse effect of the decrease flow on burrowing crayfish was predicted due to aquatic habitat loss. The predicted change in water quantity and flow in Stream C, less than one percent, due to a small decrease in drainage area was not considered by OPG to be an adverse effect, and was not carried forward for assessment of effects on aquatic life.

OPG did not predict an indirect change in the quality of habitat in MacPherson Bay due to increased discharge from the Interconnecting Road ditch. This prediction was based upon the nature of the habitat in MacPherson Bay, which is exposed to wind and wave action with rapid mixing of inflows, as well as the extent of the habitat, approximately 40 hectares. OPG's reasoning was that because of rapid mixing and the size of the habitat relative to the discharge from the ditch, measurable alterations in habitat were unlikely. Therefore, the valued ecosystem components that use MacPherson Bay, including lake whitefish, spottail shiner, smallmouth bass and benthic invertebrates, would not be affected by the increased flow in the ditch.

OPG did not predict indirect effects on aquatic life in MacPherson Bay from changes in surface water quality. All surface water drainage within the Project Area would drain to MacPherson Bay via discharge from the stormwater management pond to the Interconnecting Road drainage ditch, and be tested and compared with discharge criteria designed to prevent adverse effects on water quality. OPG did not anticipate any indirect measurable changes to valued ecosystem components in MacPherson Bay, provided that these discharge criteria are met. The Panel notes that, in light of the fact that the stormwater management pond and drainage system may constitute habitat for wildlife and aquatic biota, additional follow-up monitoring will be required to confirm OPG's predictions regarding water quality and sediment quality of the pond and drainage system.

OPG stated that there would be no direct or indirect effects on aquatic life in Baie du Doré as it had not proposed any project works or activities in or adjacent to this area. All surface water discharge from the Project Area would be diverted via the stormwater management system to the stormwater management pond, which would discharge to MacPherson Bay.

Mitigation Measures for Aquatic Life

OPG committed to specific mitigation measures to minimize effects on the aquatic valued ecosystem components in the South Railway Ditch, in accordance with best practices and the requirements of Fisheries and Oceans Canada. These measures included:

- an embedded culvert below the level of the ditch for fish passage;
- management of surface runoff; and
- best management practices for erosion and sediment control during and after construction.

OPG also committed to comply with the Fisheries and Oceans Canada Operational Statement *Timing Window of July 1 to September 30* to ensure that critical life history stages such as spawning would be protected by restricting works or undertakings in and around water to certain times of the year. This timing window was also recommended by the Saugeen Valley Conservation Authority.

Fisheries and Oceans Canada stated that authorization under section 35(2) of the *Fisheries Act* for construction of a culvert crossing of the North and South Railway Ditches would not be required provided that OPG fully implements its mitigation commitments. In addition to the above-listed mitigation measures, Fisheries and Oceans Canada indicated that OPG should isolate and dewater the culvert site during construction, and revegetate the banks upon completion of construction. The Panel expects that OPG will follow the Fisheries and Oceans Canada guidance in implementing these measures.

The proposed layout of the DGR surface facilities would avoid most of the identified burrowing crayfish habitat in the Project Area, including the northeast marsh. OPG stated that since the majority of the existing burrowing crayfish habitat would be unchanged by the project, affected individuals may relocate to more favourable conditions. OPG suggested that revegetation of the project site during decommissioning may have a beneficial effect on burrowing crayfish by potentially increasing available habitat; however, no credit was assumed for this change. OPG did not discuss revegetation that might occur during the operations phase, as areas of the project site become available for restoration.

Compliance with water quality discharge criteria at the discharge from the stormwater management pond was a key aspect of OPG’s means to prevent adverse effects on aquatic life in MacPherson Bay.

Recommendation 8.33: In order to avoid significant adverse effects to fish and fish habitat, OPG shall, during site preparation and construction, implement measures to mitigate the effects of culvert installation at the North and South Railway Ditches. Measures shall include: embedding culverts below the bed of the ditch, isolating and dewatering the culvert site during construction, revegetating the banks upon completion of construction, and deploying sediment and erosion control measures during construction. In-water works shall not occur between July 1 and September 30.

Significance of Residual Adverse Effects on Aquatic Life

OPG determined that residual adverse effects on aquatic life would not be significant. OPG predicted residual adverse effects for burrowing crayfish, redbelly dace, creek chub, variable leaf pondweed and benthic invertebrates using the South Railway Ditch habitat during construction, and burrowing crayfish using habitat at the North Railway Ditch and other sites within the Project Area disturbed during site preparation and construction, as well as during decommissioning. OPG stated that these residual adverse effects would involve removal/alteration of only non-critical habitat over a very limited portion of the Project Area. Furthermore, OPG stated that the valued ecosystem components affected were tolerant of a broad range of environmental conditions, considered common in freshwater systems in Ontario, and would not be considered keystone species. CNSC staff concurred with OPG's assessment of significance, taking into account the implementation of mitigation measures.

Panel Conclusion Regarding Effects on Aquatic Life

The Panel concludes that the project is not likely to cause in significant adverse effects on aquatic life, provided that mitigation measures are implemented. The Panel has determined, however, that additional mitigation of water quality will be required to provide adequate assurance that there will be no significant adverse effects on aquatic valued ecosystem components in MacPherson Bay caused by the discharge from the stormwater management pond. Recommendations for additional mitigation related to water quality are presented in this chapter. The Panel discusses the habitat and aquatic life of MacPherson Bay in Chapter 14.

The Panel is satisfied that implementation of OPG's planned mitigation measures during construction activities at the South Railway Ditch will prevent significant adverse effects on aquatic valued ecosystem components in that ditch.

The Panel has determined that the stormwater management system should, itself, be regarded as aquatic habitat. As such, it should be monitored for effects on aquatic life colonizing the system. This should include benthic invertebrates and fish and should consider the risk of food chain transfer of constituents of concern from water and/or sediment in the stormwater management pond to fish or aquatic birds using the pond. Depending upon the results of such monitoring, measures may be required to protect migratory bird species.

CNSC staff recommended the collection of additional baseline sediment quality data in the Interconnecting Road drainage ditch and MacPherson Bay as part of the environmental assessment follow-up program. This recommendation complements the Panel's recommendation of consideration of the drainage ditch as habitat. It also provides additional required baseline information for use in confirming the prediction of no significant adverse effects in MacPherson Bay.

Recommendation 8.34: In order to confirm the predictions in the environmental assessment regarding effects to fish and fish habitat, OPG shall develop and implement, prior to site preparation and to the satisfaction of the CNSC, a follow-up program for aquatic life in the stormwater management system and the ditch at Interconnecting Road. The program shall include the collection of supporting water quality and sediment quality data to be used to conduct a risk assessment for fish, fish habitat and aquatic birds.

8.5.4 Effects on Significant Species

Within the Local Study Area, OPG found 19 terrestrial plant species provincially ranked as vulnerable, imperilled or critically imperilled. Many of these species occurred within Inverhuron Provincial Park, MacGregor Point Provincial Park, the Baie du Doré Provincially Significant Wetland, and the Scott Point Area of Natural and Scientific Interest. OPG also identified 23 wildlife species (17 bird species and six amphibian or reptile species) considered endangered, threatened or of special concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and/or the Committee on the Status of Species at Risk in Ontario (COSSARO), and/or provincially ranked as vulnerable, imperilled or critically imperilled. OPG noted that MacGregor Point Provincial Park, the Baie Du Doré Provincially Significant Wetland, and the Scott Point Area of Natural and Scientific Interest were locations where many of the listed species had been identified.

In the Regional Study Area, OPG identified 56 terrestrial plant species, as well as 41 bird, four mammal, 10 amphibian and reptile, and 12 insect species considered to be either endangered, threatened or of special concern by COSEWIC and/or COSSARO, and/or provincially ranked as vulnerable, imperilled or critically imperilled.

Culturally, commercially or recreationally significant plant species found to occur in the Local and Regional Study Areas included:

- sugar maple;
- medicinal plants, e.g., leatherleaf and Labrador tea;
- edible plants, e.g., mushrooms;
- materials plants, e.g., sphagnum mosses;
- orchids; and
- ancient eastern white cedar specimens.

Animal species included big game and upland game bird species, such as wild turkey, furbearers, and migratory birds.

OPG did not assess effects on significant species in the Local and Regional Study Areas because there would be no direct interactions between the project activities, such as site clearing, and significant species outside of the Project Area. Indirect interactions were not assessed because as OPG had determined that there would be no indirect adverse effects on the plant valued ecosystem components in the Project Area, including heal-all, eastern white cedar, and cattail, effects farther afield on any species would not be expected to occur.

CNSC staff noted that OPG should have included the Canada warbler and the eastern meadowlark as significant species that occur within the Project Area. OPG responded to an information request regarding these two species and explained that while they had been identified in a number of locations within the Site Study Area, most of those locations fell outside of the Project Area. The one location where eastern meadowlark was identified within the Project Area did not provide suitable breeding habitat. OPG explained that the Canada warbler was not noted within the area slated for forest clearing within the Project Area. OPG determined that there would be no residual adverse effect on eastern meadowlark or Canada warbler, and CNSC staff judged this response to be sufficient.

Environment Canada identified potential adverse effects of the DGR on snapping turtle, eastern ribbon snake and eastern milksnake, which are species of Special Concern under the *Species at Risk Act*. Environment Canada described the best available information concerning mitigation measures for these species, provided recommendations based on this information, and confirmed that these measures would be effective. The mitigation measures included maintaining water levels in the western ‘finger’ of the northeast marsh (also called Wetland 4) during and after the re-routing of the drainage ditch to ensure that habitat for snapping turtle is not affected; delaying the infilling of “Wetland 3” (as identified in the Environment Canada written submission) until the latter years of the site preparation and construction phase; having a qualified biologist experienced in turtle surveys conduct a minimum of three turtle surveys of “Wetland 3”; relocating turtles located in “Wetland 3” to the northeast marsh; taking measures not to disrupt hibernation and gestation sites of eastern ribbonsnake and eastern milksnake; and ensuring that mitigation, such as appropriately designed, located and installed exclusion fencing, is in place to prevent turtles and snakes from entering the DGR site.

Environment Canada suggested that the infilling of ”Wetland 3” should be delayed until later in the site preparation and construction phase because it provides marginal habitat for snapping turtle and could serve as a refuge for turtles while OPG is working elsewhere on the site. The Panel has adopted all of the Environment Canada mitigation recommendations for these listed species.

The Ontario Ministry of Natural Resources stated that it did not anticipate an *Endangered Species Act* authorization being required for the project. The Ontario Ministry of Natural Resources noted that the project site did not include high quality habitat but that there may be high quality habitat in the surrounding area. The Ontario Ministry of Natural Resources stated that while it did not anticipate the project altering, damaging or destroying endangered species habitat, the proposed mitigation measures in place to protect habitat would be appropriate.

In response to an information request, OPG indicated that, using the Fisheries and Oceans Canada aquatic Species at Risk mapping, there was potential for habitat for three significant aquatic species within the Site Study Area: American eel, which is of special concern federally and endangered provincially; silver shiner, which is considered threatened federally and of special concern provincially; and northern brook lamprey, which is of special concern both federally and provincially. OPG pointed out that American eel breed in the Atlantic Ocean and are unlikely to have Lake Huron as part of their range, given the formidable obstacle posed by Niagara Falls. OPG acknowledged that suitable habitat for silver shiner and northern brook lamprey would exist within Stream C in the Site Study Area. OPG stated that since the only effect on Stream C would be a 0.8% decrease in flow, there would be no effect on these two species.

Panel Conclusion Regarding Effects on Significant Species

The Panel concludes that the project is not likely to cause significant adverse effects to significant species within the Project Area, provided that all recommended mitigation measures are implemented. The Panel expects that OPG will identify opportunities to protect and enhance habitat for sensitive species as part of its Biodiversity Policy. The Panel makes the following recommendations, including those from Environment Canada, to ensure the protection of these species.

Recommendation 8.35: In order to confirm the prediction in the environmental assessment that there would be no loss of significant plant species, OPG shall confirm the absence of significant plant species in the Project Area prior to site preparation. If significant species are located, OPG shall, in conjunction with appropriate federal and provincial agencies and the CNSC, take action to avoid or mitigate the potential loss.

Recommendation 8.36: In order to avoid significant adverse effects to snapping turtle habitat, OPG shall maintain appropriate water levels in the northeast marsh, during and after the re-routing of the drainage ditch, to the satisfaction of CNSC and in consultation with Environment Canada.

Recommendation 8.37: In order to avoid significant adverse effects to turtle species at risk, OPG should delay the infilling of “Wetland 3” until the latter years of the site preparation and construction phase.

Recommendation 8.38: In order to confirm the predictions in the environmental assessment regarding snapping turtles, OPG shall conduct turtle surveys of Wetland 3 throughout the years prior to its infilling. A qualified biologist experienced in turtle surveys should conduct a minimum of three surveys per year on sunny days, beginning as soon as the ice cover has melted. The third survey should occur no later than mid-June. OPG shall relocate turtles to the northeast marsh.

Recommendation 8.39: In order to avoid significant adverse effects on snapping turtles, OPG shall, to the satisfaction of CNSC, implement a management plan to relocate snapping turtles from “Wetland 3” to the northeast marsh prior to the infilling of “Wetland 3”. The plan should be reviewed by Environment Canada and the Ontario Ministry of Natural Resources.

Recommendation 8.40: In order to avoid significant adverse effects on eastern ribbonsnake, eastern milksnake and their habitats, OPG shall develop and implement a management plan, to the satisfaction of the CNSC, to ensure site preparation and construction activities to not disrupt individuals of these species, snake eggs, gestation sites, or hibernacula. OPG should seek input and advice from Environment Canada and the Ontario Ministry of Natural Resources in developing the plan.

Recommendation 8.41: In order to avoid significant adverse effects on turtles and snakes, OPG shall, to the satisfaction of CNSC, ensure that mitigation measures are in place to prevent turtles and snakes from entering the DGR Site, and “Wetland 3” in particular, prior to and during the site preparation and construction phase. Measures should include the installation of exclusion fencing along the southern and eastern edges of the DGR site. Environment Canada should be consulted regarding the specifications of the fence.

8.5.5 Radiation Effects on Terrestrial and Aquatic Species

OPG compiled data for existing radiation and radioactivity in the environment and then modelled baseline doses to terrestrial and aquatic valued ecosystem components. Naturally occurring radionuclides (notably potassium-40) and radionuclides in emissions from the Bruce nuclear site contributed to existing doses. Tritium and carbon-14 were the main radionuclides that could be clearly attributed to the waste stored at the WWMF. Other radionuclides indicative of reactor operations and associated waste were typically below detection limits.

OPG predicted that the emissions from the project would be less than or similar to the current emissions from the WWMF. Emissions of the WWMF have been measured over many years at the Bruce nuclear site through the Bruce Power Radiological Environmental Monitoring Program, supplemented by several other studies. OPG modelled doses to terrestrial and aquatic valued ecosystem components assuming a conservative bounding case where emissions would be twice existing values since more waste would have been generated by the time the project was built.

OPG used dose criteria to assess the potential effect of the DGR on terrestrial and aquatic valued ecosystem components. These criteria represented chronic dose rates that did not produce any adverse effects upon populations of plants or animals. Daily doses rather than annual doses were used to prevent a scenario where the annual dose is received within a few days.

OPG explained that the following features of the project design, taken into account in the assessment of radiation doses to non-human biota, would minimize the radiological effects on terrestrial and aquatic valued ecosystem components:

- the repository would be 680 m below ground surface;
- shielding provided by waste containers and repository structures such as closure walls for the emplacement rooms;
- emission controls;
- zoning and monitoring to prevent spread of contamination in or around the DGR;

- sump and stormwater collection and management; and
- fencing and security.

OPG determined that the existing doses to terrestrial and aquatic valued ecosystem components were all less than dose criteria established to ensure the survival of populations. The highest dose received by a valued ecosystem component was for white-tailed deer; this dose was 0.4% of the criterion for protection of white-tailed deer populations. OPG predicted that doses to terrestrial and aquatic valued ecosystem components during the operations phase would also be less than criteria. The highest dose received by a valued ecosystem component, again for white-tailed deer, was 0.8% of the dose criterion.

CNSC staff stated that there would not be any significant adverse effects on terrestrial and aquatic valued ecosystem components from radiation exposure. CNSC staff considered OPG's approach for assessing effects of radioactivity to non-human biota to be acceptable and suitably conservative. CNSC staff noted that OPG had given due consideration to past federal guidance and common international practices from the International Commission on Radiological Protection, the United Nations Scientific Committee on the Effects of Atomic Energy and the International Atomic Energy Agency.

Panel Conclusion Regarding Radiation Effects on Terrestrial and Aquatic Species

The Panel concludes that the project is not likely to cause significant adverse effects on populations of terrestrial or aquatic valued ecosystem components due to radiation doses. The Panel notes that there is already an extensive radiation monitoring program conducted by Bruce Power (the Radiological Environmental Monitoring Program); however, the Panel expects that OPG will supplement the data collected through the Radiological Environmental Monitoring Program in order that the predicted DGR-specific contributions to radiation levels can be confirmed. The Panel expects that the design of the follow-up monitoring program would focus on the Project Area and Site Study Area, and may extend into the Local Study Area.

Recommendation 8.42: In order to confirm the predictions in the environmental assessment regarding radiation effects on terrestrial and aquatic species, OPG shall conduct a follow-up program, to the satisfaction of the CNSC, of radiation levels in air, water, soil, sediment, terrestrial and aquatic biota in the Project Area and Local Study Area.

8.5.6 Panel Conclusion Regarding Effects on Plants, Animals and Their Habitat

The Panel concludes that the project is not likely to result in significant adverse residual effects to plants, animals or their habitat, taking into consideration the implementation of mitigation measures.

8.6 EFFECTS OF THE ENVIRONMENT ON THE PROJECT

OPG evaluated the potential environmental effects associated with interactions between natural phenomena and the project. These included climate change, seismic events, coastal flooding, surface flooding and severe weather.

8.6.1 Climate Change

OPG considered climate change over the life of the project, over all project phases. OPG used past and future temperature and precipitation trends to describe how climate in the region was changing and how climate was projected to change during the life of the project. OPG determined that climate change would not influence the project. Some participants expressed concerns regarding climate change, noting that storm events may get more frequent and more severe.

In its effects assessment on surface water quantity and quality, OPG gave consideration to whether these valued ecosystem components would be sensitive to changes in climate conditions. OPG recognized that if climate change were to affect stream flow, it could indirectly affect water quality. In its hydrology assessment OPG determined that climate change would not significantly alter surface water quantity and flow. Consequently, no changes to the surface water quality assessment were predicted. Since neither surface water quantity nor quality would be affected by climate change, no modifications to the DGR site water management were deemed necessary for consideration.

OPG also assessed how the project might affect climate change. OPG determined that greenhouse gas emissions from the project would not have a measurable effect on climate, and that the effect of the project on climate would be insignificant.

CNSC staff found OPG’s assessment of the effects of climate change on the project to be acceptable. Environment Canada disagreed with OPG's statement that climate change would not affect effluent flows from the stormwater management pond. It further stated, however, that provided that the stormwater management pond was designed to specifications suggested by Environment Canada, with an adequately designed treatment system, the system should be capable of accommodating climate change effects. Environment Canada stated that monitoring compliance would be achievable as long as the systems were capable of managing high flow storm events.

The Panel concludes that climate change is not likely to cause significant adverse effects on the project, taking into consideration the implementation of mitigation measures. However, the Panel is of the view that climate change should be considered and included in adaptive water management on the DGR site. A recommendation pertaining to this conclusion was presented in the section on surface and near-surface groundwater.

The Panel considers climate change to be an important challenge in the planning of surface facilities involving the management of surface water and near-surface groundwater at the DGR site. The frequency, intensity, and duration of storms have been predicted to increase as a result of climate change, which would affect the effluent flow rates into the stormwater management pond. Increases in surface runoff and leachate production can therefore be anticipated. The timelines of such changes may be shorter and the magnitudes larger than currently envisioned. As localized climate change data becomes available, adaptive management strategies will have to be in place to respond to rapid changes.

Over the operations phase of the project, it may become evident that climate change has affected the distribution and abundance of plant and animal species on the project site. The Panel expects that OPG's Environmental Management System will include consideration of and adaptation to such changes. Measures could include modifications to requirements for exclusion fencing or relocation of species.

The Panel expects that OPG would implement measures that reduce greenhouse gas emissions, in accordance with its corporate sustainability policy. The Panel agrees with OPG that the project would not significantly contribute to greenhouse gas emissions; however, the Panel understands that OPG would still be committed to minimizing its emissions.

Recommendation 8.43: In order to avoid significant adverse effects on the project due to climate change, OPG shall develop and regularly update a climate change strategy, to the satisfaction of the CNSC. The strategy should incorporate up-to-date climate change models and adaptive management, and be included in the environmental management system for the DGR.

8.6.2 Seismic Events

OPG stated that it was not likely that seismic activity would have an adverse effect on the project. OPG explained that historical records indicated that the Bruce region experiences low rates of seismic activity, and that no seismic events had exceeded magnitude 5 in the past 180 years. OPG conducted a probabilistic seismic hazard assessment for the short-term (100 years) and the long-term (1 million years). The analysis of seismic ground shaking on the emplacement rooms of the project showed that host rock would not be damaged but fractured rock could be dislodged. The analysis also showed that seismic loading had no effect on the extent of failure for shaft seals, nor did it significantly increase the predicted excavation damage zone around the shaft. OPG stated that all above-ground structures and underground facilities would be constructed in accordance with the seismic requirements of the latest edition of the National Building Code at the time of construction. OPG also indicated that an analysis of the stability of the emplacement rooms and other underground openings was being conducted for changes in rock stresses and rock support loading that could occur during a seismic event.

CNSC staff accepted OPG's assessment that it was not likely that seismic activity would have an adverse effect on the project. CNSC staff noted that it would review the detailed design of the above-ground and underground structures, including the seismic analysis, should the project be approved and proceed to licensing.

The Panel concludes that seismic activity is not likely to have an adverse effect on the project. The Panel understands that, should the project be approved, the detailed design would be based upon seismic analysis and adherence to the most recent National Building Code. The Panel discusses seismic events in the context of the project design in Chapter 6 and in the context of the postclosure safety case in Chapter 13.

8.6.3 Coastal Flooding

OPG's assessment of potential coastal flooding considered maximum lake water levels, storm surges, seiches, wind waves, and wave uprushes that could affect the project operational area inland of the Lake Huron shoreline. Some participants expressed concerns regarding the potential for coastal flooding and how such events could affect the project.

OPG predicted the 500-year maximum Lake Huron water level to be 178.6 m. OPG stated that since the planned elevation of the operational areas of the project site was expected to be about 186m above sea level, the risk of coastal flooding was low.

OPG described its assessment of other coastal flooding scenarios. OPG stated that the maximum predicted storm surge of 1.3 m would not affect the project site. Maximum wave flooding would not affect the operational area of the project; however, there would be some "wetting" of the northern tip of the Project Area. The likelihood that the Project Area would experience any wave run-ups was extremely low given that the location of the project is about one kilometre from the shoreline. OPG noted that no probable or definite tsunamis have been recorded for Lake Huron.

The Panel concludes that coastal flooding is not likely to cause significant adverse effects on the project. The Panel concurs that, given the elevation and distance from the shore, such events would be unlikely to affect the project site.

8.6.4 Surface Flooding

OPG's assessment for potential surface flooding considered the maximum flood hazards from river flow as well as from direct rainfall. OPG stated that the flood potential resulting from a probable maximum precipitation event would not impact the project site given currently planned elevations of the project operational areas and existing topography. OPG identified flooding associated with the probable maximum precipitation event as an important aspect of the design of the shaft collars. OPG noted that, as part of finalizing the site grading plan, it would be updating the flood hazard assessment to provide assurance that the maximum flood level will be below the shaft collar height considering the latest estimates of probable maximum precipitation, including consideration of climate change.

The Panel concludes that surface flooding is not likely to have an adverse effect on the project, provided that OPG implements its plans for adjusting site grading and the shaft collar according to updated probable maximum precipitation and probable maximum flood analyses. The subject of probable maximum precipitation in relation to the project design was discussed in Chapter 6.

8.6.5 Severe Weather

OPG determined that severe weather would not be likely to cause residual adverse effects given the in-design mitigation features of above-ground structures, and the fact that most of the project would be located underground. OPG's assessment of severe weather included effects from thunderstorms, lightning, hail storms, tornadoes and ice storms. In-design mitigation measures for severe weather included:

- designed to the National Building Code (most recent version if the project is approved);
- shaft collar designed to be above floods caused by the probable maximum precipitation event;
- tallest project structure would have lightning protection;
- 100-year design life for headframes and surface structures; and
- emergency back-up power systems.

Some participants expressed concerns that severe weather events could potentially affect the project. Particular concerns were expressed regarding flooding and tornadoes.

CNSC staff found that OPG's assessment of the potential effects on coastal and surface flooding and severe weather was acceptable. CNSC staff determined that OPG had not considered changes in the shoreline of Lake Huron. In response, OPG summarized factors that would influence the evolution of the shoreline and determined that the conservatism of its safety analysis had addressed the uncertainties related to coastline migration. CNSC staff found this response to be acceptable.

The Panel concludes that severe weather is not likely to have adverse effects on the project, provided that OPG implements its plans for adjusting site grading and the shaft collar according to updated probable maximum precipitation and probable maximum flood analyses, and constructs its surface facilities in accordance with the most recent National Building Code.

8.6.6 Panel Conclusion Regarding Effects of the Environment on the DGR

The Panel concludes that environmental effects associated with interactions between the project and natural phenomena, including climate change, seismic events, coastal flooding, surface flooding and severe weather, are not likely to cause significant adverse effects to the project, provided mitigation measures are implemented. The Panel stresses the importance of adaptive management in order that OPG would be capable of responding to climate change.

8.7 PANEL CONCLUSION REGARDING EFFECTS ON THE NATURAL ENVIRONMENT

The Panel concludes that the project is not likely to result in significant adverse effects on the natural environment, taking into consideration the commitments made by OPG, the proposed mitigation measures, and the additional recommendations from the Panel. The Panel is of the view that OPG adequately described the likely residual effects of the project, as well as their significance.

The Panel stresses the important role that the stormwater management system will play in ensuring that the discharge to MacPherson Bay meets all water quality criteria such that there are no significant effects on aquatic biota or their habitat. The Panel agrees with Environment Canada that the effectiveness of the stormwater management system must be assured and has made several essential recommendations to this effect. In particular, the capacity of the stormwater management system to adequately manage water quantity and quality during severe storm events must be re-visited in light of the predicted effects of climate change on the frequency and severity of such events. Furthermore, the treatment system plan required to meet all water quality discharge criteria must be in place prior to construction. This plan must be based upon an updated understanding of the risks from all constituents of concern in the discharge, including nitrogen compounds and total dissolved solids, particularly chloride.

The Panel also emphasizes the importance of a robust, timely and effective adaptive management plan. The adaptive management plan must include measures to respond to climate change, as well as unanticipated results from follow-up monitoring programs. The plan must also be capable of triggering timely adjustments in mitigation measures required to prevent effects on significant species.

The Panel notes that it will be essential for OPG, prior to shaft sinking, to verify the predictions in the environmental assessment regarding the movement of the groundwater tritium plume towards the shafts. OPG should have a contingency plan in place should the updated modelling of the plume indicate that it might reach the shafts.

CHAPTER 9 HUMAN HEALTH AND SAFETY

This chapter presents the Panel's evaluation and conclusions regarding whether there will be significant adverse effects of the project on the health and safety of workers and the public. The Panel's evaluation considered OPG's assessment methodology, commitments to mitigation of adverse effects, and follow-up monitoring. The Panel also considered specific issues raised by participants with respect to public health. This chapter is divided into two main sections: the first section deals with workers and the second section deals with the other human health valued ecosystem components, local residents, seasonal users and members of Aboriginal communities.

9.1 WORKER HEALTH AND SAFETY

During the preclosure interval of up to 100 years, OPG's proposed DGR would operate as a nuclear facility and be functionally similar to an operating underground mine. It is imperative that such a facility be stringently managed and that safety be maintained during all phases of the project. This section covers worker health and safety, which includes occupational health and safety and radiation safety. The Panel notes that conventional health and safety, radiation protection, emergency management, and fire protection are Safety and Control Areas that would be dealt with in more detail during licensing phases should the project proceed.

9.1.1 Occupational Health and Safety

Occupational health and safety refers to workplace health and safety related to conventional hazards. This section includes a description of regulatory oversight and OPG management systems, and an assessment of conventional hazards and mitigation, as well as emergency response.

Regulatory Oversight and Management Systems

OPG stated that conventional activities at the proposed DGR would be regulated under the *Ontario Health and Safety Act* for the handling and use of non-radiological materials, with strong focus on the operation and maintenance of mobile equipment. The handling of radiologic material by nuclear workers at the DGR site would also be regulated under the *Ontario Health and Safety Act*.

CNSC staff and the Ontario Ministry of Labour are the primary regulators in matters relating to occupational health and safety in uranium mines throughout Canada, and at all mines in Ontario, respectively. The Ontario Ministry of Northern Development and Mines, which administers the *Ontario Mining Act*, did not consider the proposed DGR to be a commercial mining project under that Act. OPG did, however, consider the project to be a mining venture and stated that worker activities at the proposed site would be administered by the Ontario Ministry of Labour under the *Mines and Mining Plants Regulations*, RRO 1990, O. Reg. 854. The Ontario Ministry of Labour confirmed that it would have responsibility under provincial jurisdiction for inspection of DGR operations over its entire life cycle from site preparation through decommissioning phases.

OPG stated that it would use various internal management and safety programs to manage worker health and safety, including:

- Environment, Health and Safety Management Program for nuclear facilities (W-PROG-ES-0001), 2011;
- Health and Safety Policy (OPG-POL-0001);
- Nuclear Safety Policy (N-POL-0001); and
- British Standard's Institution Occupational Health and Safety Assessment Series 18001, Management System Specification

OPG explained that it would implement health and safety management procedures specific to the project during each phase of the project. During site preparation and construction, OPG's Health and Safety Management Plan would govern the occupational health and safety of workers and contractors. OPG stated that its management plan would include measures to create and maintain a strong safety culture among workers and management, in which safety incidents could be identified and either controlled or avoided. This plan would identify how work activities should be conducted to mitigate potential adverse effects on the health and safety of employees and contractors. OPG asserted that it and its contractors would meet and exceed all legislative requirements for health and safety.

OPG stated that its objective for the conventional safety of its workers was to ensure that they can participate safely in a healthy and injury-free workplace by managing and mitigating risks associated with the activities, products and services of OPG operations. OPG planned to reduce risk through regulatory compliance, site risk assessment, work process design, worker training, and the use of effective operational controls and mitigation measures. Effective control and mitigation measures would include the selection and use of appropriate worker personal protective equipment. OPG highlighted two safety management systems to be used to govern worker personal protective equipment use for above-ground work activity, one for conventional operations and one for radiological operations. OPG noted that its requirements for underground worker personal protective equipment were compliant with *Mines and Mining Plants Regulations* (O. Reg. 854).

OPG stated that it would manage all activities during site preparation and construction according to a well-defined internal organization and management structure, designated as the Project Quality Plan. OPG noted that this plan was compliant with Canadian and international quality management standards (CAN/CSA N286-05 and ISO 9001:2008), and included health and safety as one of its major management components. Contractors would manage performance expectations for occupational health and safety for all site work according to the Project Quality Plan.

CNSC staff stated that it would require that OPG observe all provincial legislative requirements of the *Occupational Health and Safety Act* and its associated mining regulations. Through the application of standard mining and other management practices, OPG would be able to adequately manage conventional occupational hazards during the preclosure operating phases of the DGR. CNSC staff further stated that OPG had demonstrated that it would make adequate provision for the protection of workers while carrying out site preparation and construction activities.

Assessment of Conventional Hazards

OPG assessed conventional hazards associated with the proposed DGR in its Preliminary Conventional Safety Assessment. OPG summarized assessments of site activities and hazards associated with each activity during site preparation, construction and operations stages of the project site. OPG noted that the hazards and corresponding consequences during the decommissioning phase were considered to be similar to those identified for site preparation and construction.

For site preparation, OPG identified six principal occupational aspects and 18 associated job activities, such as site clearing and vegetation burning, which could create hazards to worker health and safety. In its conventional hazard assessment for these activities, it identified various hazardous conditions, potential effects to workers arising from exposure to these conditions, and feasible mitigation measures to minimize hazards. OPG identified 17 hazardous conditions, such as traffic exposure, 36 potential consequences of exposure to these conditions, including collisions, injury or death, and 74 hazard mitigation measures, such as implementation of vehicle speed control limits.

For construction, OPG identified 16 principal occupational aspects and 119 associated job activities, such as shaft sinking and blasted rock removal. OPG identified 17 hazardous conditions, such as rock removal from the shaft bottom, 36 potential worker consequences of exposure to these conditions, including falls from scaffolds, injury or death, and 74 hazard mitigation measures, including mandatory use of personal protective equipment and safety harnesses.

OPG stated that, during the preclosure construction and operations phases, the principal occupational hazards for underground workers would be from transport operations and falls of ground, which were considered to be geotechnical initiating events. OPG noted that occupational risk factors for injuries and deaths are quantifiable and statistically documented for the mining industry, and were therefore applicable to the construction and operations phases of the DGR.

For operations, OPG identified three principal occupational aspects and 17 associated job activities, such as waste package emplacement and forklift operation. For operations, OPG identified 20 hazardous conditions, such as the presence of loose rock, 40 potential worker consequences of exposure to these conditions, including falls causing injury or death, and 100 mitigation measures, including the installation of ground supports.

Numerous activities required for the completion of each phase would often occur simultaneously. Accordingly, OPG committed to develop a Health and Safety Management Plan to provide guidance to construction, management and supervisory personnel in matters such as planning, task coordination, activity monitoring, and emergency response. OPG’s safety management would incorporate practices such as the development of risk-based safety plans, hazard recognition, and extensive and thorough training of both workers and supervisors.

In summary, OPG stated that the highest conventional risk scenarios would involve transport operations, rockbursts (stress-induced violent rock failure events) and rockfalls. OPG submitted that the initiating events for these hazards, such as rockfalls within emplacement rooms, would not be likely to occur when mitigation measures are appropriately applied. Mitigation measures planned by OPG are described in Chapter 6 of this report. CNSC staff stated that underground worker injury rates during the OPG operations phase would be anticipated to be similar to those experienced in conventional underground mining activities.

Mitigation and Monitoring Related to the Primary Conventional Risk Scenarios

OPG provided descriptions of ground support measures that would be applied in the proposed DGR. OPG indicated that initiating events, such as rockfalls within emplacement rooms, would be mitigated by measures such as use of proper ground control standards, loose rock scaling and inspection protocols.

OPG stated that there would be potential for degradation of ground supports over time, but that monitoring and use of non-destructive examination of support media could mitigate support degradation and failure. OPG did not identify the support media testing procedures that it would use to verify the support effectiveness of planned reinforcement techniques.

The Panel observes that the DGR construction plan would require that some rooms be left open prior to waste emplacement for longer intervals than others, thereby creating time interval differences over which worker access and room occupancy would be required. Potential time-dependent support deterioration due to environmental exposure or the enlargement of the local Excavation Damage Zone about excavations may generate support capacity loss with time.

The Panel notes that experience at modern mines has shown that rates of worker injury and death are low, not negligible, and are quantifiable. Therefore, failures of support system components and rockfalls as initiating events for worker hazard should be planned for, no matter how unlikely they are considered to be. OPG's planned mitigation measures must reduce the risk of these scenarios to levels that are compliant with or exceed OPG's safety policy and regulatory requirements. The Panel therefore recommends the following:

Recommendation 9.1: OPG shall, before a licence to prepare the site and construct is granted, develop a program to monitor the long-term integrity of supports in the repository, to the satisfaction of the CNSC. The monitoring program should include *in situ* testing.

Rockburst events in underground mines have the potential to result in damage to equipment and injury or death to workers; therefore, the measurement of mining-induced seismic activity associated with rockburst events is fundamental to the prediction and management of risk to worker safety in the underground environment of the DGR.

OPG stated that it installed three borehole seismographs to monitor and observe seismicity within 50 km of the Bruce nuclear site. In its updated Geoscientific Verification Plan, OPG described the implementation of localized, in-repository micro-seismic surveys, which are near-field seismic studies of low energy and small scale seismic events that can occur as a result of human-induced changes to rock stresses, such as by mining. OPG planned to use these seismic surveys for short-term tomographic surveying of pillar integrity at several sites, and longer term study of pillar stress redistribution within three pillar sites. Tomographic surveying is a seismic method for generating a three-dimensional image of the internal structure of a solid object.

Natural Resources Canada recommended that additional repository-wide micro-seismic monitoring procedures be added to the Geoscientific Verification Plan in order to assess deformation and stress-related changes in the DGR environment. The micro-seismic monitoring technique, known as a rockburst location network, was identified by Natural Resources Canada as a technique that could be used to determine the location, frequency and size of micro-scale seismic events that are induced by mining activities.

Both OPG and CNSC staff concurred with Natural Resources Canada's assessment that, should the Geoscientific Verification Plan action levels, such as measured increases in rock stress, be exceeded, it would be prudent and useful for OPG to implement a micro-seismic system to characterize activity source conditions. OPG did not consider micro-seismic monitoring of this type to be applicable to the Geoscientific Verification Plan because the planned facility design features, high rock strength and known site stress conditions were predicted to create low likelihood of rockbursting events for which such seismic monitoring techniques are normally applied in mining. CNSC staff similarly stated that micro-seismic monitoring, at the repository scale, would not be a necessary component for the safety case and geotechnical feature analysis.

The Panel points out that rockbursting events do occasionally occur at a magnitude and frequency that may not qualify as a rockburst under regulation. These events may result in worker injury, even in well-designed underground excavation sites. The Panel also notes that the majority of deep, hard rock underground mining operations in Ontario operate micro-seismic monitoring networks to track the occurrence and siting of mine-scale rockburst events. OPG's geomechanical modelling of excavation stress and deformation responses during the construction and operations phases of the project illustrated that zones of overstress, delamination, or rock fracturing would develop adjacent to excavations. These conditions, though not conducive to rockbursting, are known to result in local falls of rock that can pose a risk of injury or death to workers in conventional mining operations that make use of support strategies similar to those proposed by OPG for the project.

The Panel notes that both rockbursts and falls of ground can be registered by micro-seismic monitoring networks when designed at the appropriate scale. The capability to monitor these events would provide OPG with the capacity to respond to potential occupational hazards in real time. The Panel is of the view that the application of micro-seismic monitoring procedures for the identification of potential hazard sites would enhance the capacity to mitigate adverse effects to workers if they are required to work at these sites. The Panel therefore makes the following recommendation:

Recommendation 9.2: In order to reduce the risk of worker injury due to rockburst and/or rockfall events, OPG shall install a near-field micro-seismic monitoring network, to the satisfaction of the CNSC. The monitoring network shall be installed during construction and cover the repository footprint. It should remain operational during the operations phase of the project.

Emergency Response

OPG stated that it would manage the health and safety of workers, members of the public, and the environment through its emergency preparedness and response programs, as stipulated by its Environmental Management System and its Employee Emergency Response Procedure. OPG noted that it manages the operation of the WWMF under these programs and procedures to satisfy regulations for the handling and operation of hazardous materials, both radiologic and non-radiologic, and that it has done so safely for decades. OPG expected that it would maintain similar effective emergency response capabilities for the proposed DGR, and noted that a comprehensive on- and off-site emergency response plan was in place.

OPG stated that, on-site, OPG's emergency preparedness and planning response would be integrated with the resources of Bruce Power, which coordinates site-wide fire protection and emergency response, including its Emergency Response Team, medical aid and fire prevention facilities. Off-site, OPG explained that the municipal fire department, Medical Officer of Health and Kincardine health and safety service providers work co-operatively with Bruce Power. OPG noted that the Ontario Ministry of Labour, through its Mine Rescue branch, would provide emergency response for DGR emergency situations. OPG additionally noted that, in the event of nuclear emergencies at the Bruce Power or DGR facilities, provincial and municipal agencies, including Emergency Management Ontario and the Municipality of Kincardine, would provide off-site response and aid according to their respective Provincial Nuclear Emergency Response Plan and the Municipality of Kincardine Emergency Response Plan.

OPG identified three types of events that could occur at the DGR that would require a planned emergency response: fire; rockfall within the repository; and a radiological contamination release. Malfunctions, accidents, and malevolent acts that would trigger an emergency response are discussed in more detail in Chapter 10.

OPG stated that, in advance of excavation activities, mine rescue capabilities would be established and the Emergency Response Plan updated accordingly. OPG noted that, while the DGR was not considered to be a mine under the *Occupational Health and Safety Act*, trained and qualified mine rescue teams would be provided as required by the *Mines and Mining Plants Regulations* (Reg. 854). As required by the Mine Rescue program, a second team would be required at the site before the first team could go underground and a third team must be on-route. Back-up would be provided by nearby mine rescue teams through mutual assistance agreements.

Regulatory Review of OPG's Conventional Health and Safety Plan

CNSC staff stated that the principal hazards to workers at the project would be those associated with conventional construction and mining activities. CNSC staff noted that CNSC personnel are familiar with occupational risk factors for injuries and deaths, which are statistically documented for the mining industry, due to experience with the uranium mining industry in Saskatchewan. CNSC staff stressed that regulatory enforcement of DGR equipment operation and other safety controls by CNSC and provincial regulators must be rigorous and applicable to underground mining activities.

The Ontario Ministry of Labour stated that, should the project proceed, it would place considerable emphasis on enforcement initiatives dealing with underground ventilation requirements, mobile equipment operation and fire protection procedures. The Ontario Ministry of Labour emphasized that, as for all underground mines in Ontario, a worker cohort that has specialty training in firefighting and mine rescue procedures would have to be employed at the DGR. Mine rescue training would be provided by the Ontario Ministry of Labour through its affiliate organization, Workplace Safety North. Fire safety procedures set by the Ontario Ministry of Labour include requirements for mines to hold annual fire drills for each working shift and to provide dry chemical fire suppression systems on all mobile equipment containing more than 100 litres of flammable oil. Ontario Ministry of Labour regulations also mandate the establishment of refuge stations or barrier doors for worker isolation from harm in case of underground emergency situations, including fire events, in all underground mines.

The Ontario Ministry of Labour noted that it also has the regulatory responsibility for ensuring that all equipment used in mines be kept in safe working condition and tested by competent persons. In underground mines, and at the proposed DGR, this would require that all diesel equipment emissions be tested at routine intervals to assess potential contaminant releases and compliance with ventilation designs.

Views of Participants Regarding Conventional Safety

Participants, including unions and professional organizations representing nuclear energy workers, expressed satisfaction with OPG’s record of performance with respect to conventional worker health and safety. The Canadian Union of Skilled Workers stated that it was familiar with and capable of supporting large projects such as the recent refurbishment of Units 1 and 2 at the Bruce A nuclear generating station, which employed over 2000 construction workers, and was thus larger than the proposed DGR. The Canadian Union of Skilled Workers expressed its commitment to training in specialized trades such as tunnel and mining safety. The Power Workers Union stated that it has a deeply embedded health and safety culture that helps guide members through new or unfamiliar occupational health hazards. It emphasized the open, self-critical safety culture of OPG, and pointed to its contribution to rigorous practices and policies as well as training.

Panel Conclusion Regarding Occupational Health and Safety

The Panel concludes that OPG’s review of activities and the scope of hazards was reasonable, extensive and credible. The principal activities that would be undertaken by workers during each stage of DGR development and operation were clearly defined, and appropriately described. The Panel is satisfied that OPG has committed to appropriate mitigation and control measures for each hazard.

The Panel notes that while OPG has developed an excellent conventional occupational health and safety record for its workers at its nuclear facilities in Ontario, diligence will be required to ensure worker protection during activities for which OPG has less experience, particularly those associated with mining. Mining will present additional conventional risks for workers due to the confined nature of the workplace and unique hazards posed by underground activities.

The Panel strongly agrees with OPG that the highest conventional risk scenarios for underground workers would be from transport operations and falls of ground. Based upon the mining industry injury statistics that were presented by CNSC staff, worker injuries from conventional underground hazards are probable, however, the severity and frequency of injuries can be substantially reduced through rigorous safety management. The Panel has recommended additional micro-seismic monitoring to ensure that the identification and mitigation of hazard associated with rockfall is thoroughly addressed.

The Panel stresses the importance of OPG maintaining its strong safety culture over the life of the project. OPG management systems must continue to incorporate systems and measures that encourage continuous improvement in all aspects of occupational safety to mitigate hazards and ensure worker safety. These systems must be upheld throughout site preparation, construction, operations and decommissioning. The Panel is aware of the stringent conditions, requirements and compliance verification that will be imposed by licence conditions should the project proceed. This will further ensure that OPG maintains a strong safety culture over the life of the project.

While the Panel has confidence that individual agencies have the requisite knowledge and experience to regulate worker health and safety at the DGR, it notes the importance of coordination, communication and clear understanding of roles among those agencies. The CNSC has considerable experience in regulating conventional and radiologic health and safety aspects at operating uranium mines in Saskatchewan. The Ontario Ministry of Labour employs a highly trained mine inspectorate to maintain regulatory oversight of conventional health and safety conditions at underground mines in Ontario. The DGR, if approved, represents both a unique mining operation and a nuclear facility that are expected to operate at levels of safety, effectiveness, and time span that are greater than exist for many contemporary endeavors. These features will require stringent regulatory oversight if they are to be maintained through the preclosure period and into the institutional control era of the postclosure period. As such, the Panel recommends the following:

Recommendation 9.A: The CNSC should work with the Ontario Ministry of Labour and any other agencies with roles and responsibilities related to worker health and safety to clarify roles and responsibilities for the regulatory oversight of the DGR. Building upon these relationships, the CNSC should also establish a site-specific, dedicated, and coordinated inspectorate team for the DGR site, with the objective of having qualified staff with extensive training in nuclear operations and underground hard rock mining.

9.1.2 Radiation Safety

Radiation protection includes the predicted doses to workers from the DGR, as well as the measures in place to protect workers from radiation hazards. This section describes the baseline used to assess effects of radiation, as well as predicted doses to workers and mitigation measures.

Baseline Radiation Exposure

OPG's assessment of the effects of radiation included a description of worker and public baseline radiation exposures due to natural radiation sources, such as cosmic rays and radionuclides in air, water, food, soil/rocks and construction materials. The OPG baseline information is summarized here; however, discussion of incremental doses to the public due to the project is presented in a later section in this chapter. This section focuses on occupational exposure.

According to OPG, the average annual effective dose to Canadians from all sources of natural background and man-made (anthropogenic) radiation is around 1.8 mSv/yr, with peak annual doses up to 3.0 mSv/yr. Cosmic radiation in Canada varies by region from 0.3-0.4 mSv/yr. External gamma radiation exposure originating from natural sources within rocks, soil and building materials approximates 0.35 mSv/yr, but can range up to 60% higher than the national average depending on location. OPG noted that a major contributor to the annual dose to humans is the inhalation of naturally-occurring radon gas and its decay products; in Canada, the average national dose exposure due to radon gas inhalation approximates 0.9 mSv/yr, but ranges between 0.2 and 2.2 mSv/yr.

OPG further stated that additional radiation exposures to humans result from inhalation and ingestion of tritium and carbon-14, both of which occur naturally in the environment or as by-products of nuclear power generation and from historic nuclear weapons testing. OPG reported that the average tritium concentration in Lake Huron water in 2009 was 2.0 Bq/L and the Ontario background concentration of radioactive carbon-14 in biota averaged 227 Bq/kg-carbon. OPG presented a summary of measured background dose conditions from natural and anthropogenic sources of radiation for average Ontario and local residents, as well as from activities at the Bruce nuclear site. OPG used the results of the Bruce Power Radiological Environmental Monitoring Program as part of its baseline dose assessment for members of the public. This annual program includes measurements of emissions for tritium, particulates, carbon-14 and noble gases.

OPG stated that the dose to members of the public as a result of the radionuclide emissions to air and water from the facilities at the Bruce nuclear site was approximately 0.004 mSv/yr, which is 0.21% of the total average annual public radiation dose of 2.1 mSv/yr in the vicinity of the Bruce nuclear site. The majority of the annual dose to people living in the vicinity of the Bruce nuclear site was from natural background sources (Figure 24). Of the total radioactive emissions produced from the Bruce nuclear site, approximately 97% derived from operation of the Bruce A and Bruce B reactors, and approximately 3% from the WWMF.

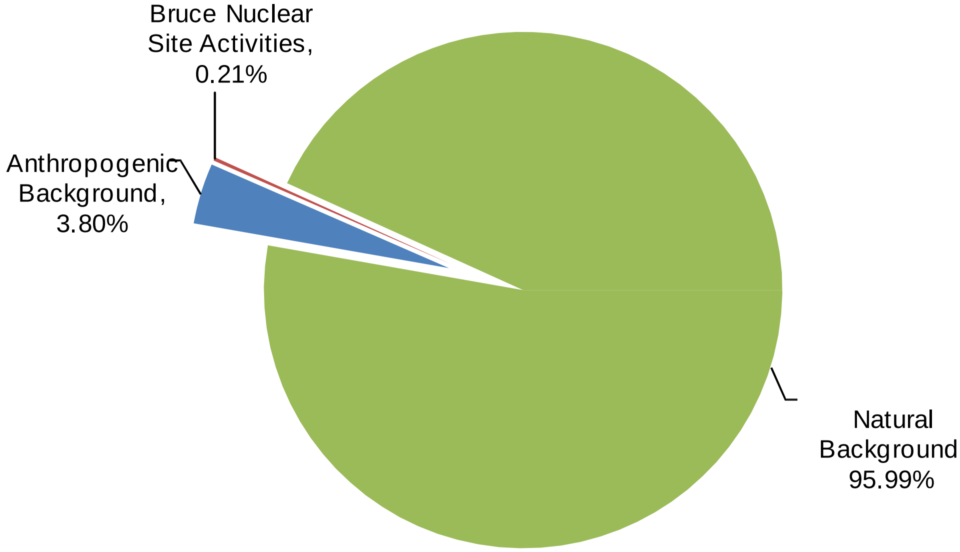


Figure 24 Public Dose Due to Bruce Nuclear Site in Relation to Background Doses in Ontario (reproduced from OPG Radiation and Radioactivity TSD Fig. 5.3.4-1)

OPG stated that doses to workers at the WWMF have remained well below annual regulatory occupational exposure limits. OPG noted that it monitors occupational doses received by nuclear energy workers at the WWMF using personal dosimetry programs to assess external gamma, neutron and internal radioactivity. OPG reported that the collective and maximum individual annual whole body doses were 6.5 person-mSv/yr and 2.8 mSv/yr, both of which were well below the annual OPG action level of 40 person-mSv/yr and the regulatory occupational exposure limit of 50 mSv/yr, respectively. CNSC staff agreed that the baseline data presented by OPG conformed to conditions that were published for nuclear energy workers and members of the public at the Bruce Power site and WWMF.

The Panel is satisfied that OPG adequately described baseline radiologic dose conditions for nuclear energy workers and members of the public and that there is a sufficient understanding of the relative contribution from natural background, Bruce Power operations and the WWMF.

Predicted Radiation Doses to Workers

OPG assessed the potential for effects from exposure to radiation from the project for nuclear energy workers and non-nuclear energy workers. This included both direct exposures and indirect exposures via air, surface water, groundwater, soil/sediment, and food, arising from transfer of waste, waste management, decommissioning and support and monitoring of the DGR lifecycle. OPG did not assess effects for the site preparation and construction, and abandonment phases because those phases would not involve direct interaction between humans and radioactive waste.

OPG explained that the bounding (maximum) direct exposure risk for nuclear energy workers would occur during the operations phase when workers would handle the majority of waste packages. As no waste packages would be handled during the decommissioning phase, dose estimates for the operations phase would represent bounding worker case values for this stage also.

Using specialized software, OPG calculated the maximum doses to workers under normal operations, including from direct gamma radiation exposure and skyshine, airborne tritium, noble gases, iodine-131 and particulates, and waterborne tritium and carbon-14, and compared them to CNSC regulatory limits, as well as OPG dose targets and compliance limits (see text box for limits and targets). Skyshine is radiation scattered back to Earth by the atmosphere.

In all but limited cases of direct radiological exposure, worker dose rate levels were predicted to be below OPG's occupational dose target of 10 mSv/yr, which is well below the regulatory limits of 50 mSv/yr and 100 mSv/5 years. OPG identified bounding case exceedance exposures for workers required to operate near stacked intermediate-level waste packages in underground emplacement rooms. OPG noted that worker exposure time would be limited in order to ensure exposures remain within dose targets. In addition, OPG's preliminary safety report outlined some specific measures that may become part of the detailed design. These measures would be implemented to ensure compliance with regulatory dose limits, OPG occupational dose targets, and the As Low As Reasonably Achievable (ALARA) principle.

OPG determined that the doses to non-nuclear energy workers would be well below the public dose limit of 1 mSv/yr. Doses to non-nuclear energy workers, both on-site and at the site boundary, would occur only during surface waste transport operations between the WWMF and DGR facilities.

CNSC Regulatory Limits and OPG Dose Targets

- Nuclear energy worker, including a pregnant nuclear energy worker: 50 mSv for one-year dosimetry period and 100 mSv for a five-year dosimetry period
- Pregnant nuclear energy worker: 4 mSv for the balance of the pregnancy
- Non-nuclear energy worker and general public: 1 mSv for one calendar year.
- OPG Occupational Dose Target: 10 mSv/yr
- Compliance Dose Limit for non-nuclear energy workers: 0.5 µSv per hour
- Boundary Dose Target (at site boundary): 10 µSv/yr

OPG stated that the maximum indirect exposure risk would also occur during the operations phase. OPG explained that indirect radiological exposure for workers would result from inhalation, skin absorption or immersion of air-dispersed radionuclides, primarily carbon-14 and tritium that could leak from waste containers stored on surface or underground. Radon was not considered to pose a significant risk. OPG determined that worst-case worker exposure conditions would develop for activities conducted close to emplaced low-level waste and intermediate-level waste containers. OPG conservatively assessed worker exposure to radioactive gases generated by release from unsealed low-level waste containers within the DGR to be approximately 0.1 mSv/yr. Worker exposure to gases might also occur when intermediate-level waste ion exchange resins that are contained in older carbon steel containers are transferred from the WWMF to the DGR. As noted by OPG, these packages would be inspected and vented if appropriate. The bounding case for worker exposure from sealed container contaminant releases, as the result of container corrosion or pressure breaching effects (for single container events), would result in worker exposures less than 1 mSv/yr, which is below OPG's dose target of 10 mSv/yr and well below regulatory limits. For non-nuclear energy workers, the indirect doses would be well below the regulatory limit or negligible.

Mitigation of Worker Exposure to Radiation

OPG stated that it has an established Occupational Radiation Protection Program at the WWMF, which would be used as the basis for the radiation protection program at the DGR. Through this program, OPG identified operations and materials that had the potential to contribute to worker occupational radiological dose, and provided guidelines for monitoring and minimizing doses to workers. OPG noted that management features for DGR worker dose control would incorporate many elements that are used at the WWMF and that have been proven to be effective, including the use of personal dosimeters, routine area radiation monitoring, enforcement of limited worker access to radiologically-controlled areas, and the removal of loose radiological contamination from containers.

OPG also proposed in-design mitigation features for the DGR to minimize radiological effects on workers, including provision of waste shielding, appropriate ventilation design and area zoning, and enhanced worker training. OPG did not propose mitigation through exhaust air filtration for air-dispersed radionuclides because the primary radiological emissions from waste, tritium and carbon-14, would be in gas or vapour form that cannot be filtered. Specific mitigation measures included activities and procedures such as use of:

- waste shielding materials and processes, as effected by enhanced container design or use of closure walls;
- ventilation controls, maintained by use of single pass, flow-through ventilation that will keep workers upstream of contaminant sources;
- mine water recovery and removal, to exclude potentially contaminated water from worker occupied zones;
- airborne and waterborne emission controls;
- work site zoning, to maintain worker offset distance from waste-filled sites;
- surface security, for restriction of access by workers into waste storage zones; and
- procedural design and worker training, for maintenance of high quality safety standards.

OPG stated that additional mitigation procedures would include application of effective container design, adoption of sequenced repository room sealing procedures to restrict worker operations to locations upstream from filled rooms, and installation of end closure walls to restrict worker access into waste-filled zones.

OPG stated that its radiation monitoring program would be designed to detect timely changes in radiological hazard levels such that mitigation measures could be implemented or worker hazards avoided. OPG's radiation monitoring commitments included:

- radioactivity assessment in vent exhaust, including measurement of radon concentrations in underground facilities;
- external radiation monitoring during site preparation and construction to ensure the exposure of construction workers (non-nuclear energy workers) to WWMF-related emissions is properly managed;

- external radiation monitoring along the boundary of the Project Area during operations and decommissioning to ensure dose rates meet specific requirements;
- radiological analysis of groundwater during site preparation and construction, operations and decommissioning phases;
- radiological analysis of surface water from the stormwater management system during site preparation and construction, operations and decommissioning phases;
- radiological analysis of sediment in MacPherson Bay and the ditch at Interconnecting Road (discharge ditch from the SWMP); and
- assessment of dose to workers via a dose monitoring program throughout the operations and decommissioning phases.

OPG's proposed radiation and radioactivity monitoring program was designed to verify:

- that construction would not affect the tritium plume from the WWMF;
- that radon levels in the underground will be low;
- predicted releases from underground; and
- predicted dose to the public.

OPG suggested that it would be appropriate to monitor the radiation fields in or near emplacement rooms and, if necessary, limit worker exposure to radiation by using shielded forklifts and/or providing greater worker stand-off distances when placing containers in these rooms. OPG did not specify whether the planned monitoring procedures for underground workers would be similar to those currently used at the WWMF for waste handling operations by surface workers, but noted that it would comply with CNSC requirements. OPG also noted that radiological monitoring would only occur at or near emplacement rooms, in contrast to monitoring practice in uranium mines in which monitoring is performed throughout all occupied work sites.

OPG stated that the revisions to the waste inventory did not affect its assessment of worker exposure estimates during the preclosure interval. OPG explained that all waste packages would be required to meet the DGR Waste Acceptance Criteria, including limits on gamma dose rates outside of pressure tube waste packages. The revisions to the inventory did not affect the ability to meet these criteria.

Regulatory Review of Radiation Doses to Workers

CNSC staff concurred with OPG's assessment and noted that OPG's history of container design and storage applications at the WWMF demonstrated that OPG could maintain worker exposure to radiological releases below regulatory limits throughout the operations phase of the project.

CNSC staff reported that the methods used by OPG to assess doses to workers and members of the public were well–established, and that the results were acceptable and conservative. CNSC staff stated that radiation and radioactivity resulting from the project was not likely to have significant adverse effects on the health of workers, taking into account the implementation of mitigation measures. CNSC staff further noted that underground uranium mines in Canada utilize extensive monitoring systems to protect workers from radiation exposure. Such systems make use of redundant methods to provide overlapping, continuous and full-time monitoring of worker radiological exposure conditions. On the basis of its experience in regulating uranium mines, CNSC staff stated that effective equipment and procedures currently exist that have the capacity to monitor worker radiological exposures.

CNSC staff's review of preclosure worker safety scenarios associated with the revised waste inventory did not identify any adverse radiological gas generation or other issues related to radiation exposure. CNSC staff stated that OPG would be required to implement standard and planned mitigation measures for radiation protection in order to maintain low doses to workers during normal operations.

Views of Participants Regarding Radiation Doses to Workers

Several participants, including unions and professional organizations representing current and former nuclear workers, such as the Canadian Nuclear Workers' Council, the Power Workers' Union and the Bruce Sub Group of the Hydro Pensioners of Ontario, expressed the view that OPG has had strong radiation protection performance at its facilities, including the WWMF. They attributed this performance to the robustness of OPG's radiation protection programs, as well as training and adherence to procedures. They also commented on the positive safety culture, work environment and relations between workers and management.

Radon

OPG identified radon as a potential source for indirect worker exposure, and evaluated exposure to radon released from waste rock into surface or ventilation air in its Radon Assessment. OPG used the CNSC's effective radon dose limits for the public and nuclear energy workers to assess the adequacy of its radiation protection plan. For workers, derived working limits for annual occupational radon gas exposure were set at 150 Bq/m^3 (equivalent to a dose rate of 1 mSv/yr) for unrestricted workplace exposure.

OPG predicted that, during DGR construction and operations, naturally occurring radon gas would emanate from the host limestone rock surrounding DGR excavations and into the confined excavation environment of the DGR. Additional radon quantities would also be generated from surface waste rock piles and released into the open air environment.

OPG assessed the radon hazard potential to humans using estimations of radon concentrations that would develop within the DGR. The concentration estimates were based upon measured radon emanation rate factors from rock, excavation geometries and planned ventilation flow conditions that were used to assess dose predictions during various periods of DGR development and operation. For the construction phase, OPG predicted radon concentrations and doses at advancing excavation sites underground. For the operations phase, OPG predicted concentrations and doses at sites where greatest radon accumulation and exposure times would occur. These sites were assessed to exist within empty and unventilated repository rooms, at the end of the fresh air access tunnel, within the exhaust ventilation tunnel, and within the ventilation shaft.

OPG conservatively modeled radon emissions from the Cobourg limestone waste rock pile to estimate exposure and dose conditions for workers and members of the public at surface locations where highest radon concentrations would develop. Bounding case sites were considered to exist on top of the waste rock pile and down-wind from the waste rock pile at the DGR site boundary.

OPG evaluated conservative (maximum) radon concentrations and dose rate estimates for various sites and phases of DGR activity. OPG estimated that, during the construction phase, the maximum worker radon inhalation dose rate would be 2.5 x 10^{-3} mSv/yr. During the operations phase, the maximum predicted worker radon exposure would occur within the ventilation exhaust tunnel near the service area, with a dose rate of 5.5 x 10^{-3} mSv/yr. During this same phase, surface workers operating on top of the limestone waste rock pile would have a radon inhalation dose rate of 4.2 x 10^{-2} mSv/yr. OPG stated that the doses for all exposure scenarios were orders of magnitude below regulatory limits.

OPG stated that there would be no significant worker radon exposure hazards. This was primarily due to the low natural uranium (and therefore radon) content existing in the limestone host rock and contained radium content in the repository waste materials. As a result, OPG was of the view that there was no need for routine radon monitoring to develop radon mitigation action levels for DGR construction or operations. OPG proposed, however, to measure radon concentrations during the construction phase and periodically during operations in order to validate its radon assessment.

CNSC staff concurred with OPG’s assessment and stated that there would be no significant radon hazard to workers or the general public, and that OPG had made adequate provisions for radon monitoring. CNSC staff stated that, based on extensive radon monitoring experience obtained through regulation of uranium mines, increased concentrations from exhaust air or waste rock pile emissions would be highly localized to sources of emission. CNSC staff explained that radon concentrations at uranium mine sites have been monitored to exist at background levels at distances one to two kilometres away from emission sources. CNSC staff further confirmed that OPG’s modelling of atmospheric dispersion of contaminants, such as radon, at the DGR site was appropriate for this assessment.

Environment Canada acknowledged that OPG had committed to regular monitoring of radiological materials that had the possibility of being released into the underground ventilation exhaust during the operations phase of the DGR, such as tritium, carbon-14 and particulates, and suggested that radon concentrations should be similarly monitored as part of this commitment. The Panel agrees with this suggestion.

The Panel notes that regulations that have been established for mines under the *Ontario Occupational Health and Safety Act* require that ventilating air must be sampled upon the initiation of mining activity and needs to be sampled only annually if initial values fall below prescribed levels. For the low levels that have been predicted, annual radon testing would be required by *Ontario Health and Safety Act* regulations.

Panel Conclusion Regarding Radiation Doses to Workers

The Panel concludes that the project is not likely to result in significant adverse health effects for workers as a result of exposure to radiation. The Panel is satisfied that OPG adequately assessed worker radiological hazards. Plans for mitigation and monitoring to ensure radiation protection were described in sufficient detail that the Panel is confident that regulatory dose limits for nuclear energy workers will be met. The mitigation features that have been proposed by OPG are considered by the Panel to be effective for mitigating worker radiologic exposures during and after waste container placement.

The Panel notes that details of the monitoring system to be deployed in the DGR would be part of the licensing phase, should the project be approved. The general features of the monitoring system, as described by OPG, are adequate, with the possible exception of radon. The Panel agrees with Environment Canada that radon gas may be a measurable component of radiological releases into the underground work environment, as will be other gases and particulates. The Panel is satisfied that radon hazards have been adequately assessed and that it is likely that radon exposures to DGR workers and members of the public at nearest receptor sites will be very low and at background concentrations. Inasmuch as OPG committed to monitor specific radioactive gases and particulates during the DGR operations phase, radon gas and radon decay product monitoring should also be included in regular radiologic release monitoring plans for site workers and off-site members of the public. Accordingly, the Panel recommends the following:

Recommendation 9.3: In order to confirm the absence of significant adverse effects from radon and radon progeny, as predicted in the environmental assessment, OPG shall conduct a follow-up program for radon, acceptable to the CNSC. Radon monitoring locations shall include: within the exhaust air shaft at surface, and near the waste rock management area. The follow-up program shall be established prior to site preparation and construction and include the establishment of baseline radon conditions.

9.1.3 Panel Conclusion Regarding Worker Health and Safety

The Panel concludes that rigorous adherence to worker health and safety plans and processes will ensure that the management of conventional hazards will meet or exceed industry standards. The Panel concludes that the project is not likely to result in significant adverse effects to worker health from radiological hazards. The Panel is satisfied that OPG has and will continue to have robust programs in place to ensure that the project activities are carried out safely. Furthermore, the Panel is satisfied with the mitigation measures proposed and commitments made by OPG to protect the health and safety of workers.

9.2 PUBLIC HEALTH AND SAFETY

The Panel's assessment of public health and safety includes public safety; effects due to physical changes in the environment, such as noise, air quality, and radiation; and changes to socio-economic, cultural and emotional determinants of health. For the purpose of the assessment, public health valued ecosystem components include local residents, seasonal users and members of Aboriginal communities.

9.2.1 Public Safety

OPG stated that the protection of the health and safety of members of the public would be managed through its Environmental Management System and its Employee Emergency Response Procedure. As outlined in Chapters 10 and 11, in the case of an emergency, OPG anticipated that local health and safety and fire service providers may be called upon to assist the specialized emergency response teams that OPG would have in place. OPG committed to working cooperatively with Emergency Management Ontario and local emergency responders to assist in the development and testing of emergency plans throughout the life of the project. OPG noted that its safety record at the WWMF demonstrated its capability with respect to effective emergency response.

As discussed in Chapter 11, OPG stated that additional demands on health care, emergency medical services, fire and police protection services which may result from project-associated population increases would not be large enough to affect levels of service. OPG committed to developing and implementing a traffic management plan for the site preparation and construction phase. The primary objective of this plan would be to minimize project-related peak hour traffic volumes; however, an associated benefit would be the management of risks of congestion-related accidents.

The Panel is satisfied that the project will not adversely affect public safety, considering OPG's Emergency Management System and its commitment to coordination with local emergency response service providers. The effectiveness of safety programs at the DGR is essential for maintaining public safety. Emergency response is further discussed in Chapter 10.

9.2.2 Overall Public Health

OPG used several indicators arising from the World Health Organization (WHO) definition of health as the basis for its assessment of health effects. The WHO definition of health is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." Thus, project-related changes in physical, socio-economic, cultural and emotional determinants of health were all evaluated.

Health Effects Associated with Physical Changes in the Environment

OPG predicted changes in air quality, noise and radiation exposure, and assessed these changes for effects on human health. OPG did not predict adverse effects on surface water quality, soil quality or groundwater quality; therefore, there was no assessment of these parameters with respect to human health. However, OPG's proposed monitoring program included monitoring of surface water, groundwater and sediments in order to verify these predictions.

CNSC staff and Health Canada agreed that there would be no adverse effects on surface water quality, soil quality or groundwater quality from release of non-radiological contaminants. Health Canada found that methods used in the assessment of changes in water quality were appropriate and that the project would not result in the exceedance of applicable water quality guidelines or standards at the point of human consumption or exposure. Furthermore, Health

Canada reviewed country foods information and stated that OPG had used an appropriate methodology to assess the risk of non-radiological contamination in country foods. Health Canada noted that predicted concentrations of non-radiological contaminants were found to be well below environmental quality standards in well water, surface water, irrigated soil and sediment.

OPG modelled air quality, noise and radiation to estimate exposure to people living in or using areas in close proximity to the project site (Figure 25). OPG used several conservative assumptions in its modelling. For example, Aboriginal people were assumed to be living close to the site, although the closest Aboriginal community was 17 km further away than the assumed location. Seasonal users were assumed to be using the closest recreational areas (Inverhuron Provincial Park and Baie du Doré) for approximately two months of the year. OPG also considered that periodic visits to the Jiibegmegoong burial site by Aboriginal people were included in the modelling.

Air Quality

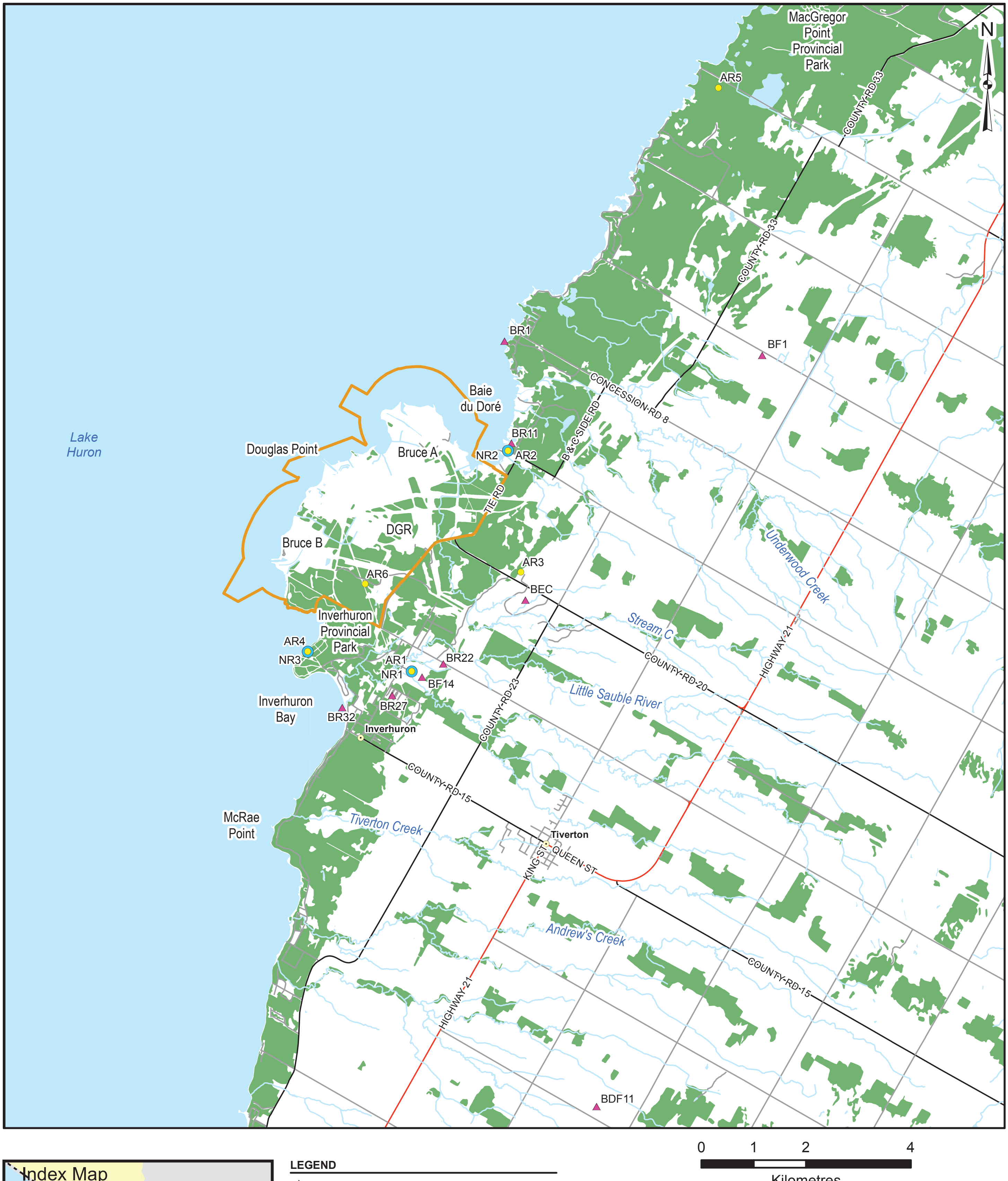
This section describes the Panel's assessment of the effects of changes in air quality on public health.

Predicted Effects of Changes in Air Quality on Public Health

OPG determined that there would be no significant adverse effects on air quality, as represented by the air quality indicators nitrogen dioxide, sulphur dioxide, carbon monoxide, and particulate matter. Effects on air quality were discussed in more detail in Chapter 8. Predicted maximum concentrations of suspended particulate matter, and particulates (PM_{10} and $PM_{2.5}$,) exceeded ambient air quality criteria over a very small area in the immediate vicinity of the Bruce nuclear site fence. These concentrations were predicted to occur during the site preparation and construction and decommissioning phases less than 0.5% of the time and were immediately reversible. OPG hypothesized that, to have a significant effect, the particulate concentrations beyond the Site Study Area would have to exceed the ambient air quality criteria more than 10% of the time. Therefore, OPG stated that the predicted particulate exceedances would not be significant. None of the other indicator compounds were predicted to exceedambient air quality criteria outside of the Bruce nuclear site fenceline for any of the project phases.

Although there were no predicted significant adverse effects on air quality in terms of the indicator compounds, OPG also used the air quality model to predict concentrations of specific compounds of concern with respect to human health. The predicted concentrations were then used in a human health risk assessment.

OPG predicted that lifetime cancer risks from exposure to carcinogenic compounds produced by the project would be below the target risk value of one in a million. OPG used air quality modelling results to calculate lifetime cancer risk from exposure to maximum estimated concentrations of carcinogenic compounds such as polycyclic aromatic hydrocarbons, benzene and formaldehyde. OPG estimated exposures for people living in close proximity to the project, using existing conditions resulting from background air quality, sources at the Bruce nuclear site, as well as the additional sources from the project.



LEGEND

- Radiological Potential Critical Group Location
- Noise Receptor
- Air Receptor
- Site Study Area [1]

NOTE

1. Site Study Area is defined by EIS Guidelines as: "includes the facilities, buildings and infrastructure at the Bruce nuclear site, including the existing licensed exclusion zone for the site on land and within Lake Huron, and particularly the property where the Deep Geologic Repository is proposed.

PROJECT

DGR PROJECT
ENVIRONMENTAL IMPACT STATEMENT

TITLE

HUMAN HEALTH RECEPTOR LOCATIONS

Golder Associates
Mississauga, Ontario

PROJECT NO. 06-1112-037			SCALE: AS SHOWN	R000
DESIGN	ASB	17 Oct 2007	FIGURE C2.3.1-1	
GIS	BC	22 Jun. 2010		
CHECK	RS	22 Jun. 2010		
REVIEW	SM	22 Jun. 2010		

Figure 25:Human Health Receptor Locations (reproduced from DGR EIS Volume 2 Appendix C Figure C2.3.1-1)

The incremental lifetime cancer risks from maximum estimated exposure to carcinogenic compounds produced by the project were two to four orders of magnitude below one in a million. These risks were estimated at the point of maximum exposure, which varied from about 1 to 12 km from the project site.

OPG also estimated exposures to non-cancer causing substances such as sulphur dioxide, nitrogen dioxide, metals, and particulates. The results were not greater than tolerable daily intake or tolerable concentration benchmarks established by Health Canada, and/or the literature, with the exception of acrolein. OPG used modelled maximum concentrations to calculate hazard quotients, which were ratios of estimated exposures to tolerable daily intake or tolerable concentrations. Most of the hazard quotients were at least two orders of magnitude below one, indicating that even maximum exposures were nowhere near exposures associated with health effects. The hazard quotients for acrolein exposure of nearby residents and members of Aboriginal communities during site preparation and construction ranged from 2.2 to 2.9. During the operations phase, hazard quotients ranged from 2.1 to 2.6. These hazard quotients were for the points of maximum exposure, which varied from about 1 to 12 km from the project site.

OPG stated that acrolein is generated by the burning of fossil fuels and wood, and that it dissipates quickly so it is unlikely to be transported over long distances. OPG noted that although exposure to acrolein can cause irritation of the eyes, throat and respiratory tract, tearing of the eyes and coughing, the symptoms are reversible. OPG found that most of the acrolein exposure for nearby residents and Aboriginal community members was due to existing concentrations, i.e., background conditions plus activities at the Bruce nuclear site, especially combustion of diesel fuel. The hazard quotients associated with existing conditions ranged from 2.1 to 2.6, compared with 2.2 to 2.9 during site preparation and construction. During the operations phase, the hazard quotients returned to those associated with existing conditions. OPG found that the maximum predicted acrolein concentration of 0.33 $\mu g/m^3$ produced by the project was lower than the range of maximum ambient acrolein concentrations measured in Ontario.

OPG determined that the residual adverse effect on human health from acrolein exposure would not be significant. This conclusion was based upon the low magnitude of exposure (hazard quotients of 2.2 to 2.9), combined with exposures being limited to the Local Study Area and effects being immediately reversible when exposure ceases. OPG considered the frequency of exposure to local residents to be “medium”, i.e., exposure could occur at regular intervals several times per month. OPG did not propose any follow-up monitoring to confirm predicted acrolein concentrations in air. Instead, OPG suggested that since the primary sources of acrolein emissions were the same as those that contribute to nitrogen dioxide levels, e.g., exhaust from diesel fuel equipment, monitoring of nitrogen dioxide levels would be sufficient.

Air Quality Mitigation Measures

As noted in Chapter 8, OPG’s mitigation measures to ensure compliance with air quality criteria would include:

- the use of construction equipment that will meet the most recent emission standards;
- maintenance of equipment in good working order;

- watering or roadways for dust suppression;
- minimization of drop heights of rock and other materials; and
- the use of vehicles meeting the newest emission standards.

Government Agency Review of OPG's Assessment of the Effects of Changes in Air Quality on Public Health

CNSC staff concurred with OPG's assessment of health effects associated with changes in air quality. CNSC staff stated that the predicted changes in air quality caused by the project would not likely result in significant adverse effects, taking into account the implementation of mitigation measures. Health Canada stated that OPG had properly characterized potential human health effects of project-related changes to air quality and noted that the proposed mitigation measures were appropriate.

Views of Participants Regarding Effects of Changes in Air Quality on Public Health

Some participants were satisfied that air quality would be appropriately mitigated, monitored and regulated. This opinion was based upon satisfaction with the existing performance and regulation of the emissions from the WWMF.

Other participants had concerns about the effects of air emissions on their health because they were close neighbours to the Bruce nuclear site, or because they did not trust that regulatory agencies were requiring sufficient monitoring information or rigorous modelling to confirm predictions. Specific concerns were raised regarding the effects of particulate emissions on sensitive populations, such as people with existing chronic lung problems. Some participants did not trust in model assumptions and expressed a preference for data from the local area. Some participants did not trust that the model predictions were conservative.

Panel Conclusion Regarding Health Effects from Changes in Air Quality

The Panel is satisfied that the air quality modelling addressed uncertainties associated with model input appropriately via the use of deliberately conservative assumptions. The Panel notes the infrequency of predicted exceedances of air quality criteria (less than 0.5% of the time) and the limitation of these exceedances to a small area adjacent to the project site.

The Panel concurs with OPG's rating of the significance of exposure to acrolein, particularly in light of the small incremental contribution to acrolein exposure by the project. The Panel notes that some participants expressed concerns regarding emissions from the Bruce nuclear site. OPG should engage interested members of the public in detailed discussions regarding the collection and interpretation of air quality data.

The Panel's conclusion depends upon the timely and effective implementation of mitigation measures as well as appropriate follow-up monitoring. The Panel notes that OPG did not propose follow-up monitoring to confirm predicted acrolein concentrations in air. The Panel is of the view that OPG should specifically monitor acrolein at receptor locations for local residents (AR1, AR2, AR3) and for members of Aboriginal communities (AR5) in order to confirm its predictions. OPG should likewise monitor nitrogen dioxide and particulates such as PM_{10} and $PM_{2.5}$, as recommended in Chapter 8.

Recommendation 9.4: In order to confirm the environmental assessment prediction of no significant adverse effects to human health from acrolein exposure, OPG shall conduct a follow-up program for acrolein during site preparation, construction and operations, to the satisfaction of the CNSC.

Noise

This section describes the Panel's assessment of the effects of noise on public health.

Predicted Effects of Noise on Public Health

OPG evaluated the effects of changes in noise levels on human health by predicting noise levels at three receptor locations near the project site and comparing these predicted noise levels to Health Canada criteria. The three locations assessed by OPG were: Albert Road adjacent to Inverhuron Provincial Park (R1); across Baie du Doré from Bruce A (R2); and, within Inverhuron Park at an existing camp site (R3). Noise predictions were based on worst-case noise emissions from all sources. In addition, all receptors were assumed to be downwind of noise sources; no reduction in noise level was assumed for upwind receptors, which was also a worst-case assumption. The maximum change in noise level was estimated by comparing predictions to the quietest hour under existing (baseline) conditions.

OPG assessed existing noise levels at the above three locations produced by activities on the Bruce nuclear site and adjacent areas; there were no exceedances of Health Canada criteria for adverse effects on human health from existing noise levels. The percentage of people "highly annoyed" by existing noise levels was estimated to range from 1.5 to 2.1%. The Health Canada "highly annoyed" threshold for adverse health effects is 6.5%. The Health Canada threshold for adverse effects from impulse noise, i.e., single bursts of sound of short duration, is 75 dBA. Existing impulse noise levels at the three locations ranged from 47-50 dBA.

OPG stated that an increase of up to 3 dB is considered to be barely perceptible. The project noise levels were predicted to be broadband in nature, meaning that no distinguishable character, i.e., prominent tones, would be present. OPG anticipated that fine details such as frequency changes and variable modulation would not be noticeable at the receptor locations, except perhaps during the quietest night-time hours.

OPG predicted noise levels caused by the project to range from 2 to 5 dBA above existing noise levels at the three receptor locations. The largest incremental increase of 5 dBA occurred at the Baie du Doré location, affecting four residences, during site preparation and construction. OPG predicted a similar increase for the decommissioning phase. OPG identified this increase as a residual adverse effect.

OPG predicted that increased noise levels caused by the project would increase the percentage of "highly annoyed" people by 0.1-0.5% during site preparation and construction, and from 4.5 to 6.2% during the operations phase. This prediction included an adjustment of +10 dB to account for the potential that site preparation and construction and operations noise sources could occur at night. These incremental increases in % "highly annoyed" were below the Health Canada threshold of 6.5%; therefore, OPG determined that there would be no adverse effect.

The Panel notes that the approach used by OPG for assessment of health effects associated with being "highly annoyed" by noise differed from that used for air quality. Health risks associated with air quality were estimated using the total exposure due to existing background, Bruce nuclear site sources and project sources. Health risk associated with annoyance caused by noise was estimated using the incremental effects of the project only. If the total % "highly annoyed" is considered, the Health Canada threshold would be exceeded at the Baie du Doré and Inverhuron Provincial Park locations during the operations phase. Notwithstanding this observation by the Panel, Health Canada stated that OPG had properly characterized the potential effects on human health resulting from changes in noise caused by the proposed project. The Panel accepts OPG's method on the basis of Health Canada's evaluation.

OPG predicted that impulse noises caused by the project would not exceed the Health Canada threshold of 75 dBA during site preparation and construction or operations. The maximum predicted impulse noise was 61 dBA at Baie du Doré during the operations phase.

OPG did not predict any sleep disturbance associated with the project during site preparation and construction or operations phases. OPG assessed the effects of project noise on sleep by using the quietest 1-hour period (typically occurring during late night or early morning hours) and then logarithmically adding project noise at the three receptor locations. OPG noted that the World Health Organization recommends that noise levels at the outside façade of a building should not exceed 45 dBA to allow residents to sleep with the windows open. OPG's predicted noise levels at the outside façades at critical receptor locations ranged from 41 to 44 dBA, with increases over existing levels occurring only at the Baie due Doré and Inverhuron receptor locations, 2 dBA and 1 dBA increases, respectively.

OPG assessed blasting noise levels, i.e., air vibrations, separately from % "highly annoyed", using a method from the Ontario Ministry of the Environment and Climate Change, Noise Pollution Control 119. OPG explained that it did not add blasting noise levels to the noise levels used to calculate the % "highly annoyed" because the predicted %"highly annoyed" would not numerically change if the energy from blasting were added. As noted by OPG, a typical blast may last for a fraction of a second and, when applying the appropriate time correction for the time period used in the determination of %"highly annoyed", e.g., night-time or 24-hours, and when applying A-weighted adjustments, the effect of blasting would not affect the %"highly annoyed".

OPG stated that all predictions of ground vibration caused by blasting met applicable regulatory limits, and all predicted air vibrations were less than the maximum limit of 128 dBL. In its assessment of blasting, OPG conservatively assumed that there would be no attenuation due to shielding by rock. OPG pointed out that although blasting for shaft development would last for about 1.5 years, the depth of the shaft after the first year would be about 450m below grade. At this depth, OPG expected that the blasting noise would not be audible at the noise receptor locations.

Mitigation of Noise Levels

OPG's commitments to noise mitigation, which were presented in Chapter 8 in more detail, included:

- maintenance of equipment in good working order;
- the use of appropriate noise control measures;
- minimization of the construction footprint to reduce vehicle travel distances;
- planting trees on the waste rock pile; and
- limiting blasting near the surface to daylight hours.

OPG stated that, during the operations phase, ventilation fans would be maintained in accordance with manufacturer's specification and maintenance records would be verified annually. OPG did not provide any specific information regarding additional mitigation for ventilation fan noise.

With respect to Kincardine Noise Control Bylaw (2008-076), OPG stated that construction activities are permitted during evening and night-time hours, provided that they are not clearly audible at the points of reception, i.e., the three receptor locations assessed by OPG that would be monitored during site preparation and construction.

As explained in Chapter 8, the phrase "clearly audible" is not quantitative, and is subject to the interpretation of individual listeners. The Panel expects that it is likely that there will be complaints regarding noise and that these complaints will be expressed in terms of noise being "audible". Monitoring cannot detect audibility, only listening can. Therefore, OPG's monitoring at the three receptor locations may not be sufficient with respect to the Kincardine noise by-law. The Panel suggests that, should the project be approved, a "Listening Panel," comprised of representatives of local residents, OPG and the Municipality of Kincardine, could be established. Membership on, and the findings of, this Listening Panel should be by consensus. The Listening Panel would then be asked to listen under conditions representative of when any noise-causing complaint occurred.

OPG stated that its follow-up noise monitoring program would take place at the three assessed receptor locations: Albert Road adjacent to Inverhuron Provincial Park (R1); across Baie du Doré from Bruce A (R2); and, within Inverhuron Park at an existing camp site (R3). The timing of monitoring would be tailored to specific site activities, i.e., representative stages that best represent maximum noise levels or specific noise scenarios, such as when OPG starts sinking the shafts or moving waste rock. Monitoring would be continuous over 48 hours. OPG noted that it would re-evaluate the monitoring program annually. OPG explained that it did not plan to increase the number of noise monitoring stations because the primary purpose of monitoring was to confirm the predicted noise levels at the three receptor locations. OPG further noted that, should monitoring results indicate that additional mitigation is required, mitigation measures could include alternatives to back-up alarms and altering configuration of the waste rock management area to achieve greater noise attenuation. OPG also stated that it would consider the effect of noise on Aboriginal uses of the Local Study Area by examining the results of monitoring data from representative time periods (summer, fall); however, it did not intend to conduct targeted monitoring to address Aboriginal use of the Local Study Area.

OPG stated that follow-up vibration monitoring during blasting would take place in accordance with regulatory requirements, including the Ontario Ministry of the Environment and Climate Change method, Noise Pollution Control 119, and the Kincardine Noise Control By-law. In addition, OPG committed to the following monitoring and follow-up activities:

- The initial series of regular production blasts shall be monitored at varying distances from each blast to characterize the site specific ground vibration attenuation rates. This would entail establishing monitoring stations between the blast site and adjacent receptors during the initial series of shaft blasts. The site specific attenuation data developed during this monitoring period should then be used to better define ground vibration effects at the closest sensitive receptors.
- Subsequent routine monitoring of all blasting operations should be carried out in the vicinity of the closest receptors to the proposed blasting operations. As extraction continues within the shaft and underground development, the actual monitoring locations should be routinely and regularly reviewed so that the closest receptors are always being monitored for ground vibration effects.
- A communication program should be implemented to keep neighbours informed of the status of activity. During blasting near surface, blasting should take place during daylight hours.

OPG determined that the predicted increase in noise levels at four residences near receptor R2 (Baie du Doré) would not constitute a significant adverse effect. OPG's hypothesis was that for a noise effects to be considered significant, the change in ambient noise would need to be disturbing, defined by OPG as a greater than 10 dB change in the quietest hour. The predicted change at the four residences near Baie du Doré was 5dB or less during site preparation and construction and decommissioning phases.

<u>Government Agency Review of OPG's Assessment of Noise Effects on Public Health</u>

Health Canada stated that OPG had provided sufficient information for assessing and addressing potential project-related effects to the acoustical environment and had properly characterized potential human health effects. Health Canada reviewed issues such as whether the calculation of the percentage of highly annoyed people included particular sound characteristics, the health effects of blasting noise, and clarification of the potential for noise to affect sleep.

The Ontario Ministry of the Environment and Climate Change stated that compliance with *Ontario Reg. 419/05-Air Pollution-Local Air Quality* would include project effects on noise or vibration. As such, OPG would be required to assess and document the impacts of all noise and vibration emissions following Ministry guidelines and guidance documents. The Ontario Ministry of the Environment and Climate Change stated that OPG would have to demonstrate compliance with MOE noise guidelines, to the satisfaction of the Ministry, at the time that it applies for application for an environmental compliance approval.

<u>Views of Participants Regarding Noise Effects on Public Health</u>

Some participants expressed concerns about noise effects from the project, particularly sleep disruption. They questioned what would actually trigger mitigation and what specific additional mitigation might be considered. OPG noted that its proposed monitoring programs would be submitted for regulatory and stakeholder review and that input received would be considered in revised programs. OPG did not provide explicit triggers for additional noise mitigation, should monitoring data or complaints from residents indicate the potential need for further action.

Instead, OPG emphasized its commitment to the noise mitigation measures listed above, and explained that the primary purpose of monitoring would be to verify its predictions.

Some participants expressed concerns that the noise effects from the project could affect the enjoyment of recreational areas such as Inverhuron Provincial Park. OPG did not consider it necessary to add monitoring locations to address future campground development proposed for an area closer to the project site than current campsites.

Panel Conclusion Regarding the Effects of Noise on Human Health

The Panel concludes that noise effects from the project are not likely to result in significant adverse effects on human health. The Panel understands, however, the particular concerns raised by participants with respect to noise and notes that there is a potential for sensitive residents or seasonal users to be “highly annoyed”, especially during night-time hours during the site preparation and construction phase. In addition, if the total (baseline plus project) % “highly annoyed” is considered, the Health Canada threshold for % “highly annoyed” would be exceeded at the Baie du Doré and Inverhuron Provincial Park locations during the operations phase. Furthermore, while blasting will consist of short-term events which might not contribute to maximum noise levels, it will contribute to the energy-equivalent sound level, i.e., the total sound energy over a given period of time, and may therefore play a role in issues of concern such as sleep disturbance. Sleep disturbance criteria are routinely based upon long-term annoyance and prolonged disturbance to sleep due to awakenings and disturbance to sleep states. Sleep disturbances may or may not contribute to the % “highly annoyed”, but if reported by residents, they should be mitigated by OPG.

The Panel expects that OPG will use its follow-up monitoring, accompanied by engagement with neighbouring residents and seasonal users, to determine whether there are individuals who become “highly annoyed” by noise. The Panel further expects that OPG will present and discuss additional mitigation for any individuals who are “highly annoyed”. Because of all of these considerations, the Panel has specific recommendations regarding the noise monitoring program. The Panel also notes its suggestion regarding the possible establishment of “Listening Panels” in the context of noise complaints about audibility under the Kincardine Noise Bylaw.

The Panel is of the view that OPG should develop explicit action levels for noise mitigation. The action levels should be acceptable to CNSC, taking into consideration the requirements of Health Canada and the Ontario Ministry of the Environment and Climate Change, and reflect the requirements of the Kincardine Noise Control Bylaw. OPG should also engage Aboriginal groups and residents in the Local Study Area to develop these triggers.

Further, the Panel is of the view that, in accordance with best practices, OPG requires additional noise monitoring locations in order to confirm the effectiveness of the noise mitigation measures. Additional monitoring locations should be determined with input from Health Canada, the Ontario Ministry of the Environment and Climate Change, the Municipality of Kincardine, Aboriginal groups and local community members.

The number of noise monitoring locations should be commensurate with current best practice and be the subject of discussion between OPG and community and Aboriginal representatives to ensure that monitoring data not only confirm EIS predictions and the effectiveness of mitigation, but are relevant and meaningful to potentially affected residents, Aboriginal people and seasonal users. The Panel stresses the need for OPG to engage local residents and Aboriginal groups to ensure that noise monitoring data and results are relevant and meaningful.

Recommendation 9.5: In order to confirm EIS predictions and the effectiveness of mitigation, the noise and vibration monitoring committed to by OPG shall be conducted to the satisfaction of the CNSC and shall be included in the environmental management system for the project. Monitoring shall take place throughout the pre-closure phases of the project. OPG should identify additional monitoring locations in consultation with Health Canada, the Ontario Ministry of the Environment and Climate Change, Aboriginal communities and residents in the Local Study Area. OPG shall develop explicit action levels for noise mitigation, acceptable to the CNSC, taking into consideration input from Aboriginal communities, and permanent and seasonal residents in the Local Study Area.

Radiation

This section describes the Panel's assessment of the effects of radiation exposure on public health.

Predicted Effects of Radiation on Public Health

OPG assessed the potential for effects from exposure to radiation for members of the public and Aboriginal groups. Site preparation and construction and abandonment phases were not included in the assessment because these phases would not involve direct interaction between humans and radioactive waste. OPG noted that the estimated total dose to the general public from the project would be consistent with the dose to the public from the WWMF and that the dose would further decrease after the above-ground waste inventories are moved into the emplacement rooms underground and progressively closed off. OPG used the results of the Bruce Power Radiological Environmental Monitoring Program as part of its baseline dose assessment for members of the public. This annual program includes measurements of emissions for tritium, particulates, carbon-14 and noble gases.

As described above, the baseline dose to members of the public as a result of the radionuclide emissions to air and water from the facilities at the Bruce nuclear site was approximately 0.004 mSv/yr. Of the total radioactive emissions produced from the Bruce nuclear site, approximately 97% derived from operation of the Bruce A and Bruce B reactors, and approximately 3% from the WWMF. The CNSC regulatory limit for public dose is 1 mSv/yr.

OPG predicted changes in direct and indirect radiation exposures for members of the public and compared them to the regulatory limit. Exposures to the maximum radioactive emissions under normal operations, including direct gamma radiation exposure and skyshine, airborne tritium, noble gases, iodine-131 and particulates, and waterborne tritium and carbon-14, were well below the public dose limit. OPG predicted that radon emissions into surface air from the ventilation exhaust during site operation would pose an inhalation dose rate of 2.7×10^{-6} mSv/yr to members of the public at the site boundary. The maximum dose from radon emissions from the waste rock pile to a member of the public located one kilometre downwind of the waste rock pile would be 2.2×10^{-5} mSv/yr.

OPG's dose estimates for "critical groups" within the general public were well below the CNSC regulatory limit. OPG explained that critical groups were relatively homogeneous groups of people whose location, habits, diet, etc., would cause them to receive doses higher than the average dose received by the general population. OPG identified candidate groups based on proximity to the sources of emissions at the Bruce nuclear site and lifestyle characteristics. The highest predicted dose was estimated for the critical group BF14, a farm located to the southeast of the Bruce nuclear site, with an individual dose of 0.004 mSv/yr to an adult and 0.007 mSv/yr to an infant. These doses were less than 1% of the public dose limit. These doses would be small relative to background radiation from natural sources. OPG pointed out that these doses would also be less than the *de minimis* dose level of 0.01 mSv/yr associated with a risk level that would be regarded as negligible in comparison to other, non-nuclear risks.

OPG stated that, due to their distance from the Bruce nuclear site, individual doses to Aboriginal peoples would be bounded by doses to individual members of critical groups residing in the Local Study Area. OPG explained that the two closest First Nations groups in the vicinity of the Bruce nuclear site are the Chippewas of Nawash Unceded First Nation, 80 km northeast on Georgian Bay, and the Chippewas of Saugeen First Nation, 25 km north on Lake Huron. The Historic Saugeen Métis Community is located at the mouth of the Saugeen River, 25 km north on Lake Huron.

OPG stated that internal doses from inhalation of radionuclides in air at the nearest Aboriginal community would be one order of magnitude lower than at the critical group location BF14. OPG estimated external doses from radionuclides in air to be at least two times less for Aboriginal community members than for a person located at the BF14 location, including accounting for a lifestyle that involved more time spent outdoors. The estimated dose from drinking water was about 10 times less at the nearest Aboriginal community than for the BF14 location. OPG further stated that consumption of plants, meat, eggs and poultry grown or raised in Aboriginal communities would produce doses well below those for the BF14 location, largely because of the lower radionuclide concentrations in air in these communities. OPG estimated doses due to consumption of fish using consumption rates from a recent diet survey of the Chippewas of Nawash, whose fish consumption was about three times that of an adult at the BF14 location. With tritium contributing most of the dose due to fish consumption, the estimated dose for an Aboriginal adult with high fish consumption was similar to that of the average BF14 adult.

Mitigation Measures for Reducing Exposure to Radiation

OPG's proposed mitigations to minimize the exposure of humans to radiation included:

- shielding;
- ventilation;
- sump and stormwater collection and management;
- airborne and waterborne emission control;
- zoning and monitoring to prevent spread of contamination;
- fencing and security; and
- operating procedures and training (including adherence to the As Low as Reasonably Achievable or ALARA principle).

As noted in the radiation dose to workers section, OPG's proposed radiation and radioactivity monitoring program was designed to verify:

- that construction would not affect the tritium plume from the WWMF;
- that radon levels in the underground will be low;
- releases from underground; and
- dose to the public.

OPG noted that since the Bruce nuclear site Radiological Environmental Monitoring Program would continue, the program data would be used for future local and regional context relative to contributions from the project, as well as for any future requirements for modelling, including air dispersion modelling and food chain modelling. The Radiological Environmental Monitoring Program would also continue to be a primary source of data for use in modelling the dose to the general public. The OPG monitoring commitments listed above would contribute additional relevant data on air, surface water, groundwater and sediments (but not soils).

Recommendation 9.6: In order to confirm the environmental assessment prediction of no significant adverse effects from exposure to radiation for members of the public, including members of Aboriginal groups, OPG shall add the collection of soil samples within the Site Study and Local Study Area to the Radiological Environmental Monitoring Program for the DGR during the Construction Phase.

<u>Government Agency Review of OPG's Assessment of Radiation Effects on Public Health</u>

CNSC staff stated that the methods used by OPG to assess radiation doses to members of the public were well established and that the resulting doses were acceptable. CNSC staff further stated that radiation and radioactivity resulting from the project were not likely to result in significant adverse effects on the health of humans, taking into account the implementation of mitigation measures. CNSC staff pointed out that radon concentrations at uranium mine sites are at background levels at distances one to two kilometres away from emission sources. CNSC staff further confirmed that OPG's modeling of atmospheric dispersion of contaminants, such as radon, at the DGR site was appropriate for the assessment of radiation effects on human health.

Health Canada concurred that OPG had properly characterized the potential human health effects resulting from changes in the radiological environment caused by the proposed project. Health Canada stated that the mitigation measures proposed by OPG to reduce human health risks associated with radiation exposure were appropriate.

Environment Canada found OPG's methods for modelling the dispersion of radionuclides, notably tritium and carbon-14, to be appropriate. Environment Canada pointed out that the maximum human dose as a result of peak DGR emissions was estimated to be 0.0021 to 0.0056 mSv/yr, which was less than the Bruce nuclear site dose of 0.0044 mSv/yr, based on 2009 Regional Environmental Monitoring Program data. Environment Canada noted that although radon concentrations on the site could potentially increase during the construction and operations phases by natural emission from rock excavation surfaces, in exhaust ventilation air, and by release from the waste rock pile, these emissions would be quite small relative to background radon concentrations. Environment Canada stated that the radon emissions would pose no offsite human inhalation hazard.

Views of Participants Regarding Radiation Effects on Public Health

Many participants expressed concerns regarding radiation effects on public health; however, these concerns were more general in nature. These concerns are discussed in later sections of this chapter. Other participants expressed the view that the dose to the public from the project would be acceptably low and meet regulatory limits, particularly once the waste has been moved from the WWMF and emplaced in the DGR.

Panel Conclusion Regarding Effects of Radiation on Public Health

The Panel concludes that changes in radiation exposure is not likely to result in significant adverse effects on human health because the predicted doses, which were derived using conservative assumptions, were well below the regulatory public dose limit. The Panel is satisfied that OPG adequately characterized the public radiation hazards and proposed acceptable mitigation measures.

The Panel understands that some participants did not accept regulatory dose limits as representing a sufficient level of protection. Furthermore, the Panel heard many concerns about the existing levels of tritium in the Local Study Area as well as calls for more health baseline studies. These topics are discussed later in this chapter.

Panel Conclusion Regarding Significance of Effects of Physical Changes in the Environment on Human Health

The Panel concludes that physical changes in the environment caused by the project, specifically air quality, noise and radioactivity levels, are not likely to result in significant adverse effects on the health of the general public, including people living near the project site, provided mitigation measures are implemented and are effective. This conclusion is based upon the Panel's confidence that effects have not been underestimated, due to the highly conservative nature of the modelling, and the assumption that OPG will fully implement all mitigation and will conduct sufficiently rigorous follow-up monitoring.

Effects on Socio-economic, Cultural and Emotional Determinants of Health

This section describes the Panel's assessment of the effects of the project on socio-economic, cultural and emotional determinants of health.

Health Effects Associated with Socio-Economic Determinants

OPG evaluated the effects of the project on socio-economic determinants through estimation of changes in income, education, health care and social services, health behaviours and employment. Estimated changes were modelled as part of the socio-economic assessment (see Chapter 11).

OPGs socio-economic assessment indicated that the project would create modest employment opportunities over the long term relative to the existing labour force at the Bruce nuclear site.

There would also be some induced employment in sectors providing goods and services to OPG. OPG noted that most project jobs would be skilled, with incomes that could result in increases in household spending, more access to better quality foods, and recreational activities. OPG added that skilled jobs are also associated with higher self-confidence and associated health benefits.

The Saugeen Ojibway Nation and the Métis Nation of Ontario raised socio-economic concerns that they believed could, in turn, affect the health and well-being of Aboriginal communities. The Saugeen Ojibway Nation expressed concerns about the effect of stigma on tourism because they currently derive economic benefits from the operation of tourist facilities such as cabin rentals. The Métis Nation of Ontario pointed out that Métis people are typically lower income; therefore, any increase in the price of land or rental housing would have a negative effect.

Public attitude research conducted as part of OPG's socio-economic assessment indicated that the presence of the project was seen by some community members as an indication of the long-term viability of the nuclear energy industry. OPG suggested that this expectation could contribute to positive attitudes toward the future well-being of the community.

OPG stated that the project would be the first of its kind in North America; therefore it would provide unique learning opportunities for students from the Local and Regional Study Areas as well as students from Ontario and beyond. It can be assumed that professional learning opportunities among DGR employees would contribute to the overall positive effect.

OPG did not predict adverse effects on the use and enjoyment of community recreational activities due to dust, noise, changes in demand as a result of increased project associated population or as a result of effects on community character, particularly regarding stigma. OPG committed to keeping its neighbours and the broader public informed concerning its activities associated with each phase of the project and stated that it would continue to make contributions to the community through its Corporate Citizenship Program.

OPG's socio-economic assessment determined that the project would have a very small effect on demand for health and safety services or social services. In addition, OPG did not anticipate any change in the demographic characteristics of the population. Therefore, no adverse effects were predicted.

The Medical Officer of Health for the Grey-Bruce Health Unit provided information on the importance of health behaviours in determining health outcomes in the region. Lifestyle choices such as smoking, diet, and activity level were major determinants of health. Adverse effects of the project on healthy behaviours could include nuisance effects of noise on recreational sites such as Inverhuron and MacGregor Point Provincial Parks, and Brucedale Conservation Area. As discussed, OPG committed to noise mitigation to prevent adverse effects, and to follow-up monitoring to indicate whether the mitigation measures are effective. OPG also committed to continue its work with various stakeholders to deliver its community and recreational initiatives and to keep its neighbours, Aboriginal communities and the broader public informed concerning the activities at the project site. OPG stated that it would maintain its contribution to the community through its Community Partnership Program.

Health Effects Associated with Cultural Determinants

OPG assessed the effect of the project on access to cultural and heritage sites and access to traditional foods. OPG determined that access to cultural and heritage sites could be disrupted through nuisances such as dust and noise as well as changed aesthetics. OPG committed to mitigate dust and noise effects, including measures to be taken to provide for Aboriginal access and conduct of ceremonies at the Jiibegmegoong burial site (see Chapter 12).

Access to traditional foods and use of the land for traditional purposes was a significant concern of Aboriginal peoples. There was particular concern about access to fish in the Local and Regional Study Area, especially lake whitefish, but also trout, salmon and bass. This concern was expressed by the Saugeen Ojibway Nation as well as the Historic Saugeen Métis and the Métis Nation of Ontario. Potential effects on fish from physical and chemical changes in the environment caused by the project were of concern, with emphasis on effects in MacPherson Bay, Baie du Doré, and spawning streams (these topics are addressed in Chapters 8 and 14). The Saugeen Ojibway Nation also raised concerns about the potential for stigma to be associated with whitefish due to perception and the proximity of the project (see Chapter 11 for a discussion of stigma). The Saugeen Ojibway Nation maintained that such stigma would lead to an avoidance of consuming fish and would also adversely affect the Saugeen Ojibway Nation commercial fishery, with associated economic effects.

The Historic Saugeen Métis and Métis Nation of Ontario expressed concerns about the effects of malfunctions, accidents or malevolent acts at the project site, particularly regarding pollution of water and effects on fish. The Historic Saugeen Métis were also concerned about cumulative effects on harvesting given the presence of wind turbines in the same area. The Historic Saugeen Métis expressed the view that the separation of Aboriginal people from their ancestral lands, for whatever reason, is a great loss and the root of many problems for Aboriginal people. The Métis Nation of Ontario pointed out that the access to or attitude towards traditional use of the land may change due to increased numbers of people using the area, rising land prices, increased rents, and intangible factors such as perceptions related to effects of a waste repository.

From the information presented by Aboriginal groups, including the Traditional Land Use study provided by the Métis Nation of Ontario, the Panel understood that the concern was not just whether there would be physical, chemical or biological changes in traditional lands, but whether there would be a change in attitude towards traditional use of the land because of the presence of the project. When questioned about its methods regarding attitude to traditional use of the land, OPG explained that in the absence of understanding the location and intensity of traditional uses, it was assumed that activities would occur at or near the fenceline of the project. OPG stated that, with the exception of noise at Baie du Doré, it did not identify any residual adverse effects that could potentially affect traditional use. For this reason, OPG stated that that there were no tangible reasons that would cause a change in attitudes.

OPG acknowledged that a nuclear facility can have a special meaning to certain segments of the population, including Aboriginal peoples; however, its assessment of effects on traditional use relied, to a large extent, on tangible effects on the aquatic and terrestrial environment. OPG committed to a continuing dialogue with the Saugeen Ojibway Nation, Historic Saugeen Métis and Métis Nation of Ontario that would include more intangible issues.

Health Effects Associated with Emotional Determinants

OPG evaluated the effect of the project on emotional determinants by considering effects on the use and enjoyment of private property, the perception of health and safety, and community cohesion. Effects were evaluated via the use of community surveys such as the public attitude research, which will be described in Chapter 11 of this report. OPG noted that it had no information specific to Aboriginal communities regarding effects on emotional determinants.

The OPG survey results indicated that a majority of people in the Local and Regional Study Areas did not expect that the project would change their feelings of personal safety and security. The results indicated that residents in the Local Study Area did not believe that the project would become a divisive issue. OPG therefore determined that there would be no effects on emotional determinants of health in the Local and Regional Study Areas.

Views of participants were divided on the subject of the effect of the project on emotional determinants of health. Part of the discrepancy between the OPG survey results and the submissions to the Panel may be due to the low sample size of seasonal residents in the OPG public attitudes research (see Chapter 11). The Panel noted that some of the strongest concerns about the effects of the project came from seasonal residents, but also some permanent residents, whose issues included the potential for a reduction in personal enjoyment of their property, a reduction in their sense of security and safety (particularly with respect to accidents, malfunctions and malevolent acts), and feelings of disenfranchisement and a lack of trust in elected officials.

Effects on Overall Health of Members of the Public

OPG stated that that the physical, socio-economic, cultural and emotional determinants of health for members of the public in the Local and Regional Study Area would not be adversely affected by the project, with the exception of potential adverse effects from exposure to acrolein in air. OPG stated that the acrolein exposures would be dominated by existing conditions and that the effects would not be significant. OPG committed to mitigation measures for air quality and noise. OPG also committed to maintaining its community programs and continuing communication with the public regarding project activities considered important to the overall health and wellbeing of local residents.

Effects on Overall Health of Aboriginal Groups

OPG’s assessment of the overall health of members of Aboriginal communities was also based upon the combination of changes in the physical environment, socio-economic factors, cultural factors and emotional determinants of health. Exposure to acrolein in air was the only adverse effect identified and this effect was not determined to be significant. In addition to its mitigation commitments, OPG committed to continued communication with Aboriginal groups regarding project activities considered important to their overall health and wellbeing.

Panel Conclusion Regarding Effects on Overall Health

The Panel concludes that the project is not likely to result in significant adverse effects on the overall health of the public or Aboriginal groups. The Panel stresses that OPG must continue to engage with members of the public and Aboriginal groups in order to ensure that their concerns about the effects of the project on physical, socio-economic, cultural and emotional determinants of health, including perceived concerns, are addressed.

Members of the Public

The Panel concludes that the project is not likely to adversely affect the overall health of members of the public. The Panel notes, however, that information regarding seasonal users was limited, particularly with respect to socio-economic and emotional determinants. The Panel heard from both permanent and seasonal residents with concerns regarding emotional determinants of health. Notwithstanding the Panel's conclusion regarding project effects on overall health, these concerns require acknowledgement and specific action, to be determined through dialogue between OPG and members of the public. Anxiety is a key emotional determinant of health, regardless of whether physical determinants have been affected or not.

The Panel is of the view that OPG's public engagement program should include plans for explicit dialogue with both permanent and seasonal members of the community who have anxiety and concerns regarding the effects of the project. The Panel notes that participation of personnel from the Grey-Bruce Health Unit in OPG's engagement activities could be beneficial, particularly with respect to addressing concerns related to emotional determinants of health.

Aboriginal Groups

The Panel concludes that the project is not likely to cause significant adverse effects on the overall health of members of Aboriginal communities. However, information regarding intangible effects on traditional use of the land was limited, including any effects on emotional determinants of health caused by the perceived effects of the project on the quality of traditional resources. The Panel expects that explicit discussion of effects on traditional uses, and thus potential effects on determinants of health, will be part of the dialogue associated with agreements between OPG and the Saugeen Ojibway Nation, the Historic Saugeen Métis and the Métis Nation of Ontario.

9.2.3 Additional Issues Raised By Participants

This section describes issues related to public health that were raised by participants in relation to the review. They include radiation exposure and cancer, tritium, and health baseline data.

Radiation Exposure and Cancer

Many participants raised concerns regarding the potential for increased risk of cancer due to radiation exposure. Some participants also expressed concern about radiation-related health effects other than cancer, such as genetic effects in children. A common statement made by several participants was that there is no safe level of exposure to ionizing radiation. This statement was often accompanied by references to the BEIR VII report, *Health Risks from Exposure to Low Levels of Ionizing Radiation*, which deals with doses in the range of near zero up to about 100 mSv of low-LET (linear energy transfer) radiation. The findings of the BEIR VII report supported the “linear-no-threshold” risk model, i.e., the risk of cancer proceeds in a linear fashion at lower doses without a threshold so that the smallest dose would still have the potential to cause an increase in risk of the development of solid cancers and leukemia in humans. Thus, any exposure, including exposure to naturally occurring background radiation or radiation used for medical diagnostics, creates an increased risk of cancer, however small that risk might be.

The definition of “safe” was a central issue for many participants in the review. CNSC staff define an acceptable level of risk due to radiation exposure as one in 100,000. This regulatory definition does not conform with the values of some participants, who argued that acceptable risk levels and dose limits are neither safe nor protective because they contain value judgements about the trade-offs between harm and the benefits of the activities generating the radiation exposure. Some participants had a fundamental objection to *any* incremental exposure to radiation above background, no matter how small.

Uncertainty was another central issue for many review participants, particularly because of the time scale of the project, including postclosure. Some participants made the point that when uncertainty was combined with fundamental issues around what constitutes “safe”, the onus for “free and informed consent” became very high. It was unclear how this consent would be obtained, and by whom.

The above opinions were not shared by all participants. Several submissions emphasized that the risk to human health associated with surface storage of radioactive waste was higher than the predicted risk of placing the waste in a DGR. The Panel received submissions from current and former nuclear workers who expressed satisfaction with the level of protection provided by their employers from the effects of exposure to radiation. The Panel also received written and oral submissions from members of the public who considered the project to constitute an acceptable level of risk to human health.

OPG stated in the EIS that cancer incidence rates in the South West Local Health Integration Network and the Grey Bruce Public Health Unit were comparable to Ontario rates when confounding factors that require consideration were taken into account. Confounding factors included lifestyle, incorporating aspects such as smoking, alcohol consumption, and obesity, genetic predisposition, access to medical care, and education. OPG noted that there were no apparent increasing trends for all types of cancers. Cancer incidence rates for First Nations communities were lower compared to the general population; however, colorectal and lung cancer rates were reportedly increasing.

CNSC staff presented information on recent studies of radiation exposure and cancer that showed no evidence of increased cancer risk among nuclear energy workers or among members of the public living within 25 kilometres of Ontario nuclear power plants. A recent CNSC study on Canadian nuclear energy workers found no dose-related increase in the risk of solid cancer mortality among 42,228 workers from Hydro Québec, New Brunswick Power, Ontario Hydro, and Atomic Energy of Canada Limited, who were first monitored starting in 1965. In another recent peer-reviewed study on members of the public living within 25 kilometres of Ontario nuclear power plants (the RADICON study), the CNSC found no evidence of childhood leukemia clusters around any of the nuclear power plants, including the Bruce nuclear site. There was no consistent pattern of cancer incidence across all ages or sexes, and the incidence of all the cancers investigated for all groups was within the natural variation of disease in Ontario. The study covered the period 1990 to 2008 for cancer incidence and 1985 to 2008 for radiation doses.

CNSC staff noted that studies conducted around 19 other nuclear power plants in other countries had found, for some sites, a relationship between distance and leukemia incidence in children but that, in all those cases, radiation exposure could not explain the relationship. It was found that distance from the nuclear power plants did not necessarily have a direct relationship with radiation exposure, i.e., people living closer to the plants did not always receive higher doses.

CNSC staff described the strengths and limitations of the RADICON study compared with international studies. The main strength of the RADICON study was that there was very good information on doses to members of the public, unlike other studies. Another was the high quality of cancer incidence data in Canada. Radiation emission spikes were taken into account in the study and it was found that emission plumes were drifting away from, not toward the population. CNSC staff found that doses closest to the nuclear power plants were, in some cases, lower than doses much further away because of factors such as prevailing wind directions and lifestyle characteristics of people. The main limitation of the study was that it dealt with the overall population and did not include information on individuals. CNSC staff noted that some studies have taken into account individual information on doses and individual information on cancer; when individuals are tracked, lifestyle variables such as smoking, diet, and exercise can be taken into consideration.

When asked about the use of longitudinal studies, where individuals are tracked over long periods of time, thus accounting for variables such as people moving in and out of areas with nuclear facilities, CNSC staff stated that the focus for such studies was on nuclear workers. CNSC staff explained that more information on cancer risk can be gleaned from studying workers, with specific information on individual doses being gathered and related to health indicators, rather than members of the public, whose doses would be low. The workers also live in the same communities as the general population and are thus also exposed to the same environmental sources, such as food and water.

The Medical Officer of Health for the Grey-Bruce region stated that the primary causes of cancer deaths in the region were tobacco use (30%) and diet, obesity and lack of physical activity (30%). Radiation was estimated to be involved in 3-7% of cancer deaths. Exposure to radon was considered to be the primary contributor to radiation risk.

Panel Conclusion Regarding the Risk of Radiation-related Cancer

Based on the information provided by CNSC staff, Health Canada and the Medical Officer of Health for the Grey-Bruce region, the Panel concludes that the risk of radiation-related cancer from the project would be acceptably low, assuming that the one in 100,000 risk benchmark represents a broad societal consensus. This also assumes that the rejection of any incremental cancer risk above that associated with background radiation, as articulated by some participants, does not have broad societal support.

The Panel took particular note of the results of the CNSC RADICON study, as well as the description of longitudinal studies of nuclear energy workers. The Panel understood that longitudinal studies of the general public would not have as great a potential to yield rigorous results because of the lower doses to the public relative to major confounding factors, such as lifestyle and heredity. The Panel strongly supports the continuing study of radiation-related health risks, including cancer, by the CNSC and suggests that, should the project be approved and constructed, DGR nuclear energy workers be included in CNSC longitudinal studies.

Given the persistence of concerns about radiation and cancer, despite the information provided by OPG, CNSC staff and Health Canada, the Panel has specific recommendations regarding providing enhanced opportunities for public input and engagement. These recommendations are presented in Chapter 11. The Panel places particular emphasis on public engagement regarding radiation and cancer because of the negative effects of anxiety associated with this topic. The Panel makes the following recommendation in this regard:

Recommendation 9.B: The Panel recommends that the CNSC continue to participate in international studies seeking to identify long-term health effects of low-level radiation exposures and suggests that DGR nuclear energy workers be included in CNSC longitudinal studies.

Tritium Levels Relative to Current Baseline Conditions

The Panel heard many expressions of concern specifically about tritium levels in surface water, groundwater, and food in the Local Study Area. The Panel focused on the incremental contribution of the project to baseline tritium levels.

Incremental Airborne Tritium Emissions

OPG stated that the primary source of tritium from the project would be off-gassing from waste packages, particularly non-processible low-level waste in drums and bins, which are not generally sealed air-tight. About 0.4% of the total tritium in the waste would be released per year. The tritium would enter the air, primarily in the form of tritium oxide, and then be deposited to soil and water via precipitation.

OPG noted that the airborne tritium pathway already exists at the WWMF, resulting in releases ranging from 0.0007% to 6.47% of the total tritium released annually from the Bruce nuclear site from 2001 to 2009. These emission levels ranged from 0 to 0.04% of the allowable derived release limits, which are based on the annual public dose limit of 1 mSv/yr.

OPG predicted that, initially, the project would result in no net change in total tritium released by off-gassing and, therefore, no change in total tritium in precipitation. The only change would be the location of tritium emissions, with more occurring within the DGR site and less within the WWMF site. OPG predicted that the DGR would eventually result in a small reduction in tritium concentrations in precipitation relative to current concentrations as waste packages are isolated underground. The estimated airborne tritium emissions during DGR operations were predicted to be about 0.2% to 0.3% of the emissions from the Bruce nuclear generating stations. There would be no emissions from the DGR after closure under the normal evolution scenario.

OPG calculated that operation of the DGR would result in a lower exposure to tritium at the critical group location BF14 relative to the baseline exposure from 2009. The ratio of tritium oxide concentration at the BF14 location in 2009 to the projected concentration in 2023, the year with the estimated highest emissions from the project, was 5.9. In other words, exposure to tritium oxide from the project at the BF14 location would be at least 5.9 times lower than baseline exposure to tritium oxide emissions from the WWMF. OPG estimated the dose to an adult at the BF14 location from a combination of tritium oxide and carbon-14 exposure to be 0.001 mSv/yr, which is 2.3% of the total dose received by an adult at that location in 2009.

Incremental Waterborne Tritium Emissions

OPG predicted that waterborne emissions of tritium from the DGR would be much lower than airborne emissions. OPG noted that waterborne emissions from the WWMF were less than 0.01% of the total releases for the Bruce nuclear site releases and 0.001% to 0.004% of derived release limits.

OPG stated that all waterborne emissions from the project would be directed through the water management system to the stormwater management pond. Sources would include process or service water used in the DGR, groundwater seepage into the underground facility, and shaft condensation water. OPG noted that groundwater in the shallow aquifer beneath the DGR site would be isolated from surface waters and the stormwater collection system by a thick till layer. Therefore, any tritium in this groundwater, in particular from the WWMF, would not normally be released into the DGR stormwater management system, except possibly during the early DGR shaft construction phase as the shafts are being excavated through the shallow aquifer. The Panel has outlined recommendations in Chapter 8 which address the possible interception of a tritium plume during shaft sinking.

OPG predicted that annual average tritium levels in the stormwater management pond would be highest during site preparation (1240 Bq/L) and during operations prior to closure of Panel 2 (1620 Bq/L). OPG estimated tritium levels during construction and operations before closure of Panel 1b to be 360 and 420 Bq/L, respectively.

OPG assumed that the discharge from the stormwater management pond to MacPherson Bay would be mixed with the nearshore current flow in a manner similar to that of the current WWMF discharge, which is via the south railway ditch to Stream C and then to Baie du Doré. OPG noted that derived release limits for the discharge of tritium and other radionuclides of concern from the stormwater management pond would be imposed to be protective of the water quality and aquatic biota of MacPherson Bay.

Effects of Tritium Emissions on Drinking Water Supplies

Lake Huron is the only potable water source that has the potential to be affected by the project via either airborne or waterborne tritium emissions. However, the OPG assessment showed that the incremental amounts of tritium in Lake Huron that would be contributed by the project would be zero via air emissions and negligible via waterborne emissions during site preparation and construction, operations and decommissioning. OPG noted that tritium was not predicted to reach either groundwater or surface water used for drinking water during the postclosure phase of the DGR (normal evolution scenario) because it decays in a few hundred years.

OPG stated that groundwater wells used for drinking water would not be affected by the project. Both OPG and CNSC staff confirmed that there are no groundwater wells within the Bruce nuclear site used as a drinking water source, including WWMF monitoring wells. OPG noted that all monitoring wells are controlled and inaccessible to the public, and are constructed in such a way that they cannot be used for drinking water. OPG further noted that, when monitoring wells are no longer required, they must be abandoned in accordance with the requirements of the Ontario Ministry of the Environment and Climate Change and the Ontario *Water Resources Act* O. Reg 903, which establishes requirements and record keeping for well abandonment. OPG stated that there was no expectation that a potable groundwater supply would be established down-gradient of the project prior to the closure of the project.

Tritium in Food

OPG stated that the project would not be expected to produce incremental tritium levels in milk, vegetables, fruits, meat or fish. OPG explained that this was because there were no predicted incremental emissions to precipitation, which is the primary pathway for tritium in food.

Doses from Tritium Exposure

CNSC staff presented information regarding doses to the public associated with the airborne and waterborne releases of tritium (plus carbon-14 and gamma radiation) during the operations phase. Estimated doses were in the order of 0.001 mSv/yr. CNSC staff noted that adverse health effects would not be expected at this low dose level, as indicated by the RADICON study described above.

OPG included tritium in the postclosure safety assessment for the normal evolution and disruptive scenarios and calculated the maximum incremental tritium concentrations in surface media, including well water, irrigated soil, sediment, and surface water. They were all found to be negligible due to radioactive decay within the DGR. In particular, the calculated incremental surface concentrations were less than 10^{-7} Bq/L in well and surface water, and less than 10^{-7} Bq/kg in irrigated soils and sediments, including the severe shaft seal failure scenario. These are orders of magnitude below natural background tritium levels. OPG determined that the only situation where tritium would be an important source of radiation exposure would be if human intrusion into the DGR were to occur up to 100 years after closure.

Panel Conclusion Regarding Incremental Tritium Levels Relative to Current Baseline Conditions

The Panel concludes that the project will result in either no net change or a decrease in tritium concentrations in air, water or food during site preparation, construction and operations. The Panel has determined that the project would result in a decreased risk from exposure to tritium relative to the WWMF on the surface, once waste is placed in the repository and isolated from the surface environment.

The Panel notes that tritium exposure would be important if the human intrusion scenario were to occur within 100 years of repository closure. The topic of the timing of human intrusion relative to OPG's assumption of institutional controls preventing such intrusion for 300 years is discussed in Chapter 13.

Health Baseline

The Panel heard several requests from participants for additional health baseline data from the Local and Regional Study Areas, particularly with respect to distinguishing effects of radiation exposure, or exposure to other constituents of concern such as particulates, from other health stressors. Accordingly, the Panel requested information from CNSC staff and the Medical Officer of Health for the Grey-Bruce Health Unit regarding the current health baseline information for the region.

CNSC staff pointed out that there are many administrative mortality and morbidity databases and large national health surveys in Canada, which are used to assess the health of Canadians. CNSC staff noted that many of these databases are historical, some dating back as early as 1950, and can provide baseline health information for the community prior to the existence of the Bruce nuclear power plant.

CNSC staff further noted that other health information is available for Grey-Bruce County, including socio-demographic characteristics, health status, health behaviours, determinants of health and health inequalities, as well as healthy child development. CNSC staff reported that the Grey-Bruce Public Health Unit compares various health indicators with the province as a whole. For example, when compared to Ontario as a whole, Bruce County has lower rates of stillbirths, lower rates of low birth weight, lower rates of congenital anomalies, similar rates of infant death, and similar levels of childhood leukemia. For the period 1986 to 2004, trends in cancer incidence and mortality rates were similar to Ontario.

The Medical Officer of Health for the Grey-Bruce Health Unit expressed interest in the RADICON study and pointed out that while the Unit releases its own cancer report based upon data from Cancer Care Ontario about every five years, the numbers are too small, due to lower population numbers, to conduct analyses for significance. The Medical Officer of Health also pointed out that a longitudinal study of the public within the Grey-Bruce Health Unit would be difficult, expensive, and unlikely to include sufficient numbers of individuals to constitute a reliable study.

The Medical Officer of Health also provided the Panel with a description of reports on health and wellness in the Grey-Bruce Health Unit. According to the Medical Officer of Health, these reports are widely published and the results can be examined at the county and even the municipality level. The Medical Officer of Health noted that indicators include the general state of health, leading causes of death, and leading causes of cancer, and that recent reports had focused on the six priority areas identified by the Ontario Ministry of Health and Long-term Care: physical activity, injury prevention, healthy eating, smoking cessation, substance and alcohol misuse and mental health promotion.

Panel Conclusion Regarding Human Health Baseline

The Panel concludes that there are sufficient baseline health data for the Local and Regional Study Areas. The Panel understands that extensive health data are collected from these areas by agencies such as Statistics Canada, Ontario Cancer Care and the Grey-Bruce Health Unit. The Panel accepts the judgement of CNSC staff and the Medical Officer of Health with respect to the adequacy of the current baseline and the emphasis on specific studies such as the RADICON study and longitudinal studies of nuclear energy workers.

Notwithstanding the Panel's conclusion, the persistent concerns from some participants indicated to the Panel that there is a need for increased and/or improved engagement with the public regarding issues associated with the potential for health effects from exposure to both radiological and non-radiological emissions from the project. Public engagement is discussed in Chapter 11.

Panel Conclusion Regarding Additional Issues Raised By Participants

The Panel concludes that the issues raised by participants regarding radiation risk and cancer, tritium, and baseline health data were adequately dealt with in the review. As noted, the Panel is of the view that there is a need for increased and/or improved engagement with the public regarding issues associated with the potential for health effects from exposure to both radiological and non-radiological emissions from the project.

9.3 PANEL CONCLUSION REGARDING EFFECTS OF THE DGR ON HUMAN HEALTH

The Panel concludes that the project is not likely to result in significant adverse residual effects to human health, taking into consideration the commitments made by OPG, the proposed mitigation measures, and the additional recommendations from the Panel. The Panel is of the view that OPG adequately described the likely residual effects of the project, as well as their significance, for workers, local residents, seasonal users and members of Aboriginal communities. The Panel emphasizes that it is important that OPG, and the CNSC, continue to engage with persons who have an interest in the project and its effects on human health.

CHAPTER 10 MALFUNCTIONS, ACCIDENTS AND MALEVOLENT ACTS

This chapter provides the Panel's assessment of malfunctions, accidents and malevolent acts that could occur over the preclosure period of the DGR, which includes the Site Preparation and Construction, Operations, and Decommissioning phases. The abandonment phase and long-term performance of the DGR phase are discussed in Chapter 13. This chapter includes an assessment of the environmental effects of conventional and radiological malfunction and accident scenarios, malevolent act scenarios, and measures to mitigate these effects. It also includes a discussion regarding operating experience at international waste repositories.

10.1 OPG'S APPROACH TO THE ASSESSMENT OF MALFUNCTIONS, ACCIDENTS AND MALEVOLENT ACTS

OPG used a formal process of identifying events, features or processes that could initiate malfunctions, accidents, or malevolent acts. OPG screened the likelihood of the events occurring using conservative bounding assumptions, and by assessing the significance of adverse effects that could result from the events. OPG assessed the significance of the effects taking into consideration design planning, safety features, experience and the application of mitigation measures.

Only credible events were assessed. According to OPG, a credible scenario would have a potential annual frequency of occurrence of greater than one in ten million (10^{-7}). Events having frequencies less than this would have very low potential for occurrence and were deemed by OPG to be non-credible. CNSC staff stated that OPG had adequately described credible and non-credible malfunctions, accidents and malevolent acts for the preclosure phases of the proposed DGR.

10.2 CONVENTIONAL MALFUNCTIONS AND ACCIDENTS

Conventional malfunctions and accidents are those that could result in direct or indirect effects on the environment through the release of non-radiological substances to the environment.

10.2.1 Selected Scenarios for Conventional Malfunctions and Accidents

OPG's assessment of conventional malfunctions and accidents included the Site Preparation and Construction, Operation and Decommissioning phases. OPG stated that there was no potential for non-radiological malfunctions or accidents to occur in the postclosure phase because there would be no physical works during that period.

OPG presented 23 separate initiating event scenarios and their potential frequencies of occurrence that could result in the release of non-radiological contaminants. OPG identified 13 credible conventional malfunctions and accidents that could be initiated by these events during

DGR construction and operations phases. OPG identified five malfunctions or accidents that would have potential adverse effect on the humans and non-human environments. Potential initiating events for non-radiological malfunctions and accidents assessed by OPG included fire; explosion/detonation; electrical accidents; spills of fuel chemicals, lubricants or oils; and vehicle accidents. OPG stated that the two bounding (most significant) accident scenarios that could result in potentially significant adverse environmental effects at the DGR site were: a liquid (chemical, fuel, lubricant) spill, which could occur at any phase of the project; and an explosion, which could develop only during the site preparation and construction phase.

10.2.2 Potential Effects of Conventional Malfunctions and Accidents

OPG assessed the potential effects of the two bounding non-radiological malfunctions and accidents on workers, the public and non-human biota. OPG's spill scenario was based on a maximum spill volume of approximately 4,500 L of diesel fuel, 200 L of a chemical or 100 L of a lubricant or oil, and assumed that mitigation measures would be taken following a spill. OPG determined that a spill was not likely to adversely affect air, surface water or groundwater quality; only vegetation within the immediate vicinity of the spill could be contaminated. In the explosion scenario, OPG stated that there would be a localized release that may interact with air quality and noise.

On the basis of its screening and effects assessment, OPG determined that credible malfunctions and accidents would not result in exceedances of non-radiological criteria, identified in its Malfunctions, Accidents and Malevolent Acts Technical Support Document, for workers, members of the public, and non-human biota. Effects on each of these are reviewed in more detail below.

Workers

OPG assessed and screened worker safety and occupational hazards relating to malfunctions and accidents. OPG noted that occupational accidents were considered collectively and with no bounding case evaluation. OPG outlined 28 hazardous activities that could occur during various preclosure stages of the DGR. Many of these hazards had the potential for serious consequences to workers, including personal injury or death. OPG stated that, provided that mitigation and control measures are used, it was anticipated that there would be no unacceptable risk to workers. OPG was of the view that, given the implementation of its Emergency Management Plan and occupational health and safety practices, adverse effects to worker safety were not likely during the preclosure period. CNSC staff concurred, noting that OPG's screening and assessment of hazards was extensive, credible, and clearly articulated.

Based on review of mining and nuclear industry operating and regulatory practices, CNSC staff determined that the malfunction and accident screening procedures used by OPG to identify worker hazards were sound and reasonable. CNSC staff noted that the principal worker safety hazards that could develop during DGR site preparation and construction phases would be the result of conventional mining and construction accidents. OPG acknowledged that, in the mining sector, the primary causes of worker injuries and deaths are related to rockfalls and underground vehicular traffic accidents. OPG stated, however, that mitigation and control measures at the DGR would result in a low likelihood of conventional accidents.

Public

OPG stated that only spills of chemicals or other liquids had the potential to adversely affect off-site members of the public. OPG determined that only vegetation within the immediate vicinity of a spill could be contaminated, and since the public cannot access the Bruce nuclear site, there was no potential that the public could come into direct contact with any potentially contaminated vegetation. Therefore, a spill at the DGR site would not have an adverse effect on members of the public. CNSC staff concurred with OPG's assessment.

OPG explained that explosion accidents during site preparation would be localized to the DGR site area and would result in a release of only noise and dust emissions to the atmosphere. These effects would be similar to those occurring during normal construction and operations activities, which, as was described in Chapter 9, would have little effect on air quality.

Some participants expressed concern that an explosion at the DGR site could potentially affect the Bruce nuclear generating station. OPG acknowledged that an explosion on the Bruce nuclear site may have an effect on people’s feelings of well-being and sense of safety and security, however, the effects of such an explosion would be limited to the DGR site and not result in the release of any radiation.

Non-Human Biota

OPG noted that spills within the DGR site or underground, if not effectively retained, could affect the site and its surroundings through aqueous dispersion. Response plans would need to be in place to prevent spills from entering the stormwater management pond. Should such efforts prove ineffective, procedures would need to be in place to prevent any further dispersion of contaminants.

OPG stated that diesel fuel or chemical spills would have restricted, on-site local impacts that would not cause changes to air quality, surface water and groundwater quality. OPG stated that spills within the surface drainage zones of the DGR site would be collected in the stormwater management ponds and held for treatment by emergency response procedures and equipment. OPG determined that it was not likely that spills would cause adverse effects on surface water quality. OPG also stated that spills could potentially cause changes to subsurface soil and geosphere quality, but these would be easily mitigated and would not be likely to result in significant adverse effects.

OPG determined that there would be no significant adverse effects on MacPherson Bay or adjacent areas in Lake Huron resulting from malfunctions or accidents. OPG explained that a spill would not reach Lake Huron and would not affect water quality, including water used for drinking or for recreational contact. OPG determined that an explosion would not affect Lake Huron water quality. OPG stated that aquatic and terrestrial biota would not be affected unless within the immediate vicinity of the spill or explosion.

OPG stated that adverse effects on the terrestrial environment as a result of a spill were unlikely. OPG explained that, as no adverse effects on other environmental components were identified, there were no pathways through which indirect effects on the terrestrial environment could occur.

10.2.3 Mitigation for Conventional Malfunctions and Accidents

OPG stated that its management strategy for the DGR was to develop, construct, operate, decommission and close the DGR in a manner that would protect workers, the public, and the environment from accident risk, while meeting or exceeding applicable regulatory requirements. OPG proposed that enhanced safety management features, such as the availability of on-site emergency response teams to respond to fires and spill events, would function throughout the preclosure period of the project. OPG stated that enhanced management features for the DGR, in addition to conventional accident prevention measures, would be provided by rigorous adherence to OPG's management and regulatory control procedures, as well as to Ontario mining regulations. OPG noted that emergency response for fire and other accident events at the DGR would be handled by the Bruce Nuclear Emergency Response Team, mine rescue teams and other local service providers.

OPG predicted that potential effects of malfunctions and accidents at the DGR underground site on humans and non-human biota would be reduced by implementing mitigation and contingency measures. OPG identified relevant mitigation measures for conventional malfunctions and accidents, including:

- monitoring;
- qualified workers, work permits, worker awareness, personal protective equipment and operator training;
- planned/preventative equipment maintenance;
- equipment design installation and operation to meet established safety permits;
- emergency response capability;
- access to refuge stations, multiple exits and safety equipment;
- emergency communication systems;
- fire detection and suppression equipment; and
- safe work practices.

OPG stated that its contingency planning during the preclosure period would make use of administrative controls, enhanced worker training and specialized emergency response training, such as mine rescue. OPG's administrative control measures would include policies for nuclear waste management and spills management, consistent with OPG's environment policy. OPG noted that emergency management procedures for its WWMF operations were regulated by OPG's Nuclear Waste Management Policy, its Nuclear Waste Management Division Environment Health and Safety Program and by Ontario's *Occupational Health and Safety Act*. The Ontario Ministry of Labour stated that, in terms of conventional occupational health and safety matters, it would provide emergency management assistance to the DGR throughout all preclosure phases.

OPG indicated that spill mitigation would be conducted by well-equipped and well-trained on-site spill response teams from its Nuclear Waste Management Division at the WWMF. OPG proposed to have spill containment measures and conduct vegetation clearing during the site preparation phase to contain effects within the site area and to protect the terrestrial environment. Environment Canada noted that OPG had not presented a detailed spill response plan that included an assessment of containment methods, locations of spills, and strategies to demonstrate that spill mitigation could be deployed in time to prevent downstream effects. Environment Canada recommended monitoring a broad spectrum of parameters, such as other metals, phosphate, and total hydrocarbons during all phases of the project to ensure that there would be no other unanticipated parameters of concern. Environment Canada stated that effluents from potential spills at the DGR facility would have to be treated in order for OPG to be in compliance with the *Fisheries Act*.

Effects on workers from explosion accidents were considered by OPG to be minimized through the use of appropriate regulatory controls, training and handling restrictions. As was described in Chapter 6 of this report, OPG's planned use of explosives at the DGR during construction would be limited in accordance with regulatory requirements and operational controls imposed for transport, storage and use of explosives. For example, no explosives would be stored underground during any part of the construction phase. Limited quantities of explosives would be transported to blasting sites and only for short periods immediately prior to use.

CNSC staff stated that the mitigation and control measures proposed by OPG were acceptable. CNSC staff noted that conventional accident hazards could be appropriately managed by the implementation of best practice standards for mining, and the adoption of conventional health and safety programs and emergency management programs.

10.2.4 Significance of Residual Adverse Effects of Conventional Malfunctions and Accidents

OPG stated that, with the application of its existing proposed mitigation and control measures, the project was not likely to cause significant adverse effects as a result of conventional malfunctions and accidents. CNSC staff agreed with OPG's assessment.

10.2.5 Panel Conclusion Regarding Conventional Malfunctions and Accidents

The Panel concludes that the bounding conventional malfunctions and accidents assessed by OPG are not likely to cause significant adverse environmental or human health effects. The Panel is satisfied with OPG's assessment of non-radiological malfunctions and accidents. OPG identified credible non-radiological malfunctions and accidents based on its reviews of past and current practices within the mining and nuclear industries. OPG's assumed conditions for each malfunction and accident event, such as spill volume and location, were logical and reasonable.

The Panel has determined that the mitigation and control measures outlined by OPG, including in-design engineered control features and use of emergency contingency planning, were well described and must be implemented. The Panel's conclusion is contingent upon OPG's application of its fire protection and emergency and spill response procedures. OPG's procedures should include effective incorporation of operational experience both from OPG and from the nuclear and mining industries world-wide.

Recommendation 10.1: OPG shall implement the mitigation measures and contingency plans identified in Table 5.3.3-1 and Section 5.5 of the Malfunctions, Accidents and Malevolent Acts Technical Support Document to the satisfaction of the CNSC, during site preparation, construction, and operations.

The Panel is satisfied that OPG has presented mitigation measures for spills, including a spill response plan. However, the Panel agrees with Environment Canada that a more detailed spill response plan, including spill scenarios, is required. The type and location of plausible spills would need to be better defined in order for OPG to determine the most effective mitigation methods and the most effective deployment of appropriate equipment in the event of a spill.

Recommendation 10.2: In order to avoid significant adverse environmental effects, including effects to fish or fish habitat, due to malfunctions, accidents or malevolent acts, OPG shall develop and implement a detailed spill response plan for all phases of the project. The spill plan must be acceptable to the CNSC and include an assessment of containment methods, locations and strategies to demonstrate that spill mitigation will be deployed in time to prevent downstream effects.

The Panel notes that the failure of underground support system components that may result in rockfalls and transportation-related incidents should be considered by OPG as probable, though not bounding, accident events. The Panel is of the view that, with the implementation of OPG's proposed operating measures, worker safety would be maintained at levels similar to or better than those of comparable commercial mining operations in the Province of Ontario. To achieve these goals, OPG's safety management systems must prioritize the mitigation measures of the malfunction and accident events that possess the highest likelihood of occurrence. The Panel is confident that OPG would apply similar emergency management procedures and policies that it uses at the WWMF to its proposed DGR. Relevant mitigation measures and contingency plans for conventional malfunctions and accidents must be adopted and applied through all stages of the project.

Recommendation 10.3: OPG shall develop and implement a plan, prior to site preparation, to reduce the likelihood of underground vehicular traffic accidents and rockfall accidents, to the satisfaction of the CNSC.

10.3 RADIOLOGICAL MALFUNCTIONS AND ACCIDENTS

Radiological malfunctions and accidents are those that could result in a release of radioactive substances.

10.3.1 Selected Scenarios for Radiological Malfunctions and Accidents

OPG identified radiological malfunctions and accidents that could occur during each phase of the project, and assessed the potential effects of each on workers, members of the public, and non-human biota. OPG ruled out the possibility of a radiological accident occurring during the site preparation and construction phases because there will be no handling of radioactive waste during each of those phases. CNSC staff agreed that, in the preclosure period, radiological effects on workers, members of the public and non-human biota would be likely to develop only during the operations phase of the DGR.

OPG identified five credible radiological malfunctions and accidents that could occur during the operation phase: fire, low-energy and high-energy container breaches, inadequate shielding, and a ventilation failure. OPG determined that only two operational accident/malfunction initiating events, these being an equipment failure and a low-level waste package drop, could pose credible risk of occurrence and have potential radiologic exposure effects on humans and non-human biota. OPG noted that the credible accident scenarios with the highest potential inventory at risk were identified as the bounding accidents.

During the decommissioning phase, waste materials would be isolated from humans and the surface environment. OPG assumed that credible radiological malfunctions and accidents that could occur during this phase would be bounded by operation phase scenario conditions.

Some participants expressed concerns regarding the combustion of zirconium, a metal present in reactor pressure tubes. They suggested that the ignition of zirconium dust in waste containers could result in a greater release of radionuclides than had been considered by OPG. OPG stated that zirconium combustion was a recognized hazard that had been appropriately addressed in its assessment scenarios. CNSC staff concurred with OPG, and stated that potential combustion effects of metal components of the waste materials, in particular zirconium, would not substantially alter contaminant releases from the DGR under the scenarios considered.

10.3.2 Potential Effects from Radiological Malfunctions and Accidents

In its assessment of all malfunction and accident scenarios, OPG determined that radiological exposures to members of the public, workers and non-human biota would be well below regulatory dose criteria.

OPG explained that the consequences of an accidental release would be limited because only a small number of packages and a small quantity of L&ILW would be handled at any time. The project design included measures to control accidental releases, so that the concentrations of radionuclides in environmental media would be greatly reduced. OPG further stated that accidents would be cleaned up as soon as possible, which would make the effects localized and short in duration.

Workers

OPG stated that, based on its assessment of credible scenarios, the bounding case radiological exposure to workers, based on a five-minute exposure time, would be well below the limit of 50 mSv/yr. OPG explained that, for workers in close proximity to the release, the doses were expected to vary from 0.01 to 6 mSv. As such, applicable criteria for workers would not be exceeded. CNSC staff concurred with this assessment.

Some participants questioned whether OPG had assessed scenarios where workers were trapped in proximity to waste packages for longer than five minutes. OPG responded that while such scenarios could result in higher doses, they were unlikely to occur due to the preventive measures that would be in place. These included the controlled movement of waste packages and having work plans to avoid hazards to workers. OPG also pointed to its radiation protection experience at the WWMF.

Public

OPG stated that, based on its assessment of credible scenarios, the doses to members of the public for a one-hour exposure at the Bruce nuclear site boundary would be below the 1 mSv/yr per year regulatory limit for the public. OPG explained that calculated doses to the public from a radiological release associated with a fire, or other accident resulting in failure of a waste package, ranged from 0.02 to 0.004 mSv, which are orders of magnitude below the regulatory limit. OPG noted that it also assessed more unlikely longer time periods and determined that doses were still below the limit. As such, the applicable criteria for members of the public would not be exceeded. CNSC staff concurred with this assessment.

OPG stated that it did not expect that there would be any releases of radiological substances as the result of explosions during the site preparation and construction phases of the project.

Although not considered to be part of the DGR environmental assessment, participants expressed concern over the potential for transportation-related accidents and their impacts on the public during the shipment of radioactive wastes from nuclear reactor sites to the WWMF. CNSC staff stated that the transportation of waste to the WWMF was an already-licensed activity. CNSC staff explained that the transportation of nuclear substances and radioactive materials such as radioactive waste is governed by the *Packaging and Transport of Nuclear Substances Regulations* "(SOR/2000-208), which are under the *Nuclear Safety and Control Act*, and Transport Canada's *Transportation of Dangerous Goods Act*, 1992 (1992, c. 34). OPG stated that in the over 40 years that it had been shipping to the WWMF, it had had six minor accidents, and that no radiological releases had occurred.

Non-Human Biota

OPG stated that only individual flora and fauna in the immediate vicinity of the project would be affected by a radiological accident, and that the overall populations of non-human biota would remain unaffected, in particular those populations spanning Bruce County. OPG also stated that, based on its assessment of credible scenarios, the applicable criteria for non-human biota would not be exceeded. CNSC staff concurred with this assessment.

10.3.3 Mitigation for Radiological Malfunctions and Accidents

As previously mentioned, OPG stated that unplanned releases would be controlled and cleaned up as soon as possible. Mitigation measures would include:

- minimization of combustible materials and ignition sources, especially near waste packages;
- waste package design;
- use of overpacking and shielding on higher activity packages;
- limited number of packages handled in any transfer;
- limited equipment speeds;
- fire detection and suppression equipment, such as automatic fire suppression systems on diesel transfer equipment;
- appropriate follow-up measures corresponding to the results of contamination and dose rate monitoring;
- access to refuge stations and safety equipment;
- appropriate worker training and operating procedures; and
- emergency communication systems.

OPG noted that these measures were considered within the design of the project and could be further emphasized during detailed design and later during operation.

CNSC staff deemed the control and mitigation measures proposed by OPG for radiological malfunction and accident events to be appropriate for reducing the likelihood and consequences of these events. CNSC staff indicated that, in addition to complying with all legislated requirements of the Ontario *Occupational Health and Safety Act*, OPG would be required to plan for the establishment of emergency and fire protection measures for protection of workers. CNSC staff recognized that OPG has satisfactory radiological spill response procedures in place at the WWMF, and expected that such spill response procedures would continue to be used by OPG during DGR construction and operation phases.

OPG's emergency response plans indicated how emergencies would be handled for surface, underground and off site situations relating to health and safety, equipment or material damage and other incidents such as fires or weather-related events. In response to a question from the Panel, OPG assessed the effectiveness of using HEPA (high-efficiency particulate air) filter systems to mitigate particulate contaminant releases from exhaust air into the surface environment in the event of fire or waste container breach events in the underground repository. OPG predicted HEPA filtration would not reduce the radiological dose to members of the public. In addition, only small changes in non-radiological doses would be expected following filtering of particulate releases from fire events. For fire and container breaching events, dose consequences for contaminant releases by way of the ventilation exhaust were predicted to be below acceptable levels at all receptor locations. OPG confirmed that the DGR would operate within the boundary of the Bruce nuclear site, have emergency response capabilities provided by Bruce Power and have the Municipality of Kincardine's own emergency response and medical facilities coordinated with the DGR.

Representatives of the Ontario Ministry of Community Safety and Correctional Services, who oversee the Provincial Nuclear Response Plan, stated that they have a mandate under the

Emergency Management and Civil Protection Act to monitor, coordinate and assist in the development of emergency management programs arising in connection with nuclear facilities. The Ministry stated that the Provincial Nuclear Response Plan would be applicable to the proposed DGR, a nuclear facility, should a potential or actual hazard to public health or the environment develop from ionizing radiation. The Ministry identified that integrated response plans exist between nuclear facility operators, municipalities and provincial agencies to prepare for and respond to nuclear emergencies or security threats at nuclear sites. Coordination of emergency response protocols is managed through Emergency Management Ontario. The Ontario Ministry of Community Safety and Correctional Services noted that it would only provide emergency management assistance to the DGR upon commencement of the operations phase, when radiologic materials would be emplaced within the facility.

The Ontario Ministry of Labour, in addition to regulating conventional occupational health and safety workplace aspects at nuclear facilities, also operates a Radiation Protection Services laboratory and enforcement branch to maintain protection for workers and the public from radiation hazards. The Ontario Ministry of Labour also has responsibility through operation of its Radiation Protection Services to conduct reactor surveillance in order to ensure public health and safety associated with particulate, gaseous and liquid radiological emissions and uptake from nuclear facilities. The Ontario Ministry of Labour would also undertake environmental monitoring at the DGR site in the event of a radiological emergency.

10.3.4 Significance of Residual Adverse Effects of Radiological Malfunctions and Accidents

OPG stated that, with the application of its proposed mitigation and control measures, the project was not likely to cause significant adverse effects as a result of radiological malfunctions and accidents. CNSC staff agreed with OPG’s assessment. CNSC staff considered OPG’s use of conservatism in its assessment of radiological contaminant releases developing from malfunctions and accidents to be adequate.

10.3.5 Panel Conclusion Regarding Radiological Malfunctions and Accidents

The Panel concludes that radiological malfunctions and accidents are not likely to result in significant adverse environmental effects. The Panel is satisfied that OPG identified credible malfunctions and accidents that would result in the release of radioactive substances, and appropriately screened them for their potential to cause adverse environmental effects to non-human biota, members of the public and workers. The Panel accepts OPG’s proposed hazard screening and mitigation plans for malfunctions and accidents of this type, and is satisfied they can be effectively implemented using the management, training and mitigation techniques outlined by OPG.

The Panel acknowledges that OPG made effective use of operating experience gained from other international repositories, in particular the Waste Isolation Pilot Plant in the United States, in its assessment of radiological malfunctions and accidents. This subject is addressed in more detail later in this chapter.

The Panel agrees that the mitigation measures proposed by OPG for radiological malfunction and accident events must be adopted and applied. The Panel makes the following recommendation:

Recommendation 10.4: OPG shall implement the mitigation measures and contingency plans identified in Section 4.4 of the Malfunctions, Accidents and Malevolent Acts Technical Support Document, to the satisfaction of the CNSC.

The Panel agrees that the emergency response plans proposed by OPG for radiological malfunction and accident events, if adopted and applied during the DGR operation phase, will prevent significant adverse effects to workers, human health and non-human biota in the surface environment.

For non-human biota, the Panel accepts OPG’s determination that radiological accidents and malfunctions during the operation and decommissioning phases of the project would not result in radiation doses that exceed dose limits for plants and animals. The accident and malfunction scenarios that could result in the release of radionuclides considered by OPG, including fire, low and high-energy container breaches, ventilation system failure, and inadequate shielding, were assessed using sufficient levels of conservatism to justify the determination of radiation exposure below dose limits. The Panel is confident that the consequences of these malfunctions and accidents were not underestimated.

10.4 MALEVOLENT ACTS

Malevolent acts are abnormal events for which intentional initiating actions may result in malfunctions or accidents within the surface or underground environments of the DGR.

10.4.1 Selected Scenarios for Malevolent Acts

OPG assessed the likelihood and consequences of malevolent act scenarios during various DGR phases and described the mitigation measures for each. OPG identified the malevolent acts of sabotage and attack to be possible scenarios during the site preparation and construction phases of the project. OPG stated that, during these phases, no radiological threats would be present because the DGR site would be isolated from the WWMF. OPG noted that during the decommissioning and postclosure phases, emplaced waste would be isolated from humans and non-human biota by engineered and geosphere barriers. As such, the risk of exposure to radiological contaminants from malevolent acts would be low.

During the operations phase of the DGR, OPG stated that credible malevolent act scenarios could include employee attack resulting in system damage, such as a fire, or a waste container breach from being pushed into the shaft. OPG also considered unlikely, though critical, scenarios such as use of incendiary devices or explosives in contact with waste containers.

CNSC staff agreed with OPG's assessment of malevolent acts during the preclosure phase based on qualitative assessment of categories including sabotage and attack.

Some participants expressed concerns regarding the potential for malevolent acts to occur at the project. Some participants suggested that OPG should have assessed events affecting waste prior to its departure from the WWMF to the DGR. The Panel notes that such events were not required for the environmental assessment because they would be covered by the existing requirements for the WWMF.

Other participants expressed concerns that some intermediate-level waste forms being shipped to or emplaced in the DGR could, if stolen, pose a significant radiological hazard. Threats of violence and theft were not considered by OPG to be credible scenarios due to the extensive protection capabilities offered by the existing security force at the Bruce nuclear site, the waste isolation measures in place, and the non-portable nature, i.e., considerable size and weight, of the waste materials.

10.4.2 Potential Effects from Malevolent Acts

OPG determined that the potential adverse effects of malevolent acts would range from on-site effects on worker safety, which would be similar to those posed by conventional accidents and malfunctions, to more significant consequences, including worker fatalities at the site of attack, injury to members of the public, and damage to non-human biota at distance from the site of attack.

OPG determined that, during the operations phase, credible malevolent act scenarios could potentially result in adverse radiological effects. OPG indicated that the effects of malevolent acts would be bounded by the effects of radiological and non-radiological malfunctions and accidents caused by unintentional human activity.

Workers

OPG stated that the effect of extreme malevolent acts could include worker fatalities, depending on their proximity to the location of the attack. OPG noted that the effect of more credible malevolent acts would be bounded by malfunctions and accidents caused by unintentional human activity, resulting in relatively low consequences for workers. CNSC staff concurred with this assessment.

Public

OPG stated that the public consequences of malevolent acts resulting in container breach, cage fall and fires, including exposure to radionuclides and non-radioactive species, would be bounded by malfunctions and accidents. As such, OPG predicted that such events would not adversely affect members of the public. OPG similarly noted that less credible acts, such as use of explosives, would result in a radiological dose to the public well below the acute accidental dose criterion of 1 mSv. CNSC staff concurred with this assessment.

Non-Human Biota

OPG stated that malevolent acts had the potential to affect non-human biota that use the Bruce nuclear site, including individual members of populations of terrestrial and aquatic biota. OPG noted that, since the greatest effect of a malevolent act would be limited to the vicinity of the DGR and because only small quantities of radioactive material would be stored at the surface at the DGR, the overall populations of terrestrial and aquatic biota would remain unaffected in the event that a malevolent act is carried out against the DGR, particularly those species with populations spanning Bruce County. OPG determined that there would be no significant adverse effects on MacPherson Bay or adjacent areas in Lake Huron resulting from malevolent acts. CNSC staff concurred with this assessment.

10.4.3 Mitigation for Malevolent Acts

OPG considered malevolent acts to be mitigatable and have a low likelihood of occurrence for a variety of reasons, including the strong security presence at the site and limited site access. Effects on workers from unlikely malevolent acts such as sabotage or attack involving explosives would be minimized through the use of appropriate regulatory controls, training and handling restrictions. OPG added that further mitigation measures would include the robustness of the waste containers, the low combustibility of waste materials, and the limited opportunity to access waste quantities due to the low rates of waste movement.

10.4.4 Significance of Adverse Effects of Malevolent Acts

OPG determined that residual effects resulting from more credible malevolent act scenarios would fall within the bounding conventional malfunction and accident scenarios. CNSC staff stated that OPG had adequately identified and assessed the potential conventional and radiological effects of malevolent acts. CNSC staff indicated that malevolent acts were not likely to result in significant adverse effects to non-human biota, members of the public and workers with the implementation of OPG's effective control and mitigation measures.

CNSC staff concurred that the effects of credible malevolent act scenarios would be bounded by those of credible malfunction and accident scenarios, and that malevolent acts would not be likely to cause significant adverse effects on non-human biota, members of the public and workers. This determination was dependent on OPG's implementation of effective mitigation measures and contingency plans.

OPG pointed out that, over the long term, deep geologic disposal of L&ILW would provide the best possible security against malevolent acts. OPG stated that, with the application of its proposed mitigation and control measures, the project was not likely to cause significant adverse effects as a result of malevolent acts. CNSC staff agreed with OPG's assessment.

10.4.5 Panel Conclusion Regarding Malevolent Acts

The Panel concludes that malevolent acts are not likely to result in significant adverse environmental effects. The Panel is satisfied that OPG has adequately characterized and assessed malevolent acts that may occur at the project during the preclosure period. OPG has demonstrated that, given its implementation of effective control and mitigation measures, credible malevolent acts are not likely to result in significant adverse effects to non-human biota, members of the public and workers, both on and off the DGR site.

The Panel agrees with OPG that two malevolent act scenarios, sabotage and attack, would be possible and have the potential to result in adverse effects, radiological and non-radiological, to workers on site and both humans and non-human biota off-site. Such malevolent act scenarios are credible, though highly unlikely to occur, given the control and mitigation measures described by OPG. The Panel is satisfied that the likelihood of violence and theft scenarios at the DGR site would not be credible, in part due to the strong security presence and nature of the stored radiological wastes at this site. The Panel concurs that the effects of OPG's credible malevolent act scenarios would be bounded by those of non-radiological malfunction and accident scenarios.

10.5 OPERATING EXPERIENCE FROM INCIDENTS AT THE WASTE ISOLATION PILOT PLANT

The Waste Isolation Pilot Plant (WIPP) is a deep underground repository located near Carlsbad, New Mexico in the United States. It is currently operated by the United States Department of Energy for emplacement of low and intermediate level transuranic radioactive waste that was created by the United States nuclear weapons program. Two separate and unrelated malfunction and accident incidents, a transport vehicle fire and a waste container breach, occurred at this facility in February 2014. This section describes the operating experience taken from the incidents at the WIPP and its applicability to the DGR.

10.5.1 Relevance of the WIPP to the DGR

OPG incorporated some aspects of the WIPP design in the design of the DGR. OPG stated that information and operating experience gained from the WIPP were relevant to its assessment of malfunction and accident scenarios for the DGR.

10.5.2 Description of the Events at the WIPP

OPG conducted a preliminary review of the incidents that occurred at the WIPP site in February 2014. OPG reported on the incidents using publically available materials issued by the United States Department of Energy. OPG stated that the vehicle fire incident and its associated effects to worker health and safety, such as breathing impairment due to smoke inhalation, were reportedly the result of inadequate equipment maintenance, lack of worker training, and ineffective emergency program management.

OPG stated that the waste container breaching event resulted in a radiological contaminant release that was dispersed through the underground areas of the WIPP site by ventilation air and released to the surface environment. A radiation monitoring system failure occurred during the incident. As a result, radiological contaminants in ventilation air were only detected for a short interval after the event. Contaminated exhaust ventilation air inadvertently bypassed WIPP's high efficiency surface filtration system and was released to the surface environment.

Some WIPP workers on surface were exposed to radiological contaminants; however, the levels found in the surface air at the WIPP site were measured to be well below regulatory dose limits for public and worker exposure.

10.5.3 Applicability of Incidents at the WIPP to the Safety Case for the DGR

This section describes the applicability of the incidents at the WIPP to the Safety Case for the DGR. Each incident is reviewed separately, followed by overall comments.

Vehicle Fire

OPG considered the vehicle fire incident to be a credible accident or malfunction event that could develop at the proposed DGR during construction and operations. OPG described this type of accident event in its preclosure and conventional safety assessments, through its detailed health, safety and environment management and emergency response plans, and in various information responses and hearing submissions.

OPG's screening process for its hazard analysis and assessment of mitigation measures reviewed aspects of fire detection, prevention and suppression of a potential fire event. OPG reported that no major changes to the DGR design would be necessary on the basis of its review of the WIPP fire incident. OPG explained that the measures and processes for fire protection that were incorporated into its DGR design, including fire hazard analyses and emergency response plans, were adequate for preventing or mitigating an event similar to the WIPP event at the DGR. Any potential non-radiological impacts to workers and members of the public from a vehicle fire event would be below criteria.

CNSC staff stated that the WIPP fire event was adequately considered by OPG as a credible conventional accident or malfunction. CNSC staff noted that OPG had appropriately assessed the effects of such a fire event on workers, the public and the environment, and that the WIPP event did not affect the results of OPG's assessment. In its review of the WIPP site fire accident, CNSC staff noted that WIPP management had applied little focus on conventional mine safety. CNSC staff stated that OPG should incorporate lessons learned from the WIPP fire to hazard mitigation programs and procedures through the:

- maintenance of high quality management systems;
- effective oversight by project managers and regulators;
- continual development of the safety case for the lifetime of the project; and
- maintenance of effective worker training and safety cultures during all project phases.

Waste Container Breach

OPG's preclosure safety assessment for the project included the examination of a similar waste package breaching scenario and the implementation of mitigation measures to limit radiological contaminated air release under this condition. OPG explained that, in the event of a waste container breach after emplacement in the DGR, the timely installation of temporary room closure walls at entrances to affected rooms could be used to isolate and restrict contaminant releases. OPG stated that closure walls would restrict any contamination release and mitigate hazards due to exposure to radiological releases within adjacent waste emplacement panel areas.

OPG stated that based on its preclosure safety assessment of credible underground accidents, which included waste package breaching events, no DGR design changes were required. In its assessment, OPG determined that no changes to the design of its planned air ventilation system would be necessary. OPG did not present details concerning the methods and procedures it would use for radiological monitoring to mitigate malfunctions or accidents.

OPG stated that regulatory exposure limits for members of the public and workers would not be exceeded for a waste container breaching event at the DGR. This was based on OPG's planned adherence to its effective and long-established nuclear safety program; strong safety culture and well-designed emergency management system; proper maintenance of critical equipment and components; maintenance of a robust, effective and regulatory compliant radiation protection program; and operation under strong oversight by regulators and internal management.

CNSC staff stated that OPG had conservatively bounded the possible effects of a release of radionuclides from a waste package due to a variety of causes in its assessment of malfunctions and accidents. CNSC staff was satisfied that OPG had demonstrated that, through the implementation of its planned mitigation and control measures, radiological and non-radiological exposures to members of the public, workers and non-human biota from similar accidents at the DGR would be well below regulatory criteria.

General Applicability of the WIPP Incidents to the DGR

OPG committed to further detailed information review of published WIPP accident event reports as additional information became available. OPG indicated that it would incorporate the review findings of accident event reports into future planning and management efforts for the project.

CNSC staff stated that, based on the available information on the WIPP events, there were no new environmental consequences or impacts that OPG should be considering in the DGR safety case. CNSC staff was satisfied that OPG had adequately and conservatively considered similar accident and malfunction scenarios for the DGR. CNSC staff stated that OPG had proposed sufficiently detailed control and mitigation measures for similar incidents, and that they would be appropriate for minimizing the likelihood and consequence of such events for the DGR. CNSC staff noted that while OPG had appropriately considered such scenarios, adverse effects to the human and natural environments could result when mitigation measures and operator contingency plans for such events are ineffective or not executed properly. As such, OPG's use of an Operating Experience program in its review of the WIPP accident events would provide a benefit in identifying appropriate control and mitigation measures that could be used to prevent similar incidents at the DGR.

Due to the similarities between the WIPP and the proposed DGR, the incidents and the subsequent media attention raised considerable concern among some review participants. Some participants stated that a key component for the safe operation of the project would be for OPG to maintain an intact and highly functioning safety culture throughout the entire preclosure period of the project. Other participants asserted that effective regulatory oversight must be maintained to prevent the degradation in OPG's safety culture. Some participants, including the Power Workers' Union, which represents workers at Ontario nuclear facilities, were of the view that the features of OPG's health and safety culture, including the independent regulatory control exercised by the CNSC, were superior to those existing at the WIPP site. Other participants expressed the view that the incidents at the WIPP demonstrated that malfunctions and accidents would be certain, not preventable, and attributable to failures within OPG's management of the DGR.

Some participants expressed the view that the incidents, which occurred within decades of the commencement of operations at the WIPP, indicated that it would not be possible for the DGR to serve its function of safely isolating radionuclides for thousands of years. They suggested that this resulted in an absence of international precedents for the DGR, and that OPG's safety case for the DGR was no longer valid. OPG disputed this position. OPG stated that the malfunction and accident events that occurred at the WIPP site did not indicate that the project would be unsafe for L&ILW disposal. OPG noted that, even if there were no international precedents for the DGR, it would not logically or reasonably follow that the proposed DGR could or should not proceed. OPG noted that having a functioning international waste storage analogue to the DGR was not a required condition for project acceptance, and that such a requirement would be contrary to the precautionary approach to decision-making, i.e., using a lack of precedent as a reason to do nothing, or to pursue an inferior long-term solution.

10.5.4 Panel Conclusion Regarding Operating Experience at the Waste Isolation Pilot Plant

The Panel concludes that OPG has adequately described the applicability of the WIPP incidents to the DGR. The Panel is satisfied that OPG reviewed the vehicle fire and radiological release events and assessed them as credible accidents for the DGR. The Panel is of the view that lessons learned and operating experience from international radioactive waste repositories will be beneficial for the safety case of the DGR, including the development of mitigation measures and contingency planning.

The Panel notes that the proposed contingency measure of using temporary closure walls to limit worker access to waste emplacement rooms would be a proactive and useful feature of OPG's safety management plan for mitigation of accidental contaminant releases. OPG did not present any details concerning potential temporary closure wall designs, their availability in the underground equipment inventory, OPG's rapid deployment capability in the event of unanticipated radiologic releases, or international experience in the design and effectiveness of temporary closure walls at other repository sites. As such, the Panel makes the following recommendation:

Recommendation 10.5: OPG shall develop detailed room closure procedures to be deployed in the event that structural failures, inadvertent radiologic releases or other malfunctions or accidents occur within, or external to, waste emplacement rooms. Room closure procedures must incorporate the design of portable closure walls, or any other engineered barrier materials within the repository excavations that can be deployed rapidly to mitigate worker hazards when such events occur. OPG shall develop these procedures prior to construction, to the satisfaction of the CNSC.

The Panel notes that the failure of radiological monitoring systems during normal operations or in cases of accidents or malfunctions can have serious consequences. A lapse of detection capability or monitoring system redundancy would restrict operational capacity to provide real-time warning of, response to and mitigation of accident events. The operating experience from the WIPP reinforces the importance of the design of the radiation monitoring system to the safety case. The monitoring system design should therefore be rigorously evaluated and included in mitigation planning by OPG.

Recommendation 10.6: OPG shall deploy fixed, real-time monitoring equipment in each active emplacement room, and on worker-operated vehicles, as part of its radiation protection program during the operations phase, to the satisfaction of the CNSC.

In accordance with OPG's commitments to continue to review the operating experience from the WIPP, the Panel makes the following recommendation:

Recommendation 10.7: To the satisfaction of the CNSC, OPG shall seek and apply operational experience gained from malfunctions and accidents at international repositories, including but not limited to the WIPP, in its contingency, mitigation and other planning processes, during all phases of the project.

10.6 PANEL CONCLUSION REGARDING MALFUNCTIONS, ACCIDENTS AND MALEVOLENT ACTS

The Panel concludes that malfunctions, accidents and malevolent acts at the proposed DGR are not likely to result in significant adverse environmental effects to humans and non-human biota, provided the implementation of mitigation measures. The Panel is satisfied that the consequences from credible and non-credible scenarios would be below regulatory criteria. The Panel is satisfied that malevolent acts would be unlikely, and that their consequences would be bounded by the consequences of malfunctions and accidents.

The Panel stresses the importance of management systems and safety culture in ensuring the protection of workers, the public, and the environment. In addition to its own practices, OPG should continue to incorporate operating experience from other nuclear facilities, as well as from conventional mines. The Panel is of the view that the emergency management oversight from regulatory agencies provides additional confidence that mitigation capacity will exist at the DGR, should any malfunction, accident or malevolent act occur, to protect human health and non-human biota both on- and off-site.

The Panel is of the view that it will be important for OPG and the CNSC to be prepared for any malfunction or accident, not only in order to protect the health and safety of workers, the public and the environment, but also because, no matter how small the consequences may be from a science point-of-view, such an event could negatively affect the public perception of the project.

Chapter 11 Social and Economic Aspects

This chapter reports on OPG's assessment of the socio-economic environment. Socio-economic valued components were relevant or important to communities in the Local and Regional Study Areas and beyond. The assessment by OPG is summarized in this chapter, along with the perspectives of review participants. The Panel provides its observations or suggestions related to the predicted effects of the project on socio-economic valued components, and provides conclusions and recommendations regarding components that fall within the *Canadian Environmental Assessment Act, 2012*. The Panel also comments on components that were not required under the Act but were a matter of interest to participants during the review. This chapter also includes the Panel's observations and suggestions in relation to methodology employed by OPG in its project planning and in the review, with emphasis on engagement with the public.

11.1 EFFECTS ON THE SOCIO-ECONOMIC ENVIRONMENT

This section describes the assessment of effects of the project on socio-economic valued components. It includes OPG's assessment, views of government departments, and views of participants.

The EIS guidelines required OPG to describe predicted changes to health and socio-economic conditions, physical and cultural heritage, and current use of lands and resources, including those used for traditional purposes by Aboriginal people that result from any changes the project may cause in the environment. Therefore, OPG's assessment focused on how project-related changes in the environment, such as changes in air quality, might affect socio-economic valued components.

11.1.1 OPG Methodology

This section describes the methodology OPG used to assess the effects of the project on the socio-economic environment. OPG used a community assets framework to describe the socio-economic environment.

Community Assets Framework

OPG employed the concept of community well-being as an overall analytical framework in its assessment of effects of the project on social and economic components. OPG presented the existing socio-economic environment in terms of the community assets framework, reproduced here as Figure 26.

OPG's rationale for the selection of the socio-economic valued ecosystem components was presented in the EIS along with the key indicators and measures for each component. OPG was of the opinion that all of the valued ecosystem components identified in the EIS Guidelines were included and fit well within the community assets framework.

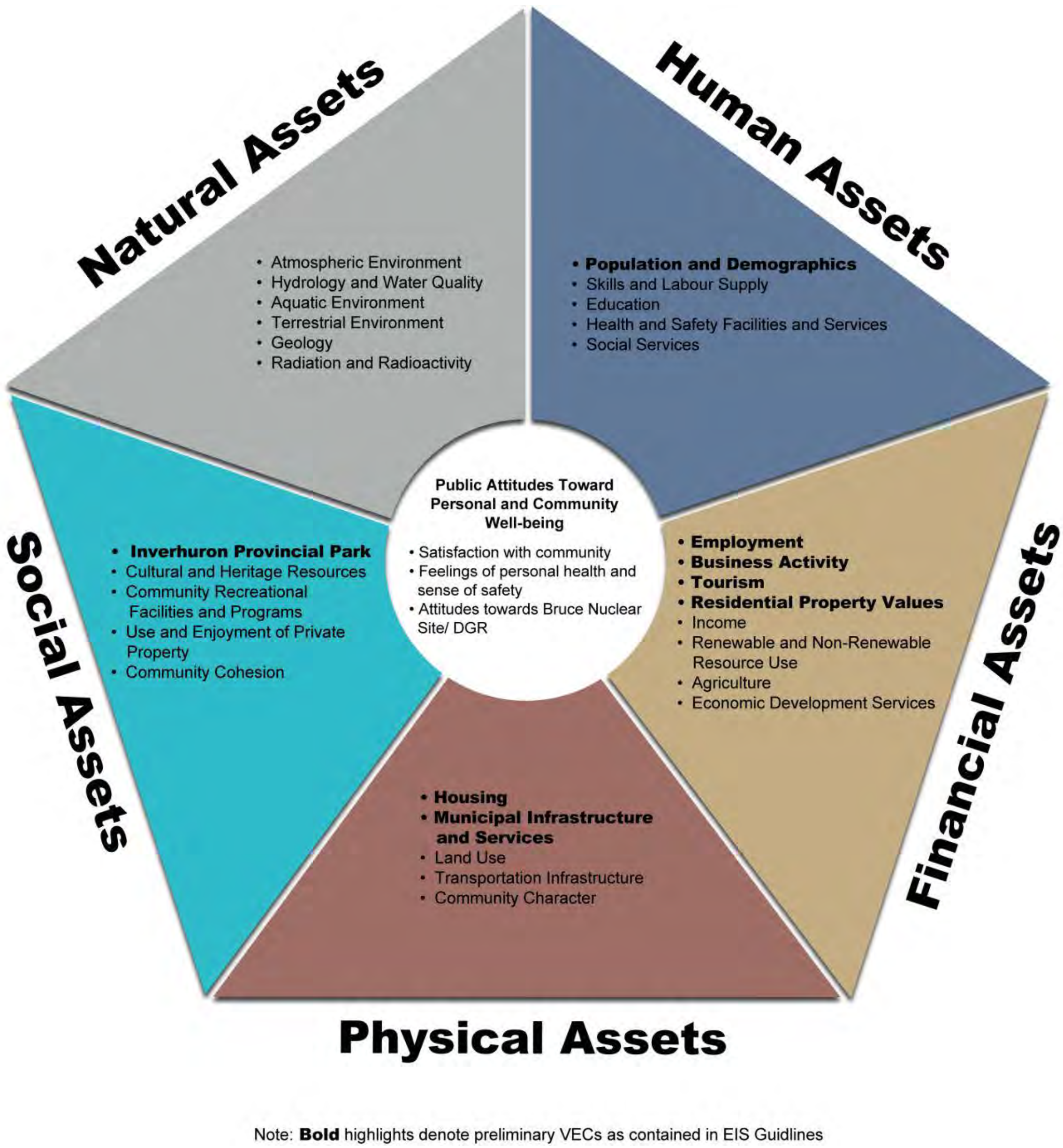


Figure 26: OPG Community Assets Framework (from DGR EIS Figure 6.10-1)

The valued social and economic components were categorized under one of five assets: human, financial, physical, social, or natural. The community assets framework encompassed:

Human Assets, which included population and demographics, skills and labour, education, health and safety facilities and services, and social services;

Financial Assets, which included employment, business activity, nuclear industry, tourism, residential property values, municipal finance and administration, income, renewable and non-renewable resource use, agriculture and economic development services;

Physical Assets, which included housing, municipal infrastructure and services, water supply, waste water treatment, conventional solid waste management, land use, transportation infrastructure and community character;

Social Assets, which included Inverhuron Provincial Park, cultural and heritage resources, community recreational facilities and programs, use and enjoyment of private property, and community cohesion; and

Natural Assets, which included the atmospheric environment, hydrology and surface water quality, aquatic environment, terrestrial environment, geology and radiation and radioactivity.

The central component of OPG's community assets framework was the concept of public attitudes toward personal and community well-being. OPG examined three broad indicators that it predicted would reflect on this component:

- people's feelings of personal health and sense of personal safety;
- people's satisfaction with community; and
- people's attitudes towards the Bruce nuclear site and the project.

In the EIS, OPG provided a description of the existing socio-economic environment as it relates to defined assets. For its assessment of the effects of the project on the socio-economic environment, OPG screened the valued ecosystem components for measurable changes. Measurable changes through direct and indirect interactions with the project were identified. Only likely effects were carried forward for assessment. All but the natural assets were considered by OPG in its socio-economic assessment. OPG considered human health and worker health and safety under natural assets.

Assessment Boundaries

OPG did not modify the assessment boundaries generally adopted for the EIS, except for the Local Study Area, where the boundaries were expanded to include the entirety of the Municipality of Kincardine.

Public Attitudes Research

OPG proposed that people's feelings of personal health, sense of personal safety and satisfaction with community would be indicators of individual and community well-being. OPG predicted that the project would have the potential to affect personal and community well-being and used public attitude research to gather information for use in the assessment of this potential effect.

OPG undertook public attitude research in 2009, focussing on obtaining attitudes of residents in the Regional Study Area. A random sample of 809 community members was surveyed by telephone. OPG explained that this sample size produced a confidence interval of plus or minus 3.5%, 19 times out of 20, meaning that, should this survey be repeated a further 20 times within a reasonable timeframe, it is likely that the same (or very similar) responses would be produced 19 times. OPG stated that the public attitude research was conducted in accordance with strict quality control standards and that the methods used by its contractor had been subject to peer review and had previously been used for projects receiving approval by the CNSC.

According to OPG, the public attitude research produced the following key findings:

- Nuclear issues were not top of mind for 98% of respondents in the Local Study Area;
- Very few respondents (2% in the Local Study Area) viewed nuclear waste as a threat to the community;
- Health care was the top issue of concern in the Local Study Area (48%) but was less of an issue in the Regional Study Area (23%);
- Economic issues were important to 19% of respondents in the Local Study Area;
- Respondents were generally proud of their community and the majority were committed to living there well into the future;
- A clear majority of respondents had confidence in the radioactive waste management techniques used at the WWMF; and,
- A minority of respondents expected a change in their level of commitment to living in the community (8% in the Local Study Area), their level of satisfaction with living there (12% in the Local Study Area) or their feeling of personal health and safety (21% in the Local Study Area).

OPG acknowledged that the public attitude research did not include a sufficient sample of seasonal residents (the sample size was 14) to determine whether seasonal residents had different opinions from the total sample. OPG decided not to make further efforts to directly reach seasonal residents as part of the 2009 public attitude research because of the positive results of the community polling conducted in 2005 by an independent contractor on behalf of the Municipality of Kincardine regarding the DGR Hosting Agreement. This polling included outreach to seasonal residents by mail. OPG also conducted one interview with a representative of a cottage rental agency. The results of the interview indicated that the presence of the Bruce nuclear site had a strong, positive effect on off-season cottage rentals and that there was an expectation of increased cottage rentals if the project were to proceed. OPG also conducted field surveys of tourists and day users at local provincial parks and conservation areas, with a total sample size of 119. The majority of respondents stated that they would not do anything differently at recreational areas because of the presence of the DGR.

11.1.2 OPG Socio-economic Assessment

The following is a summary of the OPG socio-economic assessment for each of the identified community assets: human, financial, physical, and social.

Human Assets

Human assets include: population and demographics, skills and labour, education, health and safety facilities and services, and social services. This section focuses on population and demographics, with an overview of other human assets.

Population and Demographics

OPG anticipated that the overall effect on population in the Local and Regional Study Areas would be relatively small but apparent; approximately +5% of the total projected population in the peak year of 2061. OPG anticipated that the largest associated population increase would be at decommissioning because more local residents may fill jobs in that phase.

OPG noted that experience with other nuclear or waste projects indicated that population levels may be negatively affected if residents choose to leave the community as a direct result of the project and if growth was not sufficient to offset this loss. OPG's analysis of the public attitude research indicated that, at most, 3% of the total population of the Local and Regional Study Areas may be motivated to leave the community as a result of the project. OPG stated that this value fell within the typical percentage of people that move in a given year (4%) and was well below the anticipated growth in population in the study areas over the life of the project. OPG committed to share information with local and regional land use planners and economic development officials regarding the timing and magnitude of meaningful changes in its on-site labour requirements for each phase of the project.

OPG determined that no adverse effects on population and demographics were anticipated. OPG highlighted the beneficial effect that it anticipated would occur as a result of the project from increased population associated with employment, and stated that this growth would be in support of municipal planning objectives. OPG proposed that this beneficial effect would likely be experienced by all Regional Study Area municipalities with the greatest beneficial effect in Kincardine.

Other Human Assets

Other human assets were defined as skills and labour supply, education, health and safety facilities and services, and social services. In its analysis of the direct interactions that the project may have with other human assets, OPG identified that activities at all phases of the project could result in increased use of health and safety facilities and services and that changes may be required to emergency response plans as a result of project activities. Further, OPG identified that project employment requirements may change the availability of skills and labour supply.

OPG predicted that demands on health care, emergency medical services, fire and police protection services may result from project-associated population increases. OPG expected that the effect would be small, and that the demand would barely be measurable and not noticeable in terms of levels of service provided to community members. OPG offered that interviews with stakeholders and safety and police service providers supported this positon. OPG added that police expressed some concern due to the potential increase in traffic-related incidents though these were not considered substantial enough to affect police operations or level of service.

In the case of an emergency, OPG anticipated that local health and safety and fire service providers may be called upon to assist the specialized emergency response teams that OPG would have in place. OPG committed to working cooperatively with Emergency Management Ontario and local emergency responders to assist in the development and testing of emergency plans throughout the life of the project.

OPG anticipated that there would be a small increase in school enrollment during all phases of the project due to project-related population increases. OPG predicted that the anticipated increases would be only a small fraction of the excess capacity that existed in area school boards.

OPG stated that the project would require standard engineering trades, management and support, as well as specialized skilled labour. OPG anticipated that the construction workforce would largely be sourced from outside the Local and Regional Study Areas, which were largely in the agricultural sector. OPG predicted that the relatively small number of project-related jobs associated with the construction phase that would be sourced locally would not noticeably affect local skills and labour availability and that it was not likely that any economic sector would be adversely affected by the skills and labour requirements of construction.

OPG anticipated that most of the individuals to be employed directly or indirectly by the project during the operations phase would be from the Local and Regional Study Areas. This would include employees transferred from the WWMF and other employees at the Bruce nuclear site, less-specialized indirect jobs, and jobs with goods and service providers. OPG determined that it was not likely that any economic sector would be adversely affected by the skills and labour requirements of operations.

OPG anticipated that there would be a substantial increase in employment during the decommissioning phase, relative to the operations phase. OPG expected that, during decommissioning, workers would be predominately sourced from the Local and Regional Study Areas where the skills required for construction and transportation activities were likely to be available. OPG determined that, given the existing labour pool, it was not likely that any economic sector would be adversely affected by the skills and labour requirements of decommissioning.

OPG identified potential effects from changes in the biophysical environment at educational facilities due to dust and noise produced by the project causing disruption to educational activities. However, OPG noted that there were no schools in close proximity to the DGR site where dust and noise effects were predicted to be measurable. Therefore, OPG determined that there would be no adverse effects on activities conducted at individual schools because of dust and noise.

Mitigation and Determination of Residual Adverse Effects on Human Assets

OPG committed to sharing information with local and regional land use planners and economic development officials as well as local and regional health and safety service providers regarding the timing and magnitude of meaningful changes to its on-site labour and skills requirements for each phase of the project. OPG committed to ensuring that an emergency and fire response plan would be prepared and implemented for the project.

OPG determined that there would be no residual adverse effects on labour supply, education, health and safety facilities and social services as a result of the project. OPG predicted a beneficial effect of the project due to increased educational opportunities for students.

Financial Assets

Financial assets include employment, business activity, nuclear industry, tourism, residential property values, municipal finance and administration, and other financial assets.

Employment

OPG predicted that the on-site labour force during site preparation and construction would be between 80 and 200 workers, declining to 40 workers during the operations phase. Employment during the decommissioning phase was estimated to range from four to 125 workers. Across all phases of the project, OPG estimated that 27% of the person-year requirement would be met from within the Local Study Area, 24% from within the Regional Study Area and 49% from outside the study areas. OPG pointed out that the labour force associated with the project through all phases would be a small fraction of the overall labour force at the Bruce nuclear site.

OPG's economic modelling indicated that the project would create new direct, indirect and induced employment opportunities in the Local and Regional Study Areas and would contribute to overall community well-being. OPG predicted that the number of jobs created and their distribution over time did not suggest that the municipalities in the study areas would experience any "boom" or "bust" effects as a result of the project. OPG was of the opinion that the presence of the project was seen by some in the community as an indication of the continued presence of nuclear-related activity and employment opportunities at the Bruce nuclear site and that this expectation may contribute to positive attitudes toward future well-being of the community.

Business Activity

Based on economic modelling, OPG predicted that the project would contribute directly to jobs and a demand for goods and services in the Local and Regional Study Areas, and that jobs would be created in other parts of Ontario and beyond, in some cases. OPG referenced increased business activity related to the aggregate, transportation and waste management sectors.

OPG stated that commercial businesses in the Local and Regional Study Areas would not experience nuisance or traffic-related disruption. OPG anticipated that nuisance dust and noise would be restricted to a small area in close proximity to the Bruce nuclear site in which no sensitive businesses operate. Additionally, disruption due to project-related traffic increases was not anticipated because traffic associated with the project could be accommodated within the current transportation infrastructure.

Tourism

OPG identified that the presence of the project would have the potential to directly interact with tourism by influencing community character through changing feelings of personal health or sense of safety, or by making tourist features less attractive. Additionally, temporary workers may directly increase demand for accommodation typically available to tourists. With respect to effects on tourist accommodation, OPG predicted some competition but not of sufficient magnitude to affect the tourism accommodation industry over the long term. Similarly, the increase in numbers of workers and corporate clients using accommodation in the off-season would be likely to maintain the economic viability of businesses but would not be of sufficient magnitude to create substantial reinvestment or improvement of accommodation stock over the long-term. Further, OPG stated that project workers would act as a substitute source of revenue to tourist-related businesses should there be a decrease in tourists as a result of accommodation competition.

OPG assessed the indirect interactions of the project with tourism that could decrease the attractiveness, use and enjoyment of tourist features and may affect tourism operations. OPG stated that the results of air quality and noise studies indicated that the project was not likely to result in adverse effects from dust or noise at Inverhuron or MacGregor Point Provincial Park, or in any other tourist attraction areas. OPG's surface water studies indicated that the project was not likely to measurably change the water quality at Local or Regional Study Area beaches and nearshore areas used by tourists for outdoor leisure activities. OPG determined that the project would not result in environmental effects to the Provincial parks, affect their accessibility or require park operators to modify their facilities or programs.

OPG stated that there would be no measurable change to the commercial or recreational fishery or tourism associated with wildlife viewing or hunting. OPG explained that the effects of the project on the terrestrial and aquatic environment valued ecosystem components would occur only within the Project Area, which is not, and would not, be accessible to the public.

Residential Property Values

OPG identified that there could be direct interaction with residential property values as a result of the project influencing community character, causing out-migration, or from the increased demand of the workforce. OPG acknowledged that the predicted measurable change in population associated with the project during site preparation and construction could change the demand for housing, thereby influencing the housing market and residential property values.

OPG identified indirect interactions with residential property values resulting from changes in air quality, noise levels, surface and groundwater quality and flow, and changes to radiation and radioactivity. These factors could lead to a decrease in the value of residential properties or may affect property values through the effects on water supplies. Changes to radiation and radioactivity may affect public attitudes towards feelings of health, safety or satisfaction with community.

OPG stated that decreased property values and increased marketing time typically result from noticeable effects such as dust, noise and traffic and reached the following conclusions regarding such effects as associated with the project:

- no nuisance effects because of dust;
- no nuisance effects because of noise at a nearby residence and Inverhuron Provincial Park
- perceptible noise with a low nuisance effect at Baie du Doré; and
- modest increase in traffic levels on local roads during all but the operations phase of the project.

OPG further argued that the visibility of the project, located at an existing industrial and nuclear site, was not likely to be a major determinant of residential property values. OPG acknowledged that property values could be affected should the project result in contamination beyond the site boundaries and offered that the 2004 Hosting Agreement between OPG and the Municipality of

Kincardine provided a property value protection plan to compensate property values for such losses, subject to certain conditions.

Municipal Finance and Administration

OPG stated that the project could affect municipal revenues through increased property taxes, land development, building permit fees, and development charges for the project. OPG claimed that no upgrades or improvement to municipal infrastructure were required for the project but that increased municipal expenditures were possible due to increased infrastructure and service demands from new businesses and residents.

Other Financial Assets

OPG predicted that a measurable change from project-related employment would generate a measurable increase in labour income in the Local and Regional Study Areas. OPG assessed the effects of the project on direct, indirect and induced income and determined that the project would result in the beneficial effect of creating all types of income in the Local and Regional Study Areas.

OPG stated that a measurable change in non-renewable resource use was likely and that the greatest potential for non-renewable resource use would be aggregate and fuel. OPG stated that aggregate production across Ontario would be sufficient to supply the project and that this was not likely to cause a shortage for other community uses. OPG assumed that any waste rock excavated from the DGR would remain on-site, thereby eliminating the potential for increased supply to affect local markets and production. Similarly, OPG stated that the fuel requirement for the project was not expected to be of such a magnitude as to affect fuel supply in any community or in Ontario.

OPG considered the potential effects of the project on commercial fishing in its renewable resource use analysis. Commercial, recreational and Aboriginal fishing are addressed in other sections of this report. OPG noted that forestry was not a significant activity in the region.

OPG anticipated that the project would not cause any measurable effects to agriculture, but noted that traffic-related effects, which have the potential to disrupt the movement of slow-moving farm vehicles, were expected to occur. OPG evaluated the effects of project-related noise on livestock as part of the Socio-Economic Technical Information Session. OPG's assessment weighted noise levels at all frequencies equally because of insufficient data on perceived frequency responses and sensitivities of livestock to varying noises. This was described as a conservative approach because available data suggested that animals may have a lower sensitivity than humans to the low frequency noises most associated with the types of activities that would be associated with the project. OPG suggested that livestock would readily habituate and adapt to the types of noise that would be generated by the project.

OPG predicted that the project would contribute to increased local and regional economic development throughout its lifetime. The economies would be stimulated by the increased population and skills base, employment opportunities, income and business activity. OPG expected that these positive effects would improve the attractiveness of the area to investors, particularly those in the nuclear service industry.

Mitigation and Determination of Residual Adverse Effects on Financial Assets

OPG determined that no residual adverse effects on employment would occur as a result of the project; therefore it did not identify additional mitigation. Beneficial effects were expected to flow from the creation of new direct, indirect and induced employment opportunities, which would have a positive influence on the economies of the municipalities in the Local and Regional Study Areas, as well as overall community well-being, during all project phases.

OPG determined that no adverse effects on business activities were likely as a result of the project and no mitigation was identified. OPG predicted that the project would have a beneficial effect on business activity at all phases and that this effect would be enhanced through policies to utilize local business services whenever practical and in accordance with OPG supply chain policies, procedures and standards for competitive purchasing.

OPG determined that there would not likely be any direct adverse effects from the project on community character and that the presence of the project was not expected to adversely affect the attractiveness of the Local or Regional Study Areas to tourists. OPG provided a number of reasons in support of this conclusion including that the project was not likely to cause:

- a noticeable increase in dust at key locations;
- changes in environmental conditions in shore areas used by tourists;
- increase in traffic at the entrance to Inverhuron Provincial Park or Highway 21;
- changes in the visual character of the Local Study Area; or
- changes to the things or special features that affect the use and enjoyment of parks by tourists.

Additionally, the project would not block the view of the lake from the Provincial parks or the Bruce Power Visitor Centre, or be dominant in views from Lake Huron as compared to the existing structures on the Bruce nuclear site. OPG added that, although the Bruce nuclear site was located near Inverhuron Provincial Park, there was no strong evidence of a stigma associated with the Bruce nuclear site. OPG offered that the results of park user interviews supported this conclusion. Since no adverse effects on tourism were anticipated, OPG did not identify additional mitigation measures.

OPG determined that no adverse effects on property value were anticipated, taking the property value protection plan into account, and did not identify any additional mitigation. OPG noted that while there may be some nuisance effects in close proximity to the project, due to dust and noise, these effects were not anticipated to result in changes in property values.

OPG stated that there would be no meaningful net effect on municipal finance and that it was not necessary to quantify these effects because of their small magnitude. OPG noted that the DGR Hosting Agreement (October 2004) between OPG and the Municipality of Kincardine established payments to Kincardine and the adjacent municipalities of Saugeen Shores, Huron-Kinloss, Arran-Elderslie and Brockton, based on completion of activity and approval milestones of the project. The Agreement also clarified the payments to be made regarding applicable property tax and building permits that would otherwise be payable to the Municipality of Kincardine.

OPG determined that no residual adverse effects on income, renewable and non-renewable resource use, agriculture or economic development services were anticipated as a result of the project and that the project would benefit the Local and Regional Study Areas through the creation of an appreciable amount of income. OPG acknowledged that mitigation may be warranted to minimize disruption to slow moving farm vehicles, and that farmers should be informed when oversized or slow-moving vehicles would be moving during the planting or harvesting season.

Physical Assets

Physical assets include housing, municipal infrastructure and services, water supply, waste water treatment, conventional solid waste management, land use, transportation infrastructure and community character.

Housing

OPG predicted that the effect of the project on housing would be relatively small in the context of the Local and Regional Study Areas. The highest estimated effect was a 3.4% increase in housing demand in Kincardine during site preparation and construction.

Municipal Infrastructure and Services

OPG stated that although the increase in population associated with the project may directly add to demands on municipal infrastructure and services, the municipalities in the Local and Regional Study Areas had sufficient existing capacity in their water, sewage and waste management systems to meet future demands. OPG noted that the project would not cause unacceptable levels of service along the local transportation network in the Local Study Area.

OPG noted that the Bruce nuclear site has its own potable water supply and sewage treatment plant that handles all sewage from the site and discharges clean effluent via the Douglas Point outfall. OPG noted that the plant was at capacity, largely because of processing inefficiencies from a large amount of non-sewage water diverted to the plant, and that Bruce Power was investigating the necessary improvements to the sewage treatment plant. OPG reported that the conventional solid waste generated at the Bruce nuclear site was either recycled or reused where feasible, or disposed of at off-site facilities that were licensed for the specific waste materials.

Other Physical Assets

Other physical assets were defined as land use, transportation infrastructure and community character.

OPG reported that Bruce County and the Municipalities of Kincardine and Saugeen Shores have Official (land use) Plans, and that there were no provincial land use plans that specifically applied to the study areas. OPG determined that, as was the case with all activity at the Bruce nuclear site, no Site Plan Applications or Building Permits would be required for site development and, further, that since the project would be on a licenced nuclear site, it would not be expected to change the land use or compatibility with adjacent land uses.

In referencing the results of its Traffic Impact Study (2010) which considered factors such as Bruce nuclear site employment, traffic data, site access, existing intersection operations and collision analysis, OPG claimed that the project would not result in a need for additional improvements to the road network over the forecast period, which included all project phases up to and including decommissioning. OPG noted the addition of the project would not result in unacceptable levels of service or need for additional work if improvements were undertaken to alleviate existing congestion.

OPG described that the project could affect the character of the community if it fundamentally changed key assets of the community, particularly those assets that were valued by residents for their positive influence on community character, or if the project generated a stigma associated with nuclear waste. OPG defined stigma as the negative images attached to a neighbourhood, community, other geographic area and its residents or to local products and services. OPG reported that, based on the results of public attitude research, residents in the Local Study Area valued Lake Huron, the waterfront and the lighthouse, the nature and scenery, the agricultural presence, and the close-knit feel and friendly people in the community.

OPG stated that because nuisance effects from dust and noise were not likely to have an effect on the environment, community character would not be affected, nor was the project likely to affect Lake Huron, the beachfront, the lighthouse, the natural landscape and its visual aesthetic, or agriculture. OPG anticipated that community cohesion would not be negatively affected as a result of the slight increases in population and stable demographic character of the communities.

OPG also proposed that community character could be adversely affected if the assets that were seen to be negative influences on community character were to become more pronounced as a result of the project. OPG found that the most frequently mentioned negative influences on community character in the Local Study Area were the presence of wind turbines and political issues. OPG was of the opinion that these factors would not be expected to change as a result of the project.

OPG reported that most of the stakeholders interviewed in the public attitude research felt that the project would not change the image of Kincardine and its surrounding municipalities or that it would change the image in a positive way (41 out of 72 responses). Approximately 28 of 72 respondents felt that while the image may change in a negative way, this change would likely be attributed to a pre-existing bias against the nuclear industry or because of people being uninformed of the project details.

Mitigation and Determination of Residual Adverse Effects on Physical Assets

OPG did not identify measures to mitigate effects on housing and determined that the project would have no residual adverse effects. OPG determined that the project’s lack of demand on municipal infrastructure and services, and the modest increase in population, would not lead to any residual adverse effects from the project. OPG stated that it planned to work with Bruce Power to utilize its potable water sources and enhance the existing sewage treatment plant facilities to treat the additional DGR sewage wastes. OPG was of the opinion that the project would not cause any residual effects to the natural environment that would lead to effects on municipal infrastructure and services.

OPG anticipated that the small effect that the project was anticipated to have on population would not result in noticeable induced residential development or associated changes in land uses in the Local and Regional Study Areas.

OPG stated that the visual presence of the project would have a minor effect that was not likely to influence existing or planned land uses. OPG acknowledged that additional mitigation was warranted to minimize congestion at intersections nearest to the Bruce nuclear site. OPG committed to developing and implementing a traffic management plan for the site preparation and construction phase, in collaboration with relevant stakeholders. The purpose of the plan would be to minimize the project-related peak hour traffic volumes and measures could include the staggering of worker shifts, encouraging ride sharing and the use of shuttle buses and off-peak timing of shipments of materials and wastes on and off the project site. OPG determined that there were likely no residual adverse effects on traffic infrastructure.

OPG did not expect that further development at the Bruce nuclear site, related to its already existing industrial presence, would affect community character. OPG proposed that the overall rural and small town feel of the communities would not likely be affected by the project due to the relatively small workforce.

OPG conceded that the project would introduce a new type of facility that was unique in North America and unfamiliar to the residents of the Local and Regional Study Areas. As such, there was potential for the project to be a source of stigma. OPG was of the opinion, however, that there were no strong indications that the project would result in a stigma.

OPG summarized that overall, although a small number of tourists, day users and stakeholders stated that their image of Kincardine might change as a result of the project, the indirect effects of the project (dust, noise) were not likely to change the physical aspects of the community that define its character.

Social Assets

Social assets include Inverhuron Provincial Park and other social assets, including cultural and heritage resources, community and recreational facilities and programs, and community cohesion.

Inverhuron Provincial Park

OPG public attitude research included the collection of opinions of Inverhuron Provincial Park users on the potential for the project to affect their use and enjoyment of the park, conservation areas and trails along the waterfront near the Bruce nuclear site. Park users were also asked if and how they might change their recreational behaviour at the park because of the presence of the project.

OPG reported that of the 119 users of Provincial parks and conservation areas interviewed, 104 said that the existing Bruce nuclear site had not affected their use and enjoyment of those areas and 108 said that the WWMF had not affected their use and enjoyment of those areas. Of the 13 respondents that said they would do something differently at Inverhuron Provincial Park, six indicated that they would consider no longer visiting the park, while seven indicated that they would keep a close watch on safety and would only return to the park if there were no negative effects on health or the environment.

Other Social Assets

As defined by OPG, other social assets include cultural and heritage resources, community and recreational facilities and programs, and community cohesion.

OPG identified the following direct interactions with social assets valued components:

- site preparation or decommissioning activities could cause direct disturbance of cultural and heritage resources;
- the presence of the project may affect the use and enjoyment of community and recreational facilities and programs;
- the project could cause changes in feelings of personal health or sense of safety or affect use and enjoyment of private property and community cohesion;
- increased population associated with the project may affect the use of community and recreational facilities and programs; and
- changes in population and demographics may affect community cohesion.

OPG expected that all of the identified direct interactions with social assets valued components would result in measurable changes and considered them further in the assessment.

OPG identified indirect interactions for other social assets, such as:

- changes in air quality and increased noise levels, which may decrease the attractiveness of community and recreational features and private property, thereby affecting their use and enjoyment;
- changes in surface or groundwater quality, quantity and flow, which may affect the use and enjoyment of community and recreational features and private property through potential effects on water supplies;
- changes to fish and terrestrial wildlife populations and habitats, which may affect bird watching, nature viewing and fishing opportunities, and that may affect use and enjoyment of community and recreational features; and
- changes in radiation and radioactivity, which may affect public attitudes towards feelings of health, safety or satisfaction with community.

OPG stated that changes in air quality and noise levels were expected to be of sufficient magnitude that they needed to be considered further for their potential effect on other social assets. OPG determined that the other identified indirect interactions, however, were not likely to result in adverse effects and did not consider them further.

<u>Cultural and Heritage Resources</u>

OPG reported that Archaeological Assessments for the project were completed in 2011 and that the Stage 2 assessment determined that only the extreme southeastern corner of the Project Area overlapped with culturally-sensitive area B (CSA B), which contains the Bonnett (BbHj-32) cultural heritage feature - a band of low-relief cobble piles that represent a section of a collapsed snake rail fence along the Lot 21/Lot 22 line. The remaining culturally sensitive areas

(A, C and D) were determined to be located well away from the Project Area and would not be subject to any project works or activities. The assessment also determined that the remainder of the Bruce nuclear site, including the project site, was considered to be cleared of further archaeological concern.

Aboriginal heritage resources are addressed in Chapter 12.

Community and Recreational Facilities and Programs

OPG considered that nuisance effects had the potential to be disruptive to activities and operations conducted at community and recreational facilities located near the Bruce nuclear site, if they were of sufficient magnitude over baseline conditions, particularly at those facilities with outdoor components such as MacGregor Point Provincial Park and Brucedale Conservation Area.

OPG did not expect, however, that any community or recreational facilities would experience nuisance disruption because no adverse effects for dust levels across the Local Study Area were predicted during any phase of the project, and because small, barely perceptible changes in noise levels (i.e., up to 2 dBA) were predicted at Inverhuron Provincial Park. No other outdoor recreational facilities were expected to experience a change to noise levels.

Although the project would add some volume of traffic to the road network, OPG expected that the effects would be very small and would not cause a change in existing levels of service. In addition, OPG noted that there were no community or recreational facilities present along the main transportation routes to and from the Bruce nuclear site.

OPG noted that other adverse effects on community and recreational features within the Local and Regional Study Areas may occur indirectly through demand from project-associated population increases and as a result of adverse effects on community character, particularly if a stigma was attributed to the Local Study Area and people were to take steps to avoid community and recreational facilities in the vicinity of the Bruce nuclear site. OPG determined that the predicted small population increase from the project would not change the overall demand for recreational facilities in the Local or Regional Study Area.

OPG presented information from its public attitude research, which indicated that a large majority of people (more than 86% in the Local Study Area and 75% in the Regional Study Area) had not anticipated any changes to their use of community and recreational facilities or other areas in the vicinity of the Bruce nuclear site. Similarly, OPG reported that information collected from users at MacGregor Point Provincial Park and the Brucedale Conservation Area indicated that the project would not deter users from visiting these areas in the future.

Use and Enjoyment of Private Property

OPG acknowledged that the effect of major industrial projects on the use and enjoyment of private property was a common public concern. For the purpose of this socio-economic assessment, OPG focused on the Local Study Area and evaluated the more direct relationship between the presence of the Bruce nuclear site and the Local Study Area, where nuisance and traffic effects were anticipated to be the greatest.

OPG did not predict that the project would cause nuisance effects because of dust but identified a residual adverse effect on the enjoyment of private property due to increased noise levels. As described in more detail in Chapter 9, noise levels during site preparation and construction and during decommissioning were predicted to increase by approximately 5 dBA at residences near the Baie du Doré receptor location.

OPG considered that the project might adversely affect use and enjoyment of private property if it fundamentally changed those features of the community or neighbourhood that were valued for their positive influence or prevented or constrained people from using their private property in the manner they chose. OPG conducted a site neighbour survey of 14 property owners, 4 of which responded to the survey. OPG reported that, based on the results of the site neighbour survey and from observation and professional judgement, residents in the immediate vicinity of the Bruce nuclear site used their property for a variety of purposes, the most popular of which were gardening, swimming, relaxing outside, and general outdoor recreational activities. OPG determined that the ability of residents to undertake these activities was not likely to be affected by the project.

With regard to the influence of increased growth and development on use and enjoyment of private property, OPG determined that increased population associated with the project was expected to be relatively small and adverse effects were not likely. Additionally, OPG considered whether the project may adversely affect use and enjoyment of private property if it were to adversely affect community character or if a stigma was generated because of the project. Adverse changes in community character or the attribution of a stigma would likely make the area less desirable as a place to live. OPG determined that there could be no effect as a result of stigma and proposed the lack of strong evidence for the presence of an existing stigma associated with the existing WWMF, and absence of indications that the project would result in the attribution of a stigma in the future as reasons for this determination.

OPG indicated that its visual analysis demonstrated that, from external viewpoints, the project would be a barely visible object on the horizon and would have a minor visual impact. OPG reported that the existing old steam plant stack would remain as the tallest structure on-site and that the project's surface buildings and structures would be visible from some off-site areas, along with existing buildings and structures that had a similar industrial character, but would often be screened from view. OPG noted that the presence of the existing wind turbines and hydro towers in the landscape further influenced the industrial nature of these viewsheds.

Community Cohesion

OPG defined community cohesion as people's sense of belonging to a self-defined community and provided that several factors contribute to the cohesiveness of a community, including length of residency (the longer people live in their community, the more likely they were to express satisfaction with their property, homes and community) and the demographics of households. OPG stated that it has made a contribution to community cohesion through its corporate involvement and support for community activities; from the OPG Corporate Citizenship Program; and from its financial support and hands-on involvement to registered charities and not-for-profit community, educational and environmental organizations.

OPG focussed the assessment of community cohesion on the Local Study Area, reflecting the more direct relationship between the presence of the Bruce nuclear site and the Local Study Area. OPG suggested that the project would be considered to have a negative influence on the cohesiveness of a community if it were to cause a fundamental change in those aspects that were considered to positively influence community cohesion; a change in behaviours that supported community cohesion; or movement of people from their neighbourhoods or community. OPG anticipated that none of these adverse actions were likely to occur and suggested that the project would likely be a positive influence on community cohesion in the long term.

OPG was of the opinion that continued development at the Bruce nuclear site would strengthen the presence of the site and nuclear industry employees in the community and would allow OPG to continue to provide an economic driver and be a valued corporate citizen in the Local Study Area. OPG committed to continuing its Corporate Citizenship Program and the community initiatives of its employees, and noted a number of initiatives that it has undertaken in this regard.

Mitigation and Determination of Residual Adverse Effects on Social Assets

OPG determined that the relatively small increase in population associated with the project would not impose a noticeable increase in the overall demand for the recreational opportunities provided by Inverhuron Provincial Park.

OPG determined that the project would not have any effect on Inverhuron Provincial Park as a result of stigma. The basis for this determination was the lack of strong evidence for the presence of an existing stigma associated with the existing WWMF, and the absence of evidence in the public attitude research that the project would result in the attribution of a stigma in the future.

OPG was of the opinion that Inverhuron Provincial Park would remain an important local feature that would continue to be accessible and provide benefits to community residents, tourists and other visitors. In the context of the general population growth anticipated across the Regional and Local Study Areas, OPG predicted that the park would likely continue to be attractive and utilized extensively by an increasing number of users.

OPG determined that the project would not result in direct environmental effects to Inverhuron Provincial Park or affect park accessibility, nor would any modifications to the park be required to accommodate the project. OPG predicted that any users who might choose to frequent Inverhuron Provincial Park less often or stop coming outright because of the project would likely be replaced by others who were more tolerant of local conditions or had fewer issues with the project. OPG stated that widespread measurable changes to people’s use and enjoyment of Inverhuron Provincial Park attributable to the project were not anticipated and therefore, there would likely be no adverse effects on visitation to the park.

OPG reported that it did not expect any nuisance disruption to community or recreational facilities in Inverhuron Provincial Park. No adverse effects on dust levels in the park during all phases of the project were predicted. Only small, barely perceptible changes in noise levels (up to 2 dBA) were predicted in the park. OPG added that the project would add some volumes of traffic to the road network but that these effects would be very small.

OPG determined that, because the site preparation, construction and decommissioning activities would be limited to the project site, it would be unlikely that cultural heritage features would be directly affected by the project. OPG added that it would not be likely that any unknown Euro-Canadian cultural heritage features, including deeply buried ones, would be disturbed. OPG committed that, in the unlikely event that site preparation, construction or decommissioning activities encountered artifacts that could be associated with a cultural or heritage resource, the activities would be curtailed until further assessment (a Stage 3 or 4 archaeological assessment) was undertaken to protect the resource from further disturbance and to conserve its cultural heritage value.

In response to information requests from the Panel regarding cultural and heritage resources that could be affected by the project, OPG offered the following:

- A copy of the Kincardine Heritage Register, which provided a listing of heritage buildings in the Local Study Area for the Socio-economic assessment – OPG predicted that the project would not affect these heritage buildings and structures;
- No buildings, in the Site or Local Study Areas, would be removed or demolished for the project, so no consent would be required from the Ontario Ministry of Tourism, Culture and Sport;
- Although there were shipwrecks located in Lake Huron near Kincardine and also in the Regional Study Area, there were none in the Site Study Area. OPG predicted that the project would not have a direct or indirect effect on any marine archeological sites.

OPG determined that the project would not result in direct environmental effects to community or recreational facilities or programs, affect their accessibility, nor require any modifications to accommodate the project. OPG was of the opinion that any users who might choose to frequent these places less often or stop coming outright were likely to be replaced by others who were more tolerant of local conditions or have fewer issues with the project. Overall, OPG did not anticipate widespread adverse changes to the use and enjoyment of community and recreational features across the Local Study Area that would be attributable to the project.

OPG found that the residual adverse effect of increased noise levels on use and enjoyment of private property near the Baie du Doré receptor location was not significant. OPG rated the magnitude, geographic extent, timing and duration as low and described frequency as medium, with the effect occurring at regular, although infrequent intervals. The effect was determined to be reversible with time. OPG acknowledged, however, that increased noise may reduce the enjoyment of the private properties in the Baie du Doré area in closest proximity to the Bruce nuclear site. This topic is discussed in terms of effects on health in Chapter 9.

OPG stated that the visual impact of the project's surface buildings and structures would not be significantly different to what viewers were already accustomed to seeing and the project's visual effect was not expected to indirectly affect use and enjoyment of private property. OPG added that this determination was supported by its public attitude research results.

OPG summarized that the positive influences of the project on community cohesion were more likely to be noticeable than the negative ones and that, on a community-wide basis, adverse effects attributable to the project were not considered likely. OPG committed to keeping its neighbours and the public informed concerning its activities at the Bruce nuclear site as appropriate to each phase of the project and would continue to make contributions to the community through its Corporate Citizenship Program and work with various stakeholders to deliver its community, recreational and educational initiatives.

In its summary of perspectives on community well-being, OPG reported that overall, the field research results showed that the residents, community leaders and stakeholders felt that the greatest threats to community well-being were related to financial assets and that these financial assets, along with physical and social assets, should be maintained or enhanced to support community well-being. OPG observed that the Bruce nuclear site was seen by the community as being important to its financial well-being and that many respondents stressed the importance of the community's dependence on the Bruce nuclear site for employment and economic opportunities. OPG stated that the loss of the nuclear industry would be devastating to the community, which views its financial assets as being important to community well-being.

11.1.3 Cumulative Socio-Economic Effects

As will be explained in Chapter 15, the only residual adverse effect carried forward by OPG for consideration of cumulative effects on socio-economic valued ecosystem component was the change in noise levels in the Baie du Doré area, resulting in reduced enjoyment and use of personal property during site preparation and construction and decommissioning phases. OPG determined that there would be no cumulative effects at the noise receptor locations used in the environmental assessment, which were all located close to the boundary of the Bruce nuclear site.

OPG assessed the potential for cumulative effects of the project on demographics and subsequent demand for housing, health, emergency and educational services and determined that cumulative effects were not anticipated due to the small scale of the project. OPG stated that no “boom and bust” economic effects were expected because such effects are generally associated with large transient workforces entering and leaving small rural or remote communities that do not have the infrastructure, services or past experience to cope with such rapid change. OPG pointed to the recent refurbishment of the Bruce A nuclear generating station as an example of where a project on the Bruce nuclear site, with a larger workforce than the DGR would have, did not adversely affect the socio-economic environment. OPG stated that the project would not be considered to be a major project and the additional workers would not be expected to create significant changes or undue stresses on the socio-economic environment, including tourist accommodations.

11.1.4 Summary of OPG's Socio-Economic Assessment Results

OPG was of the opinion that the project would cause one residual adverse socio-economic effect which was that off-site noise levels would be increased by a maximum of approximately 5 dBA in the Baie du Doré area during the site preparation and construction phase and during the decommissioning phase. OPG noted that this change in noise levels may reduce the enjoyment of private property in the Baie du Doré area in close proximity to the Bruce nuclear site but determined that this effect would not be significant.

OPG stated that the project would not cause any other direct or indirect residual adverse effects to valued socio-economic environment components. OPG summarized the beneficial effects of the project to socio-economic valued components as follows:

- population and demographics: a small increase in population with the greatest benefit anticipated in Kincardine;
- other human assets: increased educational opportunities for local students and others with an interest in nuclear technology;
- employment: new direct, indirect and induced employment opportunities;
- business activity: increased business activity through all project phases, which can be enhanced through policies to use local business services wherever practical and appropriate;
- municipal finance and administration: increased municipal revenue because of increases in property taxes and other revenues as well as through one-time and annual payments agreed to in the 2004 Hosting Agreement; and
- other financial assets: increased direct, indirect and induced labour income in the Local and Regional Study Areas.

OPG proposed that public attitudes toward personal and community well-being were influenced by the positive and negative effects of the project on the assets. OPG presented that the DGR would be a positive contributor to community well-being overall through increased employment opportunities, labour income and business activity, educational opportunities and municipal revenues and proposed that no significant adverse effects on the socio-economic environment were anticipated that could diminish community well-being.

11.1.5 Government Department Evaluation of Socio-Economic Effects

CNSC determined that the OPG addressed the most critical elements of the EIS Guidelines regarding effects on socio-economic conditions and that OPG had provided satisfactory responses to information requests on this subject. The CNSC noted that a certain level of conservatism was built into the socio-economic assessment and also noted that there was uncertainty in predicting the effects on the socio-economic environment.

CNSC agreed with OPG’s prediction that the project would cause off-site noise levels that may reduce the enjoyment of private property in the Baie du Doré area, and noted that, given the small geographic area and the level of frequency of the anticipated effect, this particular effect was not significant. CNSC noted that other minor adverse effects may occur in relation to the project, such as a shortage of rental housing or competition for temporary accommodation. CNSC staff stated that these effects were likely to be minor given the small work force at various phases of the project and concurred with OPG that the occurrence or magnitude of such effects cannot be accurately predicted at this time.

CNSC recommended that OPG monitor the effect of the DGR on the availability of rental housing, temporary lodging and tourist accommodation. CNSC suggested that OPG should seek to identify how many workers would be local versus non-local, and then confirm how many non-local workers planned to rent housing or utilize tourist accommodation or other forms of temporary lodging within the Local or Regional Study Areas. The CNSC suggested that, if a large number of DGR workers require rental housing, temporary lodging or tourist accommodation and the existing supply cannot accommodate demand, OPG could attempt to mitigate potential negative impacts.

The Ontario Ministry of Transportation had no concerns with the proposed DGR. The Ontario Ministry of Transportation was satisfied that the project would not adversely impact traffic operations at the intersections of Highway 21 and Bruce Road 20/Bruce Concession 4 and Highway 21 and Bruce Concession 2.

The Ontario Ministry of the Environment and Climate Change pointed out that an Environmental Compliance Approval would have to be obtained from the Ministry for the establishment, operation, alteration or enlargement of any landfill. The regulatory requirements are included in Ontario Regulation 347, *General – Waste Management* and Ontario Regulation 232/98, *Landfilling Sites*.

The Ontario Ministry of Tourism, Culture and Sport confirmed that no archaeological sites were found during OPG's assessment; therefore, no further archaeological assessments would be required. The Ministry noted that should unknown or deeply buried archaeological sites be uncovered during construction, all construction activities would have to cease, and a licensed archaeologist would have to conduct an assessment. The Ministry accepted OPG's finding that the project would not affect any built heritage and/or cultural heritage landscape.

The Ontario Ministry of Municipal Affairs and Housing noted that the availability of housing in the DGR Project Area would be a local matter and as such, the Ministry would have an extremely limited role in this issue. The Ministry explained that the Municipal Property Assessment Corporation administers a uniform, province-wide property assessment system based on current value assessment in accordance with the provisions of the Ontario *Assessment Act*, which is under the purview of the Ontario Ministry of Finance. The Municipal Property Assessment Corporation was described as an independent, not-for-profit corporation with municipal representatives comprising the majority of its directors. The Ministry suggested that any questions relating to property values throughout the project's life cycle could be addressed to the Municipal Property Assessment Corporation. The Ministry pointed out that the Municipality would be in a better position to comment on what ability, if any, existed to protect property values throughout the life cycle of the project.

11.1.6 Views of Participants

The Municipality of Kincardine commissioned a peer review of OPG's socio-economic assessment. The peer reviewers determined that with appropriate impact avoidance, mitigation measures and follow-up monitoring, the project was not likely to cause significant adverse socio-economic effects in the Municipality of Kincardine. The reviewers determined that the specific follow-up and monitoring reports created for particular nuisance effects, i.e., dust and noise, were adequate. Issues that were raised by the reviewers and resolved during discussions with OPG were:

- provision for municipal input on waste rock management area design, including placement of trees and a berm;
- development of a property value protection program at project licensing;
- additional details to be provided to the Municipality for the Centre of Energy Excellence regarding its potential for creating jobs and facilitating economic development;
- assurance that OPG was well prepared to address and monitor potential stigma effects;
- OPG's commitment that a reciprocal agreement and training for mine rescue workers will be in place; and
- OPG's commitment that follow-up plans and monitoring will address nuisance effects and that further public attitude research will provide secondary monitoring of nuisance effects.

Subsequent to the findings of the peer reviewers and satisfactory disposition of identified issues, the Municipality of Kincardine passed a resolution to endorse the peer review and confirm that the proposed project would not have significant adverse socio-economic effects in the Municipality.

The Panel received expressions of support for the project from participants who welcomed the economic activity associated with the construction and operation of the DGR. The direct and indirect effects of the project on economic activity described by participants included local housing, commercial and supply chain industrial activities, as well as tax revenue to local governments. There was also a desire to retain the community's young people in the area by providing highly skilled and well-paid jobs. The Panel heard from an organization of young professionals working in the nuclear industry who emphasized the importance of providing opportunities for technological innovation, professional development, training and employment for younger generations. Some participants emphasized that the development of the nuclear power generation industry in the area has had a profound impact on their communities, including a shift from light manufacturing to employment on the Bruce nuclear site. Thus, any prospect of continued economic stability at the Bruce nuclear site was welcomed.

Reliance on the nuclear industry was described as both a benefit and a risk, depending upon the participant. There was concern about "boom and bust" cycles associated with different phases of the project, with higher employment during the site preparation and construction phase followed by a decline during operations. There was also concern about the longer-term prospects for employment at the Bruce nuclear site, given the projected lifespan of the nuclear generating station. There was also a suggestion that opportunities for increased long-term economic diversification should be evaluated to avoid negative effects due to over-reliance on the nuclear sector.

Community cohesion was a common theme for many participants. A number of participants expressed pride in being part of a community with over 40 years of safe nuclear operations. There were many references to the highly-valued rural flavour of the communities. It was suggested that almost every household in the local communities would have a connection with someone who worked at the Bruce nuclear site. The Panel received several submissions from community groups and non-profit organizations that receive financial support from OPG; these organizations pointed out the value added to the community by OPG's support.

The Panel also received information about divisions within the local communities regarding the project which could affect community cohesion. In particular, there were concerns that payments by OPG to municipalities were a means for OPG to influence municipal councils. One participant stated that the key challenge was finding a balance between rewarding the community for their contribution to managing Ontario's nuclear waste while making sure the rewards were not so great that residents could not reject it when they were polled. Some participants were of the view that an appropriate balance had been struck via the Hosting Agreement. Others disagreed and maintained that the community was either opposed, or had been persuaded via economic incentives. Some participants argued that the payments from OPG through the Hosting Agreement were too low.

Some participants suggested that there was a so-called 'nuclear oasis' effect caused by economic dependence on and obligation to the nuclear industry, large and well-publicized industry contributions to the community and the population's comfort with nuclear operations. This 'nuclear oasis' effect was cited as the primary factor leading to acceptance of the DGR by local governments and by the population. Some participants regarded this 'nuclear oasis' effect as a negative effect because it created an unreasonably biased climate, which limited meaningful public participation.

Educational opportunities associated with the project were highlighted by several participants. The Panel heard from local educational facilities and non-profit learning organizations that were looking forward to working with OPG in the future on expanded educational opportunities associated with the project. These organizations stated that they provide college certificate programs, workshops and information sessions focussing on the development of local talent that will benefit local businesses, including the nuclear industry.

Opinions were divided regarding effects of the project on property values. Some participants stated that they were not concerned that property values would decline. This opinion was based upon experience with the presence of the Bruce nuclear site in the area, including experience during the recent Bruce nuclear generating station refurbishment activities. Other participants were concerned that the DGR would produce stigma-related effects on property values.

Several participants were critical of the property value protection plan in the Hosting Agreement, where the onus would be on the property owner to prove contamination of their property. The effects of changes in air quality and noise on property values and the enjoyment of property was a substantial concern among some participants. The Panel notes that it has recommendations related to the monitoring of air quality and noise and the inclusion of public involvement in these monitoring programs.

While some participants were convinced that support for the project was substantial and well-documented among local and regional residents, others were concerned that an objective measure of support for the project had not been obtained. The Panel heard several participants claim a lack of transparency and accountability in the process followed by elected local officials leading up to official expressions of support for the project. The wording of the question used in the "Strategic Council" polling in 2004 following the signing of the Hosting Agreement with

Kincardine was described by some participants as misleading and biased, and suggested that a referendum should have been held instead. Subsequent polling, including the public attitude research conducted as part of the environmental assessment, was criticized for the low sample size of seasonal residents and the lack of any coverage of particular communities such as Inverhuron.

Some participants maintained that the boundaries for the definition of a “willing host” community should have been much broader because, in their view, the potential effects of the project could extend to the entire Great Lakes basin.

The adequacy of financial provisions for the project was the subject of some submissions to the Panel. Concerns were raised regarding whether sufficient funds are being put aside to cover all phases of the project. There appeared to be few concerns regarding whether the current funding set aside by OPG would be sufficient for the site preparation and construction phases. However, OPG’s calculations of decommissioning costs were criticized, and the contingency factor included in the calculation of these costs was described as being too low by one participant. This participant pointed out that while a financial guarantee will be provided by OPG to the CNSC in the form of a letter of credit to cover the cost of decommissioning the project, if it is constructed and never used, no similar financial guarantee seems to be in place to cover any of the decommissioning costs of the project at the end of its useful life. Thus, the participant suggested that OPG should provide a similar guarantee and/or bond for decommissioning the project after its operational life was complete. The participant also suggested that OPG could pay an adjusted net-present-value amount for decommissioning into a trust fund as a condition of approval for site preparation and construction. The CNSC stated that it has regulatory requirements for financial guarantees that OPG would have to satisfy, should the project proceed. These requirements include CNSC Regulatory Guide G-219, *Decommissioning Planning for Licensed Activities* and CNSC Regulatory Guide G-206, *Financial Guarantees for the Decommissioning of Licensed Activities*.

The potential for stigma due to the presence of the project and subsequent effects of stigma on socio-economic valued ecosystem component such as tourism and the enjoyment of personal property were the subjects of several submissions to the Panel, including by the Saugeen Ojibway Nation. OPG maintained that widespread changes in attitudes among tourists were not expected, based upon surveys of users of recreational sites and that community character was not expected to change. In contrast, the Saugeen Ojibway Nation stated that OPG’s stigma analysis was fundamentally deficient in that it did not reference relevant case studies where concerns about stigma played a substantial role. The Saugeen Ojibway Nation expressed the view that OPG had failed to provide the Panel with material information about the potential for DGR-related stigma.

As described in Chapter 2, the Panel contracted Dr. William Leiss to prepare a report on stigma. The report reviewed the concept of stigma, reviewed case studies, and offered conclusions with respect to siting of nuclear waste repositories in the context of issues about stigma. Dr. Leiss pointed out that, whereas stigmatizing persons, such as persons within ethnic minorities, is a serious, ongoing issue for public policy, stigmatization applied to technologies, products and places is a much more ambiguous process, especially over a longer period of time. Dr. Leiss explained that stigma applied to technologies, products and places is a special case of risk perception, which can appropriately be addressed within a risk-based decision-making framework that deals not only with the scientific assessment of risk, but also with the risk perceptions of the general public. Dr. Leiss noted that stigma implies a special type of harm, one which is unnatural and permanent, a kind of harm that cannot be made better or mitigated. Therefore, it is an extreme category of risk perception that should be applied with caution to places. For example, although some places may have negative associations, such as cities with high crime, abandoned homes, or unremediated contaminated sites, the conditions creating those negative associations are not inherently permanent because measures can be taken to reduce negative effects.

Dr. Leiss emphasized that there was a difference between anticipated future stigma associated with a place, such as was the case for the proposed Yucca Mountain radioactive waste site in the U.S., and actual, documented stigma associated with operating nuclear waste facilities. Dr. Leiss emphasized that a risk management approach would be useful in the case of anticipated future stigma. In the risk management approach, citizens can ask tough questions about trade-offs between risk and benefits for the community and wait until they get evidence-based answers they can trust. Dr. Leiss maintained that stigma was not a significant issue at operating nuclear waste facilities in Finland, Sweden, South Korea and the United States because the communities were willing hosts.

The Panel asked for views regarding the issue of setting boundaries for a willing host community. Dr. Leiss stressed the importance of holding discussions regarding the setting of boundaries early a siting process. He suggested that someone outside of the community and the project should define the relevant boundary, based on relevant potential effects. A participant suggested that boundaries might be defined by the limits to the extension of stigma associated with the project. The participant also suggested that boundaries need not be definitive; rather, they may differ depending on the environmental or social impacts and the political, social and economic networks within communities.

Dr. Leiss made a distinction between effects on property values at locations with legacy issues related to poor environmental practice and regulation and effects where engineering standards and regulations are rigorous. He did not anticipate effects on property values at locations where standards were high and regulations rigorously enforced, such as would be the case for the DGR.

11.1.7 Panel Conclusion Regarding Effects on the Socio-Economic Environment

This section includes the Panel’s conclusion regarding effects under the *Canadian Environmental Assessment Act, 2012*, as well as comments relating to potential effects on other social and economic components that were described during the review.

Socio-economic Effects Assessment Under the *Canadian Environmental Assessment Act, 2012*

The Panel concludes that the project is not likely to cause significant adverse environmental effects to valued components of the socio-economic environment that may be affected by changes in the biophysical environment due to dust and noise generated by the project.

The Panel concurs with OPG regarding the lack of off-site adverse effects on air quality, specifically dust levels. The Panel emphasizes the importance of OPG's implementation of dust mitigation measures. The Panel notes that near-by residents may include people with increased sensitivity to dust exposure; therefore, as already noted in Chapter 9, the follow-up air quality monitoring program might benefit from inclusion of specific input from community members.

The Panel also concurs with OPG that the only residual adverse effect off-site would be an increase in noise in the Baie du Doré area during the site preparation and construction phase and during the decommissioning phase. The Panel considers OPG's predicted maximum increase in noise to be conservative, meaning that it is very unlikely that the increase in noise was underestimated. The Panel concurs with OPG that this increase in noise would not result in significant adverse residual effects due to the limited spatial extent of the increase in noise, as well as the low magnitude relative to existing conditions. However, the Panel notes that disturbance caused by noise can be experienced differently by different individuals. Thus, the Panel has made some suggestions in the following section regarding the involvement of community members in follow-up monitoring of noise.

The Panel recommends that the predictions of no residual significant adverse effects from off-site dust and noise levels on socio-economic valued components be confirmed through follow-up monitoring. The Panel suggests that community members be given the opportunity to provide input to the design and implementation of the follow-up monitoring program.

Recommendation 11.1: In order to confirm the environmental assessment prediction of no significant adverse socio economic effects to valued social and economic components due to dust and noise, OPG shall develop a follow-up program, acceptable to the CNSC, prior to site preparation and construction.

Assessment of Effects to other Social and Economic Components

Many of the valued social and economic components that were addressed in the review were either not components of the environment as defined in the *Canadian Environmental Assessment Act, 2012* or the effects on these components were not predicted to be caused by changes in the biophysical environment from the project, or both. Potential effects to these components, however, may be relevant or important to the community or region. Where appropriate, the Panel provides its observations or suggestions related to these components.

The Panel notes that the use and enjoyment of private property is not likely to be affected by increases in noise levels from the project, provided that noise mitigation measures are implemented. These mitigation measures are listed in Chapter 9. The Panel's Recommendation 9.5 in Chapter 9 includes the consultation with Aboriginal communities and residents in the

Local Study Area with respect to monitoring locations and the development of triggers for noise mitigation. The Panel strongly endorses the inclusion of community members in the design of follow-up noise monitoring.

The Panel notes that noise effects are subject to differences among individuals. OPG predicted that increased noise levels caused by the project would increase the percentage of “highly annoyed” people by 0.1-0.5% during site preparation and construction, and from 4.5 to 6.2% during the operations phase, with the annoyance occurring at night. This increase in "highly annoyed” people would be below the Health Canada threshold of 6.5%; therefore, OPG determined that there would be no adverse effect. However, the Panel expects that it is likely that there will be complaints regarding noise and that these complaints will be expressed in terms of noise being “audible” or “annoying”, and that these complaints will primarily be related to disturbance of sleep. As explained in Chapter 9, OPG may find the use of “Listening Panels” to be an effective follow-up monitoring technique to supplement the quantitative monitoring of noise levels. This is because quantitative monitoring cannot detect audibility, only listening can. The results of the “Listening Panels” could be used to determine the need for further mitigation of effects of increased noise levels on particular residents.

The Panel encourages OPG to include permanent and seasonal community members in discussions regarding the design of follow-up monitoring of air quality and radiation. Although dust and radiation levels were not predicted to cause adverse effects on socio-economic valued components, the Panel notes that public involvement in monitoring programs may increase mutual understanding between OPG and the community and, eventually, contribute to increased trust in the data collected to demonstrate the effectiveness of mitigation. To that end, the Panel has recommended (Recommendation 8.1) that OPG conduct follow-up monitoring to address the specific concerns of individuals living at or near the critical receptor locations used in the EIS models.

The Panel has adopted the CNSC recommendation regarding follow-up monitoring of effects of the project on rental accommodation as follows:

Recommendation 11.2: OPG shall, to the satisfaction of the CNSC, conduct a monitoring program to confirm the effects of the project on access to and availability of rental housing, temporary lodging and tourist accommodation in the Local and Regional Study Areas, during site preparation and construction.

The Panel has determined that, although OPG has made commitments related to the following issues, additional reference to them is required here in order to emphasize the importance of fulfilling these commitments and monitoring the effectiveness of any mitigation that may be required.

1. Municipal and general public input on the design of the waste rock management area

The design of the waste rock management area will include consideration of mitigation of dust and noise, as well as measures to reduce the aesthetic impacts. All of these considerations are relevant to the prevention or mitigation of effects on socio-economic valued components such as property values and the use and enjoyment of private property and public recreational areas.

In order to increase mutual understanding of best practices and effectiveness of mitigation measures, OPG should make provision for obtaining input from municipal representatives, Aboriginal groups, and the general public regarding the design of and mitigation measures for effects the waste rock management area may have on these valued components.

2. Development of a property value protection program

The existing property value protection program as articulated in the Hosting Agreement was the focus of substantial criticism. The Panel suggests that the program could be revisited and that the public be engaged in discussion about the program. The Panel notes that the property value protection program may be included within the broader discussion about stigma (see below).

3. Detailed planning for the Centre of Energy Excellence

The peer reviewers for the Municipality of Kincardine indicated that OPG had committed to addressing the Centre of Energy Excellence. The Panel notes that if the educational initiatives proposed by OPG for the project, as described in the EIS, are to be fully realized, details regarding the Centre of Energy Excellence will be required. The Panel suggests that detailed plans for the Centre of Energy Excellence be developed prior to the site preparation and construction phase of the project.

4. Monitoring of stigma and planning mitigation if required

The peer reviewers for the Municipality of Kincardine relayed that OPG was prepared to address and monitor potential stigma effects. During the hearing, the Panel asked Dr. Leiss for his suggestions regarding assessment of the risk of stigma being attached to communities or products (such as fish) because of the presence of the project. Dr. Leiss, noting the comment from the Municipality of Kincardine peer reviewers, suggested a stigma monitoring program.

Dr. Leiss explained that baseline data would be required. Baseline data could be collected on indicators such as property values, prices for locally-produced agricultural products or fish, and revenues from tourism. Dr. Leiss also noted that the baseline could also include trends. He advised that the baseline data on local indicators could be compared with reference indicators, such as Ontario-wide data. He also advised that the monitoring design should include agreement on what would demonstrate an effect and what would be deemed an unacceptable effect. Dr. Leiss stated that OPG should also have a plan for mitigation should stigma effects be observed, such as property value compensation. He noted that, through such a program, OPG would have the opportunity to contribute significantly to the understanding of the development of stigma associated with nuclear facilities and its associated effects, including establishing more clearly what the trade-offs might be with respect to the risks and benefits of the project.

The Panel suggests that, in order to confirm the predictions regarding stigma, OPG should develop a follow-up program that incorporates the collection of baseline data prior to site preparation and construction, and monitor stigma effects throughout the site preparation and construction, operations and decommissioning phases. The monitoring program should include applicable indicators and benchmarks that would indicate a stigma effect, and provisions for including input from Aboriginal groups and members of the public. OPG should collect baseline information on stigma in the Local Study Area prior to site preparation and construction according to a study design that has received input from experts, Aboriginal groups, and the public, regarding appropriate and applicable indicators and benchmarks for stigma effects. OPG should then proceed with monitoring for stigma effects of the project at appropriate intervals throughout the site preparation and construction, operations and decommissioning phases. OPG should develop measures to address any identified stigma effects.

5. Reciprocal agreements for training of mine rescue workers

The Panel notes that, with the exception of a salt mine, there are no mining operations with experienced mine rescue personnel in the region of the project. Therefore, particular attention will be required with respect to ensuring that the minimum required number of mine rescue teams will be available to work at the project during the construction, operations and decommissioning phases, in accordance with Ontario Ministry of Labour requirements.

6. Follow-up public attitude research, including monitoring of nuisance effects associated with dust and noise

The Panel notes that, in conjunction with public attitude research for the WWMF, OPG expressed plans to conduct follow-up public attitude research during the peak year of employment during site preparation and construction, subsequent to any accidents or malfunctions or associated operations resulting in a release of radioactive contamination to the environment, and during operations. Some participants suggested that the public attitude research should include an expanded set of measures and should be conducted during periods of lower employment as well as during peaks. Participants also suggested that the public attitude research be expanded to include measures of effects, including effects on the tourism and cottage rental sectors. Measures of effects would also include measures of effects associated with dust and noise. The Panel concurs with these suggestions, and emphasizes that it is important that OPG obtain an adequate sample of seasonal residents in its public attitude research.

The Panel suggests that the monitoring of stigma (as discussed above) could form part of the overall follow-up monitoring program. The monitoring framework could be established within a framework agreement between OPG and the community, which would establish a process whereby the community could be informed regarding the design and results of follow-up monitoring. The monitoring framework should be established prior to site preparation and construction, and include the collection of baseline data for stigma and any other effects measures for which there may be insufficient data to allow for confident comparison with future data.

7. Specific OPG programs for local procurement and training

OPG stated that it would utilize local business services whenever practical and in accordance with OPG supply chain policies, procedures and standards for competitive purchasing. The Panel is of the view that OPG should review its policies, procedures and standards such that opportunities for local and regional procurement of supplies and services are enhanced through actions such as supplier information and training sessions and assistance with quality assurance and control. This would help increase the local and regional benefits from the project and further improve the risk/benefit ratio for the Local and Regional Study Areas.

OPG stated that there would be increased educational opportunities for local students and others with an interest in nuclear technology; however, details regarding these opportunities were not provided. The Panel strongly suggests that OPG conduct detailed planning for educational opportunities at all levels, in consultation with local, regional, national and international educational institutions and organizations.

11.2 PUBLIC ENGAGEMENT

Public engagement was a topic of interest for many participants. This section describes the public engagement by OPG and the CNSC in relation to the project, as well as the views of participants.

11.2.1 OPG Public Engagement

OPG described the Public Participation and Aboriginal Engagement Program that it undertook for the project, from the initiation of the discussions between the Municipality of Kincardine and OPG in 2002 to the submission of the EIS in 2011. OPG explained that the program was consistent with OPG's practices on public consultation and was intended to fulfill the requirements for public participation under the *Canadian Environmental Assessment Act* and the *Nuclear Safety and Control Act*. OPG further noted that its engagement program would continue throughout the regulatory approvals process and beyond.

OPG explained that the objectives of its communication activities were to:

- keep stakeholders and the general public informed and updated;
- form or maintain open lines of communication; and
- provide an open opportunity for feedback, and have questions answered.

OPG explained that it used a variety of activities and means such as open houses; speaking engagements; a mobile exhibit; newsletters; a website; library repositories; and telephone communication to provide a broad range of opportunities for stakeholders and the general public to obtain information, ask questions, and provide comments and input to the environmental assessment project. OPG noted that it conducted briefings and consultations with key stakeholders including local property owners and ratepayer associations, unions, professional associations and non-government organizations.

OPG listed its target audiences which included Aboriginal groups, individuals, groups or organizations, the media, bureaucrats and elected officials in Ontario and Michigan. OPG explained that its Public Participation Program was initiated after the signing of the Memorandum of Understanding between the Municipality of Kincardine and OPG. The Program focused initially on the Municipality of Kincardine until 2004 and starting in 2005 included the four surrounding communities – Huron-Kinloss, Brockton, Arran-Elderslie and Saugeen Shores.

During this period, OPG informed and engaged the public and stakeholders about the study options being considered for the long-term management of the L&ILW through the Independent Assessment Study (IAS). Key components were:

- public attitude research;

- a community telephone poll concerning support for the project's concept;
- stakeholder briefings;
- a newsletter;
- open houses; and
- website development.

OPG enhanced its Public Participation Program after the submission of the DGR Project Description in December 2005. Enhancements to the Public Participation Program included increasing the level of communications and broadening the consultation area to include all of Bruce County. In addition to the four communities surrounding Kincardine, activities were held in the municipalities of South Bruce, South Bruce Peninsula, North Bruce Peninsula and Owen Sound. OPG made efforts by developing a mobile exhibit, videos and other community outreach methods, and conducted a number of open houses to seek stakeholder and public input on the valued ecosystem components.

OPG used a communications tracking tool to track and respond to comments. In some instances, comments received were reflected in the modifications to the project design. For example, comments from the general public about the proximity of the DGR to Lake Huron resulted in the design team orienting the emplacement rooms, to the extent possible, while still aligning with the primary stress direction, to extend inland from the lake. OPG conducted polls and surveys to gauge attitudes and support for the project in Kincardine and the surrounding communities. The results showed continued support and a high level of confidence for the project. During this period, briefings and consultation took place with American stakeholders, particularly with Michigan-based ones.

OPG noted that it continued to implement the Public Participation Program after the submission of the EIS. Some of the activities included:

- briefings and presentations to key stakeholders in Canada;
- distribution of the DGR newsletters and brochures;
- tours of the WWMF;
- publication of The Lake Huron Report, concerning the project's ability to protect the Great Lakes; and
- employee communications and ongoing issues management and tracking.

OPG outlined a number of engagement strategies for the remainder of the EIS assessment period in its submission for the Socio-economic technical information session. These activities included:

- continue to use a wide range of communication methods to ensure information about the project is communicated;
- engage with key stakeholders to ensure awareness of how to participate in the review process;
- broaden communications efforts outside of the Regional Study Area;
- continue to respond to questions and concerns;
- provide factual information via newsletters, fact sheets, Q&A's, videos, website, social media, and advertising campaigns;

- continue to use the mobile exhibit in the Regional Study Area; and,
- continue efforts to distinguish between the project and the Nuclear Waste Management Organization Adaptive Phased Management Process for high-level nuclear waste.

OPG highlighted engagement activities and issues raised about the project outside of Canada. Briefings and consultations were conducted with Michigan-based government officials, including State Senators and Members of Congress, and non-governmental organizations. Meetings were also held with Detroit and Washington consular and Canadian embassy officials. OPG noted that it received input from stakeholders in Michigan during the scoping hearing in 2006, the comment period for the EIS Guidelines, as well during the public review phase for the EIS.

OPG stated that it briefed local media throughout the environmental assessment process, and noted that media coverage included letters to the editor, newspaper reports, radio reports, and radio call-in shows. OPG explained that it held media days, including tours, information packages and opportunities for interviews, to ensure that the media would remain well-informed with the progress of the project and the environmental assessment. OPG further noted that it took measures to ensure that the project was featured on live radio and TV talk shows with call-in opportunities for the public, as well as issuing press releases and photographs at relevant project milestones.

OPG committed to establishing a Community Advisory Committee, should the project be approved. OPG explained that this committee would be a way for OPG to further enhance its engagement with the community. OPG noted that community advisory committees have been an effective and important opportunity for dialogue between OPG and the community at its other sites, and expressed confidence that the same would hold true for the DGR.

11.2.2 CNSC Staff Review of Public Engagement

CNSC staff stated that the design and implementation of OPG's public communications and engagement programs and plans were comprehensive and met the requirements for public participation under the *Canadian Environmental Assessment Act, 2012*, the *Nuclear Safety and Control Act*, the EIS Guidelines and CNSC Regulatory Guide G-217, *Licensee Public Information Program*. CNSC staff noted that communication plans under the program were developed annually and included descriptions of communication objectives, strategies and activities as well as target audiences and key messages.

CNSC staff stated that OPG did as much as could reasonably be expected to contact and involve different segments of the population that could have an interest in or be affected by the project. CNSC staff commented that OPG's public communications were easy to understand, used simple language, and were presented in a manner that was tailored to the target audience.

11.2.3 Views of Participants Regarding OPG's Public Engagement

Many participants expressed satisfaction with the opportunities provided by OPG to learn about the project and emphasized that they had obtained sufficient information for them to make an informed decision. The information was described as thorough, transparent, and easily understood, and available through a variety of means, including written updates delivered to homes, booths at community events, tours of the proposed DGR site, open houses, and segments on the local cable television channel.

Several participants noted that there were many opportunities for the public to ask questions and obtain responses about the project. Representatives of local media stated that OPG had regularly submitted notices, articles, newsletters, on-line materials and exhibits explaining the project and expressed the view that the information had been presented openly and transparently in enough venues that people were able to become informed if they chose to do so.

Representatives of educational institutions referred to the access to hands-on learning through work placements at OPG, and to the contributions of nuclear industry workers to curriculums. One participant expressed the view that it would have been hard to imagine any resident, for any time in the region, being unaware of the project.

Other participants had concerns about OPG's consultation process. There were comments that OPG's consultation process did not involve true dialogue; rather, the emphasis was on providing one-way information from OPG's point-of-view. Some participants suggested that the consultation was not conducted in a wide enough geographic area. Other participants were concerned that not all community groups or associations were consulted. OPG's information was described by some participants as being misleading or biased. There were some claims that some local residents were afraid to speak out in opposition of the DGR for fear of losing business. Attendance at OPG open houses was described as poor. Several seasonal residents maintained that they had not received any information about the project, nor were they aware of polling or public attitude research conducted in the community. OPG's consultation was described as being a form of participation that does not involve forming partnerships with citizens or empowering them to contribute to decision-making. One participant noted that while the information provided by OPG may have been of high quality, there were disconnects between the information and the concerns of the public. Another participant stated that when stakeholders have an opportunity to actively participate in the decision-making process and can participate in ensuring that the project is consistent with their values, their experience tends to be more positive and their attitudes towards projects more supportive.

One participant organization commissioned an academic review of OPG's public participation program. The reviewer stated that, in the context of nuclear waste, there needed to be a movement from participation towards partnership with stakeholders. Partnership would require empowerment, equity, trust and mutual learning with equal weight to local and scientific knowledge. The reviewer stated that in the partnership model, participation is a central part of decision-making, not simply a regulatory requirement. The reviewer was critical of OPG's participation methods, noting that most could be described as information dissemination vehicles. The reviewer noted that a dialogue-based process would involve tools such as carefully designed open-ended questions directed towards the stakeholders in order to gain access to community views. The reviewer noted that there was a lack of consultation with environmental non-governmental organizations and with cottagers. Several participants shared similar views.

In his report to the Panel and during the hearing, Dr. Leiss emphasized the fundamental importance of trust when engaging with the public. Dr. Leiss noted that independent peer review and independent consultation regarding the willingness of the community to be a host community would contribute to trust. Dr. Leiss also noted that there was a strong incentive for communities to develop transparent political decision processes. Dr. Leiss identified the key determinants of credibility in risk communication as:

- Accessible and understandable information;
- A sufficient level of independent judgement; and
- Providing answers to the most serious questions about risk and the acceptability of risk.

As already discussed earlier in this chapter, although it was not a prerequisite for the approval of the project, the topic of the willing host community generated considerable discussion and debate among participants. Elected officials suggested that the lack of concerns about the project expressed to the municipal councils, and that the project was not an election issue during municipal elections, were evidence that local opposition to the project was limited. Elected officials also stressed the degree to which the public had been informed about the project, and expressed trust in the results of polling.

In contrast, other participants maintained that the evidence for broad support of the project was weak because of flawed or biased methodology used in polling and a lack of broad consultation, particularly with seasonal residents. Some participants maintained that a referendum on the project would have been a more reliable indicator of the degree of support among citizens for the project. It was suggested that the 'nuclear oasis' effect created a climate that limited meaningful public participation because it would be difficult for an individual to stand in opposition to the economic lifeblood of a community. It was further suggested that OPG's public engagement methods did not necessarily create a safe space for people to express their core values, which may have included a fundamental values-based opposition to the project. Another participant expressed the view that nuclear workers are so comfortable with nuclear power that they feel that everyone else should be, but everyone else is not.

The OPG IEG provided information regarding effective public engagement regarding nuclear projects. The OPG IEG pointed out that the behaviour of the people conducting the engagement is as important as the information itself. It was suggested that there are three common factors when examining successful public engagement programs:

- competence and a track record of delivering on promises;
- decision-makers who have the public's best interests at heart; and
- a focus on listening rather than talking.

The OPG IEG noted that information is necessary but not sufficient for public engagement, and suggested that the people delivering the information need to be seen as real people who are dedicated, competent and caring. The OPG IEG also noted that site visits allow people to gain a better understanding of projects.

The OPG IEG presented additional information regarding effective public engagement. Matters of importance included:

- being clear about the extent of participation available;
- making sure that people are consulted on the issues that matter to them;
- putting forward several options for consideration so that they are not dismissed out of hand;
- explaining technical material in terms of its logic; and
- collaborating rather than following a top-down decision-making process.

One participant suggested that a framework agreement be developed between OPG and the community, which would establish a process whereby the community could be informed regarding the results of follow-up monitoring. The framework would include the presentation of the results of monitoring of air quality, noise, water quality, and radiation, the identification of any deviations from predictions, and proposed mitigation if EIS predictions are not confirmed. The Panel agrees with this suggestion, and notes that such a framework agreement could form part of the Terms of Reference for OPG's proposed Community Advisory Committee.

CNSC staff stated that the CNSC had been working on several issues with respect to achieving more effective engagement with the public, including increasing the openness in its public hearing process. CNSC staff emphasized that the CNSC's objective is to provide information that people can use to make up their own minds. CNSC staff reported that it has become more active in analysis of information needs of the public and creating accessible materials. CNSC staff described the "CNSC 101" sessions that are held in communities before Commission proceedings and outreach activities to support specific reviews, including seeking feedback from participants. CNSC staff noted that the CNSC uses its website as a tool for disseminating information and collecting feedback, and that it tracks traditional and social media so it can respond, if necessary, to information being provided.

11.2.4 Panel Conclusion Regarding Public Engagement

The Panel notes that OPG's public engagement program was deemed to be sufficient by CNSC because it met the requirements for public participation under the *Canadian Environmental Assessment Act, 2012*, the *Nuclear Safety and Control Act*, the EIS Guidelines, and CNSC Regulatory Guide G-217. The Panel agrees that OPG went to considerable lengths to disseminate accessible information about the project such that the public had sufficient opportunity to formulate informed opinions regarding the project. The Panel also agrees that OPG, the CNSC, and the Panel process provided sufficient opportunity for the public to provide input regarding the project.

The Panel received a substantial amount of information about how the public engagement program could be improved in order to achieve, in the words of one participant, a greater level of trust, legitimacy, and the capacity to address community concerns, manage expectations, tap local knowledge and negotiate mutually beneficial futures. Therefore, the Panel has some suggestions for future public engagement programs conducted by OPG and by the CNSC.

The Panel encourages OPG and CNSC to consider how to move further towards a more dialogue-based engagement model. The Panel notes that this may include explicit tools for increasing opportunities for the public to discuss their values and to explore how to achieve a values-based, as well as a science-based perspective on the project. The Panel suggests that there will be numerous opportunities to involve the public in evaluation of information which contributes to decisions about the project, particularly with respect to the collection of additional baseline data, the design of follow-up monitoring, and the determination of action levels which would trigger the requirement for mitigation.

The Panel recommends that OPG implement its commitment to establish a Community Advisory Committee as soon as possible, and certainly prior to site preparation and construction, if the project is approved. The Panel suggests that the Terms of Reference for the Community Advisory Committee include provision of community input to OPG's follow-up monitoring programs, including the monitoring of air quality, noise, and radiation. The monitoring of stigma could be an area of focus for input from the committee. The Panel suggests that the process for selection of members of the committee be discussed with key representatives of the community, and that committee members have input regarding the Terms of Reference.

The Panel further suggests that the Community Advisory Committee might be an appropriate group to develop a consensus on the method to be used for evaluating public attitude about the project. The Panel suggests that an entity independent of OPG and the municipalities could conduct an objective and transparent measurement of public attitude over the preclosure phases of the project. This may require revisions to or the replacement of the current tools used by OPG to judge public attitudes and acceptance.

11.3 PANEL CONCLUSION REGARDING SOCIAL AND ECONOMIC ASPECTS

The Panel concludes that the project is not likely to cause residual significant adverse environmental effects to valued components of the socio-economic environment that may be affected by changes in the biophysical environment. The Panel notes that mitigation and follow-up monitoring will be required to ensure that socio-economic valued components are not affected by the project. The Panel emphasizes the importance of continued public engagement by OPG, particularly with respect to follow-up monitoring.

CHAPTER 12 ABORIGINAL INTERESTS

This chapter presents the framework for Aboriginal consultation with respect to the proposed project, including the consultation and engagement activities undertaken by the Crown Consultation Coordinator and OPG, the participation by Aboriginal groups in the review process, as well as the information presented by Aboriginal groups. This chapter also summarizes the Panel's assessment and conclusions regarding effects of the project on Aboriginal interests.

12.1 ABORIGINAL CONSULTATION AND ENGAGEMENT

The role of the Panel is to identify and assess the potential environmental effects the project may have on Aboriginal interests. In support of this role, the Panel received updates from the Crown Consultation Coordinator relating to the consultation that was being undertaken and ensured that potentially affected Aboriginal peoples or communities were informed of the proposed project and were aware of the review process and the opportunity to participate in the review. As part of its mandate, the Panel received and reviewed information from OPG, the Crown Consultation Coordinator, and Aboriginal groups on the potential adverse impacts the project may have on asserted or established Aboriginal rights, title or Treaty rights.

The Panel's role is not to make any determination as to the validity of Aboriginal or Treaty rights being asserted, strength of claim determination, or whether or not the Crown's duty to consult has been met.

12.1.1 Joint Review Panel Agreement

An environmental review is an important source of information about the effects a proposed project may have on Aboriginal interests and asserted or established Aboriginal and Treaty rights. Article 4.1 of the Panel Agreement, as amended to reflect the enactment of the *Canadian Environmental Assessment Act, 2012*, states that the Panel was expected to conduct its review in a manner that permits it to obtain information and evidence about the adverse effects the project may have on potential or established Aboriginal rights, title or Treaty rights as identified to the Panel by the Saugeen Ojibway Nation and other Aboriginal groups and enables it to bring any such information and evidence to the attention of the Minister of the Environment and the Responsible Authority for the project in support of consultation between the Crown and the Saugeen Ojibway Nation and any other Aboriginal groups.

The Panel Agreement defined "Aboriginal group" as a community of Indian, Inuit or Métis people that holds or may hold Aboriginal or Treaty rights under section 35 of the *Constitution Act, 1982*.

12.1.2 EIS Guidelines

Section 2.2 of the EIS Guidelines identified the requirement for OPG to document the potential impact of the project on any asserted or established Aboriginal rights, Aboriginal title and Treaty rights. OPG was required to identify and address the concerns regarding the effects of any changes that the project may cause in the environment and the effects of those changes on the use of land and resources for traditional purposes by Aboriginal persons together with an explanation of how those concerns will be addressed.

12.1.3 Canadian Environmental Assessment Act, 2012

Paragraph 5(1)(c) of the *Canadian Environmental Assessment Act, 2012* stipulates that the environmental effects to be considered with respect to Aboriginal peoples are the effects of any change that may be caused to the environment on:

- health and socio-economic conditions;
- physical and cultural heritage;
- the current use of lands and resources for traditional proposes; or
- any structure, site or thing that is of historical, archaeological, paleontological or architectural significance.

12.1.4 Federal Government's Role

The CNSC was the only Responsible Authority for the project. CNSC staff acted as the Crown Consultation Coordinator for the federal review. The role of the Crown Consultation Coordinator included coordinating consultation activities, ensuring that the consultation was integrated into the environmental assessment and licensing processes, and forwarding project-specific issues raised by Aboriginal peoples to the appropriate parties. In its interactions with Aboriginal Groups, the Crown Consultation Coordinator addressed subjects as:

- notification and description of the project;
- public review periods for draft EIS Guidelines and Panel Agreement;
- issuance of final EIS Guidelines and Panel Agreement;
- participant funding opportunities;
- CNSC Aboriginal Consultation Framework;
- appointment of the Panel; and
- notice of public review period and public sessions.

The Federal departments involved in the review of this project participated in a whole-of-government approach to Aboriginal consultation and considered Aboriginal peoples' potential or established Aboriginal or Treaty rights pursuant to section 35 of the *Constitution Act, 1982*. The Crown Consultation Coordinator advised the Panel that in developing and implementing the Crown consultation, it relied on Canada's case law and on the consultation practices as outlined in the Department of Aboriginal Affairs and Northern Development Canada document *Aboriginal Consultation and Accommodation Updated Guidelines for Federal Officials to Fulfill the Duty to Consult* (2011). According to CNSC staff, its role as Crown Consultation Coordinator included:

- coordinating and facilitating the Crown's consultation activities during the environmental assessment and, if permitted to proceed, during all licensing phases;
- ensuring the consultation is integrated into the environmental assessment and licensing processes; and
- tracking and referring project-specific issues raised by Aboriginal peoples to the appropriate parties.

It was acknowledged by the Crown Consultation Coordinator that proponents of nuclear projects do not bear the Crown's legal obligation to consult with Aboriginal peoples under section 35 of the *Constitution Act, 1982*. However, OPG's engagement with Aboriginal groups was able to inform and assist the Crown Consultation Coordinator. In accordance with the EIS Guidelines, OPG was required to prepare an assessment of impacts on Aboriginal interests that included title or Treaty rights, Aboriginal communities, Aboriginal heritage and cultural resources and traditional use of lands and resources.

12.1.5 Funding to Aboriginal Groups

Federal government funding to Aboriginal groups was administered by the Canadian Environmental Assessment Agency. The Saugeen Ojibway Nation received $13,500.00 in Phase 1 funding to assist with their review of the draft EIS Guidelines and the draft Panel Agreement. A total of $151,025.00 was awarded in the Phase 2 Aboriginal funding envelope to the Historic Saugeen Métis, Métis Nation of Ontario and United Chiefs and Councils of Mnidoo Mnising. This funding was intended to support Aboriginal participation in the review of the EIS and preparation for and participation in the public hearing and consultation activities. Phase 3 participant funding was awarded to the Historic Saugeen Métis to assist with their participation in the September 2014 public hearing.

12.1.6 Crown Consultation

This section summarizes the consultation activities undertaken for the project by the Crown Consultation Coordinator, and the information presented by the Crown Consultation Coordinator. Several times following the Panel's appointment, the Crown Consultation Coordinator provided the Panel with updated summaries of the Crown consultation activities undertaken for the project. These updates are available on the public registry for the project.

Crown Consultation Activities for the Project

The information provided by the Crown Consultation Coordinator shows that Crown consultation for the project started in 2006, following OPG's submission of the Project Description in December 2005. The Crown Consultation Coordinator noted that between 2006 and 2008, the Saugeen Ojibway Nation were the only Aboriginal group identified that might be impacted by the project. The Crown Consultation Coordinator advised the Panel that it met with the Saugeen Ojibway Nation on multiple occasions during this period and the Saugeen Ojibway Nation participated in the environmental assessment consultation process and the 2006 CNSC public hearing on the Environmental Assessment Scoping Document and Track Report.

The Crown Consultation Coordinator identified that the Saugeen Ojibway Nation participated in the review of the draft EIS Guidelines and draft Panel Agreement, the identification of proposed candidates for appointment to the Panel, and the information gathering activities that resulted in the CNSC's recommendation to the Minister of the Environment that the project be referred to a Panel. According to the Crown Consultation Coordinator, the 2006 consultations with the Saugeen Ojibway Nation resulted in them being specifically mentioned in both the EIS Guidelines and Panel Agreement.

The Panel was advised that the Crown Consultation Coordinator completed a further review to identify other Aboriginal groups that might have an interest in the project in accordance with the Federal Government's *Aboriginal Consultation and Accommodation Interim Guidelines for Federal Officials to Fulfill the Duty to Consult* in 2008. Based on this research, the Crown Consultation Coordinator advised the Panel that it identified additional Aboriginal groups that might have an interest in the project. These groups received introductory letters, phone calls, emails and offers for face-to-face meetings. Information set out in these communications tools included:

- notification of the project;
- public review period for the draft EIS Guidelines and Panel Agreement;
- issuance of the final EIS Guidelines and Panel Agreement;
- Codification of Current Practice: Canadian Nuclear Safety Commission Commitment to Aboriginal Consultation;
- participant funding and the Aboriginal funding envelope;
- Aboriginal Consultation Framework;
- commencement of the public review period; and
- notice of the Panel's public information sessions.

According to the Crown Consultation Coordinator, these notifications and updates at key points in the process resulted in over one hundred letters being sent to identified Aboriginal groups.

The Crown Consultation Coordinator advised the Panel that the following is a complete list of Aboriginal groups that were identified as having a potential interest in the project:

- Chippewas of Nawash Unceded First Nation and the Chippewas of Saugeen First Nation, collectively referred to as the Saugeen Ojibway Nation;
- Historic Saugeen Métis;
- Métis Nation of Ontario;
    - Moon River Métis, Georgian Bay Métis & Great Lakes Métis Councils
- the United Chiefs and Councils of Mnidoo Mnising;
    - Aundeck Omni Kaning First Nation, White Fish River First Nation, Ziibaahaasing First Nation, Shequiandah First Nation, Sheshegwaning First Nation & M'chigeeng First Nation
- Wikwemikong First Nation; and
- Haudenosaunee Confederacy Chiefs.

According to submissions from the Crown Consultation Coordinator, the CNSC's *Aboriginal Consultation Framework for the Joint Review Panel Process* was sent to Aboriginal groups in February 2012. The Framework outlined the review panel process for this project and explained that the Aboriginal consultation process was to be integrated into the Panel process to the extent possible. The Framework made clear that the Panel process would be the primary mechanism for Aboriginal groups to present such matters as their traditional knowledge with respect to the project's environmental effects, the effects any change in the environment may have on their current use of lands and resources for traditional purposes, the nature and scope of their potential or established Aboriginal or Treaty rights, the adverse impacts the project may have on their potential or established Aboriginal or Treaty rights and appropriate measures to avoid or mitigate such impacts. The Framework identified the federal departments and agencies with expert or specialist information related to the project, and included a detailed description of the four phases of consultation, including an explanation of how and when to share information, and the participant funding opportunities from the Canadian Environmental Assessment Agency.

The Panel was advised that all Aboriginal groups responded to contacts made by the Crown Consultation Coordinator, except the Haudenosaunee Confederacy Chiefs. While the Crown Consultation Coordinator continued to include the Haudenosaunee Confederacy Chiefs on notices and updates, no information was forwarded by this group during the review. In addition to the direct contact by the Crown Consultation Coordinator, several Aboriginal groups also submitted proposed information requests to the Panel during the review and comment period.

According to the information presented by the Crown Consultation Coordinator at the 2013 public hearing, key issues raised by Aboriginal groups included:

- proximity of the DGR to Lake Huron;
- risk of contamination of drinking water;
- impacts on fishing and harvesting rights;
- respect for cultural heritage and traditional knowledge;
- risk of displacement in the event of an accident;
- access to, value or quality of cultural activities at the Bruce site burial ground;
- stigma;
- transportation of nuclear waste;
- alternatives assessment;
- valued ecosystem component selection; and
- planning for the used fuel repository.

Four Phases to Fulfill the Duty to Consult

The Crown Consultation Coordinator advised the Panel that it understood and recognized the importance of consulting and building relationships with Aboriginal peoples. The Crown Consultation Coordinator asked Aboriginal groups to outline the nature and scope of potential or established rights, identify how the project might affect those rights, and share traditional knowledge. The Crown Consultation Coordinator stated that it took into account the guiding principles and best practices outlined in the document *Aboriginal Consultation and Accommodation Updated Guidelines for Federal Officials to Fulfill the Duty to Consult*. These Guidelines include the following four phases:

1. pre-consultation analysis and planning;
2. Crown consultation process;
3. accommodation; and
4. implementation, monitoring and follow-up.

Based on the 2005 project description, the Crown Consultation Coordinator mapped out proposed activities, identified potential adverse impacts, made contact with Aboriginal groups who might have an interest in the project, and established a work plan for consultation. The Phase 2 Crown consultation process began in 2006 with the initial engagement, followed by the 2012 review period, and the 2013 and 2014 public hearing. It would also include consultation on this Panel report and further consultation should the project proceed to licensing.

According to the Crown Consultation Coordinator, it was available to meet with Aboriginal groups, provided regular updates and ensured that Aboriginal groups understood that the Panel hearing would be considered part of the consultation process for the proposed project. The Crown Consultation Coordinator expressed its commitment to continuing consultation and dialogue with interested Aboriginal groups should the project be approved.

Information from the Crown Consultation Coordinator about Identified Aboriginal Groups

The Crown Consultation Coordinator provided information about several Aboriginal groups, including the Saugeen Ojibway Nation, the Historic Saugeen Métis, the Métis Nation of Ontario, and the United Chiefs and Councils of Mnidoo Mnising.

Saugeen Ojibway Nation

The Chippewas of Nawash Unceded First Nation and the Chippewas of Saugeen First Nation collectively identify themselves as the Saugeen Ojibway Nation. According to the Crown Consultation Coordinator, the Saugeen Ojibway Nation traditional territory extends from the northern tip of the Bruce Peninsula to Maitland River on Lake Huron, inland to the town of Arthur, and then north to Georgian Bay, east of the city of Owen Sound, and includes the water around the Bruce Peninsula. The Crown Consultation Coordinator advised the Panel of the Treaties to which the Saugeen Ojibway Nation were a signatory, the 1998 agreement between the Saugeen Ojibway Nation and OPG for access to the Jiibegmegoong burial ground on the Bruce site and the agreement with the Ontario Government to manage a commercial fishery. According to the Crown Consultation Coordinator, the Chippewas of Nawash Unceded First Nation have three land reserves and the Saugeen First Nation have four. One reserve – the Saugeen Ojibway Nation's Fishing Islands Reserve No. 1 (also known as Saugeen and Cape Croker Fishing Islands Reserve No. 1) – is shared between the Chippewas of Saugeen First Nation and the Chippewas of Nawash Unceded First Nation.

The Crown Consultation Coordinator advised the Panel that the Saugeen Ojibway Nation had participated in the information gathering activities of CNSC staff that resulted in the CNSC's recommendation to the Minister of the Environment that the project be referred to a Panel Review. Subsequently, the Saugeen Ojibway Nation were consulted and participated in the review of the draft EIS Guidelines and the draft Panel Agreement.

Historic Saugeen Métis

According to the Crown Consultation Coordinator, the Historic Saugeen Métis assert Aboriginal communal rights in the Métis Saugeen territory, under section 35 of the *Constitution Act, 1982,* with a historic Métis community located in Southampton, Ontario. The Historic Saugeen Métis was one of the additional Aboriginal groups identified by CNSC staff in 2007. The Crown Consultation Coordinator advised the Panel in its May 2012 Crown Consultation Report that it had met with the Historic Saugeen Métis to explain both the Panel and the Aboriginal consultation processes. The Crown Consultation Coordinator asked the Historic Saugeen Métis to outline the nature and scope of their potential or established rights, identify how the project might affect those rights and share traditional knowledge. A meeting held in October 2012 provided the Historic Saugeen Métis members with an opportunity to present a history of their people in the Saugeen area.

The Crown Consultation Coordinator stated that, according to the Historic Saugeen Métis, they are an independent historic Métis community who has resided along the Lake Huron shoreline since 1818. The Historic Saugeen Métis community location of Southampton is within 20 kilometers of the proposed DGR site. The Crown Consultation Coordinator advised the Panel that the Historic Saugeen Métis refer to themselves as the Lake Huron watershed Métis and that they have lived, fished, hunted, trapped and harvested the lands and waters of the Bruce Peninsula, Lake Huron shoreline and watersheds.

Métis Nation of Ontario

The Crown Consultation Coordinator advised the Panel that the following three Métis Nation of Ontario Métis councils are located closest to the project site: the Moon River Métis Council, the Georgian Bay Métis Council and the Great Lakes Métis Council. According to submissions by the Métis Nation of Ontario, these three councils were represented by the Georgian Bay Traditional Territory Consultation Committee. The Crown Consultation Coordinator noted that the traditional Métis harvesting territory includes the project site and that these three Métis Nation of Ontario Métis Councils represent the interests in that harvesting area. The Métis Nation of Ontario's Project Specific Traditional Use Study states that the proposed project lies within the Métis Nation of Ontario's Georgian Bay Traditional Territory.

The Crown Consultation Coordinator reported to the Panel in January 2013 on two meetings with Métis Nation of Ontario representatives, held on October 18 and November 29, 2012. These meetings provided the Crown Consultation Coordinator with an opportunity to describe the project, the Crown Consultation Coordinator's role and the Panel process. Métis Nation of Ontario representatives shared information about their communities, culture and histories. According to the Crown Consultation Coordinator, the key issues raised by the Métis Nation of Ontario via submissions and meetings included:

- lack of Aboriginal representation on the Panel;
- belief that the Métis Nation of Ontario were not consulted on the selection of valued ecosystem components;
- the environmental assessment does not recognize the socio-economic environment of Métis; and
- absence of consideration of Métis rights.

United Chiefs and Councils of Mnidoo Mnising

The Aundeck Omni Kaning First Nation, White Fish River First Nation, Zhiibaahaasing First Nation, Shequiandah First Nation, Sheshegwaning First Nation, M'chigeeng First Nation, and

Wikwemikong Unceded Indian Reserve are located on Manitoulin Island in Ontario. Manitoulin Island is situated approximately 150 km north of the proposed DGR site. All but the Wikwemikong Unceded Indian Reserve are members of the United Chiefs and Councils of Mnidoo Mnising.

The Crown Consultation Coordinator noted that a meeting was held with the United Chiefs and Councils of Mnidoo Mnising Council Members and Elders on May 30, 2012 to discuss the Panel process, including background information, roles and responsibilities, construction details, and environmental assessment requirements. Representatives of OPG attended the first part of this meeting to provide an overview of the project. The Crown Consultation Coordinator advised the Panel that the United Chiefs and Councils of Mnidoo Mnising had expressed concern that the Panel would listen to but not understand their world view. According to evidence provided by the Crown Consultation Coordinator, meetings were also held with the Wikwemikong Unceded Indian Reserve but no specific issues or concerns were raised by the Wikwemikong Unceded Indian Reserve in relation to the project.

By letter dated February 14, 2013, the United Chiefs and Councils of Mnidoo Mnising invited the Panel Members to Mnidoo Mnising to educate the Panel on the Anishnabe world view and to experience “our mother” through teachings and ceremonies. In a March 2013 written reply, the Panel expressed its appreciation for the invitation but respectfully declined a one-on-one visit noting that private interaction with any given participant might challenge the transparency, openness and impartiality of the Panel. The Panel outlined the project milestones and encouraged the United Chiefs and Councils of Mnidoo Mnising to participate in the public hearing and to send any advice that they might have, along with any information on the current use of land and resources for traditional purposes that may be affected by the proposed project.

12.1.7 OPG Engagement with Aboriginal Groups

According to OPG, engagement with the Saugeen Ojibway Nation began in 2003 with presentations about the feasibility study of options for the management of L&ILW. A Memorandum of Understanding between the Saugeen Ojibway Nation and OPG was signed in 2004 and outlined communications processes, engagement activities, roundtable discussions, open houses and funding assistance. This was followed by a 2009 Protocol Agreement that provided the tools and resources for participation in the regulatory approvals process. OPG’s engagement efforts with both the Métis Nation of Ontario and the Historic Saugeen Métis began in 2008. Participation Agreements were signed with the Historic Saugeen Métis in 2010 and with the Métis Nation of Ontario in 2011, and a Memorandum of Understanding was signed with the Métis Nation of Ontario in 2014.

The Crown Consultation Coordinator stated that OPG had made best efforts to engage Aboriginal communities that may be affected by the project in a manner that was in keeping with the key elements of meaningful public participation, as described in the EIS Guidelines. The Aboriginal groups that OPG had identified were in alignment with the groups that the Crown Consultation Coordinator identified and met with. The Crown Consultation Coordinator acknowledged that OPG had committed to continuing to engage Aboriginal groups.

12.1.8 Panel Conclusion Regarding Consultation and Engagement by the Crown Consultation Coordinator and OPG

The Panel is satisfied that both the Crown Consultation Coordinator and OPG informed Aboriginal groups of the proposed project and the review process. The Panel notes that OPG's consultation began in 2003 and the Crown Consultation Coordinator consultation began in 2006. The Panel notes that participant funding was provided to the Saugeen Ojibway Nation, Métis Nation of Ontario, Historic Saugeen Métis and the United Chiefs and Councils of Mnidoo Mnising to assist with the review of the EIS Guidelines and/or review of the EIS.

The participant funding program administered by the Canadian Environmental Assessment Agency together with the agreements between OPG and the participating Aboriginal groups provided those groups with important capacity for input and participation. The Panel is of the view that Aboriginal groups were well informed of and understood how to participate in the review.

12.2 OPPORTUNITIES FOR PARTICIPATION BY ABORIGINAL GROUPS DURING THE REVIEW

This section describes the opportunities for participation by Aboriginal groups during the review. The Panel Agreement stipulated that the Panel shall conduct its review in a manner that permits it to obtain information and evidence about the adverse effects the project may have on potential or established Aboriginal rights, title or Treaty rights as identified to the Panel by the Saugeen Ojibway Nation and other Aboriginal groups.

Aboriginal groups had several opportunities to participate and provide information to the Panel throughout the review. Several Aboriginal groups submitted proposed information requests to the Panel during the public comment period. The Métis Nation of Ontario provided the Panel with a confidential Traditional Land Use Study in 2013. A March 2013 public Technical Information Session included presentations and discussion on the use of lands and resources for traditional purposes, the assessment of effects on Aboriginal interests and health effects on Métis communities. The public hearing in September-October 2013 and September 2014 allowed the Saugeen Ojibway Nation, Historic Saugeen Métis, Métis Nation of Ontario and the United Chiefs and Councils of Mnidoo Mnising to provide detailed information to the Panel through written and oral submissions. The Panel held specific hearing sessions at the public hearing in both 2013 and 2014 to consider the submissions from Aboriginal groups and to address Aboriginal interests.

As the Panel Agreement specifically identified the Saugeen Ojibway Nation, the Panel acknowledged this and took measures to ensure that their status in the review process was recognized. The Panel allocated specific times for the Saugeen Ojibway Nation to present their views at the public hearing. There was recognition at the start of the public hearing that the proceedings were taking place within the traditional territory of the Saugeen Ojibway Nation. Blocks of time, chosen by the Saugeen Ojibway Nation, were dedicated to Saugeen Ojibway

Nation presentations. The Saugeen Ojibway Nation had the opportunity to fully participate and ask questions throughout the hearing and on all topics covered at the hearing. A specific measure taken by the Panel, whenever possible, was to consider questions from the Saugeen Ojibway Nation prior to questions from other hearing participants.

In addition, the Panel made efforts to encourage the attendance at the hearing by the Historic Saugeen Métis, the Métis Nation of Ontario, and the United Chiefs and Councils of Mnidoo Mnising. The Panel incorporated their preferred days for participation into the hearing schedule.

Based on the information received from OPG, the Crown Consultation Coordinator and Aboriginal groups, described in more detail below, the Panel is satisfied that there were numerous opportunities for Aboriginal groups to come forward to express their views and concerns. The Panel is also satisfied that Aboriginal groups received notices and updates and were provided with details on how to participate through the Panel, OPG and the Crown Consultation Coordinator.

12.3 INFORMATION PROVIDED BY PARTICIPATING ABORIGINAL GROUPS

This section summarizes the information provided to the Panel by the participating Aboriginal groups, including the Saugeen Ojibway Nation, the Historic Saugeen Métis, the Métis Nation of Ontario, and the United Chiefs and Councils of Mnidoo Mnising.

12.3.1 Saugeen Ojibway Nation

The Saugeen Ojibway Nation advised the Panel that they occupy large, unceded communal lands bordering Lake Huron and Georgian Bay. Those reserves include residential communities and places of high cultural and spiritual importance. The Saugeen Ojibway Nation advised the Panel that these reserves are an important ground for their subsistence fishing, as well as for hunting and gathering. According to the Saugeen Ojibway Nation, the lands are also the base for current and future activities that include a commercial fishery, cottage leasing, and the Cape Croker Indian Park camping grounds.

The Chippewas of Saugeen First Nation Reserve No. 29 is located adjacent to the community of Southampton on the shoreline of Lake Huron between the mouths of the Saugeen and Sauble Rivers, approximately 24 km north of the Bruce nuclear site. The Saugeen First Nation Chief's Point Reserve No. 28 is located at Chief's Point to the north of Sauble Beach, at the base of the Bruce Peninsula. The First Nation also uses the Saugeen Hunting Grounds Reserve No. 60A, which is located along Highway 6 in the north of the Bruce peninsula, adjacent to the Bruce Peninsula National Park.

The Chippewas of Nawash Unceded First Nation are centered at Cape Croker Reserve No. 27, located on the north side of Colpoy's Bay, on the east shore of the Bruce Peninsula, 26 km from the town of Wiarton, approximately 80 km north of the Bruce nuclear site. The First Nation also uses the Cape Croker Hunting Grounds Reserve No. 60B, which is located along Highway 6 in the north of the Bruce Peninsula, adjacent to the Bruce Peninsula National Park. According to OPG's Aboriginal Interests Technical Support Document, the Saugeen Ojibway Nation also has reserve lands at the Saugeen and Cape Croker Fishing Island Reserve No. 1, consisting of 89 islands in Lake Huron.

According to the Saugeen Ojibway Nation, the project would be carried out within the area that they identify as Anishnaabekiing territory which they have traditionally used and occupied. The Saugeen Ojibway Nation expressed the view that they had provided significant evidence on the nature and scope of their rights and interests within their territory, and their reliance on the continued health, and perception of health, of their lands and waters.

According to the 2013 affidavit of then Chief Randall Kahgee, the Saugeen Ojibway Nation asserted, at a minimum, that their Aboriginal and Treaty rights included the following:

- the right to continue to be a distinct people living within their territory;
- the right to maintain their culture, language and way of life;
- the right to be sustained by their lands, waters and resources;
- the right to the exclusive use and occupation of their communal lands;
- the right to continued use of all of their territory;
- the right to harvest for sustenance, cultural and livelihood purposes;
- the right to be meaningfully involved in decisions that will affect their territory so that they can protect their way of life for many generations to come; and
- the right to be the stewards of their territory.

The Saugeen Ojibway Nation repeatedly identified a concern that the proposed project would pave the way for a used fuel repository on or near the Bruce nuclear site. Their claim of a real and demonstrable connection between this project and the Adaptive Phased Management siting process for a used fuel deep repository was the focus of the group's 2012 application for a determination on the scope of the review. The Saugeen Ojibway Nation asked the Panel to direct OPG to revise and resubmit its EIS to include "a project for the disposal of used nuclear fuel" in the cumulative effects assessment for the DGR review. In addition to the submissions received from OPG and the Saugeen Ojibway Nation, the Panel reviewed its authority as determined in its mandate, the APM framework for the siting process, and the definition and the treatment by the Courts of "cumulative effects" in terms of projects "that have been or will be carried out." The Panel determined that at this point in time, the APM process was not a reasonably foreseeable project as set out in the EIS Guidelines, nor was it a project that was likely to be carried out, for the purposes of cumulative effects assessment. The issue of inclusion of assessment of used nuclear fuel is discussed further in Chapter 15.

The Saugeen Ojibway Nation also raised issues related to the transportation of nuclear waste in both their written submissions and oral presentations at the public hearing. The Saugeen Ojibway Nation expressed their disagreement with OPG's conclusions that the project would result in no changes to the volumes, means or routes for the existing licensed transportation of nuclear wastes. The Saugeen Ojibway Nation expressed the view that the transportation of waste to the existing WWMF should have been considered rather than just the 100 to 200 metres of road within the Bruce nuclear site. When asked by the Panel if the Saugeen Ojibway Nation had conveyed this position to OPG, they could not recall but did identify that this had been raised with the Crown Consultation Coordinator during consultation on the EIS Guidelines. The Crown Consultation Coordinator noted that some changes had been made to the EIS

Guidelines but not to the extent desired by the Saugeen Ojibway Nation because the project was for the transfer of waste from the WWMF to the DGR rather than from other parts of Ontario to the site.

The Saugeen Ojibway Nation challenged OPG's conceptual assessment of alternative sites. It was the Saugeen Ojibway Nation's view that OPG had not discussed siting the project in a location outside the Bruce Nuclear Site. The Saugeen Ojibway Nation provided their assessment that OPG relied on the decision of the Municipality of Kincardine as justification for the site selection rather than also completing an alternate site analysis.

The Saugeen Ojibway Nation were critical of OPG's assessment of alternatives and alternative means and the additional work carried out by the OPG IEG. The Saugeen Ojibway Nation expressed the view that the OPG IEG failed to consider credible and reasonable alternatives to the project. The Saugeen Ojibway Nation stated that they did not agree with the OPG IEG's conclusion that the Canadian context did not allow for consideration of the segregation of long-lived intermediate-level waste for eventual disposal with used fuel. The Saugeen Ojibway Nation also noted that they believed the OPG IEG had failed to consider a credible theoretical granitic DGR because the assumed characteristics of the granite at the theoretical site were not ideal.

The Saugeen Ojibway Nation had specific concerns and suggestions regarding the Geoscientific Verification Plan, which were addressed in Chapter 6 of this report. It was the Saugeen Ojibway Nation's view that the Geoscientific Verification Plan needed to have what they described as a clear go/no-go decision-making function.

The Saugeen Ojibway Nation claims a "proven and exclusive" Treaty right to a commercial fishery within the Saugeen Ojibway Nation Traditional Territory, including all the waters around the Study Area and an area adjacent to the Study Area. The Saugeen Ojibway Nation presented extensive information regarding both their existing commercial fishery and the work underway to expand that fishery to maximize economic benefits to the Saugeen Ojibway Nation communities. This information is discussed in Chapter 14.

The Saugeen Ojibway Nation also provided detailed information on the use of their communal lands and Traditional Territory for camping, recreational leasing and tourism activities. According to the *SON and Tourism Report*, both the Chippewas of Saugeen First Nation and the Chippewas of Nawash Unceded First Nation have a number of cottages for rent. The Chippewas of Nawash Unceded First Nation also operate Cape Croker Indian Park.

In addition, the Saugeen Ojibway Nation expressed their concern that the project might stigmatize their fishery and increase stressors on Lake Huron to the detriment of their commercial fishery and connection to the lands and waters. The Saugeen Ojibway Nation claimed that DGR-related stigma associated with a traditional food could threaten their cultural identity. The Saugeen Ojibway Nation expressed the view that the project posed a threat to their commercial fishery and claimed that the potential impacts had not been addressed. Similarly, the Saugeen Ojibway Nation expressed the view that adverse impacts from DGR-related stigma would threaten their ability to sustain a tourism-based economy. Potential impacts on the fishery are discussed in Chapter 14. The issue of stigma and effects on tourism in discussed in Chapter 11.

12.3.2 Historic Saugeen Métis

According to submissions by the Historic Saugeen Métis, the group is a distinctive Métis community that has resided with continuity along the Lake Huron shoreline since the early 1800's. In modern times, they are organized as an independent Métis community located at Southampton. According to the Historic Saugeen Métis, the project lies within their traditional Métis territories and their members live both in close proximity to the Site Study Area and the Regional Study Area. Historic Saugeen Métis representatives stated that they reside in Kincardine, Southampton and in areas within driving distance of the project.

The Historic Saugeen Métis were originally approached by OPG in 2008 when they were represented by the Métis Nation of Ontario. In 2009, the Historic Saugeen Métis became an independent Métis community and were no longer represented by the Métis Nation of Ontario.

The Historic Saugeen Métis stated that they consist of over 200 registered descendants of historic families and have a total of between 400 and 500 members when dependent family members are included. The Historic Saugeen Métis asserted Aboriginal rights over the lands and waters in the area of the project and surrounding lands. They asserted that Métis rights are characterized as harvesting rights, a general right to harvest for food in the traditional hunting grounds of the Métis community. The Historic Saugeen Métis stated that they have subsistence fishing and land-based harvesting practices and interests in the area. They noted that they rely on these lands to harvest deer and other mammals, water and land fowl and plants. They also identified whitefish from Lake Huron as a staple together with other subsistence fishing caught along coastal shores and rivers that are tributaries of Lake Huron.

In their May 2013 submission to the Panel, the Historic Saugeen Métis stated that the project posed a significant threat to their ability to continue exercising their constitutionally-protected Aboriginal rights. However, no details or specific examples were presented at that time. Subsequent written and oral submissions by the Historic Saugeen Métis in support of their 2013 participation in the public hearing identified Baie du Doré, adjacent to the DGR site, as one of their traditional harvesting areas. Another area of interest identified by the Historic Saugeen Métis was Stream C, the largest stream entering Baie du Doré. The Historic Saugeen Métis's expression of interest in these areas did not include any suggestion of specific adverse effects on their traditional uses in either of those areas. The Panel notes that it has specifically addressed the mitigation of potential effects on both Baie du Doré and Stream C in Chapters 8 and 14.

In their August 2013 written submission to the Panel, the Historic Saugeen Métis's stated that their concerns included the safe storage of the waste with minimal impact on the water and lands that support their Aboriginal rights. According to the Historic Saugeen Métis, one of their goals relating to the project was to establish a clear, timely and effective process for communication, exchange of key information and meaningful input and consultation during all stages of the DGR. In their 2013 oral submission, the Historic Saugeen Métis expressed the view that an impact on their traditional harvesting territories was most likely to occur as a result of an accident at the proposed facility. The Panel notes that the matter of accidents and malfunctions has been addressed in Chapter 10.

The request for ongoing input and involvement was also reflected in a 2014 Historic Saugeen Métis written submission that identified a desire to be included in the circulation of future OPG monitoring reports related to hydrology, water quality and the aquatic environment and to participate in habitat rehabilitation. In their oral submission at the 2014 public hearing, the Historic Saugeen Métis recommended the construction of a fence to prevent accidental intrusions into the preserved forest, identified precautionary approaches to minimize effects, and asked to participate in the design and implementation of habitat enhancements. The Historic Saugeen Métis noted that their participation agreement with OPG provides the framework required to ensure dialogue and cooperation with respect to future monitoring and follow-up.

During their October 7, 2013 oral submission to the Panel at the public hearing, the Historic Saugeen Métis stated that since the group's rights and interests in regard to the Bruce nuclear site were first made known to CNSC staff in 2002, they have been respected in relation to activities at the Bruce site. Regarding the project, the Historic Saugeen Métis stated that they felt that consultation had been adequate and that they had received replies to some concerns specifically about the DGR process, and were able to pick up the phone when they needed to seek further information. The Historic Saugeen Métis stated at the 2013 public hearing that they felt that they were adequately consulted.

12.3.3 Métis Nation of Ontario

In their 2013 submission to the Panel, the Métis Nation of Ontario expressed concerns that fell into three specific themes, namely:

- the appropriateness of the selected valued ecosystem components used to identify effects to Aboriginal interests;
- lack of specific information in the EIS regarding Métis and the Métis Nation of Ontario's lack of resources to comment; and
- the methodology used to assess potential adverse effects to Métis way of life.

Through both oral and written submissions, the Métis Nation of Ontario expressed concern that they initially had no ability to seek professional advice on the valued ecosystem components and draft EIS Guidelines because OPG had not provided capacity for consultation. In this regard, the Métis Nation of Ontario noted that they did not receive capacity for professional review and involvement until three years after the comment period on the draft EIS Guidelines. The Métis Nation of Ontario stated that the selected valued ecosystem components did not work for identifying effects to Métis people and presented proposals for valued ecosystem components for supplemental analysis of Métis Nation of Ontario cultural sites and places, and Métis Nation of Ontario subsistence fishing, hunting and gathering. The Crown Consultation Coordinator advised the Panel that the valued ecosystem components proposed by Métis Nation of Ontario were reviewed by CNSC specialists who expressed their view that the valued ecosystem components in the EIS captured the valued ecosystem components proposed by Métis Nation of Ontario.

The Métis Nation of Ontario presented a Project Specific Traditional Land Use Study to the Panel in March 2013. The Métis Nation of Ontario requested, and the Panel agreed, that the Traditional Land Use Study would be kept confidential. The Report included traditional knowledge and resource use as well as a list of project-specific concerns. The information was reviewed by the Panel and informed its decision regarding the potential environmental effects the project could have on Aboriginal interests.

In their final written submission to the Panel in July 2014, the Métis Nation of Ontario wrote to confirm that they had signed a Memorandum of Understanding with OPG that provided assurances that Métis rights would be protected and provided capacity to address five areas of interest to the Métis Nation of Ontario. According to the Métis Nation of Ontario, through this agreement and commitments made by OPG, the Métis Nation of Ontario were able to provide their support in principle for the project.

12.3.4 United Chiefs and Councils of Mnidoo Mnising

The United Chiefs and Councils of Mnidoo Mnising provided a written submission to the Panel for the 2013 public hearing and gave an oral presentation. Their submissions spoke of their sacred teachings and their proclamation for the care and protection of mother earth. They stated that they did not want to see harm done to mother earth. Their written and oral presentations included references about not taking creation for granted and that the journey of life is centered on respect for mother earth. The United Chiefs and Councils of Mnidoo Mnising stated that mother earth was being asked to take care of the waste and suggested that there could be ceremonies to ask for permission and appease the spirits.

No specific potential environmental effects were identified by United Chiefs and Councils of Mnidoo Mnising representatives nor was there any information from the United Chiefs and Councils of Mnidoo Mnising to suggest that asserted or established Aboriginal title or Treaty rights would be impacted by the proposed project.

12.4 ASSESSMENT OF EFFECTS ON ABORIGINAL INTERESTS

This section describes the assessment of effects from the project on Aboriginal interests. It includes information from OPG, CNSC staff, and Aboriginal groups, as well as the Panel's conclusions relating to its review of this information.

12.4.1 OPG Assessment of Effects on Aboriginal Interests

OPG's assessment of effects on Aboriginal interests included the application of the EIS Guidelines and valued ecosystem components, and the prediction of effects. Specific comments are made regarding Aboriginal heritage resources, and the traditional use of land and resources.

Application of EIS Guidelines and Valued Ecosystem Components

As discussed in the EIS Guidelines, traditional knowledge, which is rooted in the traditional life of Aboriginal people, has an important contribution to make to an environmental assessment. The EIS Guidelines required that OPG incorporate into the EIS the traditional knowledge to which it had access or that it may reasonably be expected to acquire through appropriate due diligence, in keeping with appropriate ethical standards and without breaching obligations of confidentiality.

As defined in the EIS Guidelines, Aboriginal rights are those rights of Aboriginal peoples that are not found in Treaties or land claims agreements. Aboriginal title means the form of land ownership belonging to Aboriginal people and the rights coming from the Aboriginal relationship with the land. Aboriginal rights vary from group to group and are protected under section 35 of the *Constitution Act, 1982*.

OPG noted that, in general, the concerns expressed by the Saugeen Ojibway Nation related to having their traditional territory respected and acknowledged; and to maintaining the relationship established by Treaties, their traditional land use and harvesting activities, and way of life. The Saugeen Ojibway Nation use hunting grounds near the tip of the Bruce Peninsula. Of particular note was the 1993 *R. v. Jones and Nadjiwon* decision which recognized the rights of the Saugeen Ojibway Nation to fish in the waters adjacent to the Bruce nuclear site. Subsequent to that decision, Fisheries Agreements (the most recent effective April 2013) have been signed between the Saugeen Ojibway Nation and the Province of Ontario regarding the management of the commercial fishery in Lake Huron and Georgian Bay around the Bruce Peninsula.

OPG noted that the traditional Ojibway spiritual worldview was of particular relevance to the project. The worldview is that the physical world, including the rock of the earth, is the first order of creation upon which the other orders of creation – the plant world, animal world and the human world – depend for sustenance and existence. Thus, a DGR constructed in the rock of the earth would have a fundamental spiritual impact.

OPG stated that the interests of the Historic Saugeen Métis and the Métis Nation of Ontario centered on their asserted Aboriginal right to hunt and harvest in the Regional Study Area. The Historic Saugeen Métis are a rights-bearing community which have historically hunted, fished, traded and lived in the traditional Saugeen territory since the early 1800's. The Historic Saugeen Métis became independent and self-governing in 2008. Three Métis Nation of Ontario Métis councils are located closest to the project site, namely the Moon River Métis Council, the Georgian Bay Métis Council and the Great Lakes Métis Council.

OPG stated that it selected valued ecosystem components representing the interests of Aboriginal peoples based on:

- reviews of correspondence and minutes of meetings between OPG and Aboriginal organizations;
- literature pertaining to Aboriginal Treaties, land claims, fishing and harvesting rights;
- Aboriginal communities that expressed interests in the Regional Study Area;
- general ecological, socio-economic and cultural heritage interests for the Saugeen Ojibway Nation and Métis peoples; and
- previous environmental assessments for projects at the Bruce nuclear site.

According to OPG, First Nation and Métis communities were invited to participate in valued ecosystem component open houses, encouraged to add valued ecosystem components to the list and identify the valued ecosystem components that were most important to them. Valued ecosystem component Open houses were held in October 2007, November 2008, November 2009 and Summer/Fall 2010.

The valued ecosystem components selected for Aboriginal interests were:

- Aboriginal communities (population, local employment, local business activity, health);
- Aboriginal heritage resources (archaeological sites/burials and artifacts, culturally sensitive areas); and,
- traditional use of land and resources (effects of changes in air quality, water quality, the aquatic and terrestrial environment, geology, radiation and radioactivity on fishing and harvesting rights, land claims, and cultural heritage).

Prediction of Effects on Aboriginal Interests

OPG predicted that the project would create new direct, indirect and induced employment opportunities in Aboriginal communities. Changes in air quality relevant to Aboriginal communities were restricted to increases in dust levels, which were described by OPG as creating a nuisance during the site preparation and construction phase both on and in the immediate vicinity of the Bruce nuclear site. No adverse effects from dust were predicted at any Aboriginal community within the Regional Study Area. OPG stated that increased noise levels during the site preparation, construction and decommissioning phases of the project might affect Aboriginal persons who might reside in the immediate vicinity of the Bruce nuclear site. OPG did not consider it likely that Aboriginal people would be living in the small off-site area affected by increased noise levels. Therefore, no adverse effects from noise on Aboriginal communities or individuals were predicted.

Mitigation measures for air quality and noise would be those that were identified in Chapters 8 and 9 of this report. OPG did not identify any additional mitigation measures related to Aboriginal communities because no adverse effects were predicted.

Aboriginal Heritage Resources

OPG determined that there was one residual adverse effect on the Aboriginal heritage resources valued ecosystem component resulting from changes in aesthetics and increased noise and dust at the Jiibegmegoong burial site. OPG explained that the project would strengthen the industrial character of the Bruce nuclear site near where the Jiibegmegoong burial site is located, and that the main shaft headframe structure would likely be in the foreground of northerly views from the burial site. Dust and noise levels would be increased during all project phases. OPG noted that the visibility of the DGR structures, as well as dust and noise, may diminish the quality or value of activities undertaken by Aboriginal peoples at the burial site. OPG further noted that the effects would occur during site preparation, construction and operations phases, and that the waste rock pile would remain in place after decommissioning. Changes in noise and dust levels during the decommissioning phase were also expected.

OPG stated that, should the project be approved, the Saugeen Ojibway Nation would continue to have access to the Jiibegmegoong burial site. OPG stated that in-design mitigation measures to reduce the visual effect of the project would include a setback or buffer of 200m from the

Interconnecting Road to the waste rock management area as well as screening via the construction of berms and/or planting of trees. Air and noise mitigation measures would be those identified in Chapters 8 and 9.

OPG determined that the residual effect on the use of the Jiibegmegoong burial site was not significant because the burial site is located on an existing industrial site, and may be affected by dust and noise infrequently. OPG considered it unlikely that ceremonies would occur during times of increased dust and noise. Furthermore, OPG determined that adverse effects over the long-term would not occur, apart from the visibility of the waste rock pile.

Traditional Use of Land and Resources

OPG stated that the project was not likely to cause any direct measurable changes to traditional land use and resources. The only indirect measurable change would be due to changes in noise levels; however, OPG determined that noise levels arising from the project would not have an adverse effect on the traditional use of land and resources. OPG explained that if off-site noise levels were of sufficient magnitude, there would be a noticeable disruption to terrestrial valued ecosystem components, in particular those wildlife species harvested or important to Aboriginal people. However, the maximum predicted increase of 3-5 dB in the Baie du Doré area would not affect wildlife populations, including valued ecosystem components such as white-tail deer (see Chapter 8). OPG noted that traditional hunting is not permitted within the Bruce nuclear site where noise levels would be higher.

OPG also determined that the project would not cause measureable changes to the populations of aquatic species important to Aboriginal peoples' harvests. No effects on renewable resource use, namely the harvesting of fish species, were identified by OPG to adversely affect the sustainability of these resources. OPG stated that since no adverse effects on traditional land use and resources were predicted, no mitigation measures were warranted.

12.4.2 Crown Consultation Coordinator Assessment of Effects on Aboriginal Interests

The Crown Consultation Coordinator stated that the information submitted in the EIS and in responses to information requests originating with the Saugeen Ojibway Nation, Historic Saugeen Métis and Métis Nation of Ontario met the requirements of the EIS Guidelines. Based on this information, the Crown Consultation Coordinator stated that the project was not likely to result in significant adverse environmental effects on Aboriginal interests, taking into account the implementation of mitigation measures. The Crown Consultation Coordinator advised the Panel that it was not aware of any adverse impacts the project might have on potential or established Aboriginal or Treaty rights.

The Crown Consultation Coordinator stated that the information provided in the EIS and related documentation was sufficient to determine that the project was not likely to result in significant adverse effects on Aboriginal interests, potential or established Aboriginal or Treaty rights taking into account the implementation of mitigation measures.

12.4.3 Panel Assessment of Effects on Aboriginal Interests

This section describes the Panel's assessment of the information regarding effects on Aboriginal interests. It includes a summary of the views expressed by Aboriginal groups relating to the effects of the project on Aboriginal interests.

Assessment of Effects on Aboriginal Interests

The Panel has conducted a thorough assessment of all biophysically-based potential effects of the project on human health and the environment in other chapters of this report. These are effects associated with predicted measureable changes in air quality, noise, water quality, water quantity, plants, and animals caused by the project. The Panel does not share the Saugeen Ojibway Nation's view that there remains considerable uncertainty regarding the effects of the project on the waters of Lake Huron and MacPherson Bay or that there are deficiencies or uncertainties in information that would prevent the Government of Canada from reaching conclusions regarding impacts the project might have on potential Aboriginal rights and interests. Many of the Panel's recommendations are pertinent to Aboriginal interests such as recommendations regarding the required mitigation to ensure protection of water quality and aquatic life in MacPherson Bay.

The Saugeen Ojibway Nation concerns about the Geoscientific Verification Plan, assessment of alternatives and alternative means, and effects on fish (especially lake whitefish) are addressed in Chapters 5, 6, 8 and 14. The Panel has several recommendations regarding these topics.

The Panel notes that the concerns of the Saugeen Ojibway Nation regarding the effects of stigma on their commercial fishery and tourism activities should be evaluated in the context that the Saugeen Ojibway Nation's fishing and tourism activities already take place in close proximity to the world's largest nuclear power generation station while generating economic benefit. The Saugeen Ojibway Nation maintained that the stigma potentially generated by the project would be materially different than that associated with the Bruce nuclear generating stations. The Panel has concluded that stigma concerns associated with the DGR were adequately addressed in the review, as described in Chapter 11. The Panel notes that it made a suggestion regarding the establishment of a baseline for follow-up monitoring of stigma effects.

The Panel is satisfied that OPG made appropriate efforts to obtain timely input to the EIS methodology (with emphasis on the selection of valued ecosystem components) well in advance of the preparation of the EIS report, and that the Saugeen Ojibway Nation participated in consultation regarding valued ecosystem components. The Panel recognizes that input from the Métis Nation of Ontario was not received until after the EIS had been submitted. The Métis Nation of Ontario input regarding valued ecosystem components was received and examined during the hearing. The Panel understands that agreements between the Métis Nation of Ontario and OPG as well as between the Historic Saugeen Métis and OPG are intended to provide the mechanisms for the consideration and protection of Métis rights and interests.

Science-Based and Aboriginal Points of View

The Panel notes that the information provided by OPG and Aboriginal groups regarding potential effects on Aboriginal interests illustrates a divide between a strictly science-based approach and an approach that incorporates Aboriginal world views. The science-based assessment conducted by OPG focused on measureable changes to aspects of the natural environment such as air quality and noise and then evaluated whether those changes would affect Aboriginal communities, heritage resources or traditional uses of the land. Submissions by Aboriginal groups, while including reviews and comments on the science-based assessment, also presented information arising out of their world views and history. The result was that the OPG assessment of preclosure effects ended up with a narrow focus on the Jiibegmegoong burial site - the location of the only predicted residual adverse effect. The postclosure assessment did not explicitly include Aboriginal interests; rather, it focused on the prediction of effects to both humans and non-human biota assumed to live in close proximity to the DGR site. In contrast, Aboriginal submissions raised broad concerns that included effects on the cultural and spiritual connection to land and resources.

The Saugeen Ojibway Nation stated that assessment and consultation was not simply “a techno exercise or a checkbox.” According to then Chief Kahgee of the Saugeen Ojibway Nation, a high level of distrust towards government and industry has developed in Aboriginal communities due to the history of interactions between Aboriginal peoples and non-Aboriginal peoples. It was his view that this distrust has generated fears about the potential of the project to affect traditional uses and resources. The Saugeen Ojibway Nation stated that those fears would have to be addressed through processes that empower the voices of Aboriginal peoples. It was suggested that a first step might be to listen to what the Elders from the Mnidoo Mnising had said: “you must first ask permission.”

The Saugeen Ojibway Nation advised the Panel that it must set aside its preconceived notions and understanding of history and look at history through the lens of Aboriginal peoples. The Saugeen Ojibway Nation emphasized the Panel’s obligation under Treaties, including a relationship of government to government based on mutual respect. The Saugeen Ojibway Nation also emphasized the importance of free, prior, and informed consent.

The Saugeen Ojibway Nation stated that there was still a lot of work required to achieve conditions where the Saugeen Ojibway Nation people would be supportive of the project, and that this work would include incorporation of the Aboriginal voice concerning cultural and spiritual values. The work would also involve achieving a mutually-agreed upon understanding of the project such that the Saugeen Ojibway Nation people would provide informed consent. The Saugeen Ojibway Nation acknowledged the efforts made by OPG regarding recognition and incorporation of the voice of the Saugeen Ojibway Nation and stated that both the Saugeen Ojibway Nation and OPG were committed to the long period of work ahead.

Agreements between OPG and Aboriginal Groups

In an August 2013 written submission, the Saugeen Ojibway Nation informed the Panel that the Saugeen Ojibway Nation had received a letter from the President of OPG purporting to assure the Saugeen Ojibway Nation that the project would not go ahead without the Saugeen Ojibway Nation's consent. As detailed in their closing remarks, the Saugeen Ojibway Nation submitted that "the SON-OPG Commitment must be acknowledged and reflected in the EA Report and, if the project is recommended for approval, must be made a recommended condition of that approval. Further, the SON has submitted that this commitment should be acknowledged and integrated in subsequent regulatory processes to the extent possible within the relevant legislative frameworks." The Saugeen Ojibway Nation further submitted that the Panel should "make a specific recommendation to CNSC, and other responsible provincial and federal authorities as appropriate, that they continue to work with Saugeen Ojibway Nation and OPG to determine how subsequent regulatory processes, including licence applications, can reflect, be harmonized with, and act to promote the SON-OPG Commitment as well as any specific actions or measures that result from SON and OPG's engagement under the commitment."

In response to this, OPG stated in its closing remarks that "this commitment should not be a condition of EA approval or the Licence. OPG's agreement not to proceed with construction of the DGR without the support of the SON is an important feature of the relationship being built by OPG and the SON independently of the regulatory process. The presence or absence of support is not a regulatory matter and therefore not properly the subject of a condition of approval. OPG is committed to working in good faith with the SON to gain their support for the project as a requirement of the relationship with the SON rather than a requirement of an approval." OPG noted that its commitment list included non-regulatory commitments to communities, including Aboriginal groups. OPG indicated that these commitments were separate from regulatory commitments and that they would be managed directly through the relationship between OPG and the other involved parties. OPG stated that it expected that these commitments may be monitored by CNSC staff, but not subject to the CNSC's change approval.

The Panel was not a party to this letter, and it was not involved in the negotiations or discussions leading to this letter. The Panel will not endorse or comment on the content of an arrangement between private parties. However, the Panel notes its concern regarding the creation of what appears to be a private arrangement establishing a parallel process to exclusively identify and address Saugeen Ojibway Nation issues. The Panel's legal mandate and legislated parameters are clear and apply equally to all parties. A private arrangement between OPG and one Aboriginal group will not factor into the Panel's fulfillment of these obligations.

The Panel accepts that both OPG and the Crown Consultation Coordinator play a role in Aboriginal consultation; the identification of Aboriginal interests, title or Treaty rights; the prediction of effects on Aboriginal interests; the identification of mitigation; and in providing information for the Government in relation to accommodation. The Panel notes that the actions of OPG and the Crown Consultation Coordinator were often undertaken in parallel. The Panel understands that the separate agreements between OPG and the Saugeen Ojibway Nation, Historic Saugeen Métis and Métis Nation of Ontario are intended to be important tools for the ongoing consultation by OPG and acknowledges that actions related to these agreements are in addition to the Crown's ongoing commitment to consultation.

12.5 PANEL CONCLUSION REGARDING EFFECTS OF THE PROJECT ON ABORIGINAL INTERESTS

The Panel is of the view that it conducted its review in a manner that permitted it to obtain information and evidence about the adverse effects the project may have Aboriginal interests and on potential or established Aboriginal rights, title or Treaty rights as identified to the Panel by the Saugeen Ojibway Nation and other Aboriginal groups. The Panel notes that Aboriginal groups were provided with many opportunities to address potential or established Aboriginal rights, title or Treaty rights, and to provide information on their understanding of the potential environmental effects of the project both before the Panel's appointment in 2012 and at every stage leading up to the preparation of this report.

The Panel concludes that the biophysical changes caused by the project will not cause significant adverse effects on Aboriginal interests, provided all relevant mitigation measures are successfully implemented. These mitigation measures are not limited to those related to the Jiibegmegoong burial site, but also include all mitigation measures committed to by OPG or recommended by the Panel relating to effects on air quality, noise, water quality, water quantity, radiation and radioactivity, plants and animals. The detailed analysis of biophysical changes was presented throughout the review and is summarized in this report in such chapters as effects on the natural environment, human health and safety, social and economic aspects, and Lake Huron and the Great Lakes.

Through numerous written and oral submissions, the Panel received information on the unique spiritual and cultural perspectives that Aboriginal groups bring to the assessment of this project. Aboriginal groups articulated concerns that such unique world views might not align with the technical analysis and measured evaluations of the project carried out to meet prescribed legal requirements. The Panel acknowledges and respects the information regarding the cultural and spiritual connections to the land, waters and all creation. The Panel believes that important bridges have been built between the objective, scientific information for this environmental assessment and the cultural and spiritual worldviews of the Aboriginal people who participated in this review. Building community confidence and trust, demonstrating certainties and sharing information that will address anxieties is no doubt an ongoing responsibility resting on the shoulders of the Crown, OPG and the participating Aboriginal groups.

The Panel acknowledges the communication and relationship-building with OPG that was described by Aboriginal groups over the course of the review. The Panel expects that engagement will continue as part of the individual agreements entered into between OPG and the Saugeen Ojibway Nation, Métis Nation of Ontario and Historic Saugeen Métis. The Panel also reiterates the commitment of the Crown to ongoing consultation with Aboriginal groups associated with this project. The Panel suggests that the CNSC and OPG continue to build and foster their relationships with the Aboriginal groups identified during this review.

CHAPTER 13 POSTCLOSURE SAFETY CASE

This chapter addresses the postclosure safety case for the DGR. The chapter includes a brief introduction to the requirements for a safety case, and continues with two main sections: geological and hydrogeological site characterization, and postclosure system evolution and safety assessment.

13.1 REQUIREMENTS FOR THE POSTCLOSURE SAFETY CASE

In 2006 the CNSC issued Regulatory Guide G-320, *Assessing the Long Term Safety of Radioactive Waste Management*, which provided directives and the CNSC's expectations for the development of a long term safety case for the management of radioactive waste. The post-closure safety case presented to the Panel for the DGR was based on and conformed to the directives provided by the regulatory guide.

CNSC staff stated that the long-term safety case consists of "providing reasonable assurance that waste management will be conducted in a manner that protects human health and the environment." Central to the safety case is the safety assessment complemented by various additional arguments.

CNSC staff identified the essential components of the safety case that would need to be included in the safety assessment as:

- site characterization (stability of the rock formation both from a geochemical, hydrological and geological point of view, for very long periods of time);
- facility design;
- waste characterization; and
- modelling of the evolution of the repository for a period up to one million years.

CNSC staff noted that these components complement each other and provide the basis of a systematic analysis. OPG stressed that its complete postclosure safety assessment embraced and integrated the components specified by CNSC.

The EIS Guidelines required OPG to assess the project over its whole lifecycle. In the EIS, OPG summarized the assessment of the postclosure radiological and non-radiological safety of the project. Detailed analyses were provided in the Preliminary Safety Report and the Postclosure Safety Assessment. Additional materials concerning long-term safety were presented to the Panel through information requests; during a Technical Information Sessions on DGR construction in July 2012, and modelling methods and scenarios in October 2012; and during the public hearing in 2013 and 2014.

13.2 GEOLOGICAL AND HYDROGEOLOGICAL SITE CHARACTERIZATION

OPG stated that the geology, hydrogeology and geomechanical properties of the proposed DGR would be of key importance in keeping the L&ILW contained and isolated from contact with the surface environment (biosphere) for thousands of years.

The hydrogeology deals with the presence, distribution, movement and chemical composition of water in the subsurface environment while the geomechanical involves the design of rock structures based on geologic study of the mechanical behaviour of rock and rock masses to applied forces and stresses.

The geology, hydrogeology and geomechanical properties would include:

- being extremely stable, of sufficient size, and solid, so as to withstand events such as earthquakes without the formation of connections to the surface;
- not being subject to chemical processes that form cavities or interconnected pore spaces;
- having no fractures that could connect the bedrock formations, via movement of groundwater or gases, with the surface;
- being extensive and deep enough to accommodate the full size of the repository;
- having the movement of water from the repository to the surface be extremely slow, i.e., being so solid that the only way water can move is through diffusion.

OPG believed that it had identified such a rock formation at the Bruce nuclear site at a depth of approximately 680 meters (the repository horizon). It is the Cobourg Formation, a thick argillaceous (clay-rich) limestone of Middle Ordovician age. A 212 metre-thick Ordovician shale sequence directly overlies the repository horizon and provides an additional low-permeability barrier (cap rock) that would inhibit contaminant migration towards the surface. OPG provided the Panel with detailed and credible evidence that the rock formations at the proposed DGR site would fulfill these requirements and would guarantee the long-term safety of humans and non-human biota.

Developing criteria and evaluating sites for the hosting of a repository for low and intermediate-level radioactive waste in geological formations poses a unique challenge for geoscientists. As noted by several participants, geology is essentially a descriptive (explanatory) science and its predictive capabilities have only in recent times become the focus of research. OPG advanced a number of questions, i.e., geoscience hypotheses, that would have to be examined and verified to demonstrate the suitability of the Bruce nuclear site as the location for the proposed DGR. The geoscience hypotheses, related to the fundamental geologic, hydrogeologic, and geomechanical attributes of the Bruce nuclear site, may be formulated as the following set of questions:

- Are the geologic formations and conditions at the site and its surroundings highly predictable?
- Are the shallow and potable groundwater resources effectively isolated from the deeper repository horizon?

- What would be the dominant contaminant transport processes from the proposed repository?
    - Can limestone be a safe host for a nuclear waste repository?
    - What role would fractures and faults play in water and gas transport from the repository?
    - What evidence supports the dominance of diffusive transport in the host and cap rock of the proposed DGR?
- What are the multiple geological barriers that will inhibit contaminant transport from the repository? How effective will they be?
- Can the potential of the site for natural resources (minerals and hydrocarbons), both present and in the future, be considered to be low?
- What is the history of seismic activity at the site and can it predict future stability of the site?
- How stable and predictable are the geomechanical bedrock properties at the repository horizon?

Confidence in the predicted long-term isolation of the waste from the biosphere and human contact requires that the physical and chemical properties of the Cobourg Formation, as well as bedrock formations beneath and above the repository, be known with an exceptionally high degree of certainty relative to conventional mining projects. Each of the seven necessary conditions identified by OPG is examined in greater detail below.

13.2.1 Predictability of Geologic Formations and Conditions at the DGR Site and its Surroundings

OPG stated that confidence in the predictions of the movement of contaminants from the repository over a period of hundreds and thousands of years would depend on the nature and properties of the geologic formations extending out from the repository. OPG drilled six vertical deep boreholes at the Site Study Area to obtain information about the geologic formations above, beneath, and immediately adjacent to the proposed repository location. OPG observed that, over the maximum separation distance of approximately 1,300 m between boreholes, the geologic layers occurred at the same depths, did not vary significantly in their thicknesses, and did not appear to be disrupted by major fractures. OPG determined that, in terms of continuity, thickness, and the absence of disruptions, the geologic units could all be considered to be known with high confidence over this area.

In addition to the deep drill holes, OPG conducted a 2D reflection seismic survey over the Site Study Area to test the continuity of the geologic layers. This is a geophysical method of imaging the layering of stratified bedrock which is capable of detecting the deformation and disruption of the layers. Conventional 2D (dimensional) surveys show the layering in vertical slices, while more advanced 3D surveys present the layers in a volume.

Initial data analyses indicated the possible existence of discontinuities or disruptions of formation continuity. As vertical drill holes have a reduced opportunity to intersect vertical or near-vertical fractures, OPG drilled two additional deep inclined (non-vertical) boreholes at angles that would intercept the interpreted seismic discontinuities. Inclined boreholes can provide a more accurate estimate of fracture orientation and abundance. OPG did not observe any physical evidence of disruption of layers in these drill cores and a re-examination of the seismic data attributed the features as data processing anomalies.

Natural Resources Canada noted that a 3D seismic survey might have revealed more detail about possible faults than the existing standard seismic survey. In a response to an information request from the Panel, OPG stated that it did not conduct a 3D seismic survey because such a survey would have been impractical due to the large area and associated marine seismic survey required. OPG further stated that such a survey would not have substantially improved upon the information obtained through its 2D seismic survey.

Outside the area encircled by the deep drill holes, OPG relied on geologic mapping by provincial and federal agencies, and historic exploratory wells for potential hydrocarbon, mineral or salt deposits, to establish the continuity of the geologic strata on a regional scale. The distribution of locations of historic wells was distinctly skewed with the majority of wells located south of the Bruce nuclear site. The variability of data quality for available wells required careful examination and selection of data in the establishment of a three-dimensional geological framework model (3-DGFM). OPG used this model to describe sedimentary bedrock stratigraphy (layering of the different rock layers) and geometric continuity (length, width and thickness of the formations) within the 35,000 km^2 Regional Study Area, as illustrated by a cross-section shown in Figure 27.

During the technical information session on modelling, OPG described the relative contribution to confidence in regional layer traceability as high, and layer thickness as medium. Confidence in the structural framework (faults, fractures etc.) was characterized as lower since the model cannot be used to do structural interpretations.

CNSC staff noted that some uncertainties remained regarding the lateral extent of the cap rock and host rock formations, in particular with respect to the possibility of vertical faults that might disrupt these formations near the site. During the hearing CNSC staff reported that, using hydrogeological site data, it had obtained modelling results that strongly indicated the absence of any major fracture zones within at least hundreds of meters from the planned repository. CNSC staff stated that, while some uncertainties and inconsistencies remained in OPG’s assessment of geological predictability on a regional scale, CNSC staff was satisfied that it had sufficient information to concur with OPG’s assessment of the predictability of the geologic conditions at the proposed site.

OPG stated that, in the event that it were to proceed with the conceptual expansion of the DGR, which will be discussed in the cumulative effects chapter of this report (Chapter 15), it would drill a minimum of three additional deep boreholes outside the footprint of the expanded repository. OPG explained that these boreholes would be used to confirm the continuity and structural integrity of the layers peripheral to the site area of the expanded repository, as well as to confirm the consistency of physical and chemical properties of the rocks and pore fluids over an expanded area. OPG did not provide a timeframe for the installation of these additional boreholes.

Several participants, including individuals, non-government organizations, the Saugeen Ojibway Nation and the Métis Nation of Ontario, expressed concerns about the confidence in the predictability of the geology surrounding the DGR. Participants suggested that the number of

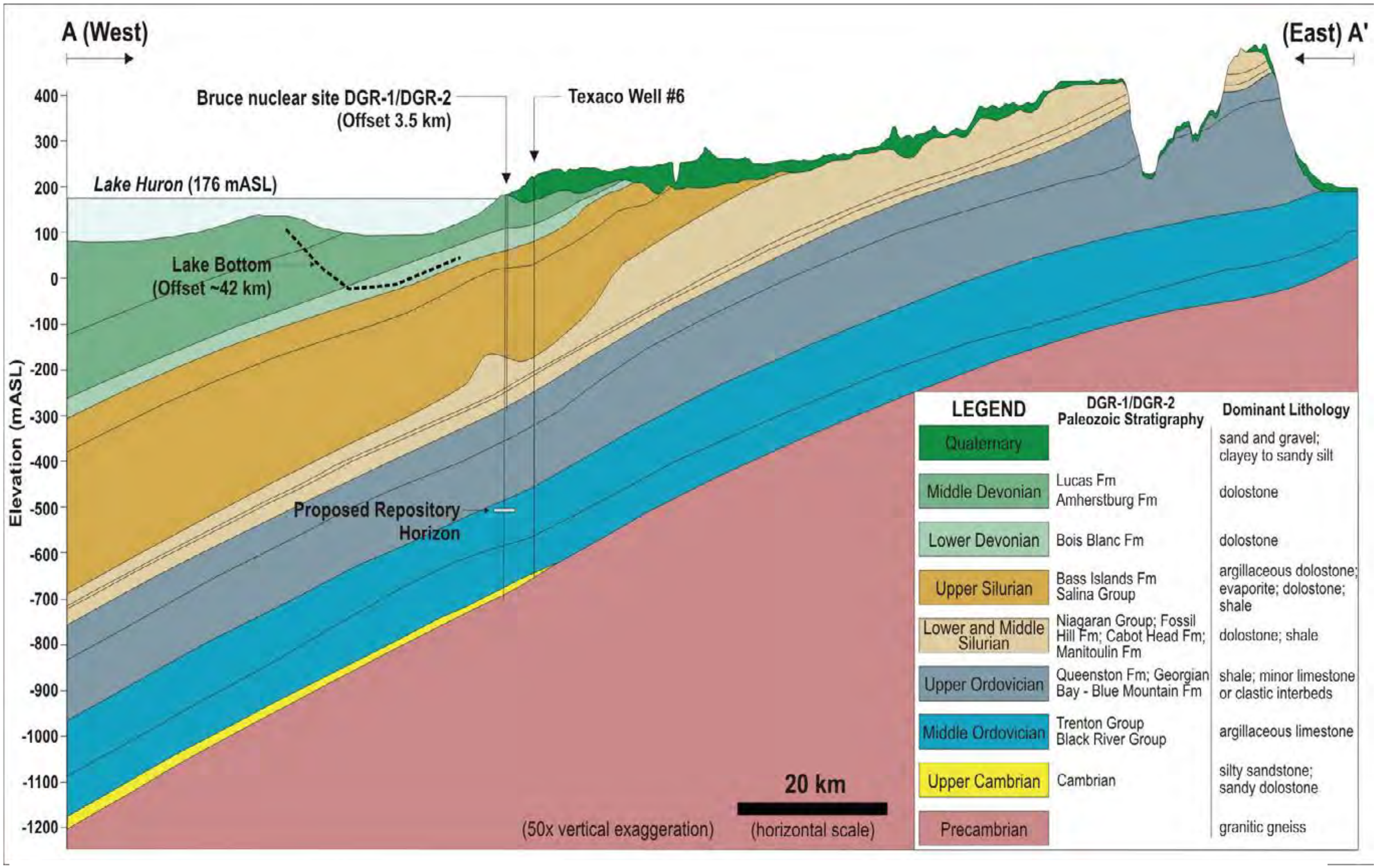


Figure 27 **Rock formations beneath the Bruce nuclear site along the eastern margin of the Michigan Basin. Note the exaggerated vertical scale that produces apparent steep slopes. Actual slopes are one degree or less (reproduced from DGR Geosynthesis TSD Figure 2.23)**

boreholes drilled and the resultant modelling was not sufficient to eliminate uncertainties. Other participants expressed the view that OPG had adequately established the predictability of the site.

OPG proposed to assess the expected and actual geologic, hydrogeologic and geomechanical repository conditions and their impacts on its safety case analyses in greater detail during the construction and operations phases of the project, as part of its Geoscientific Verification Plan.

Panel Conclusion Regarding the Geologic Conditions at the DGR Site and its Surroundings

The Panel concludes that the layer traceability, thickness and structural framework have been adequately assessed and are known with a high degree of certainty within the site area of the proposed repository. The Panel is satisfied that sufficient site exploration drilling has been completed to establish that geologic continuity exists between boreholes at the site scale. The Panel notes, however, that this certainty decreases with distance from the site, particularly to the north - east (up dip to the edge of the Michigan Basin) and under Lake Huron.

In the Panel’s view the most significant uncertainties in the regional predictability of geologic conditions arise from the uneven historic borehole distribution in the Regional Study Area and a gap in borehole coverage of approximately 100 km where borehole information from Michigan was used to extrapolate the model beneath Lake Huron. OPG’s geologic framework model did not provide data on the structures or the hydrogeologic and geomechanical properties of the rocks beyond the site area.

The Panel concurs with Natural Resources Canada that a 3D seismic survey would provide additional information regarding the stratigraphic layers, which could be used to verify the predictions regarding the geologic suitability of the site. The Panel believes that a marine 3D seismic survey under a portion of Lake Huron bordering the Bruce nuclear site would not be impeded by the interferences due to the dense electric infrastructure that can be anticipated on land. Such a survey would verify the continuity of formations and the presence or absence of possible disruptive structures under Lake Huron in the vicinity of the proposed repository.

OPG indicated that it would install additional deep boreholes in the event that the DGR is expanded. The Panel recommends that OPG install these additional deep boreholes during the site preparation and construction phase of the proposed DGR. The boreholes would enhance OPG’s Geoscientific Verification Plan by extending OPG’s geological, hydrogeological, and geomechanical investigations beyond the boundary of the proposed DGR, verifying OPG’s predictions, and providing additional confidence in the lateral continuity of geological units and their properties. As such, the Panel recommends:

Recommendation 13.1: Prior to construction, OPG shall enhance the Geoscientific Verification Plan through the inclusion of additional deep boreholes (minimum of three) that are to be drilled beyond the footprint of the proposed DGR to verify the continuity and structural integrity of the Cobourg Formation and the cap rock sequence. These boreholes should be subject to the same geologic, hydrogeologic, and geomechanical investigation as the original deep boreholes, to the satisfaction of the CNSC.

Recommendation 13.2: Before a licence to operate the DGR is issued, the Geoscientific Verification Plan should be augmented by the inclusion of a marine 3D seismic survey under a portion of Lake Huron bordering the Bruce nuclear site, to the satisfaction of the CNSC.

13.2.2 Isolation of Shallow and Potable Groundwater Resources

Uncontaminated fresh groundwater is a vital component of the water cycle for aquatic and terrestrial biota, as well as humans. Groundwater discharge into Lake Huron is one of the potential pathways by which contaminants generated during construction, operation, and after closure of the proposed DGR may affect water quality.

OPG related the stratigraphic units beneath the Bruce nuclear site directly to the hydrogeological system. Properties of the formations, such as porosity and permeability, a measure of how easily an earth material allows a fluid to pass through it, will determine the movement of water and gas. OPG noted that, with increasing depth of the deep boreholes, these properties showed changes that allowed the definition of the following four discrete zones, with increasing depth (Figure 28):

- surficial groundwater zone (down to 20 metres below the surface);
- shallow bedrock groundwater zone (20 m -169 m);
- intermediate bedrock groundwater zone (169 m - 447.7 m); and
- deep bedrock groundwater zone (deeper than 447.7 m).

OPG explained that the four discrete zones are characterized by distinct rock types, pore water compositions, and hydraulic properties. The proposed repository horizon in the Cobourg Formation at approximately 680 m depth is located nearly central in the Deep Bedrock Groundwater Zone (477.7- 840 m depth) and is distinguished by very low hydraulic conductivities. The Intermediate Bedrock Groundwater Zone is transitional and contains some rock horizons that can transmit groundwater laterally along permeable layers. The upper Shallow Bedrock Groundwater Zone is marked by formations that exhibit high rates of horizontal and vertical groundwater flow. Over the Site Study Area, a Surficial Groundwater Zone consists of a 10 to 20 metre-thick low permeability glacial till where lateral and vertical water movement was assumed to be very low. Fresh groundwater is available within the Local Study Area from lens-shaped sand and gravel layers within the clay-rich glacial deposits and from the bedrock. OPG noted that drinking water wells in the Municipality of Kincardine typically go to depths of 30 to 100 metres into the upper bedrock of the Lucas, Amherstburg and Bois Blanc Formations.

OPG’s site-specific research on the Surficial and Shallow Bedrock Groundwater Zones showed that fresh (less than 1 g/L Total Dissolved Solids) to brackish (1-5g/L total dissolved solids) groundwater is restricted to the surface glacial till deposits and bedrock to a depth of 169 m. Below that depth, salinities are too high to be considered as potential sources of potable water (Figure 29). For reference, total dissolved solids in seawater range from 30-40 g/L.

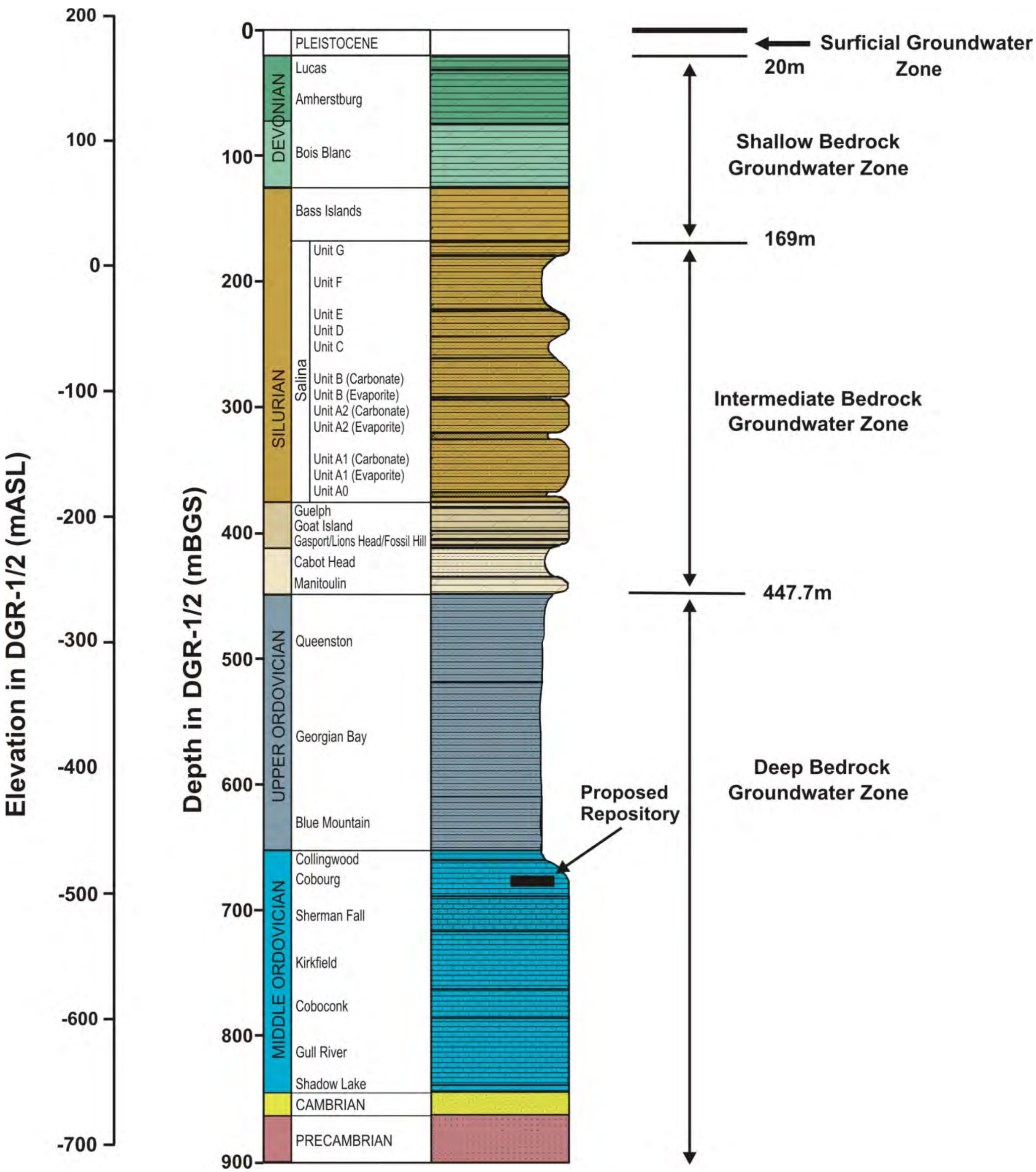


Figure 28: Rock formations beneath the site of the proposed DGR with depth intervals for the groundwater zones. The proposed cap rock seal extends from the top of the repository to the 447.7 m depth level. Indentation of the right-hand margin of the formation features in the figure provides a relative measure of the resistance of the formations to weathering. Large indentations indicate softer rocks, while lesser indentations identify harder rocks. (reproduced from CNSC hearing submission 13-P1.3A, Figure 3.2.12: Stratigraphy and Hydrogeological Regimes at the DGR Project Site).

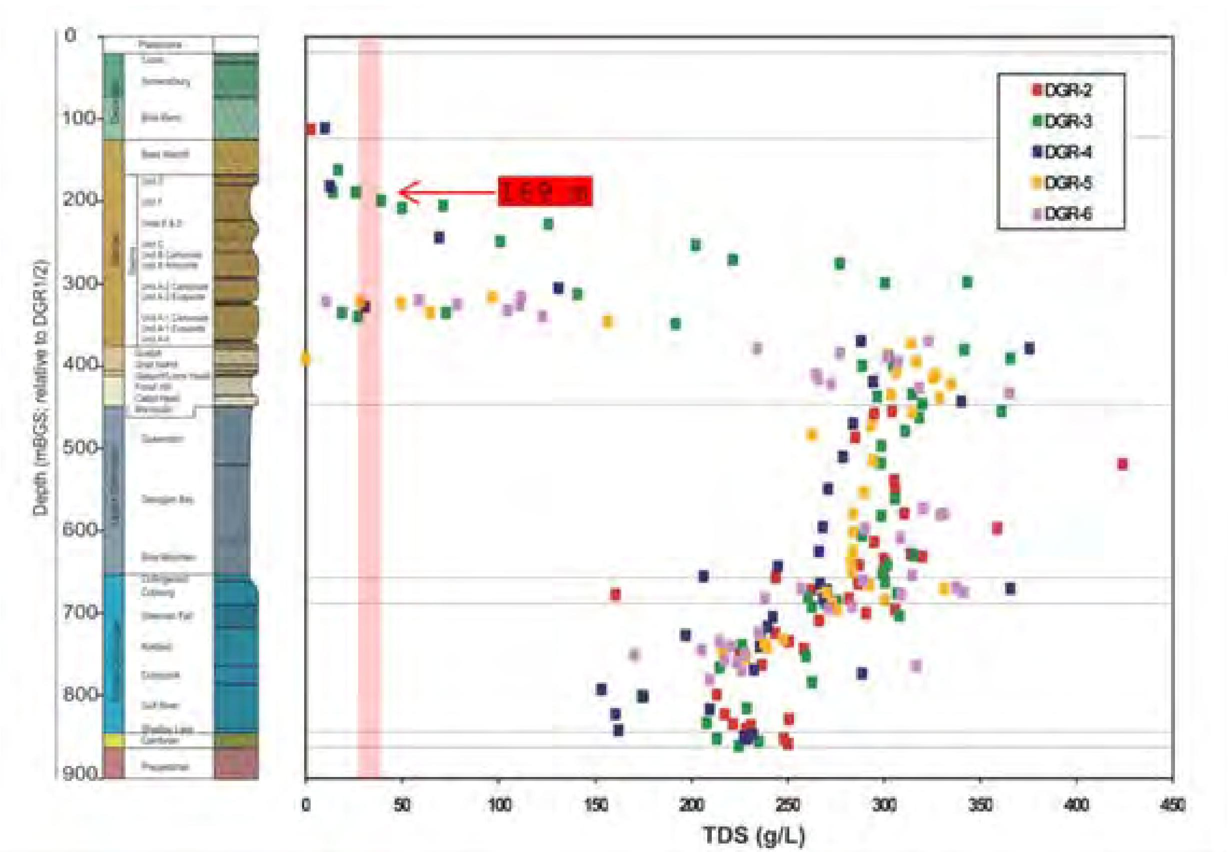


Figure 29: Total dissolved solids in grams/litre versus depth for DGR boreholes. Vertical bar shows the range of seawater composition. The arrow indicates the boundary between the shallow and intermediate bedrock groundwater zones (modified from DGR Geosynthesis TSD Figure4.6: TDS versus Depth in DGR Boreholes)

OPG explained that, below the Shallow Bedrock Groundwater Zone, salinities increase rapidly and progressively in the Intermediate Bedrock Groundwater Zone to about 10 times that of average seawater. These fluids are characterized as brines and the chlorine and bromine concentrations are consistent with an evaporated seawater origin. In the Deep Bedrock Groundwater Zone, above the proposed repository horizon, the salinities remain at this elevated level. The brines in the Cobourg limestone, the overlying cap rock sequence and Intermediate Bedrock Groundwater Zone are denser (close to 1.20 g/cm^3) than the fresh-to-brackish water of the Shallow Bedrock Groundwater Zone. OPG noted that gravity stabilizes the system and prevents the flow of denser brine from the Cobourg limestone and overlying formations at depth from moving towards the surface.

OPG also noted that there was no evidence for infiltration of glacial melt water or recent meteoric water(s), which is water originating with precipitation, down into the Cobourg limestone. The groundwater extracted from pores within the rock of the Cobourg Formation was an ancient brine with no evidence that freshwater had penetrated into this deeply buried system during the Quaternary period (2.6 million years).

In addition, OPG stated that the bedrock formations with low hydraulic conductivity that cap the proposed repository, i.e., the Collingwood, Blue Mountain, Georgian Bay, and Queenston Formations, would provide an additional barrier to the migration of contaminated water toward the surface. However, the chemical gradient produced by the contrast of high salt concentrations at depth to low concentrations near the surface would induce the migration of solutes (salts) towards the surface by the very slow process of diffusion.

Panel Conclusion Regarding the Isolation of the Shallow and Potable Groundwater Resources

The Panel concurs that the shallow and potable groundwater resources at and in the vicinity of the site are effectively isolated from the repository horizon and vice versa. The salinity and density of the groundwater at the site increase with depth and inhibit the natural flow of the deeper water towards the surface. The low porosities, permeabilities, and hydraulic conductivities of the Cobourg Formation and cap rock sequence provide additional barriers to upward, as well as downward, fluid flow. The proposed repository shafts will provide potential pathways that will have to be effectively controlled. Shallow and potable groundwater resources at and in the vicinity of the site would more likely be affected by construction and operations activities at the surface than by contaminated water flow from the repository level through the overlying rock formations.

Advection vs. Diffusion

The transport of contaminants through a body of rock can occur by two processes, advection or diffusion.

Advection: Advective transport involves the physical flow of a fluid, usually water and/or gas and dissolved components (solute) either through interconnected pore spaces or along open fractures. Open fractures concentrate the flow along discrete channels and tend to accelerate and enhance the flow of fluids and associated contaminants. The speed and efficiency of this transport mode is determined by pressure and density gradients and is expressed in terms of the hydraulic conductivity of a body of rock or formation.

Diffusion: If a fluid (water or gas) cannot flow freely, contaminants can still move through the fluid in the interconnected pore spaces by a process known as diffusion. This process is driven by chemical gradients, caused by either differences in chemical composition or concentrations. Movement occurs from areas of higher concentrations to regions of lower concentrations. As the size of the pore spaces and their interconnectedness decrease in a rock, solute diffusion decreases to a very low rate. The speed and efficiency of diffusive transport is measured by a quantity known as the diffusion coefficient. Compared to advective transport, diffusive transport is a considerably slower process.level waste.

13.2.3 Geologic Isolation and Containment of the Waste

OPG stated that the isolation and containment of the L&ILW by the geosphere at the proposed site would be governed principally by the geologic and hydrogeologic properties of the host rock formation and cap rock sequence, the presence/absence of transmissive fractures, and the transport mechanisms of contaminants into the surface or near-surface environment.

The fastest way for radioactive contaminants to reach the surface or near-surface environment would be by transmissive (open and connected) natural fractures, followed by advective flow through abundant interconnected pore spaces, and lastly by slow diffusive transport where pores are fewer and less interconnected.

Suitability of Limestone as a Host for Nuclear Waste

The choice of an argillaceous limestone formation (the Ordovician Cobourg Formation) as the host for a radioactive waste repository may initially seem puzzling, even to trained geologists. The common perception of limestone is that it dissolves easily. This perception is based upon the behaviour of limestone when it occurs in shallower formations where the interaction of the atmosphere and surface and near-surface water produces weak acids that dissolve limestone, forming pores, fissures, cavities and caverns. The interconnections of the pores and cavities may provide pathways for the movement of water (advective transport) and any dissolved components (solutes). Often such formations are good aquifers for potable water. Limestone that has undergone extensive dissolution in the near-surface environment forms rock formations known as karst. The geologic formations near the surface (upper 180 meters) at the Bruce nuclear site include good examples of such karst aquifers.

Karst that has formed early in geologic time, has been buried by overlying rock layers, and is no longer subject to active dissolution processes is known as paleokarst. Two thin paleokarst horizons at approximate depths of 325 meters and 375 meters have been identified at the Bruce nuclear site. These formations exist at depths well above the host Cobourg Formation.

Some participants suggested that the host rocks of the DGR could be characterized as having the properties of limestone found in near-surface or karst environments. They therefore believed that the Cobourg Formation would not be suitable to confine the waste for an appropriate period of time.

The Panel notes, however, that limestone is a “class” (group) of rocks whose common characteristic is that the dominant mineral constituent is calcite (calcium carbonate). This rock “class” encompasses a wide variety of compositions, grain sizes, textures, degrees of compaction, and hydraulic properties, such as porosity, permeability, and diffusivity which is a coefficient that measures the speed of diffusion of a dissolved substance in the porewaters of a rock formation. These properties are determined by the mode of formation and the subsequent geologic history of the formation. Limestone is usually formed in warm shallow marine waters by either accumulation of shell and coral fragments or chemical sediment precipitation. This sediment is then buried and compacted by younger sediments and may never again be exposed to the surface or near-surface environment during its entire geologic history. In this scenario, limestone would escape the conditions leading to karst formation. OPG has determined that the argillaceous limestone of the Cobourg Formation at the proposed DGR site is an example of such a mode of formation.

Based on visual inspections, OPG described the limestone of the Cobourg Formation at the site as generally being dense, solid and showing no visible pore spaces (Figure 30). OPG’s laboratory analyses confirmed that there were few and only very small pores and, more importantly, limited interconnections between existing pores

Figure 30: Core sample of argillaceous limestone from the repository horizon depth, Cobourg Formation, 669.8 meters below ground surface in borehole DGR-2. The limestone is dense with no visible pores, cavities, or fractures. (reproduced from DGR Geology TSD Figure 5.5.2-4)

Role of Fractures and Faults in Contaminant Transport

As previously described, OPG observed a low density of sealed fractures with mineral infills in the vertically-oriented drill cores of the Cobourg Formation taken at the proposed DGR site. OPG additionally analysed fracture occurrences in two inclined drill holes that did not intersect the Cobourg limestone. These analyses confirmed the low abundance of fractures, but only in the cap rock sequence. OPG attributed the low abundance of fractures in the Cobourg limestone to the absence of strong forces, i.e., tectonic activity, affecting the Michigan Basin during its geologic history.In its assessment of a hypothetical alternative DGR site, the OPG IEG noted that a hypothetical granitic bedrock site for the DGR in the Canadian Precambrian Shield would typically display a greater frequency of fractures and less predictability in their distribution than the proposed DGR site in limestone. The Panel's experience would support this general observation.

OPG noted that fluid flow along fractures in the Cobourg limestone is minimized by mineral infills that effectively seal the fractures. During their long history of burial under hundreds of metres of accumulating sediments, Cobourg Formation limestone and surrounding formations were densified and compacted when pores and fractures were infilled by minerals. OPG stated that radiometric analyses of the minerals in the fractures by university laboratories determined that this infilling occurred about 445 million years ago. OPG suggested that the limestone would have lost its ability to transport solutes by advective processes at this early stage in its history.

Fracturing in Rocks

Fractures, faults, and fault zones potentially provide major pathways for rapid advective transport of fluids (gases and liquids) through a body of rock. Their distribution, frequency, size, transmissivity and predictability are essential in the evaluation of the long-term containment of radioisotopes in a geologic repository. Fractures can vary in size from microscopic to megascopic (many kilometres). Fractures that show significant amounts of movement or displacement of layers are known as faults. When present at the scale of layers within a formation and showing no or little displacement, fractures are generally referred to as joints. Fractures commonly occur in sets (groups) showing common orientations and more than one set may be present at a location. On all scales, fractures may be sealed by subsequent mineral deposition that inhibits the transmission of fluids along their path. Fracture sealing can occur at various stages in the history of a rock body.

A participant, Northwatch, suggested that gases generated from the decomposing waste in the DGR during postclosure could lead to highly elevated gas pressures in repository rooms. Northwatch was of the view that such gas pressures would increase stresses in the surrounding rocks that could lead to the reactivation of existing and initiation of new fractures in the host and cap rocks of the DGR, and that such fractures could lead to gas escape resulting in radioactive discharge towards the surface and permit groundwater flow into the DGR. OPG disputed this position and noted that its gas pressure calculations used highly conservative assumptions indicating that pressures would never reach levels that could lead to fracture initiation or propagation. The CNSC concurred with the OPG analysis. Additional information on the evolution of gas pressures in the decommissioned repository is provided later in this chapter.

OPG reported that fault structures have been recorded by historic geological and geophysical surveys in the Regional Study Area, but none were noted within the Site Study Area. In more distant areas of the Michigan Basin, the basement-seated faults (i.e., faults that extend through the sedimentary rock layers of the basin into the underlying Precambrian Shield) have sometimes acted as conduits for hydrothermal fluids (hot, mineral-enriched solutions). These fluids interacted with the carbonate bedrock to form haloes of hydrothermal dolomite (a mineral formed by the chemical reaction between the hydrothermal fluid and the limestone). Such alteration zones are marked by increased porosity, permeability and hydraulic conductivities relative to their host.

The Ontario Ministry of Northern Development and Mines stated that it had the opportunity to examine the core from the deep DGR boreholes. It noted the occurrence of dolomite associated with common minor occurrences of oil and petroliferous odour, which strongly suggested a hydrothermal origin of the dolomite and the possible presence of a nearby fault zone. The Ontario Ministry of Northern Development and Mines also noted that OPG’s 2D site seismic survey showed a third potential fault in the middle of the DGR footprint that had not been tested by additional drilling. It postulated that such a fault might be a conduit for hydrothermal dolomitizing fluids and subsequently for hydrocarbons. Alternatively, a fault located outside of the area covered by the seismic survey may have been the conduit for hydrothermal fluids. The Ontario Ministry of Northern Development and Mines also noted that the faults associated with hydrothermal dolomitization are mainly strike-slip (showing horizontal movement) and may show little vertical displacement of formational contacts and layer continuity. Such structures would be very difficult to detect using the 3D Geologic Framework Model.

OPG stated that it had conducted thermometric fluid inclusion studies on fracture infill calcites from strata below the proposed repository. The paleotemperatures (temperatures at which the calcite crystallized) obtained were consistent with the regional burial history and were considered to be too low to be indicative of any hydrothermal influence associated with a nearby fault zone. Other lines of evidence cited by OPG to substantiate the absence of any conduits to a hydrothermal dolomite reservoir, and associated faults, in close proximity to the DGR footprint included: very low rock mass hydraulic conductivities, low rock porosities, and high vertical hydraulic gradients in the Ordovician sediments. OPG stated that it would conduct additional investigations during shaft sinking, in accordance with its Geoscientific Verification Plan, to confirm the evidence obtained from existing borehole data. CNSC staff concurred with OPG regarding the absence of faulting in the rock body beneath the site area and the scarcity and frequency of sealing of fractures in the cap rock and repository host rocks. However, CNSC staff also noted that uncertainty remained due to the limitation of geophysical methods from the surface to detect fractures, the irregular higher fracture frequency in one borehole, and the relatively small number of boreholes.

The Panel agrees that there can be high confidence in the absence of faults and the nature of fractures in close proximity to the DGR footprint. The lack of direct data on faults and fractures outside the area encompassed by the deep boreholes means that the Panel has less confidence in the characterization of faults or transmissive fractures in the cap rock and repository host rocks at distances further from the DGR. The Panel has recommended that OPG enhance the geoscience verifications activities in its Geoscientific Verification Plan by extending the spatial coverage of investigations to detect faults and fractures near the DGR. These activities would provide additional confidence that the absence of transmissive faults extends beyond the proximity of the DGR footprint.

Evidence Supporting the Dominance of Diffusive Transport in the Host and Cap Rock of the DGR

OPG stated that the very low permeabilities of the Cobourg limestone and the rock layers in the cap rock sequence, as well as the scarcity of any transmissive fractures or faults, would restrict the transport of fluids from the repository to diffusive processes. An additional line of evidence presented by OPG to demonstrate the dominance of diffusive transport over advection is the

Pressure Regimes in the Earth's Crust.

The pressure at any depth in the earth's crust produced by the overlying mass of rock is known as the lithostatic pressure. The pressure of water within interconnecting pores and fractures in geologic formations is known as the hydrostatic pressure. When filled with water at a pressure that is equivalent to the weight of a density- corrected hypothetical water column that extends to the surface, the system is said to be in hydrostatic equilibrium. Anomalous porewater pressures in formations can be either higher (overpressured) or lower (underpressured) than hydrostatic. Anomalous pressures are common in sedimentary rock basins. Their origin has been attributed to physical and/or chemical causes.

persistence of anomalous fluid underpressures in the Ordovician sediments of the Cobourg Formation and overlying cap rock sequence at depths of 450-770 m.

OPG explained that, since the porewaters in the Cobourg Formation and overlying cap rock sequence are underpressured by 1-3 MegaPascals, the pressure gradient in an advective transport system should drive groundwater flow into these formations rather than out of them. Convergence of the groundwater toward the proposed repository would provide a sink that inhibits transport of radionuclides to the biosphere and isolates the Shallow Bedrock Groundwater Zone from the influx of deeper-seated groundwater. OPG's model calculations indicated that the underpressure would likely persist for very long periods of time.

Northwatch noted that questions remained regarding the origin of the underpressures. In its view, these uncertainties indicated a lack of fundamental understanding of the fluid regime at the site. CNSC staff stated that the underpressure condition around the repository horizons would add conservatism to the safety case for the DGR since many of OPG's calculations in the safety assessment ignored the sink effect produced by the underpressure. The Panel's view is that, while the exact origin of the underpressures remains unresolved, this lack of resolution does not affect the safety case.

Some further lines of evidence for diffusion dominated transport presented by OPG relied on the modelling of observed natural tracers oxygen-18 (^{18}O) and bromine (Br), which can be used to monitor the movement solutes in porewaters, as well as salinity profiles. OPG's modelling results suggested that the measured porewater data over the depth interval from 450 m to 844 m could be explained by downward salt diffusion from the strata overlying the cap rock sequence. The modelled time period required to establish the observed profiles was 300 million years. OPG interpreted these results to be consistent with extremely slow solute transport by diffusion. OPG noted uncertainties in the measurements of the composition of the porewaters that could be attributed to the limits of the available analytical methods. OPG stated that these uncertainties would be addressed by the Geoscientific Verification Plan.

CNSC staff concurred that solute transport in the Deep Bedrock Groundwater Zone is essentially limited to diffusion at very low rates. CNSC staff noted that further research was being undertaken to provide additional confidence on the timing of historical fluid invasions in these sedimentary rock formations.

Panel Conclusion Regarding Contaminant Transport from the DGR and the Dominance of Diffusion

The Panel concludes that contaminant transport from the repository in the Cobourg Formation and cap rock sequence will be dominated by diffusion. The Panel is of the view that multiple lines of credible and well-documented information support this conclusion, including:

- the low frequency of fractures in the host Cobourg Formation, and where there are fractures, most are mineral-sealed;
- a lack of detectable faults in the host formation and cap rock sequence;
- the very low porosity, permeability, and hydraulic conductivity of the host rock and cap rock sequence;

- the geologically long residence time of pore fluids (over 100 million years) in the host Cobourg Formation;
- the preservation of underpressures in the host formation and cap rock sequence for geologic time periods;
- tracer profiles indicative of extremely slow element transport; and
- no chemical evidence indicating the influx of recent meteoric water.

The Panel notes that while each specific line of evidence may have some level of uncertainty, the total body of information provides considerable confidence that the transport of radioisotope contaminants through the Cobourg Formation and cap rock sequence will be dominated by extremely slow diffusive processes.

13.2.4 Multiple Geological Barriers to Contaminant Transport from the DGR

International guidelines and practice have long embraced the concept of multiple barriers for the permanent storage of intermediate and high-level nuclear waste. Each of these barriers should provide a unique and stand-alone level of protection – if any of the barriers deteriorate, the next one will come into play. The accepted tenet is that any single barrier, or even several barriers, may fail over the extensive time period of waste isolation and containment.

The Panel notes that, in other jurisdictions, including the USA, Sweden and Germany, the multiple barrier concept includes the geosphere as well as engineered barriers, such as waste containers and backfill, to confine the movement of radionuclides. This is more fully documented in Chapter 6.

OPG stated that the geosphere at the proposed site would provide multiple natural barriers of rock formations that would protect the DGR from disruptive natural events and future human intrusion. It would also help maintain favourable conditions for long-term containment and isolation of the nuclear waste, as well as limit movement of any radionuclides, should other barriers fail. OPG proposed that the bedrock formations hosting, as well as overlying and underlying, the proposed repository constitute multiple geological/hydrogeological barriers that would provide the necessary degree of containment and isolation for a defensible safety case. Multiple lines of evidence led OPG to determine that contaminants from the emplaced waste would move extremely slowly in both the host Cobourg Formation and the overlying cap rock sequence.

The foregoing discussions of OPG’s geoscience hypotheses have incorporated most of the concepts used by OPG to advance the multiple barrier hypothesis. They may be summarized as follows:

- the repository will be located at a depth of 680 m from the surface;
- the argillaceous limestone host rock of the Cobourg Formation shows very low permeability, porosity, and hydraulic conductivity;
- the repository will be capped by an approximately 200 m thick sequence of shale-dominated formations;

- the cap rock sequence is dominated by layers characterized by low permeability, porosity, and hydraulic conductivity;
- contaminant movement in the host rock and the cap rock sequence would be dominated by diffusion;
- the underpressured fluids in the repository horizon and cap rock sequence create a sink directing movement of contaminants towards the repository rather than toward the surface; and
- nearly stagnant brines have existed and will continue to exist at the repository horizon for geologic time periods.

Furthermore, OPG determined that redox conditions in the Ordovician and Cambrian formations are strongly reducing, in the range of iron- and/or sulphate reduction (Queenston Formation) and possibly methanogenesis (Georgian Bay Formation and below). Such chemical conditions in the host rock of the repository and the surrounding formations would greatly reduce the solubility of many metals in the waste and its containers, and provide an additional barrier to contaminant transport into the biosphere.As additional support for the effectiveness of the cap rock sequence as a barrier to fluid transport, OPG cited natural analogues of shale sequences that have trapped commercial quantities of natural gas and petroleum. For example, in the northern Appalachian Basin, hydrocarbons have become trapped beneath shale-rich formations, similar to the site cap rock sequence, that have acted as seals for geological time scales.

Natural Resources Canada noted the presence of thin permeable layers in the Intermediate and Deep Groundwater Zones that could act as preferential pathways for relatively rapid horizontal migration of radionuclides away from the repository site by advective-dispersive transport. These permeable layers are located above the cap rock sequence (Salina A1 Upper Carbonate and Guelph formations) and below the repository horizon (Cambrian/Shadow Lake formations). Natural Resources Canada asked OPG to consider a more appropriate conceptual model that would reproduce hydraulic gradients and porewater velocities observed in these units. In response, OPG undertook additional groundwater flow and solute transport modelling. Although these refinements increased the velocity at which radionuclides would be carried by advective transport in the thin transmissive layers, OPG determined that this represented no material change to the DGR safety case because it still took about 202 million years for radionuclides to reach the biosphere, with resulting doses being approximately 100,000 times less than the public dose criterion of 0.3 mSv/yr. Natural Resources Canada was satisfied with this response.

OPG noted that a significant sandstone aquifer occurs in the Cambrian Formation, beneath the Cobourg Formation and the repository. The Cambrian aquifer, and the immediately overlying mid-Ordovician rock units, are overpressured by about 1.5 MegaPascals. OPG attributed these pressures to regional connectivity of these layers with elevated topography. Northwatch suggested that, should this aquifer ever become connected to the underpressured DGR, the repository would be subject to a very large and rapid recharge. Northwatch was of the view that it was likely that gas build-up could lead to the generation of fractures in the overlying and underlying rocks of the repository that could potentially form a connected network of fractures to transmit fluid flow. As previously discussed, OPG’s modelling analysis of postclosure gas pressures generated in the sealed repository determined that the pressures would fall well below the threshold that would be required to initiate or propagate fractures in the Cobourg Formation and the strata underlying and overlying the repository.

CNSC staff and other participants noted that around the world there are several documented examples of “natural analogues” of radioisotope containment by multiple natural geologic barriers. These examples lend credibility to the DGR concept and test the robustness of natural systems. For example, in Saskatchewan, the world’s richest deposits of uranium have existed for millions of years without significant contaminant movement and with no radioactive signature from uranium or its daughter products evident at the earth’s surface. The containment of these highly radioactive deposits is attributed to the presence of naturally-occurring, low-permeability buffer material that surrounds the *in situ* uranium deposits.

Panel Conclusion Regarding Multiple Geosphere Barriers

The Panel concludes that the bedrock formations surrounding the DGR constitute an effective multiple barrier system. The Panel is satisfied that the physical, chemical and mechanical parameters of the Cobourg Formation and the overlying cap rock sequence described by OPG would provide multiple geologic barriers that would ensure the long-term isolation of the nuclear waste from the biosphere. The Panel’s confidence in these parameters is high for the project site area based on information obtained from measurements made in eight deep boreholes.

The Panel notes that there were limited measurements for the area beyond the site boundary, and that OPG’s modelling relied on extrapolations of the borehole data. This data will need to be supplemented. The Panel is satisfied that the acquisition of further data during shaft sinking and the implementation of the Geoscientific Verification Plan will enhance the knowledge and confidence in the host and cap rock characteristics.

In its postclosure safety assessment, OPG modelled several unlikely failure modes (Disruptive Scenarios) that could bypass the multiple natural barriers. Using highly conservative assumptions, the calculated exposure dosages for humans and non-human receptors for most of the scenarios fell well within acceptable limits. The Panel’s detailed evaluation of both the Normal Evolution Scenario and the Disruptive Scenarios can be found later in this chapter.

13.2.5 Natural Resource Potential of the Project Site

OPG assessed the potential for the DGR site to be a source of natural resources, including minerals, aggregate, and oil and gaseous hydrocarbons, in the present and for future generations. OPG noted that historical exploration for oil and gas in the Regional Study Area had not yielded commercially viable deposits within 40 km of the proposed repository site. The closest active gas deposit is located 42 km to the south in a pinnacle reef within the Guelph Formation. OPG stated that burial temperature estimates using samples retrieved from the deep DGR boreholes did not exceed approximately 90 degrees Celsius, which was considered to be too low for the generation of natural gas from the organic compounds present in the sedimentary rocks, i.e., the organic compounds have a low thermal maturity. However, the temperatures did not rule out the generation of oil from the organic compounds at the site. In addition, shale gas potential was considered to be low since the average total organic carbon content was less than 1% in the shale cap rock sequence. Neither natural gas nor naturally induced hydraulic fracturing were encountered in the deep boreholes. The presence of minor showings of liquid hydrocarbons in some of the deep drill core intervals indicated that hydrocarbons (petroleum) were either generated within the rocks in this area or had migrated into them, possibly along dolomitized fault zones.

Natural Resources Canada noted that OPG had not provided or referred to a quantitative, or even a qualitative, assessment of the hydrocarbon potential of the Cambrian and Ordovician strata present in the greater DGR region. While Natural Resources Canada agreed with OPG that, in today's economic climate, the hydrocarbon potential was "low", this did not address the long-term potential for hydrocarbon resource development. Natural Resources Canada noted that many of the resources being exploited today were also considered not economically feasible even just a few years ago.

CNSC staff were of the view that it would be necessary for OPG to conduct a quantitative evaluation of hydrocarbon resource potential of the site at the time of decommissioning, exclusively from the perspective of assessing the probability of inadvertent intrusion by future generations after repository closure. CNSC staff noted that this uncertainty did not need to be resolved at the present, since OPG had provided sufficient measures to reduce the risk of inadvertent intrusion.

The Ontario Ministry of Natural Resources' database showed that 64 wells have been drilled to explore for oil and natural gas in the land area located within 50 km of the proposed project. The Ministry noted that only two new wells had been drilled since 1991 and that the current industry interest was minimal. The Ministry considered the small number of exploratory wells drilled in the Paleozoic rocks surrounding the site insufficient to provide the data necessary to properly evaluate the oil and gas potential of the rocks. The Ministry further noted that hydrocarbon well drilling records and published geologic maps indicated that there are no beds of salt underlying the proposed site; the northern limit of salt strata in the Salina Group occurs approximately 13 km to the south.

The Ontario Ministry of Northern Development and Mines noted that further analysis would be required to determine the hydrocarbon potential of the Ordovician carbonates in the vicinity of the proposed repository. The limited subsurface data in the Regional Study Area, relative to elsewhere in southwestern Ontario, did not preclude more hydrocarbon resources than have been discovered. The Ministry observed that the numerous minor occurrences of oil and petroliferous odour in the carbonate rocks beneath the proposed repository indicated that there is, or was, a thermally active, mature petroleum system at that depth. Also, the shale horizons immediately overlying the Cobourg Formation had total organic carbon contents and thermal maturity that suggested a potential host for shale oil. The Ministry recommended that this potential resource should be more thoroughly evaluated within or adjacent to the project site.

Panel Conclusion Regarding the Resource Potential of the DGR Site

Based on the information presented by OPG and government agencies, the Panel concludes that the resource potential of the repository site is likely to be low. The Panel notes, however, that this conclusion should be verified during site preparation and continue to be verified over the life of the project.

In the Panel's view, it is not advisable to site waste repositories on lands that contain natural resources that are of current value or are likely to become so in the future. In the case of a subsurface low- and intermediate-level nuclear waste repository, an additional and more cogent consideration is the future disturbance and possible breach of confinement that may occur as the result of exploration activities for economic resources. In the case of the proposed DGR the resources of concern would be potable groundwater, gaseous and/or liquid hydrocarbon accumulations, and base metal or salt deposits. Mineral resource evaluations are works in progress. Advances in technology, new geological concepts, resource depletion, geopolitics, and other factors will determine the status of what is an economic mineral resource at some time and place. Rapid and unanticipated changes can occur, as exemplified by the current role of shale gas and oil in the energy sector.

The Panel notes that all of OPG's deep boreholes encountered oil seeps and stains, petroliferous odours, and high total organic carbon content in core samples in some of the formations. While the strata do not appear to have reached temperatures sufficiently high to lead to natural gas formation, they are in the range favourable for the formation of petroleum oil (petroleum). The Panel recognizes that there is uncertainty in OPG's assertion that potential for natural resources at the site is low both at the present and in the future. This uncertainty is based on the limites extent of the regional data, the evolution of extractive technologies for hydrocarbons, and uncertainties in energy resource futures. Consequently, the Panel makes the following recommendation:

Recommendation 13.3: Prior to site preparation and construction, OPG shall undertake a quantitative assessment of the hydrocarbon potential of the Cambrian and Ordovician strata present in the Regional and Local Study Areas, to the satisfaction of the CNSC. The assessment should consider current trends in extractive technologies for hydrocarbons and energy resource futures. OPG shall institute a periodic review of this document to reflect the evolving trends in natural resource evaluation.

13.2.6 Seismic Activity and Stability of the Site

The integrity of the repository, the shafts, and the shaft seals could be compromised by an earthquake that is capable of producing ground motions of a magnitude that exceed the design standards of the proposed repository and its access shafts. Prediction of future seismic events at a specific location relies on historica data for the region and the proximity to seismically active geologic features. The damage potential of an earthquake is determined by how the ground moves and expected ground motion can be calculated on the basis of probability.

OPG's research on seismic risks found that the region around the Bruce nuclear site is tectonically stable and that large earthquakes are unlikely. OPG evaluated the earthquake ground motions that could occur during the whole lifecycle of the DGR and determined that, due to the strength of the host rock, small earthquakes would have little effect. OPG noted that the less-likely large earthquakes could initiate rockfalls in the repository. OPG stated that the shaft liners were designed conservatively to have sufficient capacity to handle a large 1-in-100,000 year earthquake with damage limited to minor cracking. OPG noted that it had installed three borehole seismographs to monitor and observe seismicity within 50 km of the Bruce nuclear site.

CNSC staff concurred that the proposed site is in a seismically quiet location, with a low probability of seismic activity that would be of any consequence to the safety of the facility. During the hearing CNSC staff added that the bentonite/clay mixture proposed as part of the shaft seal system would not undergo liquefaction due to ground shaking induced by an earthquake.

Natural Resources Canada agreed that the seismicity rate is low in the vicinity of the planned repository and stated that OPG had adequately characterized the contemporary earthquake shaking hazard. Natural Resources Canada noted that although the rate of small nearby earthquakes was low, rare large earthquakes could pose a hazard to the repository, particularly because of its intended long life. Natural Resources Canada agreed with OPG that the lack of faulting near the repository site and the low porewater pressure in the repository rock were good indications that there have been no nearby large (surface-rupturing) earthquakes.

In assessing the contemporary earthquake shaking hazard of the site, Natural Resources Canada noted two areas in which OPG's approach may not have been conservative. These involved the maximum magnitude of earthquakes to be expected, as OPG used values lower than Natural Resources Canada or the United States Geological Survey would use, and the method of smoothing earthquake rates in space. Natural Resources Canada was satisfied that an earthquake-generated tsunami hazard was negligible during the preclosure period and noted that the project design included seven meters of freeboard for the shafts, which Natural Resources Canada considered to be an adequate mitigating measure for beyond-design flooding.

Since the DGR would have a very long design life, it is expected that the rock stress of the region regime would change over the next several glacial cycles due to ice loading effects. Natural Resources Canada noted that the historical record from Scandinavia suggests that earthquake activity is suppressed during a glaciation event and released in a pulse during deglaciation periods. Natural Resources Canada determined that there would be a higher likelihood of strong earthquake shaking during the next deglaciation cycle than was indicated by the contemporary seismic hazard assessment.

Several participants, including individuals, organizations and the Métis Nation of Ontario, expressed concerns about the potential seismic activity in the region in the future. A participant noted that the earthquake data for the region goes back one hundred and eighty years and suggested that it would be unwise to base conclusions on such a limited data set. Another participant expressed concerns about changes to the seismic stability of the site, such as slippage on known or undetected faults, which could result from future induced hydraulic fracturing for hydrocarbon extraction or the presence of carbon dioxide injection wells in the extended vicinity of the site, up to 200 kilometres away. Natural Resources Canada explained that the examples provided related to extensive porous aquifers and intensely faulted regions. Since such conditions were not encountered during OPG's site characterization, Natural Resources Canada did not believe these concerns were applicable to the DGR site.

Panel Conclusion Regarding Future Seismic Activity at the Site

The Panel concludes that the proposed DGR site is seismically quiet and not prone to earthquakes of a magnitude that would likely pose a significant hazard during the construction and operational phases of the project. The Panel agrees with Natural Resources Canada that, for the postclosure phase, OPG's predictions of the maximum magnitude earthquakes to be expected should encompass a greater degree of conservatism to align with the methodologies employed by Natural Resources Canada and the United States Geological Survey. Over the timespan of the postclosure phase, which may include multiple periods of glaciation and deglaciation, the likelihood of a major seismic event occurring at or near the repository site becomes more probable and should be incorporated into the long-term safety case. As such, the Panel recommends:

Recommendation 13.4: Prior to construction, OPG shall re-assess mean shaking levels due to a maximum magnitude earthquake, to the satisfaction of the CNSC. The reassessment shall adopt methodologies employed by Natural Resources Canada and the United States Geological Survey, and consider mitigation strategies or plans for conditions of "beyond-design" ground motions.

13.2.7 Geomechanical Stability and Predictability of the Cobourg Limestone

OPG stated that the Cobourg Formation considered for the proposed DGR was sampled through drilling and found to exhibit high rock strength, excellent rock quality in terms of degrees of intactness, and very low fracture incidence at the borehole scale. OPG noted that the local and regional sedimentary formations that compose the Michigan Basin have been subjected to multiple historic glaciation cycles of loading and unloading.

OPG explained that the effects of glaciation, in particular, can result in removal of surficial soil and rock that will reduce layers of cover formation materials that compose the geosphere barrier existing between any potential repository and the surface environment. During the next 1 million year interval, the proposed DGR would potentially be affected by up to ten glacial loading/unloading cycles. Repeated glaciation events would result in incremental stress loading to the geosphere by the overlying weight of glacial ice, followed by stress release when deglaciation follows in each cycle. OPG stated that its modelling of glacial erosion indicated that the integrity of the Ordovician cap rock formations, following glacial erosion of up to 100 meters of surface bedrock, would not detrimentally affect the integrity of the shale cap rock.

OPG, through detailed physical observations of core samples, determined that loading and unloading events of past glaciation cycles have not caused shearing along weak contact surfaces or internal damage, as evidenced by the presence of open fractures, within stiff shale cap rocks that exist above the Cobourg limestone layer. OPG's research indicated that 3 km of ice sheet existed above the site, which would have added an equivalent 30 MegaPascals excess vertical stress effect. Through its examination of physical cores, OPG did not identify rock damage and instability resulting from the influence of past glaciation at the site location.

OPG stated that the geomechanical properties of the Cobourg Formation limestone samples from OPG's site investigations showed a high degree of correlation between holes at the site and also compared favourably with similar property estimates from regional database information. Additional information on the geomechanical properties of the Cobourg limestone can be found in Chapter 6.

Panel Conclusion Regarding the Geomechanical Stability of the Cobourg Limestone

The Panel concludes that the information provided by OPG on the geomechanical properties of the bedrock materials is sound and reasonable. The Panel is satisfied that the high quality and favourable physical properties of the limestone formation demonstrate that the *in situ* rock at and above the Cobourg Formation has remained stable throughout history. The Panel is further satisfied that no evidence of detrimental effects of multiple glacial loading cycles on the geomechanical properties of these rock materials, as would be indicated by pervasive fracturing and low strength properties of core materials, has been identified.

The Panel notes that these conclusions are based largely on numerically- and spatially-limited rock core examinations. The Panel is of the view that the additional geomechanical testing at the repository scale during the construction and operational phases of the project, as outlined in the Geoscientific Verification Plan, will enhance the completeness and reliability of the information available.

13.2.8 Panel Conclusion Regarding the Suitability of the Site Geological Setting

Based on the above information, the Panel concludes that the proposed geological setting for the DGR, in the argillaceous limestone of the Cobourg Formation at the Bruce nuclear site, is suitable and will keep the L&ILW contained and isolated from contact with the biosphere. The Panel is satisfied that OPG has adequately characterized the geological and hydrogeological environment. The Panel has made recommendations to further enhance the Geoscientific Verification Plan and provide further assurance of the performance of the DGR. These include the collection of additional borehole and seismic data, confirming the resource potential of the site, and refining the seismic models for the long-term performance of the DGR. The Panel notes that the geological conditions will continue to be verified over the life of the project, through OPG's Geoscientific Verification Plan.

13.3 POSTCLOSURE SYSTEM EVOLUTION AND SAFETY ASSESSMENT

This section describes OPG's postclosure safety assessment for the proposed DGR. It includes an overview of OPG's assessment approach, as well as a review of evaluated evolution scenarios.

The EIS Guidelines required that the whole lifecycle of the DGR be assessed. A description of how the facility would perform over the long-term was required to help determine the safety of the facility and its potential effect on human health and the environment. The EIS Guidelines identified the topics that were to be addressed in the postclosure assessment as:

- demonstration of the long-term safety of the DGR;
- selection of assessment scenarios;
- additional arguments in the safety case;
- confidence in mathematical models; and
- interpretation of assessment results and comparison with acceptance criteria.

13.3.1 Assessment Approach

OPG used a five-step approach in its long-term safety case assessment that has also been followed by the Panel in its evaluation. As stated by OPG, the steps of the assessment were:

1. The assessment context was defined, documenting the high-level assumptions and the constraints, notably the regulatory requirements and the assessment timeframe.
2. The system was described, summarizing information on the waste, repository, geological setting and surface environment pertinent to postclosure safety.
3. A range of potential future scenarios was systematically identified, ranging from expected to "what if" scenarios.
4. Conceptual and mathematical models were developed to represent these scenarios to provide a quantitative analysis.
5. The scenarios were analyzed and the results were assessed with respect to the performance of the system, its overall robustness, and the nature and role of key uncertainties.

OPG's postclosure safety assessment was based on technical arguments, detailed models and data presented in a series of supporting studies and documents. These sources contributed to the derivation of a range of potential future evolution scenarios, both normal and disruptive, in support of the preliminary postclosure safety assessment. The safety assessment structure used by OPG is illustrated in Figure 31.

13.3.2 Assessment Context

This section describes the context for OPG's postclosure safety assessment, including the safety objectives, compliance criteria, regulatory requirements, and the assessment timeframe.

Overall Safety Objective for the Project

OPG based the overall safety objective for the DGR on the 2006 IAEA guidance document *IAEA Safety Requirements: Geological Disposal of Radioactive Waste* and compliance with the *Nuclear Safety and Control Act*. OPG stated the objective was "to provide safe long-term management of L&ILW without posing unreasonable risk to the environment or health and safety of humans." OPG noted that realization of this objective would entail the quantitative assessment of postclosure radiological and non-radiological safety of the proposed DGR and identification of those uncertainties that would have the greatest potential impact on the long-term performance of the DGR system.

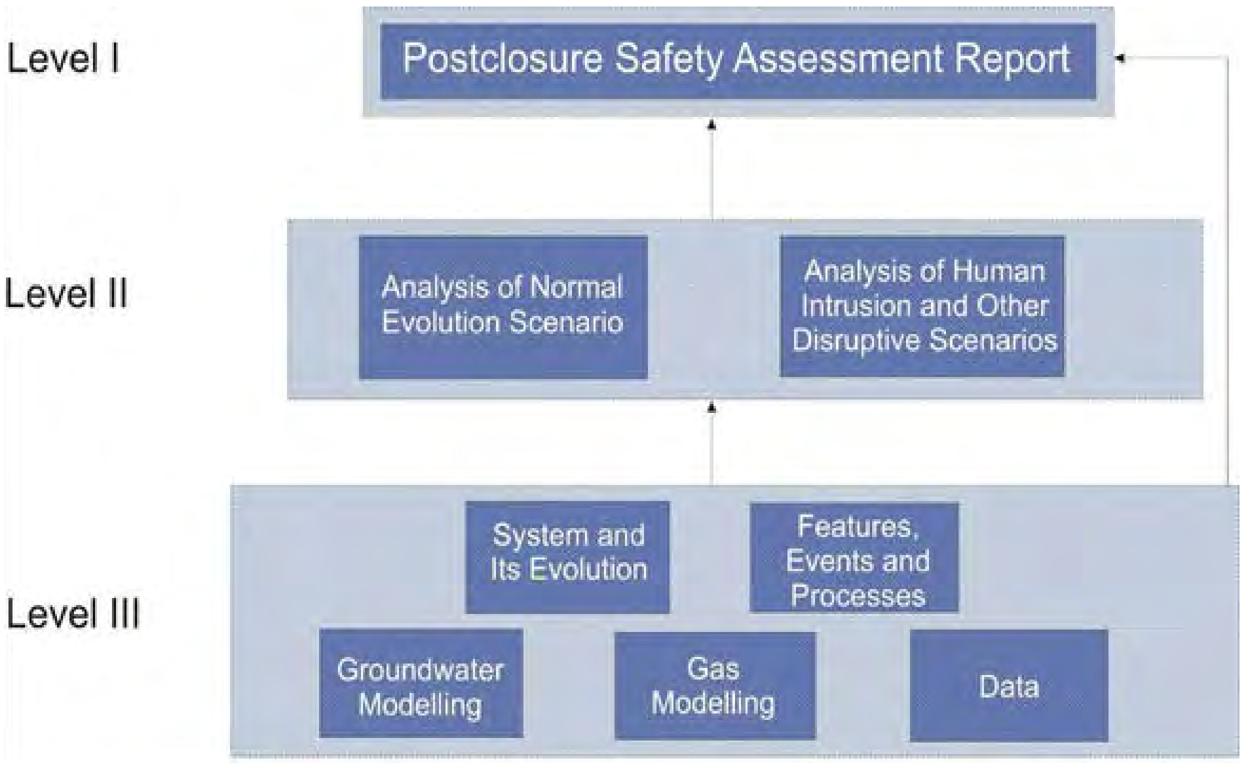


Figure 31: OPG's information structure used to develop the postclosure safety assessment (reproduced from DGR Postclosure Safety Assessment Fig. 1.5)

Compliance Criteria

OPG explained that its conclusions about compliance with the safety objective were based on the comparison of the modelled performance of the proposed DGR with performance criteria based on regulatory requirements. Two safety functions would also need to be fulfilled by the DGR after decommissioning:

- the waste would need to be isolated from the biosphere; and
- the long-term containment of the waste would have to be demonstrated.

OPG stated that the overall safety objective would be met if it could be demonstrated that:

- the DGR provided long-term isolation and containment;
- preclosure and postclosure safety criteria were met;
- the DGR system was robust; and
- the DGR could be constructed, operated and decommissioned safely.

Regulatory Requirements and Guidance

CNSC staff stated that, under the *Nuclear Safety and Control Act*, the proposed DGR would be classified as a Class 1B nuclear facility and that after cessation of operations OPG would require licences from the CNSC to decommission and abandon the DGR. CNSC Regulatory Guide G-320 provides guidance on assessing the long-term safety of radioactive waste management.

OPG compiled a comprehensive list of issues relevant to the postclosure safety assessment of the DGR that were derived from Regulatory Guide G-320. OPG also provided detailed explanations how each of these issues was addressed in the postclosure safety assessment in the Postclosure Safety Assessment report.

Assessment Timeframe

The radioactive waste destined for emplacement into the DGR contains radioisotopes with long half-lives and hazardous non-radiogenic elements that need to be isolated and contained for an extended period of time. OPG assumed that an institutional control period of up to 300 years would follow the closure of the DGR. During this period, measures would be implemented to reduce the likelihood of future human actions that could compromise the repository. OPG asserted that the assumed 300 year period of such controls, as well as societal memory, was consistent with current international practice. Institutional control is further addressed in later sections of this chapter.

Beyond this period, OPG made no assumptions with respect to institutional control, monitoring, or memory of the presence of a radioactive waste disposal site in its long-term safety assessment. OPG chose a one million year baseline period for the postclosure safety assessment. This period would encompass the time over which most of the radioactivity in the waste will have decayed and over which the maximum risk would be expected to occur. OPG determined that within this timeframe the residual radioactivity within the DGR would have dropped below that of the overlying bedrock at the site. Some analyses were extended beyond one million years to provide additional evidence that the peak effects had been identified.

Panel Conclusion Regarding Overall Objectives of the Postclosure Safety Assessment

The Panel reviewed CNSC Regulatory Guide G-320 and found the CNSC’s expectations for the development of a long-term safety case for the management of radioactive waste to be appropriate, clear, and comprehensive. The Panel is satisfied that the CNSC provided OPG with a clear set of directives and objectives to provide a robust long-term safety assessment for the DGR, and that OPG adhered to these directives in the development of its preliminary postclosure safety assessment. The Panel concurs with OPG's selection of one million years as an appropriate timeframe for the postclosure safety assessment.

13.3.3 System Features Relevant to Postclosure Safety

OPG identified the following key safety functions that would ensure the isolation and containment of the L&ILW:

1. site geology and hydrogeology;
2. repository layout;
3. shaft design and seals; and
4. waste characteristics and packaging.

Each of these safety functions has been discussed in detail in other parts of this report and has been evaluated by the Panel. They are summarized below:

Site Geology and Hydrogeology

The main safety features of the geosphere at the Bruce nuclear site identified by OPG were:

- thickness of the rock layers (approximately 680 meters) above the repository that would limit the likelihood of human intrusion and the impact of future continental ice-sheets;
- low permeability and high geomechanical stability of the rocks hosting and surrounding the DGR that would provide an effective physical and chemical barrier to the migration of contaminants from the repository;
- presence of underpressures in the Ordovician rock layers (which host and overlie the repository) that would lead to groundwater flow towards the repository (not away from it);
- tectonic and seismic stability of the site and the absence of large scale faults/fractures that could provide highly permeable pathways for contaminants towards the surface;
- presence of highly permeable rock formations (Guelph and Salina A1 above the low permeability cap rock sequence) that could divert any contaminants migrating upward from the repository or shafts along horizontal horizons; and
- absence of economically viable mineral resources that could initiate human intrusions.

The Panel's detailed consideration of OPG's long-term safety features related to the site geology was discussed earlier in this chapter.

DGR Layout and Design

OPG explained that the postclosure safety assessment of the DGR was based on the original preliminary design, rather than the final preliminary design presented in the EIS and Preliminary Safety Report. OPG stated that the significant changes from the original to the final preliminary design related to operational safety and reliability rather than postclosure safety. OPG noted that the design would likely evolve further, as the detailed design would be prepared prior to construction of the DGR. Since long-term safety is a design requirement, OPG expected that any changes would not substantially affect the conclusions of the postclosure assessment.

The key potential safety features of the DGR layout that were identified by OPG to strengthen the postclosure safety case were:

- location of the waste emplacement rooms at 680 meters depth in a thick low permeability limestone sequence (Cobourg Formation) under 200 meters of low permeability shale cap rock;
- absence of backfill for emplacement rooms, access tunnels, and ventilation tunnels, as well as preservation of highly damaged zones, to provide space for gas that may be generated from the corrosion and degradation of the waste;
- waste emplacement rooms aligned with the rock principal stress;
- thick room pillars for mechanical robustness; and
- shafts placed in an arrangement separate from the waste panels.

Shaft Design and Seals

OPG cited features of the proposed seals for the shafts and the repository that would contribute to postclosure safety:

- installation of shaft seals (after removal of the highly damaged zone) consisting of a primary bentonite/sand mix and a secondary asphalt mastic mix that would limit contaminant migration by groundwater and gas flow in the shafts;
- installation of a concrete monolith at the base of the shafts to provide long-term support to the shaft seals and the repository tunnels in the vicinity of the shafts and that might only partially limit groundwater and gas flow into or from the DGR and shafts; and
- placement of concrete bulkheads in the shafts at the levels of the more permeable Guelph and Salina A formations to prevent flow in these units from affecting the bentonite/sand mix and provide structural support for the overlying bentonite/sand mix.

The Panel's detailed considerations of DGR design features and features of the shaft design and seals relevant to long-term safety can be found in Chapter 6.

Waste Characteristics and Packaging

OPG stated that some features of the waste characteristics and packaging would enhance postclosure safety. The identified contributing features were:

- 80% of the waste volume would be low-level wate;
- relatively quick decay of tritium and carbon-14, the most important radionuclides present at the time of closure (tritium decays within a few hundred years, carbon-14 in about 60,000 years); and
- delayed release of the most important long-lived radionuclides, niobium-94 and zirconium-93, due to their predominant presence in corrosion-resistant Zircaloy.

OPG attributed only a minor long-term safety role to waste forms other than Zircaloy. While waste containers would provide an initial physical barrier to contact with groundwater, their designed life time of 50 years would not provide any long-term isolation and containment of the waste. In the postclosure safety assessment OPG did not credit the packaging with any barrier function.

In view of possible uncertainties in the amounts and concentrations of radionuclides and non-radioactive contaminants of the waste designated for the DGR, OPG's postclosure safety assessment conservatively assumed inventories by a factor of ten higher than those provided in the 2010 Reference L&ILW Inventory Report. The Panel's detailed considerations of the waste and its packaging can be found in Chapter 7.

Role of Multiple Barriers

OPG stated that the DGR would effectively be isolated from the biosphere by multiple geosphere and engineered barriers. In this report, the geosphere barriers were discussed earlier in this chapter, engineered barriers in Chapter 6, and international practice involving multiple barriers in Chapter 7.

Geosphere (Natural) Barriers

OPG listed multiple features of the DGR site that would constitute natural barriers to the movement of contaminants from the repository into the biosphere. These included:

- very low-permeability host rock;
- low permeability cap rock sequence;
- underpressures in the host and cap rock;
- lateral dispersion of contaminants along more permeable horizons above the cap rock; and
- density gradient of formational waters.

CNSC staff stated that predictable and stable rock formations with low permeability, under and above the DGR, would provide multiple natural barriers that would safely isolate and contain the waste.

Some participants pointed out that although the attributes of an undisturbed site may appear favourable, some of these may be compromised when the site has been disturbed by excavation and the emplacement of waste that, through time, would alter the environment of the host rocks. In the Panel's view, the wide range of repository evolution scenarios presented by OPG and the conservative assumption incorporated into them embraces the range of changes of the host rock environment induced by excavation activities and waste emplacement and does not affect the validity of the postclosure safety case. Several other participants expressed the view that the presence of multiple natural barriers would effectively reduce the potential danger of escape of any radioactive waste into the biosphere from the repository.

Engineered Barriers

As noted above, OPG provided design features of the DGR site that would act as engineered barriers to contaminant transport:

- shaft seals consisting of a primary bentonite/sand mix and a secondary asphalt mastic mix;
- installation of a concrete monolith at the base of the shafts; and
- installation of closure walls to isolate filled emplacement rooms.

OPG noted, however, that the concrete bulkheads in the shaft seals would not be durable barriers to contaminant transport in the long term. Also, end walls and closure walls that would be used to isolate filled waste emplacement rooms and filled panels would be designed for operational safety and would not be intended to have a postclosure safety role.

Some participants suggested that it was highly unlikely that the very low permeabilities of the host bedrock could be approached by the proposed seal materials for the shafts. As a result, participants were of the view that the seals would permanently represent the weakest point in the long-term safety case. OPG and CNSC staff concurred with this assertion.

Some participants noted that the dose criterion could be reached or exceeded if there was a partial breakdown, however unlikely, of a single barrier, the shaft seals and excavation damaged zone. The participants suggested that this illustrated a lack of defense-in-depth for the DGR system even when all other factors in the performance calculations were considered to be conservative. OPG recognized the low-probability scenario of a shaft seal breakdown and modelled it as one of its disruptive scenarios.

CNSC staff highlighted that the shaft seals represented the sole long-term engineered barrier for the DGR. In its consideration of Disruptive Scenarios, CNSC staff stated that some Disruptive Scenarios (Failed Shaft Seals, Undetected Vertical Faults, Poorly Sealed Borehole) represented cases where one of the two barriers (the geosphere or shaft seals) fail. In the Human Intrusion Scenario both barriers would be circumvented. These scenarios are further described in the following section of this chapter.

Panel Conclusion Regarding Key Safety Functions and System Features Used to Develop the Postclosure Safety Assessment

The Panel concludes that OPG's identification of key safety functions, and the system features associated with them, was comprehensive and credible. The Panel concurs that the key safety functions identified by the CNSC and OPG should be the primary components of a rigorous long-term safety assessment for the DGR.

13.3.4 System Evolution Scenarios

This section describes the evolution scenarios for the long-term safety case for the DGR. These include the Normal Evolution Scenario and the Disruptive Scenarios.

Identification and Development of Future Evolution Scenarios

Both CNSC Regulatory Guide G-320 and the EIS Guidelines required OPG to include a scenario of the normal evolution of the site and facility with time in its postclosure safety assessment. The Normal Evolution Scenario would represent a reasonable evolution of the repository system. Additional scenarios were required to examine the effects of disruptive events or modes of containment failure. These unlikely or "what if" cases used to test the robustness of the DGR system, and in part assess the uncertainties associated with the evolution of the system, were called Disruptive Scenarios.

Regulatory Guide G-320 stipulates that development of assessment scenarios should include identification of human and environmental receptors that may be exposed to radioactive and hazardous substances. To identify and define scenarios that would meet these requirements, OPG considered the various external, internal and contaminant factors that could affect the DGR system during its evolution. The factors were then further categorized as features, events, or processes, as illustrated in Figure 32.

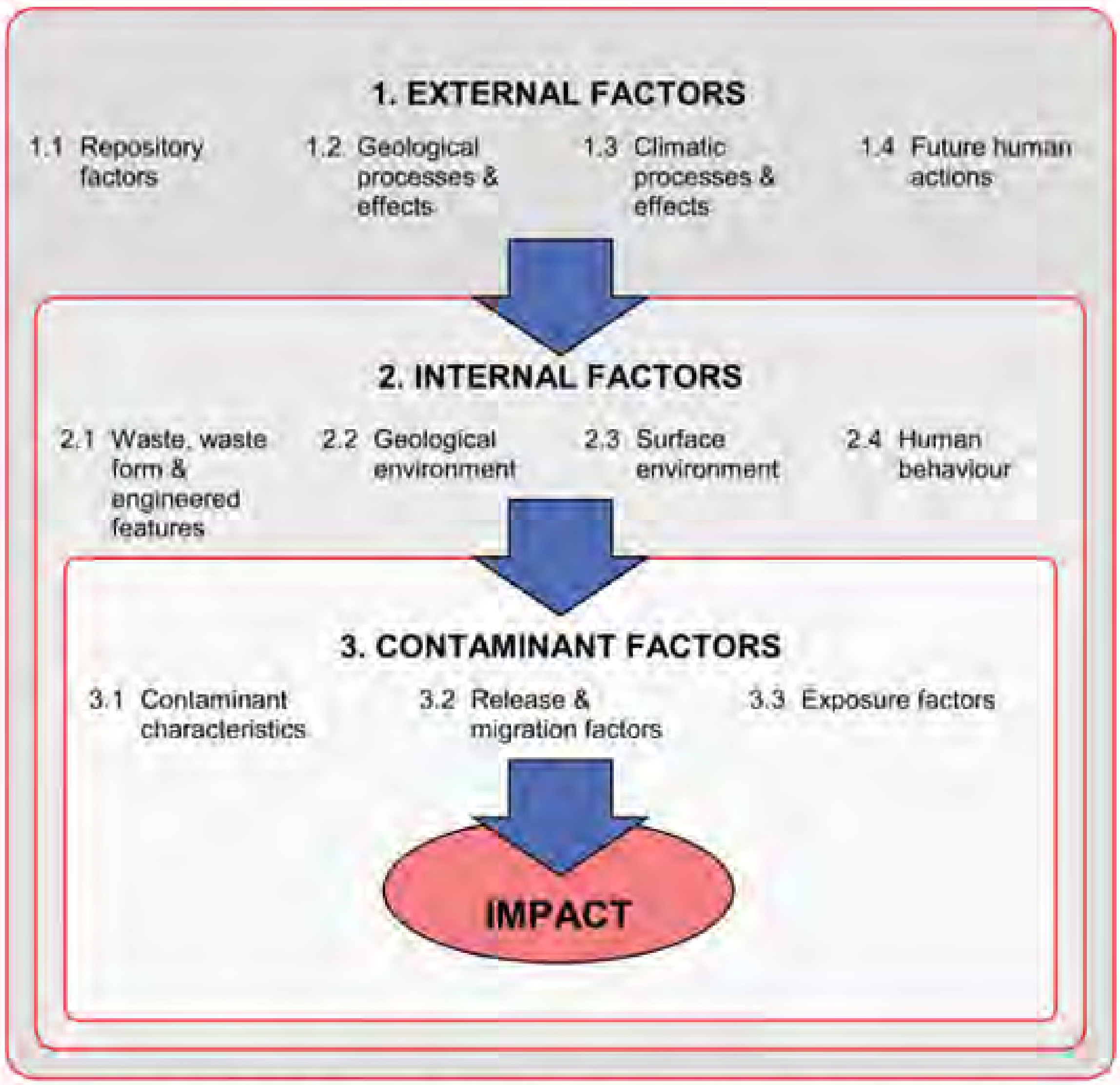


Figure 5.1: External, Internal and Contaminant Factors/FEPs

Figure 32: Flowchart illustrating the identification of project effects using features, events and processes (FEPs) (reproduced from the DGR Postclosure Safety Assessment Figure 5.1)

OPG compiled a list of 53 external factors and almost 200 internal factors based partly on lists developed by the Organisation for Economic Co-operation and Development Nuclear Energy Agency and the IAEA. External factors are features, events and processes such as earthquakes that originate outside the temporal and spatial boundaries of the DGR and provide the system with its boundary conditions. Internal factors are features, events and processes such as waste form and packaging that originate within the spatial and temporal boundaries of the DGR system.

OPG then selected the factors that were likely to affect the DGR system and its evolution in order to develop a Normal Evolution Scenario that would represent a reasonable evolution of the repository system. OPG used the effects of less likely factors, those that might lead to abnormal degradation and loss of containment, to derive the four most likely Disruptive Scenarios. In its list of internal factors, OPG included a number of contamination factors, i.e., contaminant release and migration factors that would not generate new scenarios but would lead to different calculation cases for the Normal Evolution Scenario.

OPG used professional judgment to identify the main processes and to conceptualize the system. CNSC staff acknowledged that it was not feasible to include all processes that govern the migration of contaminants from the repository to the biosphere into any type of model. However, CNSC staff considered OPG's conceptual models to be sufficiently conservative and to appropriately support the safety case.

Normal Evolution Scenario

For the postclosure safety assessment, OPG conceptualized the stages in the normal evolution of the DGR over the timeframe of one million years. The progressive key features, events and processes may be summarized as follows and are illustrated in Figure 33.

- 0 - 10,000 years
    - the repository would quickly become anaerobic;
    - the repository would begin to fill slowly with water (brine) seeping in from the shafts and the surrounding rocks;
    - the waste packages would undergo slow anaerobic degradation and generate gases (predominantly methane and tritium);
    - the main radioactive components of the gases would be carbon-14 and tritium;
    - the repository would remain mostly unsaturated (not filled with water);
    - all waste packages would have degraded by the end of this period and other contaminants would be released into the repository water; and
    - most radioactive contaminants would be contained within or near the repository by the low-permeability host rock, or would decay.
- 10,000 - 100,000 years
    - the carbon-14 would decay completely;
    - some contaminants may slowly migrate, by diffusion or other mechanisms, up the sealed shafts and through the geosphere into the shallow geosphere and the surface environment;
    - people living on or near the site could be exposed to small amounts of released contaminants through from groundwater drawn from a well located on a farm, consumption of local produce, by hunting, or through fishing in Lake Huron; and
    - the Bruce site may go through one glacial cycle with cooling and subsequent ice-sheet development.
- 100,000 - 1,000,000 years
    - only long-lived radionuclides such as chlorine-36, zirconium-93, iodine-129 and uranium-238 would remain;

- o repeated glaciations could occur and cover the site with a periodicity of around 100,000 to 120,000 years;
- o the gas pressure would equilibrate toward the host rock steady-state hydraulic pressure; and
- o by the end of this period the residual radioactivity of the repository would be approximately equal to that of the overlying rocks.

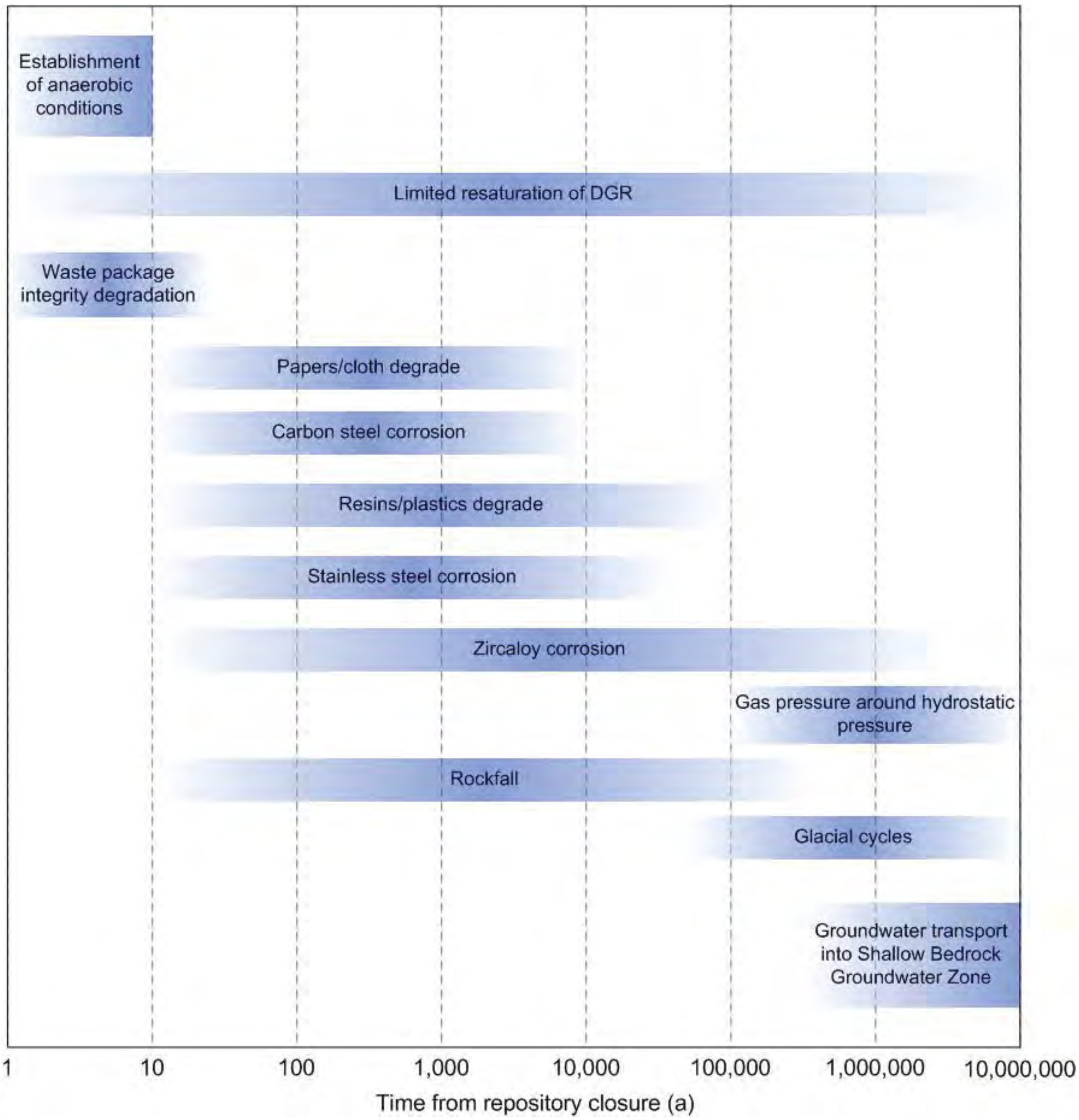


Figure 33: Timeframes for Key Features, Events and Processes of the Normal Evolution Scenario (reproduced from DGR Postclosure Safety Assessment Figure 6.4)

OPG noted that rockfall in the repository rooms and tunnels, as a result of the release of rock stresses, would be expected. External events such as strong earthquakes and the postulated ice-sheet advances and retreats could induce loads on the DGR rooms and tunnels that would also lead to rockfall. OPG stated that its geomechanical modelling showed that rock deterioration and collapse would continue until the open space of the rooms and tunnels would be filled. At that stage, the system would become self-supporting and mechanically stable. The modelling also demonstrated that the rockfall zone would propagate for approximately 10 meters into the repository roof before stabilization and would not extend into the overlying geologic formations. For the postclosure safety assessment, OPG conservatively assumed that full rockfall would occur quickly after closure and would fill all open spaces in the rooms and tunnels.

Disruptive Scenarios

In its identification and selection of Disruptive Scenarios, OPG concentrated on the evaluation of identified external factors that could potentially compromise the isolation and containment safety functions of the DGR. Screening criteria relied on professional judgment that considered the likelihood of each failure mechanism. OPG explained that, since the long-term safety of the DGR would rely mainly on the strength of the geosphere barrier and the shaft seals, the considerations focused on scenarios in which these could be bypassed.

OPG considered the following four base case Disruptive Scenarios, and examined variant conditions for each:

- Inadvertent human intrusion
    - assessed the consequences of an exploration borehole that intercepted the repository;
    - stipulated that the borehole may penetrate into the overpressured Cambrian Formation ;
    - evaluated the radiological effect on human receptors and non-human biota due to contaminant release by groundwater, gas or drill core;
    - included contaminated groundwater penetration into the shallow geosphere and radiological exposures of human users; and
    - assumed that human intrusion would not occur for a 300 year period after repository closure due to effective institutional controls.
- Severe shaft seal failure
    - assessed the impact of rapid and complete shaft seal degradation and increased degradation of the repository/shaft excavation damaged zones;
    - assumed that with respect to all other parameters the evolution of the DGR would proceed in the same manner as the Normal Evolution Scenario;
    - the base case conservatively assumed a degraded shaft porosity of 30% and enhanced hydraulic conductivity of 10^{-9} m/s;
    - an extremely conservative calculation case assigned a permeability of the shaft seal 100 times higher than the base case, i.e., that of fine silt and sand, rendering the shaft seal ineffective as a barrier; and
    - the seal degradation was assumed to be present at the time of closure.
- Poorly sealed borehole

  - assessed the consequences of a poorly sealed deep borehole that had been used for site investigation of the DGR and monitoring;
  - the borehole was assumed to be located 100 meters from the DGR, consistent with the nearest existing or planned deep borehole;
  - the borehole would provide an enhanced permeability pathway between the repository and the overlying groundwater zones and the surface environment; and
  - assumed that the evolution of the DGR would proceed in the same manner as the Normal Evolution Scenario.

- Transmissive vertical fault
  - assessed the impact of the presence of a transmissive vertical fault that was not detected during prior surveys;
  - the fault would extend from the Precambrian beneath the repository into the permeable Silurian rocks (Guelph and Salina A1) at intermediate depths;
  - the fault was assumed to be located 500 meters to the northwest of the repository (beyond the boundaries of the detailed site investigations for the DGR);
  - an alternative case study provided the same analysis for a fault located 100 meters southeast of the repository;
  - the fault could provide an enhanced permeability pathway that would bypass the low-permeability geosphere; and
  - assumed no sorption of contaminants by minerals in the fault zone.

Likelihood of disruptive scenarios

For each of the Disruptive Scenarios, OPG provided reasons that addressed the highly unlikely occurrence of the scenario that justified their consideration as “what if” cases:

- Inadvertent human intrusion
  - lack of incentive due to absence of commercially viable natural resources at the site;
  - small footprint of the DGR panels (approximately 0.25 km^2); and
  - depth of the repository at 680 meters.

- Severe shaft seal failure
  - quality control measures that would be applied to the DGR shaft seal closure;
  - seals would consist of multiple durable material layers; and
  - shaft seals would be supported by the concrete monolith at their base.

- Poorly sealed borehole
  - deep boreholes would be located at least 100 meters from the repository;
  - boreholes would be properly sealed on completion of site investigation/monitoring activities; and
  - borehole sealing would employ proven engineering practice and quality control.

- Transmissive vertical fault
  - regional lack of interpreted fault structures within 25 km of the site;

- o absence of indicators of faulting in the drilled site characterization/monitoring boreholes;
- o lack of clear evidence of faulting in a 2D seismic reflection survey at the site;
- o absence of features indicating fault movements in the micro-seismic monitoring in the vicinity of the site; and
- o persistence of overpressures and underpressures in the geosphere of the site.

Postclosure Period of Institutional Control

OPG stated that the Inadvertent Human Intrusion scenario was unique among the Disruptive Scenarios because it had the potential to bypass the natural and engineered barriers of the DGR and compromise the isolation and containment of the waste. OPG noted that the timing of the intrusion would significantly affect the potential doses for both humans and non-human biota. OPG explained that human intrusion shortly after decommissioning and closure would result in higher doses since some of the short-lived radioisotopes, such as tritium, would not have had sufficient time to decay.

CNSC Regulatory Guide G-320 states that while institutional controls may be part of the design of a radioactive waste management system as a necessary safety measure or to enhance the confidence in the system, long-term management options should not rely on long term institutional controls as a safety feature unless they are absolutely necessary. It further states that, as a result of the uncertainties associated with future human activities and the evolution and stability of societies, current international practice generally limits the reliance on institutional controls as a safety feature to a few hundred years.

OPG assumed a period of institutional control of up to 300 years for its postclosure safety assessment. OPG anticipated that institutional controls would be put in place as part of a Licence to Abandon the DGR, which would have to be granted by the Canadian Nuclear Safety Commission. OPG expected that the site would remain under municipal or provincial land use controls that would prevent the authorization of deep drilling near the DGR site, and that the site could be recognized in national and international records. In addition, OPG suggested that a durable marker could be placed at the site surface and/or subsurface at closure.

OPG stated that human intrusion by drilling into the DGR was not considered to be credible for a period of 300 years because of societal memory and institutional controls. Consequently, all model calculations of doses for Inadvertent Human Intrusion presented by OPG in the EIS and the Preliminary Safety Report started at 300 years after repository decommissioning and closure. OPG based its choice of institutional control period on the up-to-300-year institutional control period adopted by other countries that either have, or were in the process of developing, deep geologic repositories. In response to an information request by the Panel, OPG provided dose calculations for a highly conservative “what-if” scenario of no institutional control after repository decommissioning and closure, and with inadvertent intrusion by drilling within the first 100 years after closure. OPG estimated that human intrusion earlier than 300 years would result in a maximum dose to the drill crew or a person living on the repository site about 4 mSv higher than for intrusion at 300 years, which would result in a maximum dose of about 1 mSv. The increased dose would be due largely to tritium exposure. OPG noted that the location of the

DGR on the Bruce nuclear site, and its depth 680 metres below surface, would minimize the likelihood of inadvertent intrusion in the near term.

CNSC staff stated that it was satisfied that the information provided by OPG was sufficient for the purpose of the assessment. CNSC staff noted that while institutional controls such as land use zoning would most likely prevent inadvertent intrusion over the near term, it would be difficult to predict how, or even if, these types of controls would exist beyond the next few hundred years. As a matter of precaution, CNSC staff considered the loss of institutional control to be a future event with a high likelihood of occurring in a few hundred years. CNSC staff noted that, even if there were a loss of institutional control, the risk to humans would be acceptably low, given that the probability of human intrusion and its associated dose was low. Natural Resources Canada suggested that consideration should be given to what additional mitigation measures or institutional controls might be put in place to ensure restricted access to the DGR site for the long-term.

Some participants expressed the view that the proposed 300-year duration of institutional control was an arbitrary timeframe. Other participants suggested that it was too short, given the presence of long-lived contaminants. OPG noted that the period of monitoring following DGR closure would be determined in consultation with the community and regulatory authorities many decades from now, and was not necessarily limited to the assumed 300-year timeframe.

The Canadian Environmental Law Association proposed that, upon closure, monitoring well nests should be installed over the sealed shafts and a monitoring period of 1000 years. OPG suggested that such monitoring well nests could compromise the integrity of the sealed shafts.

Panel Conclusion Regarding Postclosure Institutional Control

The Panel concludes that, while there is a degree of uncertainty associated with the timeframe for institutional control, OPG has satisfactorily demonstrated that, under the modelled, unlikely disruptive scenario involving human intrusion into the repository by drilling of an exploration hole, the dose to humans would be well below values that would represent an unacceptable risk to human health. The Panel also agrees with OPG that the location and depth of the DGR would minimize the likelihood of inadvertent intrusion. The Panel notes that OPG followed CNSC guidance in that it did not rely on long-term institutional control for its safety case.

That said, the Panel considers institutional control to be an important topic; as mentioned, there are some uncertainties associated with the timeframe for institutional controls. OPG’s selection of a 300-year period was not necessarily based on scientific or historic evidence but rather on international practice (not experience). In addition, OPG’s confidence in the effectiveness of institutional controls, including future land zoning restrictions, relied on its evaluation of a low potential of the site for hydrocarbon resources. As discussed earlier in this chapter, provincial and federal agencies questioned the robustness of this position in view of the scarcity of local data and the rapid shifts in global energy futures.

The Panel further notes that, in the near-term (within 100 years), the dose to humans in the unlikely intrusion scenario was above the CNSC public dose limit, although the low likelihood produced an acceptable level of risk. As such, the Panel is of the view that it would be prudent for the CNSC and other government agencies to establish means to provide institutional control as far into the future as possible, and that additional considerations for long-term institutional control should be initiated at an early stage in the project. Should the project be approved, an evaluation of a range of institutional control options, perhaps including permanent signage, secure records, or physical surface or sub-surface barriers that would function after institutional controls are no longer effective, would be needed to prepare for the decommissioning and abandonment phases. The Panel notes that OPG would be required to obtain a Licence to Abandon the DGR from the CNSC, and would have to conform to regulatory requirements at that time. The Panel is of the view that the CNSC, along with other government agencies and through international cooperation, should develop requirements for long-term institutional controls for geologic nuclear waste sites.

Recommendation 13.A: The CNSC, in consultation with other government agencies including Natural Resources Canada and the Ontario Ministry of Natural Resources, should evaluate institutional control options to restrict access to the surface and sub-surface of the DGR site. The evaluation should be completed in time to support the decommissioning licensing phase.

Adequacy of Disruptive Scenario Selection

OPG considered other potential disruptive scenarios using the safety function and argument approach, but ruled them out for a number of reasons. Some of the external events that could lead to loss of isolation and containment, such as large earthquakes and glaciation, were already bounded by the selected scenarios. Others, such a tsunamis, meteor hits or volcanic activity, were assigned a very low probability of damaging the repository. OPG also reviewed each external factor, using the assessment context and system description, to determine whether it was possible to have one or more alternative states to the state considered in the Normal Evolution Scenario. This approach led OPG to the same set of Disruptive Scenarios as identified by the safety argument approach. CNSC staff stated that the four Disruptive Scenarios proposed by OPG were sufficient to assess the risk associated with low probability events as they were considered bounding worst-case scenarios.

Some participants, including Northwatch, identified the elevation of gas pressures in the closed repository as a possible disruptive scenario and suggested that it should have been evaluated. In this scenario gas pressures would rise to levels that would lead to the formation and propagation of fractures into the cap rock sequence, which could then provide multiple pathways for contaminant transport into the upper groundwater zone. Consideration of such a scenario leads to an examination of OPG's modelling of gas generation in the DGR after decommissioning and closure.

<u>Gas Generation Modelling</u>

OPG used a Gas Generation Model (GGM) to determine that the main gas to be generated in the closed repository would be methane with some hydrogen and carbon dioxide. OPG conservatively assumed that both corrosion of materials and microbial activity would be active, thus maximizing the amount of gas generation. Normally, waste packages would degrade into a range of species, many of which are solid or liquid, and some of which are gases. For the safety case modelling OPG made the conservative assumptions that all materials would fully degrade into gases. Additional conservative assumptions were:

- the organics in the waste would be fully degraded into carbon dioxide and methane; and
- enough water would be present to completely corrode all the metal.

OPG explained that, subsequent to their generation, the mix of gases within the repository would be dominated by microbial processes. For the Normal Evolution Scenario, OPG examined a number of variant scenarios that provided bounding values.

The low permeability of the host Cobourg Formation would largely confine the gas within the repository. OPG's calculations of gas pressures, using the stated conservative assumptions and variant scenarios, demonstrated that repository gas pressures would equilibrate at approximately seven to nine MegaPascals, which was significantly less than the lithostatic (overburden) pressure of 17 MegaPascals and regional horizontal stresses of 20-30 MegaPascals. OPG noted that the 7 to 9 MegaPascals range would roughly correspond to the natural hydrostatic pressure at the repository level. OPG stated that the magnitude of the confining pressures at the repository level would prevent significant fracturing due to gas pressures, as was discussed earlier in the chapter.

CNSC staff stated that OPG had provided sufficient information and incorporated sufficient conservatism into its models to support the safety case. CNSC staff noted that OPG's predictions of gas generation depended on physical/chemical processes related to the corrosion of metals and the degradation of waste inside containers by microbes. Since there are few examples for validating models of microbial processes, CNSC staff considered the study of gas generation processes to be an important feature of the Geoscientific Verification Plan.

Some participants pointed out a contradiction in OPG's analysis of gas generation in the closed DGR. It was noted that gas generation reactions would require the presence of water, but gas build-up in the DGR would dispel water from the repository. It was not clear to the participants how these opposing effects would balance. The Panel is satisfied that OPG's modelling of numerous gas generation scenarios was sufficiently conservative to bound this apparent contradiction.

Panel Conclusion Regarding the Characterization of the Normal Evolution and Disruptive Scenarios

The Panel concludes that OPG's conceptualization of the Normal Evolution and Disruptive Scenarios for the decommissioned DGR closely followed the guidance provided by CNSC staff and conformed to international practice. The conceptual models were developed using a logical, comprehensive, and transparent methodology. The Panel concludes that the conceptual models include appropriate sets of features, events, and processes which, when considered in their entirety, constitute an adequately precautionary approach to the postclosure assessment. The Panel notes the importance of postclosure institutional control at the site to prevent inadvertent human intrusion. The Panel has made a recommendation regarding the nature and length of postclosure institutional control of the site.

The Panel concurs with OPG and CNSC staff that gas evolution in the closed DGR was modelled using highly conservative assumptions, and that the calculated peak pressures would not reach levels leading to significant fracture generation and propagation in the host rocks or cap rock sequence. The Panel is of the view that refinement of gas generation modelling should play an important role in the Geoscientific Verification Plan in order to reduce uncertainties, particularly with respect to the role and nature of microbial reactions. Since corrosion of metals would add considerably to gas generation, the Panel recognizes the importance of reducing the amount of metal in the DGR, through recycling, to reduce gas pressures in the closed repository, as was described in Chapter 7.

Recommendation 13.5: In order to confirm predictions in the environmental assessment, OPG shall provide additional gas generation modelling for the decommissioned DGR as part of its Geoscientific Verification Plan, which will validate the microbial degradation processes of the waste. OPG shall also augment the Geoscientific Verification Plan to include modelling of gas generation from decommissioning waste to ensure that there will be timely information available for the design and implementation of the mitigation measures associated with reduction of gas generation. These verification activities should be carried out prior to operations, to the satisfaction of the CNSC.

13.3.5 Calculation Cases and Mathematical Models

OPG presented calculation cases and mathematical models to support its long-term safety assessment. This section presents an overview of the use of models in the assessment.

Predictive Capacity of Models

Throughout the review, OPG and CNSC staff stressed that the purpose of scenario identification and modelling was not to predict the future but to develop a sufficiently comprehensive range of possible future evolutions of the DGR against which the system performance could be assessed. OPG noted that the modelling results should be seen as indicative and not predictive; some of the results could be used as performance indicators, such as contaminant amounts and generation rates, and others as safety indicators, such as radiation doses and environmental concentrations. OPG acknowledged that, due to the long time period covered by the postclosure safety assessment, the reliability of quantitative assessments diminished with increasing timescale as the result of growing uncertainties.

Many participants rejected the notion that models could provide meaningful information on the future evolution of the DGR over a timeframe of one million years. They suggested that natural systems were too complicated and dynamic for models to accurately represent future conditions. Some participants noted a 2006 quote by Dr. Allison Macfarlane, a geologist and later chair of the U.S. Nuclear Regulatory Commission, "... geologists know that geologic systems are thermodynamically open systems where all the features, events, and processes are neither knowable nor predictable." Another participant stressed that the reliability of the performance predictions were influenced by the accuracy of the assumptions upon which the models were built.

The Panel notes that the CNSC Regulatory Guide G-320, the EIS Guidelines, and OPG reports and submissions frequently referred to “predictive models” and “predictions”. In the Panel’s opinion, such usage, not qualified by probabilities or uncertainties, led to unfortunate confusion among participants and the public.

Steps in the Modelling Process

Guidance for the development of assessment models was provided in CNSC Regulatory Guide G-320. The EIS Guidelines stressed that models should be consistent with the quality and quantity of data available to characterize the site, waste, exposure pathways, and receptors. OPG was to implement a systematic process that would ensure that the data is accurate and representative.

OPG used a systematic and iterative approach to develop models that would simulate the migration of contaminants from the repository via various pathways. The initial step in the modelling of postclosure processes was the development of a conceptual model for each scenario in the assessment by using input from the assessment context, the system description, and the features, events, or processes lists for the DGR, as shown in Figure 34. CNSC staff noted that the processes governing the migration of contaminants are complex and numerous, and that expert judgment was required to identify the main processes. For each scenario OPG designed the conceptual model to provide a description of the release, migration and eventual receptors of the contaminants. OPG explained that the conceptual models provided the assumptions and simplifications that had to be adopted regarding the geometry and dimensionality of the system, its temporal and spatial boundary conditions and the nature of the relevant physical and chemical processes. OPG then checked the features, events and processes identified for the system against the conceptual model to ensure that important issues had not been neglected.

As a next step, OPG considered the various sources of uncertainty associated with the model, either data uncertainties or uncertainties in the conceptual model. Calculation cases for each scenario were then selected that would allow the bounding of the scenario using conservative assumptions. To quantify the assessment, the OPG translated the conceptual model for each calculation case into mathematical equations that yielded a mathematical model with specific data requirements. The mathematical models and associated data were then implemented in a software tool to generate a computer model. Once the initial results of the computer model were analyzed, they could lead to refinements of the conceptual model and a reiteration of the process.

The endpoints of the modelling calculation cases were:

- radiation doses to humans;
- environmental concentrations of radionuclides and non-radioactive elements and chemical species; and
- concentrations and movements of contaminants at various spatial domains.

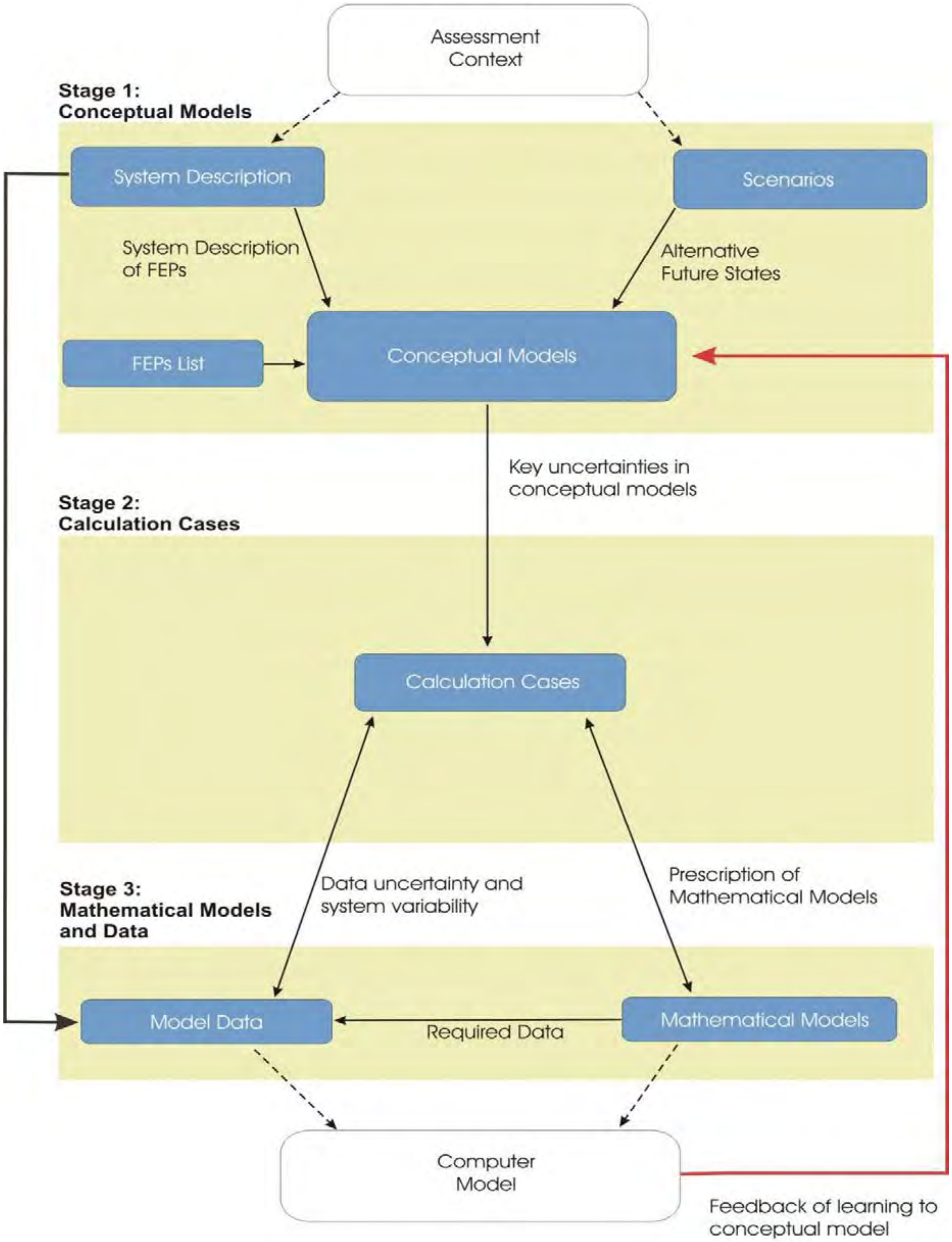


Figure 34: Modelling Approach used for Normal and Disruptive Postclosure Scenarios (reproduced from DGR Postclosure Safety Assessment Figure 6.1)

Addressing Uncertainties

OPG emphasized that the appropriate treatment of uncertainties played a central role in the assessment to provide confidence in the modelling approaches and the credibility of modelling results. OPG noted that uncertainties arose primarily from:

- the very long assessment timeframe of one million years;
- the complexity and diversity of the physical, chemical, and biological processes involved in the repository evolution; and
- the natural variability of properties of the geological, hydrogeological, geomechanical, and biological components of the system.

The uncertainties could be categorized as:

- uncertainties in the evolution of the system (scenario uncertainty);
- the selection of components of the conceptual models (model uncertainty);
- the choice of scenario assumptions (model uncertainty);
- the mathematical formulations and computer models of the assessment model (model uncertainty); and
- the quality of the input parameters and data (data uncertainty).

OPG addressed uncertainties in the safety assessment by:

- using conservative assumptions;
- performing sensitivity analyses; and
- providing bounding assessments.

In its safety assessment OPG used multiple conservative assumptions wherever there were uncertainties in the input parameters for the models or the processes governing the evolution of the DGR system. As an example of the former, in the Normal Evolution Scenario, OPG assessed the potential impact of having 10 times more waste emplaced in the repository than would be present in the current inventory. As an example of the latter, the waste containers would not provide any barrier function to contaminant release in any of the proposed scenarios. The conservative calculations intentionally over-estimated potential future impacts of the scenarios under consideration.

OPG used bounding assessments to provide estimates of the limits of potential impacts (worst-case predictions) and to demonstrate that there would be no unacceptable long-term effects. OPG improved confidence in the prediction of safety by considering scenario cases that used limiting parameter values that lie at the extreme ranges of expected values, for example, maximum thermodynamic solubility limits.

OPG's mathematical approach to analyze the normal and disruptive scenarios relied almost exclusively on deterministic models. Deterministic models use single-valued input data to calculate a single-valued endpoint that can be compared to an acceptance criterion. OPG used sensitivity analysis to investigate the influence of input data variability. In this approach individual deterministic calculations were repeated using a range of credible values (but not a complete coverage) of input parameters. Usually the governing parameters, i.e., those that would most influence the outcome of scenarios, were chosen and varied for the sensitivity analysis.

Panel Conclusion Regarding Model Development and Uncertainty Treatment

The Panel notes that OPG exercised precaution in its model development by acknowledging that the treatment of uncertainties would play a major role in the credibility of model calculations. The Panel concurs with OPG and CNSC staff that the use of conservative assumptions, sensitivity analyses, and bounding scenarios provided credible and acceptable means of reducing uncertainties. The Panel understands that the models presented by OPG were indicators of performance and safety, and not predictions of the future.

In Regulatory Guide G-320, the CNSC noted that either deterministic or probabilistic calculations would be appropriate for the treatment of uncertainties in the assessment. Probabilistic models are typically based on input values sampled from parameter distributions and the calculated results provide the probability that a scenario with particular input data values will actually occur. CNSC staff also stated that the results of sensitivity analyses and probabilistic analyses would not be directly comparable, but that they could be used in a complementary manner to increase confidence in the demonstration of long-term safety. OPG performed limited probabilistic uncertainty analysis of key radionuclides in well water for one of the Normal Evolution Scenario cases (NE-PC). To enhance confidence in the outcomes of the evolutionary models and the long-term safety assessment of the DGR, the Panel recommends that OPG perform additional probabilistic model calculations prior to operations.

Recommendation 13.6: Before a licence to operate the DGR is issued, in order to confirm the predictions in the EIS and Postclosure Safety Assessment regarding the ability of the DGR to perform in a manner that will protect human health and the environment, OPG shall perform probabilistic calculations for radiation exposures to humans and non-human biota for the Normal Evolution and Disruptive Scenarios, to the satisfaction of the CNSC. These calculations should supplement the deterministic calculations in the current long-term safety case assessment in order to increase confidence.

13.3.6 System Performance and Robustness

This section describes the model acceptance criteria and results.

Acceptance Criteria

CNSC staff stipulated that the determination of compliance of the results of assessment model calculations with regulatory requirements required their evaluation against limits imposed by the *Nuclear Safety and Control Act* and its associated regulations, as well as other applicable legislation. As stated in the EIS Guidelines, the acceptance criteria for a long-term assessment are current regulatory limits, standards, objectives and benchmarks. OPG, in consultation with CNSC staff, provided acceptance criteria for:

- the radiation exposure of humans that may arise from the Normal Evolution Scenario;
- the radiation exposure of humans that may arise from low-probability Disruptive Scenarios;
- the radiation effects on non-human biota of Normal Evolution and Disruptive Scenarios; and
- the effects of non-radioactive contaminants on both humans and biota.

OPG stated that the acceptance criteria adopted for public radiological exposures arising from the Normal Evolution Scenario were:

- a dose constraint of 0.3 mSv/yr to the critical group, i.e., the group of people representative of those individuals in the population that are expected to receive the highest annual radiological dose;
- doses to be calculated for an average adult member of the critical group;
- the assessment to encompasses the time of maximum calculated impact; and
- the dose be optimized by ensuring that it would more than meet the regulatory limits.

OPG explained that these dose constraints were approximately an order of magnitude below the annual Canadian individual dose received from natural background radiation. In addition, exposure levels for the critical group would be below the regulatory public dose limit of 1 mSv/yr. CNSC staff stated that it based its approval of the criteria on Regulatory Guide G-320, the 2007 Recommendations of the International Commission on Radiological Protection and IAEA Geological Disposal of Radioactive Waste, Safety Requirements No. WS-R-4.

For Disruptive Scenarios, OPG imposed a different set of radiological criteria, in response to the speculative nature of some of the scenarios, which were:

- a dose criterion of 1 mSv per year for credible scenarios (the current public dose limit for CNSC licensed facilities); and
- any scenario with calculated doses exceeding 1 mSv per year to be examined on a case-by-case basis taking into account the likelihood and nature of the exposure, uncertainty in the assessment, and conservatism in the dose criterion.

OPG explained that, where the probability of exposure could be quantified without excessive uncertainty, a measure of risk was calculated based on the probability of exposure and the health effects if the exposure occurred. As a general guide, OPG compared the probability with a reference health risk value of 10^{-5}/yr. The reference health risk value of 1 in 100,000 is provided in guidance from the International Atomic Energy Agency. The reference health risk represents 1 additional serious health outcome (e.g., cancer) in 100,000.

The radiological acceptance criteria for non-human biota adopted by OPG, and accepted by the CNSC, were based on dose benchmarks developed in relation to discharge of radionuclides from nuclear facilities. OPG provided No Effects Concentrations for various media, including groundwater, soil, surface water, and sediment, which defined the highest permissible concentration in each medium for all indicator species. OPG stated that exceedance of a No Effects Concentration under the Normal Evolution Scenario would trigger an Ecological Risk Assessment. Under the Disruptive Scenarios, acceptability would be judged on a case-by-case basis taking into account the likelihood and nature of the exposure, uncertainty in the assessment, and conservatism in the dose criterion.

For non-radioactive contaminants, OPG's criteria were based on federal (Canadian Council of Ministers for the Environment - CCME) and provincial (Ontario Ministry of the Environment and Climate Change) guideline concentrations for groundwater, surface water, soil and sediment. In each case, OPG used the most conservative concentrations from these sources. OPG stated that, if any concentrations exceed these criteria under the Normal Evolution Scenario, they were assessed further in a tiered approach with decreased conservatism in models. For Disruptive Scenarios, the acceptability was judged using the same methodology employed for radiological contaminants. CNSC staff stated that, provided the results of the assessment model calculations met the above acceptance criteria, CNSC staff considered the associated risk to be acceptable.

Panel Conclusion Regarding Acceptance Criteria

The Panel concludes that the acceptance criteria for radiation doses to humans used by OPG are appropriate and reflect the dose limits established by the Canadian Nuclear Safety Commission. The Panel notes that the CNSC dose limits reflect the recommendations of the International Commission on Radiological Protection. As discussed in Chapter 9, the Panel is aware that some participants were of the view that the CNSC dose limits are not sufficient. However, the Panel is satisfied with the level of protection afforded by the dose limits, and notes that the dose limits were used in combination with the acceptable likelihood of effects of 1 in 100,000 (for the Disruptive Scenarios).

The Panel concludes that the acceptance criteria for radiation doses to non-human biota are sufficiently conservative to ensure protection of these biota. The Panel notes that the criteria were derived using no effect values for relevant indicator species and, as such, incorporate an appropriate level of conservatism.

The Panel concludes that the acceptance criteria for non-radiological exposure represented current regulatory guidance and associated conservatism to ensure protection of human health and non-human biota.

Key Results for the Normal Evolution Scenario

OPG's principal evaluation of the Normal Evolution Scenario was presented in the Normal Evolution Scenario Reference Case which encompassed the site characteristics, repository design and evolution in the most detail. The Reference Case included factors and processes such as:

- overpressure in the Cambrian sandstone below the DGR;
- measured underpressures and partial gas saturations in the host Ordovician formations;
- gas generation and build up within the repository; and
- groundwater and gas flow through repository, host rock and shaft seals.

OPG stated that all modelling cases of the Normal Evolution Scenario shared a number of common conservative assumptions including:

- the waste containers would play no role in waste retention;
- the amount of emplaced waste would be 10 times the anticipated inventory;

- solubility limits and sorption were neglected or conservative values were assumed;
- microbial reactions would occur as long as moisture was present; and
- waste organics would degrade fully to gas.

OPG also investigated a set of additional variant scenario cases of the Normal Evolution Scenario in which the assumptions and parameters of the Reference Case were altered to more conservative conditions to cover uncertainties not addressed in the reference evolution. OPG explained that an alternative Normal Evolution Scenario Simplified Base Case received special attention and differed from the Reference Case by:

- assuming that the underpressure in the host formation was of recent origin and dissipated relatively quickly; and
- stipulating a steady hydraulic gradient vertically upwards.

OPG noted that this case was further investigated using a substantial number of variant scenario cases. Endpoints of all the calculation cases provided maximum calculated effective dosages for humans and biota located at and around the DGR site. According to OPG, the key results of the modelling included:

- less than 0.1% of the initial waste activity would be released into the geosphere around the repository, and much less would be released into the shafts;
- gases would be largely contained within the repository and geosphere and the dominant gas would be methane;
- concentrations in the shafts would be low because contaminant transport would be dominated by diffusion;
- the low-permeability geosphere and shaft would attenuate the release of contaminants, providing time for radioactive decay to decrease the radioactivity in the repository;
- the pathway for contaminants into Lake Huron would be advective transport in the Shallow Bedrock Groundwater Zone and groundwater discharge into the bottom of the lake;
- full saturation of the closed repository would take more than one million years due to the low permeability of the host rock and gas pressures in the repository; and
- for all calculated cases the maximum effective dose for receptors would be more than five orders of magnitude below the 0.3 mSv/yr public dose criterion.

Calculated Doses for Humans

OPG chose a highly conservative set of conditions in its evaluation of potential human receptor doses for the Normal Evolution Scenario. The critical receptor group were the occupants of a hypothetical family farm living on the site. The group was assumed to be self-sufficient and to use groundwater from a well for drinking, domestic water usage, and irrigation. The well would be drilled into the Shallow Bedrock Groundwater Zone at a location that maximized capture of any contaminants released from the shafts.

OPG determined that predicted doses from the Normal Evolution Scenario and all conservative variant scenarios would be 100,000 times lower than the public dose limit of 1 mSv per year and the acceptance dose criterion of 0.3 mSv per year (Figure 35). Moreover, the maximum dose would not be realized for more than a million years and the potential dose would decrease rapidly with distance from the site. For comparison, the maximum calculated doses were approximately six orders of magnitude below the annual Canadian individual dose received from natural background radiation, as shown in Figure 35.OPG also considered the doses to human receptors who maximize their use of the Lake Huron with a high fish diet. The calculated maximum dose for this group would be more than two orders of magnitude lower than the "site resident" critical group.

CNSC staff stated that these results constituted an acceptable level of risk. CNSC staff explained that such minute doses would not result in adverse health effects for a timespan of one million years, even for humans residing immediately over the site. The dose due to the repository would only add an insignificant amount to the natural background radiation received by everyone residing above or near the repository.

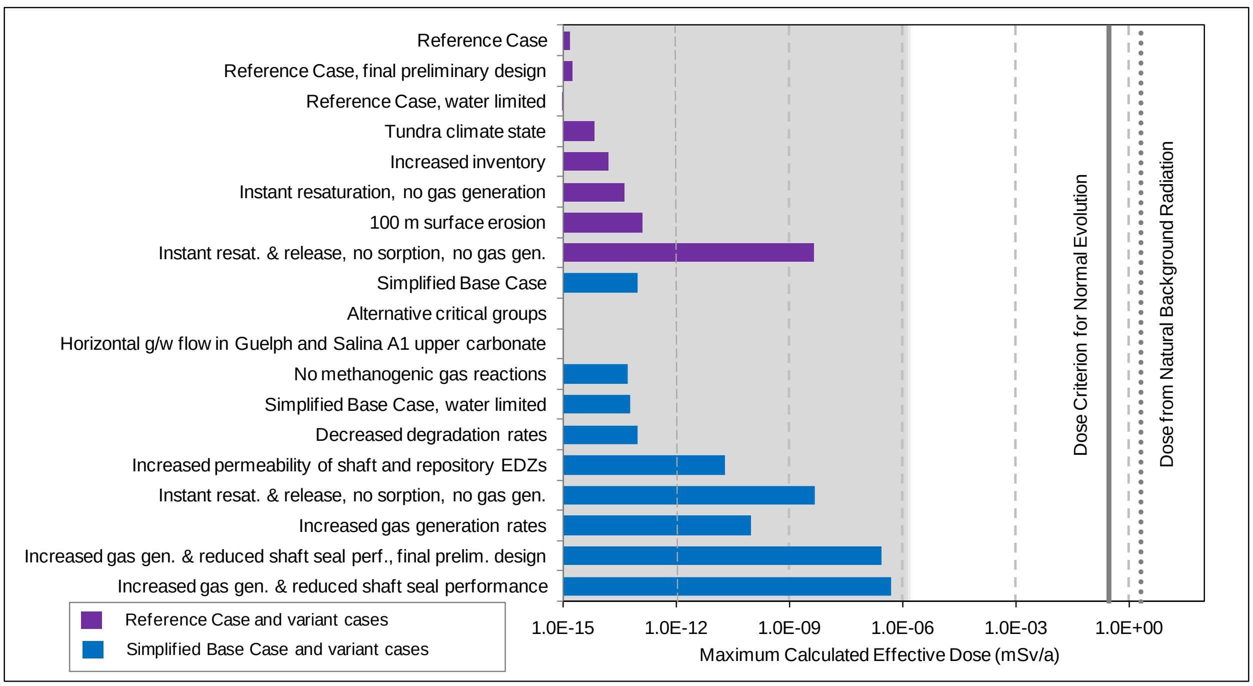


Figure 35: Normal Evolution Scenario: Maximum Calculated Doses for all Calculation Cases (reproduced from the DGR Postclosure Safety Assessment Figure E1)

Calculated Doses for Plants and Animals

For non-human biota, OPG assessed only the main calculation cases, i.e., the Normal Evolution Reference Case Scenario and the Normal Evolution Simplified Base Case Scenario. OPG determined that the maximum calculated radionuclide concentrations added to the selected media of the biosphere by the presence of the repository, i.e., well water, soil, surface water, and sediment, would be more than ten orders of magnitude lower than the no effects concentrations specified in the acceptance criteria, as shown in Table 6.

Table 6: Summary of Maximum Calculated Biosphere Concentrations (information reproduced from DGR Postclosure Safety Assessment Table 7.10)

Calculation Case	Well Water (Bq/L)	Soil (Bq/kg)	Surface Water (Bq/L)	Sediment (Bq/kg)
NE-RC: Reference Case	6×10^{-15}	5×10^{-15}	1×10^{-17}	1×10^{-14}
NE-SBC: Simplified Base Case	3×10^{-12}	4×10^{-12}	6×10^{-15}	3×10^{-13}

CNSC staff stated that OPG's approach for assessing the effects of ambient radioactivity to non-human biota was acceptable. CNSC staff agreed with OPG that there would be negligible effects on non-human biota during the normal evolution of the project.

OPG stated that, for non-radioactive contaminants such as zirconium, niobium, cadmium and lead, the added concentrations in these media would be more than five orders of magnitude lower than the environmental quality standards in the acceptance criteria, as shown in Table 6.

For comparison, OPG noted that naturally-occurring potassium-40 levels in lake sediments from the Regional Study Area reach about 250 Bq/kg, and that surface waters have provincial background concentrations ranging from 0.02 to 0.19 Bq/L gross-beta.

Effects on Lake Huron

OPG considered a variant case in which horizontal groundwater flow in the Guelph and Salina A1 upper carbonate (Intermediate Bedrock Groundwater Zone) could lead to advective transport of contaminants and the discharge of contaminated groundwater into the nearshore lake bed of Lake Huron. Contaminants from the shaft release could also enter the upper carbonate aquifer of the Shallow Bedrock Groundwater Zone, at 144 m below ground surface, and travel in a northwest direction for 1.25 km towards Lake Huron. OPG noted that, on entering either of these horizontal transmissive groundwater zones, the contaminants would be subject to hydrologic dispersion resulting in a dilution of their concentrations. OPG stated that the maximum rate of transfer to the lake was calculated to be very low (3×10^{-6} Bq/yr) for the Normal Evolution Reference case.

Uncertainties

The CNSC Regulatory Guide G-320 directed OPG to undertake a formal uncertainty analysis of evolutionary scenarios and to identify the sources of uncertainty. OPG addressed the uncertainties associated with the Normal Evolution Scenario by investigating a comprehensive selection of additional calculation cases that incorporated highly conservative assumptions to bound the scenarios. Notable examples of highly conservative assumptions used in the scenario cases were:

- instantaneous release of all radionuclides and non-radioactive contaminants upon repository closure;
- no solubility limits for all radionuclides and non-radioactive contaminants;

- no sorption of any radionuclides and non-radioactive contaminants by minerals and rocks that may come into contact with the contaminants;
- instantaneous resaturation of the repository (complete filling of the repository with groundwater);
- higher than expected gas generation amounts and rates;
- degraded shaft seal performance occurring immediately upon repository closure; and
- presence of higher permeability shaft excavation damaged zone conditions.

OPG stated that, in all cases the maximum calculated effective doses remained 100,000 times lower than the public dose limit of 1 mSv per year and the acceptance dose criterion of 0.3 mSv per year.

Panel Conclusion Regarding Doses to Humans and Non-human Biota During Normal Evolution

The Panel concludes that OPG adequately assessed the Normal Evolution Scenario. In the Panel's view most of the conservative assumptions for the normal evolution of the repository have very low probability of occurrence, and in some cases they may be physically and chemically impossible, such as the instantaneous release of all contaminants. The Normal Evolution Scenario is well bounded by conservative variant scenarios and provides the Panel with a strong sense of confidence that the waste would be isolated and contained in the repository for a period of one million years with minimal releases into the biosphere.

Modelled maximum receptor doses for all conservative variant scenarios were 100,000 times lower than the public dose limit of 1 mSv per year and the acceptance dose criterion of 0.3 mSv per year. The magnitude of the difference between public dose limits and the maximum modelled values assures the Panel that any existing uncertainties would not fundamentally alter the conclusion that both humans and the biosphere would be fully protected.

Key Results for Disruptive Scenarios

The Disruptive Scenarios present repository failure modes that have low probabilities, but that cannot be entirely ruled out. For each of the Disruptive Scenarios, OPG performed a base case reference calculation that was supplemented by variant calculations which incorporated modified parameters and assumptions. OPG determined that the primary risks in the Disruptive Scenarios would arise from the release of bulk gas containing carbon-14 from the repository. The potential impacts would therefore decrease to well below the dose criterion after about 60,000 years due to the decay of carbon-14.

According to OPG, the key results for the Disruptive Scenarios were:

- Inadvertent Human Intrusion Scenario
    - with saturation of the repository at less than 1% (Base Case), liquid would not be released via an intruding borehole;
    - with repository gas pressures in the repository higher than atmospheric pressure throughout the assessment period, gas would be released through the borehole;

- key contaminants of intrusion into Panel 1 (with highest radionuclide concentration) would be carbon-14, nickel-59, niobium- 93m, niobium-94 and zirconium-93;
- the important radionuclides in the released gases would be carbon-14 and radon-222; and
- concentrations of carbon-14 in the released gases would peak after 3000 years, while the decrease of radon-222 for the initial 10,000 years would reverse due to the decay of uranium-238 and uranium-234.

* Severe Shaft Seal Failure Scenario
    - the degraded shaft seals would permit more rapid water inflow into the repository (increasing repository saturation and gas generation);
    - gas generation and reduced shaft seal functionality would allow gas pressure to open a pathway and venting of repository gas up the shafts;
    - in the Base Case scenario the gas pathway would be established after about 20,000 years;
    - about 5% of the gas flux would be dissolved in the shallow groundwater and concentrations of carbon-14 in well water would peak at about 3 Bq/L after about 23,000 years;
    - most of the gas would reach the biosphere as a free gas;
    - the air in a house located directly above the main shaft would receive a peak radionuclide concentration of about 16,000 Bq/m^3 after about 23,000 years.

* Poorly Sealed Borehole Scenario
    - assumed instantaneous resaturation of the repository at closure which maximizes the release of contaminants to groundwater;
    - the borehole would have limited influence on the hydraulic conditions at the repository horizon;
    - horizontal flow rates into the borehole would be comparable to diffusion rates of the host rocks;
    - flow of water up the poorly sealed borehole would be up to 15 m^3/yr; and
    - the key transport pathway of contaminants would be diffusion from the repository to the borehole, followed by movement up the borehole and dispersion in the permeable upper groundwater zone.

* Vertical Fault Scenario
    - the faults would have only minor impacts on the hydraulic conditions in the repository;
    - since the fault would penetrate into the overpressured Cambrian, groundwater flow would be directed away from the fault and contaminants from the DGR would have to diffuse against this gradient;
    - to be transmitted up the fault to the Guelph Formation, contaminants would have to diffuse downwards to the Cambrian and then via groundwater flow to and up the fault;
    - closer proximity of the fault to the DGR would have relatively little impact on peak calculated doses; and

- o radionuclide transfer rates to the Guelph Formation would peak at about 3 MBq/yr after more than a million years.

As previously discussed, for the Inadvertent Human Intrusion Scenarios base case, OPG assumed that the site would remain under institutional control for a period of 300 years after decommissioning, and that human intrusion during that period would not be likely. OPG calculated maximum doses for the period starting at 300 years after decommissioning. In addition to the base case, OPG also modelled a conservative variant case that assumed immediate intrusion after decommissioning. OPG considered the scenario of inadvertent deep drilling into the repository within 100 years of closure to not be credible. Implicit in this assumption was OPG's determination that the natural resource potential of the DGR site was low. The validity of this assumption was discussed in detail earlier in this chapter.

Calculated Doses for Humans

For each Disruptive Scenario, OPG selected specific groups of people that could be exposed to the radioactive and/or non-radioactive contaminants that would enter the biosphere. Estimated dose exposures for each case are shown in Figure 36.

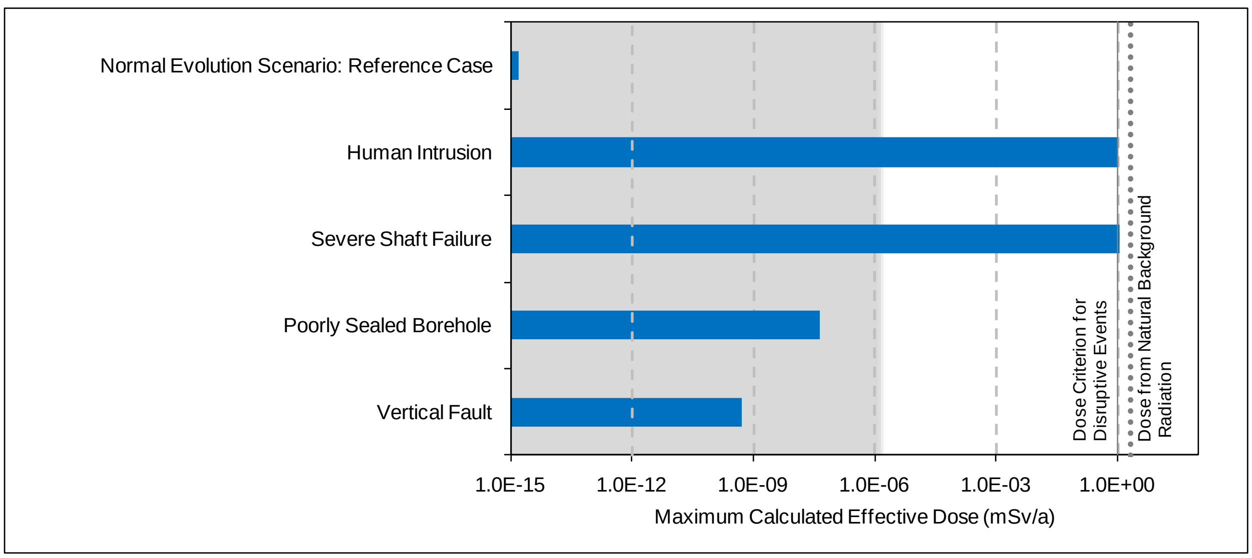


Figure 36: Summary of Maximum Calculated Doses for all Disruptive Evolution Scenarios (reproduced from DGR Postclosure Safety Assessment Figure E2)

<u>Doses: Inadvertent Human Intrusion Scenario</u>

OPG noted that for the base case, exposures to radionuclides could arise from the handling and exposure of drill cores and the venting of gases via the borehole. A less probable scenario involved the penetration of a borehole through the repository into the overpressured Cambrian Formation, which was not properly sealed. In this case contaminants could be released from the repository through the borehole.

OPG estimated that:

- the doses received by the drill crew would peak at about 1 mSv due mainly to exposure to niobium-94 in the drill core debris;
- the dose to a nearby resident, i.e., within 100 m of the drill site, would peak at about 0.1 mSv/yr due to inhalation of carbon-14 released from the borehole; and
- the dose to a future site resident exposed to soil contaminated with the extracted core would be dominated by external irradiation from niobium-94 and would peak at about 1 mSv/yr.

OPG noted that the peak dose would be higher for inadvertent intrusion within the first 100 years due to the potential for release of tritium, which would not have fully decayed. OPG stated that the peak dose to the drill crew or a person living on the repository site from such an early intrusion would be about 4 mSv/yr higher than for intrusion at 300 years. OPG noted that the potential dose impacts would decrease over long times, and the impacts of inadvertent human intrusion would fall below the dose criterion after about 10,000 years.

OPG used average exploratory deep borehole drilling rates and the area of one of the repository panels to estimate a probability of human intrusion of 10^{-5}/yr (1 in 100,000).

Based on a probability of 10^{-5}/yr, a peak dose of 1 mSv and a health risk of 0.057/Sv, adopted from the International Commission on Radiological Protection, OPG derived an associated risk of around 6×10^{-10} (6 in 10 billion) serious health effects, such as cancer, per year, which was well below the reference health risk value of 10^{-5}/yr.

OPG also evaluated a scenario involving penetration of the borehole into the Cambrian and poor sealing of the borehole, and determined that the peak calculated dose to an adult site resident would be around 30 mSv/yr for intrusion in 400 years. The dose would be dominated by exposure to carbon-14 through the use of well water for crop irrigation. Using the intrusion probability of 10^{-5}/yr, the peak dose would equate to a risk of around 2×10^{-8} (2 in 100 million) serious health effects per year, which is more than two orders of magnitude below the reference health risk value of 10^{-5}/yr.

<u>Doses: Severe Shaft Seal Failure Scenario</u>

OPG stated that for the Severe Shaft Seal Failure scenario, site residents living in a self-sufficient farm building located directly above the main shaft would be the most severely affected group. The dominant exposure pathways would be inhalation within the house and ingestion of plant produce, each of which would contribute about 40% of the calculated peak dose. The dominant radionuclide would be carbon-14, which would contribute about 75% of the peak calculated dose. The calculated dose to the site resident would reach a maximum of around 1.3 mSv/yr after about 23,000 years when bulk gas dominated by methane would reach the shallow groundwater system. OPG assigned a scenario likelihood of around 10^{-1} or less per year for the base case, which would result in the risk of serious health effects that would be less than the reference health risk value of 10^{-5}/yr.

For the degradation Shaft Seal Failure case (SF-ED), OPG assumed that the shaft seals had the permeability of sand/silt. In this case, an adult site resident living above the repository would receive a calculated dose that could reach about 80 mSv/yr after around 3,800 years. OPG emphasized that this calculation case was extremely conservative and was undertaken with the purpose of investigating the sensitivity of dose impacts to shaft seal properties.

Doses: Poorly Sealed Borehole Scenario

OPG stated that contaminant transfer from the repository to the borehole would be delayed by nearly 100,000 years due to the very slow diffusion of the contaminants from the repository to the borehole. Consequently, some of the shorter half-life radioisotopes would have undergone a significant amount of decay and doses would be dominated by long-lived zirconium-93 and nickel-59. OPG stated that adult residents living directly above the repository and consuming water from a 80-metre deep well in the shallow groundwater zone would receive calculated maximum doses at 4×10^{-8} mSv/yr after about 900,000 years which would be many magnitudes lower than the public dose limit of 1 mSv per year and the acceptance dose criterion of 0.3 mSv per year.

Doses: Transmissive Vertical Fault

OPG stated that the peak calculated dose to nearshore residents close to Lake Huron, the most exposed group, would be 3×10^{-10} mSv/yr. Consumption of water from the Guelph Formation obtained directly at the site of the fault would result in a dose of around 0.3 mSv/yr. However, OPG pointed out that the total dissolved solids concentration in the Guelph Formation groundwater is 13 times higher than seawater and would not be suitable for human consumption.

Calculated Doses for Plants and Animals

Concentrations: Inadvertent Human Intrusion Scenario

OPG noted that if contaminated drill core material were left on the site and mixed with the soil, the screening criteria for non-human biota for carbon-14 and niobium-94 would be exceeded by a factor of about 20. All other radionuclides would be below their criteria by a factor of at least 7. OPG considered the risks of such an occurrence to be low since leaving drilling debris on site is in contravention of current regulations and because any exposure would be localized.

Concentrations: Severe Shaft Seal Failure Scenario

OPG determined that, in this scenario, gases containing peak releases of carbon-14 would reach the groundwater in the shallow groundwater zone and directly enter the biosphere after about 23,000 years. For the Base Case, OPG determined that:

- peak calculated concentrations for carbon-14 in soils and sediments would remain below the no effects concentrations for protection of non-human biota;
- peak calculated carbon-14 concentration in local surface water (in a local stream) of 0.3 Bq/L would be a factor of 1.4 above the associated screening no effects concentrations for the protection of non-human biota. Due to the decay of carbon-14, these consequences would only apply if the shaft seal failure occurred within about 50,000 years after DGR closure;
- calculated biosphere concentrations for all other radionuclides would be more than seven orders of magnitude below their associated criteria; and

- there would be only a negligible release of non-radioactive contaminants via the groundwater pathway, and all calculated values would be many orders of magnitude below the environmental quality standards.

Concentrations: Poorly Sealed Borehole Scenario

OPG stated that, under this scenario, its calculations showed that radionuclide concentrations for biosphere media would be more than seven orders of magnitude lower than no effects concentrations for non-human biota. For non-radioactive contaminants concentrations would be more than three orders of magnitude smaller than associated environmental quality standards

Concentrations: Transmissive Vertical Fault

In this scenario, OPG assumed that horizontal groundwater flow in the Guelph and Salina A1 formations would discharge into the nearshore of Lake Huron. OPG noted that because the discharge point location was not well known, it was conservatively chosen to be about 1 km from the shore, though it was likely to be significantly further. The calculated concentrations were at least seven orders of magnitude smaller than the no effects concentrations for non-human biota. Concentrations of non-radioactive contaminants would remain at least four orders of magnitude below associated environmental quality standards.

Effects on Lake Huron

For all Disruptive Scenarios OPG considered contaminant pathways that would lead to discharges into the nearshore environment of Lake Huron. OPG's calculations showed that contaminants could be released into the Guelph and the Salina A1 upper carbonate formations, which are more permeable than the surrounding geosphere. An additional pathway would be the Shallow Bedrock Groundwater Zone. Horizontal flow along these permeable layers could carry contaminants into the nearshore lake environment over a distance of approximately one kilometre. OPG noted that the contaminants would show the highest concentrations in the shore region of the lake close to the site.

For the Severe Shaft Seal Scenario, OPG stated that since the predominant radiological contaminant release would be of gas, there would be essentially no transfer of radionuclides into groundwater of the shallow groundwater system or to the lake. For the Human Intrusion Scenario, OPG determined that the groundwater pathways to the lake would only be active if the borehole penetrated into the overpressured Cambrian Formation. No calculations of the timing, concentrations, or amounts of contaminants that would reach the lake shore were provided for this scenario.

For the Vertical Fault scenario, OPG stated that peak calculated concentrations in contaminated groundwater from the Guelph Formation at the point of discharge into the lake would be very small, at 3×10^{-4} Bq/m^3 after one million years. The dominant radioisotopes would be zirconium-93 and its daughter product niobium-93m. OPG noted that the relatively low contaminant releases to the Guelph Formation, together with dispersion within the lake, would yield calculated concentrations much smaller than the no effect concentrations for non-human biota.

Uncertainties

CNSC Regulatory Guide G-320 directed OPG to undertake a formal uncertainty analysis of evolutionary scenarios and to identify the sources of uncertainty. OPG addressed the model and data uncertainties for each of the disruptive scenarios through the evaluation of a comprehensive set of calculation cases that were designed to bound the effects of these uncertainties. OPG provided a list of the uncertainties that were considered:

- repository resaturation;
- waste inventory;
- contaminant release rates;
- gas generation;
- geosphere gas properties;
- geosphere transport properties;
- shaft seal performance;
- geosphere over- and underpressures;
- geosphere horizontal flow;
- critical groups; and
- glaciation.

Assessment of Results of Disruptive Scenarios

CNSC staff stated that the four Disruptive Scenarios assessed by OPG were sufficient to bound worst-case scenarios and represented acceptable risk. The CNSC staff written submissions did not include a detailed explanation of its evaluation of the results of two of the Disruptive Scenarios (Human Intrusion and Severe Shaft Failure) where the predicted doses to the public exceeded 1 mSv per year. The maximum calculated dose from the human intrusion with shallow groundwater release case was 30 mSv/yr. The maximum calculated doses from severe shaft failure were 1.1 mSv/yr (base case) and 80 mSv/yr (extreme degradation). CNSC staff described these results as being similar to the natural background radiation dose rate and as “around” the dose criterion of 1 mSv/yr (2013 submission) or “at or below” the dose criterion (2014 submission). CNSC staff explained that for the Disruptive Scenarios, calculated doses were judged against the dose criterion of 1 mSv/yr or the human health risk criterion of 1 in 100,000 per year.

CNSC staff did not comment on OPG’s rationale in support of its extremely low estimates of the risk of serious health effects from both human intrusion and severe shaft failure. OPG assumed that human intrusion had a 1 in 100,000 chance of occurring per year. This low likelihood, combined with an assumed health risk of 0.057/Sv (adopted from the International Commission on Radiological Protection) produced a risk of serious health effects for a future resident of about 6 in 10 billion, well below the reference health risk of 1 in 100,000 per year. Even with a likelihood of severe shaft failure of 1 in 10 per year, the risk of serious health effects would be less than the required 1 in 100,000. According to OPG, the actual likelihood of severe shaft failure could “reasonably be considered” to be much lower than 1 in 10.

Panel Conclusion Regarding Disruptive Scenarios

The Panel concludes that the Precautionary Principle was satisfactorily applied to Disruptive Scenarios for humans and non-human biota. The Panel concludes that OPG adequately assessed Disruptive Scenarios, and is satisfied that the results are well below either the public dose criterion or the human health risk criterion. The Panel agrees with OPG that the likelihood of the human intrusion and severe shaft failure scenarios is very low and, therefore, the risk of serious health effects for a future resident living immediately above the DGR would be acceptable. The Panel also agrees with OPG that the risks to non-human biota from Disruptive Scenarios are extremely low.

The Panel is of the view that OPG should provide, for all variant cases of the Disruptive Scenarios, clear and accessible evaluations of the amounts and activities of discharges into Lake Huron via the Shallow and Intermediate Groundwater Systems, including groundwater pathways to the lake which would be active if a borehole penetrated into the overpressured Cambrian Formation. The Panel's recommendation is based upon the need for plain language explanations, as well as the importance of being able to find information regarding the potential for effects on Lake Huron in one place. As such, it makes the following recommendation.

Recommendation 13.7: In order to confirm the predictions in the environmental assessment regarding potential long-term effects of Disruptive Scenarios on Lake Huron, OPG's future modelling for all variant cases of the Disruptive Scenarios shall provide clear and accessible evaluations of the amounts and activities of discharges into Lake Huron via the shallow and intermediate groundwater systems, to the satisfaction of the CNSC.

Modelling Implications on DGR Design

OPG's postclosure safety assessment was based on the original and final preliminary design of the DGR. OPG noted that, as a result of the model calculations, new insights were gained and some changes were incorporated in the design of DGR, including:

- backfilling of the repository would not add significantly to the containment of the DGR, but would result in a higher gas pressure within the repository after closure;
- increased separation of the emplacement rooms from the shafts;
- the importance of the shaft seal in limiting the movement of contaminants in groundwater and gas from the repository;
- role of the excavation damaged zone around the concrete monolith as a key pathway of groundwater and gas to the shafts; and
- possibility of the horizontal diversion of some contaminants migrating up the shafts into higher permeability Silurian formations.

Model Calibration, Verification and Validation

OPG stressed that all the computational models used in the postclosure safety assessment were rigorously calibrated and verified. Calibration was achieved by setting adjustable parameters within the mathematical equations to minimize the differences between the calculated and measured responses of the system. Verification, the process of confirming the proper functioning of computer codes with respect to the conceptual model or mathematical model, was implemented using several different approaches. Confidence was provided, for example, through participation in international co-operative projects in which the same problems were solved using different computer codes and the results compared to establish that equivalent results were obtained.

When a model has been validated, its accuracy has been checked against the performance of the real system. The outcomes of a validated model can be treated as predictions. OPG noted that it was not possible to make predictions for one million years, making validation impossible. Instead models can be used to give bounds to estimates of what impacts would be in the very long term. The CNSC Regulatory Guide G-320 states that, in the context of radioactive waste management, validation is the process of building confidence that a model adequately represents a real system for a specific purpose.

CNSC staff stated that conservative assumptions, alternate models, site specific data, sensitivity analysis, verification/validation and quality assurance/quality control procedures were applied to the OPG safety assessment, providing confidence that the calculated doses were likely to have been over-predicted in most cases. CNSC staff confirmed that the Precautionary Principle had been satisfactorily applied by OPG. Both the Normal Evolution and Disruptive Scenario safety assessments were described by CNSC as being conservative. CNSC staff noted that all maximum calculated doses for the Normal Evolution Scenario were at least 100,000 times below the public dose limit of 1 mSv per year.

Panel Conclusion Regarding Postclosure Safety Case Modelling

The Panel agrees with CNSC staff that the modelling approaches employed by OPG, and their conclusions, were systematic and supported by conservative assumptions, sensitivity analyses, and bounding scenarios that provided confidence that foreseeable contingencies in the future evolution of the DGR have been adequately assessed. The Panel differs from CNSC staff in its assessment of the level of clarity that OPG provided about the application of the Precautionary Principle in the postclosure safety case. The Panel has provided a recommendation that asks for more clarity in future iterations of the assessment. The Panel notes that modelled effects on Lake Huron, for both radiological and non-radiological contaminants for all scenarios, were not always provided in an accessible manner. In view of the broad concern by the public of the possible effects of the DGR on the water quality of the lake, the Panel has provided a recommendation regarding the provision of clear, lay language information regarding how the migration of contaminants to Lake Huron was estimated for all disruptive scenarios and the level of precaution used in that estimation.

The Panel concludes that confidence building in the computer simulation models for the DGR can be and should be enhanced by systematic and diligent data acquisition during the construction and operational phases of the project. The means to achieve this hinges on the rigorous and successful application of the Geoscientific Verification Plan and a proactive adaptive management system.

CNSC Evaluation of the Postclosure Safety Assessment

CNSC staff stated that the postclosure long-term safety case for the project was adequately assessed for normal evolution and disruptive scenarios, and that OPG had presented credible arguments for the safety case. CNSC staff noted that conservative assumptions, alternate models, sensitivity analysis, verification/validation, and quality assurance and quality control procedures were applied in the safety assessment, providing confidence that the calculated impacts were likely to have been over-predicted for most cases.

CNSC staff was satisfied that the proposed Geoscientific Verification Plan would reduce uncertainties and verify the long-term safety case. CNSC staff expected verification activities to continue through the site preparation, construction, operational and decommissioning phases of the project to ensure that doses to the public and the environment would remain as low as achievable.

At the hearing CNSC staff identified three conditions that, if not met, would have a major impact on the postclosure safety case:

- low permeability of host and cap rock;
- absence of major fractures; and
- absence of economically viable resources.

CNSC staff noted that data to confirm that the above three conditions are met would be an essential part of the Geoscientific Verification Plan; however, the data alone would be insufficient. The interpretation of the data would be done with the aid of criteria, also called action levels or thresholds, developed to indicate when measured conditions differ sufficiently from expected that action must be taken. CNSC staff outlined the process that it would use with respect to significant deviation from expected conditions. OPG would be required to report these deviations to CNSC staff. If the deviations exceeded a pre-determined action level, and those deviations were for conditions essential to the safety case, a re-assessment of the OPG safety case would be triggered. The re-assessment could include additional in-design mitigation and re-modelling of the repository performance. If the safety case was reaffirmed via design changes, there would likely be a requirement for an amendment to the licence or changes to the design that would trigger a regulatory process.

The Panel sought a more clearly defined set of criteria that CNSC staff would use to identify when data from OPG's geoscience verification program reached or exceeded action levels. CNSC explained that criteria and action levels would be developed as part of the detailed design process. The Panel expects that CNSC staff will develop a comprehensive set of criteria and action levels for all Geoscientific Verification Plan data as well as data from other programs such as the waste inventory verification program. This system will be used by CNSC staff to thoroughly and effectively check the continuing validity of the safety case as information about the actual repository conditions becomes available. This will include information about the three major conditions required for the safety case, but would also extend to information that would assist in further enhancing the safety case via adjustments to in-design mitigation.

The Panel recommends that the CNSC establish action levels for key indicators of the essential components of the safety case prior to the issuance of a licence to prepare site and construct the DGR. These action levels would define, in quantitative terms, the tolerable deviation from expected conditions and the degree of statistical certainty required for each measured variable. The Panel expects that the criteria for each key indicator may cover a range. The lower part of the range would cover situations where confirmation of deviation from expected conditions would be required. The upper part of the range would correspond with conditions where the key indicator was confirmed to significantly deviate from expected conditions such that changes in design and/or operations would be required.

13.4 PANEL CONCLUSION REGARDING THE POSTCLOSURE SAFETY ASSESSMENT

The Panel concludes that the DGR is not likely to cause significant adverse environmental effects over the long term. The Panel is satisfied that OPG based its postclosure safety assessment on recommendations in the CNSC Regulatory Guide G-320. The Panel determined that OPG demonstrated an understanding of the waste management system through a well-structured, well-documented, transparent, and traceable methodology. The assessment documentation provided a clear and complete record of how decisions were made and what assumptions were adopted. Models were based on the best technical and scientific information available at this time and used conservative assumptions to bound potential effects over the lifecycle of the project.

OPG's postclosure safety assessment was supported by multiple studies and lines of evidence that addressed repository design, site geology and hydrogeology, waste management practices, and repository evolution modelling of both Normal Evolution and Disruptive Scenarios. The sum of these studies, as well as each of the components, have provided the Panel with confidence that OPG's assessment is comprehensive and satisfies the requirements set forth in CNSC Regulatory Guide G-320 and the EIS Guidelines.

The Panel accepts that releases of radiogenic and non-radiogenic contaminants from the DGR, over the assessed postclosure period of one million years, would be extremely low for the normal evolution of the repository. Doses to humans and non-human biota would be negligible relative to internationally accepted dose limits. In particular, the Panel notes that the DGR would not adversely affect the water quality or biota of Lake Huron and the other Great Lakes during postclosure, as detailed in Chapter 14. The Panel's confidence in these findings is supported by the high degree of conservatism adopted by OPG in its choice of data and assumptions for a broad range of calculation cases and bounding scenarios that provide large margins of safety.

The calculated doses from two low-probability Disruptive Scenarios, human intrusion within 300 years or severe shaft failure, could exceed regulatory limits for a group resident immediately above the repository. The low likelihood of these scenarios combined with an assumed health risk yielded health risk values well below the reference health risk of 1 in 100,000 per year. The Panel concurs with OPG and CNSC staff that the low risk of serious health effects for a future resident living immediately above the DGR would be acceptable.

The Panel has provided a recommendation (Recommendation 13.A) to government regarding the evaluatation of institutional control options to restrict access to the surface and sub-surface of the DGR site. and further decrease the probability of the Inadvertent Human Intrusion Scenario.

The integrity of the DGR Postclosure Safety Assessment confirms the Panel's conclusion that the storage of the L&ILW at 680 m depth in the Cobourg Formation at the Bruce nuclear site is the most effective and safest option for the long-term management of L&ILW.

Role of the Geoscientific Verification Plan in Adaptive Management

The geoscientific assumptions and data used by OPG for the preliminary safety case were primarily derived from eight deep boreholes, of which six were developed to the depth of the planned repository horizon, and associated laboratory testing programs.

In 2014, OPG presented an updated and more detailed Geoscientific Verification Plan that outlined additional investigations and monitoring activities that would be carried out during shaft sinking and lateral development of the repository in order to strengthen the safety case. In some cases geoscientific activities would extend into the operations phase of the project. In the Geoscientific Verification Plan, OPG distinguished two sets of verification activities, those related to geotechnical verification and those addressing geoscience verification. OPG stated that while the geotechnical verification activities would be used to confirm repository design and assure safe underground excavation practices, the geoscience verification activities would be principally conducted to reaffirm the DGR safety case. The geotechnical verification activities are discussed in Chapter 6, whereas the conclusions presented here focus on the geoscience verification section of the Geoscientific Verification Plan. The proposed geoscience verification and monitoring activities included:

- characterization of excavation damage zone using geophysics, hydraulic testing and coring;
- geological mapping;
- seismic reflection survey to characterize the configuration of Precambrian surface below the repository;
- long-term diffusion tests; and
- seal material performance tests.

The geoscience verification activities would be used to test the assumptions and data used in the development of the Postclosure Safety Assessment and to confirm that the Cobourg Formation and overlying rock formations would contain and isolate the L&ILW for a time period of one million years.

CNSC staff reviewed OPG’s proposed studies of fracture mineral infill and dating, multi-phase flow, long-term diffusion, microbial activity and seepage water and determined that these studies would provide additional confidence in understanding the ability of the geosphere to provide long-term containment and isolation of the waste. CNSC staff noted that the proposed Geoscientific Verification Plan studies, as described, would provide multiple lines of evidence to support OPG’s assessment that the geosphere would provide acceptable long-term containment and isolation of the waste in the DGR.

In response to an information request, OPG stated that if data arising from any of the geoscience verification activities are materially different than those used in DGR safety analyses the following actions would be taken: (a) the data would be assessed to determine its reliability, and (b) new analyses would be undertaken to test the implications on the DGR Safety Case. OPG did not provide information or limits when data would be considered to be “materially different.” Furthermore, OPG stated that data gathered during implementation of the Geoscientific Verification Plan geoscience verification would be used to reaffirm the geosphere conceptual model and understandings as presented in the DGR Geosynthesis Report and to update the DGR Safety Case to re-evaluate dose consequences and margins of safety. OPG affirmed that this information would not be presented until OPG applied for the DGR Operating Licence required under the *Nuclear Safety and Control Act*. Consequently, OPG did not provide specific action levels for the outcomes of geoscience verification activities that would initiate a re-examination of the postclosure safety case. However, some of the geotechnical verification activities would identify parameter changes that could have a bearing on the long-term postclosure safety case.

Some participants commented about the proposed Geoscientific Verification Plan. They expressed that, rather than action levels that would trigger a re-assessment of the safety case and subsequent engineering solutions to encountered problems, the Geoscientific Verification Plan should have included go/no-go criteria for certain properties. Some participants were concerned that, should the DGR be approved, the safety case would be diminished over time under the guise of adaptive management. Participants were also concerned that the verification activities and results would not be transparent, or subject to public scrutiny.

The Panel notes that the geoscience activities of the Geoscientific Verification Plan would provide information on key indicators used to assess and address assumptions and uncertainties in the Postclosure Safety Assessment. In the Panel's view, it is likely that the geoscientific investigations and monitoring activities of the Geoscientific Verification Plan will yield some results that deviate from the assumptions and data used in the Postclosure Safety Assessment. The enhancement of confidence in the Postclosure Safety Assessment requires the determination of predefined action levels for specific parameters that could trigger the requirement to reaffirm the safety case and, possibly, implement design modifications.

The Panel concludes that OPG, in conjunction with the CNSC, needs to develop an adaptive management system that actively, and in real time, incorporates the Geoscientific Verification Plan in decision-making as the DGR is constructed and operated. The adaptive management system would also support updates to re-confirm and enhance the Postclosure Safety Assessment. By being active, rather than reactive, the plan should be structured to induce deliberate learning about the managed system, so that management can be improved in the face of uncertainty.

The Canadian Environmental Assessment Agency has an Operational Policy Statement, *Adaptive Management Measures under the Canadian Environmental Assessment Act,* which provides the rationale for adopting adaptive management to a project. The Panel considers the following to be particularly cogent for the project:

- the amount of prior experience with the specific type of project is limited;
- the possibility that a mitigation measure may not function as intended;

- the extent of knowledge and understanding of key environmental indicators and action levels;
- the likelihood of broad-scale environmental change that would affect the project or influence the nature of mitigating its environmental effects;
- the likelihood that advances in scientific knowledge or technology over the life of the project may enable improved mitigation measures;
- the extent to which public concern about specific issues could be alleviated or reduced through a commitment to follow-up or adaptive management as appropriate; and
- the opportunity to learn from the results of follow-up or adaptive management and improve the current project or the quality of future EA.

The Operational Policy Statement also provided key factors that should be considered when planning for adaptive management:

- capacity and management commitment for development, implementation and monitoring of adaptive management measures;
- identification of key indicators to assess and address assumptions and uncertainties;
- predetermined action levels to determine the requirement of corrective management measures;
- identification of testable predictions; and
- identification of a range of available options to adapt and manage the project.

The Panel recognizes that OPG has the capacity to institute active adaptive management measures to the postclosure safety assessment. In the Geoscientific Verification Plan, OPG has identified the key geoscience indicators that would have to be addressed to verify assumptions and reduce uncertainties. However, the Panel notes that, while OPG provided action levels for geotechnical verification activities, the Geoscientific Verification Plan for geoscience activities lacks complete and clearly defined action levels that would trigger corrective management measures. In addition, the geoscience verification activities do not identify specific options to adapt, modify and manage the project in response to changes in key indicators. OPG recognized that the geoscience verification activities may have to be iterative as new data are acquired. The Panel directs OPG to implement an active adaptive management system that includes all the key factors specified in the Canadian Environmental Assessment Agency's Operational Policy Statement on adaptive management.

The Panel considers the establishment of a rigorous and reliable adaptive management system essential to the long-term Postclosure Safety Case for the DGR. The adaptive management system must be designed to recognize that the postclosure safety case must hold over a time period not previously encountered in project planning. As the project proceeds, learning and adaptation will have to be key components to ensuring the long-term successful isolation and confinement of the L&ILW. Given that some of the geotechnical verification activities of the Geoscientific Verification Plan may affect the postclosure safety assessment, the adaptive management system should be in place prior to the commencement of the site preparation and construction phase. The Panel therefore recommends that:

Recommendation 13.8: In order to enhance postclosure safety of the DGR, OPG shall develop an active adaptive management system in support of its Postclosure Safety Assessment. The management system shall include the geoscience verification activities of the Geoscientific Verification Plan with additions that ensure consideration of full, complete and clearly defined action levels for all geoscience verification activities. The action levels shall include critical action levels associated with fundamental components of the safety case, i.e., low permeability of host and cap rock; absence of major fractures; and, absence of economically viable resources. In addition, the system shall identify specific options to adapt, modify and manage the project in response to changes in key indicators. The adaptive management system shall be developed to the satisfaction of the CNSC prior to the start of the site preparation and construction phase of the DGR.

CHAPTER 14 LAKE HURON AND THE OTHER GREAT LAKES

The protection of Lake Huron and the Great Lakes was a dominant theme in written and oral submissions to the Panel. The location of the proposed DGR, 1.2 km from the shoreline of Lake Huron, was a catalyst for concerns and comments about drinking water quality, recreational use, aquatic ecology, and the economic, cultural and spiritual value of the lake. This chapter provides an overall view of the Panel's assessment of the effects of the proposed DGR on Lake Huron.

The Panel's evaluation of the effects of the project on Lake Huron began with a focus on MacPherson Bay because the bay would receive direct surface discharges from the DGR stormwater management system during the construction, operations and decommissioning phases. Baie du Doré and the shoreline extending to Douglas Point were also included in the evaluation of "near-field" effects in Lake Huron. The Panel then extended its review to the potential for groundwater discharges to the lake from the underground repository itself, either during the preclosure phases or during postclosure.

Finally, the Panel examined the nature and basis of concerns and comments from many participants about Lake Huron and the other Great Lakes, as expressed in written and oral submissions, resolutions, and petitions. This evaluation includes an overview of the primary risks to the ecology of the Great Lakes in order to put the risks associated with the project into context and perspective. A review of Canada's obligations under the *Great Lakes Water Quality Agreement* is also provided, including actions taken by Canadian representatives to notify representatives of the United States according to provisions of the Agreement. The Panel's review included the role of scientific information, the consideration of submissions from the public and Aboriginal groups, and priorities with respect to protection of the Great Lakes.

14.1 MACPHERSON BAY, BAIE DU DORÉ AND DOUGLAS POINT

This section covers the Panel's assessment of project effects on MacPherson Bay, Baie du Doré and Douglas Point. It includes a description of the existing environment, the potential effects, and Panel conclusions.

14.1.1 Existing Environment

OPG described MacPherson Bay (Figure 37) as a wind-swept environment with a bottom substrate dominated by bedrock and cobble substrates. About 70% of the Bay was reported to be less than two metres deep and subject to extensive wave action. OPG stated that the exposed nature of MacPherson Bay meant that habitat was restricted, offering little cover or protection from currents and predators, unsuitable for critical life history stages of many fish species (such as spawning and rearing of young), and offering minimal foraging areas. OPG reported that it caught 14 species of fish in the shallow waters of MacPherson Bay, seven of which were regarded as nearshore species, such as round goby, spottail shiner, white sucker and longnose gar. Round gobies, a species invasive to the Great Lakes, comprised 78% of the

Figure 37: MacPherson Bay Near the Proposed Discharge Point (reproduced from DGR Joint Review Panel Project Site Visit (June 7, 2012) Report)

catch by numbers. OPG noted that round goby feed aggressively on eggs and fry of other benthic fish species, including whitefish.

OPG identified that the plant community of MacPherson Bay reflected its relatively harsh environment. Periphyton distribution was spatially variable and affected by the movement of water currents. The littoral phytoplankton community was found to move continuously along the shoreline. OPG did not observe any aquatic macrophytes, such as cattails, bulrush or sedges, in the bay. Sampling showed an unproductive habitat with little or no periphyton along most of the shoreline. Phytoplankton are microscopic plants (algae) that live in the water column. Periphyton is the mixture of algae, bacteria and other tiny organisms that live on the surface of submerged plants, woody debris or on the substrate itself.

OPG further stated that the invertebrate community of MacPherson Bay was also limited. About 96% of the bay was dominated by low densities of zebra mussels. Aquatic earthworms, freshwater scuds and sow bugs were also observed occasionally amongst the coarse material in the bay.

OPG reported that lake whitefish and round whitefish were not as numerous in MacPherson Bay as at other sampling locations. OPG did not capture any larval lake whitefish in larvae traps deployed in MacPherson Bay for 629 trap nights in 2007; however, one whitefish larva was captured at the mouth of the bay during larval tow sampling. During 2010 and 2011 field sampling campaigns, OPG found that the catch per unit effort was highest at Scougall Bank for both lake whitefish and round whitefish, 24.42 per km and 16.84 per km, respectively, in 2010. Scougall Bank is located about 8.8 km north of MacPherson Bay. MacPherson Bay had either the lowest or second lowest catch per unit effort, 3.51 per km for lake whitefish and 9.82 per km for round whitefish in 2010.

OPG described Baie du Doré (Figure 38) as a calmer environment where fine sediments can accumulate. OPG noted that it is a provincially significant wetland area that provides spawning, nesting, rearing and feeding habitats for resident warm and cool water fish species such as pike, bowfin, smallmouth bass and shiner. OPG stated that the environment of Baie du Doré provides a more stable and productive temperature regime. Overall, Baie du Doré and its largest tributary, Stream C, were considered by OPG to be more diverse, sensitive and productive than MacPherson Bay with its man-made, drainage-ditch tributaries.

Figure 38: Baie du Doré (reproduced from DGR Joint Review Panel Project Site Visit (June 7, 2012) Report)

The Saugeen Ojibway Nation provided information from its own fisheries studies in Lake Huron, including studies in the area of MacPherson Bay, Baie du Doré and Douglas Point. The Saugeen Ojibway Nation explained that Saugeen Ojibway Nation-sponsored research, conducted in collaboration with Bruce Power and involving the Universities of Guelph, McMaster, and Regina, had focused on the effects of the Bruce nuclear generating stations on lake whitefish populations. The Saugeen Ojibway Nation noted that the whitefish population in the study area might be a local population rather than a lake-wide population, which would place localized effects on water quality or habitat into a different perspective. The Saugeen Ojibway Nation stated that MacPherson Bay is one part of the Douglas Point region, a highly-connected ecosystem dominated by currents which vary diurnally, seasonally and in response to pumping at the Bruce nuclear generating stations. The Saugeen Ojibway Nation noted that plankton and fish larvae go where the lake currents take them. The Saugeen Ojibway Nation also commented that Lake Huron is a rapidly changing ecosystem, at a pace which most people may not realize.

The Saugeen Ojibway Nation provided information that indicated that there was significant habitat diversity and species diversity in the study area. The Saugeen Ojibway Nation noted that the species diversity in MacPherson Bay was exceptional given the nature of the habitat. In addition, sampling by the Saugeen Ojibway Nation fisheries study team in the Inverhuron and Holmes areas had yielded species that had not been recorded by OPG. In contrast, round gobies were not caught at all, demonstrating variability with sample year and site. The Saugeen Ojibway Nation described Douglas Point as an “oasis” of fish habitat due to the habitat diversity at that location.

The Saugeen Ojibway Nation emphasized the value of traditional knowledge regarding the fishery of the Inverhuron, Baie du Doré, and Douglas Point areas. For example, the Saugeen Ojibway Nation explained that traditional knowledge regarding the perch fishery in Baie du Doré could provide an historic perspective for use in comparing current fish abundance and productivity. Traditional knowledge would also be useful regarding the evaluation of cumulative effects over time.

The Saugeen Ojibway Nation expressed the view that the study area for evaluating effects of the project should have been based upon a broader understanding of the nearshore ecosystem which is dominated by water currents that change direction from south-to-north (80% of the time) to north-to-south (20% of the time). The Saugeen Ojibway Nation explained that the direction and speed of water currents would affect the dispersion of the discharge from the DGR stormwater management pond, as well as unexpected releases caused by severe high-flow events or spills.

The Ontario Ministry of Natural Resources provided information on the nearshore fish community in Lake Huron from a 2008 study of eight locations, including Stokes Bay on the northern Bruce Peninsula. While there were no sampling locations in the MacPherson Bay-Douglas Point area, the Ministry suggested that the general conclusions regarding the relationship between habitat and the composition of the fish community may be relevant. The Ministry stated that the study found that, next to vegetated areas, coarse habitat was the most productive. The Ministry explained that the study found that greater numbers of Cyprinids (minnows), Moronids (bass), and Catostomids (suckers) were caught over coarse habitat, and that species diversity was greatest over coarse habitat. The invasive round goby was present in most locations and over all habitat types.

14.1.2 Effects on MacPherson Bay, Baie du Doré, and Douglas Point

OPG stated that there were no measurable changes expected to the aquatic valued ecosystem components, including lake whitefish, in Lake Huron, MacPherson Bay, and Baie du Doré from vibrations due to blasting, or changes to surface water quality or quantity. OPG stated that there would be no activities in the waters of MacPherson Bay or Baie du Doré that would change the habitat, and that there would be no stormwater discharges to Baie du Doré. OPG further stated that the discharge from the stormwater management pond to MacPherson Bay would meet any environmental compliance approval requirements at the point of discharge from the stormwater management pond, and noted that the discharge requirements would be set to comply with regulatory requirements and be protective of the water quality and aquatic life in MacPherson Bay. OPG predicted that changes to water quality in MacPherson Bay and other near-field areas such as Baie du Doré from dust deposition or near-surface groundwater flow from the site to the lake would not be measurable. Due to these predictions, OPG screened out effects on the nearshore and offshore habitats of Douglas Point at an early stage in its assessment.

OPG confirmed that there are other drainage ditches from the Bruce nuclear site that discharge to MacPherson Bay and that none of these ditches are subject to environmental compliance approvals. OPG noted that it did not assess the cumulative effects of these discharges, when combined with the discharge from the stormwater management pond, because OPG had predicted that the stormwater discharge would not cause measurable effects.

OPG stated that it would confirm the effectiveness of the stormwater management system via monitoring during the site preparation and construction, and operations phases. OPG's proposed surface water quality follow-up monitoring program focused on verification of the prediction that there would be no effect on surface water quality. OPG stated that it would monitor underground water prior to discharge to surface runoff, and from there to the stormwater management pond, as well as waste rock characteristics, in order to confirm the effectiveness of mitigation measures underground, including oil/water separators to remove oils and greases, and to confirm the predicted absence of acid rock drainage from the waste rock. The discharge from the stormwater management pond would be monitored to confirm compliance with the established discharge criteria. OPG committed to collecting additional pre-licensing baseline data for surface water quality to supplement the data provided in the EIS.

CNSC staff stated that MacPherson Bay would be protected during site preparation, construction and operations, provided that OPG implements proper source reduction measures and additional treatment of stormwater, and meets discharge criteria. CNSC staff based this position upon a Preliminary Quantitative Risk Assessment to determine if an environmental risk to MacPherson Bay would remain after the implementation of OPG's mitigation measures. CNSC staff determined that the discharge from the stormwater management pond to MacPherson Bay would not cause deleterious effects on aquatic life in the bay. Environment Canada concurred with this determination. This conclusion was based upon the assumption that water treatment would reduce all constituents of concern except chloride to concentrations below discharge criteria prior to discharge to MacPherson Bay. The discharge criteria would be federal and/or provincial criteria or guidelines developed to protect all aquatic life. CNSC staff assumed the chloride would be rapidly dispersed and diluted in MacPherson Bay; therefore, significant adverse effects from chloride were not expected.

Environment Canada stated that monitoring of key indicators in MacPherson Bay would be required to confirm the protection of aquatic life. These key indicators would address water quality, sediment quality, and benthic invertebrate community valued ecosystem components. The Panel included a recommendation covering these indicators in Chapter 8.

As discussed in detail in Chapter 8, the stormwater management pond must be of sufficient size to contain the volume of water produced by large storm events and to prevent uncontrolled release of untreated water to Lake Huron over the lifetime of the surface facilities, which would be several decades. The Panel recommended in Chapter 8 that OPG review expected changes in the return period of severe storm events caused by climate change, and if necessary, develop a revised design of the stormwater management pond to ensure sufficient retention time and compliance with the *Fisheries Act*. The Panel also recommended in Chapter 8 that OPG prepare a contingency plan to mitigate effects of uncontrolled overland flow to MacPherson Bay and Baie du Doré during the period of site preparation before the stormwater management system is fully functional.

Notwithstanding the potential for required changes in pond design capacity, OPG maintained that unexpected releases from the stormwater management system into MacPherson Bay during the 100 year storm, or in the event of a mechanical failure, would not affect lake whitefish. This was based upon OPG's assessment that whitefish were not selecting MacPherson Bay for critical life history stages.

The Saugeen Ojibway Nation expressed the view that uncertainty remained concerning the effects of the project on MacPherson Bay. The Saugeen Ojibway Nation fisheries specialists indicated that the bay offers some good nursing habitat for lake whitefish. The Saugeen Ojibway Nation suggested that more data were necessary to fully understand the role of MacPherson Bay in the overall ecology of Lake Huron, and that, to date, the data were insufficient to draw the conclusion that there will be no measureable effects on lake whitefish. The Saugeen Ojibway Nation asserted that OPG could not reasonably assign significance of ecological effect in the absence of an understanding of structure and function of the ecosystem. The Saugeen Ojibway Nation indicated that the uncertainty was compounded by continuing questions regarding the design and function of the stormwater management pond.

The Panel notes that, because of the uncertainty regarding the use of MacPherson Bay by lake whitefish, it is important that OPG prevent unplanned releases of surface runoff from the DGR site during site preparation and construction. If MacPherson Bay provides nursery habitat for lake whitefish, unplanned releases of surface runoff could affect the habitat via deposition of sediments on feeding grounds, thus reducing the food supply for young fish. Thus, the Panel has made recommendations in Chapter 8 regarding re-visiting the design capacity of the stormwater management system in light of the effects of climate change on the frequency and intensity of storm events and regarding mitigation of uncontrolled overland flow prior to the stormwater management system being fully operational.

The independent peer reviewer retained by the County of Bruce expressed the view that OPG had not substantiated the stormwater management pond source terms, nor the quality of the discharge water, and suggested that the pond should be operated with the discharge closed until such time as the quality of the discharge water can be confirmed. The characterization of the mixing of the discharge with MacPherson Bay waters was identified as an additional requirement to confirm the prediction of no adverse effects to water quality or aquatic life in the bay. The peer reviewer acknowledged that prior to discharge of any effluent from the stormwater management pond, OPG must obtain an Environmental Compliance Approval from the Ontario Ministry of the Environment and Climate Change but noted that the final expected discharge quality, operating configuration and monitoring protocol would not be known until the Environmental Compliance Approval was approved. The Panel included a recommendation in Chapter 8 that requires OPG to conduct a dispersion study in MacPherson Bay such that mixing of the discharge can be understood.

OPG explained that the stormwater management pond could be operated in a closed position for an extended period of time during site preparation and initial construction because there would not yet be large flows to the stormwater system from underground water. OPG stated that this early period would be used to establish mitigation options to ensure that discharge criteria could be met well in advance of higher flows from the underground workings.

OPG determined that there would be no significant adverse effects on MacPherson Bay or adjacent areas in Lake Huron resulting from malfunctions, accidents or malevolent acts. This conclusion applied to both the preclosure and postclosure phases of the proposed project. OPG assumed that the effects of the two conventional malfunction and accident scenarios assessed (spill of diesel, chemical, lubricant or oil and an explosion during site preparation and construction) would be quickly contained and mitigated. OPG explained that a spill would not reach Lake Huron and would not affect water quality, including water used for drinking or for recreational contact. OPG determined that an explosion would not affect Lake Huron water quality. OPG stated that aquatic and terrestrial biota would not be affected unless within the immediate vicinity of the spill or explosion. The assessment of effects resulting from sabotage or attack found that overall populations of terrestrial and aquatic biota would remain unaffected while acknowledging that individual plants or animals on the DGR site could be affected. The assessment showed that effects of the more credible malevolent act scenarios fell within the bounds of effects caused by malfunctions and accidents. This result reflects the fact that the DGR would be entirely contained within the Bruce nuclear site and protected by the security measures at the Bruce nuclear site throughout site preparation, construction, operation and decommissioning. OPG pointed out that, over the long term, deep geologic disposal of L&ILW would provide the best possible security against malevolent acts.

CNSC staff stated that OPG had adequately assessed radiological and conventional malfunctions, accidents, and malevolent acts, and concurred with OPG that adverse effects on the environment would not be likely to occur.

14.1.3 Panel Conclusion Regarding Effects on MacPherson Bay, Baie du Doré and Douglas Point

The Panel concludes that the project will not cause significant adverse environmental effects on MacPherson Bay or other near-field areas such as Baie du Doré and the shoreline and offshore areas extending to Douglas Point, provided that:

- discharge criteria are developed to comply with section 36 of the *Fisheries Act* for all potential constituents of concern, including, but not limited to, suspended solids, total dissolved solids (with emphasis on chloride), nitrogen compounds, and oils and greases;
- discharge criteria are met at the point of discharge from the stormwater management pond;
- OPG prepares a contingency plan to mitigate effects of a major storm event prior to the presence of a functional stormwater management system;
- the stormwater management system of drainage ditches and pond is of sufficient capacity to prevent or minimize uncontrolled discharge of water and sediments to the receiving environment, including climate-change related increases in the frequency and/or severity of storm events;
- a comprehensive monitoring program is implemented in MacPherson Bay that includes water quality, sediment quality, and the benthic invertebrate community;
- a rigorous environmental management system is in place that produces timely and appropriate responses to any and all monitoring information, as well as malfunctions, accidents, and malevolent acts; and
- OPG implements all identified mitigation measures and contingency plans regarding malfunctions, accidents, and malevolent acts.

There are different opinions among specialists regarding the nature and extent of fish habitat in MacPherson Bay. However, the Panel is of the view that, provided that the above requirements with respect to discharge from the stormwater management pond are met, significant adverse effects on aquatic valued components, including lake whitefish, would not be likely to result from the project. The Panel understands that the Saugeen Ojibway Nation is engaged in co-operative research with Bruce Power regarding the effects of the operation of the Bruce nuclear generating station. The Panel is of the view that OPG should work with the Saugeen Ojibway Nation to deal specifically with the effects associated with the DGR and MacPherson Bay.

Recommendation 14.1: In order to confirm environmental assessment predictions regarding effects on lake whitefish, OPG shall develop a follow-up program which includes provisions to incorporate input from interested stakeholders, including the Saugeen Ojibway Nation fisheries specialists. The follow-up program should reflect the increasing understanding of the role of MacPherson Bay in the ecology of the area, and should include mitigation measures that may be implemented to protect lake whitefish and lake whitefish nursery areas, to the satisfaction of the CNSC.

14.2 POSTCLOSURE EFFECTS OF THE PROJECT ON LAKE HURON

OPG stated that it was confident that Lake Huron and the other Great Lakes would be protected after the closure of the DGR. OPG's confidence was based on many reasons, including:

- the location of the repository 680 metres deep in the stable, low-permeability rock of the Cobourg Formation beneath a 200-metre-thick layer of low-permeability shale cap rock;
- the vertical isolation of Lake Huron from the DGR by low permeability rock formations;
- the extremely slow, diffusion-based contaminant movement for the longer-lived radionuclides;
- the short-lived nature of most of the low and intermediate-level waste, which would decay long before any migration of those short-lived radionuclides could take place;
- the existence of a deep-seated, ancient and stable groundwater domain at the depth of the repository, which indicated that conditions have been diffusion-dominated over geologic time, including during major perturbations;
- groundwater modelling that showed contaminants would take several million years to reach the upper groundwater levels that may connect to Lake Huron;
- the location of the DGR in an area of low seismic activity;
- the design features of the DGR that would address natural events such as floods;
- OPG's confidence in its understanding of the geology of the site; and
- highly conservative modelling of “what if” scenarios, including deliberate intrusion into the DGR, which showed that even under these conditions, health risks to people right at the site would be below regulatory limits and risks for people living along the shoreline of the lake would be many magnitudes lower.

In summary, OPG's analysis determined that postclosure protection of Lake Huron would be provided by the extremely low permeability of the host rock and the nature of the deep groundwater system, which was shown to contain very old, very saline water that had remained in place for millions of years, with no connection to the lake. Modelling of contaminant movement up from the proposed DGR to more permeable geological layers and from there to Lake Huron produced predicted concentrations of radionuclides in the lake that were orders of magnitude lower than acceptable limits for drinking water.

CNSC staff agreed that the DGR would not likely result in any significant adverse effects to Lake Huron because of the natural barriers provided by the rock formations and the diffusion-dominated nature of any contaminant migration that might occur. CNSC staff was satisfied that OPG's modelling was sufficient to demonstrate that there would be no effects to Lake Huron.

Many participants expressed views about the potential for the project to have postclosure effects on Lake Huron. A summary of these views is provided below.

14.2.1 Panel Conclusion Regarding Postclosure Effects of the DGR on Lake Huron

As was described in Chapter 13, the Panel is satisfied that OPG has adequately characterized the postclosure performance of the DGR. The Panel concurs with CNSC staff and OPG that there would be no postclosure effects to Lake Huron.

14.3 SUMMARY OF COMMENTS RECEIVED REGARDING LAKE HURON AND THE OTHER GREAT LAKES

In contrast to OPG and government agency conclusions regarding Lake Huron, the location of the proposed DGR, 1.2 km from the shoreline of Lake Huron, triggered a strong reaction from many participants who had concerns about the project. The Panel received submissions, including signatures on petitions, from individuals and organizations representing a wide array of professions, including scientists and engineers. One of the most common reasons given for this reaction was that the project location defied common sense. The argument from these participants was that common sense would dictate that if there was an unacceptable level of uncertainty about the safety of the DGR, then the DGR should not be approved, particularly when the consequences to the lake could be so dire.

Other issues regarding the project location near Lake Huron included:

- the opinion that there had been insufficient consultation with the public living in the Great Lakes basin - both in Canada and the U.S.
- the position that OPG had not adequately considered cumulative effects at the lake-wide or Great Lakes Basin scale;
- the view that OPG had underestimated the likelihood and consequences of earthquakes;
- the belief that the project would result in broad-scale contamination of drinking water and aquatic life;
- the potential economic consequences of such contamination; and
- the lack of consideration of a specific alternative location.

In addition to written and oral submissions, the Panel received forty-one resolutions opposing the project from cities and towns in the Great Lakes basin as well as from other locations in the United States and Canada. Twenty-four of these resolutions made very similar points as follows:

- the Great Lakes are an irreplaceable natural resource, containing 20% of the world's and 95% of the United States' fresh water;
- the Great Lakes are vital to the economic and agricultural wellbeing of Canada and the United States;
- Lake Huron and the connecting water, including Lake St. Clair, are a source of drinking water for millions of people in the United States and Canada, and First Nations;
- under the 2012 *Protocol Amending the Agreement between Canada and the United States of America on Great Lakes Water Quality*, the governments of the United states and Canada

acknowledge the importance of anticipating, preventing and responding to threats to the waters of the Great Lakes;

- the Governments of Canada and the United States share a responsibility and an obligation to protect the Great Lakes from contamination from various sources of pollution, including the potential leakage of radioactivity from an underground nuclear waste repository; and
- the potential damage to the Great Lakes from any leak or breach of radioactivity far outweighed any suggested economic benefit that might be derived from burying radioactive waste at the DGR site.

The Panel also received a resolution passed by the Michigan State Senate. This resolution urged Canadian officials to thoroughly review the project and the issues outlined in the resolution. Those issues included:

- the critical importance of the Great Lakes for drinking water, recreational activities, and water for agriculture;
- Michigan's siting criteria for disposal of low-level radioactive waste prohibit any site located within ten miles of the Lakes Michigan, Huron, Superior and Erie, the Saint Mary's River, the Detroit River, the St. Clair River or Lake St. Clair (with the exception of operating nuclear generating stations);
- international agreements between the United States and Canada state that radiological contamination should be reduced with emphasis on the concept of prevention;
- siting of a nuclear waste repository in limestone would be the first of its kind;
- sound scientific principles and analyses be used to determine whether limestone is appropriate for the safe long-term storage of radioactive waste; and
- information regarding alternative sites that were considered should be made available.

The Great Lakes and St. Lawrence Cities Initiative, an organization of over 100 Canadian and U.S. cities, stated its opposition to the project. The Initiative's submission stated that its primary concerns were the proximity of the DGR to Lake Huron and the failure to consider any other location for the facility. While acknowledging that there had been extensive community outreach by OPG and extensive information available on-line, the Great Lakes and St. Lawrence Cities Initiative stated that, regardless of the suitability of the geology and the engineering of the DGR, it seemed "unwise" for OPG to locate radioactive waste close to the largest source of freshwater in the world. The Great Lakes and St. Lawrence Cities Initiative noted that several members within the organization supported the project.

Some participants used a moral and ethical framework as a basis to express concerns about the project. Participants described the Great Lakes as a cherished and precious natural resource that required good stewardship from industry, leaders, and the general public. Thus, any risk of contamination from the DGR was considered to be too great a risk. It was also expressed that a disturbance of the 'ancient depths' of the earth so close to Lake Huron represented a total lack of sensitivity towards the earth.

Aboriginal people expressed concerns about both real and perceived effects on Lake Huron and its resources, especially fish. The Saugeen Ojibway Nation stated that the project would affect their people's connection to and perception of the land and waters, including Lake Huron. The Saugeen Ojibway Nation stated that their perception of the value of plants and animals on the land and in the waters could be affected. There was particular concern regarding the perception of the value of lake whitefish, a species which they identified as being central to many of their traditional practices. The Historic Saugeen Métis and the Métis Nation of Ontario made statements regarding the potential for the effects of the project to affect the ability of Métis people to continue their traditional subsistence fishing in Lake Huron.

The Panel frequently heard concerns about the DGR put into the context of "out of sight, out of mind." Several submissions focused on the view that the waste must remain retrievable and readily monitored so that active intervention would be possible should radionuclides be released into Lake Huron. Some participants suggested that the long-term performance of an underground repository was not sufficiently understood; therefore, decommissioning leading to closure and abandonment was viewed as posing too high a risk to Lake Huron.

Some participants expressed little trust in the scientific and technical information presented by OPG. The OPG determination that significant adverse effects to human health or the environment, including Lake Huron, were unlikely was not viewed as credible by some participants, nor did they accept the CNSC and other regulatory or government agencies' concurrence with this determination. Some participants expressed the view that there was insufficient precaution in the OPG assessment. There were concerns about how difficult (if not impossible) it would be to mitigate the effects of a major release of radionuclides. Other submissions did not identify specific issues with OPG's methods; rather, they expressed distrust and scepticism that, in some cases, arose from the view that there would be an unjust distribution of the benefits and risks of the project.

In contrast to the views summarized above, several other participants expressed support for the project's location. One of the frequently-cited reasons for support was that the project represented a lower risk to Lake Huron than the existing surface storage at the WWMF. These participants emphasized that the DGR would be placed in rock with properties that would limit release of radionuclides to extremely low levels over periods of hundreds of thousands of years. Some participants noted that the consequences of events such as earthquakes would be less if the waste were located in deep, stable rock formations than if they were placed in less stable formations or on surface. Participants similarly stated that the risk from severe weather and malevolent acts was greater at the surface than it would be underground. Several participants made the point that locating the project on the Bruce nuclear site made sense because it would take advantage of an experienced workforce and would not require transportation of the waste elsewhere.

14.4 THE CURRENT STATUS OF THE ECOSYSTEMS OF LAKE HURON AND THE OTHER GREAT LAKES

This section consists of an overview of the current status of and primary risks to the Great Lakes, including information relating to international agreements between Canada and the United States.

14.4.1 Primary Risks to the Great Lakes

The Panel reviewed information provided by federal and provincial agencies regarding the current status of the ecosystems of Lake Huron and the other Great Lakes in order to provide a broader context for its evaluation of the potential effects of the project. The Panel was particularly interested in the risk associated with current and potential future radionuclide levels in the lakes relative to other risks. The broader perspective provided by information on the current conditions and highest risks to the lakes assisted the Panel in its evaluation of the submissions that expressed broad concerns about the effects of the project.

According to the *State of the Great Lakes 2011* report, issued by Environment Canada and the U.S. Environmental Protection Agency, the primary stressors affecting Lake Huron's ecosystem include:

- development;
- dams and barriers;
- non-point source pollution, such as runoff from agricultural land;
- invasive species; and
- climate change.

The *State of the Great Lakes 2011* report indicated that these stressors are resulting in habitat degradation and loss.

Environment Canada stated that phosphorous entering Georgian Bay from agricultural, municipal and cottage septic systems was causing nearshore algae problems, and that Environment Canada had expanded one of its existing programs to address this problem. Environment Canada also stated that declining water levels in Georgian Bay were an ongoing concern. Both Environment Canada and the Ontario Ministry of Natural Resources pointed to concerns that climate change would cause greater fluctuations in lake levels and possibly lower overall water levels.

The Ontario Ministry of Natural Resources stated that its overall objective, established in 1995, was, over 20 years, to restore an ecologically balanced fish community dominated by top predators and consisting largely of self-sustaining indigenous and naturalized species capable of sustaining annual fish harvests of 8.9 million kilograms. Its objectives in support of this broad objective that were of particular relevance to the proposed project included:

- maintaining the present diversity of the coregonid family of fish, which would include lake whitefish;
- protecting and restoring the integrity, connectivity, functionality of spawning and nursery and feeding areas for fish;
- protecting and rehabilitating nearshore habitats; and
- protecting and restoring water quality throughout the Lake Huron basin.

The Ontario Ministry of Natural Resources explained that the primary risk to the sustainability of the Lake Huron ecosystem was invasive species, primarily the zebra and quagga mussels. The Ministry explained that nutrients entering the lake were being captured by mussels in nearshore areas, resulting in a decline in fish production in deeper water areas. The Ministry further stated that another non-native species, the spiny water flea, had added a layer into the food web, hence changing the flow of energy through the food web. The spines on the water fleas can injure or kill small-bodied fish that eat them, thus reducing the numbers of prey species.

Positive indications in Lake Huron and the other Great Lakes noted in the *State of the Great Lakes 2011* report included increased protection and restoration of coastal wetland habitats, removal of barriers created by dams, and the restoration of riparian habitat. Levels of many so-called "legacy chemicals" such as pesticides have been declining.

The Ontario Ministry of Natural Resources noted that the collapse of alewife, an invasive species, had allowed walleye and yellow perch abundance to increase in Saginaw Bay on the Michigan side of Lake Huron. The Ministry also noted that there had been increased levels of natural reproduction of lake trout in Lake Huron.

Both the Ontario Ministry of Natural Resources and Environment Canada agreed that there was no overlap between the primary risks to the Lake Huron ecosystem and the proposed project. In other words, the project would not add to existing stress caused by factors such as invasive species and non-point source pollution.

The Panel examined the potential for interactions between release of stormwater from the proposed stormwater management system on the project site and stressors associated with the operation of the Bruce nuclear generating stations, i.e., impingement, entrainment and thermal discharge. Impingement is the trapping of fish against the screens of intake structures. Entrainment occurs when fish and fish eggs and larvae are sucked into intake structures. The question was whether there might be a potential for reaching a "tipping point" where the combination of stressors from the project and the Bruce nuclear generating stations would cause significant effects on fish populations.

The Ontario Ministry of Natural Resources explained that long-term monitoring data had indicated improvements in the fish community. For example, lake trout, a native top predator, was starting to become wild and self-sustaining in some parts of the lake. A native walleye species and yellow perch were showing large levels of natural reproduction and abundance in some parts of the lake. Ciscoes were also coming back naturally in a number of areas of the lake. Therefore, the Ontario Ministry of Natural Resources' data indicated a movement away from a tipping point rather than approaching one, notwithstanding the over-arching concerns about ecosystem-level changes caused by invasive species.

Environment Canada stated that the potential for approaching tipping points in nearshore areas of the Great Lakes had been a focus of government for a decade. Environment Canada noted that the most severely degraded nearshore areas had been identified as "areas of concern," pursuant to the *Great Lakes Water Quality Agreement*, and that there had been a significant effort in restoring those areas, on both sides of the border. Environment Canada further noted that the 2012 *Great Lakes Water Quality Agreement* included a commitment to develop, within three years, an integrated nearshore framework that would identify those nearshore areas under particular threat; however, the framework had not yet been put in place.

Environment Canada explained that indicators of so-called tipping points in the vicinity of the proposed project, such as MacPherson Bay, would include increases in nutrients such as nitrogen, which can contribute to undesirable algal blooms; overall water quality in relation to water quality objectives; sediment quality; and changes in the benthic community. These indicators would be compared to baseline data. Environment Canada reiterated that in order to prevent a tipping point, the effluent discharged from the stormwater management pond must meet the requirements of the *Fisheries Act*, and that there must be a follow-up monitoring program that encompasses key indicators.

The purpose of the 2012 *Great Lakes Water Quality Agreement* is to restore and maintain the chemical, physical, and biological integrity of the Waters of the Great Lakes. To achieve this purpose the Government of Canada and the Government of the United States agree to maximize their efforts to:

a) cooperate and collaborate

b) develop programs, practices and technology necessary for a better understanding of the Great Lakes

14.4.2 The Great Lakes Water Quality Agreement and the Great Lakes Fisheries Commission

A number of participants questioned whether agencies and officials in the United States had been notified regarding the proposed project. This notification is required under the 2012 *Great Lakes Water Quality Agreement*.

In addition, the Parties "recognizing the inherent natural value of the Great Lakes Basin Ecosystem, are guided by a shared vision for a healthy and prosperous Great Lakes region in which the Waters of the Great Lakes, through sound management, use and enjoyment, will benefit present and future generations of Canadians and Americans".

Environment Canada stated that it had the overall lead responsibility for coordinating the implementation of the 2012 *Great Lakes Water Quality Agreement* for the Government of Canada, and that many federal departments and agencies, through activities and programs under their jurisdiction and mandates, contribute to the implementation of the Agreement.

Environment Canada explained that the Government of Canada and the Government of the United States are responsible for decision-making under the *Great Lakes Water Quality Agreement*. The Great Lakes Executive Committee was established to assist coordinating, implementing, reviewing and reporting on programs, practices and measures undertaken to achieve the purpose of the Agreement. The Government of Canada and the Government of the United States co-chair the Great Lakes Executive Committee, and membership includes federal agencies, state and provincial governments, tribal governments, First Nations, Métis, municipal governments, watershed management agencies, and other local public agencies, as well as observers from the Great Lakes Commission, the Great Lakes Fishery Commission, the International Joint Commission, non-governmental organizations, the province of Québec, and interested members of the public.

Environment Canada confirmed that the notification requirement under the 2012 *Great Lakes Water Quality Agreement* had been met for the project. On June 21, 2013, Canada, through the Great Lakes Executive Committee Co-chair, notified the U.S. and the Great Lakes Executive Committee of the September 16, 2013 DGR public hearing start date and the process for participating.

Environment Canada explained that there are two notification requirements under the *Great Lakes Water Quality Agreement*. One is notification regarding proposed projects, which had occurred for the proposed DGR. The other is for any spills or unforeseen releases to the environment. Therefore, should spills or other unplanned releases occur, as described in OPG's malfunction, accident, or malevolent act scenarios, Environment Canada would be responsible for timely notification of U.S. agencies.

The Ontario Ministry of Natural Resources explained that fisheries-related trans-boundary information and data sharing takes place via the Great Lakes Fisheries Commission. Information on other components of the lake ecosystem, such as plankton, zooplankton and small-bodied fish species, is also shared. The Ministry also pointed out that it works with the Lake Huron Bi-National Partnership under the *Great Lakes Water Quality Agreement* regarding water quality. The Ministry noted that meetings take place several times per year, depending upon the particular committee; therefore, information sharing takes place on a regular basis.

14.4.3 Radiation Levels in the Great Lakes

The potential for the release of radionuclides from the DGR to Lake Huron (and beyond) was a primary concern of many participants. OPG stated that there would be no significant adverse effects from radiation on Lake Huron from either normal operations or accidents and malfunctions during the site preparation, construction, operations and decommissioning phases or so-called "disruptive scenarios" after closure of the repository. Government Agency reviewers concurred with this position. Notwithstanding these statements from OPG and regulatory reviewers, some participants maintained that the DGR posed an unacceptable risk to the drinking water of millions of people in the Great Lakes basin, as well as to the ecology of the lakes.

OPG stated that, according to several studies, natural background radiation, which comes from radioactive elements in the earth's crust and from cosmic radiation originating in space, was by far the greatest contributor to the total radiation exposure of Great Lakes basin residents. OPG noted that, according to one study, the average background dose received by people in the Great Lakes basin was about 2.6 mSv/yr. OPG further noted that global fallout from atmospheric nuclear weapons tests conducted before 1963 was the largest source of human-caused radiation in the basin; however the decay of fallout radionuclides in the 52 years since the *Limited Nuclear Test Ban Treaty* had led to discharges from the nuclear fuel cycle facilities in the basin becoming the primary anthropogenic source.

OPG noted that almost every component of the nuclear fuel cycle, including uranium mines, fuel preparation facilities, nuclear power plants and nuclear waste management facilities is present in the Great Lake Basin. The estimated doses from exposure received by individuals living in the immediate area of these sources were one to two orders of magnitude lower than the doses from natural background plus fallout. Observed concentrations of radionuclides that are important contributors to overall dose were two to seven orders of magnitude lower than guideline concentrations derived to ensure that an annual exposure limit of 0.1mSv/yr is met.

Tritium is one of the primary radionuclides associated with emissions from Canadian nuclear generating stations; therefore, there are extensive monitoring data available. CNSC staff reported that concentrations of tritium in municipal drinking water sources close to nuclear facilities in Ontario varied from 7 Bq/L to 18 Bq/L. CNSC staff noted that these values were well below both the current Canadian drinking water quality guideline of 7,000 Bq/L and also below the proposed Ontario Drinking Water Advisory Council limit of 20 Bq/L. The guideline of 7,000 Bq/L would represent a dose of 0.1 mSv/yr assuming a consumption of two litres per day for an entire year. As previously mentioned, the CNSC public dose limit is 1 mSv/yr.

Information presented by OPG on historic levels of tritium in Lake Huron showed that all tritium levels were well below Bruce Power's commitment of 100 Bq/L. Figure 39 shows that levels were all less than 10 Bq/L since the mid-1990s.

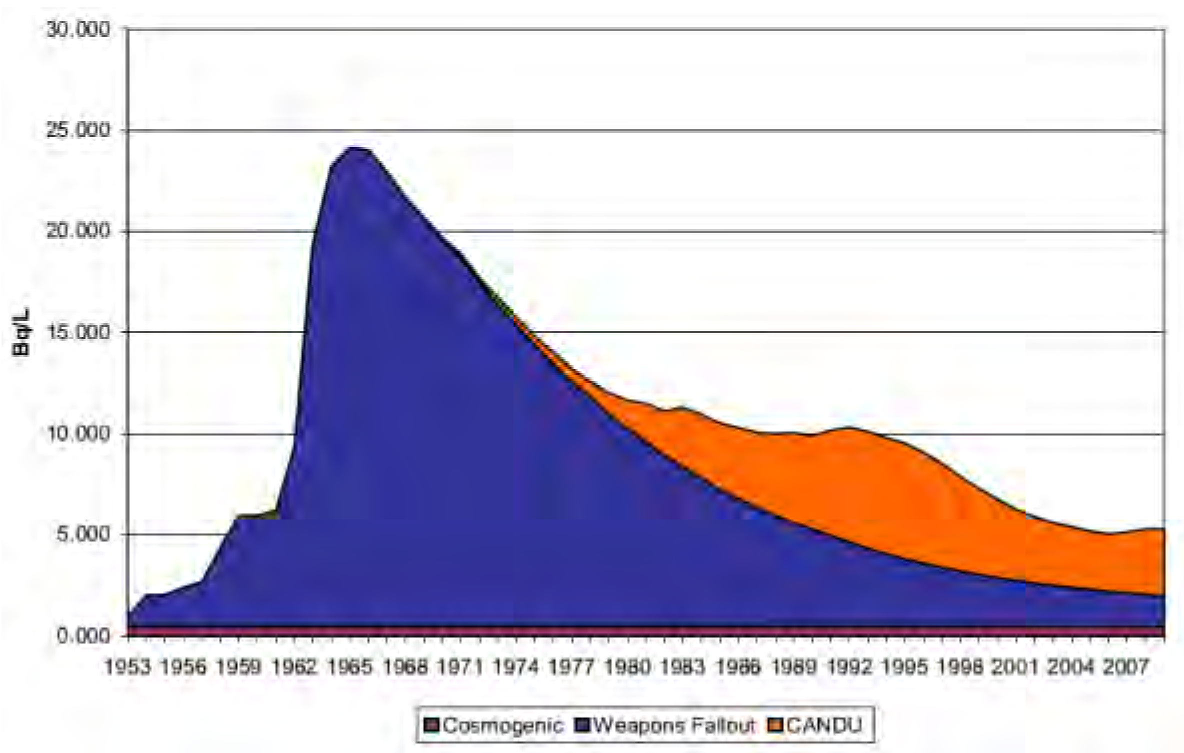


Figure 39: Historic Levels of Tritium in Lake Huron (Bruce Power 2010) (reproduced from Consolidated IR Responses, EIS-05-210 Figure 1)

14.4.4 Relative Contribution of the DGR to Radiation in the Great Lakes

OPG's studies and analyses showed that the project would contribute negligible quantities of radionuclides to Lake Huron and would not affect water quality or the health of anyone using Lake Huron for drinking water, recreation or other purposes. This conclusion applied to both the preclosure and postclosure phases. During the preclosure period, releases of waterborne and airborne emissions from the DGR would be a small fraction of the existing emissions from the Bruce nuclear site, and OPG predicted that these emissions would decline with time as more of the waste now at the surface was placed underground. Furthermore, OPG predicted that emissions would be a tiny fraction of the allowable derived release limits for the protection of the public. OPG stated that, during the postclosure phase, there would be no direct pathways between the DGR and Lake Huron, nor would there be a sufficient quantity of mobile radionuclides, nor sufficient total radioactivity to cause effects on Lake Huron water quality. This conclusion applied to both the normal evolution scenario and disruptive scenarios.

CNSC staff also stated that there would be no radiation-related effects on Lake Huron from the project. This conclusion applied to drinking water quality, human health, and the health of the aquatic ecosystem.

14.4.5 Cumulative Effects on the Great Lakes

OPG stated that there would be no likely adverse cumulative effects of the project plus existing and planned projects and activities which overlap spatially, including on Lake Huron, or over time. The cumulative effects assessment is reviewed in detail in Chapter 15.

CNSC staff agreed with OPG's conclusion regarding cumulative effects. CNSC staff explained that there had been no exceedances of action levels, which are deliberately set below release limits in order to serve as an indicator for operating performance, or regulatory release limits from the Bruce nuclear site. This information was relevant in terms of the performance of existing CNSC-licensed facilities that were considered in the cumulative effects assessment. CNSC staff also noted that compliance verification measures for licensed facilities include, but are not limited to: frequent inspections; independent laboratory testing of environmental media such as air, water and rock; and ongoing evaluation of the licensees' environmental protection measures and environmental monitoring programs. CNSC staff stated that these measures would be applied to the DGR and would ensure that project activities will be in compliance with the CNSC's regulatory requirements to protect the environment, including Lake Huron.

The Panel asked the Ontario Ministry of Natural Resources and Environment Canada to comment on whether there would be any overlap between the primary stresses on Lake Huron, including invasive species, non-point source pollution and climate change, and the project. Both agencies stated that there would be no overlap. Environment Canada pointed out that the *Great Lakes Water Quality Agreement* allows for Canada and the United States to identify, at any time, chemicals and substances that they think are a concern to the Great Lakes, and then to target them for ecosystem-specific action. Environment Canada noted that, in the future, identified substances could include substances associated with the project, should either Canada or the United States deem this to be necessary.

14.5 PANEL CONCLUSION REGARDING EFFECTS OF THE PROJECT ON LAKE HURON AND THE OTHER GREAT LAKES

The Panel concludes that the project is not likely to have significant adverse effects on the water quality or aquatic ecosystems of Lake Huron or the other Great Lakes. This conclusion would also apply to MacPherson Bay during the preclosure phase of the DGR provided that mitigation measures, including the Panel's recommendations, are implemented.

Information presented to the Panel by OPG, CNSC, Environment Canada, Natural Resources Canada, Health Canada, the Ontario Ministry of the Environment and Climate Change, and the Ontario Ministry of Natural Resources demonstrated that:

- radiation releases from the project during preclosure and postclosure phases would be extremely low relative to current radiation levels and negligible relative to dose limits for the protection of the public;
- malfunctions, accidents, and malevolent acts during the preclosure phase would not have the potential to release sufficient radiation to exceed dose limits for the protection of the public;
- natural processes, barriers and physical laws present and active during the normal evolution of the postclosure phase could not produce the conditions that would result in exceedances of regulatory limits for the protection of the public;
- disruptive scenarios during the postclosure phase would expose humans present in the immediate vicinity of the DGR to some level of radiation, however, even the most extreme disruptive event would not result in exceedances of dose limits related to human uses of water from Lake Huron;
- information provided confirmed that Canada has met the notification requirement under the *Great Lakes Water Quality Agreement* with respect to the project;
- the project will not contribute significantly to any of the current primary risks to Lake Huron and the other Great Lakes;
- the project will not contribute to cumulative effects to Lake Huron, provided all discharges comply with statutes and regulations, notably the *Fisheries Act*; and
- there would be no significant adverse effects on the use by Aboriginal peoples of drinking water, fish or other species in Lake Huron due to radionuclides or other chemicals of concern.

The Panel is aware that notwithstanding its conclusion regarding the effects of the project on Lake Huron and the other Great Lakes, there will be people who maintain that such a project should never be located so close to any of the Great Lakes because of the extremely high value of the lakes to millions of people. The Panel respectfully suggests that such opinions are values-based rather than science-based. Values-based opinions have a legitimate role in decision-making and should be part of any discussion involving the Precautionary Principle and sustainability (see the Panel's comments on these topics in Chapter 3).

The Panel notes that some people, particularly Aboriginal people, may have concerns about effects on Lake Huron that are based upon their worldview and accompanying spiritual requirements regarding showing respect for the earth. This would include asking permission of the earth to construct the DGR. The Panel expects that such concerns will be part of the ongoing dialogue between OPG and Aboriginal peoples under the terms of various agreements. Further, the Panel expects that future licensing requirements for public engagement will include the respectful attention to such concerns from Aboriginal and non-Aboriginal peoples.

The Panel fully agrees that Lake Huron and the other Great Lakes are precious resources that demand society's highest level of protection and regard. To that end, the Panel applauds the efforts of Canadian and American federal, state, provincial, and municipal agencies, as well as First Nation, tribal, Métis, and private groups, as they address the primary risks to the lakes. The Panel notes that the future sustainability of the Great Lakes depends upon society's collective ability to reduce the significant stressors on the lake, notably invasive species, habitat disruption or destruction, non-point source pollution (particularly nutrients associated with algae blooms), and climate change. The relative position of the proposed project within the spectrum of risks to the Great Lakes is a minor one; albeit one that demands strict attention and regulation.

CHAPTER 15 CUMULATIVE EFFECTS

This chapter presents the Panel's evaluation and conclusions regarding whether there will be significant residual cumulative effects in relation to the project. The Panel's evaluation included consideration of OPG's assessment methodology, comments from government agencies, the review conducted by Dr. Peter Duinker, and the views of participants. The EIS Guidelines specifically directed OPG to address the management of decommissioning waste in its cumulative effects assessment. This explicit direction together with the Panel's requests for additional information on decommissioning waste are reflected in the attention given to this subject in this chapter. This chapter also presents some general Panel comments on the state of cumulative effects assessment as it is currently practiced in Canada under the *Canadian Environmental Assessment Act, 2012*.

15.1 OPG CUMULATIVE EFFECTS ASSESSMENT

This section includes an overview of OPG's cumulative effects assessment, including its methodology and results.

15.1.1 Methodology

OPG defined cumulative effects as the combination of incremental effects caused by the project with the effects caused by other projects or activities on-site and off-site, including past, present and reasonably foreseeable projects. OPG stated that its method for assessment of cumulative effects was consistent with the EIS Guidelines and the Canadian Environmental Assessment Agency's *Cumulative Effects Assessment Practitioners Guide, 1999* (the Practitioners Guide).

OPG's methodology involved the following steps:

1. Carry forward the likely residual adverse effects on valued ecosystem components as well as beneficial effects from the assessment of effects of the project
2. Identify other projects that have the potential to act cumulatively with the project
    - Past and existing projects and activities
    - Effects captured under OPG's assessment of existing conditions
    - Certain/planned projects and activities
    - Approved projects yet to start construction and/or operations
    - Projects which are well advanced in the planning process but have not yet been approved
    - Reasonably foreseeable project and activities
    - Projects which have started in the approval process and are on the path to obtaining approval
    - Small routine activities (e.g., routine building and infrastructure upgrades)
    - Emplacement of decommissioning waste (required by the EIS Guidelines)
3. Assess the cumulative effects
4. Identify residual adverse cumulative effects and assess for significance

OPG stated that malfunctions and accidents were considered too rare to be assessed together with those caused by normal operational activities. OPG's assessment of malfunctions and accidents is presented and reviewed in Chapter 10. OPG determined that credible malfunctions and accidents would not be likely to cause significant adverse effects.

OPG carried forward residual adverse effects on the following valued ecosystem components that were predicted to be caused by the project:

Surface water quantity and flow: a 31% reduction in surface water quantity and flow in the North Railway Ditch upstream of Stream C and a 114% increase during site preparation and construction and 61% increase during operations in surface quantity and flow in the drainage ditch at Interconnecting Road

Eastern white cedar: loss of eastern white cedar in the Project Area during site preparation and continuing through the project life

Burrowing crayfish: a portion of habitat in the South and North Railway Ditches as well as other ditches adjacent to the abandoned rail spur in the western portion of the Project Area would be removed during site preparation and construction

Redbelly dace, creek chub, variable leaf pondweed and benthic invertebrates: a portion of non-critical habitat would be removed in the South Railway Ditch during construction of the rail bed crossing

Air quality: an increase in concentrations of air quality indicators during site preparation, construction, operations and decommissioning phases

Noise levels: an increase in noise levels during site preparation and construction and decommissioning phases

Human Health: effects to overall health for local residents and members of Aboriginal communities resulting from exposure to acrolein in air during the site preparation and construction phase

Aboriginal Heritage Resources: a reduction of the quality or value of ceremonial activities at the Jiibegmegoong burial site from changed aesthetics and temporary dust and noise

Humans and non-human biota: exposure to radiation: radiological emissions produced by the project (this was included despite no residual adverse effects being identified for the project)

Social Assets: a change in noise levels in the Baie du Doré area resulting in reduced enjoyment and use of personal property during site preparation and construction and decommissioning phases

OPG identified several beneficial effects of the project to the socio-economic valued ecosystem components (see Chapter 11); however, it did not assess the potential for cumulative beneficial effects. Cumulative effects assessment under the *Canadian Environmental Assessment Act, 2012* must consider residual adverse biophysical effects that could combine with past, present or reasonably foreseeable projects to affect socio-economic valued ecosystem components; however there is no requirement to carry forward beneficial effects.

OPG identified 19 past and existing projects, 6 certain and planned projects and 6 reasonably foreseeable projects and activities for consideration within the cumulative effects assessment and screened these projects or activities according to whether they would result in the same type of environmental effects, occur at the same time, or affect the same geographic location (figure 40) as the residual adverse effects of the project Application of these screening criteria resulted in different projects and activities being carried forward for different valued ecosystem components. The Bruce A and Bruce B nuclear generation station operations and refurbishment, WWMF operation including incineration and future upgrades, the Bruce to Milton transmission line, municipal/county road upgrades, additional transmission, and the centre of site (all facilities required to support the operation of the Bruce nuclear site) additions and modifications had the most frequent overlaps in type of effect over time and space across the valued ecosystem components. The EIS guidelines required the inclusion of the expansion of the DGR to accommodate decommissioning wastes.

15.1.2 OPG Cumulative Assessment Results

OPG did not identify any overlaps between other projects and the DGR project with respect to surface water quantity and flow. Surface water quality was not carried forward to the cumulative effects assessment because OPG determined that there would be no residual adverse effects on this valued ecosystem component. OPG assumed that the stormwater management system would be completely effective in diverting surface water drainage away from Stream C, Baie du Doré, and the wetlands on the project site as well as in achieving compliance with water quality discharge criteria prior to discharge to MacPherson Bay.

OPG considered that overlaps of effects on eastern white cedar would occur with additions to the centre of site facilities. The additional land clearing and habitat loss were described by OPG as small and not likely to result in adverse cumulative effects. OPG stated that expansion of the project to accommodate decommissioning wastes would not require any additional land clearing.

OPG determined that WWMF upgrades or the Western Used Fuel Dry Storage Facility expansion could interact with residual adverse effects for aquatic species in the South Railway Ditch as well as burrowing crayfish in the North and South Railway Ditch. However, OPG pointed out that if the DGR was constructed, there would be a decreased requirement for new buildings at the WWMF. An additional rail bed crossing over the South Railway Ditch may be constructed as part of the Western Used Fuel Dry Storage Facility expansion; however, the cumulative disturbance (40m) would be small relative to the total length of the ditch (1,250m), resulting in a low magnitude effect that would be mitigated using the same mitigation measures described for the project. Therefore, OPG found that the WWMF upgrades and Western Used Fuel Dry Storage Facility expansion would not be likely to cause cumulative effects on the redbelly dace, creek chub, variable leaf pondweed, burrowing crayfish and benthic invertebrates.

Eleven projects were identified that could act cumulatively with the DGR project with respect to emissions of particulate matter and combustion products to air, including 5 existing projects, three certain/planned projects and three reasonably foreseeable projects. Since residual

1	Bruce A (Operation and Refurbishment)	14	Commercial Fisheries
2	Bruce B (Operation)	15	Aboriginal Fisheries
3	Western Waste Management Facility (WWMF) (Operation and Decommissioning)	16	Heavy Water Plant Decommissioning
4	Western Used Fuel Dry Storage Facility (WUFDSF)	17	Hydro One Switchyard Operations and Maintenance
5	Centre of Site Facilities	18	Inverhuron Provincial Park
6	Bruce Eco-Industrial Park	19	Bruce to Milton Transmission Line
7	Douglas Point Nuclear Generating Station (Decommissioning)	20	Bruce A Decommissioning and Safe Storage
8	On-site Landfill	21	Bruce B Decommissioning and Safe Storage
9	Ripley Wind Farm	22	RWOS1 Safe Storage
10	Huron Wind Farm	23	WWMF Upgrade
11	Enbridge Wind Farm	24	Municipal County Road Upgrades
12	Water Supply Plants (WSPs)	25	WUFDS Expansion
12a	Kincardine WSP	26	Bruce B Refurbishment, Continued Operations, Decommissioning and Safe Storage
12b	Southampton WSP	27	Additional Transmission
13	Water Pollution Control Plants (WPCPs)	28	Additional Wind Power
13a	Bruce Eco-Industrial Park Sewage Processing Plant	29	Centre of Site Additions and Modifications
13b	Kincardine WPCP	30	Transfer of fuel to long-term repository
13c	Port Elgin WPCP	31	DGR for Decommissioning Waste at Bruce nuclear site
13d	Southampton WPCP		

Figure 40:General Location of other Projects and Activities Considered in the Cumulative Effects Assessment (reproduced from DGR EIS Figure 10.4.1)

LEGEND

- Site Study Area [1]
- Project Area (OPG-retained lands that encompass the DGR Project)

NOTE

1. Site Study Area is defined by EIS Guidelines as: "includes the facilities, buildings and infrastructure at the Bruce nuclear site, including the existing licensed exclusion zone for the site on land and within Lake Huron, and particularly the property where the Deep Geologic Repository is proposed.

REFERENCE

Base Data Provided by 4DM, November 2007.
Imagery and Topo Collected and Processed by Terrapoint Canada Inc., Acquisition Date: Nov. 12, 14, and 15, 2006, Ground Resolution: 0.25m,
Datum: NAD 83 Projection: UTM Zone 17N

0 125 250 500 750 1,000
Metres

PROJECT
DGR PROJECT
ENVIRONMENTAL IMPACT STATEMENT

TITLE
GENERAL LOCATION OF OTHER PROJECTS AND ACTIVITIES CONSIDERED IN THE CUMULATIVE EFFECTS ASSESSMENT

Golder Associates
Mississauga, Ontario

PROJECT NO. 6-1112-037			SCALE: AS SHOWN	R000
DESIGN	ASB	03 Aug. 2006	FIGURE 10.4-1	
GIS	BC	28 Jun. 2010		
CHECK	KC	28 Jun. 2010		
REVIEW	MAR	28 Jun. 2010		

adverse effects on human health would be as a result of changes in air quality, OPG considered cumulative effects on human health through its assessment of air quality. OPG pointed out that the air quality model used for assessment of effects of the project on air quality already included emissions from Bruce A and Bruce B, the WWMF and the centre of site facilities. Furthermore, OPG stated that emissions from operations of the industries in the Bruce eco-industrial park and vehicle emissions were likely captured in the background air quality that was added to the model predictions. Accordingly, OPG determined that emissions from these projects and activities would not be likely to result in measurable cumulative effects beyond those already captured in the modelling.

OPG determined that construction activities for the Western Used Fuel Dry Storage Facility expansion and the refurbishment of Bruce B would not produce measurable cumulative effects to air quality. The environmental assessment completed for the Western Used Fuel Dry Storage Facility expansion indicated that dust and particulates would be well below Ontario Ministry of the Environment and Climate Change criteria and that the release of dust and particulates would be of very short duration. The refurbishment of Bruce B was considered in the environmental assessmentfor the New Fuel Project for Bruce B, which included effects of construction activities for refurbishment and determined that there would be no residual adverse effects associated with particulates or combustion products.

OPG ruled out cumulative effects on air quality from management of decommissioning waste at the DGR because it assumed that the decommissioning wastes would be placed after completion of the operations phase and installation of the closure walls in the current DGR layout. OPG predicted, therefore, the air quality effects from the construction of emplacement rooms for decommissioning wastes would not overlap with air quality effects of the project.

OPG assumed that cumulative effects of centre of site additions and modifications on air quality would be mitigated with the implementation of best management practices, resulting in no measurable cumulative effect in the Local Study Area.

OPG identified four existing projects, two certain/planned projects and two reasonably foreseeable projects that could act cumulatively with the DGR project with respect to noise levels. Since the potential adverse cumulative effects on the socio-economic environment would be as a result of changes in noise levels, OPG considered these effects through its assessment of cumulative effects on noise. OPG explained that current noise levels on-site and at the receptor locations included the effects of the existing operations of Bruce A and Bruce B, the Huron Wind Farm and Hydro One switchyards. Therefore, these existing and ongoing noise emissions would not likely result in additional cumulative effects.

OPG ruled out cumulative effects on noise levels from Bruce B refurbishment or Bruce A and B decommissioning activities because the environmental assessmentfor the New Fuel Project for Bruce B did not identify residual adverse effects on noise levels, and noise levels during decommissioning were expected to be similar to those during refurbishment.

OPG assumed that cumulative effects of centre of site additions and modifications on noise levels would be mitigated with the implementation of best management practices. Furthermore, these activities were described as being much smaller in scale than the DGR project and would occur for a shorter duration. Therefore, OPG determined that there would be no cumulative effects at the noise receptor locations used in the environmental assessment.

No residual adverse effects were identified for exposure to radiation and radioactivity from the DGR project; however, OPG considered that there could be additive effects with radiological effects from other projects. Seven existing projects, five certain/planned projects and four reasonably foreseeable projects, including the transfer of used fuel off the Bruce nuclear site to a long-term repository, were identified as having the potential to act cumulatively with the project.

The public dose estimates for the DGR project were less than 1 µSv/yrr. The annual dose to the public from activities on the Bruce nuclear site was approximately 4 µSv/yr based on data from 2009 reported to CNSC. This dose included releases from Bruce A, Bruce B, WWMF, the Western Used Fuel Dry Storage Facility, centre of site facilities, Douglas Point and Radioactive Waste Operation Site 1 facilities. OPG assumed that the dose from the refurbishment of Bruce B would likely be similar to that experienced during the refurbishment of Bruce A. Site upgrades were assumed to be unlikely to produce a measurable dose compared to other emissions on-site. The public dose estimate for the transfer of used fuel off the Bruce nuclear site was less than 0.2 µSv/yr. Therefore, OPG determined that there would no adverse cumulative effect with respect to exposure to radiation and radioactivity.

The Panel assumes that since the residual adverse effects on Aboriginal heritage resources (specifically the Jiibegmegoong burial site) carried forward into the cumulative effects assessment were related to changes in aesthetics, dust and noise, OPG's assessment of cumulative effects on dust and noise levels summarized above would also apply to the burial site and no residual adverse cumulative effects would be expected. However, the Panel notes that OPG did not explicitly describe the assessment of cumulative effects on aesthetics associated with effects on Aboriginal heritage resources.

15.1.3 Potential Expansion of the DGR to Accommodate Decommissioning Waste

The EIS Guidelines specifically identified the management of decommissioning waste as a reasonably foreseeable potential future project that should be addressed by OPG. As such, OPG considered the expansion of the DGR and placement of decommissioning waste in the DGR in its cumulative effects assessment. OPG stated that the total decommissioning waste from the Pickering, Darlington and Bruce nuclear generating stations would require a future approval for an approximate doubling of the underground capacity of the DGR from approximately 200,000 m^3 to approximately 400,000 m^3. OPG determined that expanding the DGR to accommodate decommissioning waste would not result in cumulative effects on the environment.

During the hearing in September 2013, OPG informed the Panel that the decommissioning of the Pickering nuclear generating station was expected to take place earlier than had been anticipated in the EIS. Thus, a decision by OPG to seek a licence to expand the DGR to accommodate the associated decommissioning waste could be required earlier than had been assumed. This change in timing and the impact of that change on the information originally provided in the EIS created confusion and concern for some participants, who interpreted this information as having an immediate impact on the project being reviewed by the Panel.

Other than timing, OPG stated that no other major aspects associated with the placement of decommissioning waste had changed. OPG re-affirmed its cumulative effects assessment results that were reported in the EIS.

In order to supplement the information already on the record regarding decommissioning waste and a possible future expansion of the DGR, the Panel requested additional details, including: a technical assessment for the disposal of all decommissioning waste; the anticipated timing of any expansion activities; conventional safety of occupied spaces for extended timelines; short-term and long-term safety implications of expanding the DGR; and maximum doses for each Disruptive Scenario. This analysis was required to address the EIS Guidelines requirement that OPG include the management of decommissioning waste in its cumulative effects assessment. The Panel hoped that this information would also provide participants with a better understanding of the analysis by OPG in support of that assessment.

The Panel acknowledges that any reference to the expansion of the DGR in this chapter is subject to the fact that any such expansion is conceptual at this time and would be subject to regulatory approval and CNSC licencing requirements should OPG someday decide to make such an application. OPG did not present the information to seek approval for the expansion of the proposed DGR.

15.1.4 OPG's Technical Assessment of Conceptual DGR Expansion to Accommodate Decommissioning Waste

OPG stated that information provided in its technical assessment showed that expansion could be achieved without major changes to the DGR facility infrastructure or safety case. OPG emphasized that further analysis would be required in support of a licence application and regulatory approvals prior to expansion.

OPG stated that the conceptual expansion would remain within the DGR project fence line, and that DGR surface and underground systems, structures, and facilities would be used for construction and operation. All emplacement activities would cease prior to the commencement of any expansion activities in the underground repository.

Timing of Expansion of the DGR

OPG stated that there would be a broad range of time from the mid 2030's to the mid 2060's in which OPG may take the business decision to apply for a licence to expand the DGR to accommodate decommissioning waste. OPG presented both an "early" and a "late" scenario.

OPG explained that, in the early scenario, OPG would make the decision to seek approval to expand the DGR near the end of 2035 and, if licensed, the repository would be available to receive decommissioning L&ILW in 2044. OPG noted that this would be the earliest start date for Pickering nuclear generation station decommissioning. In the early scenario, decommissioning waste would not require sustained interim storage at the reactor site or at the WWMF.

In the late scenario, OPG would make the decision to seek a licence to expand the DGR in the 2060’s at the end of the proposed DGR operations period. OPG stated that, at that time, it would consider various options for the long-term management of decommissioning L&ILW and then make a decision on whether to send the decommissioning wastes to the DGR, subject to regulatory approval of the expansion and receipt of the required licence. OPG explained that, in the late scenario, Pickering decommissioning L&ILW would be placed in interim storage (if the decision was to place it in the DGR) or alternative means for disposal would be identified.

Underground Features

OPG presented a conceptual expansion that included development of two additional panels having a total of 32 emplacement rooms and extended ventilation tunnels (Figure 41). OPG stated that the expansion would accommodate the disposal of additional waste while minimizing changes to the infrastructure and operational features of the current proposed DGR. All expansion excavations would be constructed at the same depth as the current proposed DGR within the Cobourg Formation. OPG noted that the host Cobourg Formation is present beneath the entire Bruce nuclear site and was expected to accommodate such an expansion (Figure 42). OPG further noted that the suitability of the geosphere would have to be confirmed by drilling a minimum of three additional deep boreholes outside the footprint of the expanded repository.

OPG expected that underground service areas used during construction of the DGR could be re-established for the expansion process. The ventilation system airflow would be returned to the higher capacity required for construction. OPG expected that airflow requirements would be similar to those required during the original DGR construction and that the major ventilation equipment installed during the initial construction of the DGR would be suitable for use during expansion. The waste rock handling system would have to be re-established via re-installation or refurbishment.

OPG presented two conceptual development scenarios that could minimize both construction and operations intervals for the DGR expansion, based on the timing described above. OPG described sequencing, design and reinforcement measures that could be applied to ensure the short-term integrity of expansion sites throughout construction and future operations phases. OPG stated that, by limiting the duration of expansion activities and using appropriate ground support measures, potential worker exposure to conventional occupational hazards and radiologic sources during any DGR expansion could be mitigated.

OPG stated that the protection of workers from radiation would be a component of the design planning process for any conceptual expansion. OPG stated that, for both conceptual scenarios, the ventilation network design would remain generally unchanged from the proposed DGR. OPG expected that it could extend access and exhaust ventilation tunnels surrounding room panels to maintain the integrity of the ventilation system and closure plugs. OPG explained that barriers could be used to prevent worker access to filled emplacement rooms and that the ventilation system could be deactivated using closure walls. Fresh ventilation air would then circulate only to worker accessible areas to permit continuing waste emplacement operations.

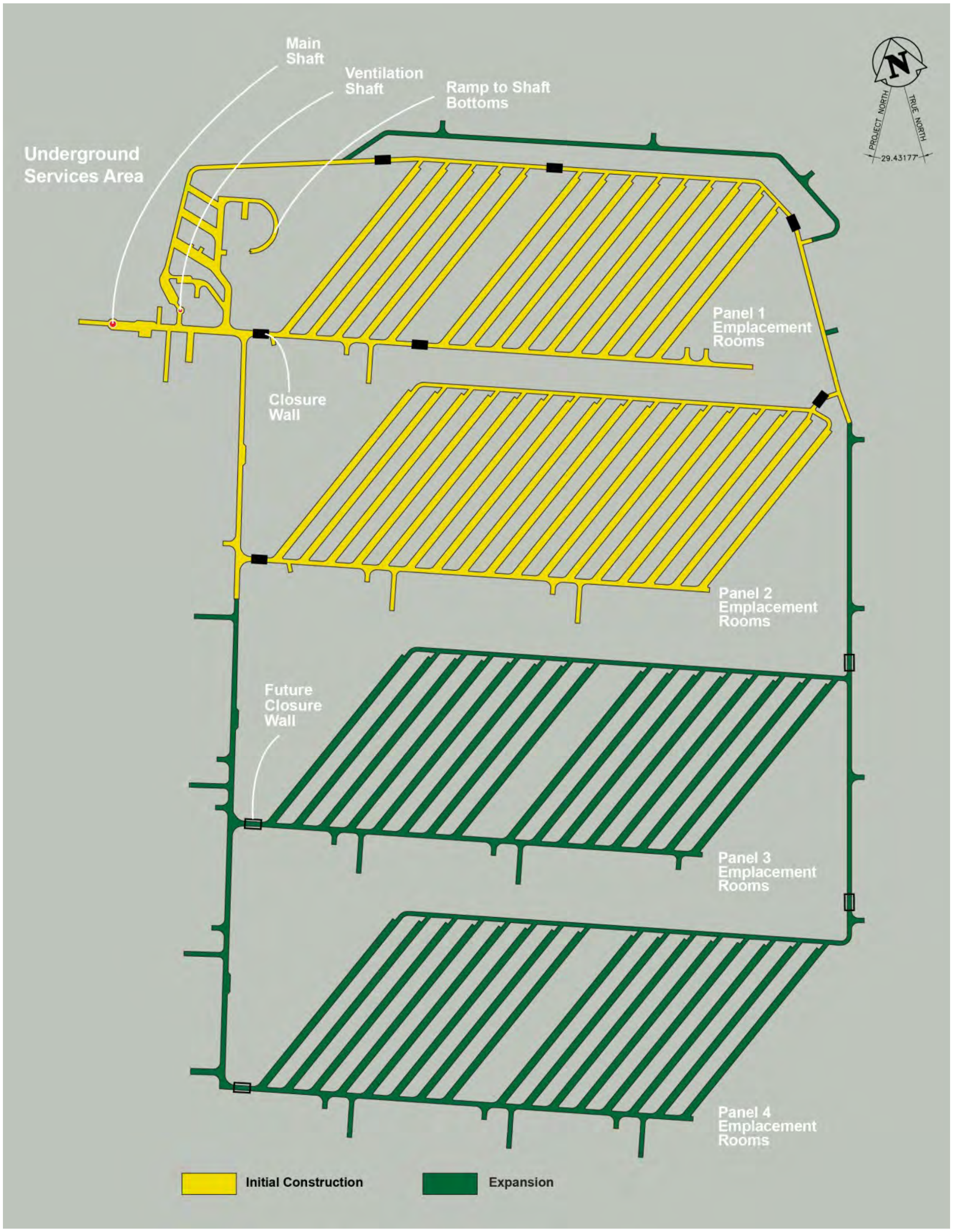


Figure 41: OPG's DGR for L&ILW – Conceptual Expansion Layout (reproduced from OPG Consolidated IR Responses, EIS-12-512 Attachment A Figure 2)

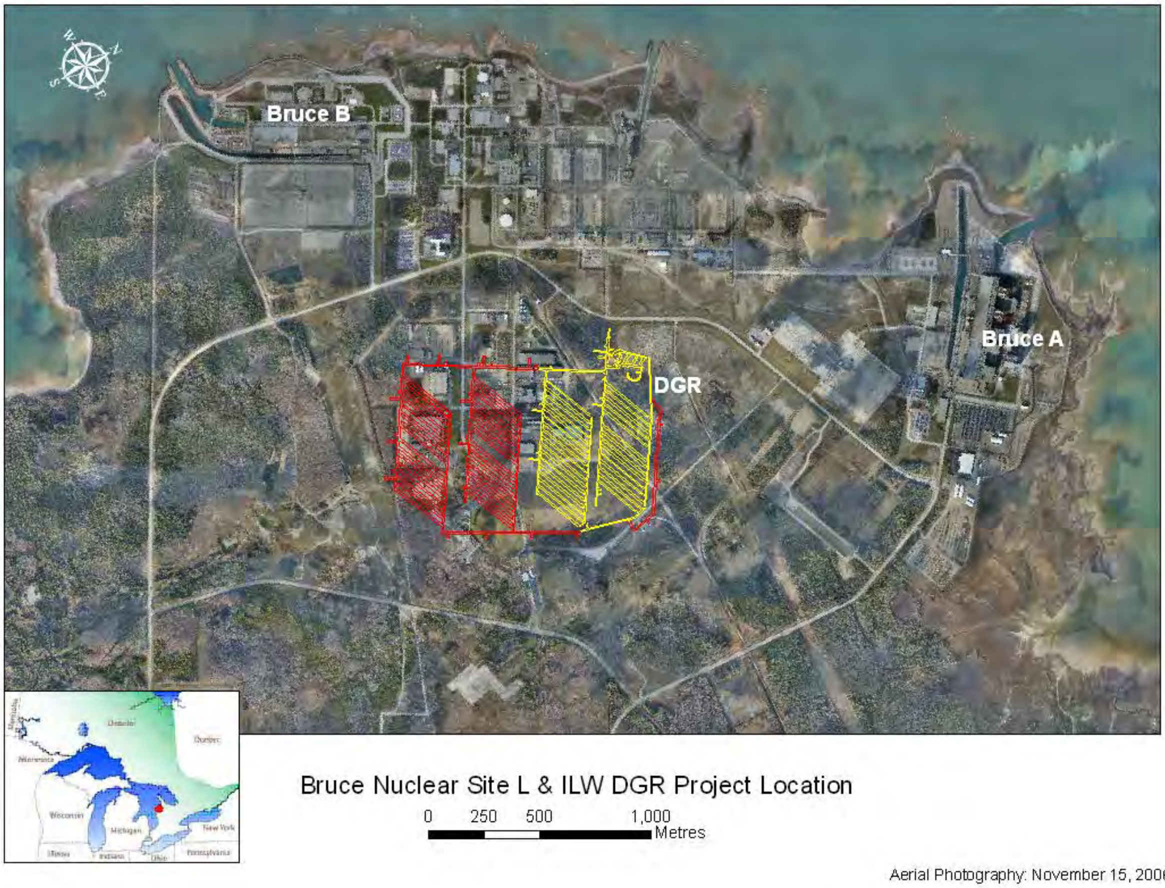


Figure 42: Relative Positioning of the Expansion Layout (reproduced from OPG Consolidated IR Responses, EIS-12-512 Attachment A Figure 3)

OPG predicted that, should the DGR be expanded, the height of the waste rock management area would increase by about 20 metres to a total height of 35 m, and that the footprint area would increase by approximately 2 ha, from 9 ha to 11 ha. OPG stated that the stormwater management pond would be sufficient to handle the surface runoff and underground water discharge that would occur during the construction and operation of the expanded repository. OPG did not anticipate any change in the quality and quantity of water pumped to the surface; however, should there be a need to increase the holding capacity of the stormwater management pond, OPG stated that there would be sufficient space to the south-west to extend the pond. OPG expected that any water treatment processes deemed necessary could be installed and commissioned prior to the start of expansion. OPG expected that the removal of fine sediments from the stormwater management pond, which would be part of its ongoing operational management, would involve the retention of fines within the project site or the Bruce nuclear site. OPG stated that, should there be a need to dispose of the fines off-site, they would be sampled and analyzed for identification of any required off-site waste management measures (Figure 43).

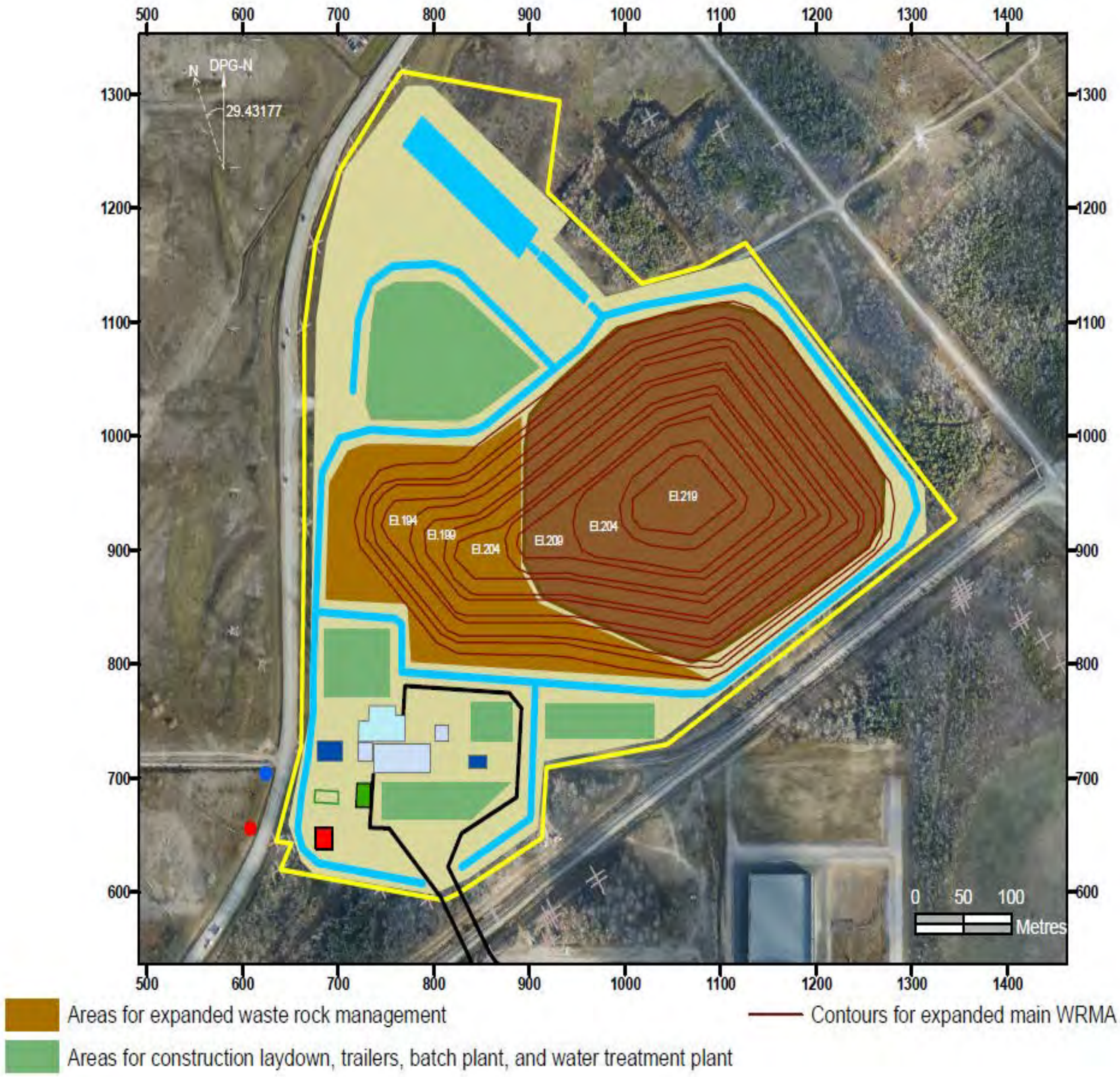


Figure 43: Expansion Surface Layout (reproduced from OPG Consolidated IR Responses, EIS-12-512 Attachment A Figure 4)

OPG expected that there would be either no effects or minor effects on surface services such as electrical supply, service water, or underground dewatering.

OPG stated that emissions to the surface environment during the construction of an expanded repository, including dust and noise, would be similar to those that would occur during the initial construction. OPG stated that the monitoring and mitigation planned for initial construction would also be implemented during expansion.

OPG expected that air emissions due to the operation of an expanded repository would be similar to the emissions from Panels 1 and 2 of the proposed DGR because: most of the rooms in Panels 1 and 2 would be isolated by closure walls; the characteristics of the wastes would be sufficiently similar to currently proposed wastes; and, the sequence of waste emplacement operations would be similar to the sequence used during initial operations (i.e., a small number of active rooms, minimal ventilation through waste-filled rooms and periodic isolation of a series of waste-filled rooms with closure walls).

Wastes Arising from Decommissioning

As part of its cumulative effects assessment OPG described the nature of decommissioning waste. OPG estimated that decommissioning wastes would be approximately 10-20% intermediate-level waste by volume, which would be comparable to the 20% intermediate-level waste volume from operations and refurbishment for the proposed DGR. OPG pointed out that the exact volume ratios would depend on the waste treatment and volume reduction options available at the time of decommissioning.

OPG stated that low level-waste from decommissioning would be expected to include the same lightly contaminated tools, cleaning materials and other supplies as operations waste. It would also include large amounts of materials from the dismantling of facility systems, structures and buildings.

OPG stated that intermediate-level waste from decommissioning would include components from dismantling reactor systems and immediate structures, similar to irradiated core components and retube wastes currently received at the WWMF. OPG noted that the intermediate-level waste would not be expected to include significant amounts of ion exchange resins as these would have been removed at station shutdown. OPG further noted that intermediate-level waste from decommissioning would contain a similar high proportion of metal, as with intermediate-level waste from refurbishment, and would also have higher activity steel from the reactor core.

OPG stated that the waste types from decommissioning would be similar to those arising from operations and refurbishment, but would differ in amounts and in key radionuclides. OPG explained that the inventories of certain radionuclides were expected to be higher for decommissioning waste due mostly to the presence of Ni-63, which is a component of activated stainless steel associated with the reactor core. Other radionuclides predicted to be present in higher amounts were activation products in metal such as Ni-59 (101,000 year half-life), Ni-63 (100 year half-life), Fe-55 (2.7 year half-life) and Co-60 (5.3 year half-life) as well as activation products in concrete such as Cl-36 (301,000 year half-life) and Ca-41 (102,000 year half-life).

OPG noted that the radionuclide inventory of decommissioning waste, over time, would reflect the shorter half-lives of many radionuclides present in intermediate-level waste (Figure 44).

Implications of Expansion on Short-Term DGR Safety

OPG stated that it had applied a holistic planning approach to the project since the initial conceptual design phase, and that it would continue to apply this approach for any potential expansion. Thus, key construction and operational aspects, including extending the operational life, were assessed for potential effects of an expanded DGR.

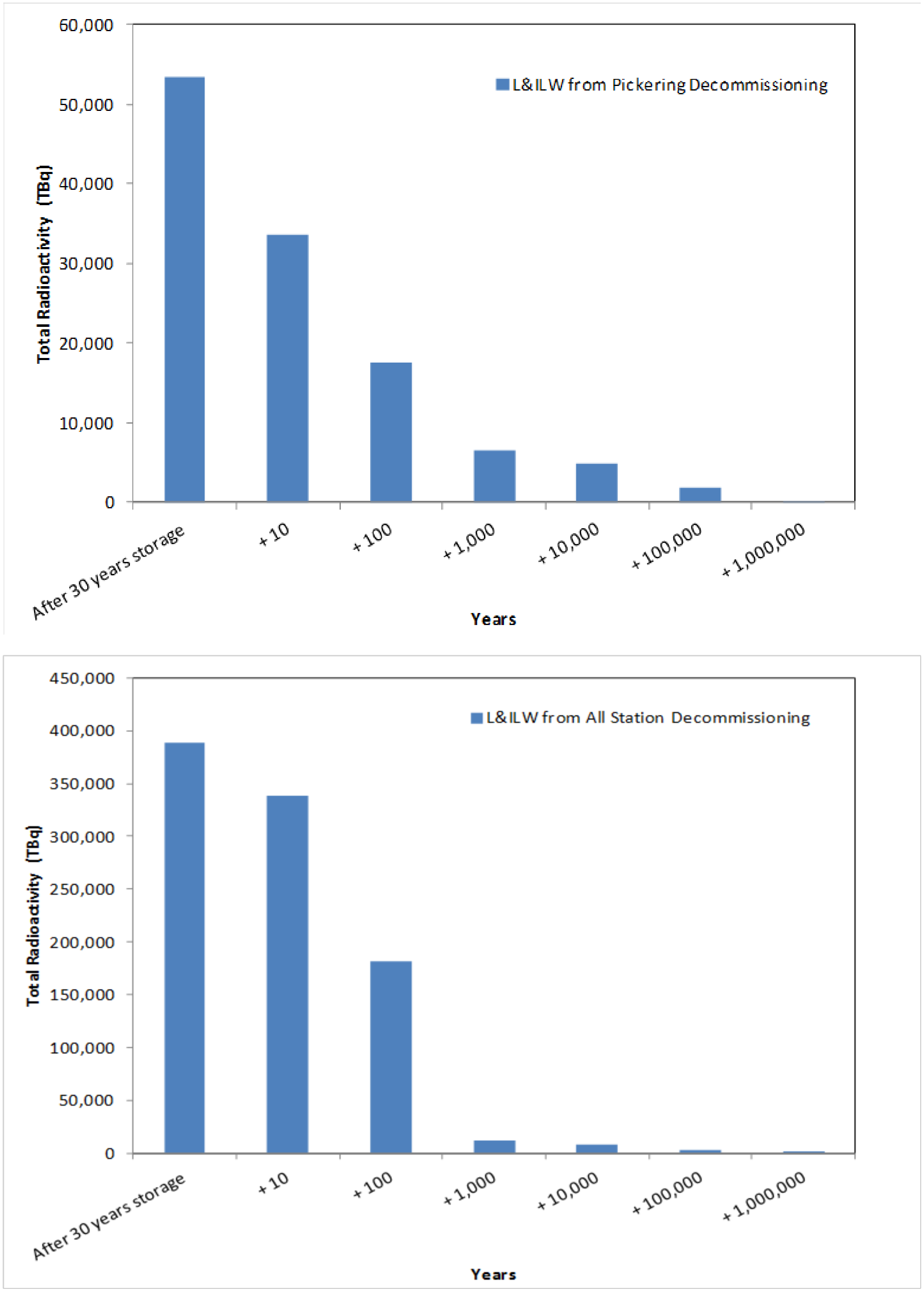


Figure 44: Total and Projected Radionuclide Inventory of L&ILW from Decommissioning (top: Pickering stations; bottom: all stations) (reproduced from OPG Consolidated IR Responses, EIS-12-512 Attachment A Figure 5)

OPG explained that additional site characterization, to at least the same level of detail as with the current application, would be required to support an application to expand the DGR. OPG noted that if variations in the lateral and vertical extent of the Cobourg Formation were identified, the implications would be evaluated in terms of any future decision to proceed with expansion. OPG further noted that a precise determination of the required additional site characterization could only be made if and when OPG applies for expansion approval.

OPG stated that it designed the excavations for the proposed DGR to have a nominal 100-year life. OPG expected that this would ensure that difficult-to-replace structures such as shaft headframes and concrete shaft liners would remain operational during the placement of decommissioning waste. OPG noted that it would consider the need for refurbishing and/or replaceing other structures, systems, equipment and components that have shorter design lives.

OPG listed a number of measures that would ensure the integrity of occupied underground spaces throughout the life of the DGR. These measures would address issues such as corrosion of rock bolts and cable bolts, monitoring of rock deformation/movement, and replacement of rock support systems after a nominal 60 years. OPG noted that these measures could continue to be applied should the DGR be expanded.

OPG stated that the characteristics of decommissioning waste that would most affect safety would be the higher radionuclide inventory and the larger amounts of concrete and metal. OPG expected that inhalation dose, largely from tritium and carbon-14, would be similar to or less than from waste arising from operations and refurbishment. However, the external irradiation dose from Co-60 in decommissioning wastes would require mitigating measures such as shielding or greater stand-off distance. OPG did not expect differences in waste package off-gassing during the conceptual operations phase compared to that expected from the proposed DGR. OPG noted that all waste packages would have to meet DGR waste acceptance criteria. OPG expected that its design of the repository ventilation systems would adhere to ALARA principles, and would keep workers in the fresh air supply and minimize worker exposure to radiation.

Implications of Expansion on the Long-Term DGR Safety Case

OPG did not expect that either mixing or segregating decommissioning wastes from operational and refurbishment wastes would create a significant postclosure safety advantage. OPG explained that the exact sequencing of emplacement rooms for expansion would depend, in part, on the timing of nuclear power plant decommissioning. OPG stated that, should waste from decommissioning be received before Panel 1 is completely filled, it would be practical to place waste in Panel 1 first.

OPG noted that the gas generation potential in L&ILW from decommissioning, due to waste degradation over the long term, could be larger than that from operations and refurbishment due to higher metal content. OPG stated that this would have to be taken into account in the repository design and safety assessment supporting the safety case for expansion. OPG suggested that metals and organics that reside in the low-level waste from decommissioning may be reduced through future volume reduction and/or decontamination and recycling technologies. OPG also noted that increased space may be required to accommodate gas generation from decommissioning L&ILW.

OPG stated that the main differences in sources of risk between the currently proposed DGR project and a future expansion to accommodate decommissioning waste would be from the increased total radionuclide inventory, the increased repository footprint, and the increased gas generation from metal. OPG calculated that adding decommissioning waste to an expanded repository would result in a postclosure peak dose approximately double the dose calculated for the proposed DGR. OPG stated that the most important radionuclides in terms of the higher dose scenarios for the long-term safety case were carbon-14 and Nb-94, and noted that decommissioning wastes would have roughly similar amounts of these radionuclides compared to amounts in the currently proposed project.

OPG determined that the higher amounts of other radionuclides such as Ni-59, Ni-63, and Cl-36 in decommissioning waste had a limited effect on calculated peak doses because of the dominance of carbon-14, Nb-94, or Zr-93/Nb-93m in determining the total dose. Table 7 shows differences in percentage contribution to maximum calculated effective doses between the proposed DGR and a conceptual expanded repository containing decommissioning waste for the four disruptive scenarios.

Table 7: Percentage Contribution to Maximum Calculated Effective Doses for Selected Radionuclides in Wastes (information reproduced from OPG Consolidated IR Responses, EIS-12b-512 clarification, Table 1)

Radionuclide	**Human Intrusion**		**Severe Shaft Seal Failure**		**Poorly Sealed Borehole**		**Vertical Fault**	
	Proposed DGR	With Decom. Waste	Proposed DGR	With Decom. Waste	Proposed DGR	With Decom. Waste	Proposed DGR	With Decom. Waste
C-14	0.007	0.004	~100	~100	<0.001	<0.001	<0.001	<0.001
Ni-59	0.016	0.72	<0.001	<0.001	0.007	2.7	<0.001	0.003
Cl-36	0.092	2.5	<0.001	<0.001	0.25	5,6	0.005	0.076
Zr-93/Nb-93m	0.005	0.008	<0.001	<0.001	96.1	90.6	99.6	99.8
Nb-94	99.1	83.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Notwithstanding the differences between the proposed DGR and a conceptual expanded DGR, in both cases, OPG's calculated postclosure maximum doses were many orders of magnitude below the dose criterion of 0.3 mSv/yr for the normal evolution scenario and within the risk criterion of 1 in 100,000 for disruptive scenarios.

OPG emphasized that its assessment of the expansion scenario was very preliminary. OPG noted that an application for a licence to expand the DGR would have to be supported by detailed waste characterization and a full safety assessment using a detailed repository expansion design.

15.2 OPG'S SUMMARY STATEMENTS REGARDING SIGNIFICANCE OF CUMULATIVE EFFECTS

OPG found no residual adverse cumulative effects on the environment from any phase of the DGR project plus existing, planned or reasonably foreseeable projects; therefore, in the opinion of OPG, no assessment of significance was required. OPG referred to implementing follow-up monitoring to confirm that adverse effects do not occur. OPG also reiterated its commitment to in-design mitigation measures as further assurance that cumulative effects would not occur.

OPG stated that the conceptual expansion of the DGR to accommodate decommissioning waste would have no adverse cumulative effects on the environment, short-term safety, or long-term safety. OPG noted that there would be a broad range of time for adaptive management decisions to be made regarding decommissioning waste.

15.3 GOVERNMENT AGENCY EVALUATIONS OF OPG'S CUMULATIVE EFFECTS ASSESSMENT

CNSC stated OPG's cumulative effects assessment had met all of the requirements and had satisfied CNSC expectations as documented in the EIS guidelines. CNSC stated that OPG's cumulative effects assessment adequately demonstrated that there would be no likely adverse cumulative effects on the environment as a result of the DGR project. The assessment was described by CNSC as a broad quantitative and qualitative assessment of the likely effects of the existing, planned and future projects at or in the vicinity of the DGR project site.

CNSC requested additional information about the cumulative effects on DGR project workers from exposure to radiation and radioactivity. OPG's response included the statement that cumulative doses to individual workers would be ascertained through OPG's dosimetry program and doses would be kept below CNSC regulatory limits as well as As Low As Reasonably Achievable (ALARA) objectives. OPG reported that the annual cumulative radiation dose to nuclear energy workers would be well below the CNSC regulatory limits and that no additional mitigation would be required.

OPG also expected that non-nuclear energy workers would receive cumulative doses less than the 1 mSv/yr dose limit for the general public assuming 2000 working hours per year. OPG noted that the dose rate had always been less than 0.5 µSv/hr at the perimeter of the WWMF, and that measured tritium levels would lead to a low inhalation dose rate. CNSC added that tritium in air concentrations measured at the Bruce nuclear site would result in doses less than 0.0002 mSv/yr. CNSC staff determined that there would be no likely adverse cumulative effects from radiation and radioactivity.

CNSC evaluated the safety implications of the theoretical expansion of the DGR to accommodate decommissioning waste in terms of:

- effect of changes in timeline;
- characteristics and inventory of wastes from decommissioning;
- possible mitigations such as decontamination and recycling of low level metal, changes to waste containers, additional shielding;
- application of experience from the DGR project;
- possible modifications of containers to meet radiation protection requirements; and,
- sampling and testing needed near the area of expansion of the repository.

CNSC determined that expansion of the DGR to accommodate decommissioning waste would not produce significant incremental adverse effects on the environment during construction, operation, closure or postclosure. The basis for this determination was that there would be similar activities, emissions (e.g., of dust and noise), and mitigation during construction and operation and no change in concept performance during postclosure. Furthermore, CNSC pointed out that all activities would have to remain within regulatory requirements to ensure safety and environmental protection.

CNSC stated that the additional information and clarifications provided by OPG regarding decommissioning waste characterization, radionuclide inventory, and timelines did not change the predicted effects of the DGR project expansion relative to what had already been described in the EIS. CNSC determined that expansion of the DGR project remained a reasonably foreseeable project that was adequately described and assessed conceptually for the purposes of cumulative effects assessment.

Environment Canada noted that its comments and recommendations regarding surface water quantity and quality, air quality, accidents and malfunctions, migratory birds, and species at risk incorporated cross-cutting environmental assessment considerations such as cumulative effects and climate change (in the context of effects of the environment on the project). Environment Canada stated that the stormwater management system must be designed to handle expansion for decommissioning waste. Environment Canada re-iterated its recommendation that the maximum flood hazard assessment and design of the stormwater management system be re-visited in light of the effects of climate change. It was also noted that timing and cessation of water treatment would be different in the case of DGR expansion for decommissioning waste because leachate contaminant levels produced by the waste rock management area would take longer to decline.

Natural Resources Canada stated that the information provided by OPG in its responses to information requests regarding decommissioning wastes did not change its conclusions in relation to the DGR project from a geology, hydrogeology and seismic hazard perspective. Natural Resources Canada examined OPG’s response related to contingencies for unexpected variation in lateral and vertical extent of the Cobourg Formation and was of the view that significant variations in the Cobourg Formation were unlikely.

The Ontario Ministry of the Environment and Climate Change stated that the information previously provided by the Ministry addressed decommissioning wastes in terms of the types of provincial environmental approvals that would be required. The Ministry stated that an application for approval of an expanded DGR would be evaluated against the same environmental standards which had previously been identified. The Ministry expected that it would be consulted prior to submission of an application for expansion of the DGR.

15.4 SAUGEEN OJIBWAY NATION EVALUATION OF OPG'S CUMULATIVE EFFECTS ASSESSMENT

15.4.1 The Saugeen Ojibway Nation Application for Inclusion of a High Level Nuclear Waste Project

On August 9, 2012, the Saugeen Ojibway Nation submitted to the DGR Secretariat a document entitled Saugeen Ojibway Nation's Application for a Determination on the Scope of Review of OPG's DGR Project and the Inclusion of a Project for the Long-Term Management of High Level Nuclear Wastes. In this document, the Saugeen Ojibway Nation submitted that OPG had failed to consider the project for high level radioactive waste (also called the Adaptive Phased Management or APM Project) as part of the assessment of cumulative environmental effects of the DGR project.

According to the Saugeen Ojibway Nation, the high level radioactive waste project is reasonably foreseeable and should have been included as part of the cumulative environmental effects assessment for the following reasons: 1) the proposed DGR site is a suitable location for a high level nuclear waste repository; 2) Nuclear Waste Management Organization had begun formal consideration of sites within the study area; and 3) Nuclear Waste Management Organization and OPG repeatedly refused to confirm that the Bruce site was not considered for high level radioactive waste. The Saugeen Ojibway Nation submitted that the Panel should send specific directions to OPG to amend its EIS to include consideration of a high level radioactive waste project and to provide full consequential data and analysis.

On February 1, 2013, the Panel issued a letter to the Saugeen Ojibway Nation and to OPG directing them to file submissions as to whether or not the cumulative effects analysis of the DGR should include the consideration of the cumulative effects of the DGR in combination with the APM siting process. The Panel received the submissions and made them available on the public registry. The Panel issued its decision on March 27, 2013, which is available on the public registry.

In its decision, the Panel rejected the Saugeen Ojibway Nation's request on the basis that the APM siting process is not a project that met the *Canadian Environmental Assessment Act, 2012* and the Panel's Terms of Reference cumulative effects criteria of "projects that have been or will be carried out." The Panel considered the specific wording of its mandate, the guidance and treatment of cumulative effects provided by the Courts and related Canadian Environmental Assessment Agency policies. As mentioned previously, with regards to the project for L&ILW, the Panel's Terms of Reference specifically state that the Review will include a consideration of any cumulative environmental effects that are likely to result from the project in combination with other projects "<u>that have been or will be carried out</u>." (emphasis added) The DGR *Terms of*

Reference, incorporate the same wording as the *Canadian Environmental Assessment Act, 2012* with regard to cumulative effects with no amplification of the requirements as was the case in the *Alberta Wilderness Assn. V. Cardinal River Coals Ltd.* [1999] 3 FC 425 decision. In addition, the Panel concluded that the APM process is not a "reasonably foreseeable" project as set out in the EIS Guidelines for the preparation of the Environmental Impact Statement for the project. A complete version of the Ruling is available on the public registry.

The CNSC, as regulatory authority, did not require the inclusion of a high level nuclear waste project in the cumulative effects assessment. The CNSC, in its written submission to the Panel, referred to the Panel's opinion that the high level nuclear waste project (or APM project) was not required to be assessed and made no further comment.

After the Panel released its opinion, the Saugeen Ojibway Nation continued to take the position that the high level nuclear waste project ought properly to have been included in the cumulative effects analysis of the DGR project. The Saugeen Ojibway Nation referred to the lack of inclusion of a high level nuclear waste project as a fundamental deficiency.

15.4.2 The Saugeen Ojibway Nation Submission Regarding the Disposal of Decommissioning Wastes

The Saugeen Ojibway Nation raised concerns about what it referred to as the now-certain plans for expansion of the DGR for the disposal of decommissioning wastes. They interpreted the change in timing of the placement of decommissioning wastes as a significant change in the nature and scope of the project; therefore, OPG could no longer claim community support because the project was no longer what the public had been consulted about. The Saugeen Ojibway Nation maintained that it would be highly imprudent to approve the DGR project now in reliance on future, highly speculative regulatory processes. In the view of the Saugeen Ojibway Nation, it would not be consistent with good and precautionary planning to leave critical project characteristics to be addressed in downstream regulatory processes.

The Saugeen Ojibway Nation stated that any future plans to expand the DGR project or to materially change its uses and characteristics must acknowledge the requirement of Saugeen Ojibway Nation community acceptance for expansion or changes. This acceptance would be obtained in the context of what the Saugeen Ojibway Nation called a broader plan of nuclear waste management designed to address concerns that approval of the DGR project would open the door to more and more nuclear waste coming into their territory.

Concerns similar to those expressed by the Saugeen Ojibway Nation were raised by several participants and participant groups via a request for ruling to the Panel. The next section discusses that request for ruling.

15.5 EVALUATION OF OPG'S CUMULATIVE EFFECTS ASSESSMENT BY PARTICIPANTS

This section includes a discussion regarding the request for a ruling from participants regarding decommissioning wastes and views of participants on OPG's cumulative effects assessment.

15.5.1 Request for Ruling Regarding Decommissioning Wastes

In September 19, 2013, the Canadian Environmental Law Association submitted a request for ruling on behalf of it and 30 other participant organizations regarding decommissioning wastes. The request for ruling asked that:

- The Panel order OPG to clearly state whether or not decommissioning waste from Ontario nuclear power plants is intended to be placed in the DGR for L&ILW at any time in the future of the project; andif OPG confirms its intention, then,
- the Panel adjourn the Hearing and direct OPG to revise and resubmit its EIS with a detailed assessment of impacts including waste characterization and amounts, radionuclide inventory, timing of placement of decommissioning waste, configuration of the repository, effects on preclosure and postclosure safety, and all changes to costs in every stage of the DGR as a result of inclusion of decommissioning waste.

The Panel's ruling stated that, contrary to what was alleged by the Canadian Environmental Law Association and the other organizations, the Panel was satisfied that the consideration of the decommissioning waste had been included and treated in the EIS as per the EIS Guidelines as part of the cumulative effects assessment. The Panel noted that OPG had made clear statements regarding its intention to place decommissioning waste in the proposed DGR. The Panel also noted that the principal change from what was presented in the EIS was timing of placement, which would possibly be earlier than previously stated. There would be no change in the proposed volume of decommissioning waste and no change in the characterization of the waste as assessed in the cumulative effects section of the EIS. Furthermore, the Panel noted that OPG had made a clear commitment to meet all environmental assessment and regulatory requirements under the *Canadian Environmental Assessment Act, 2012* and the *Nuclear Safety and Control Act* if OPG identifies the need for expansion of the DGR to accommodate decommissioning waste. The Panel concluded that there was no need to order OPG to further clarify its intention to place decommissioning waste in the DGR and that it would not adjourn the hearing.

Subsequent to the hearing in 2013, the Panel issued several information requests regarding expansion of the DGR to accommodate decommissioning wastes. The Panel re-convened the hearing in September 2014 where decommissioning wastes were again discussed. The responses to the information requests plus information received at the hearing provided the Panel with additional information, summarized earlier in this chapter. The additional information provided by OPG added useful information which confirmed the Panel's earlier conclusions regarding the assessment of cumulative impacts of decommissioning waste placement in the DGR.

15.5.2 Evaluation of OPG's Cumulative Effects Assessment

The Canadian Environmental Law Association questioned OPG's claim that the cumulative effects assessment was consistent with the Practitioners Guide. In the opinion of the Canadian Environmental Law Association, OPG did not consider the guide's statement that a cumulative effect on a valued ecosystem component may be significant even though each individual project-specific assessment of that same valued ecosystem component concludes that the effects are insignificant. The Canadian Environmental Law Association stated that OPG's explanation that all non-trivial effects that remained after mitigation, i.e., residual adverse effects, were carried forward and considered illustrates that OPG missed the intent of cumulative effects assessment, which is premised on the recognition that the accumulation of trivial impacts may ultimately lead to significant effects. The Canadian Environmental Law Association also noted that the EIS Guidelines, as well as the Practitioners Guide, call for consideration of different forms of effects, such as synergistic, additive and induced. The Practitioners Guide states that if the incremental effects of a project on a valued ecosystem component are more complex than simple incremental additive effects, then the effects should be assessed on that basis or an explanation should be provided as to why it is not reasonable or possible to do so. The Canadian Environmental Law Association characterized OPG's approach as one that did not recognize the potential for indirect and induced effects. The Canadian Environmental Law Association noted that OPG referred to indirect effects and synergistic effects as synonymous, which would be an error. The Canadian Environmental Law Association also noted that OPG did not provide any explanation for how the so-called multi-feature valued ecosystem components referred to by OPG "inherently considered the combined effects of multiple stressors" as stated by OPG in a response to an information request.

The Canadian Environmental Law Association stated that while OPG had provided a preliminary discussion of thresholds for use in indicating effects on valued ecosystem components, it did not describe how it would assess or monitor the long-term integrity of the ecological system. Further, the Canadian Environmental Law Association noted that OPG did not explain how the overall integrity and resilience of the ecosystem would be maintained, including how ecosystem-level thresholds would be identified and related effects managed through the measurement of valued ecosystem components.

The Canadian Environmental Law Association echoed the concerns of the Saugeen Ojibway Nation regarding the lack of inclusion of high level nuclear waste in the cumulative effects assessment.

Other participants expressed concerns that future regulatory processes that would consider the expansion of the DGR to accommodate decommissioning waste would not be as rigorous as the Panel process. Specific concerns included stormwater management during expansion, effects of differences in decommissioning wastes on the safety case, and higher gas generation due to the higher metal content in decommissioning wastes. There was also concern that accidents and malfunctions had not been included in the cumulative effects assessment.

15.6 EXPERT ADVICE ON OPG'S CUMULATIVE EFFECTS ASSESSMENT

The Panel retained Dr. Peter Duinker to conduct a review of OPG's cumulative effects assessment. The review was to consider the Practitioners Guide, the Operational Policy Statement, the EIS guidelines, the EIS, and responses to information requests related to cumulative effects.

Dr. Duinker found that OPG had taken a much more constrained view of cumulative effects than described in the Practitioners Guide. Dr. Duinker stated that OPG's requirement that cumulative effects only occur when all three criteria (type of effect, timing and location) overlap was not in accordance with guidance materials, nor with the general literature. The most serious issue raised by Dr. Duinker was OPG's requirement that the type of effects must be the same. In his view, this ignored the potential presence of substantially different pathways of effects on a valued ecosystem component; e.g., effects on fish from effluent produced by the DGR project plus sewage-related pollutants plus pressures on the population created by fishing.

Dr. Duinker identified unclear logic in OPG's evaluation of certain cases where the DGR project was assessed as leading to a residual adverse effect on a valued ecosystem component and yet the assessment of cumulative effect found no residual adverse cumulative effect. An example of this was OPG's finding that additional loss of Eastern white cedar caused by centre of site additions and modifications was not likely to cause a residual adverse cumulative effect on cedar. Dr. Duinker pointed out that no matter how small an additional effect might be from other projects or activities, if the DGR project has a residual adverse effect and other projects would create more of such an effect, which would lead to a finding of residual adverse cumulative effect. The next logical step would then be to assess the significance of the residual adverse cumulative effect; it would be at that point that the relative magnitude of effect would be factored into the assessment.

Dr. Duinker questioned OPG's interpretation that indirect effects are synonymous with synergistic effects, as did the Canadian Environmental Law Association. It appeared that while OPG identified some indirect effects as they are understood by most practitioners, synergistic effects (where combined effects of two stressors are more than the sum of the effects of each stressor acting alone) were not identified, nor were they assessed.

Dr. Duinker stated that it was illogical to argue (as OPG did) that a finding of no likely adverse cumulative effect justifies the selection of indicators for monitoring based solely on the project's effects on valued ecosystem components. He pointed out that the purpose of monitoring was to reveal whether effect predictions are correct and based on solid evidence and reasoning. He maintained that consideration of cumulative effects should include recognition that there may be other variables within pathways of cumulative effect that should be monitored. Dr. Duinker stated that the conclusion of no likely adverse cumulative effects requires confirmation through monitoring and there was ample justification to consider variables that are not part of the cause-effect pathways associated with the DGR project on its own.

Dr. Duinker was of the view that the OPG cumulative effects assessment had flaws of approach and method. However, he cautioned that despite this opinion, he did not draw any inference that a cumulative effects assessment conducted using a different methodology would have identified significant adverse cumulative effects. In his opinion, a competent cumulative effects assessment would require a grounding in scientific principles and approaches to assessment practice that go far beyond the published guidance of the Canadian Environmental Assessment Agency and the Panel Terms of Reference.

15.7 PANEL CONCLUSION REGARDING CUMULATIVE EFFECTS

The Panel concludes that the project is not likely to cause significant adverse cumulative environmental effects. The Panel acknowledges that Dr. Duinker identified issues with OPG's cumulative effects assessment methodology; however, Dr. Duinker did not draw any inference that the DGR project would cause significant adverse cumulative effects. The Panel's conclusion is based on its own careful evaluation of the adverse effects of the DGR project. The Panel evaluated all adverse effects of the DGR project, not just those carried forward by OPG to its cumulative effects assessment. This evaluation led to the Panel's determination that adverse effects on the valued ecosystem components caused by the DGR project would be too limited in magnitude, spatial extent, duration and/or frequency to cause significant cumulative effects when acting in combination with the effects of past, current or reasonably foreseeable projects. The Panel determined that its conclusion would apply when considering the potential for synergistic effects such as enhanced toxicity of one metal caused by increased concentrations of another metal, or indirect effects, such as shifts in food chain structure or function caused by an effect on one component of that food chain. The fundamental basis for the Panel's conclusion is that, even with highly conservative predictions of adverse effects, particularly for stressors such as air quality parameters, noise and radioactivity, the relative contribution of the DGR project to cumulative stress on the valued ecosystem components would be very small, and would not result in concentrations which exceed regulatory criteria and would often not be measurable. For example, the combination of all sources of suspended particulates in air would still result in off-site concentrations that meet air quality criteria. Furthermore, as discussed in Chapter 14, the stressors produced by the DGR project are not likely to interact directly, indirectly, or synergistically with the primary stressors currently affecting Lake Huron. Therefore, it is not likely that the cumulative effects of the DGR project plus the other activities and projects assessed by OPG would result in crossing "tipping points" where the ecosystem structure or function of Lake Huron would be adversely affected.

The Panel has already noted the importance of a consistent, long-term commitment to mitigation of DGR project effects, particularly for surface water quality, air quality and noise. The Panel emphasizes the importance of follow-up monitoring to confirm the absence of significant adverse cumulative effects. The Panel notes that the most appropriate indicators of cumulative effects will be examined should the DGR project be approved and proceed to licensing.

The Panel concludes that the project is not likely to cause significant adverse cumulative effects due to malfunctions and accidents. As stated in Chapter 10, the Panel concludes that conventional and radiological malfunctions and accidents occurring on the DGR site are not likely to cause significant adverse environmental effects. In addition, the Panel concurs with OPG's assessment that credible malfunction and accident events would not be likely to cause significant adverse effects. The Panel is of the view that it is unlikely that multiple credible events that overlap temporally and spatially would occur at the DGR site. The Panel therefore concludes that effects from malfunctions and accidents are not likely to interact temporally and spatially with other effects. The Panel points out in Chapter 10 that OPG's mitigation and control measures for malfunctions and accidents, including in-design engineered control features and use of emergency contingency planning, were well described and must be implemented. The Panel reiterates its conclusion that it is satisfied that the assessment of malfunctions and accidents was appropriate for the project and not underestimated.

Likewise, the Panel concludes that the project is not likely to cause significant adverse cumulative effects due to malevolent acts. The Panel states in Chapter 10 that given OPG's implementation of effective control and mitigation measures, credible malevolent acts are not likely to result in significant adverse effects to non-human biota, members of the public and workers, both on and off the DGR site.

The additional information provided by OPG regarding decommissioning waste, together with the assessment presented in the EIS, satisfies the Panel that the cumulative effects of inclusion of decommissioning wastes have been adequately addressed by OPG and that no significant adverse effects to the environment are likely to occur, provided that mitigation measures are effective and adaptive management is actively practiced to adjust to new information that will become available over the next two to four decades.

In response to the request from the Saugeen Ojibway Nation, the Panel determined that the Adaptive Phased Management process was not a reasonably foreseeable project for the purpose of the cumulative effects assessment. The Panel is satisfied that OPG considered the transfer of used fuel off the Bruce nuclear site to a long-term repository as part of its cumulative effects assessment.

15.8 PANEL GENERAL COMMENTS ON THE CURRENT PRACTICE OF CUMULATIVE EFFECTS ASSESSMENT

The Panel notes the disparity between the review of the cumulative effects assessment by CNSC and other regulatory agencies and the comments provided by Dr. Duinker and certain participants. Dr. Duinker was of the opinion that cumulative effects assessment should go "far beyond" the guidance provided by the Canadian Environmental Assessment Agency and the Panel. The comments by the Canadian Environmental Law Association focused on the differences between the Practitioners Guide and OPG's assessment. The Panel is of the view that the difference between the general guidance provided by the Operational Policy Statement and the more specific and detailed guidance provided in the Practitioners Guide was a basis for the difference between Government Agency reviews and the reviews by Dr. Duinker and participants. The Panel notes that the Practitioners Guide is dated and does not necessarily reflect the current thinking in relation to cumulative effects assessment. The Panel understands that the Canadian Environmental Assessment Agency has made updated guidance for the assessment of cumulative effects available in draft form for public review and comment. The Panel welcomes updated guidance and hopes that it provides additional advice with respect to the process for carrying residual effects forward in the assessment; the determination of significance of adverse cumulative effects; methods for dealing with indirect effects; methods for dealing with synergistic or antagonistic effects; and processes for identifying the most appropriate valued ecosystem component and indicators of cumulative effects.

CHAPTER 16 PANEL CONCLUSIONS, MITIGATION AND FOLLOW-UP

16.1 INTRODUCTION

This chapter presents the conclusions, mitigation measures and requirements for a follow-up program in the format outlined in the Amendment to the Agreement to Establish a Joint Review Panel, August 3, 2012.

16.2 LEGISLATIVE FRAMEWORK

An environmental assessment must take into account mitigation measures that are technically and economically feasible and that would mitigate any significant adverse environmental effects of a project, as well as the requirements of a follow-up program in respect of that project. Pursuant to the *Canadian Environmental Assessment Act, 2012*, mitigation measures are measures for the elimination, reduction or control of the adverse environmental effects of a project, and include restitution for any damage to the environment caused by those effects through replacement, restoration, compensation or other means. A follow-up program means a program for verifying the accuracy of the environmental assessment and determining the effectiveness of mitigation measures.

The Minister of the Environment must take the implementation of any mitigation measures that the Minister considers appropriate into account in deciding if the project is or is not likely to cause significant adverse environmental effects.

For the project to go forward, the Minister must establish the conditions in relation to the environmental effects as referred to in subsections 5(1) and 5(2) of the *Canadian Environmental Assessment Act, 2012* with which OPG must comply. The conditions must include the implementation of mitigation measures and a follow-up program that were taken into account in reaching the environmental assessment decision.

16.3 PANEL RECOMMENDATIONS

To avoid significant adverse environmental effects, OPG must implement all of the items that it has committed to in its October 17, 2014 List of Commitments from the Additional Hearing Days in September 2014 and in its August 25, 2014 Updated DGR Project Consolidated Commitment Lists Report.

16.3.1 Fish and Fish Habitat

In relation to effects on fish, as defined in section 2 of the *Fisheries Act* and fish habitat as defined in subsubsection 2(1) of that Act (the *Canadian Environmental Assessment Act, 2012* subparagraph 5(1)(a)(i) environmental component), the Panel concludes that the project is not likely to cause significant adverse environmental effects, provided that OPG implements the following mitigation measures:

Recommendation 8.20: In order to avoid significant adverse effects to nearshore habitat in MacPherson Bay, OPG shall submit, prior to construction and to the satisfaction of the CNSC, a management plan that provides a detailed description of the options available to increase the capacity of the drainage ditch at Interconnecting Road in the event the flow exceeds the capacity of the ditch. The plan shall identify the relative potential effects of each of the options on the ecology of MacPherson Bay, and consider the relative effects when selecting and implementing the preferred option.

Recommendation 8.33: In order to avoid significant adverse effects to fish and fish habitat, OPG shall, during site preparation and construction, implement measures to mitigate the effects of culvert installation at the North and South Railway Ditches. Measures shall include: embedding culverts below the bed of the ditch, isolating and dewatering the culvert site during construction, revegetating the banks upon completion of construction, and deploying sediment and erosion control measures during construction. In-water works shall not occur between July 1 and September 30.

Recommendation 10.2: In order to avoid significant adverse environmental effects, including effects to fish or fish habitat, due to malfunctions, accidents or malevolent acts, OPG shall develop and implement a detailed spill response plan for all phases of the project. The spill plan must be acceptable to the CNSC and include an assessment of containment methods, locations and strategies to demonstrate that spill mitigation will be deployed in time to prevent downstream effects.

To verify the accuracy of the prediction of effects on fish and fish habitat and to determine the effectiveness of mitigation measures, OPG shall undertake the following:

Recommendation 8.15: In order to confirm the predictions in the environmental assessment and ensure compliance with the *Fisheries Act*, OPG shall, to the satisfaction of the CNSC and in consultation with Environment Canada, monitor concentrations of relevant contaminants of concern and conduct acute and chronic toxicity tests on the contents of the stormwater management pond prior to discharge.

Recommendation 8.16: In order to confirm the predictions in the environmental assessment, and to ensure compliance with the Fisheries Act, OPG shall implement a follow-up program, to the satisfaction of the CNSC, to monitor a broad spectrum of parameters (e.g., other metals, phosphate, total petroleum hydrocarbons) at the point of discharge of the storm water management pond quarterly, during site preparation and construction, and later during operations.

Recommendation 8.17: In order to verify predictions in the environmental assessment and the effectiveness of the mitigation of water quality by the stormwater management system, and as support for the design of the follow-up monitoring program in MacPherson Bay, OPG shall, in consultation with Environment Canada and to the satisfaction of the CNSC, conduct an effluent dispersion study in MacPherson Bay after commissioning of the stormwater management pond.

Recommendation 8.18: In order to verify predictions in the environmental assessment and the effectiveness of the mitigation of water quality by the stormwater management system, OPG shall, in consultation with Environment Canada and to the satisfaction of the CNSC, conduct follow-up monitoring in MacPherson Bay during site preparation and construction, and later during operations. The follow-up monitoring program shall include water quality, sediment quality, benthic invertebrate community indicators, and caged bivalve studies at sampling locations and frequencies determined in consultation with Environment Canada and to the satisfaction of the CNSC. OPG shall ensure that there are adequate baseline data for all follow-up monitoring indicators prior to site preparation.

Recommendation 8.19: In order to verify predictions in the environmental assessment, OPG shall develop, to the satisfaction of the CNSC, a follow-up program for flow reduction rates in the North Railway Ditch and Stream C, during site preparation and construction. If monitoring results indicate differences from predictions, OPG shall, to the satisfaction of the CNSC, determine whether mitigation measures are required to ensure there are no significant adverse effects on surface water quantity.

Recommendation 8.34: In order to confirm the predictions in the environmental assessment regarding effects to fish and fish habitat, OPG shall develop and implement, prior to site preparation and to the satisfaction of the CNSC, a follow-up program for aquatic life in the stormwater management system and the ditch at Interconnecting Road. The program shall include the collection of supporting water quality and sediment quality data to be used to conduct a risk assessment for fish, fish habitat and aquatic birds.

Recommendation 14.1: In order to confirm environmental assessment predictions regarding effects on lake whitefish, OPG shall develop a follow-up program which includes provisions to incorporate input from interested stakeholders, including the Saugeen Ojibway Nation fisheries specialists. The follow-up program should reflect the increasing understanding of the role of MacPherson Bay in the ecology of the area, and should include mitigation measures that may be implemented to protect lake whitefish and lake whitefish nursery areas, to the satisfaction of the CNSC.

16.3.2 Aquatic Species at Risk

In relation to effects on aquatic species as defined in subsection 2(1) of the *Species at Risk Act* (the *Canadian Environmental Assessment Act, 2012* subparagraph 5(1)(a)(ii) environmental component), the Panel concludes that the project is not likely to cause significant adverse environmental effects, provided that OPG implements the following mitigation measures:

Recommendation 8.36: In order to avoid significant adverse effects to snapping turtle habitat, OPG shall maintain appropriate water levels in the northeast marsh, during and after the re-routing of the drainage ditch, to the satisfaction of CNSC and in consultation with Environment Canada.

Recommendation 8.37: In order to avoid significant adverse effects to turtle species at risk, OPG should delay the infilling of “Wetland 3” until the latter years of the site preparation and construction phase.

> **Recommendation 8.39:** In order to avoid significant adverse effects on snapping turtles, OPG shall, to the satisfaction of CNSC, implement a management plan to relocate snapping turtles from "Wetland 3" to the northeast marsh prior to the infilling of "Wetland 3". The plan should be reviewed by Environment Canada and the Ontario Ministry of Natural Resources.

To verify the accuracy of the prediction of effects on aquatic species at risk and to determine the effectiveness of mitigation measures, OPG shall undertake the following:

> **Recommendation 8.3**8: In order to confirm the predictions in the environmental assessment regarding snapping turtles, OPG shall conduct turtle surveys of Wetland 3 throughout the years prior to its infilling. A qualified biologist experienced in turtle surveys should conduct a minimum of three surveys per year on sunny days, beginning as soon as the ice cover has melted. The third survey should occur no later than mid-June. OPG shall relocate turtles to the northeast marsh.

16.3.3 Migratory Birds

The Panel concludes that the project is not likely to cause significant adverse effects to migratory birds, as defined in subsection 2(1) of the *Migratory Birds Convention A*ct, *1994* (the *Canadian Environmental Assessment Act, 2012* subparagraph 5(1)(a)(iii) environmental component).

To verify the accuracy of the prediction of effects on migratory birds and to determine the effectiveness of mitigation measures, OPG shall undertake the following:

> **Recommendation 8.32:** In order to confirm the predictions in the environmental assessment regarding effects to migratory birds and migratory bird habitat, OPG shall develop and implement a follow-up program, prior to site preparation and to the satisfaction of the CNSC. The program shall include management measures to effectively avoid or minimize the risk of detrimental effects to migratory birds, their nests and eggs, if adverse effects are observed. The plan shall include the provision that if nests are found in open areas, these nests be flagged, marked and buffers placed around them so that no work within the buffer areas occurs until the nesting cycle is complete.

16.3.4 Federal Lands and Lands Outside of Ontario and Canada

The Panel concludes that the project is not likely to cause significant adverse effects on federal lands, in a province other than Ontario or outside of Canada (the *Canadian Environmental Assessment Act, 2012* paragraph 5(1)(b)).

16.3.5 Aboriginal Peoples

The Panel concludes that the project is not likely to cause significant adverse effects with respect to Aboriginal peoples (the *Canadian Environmental Assessment Act, 2012* paragraph 5(1)(c)).

16.3.6 Federal Authority

In order for the project to go forward, a Licence to Prepare Site and Construct pursuant to the *Nuclear Safety and Control Act* must be obtained. To avoid significant adverse environmental effects on environmental components not otherwise referred to in paragraph 5(1)(a) and (b) of the *Canadian Environmental Assessment Act, 2012*, OPG must implement the following mitigation measures:

Recommendation 7.1: In order to avoid significant adverse effects to human health and the environment due to potential actinide exposure, OPG shall develop and establish thresholds and appropriate screening methods for actinides, to the satisfaction of CNSC, for all waste packages to be emplaced in the DGR. OPG shall also develop a contingency plan for managing waste packages that exceed these thresholds. The thresholds, screening methods and contingency plans should be in place before an operating licence is issued.

Recommendation 7.7: Before a licence to operate the DGR is issued, and in order to reduce the likelihood of significant adverse environmental effects due to a container breach before closure of the DGR, OPG shall provide, to the satisfaction of the CNSC, an inspection protocol for waste containers, beyond visual inspection, that must be followed before their placement in the DGR. The protocol shall include procedures that ensure that container venting mechanisms will remain functional following emplacement in the DGR.

Recommendation 7.9: In order to avoid significant adverse effects to human health, before a licence to operate the DGR is issued, OPG shall develop and implement, to the satisfaction of the CNSC, a detailed plan on how it would mitigate a scenario where intermediate-level waste containers fail in filled chambers at a time when the DGR was still in operation. The plan should evaluate the anticipated exposures to the workforce if the rooms were completely filled, as well as during the period when the retrieval of containers would still be possible via planned access routes.

Recommendation 7.10: In order to prevent significant adverse effects to human health, due to container breaches, OPG shall investigate and report to the CNSC, on a regular basis starting prior to construction and until the end of the Operations phase, on the effectiveness of existing and emerging imaging technologies which could be used to detect waste-to-container interactions that may lead to container breaches. If effective non-destructive testing methods become available they should be promptly instituted to supplement visual inspections of waste packages.

Recommendation 8.2: Prior to site preparation, OPG shall finalize and submit a detailed plan to manage air emissions, to the satisfaction of CNSC. The management plan should be reviewed by Environment Canada, Health Canada and the Ontario Ministry of the Environment and Climate Change. The plan should include details of the mitigation measures, including thresholds for corrective management actions; frequency of site inspections; and record keeping.

Recommendation 8.3: In order to avoid significant adverse effects on near-surface hydrology, prior to beginning construction of the stormwater management system, OPG shall verify that the overburden stratigraphy at the site is the same as predicted in the EIS. If unexpected, higher permeability, stratigraphy is encountered, OPG must assess the potential effect on water levels in the northeast marsh and evaluate and implement mitigation options.

Recommendation 8.8: In order to avoid significant adverse effects to near-surface groundwater, OPG shall place a liner, acceptable to CNSC, under the waste rock management areas to direct leachate to a treatment facility or the stormwater management pond. The liner shall be placed during site preparation and construction, and be developed in consultation with Environment Canada.

Recommendation 8.9: In order to avoid significant adverse environmental effects to near-surface groundwater, OPG shall not dispose of waste rock outside the boundaries of the stormwater management pond collection system, during any phase of the project, without the permission of the CNSC.

Recommendation 8.11: In order to avoid significant adverse effects to surficial and shallow bedrock groundwater, OPG shall place a liner under the stormwater management pond. The liner shall be placed during site preparation and construction. The specifications of the liner should be developed in consultation with Environment Canada.

Recommendation 8.12: In order to avoid significant adverse effects to surface water quality, OPG shall, prior to construction, submit to the CNSC a plan for treatment of all water destined for discharge from the stormwater management pond. OPG shall treat stormwater management pond releases, to the satisfaction of the CNSC, such that they comply with section 36 of the *Fisheries Act* throughout construction, operations and decommissioning.

Recommendation 8.13: In order to prevent significant adverse environmental effects due to over-topping of the stormwater management system, OPG shall review and, if necessary, revise the design of the stormwater management system, to the satisfaction of the CNSC, based upon an assessment of the likelihood of significant changes in the return period and magnitude of major storm events.

Recommendation 8.14: In order to prevent significant adverse effects to surface water, OPG shall, to the satisfaction of the CNSC, prepare a contingency plan to mitigate effects of severe storm-related uncontrolled overland flow to Stream C, Baie de Doré, and MacPherson Bay during the period of site preparation before the stormwater management system is fully functional.

Recommendation 8.40: In order to avoid significant adverse effects on eastern ribbonsnake, eastern milksnake and their habitats, OPG shall develop and implement a management plan, to the satisfaction of the CNSC, to ensure site preparation and construction activities to not disrupt individuals of these species, snake eggs, gestation sites, or hibernacula. OPG should seek input and advice from Environment Canada and the Ontario Ministry of Natural Resources in developing the plan.

Recommendation 8.41: In order to avoid significant adverse effects on turtles and snakes, OPG shall, to the satisfaction of CNSC, ensure that mitigation measures are in place to prevent turtles and snakes from entering the DGR Site, and "Wetland 3" in particular, prior to and during the site preparation and construction phase. Measures should include the installation of exclusion fencing along the southern and eastern edges of the DGR site. Environment Canada should be consulted regarding the specifications of the fence.

Recommendation 8.43: In order to avoid significant adverse effects on the project due to climate change, OPG shall develop and regularly update a climate change strategy, to the satisfaction of the CNSC. The strategy should incorporate up-to-date climate change models and adaptive management, and be included in the environmental management system for the DGR.

To verify the accuracy of the prediction of environmental effects and to determine the effectiveness of mitigation measures, OPG shall undertake the following:

Recommendation 6.2: In order to verify predictions in the environmental assessment and avoid effects of the environment on the project, OPG shall, prior to construction, conduct and prepare an updated assessment of the probable maximum precipitation event. The updated probable maximum precipitation event shall incorporate the potential effect of climate change and a rigorous sensitivity analysis shall be performed. The shaft collar height shall be increased to an appropriate elevation based on the updated probable maximum precipitation event, to the satisfaction of the CNSC.

Recommendation 6.4: In order to confirm the predictions in the environmental assessment regarding post-closure containment of radionuclides and other contaminants, OPG shall initiate long-term testing of seal material behaviour under similar conditions and depths to those that each seal material will experience at the proposed DGR site. The testing program shall include experimental and theoretical demonstrations of the long-term performance of the seals. OPG shall consider the chemical, hydraulic and physical interaction of the seals with specific rock formations and the associated excavation damage. The rock formations to be considered shall include the host and cap formations, and other formations that influence the long-term safety case. The test program shall commence as soon as possible prior to site preparation and construction, and be conducted to the satisfaction of the CNSC. The safety case should be updated taking the results of this work into consideration.

Recommendation 7.5: In order to confirm the predictions in the environmental assessment that there will be no significant adverse effects to human health and the environment due to releases of container contents prior to their emplacement in, and the closure of, the repository panels, OPG's Waste Acceptance Criteria shall be finalized and approved by the CNSC before a licence to operate the DGR is issued. The Waste Acceptance Criteria should be reviewed by both the CNSC and an independent third-party, acceptable to the CNSC.

Recommendation 7.6: Before a licence to operate the DGR is issued, to confirm the prediction in the environmental assessment that no further measures are required to control condensation from, and leakage of, sludges following packaging, OPG shall perform research, and report on, the predicted long-term stability (up to decommissioning) of the solidified active liquid waste sludges and the potential release of liquids when exposed to conditions applicable to the DGR, to the satisfaction of CNSC.

Recommendation 8.1: In order to confirm the prediction in the environmental assessment of no significant adverse effects on air quality, and to address specific concerns of individuals living at or near the critical receptor locations used in the EIS models, OPG shall, to the satisfaction of the CNSC, conduct a monitoring program for NOx and particulates, including PM_{10} and $PM_{2.5}$, during site preparation and construction.

Recommendation 8.4: In order to verify predictions in the environmental assessment regarding the shallow bedrock aquifer, OPG shall, prior to site preparation, update the hydrogeologic properties of the till cover in the water balance and surface water/groundwater interaction numerical models. The models should be updated to the satisfaction of the CNSC, as more data become available.

Recommendation 8.5: In order to verify predictions in the environmental assessment regarding leachate quality, prior to construction OPG shall improve the characterization of the leachate that will be generated by the waste rock piles, by performing kinetic leach tests on existing core samples. During shaft excavation OPG shall conduct field cell studies on the material being deposited in the dolostone, shale, and limestone waste rock piles to verify leachate compositions and the acid generation potential under prevailing conditions.

Recommendation 8.6: In order to verify predictions in the environmental assessment regarding leachate quality, prior to construction OPG shall submit to the CNSC a waste rock characterization program for contaminants of concern other than those linked to acid generating potential (including, but not limited to metals and metalloids released under alkaline conditions, total dissolved solids and hydrocarbons). The OPG waste rock characterization program shall be based on sampling full-strength leachates and be valid for the duration of construction.

Recommendation 8.7: In order to verify the predictions in the environmental assessment that there will be no significant adverse effects to aquatic life from the waste rock pile runoff, OPG shall, to the satisfaction of the CNSC, develop a waste rock follow-up program. The follow-up program shall occur through all preclosure phases of the project and shall address the quantity and quality of leachate and surface runoff directed to the stormwater management system, and shall include sampling of full strength leachates.

Recommendation 8.10: In order to verify the predictions in the environmental assessment regarding the effectiveness of the design of the stormwater management system, OPG shall calibrate and verify hydrological and water quality models over the life of the project with new information as it becomes available, including but not limited to, leachate geochemistry and flow rates. The models should be calibrated and verified prior to site preparation, at the end of construction, and periodically during operations, to the satisfaction of the CNSC.

Recommendation 8.21: In order to confirm predictions in the environmental assessment regarding effects on wetland water levels, OPG shall conduct monthly monitoring of water levels in the northeast marsh, beginning prior to site preparation and construction in order to establish a baseline. A follow-up program shall then be established, in consultation with Environment Canada and to the satisfaction of the CNSC.

Recommendation 8.22: In order to confirm the predictions in the environmental assessment, OPG shall conduct a sediment quality follow-up program in MacPherson Bay during construction and operations. Prior to construction, OPG shall collect additional baseline sediment quality data at the ditch at Interconnecting Road and MacPherson Bay. All sampling shall be conducted to the satisfaction of the CNSC.

Recommendation 8.23: Prior to site preparation and construction, OPG shall use information from existing and planned groundwater monitoring wells for verification of the environmental assessment predictions regarding the zone of influence from dewatering during excavation and construction. The verified predictions regarding the zone of influence shall be used for the final design of shaft excavation procedures and infrastructure, including mitigation of groundwater inflow from surficial and shallow bedrock groundwater zones

Recommendation 8.24: During construction, in order to confirm predictions in the environmental assessment, OPG shall implement a follow-up program for groundwater quality and groundwater inflow rates into the shafts and repository, to the satisfaction of the CNSC. If groundwater inflows exceed predicted values or if the zone of influence is larger than expected, OPG shall implement mitigation measures to either reduce groundwater inflow or the zone of influence. If groundwater loadings and/or concentrations of contaminants of concern exceed environmental assessment predictions, OPG shall implement mitigation measures to avoid adverse effects to surface water quality, to the satisfaction of the CNSC.

Recommendation 8.25: In order to verify the predictions in the environmental assessment, OPG shall, prior to shaft sinking, enhance its capability to detect and monitor the movement of the tritium plume originating from the WWMF by adding an adequate number of monitoring wells up-gradient of the DGR shafts, to the satisfaction of the CNSC.

Recommendation 8.26: In order to verify the predictions in the environmental assessment, prior to shaft sinking, OPG shall conduct a comprehensive assessment of the migration of the tritium plume originating from the WWMF site, to the satisfaction of the CNSC. The assessment shall include updated modelling of the tritium plume migration. If groundwater modelling or monitoring indicates that the tritium plume may reach the shaft before the shaft collars are installed, OPG shall prepare a contingency plan, to the satisfaction of the CNSC.

Recommendation 8.27: In order to confirm the absence of significant adverse effects on plants and plant communities, OPG shall monitor the presence of cattails and other aquatic plants important as habitat within the stormwater drainage system, including the stormwater management pond. Baseline conditions should be established prior to habitat disturbance, and follow-up monitoring should take place after the disturbance of habitat during site preparation, construction and operations phases. This monitoring program should be conducted to the satisfaction of the CNSC and be included in the OPG environmental management system for the project. OPG shall address any significant adverse change in these plant communities that, in turn, would have the potential to affect significant species, such as amphibians and reptiles, in accordance with the *Species at Risk Act*.

Recommendation 8.28: In order to confirm the absence of significant adverse effects on plants and plant communities as predicted in the environmental assessment, OPG shall implement a follow-up program to monitor the naturalization of disturbed areas, during construction and operations, to the satisfaction of the CNSC. If monitoring indicates the presence of invasive plant species and noxious weeds, OPG shall implement appropriate mitigation measures.

Recommendation 8.29: In order to verify the prediction in the environmental assessment that there will be no significant adverse effects on plants due to changes in air quality, OPG shall monitor indicators of effects of changes in air quality on plants, both on the Project Area and in the Site Study Area. This monitoring shall occur during site preparation and construction and be conducted to the satisfaction of the CNSC.

Recommendation 8.31: In order to confirm predictions in the environmental assessment regarding effects on aquatic and semi-aquatic species, prior to construction OPG shall submit a follow-up program to the satisfaction of the CNSC. The program shall contain mitigation measures to be taken, should concentrations of total dissolved solids in the storm water management system be observed at levels with the potential to affect sensitive plant or animal species. The plan shall include provisions for the establishment of a self-sustaining plant community that will provide habitat for amphibians, birds, invertebrates and small-bodied fish.

Recommendation 8.35: In order to confirm the prediction in the environmental assessment that there would be no loss of significant plant species, OPG shall confirm the absence of significant plant species in the Project Area prior to site preparation. If significant species are located, OPG shall, in conjunction with appropriate federal and provincial agencies and the CNSC, take action to avoid or mitigate the potential loss.

Recommendation 8.42: In order to confirm the predictions in the environmental assessment regarding radiation effects on terrestrial and aquatic species, OPG shall conduct a follow-up program, to the satisfaction of the CNSC, of radiation levels in air, water, soil, sediment, terrestrial and aquatic biota in the Project Area and Local Study Area.

Recommendation 9.3: In order to confirm the absence of significant adverse effects from radon and radon progeny, as predicted in the environmental assessment, OPG shall conduct a follow-up program for radon, acceptable to the CNSC. Radon monitoring locations shall include: within the exhaust air shaft at surface, and near the waste rock management area. The follow-up program shall be established prior to site preparation and construction and include the establishment of baseline radon conditions.

Recommendation 9.4: In order to confirm the environmental assessment prediction of no significant adverse effects to human health from acrolein exposure, OPG shall conduct a follow-up program for acrolein during site preparation, construction and operations, to the satisfaction of the CNSC.

Recommendation 9.5: In order to confirm EIS predictions and the effectiveness of mitigation, the noise and vibration monitoring committed to by OPG shall be conducted to the satisfaction of the CNSC and shall be included in the environmental management system for the project. Monitoring shall take place throughout the pre-closure phases of the project. OPG should identify additional monitoring locations in consultation with Health Canada, the Ontario Ministry of the Environment and Climate Change, Aboriginal communities and residents in the Local Study Area. OPG shall develop explicit action levels for noise mitigation, acceptable to the CNSC, taking into consideration input from Aboriginal communities, and permanent and seasonal residents in the Local Study Area.

Recommendation 9.6: In order to confirm the environmental assessment prediction of no significant adverse effects from exposure to radiation for members of the public, including members of Aboriginal groups, OPG shall add the collection of soil samples within the Site Study and Local Study Area to the Radiological Environmental Monitoring Program for the DGR during the Construction Phase.

Recommendation 11.1: In order to confirm the environmental assessment prediction of no significant adverse socio economic effects to valued social and economic components due to dust and noise, OPG shall develop a follow-up program, acceptable to the CNSC, prior to site preparation and construction.

Recommendation 13.5: In order to confirm predictions in the environmental assessment, OPG shall provide additional gas generation modelling for the decommissioned DGR as part of its Geoscientific Verification Plan, which will validate the microbial degradation processes of the waste. OPG shall also augment the Geoscientific Verification Plan to include modelling of gas generation from decommissioning waste to ensure that there will be timely information available for the design and implementation of the mitigation measures associated with reduction of gas generation. These verification activities should be carried out prior to operations, to the satisfaction of the CNSC.

Recommendation 13.6: Before a licence to operate the DGR is issued, in order to confirm the predictions in the EIS and Postclosure Safety Assessment regarding the ability of the DGR to perform in a manner that will protect human health and the environment, OPG shall perform probabilistic calculations for radiation exposures to humans and non-human biota for the Normal Evolution and Disruptive Scenarios, to the satisfaction of the CNSC. These calculations should supplement the deterministic calculations in the current long-term safety case assessment in order to increase confidence.

Recommendation 13.7: In order to confirm the predictions in the environmental assessment regarding potential long-term effects of Disruptive Scenarios on Lake Huron, OPG's future modelling for all variant cases of the Disruptive Scenarios shall provide clear and accessible evaluations of the amounts and activities of discharges into Lake Huron via the shallow and intermediate groundwater systems, to the satisfaction of the CNSC.

16.3.7 Non-*Canadian Environmental Assessment Act, 2012* Recommendations to be Addressed in the Event Permission is Granted to Consider a Licence to Prepare Site and Construct

In addition to its conclusions regarding significant adverse effects, mitigation and follow-up under the *Canadian Environmental Assessment Act, 2012*, the Panel also recommends that the following be addressed in the event that permission is granted to proceed with a Licence to Prepare Site and Construct:

Recommendation 3.1: Before a Licence to Prepare Site and Construct is granted, OPG shall submit to the CNSC an updated list of mitigation commitments for each identified adverse effect. OPG shall remove out-dated or redundant commitments from this list.

Recommendation 6.1: Prior to construction, OPG shall provide, to the satisfaction of the CNSC, detailed designs for all above-ground and underground structures to demonstrate compliance with the National Building Code of Canada.

Recommendation 6.7: OPG shall include in its adaptive management system a complete and clearly defined set of action levels, which would trigger a safety review process and, if necessary, mitigation. The management system shall be completed to the satisfaction of the CNSC prior to construction.

Recommendation 6.8: OPG shall perform additional geomechanical characterization work at sites located throughout the repository footprint to increase the quantity and the spatial distribution of site data collected during the preliminary site investigation phases. This work shall commence during site preparation and construction and should continue during operations, and be completed to the satisfaction of the CNSC.

Recommendation 6.9: OPG shall, during construction, undertake additional *in situ* stress magnitude and orientation testing at the depth of the repository within the Cobourg Formation. *In situ* stress measurement tests shall be conducted at sites located apart from the two planned Geoscientific Verification Plan shaft sites and be completed prior to emplacement room construction activities. OPG should consider third-party review of *in situ* testing and stress data information. All testing shall be done to the satisfaction of the CNSC.

Recommendation 9.1: OPG shall, before a licence to prepare the site and construct is granted, develop a program to monitor the long-term integrity of supports in the repository, to the satisfaction of the CNSC. The monitoring program should include *in situ* testing.

Recommendation 9.2: In order to reduce the risk of worker injury due to rockburst and/or rockfall events, OPG shall install a near-field micro-seismic monitoring network, to the satisfaction of the CNSC. The monitoring network shall be installed during construction and cover the repository footprint. It should remain operational during the operations phase of the project.

Recommendation 10.1: OPG shall implement the mitigation measures and contingency plans identified in Table 5.3.3-1 and Section 5.5 of the Malfunctions, Accidents and Malevolent Acts Technical Support Document to the satisfaction of the CNSC, during site preparation, construction, and operations.

Recommendation 10.3: OPG shall develop and implement a plan, prior to site preparation, to reduce the likelihood of underground vehicular traffic accidents and rockfall accidents, to the satisfaction of the CNSC.

Recommendation 10.4: OPG shall implement the mitigation measures and contingency plans identified in Section 4.4 of the Malfunctions, Accidents and Malevolent Acts Technical Support Document, to the satisfaction of the CNSC.

Recommendation 10.5: OPG shall develop detailed room closure procedures to be deployed in the event that structural failures, inadvertent radiologic releases or other malfunctions or accidents occur within, or external to, waste emplacement rooms. Room closure procedures must incorporate the design of portable closure walls, or any other engineered barrier materials within the repository excavations that can be deployed rapidly to mitigate worker hazards when such events occur. OPG shall develop these procedures prior to construction, to the satisfaction of the CNSC.

Recommendation 10.6: OPG shall deploy fixed, real-time monitoring equipment in each active emplacement room, and on worker-operated vehicles, as part of its radiation protection program during the operations phase, to the satisfaction of the CNSC.

Recommendation 10.7: To the satisfaction of the CNSC, OPG shall seek and apply operational experience gained from malfunctions and accidents at international repositories, including but not limited to the WIPP, in its contingency, mitigation and other planning processes, during all phases of the project.

Recommendation 11.2: OPG shall, to the satisfaction of the CNSC, conduct a monitoring program to confirm the effects of the project on access to and availability of rental housing, temporary lodging and tourist accommodation in the Local and Regional Study Areas, during site preparation and construction.

Recommendation 13.1: Prior to construction, OPG shall enhance the Geoscientific Verification Plan through the inclusion of additional deep boreholes (minimum of three) that are to be drilled beyond the footprint of the proposed DGR to verify the continuity and structural integrity of the Cobourg Formation and the cap rock sequence. These boreholes should be subject to the same geologic, hydrogeologic, and geomechanical investigation as the original deep boreholes, to the satisfaction of the CNSC.

Recommendation 13.3: Prior to site preparation and construction, OPG shall undertake a quantitative assessment of the hydrocarbon potential of the Cambrian and Ordovician strata present in the Regional and Local Study Areas, to the satisfaction of the CNSC. The assessment should consider current trends in extractive technologies for hydrocarbons and energy resource futures. OPG shall institute a periodic review of this document to reflect the evolving trends in natural resource evaluation.

Recommendation 13.4: Prior to construction, OPG shall re-assess mean shaking levels due to a maximum magnitude earthquake, to the satisfaction of the CNSC. The reassessment shall adopt methodologies employed by Natural Resources Canada and the United States Geological Survey, and consider mitigation strategies or plans for conditions of “beyond-design” ground motions.

16.3.8 Non-*Canadian Environmental Assessment Act, 2012* Recommendations Related to Future Licences

In addition to its conclusions regarding significant adverse effects, mitigation and follow-up under the *Canadian Environmental Assessment Act, 2012*, the Panel also recommends that the following be considered during future licensing should the project be permitted to proceed:

Recommendation 3.2: As part of its public information program, OPG shall prepare succinct, plain language explanations of the application of the Precautionary Principle to any future studies or assessments regarding the DGR. These explanations should be included in any future public proceedings regarding the DGR.

Recommendation 6.3: In order to enhance post-closure containment of radionuclides and other contaminants OPG should, prior to decommissioning, and to the satisfaction of the CNSC, identify materials and procedures that could be used to enhance the effectiveness of the monolith and surrounding transmissive zone as a barrier against contaminant transport to the shaft.

Recommendation 6.5: In order to enhance post-closure containment of radionuclides and other contaminants, OPG shall research comparative seal behaviour of bentonite/sand mixtures having composition ratios other than 70/30. The test program should commence prior to site preparation and construction and be conducted to the satisfaction of the CNSC.

Recommendation 6.6: In order to enhance post-closure containment of radionuclides and other contaminants, prior to construction, OPG shall initiate research on a range of potential candidate seal materials to assess the influence of DGR *in situ* saline groundwaters on the effectiveness of these materials as a barrier. At the time of decommissioning, OPG should select the seal materials with the best observed performance for use in the DGR, in conjunction with CNSC and based on the results of the research.

Recommendation 6.10: Prior to decommissioning, in order to enhance post-closure containment of radionuclides and other contaminants, OPG should develop measures, acceptable to the CNSC, to monitor and mitigate stress-induced fracturing of shaft walls prior to placement of shaft seal materials.

Recommendation 7.2: In order to ensure that the Waste Inventory Verification Plan continues to be revised and updated at appropriate intervals, prior to and throughout the Operations phase, OPG should subject the Waste Inventory Verification Plan to periodic review by an external third party, acceptable to the CNSC, at intervals determined by, but not limited to, the addition of new waste streams.

Recommendation 7.3: In order to retain flexibility to reduce the volume of waste stored in the DGR, OPG should prepare, to the satisfaction of CNSC and before a licence to operate the DGR is issued, an adaptive management plan that includes management actions to exploit potential future options for the disposal of low-level waste.

Recommendation 7.4: OPG should minimize the volume of waste stored in the DGR to the extent practicable through waste reduction and recycling initiatives.

Recommendation 7.8: In order to protect human health and the environment during operations, OPG should take all steps necessary to ensure the integrity of waste packages over the entire preclosure period of the DGR, to the satisfaction of the CNSC.

Recommendation 8.30: In order to enhance the potential of the Project Area as future habitat, OPG shall, prior to decommissioning, submit a detailed revegetation plan for the waste rock pile to the CNSC. OPG should consult with Environment Canada when developing the plan.

Recommendation 13.2: Before a licence to operate the DGR is issued, the Geoscientific Verification Plan should be augmented by the inclusion of a marine 3D seismic survey under a portion of Lake Huron bordering the Bruce nuclear site, to the satisfaction of the CNSC.

Recommendation 13.8: In order to enhance postclosure safety of the DGR, OPG shall develop an active adaptive management system in support of its Postclosure Safety Assessment. The management system shall include the geoscience verification activities of the Geoscientific Verification Plan with additions that ensure consideration of full, complete and clearly defined action levels for all geoscience verification activities. The action levels shall include critical action levels associated with fundamental components of the safety case, i.e., low permeability of host and cap rock; absence of major fractures; and, absence of economically viable resources. In addition, the system shall identify specific options to adapt, modify and manage the project in response to changes in key indicators. The adaptive management system shall be developed to the satisfaction of the CNSC prior to the start of the site preparation and construction phase of the DGR.

16.3.9 Recommendations to Government

In the course of the review, the Panel has identified several areas where the Canadian Environmental Assessment Agency can improve upon the current guidance for the conduct of environmental assessments under the *Canadian Environmental Assessment Act, 2012*, as well as improving public access to records from completed environmental assessments. The Panel has also made several recommendations to the Canadian Nuclear Safety Commission, which it feels will improve on the future regulatory oversight of the DGR.

Recommendation 3.A: Future guidance for the conduct of environmental assessments under the *Canadian Environmental Assessment Act, 2012* should include an explicit list of sustainability indicators for use in each category of project, such as mining, oil and gas, linear development, and ports and harbours. The guidance should include examples of how sustainability can better be incorporated into the evaluation of significance of adverse effects.

Recommendation 3.B: Future guidelines for the conduct of environmental assessment under the *Canadian Environmental Assessment Act, 2012* should include explicit recognition of the role of values in establishing the appropriate level of precaution, and, further, should provide guidance regarding the methods and approaches for use in incorporating values into the application of the Precautionary Principle. Explicit consideration of the values inherent in Aboriginal world views should be included. Applicable case studies illustrating the role of values in establishing the level of precaution should be described.

Recommendation 3.C: To allow convenient public and Government Agency access to all records related to the review of the project, the complete Canadian Environmental Assessment Registry for the project should remain available for the duration of the project and as far into the future as possible.

Recommendation 7.A: In order to further the goal of waste reduction, as required by CNSC Regulatory Policy P-290, the CNSC should develop guidance for waste reduction, setting goals and timelines relevant to the project.

Recommendation 7.B: In anticipation of future decommissioning waste streams, the CNSC should review its classification and management criteria for intermediate-level waste and compare them with international practice.

Recommendation 9.A: The CNSC should work with the Ontario Ministry of Labour and any other agencies with roles and responsibilities related to worker health and safety to clarify roles and responsibilities for the regulatory oversight of the DGR. Building upon these relationships, the CNSC should also establish a site-specific, dedicated, and coordinated inspectorate team for the DGR site, with the objective of having qualified staff with extensive training in nuclear operations and underground hard rock mining.

Recommendation 9.B: The Panel recommends that the CNSC continue to participate in international studies seeking to identify long-term health effects of low-level radiation exposures and suggests that DGR nuclear energy workers be included in CNSC longitudinal studies.

Recommendation 13.A: The CNSC, in consultation with other government agencies including Natural Resources Canada and the Ontario Ministry of Natural Resources, should evaluate institutional control options to restrict access to the surface and sub-surface of the DGR site. The evaluation should be completed in time to support the decommissioning licensing phase.

APPENDIX 1 – PARTICIPANTS IN THE REVIEW

Federal Departments and Agencies

Canadian Nuclear Safety Commission
Environment Canada
Fisheries and Oceans Canada
Foreign Affairs and International Trade Canada
Health Canada
Natural Resources Canada

U.S. Departments and Agencies

U.S. Environmental Protection Agency
Michigan Department of Environmental Quality

Provincial Ministries and Agencies

Ontario Ministry of Community Safety and Correctional Services
Ontario Ministry of Energy
Ontario Ministry of the Environment and Climate Change
Ontario Ministry of Health and Long-Term Care
Ontario Ministry of Labour
Ontario Ministry of Municipal Affairs and Housing
Ontario Ministry of Natural Resources and Forestry
Ontario Ministry of Northern Development and Mines
Ontario Ministry of Tourism, Culture and Sport
Ontario Ministry of Transportation
Saugeen Valley Conservation Authority

Municipal Governments

Bay County Board of Commissioners, Michigan
Burnside Township, Brown City, Michigan
City of Algonac, Michigan
City of Brampton
City of Burlington
City of Croswell, Michigan
City of Duluth, Minnesota
City of Hamilton
City of Lapeer, Michigan
City of London
City of Marathon
City of Memphis, Michigan
City of Mississauga
City of Niagara Falls
City of Niagara Falls, New York
City of Oregon, Ohio
City of Rochester, New York
City of Rogers City, Michigan
City of Sault Ste. Marie
City of Sheboygan, Wisconsin
City of Toronto
City of Thunder Bay
City of Wayne, Michigan
City of Windsor
Cooks County, Illinois
County of Bruce
Greenwood Township, Michigan
Lynn Township
Macomb County Board of Commissioners and Water Quality Board – Macomb County, Michigan
Marine City Commission – Marine City, Michigan
Merritt Township, Michigan
Municipality of Arran-Elderslie
Municipality of Brockton
Municipality of Huron-Kinloss
Municipality of Kincardine
Municipality of Northern Bruce Penisula
Municipality of South Bruce
Paris Township, Ruth, Michigan
Port Huron City, Michigan
St. Clair County Water Board – St. Clair County Michigan
Town of Ajax
Town of Blue Mountains
Town of Oakville
Town of Saugeen Shores
Township of Clinton, Michigan
Township of Essexville, Michigan
Township of Ira, Michigan
Township of Lake Huron County, Michigan
Village of Lexington, Michigan
Village of North Branch, Michigan
Village of Peck, Michigan

Aboriginal Groups

Chippewas of Georgina Island First Nation
Historic Saugeen Métis
Métis Nation of Ontario
Ontario Native Women Association
Saugeen Ojibway Nation
United Chiefs and Councils of Mnidoo Mnising

Elected Officials

Terry Brown, Representative, Michigan State House of Representatives
John Dingell, U.S Member of Congress
Michael Chong, MPP for Wellington-Halton Hills
Dan Kildee, U.S. Member of Congress
Hoon-Yung Hopgood, Senator, Michigan State Senate
Sander Levin, U.S. Member of Congress
Irene Mathyssen, MP for London-Fanshaw
Phil Pavlov, Senator, Michigan State Senator
Gary Peters, U.S. Member of Congress
Sarah Roberts, Representative, Michigan State House of Representatives

Organizations

Algoma Manitoulin Nuclear Awareness
Algonquin Eco Watch
Alliance for the Great Lakes
BHN Holdings Company Ltd.
Beach Community Energy Co-operative
Beyond Nuclear
Bluewater Coalition
Blue Water Sport fishing Association
Brockton Residents' Association
Bruce County Marketplace Magazine
Bruce Peninsula Environment Group
Bruce Steakhouse
Cameco Corporation
Canadian Association of Nuclear Host Communities
Canadian Coalition for Nuclear Responsibility
Canadian Environmental Law Association (CELA)
Canadian Nuclear Association
Canadian Nuclear Society
Canadian Nuclear Workers' Council (CNWC)
Canadian Voice of Women for Peace – Ottawa Chapter
Citizens Clearing House on Waste Management
Citizens for Alternatives to Chemical Contamination
Coalition for a Nuclear Free Alberta
Coalition for a Nuclear Free Great Lakes
Committee for Future Generations
Concerned Citizens of Renfrew County
David Suzuki Foundation
Don't Waste Michigan
Downtown Kincardine BIA
Durham College
Durham Nuclear Awareness
Great Lakes and St. Lawrence Cities Initiative
Great Lakes United
Great Lakes Water Keeper
Greenpeace
Hardy Stevenson and Associates Ltd.
Huron County Federation of Agriculture
Huron-Grey-Bruce Citizens Committee on Nuclear Waste
Hydro Pensioners of Ontario – Bruce County Sub Group
Hydro Pensioners of Ontario – Toronto District
International Institute of Concern for Public Health (IICPH)
Inverhuron District Rate Payers Association
Just One World
Kincardine &District Chamber of Commerce
Kincardine Times
Kincardine Trails Association
Labourers Union
Lake Erie Waterkeeper
Lake Huron Fishing Club
Lake Huron Learning
Lawyers' Committee on Nuclear Policy
Lucknow and District Kinsmen
Michigan Agri-Business Association
Michigan League of Conservation Voters
National Farmers Union Huron Local
North American Young Generation in Nuclear
Northwatch
Nuclear Information and Resource Service
Nukewatch
Ontario Clean Air Alliance
Ontario Society of Professional Engineers
Organization of Canadian Nuclear Industries
Penetangore Regional Economic Development Corporation
Pickering Nuclear Community Advisory Council
Port Elgin Tourist Association
Power Workers' Union
Pro-Repo
Provincial Council of Women of Ontario
Repository Hornepayne
Sargent Event Communications Inc.
Saugeen Shores Chamber of Commerce
Save Our Saugeen Shores
Sierra Club Canada
Sierra Club Michigan
Sierra Club, Ohio Sierra Club Nuclear Free Committee
Siskinds LLP
Society of Professional Engineers and Associates
Southampton Residents Association
St. Clair County Community College
Stop the Great Lakes Nuclear Dump
The Canadian Peregrine Foundation
The Canadian Union of Skilled Workers
The Inverhuron Committee Inc.
The Pickering Nuclear Advisory Council
The Society of Energy Professionals
Toledo Coalition for Safe Energy
Tourism Industry Coalition of Michigan
Transformation Services Group
United Church of Canada – Toronto Conference
Walkerton Kinsmen Club
Women's Healthy Environments Network
Women's House Serving Bruce & Grey
Women in Nuclear Canada
University of Ottawa
University of Toronto
York University
Xi Zeta Gamma Chapter of the Kincardine Beta Sigma Phi
Xylene Power Ltd.
ZeroWaste4ZeroBuring

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Kathy Barns
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Keith Battler
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J. Knox
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Paul Kuster
Cindy Kuzminski
Leonard Kuzminski
Norm Lachance
Louisette Lanteigne
Jim Large
Dietrich E. Lauckner
Graham Lawson
Nigel Lawson
Patricia Lawson
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William Leiss
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Ethyl Rivera
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Meghan Robinson
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John Sass
C.B. Sawyer
Greg Schmalz
Terrence Scheich
Barry Schmidt
Shirley Schmidt
Christie Seely
Donald (Tim) Seitz
Paul Sheridan
Stephen Shuput
Robert Shave
Aron Shevis
John Sifton
Gerald Robert Simpson
L. Sgl
Dave Slarge
Eileen Smith
Elizabeth Smith
Mike Smith
Heather Spence
Jutta Splettstoesser
Lana Splettstoesser
Ralph Splettstoesser
Terry Squire
David B. Stevens
M. St. John
P. St. John
Peter Storck
Doug Storrey
Glenn Sutton
Gabrielle Swanberg
Amy Szczepanski
Jan Tache
Judith Thierry
Brenda Thompson
Gord Thompson
Ron Thompson
Gene Threndyle
Anna Tilman
Vivian Tits
Janet Townley
James Tyree II
Gene Ulmer
Curt Valmy
Peter Venton
Ann Voges
Jacqueline Wakefield
Julie-Ann Wang
Elaine Wassermann
Sharon Walters
Jennifer Webb
Emily Weber
Nicole Weber
Rachel Western
Isabel Wetram
Dean Whalen
Monica Whalley
William Whyte
William Wilgus
Mary Jane Williams
Alan Wilson
Anne Wilson
Patricia Wilson
Larry Wiwchar
Arthur Wolf
Margret Wolf
Debby Wolfe
David Wood
W. John Woodcock
J.C. Woodrow
Hugh Wright
Shell Wright
Howard Wrightson
N. Wunder
Bernard Yozwiak
Silvaine Zimmermann