nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Climate Change

The range of potential impacts of climate change, from global warming to glaciation, must be factored into the long-term management of used nuclear fuel. The Adaptive Phased Management (APM) approach was selected in part to address these impacts. The Nuclear Waste Management Organization (NWMO) has programs underway to further acknowledge the potential risks in the planning and decision-making process.

Introduction

The Earth's climate changes over time. Twenty thousand years ago, the world was in an ice age. Global temperatures were several degrees colder than present, and glaciers covered much of Canada. Then, the Earth warmed up, and for the past 10,000 years, the global average climate has been relatively stable.

The global climate is currently warming. During the past century, the global average temperature has increased about 0.7°C [IPCC 2007], while the Canadian average temperature has increased about 1.3°C [NRCan 2008]. The potential extent and duration of this warming are not certain. Current predictions suggest that the global average temperature could increase 1 to 6°C by 2100 [IPCC 2007]. In the very long term, thousands of years in the future, the climate may cool again, and another ice age may begin [NRCan 2008].

Climate change is a concern for the long-term management of used nuclear fuel because of the uncertainty in predicting climate and the potential range in climate over the long time periods during which the used fuel must remain contained and isolated. This paper provides a brief overview of the possible impacts of climate change in Canada, from global warming to glaciation, and the potential implications for the long-term care of used fuel.

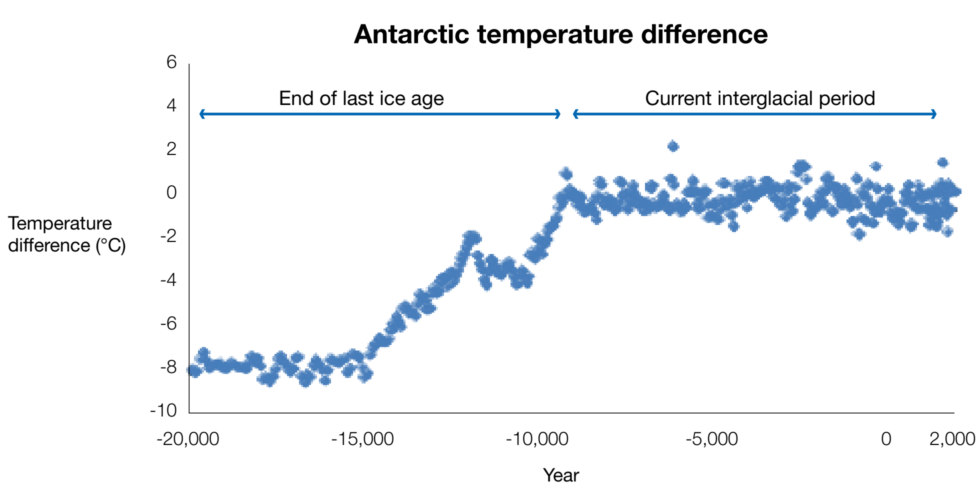

Figure 1: Change in temperature over the past 20,000 years from Antarctic ice core data, showing relatively stable climate conditions since the end of the last ice age [NOAA 2001].

Global Warming

POTENTIAL IMPACTS OF GLOBAL WARMING ON CANADA

There is ample documented evidence of a changing climate and its impacts across Canada, summarized in *Canada's Fourth National Report on Climate Change* [EnvCan 2006] and *From Impacts to Adaptation: Canada in a Changing Climate 2007* [NRCan 2008].

In northern Canada, mean annual temperature increases approach 0.5°C per decade over the past 50 years. The impacts include decreased sea ice and glacier extent, decreased river flows, permafrost warming and melt, enhanced coastal erosion and ecosystem changes. In future, the Arctic and southern and central prairies are projected to experience the greatest warming [NRCan 2008].

Average annual precipitation is expected to increase in most regions of Canada. However, throughout most of southern Canada, there will be little change (or a reduction) in precipitation during summer months and increased precipitation during winter months [NRCan 2008]. Changes are also expected in the frequency of extreme events such as heat waves, droughts, floods and storms.

Warmer water temperatures and lower seasonal flows will lead to degraded water quality. Warmer winter temperatures will increase the frequency of mid-winter thaws and rain-on-snow events, which increases the risk of winter flooding. Despite forecasts of increases in regional precipitation, the increase in evaporation caused by higher temperatures is expected to lead to an overall decrease in Great Lakes water levels [NRCan 2008].

These changes will have implications for all sectors of the Canadian economy and public health. For example, in the forestry sector, drier conditions will create more droughts increasing the probability of more frequent and intense forest fires. Sea level rise may impact groundwater salinity and increase storm surge flooding in coastal communities. Infrastructure, such as roads and bridges, may be weakened by a decreased water table or thawing of permafrost. For many communities, particularly those dependent upon natural resources or tourism, a changing climate may threaten economic sustainability.

POTENTIAL IMPLICATIONS OF GLOBAL WARMING FOR MANAGEMENT OF USED NUCLEAR FUEL

Over the next 100 years, the key activities of the NWMO will be the identification of a central site in a willing host community, construction of the surface and underground facilities, transport of the used fuel to the central facility, and placement of the material in the facility.

With respect to siting, new facilities must consider the potential effects of climate change. Sites near the ocean must consider the potential for future increase in sea level and coastal erosion. Surface facilities and very shallow underground storage facilities for used fuel may be affected by extreme weather events. High winds, intense storms, flooding, and erosion may damage structures, cause loss of power supply, increase forest fires, etc. The effects of these events should be considered in the site selection process and design of these facilities.

Used nuclear fuel will be transported to the central facility by road, rail and/or water. The potential impacts of climate change on transportation are manageable, if climate change considerations are included in the planning. Increased frequency of extreme weather events may decrease the number of days suitable for transportation. Shipping of used fuel from existing nuclear reactor sites may be aided by a longer ice-free shipping season, but also restricted because of lower water levels affecting docking facilities or shipping passages. The opportunities for transport may change over the course of the period of shipment of used fuel. The NWMO approach emphasizes flexibility, so both the timing and nature of transportation may be adjusted to adapt to climate change.

Facilities deep underground in low permeability bedrock are naturally isolated from surface environmental effects. Once the used fuel has been emplaced underground, a suitably sited deep repository is not expected to be sensitive to the potential surface changes resulting from global warming.

Glaciation

POTENTIAL IMPLICATIONS OF GLACIATION ON CANADA

Over the past two million years, the Earth's climate has repeatedly fluctuated between glacial and interglacial conditions. Changes in the amount of sunlight reaching polar regions due to slow natural variations in the orbit of the Earth around the sun are believed to be the primary driver of these climate changes.

The last glacial period ended approximately 10,000 years ago. The Earth's present climate, if allowed to evolve naturally, might last an additional 20,000 years or so before glacial conditions would return [NRCan 2008]. However, other factors are also relevant, and when climate change would again support widespread glaciation is not certain. But in planning for the very long term, it is prudent to assume that glacial conditions will return.

During previous glacial periods or ice ages, much of Canada was covered with ice. Ice sheets first formed in a few northern locations, and then expanded from these cores. Over a typical 100,000-year glacial cycle, the ice sheet would advance and retreat several times, each time moving huge quantities of sand, soil and rock debris across the landscape. Large lakes and rivers would be formed in front of the ice. The weight of the ice sheet would cause depression of the Earth's surface under the ice and rebound after its retreat. There would be an increased frequency of earthquakes, notably during ice sheet retreat.

The cooler surface temperatures would create tundra-like conditions on the surface and cause formation of permafrost. In the vicinity of the ice sheet, the groundwater conditions would be further affected with changes in the groundwater flow and fresh oxygenated water pushed deeper into the rock.

POTENTIAL IMPLICATIONS OF GLACIATION FOR MANAGEMENT OF USED NUCLEAR FUEL

At the time of any future glaciation, the NWMO plan would have used fuel placed within a sealed and closed deep repository. Although the glaciation would drastically affect surface conditions, the potential impacts decrease with depth. At proposed depths for a used fuel

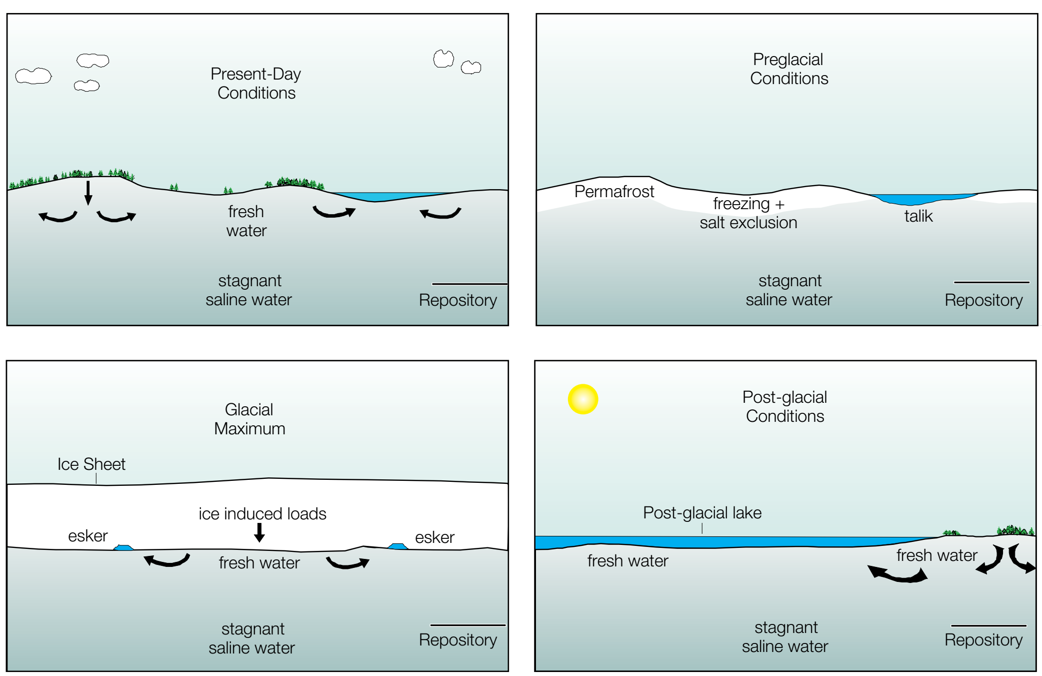

Figure 2: Illustration of the changes in conditions over a glacial cycle.

repository (500 to 1,000 m), the main potential effects are increased stresses on the used fuel containers due to the weight of the ice sheet, increased frequency of earthquakes, and changes to the groundwater flow and groundwater chemistry.

Since Canada has seen nine major glaciation cycles within the past one million years, we can look within the rocks to see a record of the magnitude of these potential impacts at different sites. Using data and models from this historic record, we can better understand the likely impact of future glacial conditions in Canada and take this into account in both design and siting. For example, the current reference used fuel containers are designed to withstand the load of a three-kilometre-thick ice sheet.

Earthquakes induced as a result of glaciations may occur even in otherwise currently seismically quiet areas, but they are most likely to occur along existing faults. Therefore, siting of a repository would consider the locations of major faults.

Finally, there is good evidence that deep rock locations in Canada can contain pore waters that are millions of years old, indicating that the passage of multiple ice ages over the past one million years has not perturbed the groundwater at these depths, and thereby providing confidence that the site would be unperturbed by glaciation in the future as well. These factors would also be considered in the siting process.

Managing the Uncertainty

The NWMO recognizes the risks that climate change poses to the long-term care of used nuclear fuel, over the near and long term. Adaptive Phased Management, specifically the phased decision making and continuous learning, allows for the incorporation of new knowledge and changing circumstances during implementation.

Our work program includes the study of climate change scenarios to provide a way to think about the issues, development of siting factors to mitigate the risks, and planning in the design of facilities to minimize the known risks.

References

EnvCan. 2006. *Canada's Fourth National Report on Climate Change*. Environment Canada. (**http://www.ec.gc.ca/climate/home-e.html**)

NRCan. 2008. *From Impacts to Adaptation: Canada in a Changing Climate 2007*. Natural Resources Canada. (**http://adaptation.nrcan.gc.ca/assess/2007/index_e.php**)

IPCC. 2007. *Fourth Assessment Report, Climate Change 2007: Synthesis Report, Summary for Policymakers*. Intergovernmental Panel on Climate Change. (**http://www.ipcc.ch**)

NOAA. 2001. Petit, J.R. et al., Vostok Ice Core Data for 420,000 Years, IGBP PAGES/ World Data Center for Paleoclimatology Data Contribution, Series#2001-076. NOAA/NGDC Paleoclimatology Program, Boulder USA. (**http://www.ncdc.noaa.gov/paleo/icecore/antarctica/vostok/vostok_isotope.html**)

For more information, please contact:

Jamie Robinson Director, Strategic Communications
Tel 647.259.3012 Fax 416.934.9978
Email jrobinson@nwmo.ca

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Nuclear Waste Management Organization
22 St. Clair Avenue E., Sixth Floor, Toronto, Ontario M4T 2S3 Canada
Tel 416.934.9814 Toll Free 1.866.249.6966
www.nwmo.ca