Part II: Deep Geological Repository Conceptual Design
Geological Disposal - International Experience

**New Mexico, U.S. Waste Isolation Pilot Plant (WIPP)**
- Located in the desert
- The underground repository was excavated in 250 million year-old bedded salt ~ 660 m below surface
- Began operations in 1999

**Sweden Forsmark Facility**
- Located at the Forsmark nuclear power station site
- The underground repository is in crystalline rock ~ 60 m below the Baltic Sea
- Began operations in 1988

**Finland Olkiluoto Facility**
- Located near the Olkiluoto nuclear power station
- The underground repository was excavated to a depth of 70-100 m in crystalline rock
- Began operations in 1992
- Proposed DGR site in Kincardine, Ontario;
- 680 m below surface, in limestone capped by 200 m of shale;
- Intact rock formations without major faults or fractures for more than 450 million yrs;
- Separate emplacement vaults for 160,000 m$^3$ L&ILW;
- 2005 – poll among Kincardine residents supports the DGR project.
Conceptual Design

- Nominal capacity: 160,000 m$^3$. Modular design allows expansion, as required;

- Surface facilities: 2 admin buildings and a waste receipt building;

- Two shafts: 6.5 m $\Phi$ main shaft, 4.5 m $\Phi$ ventilation;

- 40–ton high load capacity hoist to transfer waste packages to the repository level;

- Underground facilities: waste receiving area, equipment maintenance, emplacement rooms and refuge stations;

- Transfer of waste packages begins in 2018;

- Shafts will be sealed and backfilled during decommissioning.
Darlington Intake/Discharge Tunnels (0.9 to 1.8 km beneath Lake Ontario)

Barberton Mine (Ohio), 700 m deep in Columbus Limestone
- Excavation by electrically powered roadheader;
- Safer than drill and blast – no explosives
- “vertical roadheader” to sink shaft more flexible in shaft diameter
- Requires less ventilation
Ventilation System

- HVAC system provides heating / cooling
- Exhaust fans on surface create a pressure differential between the 2 shafts;
- Workers kept in fresh air
DGR Emplacement Room

- Concrete floor to provide flat and stable surface for stacking of waste packages;
- Minimize excavation by categorization of room into similar sizes;
- LLW & ILW will be segregated due to different package sizes and stacking needs;
- Each room isolated (not sealed) with concrete wall when full with low ventilation.
Packages in DGR

- LLW – 130,000 m³ (~39,000 packages)
- Standard size containers will be transferred “as is”
- Large objects – segmented and grouted

- ILW – 34,000 m³ (~12,000 packages)
- ILW will be transferred in radiation shields
The DGR
DGR falls under federal jurisdiction, i.e. NSCA, OHSA, FRPR
- Surface facilities: NBC, NFC
- Underground: Ontario Mining Regulations (OMR)

Detection: smoke and CO detectors in work areas with audible and visual alarms, and “stench gas”

Suppression: foam based fire extinguishers, mobile inert gas for closed rooms

All mobile equipment is fitted with hand-held fire extinguishers.
Refuge Stations

- Two permanent and two mobile refuge chambers

- Refuge chambers are:
  - Constructed with fire resistant material
  - Capable of holding up to 25 persons
  - Equipped with voice communication;
  - Provided with first-aid equipment, compressed air and potable water.
Waste retrieval

- Waste retrieval by reversing the emplacement process, if required.
- Same radiation control, shielding and transportation equipment
- Buffer storage area will be established.
Sealing of Repository

Conceptual design requirements of the sealing system:

- Limit release of radioactivity;
- Limit flow of groundwater;
- Compatible with chemical and mechanical conditions of the surrounding host rock;
- Maintain its structural integrity without maintenance;
- Prevent accidental entry;
- Use existing construction technologies and materials;
- Able to withstand 14 MPa
Post Disposal Gas Generation

- Oxic environment:
  - microbial degradation of organic wastes;

- Anoxic environment:
  - $3\text{Fe} + 4\text{H}_2\text{O} \rightarrow \text{Fe}_3\text{O}_4 + 4\text{H}_2$
  - $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 3\text{CO}_2 + 3\text{CH}_4$
  - Small amount of $\text{H}_2$ also produced by $\text{H}_2$ generating bacteria

- Max 8 MPa $\text{H}_2$, 6 MPa $\text{CO}_2 + \text{CH}_4$. 
Gas Mitigation Options

- Mitigation of H₂:
  - Passive Autocatalytic Recombiner in oxic condition
  - Methanogenesis in anoxic condition
    - \( CO₂ + 4H₂ \rightarrow CH₄ + 2 H₂O \)

- Mitigation of CO₂:
  - By MgO:
    - \( MgO + H₂O (aq \text{ or } g) \rightarrow Mg(OH)₂ \)
    - \( 5Mg(OH)₂ + 4 CO₂ (aq \text{ or } g) \rightarrow Mg₅(CO₃)₄(OH)₂ \cdot 4H₂O \)
  - By concrete:
    - \( Ca(OH)₂ + CO₂ \rightarrow CaCO₃ + H₂O \)
Other Mitigation Options

- Minimize metal in container design;
- Use passivable materials (e.g. stainless steel, concrete) for waste packages;
- Repository void volume to accommodate gas generation;
- Use high permeability materials for shaft backfill;
- Strategic waste emplacement.
Site Geology
Geological Evidence

- Geotechnical Feasibility study considered geologic, hydro-geologic, seismic and geo-mechanical characteristics of bedrock;

- Proposed site has ideal setting as rock formations are isolated from groundwater sources;

- Pore water at 600 m showed high salt content – trapped > 1,000,000 years.
Areas being investigated include:

- Physical and chemical properties of sedimentary bedrock – via borehole testing;
- Seismic activity – seismic reflection survey and borehole seismograph network;
- Presence of oil and gas reserves - boreholes;
- Capacity of rock to protect surface and groundwater resources – shallow bedrock groundwater monitoring wells.
Geoscience Attributes

- Borehole testing consistently show site is comprised of 34 individual layered bedrock of Cambrian to Devonian age (543 – 350 million yrs);
- Regional geologic knowledge allows bedrock characteristics to be estimated
Geoscience Attributes

- **Multiple Natural Barriers:**
  - Surrounded by multiple layers of low permeability sedimentary rock;
  - Horizon comprised of ~200 m Ordovician age (450 million yrs) shale;
  - Sequence of shales, dolostones and evaporites above the shale posses low permeabilities.
Geoscience Attributes

- **Seismically Quiet:**
  - Bruce located in the stable interior of the North American continent;
  - Historic seismic records show no events exceeding M5 in the past 100 years;
  - Seismicity monitoring network has not detected activity > M2.5.
Geoscience Attributes

- **Isolated Shallow Groundwater Resources:**
  - Chemistry of bedrock water shows salinity increases with depth, TDS 100 – 300 g/L;
  - With local shallow or near surface bedrock wells (< 100 m depth), chemistry of ground and pore waters indicate old deep groundwater system – no mixing with glacial or present-day freshwater.
Geoscience Attributes

- **Natural Resources Potential:**
  - Has no significant oil / gas within 10 km of Bruce;
  - Site does not contain known industrial minerals / metals that cannot be obtained elsewhere.
Geoscience Attributes

- **Transport Diffusion Dominated:**
  - Deep groundwater system shows no glacial perturbation or post-tectonic cross-formational mixing;
  - Low permeabilities measured show consistencies with a diffusion dominant environment;
  - University of Waterloo performed simulations of the regional groundwater system – stable diffusion dominant system enclosing the repository.
Safety Assessment

- **Preliminary safety assessment considers:**
  - Normal operation and accidents during pre-closure and post-closure;
  - Effects on human and biota

- **Key results:**
  - Host rock retards radionuclide movement;
  - Shaft is a potential pathway;
  - Long re-saturation period
  - Gas generation in the DGR

Diagram:
- Site Characterization Data
  - Waste Inventory Forecast
  - Facility Design

- Preliminary Safety Assessment
- Updated Safety Assessment
- Preliminary Safety Report
An International Perspective

- **Geoscience Review Group (GRG):**
  - Representatives from France, Switzerland, US and Canada
  - Provides guidance on:
    - Field laboratory measurement methods;
    - Interpretation of field and laboratory data;
    - Geoscientific investigations in sedimentary rock;
    - Strategies for geosynthesis development.
Segregated funds for the long-term management of L&ILW

Funds for the management of used fuel is separate

The Ontario Nuclear Funds Agreement provides provincial oversight
Hosting Agreement

- Kincardine, Saugeen Shores, Huron-Kinloss, Arran-Elderslie and Brockton will receive $35 million (2004 dollars) over 30 years subject to:
  - Environmental assessment guidelines
  - Environmental assessment approval
  - Construction license
  - Operating license

- Accommodate all L&ILW produced until 2035 and OPG reactor decommissioning waste - ~ 200,000 m³

- Provision to negotiate repository expansion for new build reactors

- No used nuclear fuel in DGR
## Schedule

### Path Forward

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>2007-2009</td>
<td>Ongoing Environment Assessment and site characterization studies</td>
</tr>
<tr>
<td>2011</td>
<td>Environmental Assessment Review Panel appointed</td>
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<tr>
<td>2011</td>
<td>OPG Submits Environmental Impact Statement to Review Panel</td>
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<tr>
<td>2011</td>
<td>Public Review of Environmental Impact Statement</td>
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<tr>
<td>2012</td>
<td>Public Hearing</td>
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<tr>
<td>2012</td>
<td>Review Panel Issues Report to Minister</td>
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<tr>
<td>2012</td>
<td>Cabinet decides on Acceptability of Environmental Impact Statement</td>
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<tr>
<td>2012</td>
<td>CNSC considers Construction License application</td>
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<tr>
<td>2012-2017</td>
<td>Construction, subject to licensing</td>
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<tr>
<td>2017</td>
<td>Seek operating license from CNSC</td>
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<tr>
<td>2017/2018</td>
<td>DGR operation begins, subject to licensing</td>
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