Planning and Implementation of the Closure of a Canadian Uranium Mine: A Multidisciplinary Approach

Tamara Yankovich
2nd MODARIA Plenary Session
13 November 2013
Vienna, Austria
Talk Outline:

- Definitions and Context
- Overview of Gunnar Remediation Project
- Establishment of monitoring program
- Environmental assessment
- Licensing documentation
- Key conclusions.
System of Radiation Protection:

- **Three Exposed Groups:**
  - Workers
  - Patients
  - General public

- **Three Exposure Situations:**
  - Planned exposures
  - Emergency
  - **Existing exposures**

- **Three Radiation Protection Principles:**
  - Justification
  - Limitation
  - Optimization
Existing Exposure Situations:

- Problem already exists when a decision on the need for control needs to be taken.

- Existing exposure situations
  - Natural background radiation (e.g., radon)
  - Residual radioactive material from past practices not subject to regulatory control, or not subject to regulation in accordance with current standards (e.g., when standards become more stringent over time) => **Nuclear legacies**
  - After an emergency exposure situation is finished

Lessons Learned from existing situations can be applied to “proactive” decision-making and prevention of impacts for Planned Exposure Situations
Types of Existing Sites:

- High-background sites
- Operating Sites (non-legacy):
  - Research laboratories
  - Research reactors
  - Nuclear Power Plants (NPP)
  - Uranium mines/mills
  - Hospital or medical facilities
  - Isotope production facilities
- Legacy Sites:
  - Operating legacy sites
  - Orphaned or abandoned sites
  - Closed/decommissioned sites
- Post-accident Sites
Some Relevant Concepts and Terminology:

In general, orphaned or abandoned mines can be defined as:

_Those sites for which there is no owner, or the owner cannot or will not finance the costs of remediation._

Responsibility for such sites typically ends up with Government (Provincial or Federal).

There are >10,000 such sites in Canada, including a number of uranium mine/mill sites in Northern Saskatchewan.

70 such sites are uranium mines.

Reference: Tremblay, 2005
Cleanup of the Gunnar, Lorado and 36 Satellite Mine Sites in Northern Saskatchewan

Remediation will be conducted to address historic issues with long-term monitoring to follow.
The Focus of this Talk is the Gunnar Uranium Mine/Mill Site: History

- Operated from 1953-1964
- Average grade was 0.18%.
- ~8.5 million tons of rock mined and processed
- Open pit and underground mine.
- Over 5 million tons of unconfined tailings
- The pit and subsurface workings were flooded, shaft plugged with concrete, and mine site abandoned
- All buildings, tailings, and waste rock piles were left on site “as is”.
Project Objectives:

- To eliminate or reduce public safety hazards and environmental risks now and in the future.
- To develop sustainable remediation options that are technically and economically feasible.
- To establish a responsible and cost-effective environmental monitoring program, while minimizing long-term care and maintenance at the Site.
Project Endpoints:

• Site does not pose unreasonable public health or environmental risks.
• The flora and fauna adjacent to the site are not significantly impacted by contaminants.
• The traditional use of resources adjacent to the site are safely conducted.
• The desire is to have the site managed through the institutional controls program for long-term care and maintenance.
# Phases of Remediation:

- **Pre-remediation** – planning and approvals
- **Remediation** – plan implementation
- **Post-remediation** – monitoring and follow-up
- **Long-term Monitoring** – leading to institutional control

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-remediation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remediation</td>
<td>Environmental Assessment</td>
<td>Preparation of Licence Documentation</td>
<td>Detailed Engineering</td>
<td>Remediation (4 to 7 years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-remediation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-term Monitoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
System of Radiation Protection:

- **Three Exposed Groups:**
  - Workers
  - Patients
  - General public

- **Three Exposure Situations:**
  - Planned exposures
  - Emergency
  - *Existing* exposures

- **Three Radiation Protection Principles:**
  - Justification
  - Limitation
  - Optimization
Radiation Protection Principles:

- **Justification** – actions should be commensurate with risk, with adequate net benefit
- **Optimization** - key impacts should be weighed out and balanced with consideration of relevant factors and in consultation with interested parties
- **Limitation** – establishment of “targets”, taking account of the situation
Key Aspects of the Gunnar Mine Site:

- Dry Tailings
- Buildings and Structures
- Mine Pit
- Waste Rock Piles
- Wet Tailings

Site is under Licence Exemption until December 31, 2016.
Environmental Assessment (EA) in Canada:

- In Canada, for activities that require an EA, no work is typically undertaken until the EA has been approved by regulatory agencies and has undergone a Public consultation process.
BUT for Abandoned Legacy Sites, Depending on the Situation, and How Imminent the Safety Risk,

The Challenge May Lie in Balancing Scientific Understanding with the Need to Decide...

... where time-frame matters (!)

For example, for abandoned sites, there are not always records or monitoring data available to support ‘sustainable’ and informed decisions for remediation; however, environmental management and regulatory compliance typically happens ‘now’ and if a site is in a significant state of deterioration resulting in imminent risk, immediate action would be needed to stabilize the situation.

KEY POINT – It is very important to weigh out and prioritize risk, and to act accordingly.
Environmental Assessment (EA) in Canada:

- In Canada, when an EA is required, no work is typically undertaken until the EA has been approved by regulatory agencies and has undergone a Public consultation process.
- That said, Canadian regulatory agencies permitted deteriorating buildings and structures to be taken down at the abandoned Gunnar Uranium Mine/Mill Site to address “imminent” Public safety issues.
- Abatement and demolition work on the Site was to be completed by no later than October 2011.
For the Gunnar Site, in the Short Term – Putting Public Safety First to Address our History

- Dismantling of buildings and structures on the Gunnar Mine site that fail a structural safety assessment.
- Removal of risks on the site related to hazardous substances and materials (including asbestos).
- Addressing safety issues related to site maintenance (e.g., old sumps, tripping hazards, etc.)
2010 Work was Focused On:

- Development of safe work plans, including:
  - Occupational Health and Safety Plan
  - Structural Safety Assessment
  - Hazardous Substances and Materials Inventory
  - Demolition Plan
  - Waste Management Plan
- Establishment of barriers.
- Removal of overhead hazards.
- Abatement and demolition of non-process buildings (e.g., wooden structures).
- Securing the site.
2010 Demolition Work:

Summary of Buildings Down:

- 2 wooden barges
- 4 bunkhouses
- 2 Married Quarters
- Mine Manager’s Residence (Lodge)
- Wooden fishing shacks
- Small wooden residences
- School
- Curling rink (as shown in photos)

Initial focus was placed on high risk, non-process buildings and structures.
Bunkhouses: Before
Bunkhouses: After
2010 Demolition: School

Before:

After:
Addressing Other Safety Issues:

(some examples)

- Filling in old sumps
- Construction of berm as barrier around Gunnar Pit
- Clean-up of site debris
- Low- and moderate-risk asbestos abatement in the Community Centre
2010 Asbestos Abatement:

Independent Asbestos Expert
But what do you do with the waste until the Environmental Assessment is approved and can it be safely secured and stored?
Focus of the 2011 Demolition Work:

- Mobilization to the Gunnar Mine Site on the ice road.
- Establishment of a camp.
- Development of safe work plans.
- Establishment of a temporary hazardous materials storage facility.
- Abatement and demolition of process buildings (including mill, acid plants, water tank, head-frame and others).
- Planning transport of hazardous materials off-site.
- Maintaining site security.
2011 Demolition Work: Summary of Buildings Down

- Maintenance Warehouse
- Geology Mine Dry
- Administrative/Engineering Building
- 2 Acid Plants
- Fine Crushed Waste Bin and Surge Bin Transfer Towers
- Powerhouse
- Water Tank
- Two Acid Tanks
- Mill
- Small Buildings and Structures
- Head-frame
Head-frame Footprint: After
Mill Complex: Before
Mill Complex: After
Sulphur Pad:

Before

After
Acid Plants: Before
Acid Plants: After
Demolition of the Gunnar Head-frame:
Due Diligence: Inspections of Demolition Footprints at Gunnar
2011 Progress: Summary of Demolished Buildings

Before

Dismantling of ~85 buildings and structures, and 15,000 lineal feet of utilidor.

After

Completed Ahead of Schedule With No Loss Time Injuries
2011 Progress: Summary of Demolished Buildings

Before

After

Photo provided courtesy of Woodland Aerial Photography
In the Long Term –
Securing All Aspects of the Gunnar Site

Site is under Licence Exemption until December 31, 2016.
Simplified Remediation Alternatives:

- **Mine Pit:**
  - Leave as a water body or dewater and use as a waste disposal site?

- **Tailings and Waste Rock:**
  - Contour/stabilize and cover?
  - Relocate to mine pit?
  - Relocate ‘contaminated’ waste rock to an engineered lined landfill and use ‘clean’ waste rock as cover on tailings?

- **Waste Disposal:**
  - Dispose of in the mine pit or an approved landfill?
In Canada, “preferred” and “alternative” remediation options are typically identified as part of the environmental assessment (EA) process and are documented in the Environmental Impact Statement (EIS) before initiation of the Project (representing a definitive decision on what the Project will entail).

However, due to the lack of records and monitoring data, this approach may not be feasible when planning the remediation of abandoned sites that operated under a different regulatory regime, due to the lack of historical information regarding the Site.
Environmental Assessment (EA) in Canada:

- In such cases, it may be logical to collect missing information after the EA has been approved, as part of Site licensing.
- Information gaps can then be captured as part of a decision-tree approach, or flow diagrams, that identify key questions that need to be answered once more data and information has been collected.
- This allows informed decisions to be made on remediation options, based on the information collected.
- Unlike a typical EA (with identified “preferred” and “alternative” options), through a decision-tree approach, remedial options can be selected later in the process, as more information becomes available.
All possible remediation options were identified and pre-screened to identify potentially feasible remedial options (options with a ‘fatal flaw’, such as those that would not meet regulatory compliance, were screened out at this stage).

Each key Site Aspect (e.g., tailings, waste rock, pit, contaminated soils, process areas) was then evaluated individually based on Constructability, outcomes of the Human Health and Ecological Risk Assessment (HHERA), and Public Preference.

A gap analysis was undertaken for all viable remediation options.

Flow diagrams, or “decision-trees”, were established to map out plans to fill in key information gaps that are required in decision-making (i.e., to identify remediation options).
Screening of Remedial Options:

- Each category was further sub-divided into sub-criteria, as follows:
  - **Constructability** – potential risk to workers and the environment during the active remediation phase; constructability/feasibility/efficacy of the remedial option from an ‘execution’ point of view (i.e., can it be done technically and cost-effectively? Is it an “accepted”/vetted technology or approach?)
  - **Public Preference** – ranked into categories based on community meetings, surveys and other inputs from the public.
Sample Waste Rock Decision Tree - Gunnar:

Re-slope for Long Term Stability and Safety; Clean-up debris on waste rock piles

Leave waste rock in place?

 Assess Potential Cover Options
   - Waste Rock
   - Till
   - Membrane

Relocate waste rock to pit?

Dewater pit and relocate waste rock to pit

Design Cover
   - Water or soil cover to fill dewatered pit?
     - Membrane?
**Historical Flow Path**
Moving tailings to an
Bare tailings and
St. Mary's
Relocation poses
Submerging tailings
Tailings relocation
Need to determine
Relocation to pit
Multiple flow paths to
Site
Tailings
Gunnar
Main
Aspect
IAEA
Source:
- Bare tailings and immediate area

**Intermediate Pathways:**
- Historical flow path between Gunnar Main and Gunnar Central
- Multiple flow paths to Lake Athabasca: Catchment 3, soccer field, acid plant, open pit, waste rock seep, etc.

**Site Aspect**
- **Main Tailings**
- **Receiving Environment:**
  - St. Mary's Channel/Zeemel Bay/Lake Athabasca

**Risk**
- **Gamma Exposure**
  - Yes
  - Rationale: It is generally not acceptable to leave accessible areas of unconfined tailings or accessible areas where levels of gamma radiation exceed allowable dose limits exposed.
  - **Human Health Risks (non-Gamma)**
    - No
    - Rationale: Hunting or fishing not occurring in this area and will not be encouraged in future.
  - **Ecological Risks (non-Gamma)**
    - Yes
    - Rationale: Ingestion risk
  - **Physical Hazards**
    - No
    - Rationale: No physical risks present

**Is Risk a Driver for Remedial Action?**
- **Gamma Exposure**
  - Yes
  - Rationale: It is generally not acceptable to leave accessible areas of unconfined tailings or accessible areas where levels of gamma radiation exceed allowable dose limits exposed.
  - **Human Health Risks (non-Gamma)**
    - No
    - Rationale: Hunting or fishing not occurring in this area and will not be encouraged in future.
  - **Ecological Risks (non-Gamma)**
    - Yes
    - Rationale: Ingestion risk
  - **Physical Hazards**
    - No
    - Rationale: No physical risks present

**Remedial Options**
- **Gamma Exposure**
  - Yes
  - **'Do Nothing' only acceptable where equipment accessibility is poor.**
  - **Cover taillings**
  - **Relocation**
  - **'Do Nothing' (i.e. gamma shield only)**
  - Potentially augment cover design proposed for mitigation of gamma exposures, above.

**Decision**
- Cover is the preferred option over relocation. For the following reasons:
  - Relocation poses additional risk through release of contaminated porewater.
  - Need to determine where the tailings should go.
  1. Relocation to pit would require treatment of entire pit take. Tailings would completely fill the pit, leaving no room for water treatment residuals.
  2. Tailings relocation would be costly; need to account for transportation and cost of backfilling the Gunnar Main footprint.
  3. Moving tailings to an alternate terrestrial location makes no practical technical sense.
  4. Submerging tailings in a natural water body at the site would create a risk to the aquatic pathway where one does not currently exist.

**Rationale:**
- Triangular tailings mass immediately east of Gunnar Main boundary must be addressed in terms of gamma exposure, either by covering as an extension of Gunnar Main, or by consolidating them with Gunnar Main. Thinly dispersed tailings farther afoot from Gunnar Main may be left as-is.

**Gamma Shield to Incorporate Capillary Break, if Necessary to Limit Capillary Rise of Contaminants from Underlying Tailings to the Surface to Maintain Reductions in Risk to Ecological and Human Health.**
Contaminant flux estimates to be made for the post-cover construction (gamma shield) scenario to determine if design needs to be augmented somehow to mitigate risks in the intermediate pathway(s) and receiving environment.
Intermediate pathway between Gunnar Main and Gunnar Central largely inaccessible and will likely remain as-is. Thinly dispersed tailings in Catchment 3, farthest afoot from Gunnar Main also likely to remain as-is, regardless of gamma dose.

**Monitoring/Modelling**
Required to determine whether a gamma barrier at Gunnar Main and immediate vicinity will mitigate ecological and human health risks in the receiving environment.
Decisions Will be Made Based on Monitoring Data:

- Radon monitoring
- Surface water sampling
- Quantification of water flows
- Waste rock characterization
- Groundwater sampling
- Vegetation sampling
- Fish sampling
- Building a quantitative Site-wide model to estimate contaminant flux (or loads)
Gamma Dose Rates
Monitoring Pathways:
Gunnar Climate, Radon and Dustfall Monitoring Locations:
Surface Water and Other Monitoring:
Monitoring Pathways:
Characterization of Water Budgets through Flow Monitoring:

Resultant monitoring data will be used to parameterize a quantitative Site-wide model, which will serve as the basis for decisions at key decision-tree points during Site licensing.
Groundwater Monitoring at Gunnar
Groundwater Monitoring: EM31 Survey to Select Process Locations
Delineation of Hydrocarbons and Tailings Characterization
Groundwater Monitoring:
Installation of 82 Piezometers
## Tiered Licensing Documentation:

### Detailed Remediation Plan

### Quality Assurance/Quality Control

## Detailed Work Packages

- Gunnar Mill Demolition
- Gunnar Ancillary Facilities
  - Gunnar Tailings
  - Gunnar Waste Rock
  - Gunnar Pit
  - Lorado Tailings
- Haz/Op Procedures

## Radiological Programs

- Radiological Code of Practice
- Radiological Monitoring Locations and Schedule
- Dosimetry Monitoring
- Radiological Close Out Criteria

## Environmental Programs

- Environmental Code of Practice
- Environmental Monitoring Locations and Schedule
- Follow Up Monitoring Program

## Procedures, Work Instructions and Forms
Summary of Key Conclusions:

- Imminent risk to public safety led to the justification to dismantle of ~85 buildings and structures and 15,000 lineal feet of utilidor prior to the EA being approved for the remediation work at the abandoned Gunnar uranium mine/mill site in northern Saskatchewan.
Summary of Key Conclusions:

- It was determined that due to the lack of records and monitoring data for the abandoned Gunnar Uranium Mine/Mill Site, there was inadequate information available for selection of remedial options through optimization as part of the EA process.
- To address this gap, extensive characterization was carried out and a monitoring program established.
- Decision trees were developed for potentially feasible options and will be used as a framework during licensing to make informed decisions based on monitoring data collected over time.
- Remediation of Site Aspects using well-established technologies will be initiated relatively early in the schedule, with more complex aspects being addressed when more information is available.
Summary of Key Conclusions:

- With respect to **limitation**, in planning the dismantling work, **dose limits** were established for the workers, assuming the crew of up to 90 workers was living on the camp on-site and working at Gunnar. These **dose limits** were reviewed and approved by regulatory agencies.
- Dose assessments were conducted to determine the siting of the camp, such that doses to workers were minimized in accordance with the ALARA principle, and workers were only permitted to spend time on the waste rock and tailings if they were doing work there.
- For the longer term, site **clearance criteria** are being set based on an assumption of industrial land-use, although efforts are being made to minimize the size of the mining footprints on the Gunnar Site.
Thank You!

Any Questions?