Sustainability Appraisal of Revegetation Options for Mine Remediation in Northern Canada

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“cleanup activities use energy, water and material resource to achieve... objectives. The process ... therefore creates an environmental footprint of its own.” (US EPA, 2008)

“there is increasing pressure for the regulators of contaminated sites ... to consider net impacts as part of their criteria” (SURF-US, 2009)
“the practice of demonstrating, in terms of environmental, economic and social indicators, that the benefit of undertaking remediation is greater than its impact and that the optimum remediation solution is selected”

(CL:AIRE, 2010)
Gunnar Uranium Mine Site

- Uranium mine and mill
- Operated 1953-1964
- SRC manages the decommissioning and rehabilitation of the site
Gunnar Site Remediation Project

- 82 ha of unconfined tailings in 3 locations
- to be capped with engineered cover
- revegetation with native plants
  - End-point: grass-legume community with 60-80% cover
Previous Related Studies

1. Field trial of natural recovery of borrow area at Gunnar

2. Greenhouse and field trials of soil amendments:
   ✓ Borrow material proposed for tailing cover (low carbon sand and gravel mixture)
   ✓ Amendments: peat, biochar, NPK
   ✓ Native plant species

3. Biochar production:
   ✓ Fast/slow pyrolysis units
   ✓ various feedstock
# Revegetation Options

<table>
<thead>
<tr>
<th>Natural Recovery</th>
<th>Peat</th>
<th>Commercial Biochar</th>
<th>Local Biochar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implement wind erosion control</td>
<td>Apply peat to increase topsoil organic matter content to 2%</td>
<td>Apply biochar to increase topsoil organic matter content to 2%</td>
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</tr>
<tr>
<td>Wind breakers procurement, installation, and maintenance</td>
<td>Peat procurement and application</td>
<td>Biochar procurement and application</td>
<td>Mobile pyrolysis unit procurement and operation</td>
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<tr>
<td>Tree suppression</td>
<td>Peat procurement and application</td>
<td>Biochar procurement and application</td>
<td>Biochar production and application</td>
</tr>
<tr>
<td>Weed mgmt.</td>
<td>Seeding</td>
<td>Seeding</td>
<td>Fertilizer application</td>
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<td>Seeding</td>
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<td>&gt;10 years</td>
<td>2-3 years</td>
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</table>
Study Objectives

- Carry out a sustainability appraisal to compare the economic, environmental and societal attributes of revegetation options for a case study

- Test tiered sustainability appraisal method
Tiered Approach to Sustainability Appraisal

**Tier 1**
- Qualitative assessment
- Decision on sustainability of options?
  - Yes: Decision
  - No: Tier 1

**Tier 2**
- Quantitative (simple) assessment (e.g. MCA)
- Decision on sustainability of options?
  - Yes: Decision
  - No: Tier 2

**Tier 3**
- Quantitative (complex) Assessment (e.g. CBA)
- Decision on sustainability of options?
  - Yes: Decision
  - No: Tier 3

Record decision and implement remediation

Courtesy of: Jonathan Smith and Paul Bardos (CL:AIRE, 2010)
Tier 1 – Qualitative Screening
Expert Panel Review - Methods

Panel Composition

- Two environmental engineers
- Socio-economic specialist
- Revegetation specialist

Methods

- Document review
- Consultation with interested parties
- Option scoring (from 1 to 4)
- 19 Criteria

Assessment Criteria

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Social</th>
<th>Economic</th>
</tr>
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<tbody>
<tr>
<td>✓ Biodiversity Footprint</td>
<td>✓ Occupational Risks</td>
<td>✓ Project cost</td>
</tr>
<tr>
<td>✓ Air Quality</td>
<td>✓ Site Aesthetic</td>
<td>✓ Project risks</td>
</tr>
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<td>✓ Energy Consumption</td>
<td>✓ Land Use</td>
<td>✓ Economic Opportunities</td>
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<tr>
<td>✓ Greenhouse Gases</td>
<td>✓ Public Safety</td>
<td>✓ Province Revenue</td>
</tr>
<tr>
<td>✓ Carbon Sinks</td>
<td>✓ Community Perception</td>
<td>✓ Job Opportunities</td>
</tr>
<tr>
<td>✓ Waste Generation</td>
<td>✓ Community Involvement</td>
<td>✓ Job Diversity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Technical Feasibility</td>
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### Tier 1 – Qualitative Screening: Expert Panel Review - Results

#### Environmental

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<tr>
<td>Natural revegetation</td>
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### Overall Outcome

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<tr>
<th>Aspect</th>
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<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
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<tbody>
<tr>
<td>Environmental</td>
<td>the most preferred option</td>
<td>the second-preferred option</td>
<td>the least preferred option</td>
<td>the most preferred option</td>
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<tr>
<td>Social</td>
<td>the least preferred option</td>
<td>the second-preferred option</td>
<td>the less preferred option</td>
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</tr>
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<td>the least preferred option</td>
<td>the most preferred option</td>
<td>the second-preferred option</td>
<td>the second-preferred option</td>
</tr>
<tr>
<td>Overall Results</td>
<td>the least preferred option</td>
<td>the second preferred option</td>
<td>the least preferred option</td>
<td>the most preferred option</td>
</tr>
</tbody>
</table>
Tier 2 – Semi-Quantitative Screening Stakeholder Survey - Methods

Participants (internal to SRC)

- Aboriginal and local community
- Decision maker
- Environmental consultant
- Technical specialist
- Finance specialist

Methods

- Multiple-Criteria Decision Analysis
- 9 Criteria

Assessment Criteria

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Tier 2 – Semi-Quantitative Screening
Stakeholder Survey - Methods

- Multiple Criteria Decision Analysis
  - Expert Choice (web-based software)
  - Pairwise comparisons

With respect to Social Criterion 1: Occupational risks
which of the two alternatives below is more preferable

Social Criterion 1: Occupational risks
This criterion comprises minimization of risks associated with carrying out the project.
Factors to be considered:
- Transportation to site
- On-site operations
- Working at a remote, poorly accessible site

Natural Revegetation

Extremely
Very strongly
Strongly
Moderately
Equal
Moderately
Very strongly
Extremely

Local Biochar

installation of wind breaks and site natural recovery accompanied with tree suppression and active weed management

application of locally produced biochar, fertilizer application, and native plant seeding
Tier 2 – Semi-Quantitative Screening Stakeholder Survey - Results

**Option Comparison**

### Environmental Criteria
- **Natural Recovery**
- **Peat**
- **Commercial Biochar**
- **Local Biochar**

- **Biodiversity**
- **Air Quality**
- **Greenhouse Gases**

### Social Criteria
- **Natural Recovery**
- **Peat**
- **Commercial Biochar**
- **Local Biochar**

- **Occupational Risks**
- **Community Involvement**
- **Land Use**

### Economic Criteria
- **Natural Recovery**
- **Peat**
- **Commercial Biochar**
- **Local Biochar**

- **Project cost**
- **Project risks**
- **Economic Opportunities**

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**Criterion Comparison**

**Weighting Factor (%)**

<table>
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<th>Criterion</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Greenhouse Gases</td>
<td>19</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>16</td>
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<tr>
<td>Project risks</td>
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<tr>
<td>Air Quality</td>
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<td>Economic Opportunities</td>
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<td>Project cost</td>
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<tr>
<td>Land Use</td>
<td>6</td>
</tr>
<tr>
<td>Community Involvement</td>
<td>6</td>
</tr>
<tr>
<td>Occupational Risks</td>
<td>4</td>
</tr>
</tbody>
</table>

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**Overall Outcome**

- **Local Biochar**: 100
- **Peat**: 81
- **Natural Recovery**: 72
- **Commercial Biochar**: 70
Tier 3 – Quantitative Analysis
LCA and LCC Screening

3 options examined
- Peat
- Local Biochar
- Commercial Biochar

Two analyses
- Screening Life Cycle Assessment (LCA)
- Screening Life Cycle Cost Analysis (LCC)

Models based on readily and publicly available information
Revegetation of the largest Gunnar tailing (53 ha)

Focused on **differences**

- Excluded
  - activities similar between the revegetation options (e.g. seeding, fertilizing, monitoring)

- Included
  - Organic soil amendment acquisition and application
  - Transport of materials and personnel
  - Equipment operation and maintenance
Tier 3 – Quantitative Analysis
Life Cycle Assessment

![Bar graph showing the impact of different sources on various environmental issues.](chart.png)
Tier 3 – Life cycle cost - Results

- Peat
- Commercial Biochar
- Local Biochar

- O&M of mobile unit
- Biomass transport and handling
- Capital cost of mobile unit
- Application of amendment
- Transport amendment and equipment
- Acquisition of amendment

$ million vs. Tier 3 costs
No immediate answer
- Biochar options more environmentally preferable
- Peat the most cost-effective

Limitations:
- Outcome sensitive to assumptions
Local Biochar – most preferred option
- Socially acceptable
- Environmental gains and economic opportunities
- But more costly and higher technical risks than peat

Key lessons
- Improved understanding of the sustainability gaps of the project
- “Sustainable” is a relative term
- Stakeholders participation is key
- Trade-offs

Sustainability appraisal approach
- Strong method to apply sustainability to a wide range of projects
- Goes beyond common evaluation criteria
- Provides information to support decision making
- Should be integrated at onset of a project
Paper “Environmental, Social, and Economic Benefits of Biochar Application for Land Reclamation Purposes” (Petelina et al., 2014) is available in proceedings of the BC 2014 Mine Reclamation Symposium.
References

- Petelina E. 2014. Restoration of Native Plant Cover after Uranium Mining: a Case Study from Northern Saskatchewan, Canada. (Master’s report).