Mine Water Remediation at Large-Scale Metal Mines: Balancing Near-Term Expenditures for Source Control with Long-Term Expenditures for Collection and Treatment

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Remediation goals
- Compliance with water quality standards
- Protection of human health and environment
- Achieve post remediation land uses

Always limited capital
- Common disagreement among stakeholders
  - Governmental agencies responsible for environmental protection
  - Mining corporations and other responsible parties
  - Other stakeholders

In mature regulatory environment of US, walk-away solutions are seldom achieved...

Remedies often include near-term expenditures for source control...

What is an Appropriate Balance?

Source Controls
- Characterization
- Consolidation
- Covers

Water Management
- Collection
- Conveyance
- Treatment

Near-term Expenditures

Long-term Expenditures

...and long-term expenditures to provide for water management!

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Why do we care?

- Facilitate better decisions
- Prioritize limited funding
- Understand goals and perspectives of stakeholders

Who should care?

- Mining Company Representatives
- Governmental Representatives
- Researchers
- Consultants

Potential Means to Achieve an Appropriate Balance

Economic Evaluations:
- Cost estimates of potential remedial strategies
- Present value analyses evaluating expected short-term and long-term expenditures
- Cost estimate risk analysis

Other Considerations:
- Human health and ecological risk
- Uncertainty in future regulations
- Remedy performance risks
- Sustainability considerations
- Funding considerations

Engineering Cost Estimates of Potential Remedial Strategies

- Generally completed for potential remedial strategies
- Short-term expenditures
  - Earth moving
  - Low permeability covers
  - Construction of major treatment infrastructure
- Long-term expenditures
  - Mine water management, treatment
  - Remedy maintenance

Present Value (PV) Analysis

- Means to understand economic efficiency of potential remedial strategies
- Economic efficiency is defined as:
  - “expenditures by either private industry or government agencies that manage the environmental liability associated with mine water in an efficient manner”
- Established method that estimates the value in current dollars of a series of future expenditures

Components of PV Analysis

- Defined series of future expenditures
- Discount rate
  - accounts for the productivity of capital if applied to alternative uses
- Period of analysis
- Facilitates comparison of strategies with varying short-term versus long-term expenditures
Example PV Calculation for Long-term Water Treatment

- Estimate assumes 30 years of water treatment
- Annual inflows w/ avg. precip: 400,000,000 liters
- Treatment cost: $3.00 per 1000 liters
- Annual Treatment Cost (present dollars): $1,200,000.00
- Capital Cost: $5,000,000
- Discount Rate: 3.00%
- Total PV: $44,119,000

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Cost Estimate Risk Analysis

- Unfortunately, during feasibility study or scoping stages, cost estimates are tenuous
  - Ultimate design scope may be unknown
    - Design quantities?
    - Design details?
  - Implementation schedule may be unknown
    - Diesel fuel cost?
    - Cover cost?
- Cost estimate risk analysis uses Monte Carlo simulation to address these issues

Monte Carlo Simulation in Cost Estimate Risk Analysis

- Propagate uncertainties associated with each input through the cost estimate
- Provide a probabilistic estimate of cost risk for a given remedial strategy
- Define specific probability distribution for various inputs to cost estimate
  - Historical costs adjusted for inflation
  - Range of uncertainty in volume estimates
  - Professional judgment etc.

Monte Carlo Simulation in Cost Estimate Risk Analysis (continued)

- Facilitates cost comparisons for various strategies using a standard probability level
- Identifies critical elements that are “drivers” to the overall cost risk
- Prepares decision-makers for potential costs at later design stages
- Facilitates better decisions

Other considerations for effective remediation decisions

- Clearly, cost is not the only issue
- Other issues may include
  - Mitigation of other human health or ecological risks
  - Uncertainty in future regulations
  - Remedy performance risks
  - Sustainability considerations
  - Funding considerations

Alternative remediation strategy that exceeds $44 million total cost would be less economically efficient than this strategy (assuming equal environmental protection)

Provides a basis for comparison of various approaches (e.g. source control strategy involving extensive earthwork, versus treatment strategy)

Example of present value estimate at various discount rates

<table>
<thead>
<tr>
<th>Annual Mine Water Treatment Volume (liters)</th>
<th>Mine Water Treatment Cost ($ per 1000 liters)</th>
<th>Initial Treatment Plant Capital Cost</th>
<th>Discount Rate</th>
<th>Present Value of Mine Water Treatment 100 year duration</th>
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Other issues may include

- Mitigation of other human health or ecological risks
- Uncertainty in future regulations
- Remedy performance risks
- Sustainability considerations
- Funding considerations

Priorities of these issues in mine remediation and closure decisions may be viewed differently by various stakeholders.
Mitigation of other human health or ecological risks

- Other risks may be present...
  - Incidental ingestion, inhalation
    - Lead risks at Pb-Zn-Ag deposits
    - Arsenic risks at Au or U-V deposits
  - Wind dispersion
    - Tailings
    - Dust
    - Asbestos

**May require source control remedy regardless of mine water cost analysis**

Uncertainty in Future Regulations

- Problematic issue for mine water remediation in US
- Surface water standards may change every three years in Triennial Review
- Most problematic for industry in US
  - Pollutant discharge permits may change each 5 years
- When considering long-term treatment, discharge standards that will apply in future are strictly unknown
- Remedies focused on water treatment may be more flexible

Remedy Performance Risks

- How well will source controls work?
  - What if they don’t work as well as expected?
- Source control remedies particularly subject to this risk
  - High near-term expenditures
- Treatment remedies less subject to this risk
  - Lower near-term expenditure

Funding Sources for Mine Remediation

- May drive decisions for some stakeholders
- Private industry
  - Competing needs/investments
  - Future liability
- Government funding
  - Types of funding mechanisms
  - Timing and sourcing
  - Risk of loosing future govt. funding sources
  - Risk of bankruptcy of regulated mining companies
- Can we influence future legislation?

Conclusions

- Mine water mitigation at large-scale metal mines technically challenging and expensive
- Need to achieve an appropriate balance between near-term and long-term expenditures
  - Meet the requirements of environmental laws
  - Protect human health and environment
  - Manage level of capital expenditures
    - Private mining corporations
    - Government agencies
  - Efficiently mitigate legacy sites
  - Facilitate continued mineral production and environmental protection in future