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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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Mine Water Remediation at Large-Scale Metal Mines

- 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…

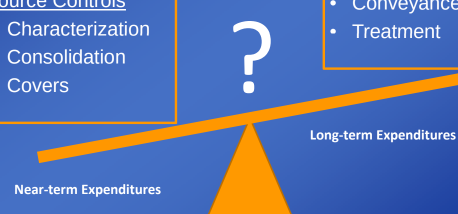
Remedies often include near-term expenditures for source control…

…and long-term expenditures to provide for water management

What is an Appropriate Balance?

Source Controls
- Characterization
- Consolidation
- Covers

Water Management
- Collection
- Conveyance
- Treatment



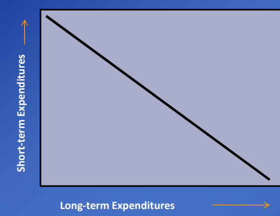
Why do we care?

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

Who should care?

- Mining Company Representatives
- Governmental Representatives
- Researchers
- Consultants

Higher short-term expenditures designed to facilitate lower long-term expenditures



Expenditures that reduce mine water generation designed to reduce long term water treatment costs

Regulators, responsible parties, and stakeholders may disagree regarding the appropriate balance between short-term and long-term expectations

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

$$PV_{total} = \sum_{t=1}^{t=n} \frac{X_t}{(1+i)^t}$$

Where X_t is the payment in year t and *i* is the discount rate

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%	

Year	Capital Cost	Treatment Cost	Total Cost	Discount Rate	Present Value
				Total PV:	$44,119,000
0	**5,000,000**	$1,200,000	$6,200,000	1.00000	$6,200,000
1	0	$1,200,000	$1,200,000	0.97087	$1,165,049
↓	↓	↓	↓	↓	↓
10	0	$1,200,000	$1,200,000	0.74409	$892,913
↓	↓	↓	↓	↓	↓
20	0	$1,200,000	$1,200,000	0.55368	$664,411
↓	↓	↓	↓	↓	↓
30	0	$1,200,000	$1,200,000	0.41199	$494,384
↓	↓	↓	↓	↓	↓
40	0	$1,200,000	$1,200,000	0.30656	$367,868
↓	↓	↓	↓	↓	↓
100	0	$1,200,000	$1,200,000	0.05203	$62,439

Example of present value estimate at various discount rates

Annual Mine Water Treatment Volume (liters)	Mine Water Treatment Cost ($ per 1000 liters)	Initial Treatment Plant Capital Cost	Discount Rate	Present Value of Mine Water Treatment (100 year duration)
400 million	$ 3.00	$ 5 million	7 percent	$ 23.3 million
400 million	$ 3.00	$ 5 million	5 percent	$ 30.0 million
400 million	$ 3.00	$ 5 million	3 percent	$ 44.1 million

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

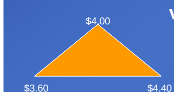
Provides a basis for comparison of various approaches (e.g. source control strategy involving extensive earthwork, versus treatment strategy)

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

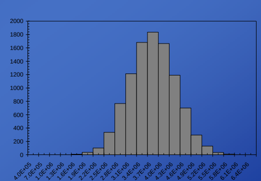
- Propagate uncertainties associated with each input through the cost estimate
- Provide a probabilistic estimate of cost risk for a given remedial strategy
- Define specific probability distribution for various inputs to cost estimate
  - Historical costs adjusted for inflation
  - Range of uncertainty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



Example of a triangular distribution for future diesel fuel costs

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



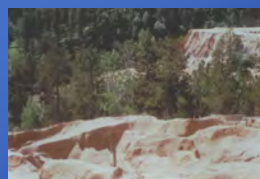
Other considerations for effective remediation decisions

- 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

Priority 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