

General Challenges with Estimating Mine Drainage Chemistry

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Introduction



- Mine drainage chemistry predictions are estimates
- Assess risk, uncertainty, and variability
- Conservatism
- Iterative approach
- On-going monitoring and adaptive management through operations and closure

Challenges



 Geology Comprehension - Outside of the orebody - Mine plan and mine waste Characterization - Timing - Iterative approach – Mine plan Physical Environment - Hydrology - Hydrogeology - Water Balance







- Understanding Geology is an important first step in geochemical characterization:
 - Ore deposit model/type
 - Identity the distribution of rock types with respect to ore zone and pit/underground workings
- Usually drilling is centered around resource delineation, not waste rock.
- Important to design drill program that intersects potential waste rock units



- VMS deposit with a steeply dipping massive sulphide zone
- Most likely an underground operation, with decline in footwall
- All drill holes in hanging wall, little information from footwall





- Drift development for advanced underground exploration
- Limited drill holes and no geologic interpretation in area of decline
- Difficult to assess heterogeneity of lithologies in area and along proposed decline route









• Estimation

• Iterative Approach - Continual Refinement

 Balance of Time/Cost with Uncertainty/Conservatism



Estimation of ML/ARD Potential

- Easy to draw definitive conclusion for NPR > 4.0 or NPR < 1.0
- Grey Zone (1.0 < NPR < 4.0)

ARD Potential	Initial Screening Criteria (NPR)	Comments
Likely	<1	Likely to be ARD generating unless sulphide minerals are unreactive.
Possibly	1 – 2	Possibly ARD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides.
Low	2 - 4	Not potentially ARD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP.
None	> 4	No further ARD testing required unless materials are to be used as a source of alkalinity.

From Price (1997)

Grey Zone





Conclusions are difficult to make on material that falls within the "Grey Zone"

 Reactivity is dependent on type of NP and reactivity of the sulphide minerals
 High Uncertainty



• Estimation Refinement Process:

- Initial Phase of Static Testing (2 to 4 months)
- In Depth Static Test Assessment (2 to 4 months)
- Mineralogy (2 to 4 months)
- Laboratory Humidity Cell Tests Kinetic Test (>10 months)
- Field Bin Tests Kinetic Tests (>1 year)
- Tailings Column Tests (>10 months)
- Field Pad Tests Kinetic Tests (years to decades)
- Seepage Monitoring from Waste Rock Dump and Tailings (decades to perpetuity)

Increasing Scale/Time = Improved Confidence



Static Testing

Initial Phase Results Direct Second Phase Sampling and Kinetic Testing



- 1. Further in-depth static sampling of Volcanic, Metasediment and Dyke Units
- 2. Installation of Field Bins Representing The Major Mineable Units
- 3. Humidity Cells Initiated for Each Lithology



Static Testing

Second Phase Of Testing Allowed For Further Honing of Testing



1. Static test results show the need for another humidity cell to represent the low S low NPR Volcanic material

2.

Further sampling indicates the variability of metasediments and volcanics = in-depth mineralogy



Mineralogy

- Identify mineral reactivity (type, habit, nature)
- Results give <u>CONTEXT</u> for interpreting static and kinetic testwork

Initial Investigation

- Petrography
- Rietveld X-ray Diffractometry

In-depth Characterization

- Scanning Electron Microscopy (SEM)
- Electron Dispersion Spectrophotometry (EDS)
- Laser Ablation
- Microprobe





Lab-Based Kinetic Testing

- Humidity Cells chosen based on static test results and geology
- Humidity Cells best estimate of weathering under <u>IDEAL</u> conditions
- Results are estimates of how material will behave under <u>IDEAL</u> conditions





Field Bin Testing

- Field Bins are larger scale humidity cells
- Longer time scale
- In situ kinetic test, exposed to field conditions
- Results can be used to estimate the potential for waste material to generate acid and leach metals





Field Pad Testing

- Scaled waste rock piles
- Field truth humidity test results
- Test mixing of material in dumps
- Typically applied to material that needs further field based characterization to estimate larger scale behavior





Refinement of drainage estimates

- Geology
- Mine plans
- Waste management plans



Refinement – Mine plans change – Open vs. Underground vs. Combination – Amount of waste rock may change

Mineable units may change





Refinement

- Geology better understood
 - Refinements of estimates based on better geological understanding
 - Initial drainage estimates used as a tool for mine planning and feasibility assessment
 - Hot units may be avoided or need special management, characteristics of geology dictates waste management and mine plan refinement
 - Waste management requirements can lead to changes in approach – sub-aerial/sub-aqueous



Balance of Time/Cost with Uncertainty

- Information Is Key (Geology/Mine Plan)
 - Lack of availability of background information can be costly
 - Vague Geology
 - » Means Further Background Investigation Can Increase Time and Cost of Characterization
 - » Increases Uncertainty in Characterization Can Result in Further Investigations and Refinement
 - Varying Mine Plan
 - » Changes Can Result In Varying Approach/Scope Increasing Time and Cost
 - » Develop mine plan in concert with mine waste characterization







Waste Rock Hydrogeology and Water Balance

- Short-term
 - Attenuation of flow variability peak flow reduction
 - Storage years to decades to "wet up"
 - Reduction in runoff
- Long-term
 - Increase in base flow
 - Increase in flow rates and unit yield







Average Monthly Runoff





Average Monthly Dilution





Average Monthly Sulphate Concentration





- Timing and release of mine seepage results in lower dilution, higher concentrations in the receiving environment
- Difficult to predict beyond current level of understanding
- Estimates require built-in conservatism
- On-going monitoring and adaptive management required to limit impacts

Summary



- Estimation rather than a prediction
- Iterative approach

 Mine plan evolution
 Waste management
- Scaled approach
 - Increasing scale/time = increasing confidence

Summary



- Comprehension of site conditions

 Hydrogeology and water balance
 Long-term and short-term impacts
 Built in conservatism to compensate for high degree of uncertainty

 On-going monitoring and adaptive
 - management
 - Operations and post-closure

Thank you



