Metal Sulfide Mining

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Metal Sulfide Mining

- What is a Sulfide Mine?
- What is Acid Mine Drainage (AMD)
- What are the Risks of AMD?
- How “Sure” are Financial Sureties for Sulfide Mines?
- Example – NorthMet Project

Metal Sulfide Mining

Metals Mined as Oxides

- Iron (Hematite - Fe_2O_3, Magnetite Fe_3O_4), Magnesium, Titanium, Tin, Aluminum

Base Metals Mined as Sulfides

- Copper (Bornite - Cu_5FeS_4), Lead, Zinc, Molybdenum, Nickel

Precious Metals Mined with Sulfides

- Gold, Silver, Platinum

Typical Copper Sulfide Deposit

- 3% – 5% sulfide minerals
- 0.5% - 1.0% copper sulfides
- Iron Pyrite (FeS_2) – most common sulfide mineral

Nickel Sulfide Deposits

- Voisey's Bay – ore 15% Ni sulfide, 10% Cu sulfide, 70% FeS
- NorthMet – ore 0.24% Ni sulfide, 0.70% Cu sulfide, 0.58% FeS

Acid Mine Drainage

AMD = Sulfide Minerals (Metal Ion + Sulfur) + Oxygen + Water

Pyrite + Oxygen + Water = Sulfuric Acid + Ferric Hydroxide (orange)

$FeS_2 + O_2 + H_2O = H_2SO_4 + Fe(OH)_3$


Landusky Mine, Montana

Acid Mine Drainage
Metals of Concern

Acid pH Metals

- Copper
- Lead
- Mercury
- Cadmium
- Aluminum
- Silver
- Cobalt
- Uranium
- Zinc
- Nickel
- Molybdenum

Neutral pH Metals

- Arsenic
- Selenium
- Antimony
- Thallium


Mike Horse Mine, Montana

Dangers of Acid Mine Drainage

People

- Mercury (2 ppb)
- Lead (15 ppb)
- Arsenic (10 ppb)
- + more

Aquatic Organisms
(Fish / Insects / Plants)

- Cadmium (0.25 ppb)
- Mercury (0.77 ppb)
- Lead (2.5 ppb)
- Selenium (5 ppb)
- Copper (9 ppb)
- Nickel (52 ppb)
- Zinc (120 ppb)
- + more

1 part per billion ↔ 1 gallon of oil / 23.8 million barrels of oil **(42 gallons/barrel)**

Predicting Acid Mine Drainage

Acid-Producing Minerals

- Pyrite (FeS_2)
- Pyrrhotite (FeS)

VS.

Acid-Neutralizing Minerals

- Calcium & Magnesium Carbonates

Calcite – $CaCO_3$

Dolomite – $CaMg(CO_3)_2$

Minor contributors

- Plagioclase Feldspar
- Biotite
- Chlorite
- Amphibole
- Olivine

Prediction Complications

- Rate of Dissolution

(carbonates dissolve >> sulfides oxidize)

- Physical Isolation

(carbonates coated with iron hydroxide)

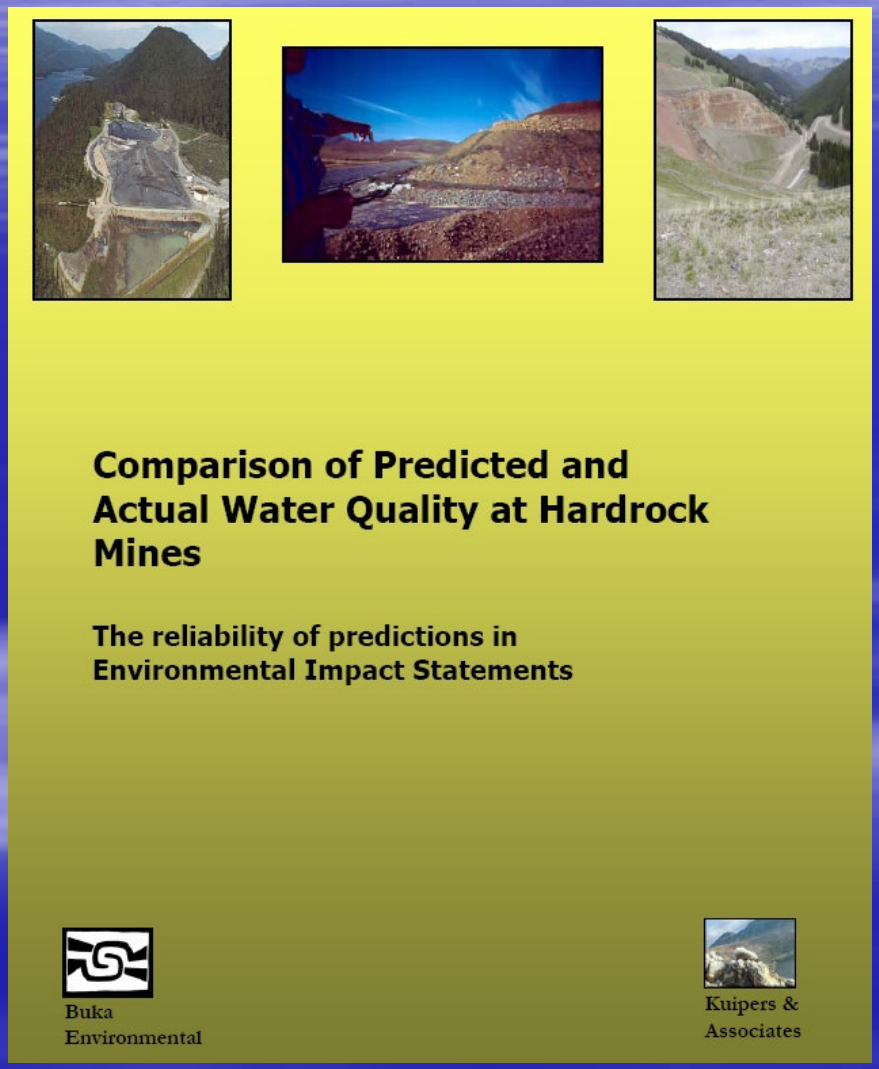
- Biologic Acceleration

(Thiobacillus Ferroxidans)

- Metals Leaching (neutral and high pH)

(arsenic, selenium, antimony, thallium)

How Good Are We at Predicting ARD?



Kuipers, J.R., Maest, A.S., MacHardy, K.A., and Lawson, G. 2006. *Comparison of Predicted and Actual Water Quality at Hardrock Mines: The reliability of predictions in Environmental Impact Statements.* Copyright © 2006 by Kuipers & Associates and Buka Environmental

Kuipers-Maest Study Results:

- 100 percent of mines predicted compliance with water quality standards before operations began.
- 76 percent of mines studied in detail exceeded water quality standards due to mining activity

Kuipers-Maest Study Results:

- Mitigation measures predicted to prevent water quality exceedances failed at 64 percent of the mines studied in detail.
- 85% of the mines near surface water with elevated potential for acid drainage or contaminant leaching exceeded water quality standards

Kuipers-Maest Study Results:

- 93% of the mines near groundwater with elevated potential for acid drainage or contaminant leaching exceeded water quality standards.
- Of the sites that did develop acid drainage, 89% predicted that they would not.

Financial Surety for Mine Closure

Major Issues with Financial Sureties

- Realistic Costs must be used to establish the amount of the surety
- The Surety must be in form that is redeemable and readily available

Alaska Surety Case Study

Alaska Large Mine Reclamation Bonding – 2005,
Center for Science in Public Participation, 2006

- Reclamation sureties were underestimated by 43% (average of $11 million)
- One Alaska mine bankruptcy (Illinois Creek, USMX/Dakota Mining) was underfunded

Alaska Surety Case Study

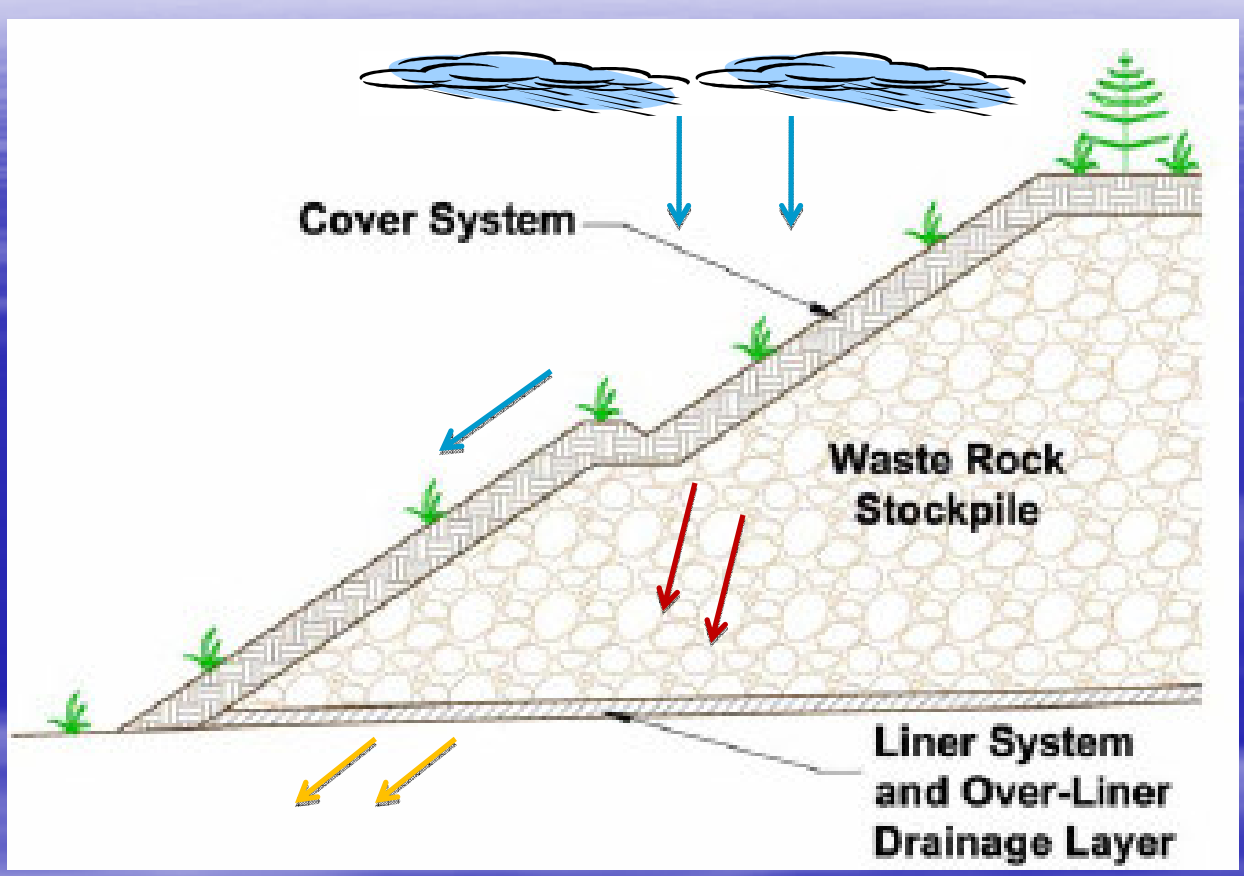
Study Recommendations

- State and Federal Agencies should hire a professional consulting firm to calculate mine reclamation costs
- Mines that require water treatment in perpituity should not be permitted

NorthMet Project

- Duluth Complex – “copper and nickel sulphides -- disseminated pyrrhotite and chalcopyrite in a coarse plagioclase gabbro”
- ore 0.24% Ni sulfide, 0.70% Cu sulfide, 0.58% FeS
- waste rock averages 0.08% S (sulfur), can have up to 6% S content

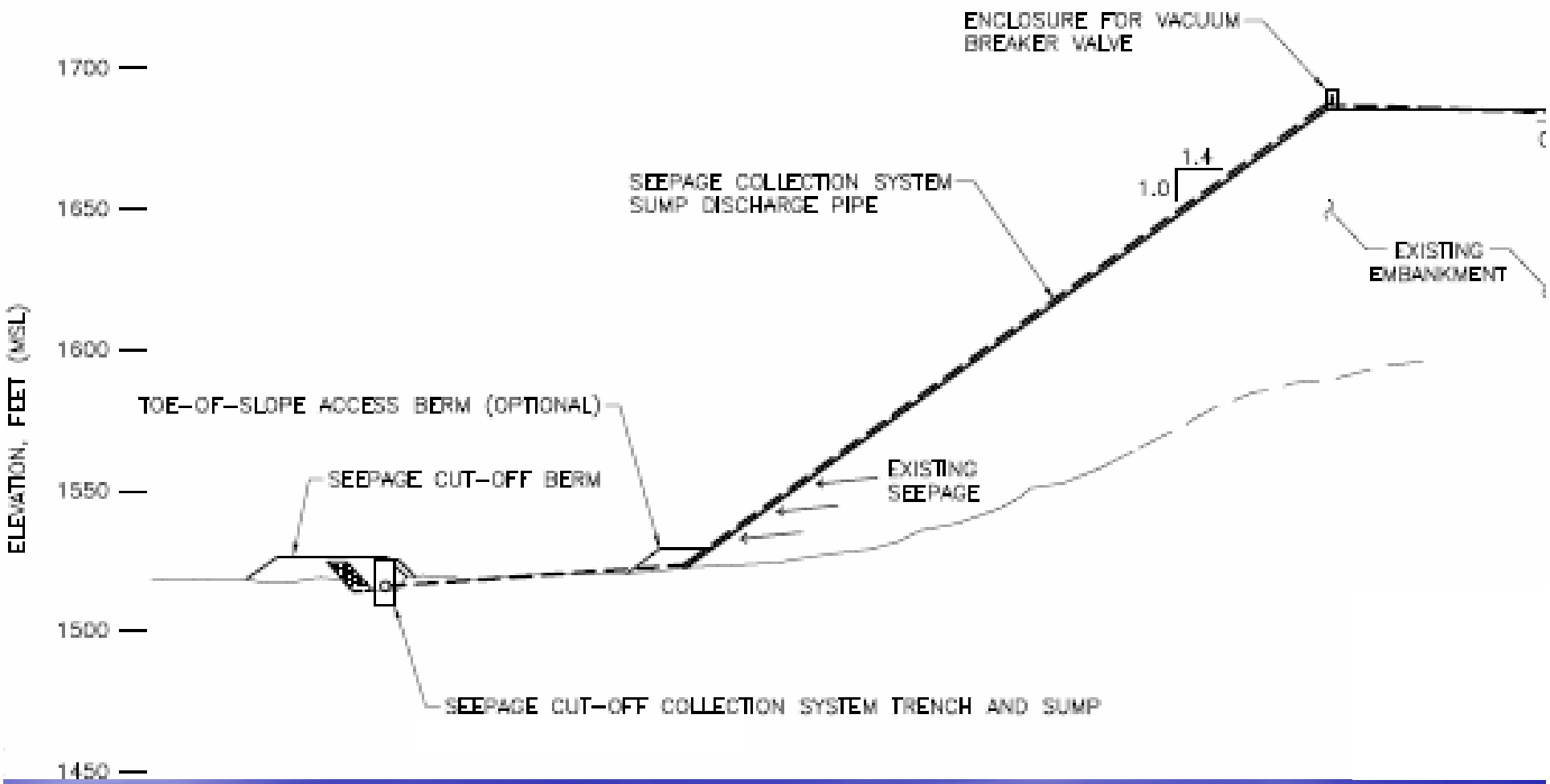
Waste Rock Seepage



Potential Issues:

- Seepage water quality
- Long term effectiveness of Cover & Liner

Tailings Seepage



Potential Issues:

- Seepage water quality
- Dam stability under seismic loading

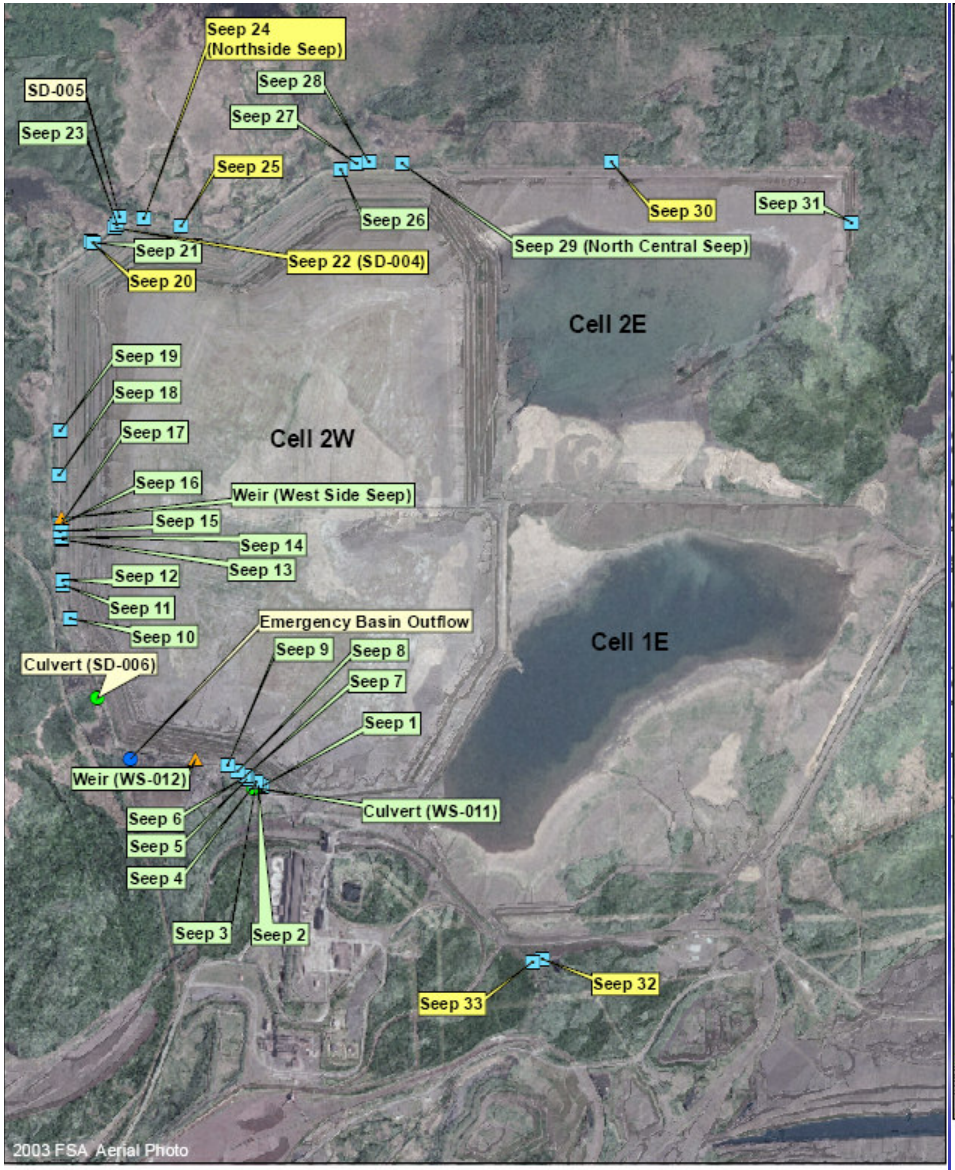


Figure 6
Seep Locations
Tailings Basin

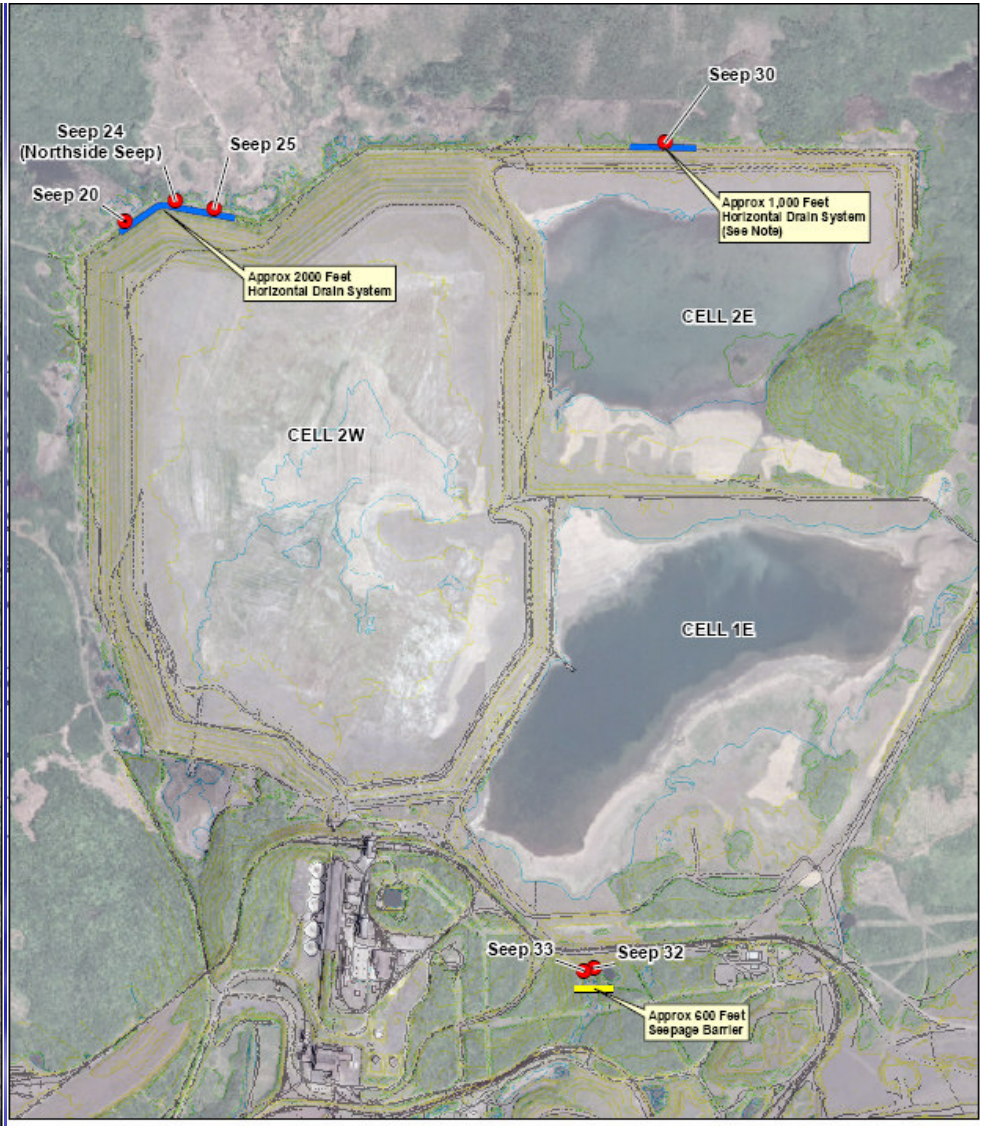


Figure 2
Implementation Strategy
Tailings Basin Modifications
to Control Seeps

Present discharge exceeds water quality standards for bicarbonates, hardness, conductivity, and iron. (RS55T, p. iv.) New floatation tailings are not projected to be “non reactive” but the contamination in the seepage from the new floatation tailings will likely be worse than that in the present discharges.

ISSUES

- Will there be AMD/Metals Leaching at NorthMet? Yes, there is some risk.
- How much risk are you willing to accept?
- Less Risk → Higher Mining Costs