A Review of Performance of the Whistle Mine Backfilled Pit Cover System – Four Years after Construction

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Presentation Outline

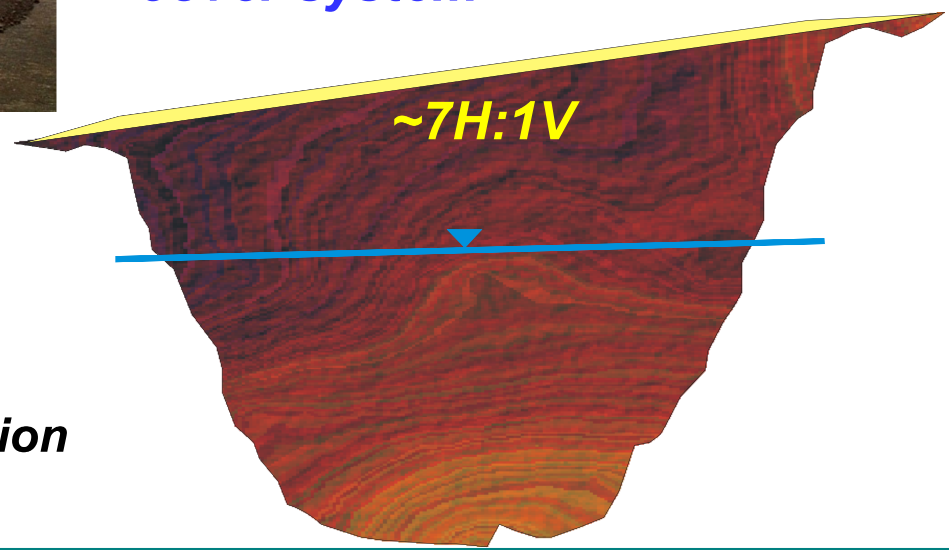
- Background
- Cover System Design Approach
- Cover and Landform Design Modelling
- Sustainability of the Cover and Final Landform
- Construction of the Pit Cover
- Performance of the Pit Cover
- Concluding Remarks

Background

- Site ~ 60 km NW of Sudbury
- Canadian Shield – numerous bedrock outcrops and lakes
- Open pit mining (nickel) between 1988-91 & 1994-98
- 6.4 Mt of waste rock on surface – 80% is mafic norite, avg. S of 3%
- Several acidic seeps developed
- Semi-humid climate – annual precip. of 900 mm (30% as snow) & potential evaporation of 520 mm

Background *(cont')*

- ***Not feasible to reclaim WRDs in-place***
- ***Based on available data, Inco decided to relocate all waste rock to open pit (with lime addition @ 2kg/tonne) & construct an engineered cover system***



- ***Pit surface area ~ 10 ha***
- ***Objectives of the pit cover:***
  1) ***Limit oxygen ingress!!***
  2) ***Reduce meteoric water infiltration***
  3) ***Growth medium for vegetation***

Cover System Design Approach

Cover System Field Trials

Geochemical Modelling

Selection of Barrier Layer Material

Soil-Atmosphere Cover Design Modelling

Erosion and Landform Evolution Modelling

Slope Stability Analysis

Consideration of Processes Potentially Impacting on Sustainable Performance

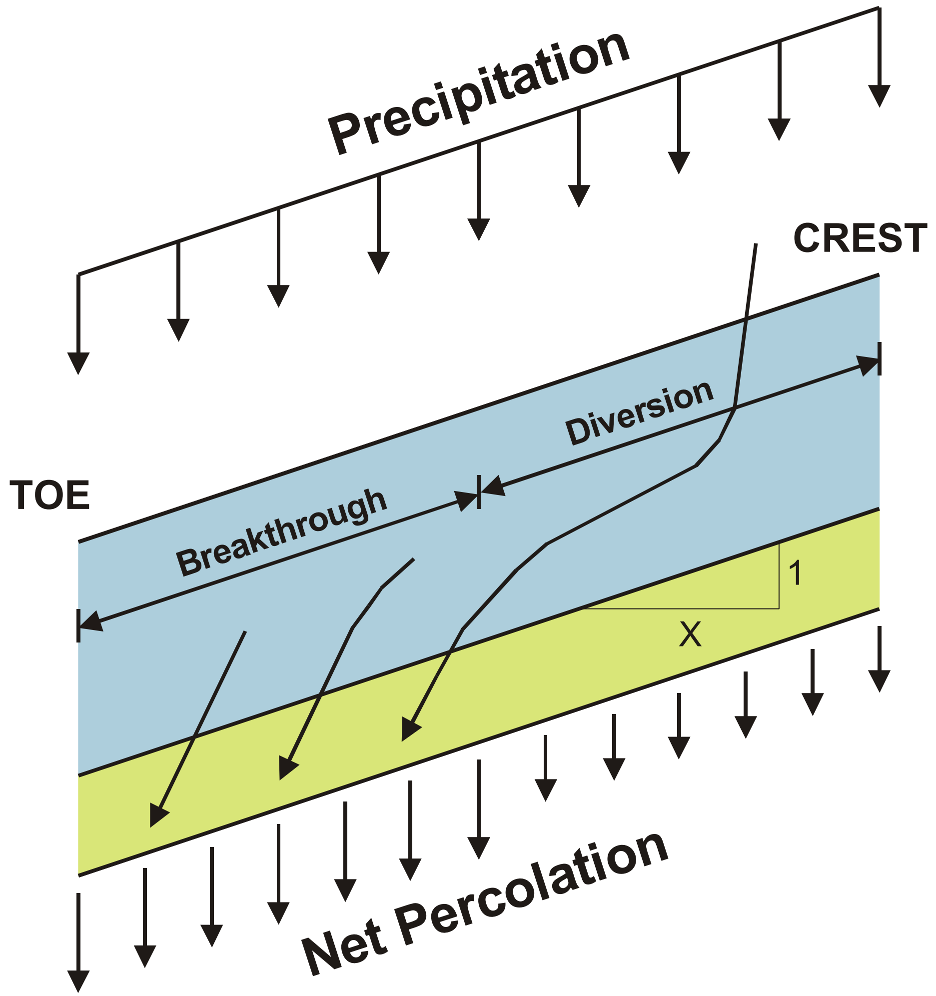
Cover Design Criteria!

Preliminary Cover Design Modelling

Barrier Layer Thickness	Growth Medium Layer Thickness	Simulation	Barrier Layer Deg of Saturation
30 cm	90 cm	Initial conditions	90%
		Dry year – run 1	78%
45 cm	90 cm	Initial conditions	92%
		Dry year – run 1	82%
60 cm	90 cm	Initial conditions	93%
		Dry year – run 1	85%
		Dry year – run 2	78%
30 cm	120 cm	Initial conditions	93%
		Dry year – run 1	83%
45 cm	120 cm	Initial conditions	98%
		Dry year – run 1	94%
		Dry year – run 2	90%
		Dry year – run 3	86%

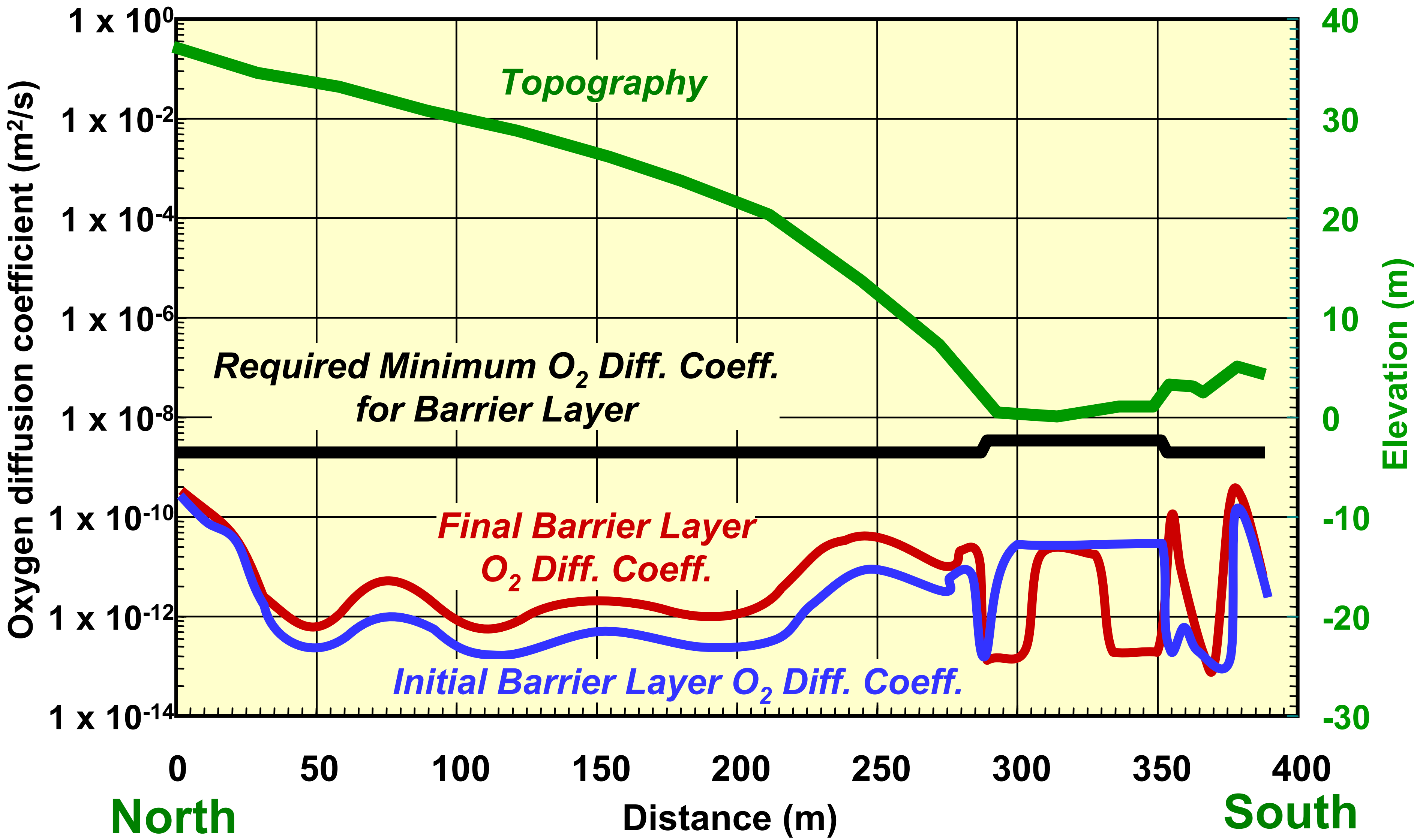
Detailed Cover Design Modelling

2-D Cover System Performance

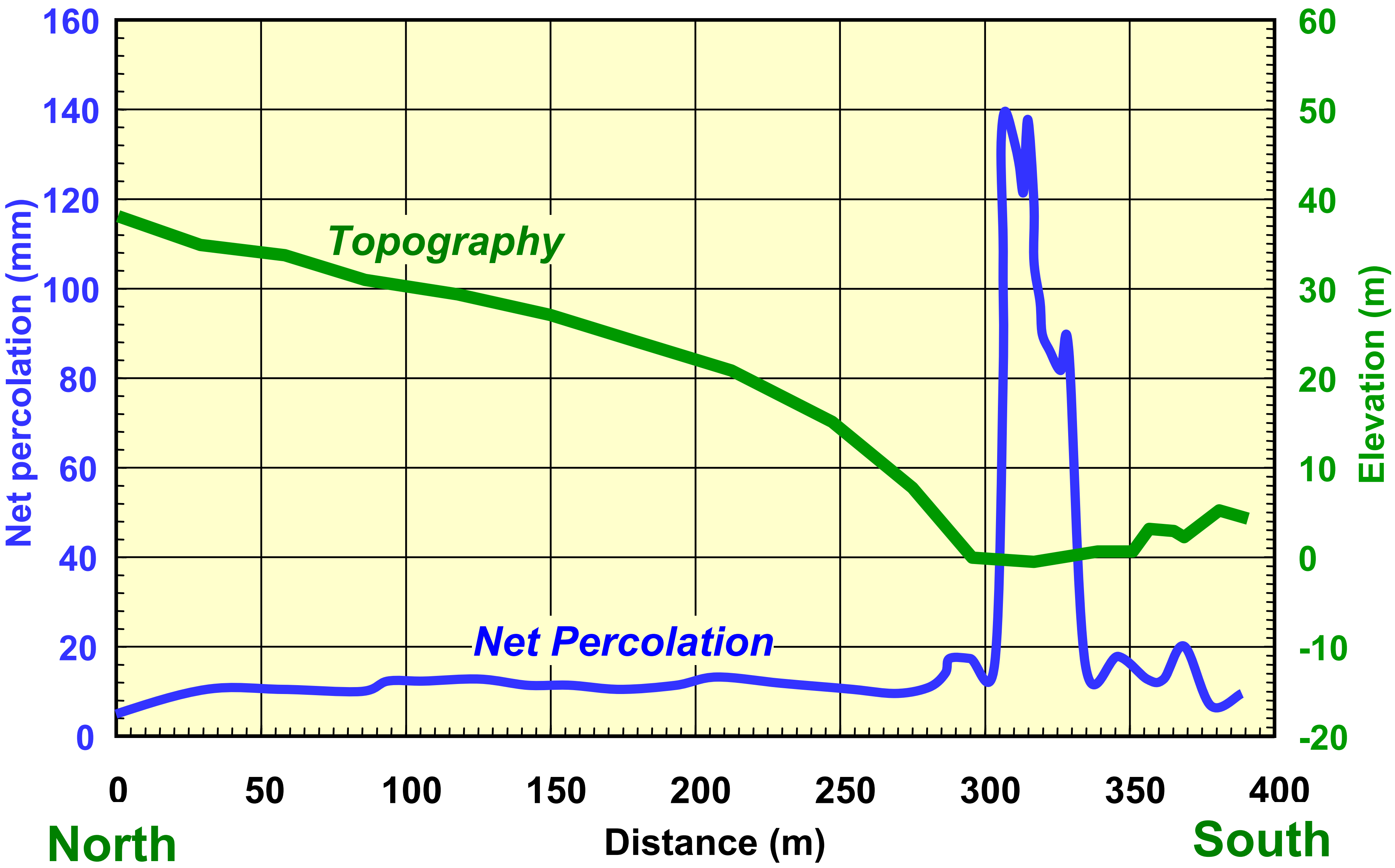


Lower Slope	Upper Slope
Increased Net Percolation	Low Net Percolation
Higher Degree of Saturation	Decreased Degree of Saturation
Lower *In Situ* Oxygen Conditions	Higher *In Situ* Oxygen Conditions

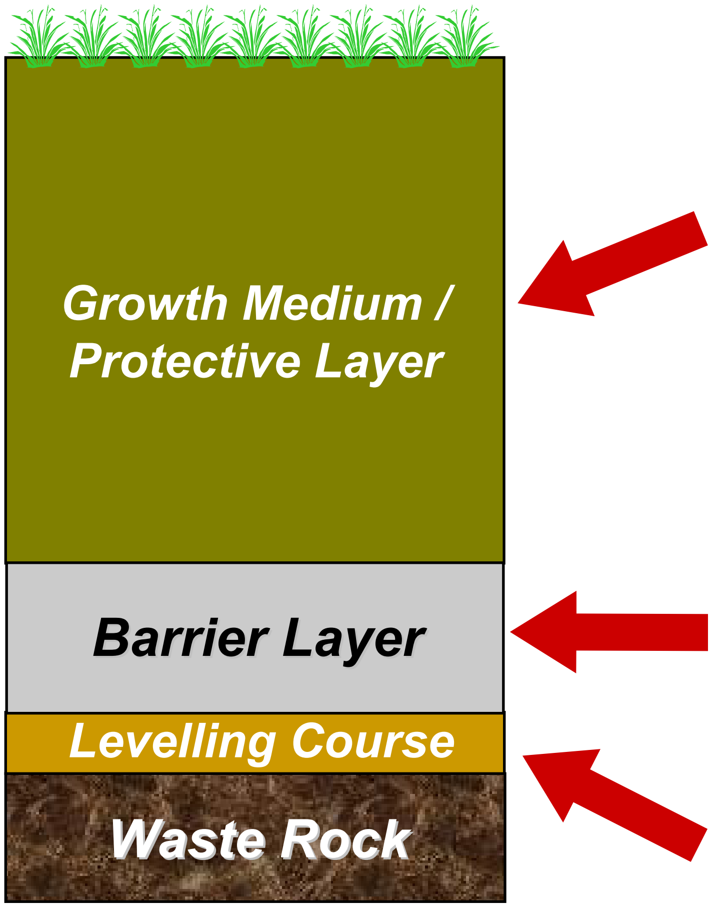
Detailed Cover Design Modelling



Detailed Cover Design Modelling



Preferred Cover System Design

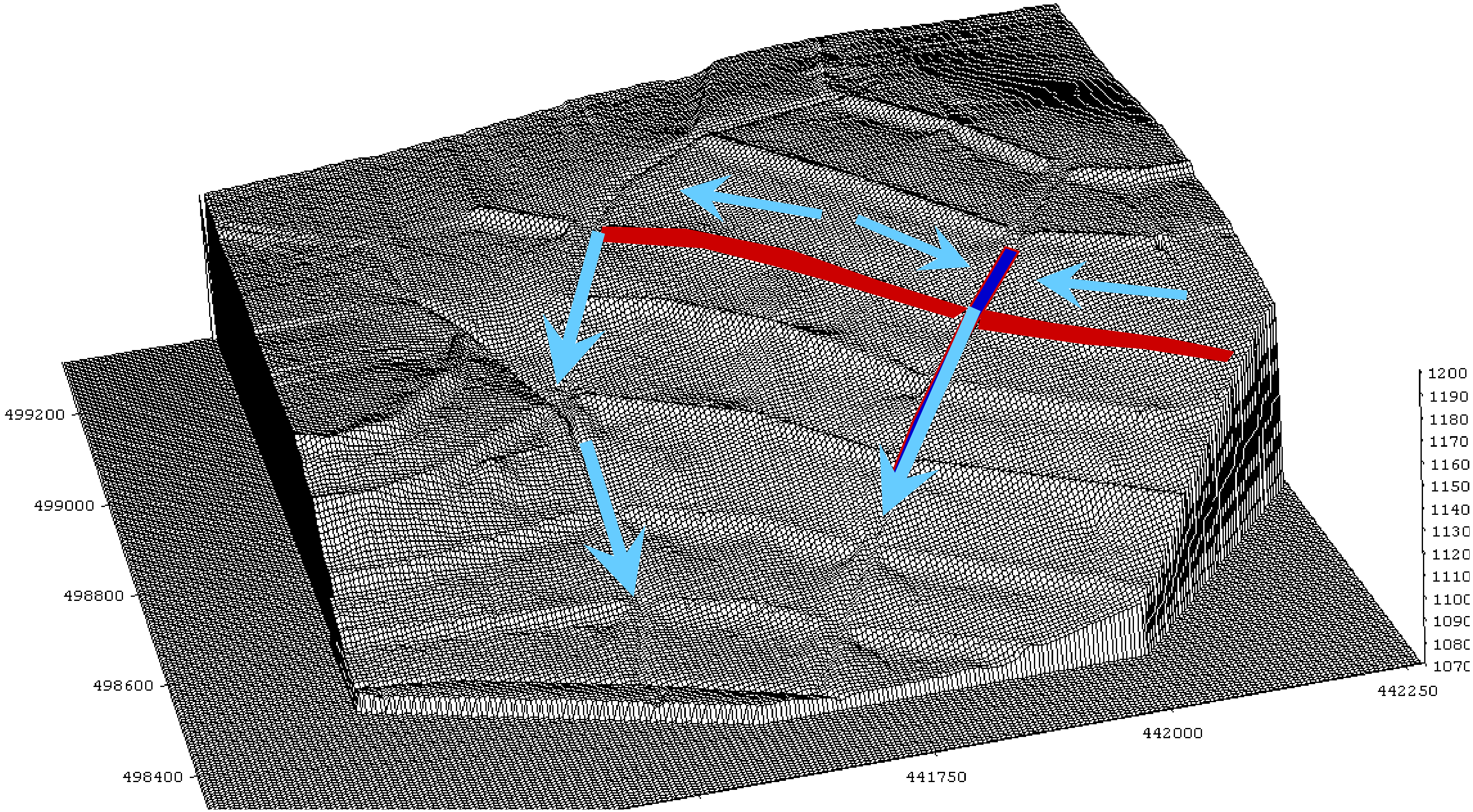


- *Non-compacted sandy-gravel till*
- *120 cm minimum on slope, with 8 cm of topsoil admixed to the near surface material*
- *60 cm minimum in the ponds*

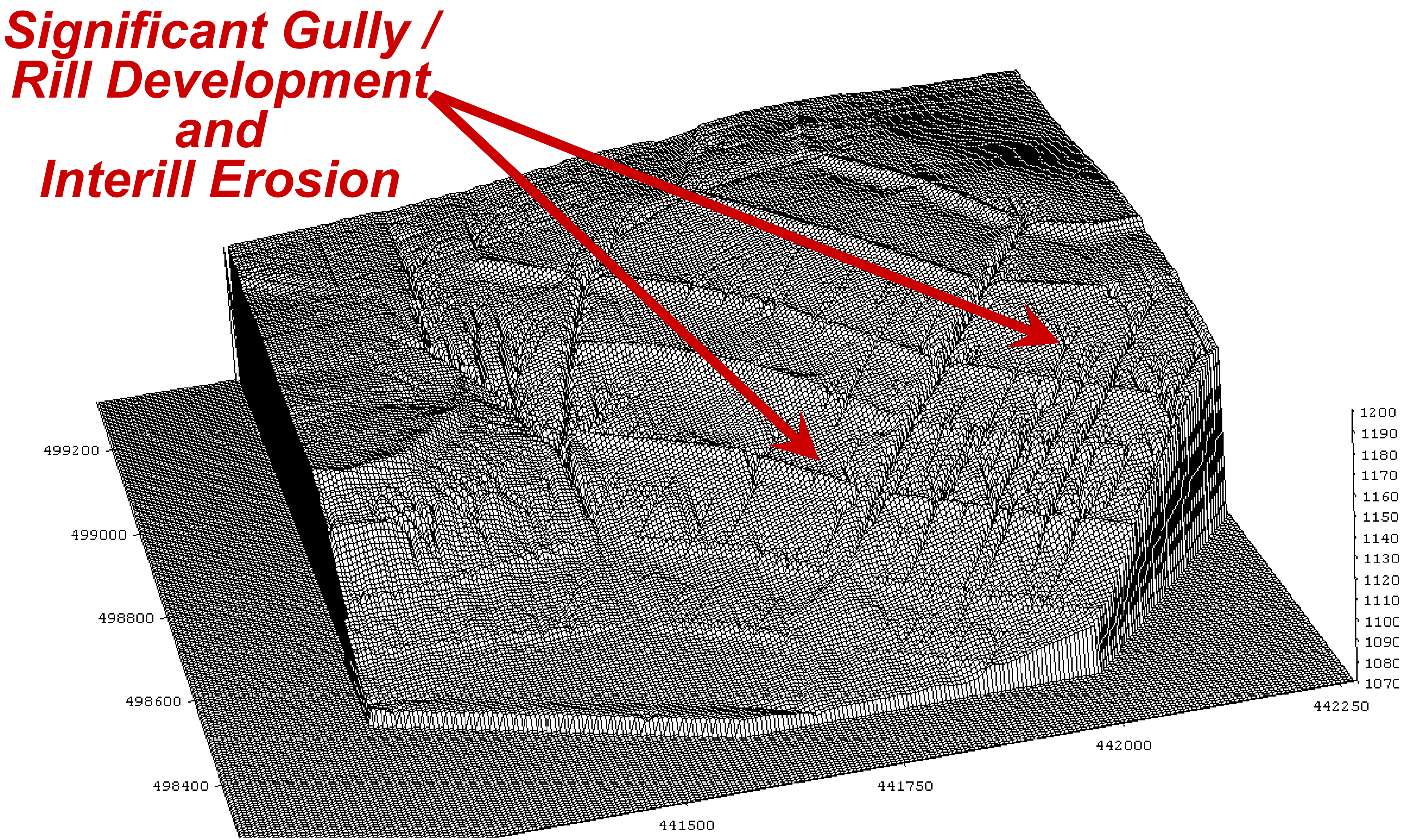
- *Compacted Copper Cliff clay*
- *45 cm minimum on slope*
- *60 cm minimum in the ponds*

- *Non-compacted sandy-gravel till (~ 10 cm thick)*

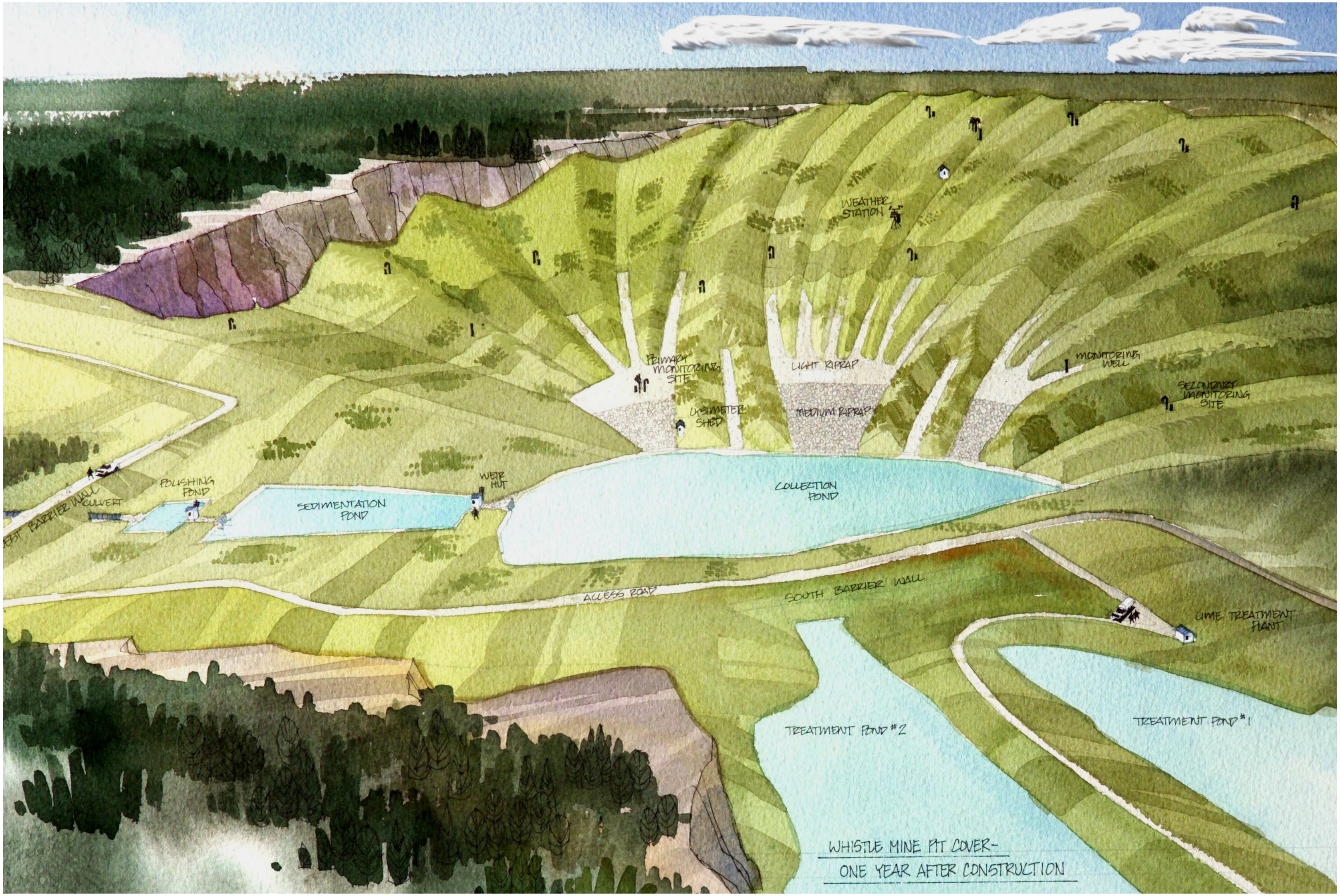
Original Landform Design – Input to the SIBERIA Model



Original Landform Design – Output from the SIBERIA Model (after 100 yrs)



Preferred Final Landform Design



Sustainable Cover Performance

INITIAL PERFORMANCE

Physical Processes

- Erosion
- Slope Instability
- Wet/Dry Cycles
- Freeze/Thaw Cycles
- Consolidation/Settlement
- Extreme Climate Events
- Brush Fires
- Construction

Chemical Processes

- Osmotic Consolidation
- Dispersion/Erosion
- Dissolution/Precipitation
- Acidic Hydrolysis
- Mineralogical Consolidation
- Sorption
- Salinization
- Oxidation

Biological Processes

- Root Penetration
- Burrowing Animals
- Bioturbation
- Human Intervention
- Bacteriological Clogging
- Vegetation Establishment

LONG-TERM PERFORMANCE

(Adapted from INAP, 2003)

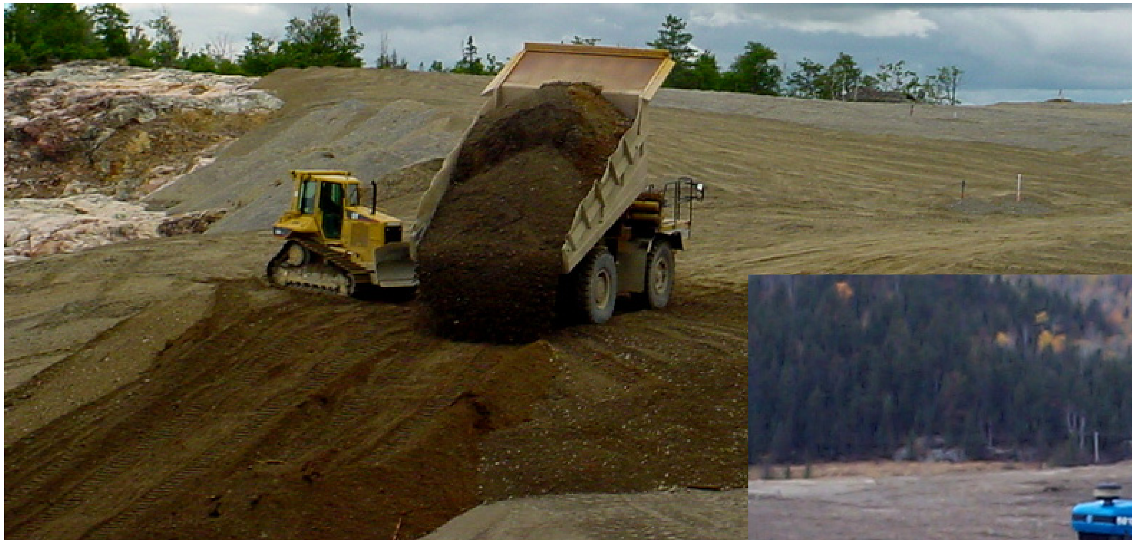
Design Elements Addressing Issue of Sustainable Performance

- Erosion control measures
- Revegetation plan
- Growth medium layer
  - Competent material
  - Thickness!
- Barrier layer
- Geotextile
- Performance monitoring system

Key Construction Activities

- *Started May 2004*

Key Construction Activities *(cont')*



- ***Completed November 2005***

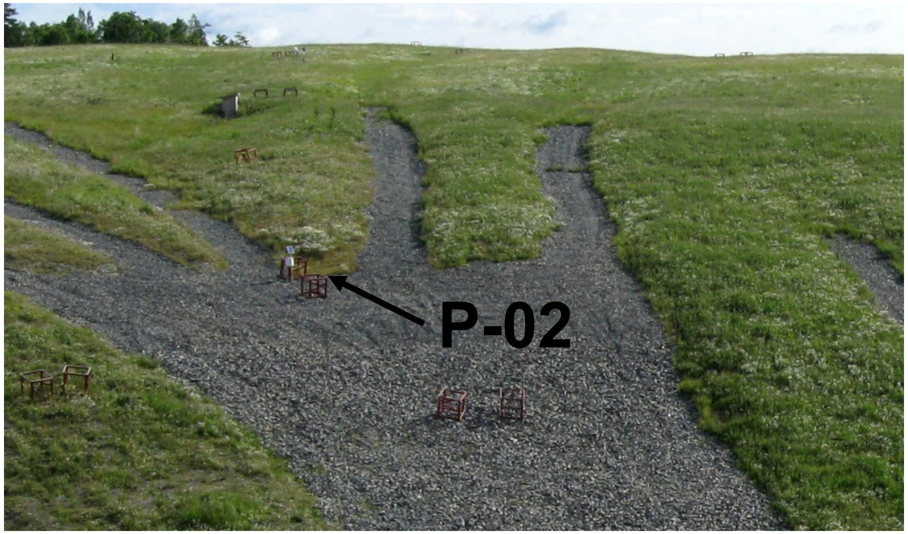
Pit Cover – 2006

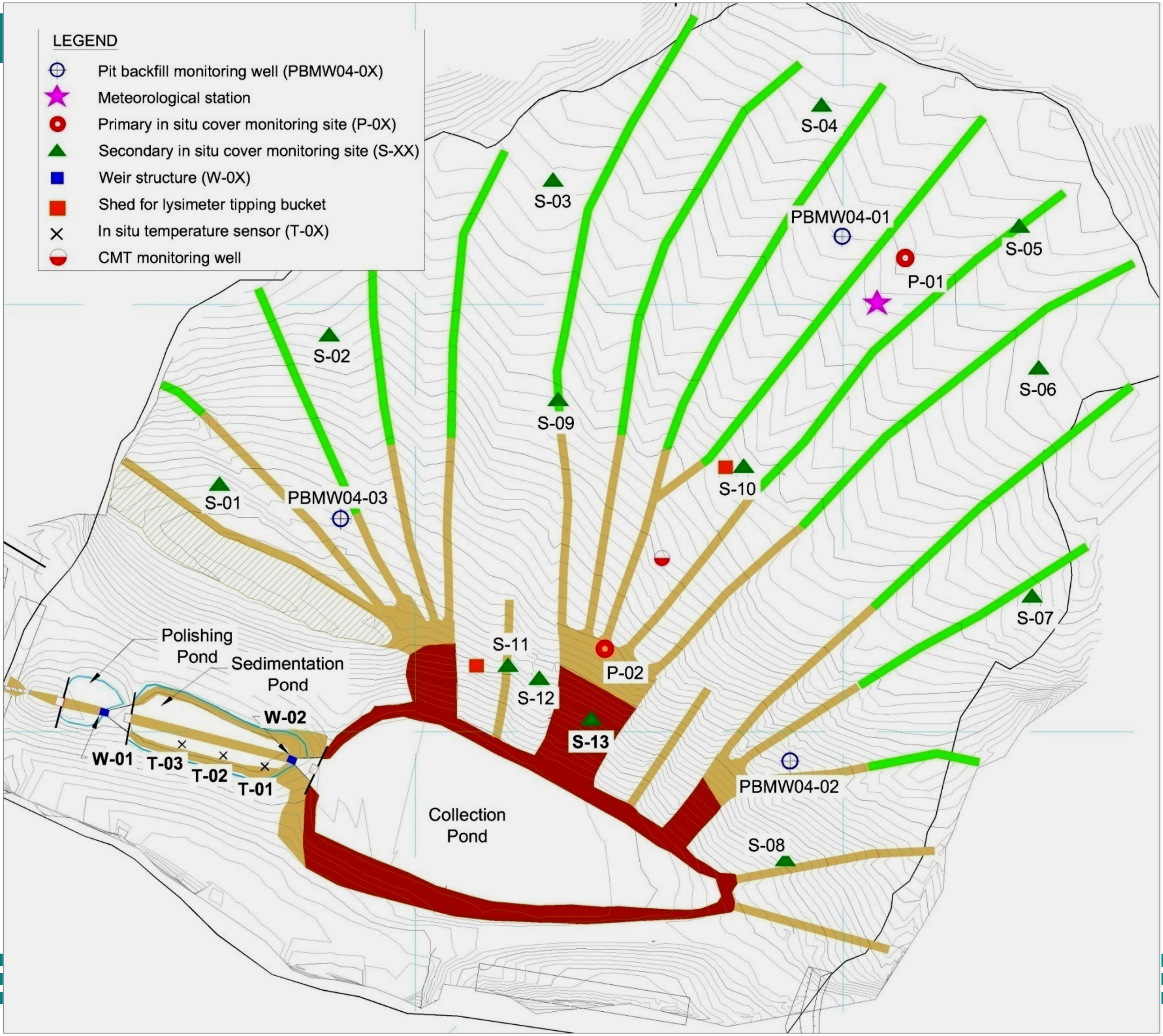
Pit Cover – 2009

Cover Performance Monitoring

- ***Primary** in situ cover monitoring sites (x 2):*
  - *Automated*
  - *Net percolation*
  - *Suction / water content*
  - *Temperature*
  - *O_2 / CO_2 (manual)*

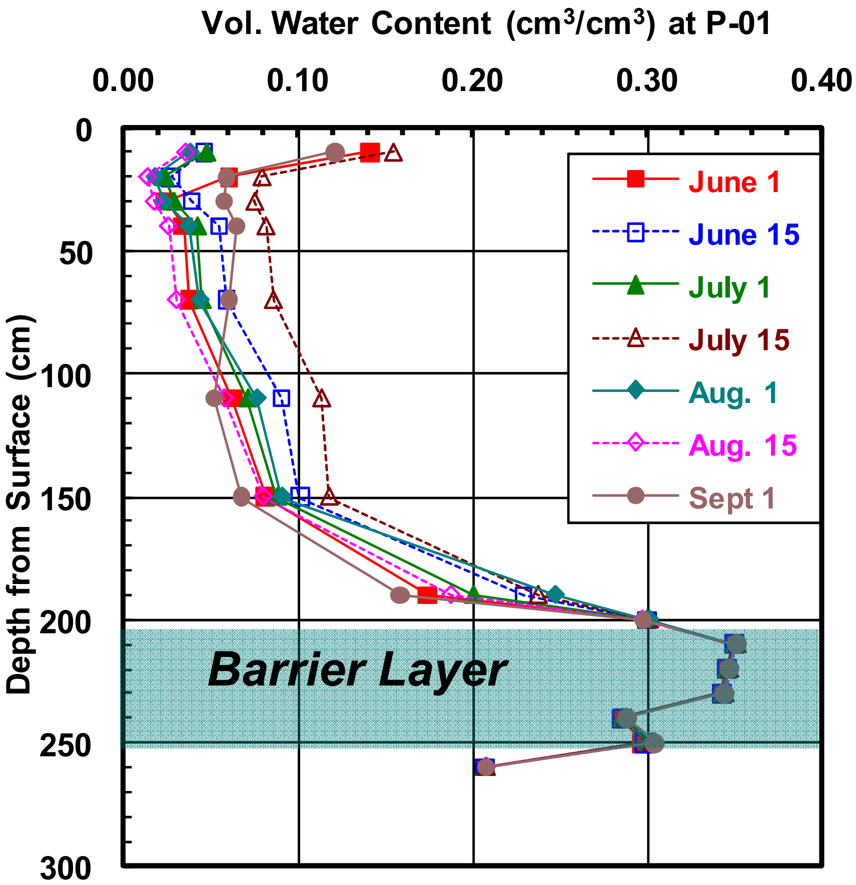
- ***Secondary** in situ cover monitoring sites (x 13) (portable soil w/c probe & O_2 / CO_2 gas analyzer)*
- *Groundwater monitoring wells*
- *Surface runoff (automated weirs)*
- *Meteorological monitoring*

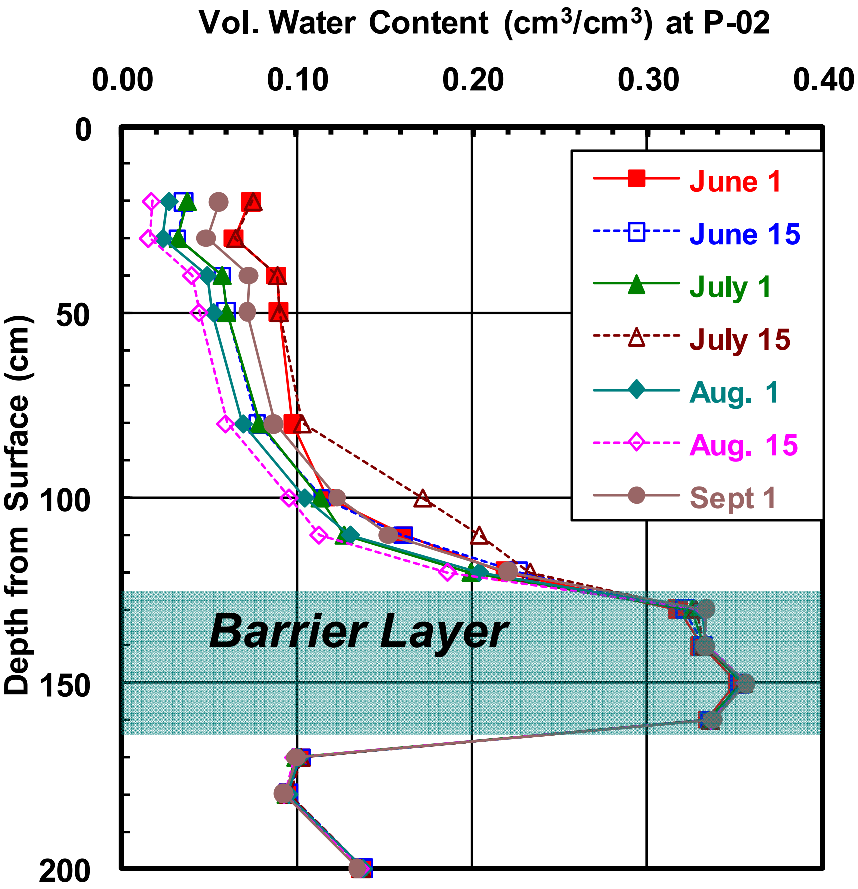




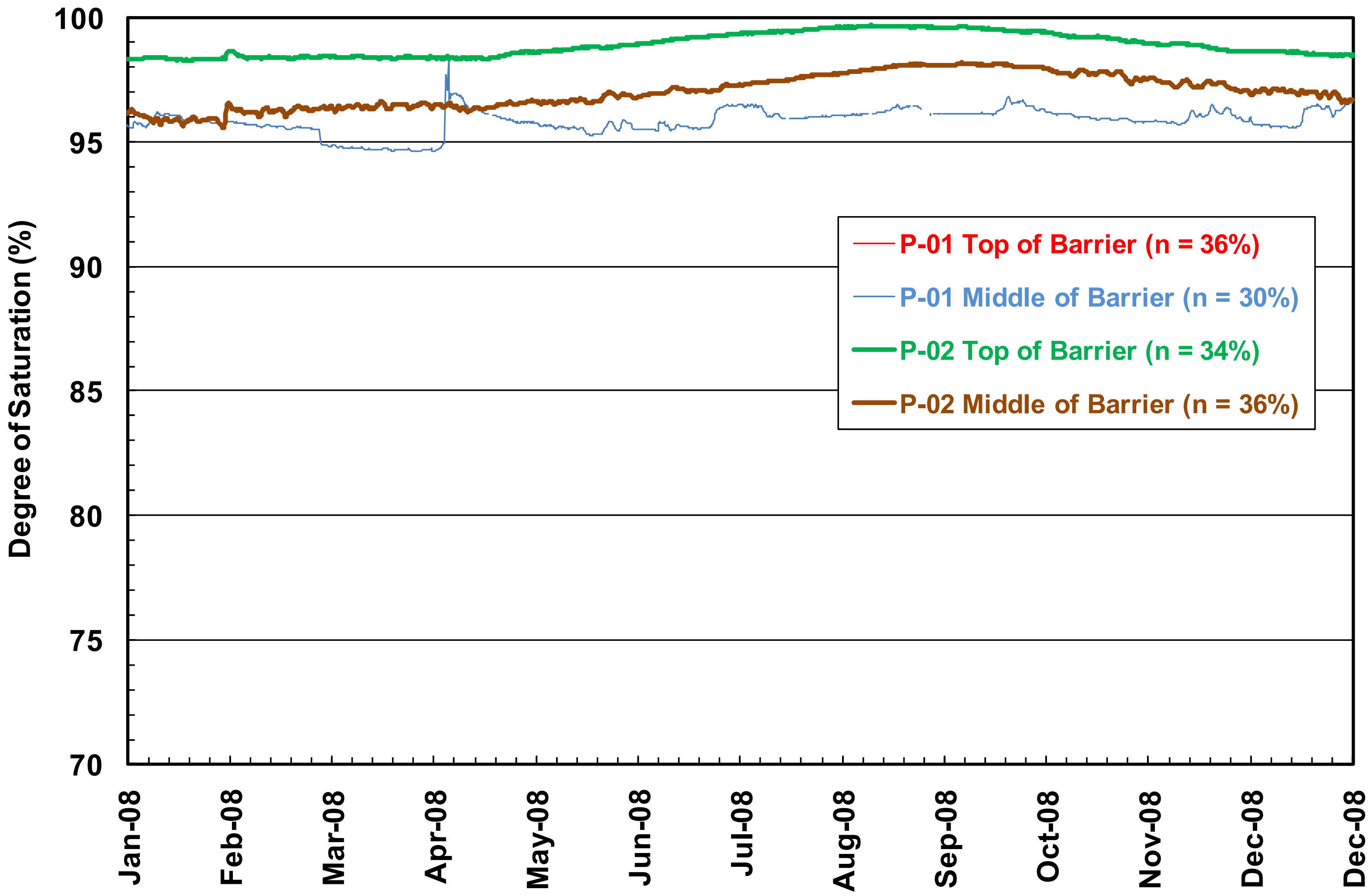
LEGEND
Pit backfill monitoring well (PBMW04-0X)
Meteorological station
Primary in situ cover monitoring site (P-0X)
Secondary in situ cover monitoring site (S-XX)
Weir structure (W-0X)
Shed for lysimeter tipping bucket
In situ temperature sensor (T-0X)
CMT monitoring well
S-01
S-02
S-03
S-04
S-05
S-06
S-07
S-08
S-09
S-10
S-11
S-12
S-13
P-01
P-02
PBMW04-01
PBMW04-02
PBMW04-03
Polishing Pond
Sedimentation Pond
Collection Pond
W-01
W-02
T-01
T-02
T-03

Water Content Profiles Measured in 2008





Degrees of Saturation for the Pit Cover Barrier Layer

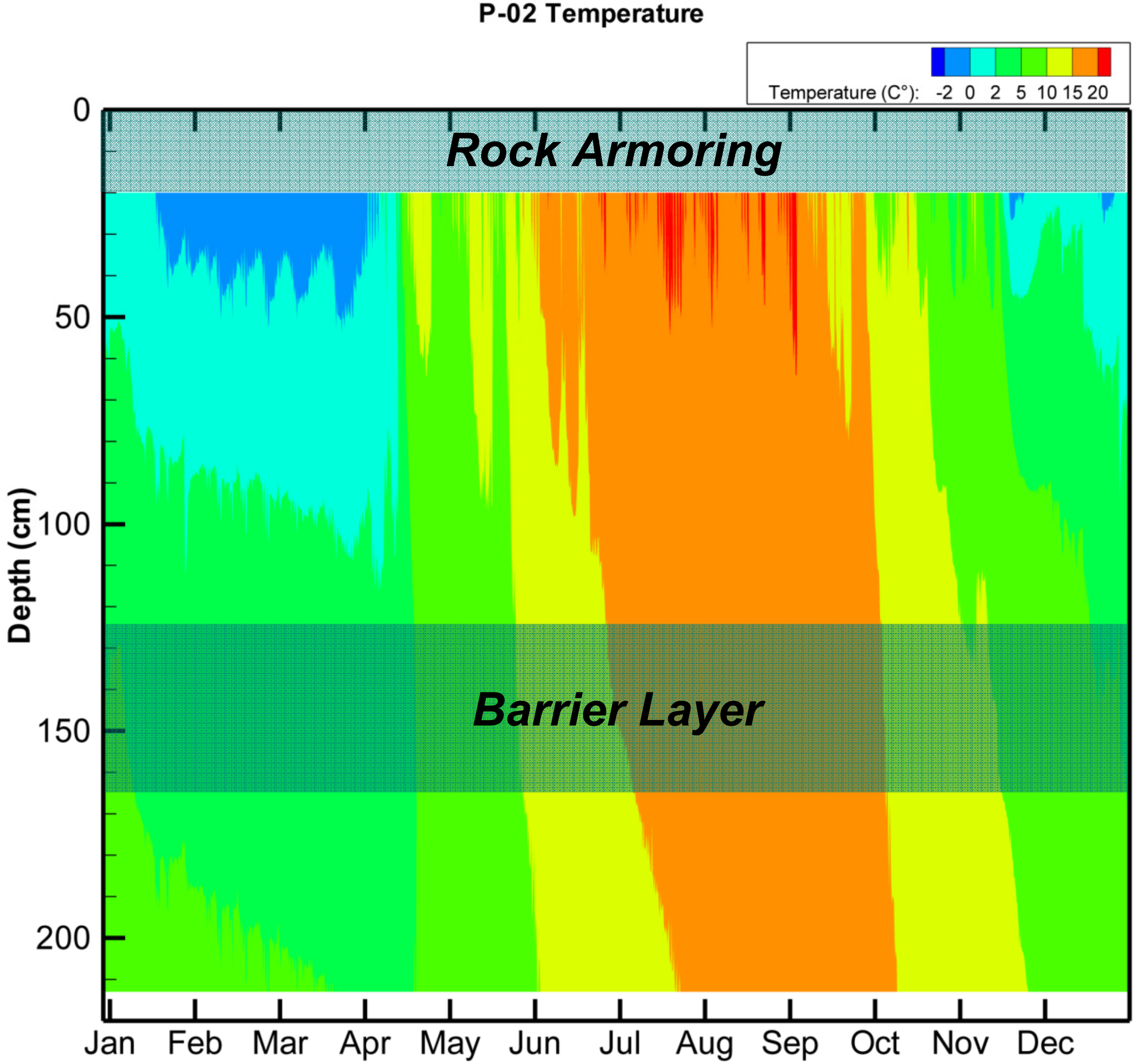


Pit Cover Water Balance

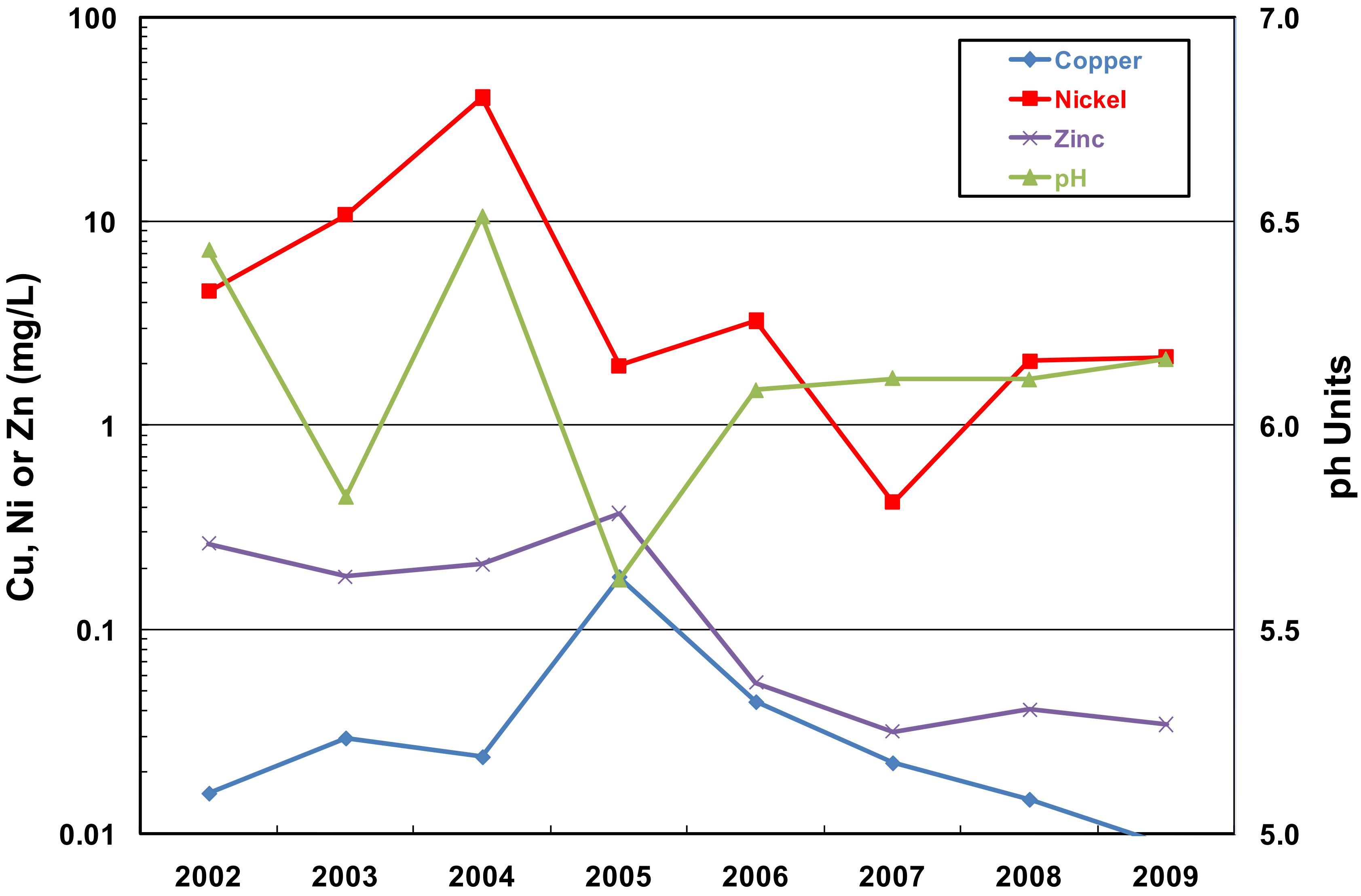
	2006		2007	
	Value (mm)	Percentage of Total Precipitation	Value (mm)	Percentage of Total Precipitation
Precipitation	765	-	584	-
Runoff and interflow	475	62.1%	228	39.0%
Evapotranspiration	269	35.2%	332	56.8%
Net percolation	21	2.7%	16	2.7%
Change in storage	0	0	9	1.5%

- Net percolation measured in 2008 was 11 mm or 1% of precipitation

Soil Temperature Contours - 2008



Evolution of Pit Water Quality



Concluding Remarks

- ***Pit cover performing as expected …***
  - ***Growth medium for a variety of local plant species***
  - ***Minimal soil erosion … stable landform***
  - ***H_2O and O_2 ingress substantially reduced since 2005***
- ***Final landform analogous to a natural system … will aid in the sustainability of the pit cover***
- ***Quality of site runoff and pit overflow waters improving with time***

Concluding Remarks

- *Ultimately decommission collection ponds, batch treat pit overflow water*

Concluding Remarks

- *2009 recipient of the Tom Peters Memorial Mine Reclamation Award (CLRA)*