Closure Planning and Implementation at Vale Inco's Whistle Mine

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MEND MANITOBA WORKSHOP
Challenges in Acidic Drainage for Operating, Closed or Abandoned Mines
Winnipeg, MB – June 4-5, 2008

O'Kane Consultants

Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

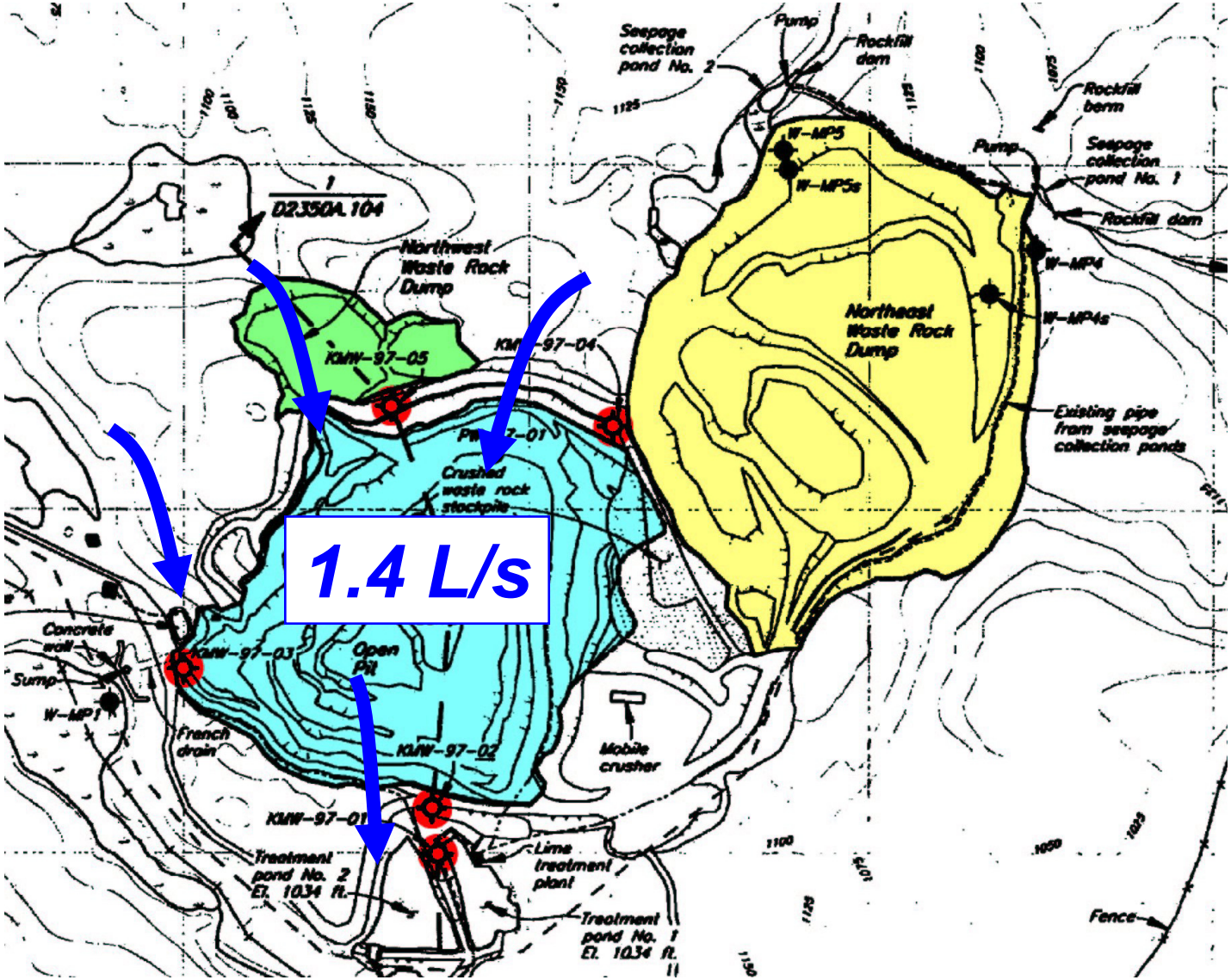
Presentation Outline

- Background
- Cover System Design Approach
- Cover Modelling
- Landform Evolution Modelling
- Sustainability of the Cover and Landform
- Key Construction Activities
- Performance Monitoring

Background

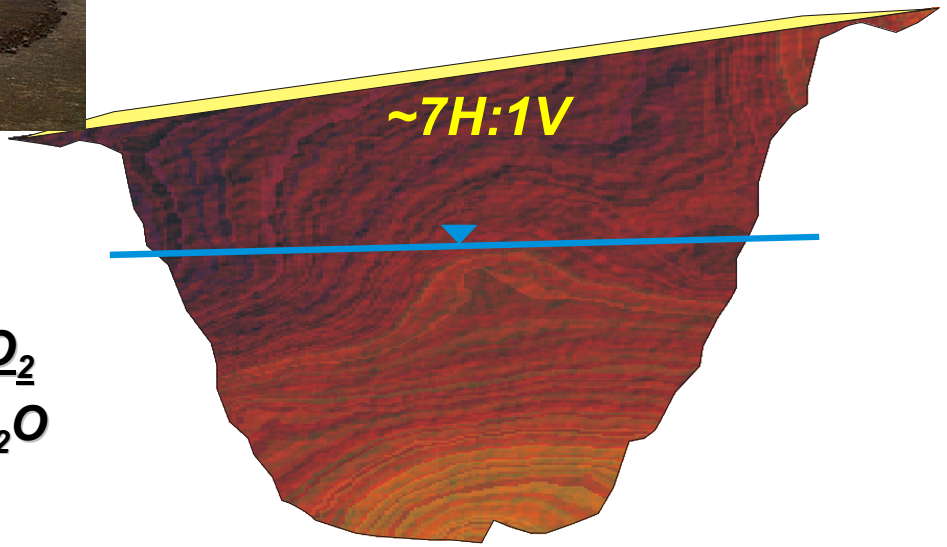
- ~60 km from Sudbury, ON
- Canadian Shield – numerous bedrock outcrops and lakes
- Open pit mining (nickel) between 1988-91 & 1994-98
- 6.4 Mt of waste rock on surface – 80% is mafic norite, avg. S of 3%
- Several acidic seeps developed
- Semi-humid climate – annual precip. of 900 mm (30% as snow) &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

Background (cont')



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) and place a cover system



- Pit surface area – 10 ha
- Objectives of cover system:
  - reduce ingress of atmospheric O_2
  - reduce infiltration of meteoric H_2O
  - growth medium for vegetation

Cover System Design Approach

Cover System Field Trials

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Geochemical Modelling

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Selection of Barrier Layer Material

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Soil-Atmosphere Cover Design Modelling

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Erosion and Landform Evolution Modelling

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Slope Stability Analysis

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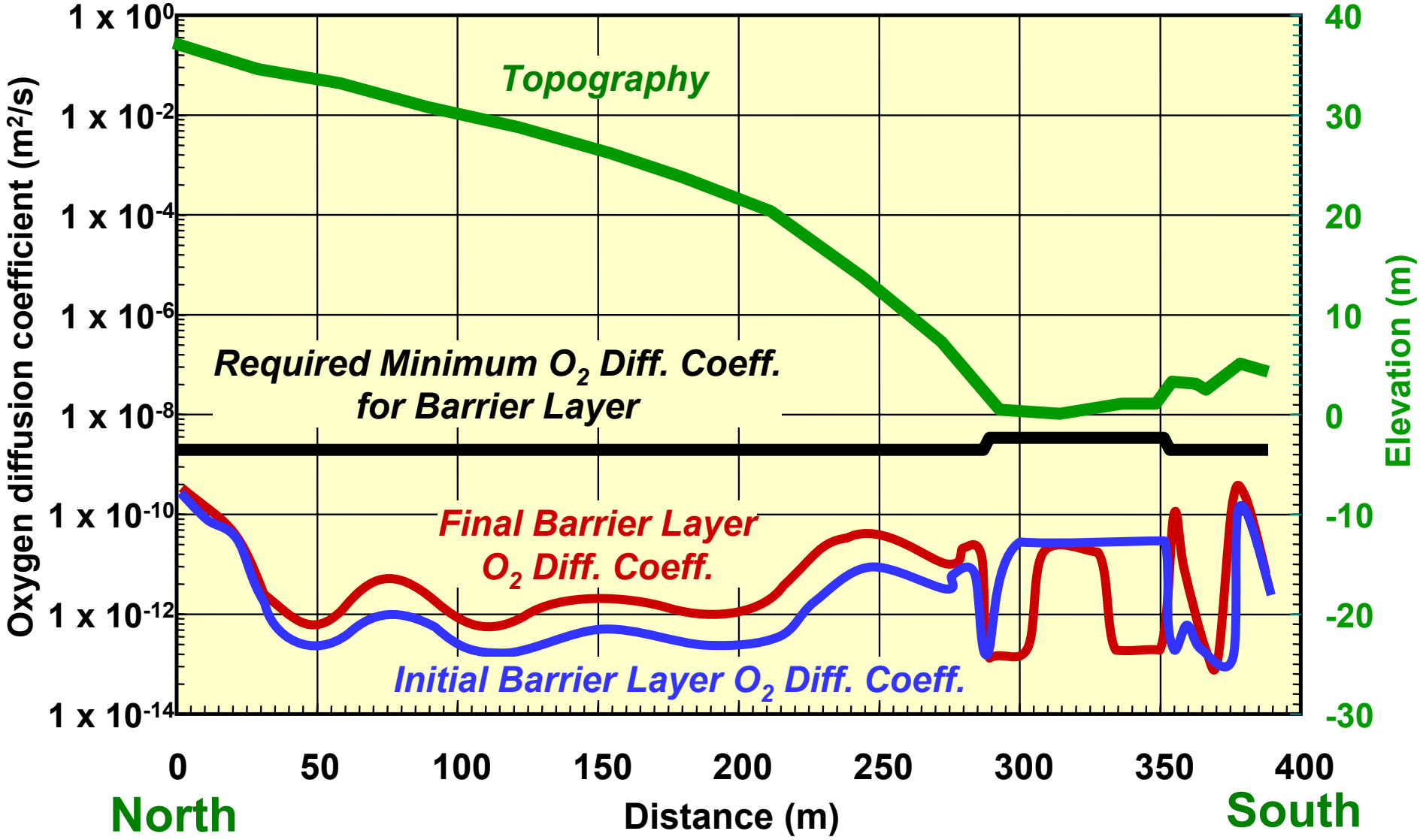
Consideration of Processes Potentially Impacting on Sustainable Performance

Cover Design Criteria!

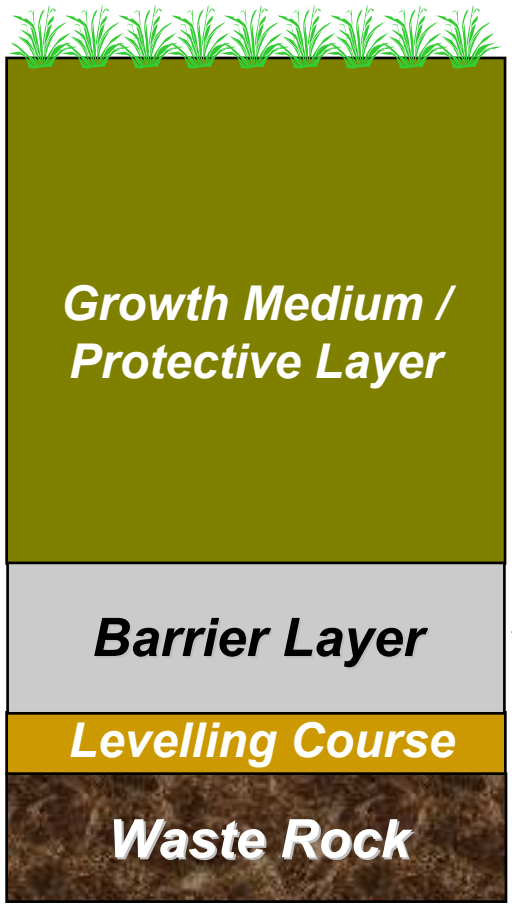
Preliminary Cover Design Modelling

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



Final Cover System Design

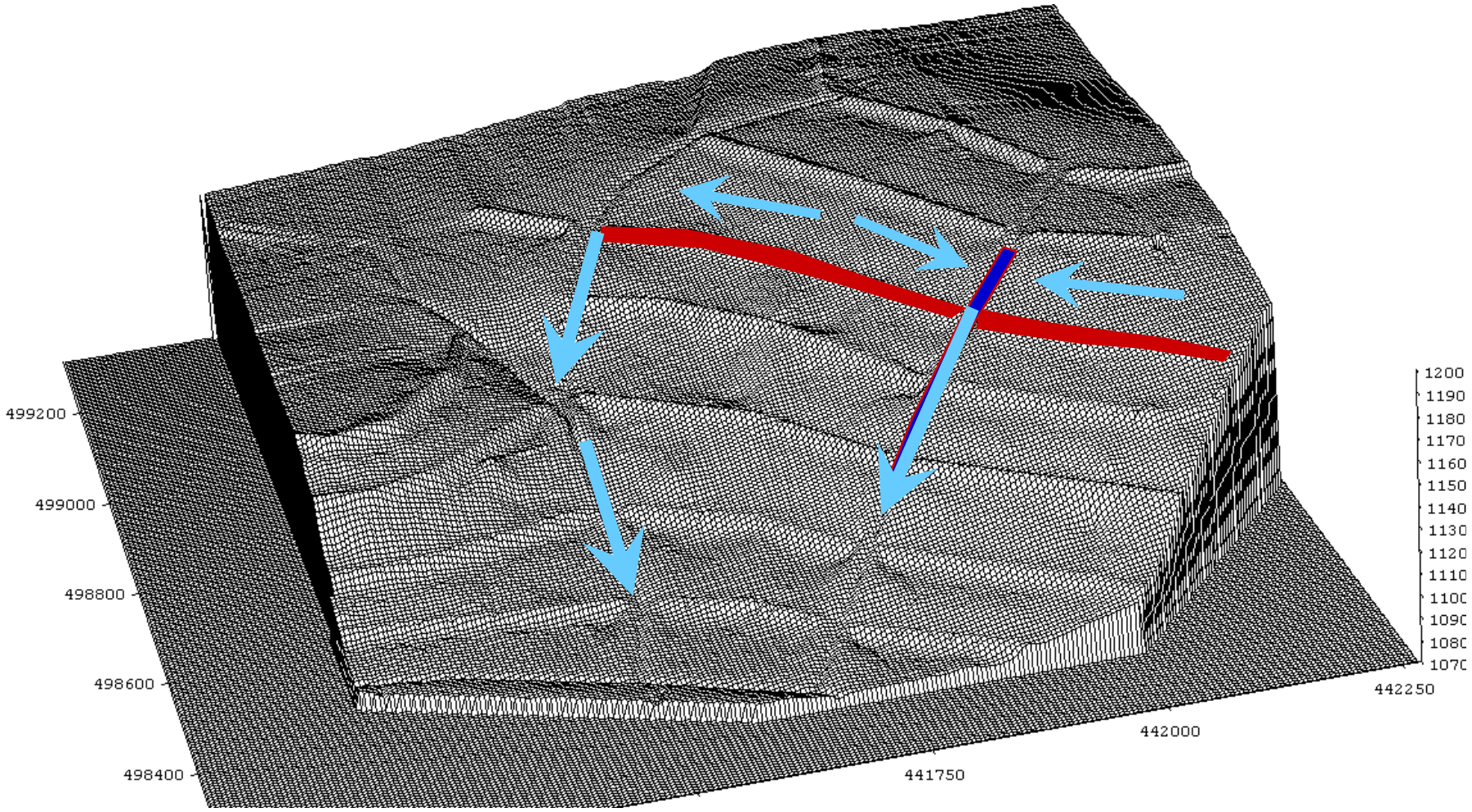


- Non-compacted sandy-gravel till
- 120 cm minimum on slope, with 8 cm of topsoil admixed to the near surface material
- 60 cm minimum in the ponds

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

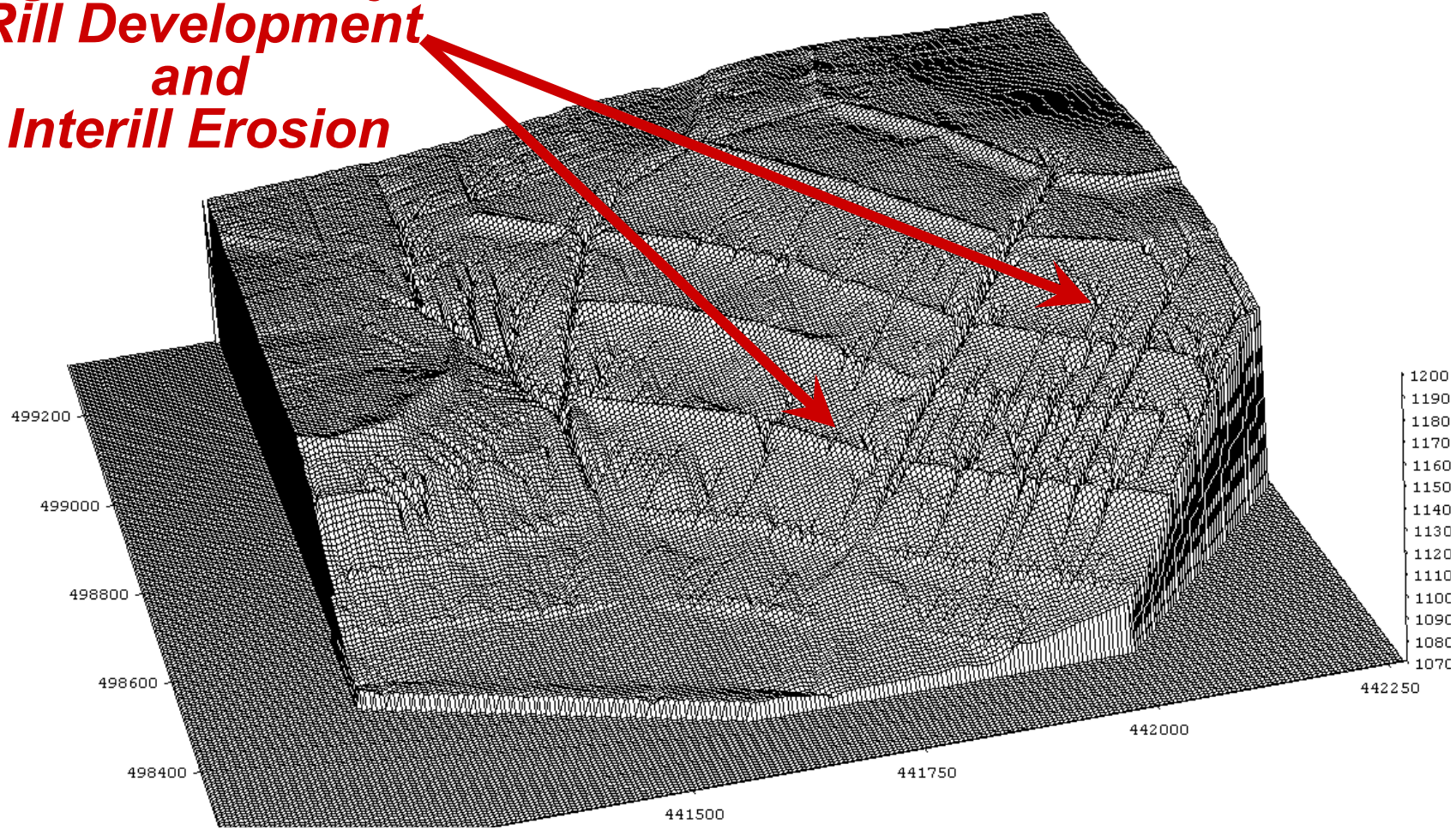
- Non-compacted sandy-gravel till (~ 10 cm thick)

Original Landform Design – Input to the SIBERIA Model

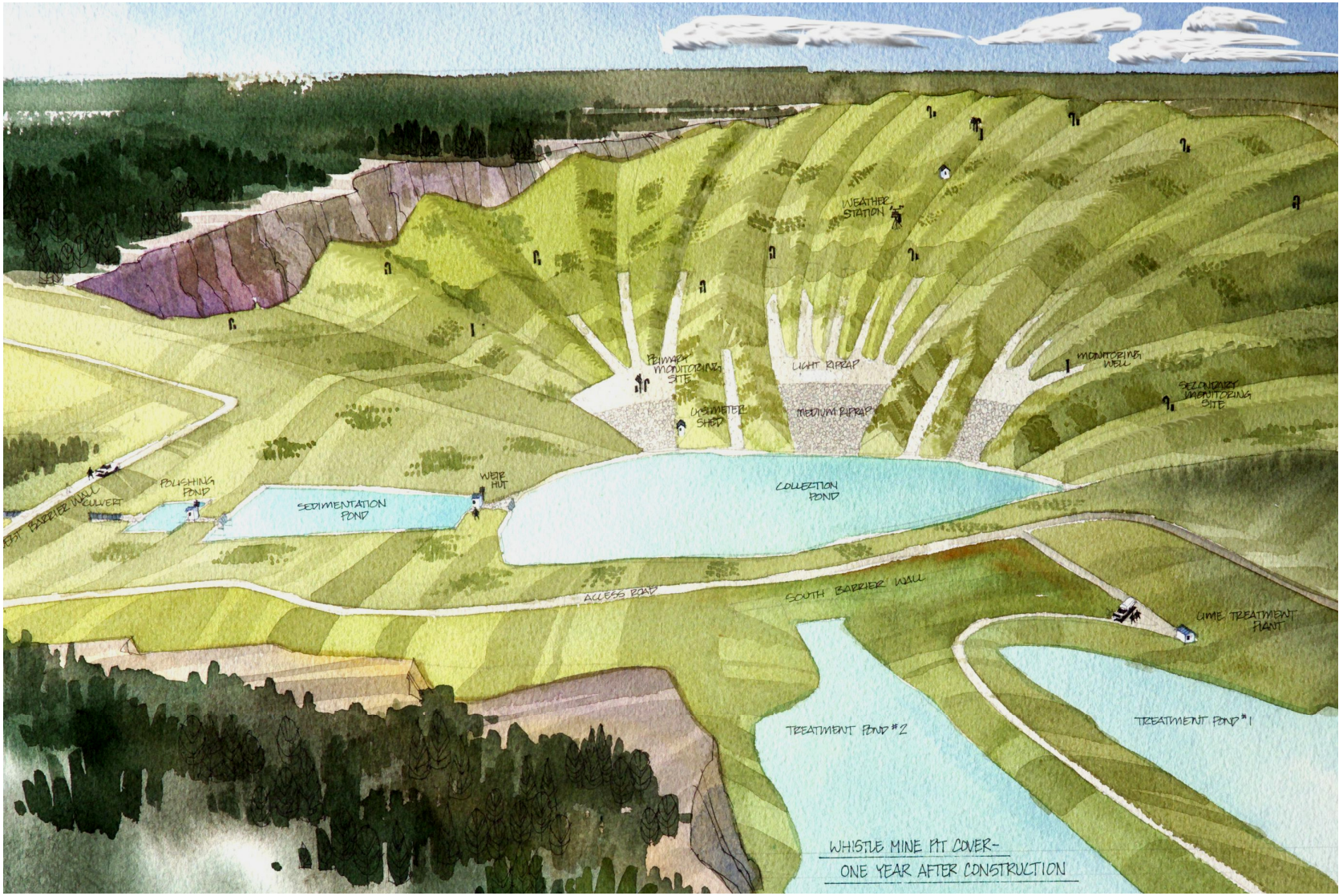


Original Landform Design – Output from the SIBERIA Model (after 100 yrs)

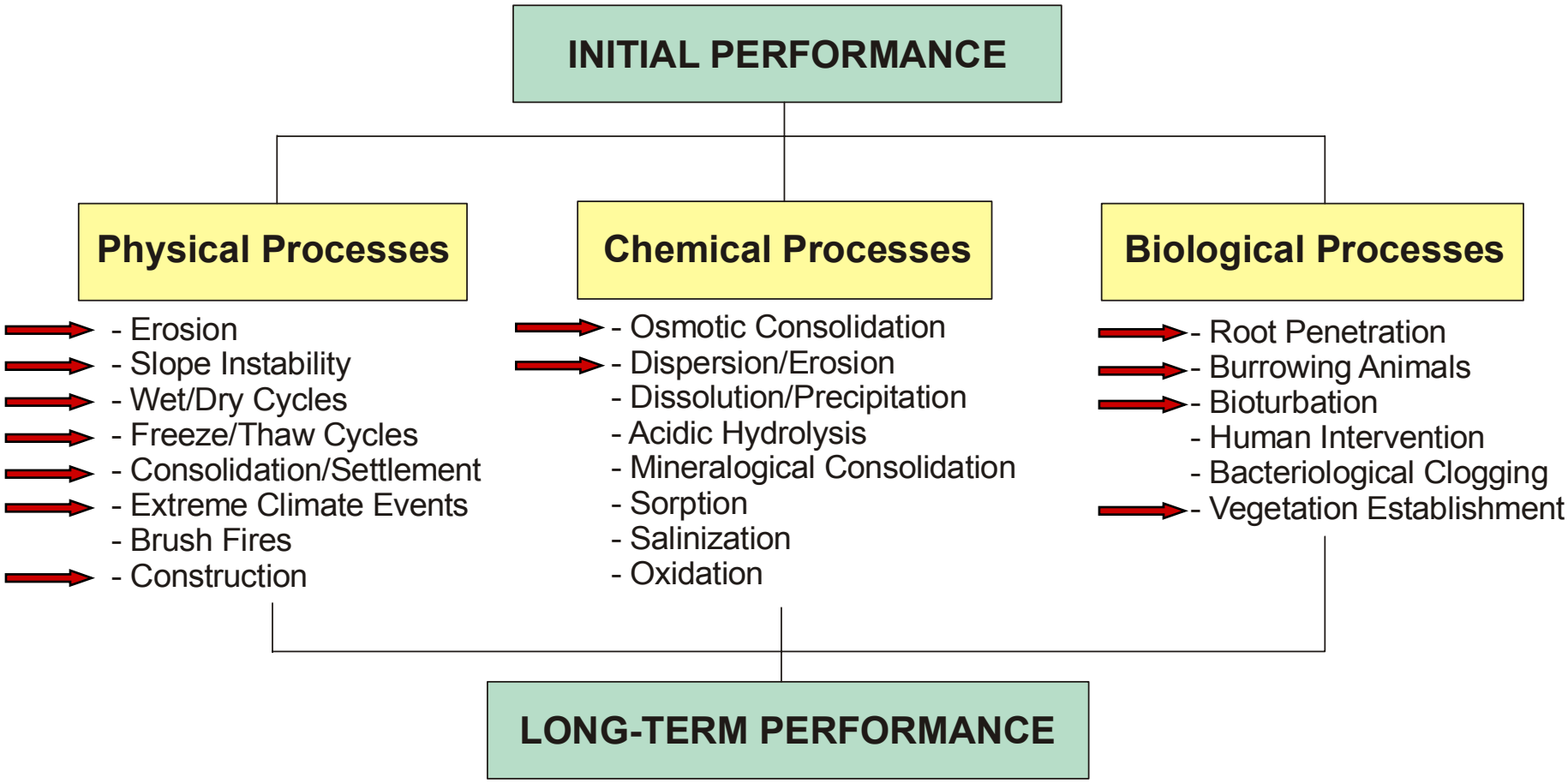
Significant Gully / Rill Development and Interill Erosion



Final Landform Design



Sustainable Cover 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

Key Construction Activities (cont')

Key Construction Activities (cont')

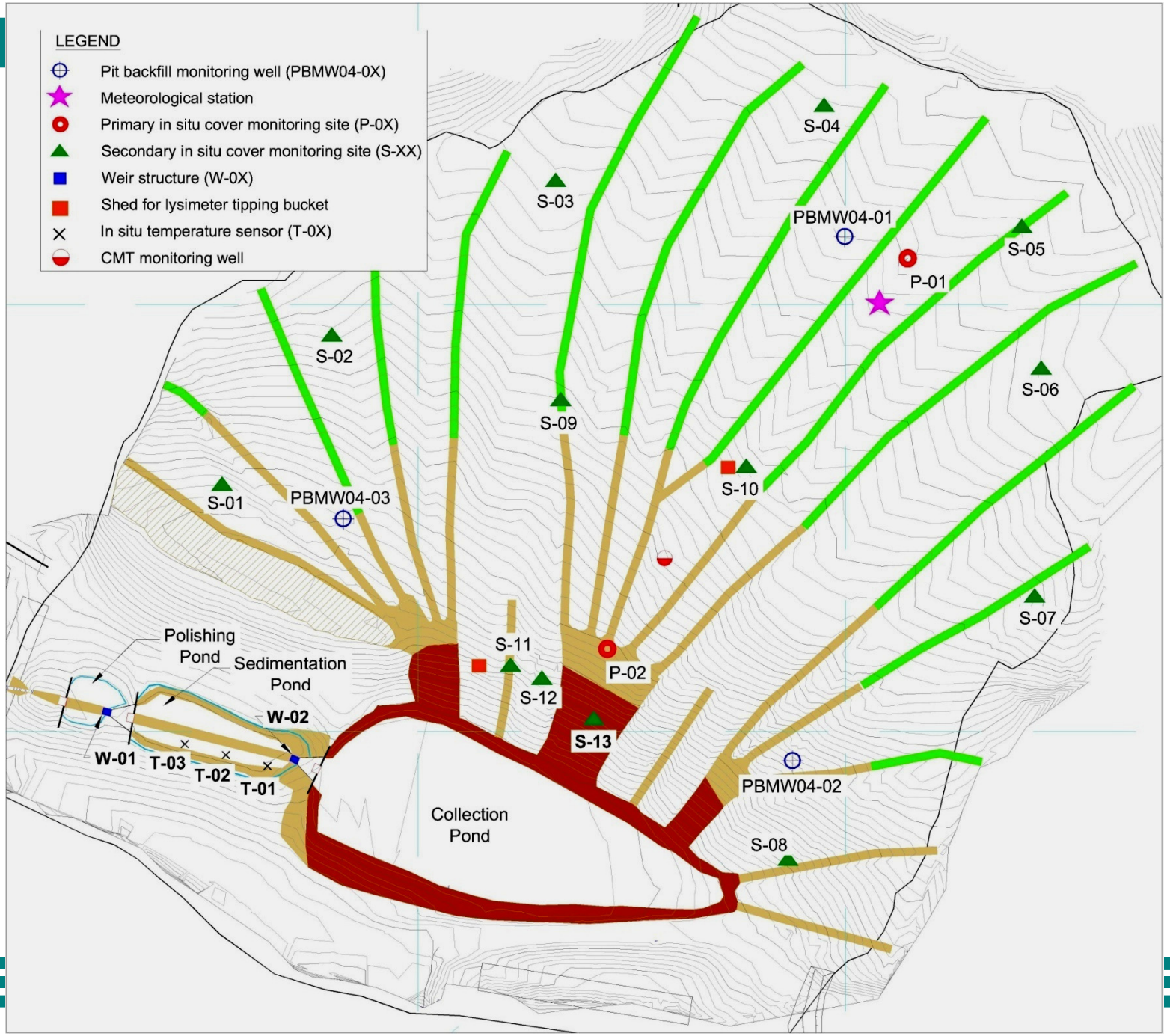
Key Construction Activities (cont')

Key Construction Activities *(cont')*

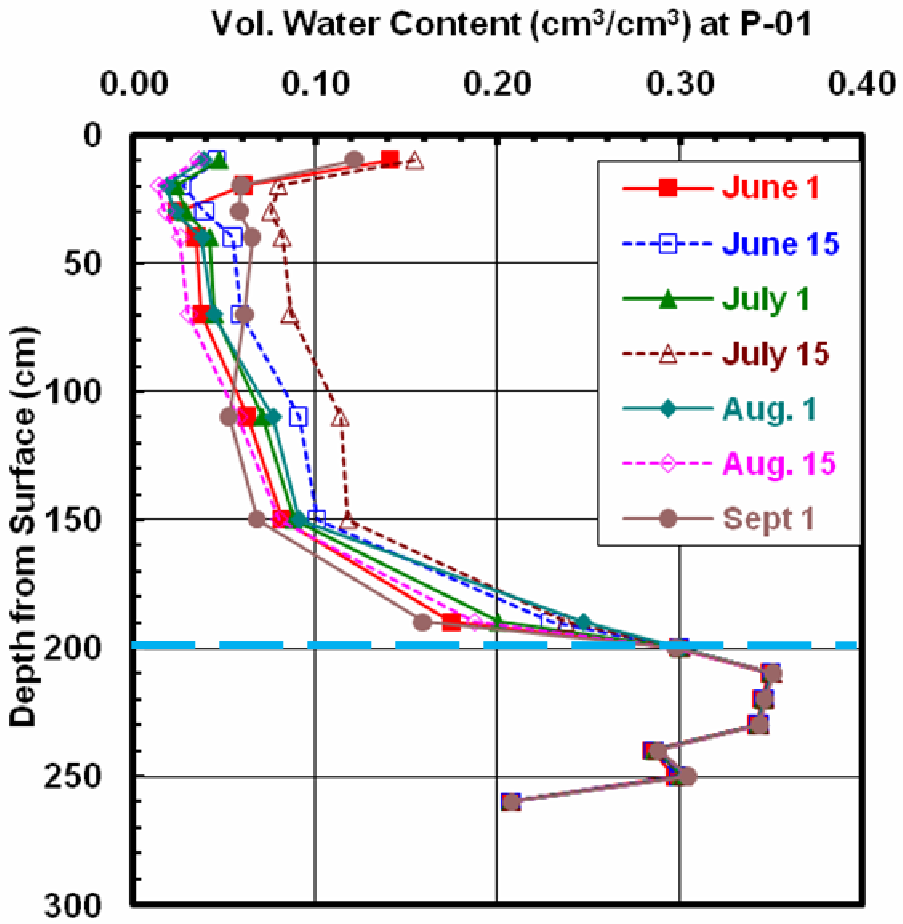
Cover Performance Monitoring

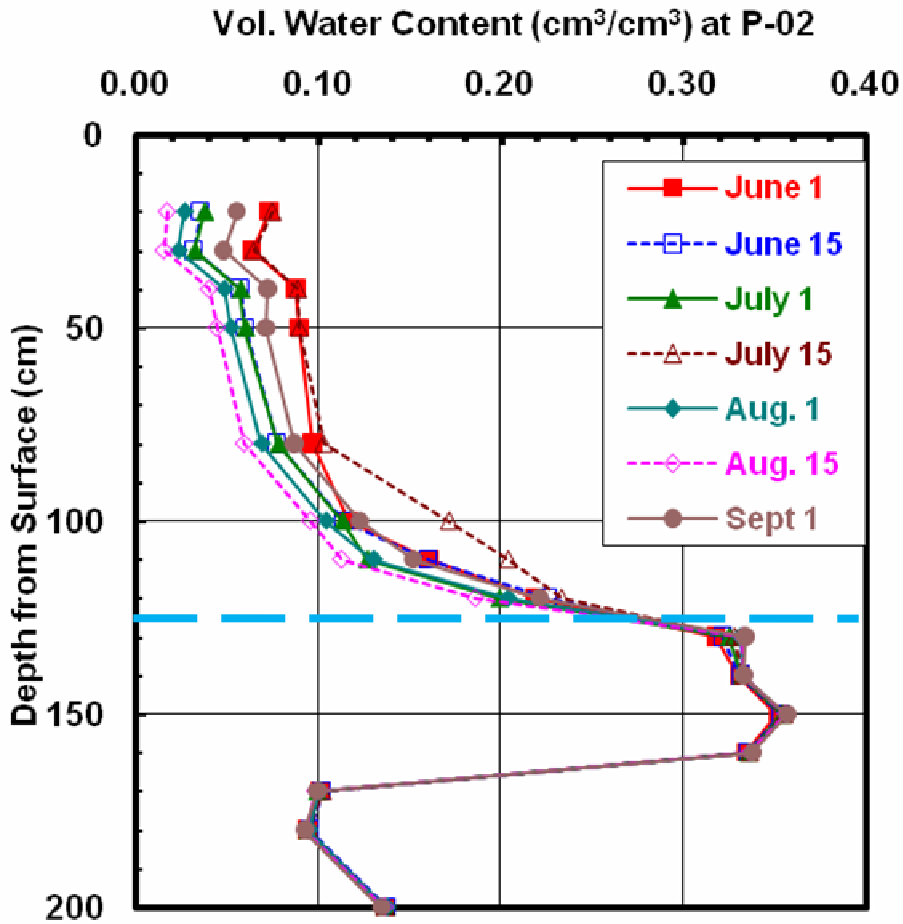
- *Primary in situ cover monitoring sites (x 2):*
  - *Automated*
  - *Net percolation*
  - *Suction / water content*
  - *Temperature*
  - *O_2 / CO_2 (manual)*

- *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*

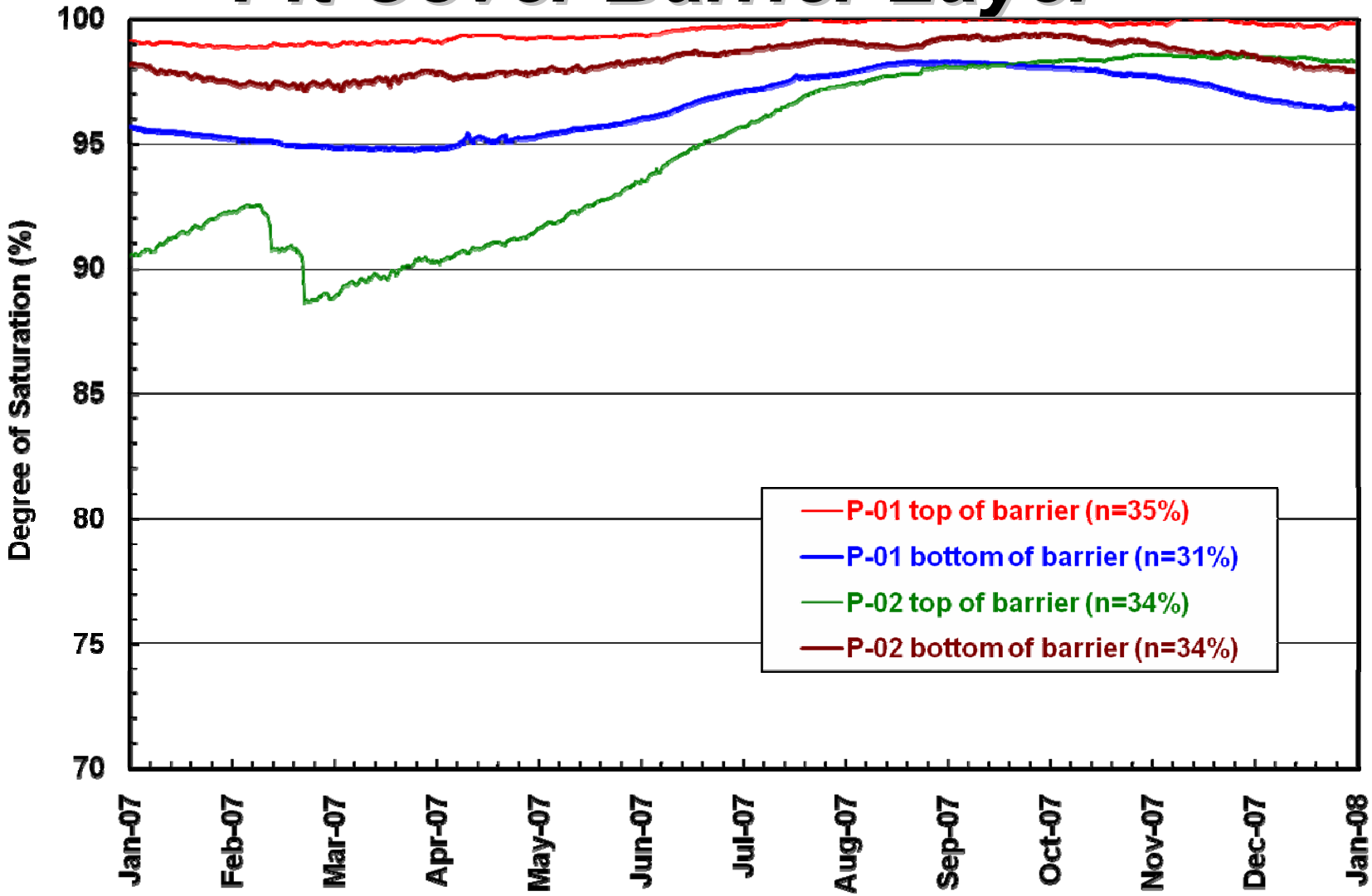

LEGEND
Pit backfill monitoring well (PBMW04-0X)
Meteorological station
Primary in situ cover monitoring site (P-0X)
Secondary in situ cover monitoring site (S-XX)
Weir structure (W-0X)
Shed for lysimeter tipping bucket
In situ temperature sensor (T-0X)
CMT monitoring well
S-01
S-02
S-03
S-04
S-05
S-06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

Water Content Profiles Measured in 2007





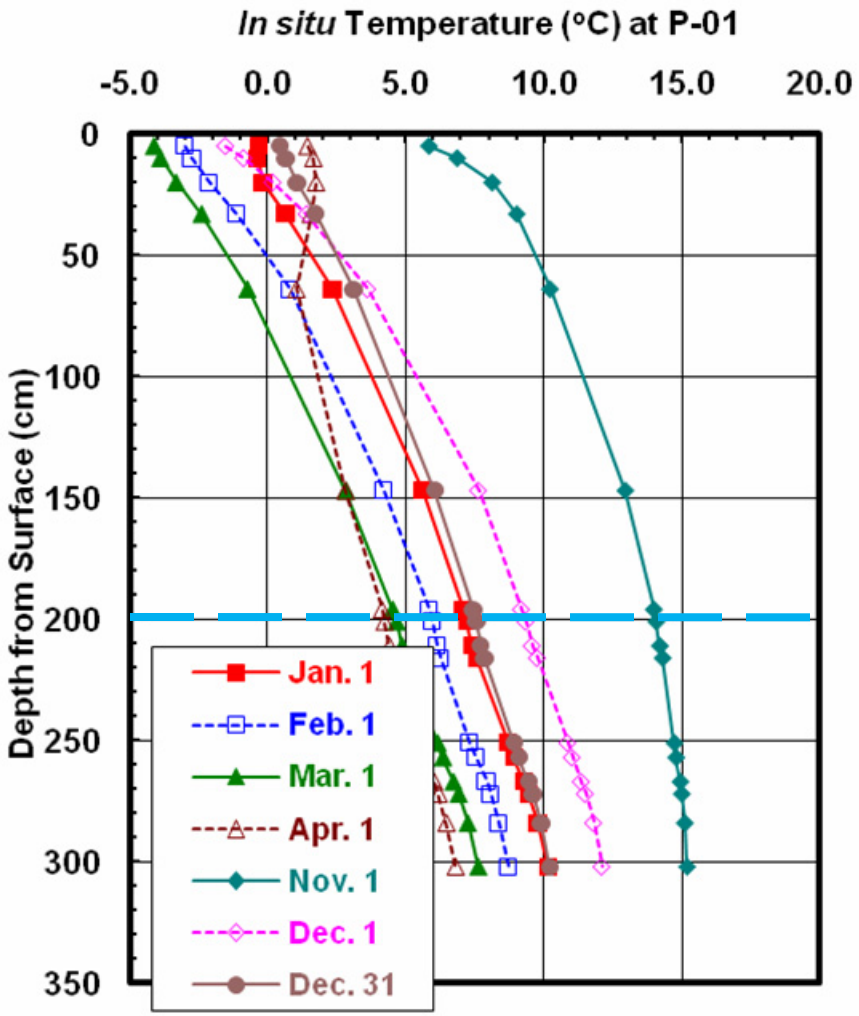
Degrees of Saturation for the Pit Cover Barrier Layer

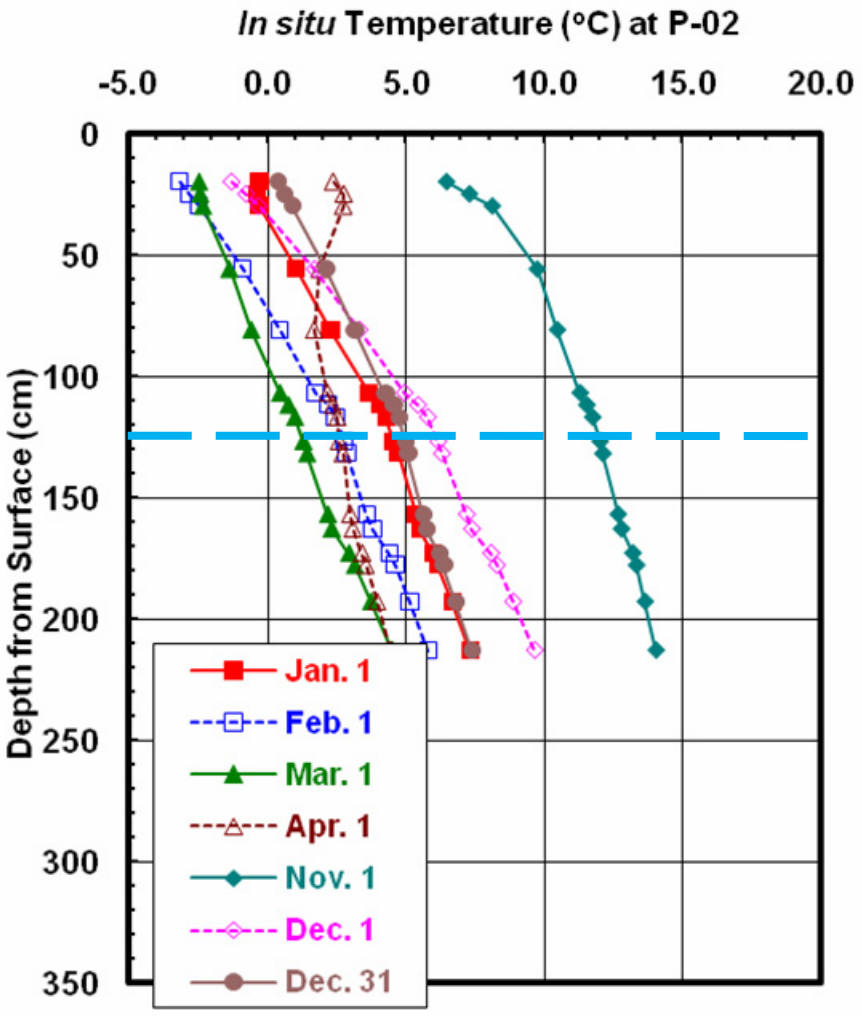


Pit Cover Water Balance

	2006		2007	
	Value (mm)	% of Precip.	Value (mm)	% of Precip.
Precipitation	765	-	584	-
Runoff & interflow	475	62%	228	39%
Evapotranspiration	269	35%	332	57%
Net percolation	21	3%	16	3%
Change in storage	0	0	9	1%

Soil Temperature Profiles Measured in 2007





Concluding Remarks

- Cover design – based on site-specific performance
  - Observations from test cover field trials
  - Geochemical predictions … limit O_2 ingress most critical!
  - Cover performance on slope … verified w/ 2-D model
- Pit cover performing as expected – substantial reduction in O_2 and H_2O ingress since construction
  - Net percolation will decrease as vegetation cover matures
- Final landform analagous to a natural system … will aid in the sustainability of the pit cover
- Anticipated that Vale Inco will walk-away from site in next 100 yrs