

A grayscale photograph of a large, conical pile of rocks or rubble in an open field. The pile is the central focus, with a small white structure visible at its base. The foreground is a flat, light-colored surface, possibly snow or sand, with some faint tracks. The sky is a uniform light gray.

# **Geochemistry of the UBC Constructed Waste Rock Pile Experiment, Cluff Lake, Saskatchewan**

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# Outline

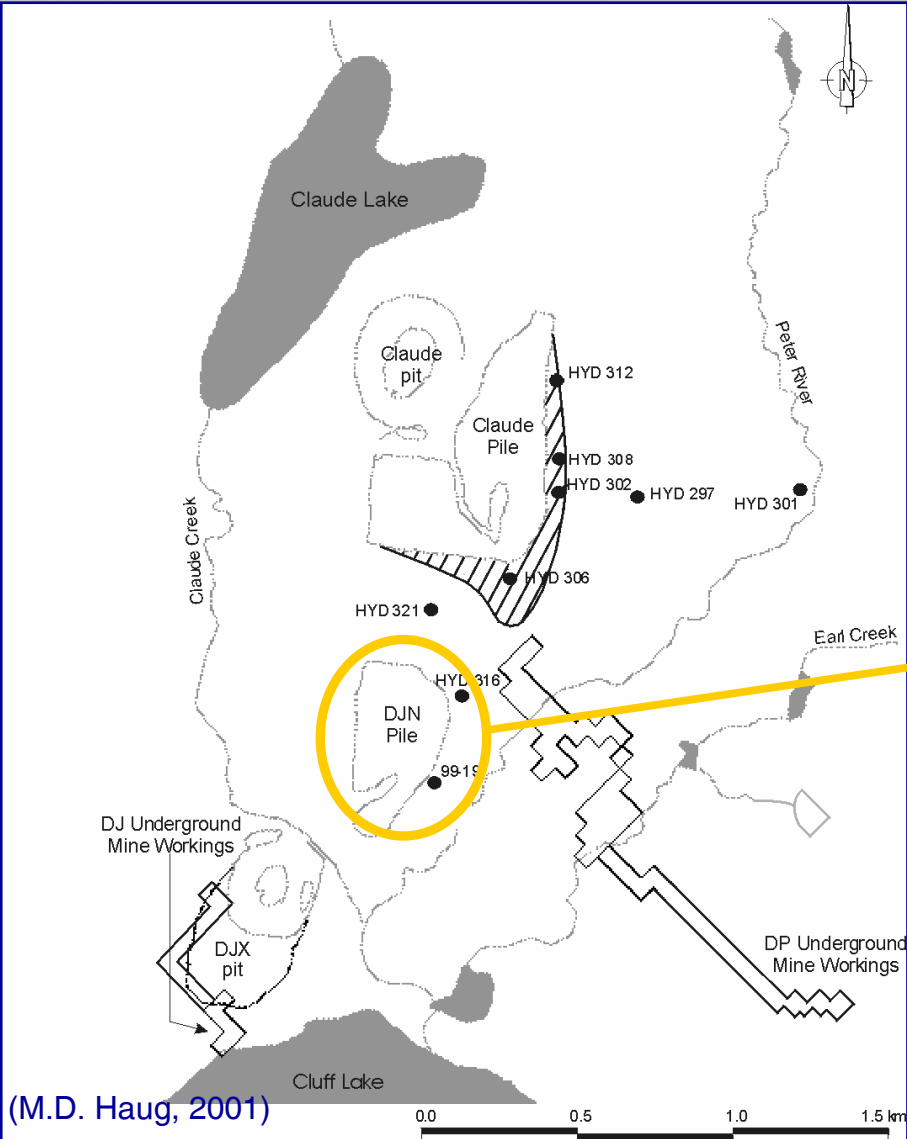
- Introduction/Overview of constructed Waste Rock Pile
- Waste Rock Background Data
- Geochemistry Results
- Conclusions





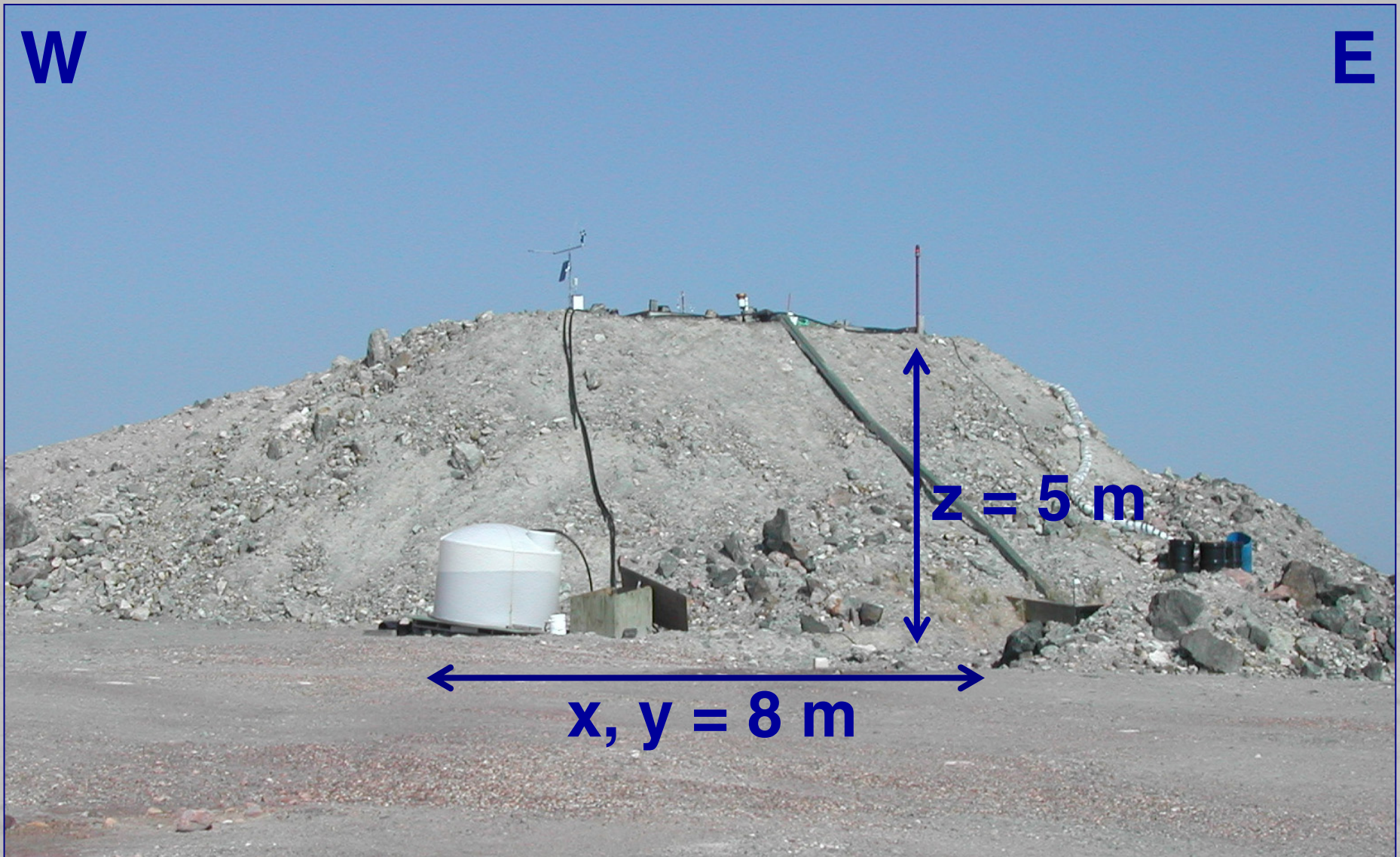


# Mine Site and Waste Rock Piles





# Waste Rock Pile



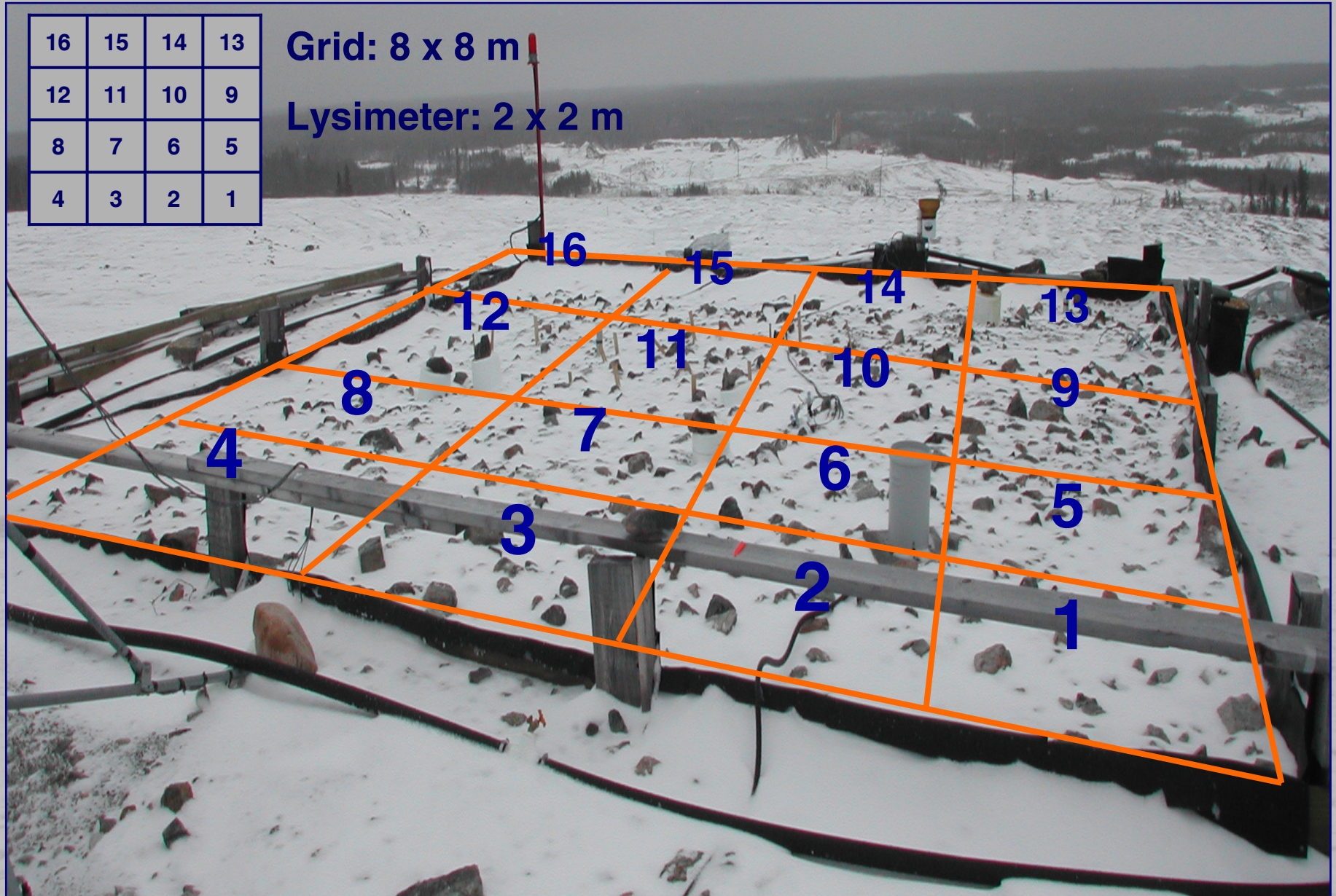


# Waste Rock Pile – Lysimeter Grid

16	15	14	13
12	11	10	9
8	7	6	5
4	3	2	1

Grid: 8 x 8 m

Lysimeter: 2 x 2 m





# Waste Rock Pile – Outflow Sampling



# Climate

Mean Annual Precipitation	451.4 mm
Mean Annual Rainfall	310.7 mm
Average frost-free period	< 90 days
Snow Fall	October - May
Average mean daily temperature (summer)	14.7 °C – 17.0 °C
Average mean daily temperature (winter)	-17.5 °C – -20.3°C
Absolute Temperature Range	-49 °C - 36°C

(Cogema, 2001)



# Geology/Mineralogy

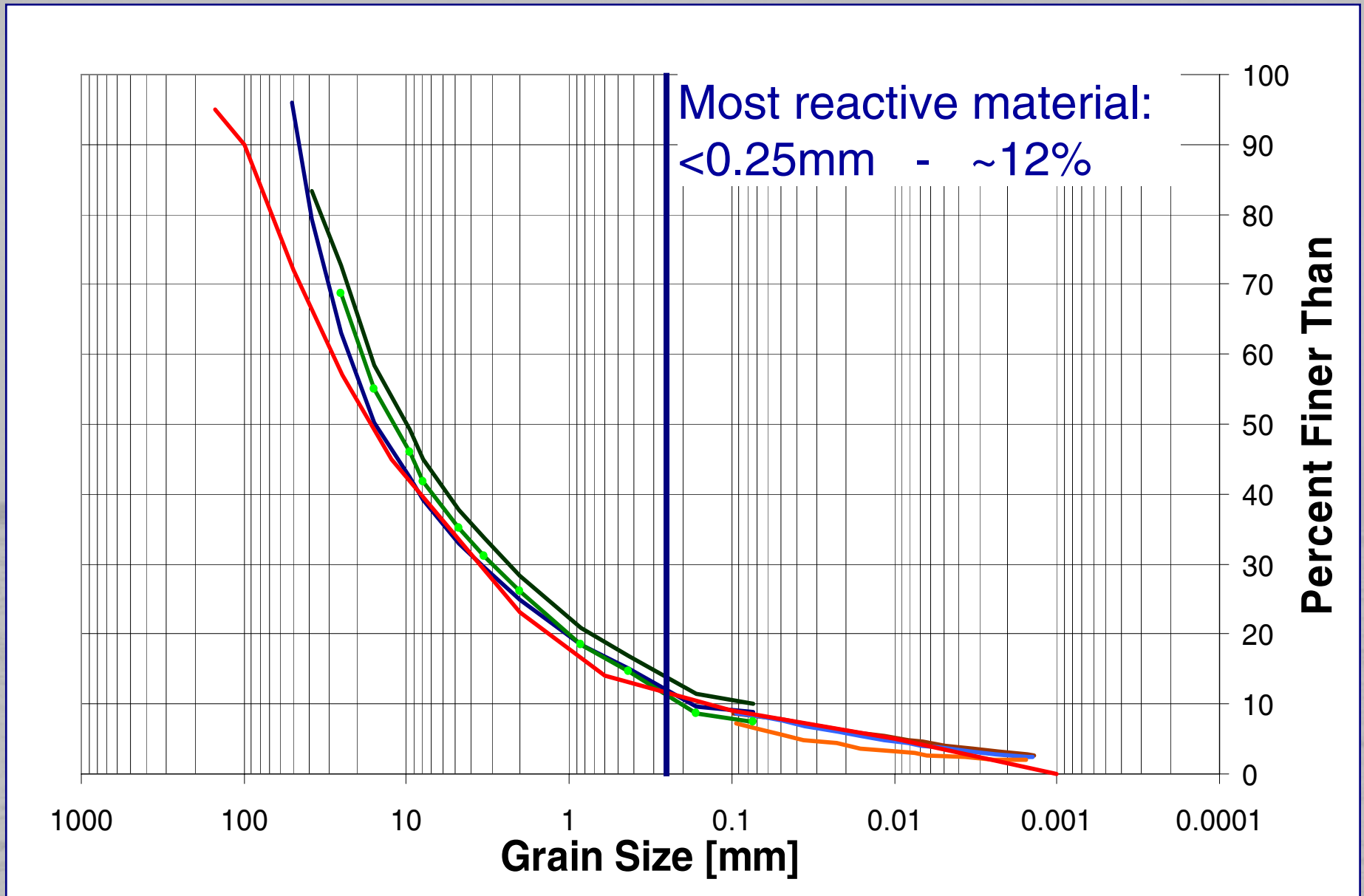
<b>Dominant Rocks</b>	<b>Peter River Gneiss Granitic Gneisses (Earl River Complex) Small amounts of Athabasca Sandstone</b>
<b>Dominant Minerals</b>	<b>Quartz, Fe-rich Amphibole</b>
<b>Minor mineral phases</b>	<b>Biotite, Pyrite, Chalcopyrite, Th-rich Monazite, Apatite, Zircon, Rutile</b>
<b>Average S content</b>	<b>0.45 wt %</b>



35 cm

(M.D. Haug, 2001; Hollings et al., 2000)

# Grain Size Distribution





# Waste Rock Samples





# Trace Elements

Whole Rock (M.D. Haug)	As ppm	Co ppm	Cu ppm	Mo ppm	Ni ppm	Pb ppm	U ppm	V ppm	Zn ppm	TOTAL S %
	23	33	39	5	45	9	12	82	8	0.47
	15	41	40	5	42	9	14	87	10	0.76
	18	38	39	5	43	9	13	85	9	0.65
Outflow	<1	17	1	<1	126	<1	85	<1	4	-

(M.D. Haug, 2001)

- Low uranium content
- High sulfur content
- Significant amounts of Co, Cu and Ni
- Outflow samples [mg/l]: relatively high Ni and U



# SWEP Analysis Summary

pH	SO <sub>4</sub> mg/L	As mg/L	Co mg/L	Cu mg/L	Mo mg/L	Ni mg/L	Pb mg/L	U mg/L	V mg/L	Zn mg/L
5.2	54	<0.030	0.025	< 0.002	< 0.005	0.18	< 0.010	<0.050	< 0.010	0.016
4.9	71	< 0.030	0.056	0.002	< 0.005	0.21	< 0.010	0.080	< 0.010	0.006
5.0	63	< 0.030	0.042	0.002	< 0.005	0.20	< 0.010	0.07	< 0.010	0.010

(M.D. Haug, 2001)

- SWEP: Solid Waste Extraction Procedure  
Measures extractability of surface oxidation products
- Nickel and uranium are easily extracted
- Low pH, high sulfate concentration

# Acid Base Accounting Summary

Paste pH	Total S (Wt.%)	SO <sub>4</sub> S (Wt.%)	S S* (Wt.%)	AP** (kg/tonne)	NP (kg/tonne)	NET NP (kg/tonne)	NP/AP Ratio	Fizz Test Rating
5.2	0.44	0.08	0.36	11.1	4.6	-6.5	0.4	none
5.6	0.76	0.10	0.66	20.6	2.8	-17.8	0.1	none
4.7	0.41	0.02	0.39	12.1	4.2	-7.9	0.3	none
4.6	0.33	0.12	0.21	6.5	2.2	-4.3	0.3	none

\*Based on difference between total sulphur and sulphate-sulphur

(M.D. Haug, 2001)

\*\*Based on sulphide-sulphur

- NET NP < 0
  - NP/AP Ratio < 1
  - paste pH < 7
- High potential for acid generation



# Leaching Efficiencies (%)

- Leach Column Tests Summary

Analyte Week	As	Co	Cu	Mo	Ni	Pb	SO <sub>4</sub>	U	Zn
1	0.11	3.25	0.19	0.01	9.52	0.00	5.95	25.2	1.17
10	0.33	9.39	1.05	0.06	27.0	0.00	18.5	72.3	5.06
20	0.38	11.5	1.82	0.07	31.8	0.00	24.3	77.0	7.44
30	0.38	12.5	2.30	0.07	34.3	0.00	27.3	78.6	8.44

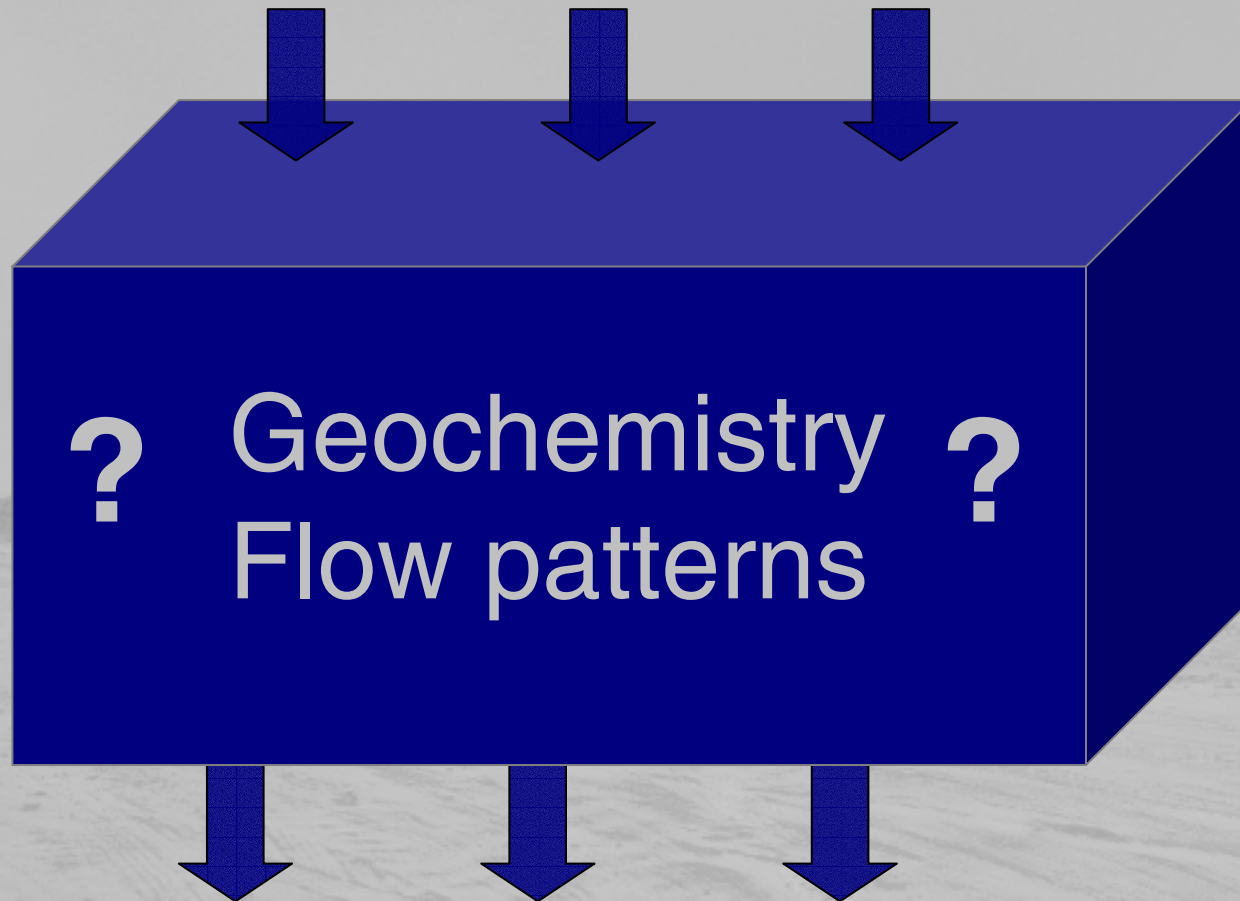
(M.D. Haug, 2001)

- Humidity Cell Tests Summary

Analyte Week	As	Co	Cu	Mo	Ni	Pb	SO <sub>4</sub>	U	Zn
1	0.36	1.45	0.10	0.00	4.75	0.00	2.85	11.1	1.18
10	0.81	5.78	0.55	0.00	20.0	0.00	11.1	50.4	4.05
20	0.81	6.75	0.79	0.00	23.1	0.00	12.7	57.3	4.89
30	0.81	7.33	1.04	0.00	24.7	0.00	13.6	61.3	5.51

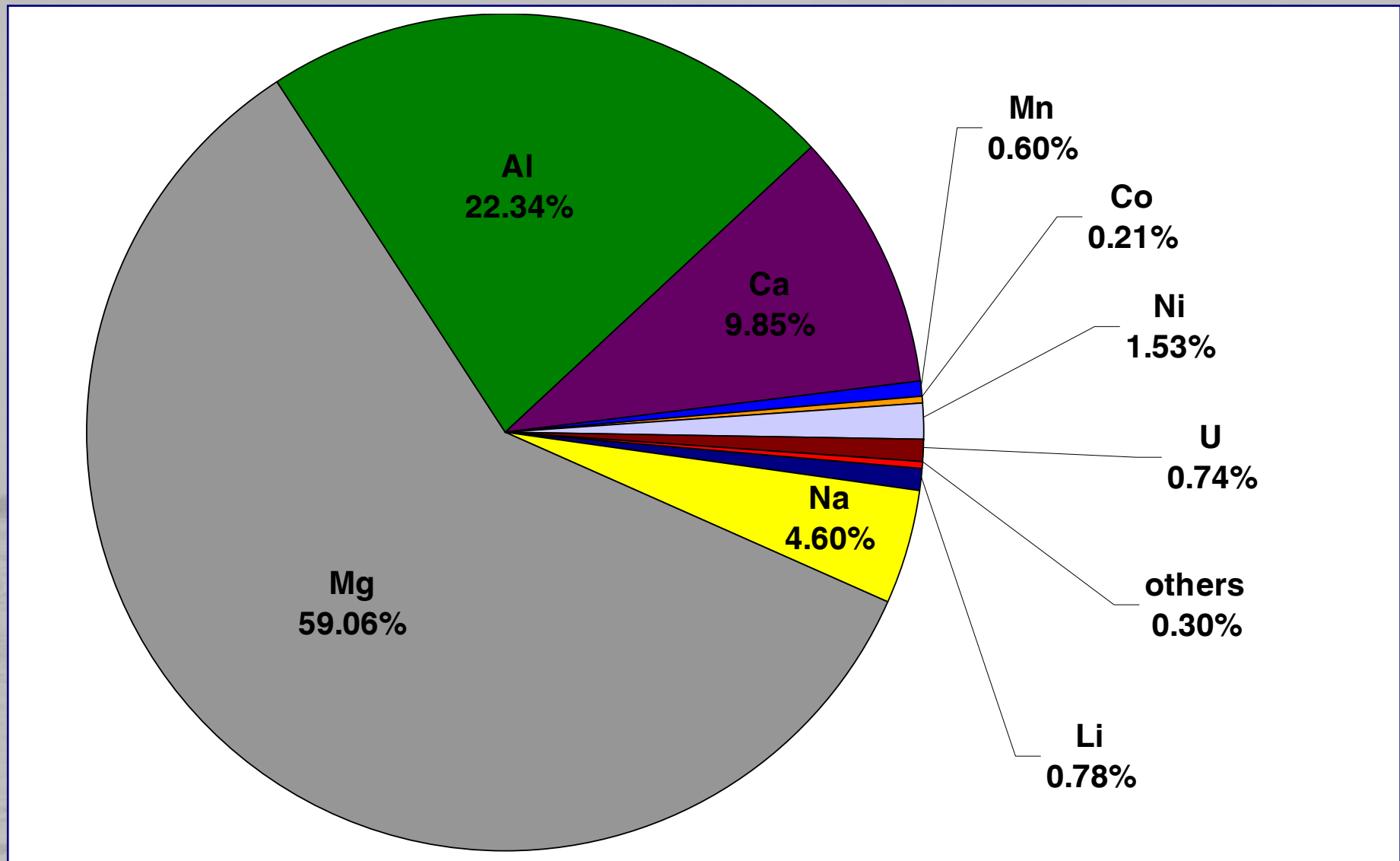
(M.D. Haug, 2001)

# Problem Statement

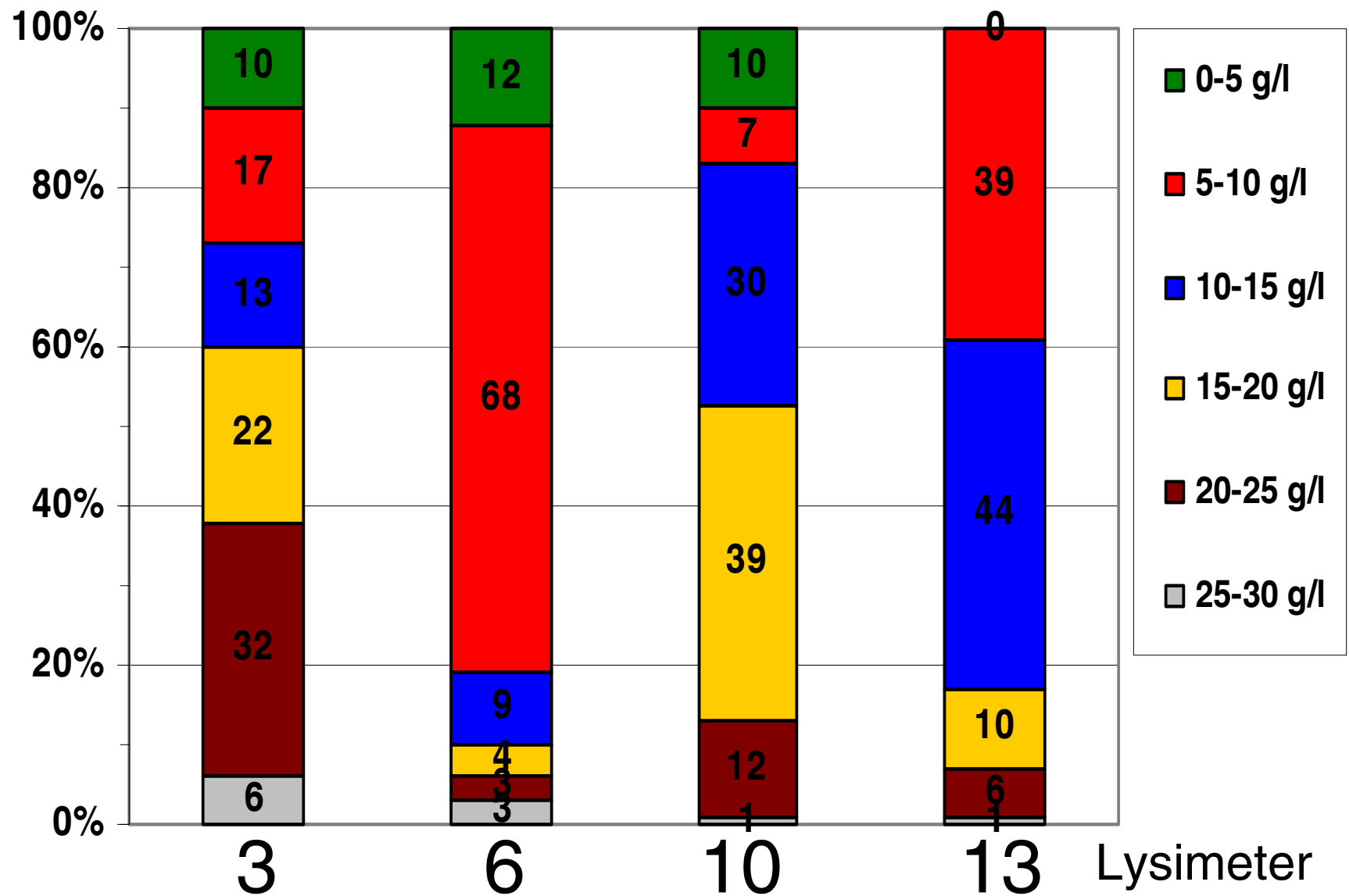




# Average Distribution of Major Cations



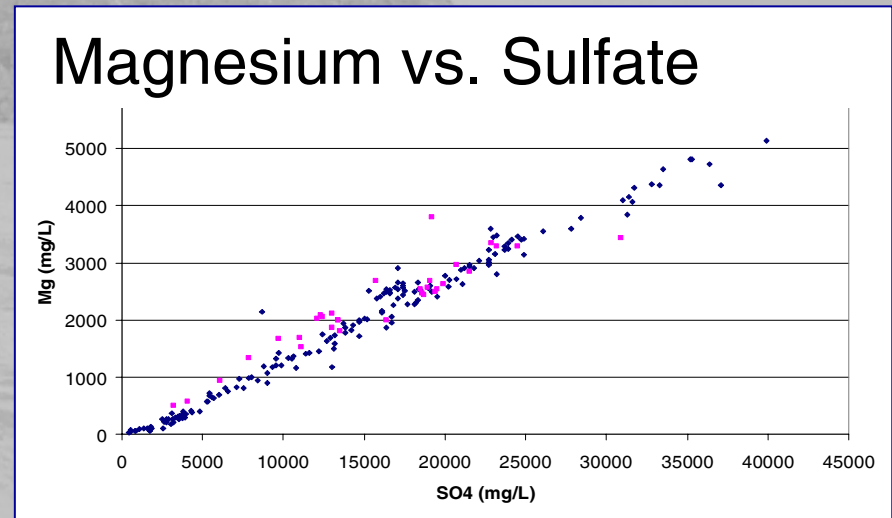
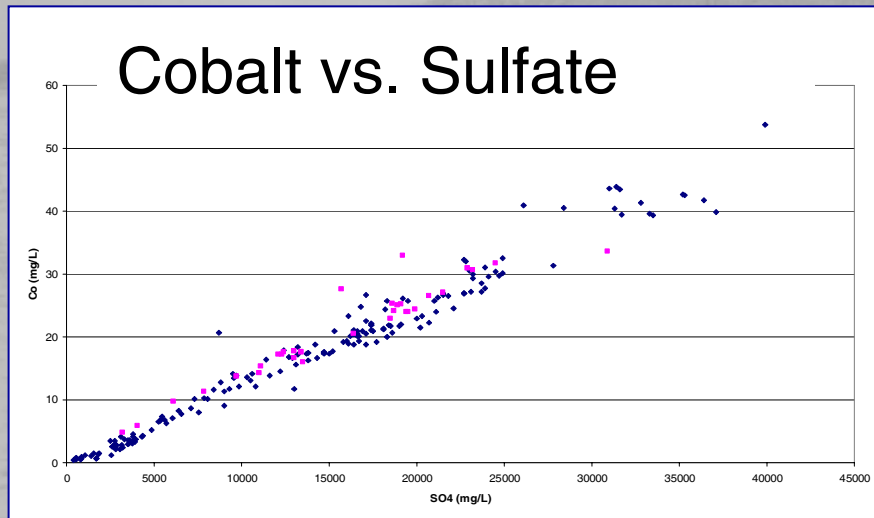
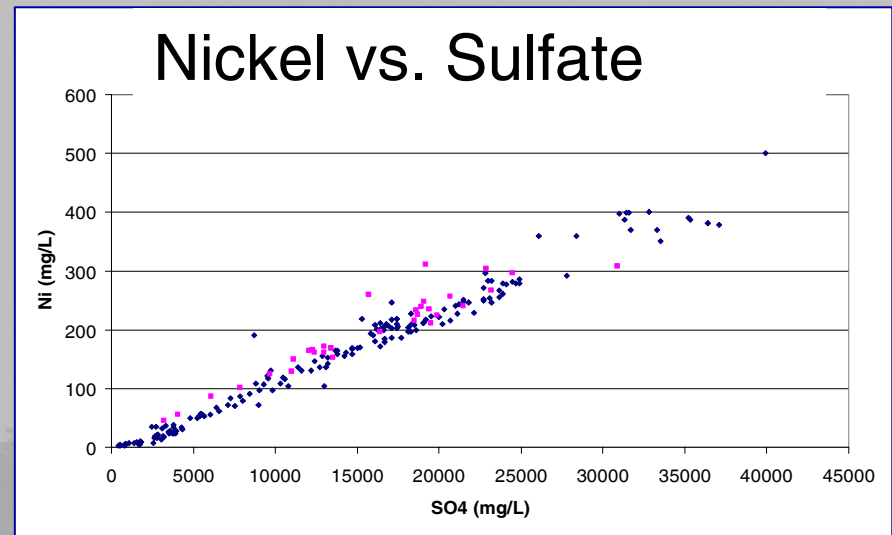
# Variations in Sulfate Concentrations



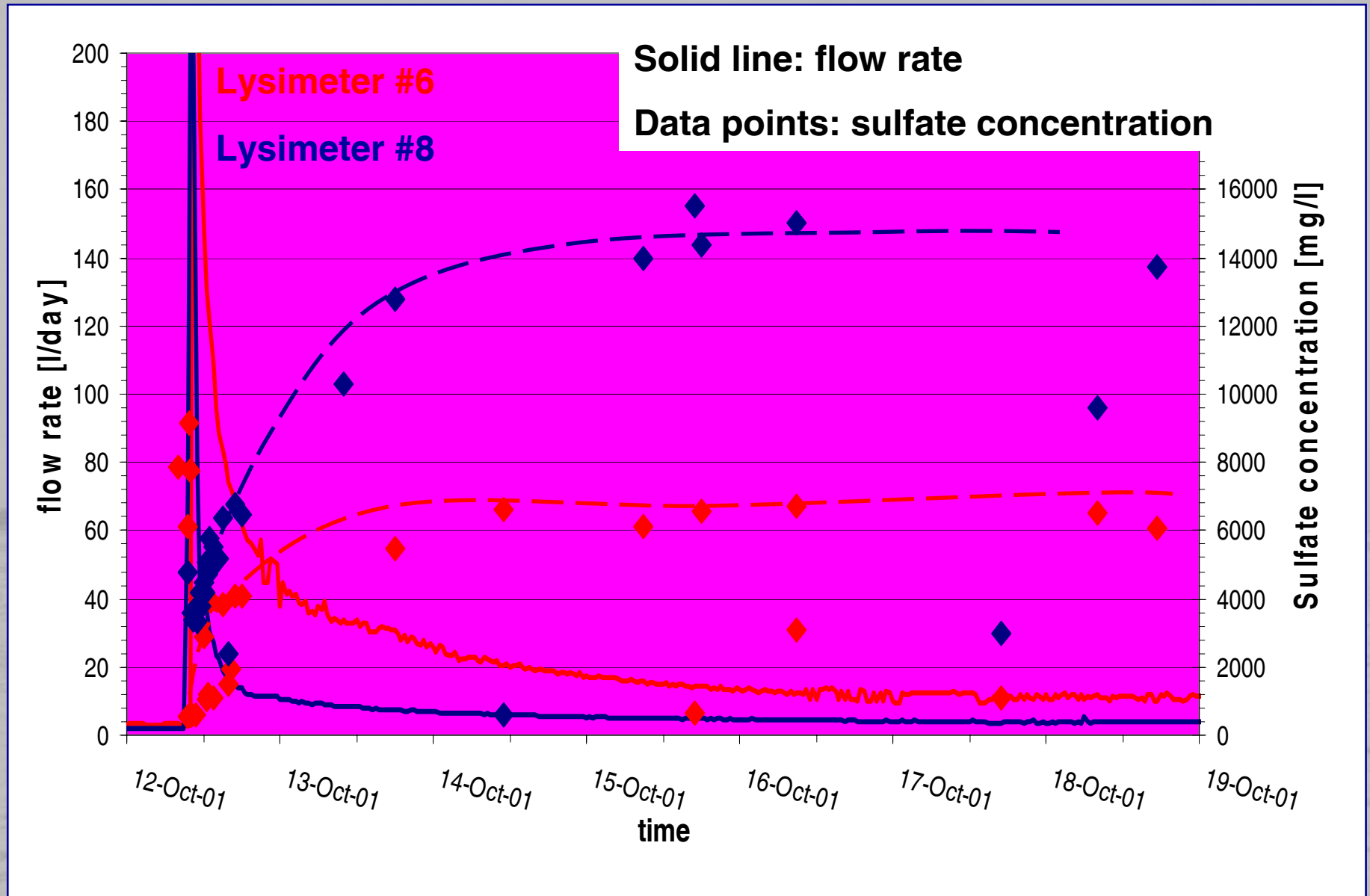


# Outflow Chemistry

- Good correlation between sulfate and many cations: Ni, Co, Mg, Al, Mn, Zn, etc.

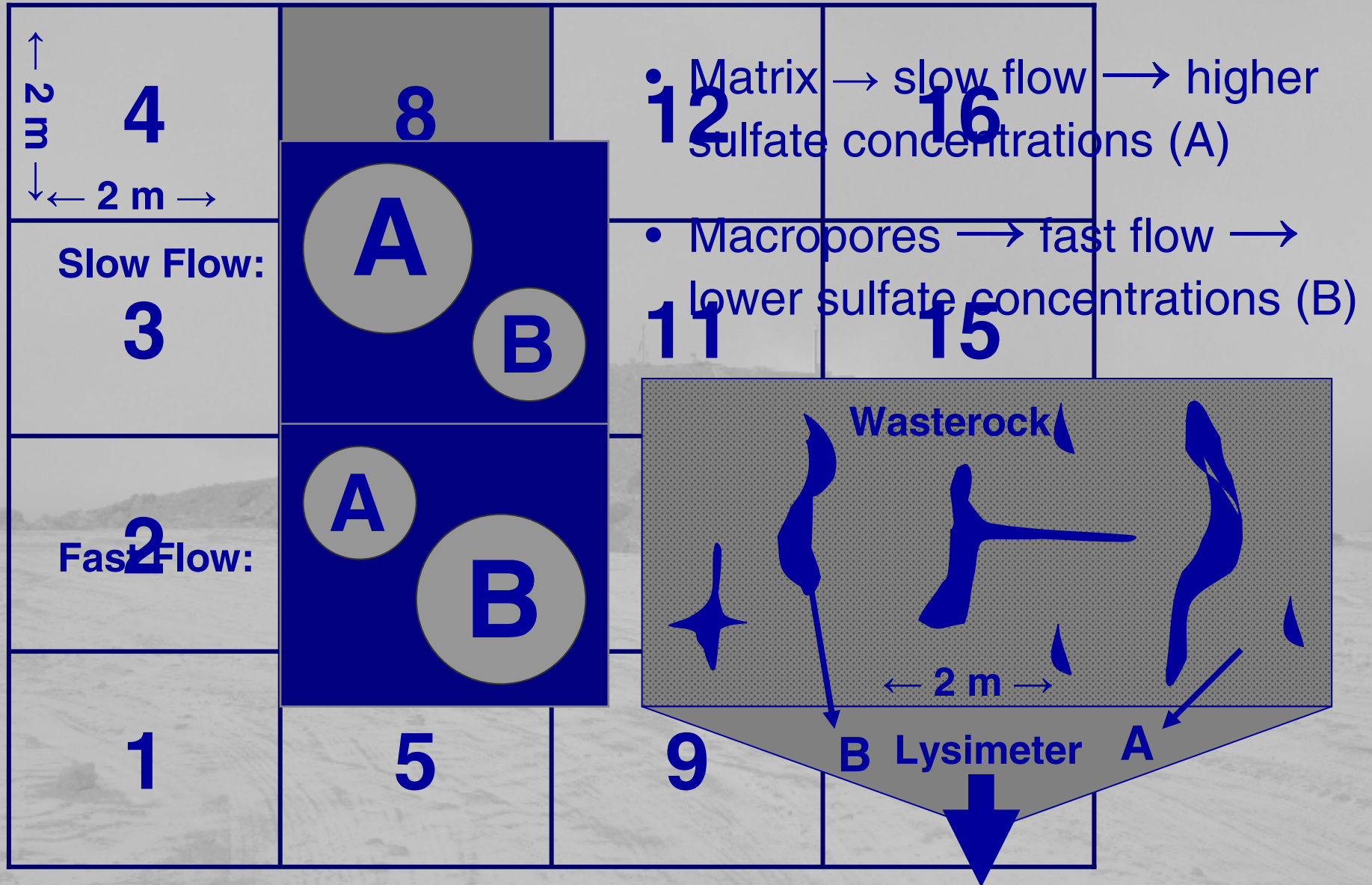


# Waste Rock Outflow: Quantity and Quality

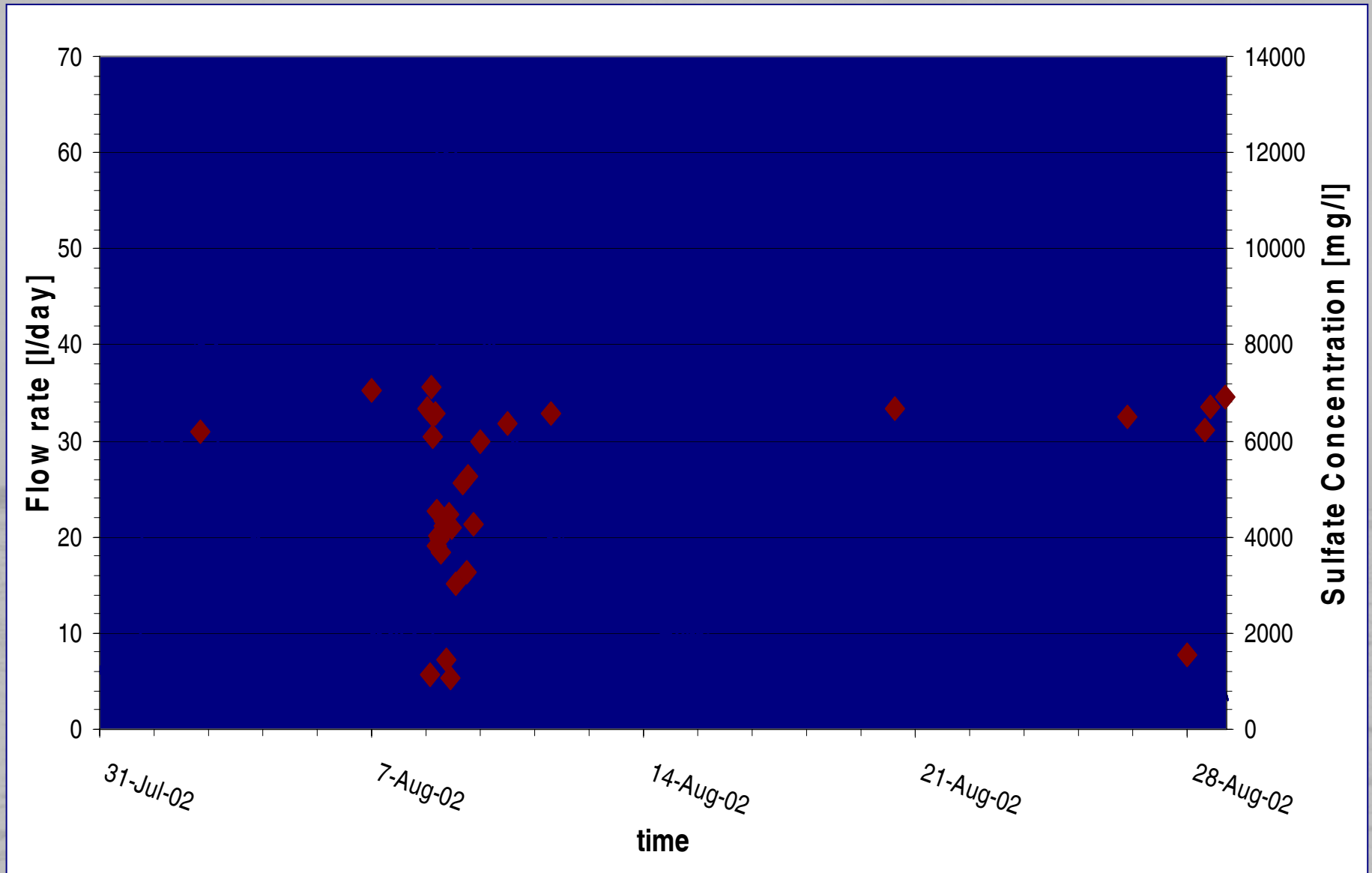




# Waste Rock Outflow: Quantity and Quality



# Waste Rock Outflow: Quantity and Quality





# Loading Calculation

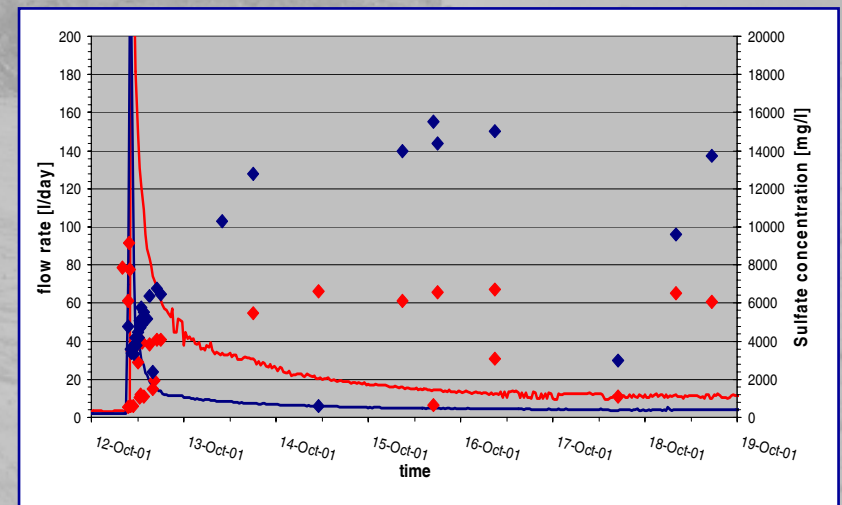
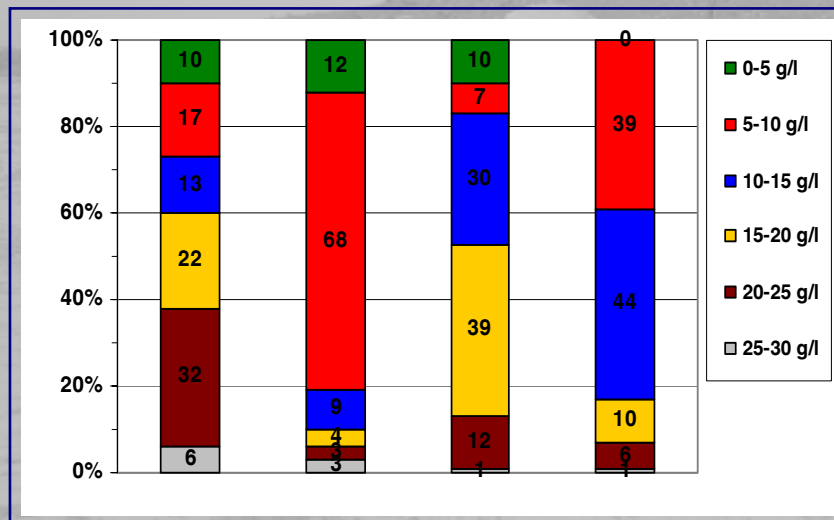
Density of waste rock	[kg/m <sup>3</sup> ]	2000
Volume of waste rock	[m <sup>3</sup> ]	320
S content	[wt%]	0.45
Total initial S weight	[kg]	2880
Removed mass of S	[kg]	30.5
S removed (12 months)	[%]	~1
Sulfate release	[mg SO <sub>4</sub> /(kg*week)]	2.7
Sulfate release (Hollings et al. 2000)	[mg SO <sub>4</sub> /(kg*week)]	3.1-91

# Conclusions

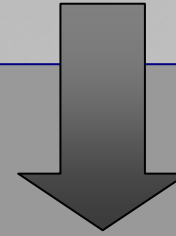
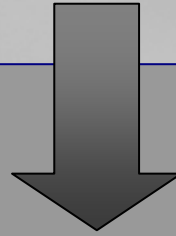
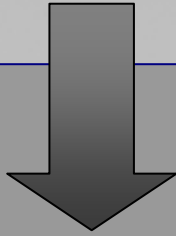
High variability of sulfate concentrations in outflow

space

time



# Infiltration Rate



Waste rock structure

Grain Size Distribution



Flow paths

12% < 0.25mm  
Reactive Material



Flow Rates



Sulfate Concentration



Metals (U, Ni, Co, Cu, ...)



# Acknowledgments



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& Cluff and Key Lake staff