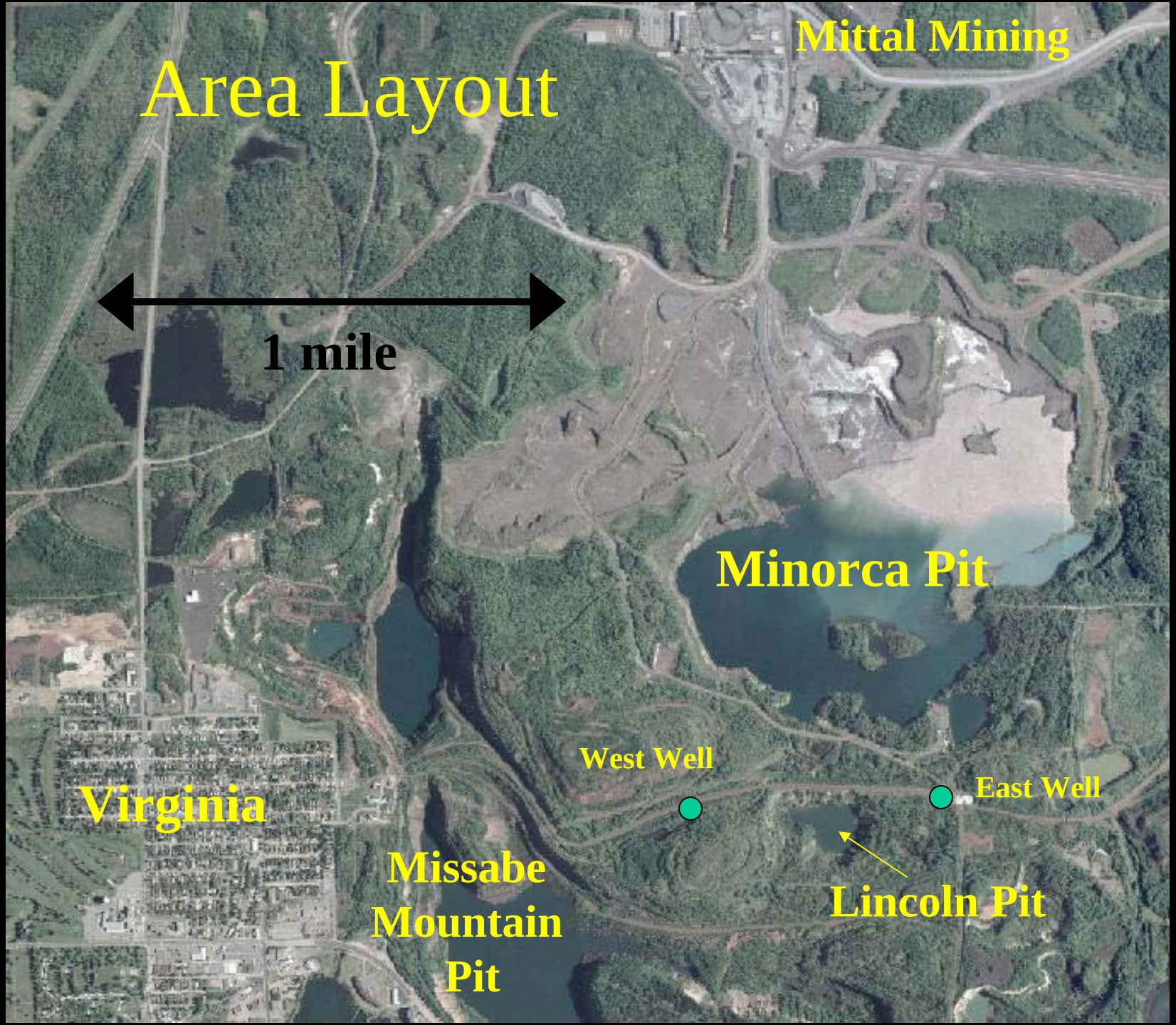
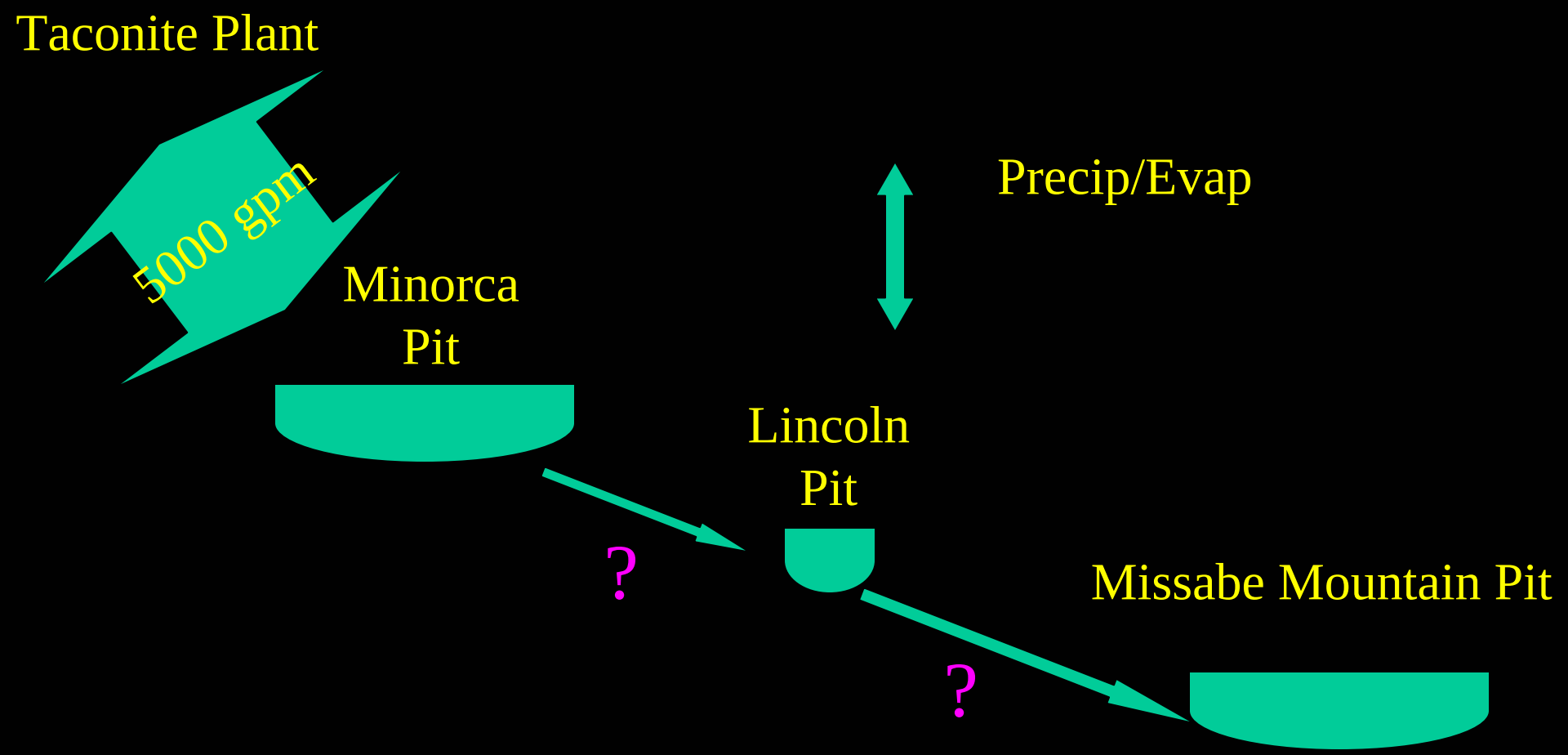
Use of Halides to Constrain Hydrology of an Open-Pit Tailings Disposal Site in NE Minnesota

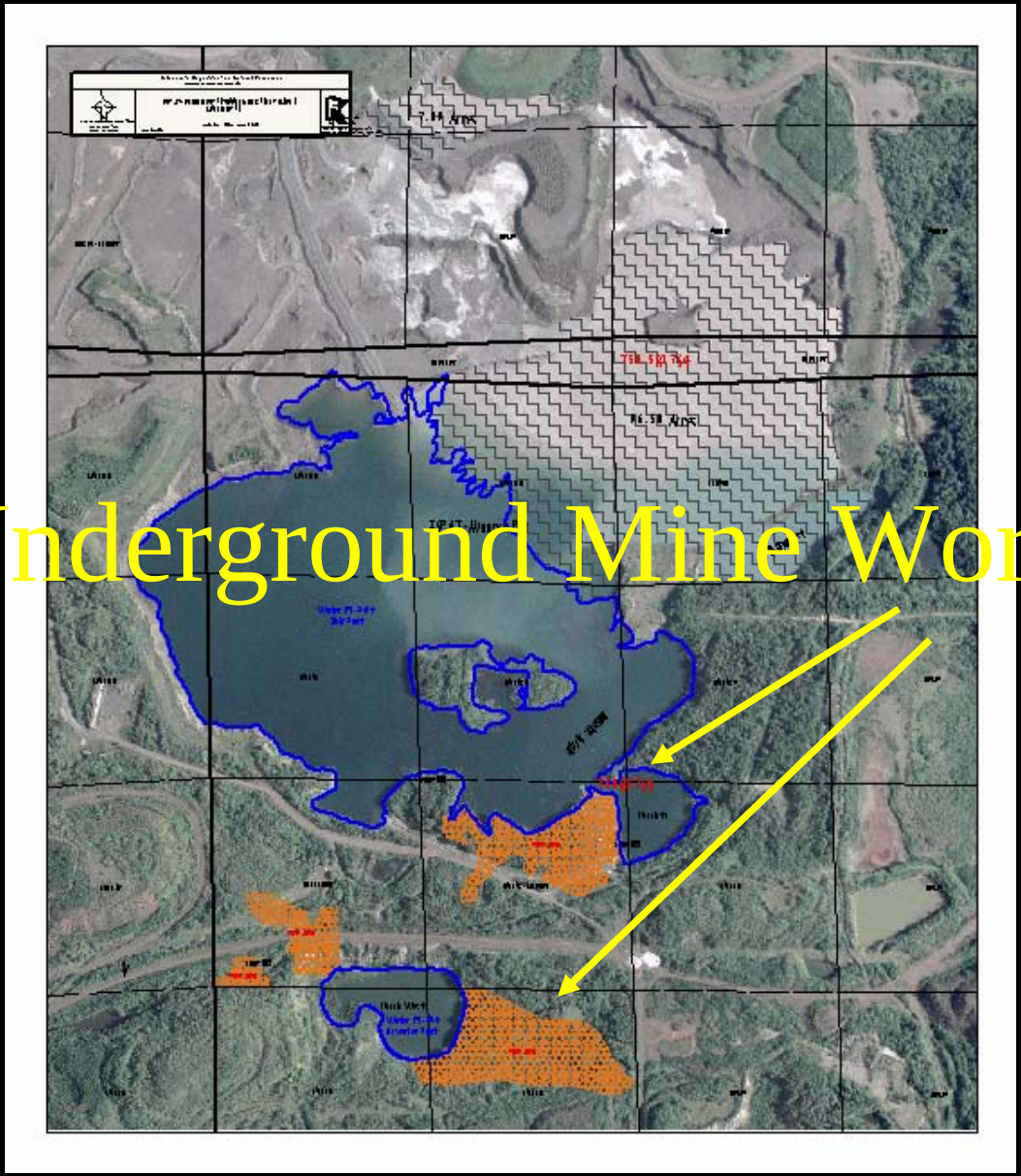
Michael E. Berndt and Robert Leibfried
Minnesota Department of Natural Resources
Division of Lands and Minerals
St. Paul, MN 55155


Area Layout
Mittal Mining
1 mile
Minorca Pit
West Well
East Well
Virginia
Missabe
Mountain
Pit
Lincoln Pit

Hydrologic Questions:



“Pipe flow” or reactive transport?

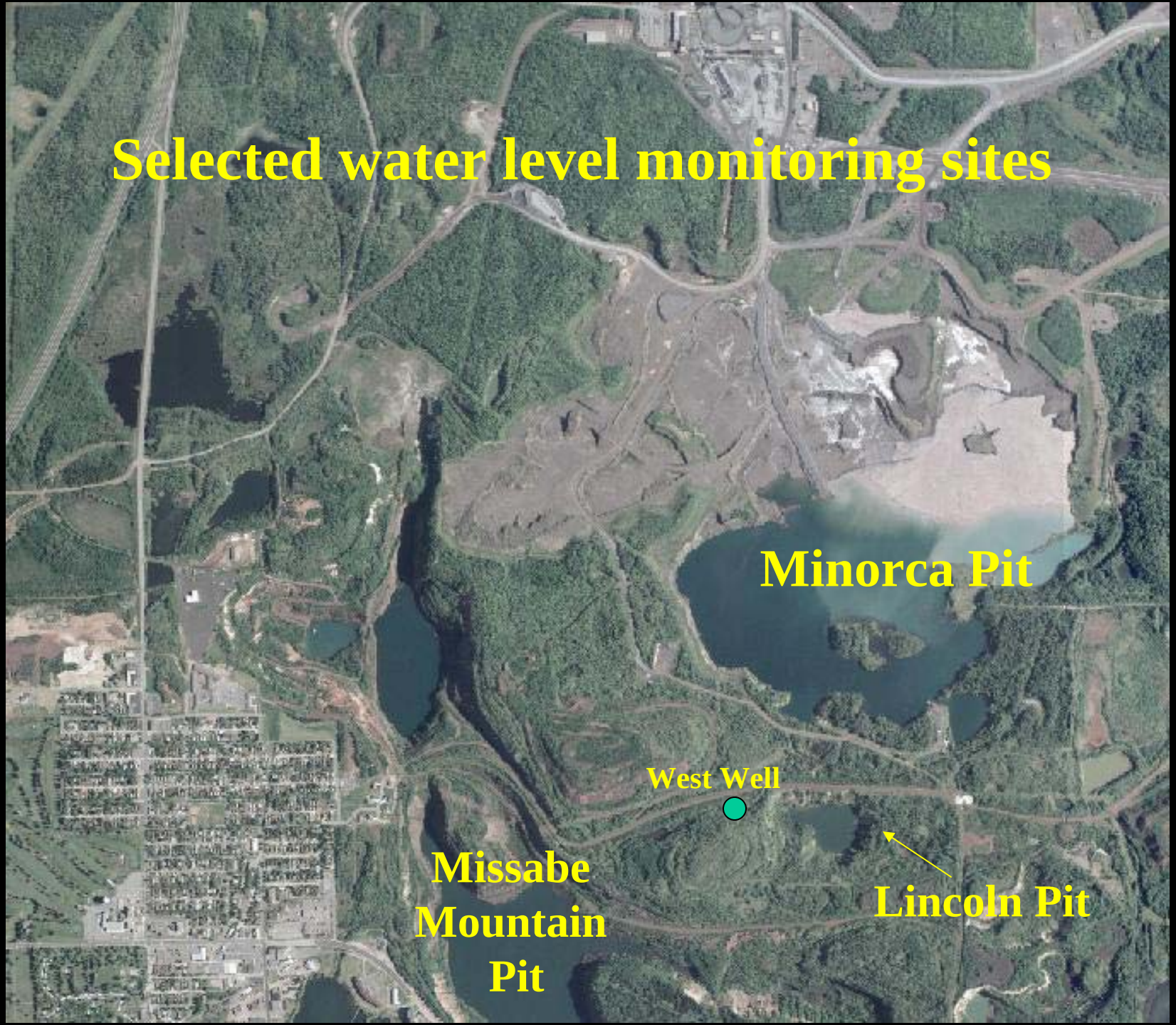


Approach:

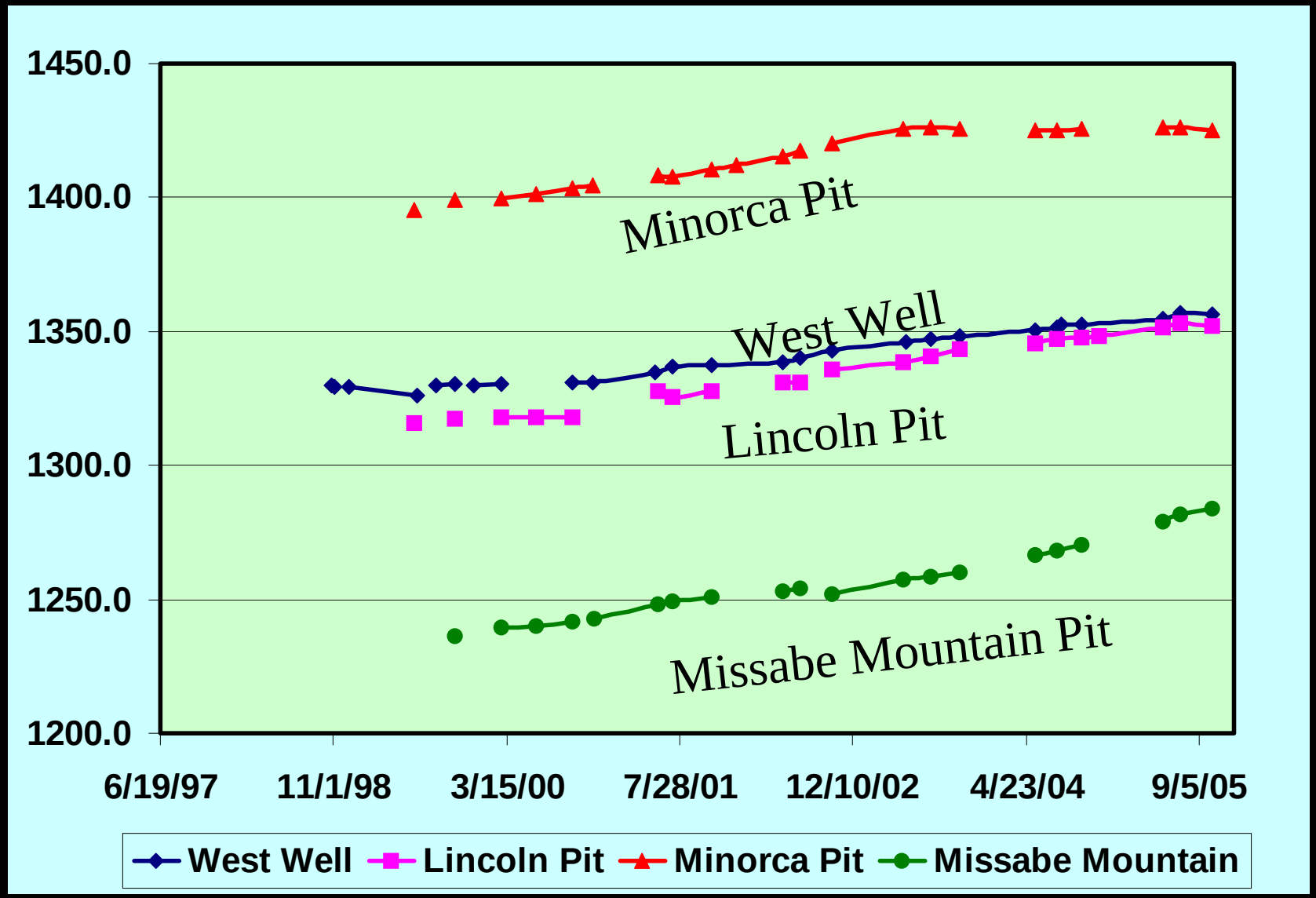
Systematically monitor halides (Br, Cl).

Goals:

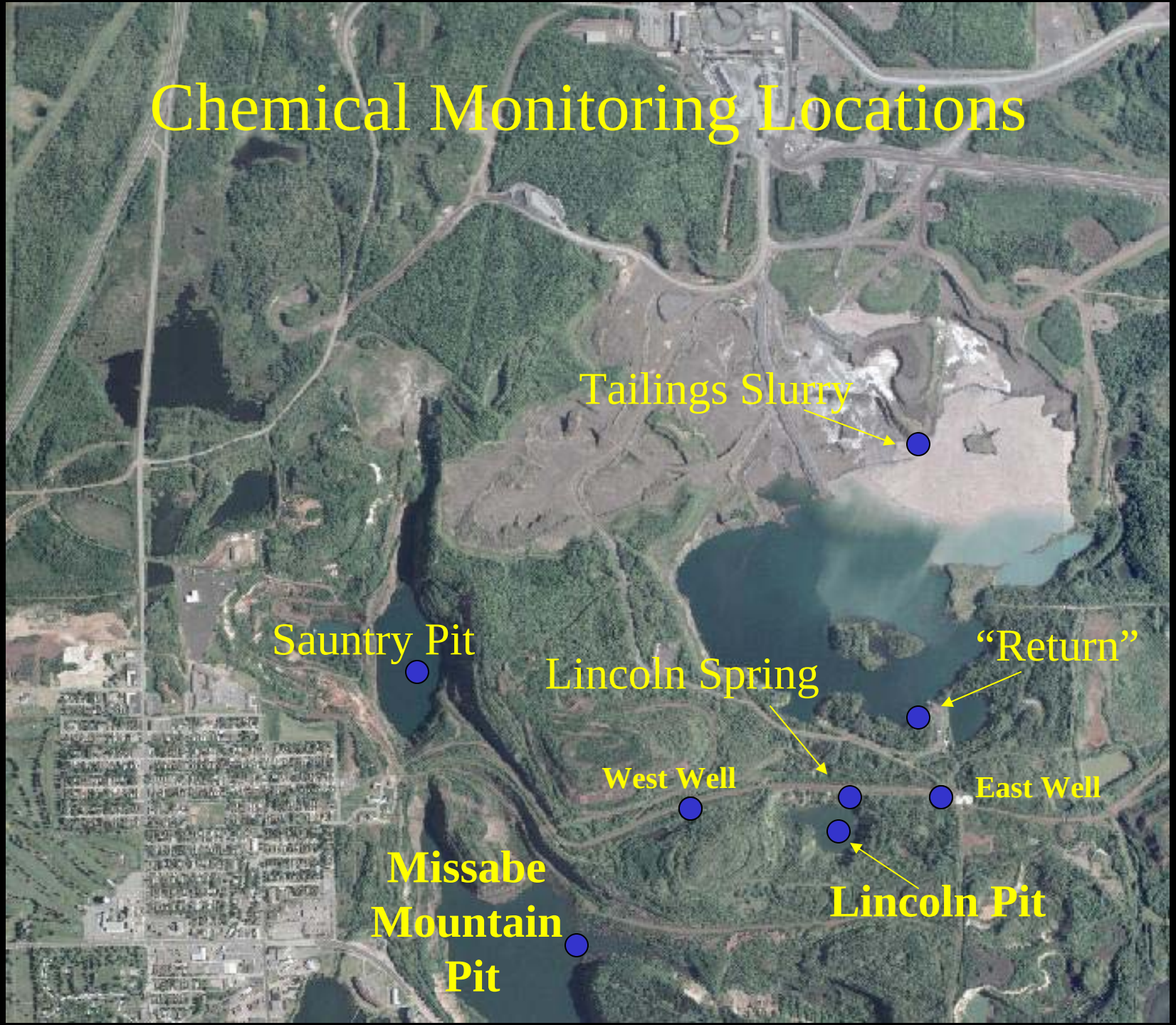
Find primary flow paths.
Evaluate chemical changes relative to Br and Cl.
Constrain water balance using Br and Cl mixing calculations.


Selected water level monitoring sites
Minorca Pit
West Well
Missabe
Mountain
Pit
Lincoln Pit

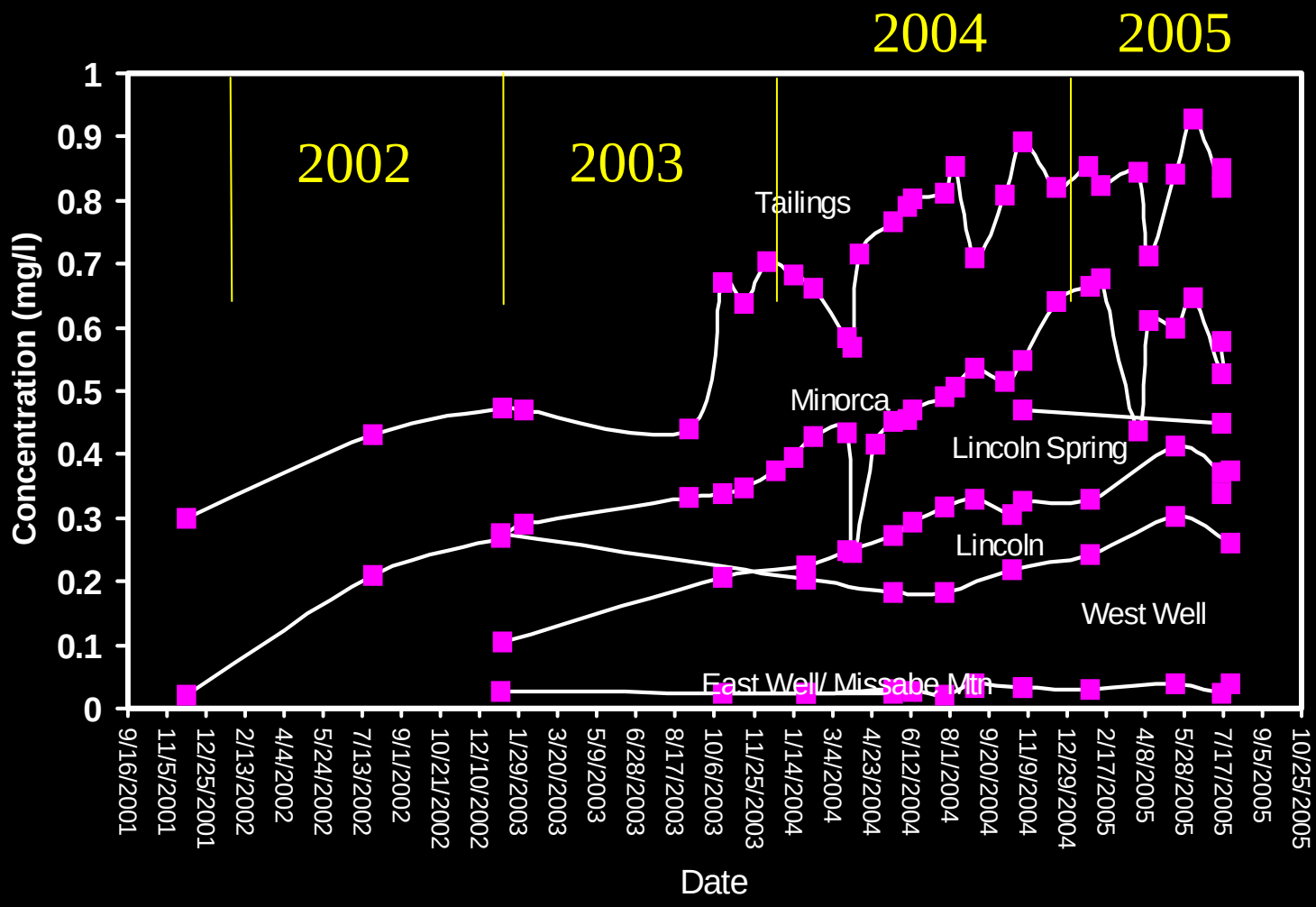
Water Levels



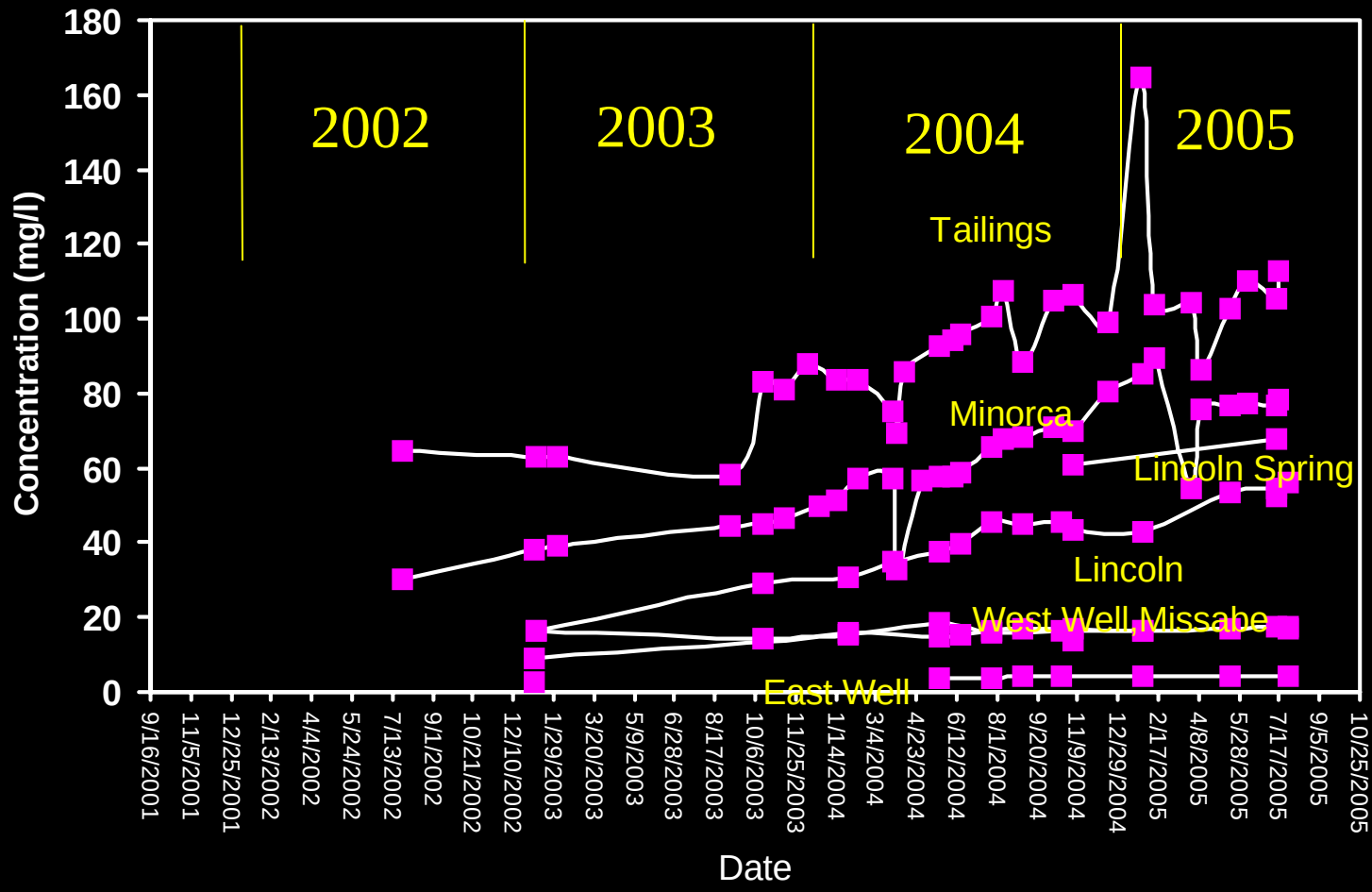
Primary water flow paths?


Chemical Monitoring Locations
Tailings Slurry
Sauntry Pit
Lincoln Spring
"Return"
West Well
East Well
Missabe Mountain Pit
Lincoln Pit

Bromide vs t for: Minorca Pit area



Chloride vs t for samples sites in the Minorca Pit area

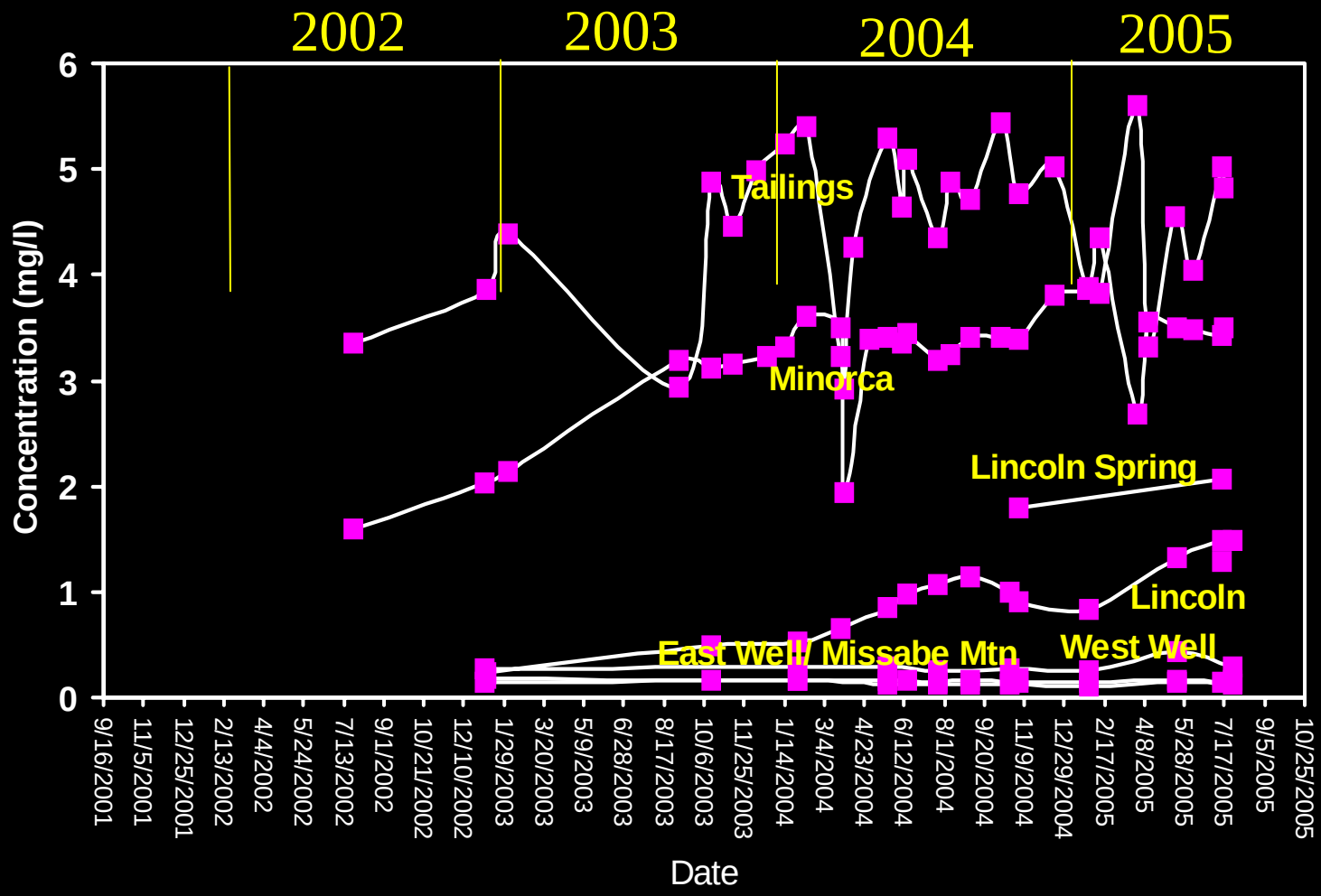


Chemical “Attenuation”?

Chemical Change Table/ Minorca Pit to Lincoln Pit

	Minorca Return	Lincoln spring	Lincoln surface	Lincoln 30 ft	Comment
Date	6/16/2004	11/3/2004	11/3/2004	11/3/2004	
pH	8.2	7.6	7.5	7.5	PCO2 increase
Br (ppm)	0.47	0.47	0.33	0.33	<4.5 month res. time
Cl (ppm)	59	61	43	43	<4.5 month res. time
F (ppm)	3.4	1.8	0.90	0.91	Fluorite, Ads. FeOx
SO4 (ppm)	66	65	56	56	
Na (ppm)	42	42	30	31	
Mg (ppm)	61	49	43	44	
Si (ppm)	8.3	7.9	6.4	6.5	
K (ppm)	6.5	5.1	5.2	5.1	
Ca (ppm)	37	58	64	65	
Li (ppb)	17.2	10.6	8.9	9	Ads. Clays
B (ppb)	80	56	33	38	Ads. Clays
P (ppb)	0.9	2.1	0.2	0	
Fe (ppb)	1.4	33	28	28	
Mn (ppb)	45	0.16	450	440	Fall Overturn in Lincoln
As (ppb)	2.7	0.43	0.38	0.42	
Rb (ppb)	5.88	1.03	1.24	1.24	Ads. Clays
Sr (ppb)	158	155	169	169	
Mo (ppb)	95	8.7	3.1	3.3	FeOx adsorption

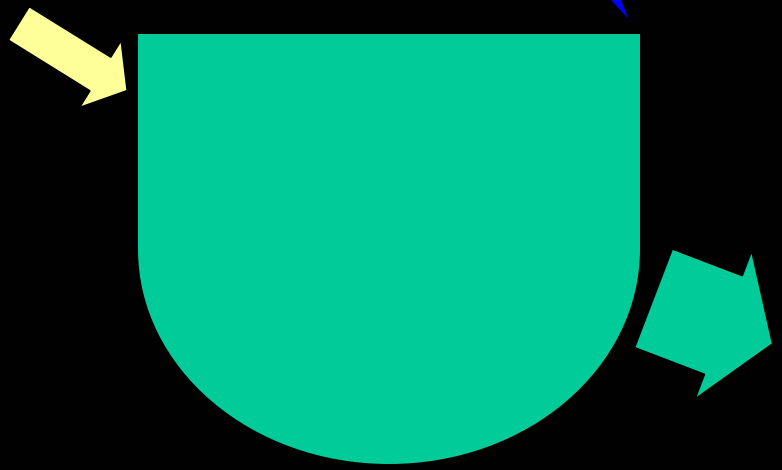
Fluoride vs t for samples sites in the Minorca Pit area



Lincoln Pit Water Balance

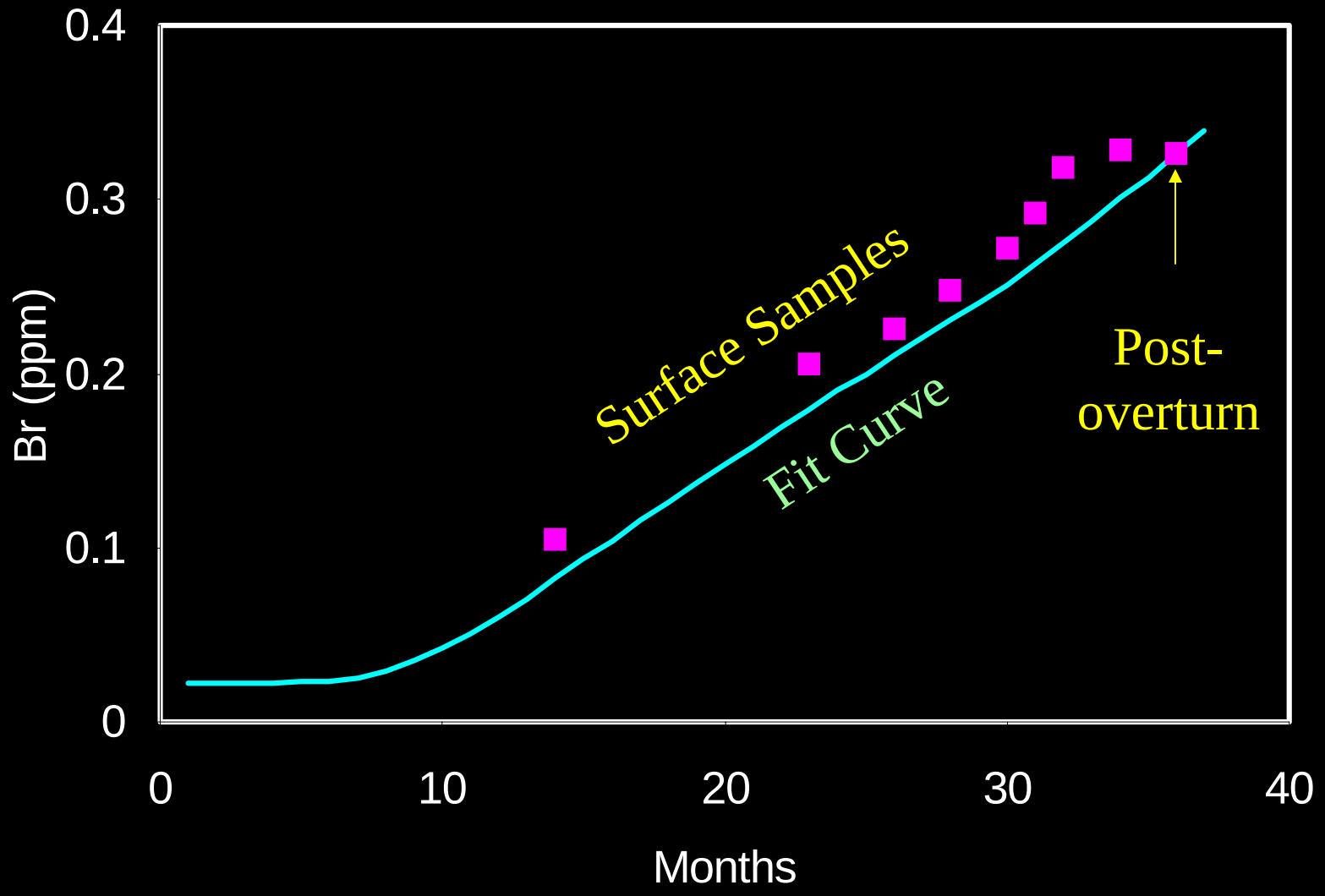
Precip. known
Br = 0

Flow rate from Minorca unknown
Br = delayed Minorca Br



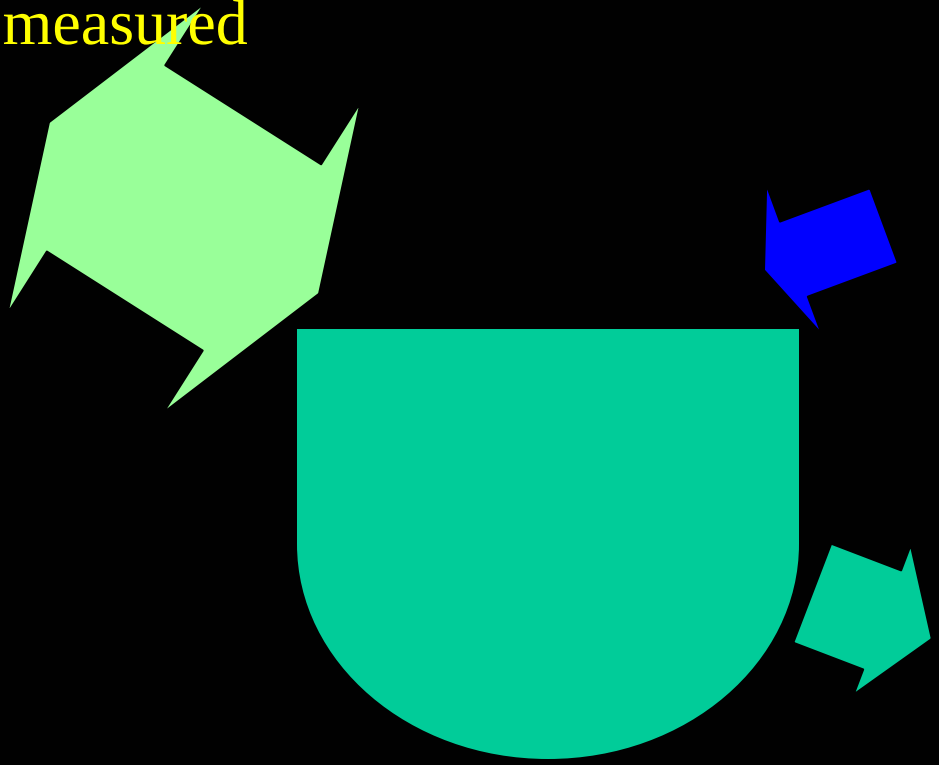
Flow rate to Missabe Mtn unknown
Br = Lincoln Pit value

Lincoln Pit Br fit: (150 gpm flowing from Minorca to the Lincoln pit, 120 gpm from Lincoln Pit and towards Missabe Mountain)



Minorca Pit Water Balance

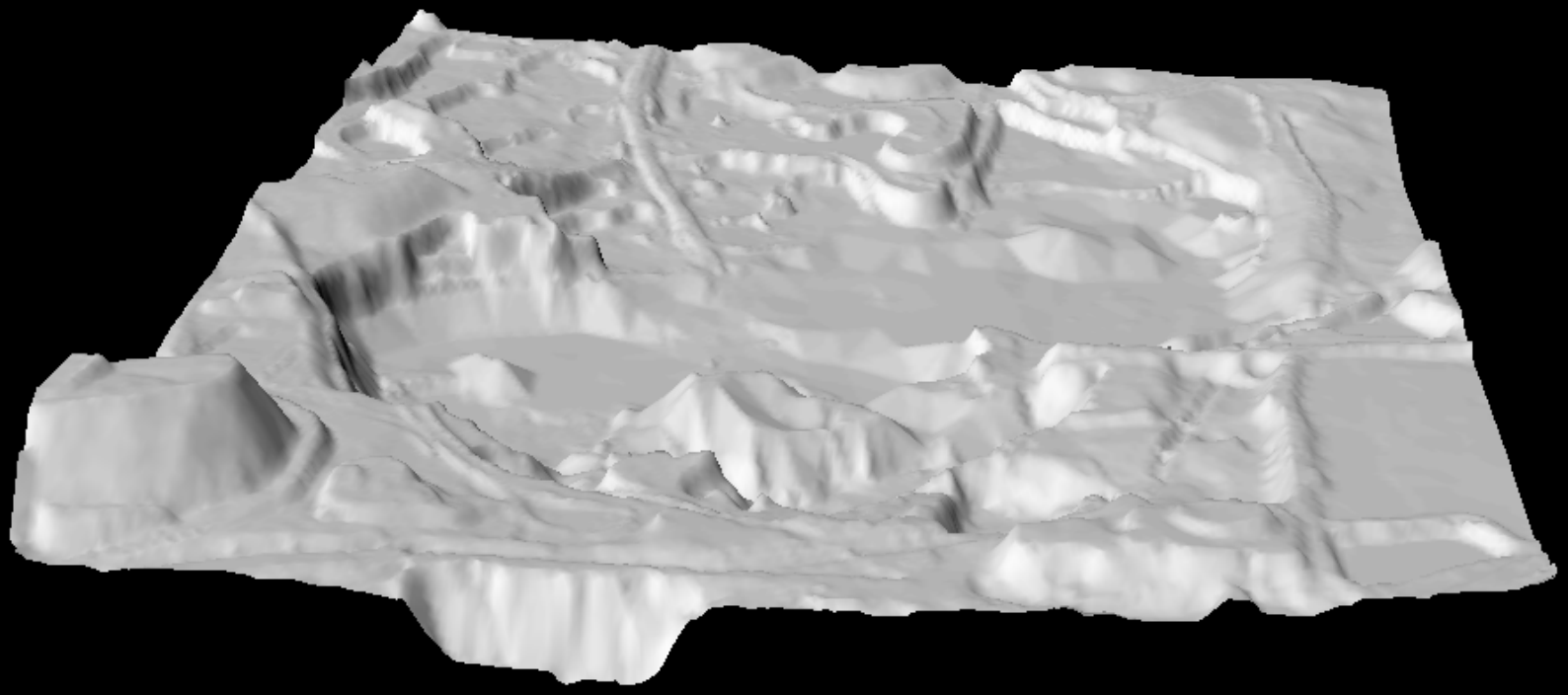
Pumping records too imprecise
Br = in, out measured



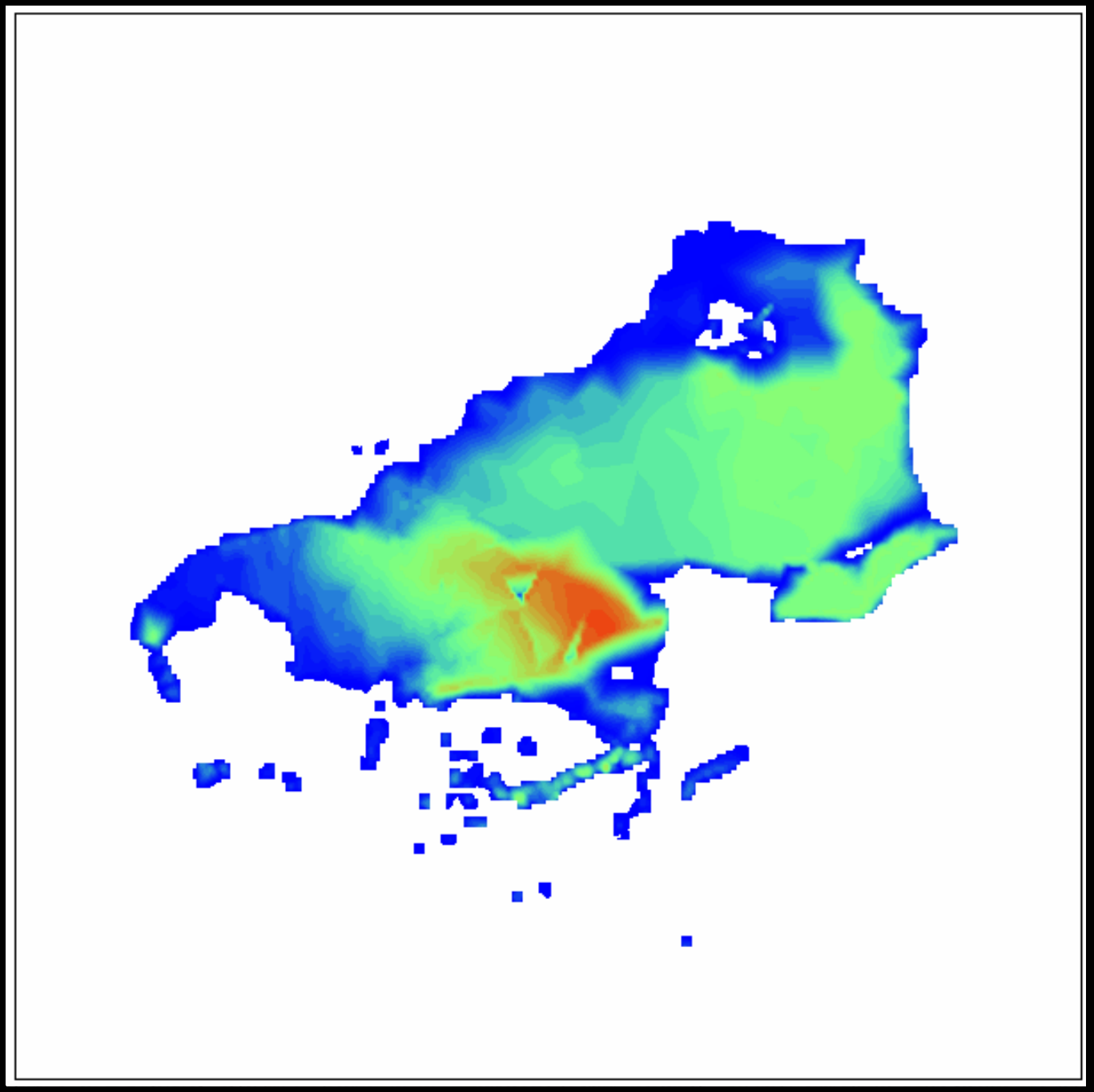
Precipitation
Br=0

Groundwater flow rate out - not known
Br = Minorca Value

3D-digital image of Minorca Pit used for pit volume calculations

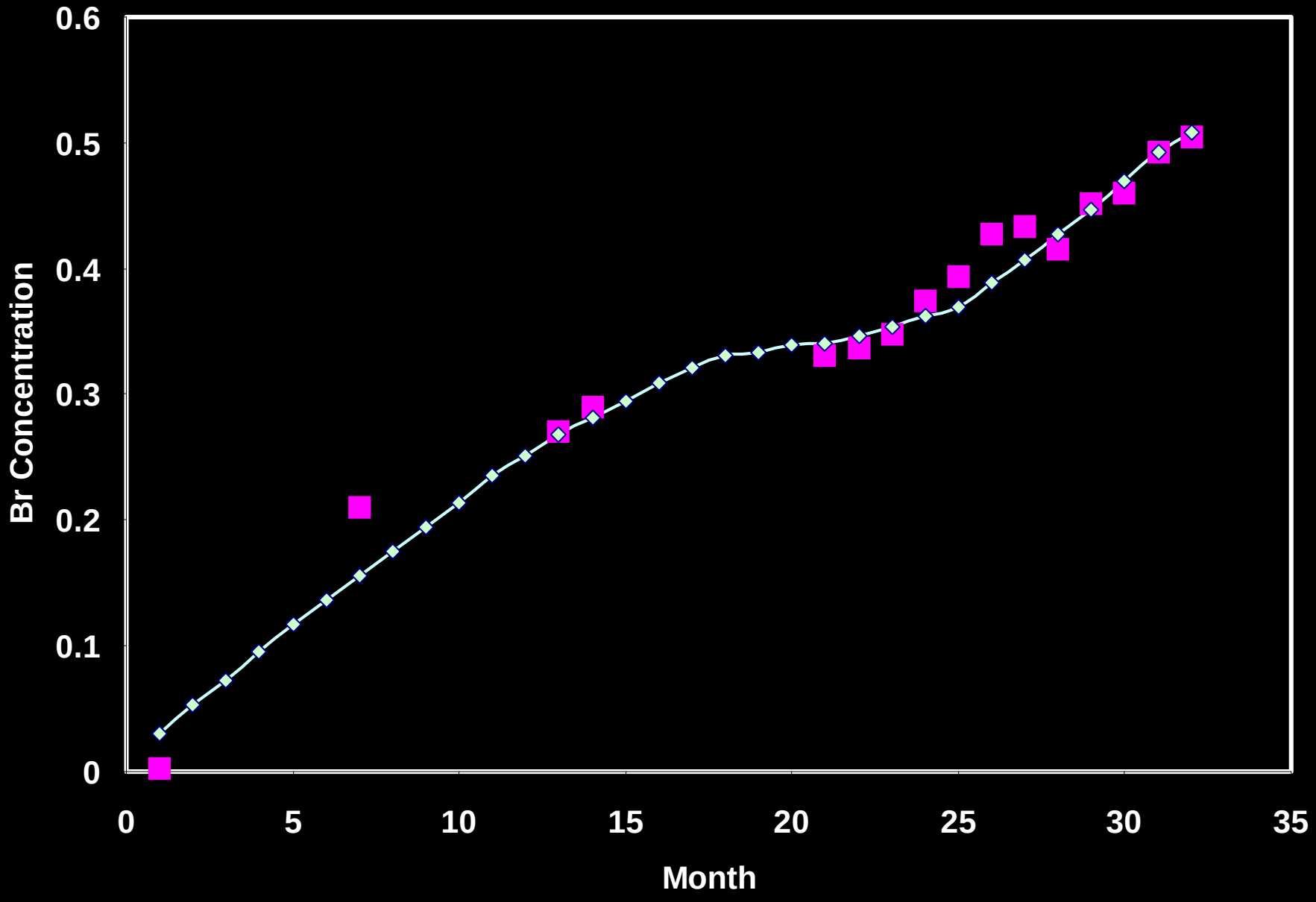


(similar data set also derived for the Lincoln pit)



Tailings Isopach Map (Minorca Pit June ’04)

Minorca Br fit. 150 gpm flowing out via groundwater



Halide monitoring applications for in-pit disposal operations

-flow path detection is straight forward.

-chemical attenuation and dilution demonstrated; not a pipe-flow situation

-water balance application is complicated (stratification, changing pit volumes, etc….); requires meticulous record keeping and assumptions.

(Specific: estimate about 120 gpm of water similar to Lincoln Pit Water, but even further attenuated, is entering Missabe Mountain Pit. Not detectable with halides so far)

Acknowledgements:

Iron Ore Cooperative Research
Mittal Steel
Environmental Cooperative Research

Dan Steinbrink, John Adams, John Folman (Mn DNR)

Scott Alexander and Rick Knurr, U of MN Geol. Dept.