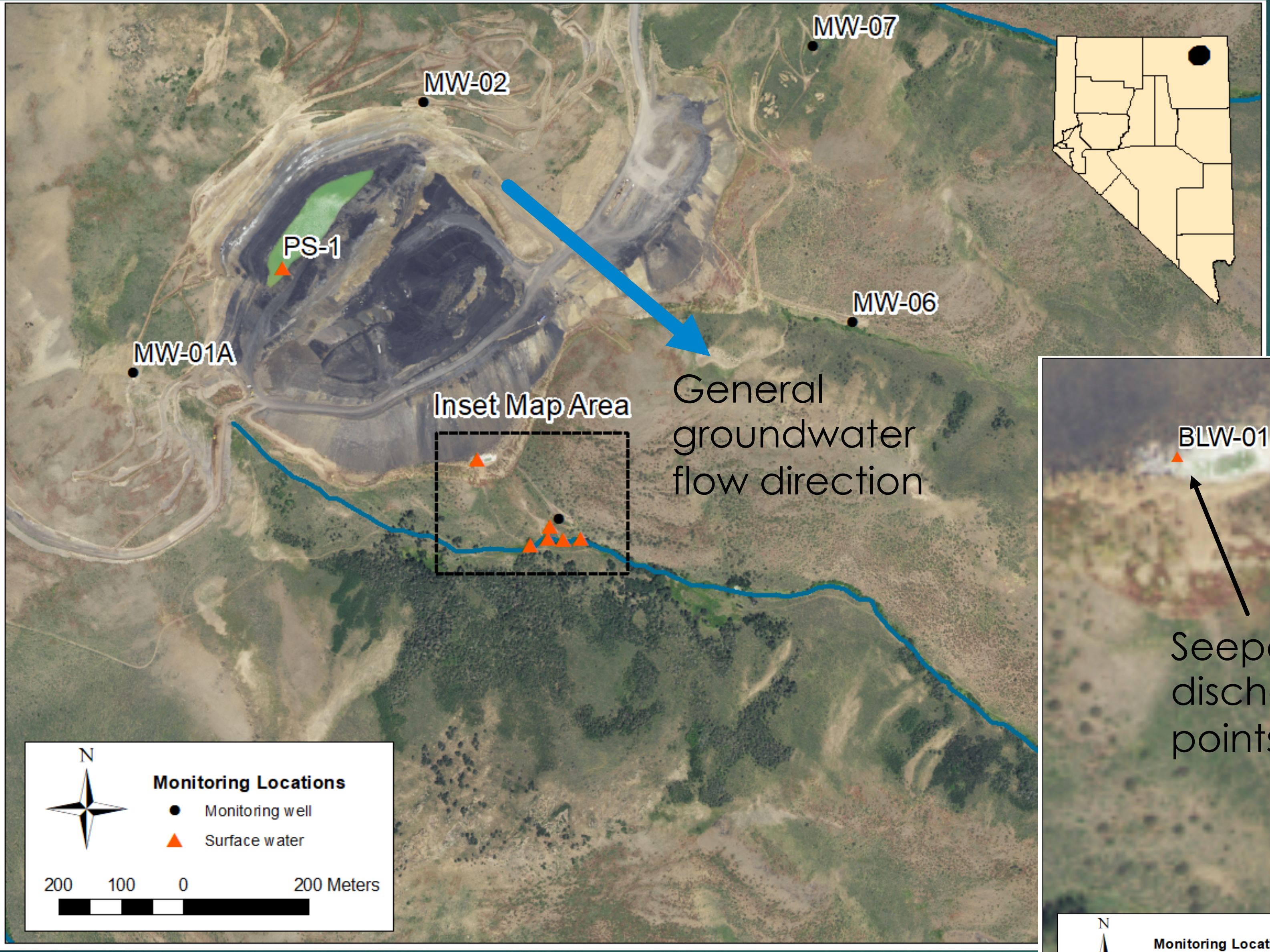
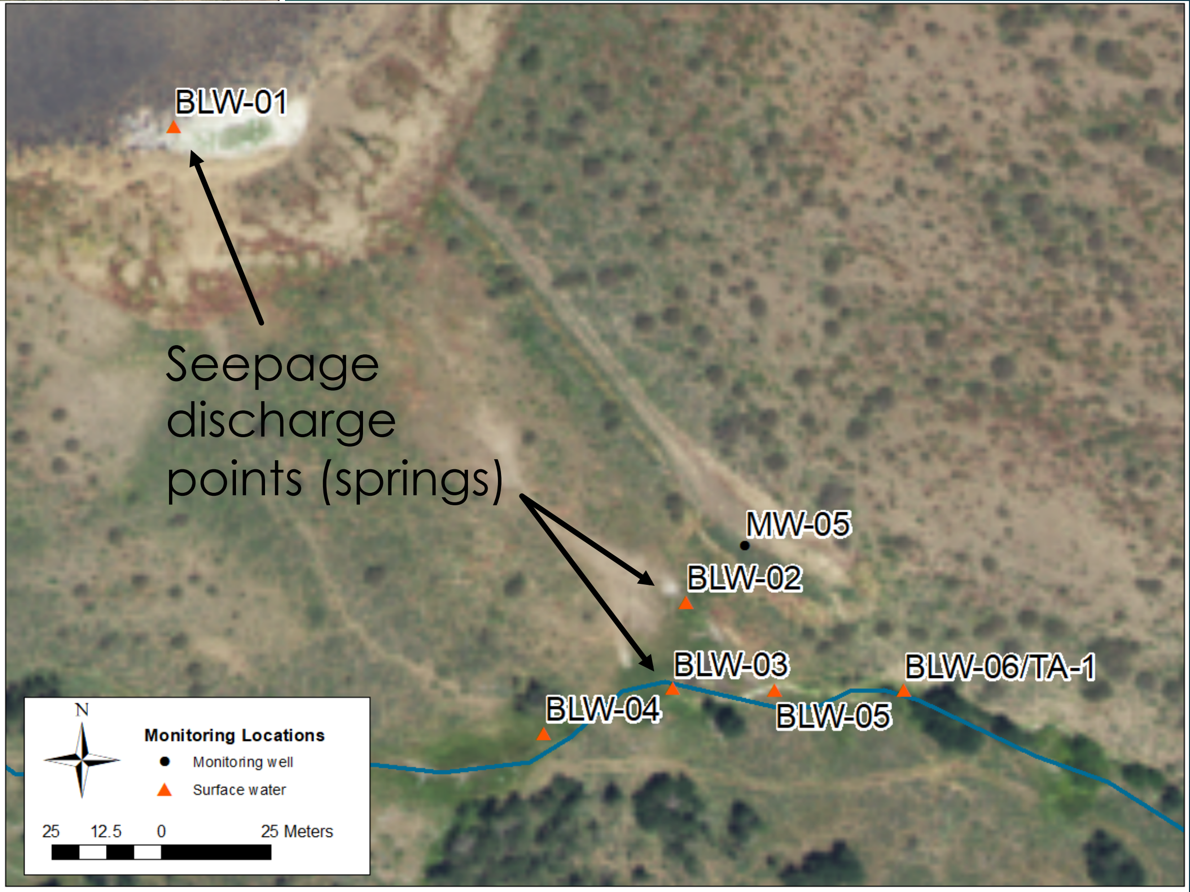
Evaluating mine-waste seepage water and solute sources using stable isotopes and inverse geochemical modeling

Connor Newman[1] and Jeff Mann[2]
[1]Nevada Division of Environmental Protection
[2]National Oilwell Varco

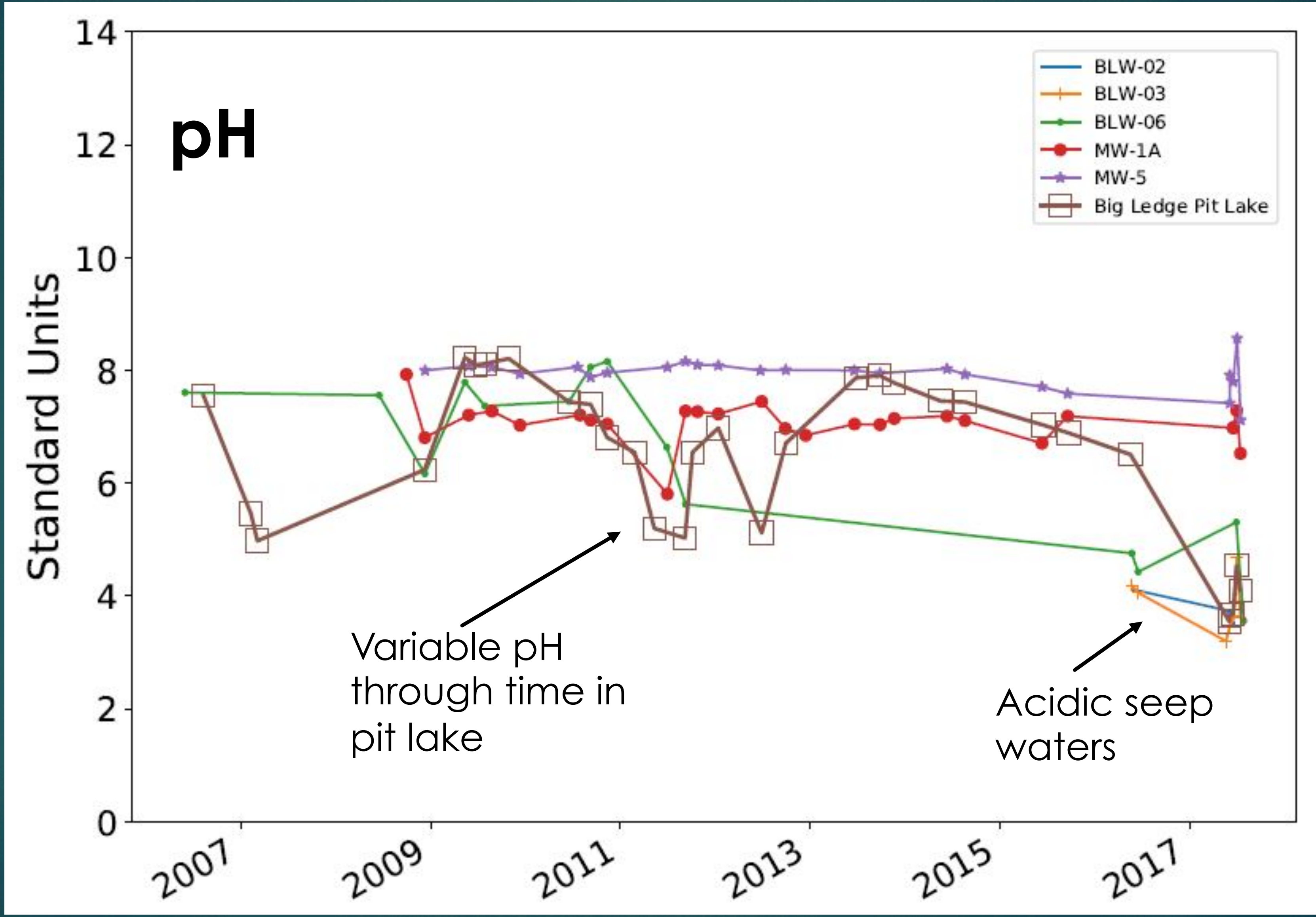
Site Location



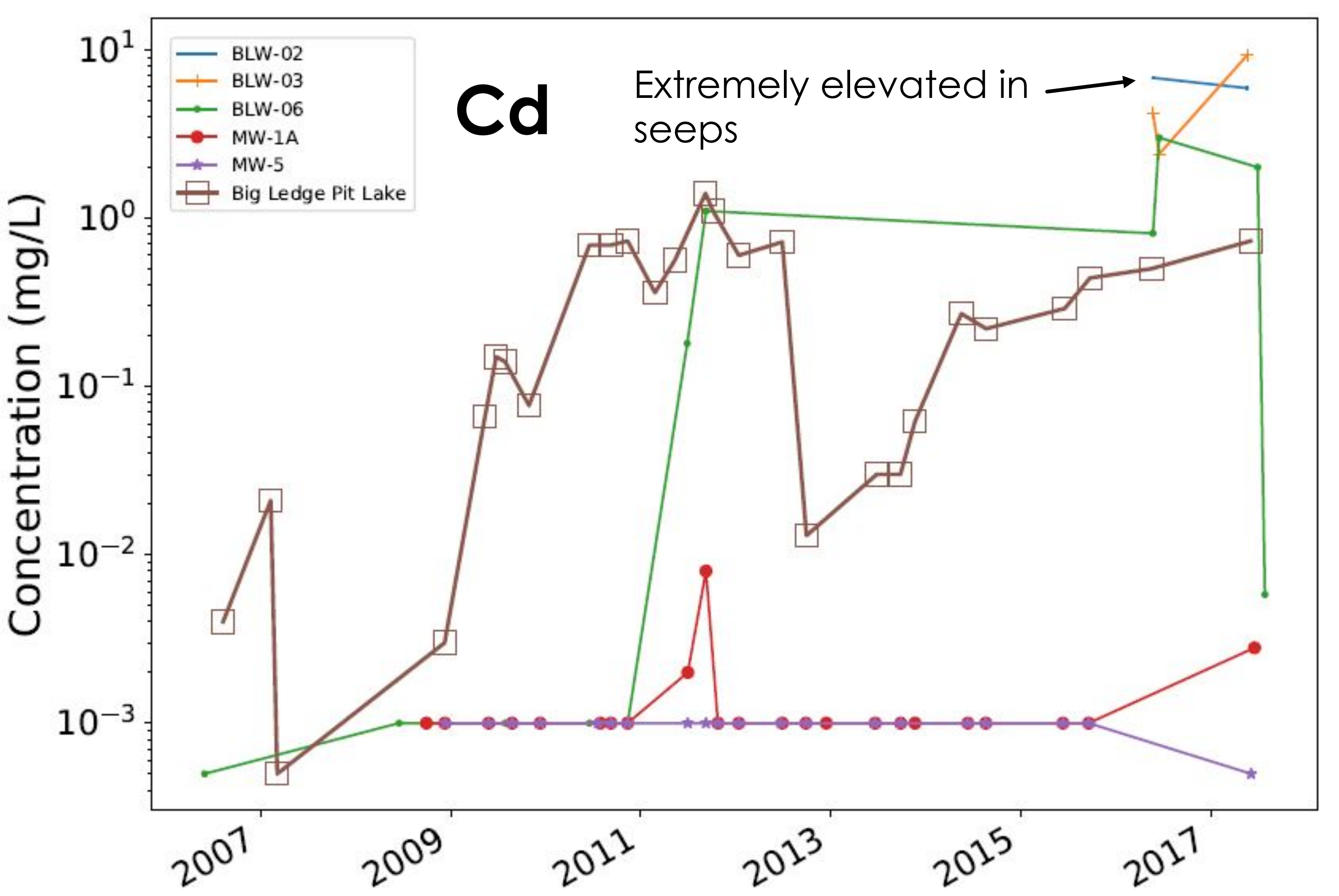


Waste Rock Seepage

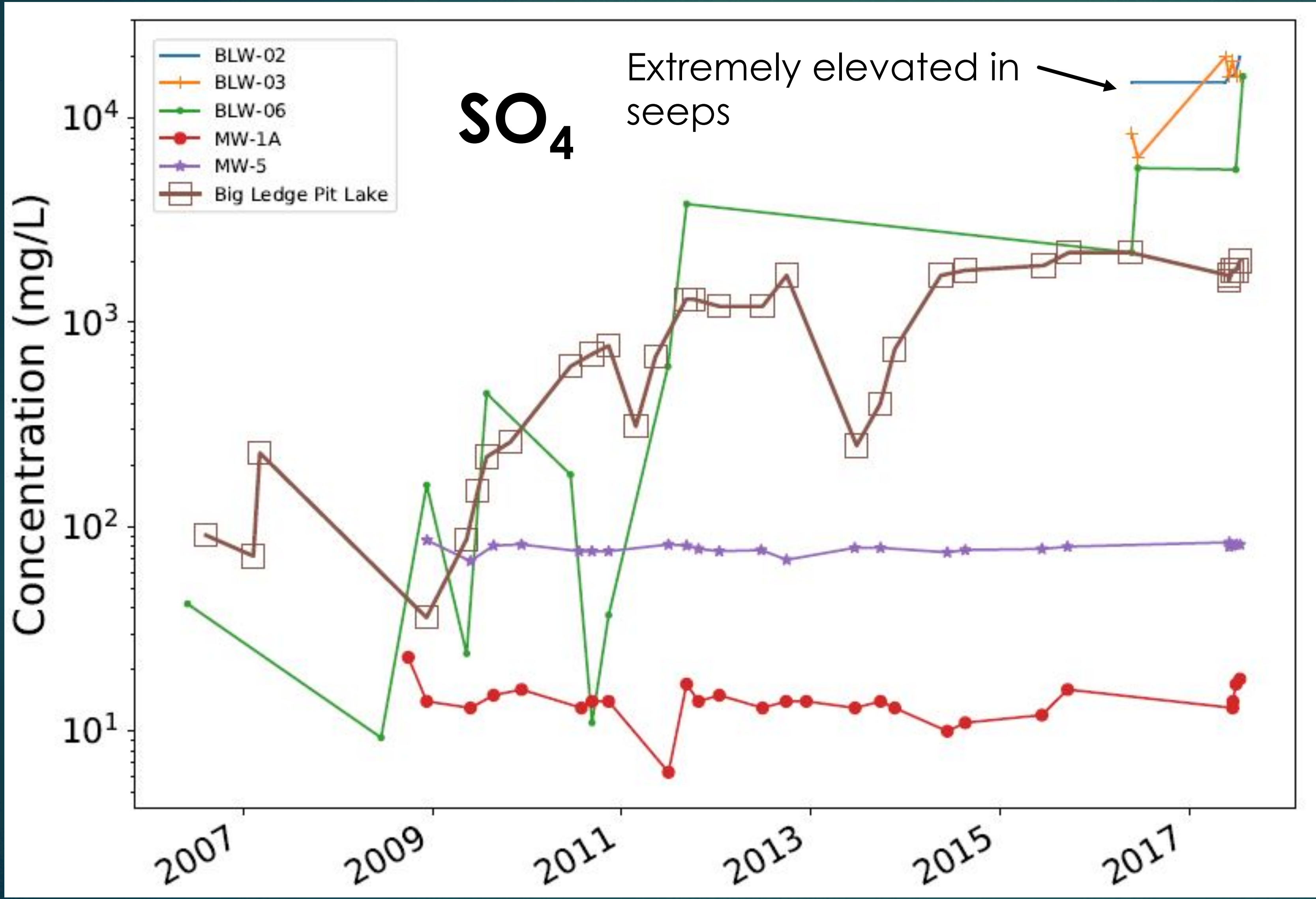
Geochemical Characteristics



Geochemical Characteristics



Geochemical Characteristics

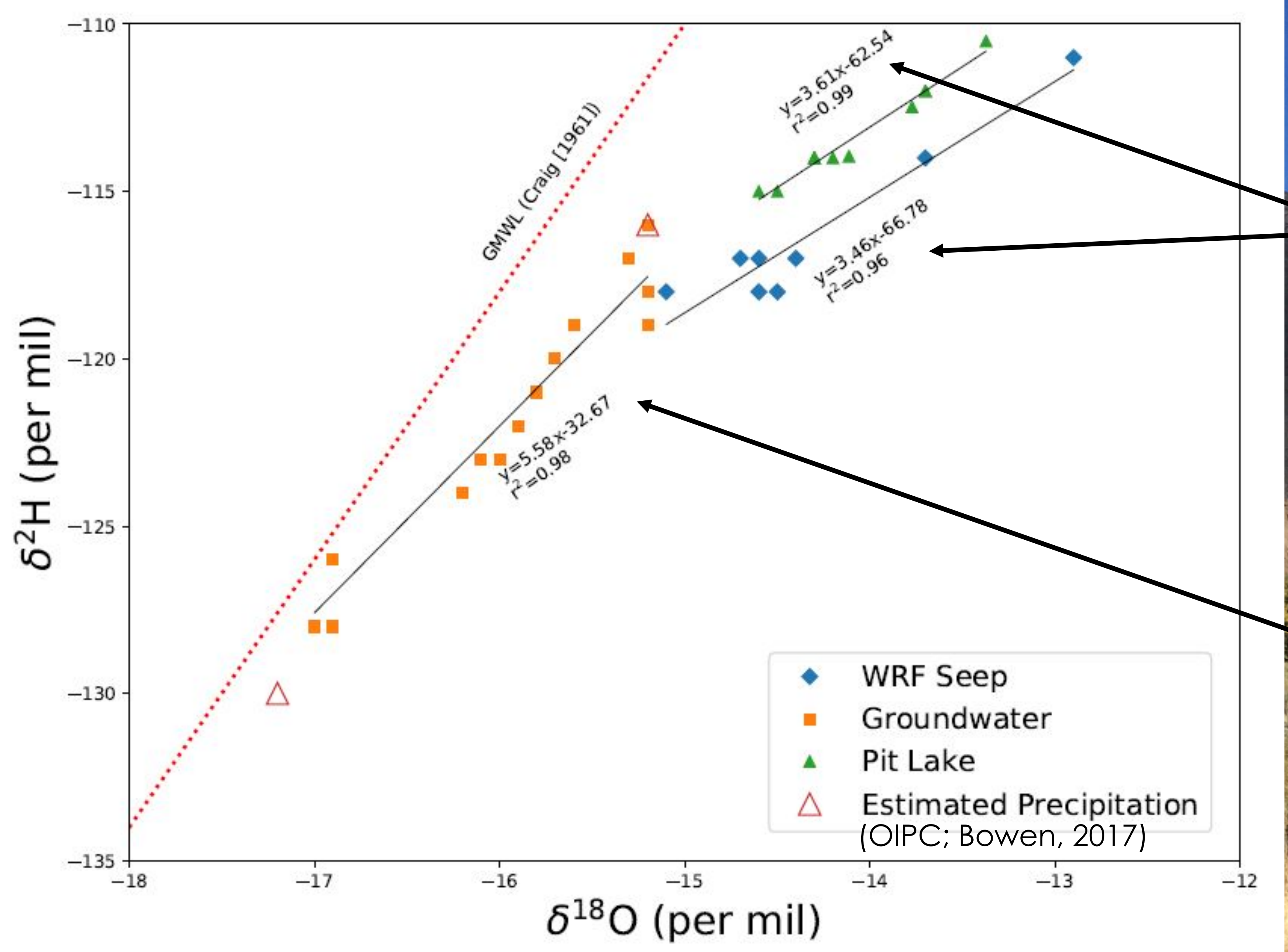


Efflorescent sulfate salts at seep area

Study Goals and Methods

- Evaluate pit-lake hydrology (flow-through or terminal)
- Determine likely sources for water and solutes in the seepage, and identify potential flow paths
  - Isotopic tracers (δ^2H, $\delta^{18}O$, $\delta^{34}S$)
  - Mixing calculations and inverse geochemical modeling
  - Cross-correlations analysis
- Evaluate potential management and closure options

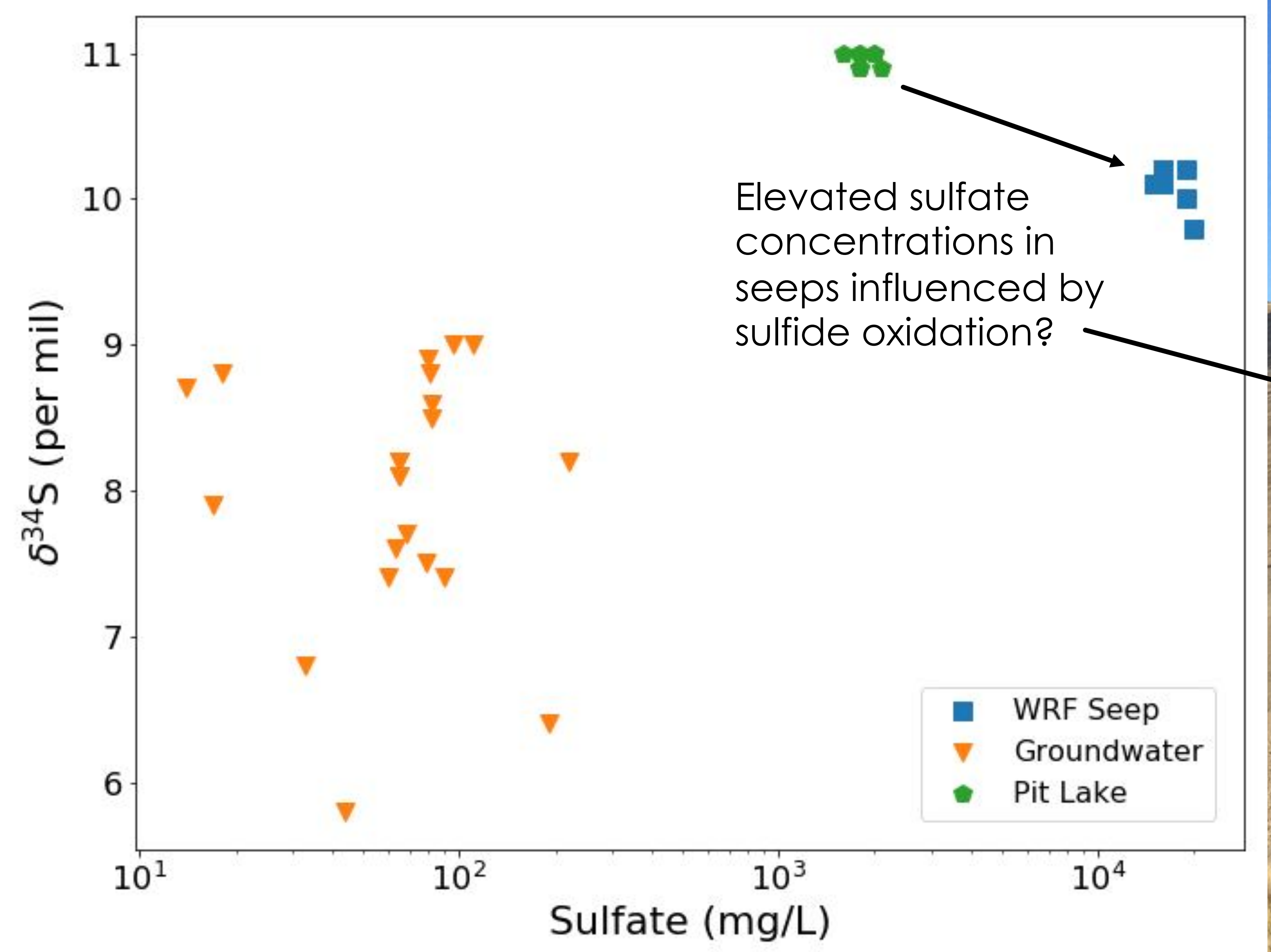
Water Isotope Results



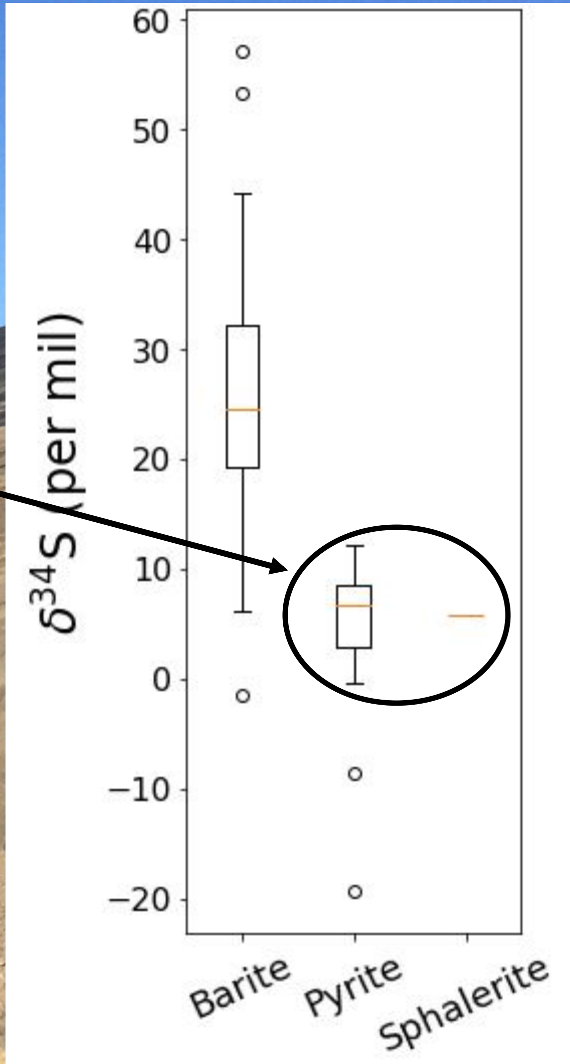
Nearly equal slopes for evaporation lines of pit lake and seeps

Groundwater representative of winter and spring recharge

Sulfur Isotope Results

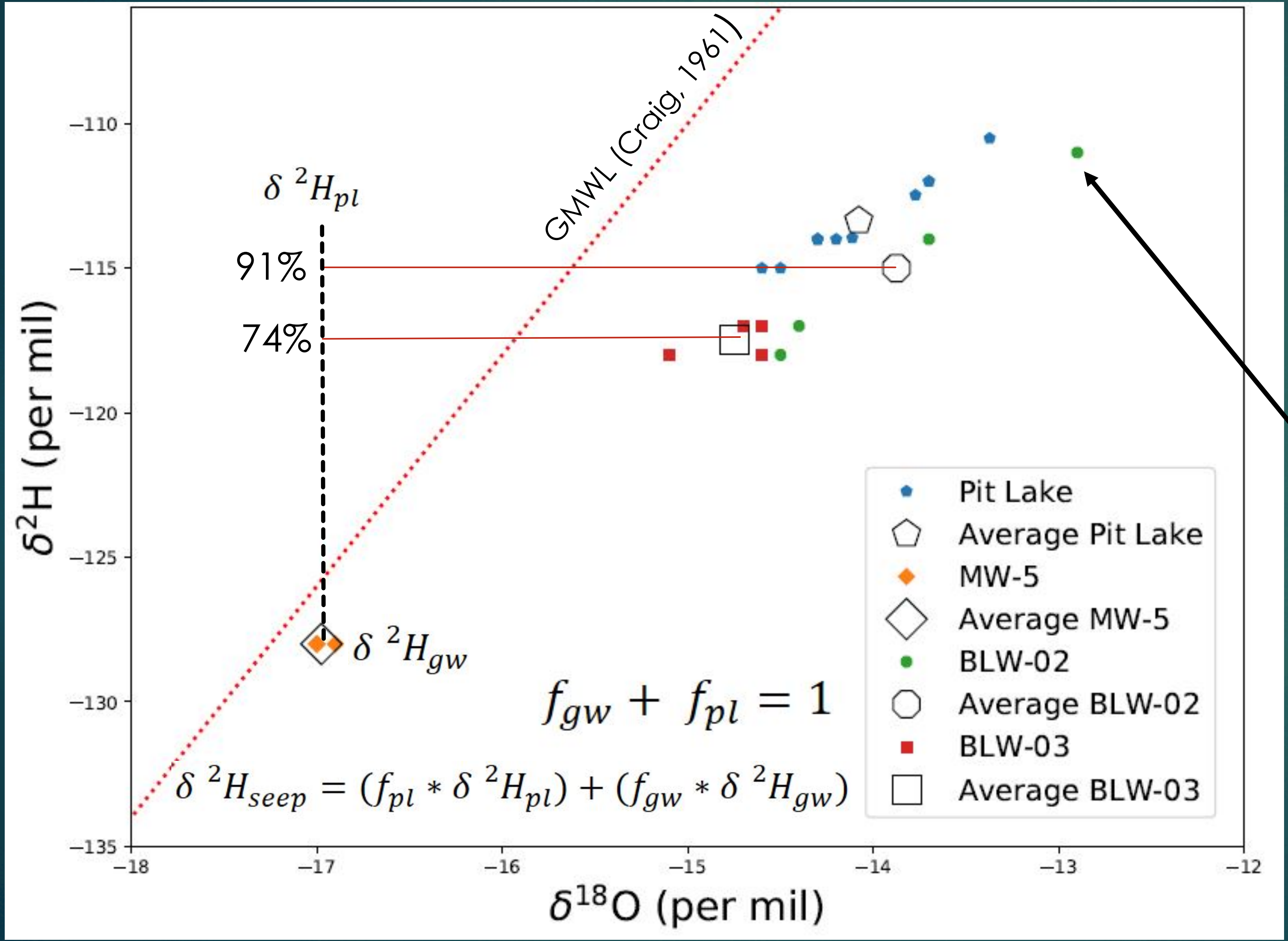


Elevated sulfate concentrations in seeps influenced by sulfide oxidation?



Mitchell, 1977; Muntean et al., 2011; Thompson et al., 1994

Isotope Mixing Calculations



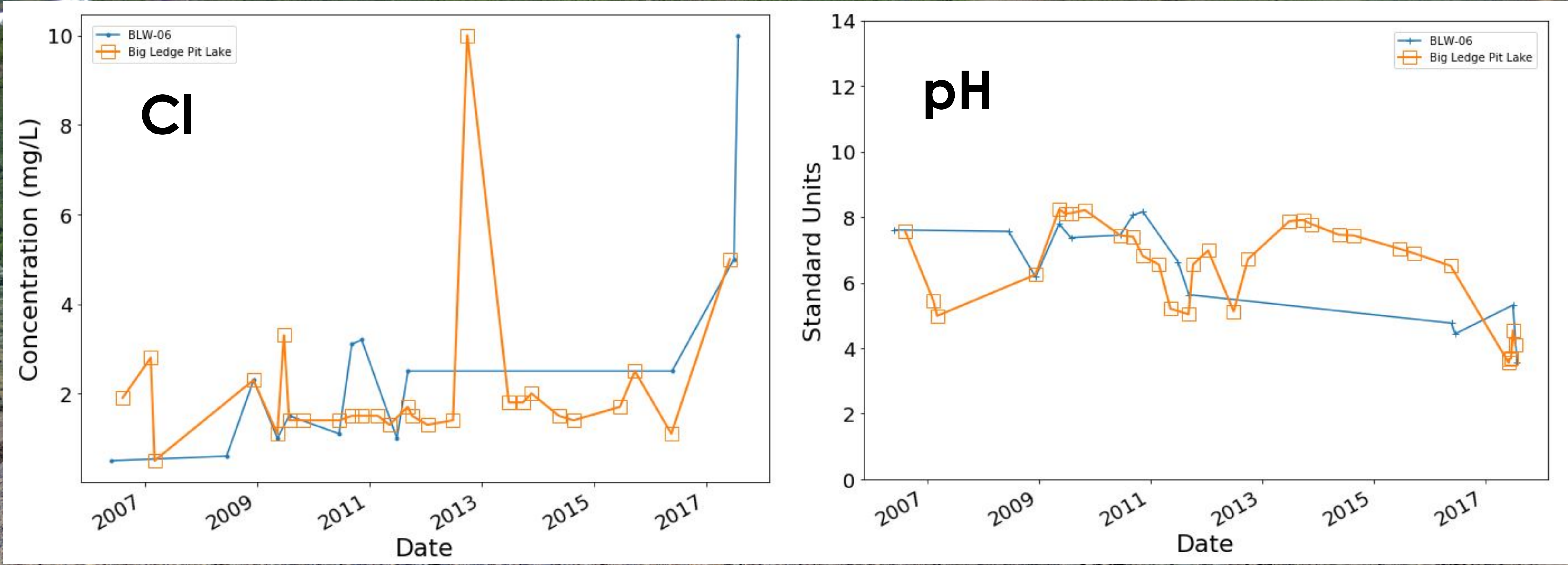
Using $\delta\,^2H$ as a conservative tracer, results indicate that pit-lake outflow could make up ~74%-91% of seepage water

The composition of BLW-02 indicates ongoing evaporation or input of $\delta\,^{18}O$ from an unknown source

This does not account for other potential water sources on the site

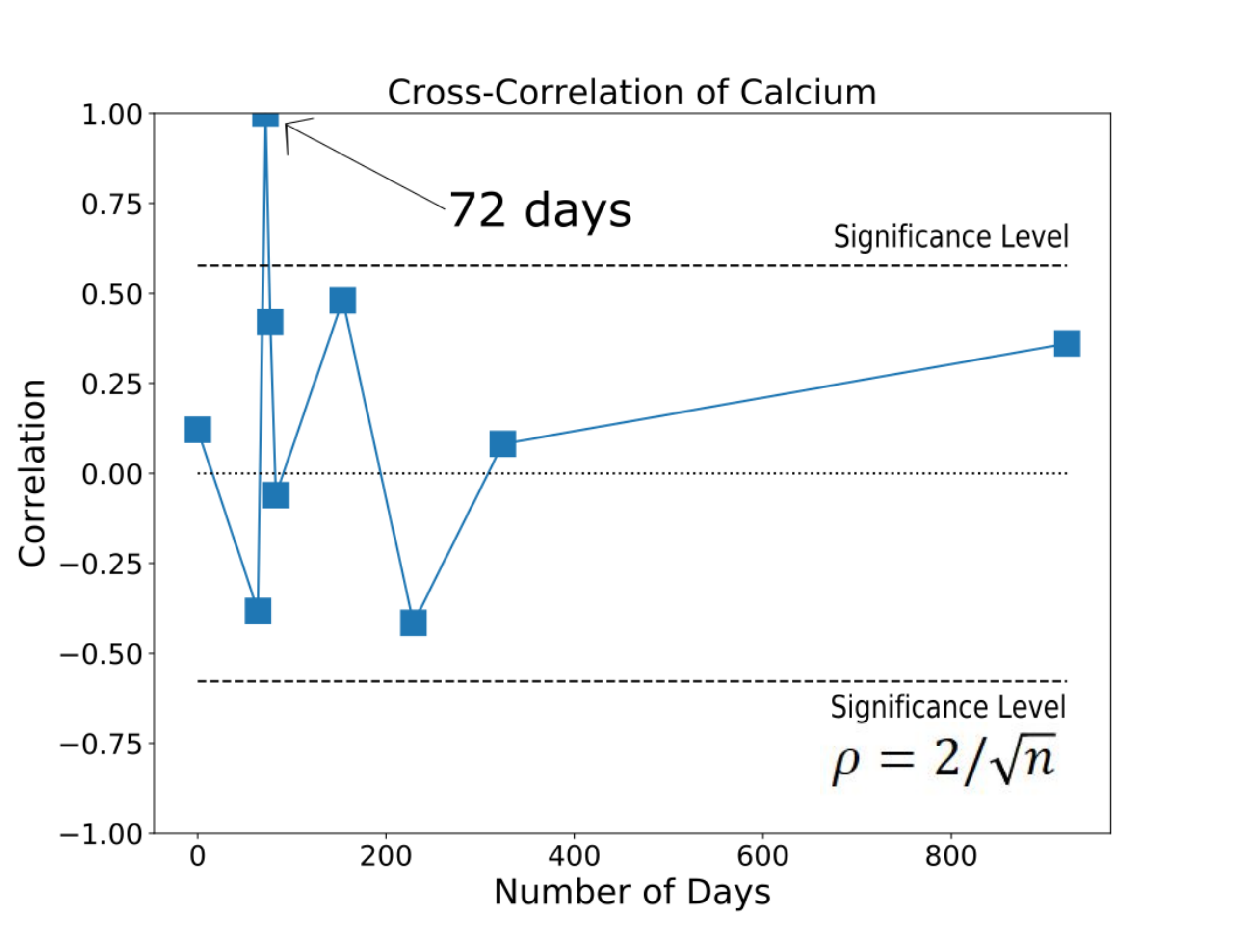
Cross-Correlation

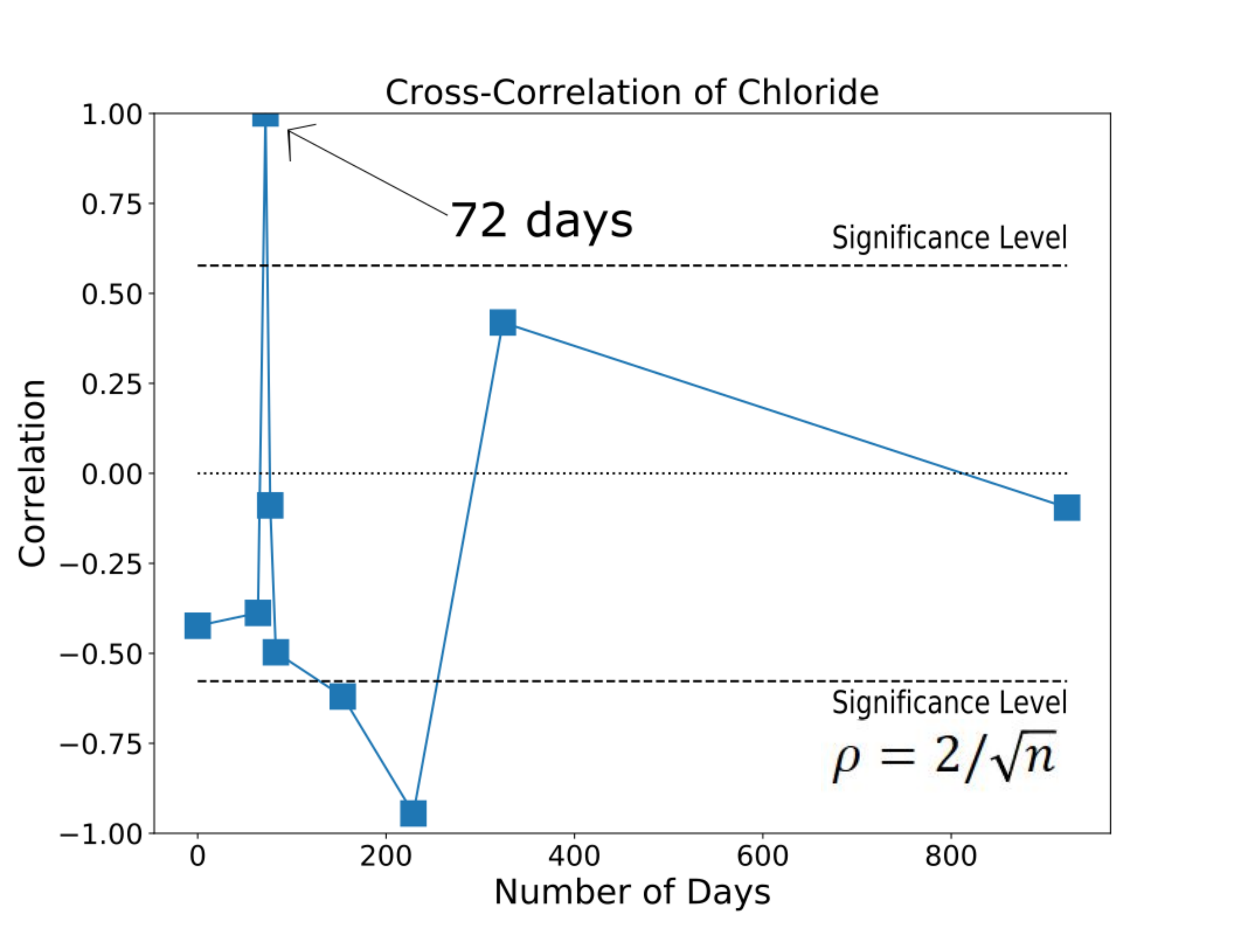
A method to evaluate relationships between time-delayed datasets (e.g., Lee et al., 2006)



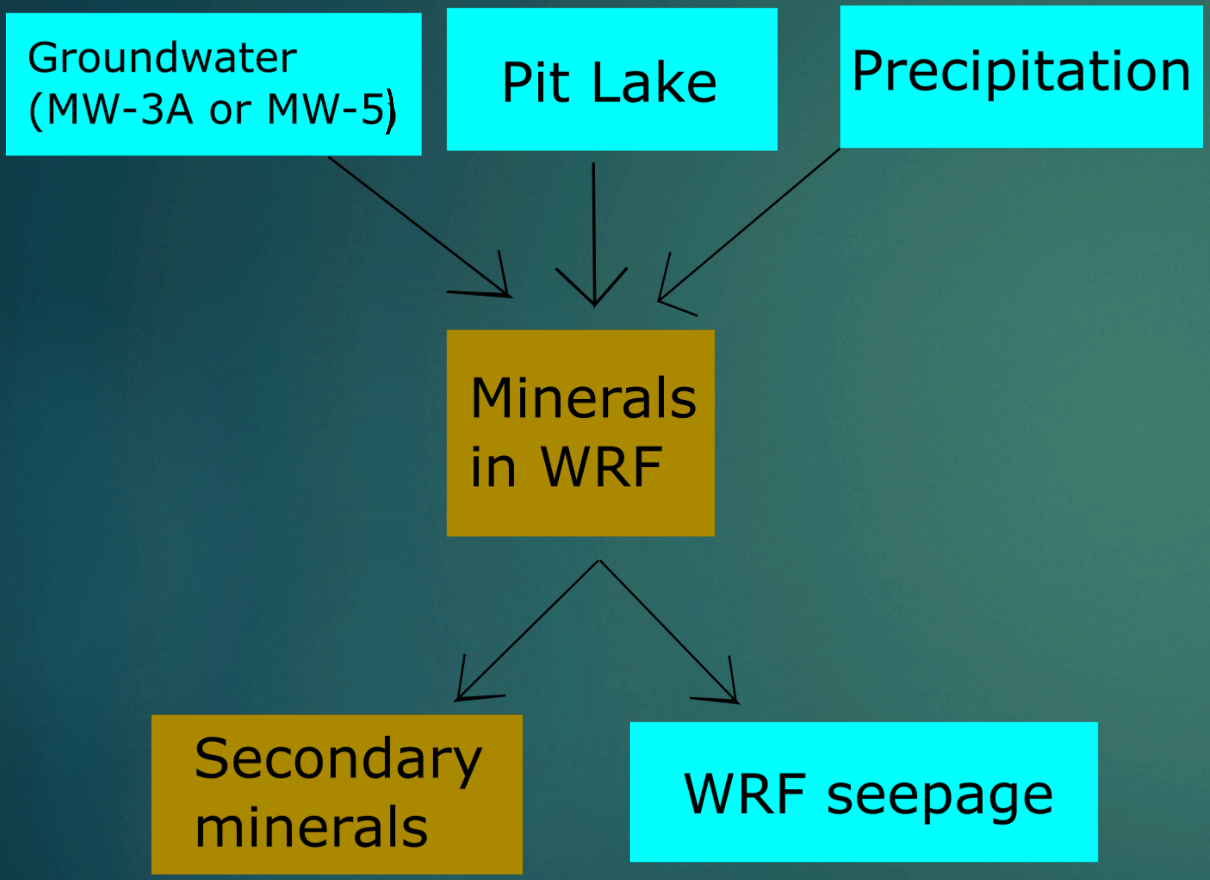
Cross-Correlation Results

Several constituents are consistent with ~70 day travel time





Inverse Modeling



- Inverse modeling can indicate mixing relationships and potential mineral phases (e.g., Glynn and Brown, 2012)
- Various models were set up with different groundwater inputs and mineral equilibrium assumptions
- The inverse modeling would be made more robust by including isotopes, but data gaps exist

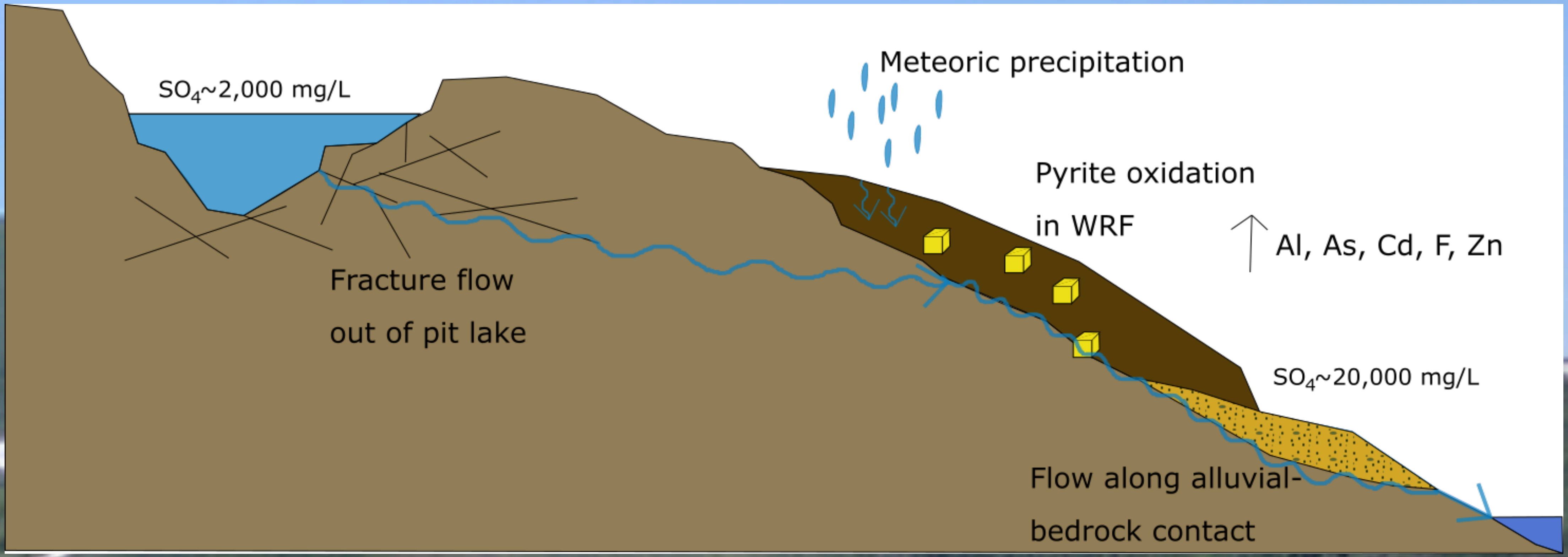
Inverse Modeling Results

- A variety of inverse models are compatible with site observations
- All models include dissolution of sulfide minerals and precipitation of metal oxyhydroxides and salts
- The fraction of the pit lake is broadly similar to that calculated using isotope mixing

Minerals Dissolved	Minerals Precipitated	Minerals Either Ppt. or Diss.	Fraction of pit-lake water in seeps
Pyrite, sphalerite, fluorite, galena	Manganite, gypsum, epsomite	Melanterite, ferrihydrite	0.78-0.99

Conclusions

- The Big Ledge pit lake is a flow-through system, which discharges to surface water



Conclusions

- The Big Ledge pit lake is a flow-through system, which discharges to surface water
- Multiple methods (isotope mixing and inverse geochemical modeling) indicate that pit-lake discharge makes up at least ~75% of waste rock seepage
- Mineral equilibrium (both dissolution and precipitation) is an important process in controlling the mass balance of seepage
- Groundwater flow in the area is likely fracture controlled based on the hydraulic gradient and statistical analysis of travel time
- Isotopes are a useful method to evaluate pit-lake hydrology, and hydrologic studies should utilize multiple methods

Potential Ongoing Work

- Determine the isotopic composition of sulfate salts and sulfide minerals specific to the site
- Calibrate a groundwater-flow model to quantify the pit-lake water budget
- Utilize predictive geochemical modeling to evaluate different closure scenarios


Thank you!
Questions?
c.newman@ndep.nv.gov

References

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