Profiling stable isotopes of water signatures to define mass transport mechanisms from water capped fluid tailings in the oil sands industry

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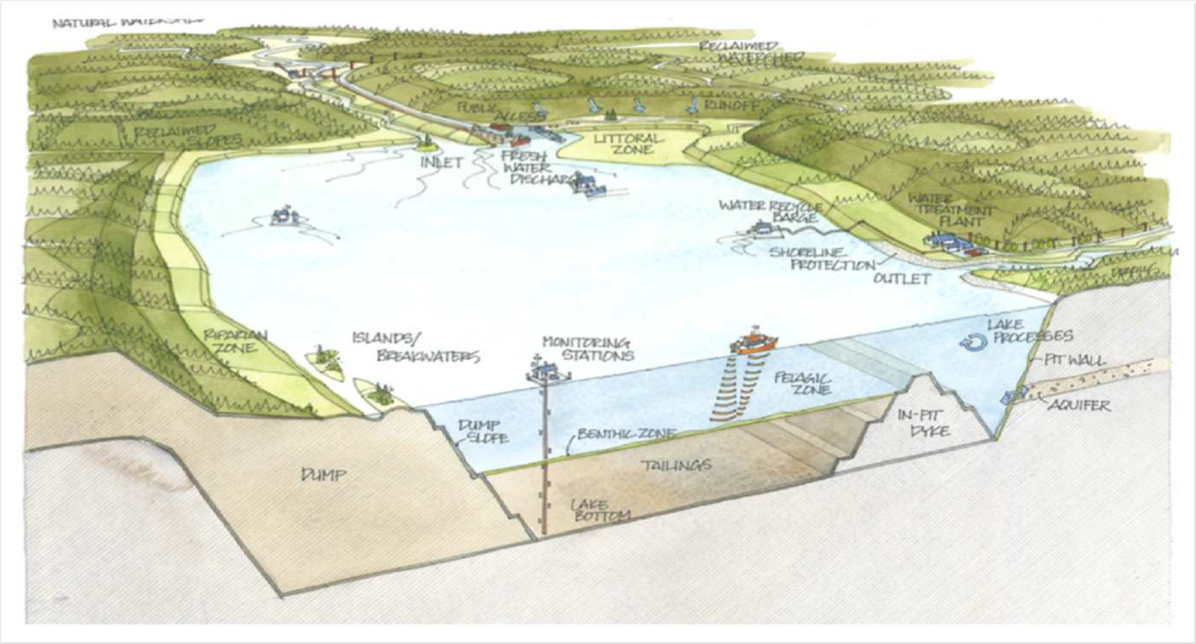
INTRODUCTION: END PIT LAKES

- Oil sands mine closure landscape
  - Establish lake ecosystem
  - Provide treatment for mine waters
  - Store oil sands tailings



EPL Guidance Document, Cumulative Environmental Management Association: cemaonline.ca

BACKGROUND: FLUID FINE TAILINGS

- Oil sands ore composition (by weight)
  - 10% bitumen, 5% water, 85% minerals

- Fluid fine tailings
  - Disperse particles (clay)
  - Low settlement rates
  - High water content
  - Relatively warm

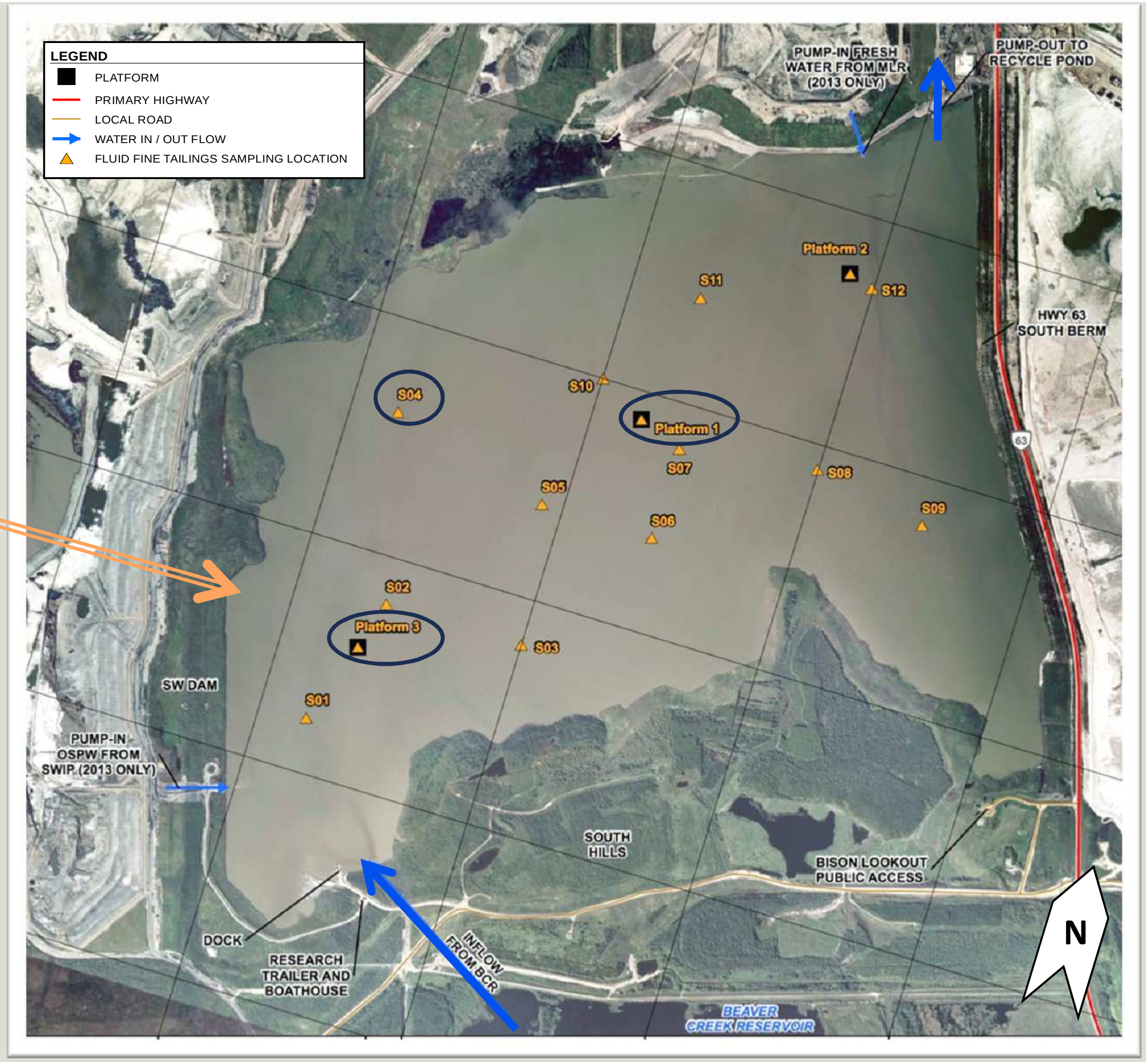
BACKGROUND: SITE DESCRIPTION

Mildred Lake Mine

Operator: Syncrude Canada Ltd.

Base Mine Lake

- Filled: 1994-2012
- 186 M m^3 FFT
- Water cap: ~8.5 m



BACKGROUND: MASS TRANSPORT

Diffusion

- Molecular mass transfer over concentration gradient
  - Tailings vs. freshwater

Advection

- Mass carried by fluid flow
  - Tailings settlement causes upward pore water flux

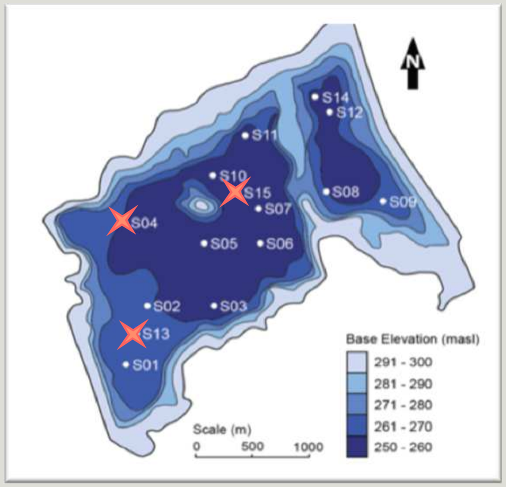
Chemical mass transfer

- Addition/removal of mass
  - Reactions in tailings

FIELD INVESTIGATION

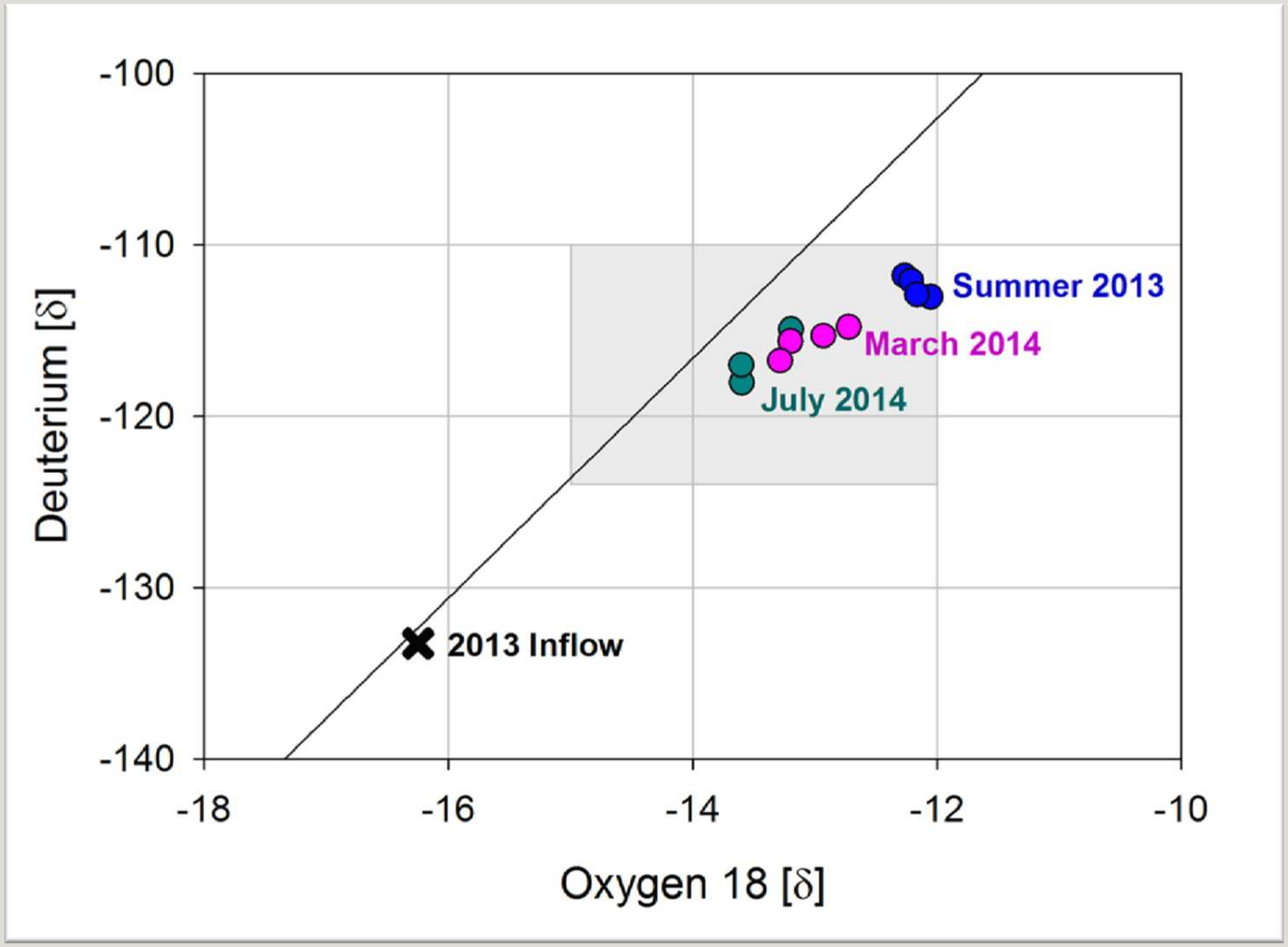
- Isotope cataloguing, May 2013 – ongoing

- Interface sampling program, July 2014
  - Fixed interval fluid sampler
    - 3 m sample zone (centered at mudline)
    - 10 cm sample interval
    - 3 locations (S04, S13, S15)

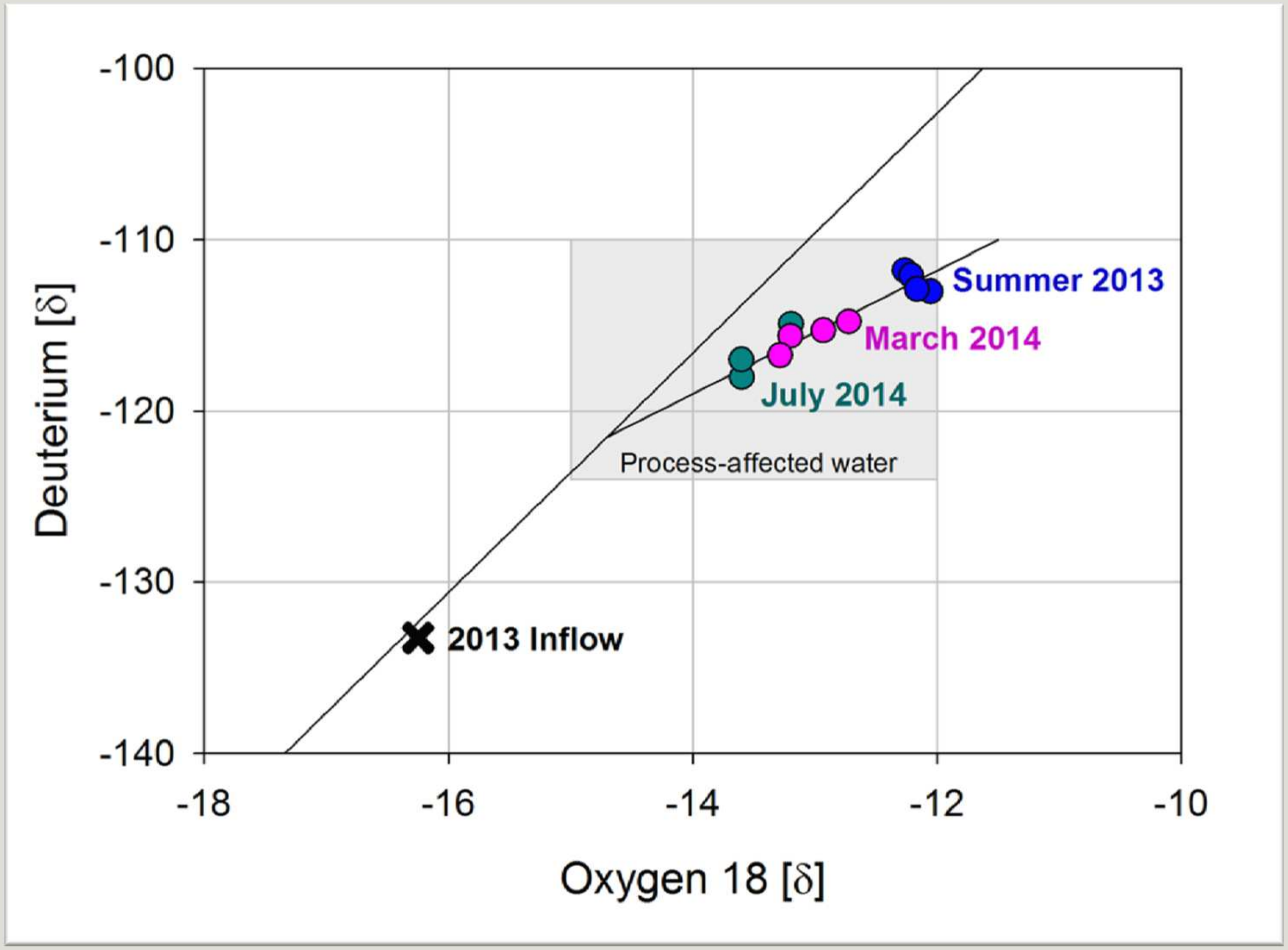


- Sample analysis
  - Picarro L-2120-i Cavity Ring Down Spectrometer
    - Vapour equilibration technique

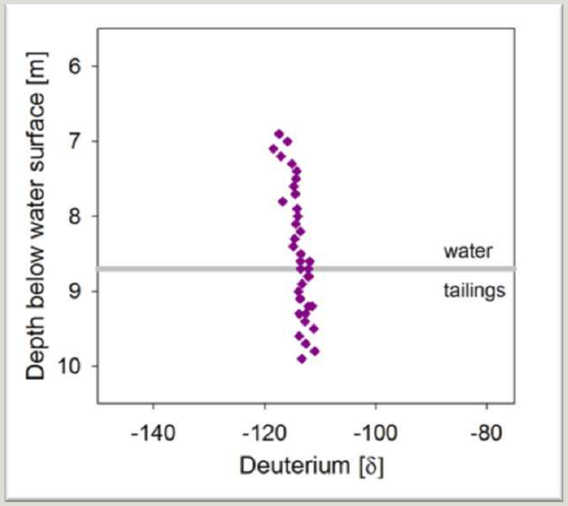
FIELD RESULTS: ISOTOPE TRENDS

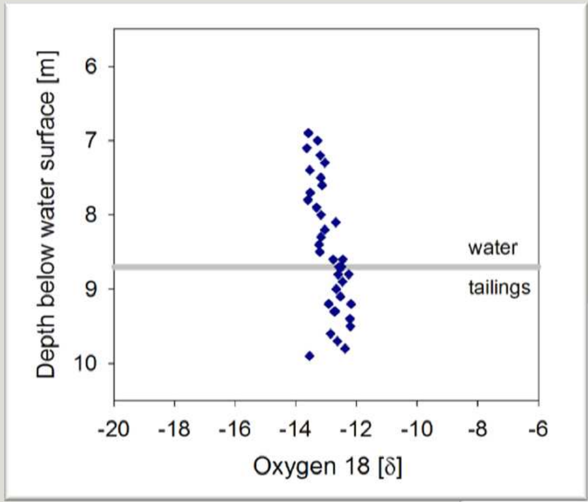


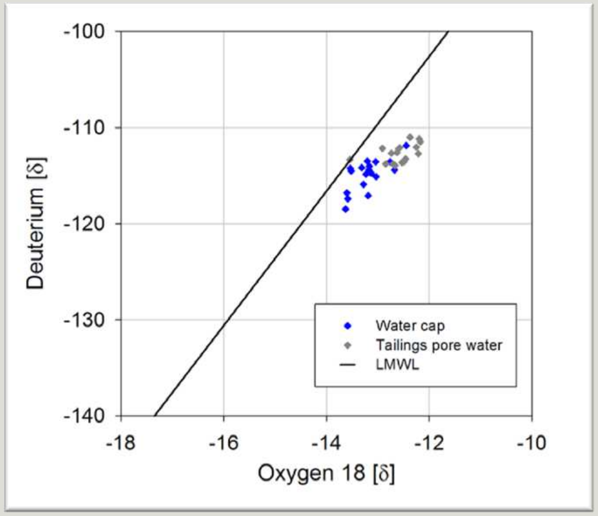
FIELD RESULTS: ISOTOPE TRENDS

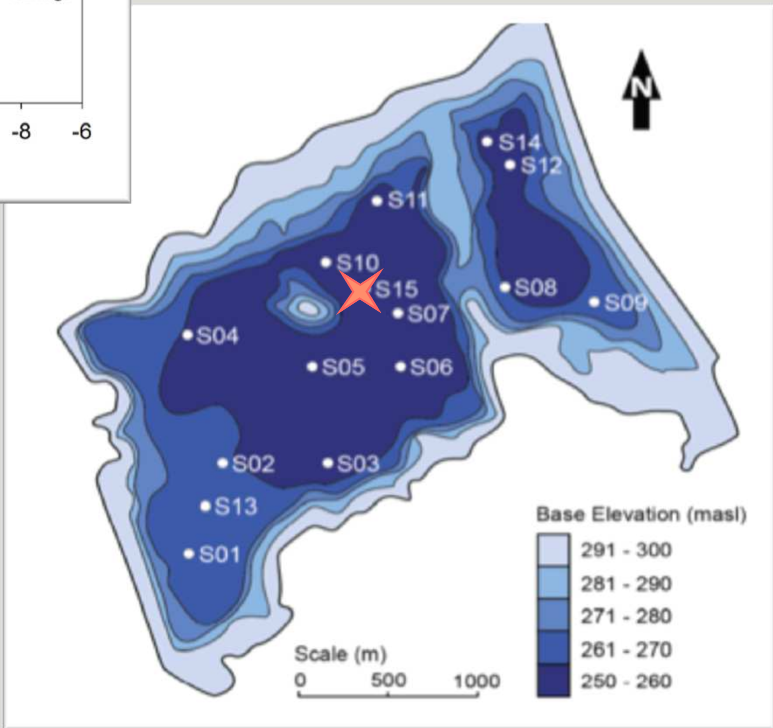


FIELD RESULTS: S15

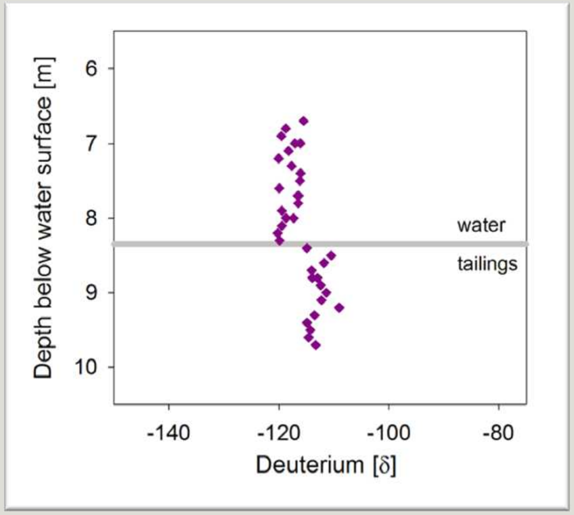


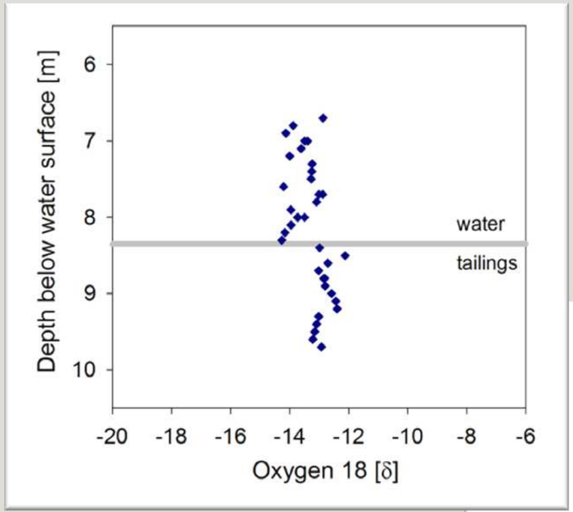


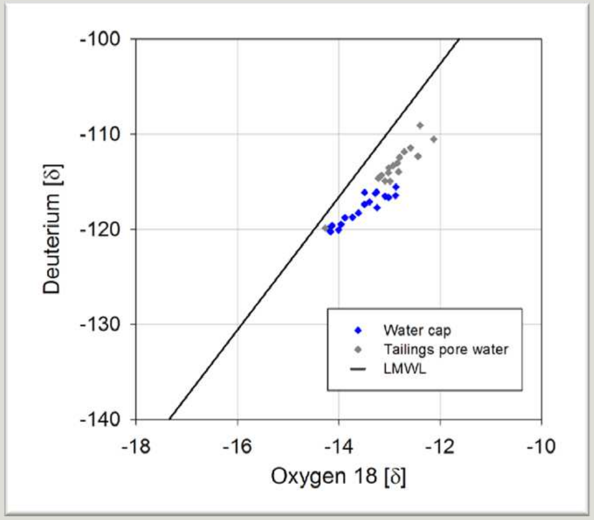


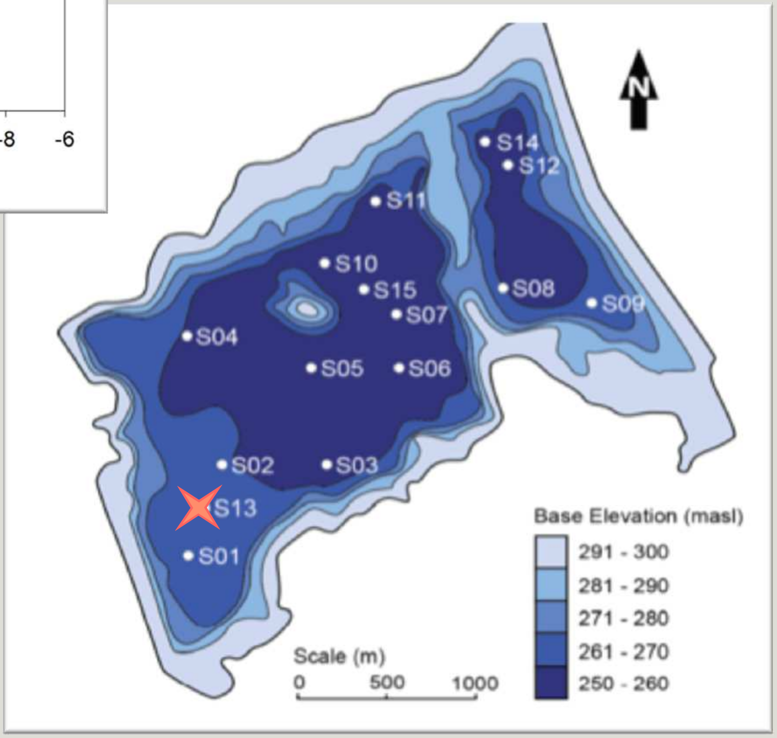


FIELD RESULTS: S13

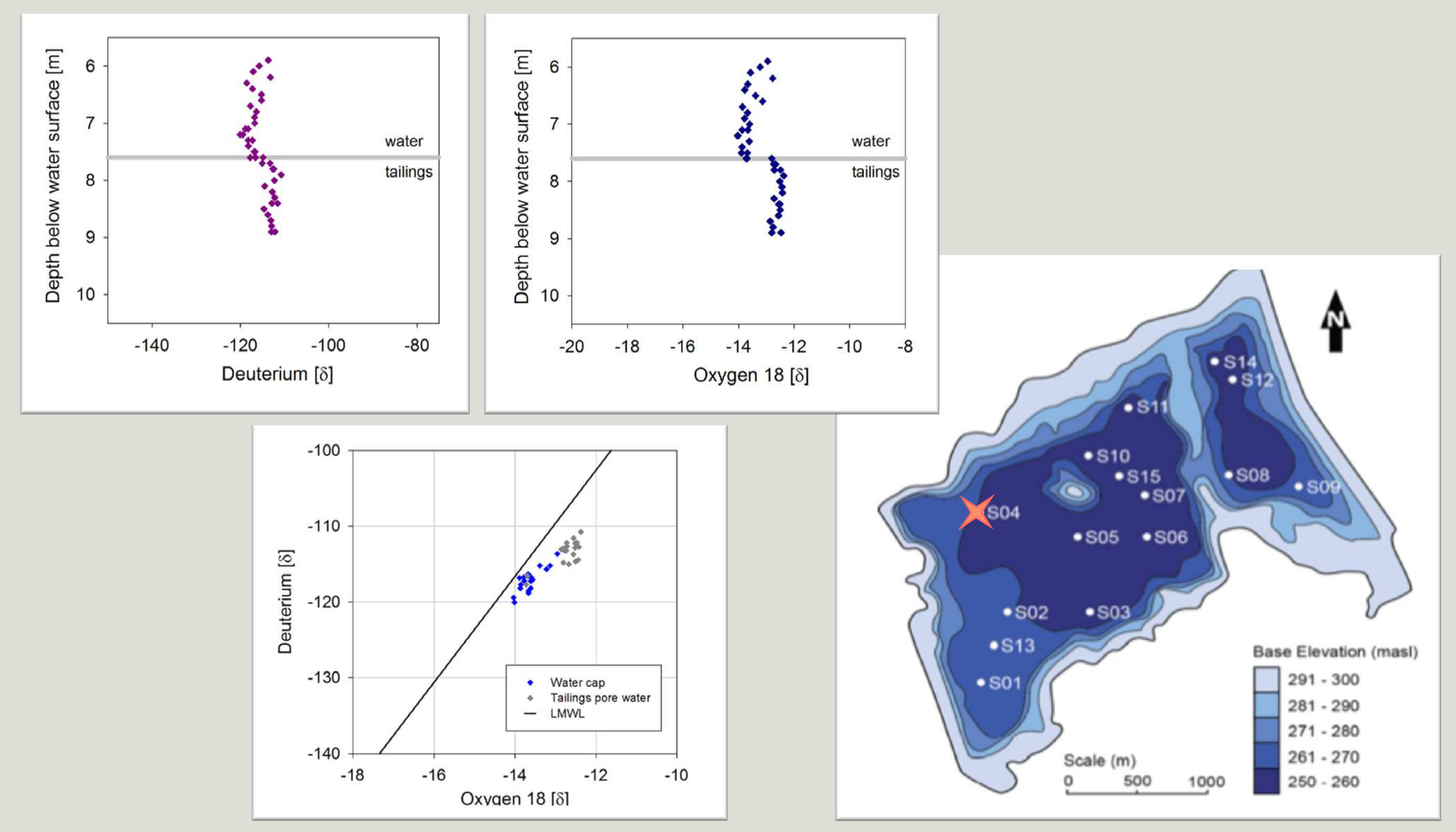








FIELD RESULTS: S04



MODEL DEVELOPMENT

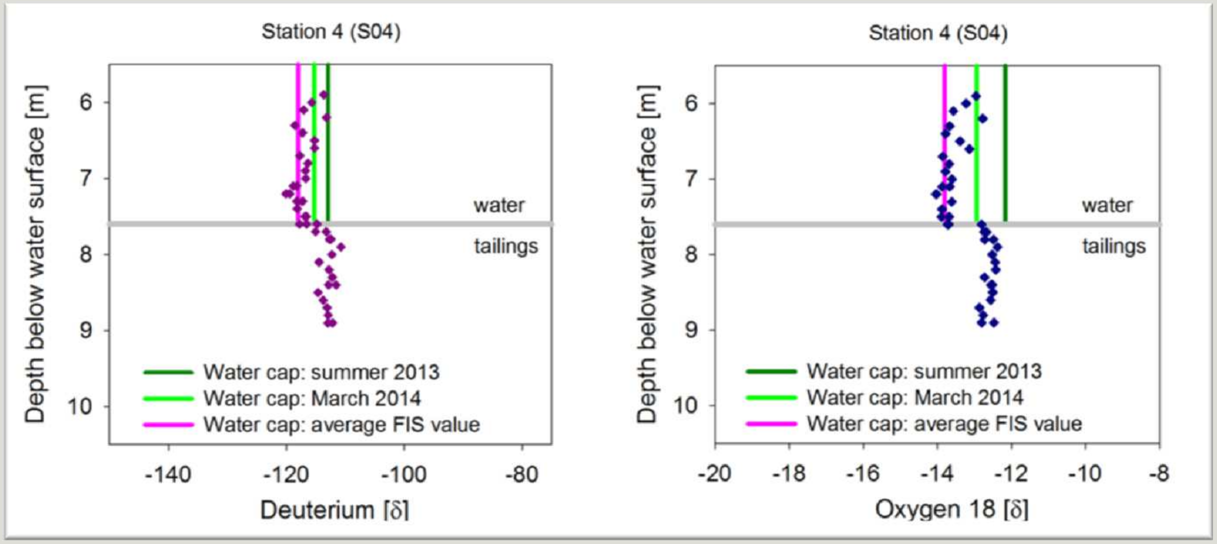
- Mass transport
  - Diffusion and advection
    - GeoStudio© (CTRAN/W + SEEP/W)
  - 1D model: vertical tailings profile
  - Boundary and initial conditions
    - Established using field measurements
  - Parameters: Values:

Parameters	Values
Saturated water content	0.85
Diffusion coefficient	10.8 x 10^{-5} m/day (1.25 x 10^{-9} m/s)
Dispersivity	0.09

MODEL 1: FIXED CONCENTRATION

- Top boundary condition
  - Constant concentration based on sample results

δD = -118.0 ‰ **δ^{18}O** = -13.8 ‰

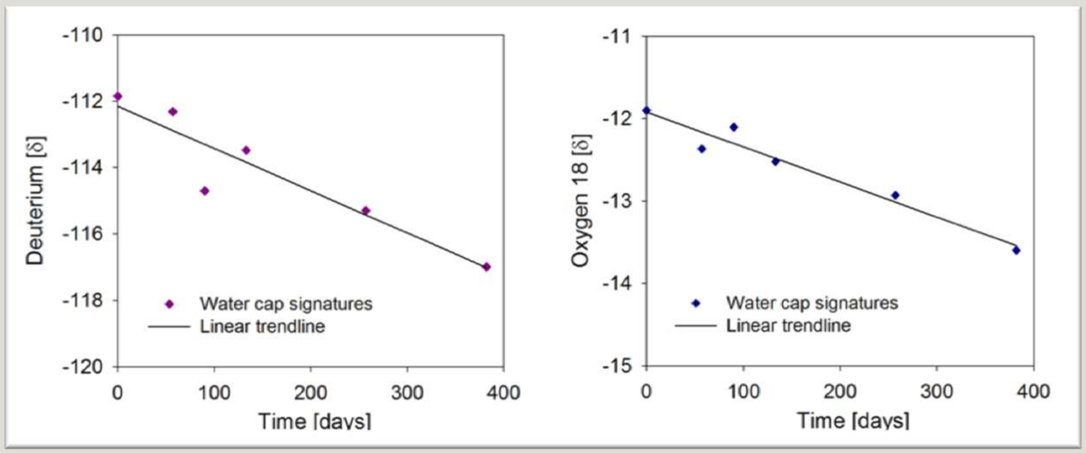


- Initial FFT concentration
  - Average signature in tailings (near interface)

δD = -112.2 ‰ **δ^{18}O** = -12.4 ‰

MODEL 2: LAKE MIXING

- Top boundary condition
  - Assume lake water **fully mixed**
  - Linearly decreasing concentration



- Initial FFT concentration
  - Same as Model 1

δD = -112.2 ‰ **δ^{18}O** = -12.4 ‰

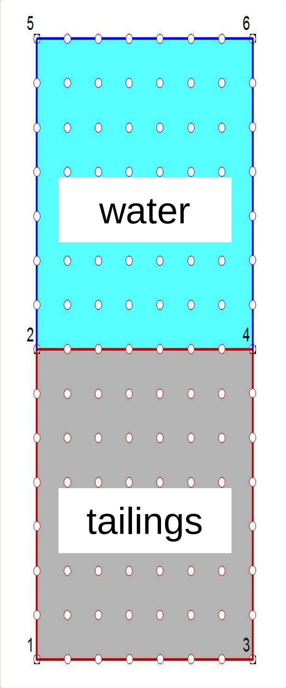
MODEL 3: LAKE DIFFUSION

- Top boundary condition
  - Water column with constant mass
  - Assumes **no mixing**
  - Initial water concentration based on FIS

    δD = -118 ‰ **δ¹⁸O** = -13.8 ‰

- Initial FFT concentration
  - Same as Models 1 and 2

    δD = -112.5 ‰ **δ¹⁸O** = -12.5 ‰

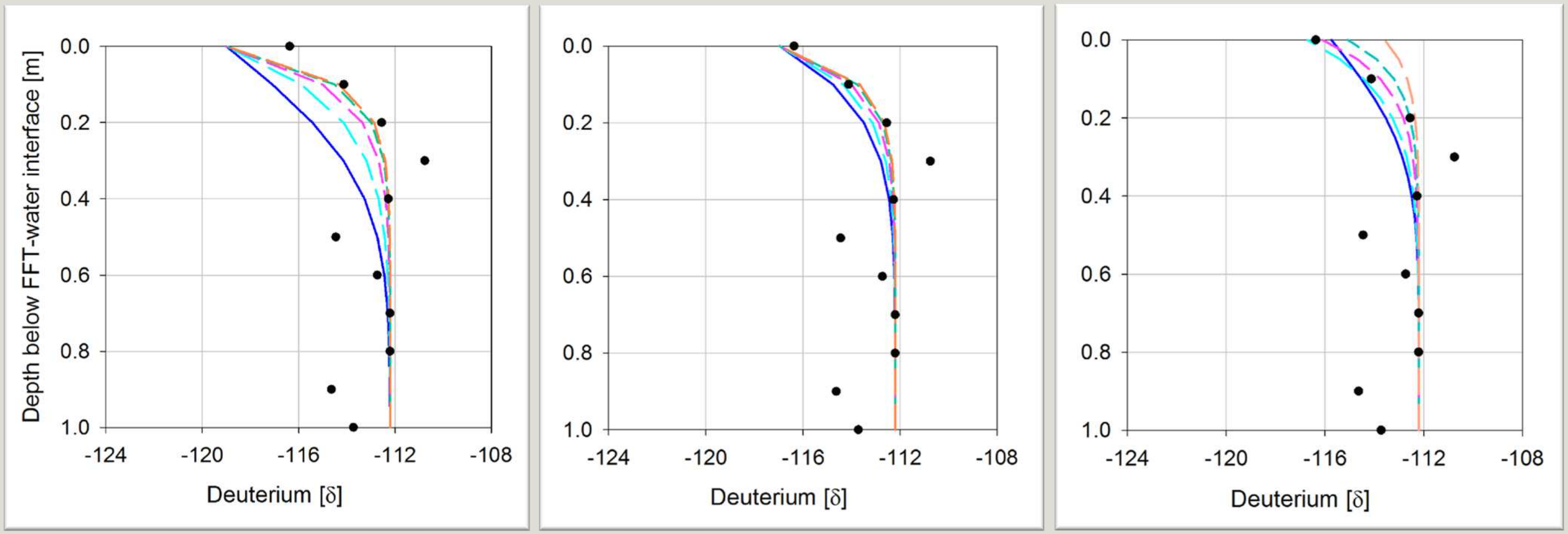


NUMERICAL RESULTS: DEUTERIUM

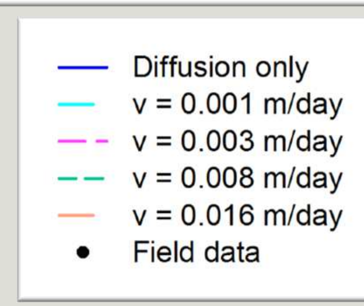
Model 1
Fixed concentration

Model 2
Lake mixing

Model 3
Lake diffusion

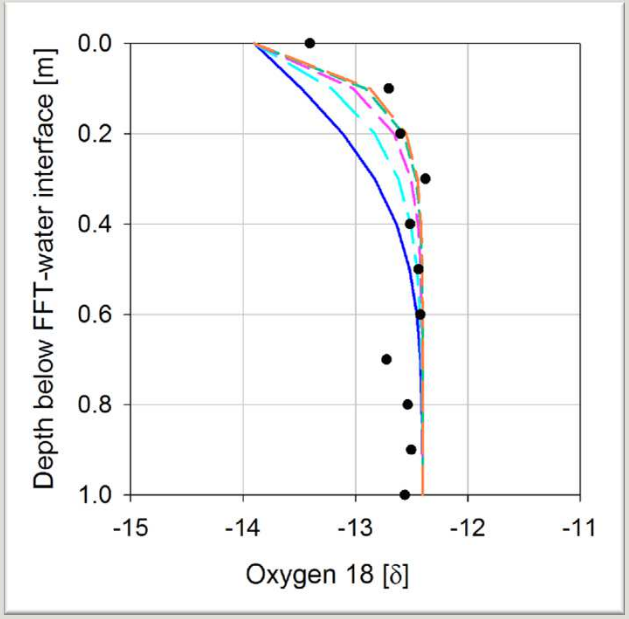


- Best fit?
  - Model 2 vs. Model 3
  - Variability in field data

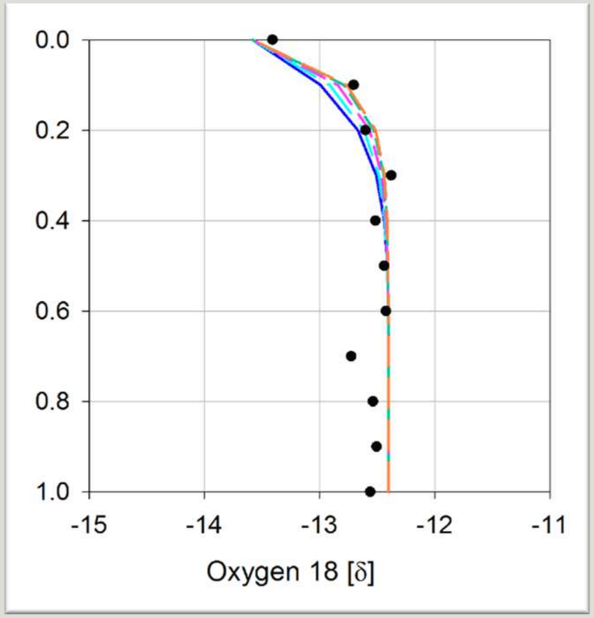


NUMERICAL RESULTS: OXYGEN 18

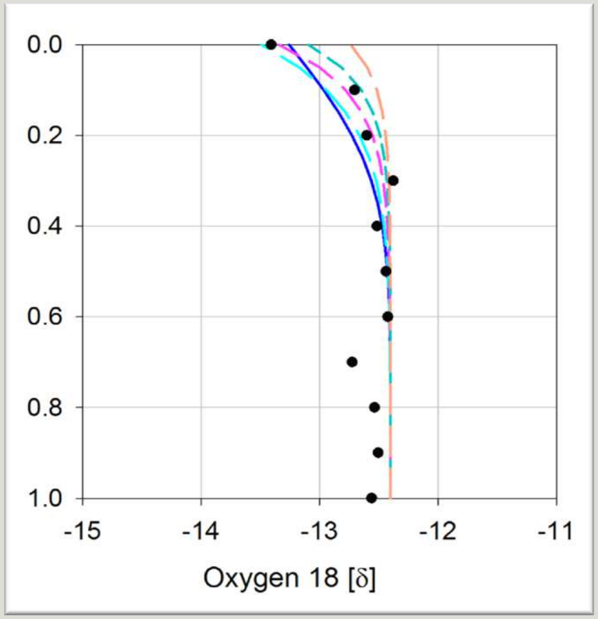
Model 1
Fixed concentration

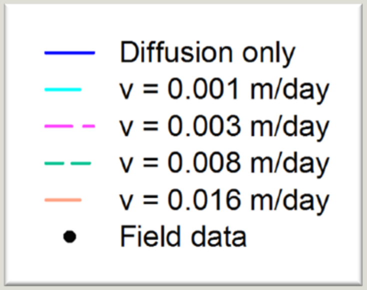


Model 2
Lake mixing



Model 3
Lake diffusion





- Less variability in field data
- Initial mass transport assessment:
  - Advection ~0.003 m/d

STABLE ISOTOPE INSIGHT

- Initial profiles show:
  - Water cap still ‘process affected water’
  - Differential effects of fresh water inflow
  - Advective transport dominant when ‘break’ at interface

- GeoStudio© models:
  - Potential advective mass transport (0.003 m/day)
  - Corresponds with tailings settlement models

CONCLUSIONS

- Isotope trends provide insight on mass transport
  - e.g. If ‘break’ at interface persists: advection dominant
- Simple model created in GeoStudio©
  - Observe effects of varying boundary conditions
- Potential applications:
  - Assess mass loading to End Pit Lakes
  - Corroborate existing tailings settlement models

ACKNOWLEDGEMENTS

Syncrude
Securing Canada's Energy Future

NSERC
CRSNG

University of Saskatchewan
College of Engineering

QUESTIONS