



# Biogeochemistry of Saturated Rock Fill Facilities, Elk Valley BC

Presentation for BC MEND, 2025

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# Acknowledgements

- Work on SRFs has spanned over 15 years, has involved a highly collaborative team across disciplines, consultancies, academic partners, and Elk Valley Resources staff (formerly Teck Coal)
- Contributors include:
  - **EVR/Teck Coal (including R&D, operations, regional water quality modelling, permitting, environmental compliance, engineering, etc.)**
  - **SRK (geochemistry, hydrogeology, engineering, permitting support)**
  - **Enviromin (microbiology)**
  - **USASK (geochemistry and hydrogeology)**
  - **MSU (microbiology)**
  - **Geosyntec (carbon characterization)**
  - **OKC (field support)**
  - **WSP/Golder (regional water quality modeling)**
  - **Wood and Tetra Tech (wellfield engineering)**
  - **Nupqu (sampling)**
  - And many more operators, site & field staff, analytical lab staff, coop students, etc.

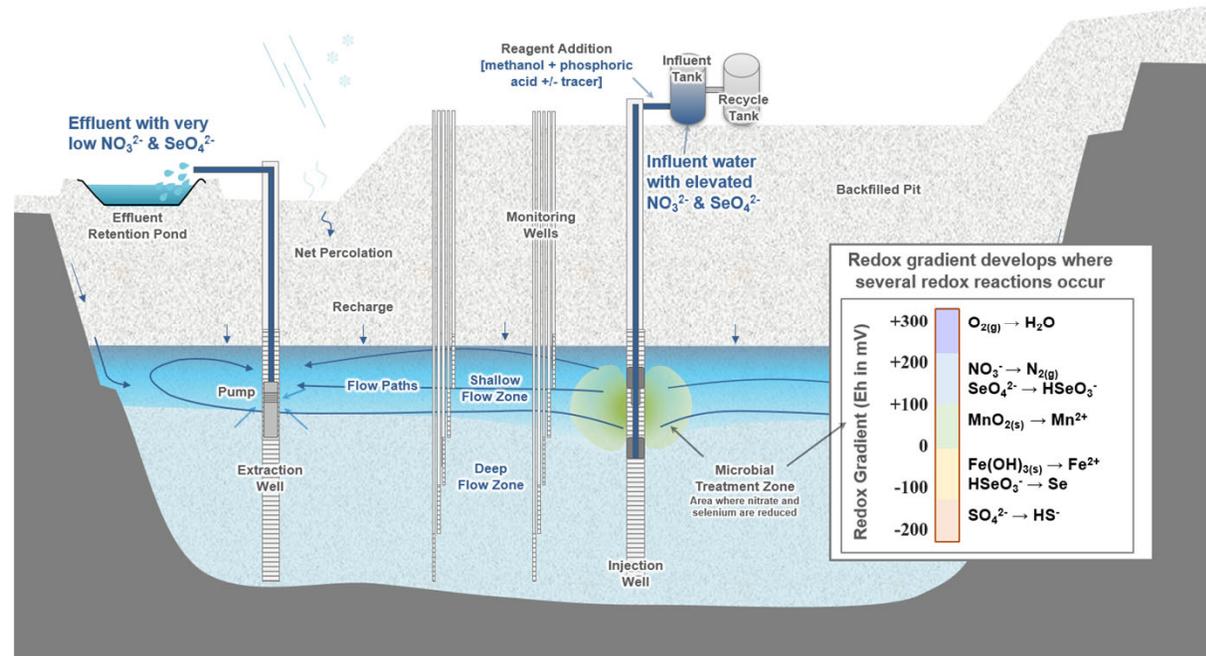


SRF expert advisory panel, subject matter experts, and technical team on a site tour at EVO SRF in 2018. From left to right: Steve Day, Marcie Schabert, Silvia Mancini, Shannon Shaw, Lisa Kirk, Len deVlaming, Seth D'Imperio, Rob Klein, Jim Hendry, Brent Peyton, Andrzej Prezpiora, Dan Mackie, Juris Harlamovs, Daryl Hockley, Lee Barbour



# Intro to SRF Biogeochemistry

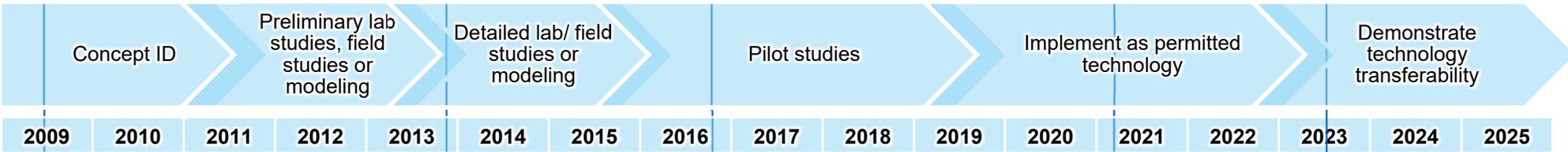
- Previously mined pits are backfilled with waste rock and filled with water from precipitation
- Treatment utilizes microbially mediated reduction reactions or bioreduction
- These reactions transform nitrate and selenium (selenate) from soluble to non-aqueous forms
- Naturally occurring bioreduction is enhanced through the addition of carbon (as methanol) and nutrients (phosphoric acid) to support a larger community of reducing microbes
- Nitrate and selenium rich influent is injected into the saturated zone with reagents; the water travels through the SRF monitoring network to extraction, and then sent to a buffer pond



# R&D SRF Technology Timeline

## Concept Identification

- Correlation of  $SO_4$  and Se in Elk Valley Waters
- Samples from backfilled pits had similar  $SO_4$  but very low Se



## Preliminary Studies

- Sampled a number of backfilled pits, conducted batch tests and identified:
- Se, Fe and  $NO_3$  reducing bacteria naturally present
  - Capable of Se and  $NO_3$  removal

## Detailed Studies

- Column studies demonstrated biological Se and  $NO_3$  removal rates in flowing systems
- Push-pull tests

## Pilot Field Test (EVO)

- 500  $m^3/d$  field test,
- 250  $ug/l$  Se and 40  $mg/l$   $NO_3$
- >90% Se and  $NO_3$  removed

## Inventory of Backfilled Pits

- Selected EVO F2 Pit:
- Small contributing watershed
  - Candidate influent water source nearby
  - Hydraulic sink & large saturated zone
  - Water level well below decant elevation

## Pilot Studies

- Detailed geochem & mineralogical characterization on in-pit WR
- Water quality monitoring of in-situ water
- Microbial characterization & continued lab program
- Hydrogeological characterization of the pit indicating large volumes of water can be conveyed
- Water balance and groundwater modelling assessment completed

## Phase 2 Expansion (EVO)

- Up to 20,000  $m^3/d$  hydraulic capacity
- Treating Erickson Creek water and Natal Pit
- >90% Se and  $NO_3$  removed

## Phase 2 (FRON)

- Pre-commissioning → Commissioning → Normal Operations (Dec 10, 2023)
- Rates between ~10,000 & 20,000  $m^3/d$ ,
- Influent from Eagle 4, Turnbull TSF, Clode and Liverpool Ponds: ~60  $ug/l$  Se and 60  $mg/l$   $NO_3$  as N
- Discharge to Clode Settling Ponds from June 2023 onwards
- >95%  $NO_3$  removed and ~87% Se removed

## Phase 1 (FRON)

- Pre-commissioning
- Rates to balance recharge averaging between 2500 and 4500  $m^3/d$ ,
- Eagle 4 in-situ influent: variable Se from ~20 to 80  $ug/l$  Se and initially 250  $mg/l$   $NO_3$  as N but decreasing
- Developed biomass around all IWs in preparation for Phase 2

# Key Aspects

## Elkview (EVO)



## Fording River North (FRO-N)



<b>Catchment Size</b>	0.8 km <sup>2</sup>	2.4 km <sup>2</sup>
<b>Waste Rock</b>	18 million BCM, backfilling began in 1990s	300 million BCM, backfilling began in 2010s
<b>Pit Geometry</b>	Ovoid shape (~900 m x 700 m)	Long & narrow (~1.5 km x 200 m)
<b>Total Volume of Saturated Zone</b>	20.5 million m <sup>3</sup>	7.3 million m <sup>3</sup>
<b>Pre Start-Up Nitrate Concentration</b>	<1 mg/L as N	~200 mg/L as N
<b>Pre Start-Up Selenium Concentration</b>	~10 µg/L	~40 µg/L
<b>Start-Up Date</b>	January 2018	January 2022

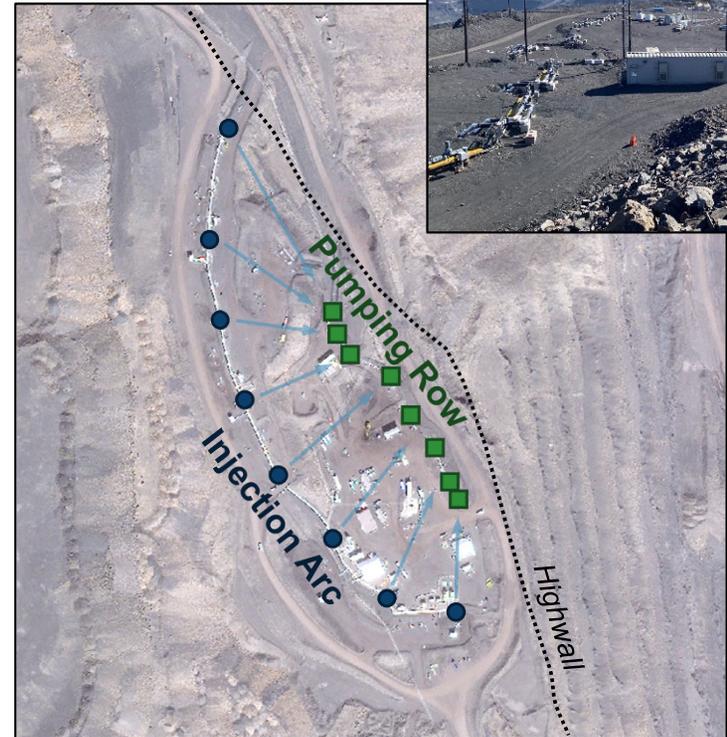
# SRF Wellfield Layouts



Elkview (EVO)

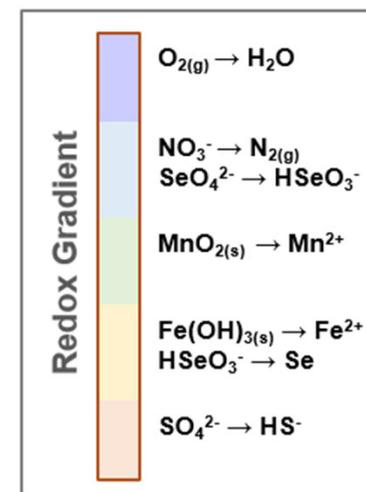


Fording River North (FRO-N)



# Data Presentation

- Data presented is focused on the middle portion of each wellfield and water in the shallow flow zone
- Time period for data used is from the start of FRO-N P2 Operations (Dec 10, 2023) to Sept 10, 2025 (for both SRFs)
- Most slides use box & whisker plots to show the results for each SRF grouped by area:
  - Influent: injected water to be treated
  - Near Injection: nearest injection wells, within 20 m of injection
  - Mid Wellfield: at EVO ~ 35 m from injection and ~ 30-75 m for FRO-N
  - Near Extraction: ~ 75 m for EVO and ~ 100-110 m for FRO-N
  - Extraction: Pumping wells in the area of focus
  - Buffer Pond (In and Out): combined effluent in forward flow
  - Mean residence time through EVO is ~ 11-53 days and ~ 7-10 days through FRO-N

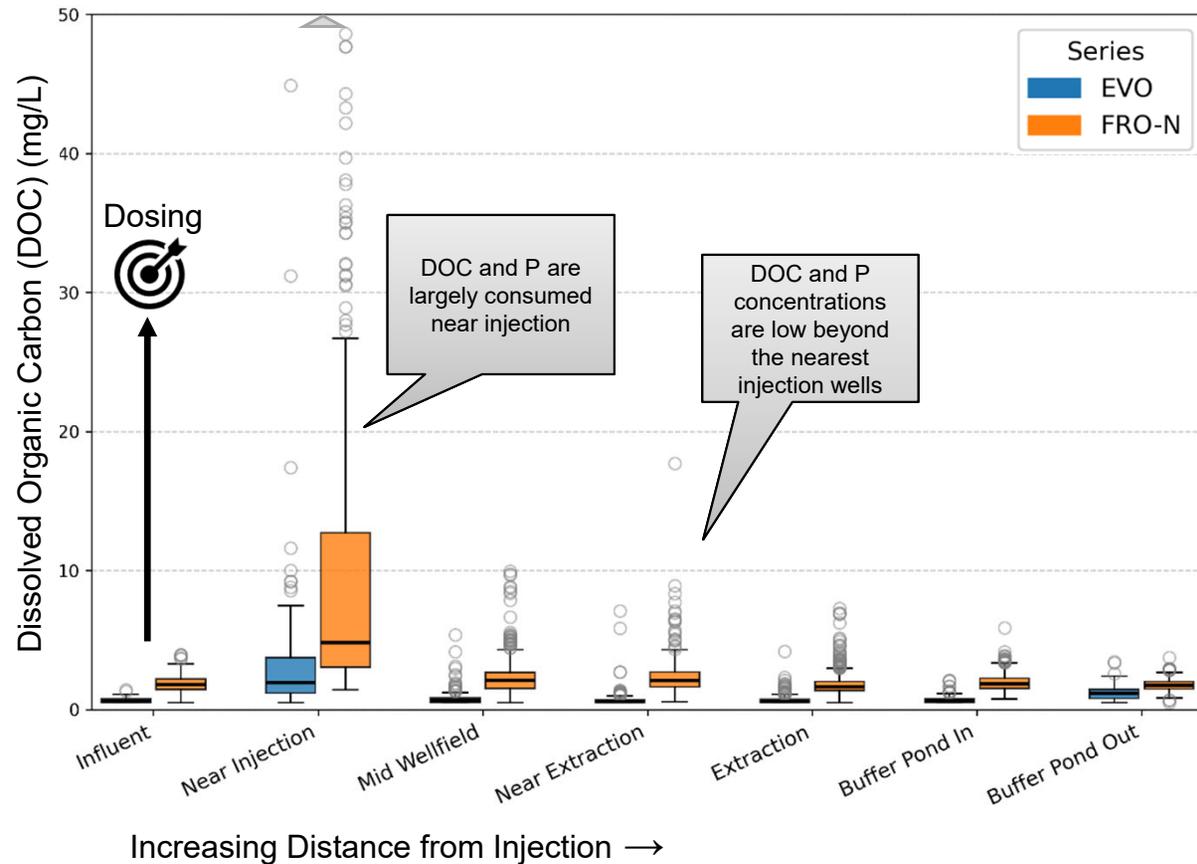




# Monitoring Results

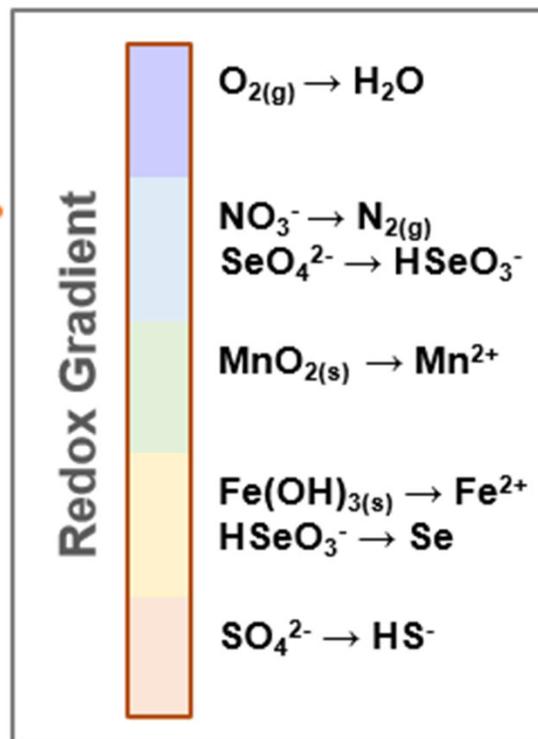
# Carbon & Phosphorous

- Carbon (DOC) and Phosphorous (P) are dosed in influent water to support biomass growth and respiration
- Initial dosing was determined experimentally and adjusted operationally
- Dosing is based on the influent nitrate concentration (COD:N)
- Both reagents are pulsed
- DOC and/or P persisting beyond the near injection “biomass zone” is not beneficial after nitrate and selenium have been removed



# Redox Ladder

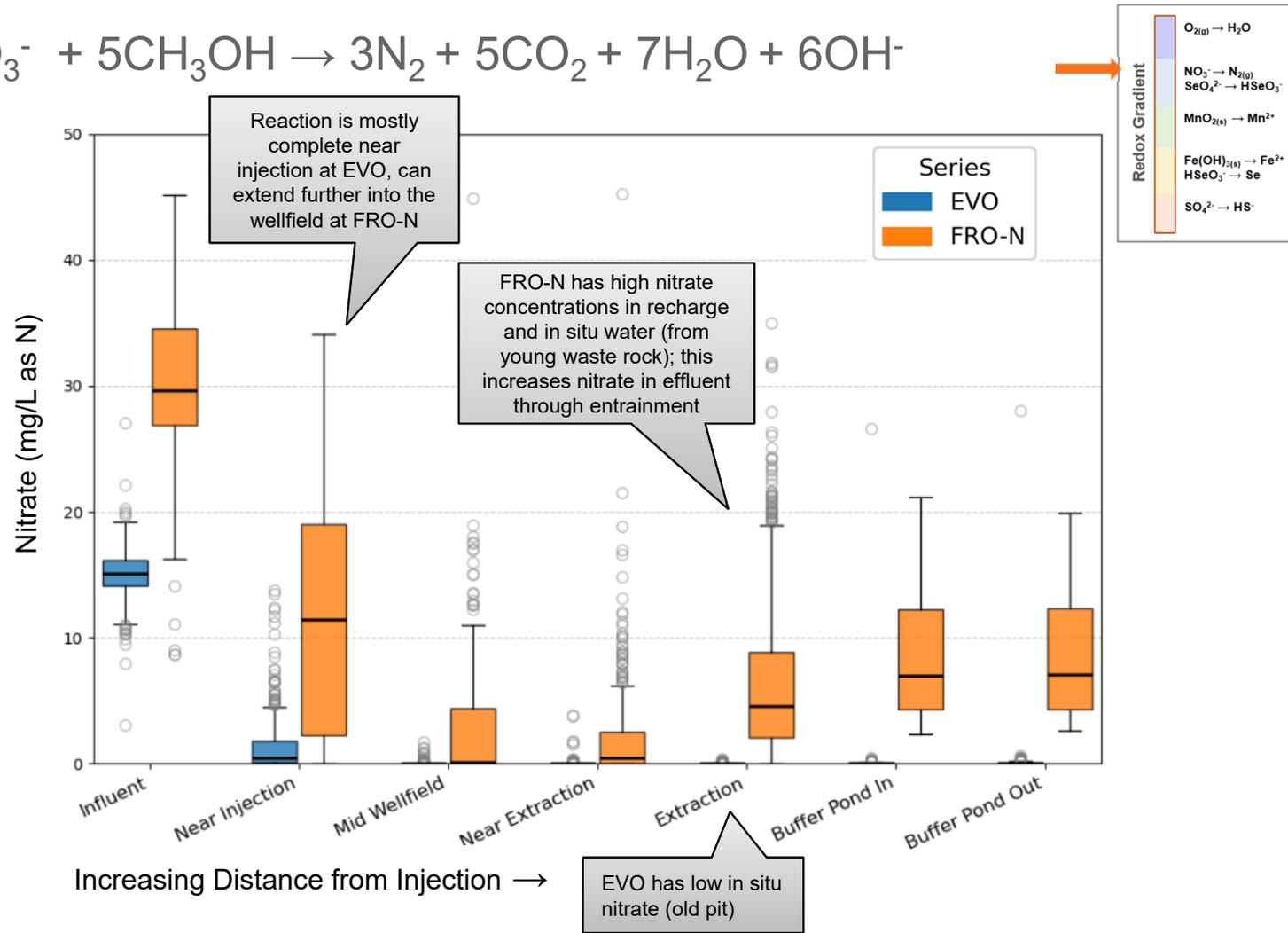
- Next group of slides will step down the redox ladder focusing on each electron acceptor
- Nitrate, selenium and sulphate are present in the influent water; manganese and iron are present in the backfilled waste rock mineral phases



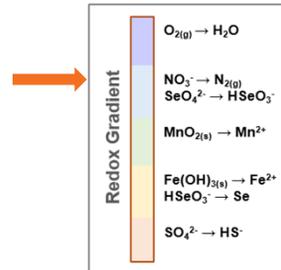
# Nitrate



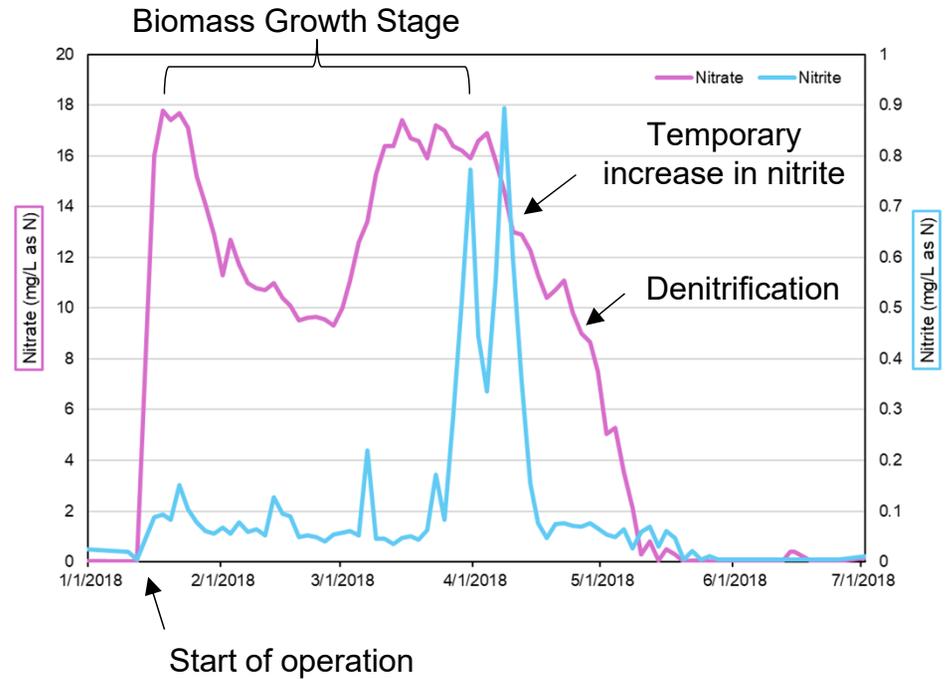
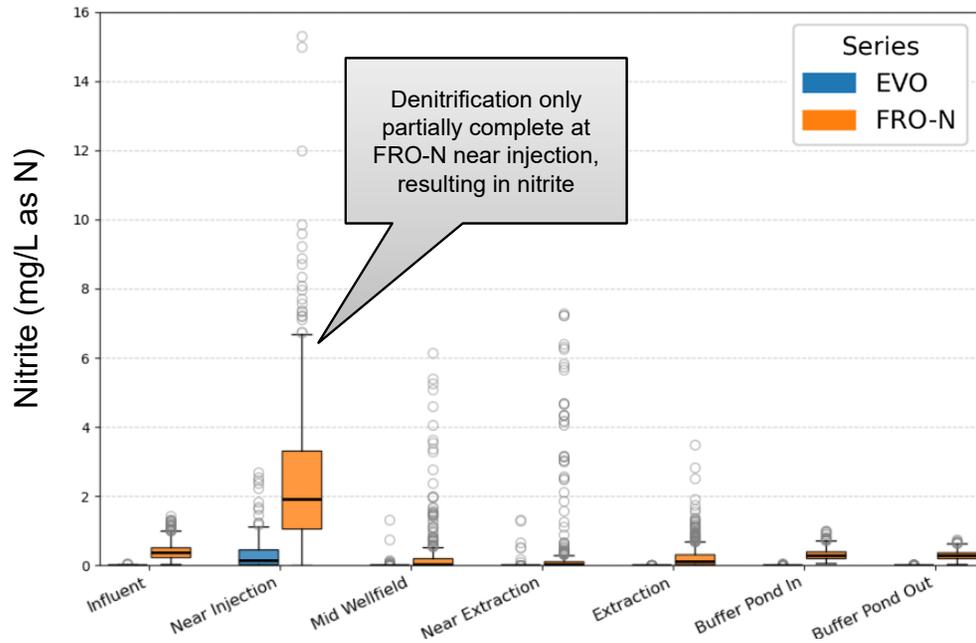
- Influent nitrate is treated through denitrification
- Supported by isotopic data and literature
- Nitrate loads removed typically >300 kg/d
- FRO-N at times is >500 kg/d



# Nitrite



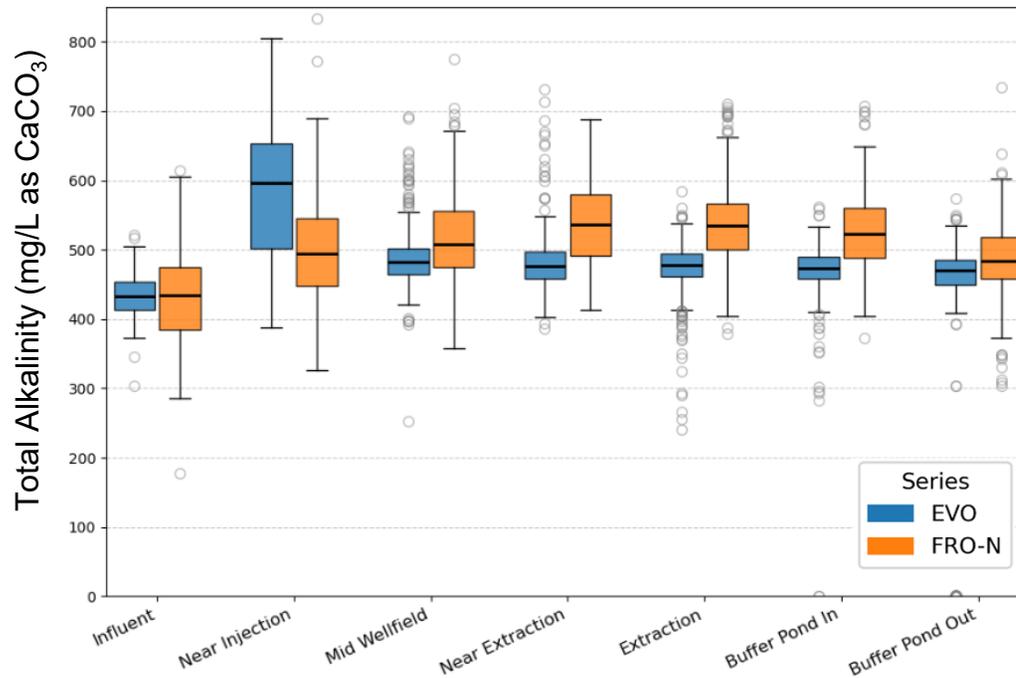
- Nitrite is a useful indicator of the onset of denitrification and can be elevated before denitrifying bacteria are fully established
- Also see nitrite when denitrification is incomplete e.g. if carbon is too low and can indicate system perturbations



# Alkalinity



- Alkalinity in the backfilled pits is ~300 to 800 mg/L as  $\text{CaCO}_3$
- Denitrification also adds alkalinity (3.57 mg as  $\text{CaCO}_3$  per mg of  $\text{NO}_3^-$  (as N) reduced)
- Saturated conditions keep  $\text{pCO}_2$  elevated, suppressing calcite precipitation until effluent can off-gas

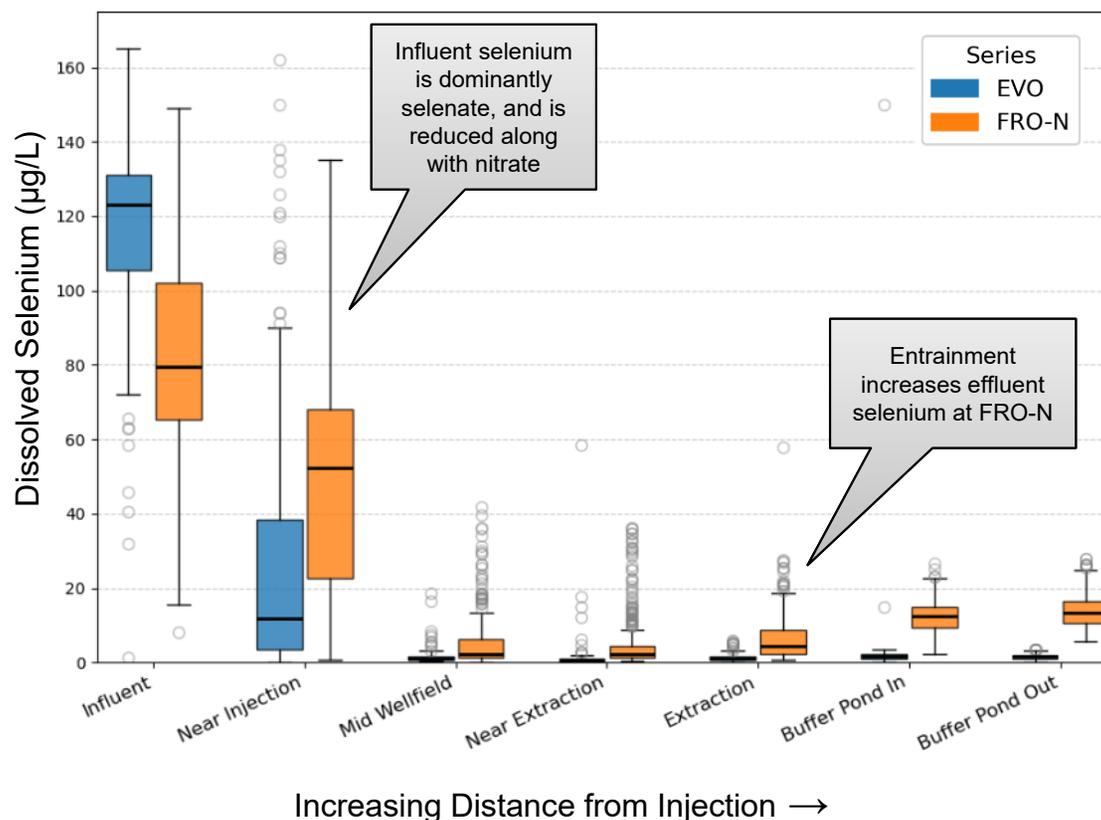
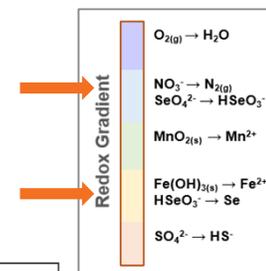


Increasing Distance from Injection →

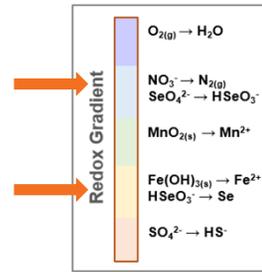
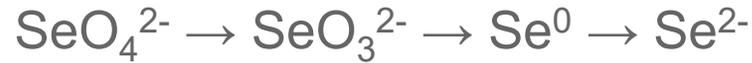
# Selenium



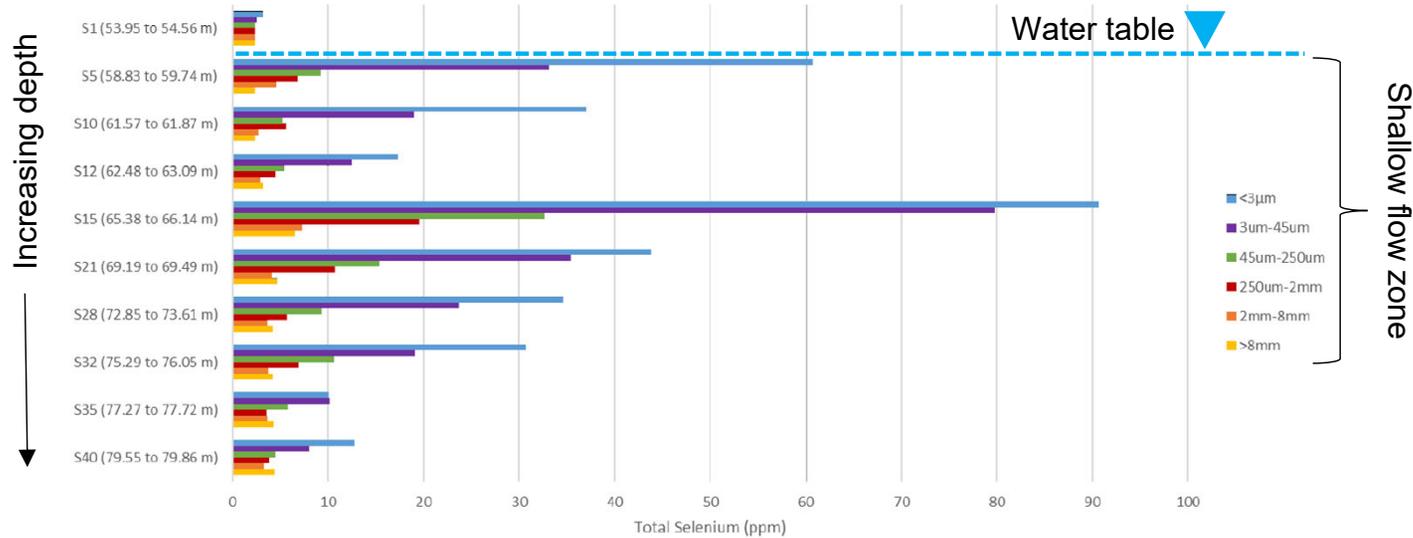
- Reduction from selenate to selenite ( $\text{SeO}_3^{2-}$ ) occurs in similar REDOX conditions to denitrification
  - Selenite is more likely to adsorb to material in the SRF (e.g., ferrihydrite)
- At lower redox, selenite can be further reduced to:
  - Insoluble elemental selenium ( $\text{Se}^0$ ) and selenide ( $\text{Se}^{2-}$ )
- Selenium loads removed are typically >1 kg/d
  - EVO at times is >2.5 kg/d



# Selenium



- Solid samples retrieved from ~5m lateral distance from injection at EVO indicated selenium attenuation occurs in the smallest size fractions within the shallow flow zone



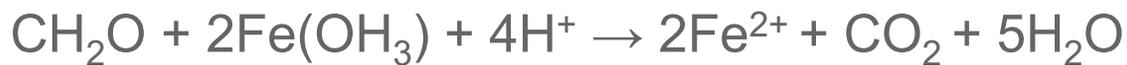
- XANEs analyses on the smaller size fractions identified selenium attenuated as selenite adsorbed to ferrihydrite and zero-valent selenium best represented by the selenium sulfide ( $\text{Se}_n\text{S}_{8-n}$ )

# Selenium Species

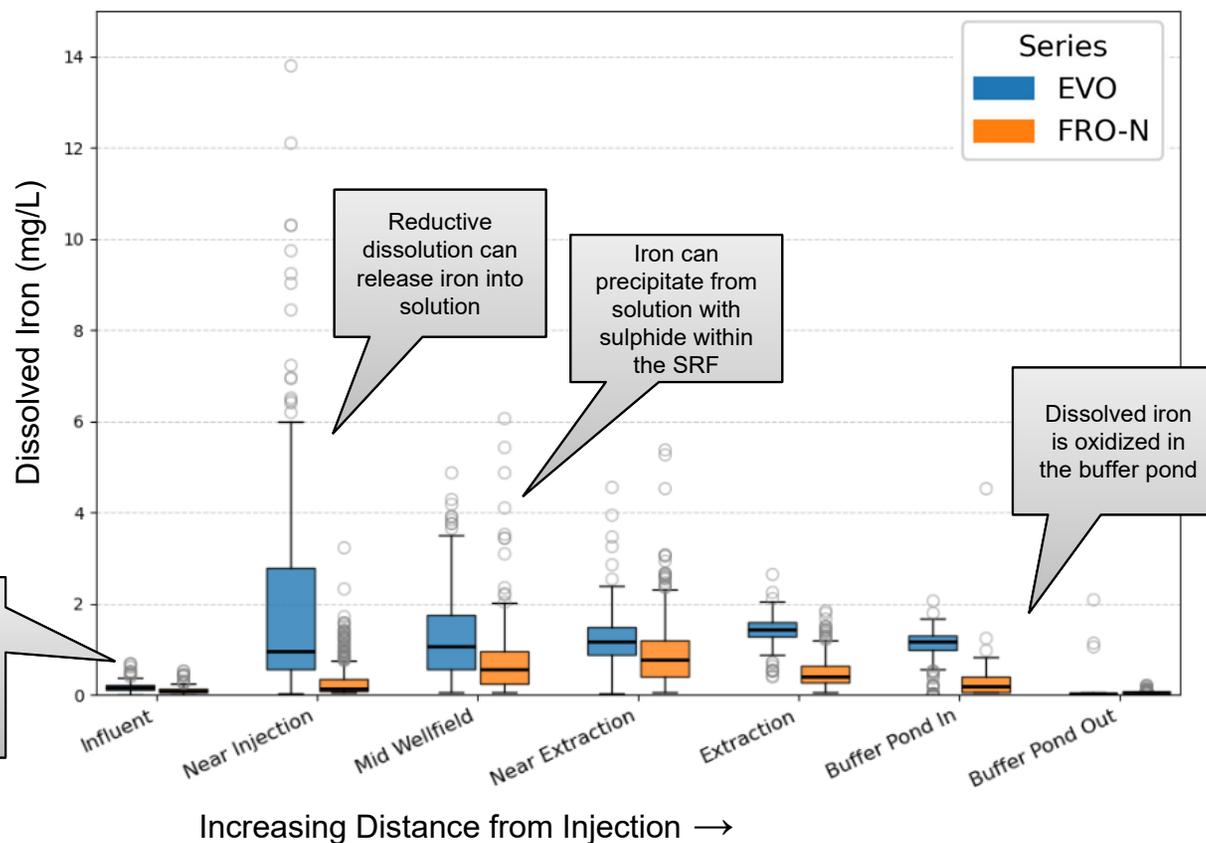


- Selenium in the influent is dominantly as selenate with minor selenite
- It's expected that some organo-selenium species are generated within the biomass and therefore organo-selenium species are occasionally detected in monitoring wells:
  - Concentrations of all organo-selenium species are generally low, often below DLs
  - Near injection, the occasional detection of methylseleninic acid ( $\text{CH}_3\text{SeO}_2\text{H}$ ), selenocyanate ( $\text{SeCN}$ ) and selenosulfate ( $\text{SeSO}_3$ ) are seen.
  - As water moves away from the biomass, concentrations of the above organo-selenium species decrease; and occasional detection of dimethylseleneoxide ( $(\text{CH}_3)_2\text{SeO}$ ) is observed.
  - In effluent, there is sometimes concentrations above detection for dimethylseleneoxide, methylseleninic acid and selenocyanate; concentrations in the SRF effluent are below values observed in similar tank-based systems.

# Iron



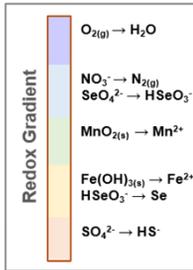
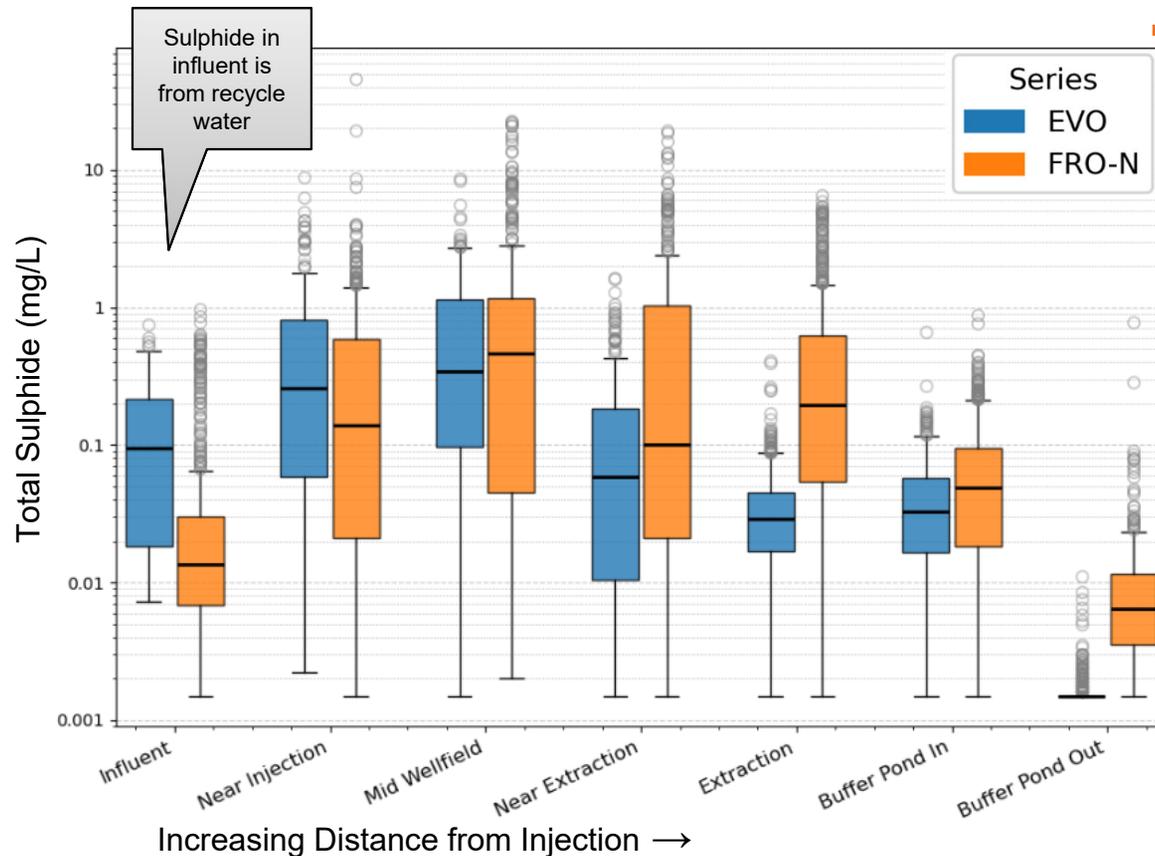
- Iron in the SRF system is not from influent water, but from the presence of iron minerals in the backfilled waste rock
- In the absence of nitrate, iron acts as a redox buffer



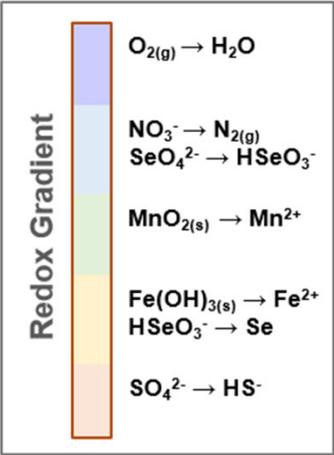
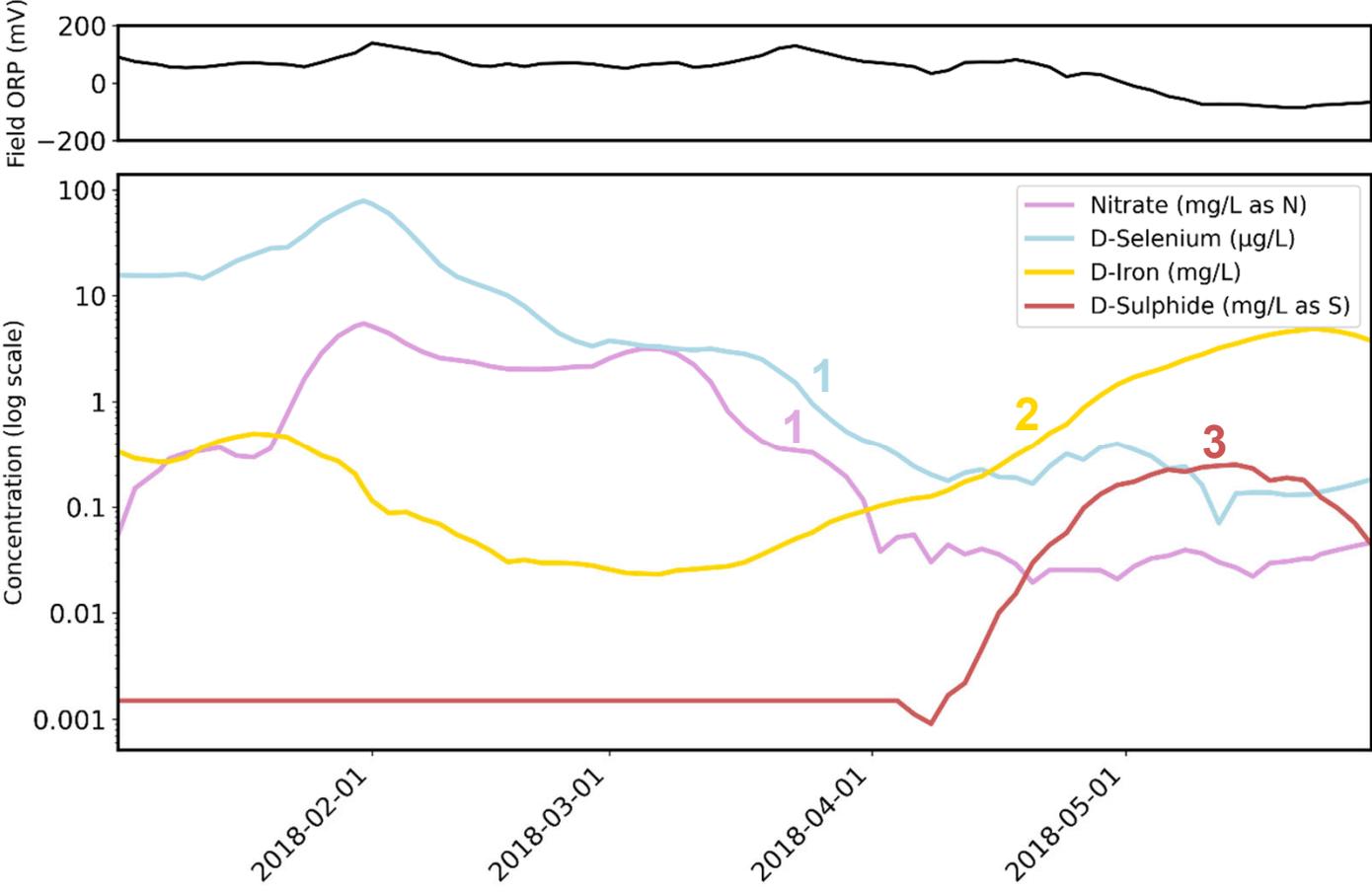
# Sulphate/Sulphide



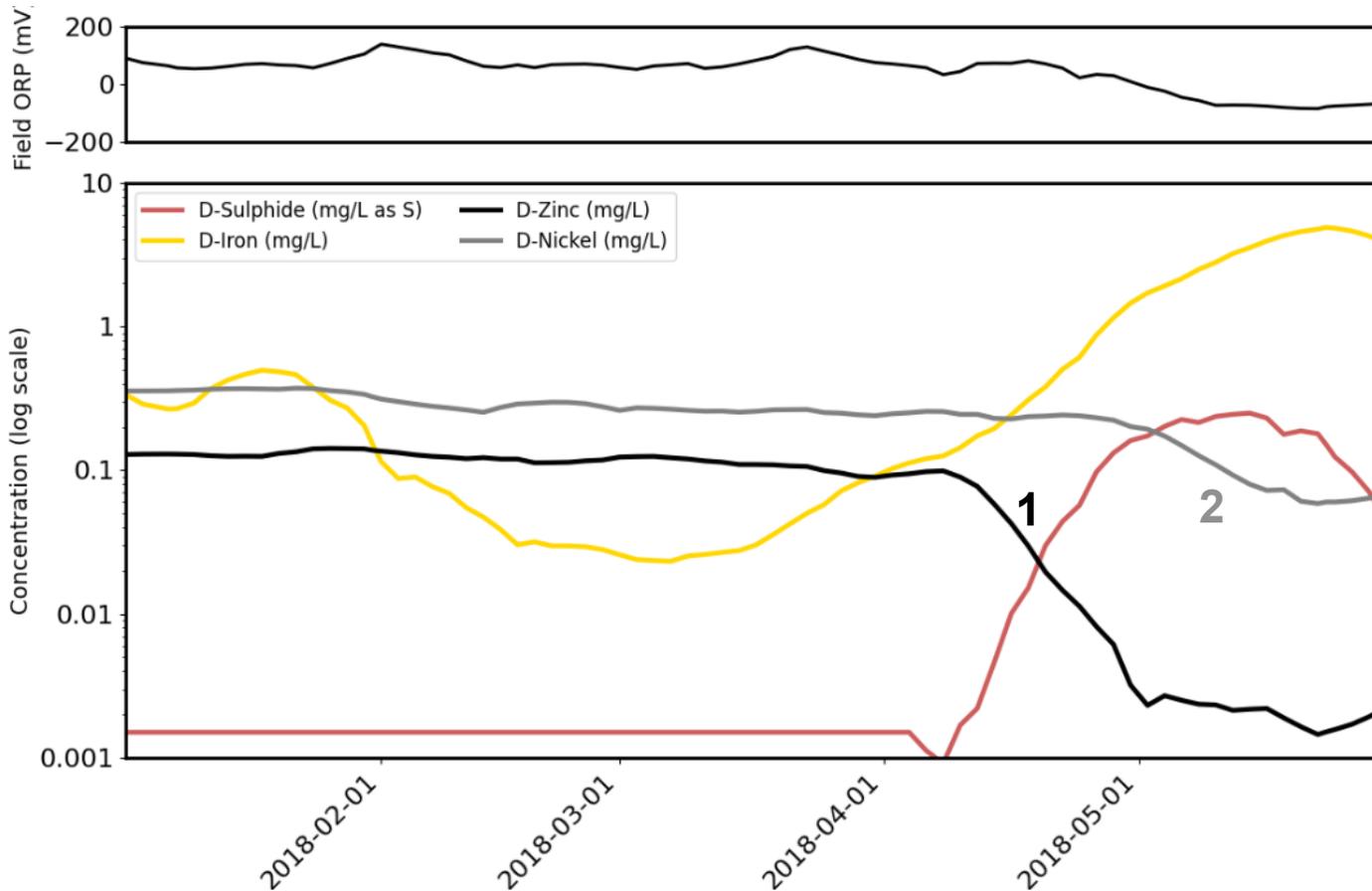
- Influent has elevated sulphate but is generally low in sulphide except during times of recycling of sulphide-bearing effluent
- Sulphate reduction occurs in the biomass zone
- Sulphide is expected to largely precipitate out of solution, co-precipitating cations with it (e.g., Fe, Cd, Zn, Ni)



# Overall REDOX Sequence

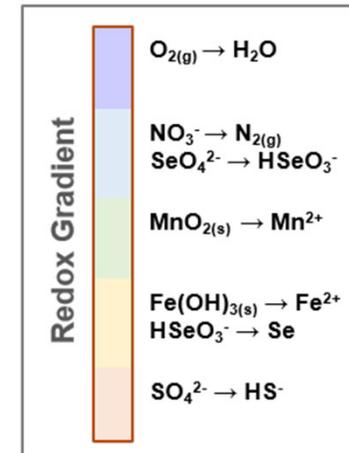


# Overall REDOX Sequence & Trace Metals



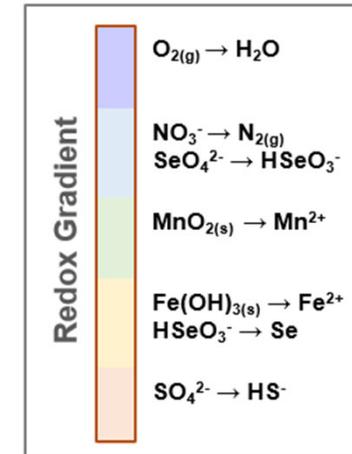
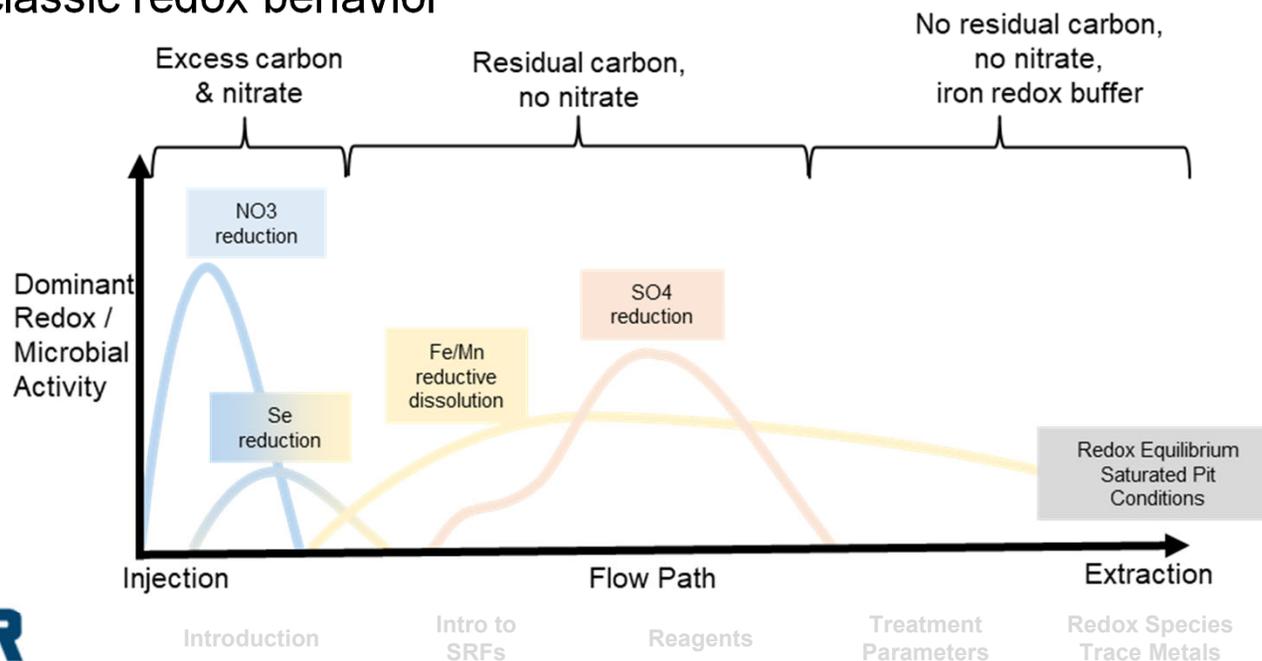
• As sulphide increases, see a decrease in:

1. Cadmium & Zinc
2. Nickel & Cobalt



# Conclusions

- The SRF technology has been demonstrated at two full scale facilities in the Elk Valley
- The two facilities have a number of differences, but the biogeochemical processes remain consistent
- The observed water chemistry, corroborated by mineralogical analyses, demonstrates classic redox behavior



Thank You

