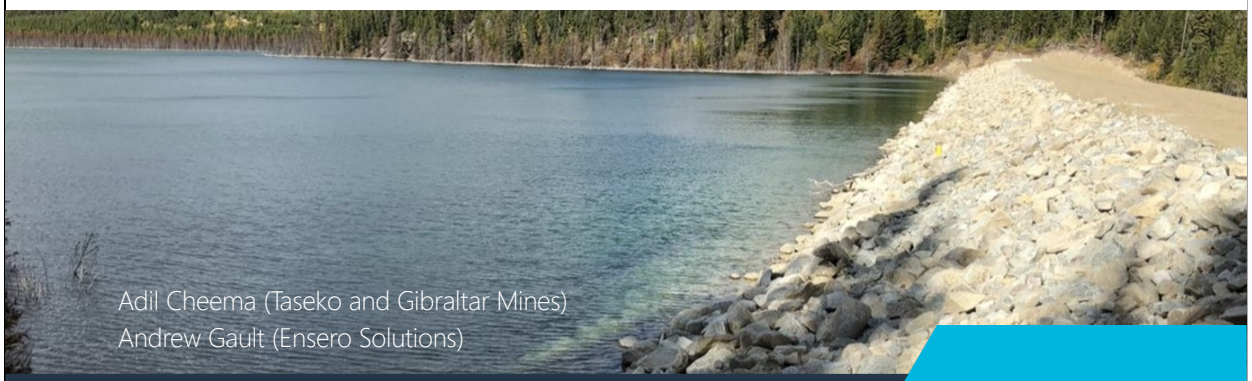
Development and Implementation of In-Situ Denitrification Treatment in Gibraltar Mines TSF



Adil Cheema (Taseko and Gibraltar Mines)
Andrew Gault (Ensero Solutions)

ENSERO solutions

Taseko

Adil

Agenda

- Site / Project Background
- Treatment Options Assessment
- Pilot-Scale Trials
- Treatment Planning and Design
- Treatment Implementation & Monitoring
- Results

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Gibraltar Mine

- Mine:
  - 5 open pits (Gibraltar, Pollyanna, Granite, Connector, Extension)
  - Conventional mining method - drill, blast, shovel, haul
- Processing Plants:
  - 2 parallel concentrators, Moly & SX/EW plant
  - 85,000 tpd processing capacity
- Tailings Storage Facility (TSF) / Reclaim Water:
  - Tailings supernatant reclaimed for reuse in processing plants
  - Comprehensive water management infrastructure containing a network of pipelines, containment ditches, ponds, pit lakes
  - Surplus water balance
    - Permitted for seasonal off-site discharge at a prescribed water quality

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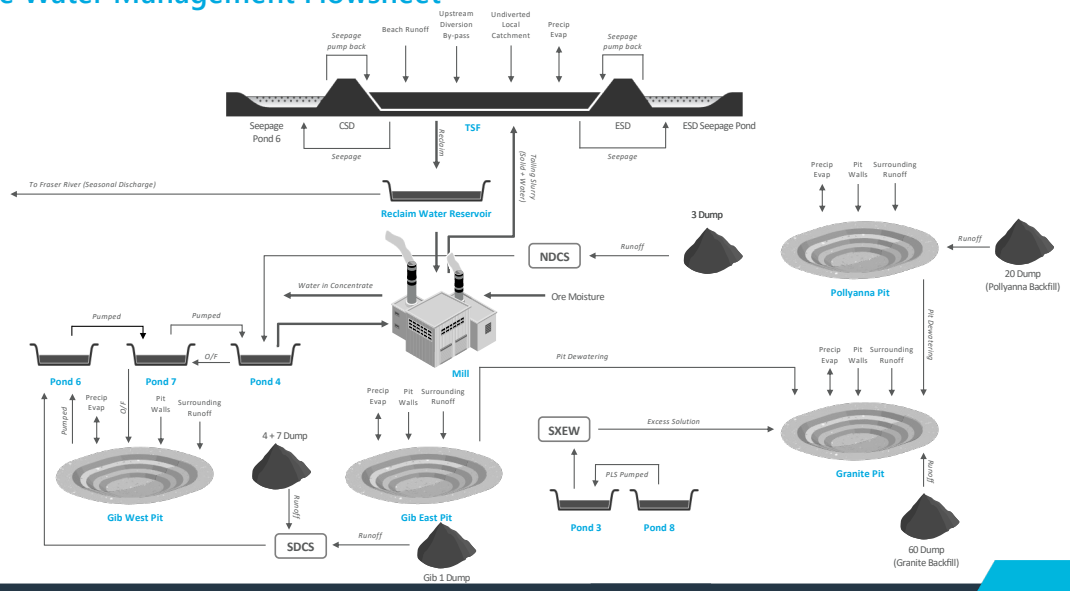
Site Water Management Flowsheet



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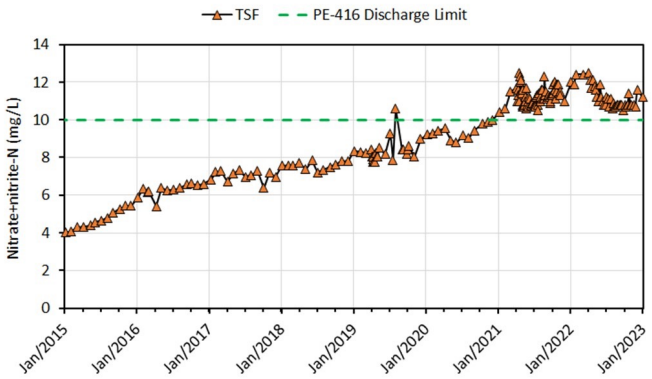
Elevated Nitrate + Nitrite

- Permitted to discharge water from TSF to Fraser River subject to discharge standards
- Rising nitrate+nitrite-N concentrations in TSF
  - Discharge prevented by nitrate+nitrite-N concentrations above 10 mg/L limit
- Site water balance temporarily maintained through utilization of Granite pit
- Site wide nitrogen sampling program conducted in 2021
  - Identified SDCS as highest source; diverted to Granite pit
  - Trialed change in bulk explosive product
    - resulted in more efficient combustion and reduced nitrate seepage potential
- Ensero engaged to develop treatment options assessment in 2021



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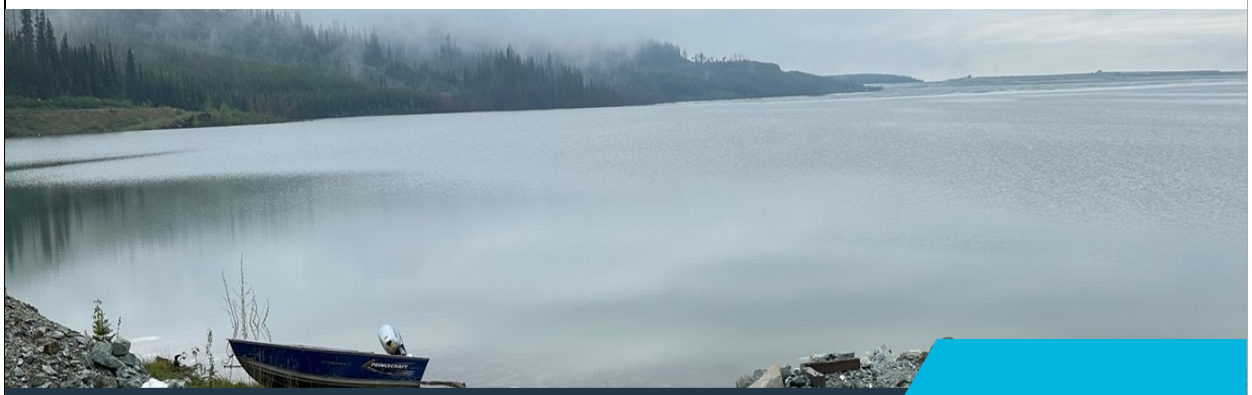
Phase 1: Treatment Options Assessment

Finding the Solution



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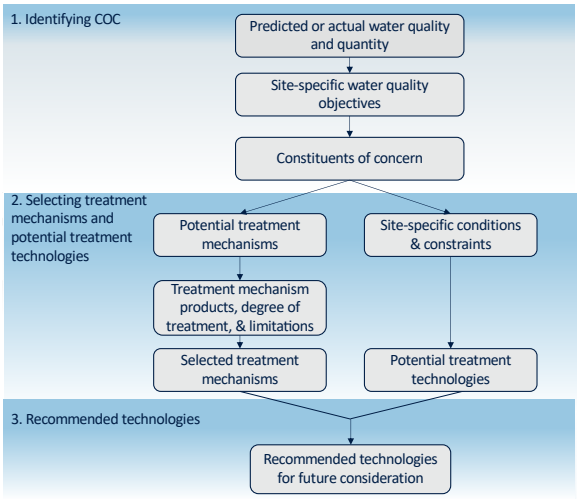
Phase 1: Treatment Options Assessment Process



- TSF water quality data reviewed against discharge criteria
  - Nitrate+nitrite-N remained the primary constituent requiring treatment
- Short-term treatment options identified and ranked based on a set if criteria which included:
  - HSE, Waste Generation, Implementation Schedule, Required Infrastructure, Footprint, Volume, Complexity, Commercial Maturity, Economics
- Treatment options considered included:
  - RO, IX, BCR, In-situ removal by phytoplankton growth, In-Situ microbial denitrification
- In-situ microbial denitrification advanced as preferred option
  - Doesn't generate waste by-product
  - Requires minimal (temporary) infrastructure
  - Singular batch treatment treating entire TSF volume
  - Most cost and schedule effective

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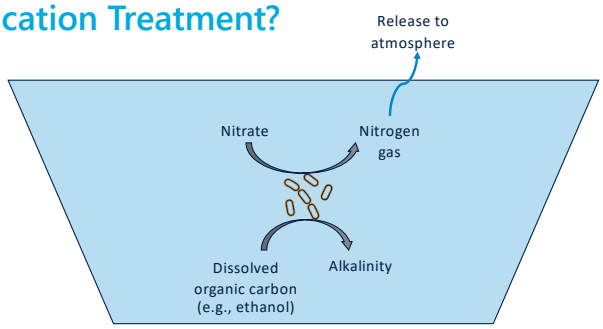
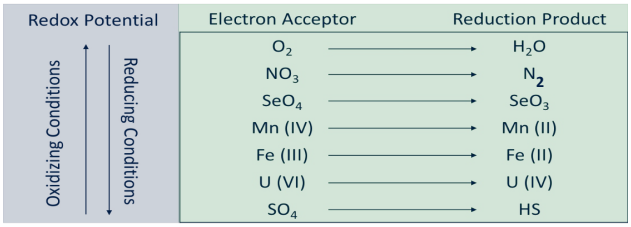
What is In-Situ Microbial Denitrification Treatment?

- Harness naturally occurring bacteria in lake to remove nitrogen species
  - Provide "food" for bacteria – organic carbon (e.g., ethanol)
- Denitrifying bacteria convert nitrate to nitrogen gas per redox ladder
  - Oxygen first, then nitrate
  - Organic carbon partially turned into alkalinity
- Biological denitrification commonly used in municipal and drinking water treatment plants for decades
- Successfully applied in-situ treatment at mines in other jurisdictions (e.g., Sweetwater, WY; Barite Hill, SC; Anchor Hill, SD)





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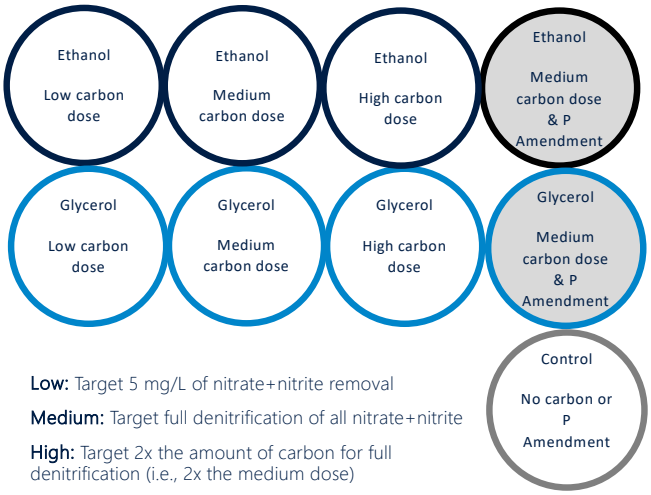
Phase 2: Pilot-Scale Trials

Treatability Testing

Andrew

Pilot-Scale Tests

Experimental set-up



Low: Target 5 mg/L of nitrate+nitrite removal

Medium: Target full denitrification of all nitrate+nitrite

High: Target 2x the amount of carbon for full denitrification (i.e., 2x the medium dose)

Trials conducted at 10°C

ENSERO solutions Taseko

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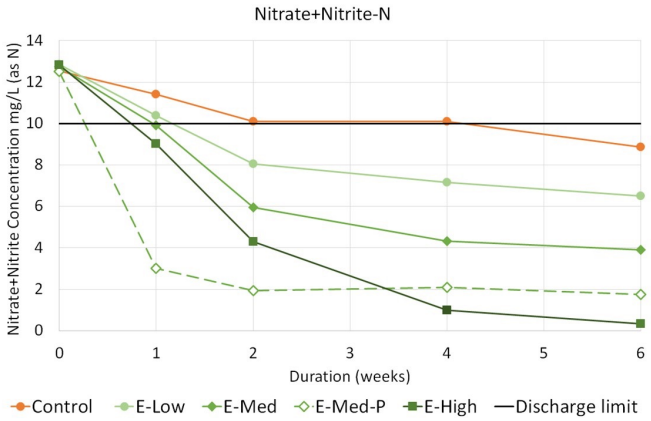
Pilot-Scale Tests

Results – Nitrate+Nitrite

- Results for Ethanol-dosed trials
  - Nitrate+nitrite below discharge limit within 1-2 weeks
  - Extent of treatment corresponded to carbon dose
  - Treatment faster in phosphorus-dosed trials
- Similar results observed for glycerol
- Treatment of nitrate mainly through denitrification and not interconversion between nitrogen species which could regenerate nitrate later

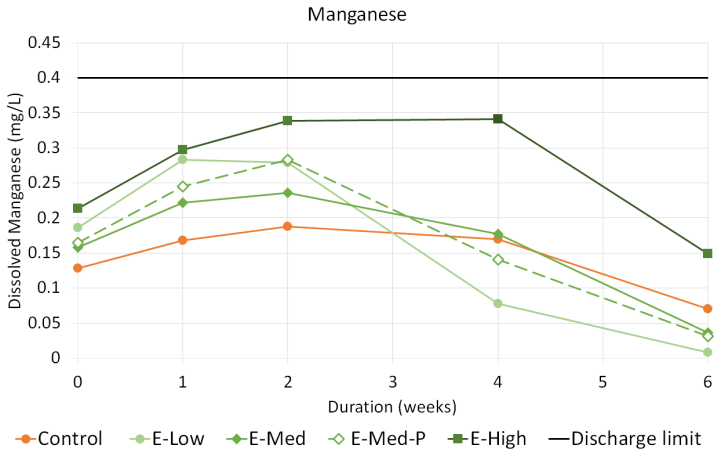


Andrew

Pilot-Scale Tests

Results – Manganese

- Manganese leaching was a potential concern prior to pilot
  - Sits close to denitrification process in redox ladder
- Dissolved manganese initially leached from tailings but remained below the discharge limit
  - Week 6 – declined to conc at start of trial (or lower)
- Pilot setup has much higher tailings to water ratio than in TSF
  - Conservative approach to evaluate risk of manganese leaching from tailings
- Overall, data suggest adverse manganese leaching is not anticipated



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Phase 3: Treatment Planning and Design

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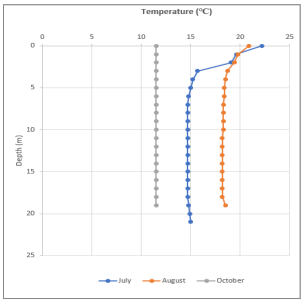
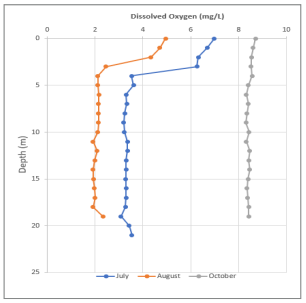
Site Execution Planning

- Additional site characterization
  - Thermocline and oxygen chemocline develops in summer
  - No difference in nitrate concentrations across water column
  - Thermocline breaks down in late fall with re-oxygenation of water column
- Microbial analysis
  - Nitrate-reducing microbes made up significant portion of microbial community (10-34%) in water column
- Develop site execution plan for full scale implementation
  - Calculate ethanol dosing for TSF
  - Develop application strategy and design injection system
  - Process engineering design drawings (PFD, P&ID, General Arrangement, Containment Area, Grounding Design etc.)
  - Collect additional baseline data





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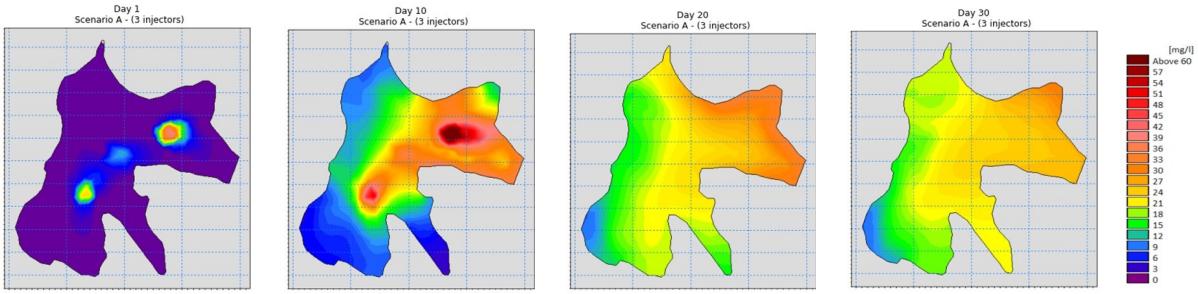
Mixing Modelling

- Three-dimensional model of ethanol mixing in TSF created using MIKE3 FM platform
- Modelled ethanol addition over 10 days at three locations
  - Delivered 10 m beneath water surface (below thermocline)
  - Mixing largely driven by currents created by mill intake and tailings deposition
  - Ignores lake turnover, which would enhance mixing
- Good mixing throughout TSF observed within 20 days of end of ethanol addition (i.e., day 30)



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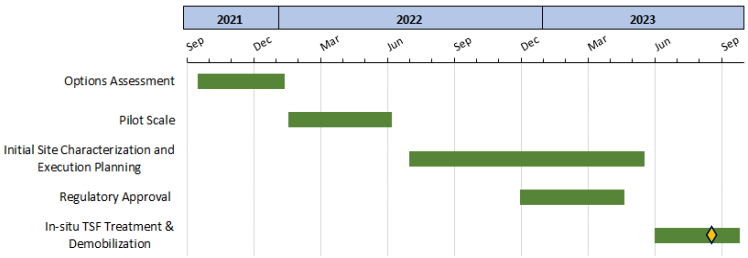
Regulatory/Indigenous Engagement and Approvals

- Proposed treatment approach and design presented over several technical advisory committee meetings
  - Indigenous Communities, Regulators (BC ENV, EMLI) and local stakeholders
  - Went through formal Q & A process during Q1 of 2023
  - Permit Amendments issued to proceed with treatment in April 2023
  - Finalized Treatment plan by end of May 2023
  - Proceeded with treatment implementation in June 2023



Adil – to hand over to Andrew following this slide

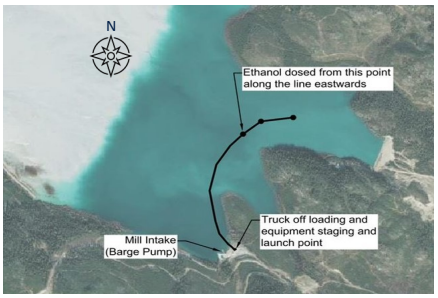
~20 months from start of treatment option assessment to treatment implementation -

Phase 4: Treatment Implementation and Monitoring

Andrew

Carbon Amendment

- 603 m^3 of ethanol was added to TSF across 8 days
  - June 8 – 16, 2023
- The pictured staging area hosts the ethanol storage tank, pump, containment berm
- HDPE ethanol distribution line
  - Coiled HDPE pipes were straightened, and sections of pipes were fused on the shore before being pulled onto the TSF pond.
  - HDPE pipe fitted with floats spaced approximately 150 m apart, anchored every 375 m
  - Service leak test of the distribution line conducted prior to ethanol addition
- Ethanol added sequentially at three injection locations at 10-15 m below water surface, beginning with the farthest (also deepest) injection point.



Andrew

Gibraltar TSF In-Situ Treatment

Pictures

Andrew

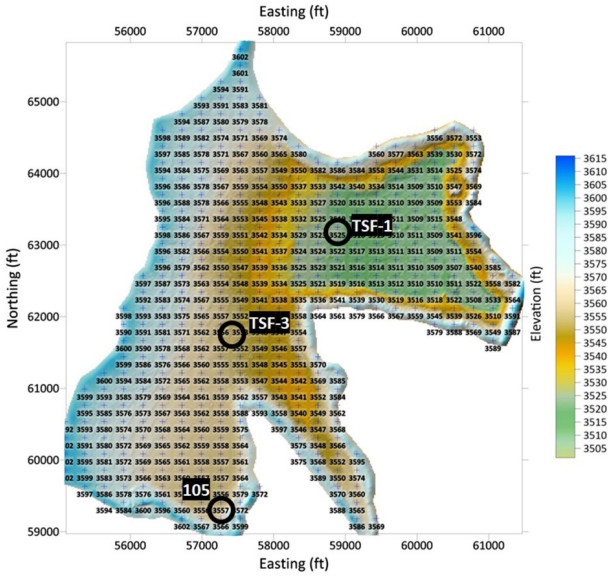
Gibraltar TSF In-Situ Treatment

Pictures

Andrew

Monitoring and Sampling

- Samples collected at two TSF locations & barge pump (station 105)
  - Surface, mid depth, and bottom waters
- Sample collection:
  - Baseline one week prior to ethanol addition
  - During ethanol addition
  - Weekly following end of ethanol for 2 months
- Field analysis
  - pH, DO, temperature, conductivity
- Lab analysis
  - Major anions (SO_4, NO_3, NO_2, Cl), alkalinity
  - Ammonia, dissolved organic carbon
  - Total and dissolved metals
- Microbial sampling of water column prior to and following ethanol addition



Andrew

In-Situ Monitoring

- Monitoring barges were also deployed at two TSF locations
  - Sondes suspended from barges at surface, mid depth, and bottom waters based on thermocline
- Collect real time (~hourly) data for:
  - pH, temperature, DO, ORP, conductivity
  - Nitrate

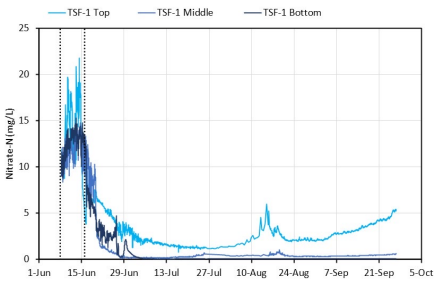
Andrew

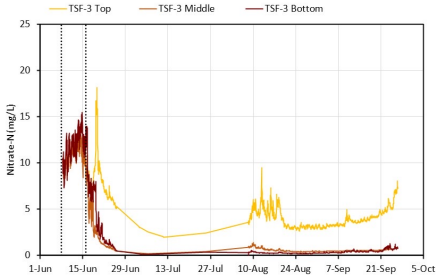
Phase 5: Results

Andrew

In-Situ Monitoring Results

- Rapid response – nitrate-N concentrations declined markedly within 2 weeks of end of ethanol addition
- Stabilized thereafter, with small increase in September as nitrite oxidized to nitrate due to TSF re-oxygenation





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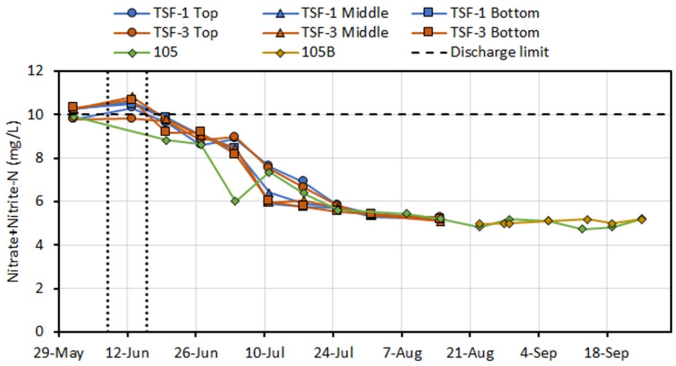
Sampling Results – Nitrate+Nitrite-N

- Treatment achieved within 2 months of ethanol addition
- Nitrate+nitrite-N concentrations stabilized ~5 mg/L
  - Consistent with partial denitrification target
- Passed multiple rainbow trout toxicity tests
- Discharge to Fraser River initiated Aug 18 (station 105B)



Vertical dashed lines indicate start and end of ethanol addition

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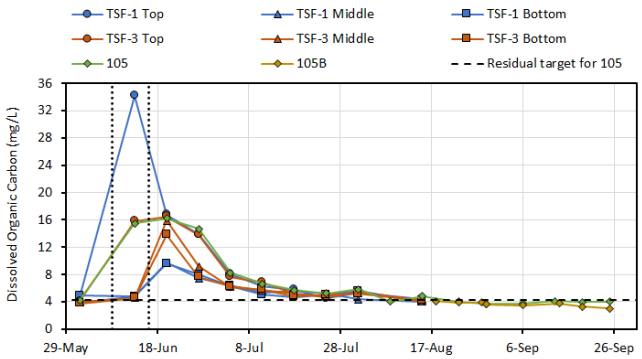
Results – Dissolved Organic Carbon

- Baseline concentrations prior to ethanol addition (3.7 to 4.9 mg/L)
- DOC consumption complete (i.e., baseline concentrations met) ~2 months after ethanol addition
  - Met DOC residual threshold required as part of amended BC ENV permit



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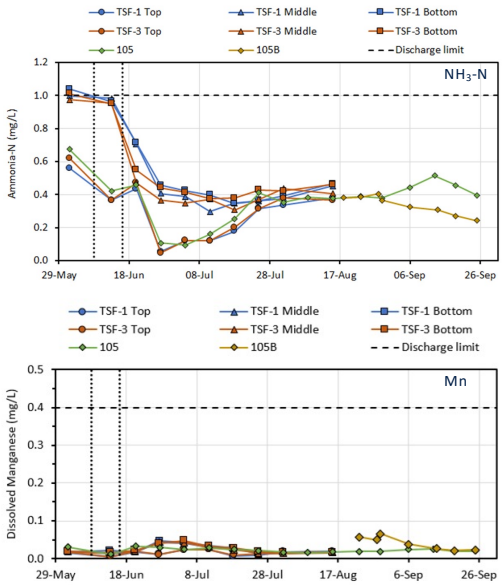
Results – Ammonia, Manganese

Ammonia

- Concentration decreased after ethanol addition
- Likely some biological uptake
- Shows nitrate decrease not due to conversion to ammonia

Manganese

- Small amount of release observed in bottom waters
- Order of magnitude below discharge standard



Andrew: to hand back over to Adil for Final slide

Conclusions

- In-situ denitrification treatment successful!
- Within 2 months of ethanol addition:
  - Targeted partial denitrification achieved and nitrate+nitrite concentration stabilized
  - Ethanol fully consumed with DOC levels returning to baseline level
  - No generation of ammonia or soluble manganese
  - Passed multiple rainbow trout toxicity tests
- No treatment waste products generated
- Allowed restart of TSF discharge to Fraser River on Aug. 18, 2023
- With implementation of nitrogen management at site, TSF water quality expected to meet discharge standards in 2024+

Adil

Note: Discharged ~827,557 m^3 in 2023

Questions?

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