

Hydrogeochemical Characterization to Evaluate the Potential for *In Situ* Selenium Reduction



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Background

- Characterization program conducted at Teck Coal Fording River Operations in British Columbia
- Scope of work included:
 - Geophysics transects
 - Installation of nested groundwater monitoring wells
 - Hydraulic conductivity tests
 - Monitoring and sampling of groundwater and surface water





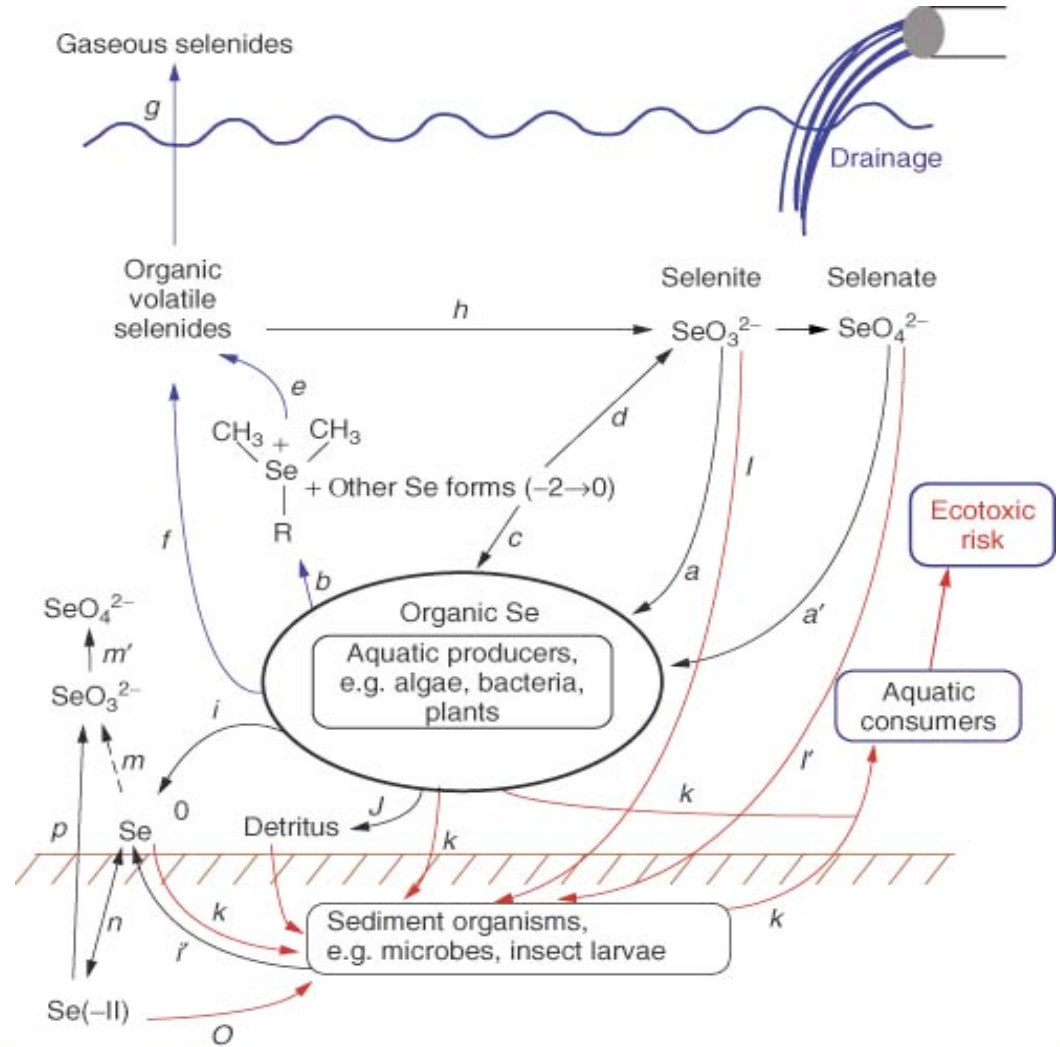
Selenium

- Present in both inorganic and organic forms
- Solid, liquid and gas phases
- Is an essential nutrient and is also a contaminant at higher concentrations
- Selenium distribution and chemistry is complex and driven by redox conditions, biological activity, pH and sorption
- DO and nitrate must be removed before significant selenium reduction can occur
- **CCME guideline for selenium is 0.001 mg/L**

Selenium Chemistry

- 4 primary oxidation states
 - +6 selenate (SeO_4^{2-})
 - +4 selenite (HSeO_3^- and SeO_3^{2-})
 - elemental selenium Se_0
 - -2 selenide Se^{-2}

- Driven by
 - Redox conditions
 - Biological activity
 - Sorption processes

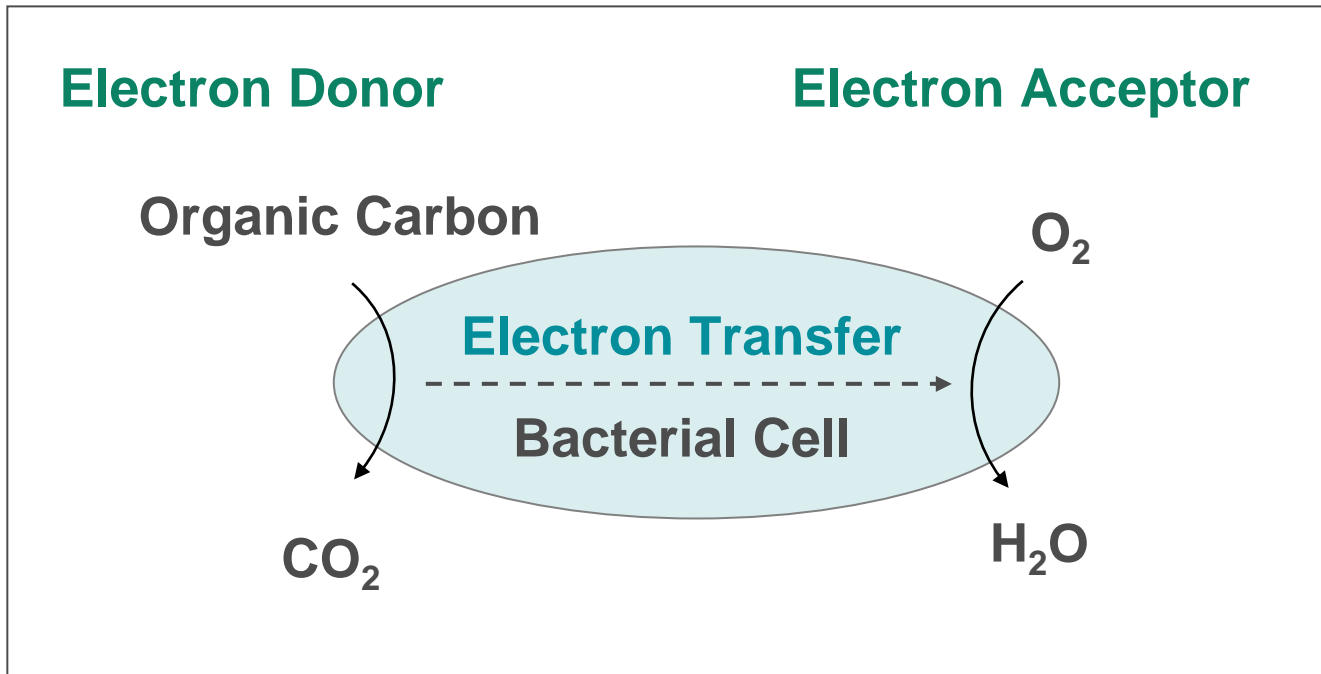




Biological Treatment Primer

BIOLOGICAL TREATMENT PRIMER

- Biological treatment relies on oxidation reduction reactions
- The processes that occur in natural environments are based on energetic favorability



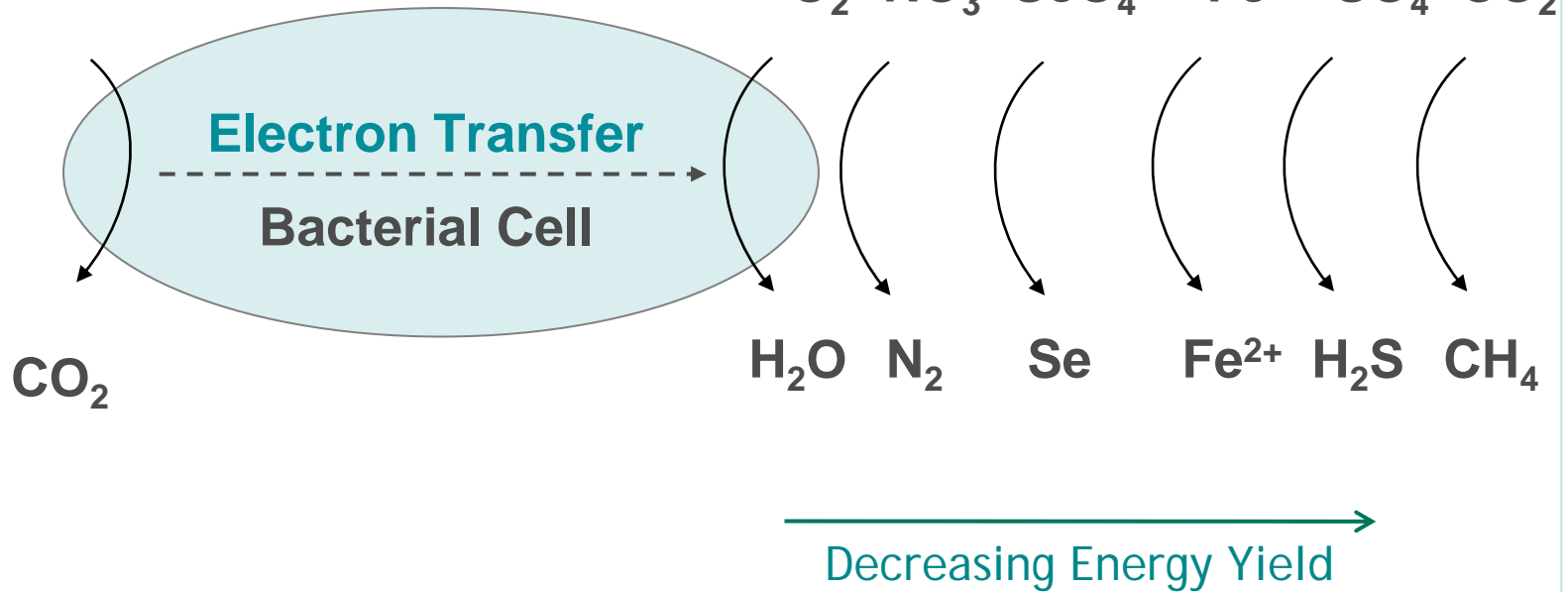


Biological Treatment Primer

Electron Donor

Electron Acceptor

Organic Carbon





Fording River Coal Mine





Geophysical Survey

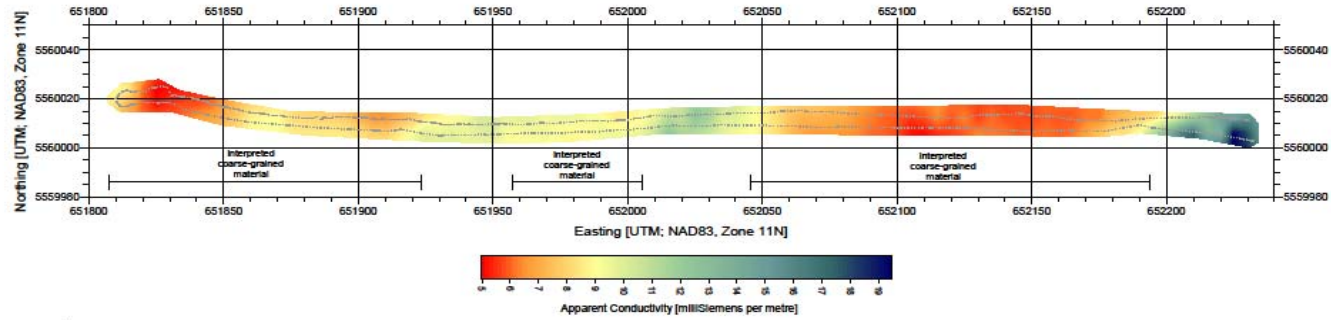
- Two 1 km transects
- One at the base of the STP
- Second south of Kilmarnock settling ponds
- Electrical Resistivity Imaging and electromagnetic (EM31) surveys conducted
- Used to select drilling locations
- Delineated channel and non-channel deposits
- Used with K-test results to estimate flux through valley



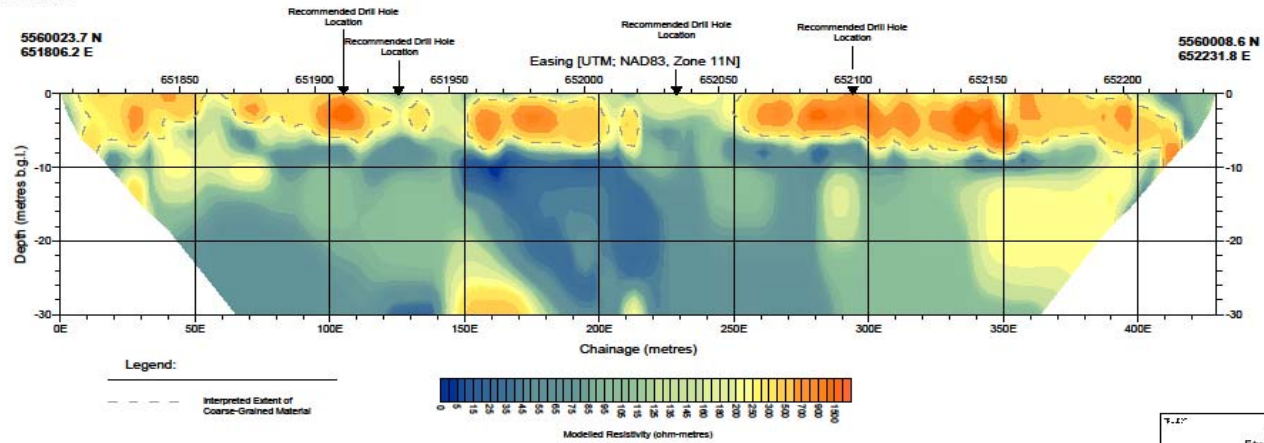


South Tailings Pond Transect

Line A - EM31 Conductivity Contour Map (Vertical Dipole - 5m Depth)



Line A - Modelled ERI Section



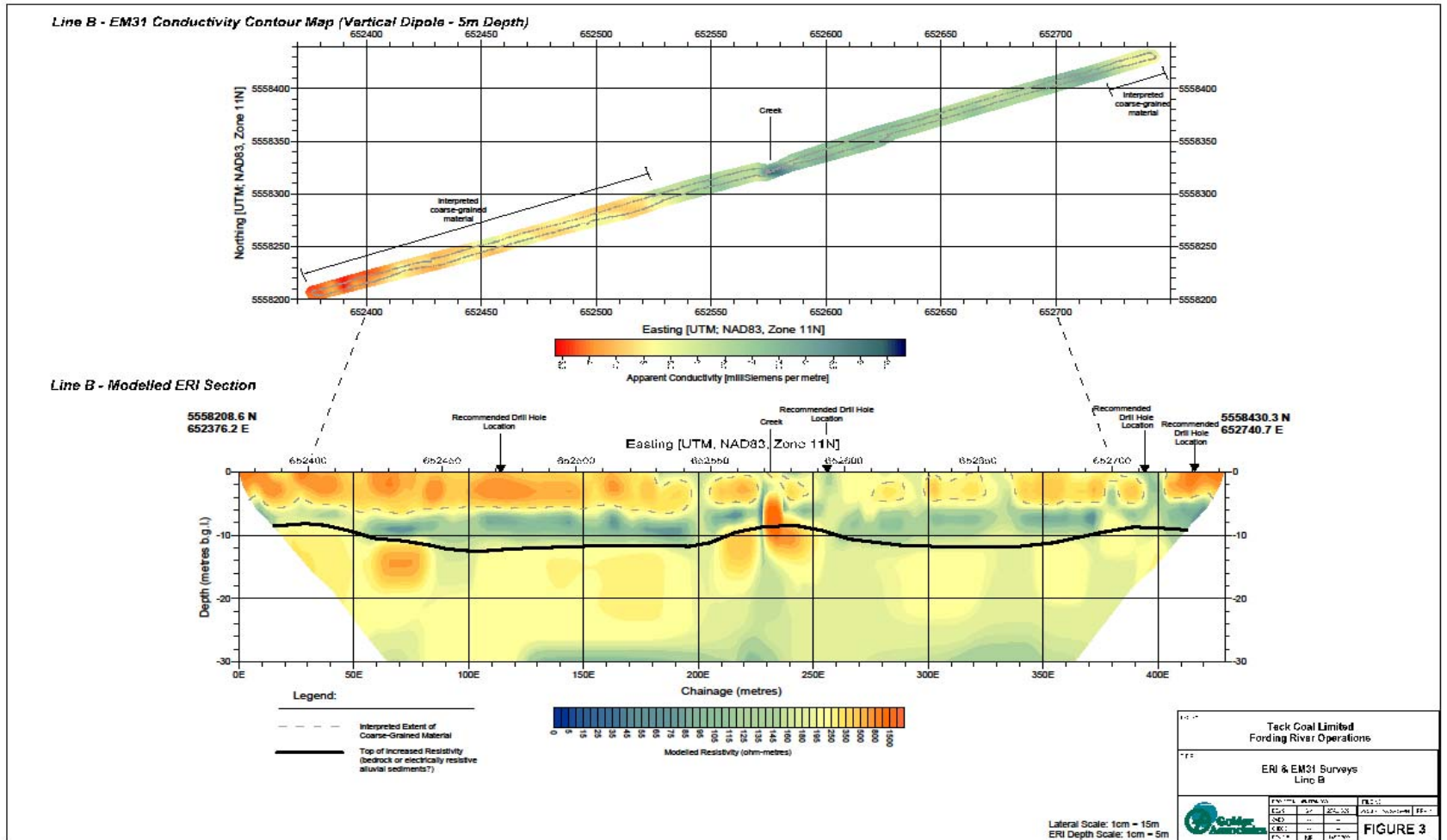
Lateral Scale: 1cm = 15m
ERI Depth Scale: 1cm = 5m

T-17		Teck Coal Limited Fording River Operations	
T-1		ERI & EM31 Surveys Line A	
REV	DATE	BY	APP
01	2010-09-03	WJ	WJ
02	2010-09-03	WJ	WJ
03	2010-09-03	WJ	WJ

FIGURE 2



Kilmarnock Alluvium Transect





Drilling Program

- Barber Rig
- Four sets of nested wells
- Gravel with varying amounts of sand
- Bedrock encountered in STP wells





South Tailings Pond





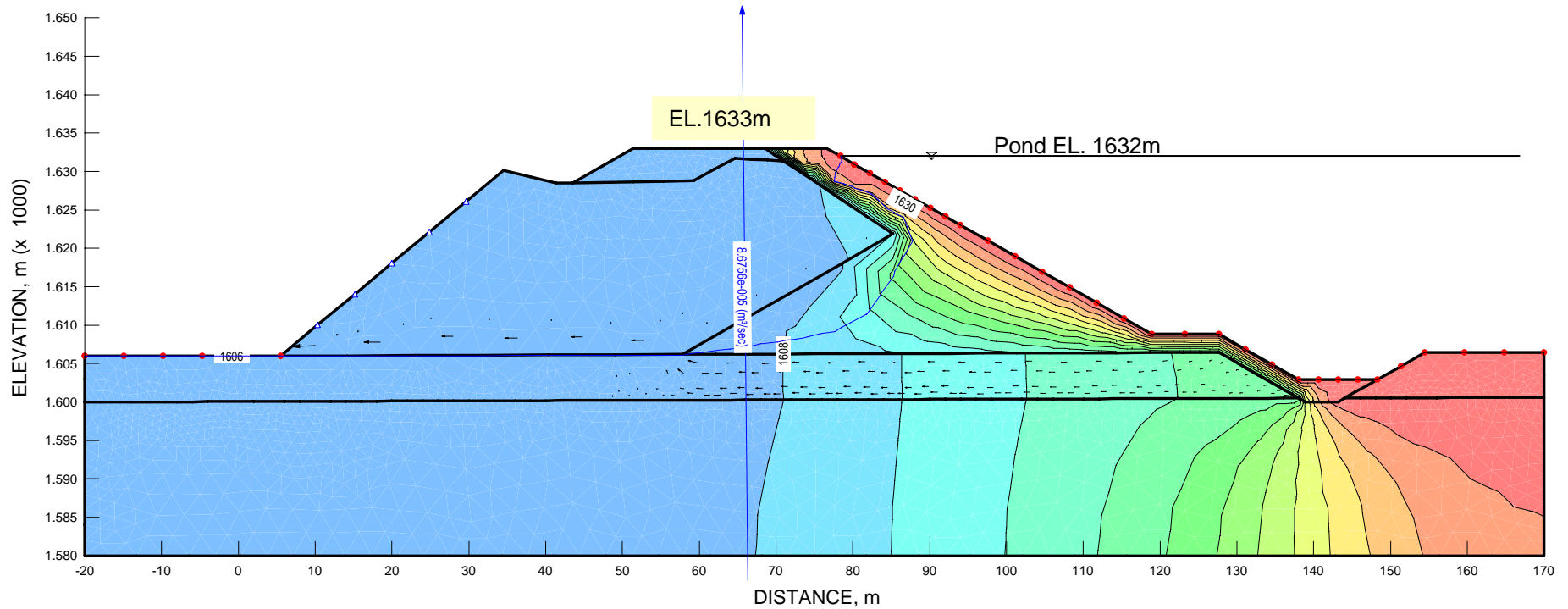
South Tailings Pond

- Located on the fluvial sands, gravels and glacial till of the Fording River valley
- Currently used for ongoing tailings discharge from the process and wash plant operations
- Water is also reclaimed and is re-used in the process plant





South Tailings Pond



**SEEPAGE ANALYSIS
MAIN EMBANKMENT- EL. 1633m
MAXIMUM WATER HEAD**



Sampling Points at South Tailings Pond

- 13 groundwater sample locations
 - Four installed by Golder in 2009
 - Eight existing standpipes around the STP
 - Seepage return well
- 8 surface water sample locations





Groundwater at STP

- Groundwater levels vary in the nested wells
- A downward gradient exists in the nested wells
- Seepage from STP likely to the Kilmarnock alluvium to the south and the Fording River to the west
- Groundwater flow below and immediately adjacent to the STP likely comprises mostly or entirely STP seepage



Water Chemistry for STP

- Shows some indication of conditions suitable for selenium attenuation, specifically reduction
- Reducing conditions are evident by:
 - Low DO
 - Negative Eh measurements
 - Presence of reduced redox species
- Results indicate that the STP itself and seeps do not support selenium reduction





Water Chemistry at STP

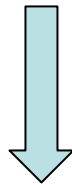
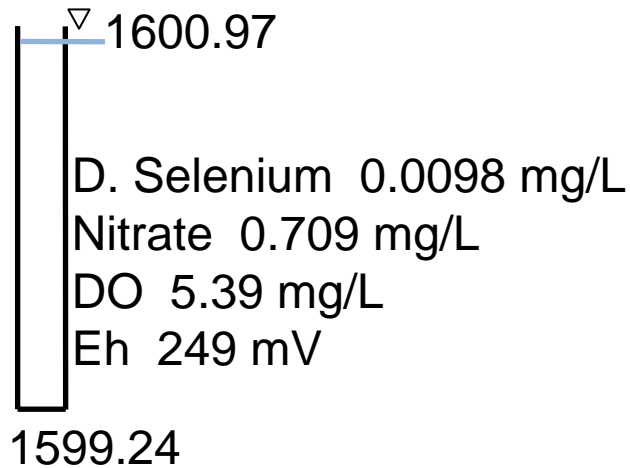
- Groundwater wells on the west and main embankment, conditions are reducing
- The nested wells and seepage return well show low DO, but relatively high positive Eh
- The Fording River shows oxidizing conditions



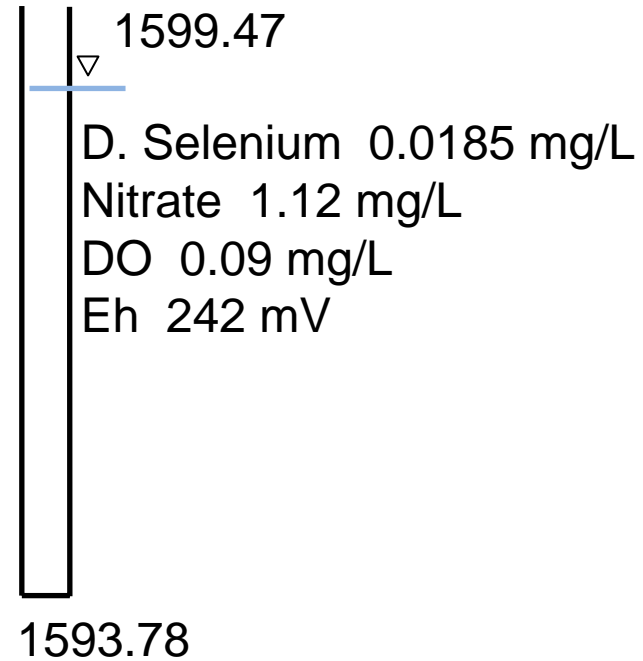


Water Chemistry at STP

09-03A



09-03B





Kilmarnock Alluvium





Kilmarnock Alluvium

- Average flow rate of 110,702 m³/day
- Two phases of settling ponds
- Underlain by fluvial sands and gravels
- Depth to groundwater ranges from 6.25 to 10.52 m bgs





Sampling Points at Kilmarnock

- Four groundwater sample locations installed by Golder in 2009
- Four to seven surface water sample locations depending on the time of year





Water Chemistry for Kilmarnock Alluvium

- Results indicate no reducing conditions
- Increase in NO_3 and Se as compared to STP
- DO values near solubility levels
- High positive Eh values
- Attenuation evaluated using two scenarios





Scenario One

- Groundwater represents only seepage from settling ponds
- Groundwater flow through upgradient areas is prohibited
- Groundwater mounding is expected to be significant
- Selenium concentrations represent approximately 30% of pond inflow





Scenario Two

- Represents a mixing of groundwater flow through and pond recharge
- Assumes STP nested wells represent upgradient groundwater
- Simple mixing calculation for selenium
- 75% of groundwater may be flow through from nearby STP
- 25% represents pond recharge





Conclusions

South Tailings Pond

- Not conducive to selenium reduction
- Lower selenium concentrations in STP seepage samples and nearby groundwater suggests some selenium attenuation
- Within the underlying groundwater system, the groundwater is oxygenated within a short distance from STP
- Selenium added to the groundwater is expected to migrate downgradient with limited attenuation



Conclusions

Kilmarnock Alluvium

- Reducing conditions do not exist in the alluvium or settling ponds
- DO values are near solubility and high positive Eh values
- Simple mixing calculations suggest selenium attenuation for the settling ponds between 50% and 70%
- Further data and evaluation is needed



Related Research

- Active Pilot Treatment System
- Pit Lake Profiling
- PRB Evaluation
- Passive Treatment System





Thank-you

- Ron Jones, Teck Coal
- John Pumphrey, Teck Coal
- Environmental Group at Teck Coal Fording River Operations
- Tom Rutkowski, Golder
- Marc Bowles, Golder

