



# Performance of Low-permeability Tailings Cover, Arctic Gold and Silver Mine, Yukon

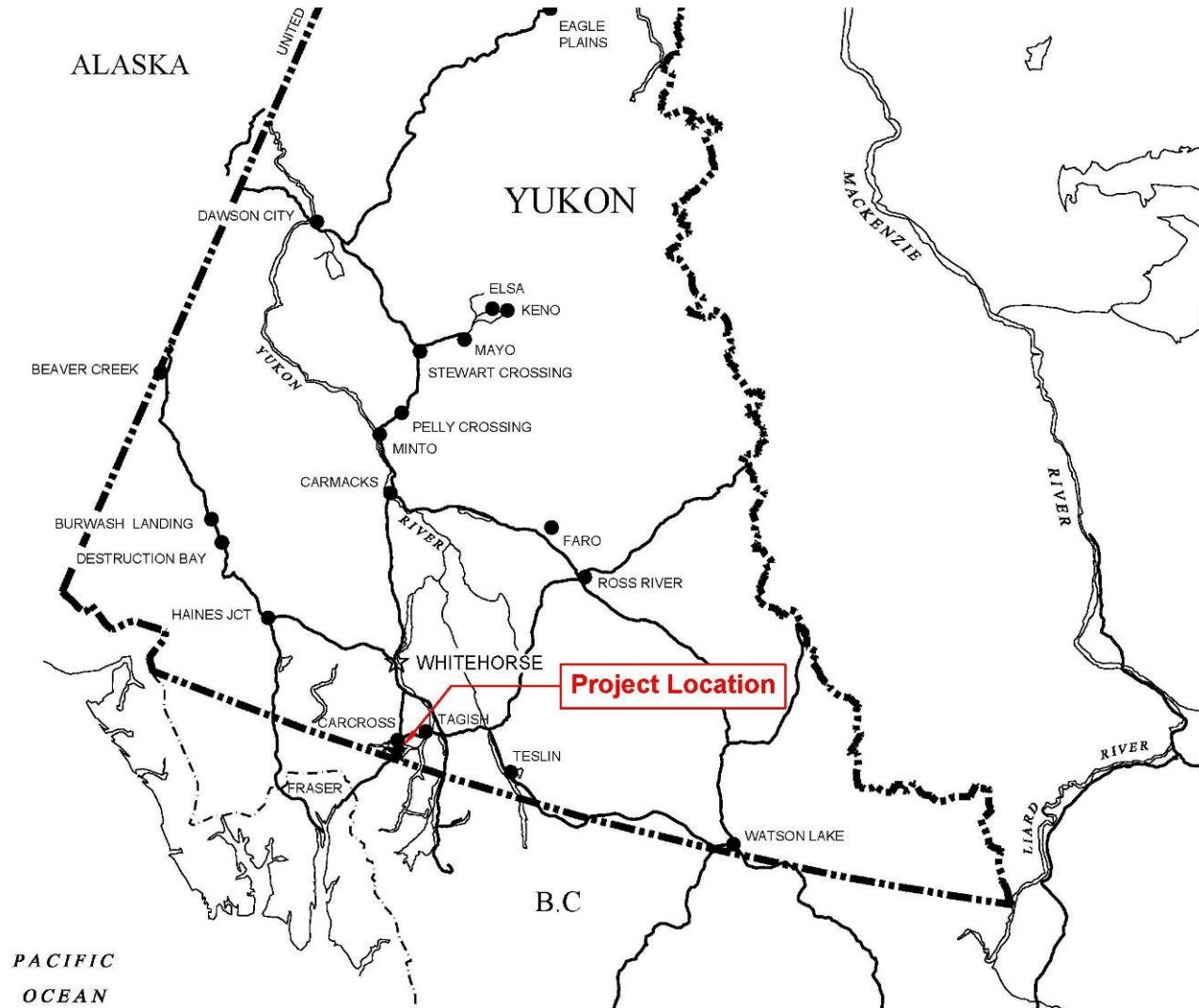
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Whitehorse, Yukon

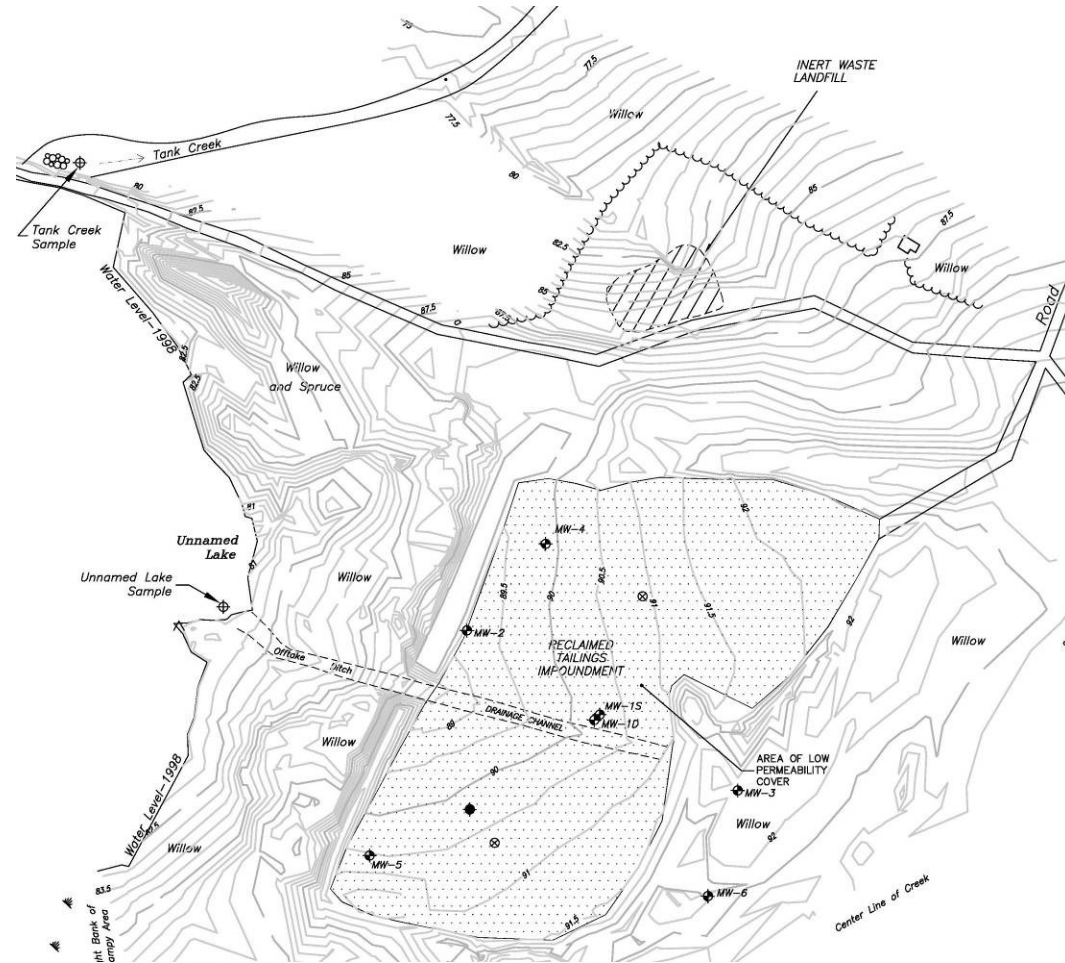
Northern Latitudes Mine Reclamation Workshop, Fairbanks, AK, May 11-12, 2011

# Project Location



# Site History

- Arctic Gold and Silver Mine produced 180 t of ore per day during the late 1960s (total of about 47,000 t).
- Mill produced gold and silver concentrate.
- Underground workings were located several kilometres from mill and tailings site.
- All operations ceased in 1969.



# Tailings - General

- Waste stream from milling operation included tailings and process water which were discharged to 1.8 ha tailings impoundment.
- A total of about 27,000 m<sup>3</sup> of tailings were discharged.
- Some tailings spilled into adjacent lake or were wind blown creating a plume to the northeast of the impoundment.
- Tailings thickness ranges from 1.4 to 2.5 m.
- Oxidized tailings thickness ranged from 0.8 to 1.7 m (1999).

# Tailings - Geochemistry

- Tailings are strongly acidic and contain high levels of total and soluble arsenic.

Parameter	Range	Average
<b>Acid Base Accounting</b>		
Paste pH	1.8 to 3.5	2.6
AP (kgCaCO <sub>3</sub> /t)	0.63 to 92	20
NP (kgCaCO <sub>3</sub> /t)	-23 to -2.5	-12
NNP (kgCaCO <sub>3</sub> /t)	-107 to -3.1	-33
<b>Solids Metals</b>		
Al(%)	0.09 to 0.41	0.22
As (ppm)	3193 to > 10,000	6712
Cu (ppm)	29 to 1266	164
Fe (%)	1.1 to 5.73	2.8
Pb (ppm)	590 to 4222	1730
Ag (ppm)	25 to > 200	82
Zn (ppm)	33 to 643	183
<b>Soluble Metals</b>		
Al (mg/L)	3.1 to 99	33
As (mg/L)	0.3 to 50	17
Cu (mg/L)	0.34 to 6.4	3.4
Fe (mg/L)	6.5 to 287	136
Pb (mg/L)	<0.05 to 3.7	1.4
Ag (mg/L)	0.03 to 0.2	0.12
Zn (mg/L)	0.36 to 13	5.6

# Tailings - Reclamation

- Remediation Plan was developed in 1999 based on a “consolidate and cover” approach.
- Remediation activities were conducted between July 1999 and September 2000.
- Reclamation activities included:
  - Leveling and grading of existing tailings;
  - Placement of 0.5-0.6 m of sand and gravel fill over tailings;
  - Covering the tailings with a final 0.3 m thick layer of clayey silt; and,
  - Revegetation of the cover surface.

# Tailings - Reclamation



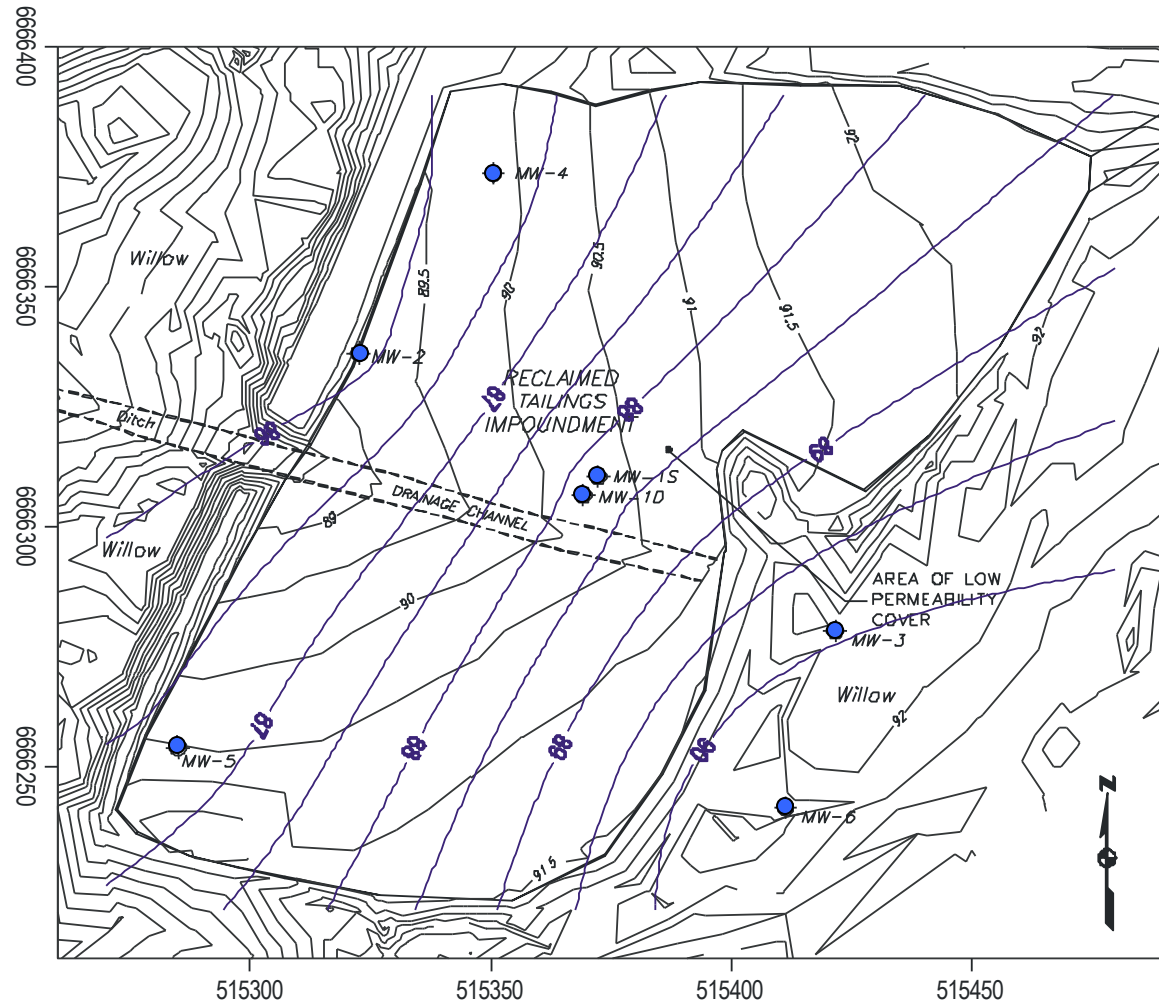
# Low-permeability Tailings Cover

- Composite cover system consisting of clayey silt underlain by sand and gravel layer.
- Cover system uses capillary barrier concept.
- Cover is intended to act as oxygen and infiltration barrier.



# Hydrogeological Regime

- Six groundwater monitoring wells.
- Shallow aquifer underlying tailings consists of till (hydraulic conductivity of about  $10^{-5}$  to  $10^{-6}$  m/s).
- General flow direction is toward NW.
- Hydraulic gradient  $\sim 0.035$  m/m.
- Flow velocity in the order of metres to tens of metres per year.



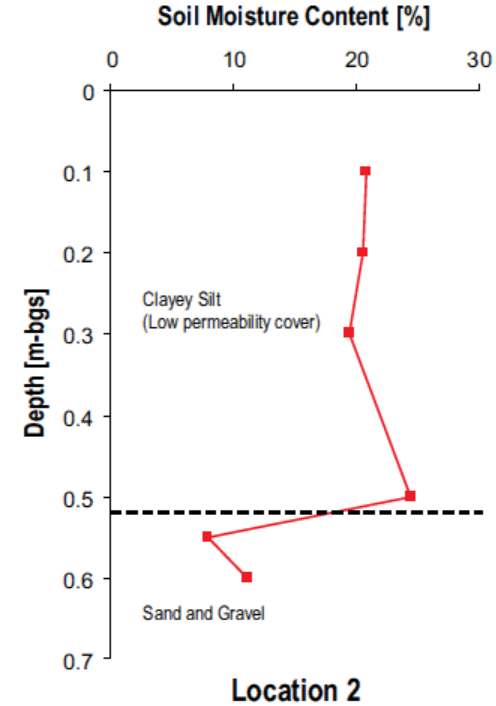
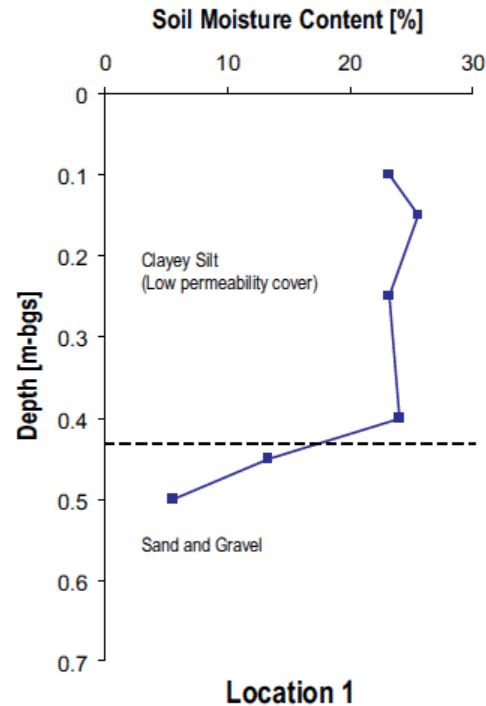
- Leachate from tailings has caused high metals concentration and low pH in groundwater passing underneath the impoundment.
- Examples:
  - pH < 3
  - Diss. Arsenic > 80 mg/L
  - Diss. Cadmium > 1.5 mg/L
  - Diss. Copper > 8 mg/L
  - Diss. Iron > 3,000 mg/L
  - Diss. Zinc > 100 mg/L
- Background wells show much lower concentrations (mostly below applicable water quality standards).

# Cover Performance Assessment

- Cover performance assessment was initiated in 2001 shortly after installation of the cover.
- Performance assessment included:
  - Moisture profiles;
  - Oxygen profiles;
  - Ground temperature profiles;
  - Groundwater quality;
  - Surface water quality; and,
  - Groundwater level monitoring.
- Performance assessments were repeated in 2002 and 2009.

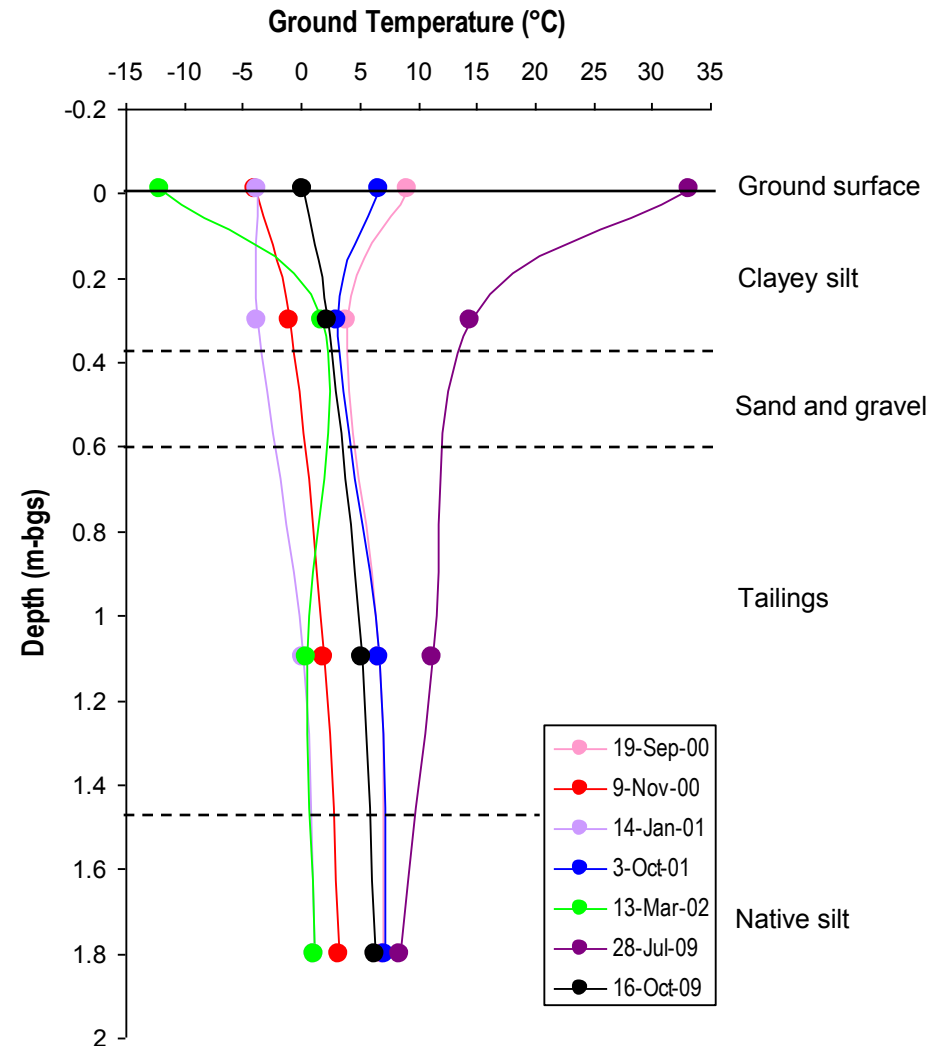
# Soil Moisture Profiles

- Silt was close to fully water saturated.
- Moisture content decreased in sand and gravel.
- Significant decrease in moisture content at the silt/sand and gravel interface indicates that cover is acting as infiltration barrier.

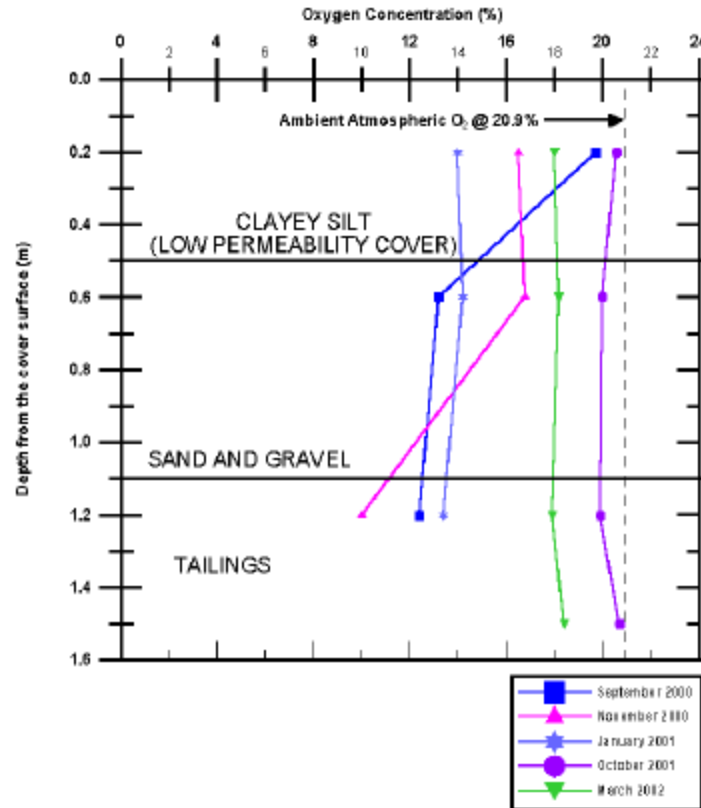
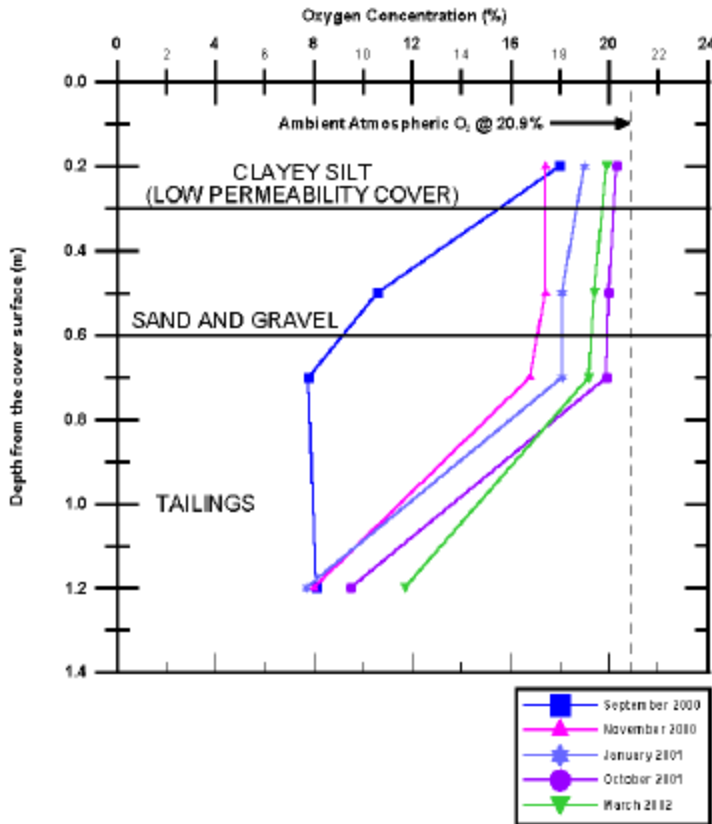


# Ground Temperature Profile

- Ground temperature profiles show typical seasonal variations.
- No general temperature increase was observed within the tailings that could indicate exothermic reactions causing ARD.



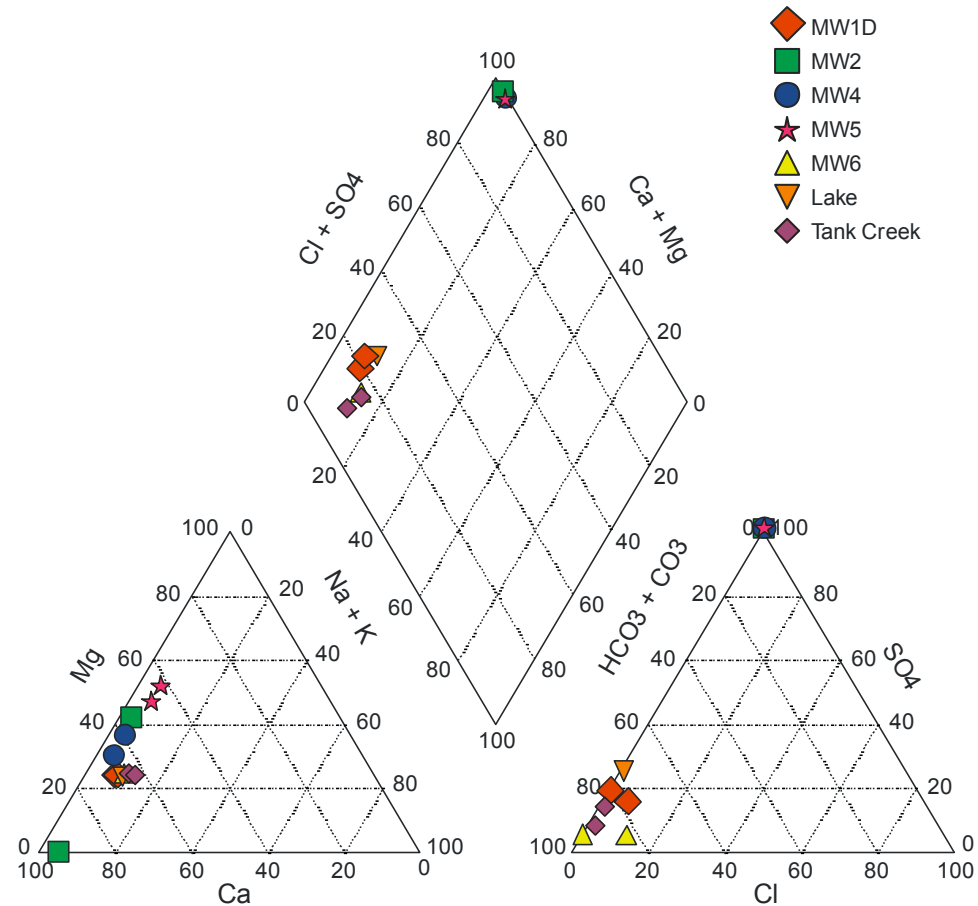
# Oxygen Profiles



- Oxygen concentrations generally increased with no clear decrease within cover.
- Cover does not seem to effectively function as an oxygen barrier.

# Groundwater Quality

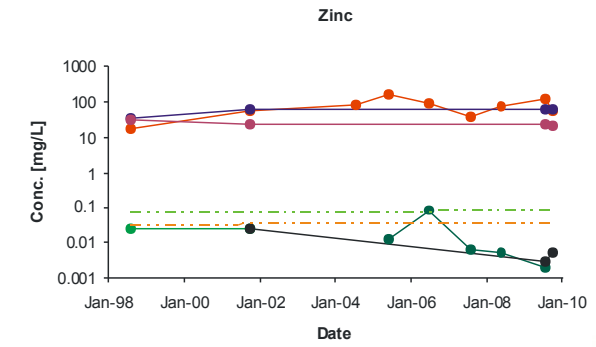
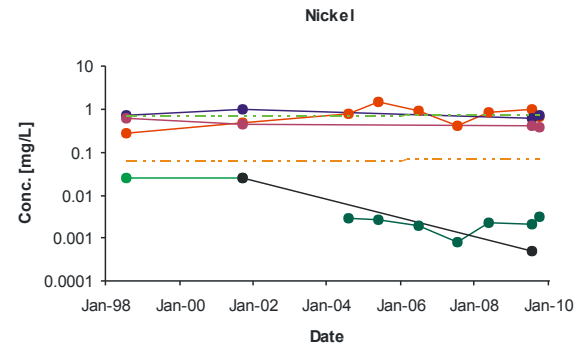
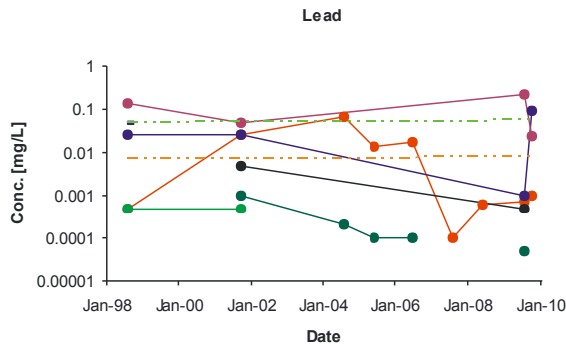
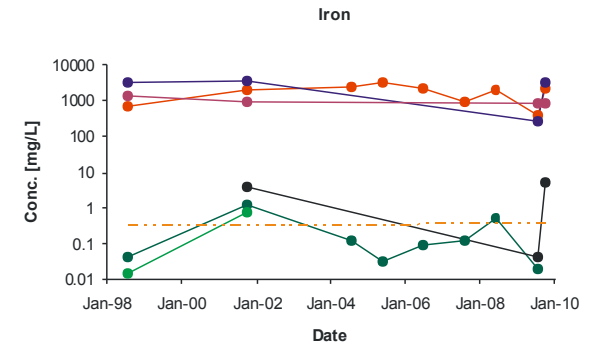
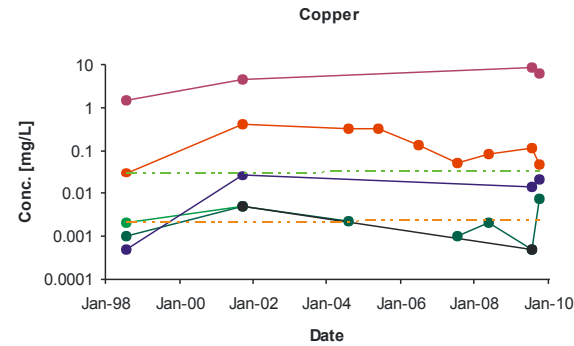
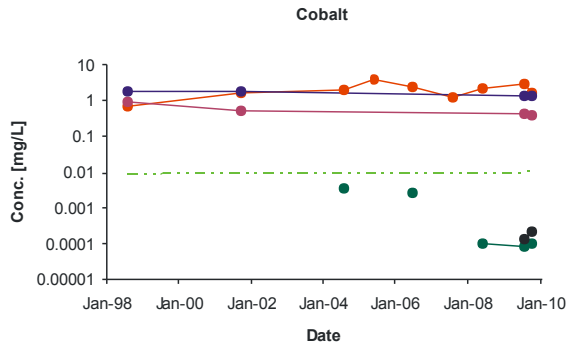
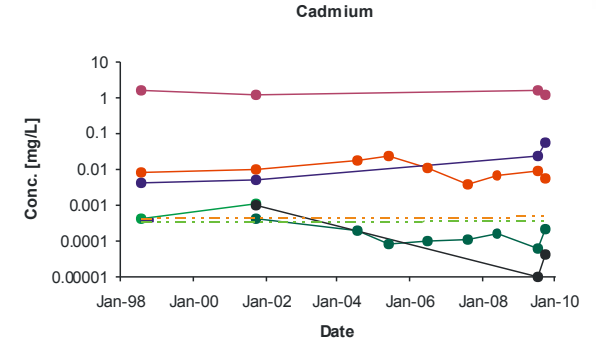
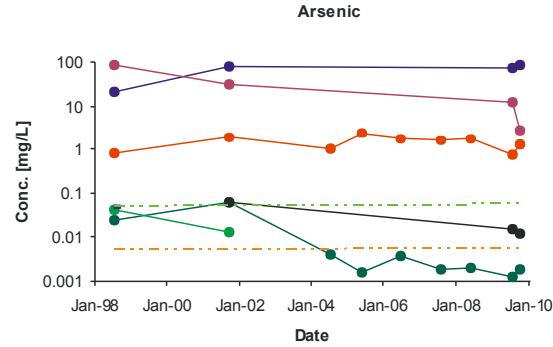
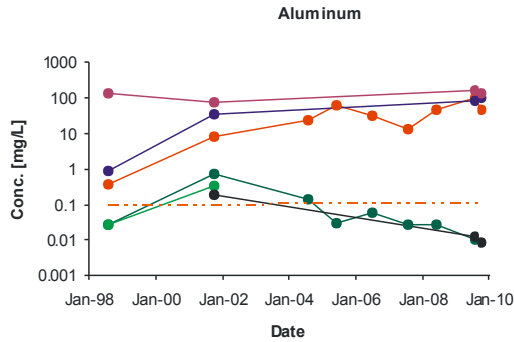
- Background water quality is considerably different from groundwater quality beneath tailings impoundment.
- Downgradient wells MW2, MW4, and MW5 are most affected.



# Groundwater Quality



- MW-1D
- MW-2
- MW-3
- MW-4
- MW-5
- MW-6
- CCME Guidelines
- CSR Standards



# Groundwater Quality

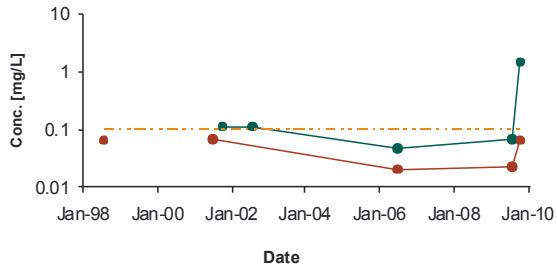
- Groundwater upgradient of tailings impoundment has relatively low dissolved metals concentrations and near neutral pH.
- Groundwater quality beneath the covered tailings is strongly affected by leachate from tailings (low pH, high dissolved metals concentrations).
- Several dissolved metals (e.g., As, Cd, Co, Cu, Pb, Ni, Zn) exceed Yukon CSR water quality standards.
- Most dissolved metals concentrations are fairly constant with no obvious temporal trends between 1998 and 2009 sampling events.

# Surface Water Quality

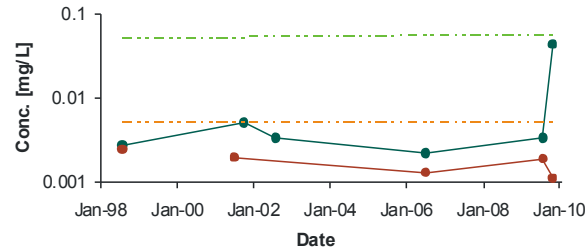


- Lake
- Tank Creek
- - - CCME
- - - CSR

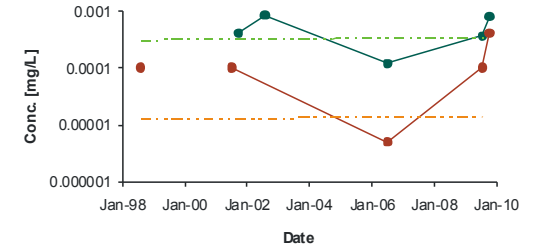
**Aluminum**



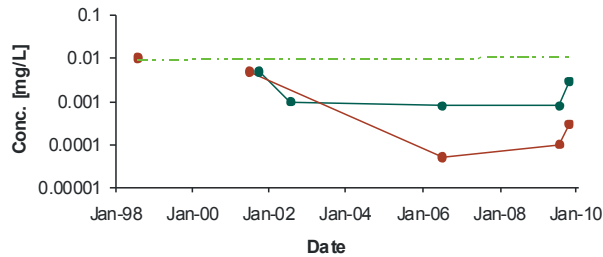
**Arsenic**



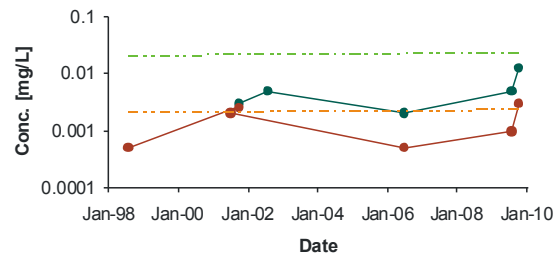
**Cadmium**



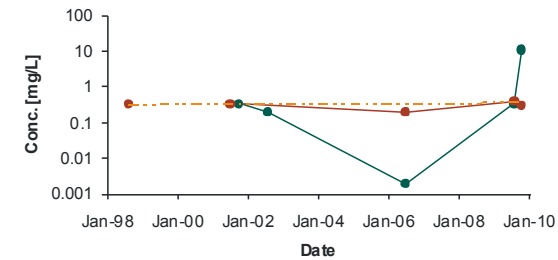
**Cobalt**



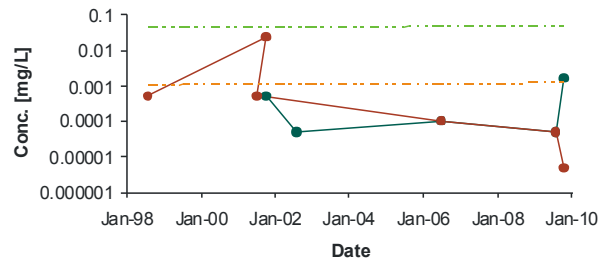
**Copper**



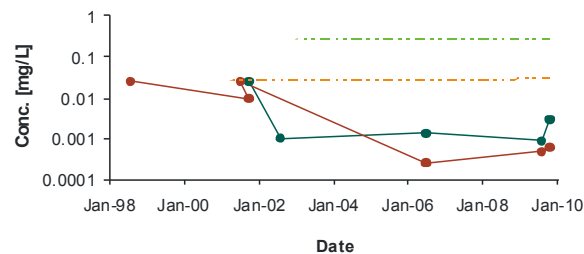
**Iron**



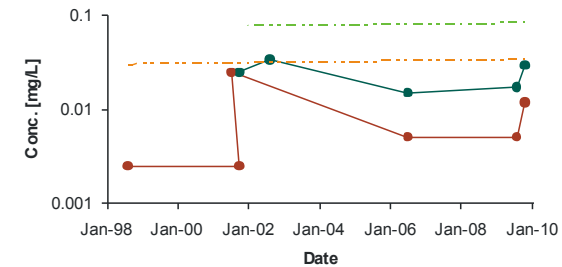
**Lead**



**Nickel**



**Zinc**



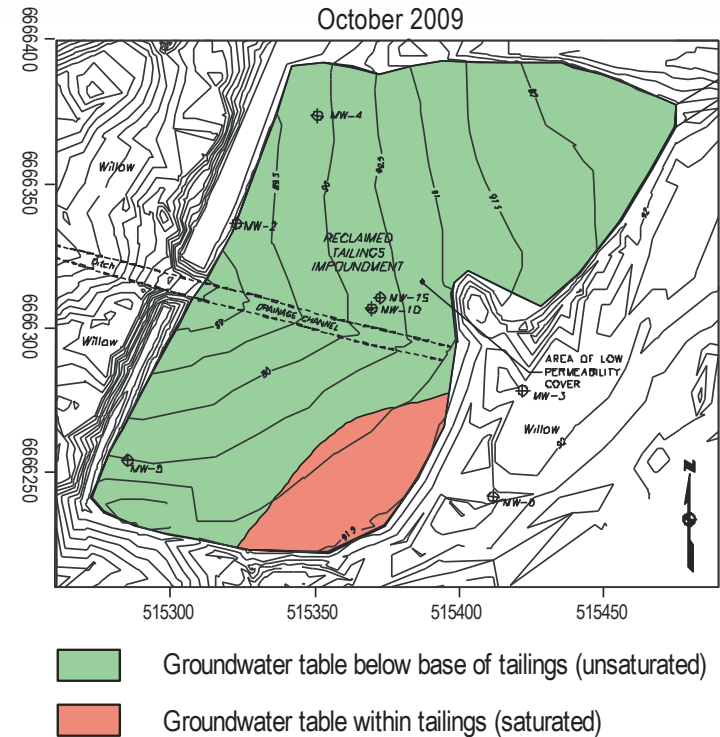
# Surface Water Quality

- Surface water downgradient of tailings impoundment shows much lower metals concentrations compared to groundwater.
- Some metals do exceed water quality guidelines slightly (e.g., Cd, Cu).
- Insufficient baseline data available to determine if these exceedances are natural or due to impact from tailings.



# Possible Reasons for Persistent Impact

- Measured and interpolated groundwater elevations suggest that some of the tailings might be below the groundwater table – at least seasonally.
- Infiltration through tailings cover along preferential flow path (e.g., surface cracks in silt layer, plant roots).
- Slow groundwater flow velocity (metres to tens of metres per year), i.e., affected groundwater beneath tailings may not have been replaced yet.



Surface cracks in tailings cover

# Summary and Conclusions

- Collected field data are inconclusive with respect to performance of tailings cover.
- Soil moisture and ground temperature profiles suggest that cover acts as infiltration barrier and limits ARD processes.
- Oxygen profiles and persistent groundwater contamination suggests ongoing ARD processes and impact from tailings on groundwater quality.
- Integrated approach is necessary to assess cover performance (no single parameter is able to provide this information).
- Continued monitoring is recommended to assess long-term performance of tailings cover.



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**Thank You!**