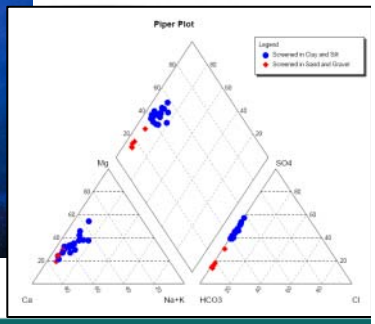


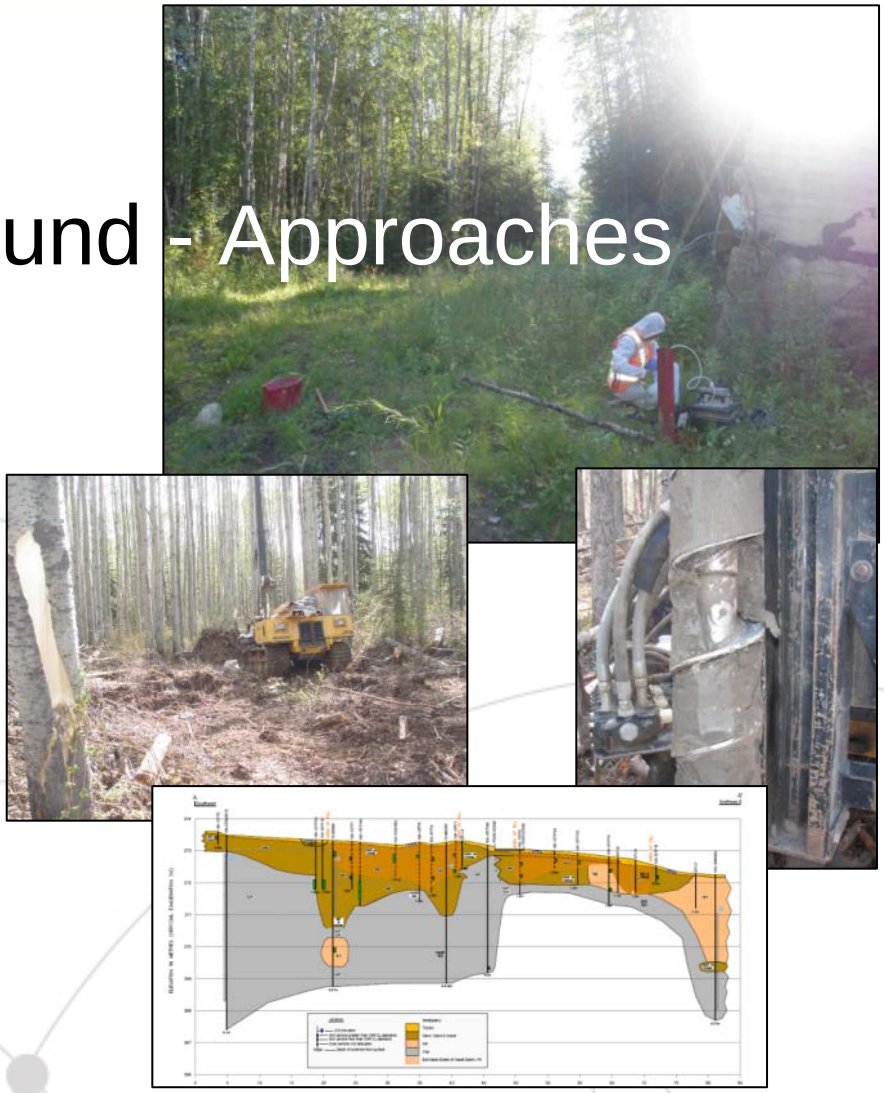
Investigating Background Groundwater Quality at Contaminated Sites – A Hydrogeochemical Approach

Remediation Technologies Symposium 2011, Banff, Alberta (October 2011)

Presented by: Stephen Munzar[1]

Presentation Outline

- Introduction
- Determining Background - Approaches
- Case Study
  - Introduction
  - Data Collected
  - Results
  - Conclusions



Introduction

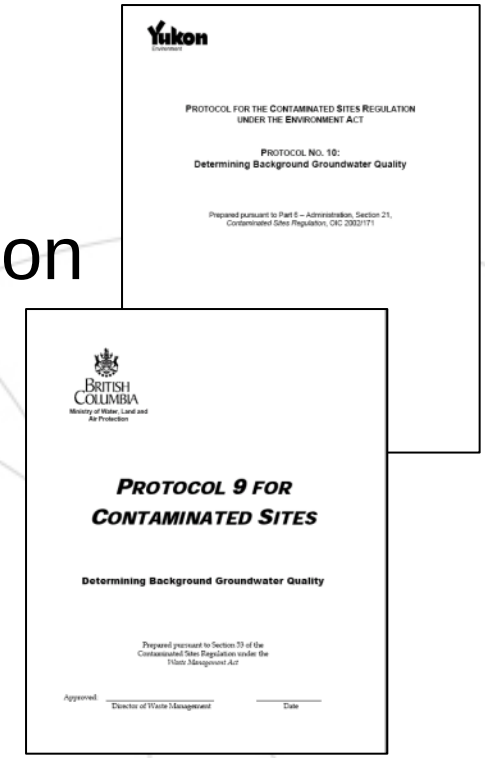
- **Common definition of background GW Quality:**
  - Natural ambient groundwater quality not influenced by anthropogenic sources
  - Commonly considered the groundwater quality “upgradient” of potential or known contaminant sources
- **Why and when do we determine background?**
  - Confirm natural presence of a substance
  - Prevent / limit unnecessary investigation / remediation of natural substances
  - To define a site specific local background concentration for a natural substance
  - To define the ambient or baseline groundwater conditions

Determining Background Conditions

- **Common Approach:**
  - Install upgradient monitoring wells outside of influence of site contamination
  - Groundwater chemistry represents ambient non-anthropogenic conditions
  - Statistically derive background concentration(s)
- **Potential Issues / Concerns:**
  - Upgradient wells completed in different geology and/or flow setting (not representative of background)
  - Concentrations of inorganic constituents tend to be “spotty” (variability)
  - Statistics may bias defined background concentrations

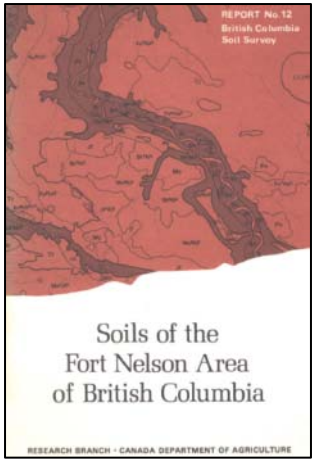
Regulatory

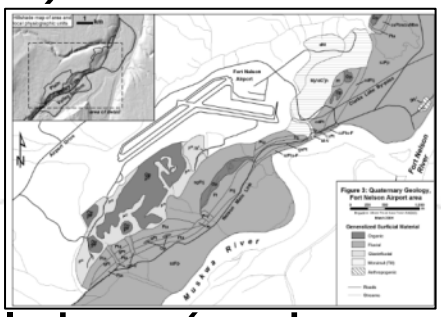
- **Regulatory Requirements in BC / Yukon:**
  - Install / sample min. 3 background wells
  - Locate wells outside influence of anthropogenic sources within same geologic/hydrogeologic setting
  - Sample wells min. two events
  - Calculate 95th percentile concentration



Scientific Based Approach

1. Thorough desktop research:
   - Regional surficial & bedrock geology
   - Soil mapping studies
   - Hydrogeology & geochemistry
2. Site history (source & potential contaminants)
3. Develop preliminary conceptual model
4. Define *local* geology & hydrogeology
5. Soil/sediment mineralogy (if beneficial)
6. Collect additional groundwater geochemical data (major cations, anions, alkalinity)
7. Refine, confirm, or refute preliminary conceptual model





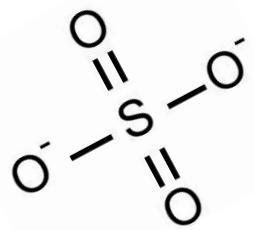
Case Study Background

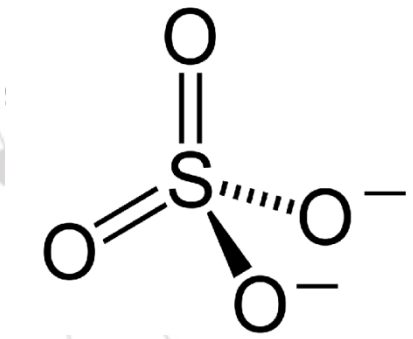
- Located adjacent to Fort Nelson Airport, NE British Columbia
- Used as refuse dumping area from 1952-1960s from the housing barracks located at the airport
- 3 Historical dumping sites and a sewage system:
  - Site 9 – Former Lower Housing Dump
  - Site 10A – Former Concrete Debris Dump
  - Site 10B – Former Upper Housing Dump
  - Site 11 – Sewage Disposal System
- Material observed in dumps - concrete, garbage, sheet metal, electrical cable, glass, random metal debris, metal cans, dishes, tiles, lumber and coal (one site)
- Multiple site investigations completed to characterize soil and groundwater quality – **Dissolved [sulphate] > CSR AW Standards**

Study Objectives

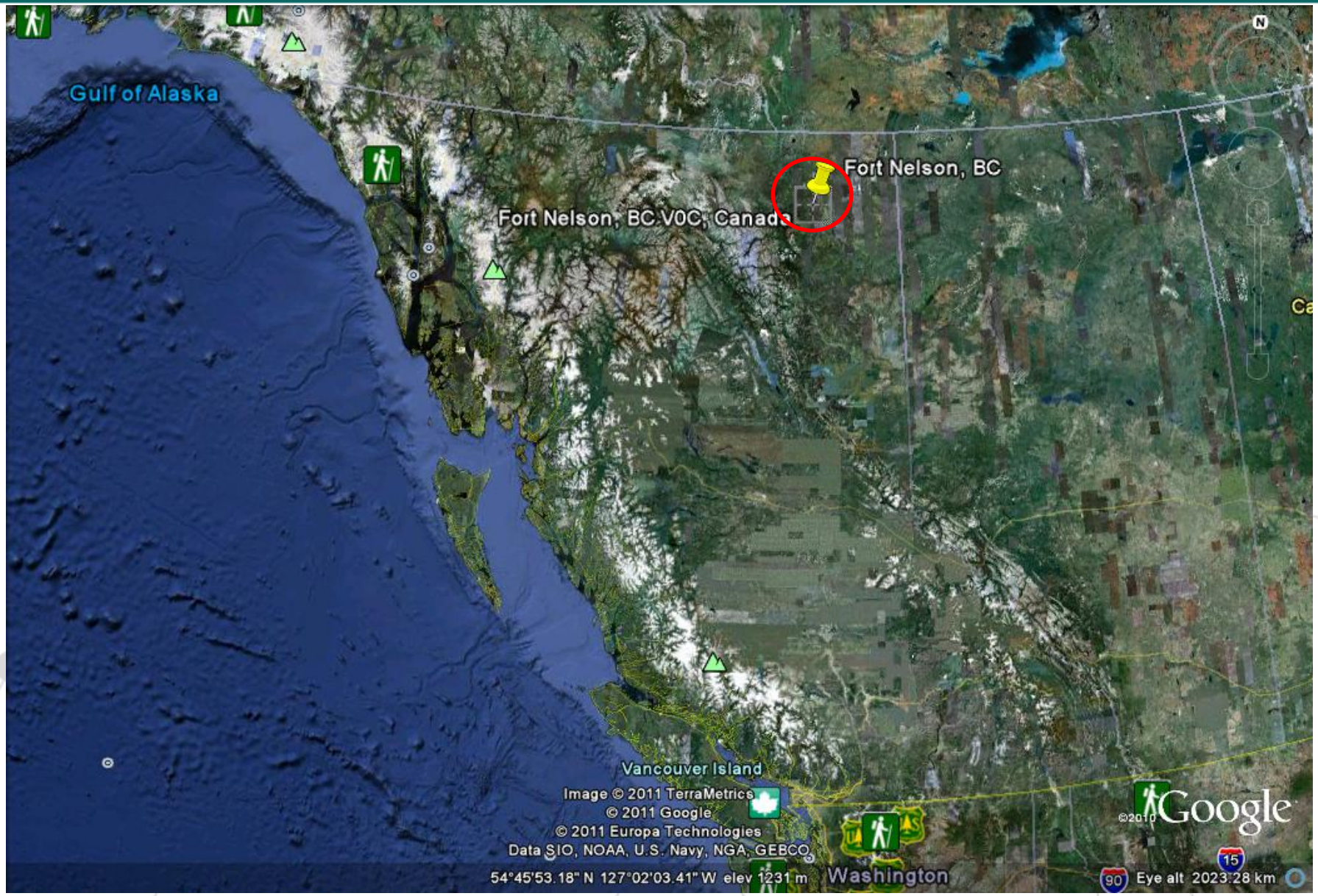
1. Determine if sulphate is naturally occurring or anthropogenic
2. If naturally occurring, determine why it is elevated, and define a local background concentration

SO_4

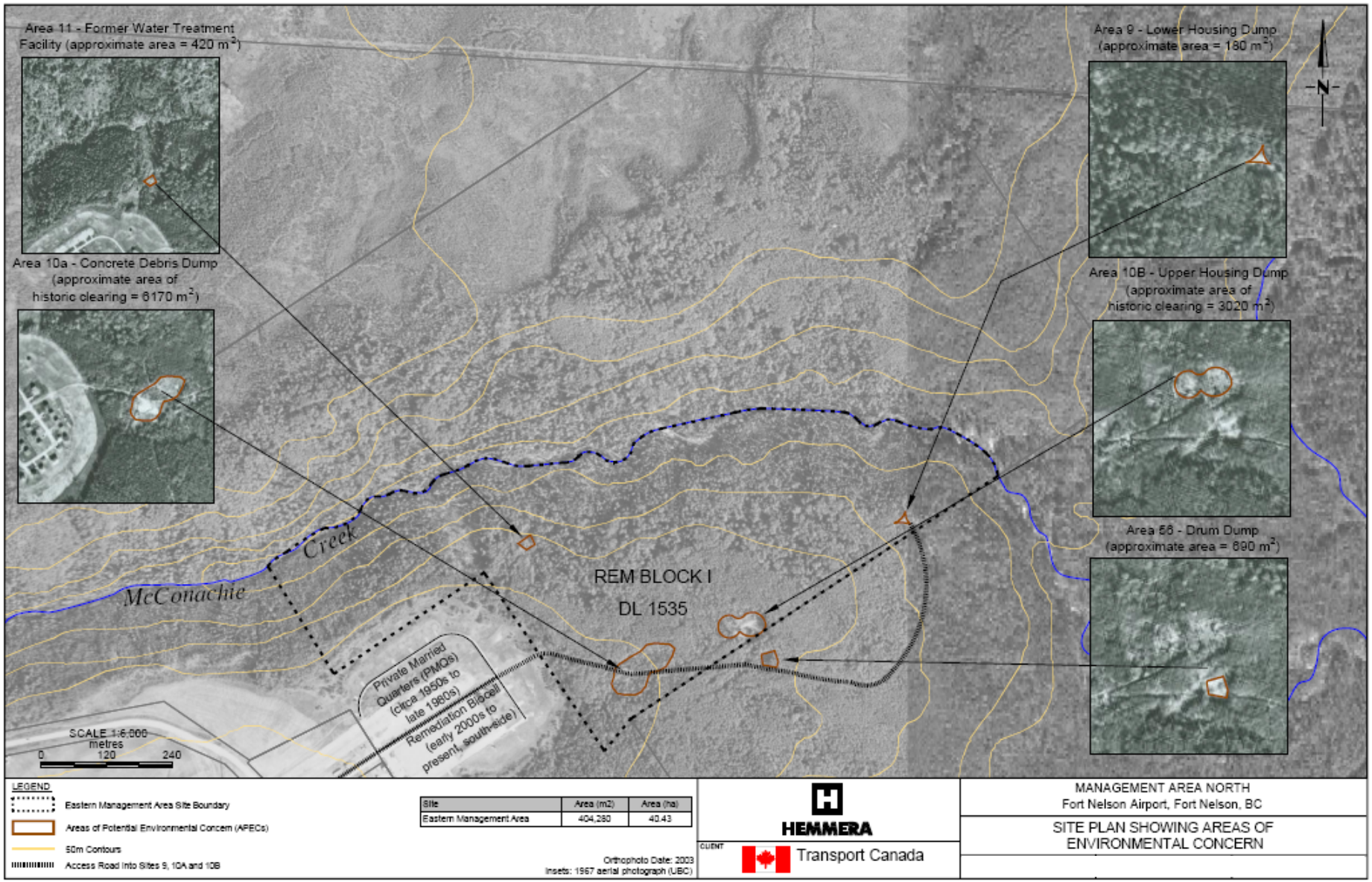




Study Location



Site Layout


Area 11 - Former Water Treatment Facility (approximate area = 420 m²)
Area 9 - Lower Housing Dump (approximate area = 180 m²)
Area 10a - Concrete Debris Dump (approximate area of historic clearing = 6170 m²)
Area 10B - Upper Housing Dump (approximate area of historic clearing = 3020 m²)
Area 66 - Drum Dump (approximate area = 890 m²)
N
McConachie Creek
REM BLOCK I
DL 1535
Private Married Quarters (PMQs) (circa 1950s to late 1980s)
Remediation Blocell (early 2000s to present, south-side)
SCALE 1:6,000
metres
0
120
240
LEGEND
Eastern Management Area Site Boundary
Areas of Potential Environmental Concern (APECs)
50m Contours
Access Road into Sites 9, 10A and 10B
Site | Area (m2) | Area (ha)
Eastern Management Area | 404,280 | 40.43
Orthophoto Date: 2003
Insets: 1967 aerial photograph (UBC)
HEMMERA
CLIENT
Transport Canada
MANAGEMENT AREA NORTH
Fort Nelson Airport, Fort Nelson, BC
SITE PLAN SHOWING AREAS OF ENVIRONMENTAL CONCERN

Data Collected for Background

- Desktop information (geology, etc.)
- Local surficial geology (intrusive invest.)
- Collection and analysis of speciated sulphur in soil
- Mineralogical (petrographic) sample submission / analysis
- Site wide groundwater sampling for dissolved metals, anions

Results

Geology

Surficial Geology

- *Regional* - glaciolacustrine deposits (silts and clays) common to peace region
- *Local* - Silt and clay capped with thin (0.5-1.0 m) sand and gravel

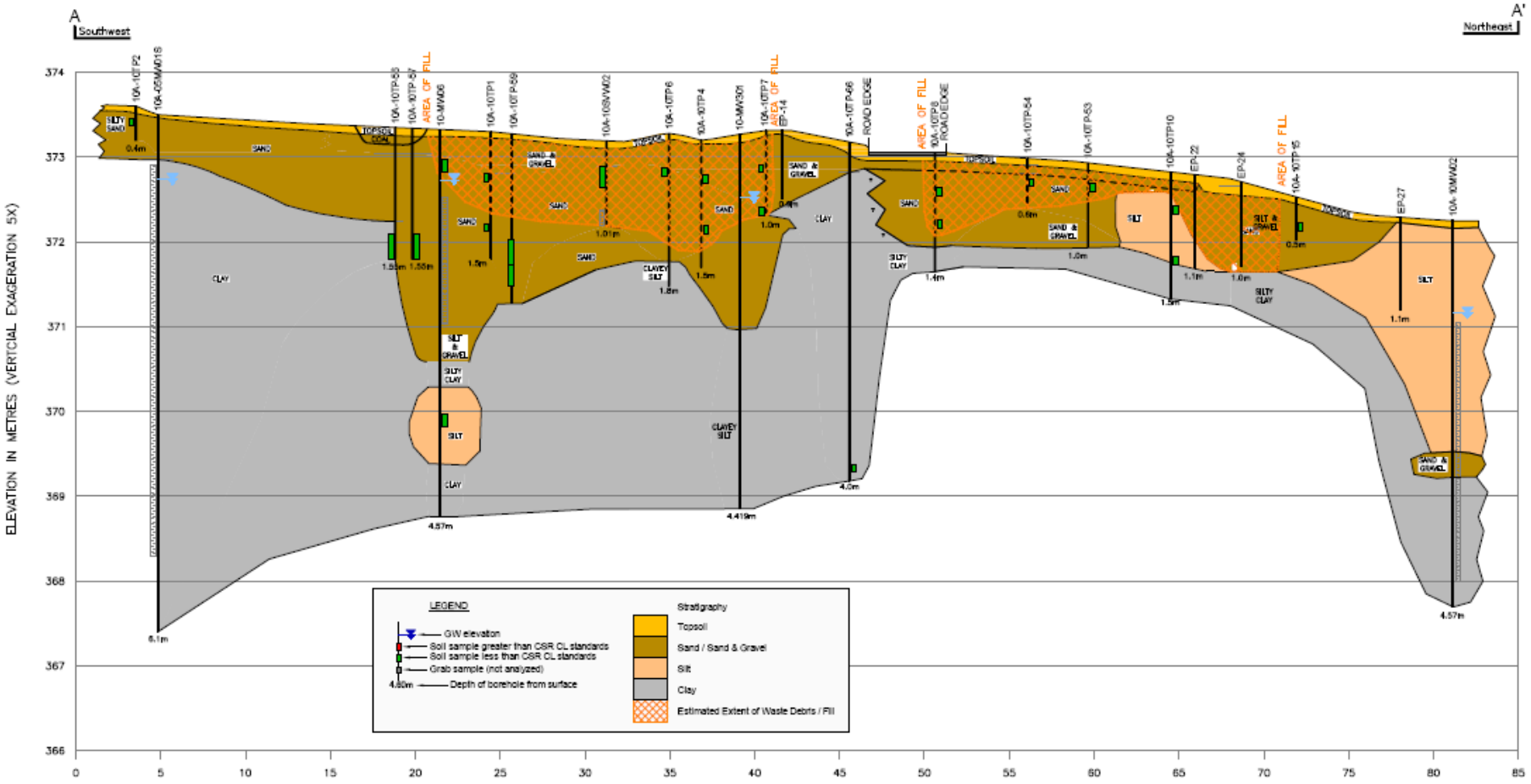
Bedrock Geology

- *Regional* - Marine shales and siltstones of the Lower Cretaceous Buckinghorse Formation, Fort St. John Group.
- *Local* – Not observed (anticipated >50 m deep)

Published Regional Soil Maps/Reports

- Soil chemistry reflects/mirrors the bedrock chemistry
- Marine shales commonly contain anhydrite ($CaSO_4$) and gypsum ($CaSO_4 \cdot 2H_2O$) & other sulphate minerals
- Fort Nelson soils are relatively saline and contain accumulations of gypsum and carbonate minerals.

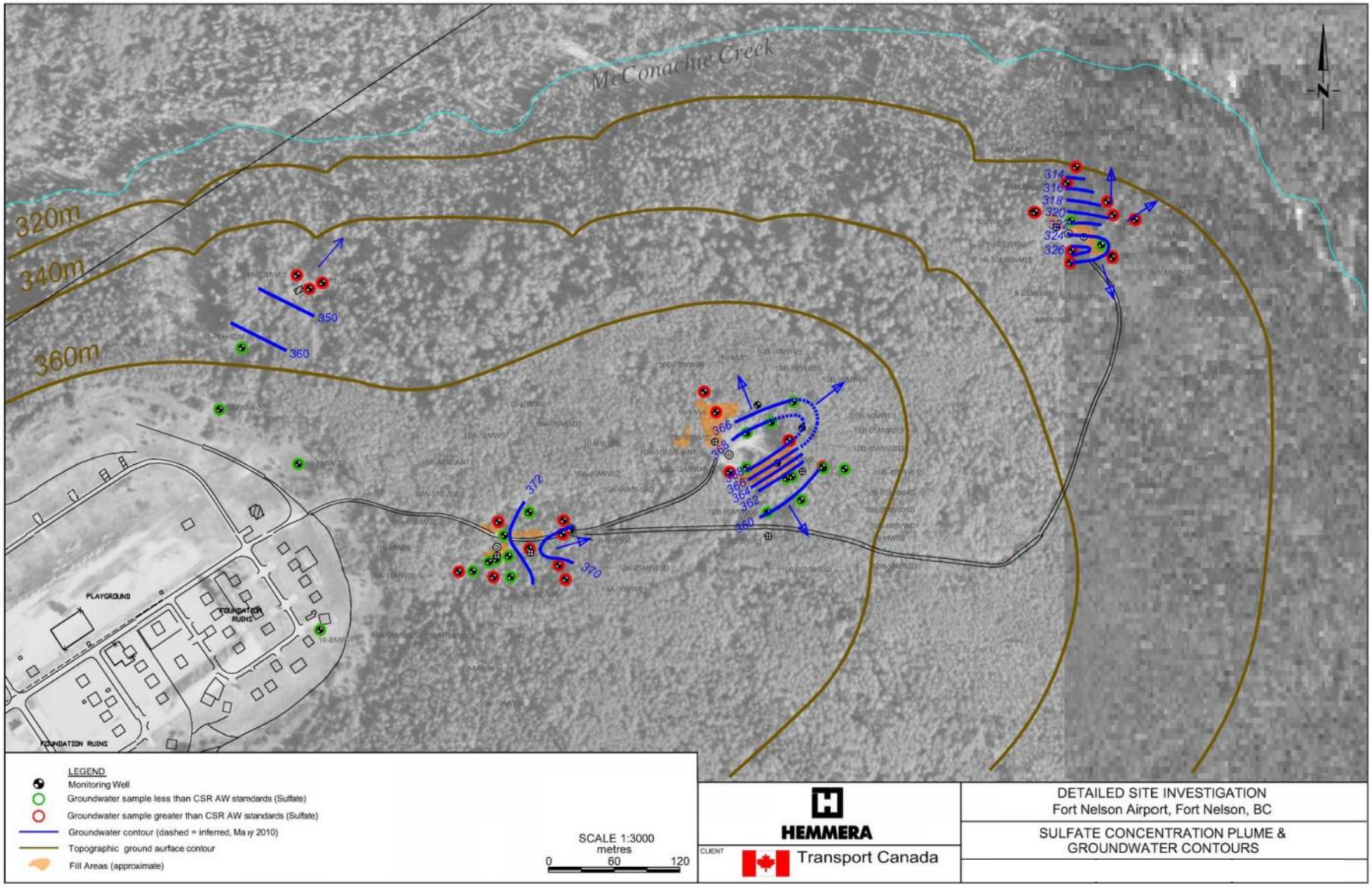
Geologic Cross-Section



Hydrogeology

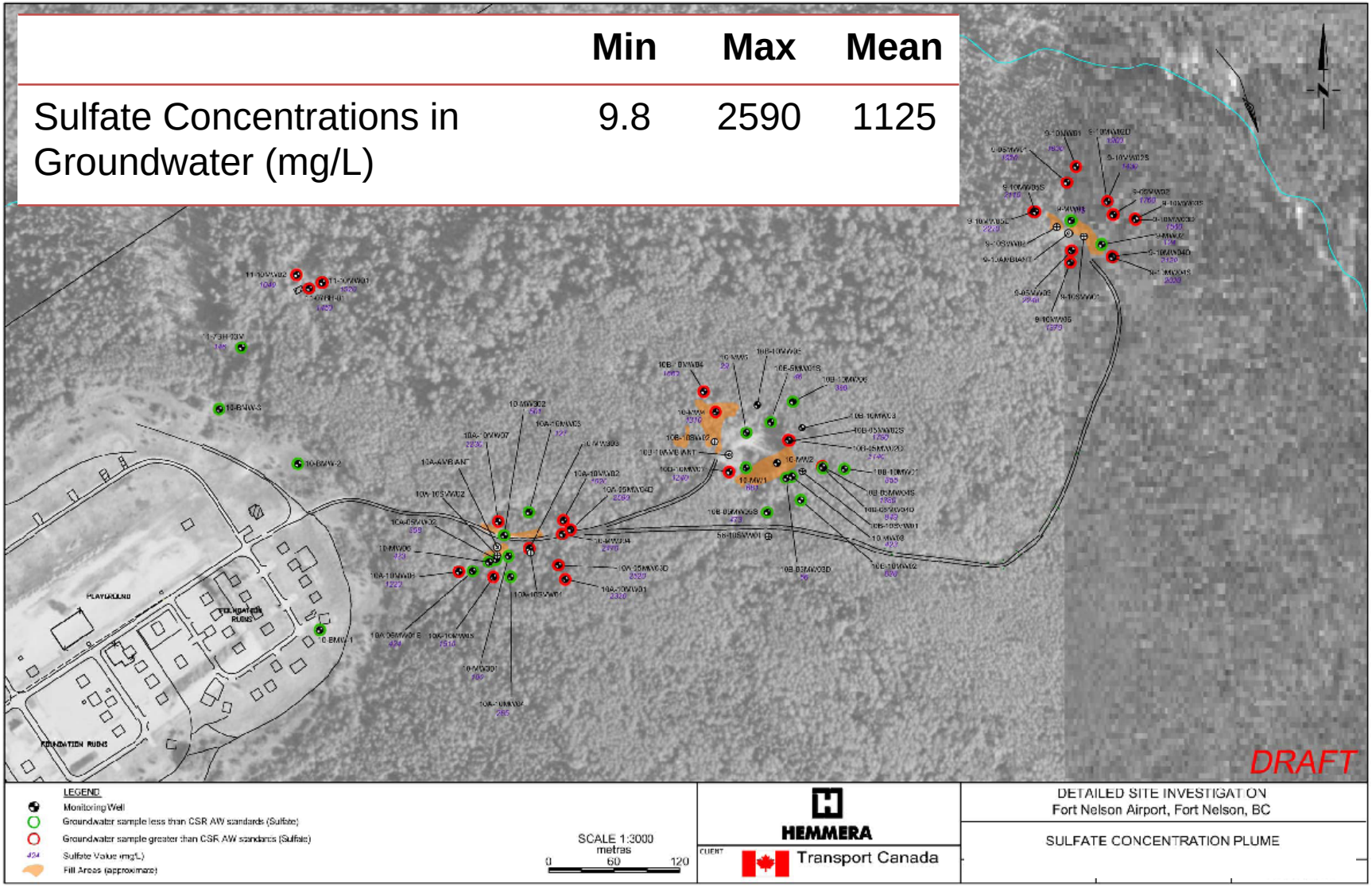
- Local groundwater is mainly perched within the glaciolaccustrine silt/clay deposits
- Groundwater flow directions and gradients mirror topography
- Groundwater flows either towards the north, east or south depending on location along the ridge

Local Groundwater Flow Direction



Sulphate Distribution

	Min	Max	Mean
Sulfate Concentrations in Groundwater (mg/L)	9.8	2590	1125



Preliminary Assessment Results

- Housing dumps may have contained drywall?
- Thin layer of coal at one dump site (sulphide minerals in the coal?)
- Bedrock geology consists of *marine* shales
- Surficial geology consists of silt and clay
- Regional soil studies - chemistry mirrors marine bedrock chemistry (saline soils), gypsum ($CaSO_4 \cdot 2H_2O$) accumulation near surface
- Soil results - elevated barium (barite $BaSO_4$?)
- Groundwater chemistry - elevated SO_4 (widespread) not co-incident with potential sources

Preliminary Conceptual Model

- SO_4 in groundwater associated with:
  - Barite ($BaSO_4$) that could be naturally occurring and sourced from marine shales
  - Gypsum ($CaSO_4 \cdot 2H_2O$) sourced from drywall or naturally occurring gypsum in soil (regional soil survey)
  - Coal containing sulphide (FeS_2) minerals that have oxidized and released SO_4

Test Preliminary Conceptual Model

- To confirm or refute Barite, Gypsum or Sulphide source:
  - Need speciated sulphur analysis in soil
  - Soil mineralogy
  - Groundwater chemistry data (metals and anions)
  - Chemical cross-plots e.g. Ba vs. SO_4, Ca vs. SO_4, and Fe vs. SO4

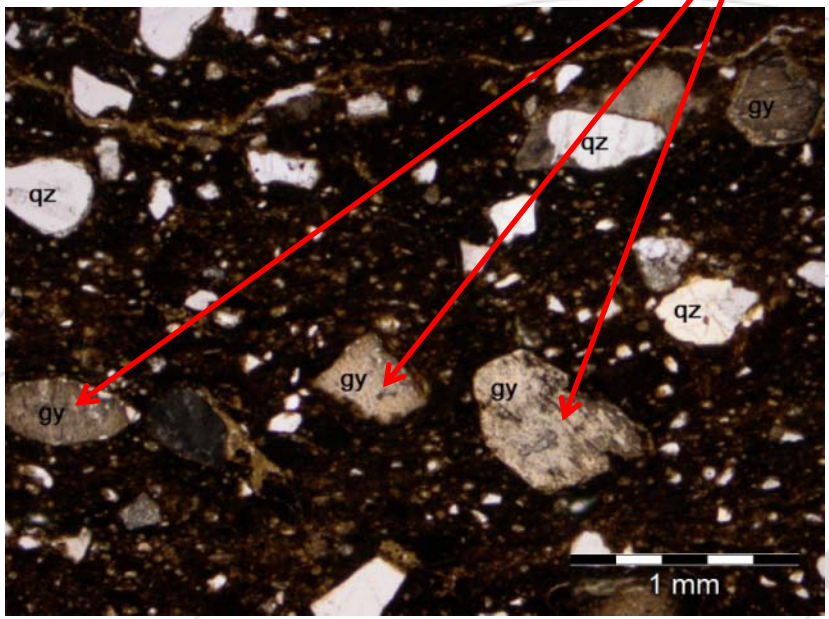
Soil Analytical Results: Speciated S

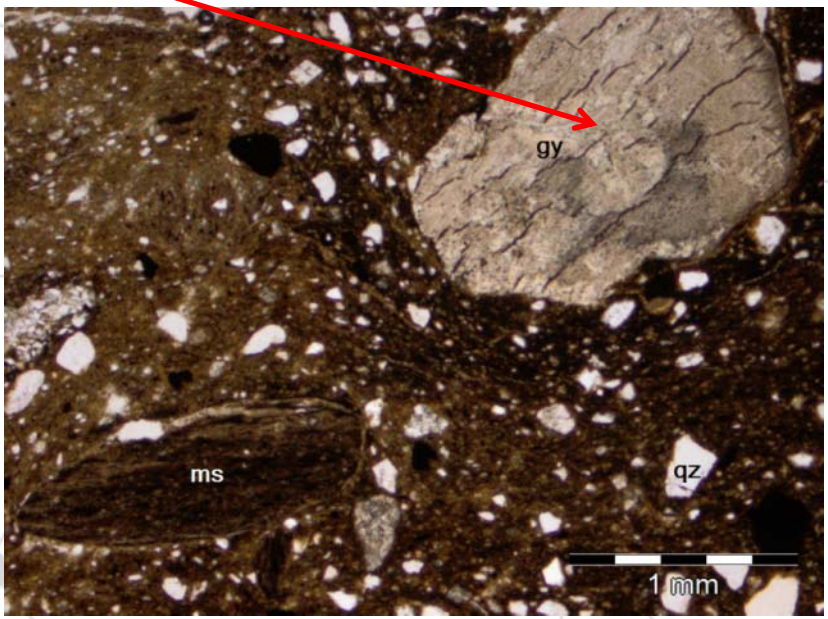
Sample ID	Sample Location	Sample Depth (mbgs)	Soil Type	Sulfate Concentration (ppm)	Sulphide (ppm)
9-10TP-50	Fort Nelson Airport - Site 9	1.8 - 2.0	Silt and Clay	11800	700
9-10TP-51	Fort Nelson Airport - Site 9	4.7 - 4.9	Clay	3200	300
9-10TP-74	Fort Nelson Airport - Site 9	3.6 - 3.9	Clay	5900	300
9-10TP-75	Fort Nelson Airport - Site 9	7.3 - 7.6	Clay	12200	1900
10A-10TP-63	Fort Nelson Airport - Site 10A	3.45 - 3.65	Clay	4000	100
10A-10TP-64	Fort Nelson Airport - Site 10A	4.1 - 4.3	Clay	1900	1700
10A-10TP-65	Fort Nelson Airport - Site 10A	3.9 - 4.0	Clay	4300	200
10A-10TP-66.1	Fort Nelson Airport - Site 10A	3.8 - 3.9	Clay	3200	200
10A-10TP-66.2	Fort Nelson Airport - Site 10A	3.8 - 3.9	Clay	2900	200
10A-10TP-67	Fort Nelson Airport - Site 10A	4.7 - 4.8	Clay	100	4300
10B-10TP-53	Fort Nelson Airport - Site 10B	4.1 - 4.2	Clay	300	100
10B-10TP-79	Fort Nelson Airport - Site 10B	3.3 - 3.4	Clay	200	100
10B-10TP-80	Fort Nelson Airport - Site 10B	3.3 - 3.4	Clay	200	<0.01
11-10TP-1	Fort Nelson Airport - Site 11	3.05 - 3.15	Clay	800	300
10BMW-1.1	Fort Nelson Airport - Site 10B	1.2 - 1.4	Sand and Gravel	100	<0.01
10BMW-1.4	Fort Nelson Airport - Site 10B	4.3 - 4.7	Clay	200	4000

Mineralogy Results

Mineralogy Results

- Polished thin sections prepared for one sample where 12,200 ppm SO_4 was reported in soil
- Several grains of gypsum >1% (i.e. >10,000 ppm)

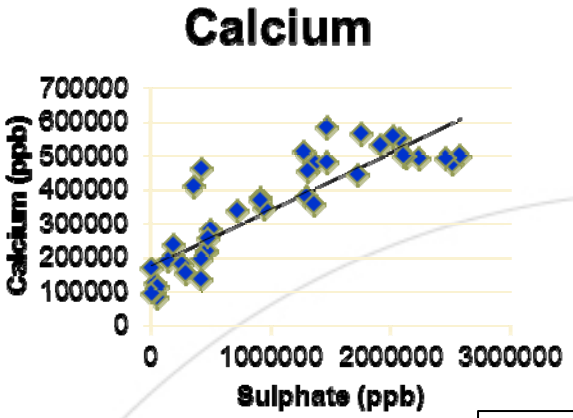


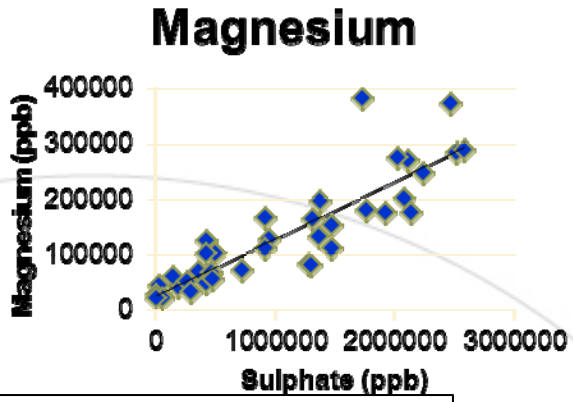


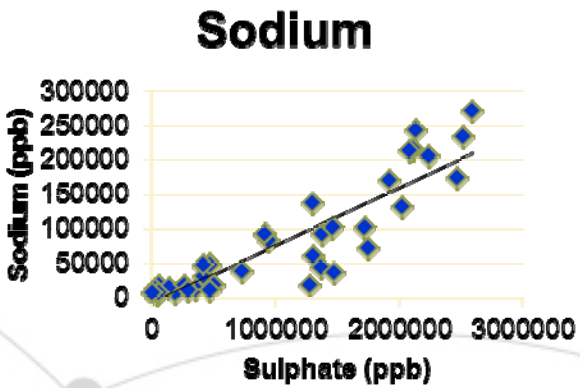
Chemical Cross-Plots & Piper Plots

Chemical Cross-Plots

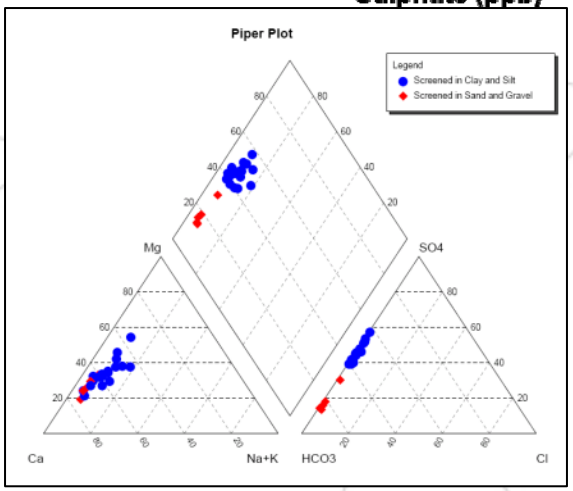
- Conc. of 33 parameters (metals and anions) plotted vs SO_4 conc.
- Dissolved Ca, Mg, and Na correlated positively with SO_4 (<u>Not</u> Ba & Fe)







Piper Plots



Dissolved SO_4 Chemical Signature

Typical mineralogy containing Ca, Mg, Na and SO_4 include:

Mineral Name	Mineral Formula	Mass Ratio (Ca, Na, Mg:SO4) in the mineral	Mass Ratio Based on Groundwater Analytical Results (Range)
Gypsum / Anhydrite	$CaSO_4 *2H_2O$	0.42 ($Ca:SO_4$)	0.2 – 0.6 ($Ca:SO_4$)
Epsomite	$MgSO_4*7H_2O$	0.25 ($Mg:SO_4$)	0.1-0.4 ($Mg:SO_4$)
Thenardite	Na_2SO_4	0.48 ($Na:SO_4$)	0.01 – 0.07 ($Na:SO_4$)

- Dissolved mass ratios agree well with mineral mass ratios
- These are minerals commonly occur in evaporitic sedimentary deposits such as marine shales

Refinement of Prelim. Conceptual Model

- Barite not a major source of dissolved SO_4
- Sulphide not a major source of diss. SO_4
- Gypsum is a more likely source
- Remaining questions:
  1. Could natural gypsum solubility account for concentrations measured?
  2. Is the source of gypsum from natural or anthropogenic?

1.Gypsum Solubility

- Max SO_4 concentration 2,590 mg/L
- Literature – 3,150 mg/L to 5,000 mg/L in more saline soil environments
  - Translates to SO_4 concentrations of 1,750 to 2,790 m/L
  - $[SO_4]$ in seawater ~2,700 mg/L
- Conclusion:
  - Gypsum alone could account for the concentrations reported in groundwater

2. Sources of SO_4

Potential Anthropogenic Sources:

Drywall: Potentially disposed during dumping?

BUT:

- Drywall *not* observed in fill materials
- Only 3 of 4 sites were dump sites
- Dissolved SO_4 concentrations at dump sites generally low

Coal: Can contain pyrite (FeS_2) when oxidized can release sulphate and iron.

BUT:

- Coal was only deposited at only one dump site
- No correlation between SO_4 and Fe in groundwater

Conclusion: **Anthropogenic Derived Sulphate is Unlikely**

2. Sources of SO_4 (Cont'd)

Natural Sources:

Natural Sulphate Minerals: **e.g.** Gypsum

- Bedrock comprised of marine shales
- Soil mapping indicate presence/accumulation of gypsum in soils
- High SO_4 concentrations deep in native soil (>12,000 ppm)
- Mineralogy confirms natural gypsum (>10,000 ppm)
- Strong positive correlation between Ca & SO_4 and Mg & SO_4
- Ca:SO4 and Mg:SO4 ratios in groundwater suggest sulphate mineral source
- Gypsum is fairly soluble in water 3,150 mg/L pure

Study Conclusions

- Natural gypsum in soil was the source of SO_4 in groundwater
- Identifying 3 background well locations was challenging
- Ministry liked the approach due to the supplemental scientific based multiple lines of evidence provided

Lessons Learned:

- 3 background wells may often not be enough
- Always useful to develop a conceptual model to explain the occurrence of the constituent in question – and collect key data to support/refute the conceptual model

THANK YOU!

QUESTIONS?

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