Extraction System Optimization: The Importance of Proper Characterization of a Groundwater Plume

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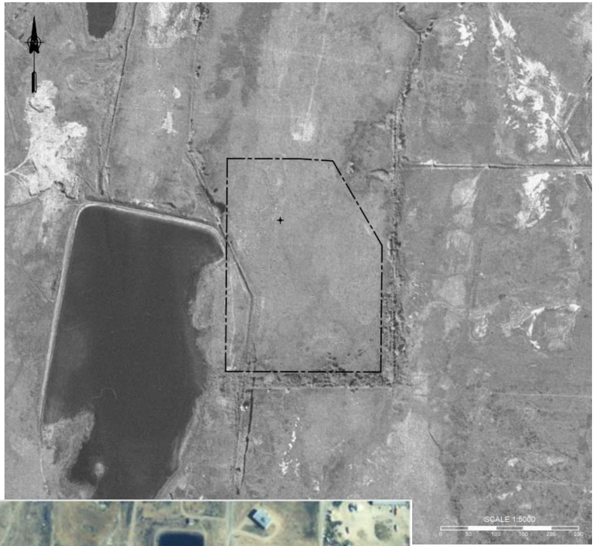
Janine Wildschut, Ph.D., P.Biol., Flint Environmental Services
Stephen Livingstone M.Sc., P.Geo., Geocentric Environmental Inc.

Outline

- History of the site
- Summary of the work conducted up to 2019 and the 2020 work plan.
- Summary and findings of Flint’s 2020 work.
- Summary of work conducted by Flint in 2021.
- Site outlook.



1962

1969

1986

2011

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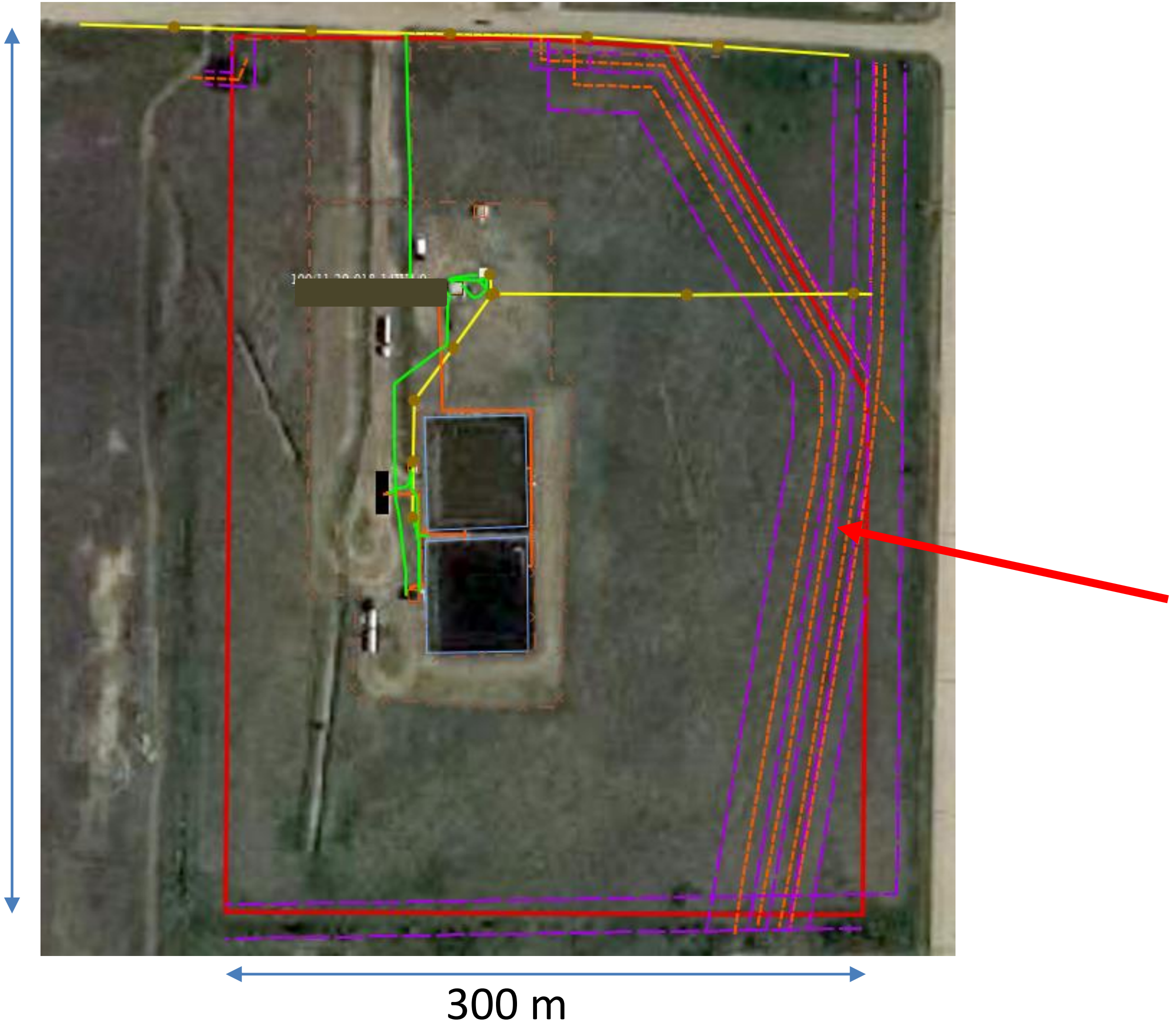

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1991 to 2017

- Starting in 1991, environmental site assessments confirmed CaCl impacts to soil and groundwater.
- In 1992 and 1993, liner inspections found 86 pinholes, as well as moderate to large holes due to gopher activities. A poorly patched tear was also leaking.
- In 1998, the ~30-year-old pond was decommissioned, and two new ponds were constructed.
- It was reported that brine impacted soil was used to line and berm the new ponds.
- Between 1991 and 2012, 28 groundwater monitoring wells were installed to depths ranging from 5.6-12.0 mbgs, and bi-annual groundwater monitoring was conducted.

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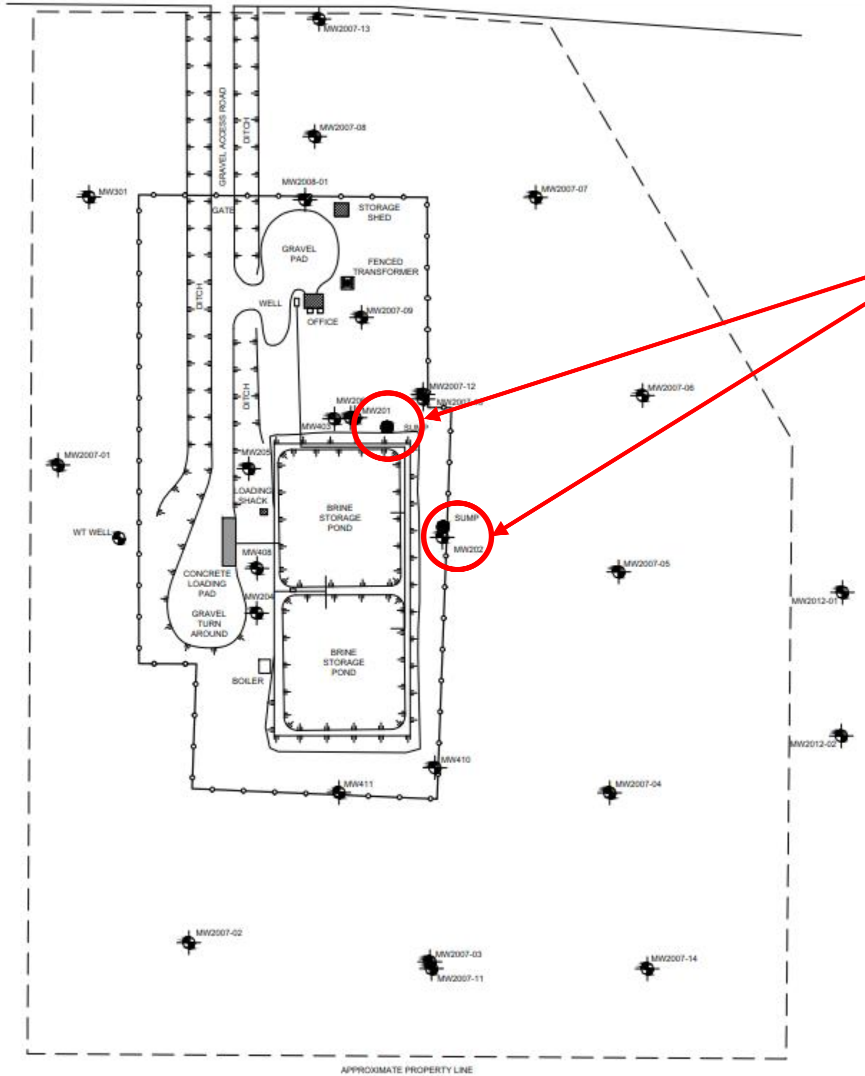

Recovery Wells

2017 Figure of Site

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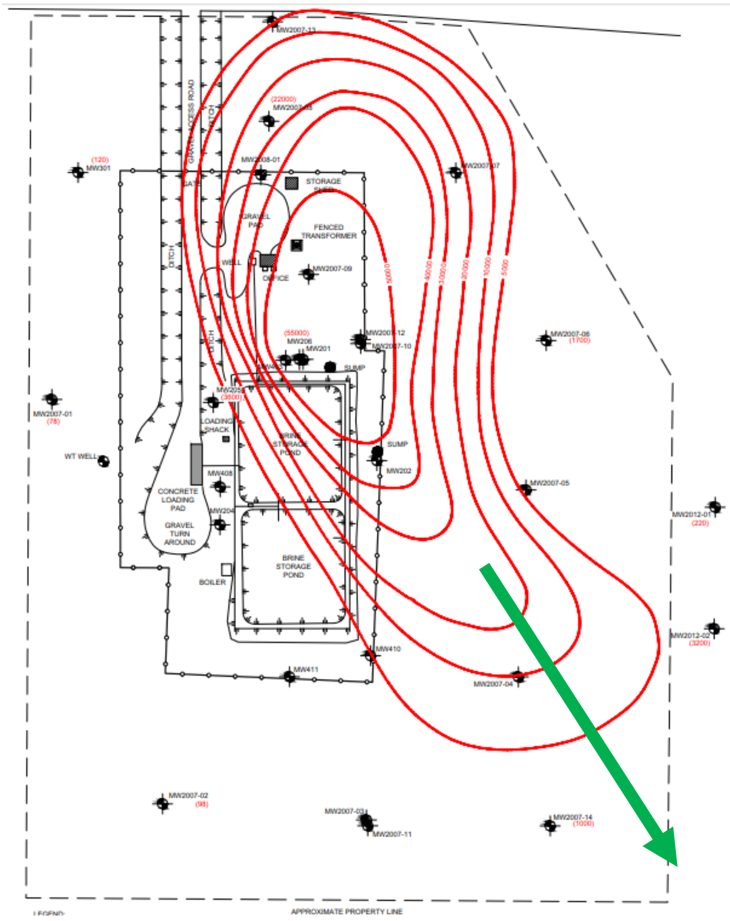

2017 (Spring) Chloride Concentration (mg/L) Contours of Intermediate Monitoring Wells (3-4 mbgs)

2018-2020

- Site owner learns that previous consultant was reusing annual monitoring data.
- New consultant takes over in 2018.
- Key actions by new consultant:
  - Decommissions several of the monitoring wells due to them being screened through a confining layer.
  - Installs 5 extraction wells around the ponds.
  - Delineation activities of soil and groundwater.

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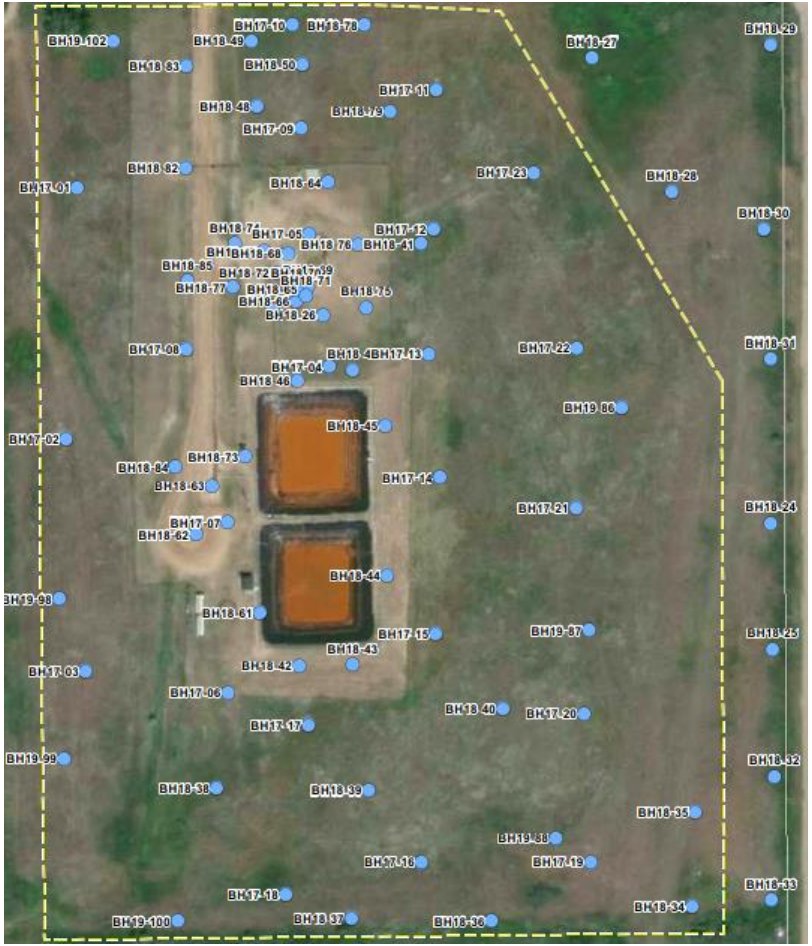
Extraction wells were installed…

Additional soil delineation was completed…



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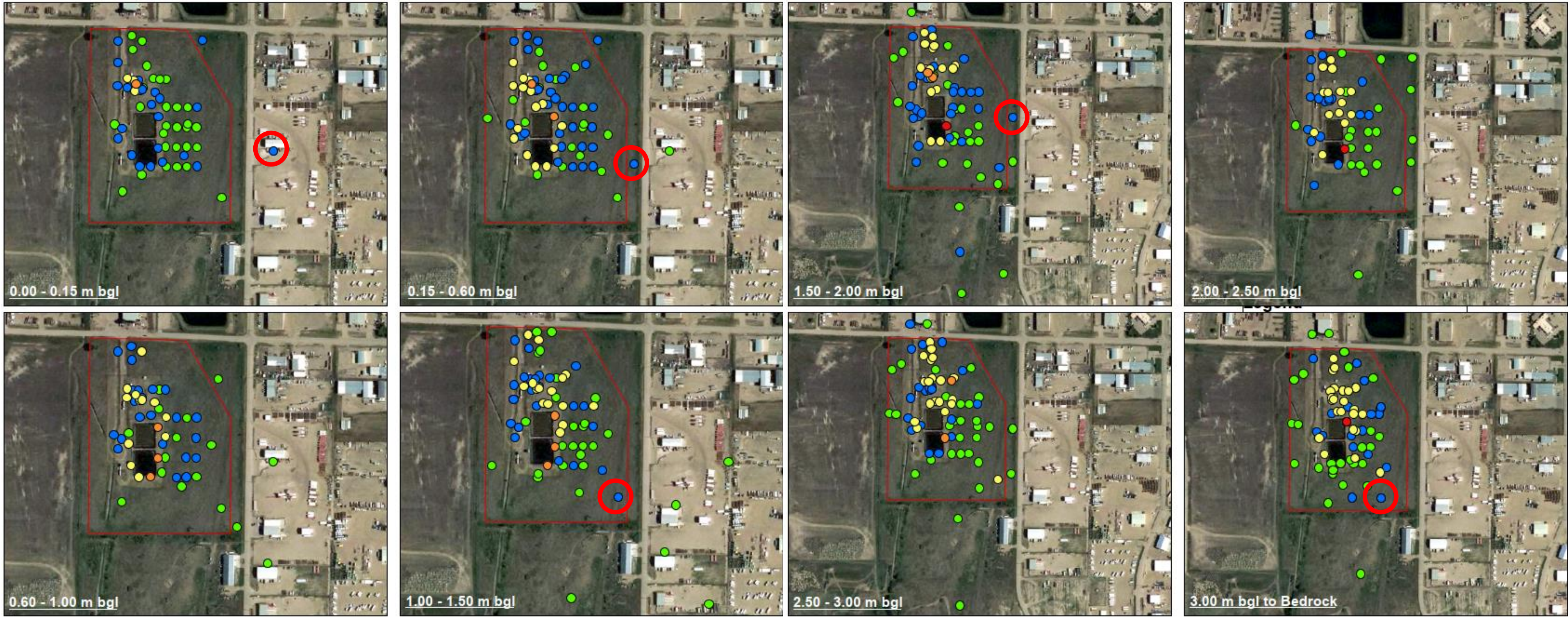

Legend

Chloride (mg/kg)

- <100
- 100 - 1000
- 1000 - 5000
- 5000 - 10000
- > 10000
- Site Boundary

<u>2018 Soil Delineation Conclusions</u> - Confirm 100-1000 mg/kg of chlorides at a few offsite and/or eastern/southern boreholes in overburden.

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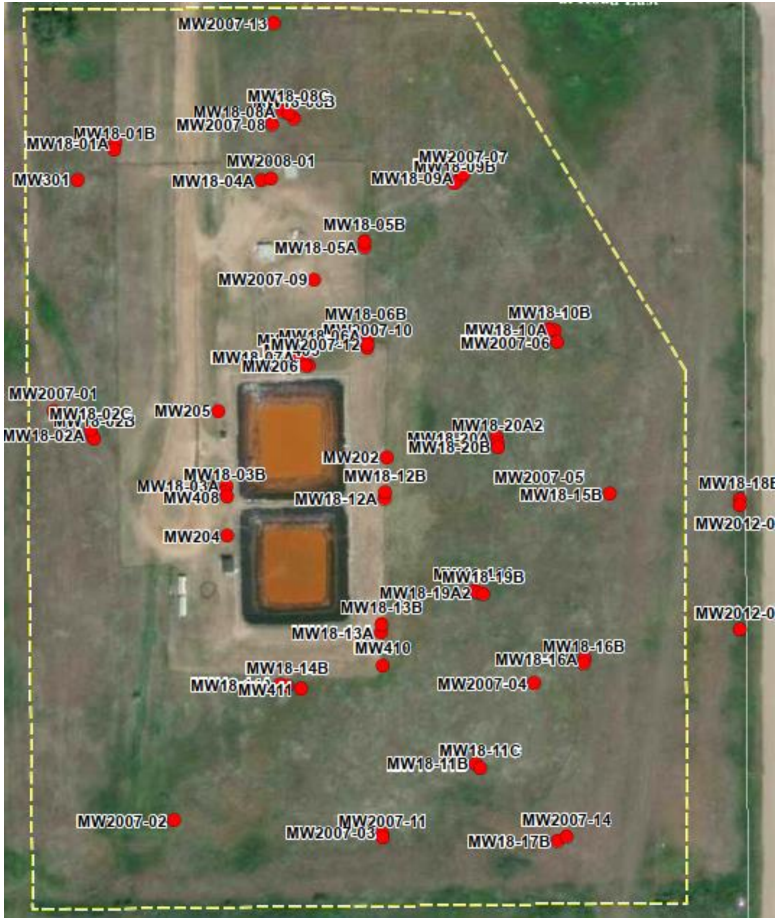
Additional groundwater delineation was completed…



- 44 monitoring wells
  - 17 in overburden
  - 24 in interbedded coal unit
  - 3 in deeper sandstone/shale
- 5 groundwater extraction wells

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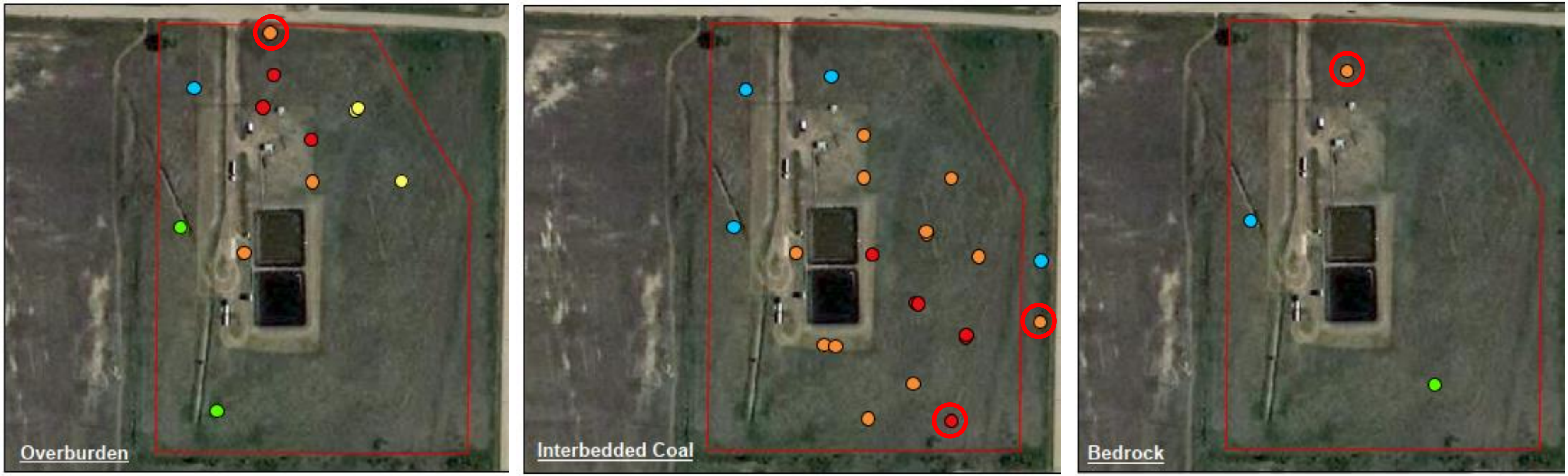

Legend

Chloride (mg/L)

- < 120
- 120 -250
- 250 - 1000
- 1000 - 10000
- 10000 - 19000
- Site Boundary

2018 Groundwater Delineation Conclusions - Confirmed 1,000-10,000 mg/L of chlorides at offsite (eastern) and northernmost monitoring well and up to 19,000 mg/L at southernmost monitoring wells

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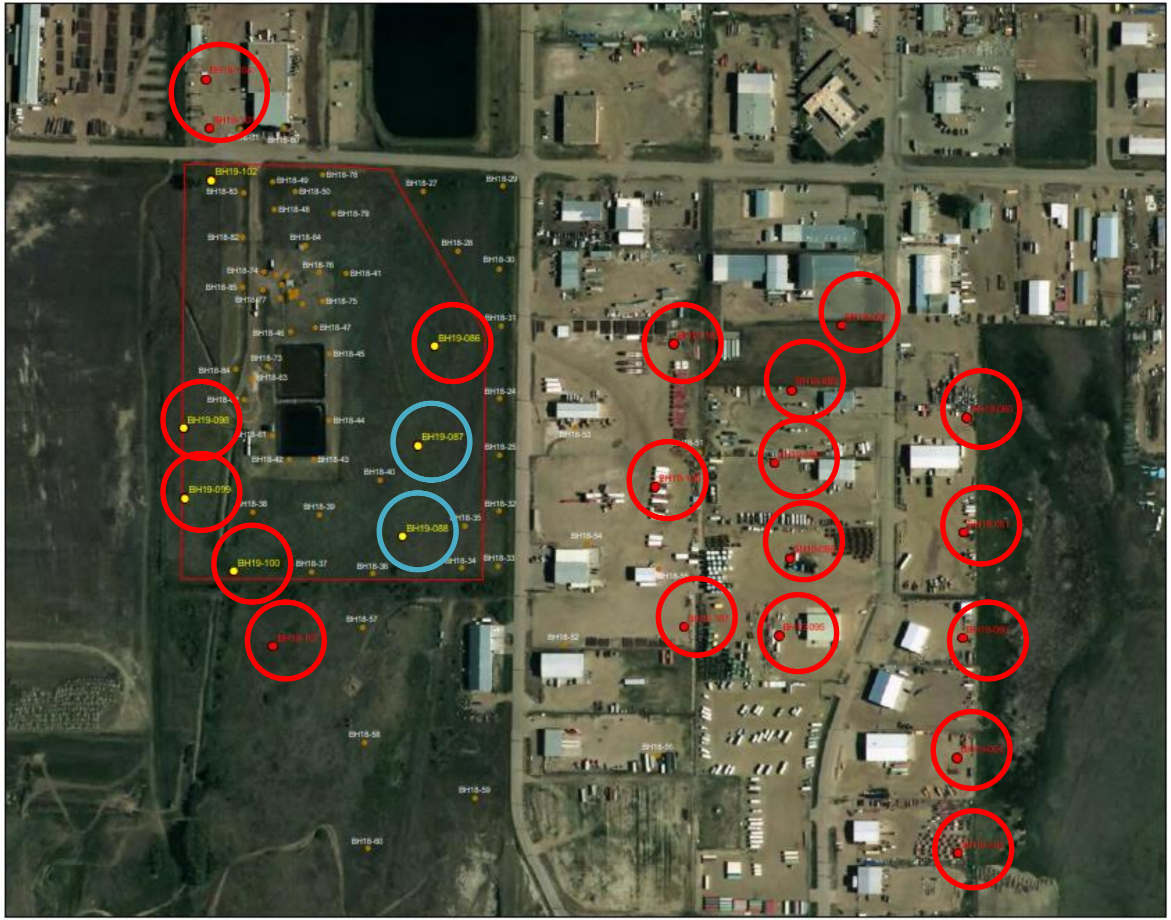
Are there significant offsite impacts? The plan was to find out in 2019. In addition to installing extraction wells at the site boundary to stop impacts from going offsite.



- The 2019 work plan was to advance 7 BHs into bedrock onsite and 14 BHs into bedrock offsite.
- Two extraction wells were going to be installed at the SE corner of the property.

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2019 Work Plan and Cost Estimate

- Advance 21 boreholes on and offsite to delineate chloride impacts in bedrock.
- Install 2 extraction wells at the eastern (south) boundary to inhibit chloride impacts from going offsite.
- Figure out how to fix the 2018 extraction wells as they were not pumping well.
- **Cost Estimate: $670,000**

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Client Requests a Second Opinion

- After reviewing all available data a few key components were found to be missing:
  - a conceptual site model
  - an extraction system design diagram
  - an advanced understanding of the site hydrogeology and contaminant fate and transport
  - a risk assessment

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Proposed 2020 Plan

- Update the geological and hydrogeological framework and conceptual site model.
- Evaluate the historical brine source areas.
- Develop 3D visualization models based on all current and historical soil and groundwater chloride chemical results.
- Review and evaluate the groundwater geochemistry, fate and transport, and chloride plume stability.
- Review and evaluate the groundwater extraction system, capture zones, and volume recovery.
- Optimize the groundwater extraction system with an updated containment strategy.
- Propose new supplemental extraction well locations to optimize extraction system.
- Propose new delineation well locations.

Approximate cost = $100,000

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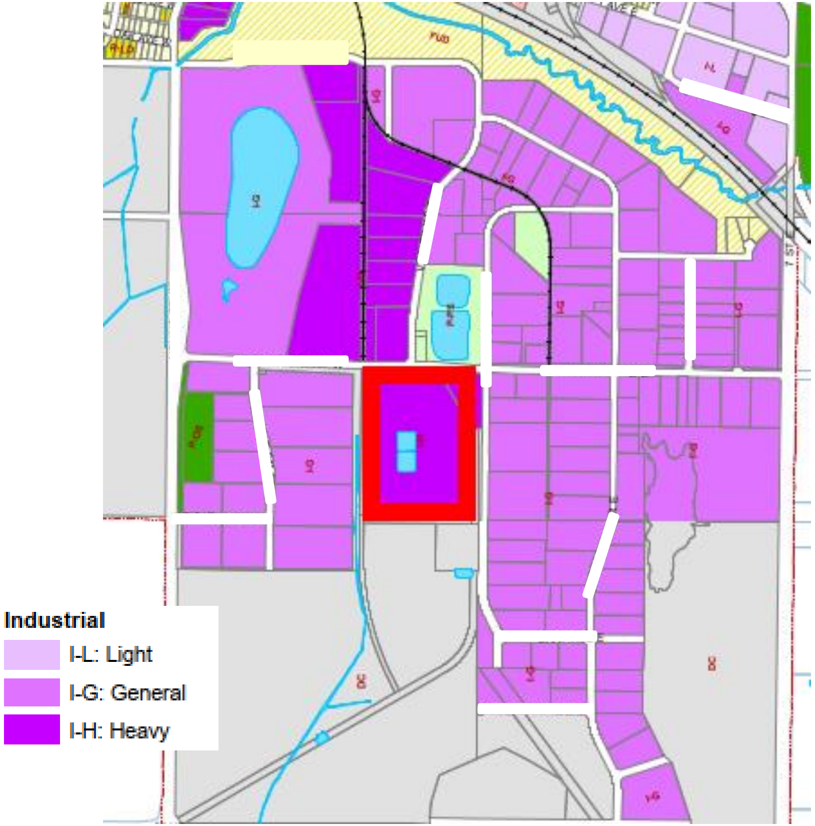
Site Topography

Surrounding Land Use



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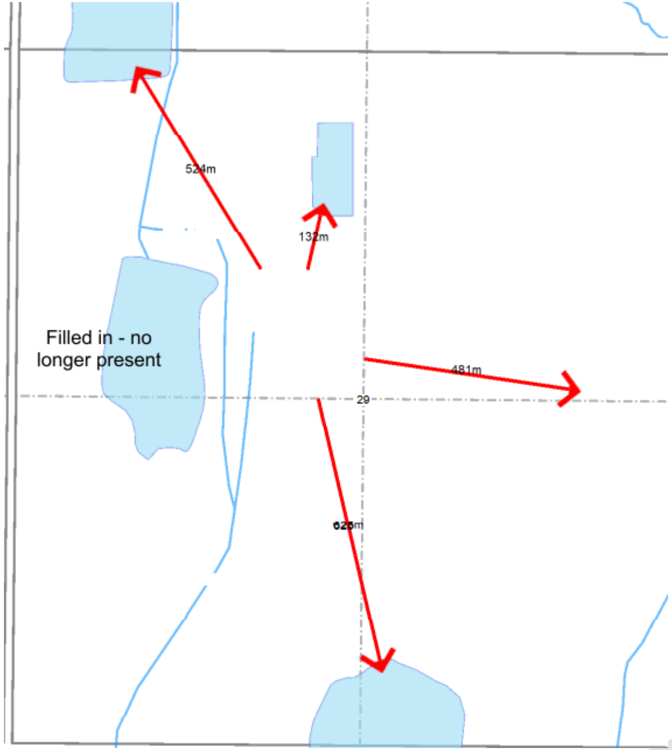
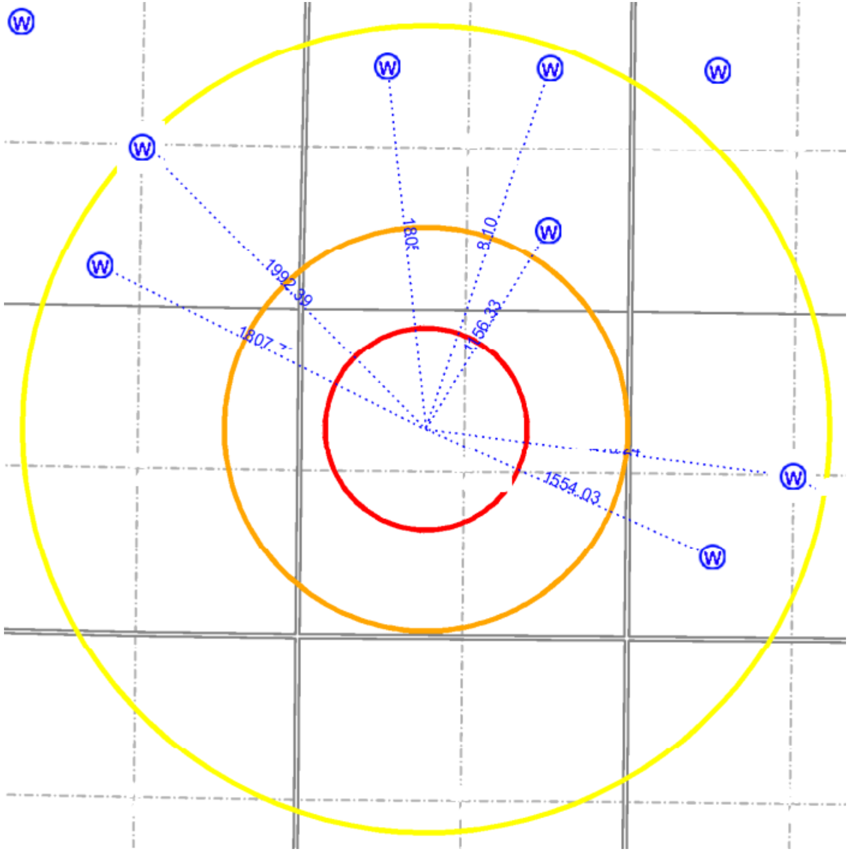
Surface Water Bodies



Distance to Water Wells



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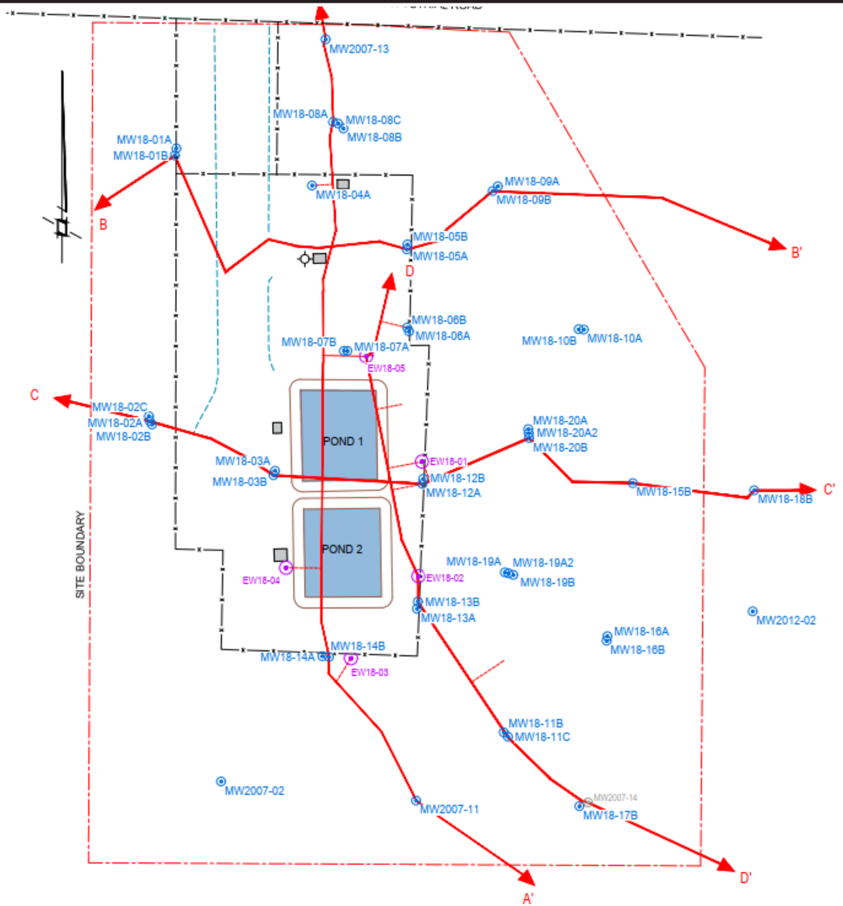
New Cross Sections to Determine Geology



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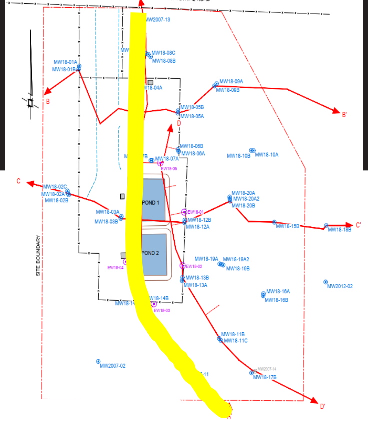
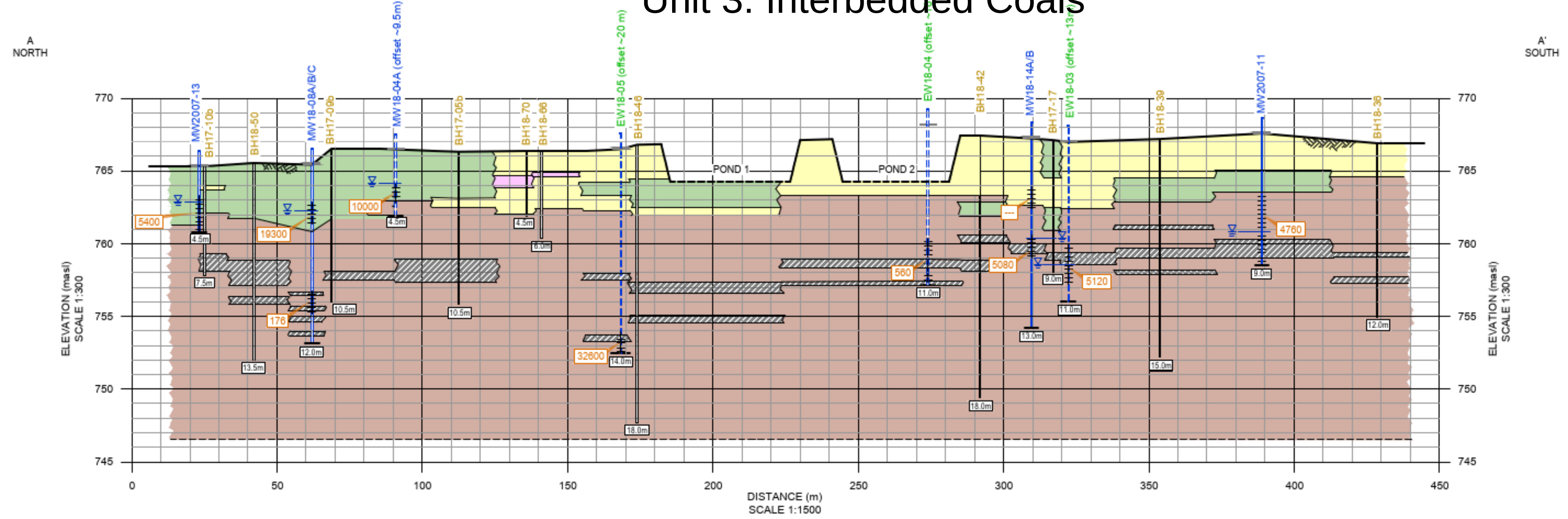


Site Geology

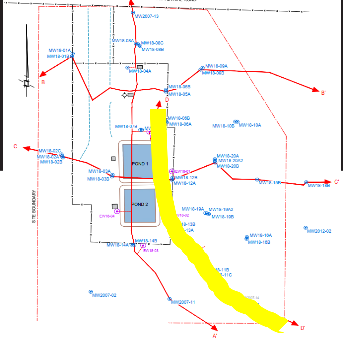
Unit 1: Surficial Clay Till to Sand to Silty Sand overburden unit

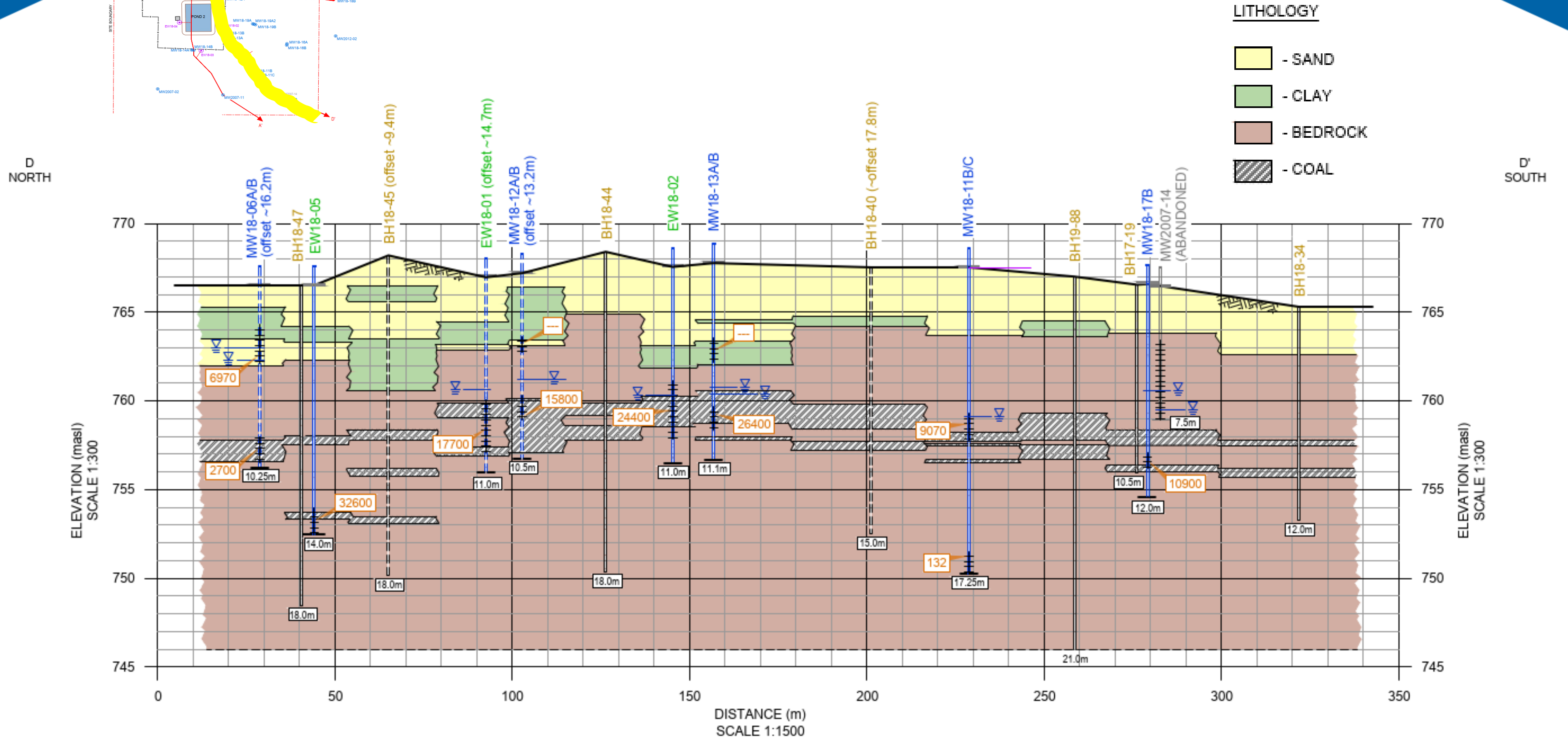
Unit 2: Bedrock-Interbedded Shales and Sandstones;

Unit 3: Interbedded Coals

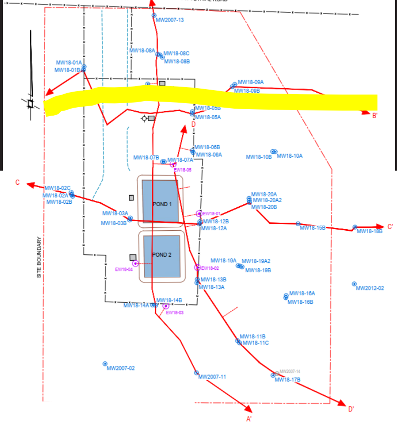


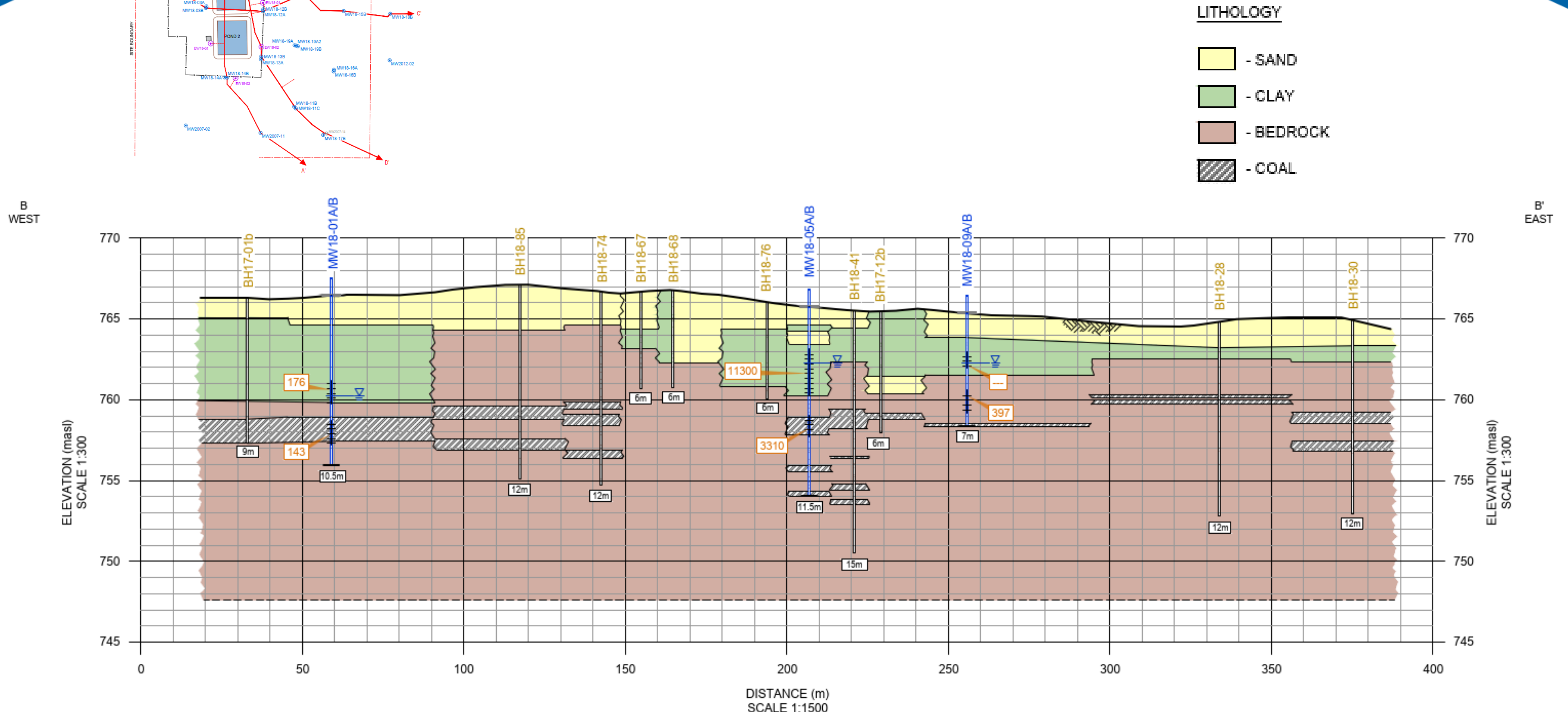
Site Geology



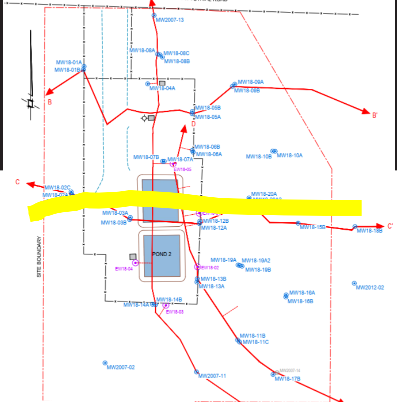


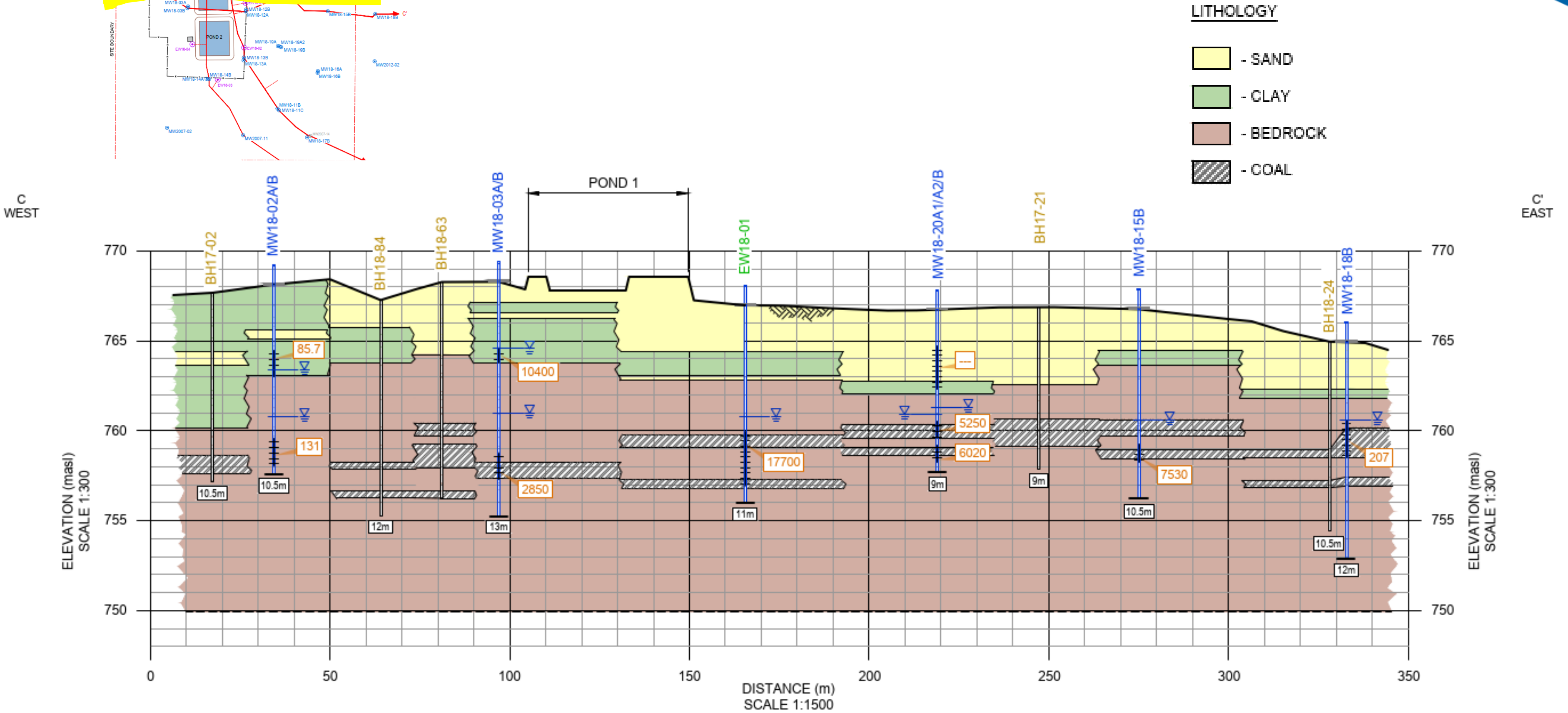
Site Geology





Site Geology

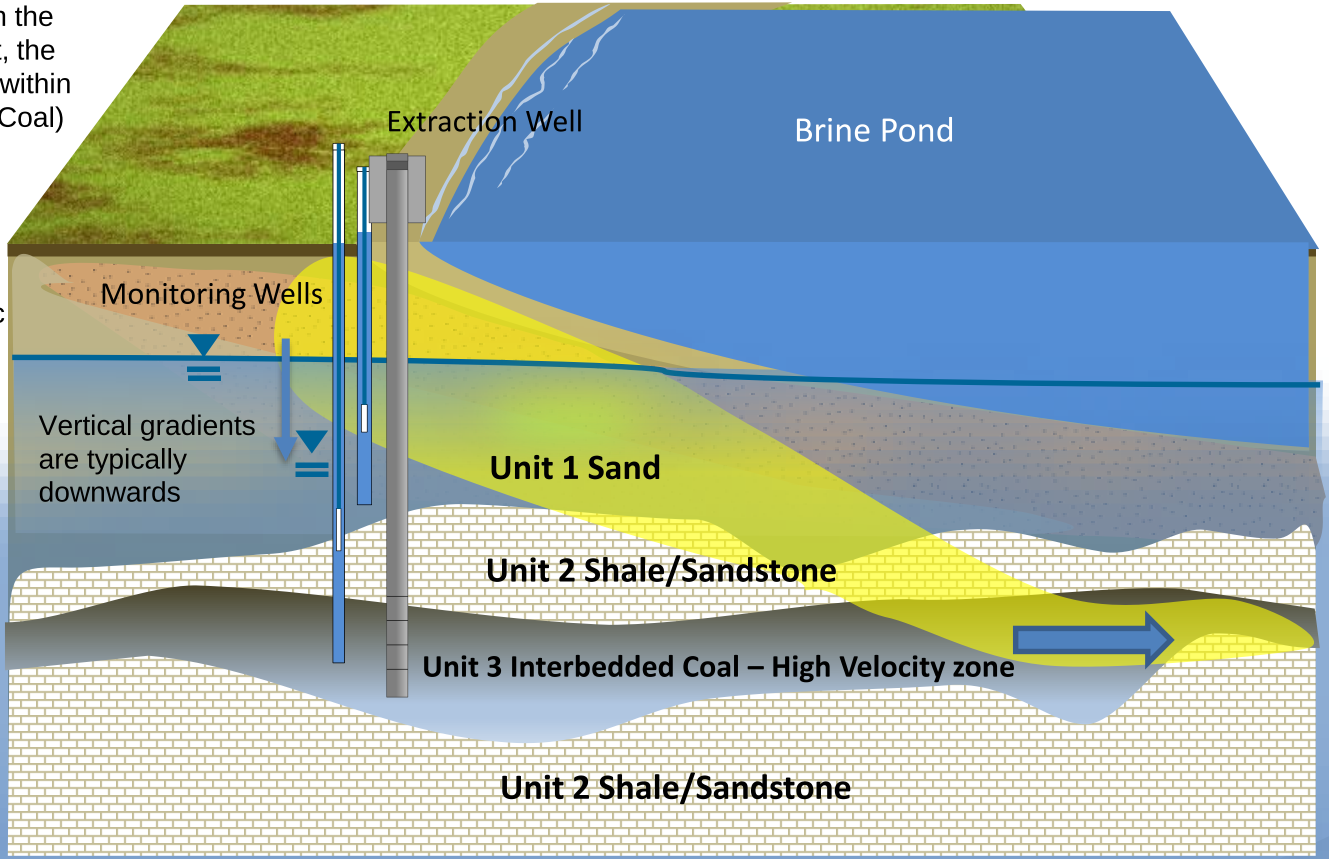




Conceptual Model Schematic

The water table is found primarily in Unit 1 in the central and northern portion of the Site. In the south and southeast, the water table is found within Unit 3 (Interbedded Coal)

Unit 1 Clays Tills have lower hydraulic conductivity (K) and lower Cl values.



Groundwater flow in Unit 1 and Unit 3 towards the south-southeast

Unit 3 Interbedded Coal K values are typically an order of magnitude higher ($1x10^{-4}$ m/sec) than the Unit 2 Sandstones and the Unit 1 Clay Tills

Linear velocity (VL) for the Site within the coal unit was estimated to be on the order of 2 m/year

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Source Areas

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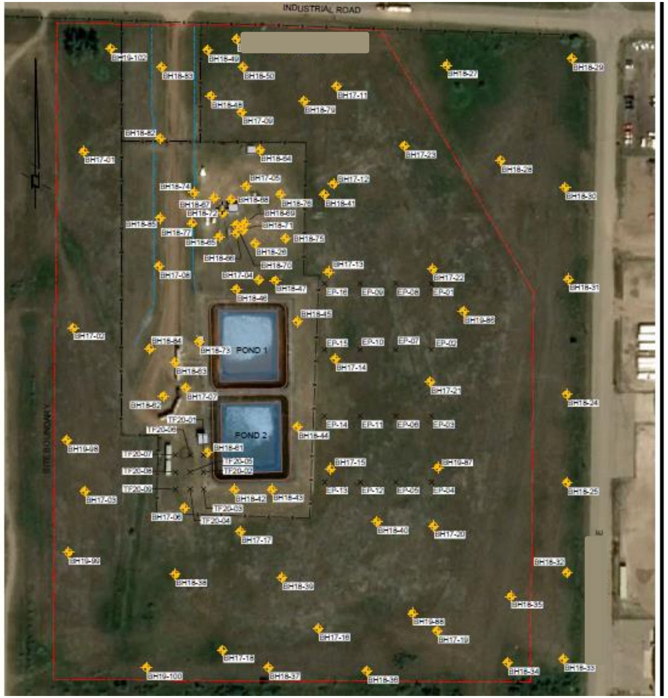
Source Area - Soil Impact Evaluation

The purpose: To evaluate the soil impacts and to provide insight into the remedial target zones, and approach.

Borehole Data Base



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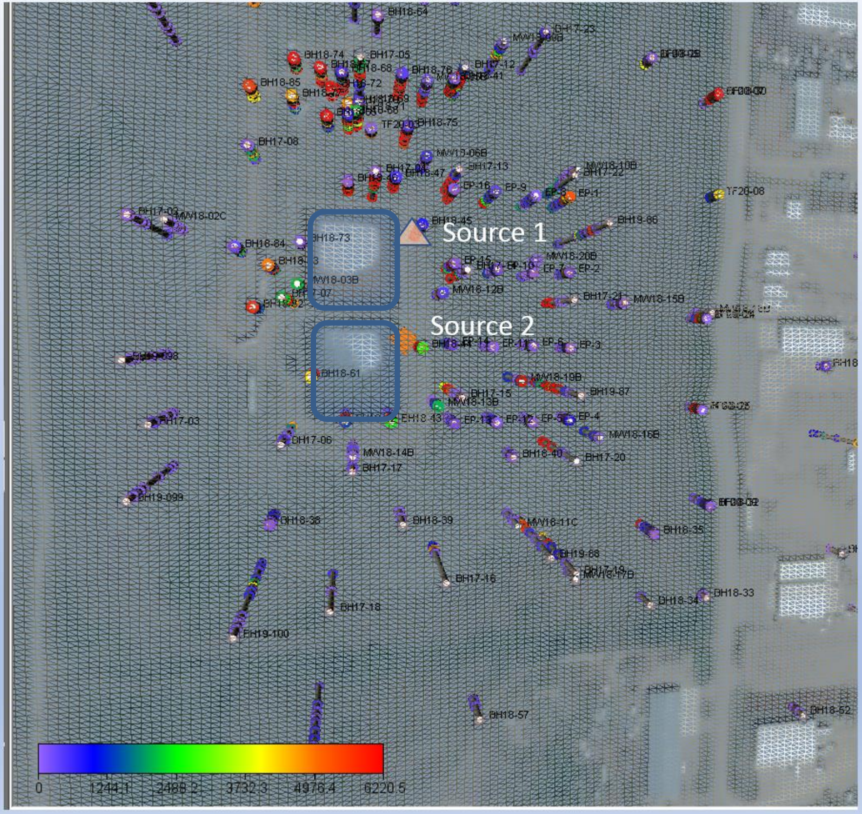
Soil Source Areas

Chloride Impacts
>5000 mg/kg



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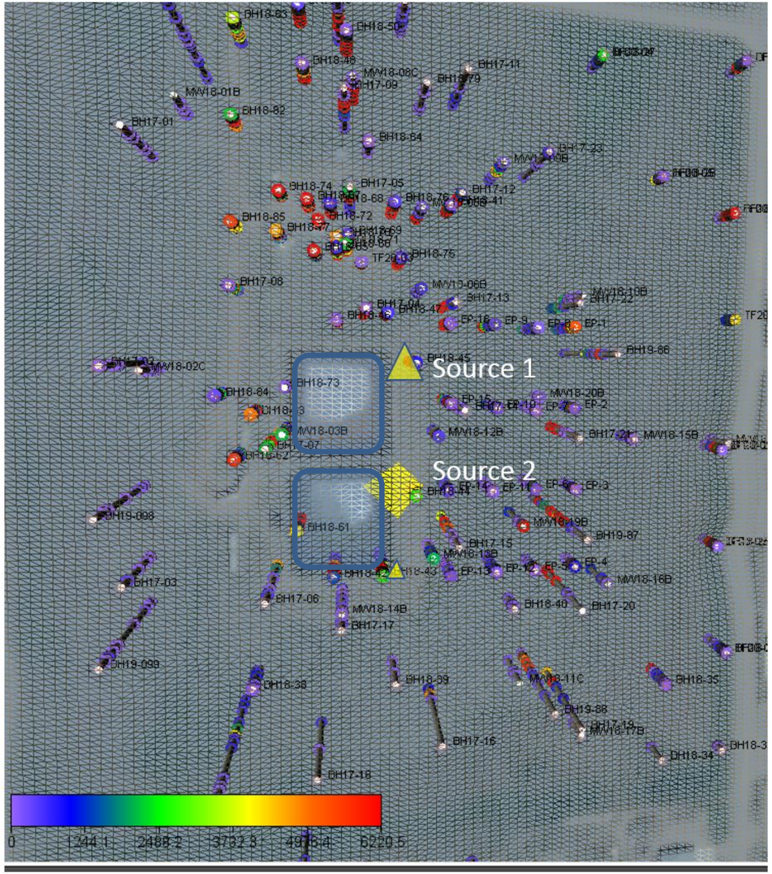
Soil Source Areas

Soil Chloride Impacts >4000 mg/kg



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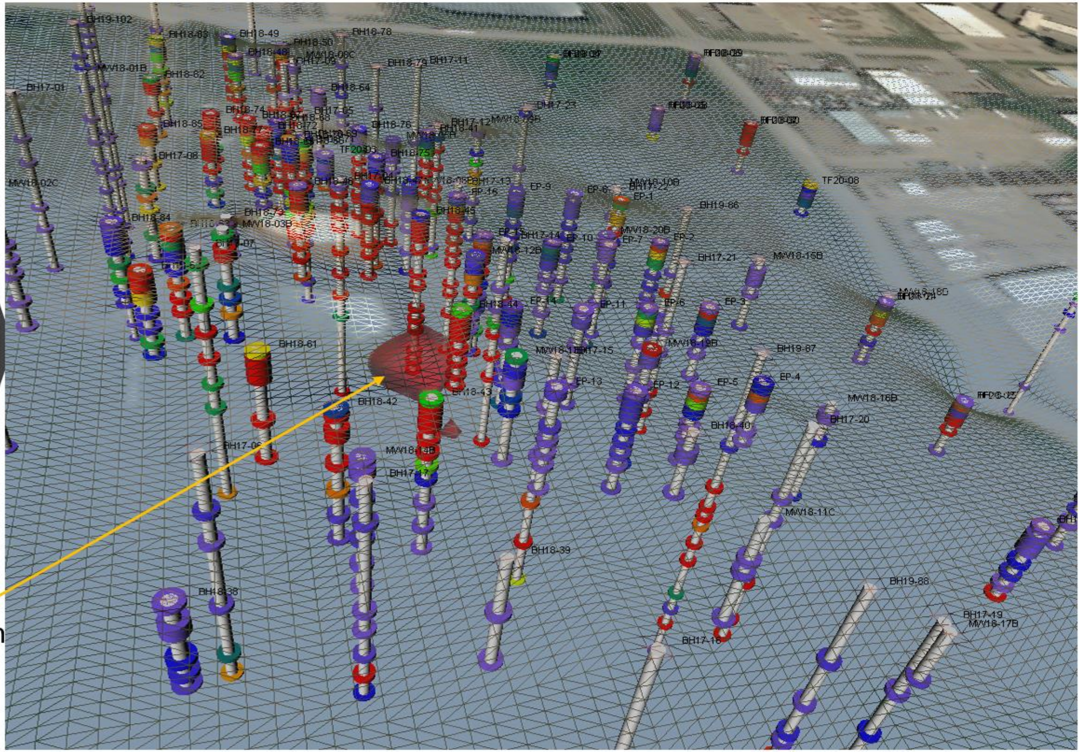
Soil Source Areas

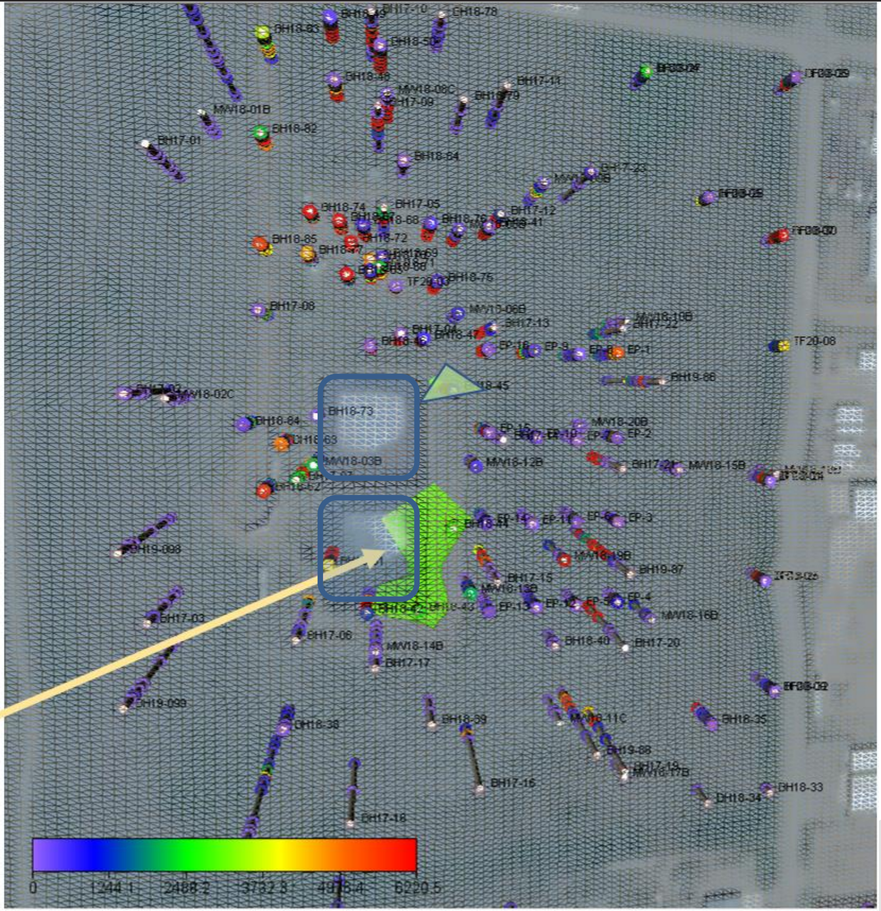
Soil Chloride Impacts >4000 mg/kg



Source Area 2. Vertically discrete at depth near watertable

Soil Source Areas

Soil Chloride Impacts >3000 mg/kg



Source 2 Area near surface and at depth; along eastern and southern flank

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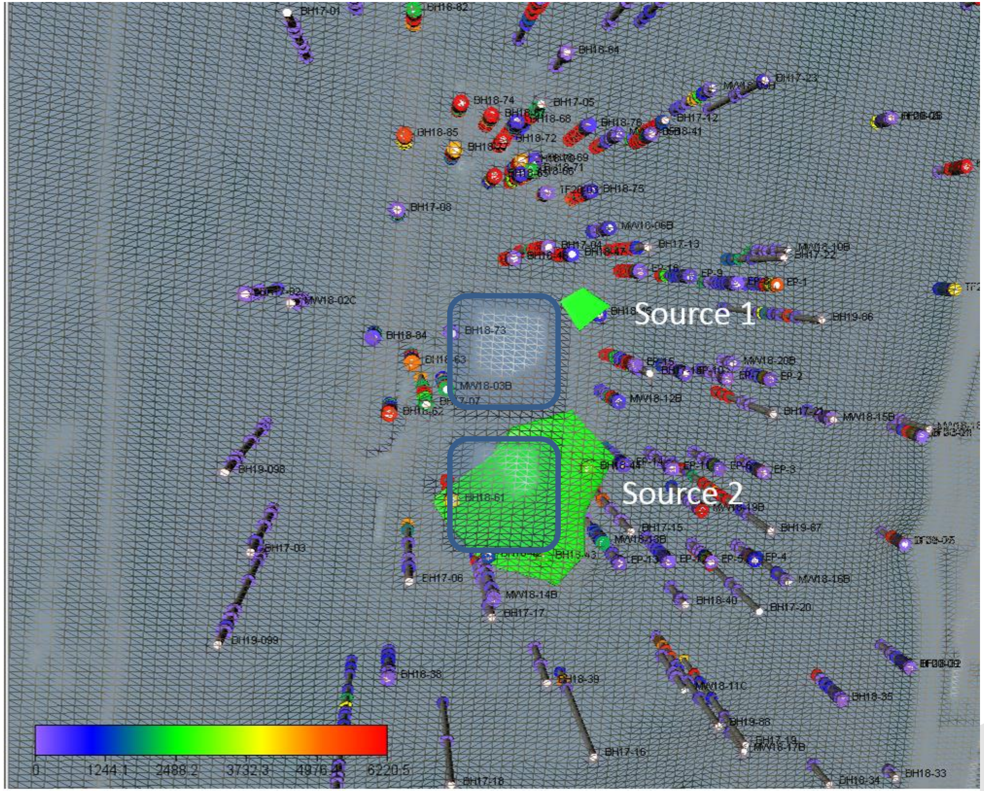
Soil Source Areas

Soil Chloride Impacts >2,500 mg/kg



Source 1 is laterally limited;
Source 2 encompasses the east, south and portions of western flank of brine pond 2

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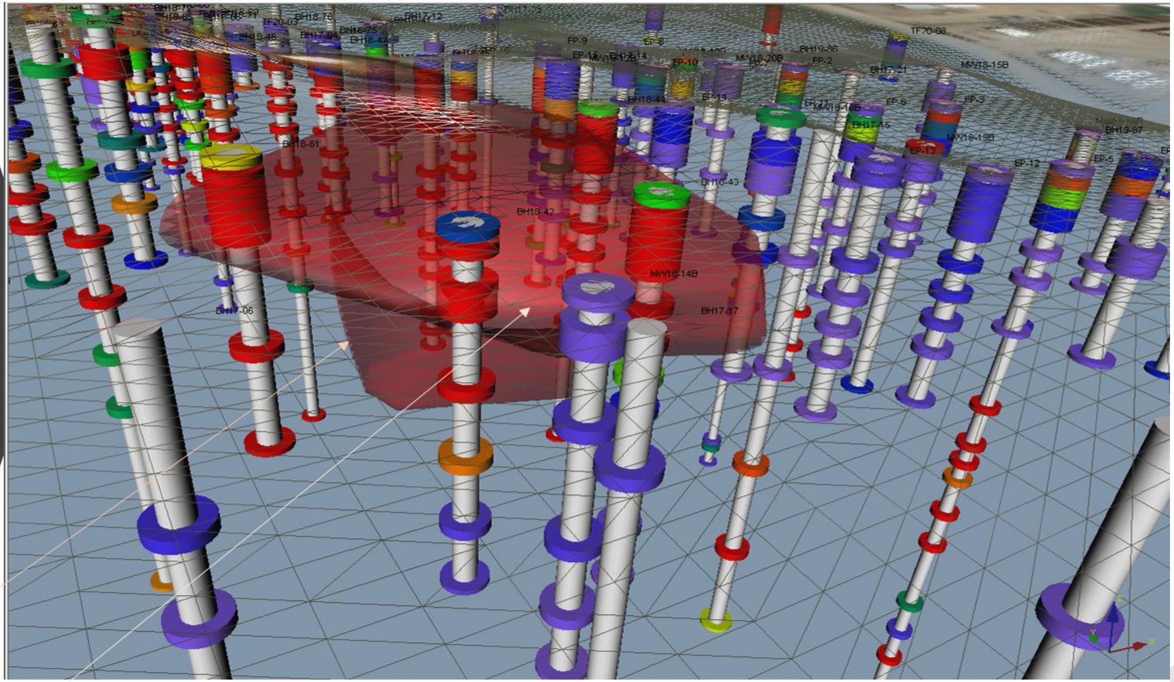
Soil Source Areas

Soil Chloride Impacts >2,500 mg/kg

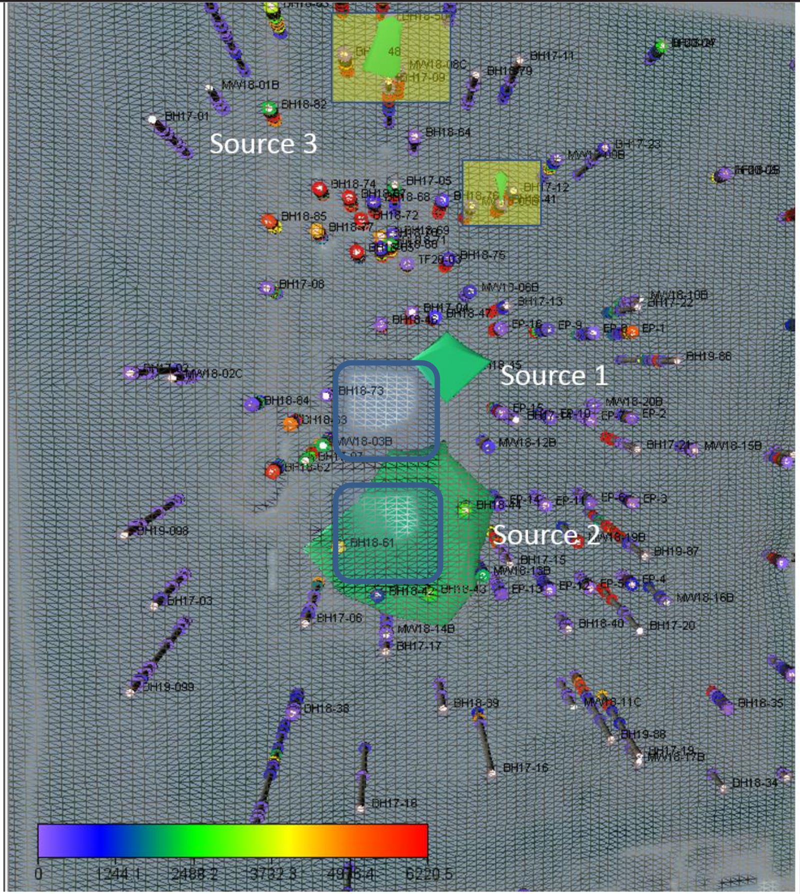


Source 2 along eastern flank
Impacts at near surface and at depth;

Along southern flank impacts are more surficial

Soil Source Areas

Soil Chloride Impacts >2,000 mg/kg



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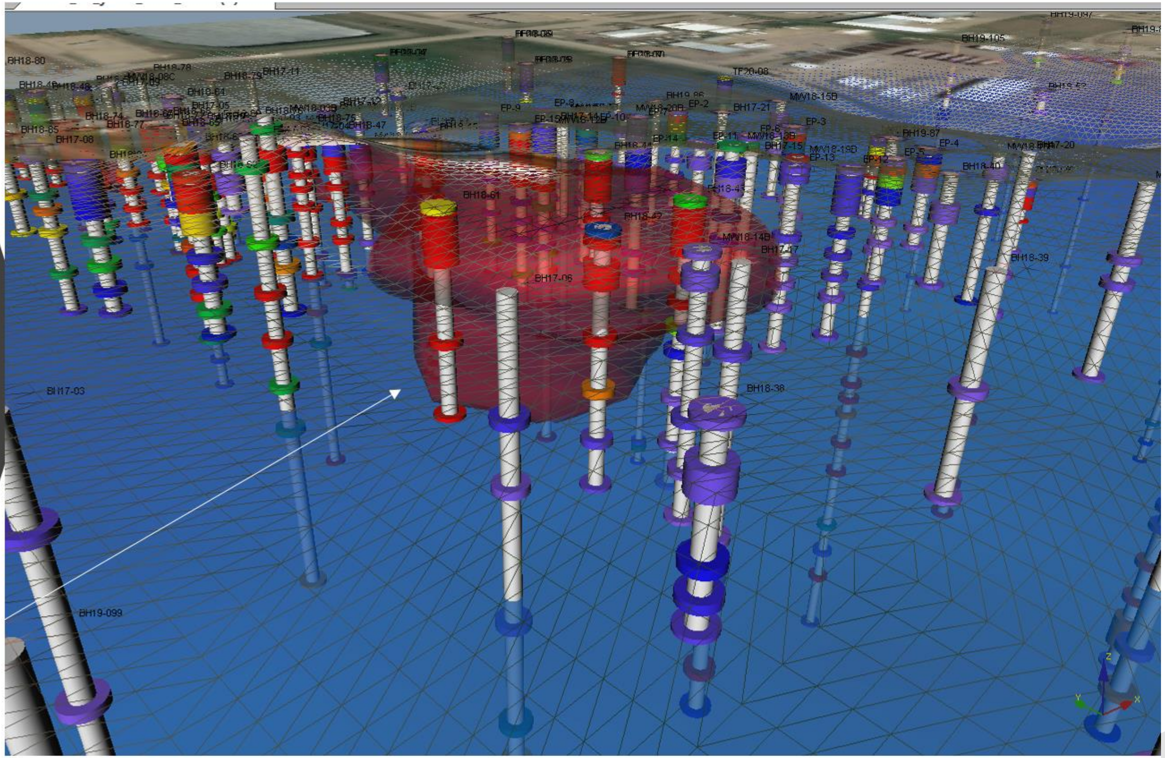
Soil Source Areas

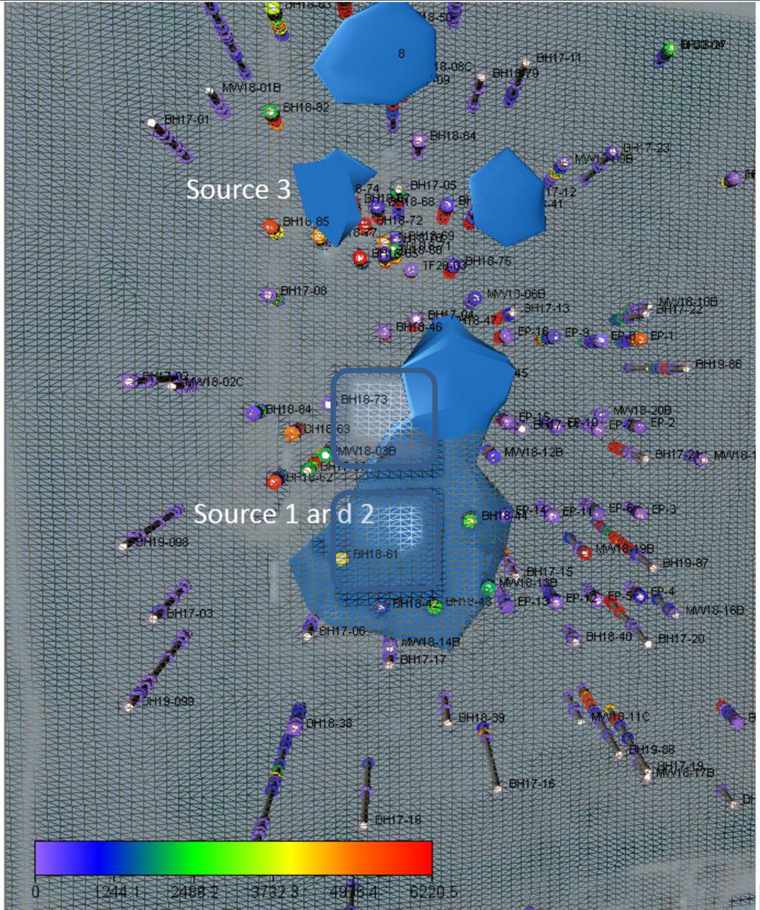
Soil Chloride Impacts >2,000 mg/kg



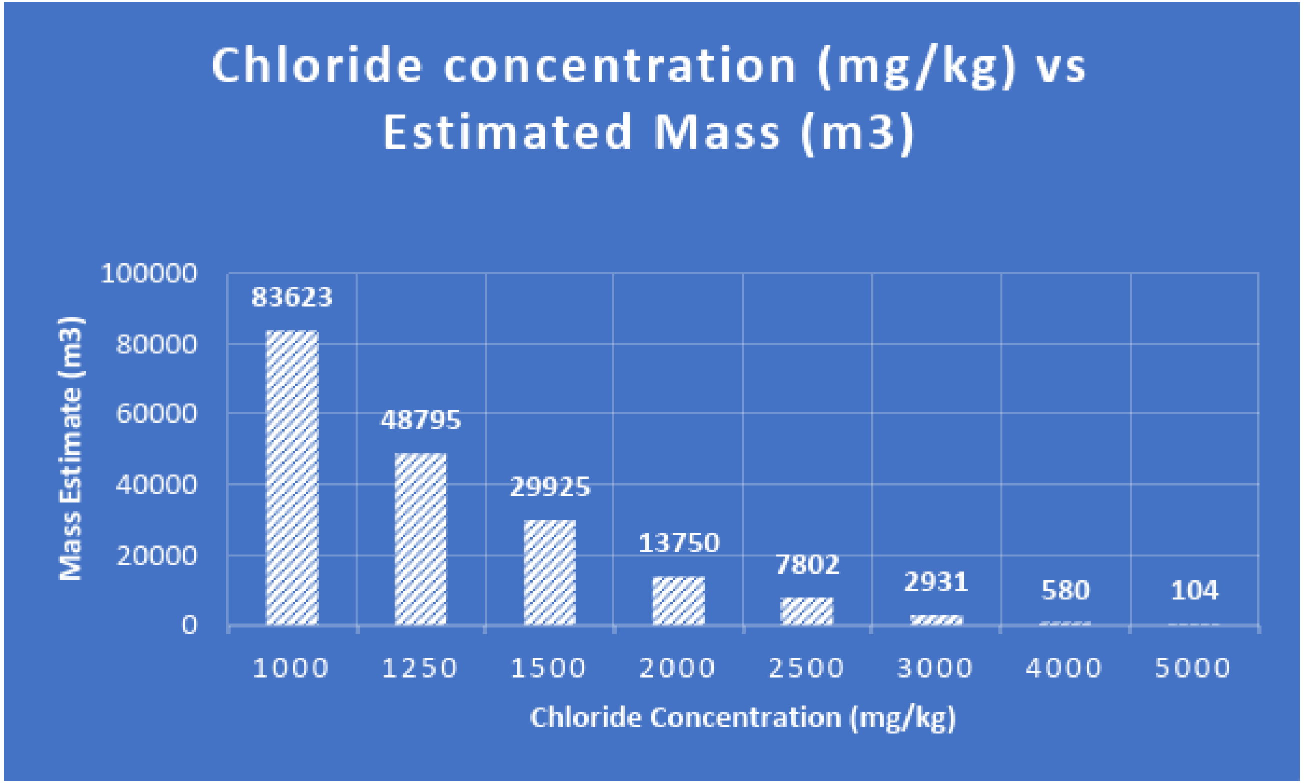
Source 2 Impacts at near surface and at depth, extending to top of watertable

Soil Source Areas

Soil Chloride Impacts >1,500 mg/kg



Soil Chloride Volumes (m^3) vs Chloride Concentration Thresholds (mg/kg)



Soil Source Areas- Summary

- There appear to be two primary sources primarily around the two brine ponds
  - **At the NE corner of Brine Pond 1 (Source 1)**
    - 8,190 mg/kg at 0.6-1.0 mbgs and to a maximum of 21,300 mg/kg at 7 m.
  - **At the NE corner of Brine Pond 2 (Source 2)**
    - From surface to water table at 3 m, the impacts are more widespread and at lower concentrations compared to Source 1. The centre of mass is around EW18-02.
    - Impacts appear to extend vertically downwards to the water table with minor lateral impacts next to the Brine Ponds. Around the southern flank of Brine Pond 2, the impacts appear to be more shallow and do not extend to deeper depths.

***Source Area 3 - Discrete Operational Northern areas.** At lower concentrations (i.e. 1,500 to 2,000 mg/kg), discrete sources (collectively Source 3) are found to the north of the fence line south of Industrial Road East and proximal to the Production Well, pipeline to Brine Production Well, operation and AST storage areas.

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Groundwater Plume Evaluation

The purpose of the groundwater data evaluation was to assist in the interpretation of the spatial distribution of the brine/chloride impacted groundwater, links to soil source areas impacts to provide insight into the placement of new extraction wells.

Specifically, the objectives were to:

- Develop a robust 3D visualization model based on the latest groundwater chloride chemical results;
- Present the spatial distribution of the chloride groundwater impacts in 3D for evaluation of the source area(s);
- Evaluate the groundwater fate and transport using a bromide (Br) tracer and
- Determine potential new delineation well locations downgradient from the active source areas.

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Groundwater Plume Evaluation

Groundwater Chloride Impacts >30,000 mg/L

The highest concentration of 40,000 mg/L was reported at a depth of 8.5 m bg within the Unit 3 regional coal seam

Groundwater Maximum Chloride Concentration Centre of Mass, Unit 3 Interbedded Coal

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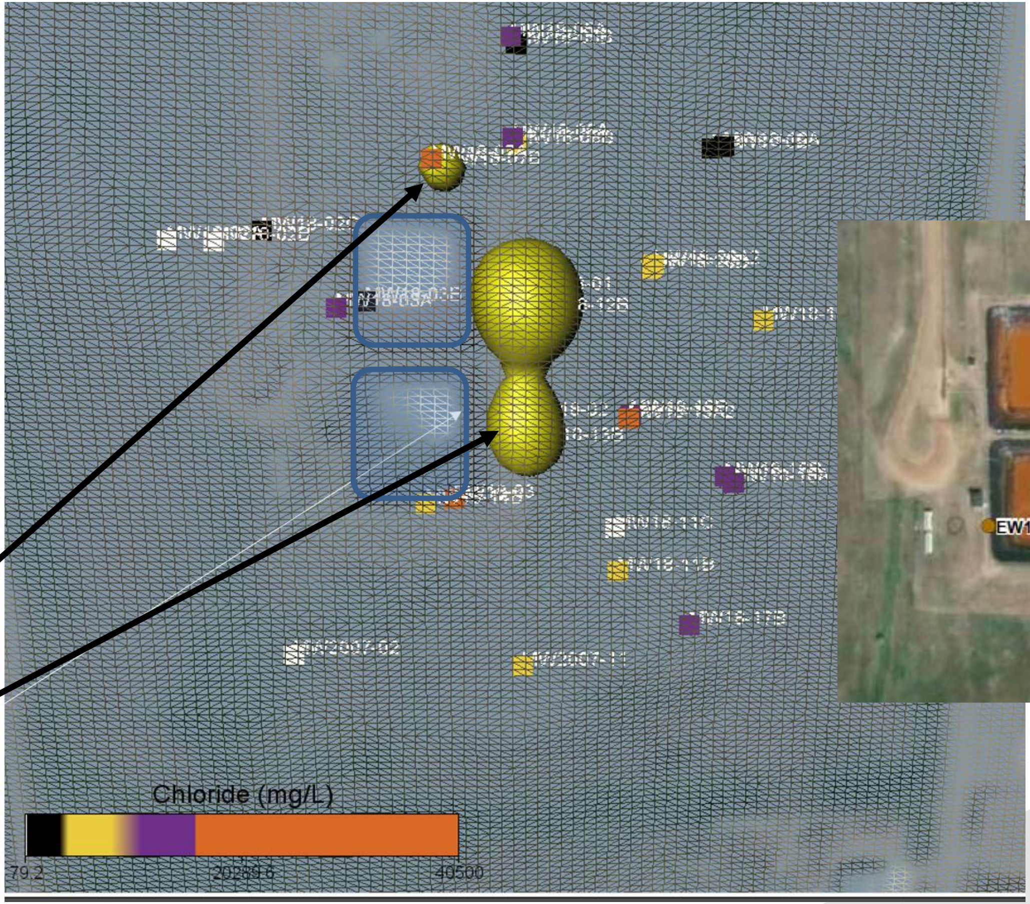
Groundwater Plume Evaluation

Chloride Impacts >20,000 mg/L

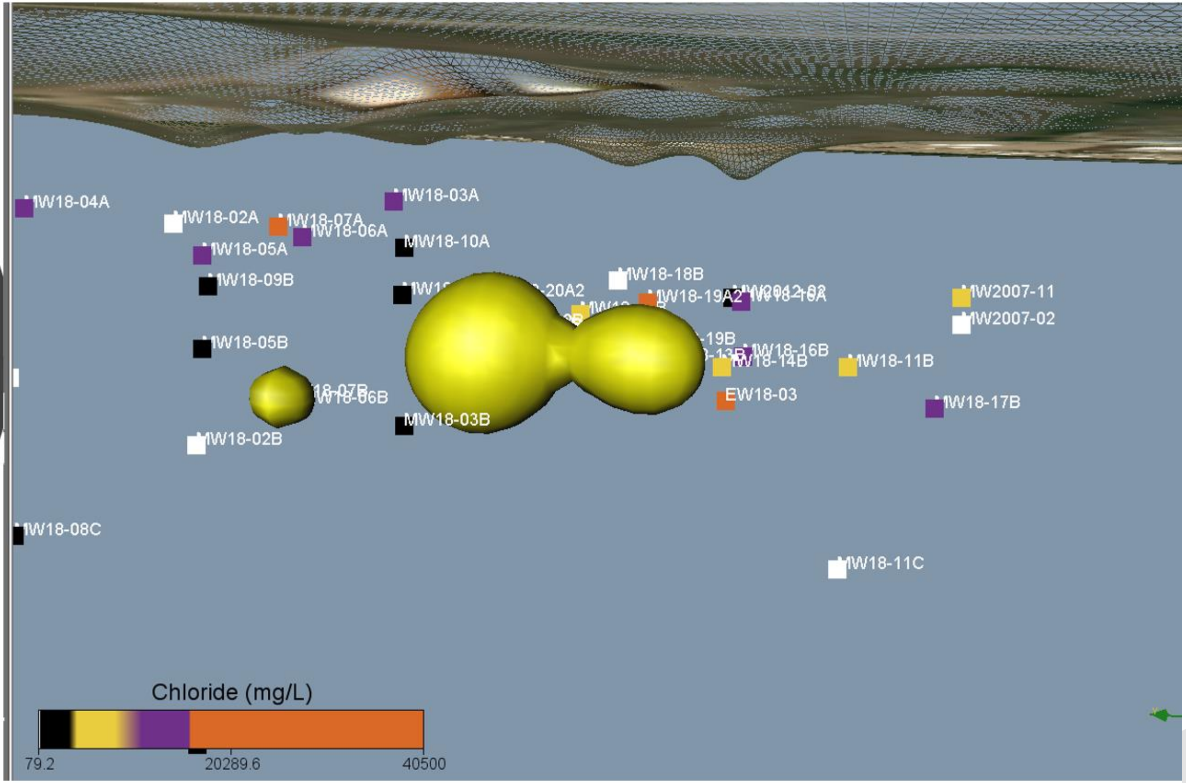


Main Groundwater Plume in Unit 3 Interbedded Coal

Groundwater Plume Evaluation

Chloride Impacts >20,000 mg/L

Subsurface Viewing east in Unit 3 Interbedded Coal



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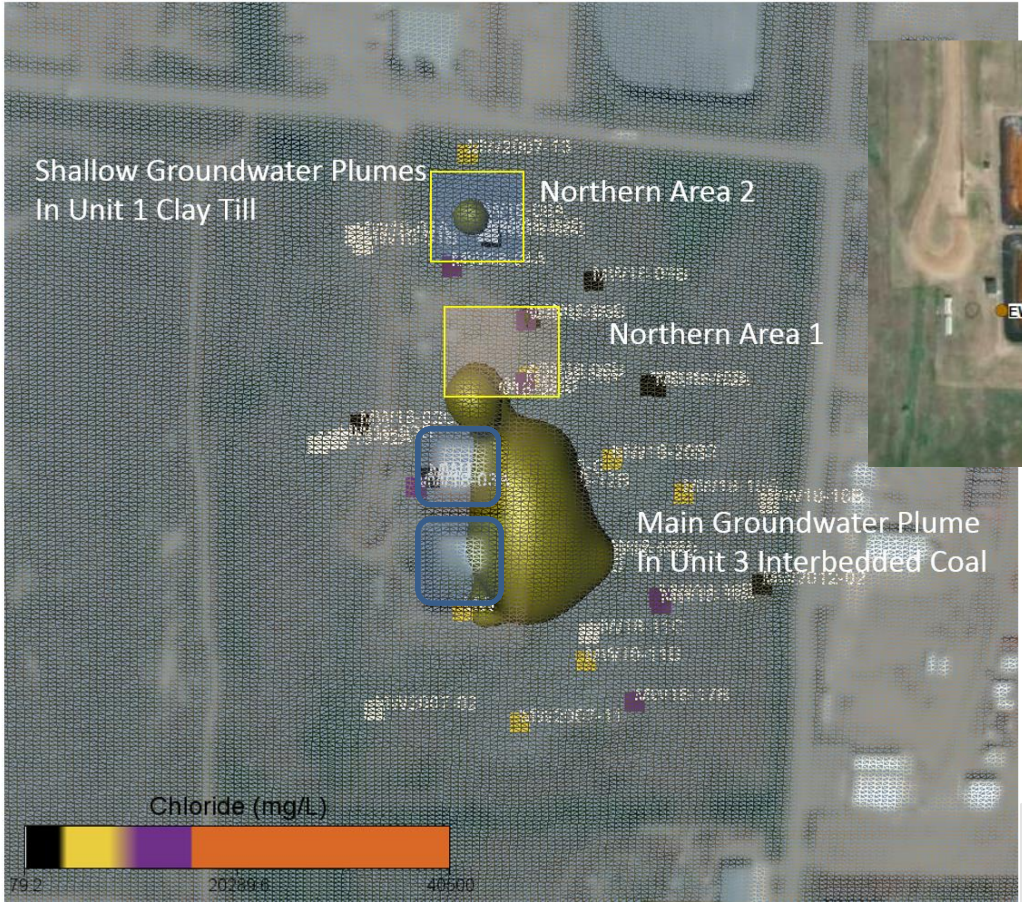
Groundwater Plume Evaluation

Chloride Impacts >15,000 mg/L



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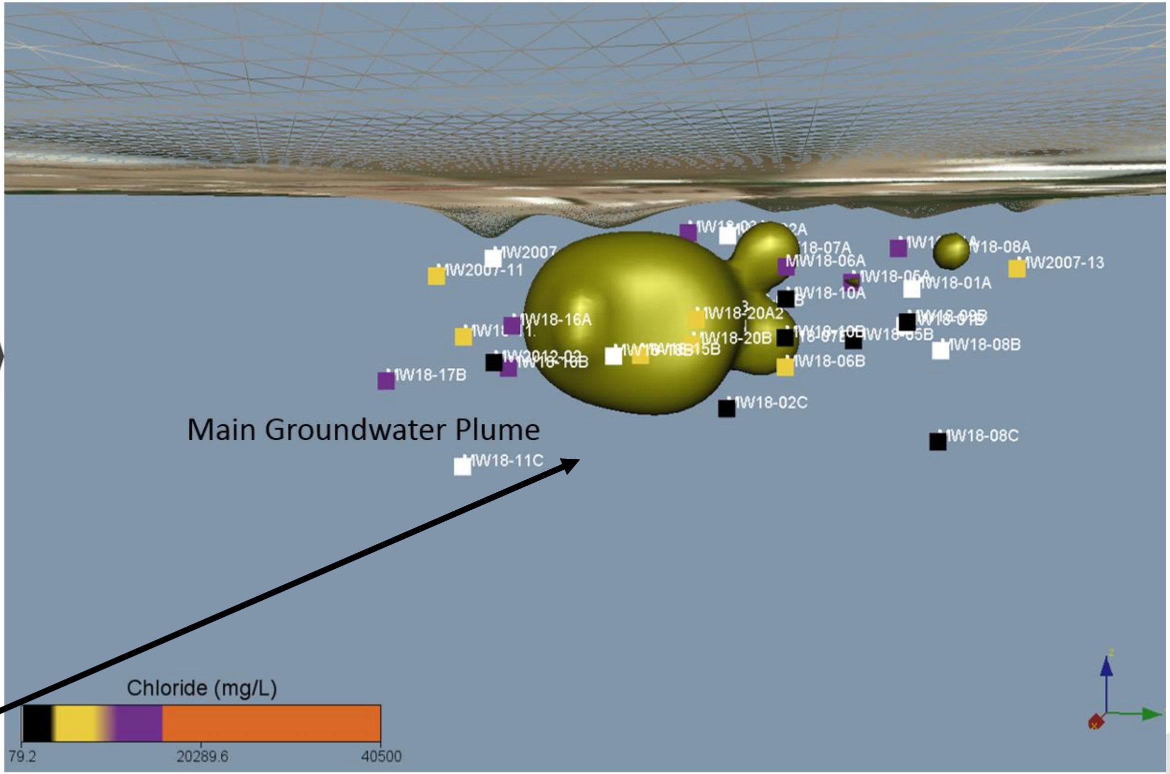
Groundwater Plume Evaluation

Chloride Impacts
>15,000 mg/L



Main Groundwater Plume
In Unit 3 Interbedded Coal

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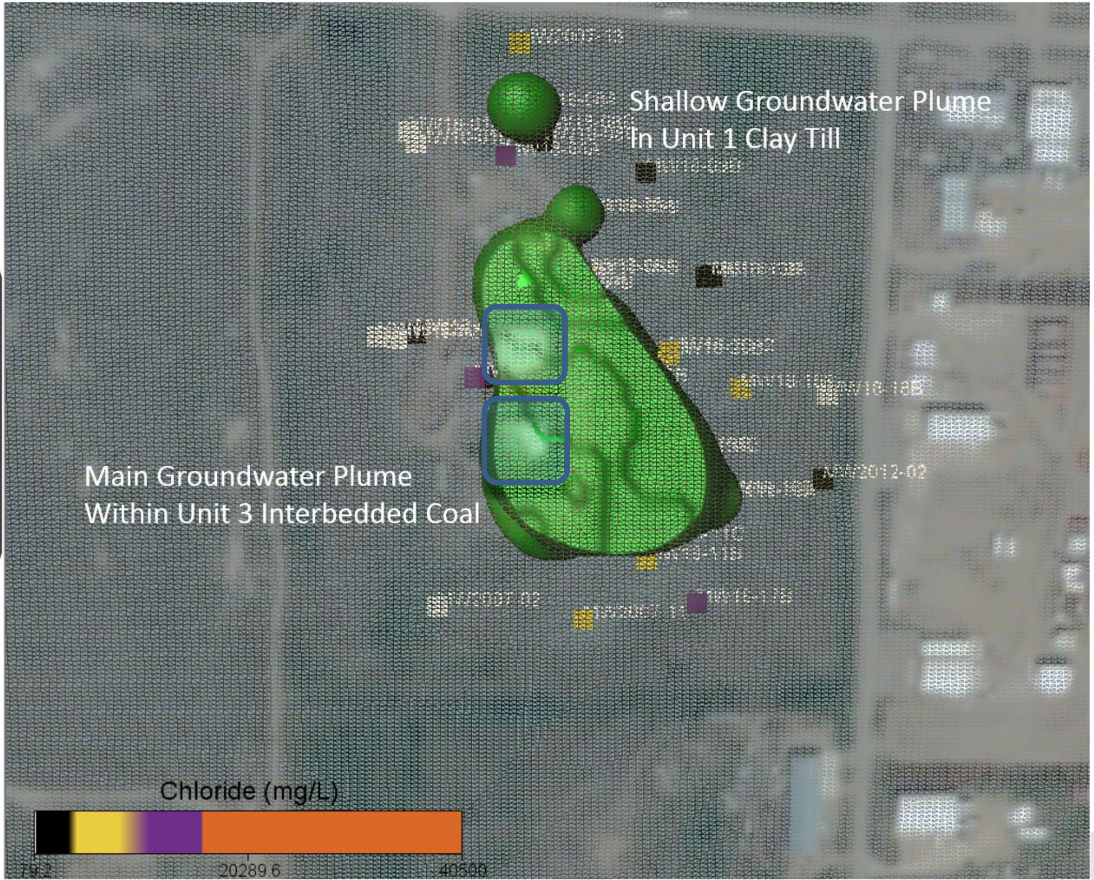
Groundwater Evaluation

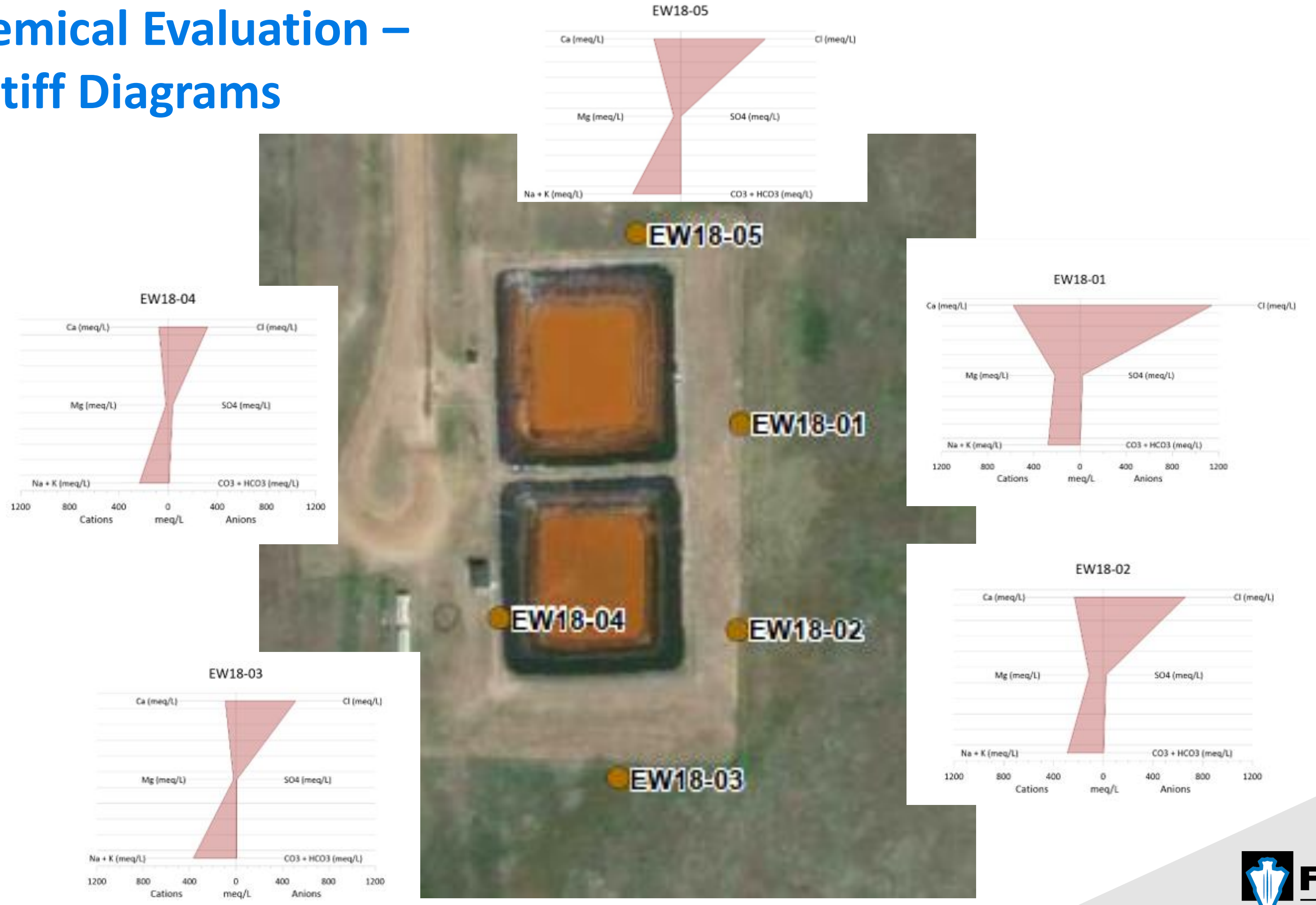
Chloride Impacts
>12,000 mg/L



Groundwater Evaluation

Chloride Impacts
>11,000 mg/L

Geochemical Evaluation – Stiff Diagrams



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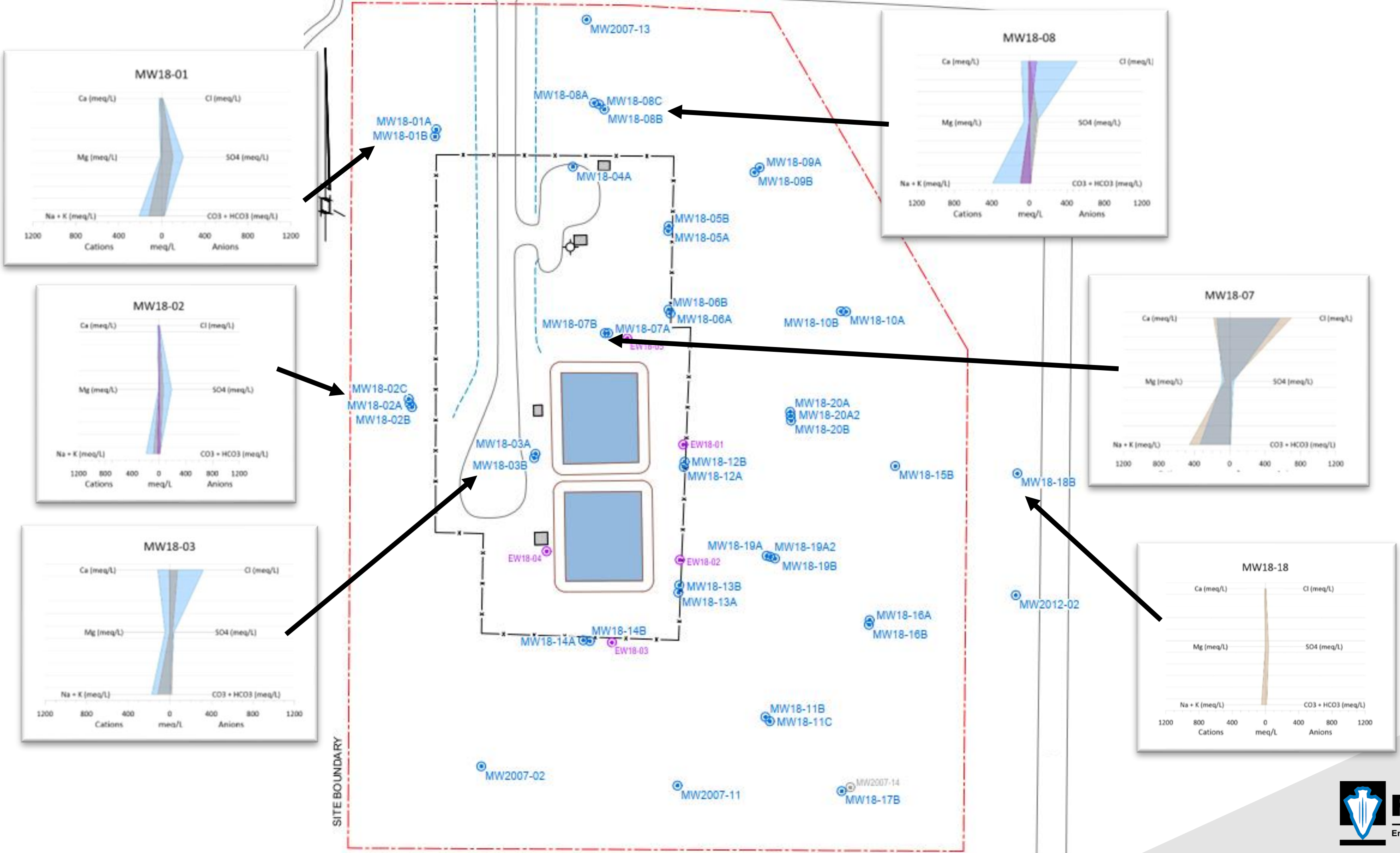

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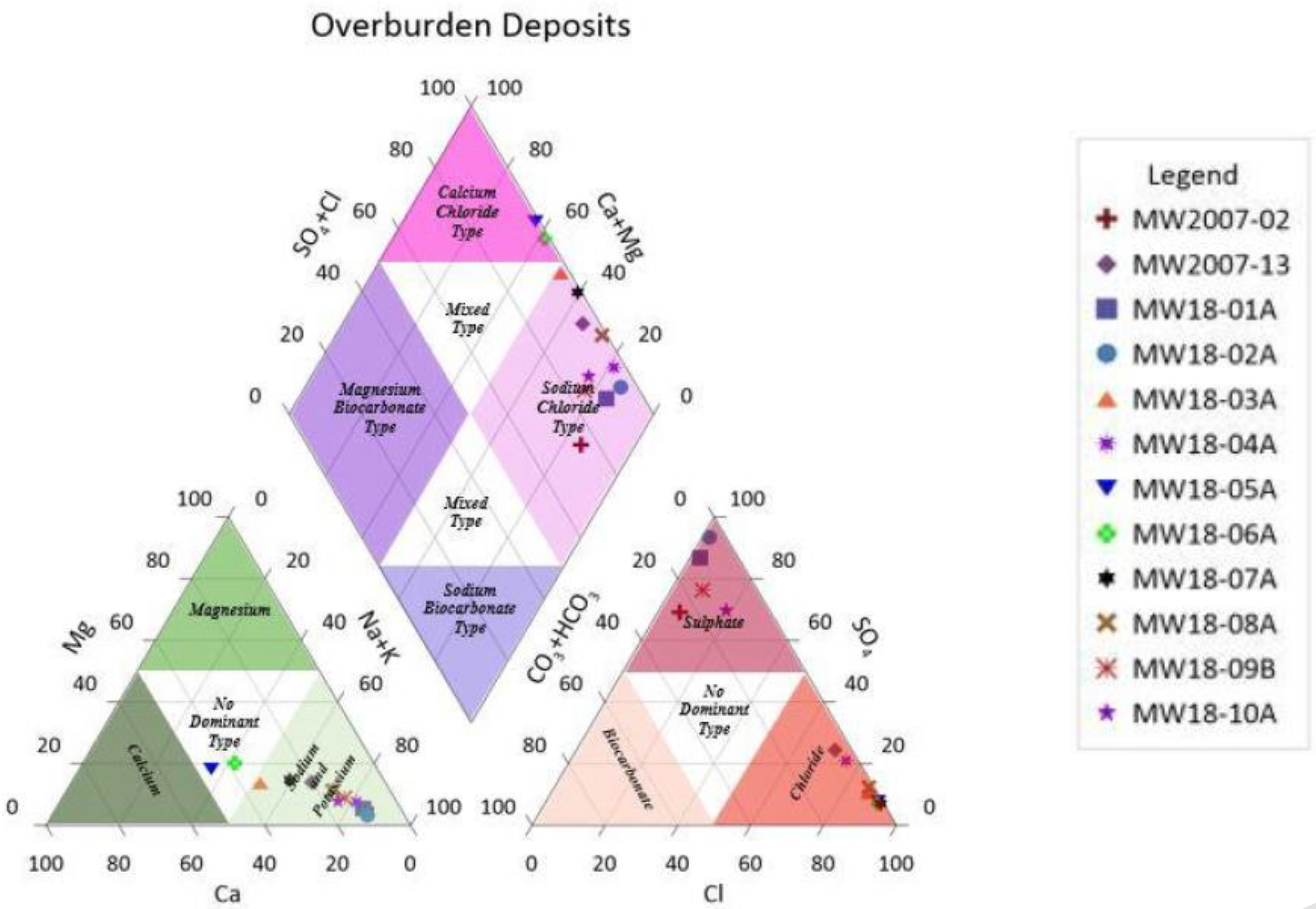
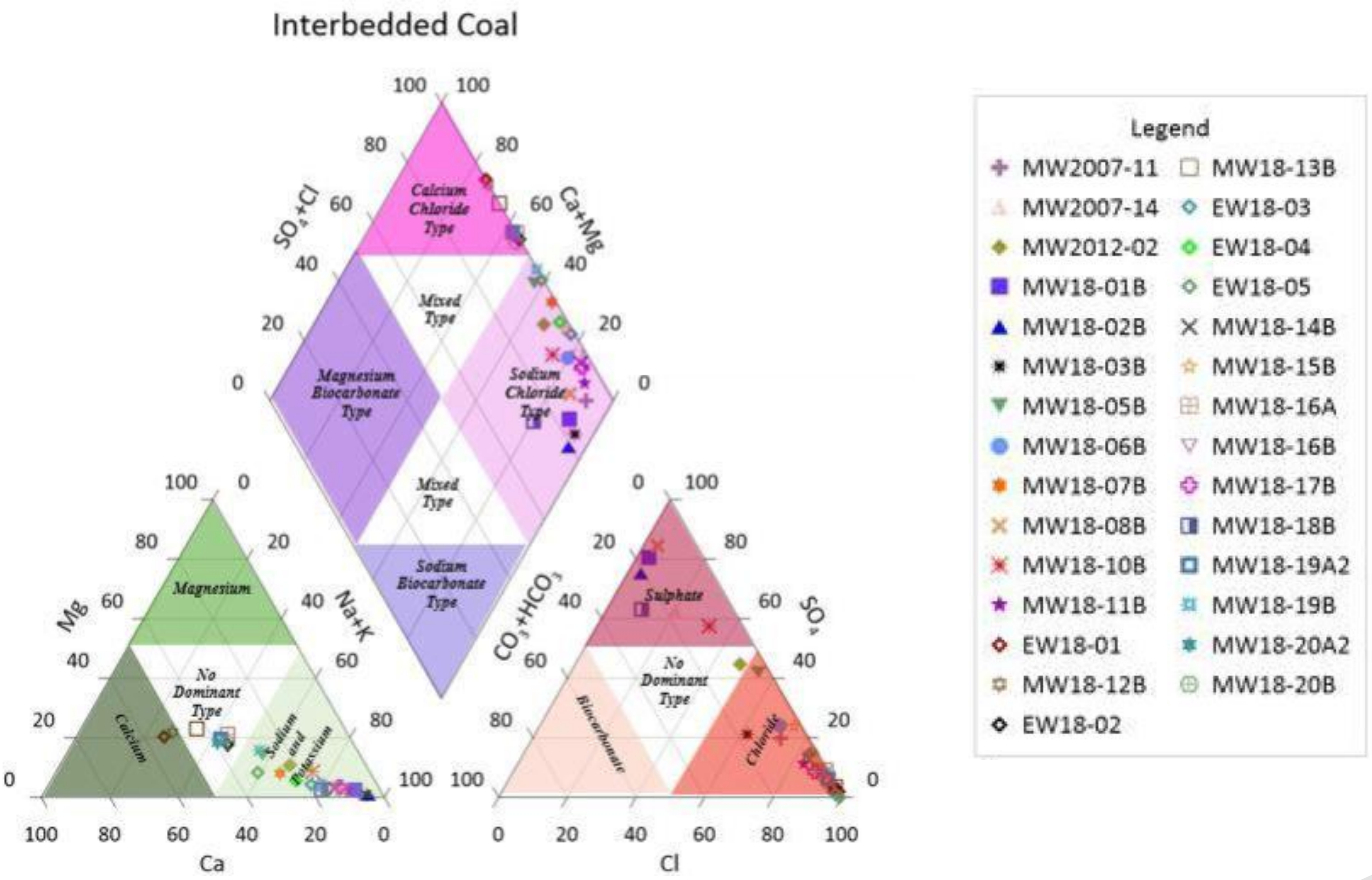
Piper Diagram – Overburden Deposits



Piper Diagram – Interbedded Coal



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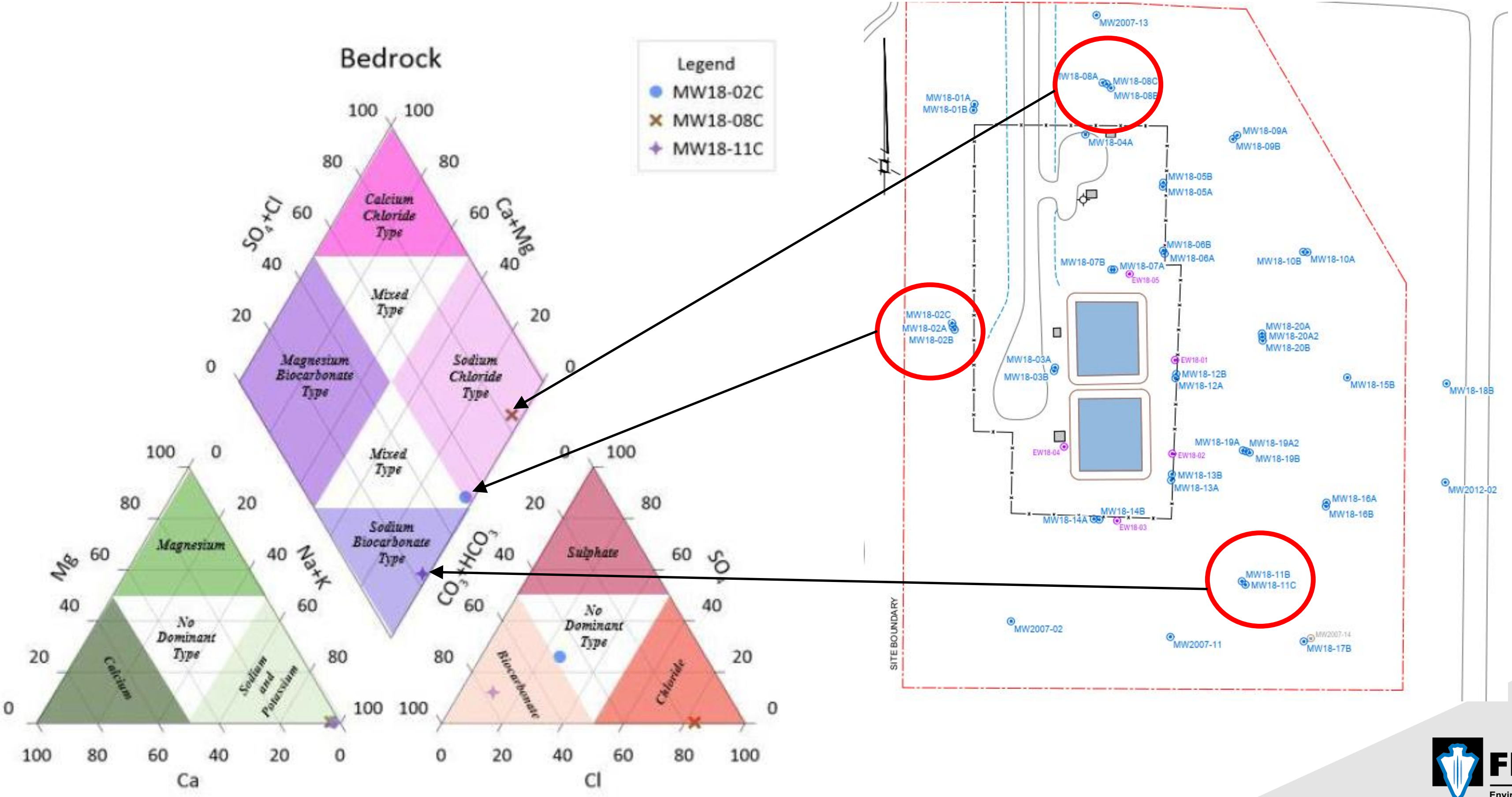
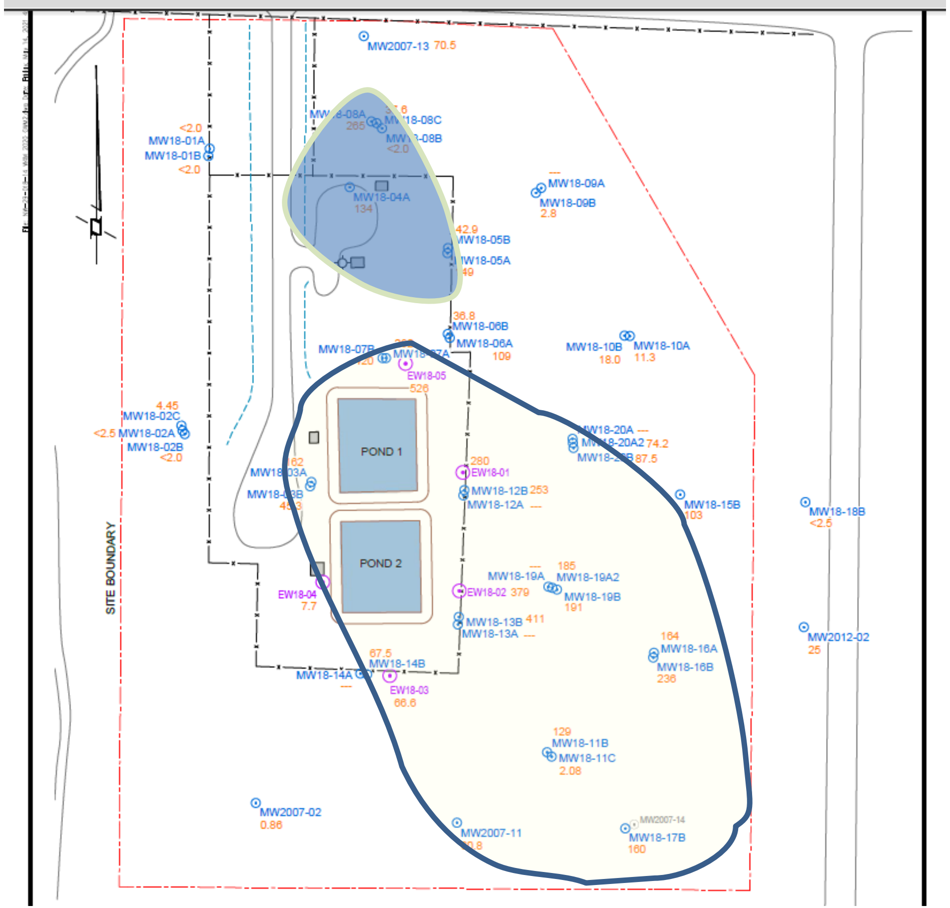
Piper Diagram – Bedrock



Geochemical Bromide Evaluation



Geochemical Evaluation

- The geochemical evaluation support that the brine solution impacts are predominately around EW18-05, EW18-01 and EW18-02 along the north and east of the current pond locations.
  - Monitoring wells in this area show a dominant Ca and Cl water with very low SO_4 and Na.

- Downgradient and along the flow path, Na becomes more dominant as Cl concentrations are reduced.

- Extraction wells EW18-03 and EW18-04 have less dominant Ca chemistry.

- For some wells (e.g. MW18-18B) that are located close to the site boundary, road salt likely contributes to the elevated Na concentration.

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Summary - Groundwater Fate and Transport CSM

Soil Impacts

- **Brine Ponds** - The highest concentration occurs adjacent to Brine Pond 1 and 2 along the eastern flanks of the ponds. The soil concentrations are elevated at surface to a depth of 7 m bgs. The impacts appear to be spatially discrete with limited lateral migration to the east. As such, the soil impacts appear to be well delineated within known areas.
- **North of Brine Ponds -** At lower concentrations, discrete sources are found to the north of the fence line, and proximal to the brine Production Well, pipeline to the brine well and AST storage areas.

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Summary - Groundwater Fate and Transport

Groundwater Plume Architecture

- The chloride groundwater plumes are well defined within the site boundaries and are consistent with the known historical source areas and the elevated chloride concentrations in soil.
- The centre of mass of the Main Groundwater Plume is found along the eastern flanks of the brine ponds and is laterally discrete and well defined.
- The Main Groundwater Plume has been established in the high velocity Unit 3 Interbedded Coal unit and is moving in a south easterly direction along the regional groundwater flow direction.
- To the north, shallower Unit 1 overburden groundwater impacts are separate from the Main Groundwater plume and these impacts are associated with local and discrete surficial soil impacts. The groundwater flow direction is to the south/southeast and not off-site to the north.
- Road salt contributions to groundwater impacts are likely along the eastern and northern site boundaries.

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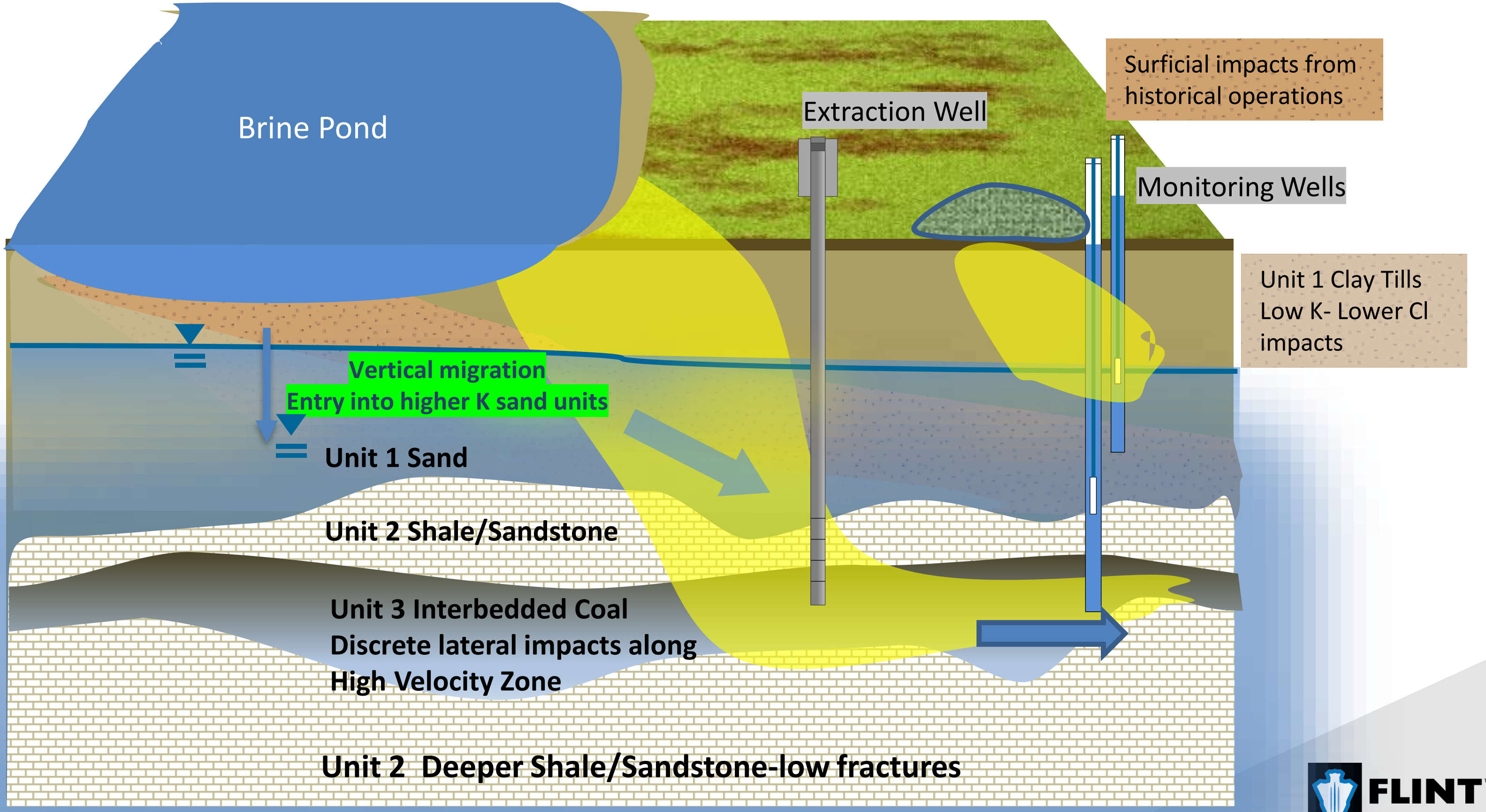
Conceptual Model of Groundwater Fate and Transport



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Groundwater Remedial Extraction and Optimization

Current Extraction Wells

- The extraction wells were installed with screens across the Unit 3 Interbedded Coal seams within the shallow bedrock.
  - EW18-01 to EX18-04 were drilled to 11 m bgs with 3 m long screens from 8 – 11 m bgs.
  - EW18-05 was drilled to a depth of 14 m bgs with a 3 m long screen from 11 – 14 m bgs.
- The 3 m long well screens are positioned in the Unit 3 Interbedded Coal - shale/coal.

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Groundwater Remedial Extraction and Optimization

Extraction Rates

Extraction Well ID	July Test Duration (hrs)	July Test Calculated Flow Rate (LPM)	September Test Duration (hrs)	September Test Calculated Flow Rate (LPM)
EW18-01	48	0.02	72	0.02
EW18-02		0.04		0.05
EW18-03		0.28		0.78
EW18-04		7.51		3.80
EW18-05		6.27		4.52

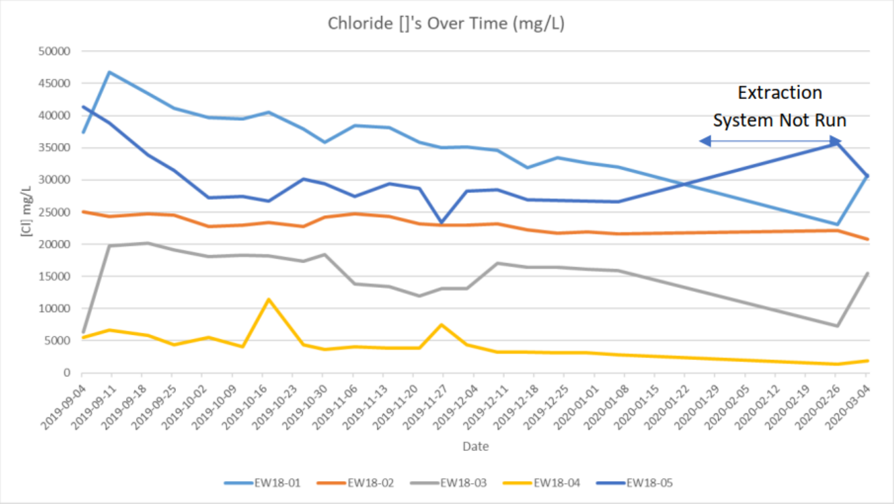

Figure 2 - Chloride Concentrations Over Time

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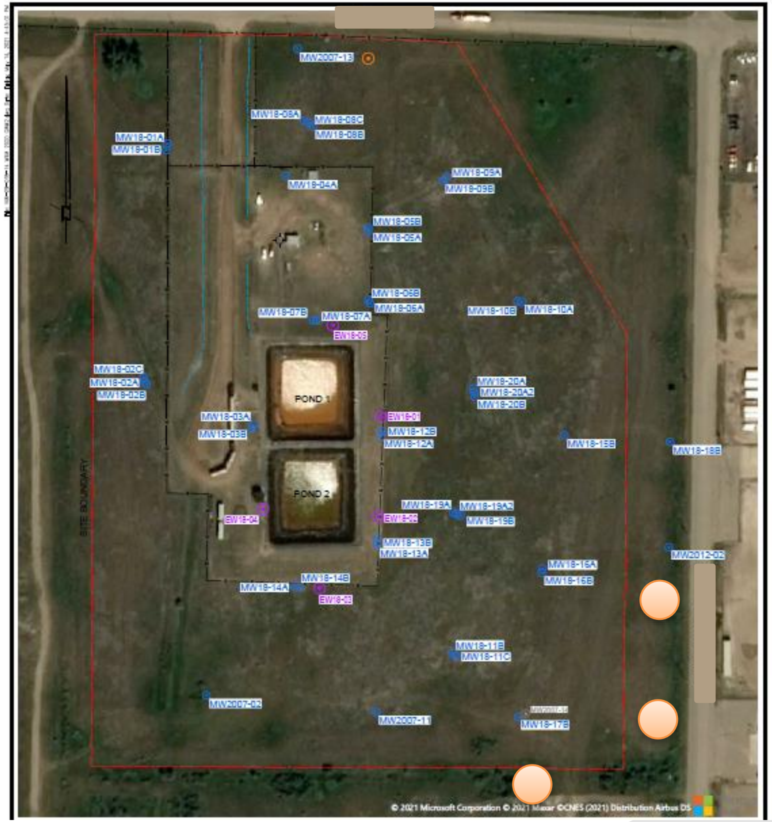
New Extraction and Delineation Well Locations



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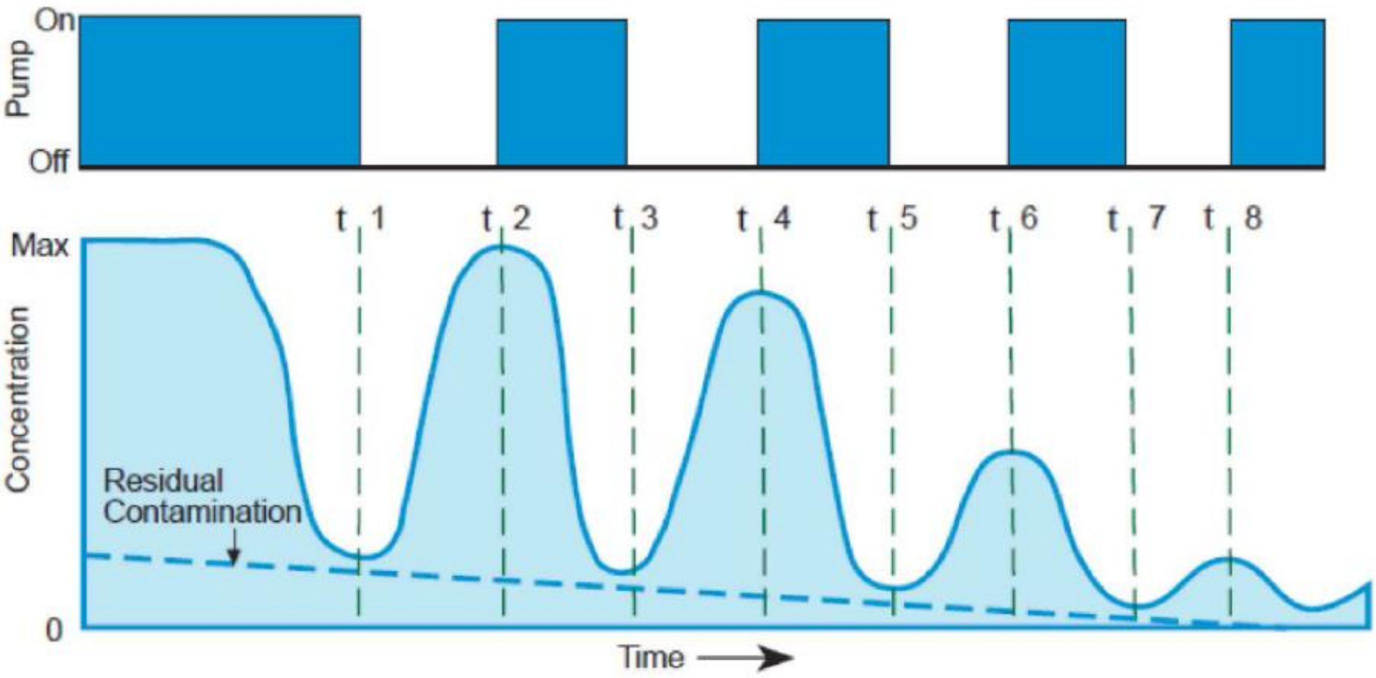
Groundwater Extraction and Optimization – Pulsed Recovery



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Path Forward

- Pump testing of newly installed extraction wells.
- Continue annual groundwater monitoring program.
- Continue efforts to recycle extraction water to create product for the client.
- Additional statistical analysis to evaluate the long-term plume stability.

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Thank You

- Steve Livingstone - Geocentric Environmental Inc.
- Neil Barnsdall – Flint Environmental
- Geo Tactical Remediation Ltd.
- Sequoia Environmental Remediation Inc.
- Ernco Environmental Drilling and Coring Inc.

- QUESTIONS?

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