NOT YOUR MOTHER'S MIX MASTER
In-Situ Remediation of Tetrachloroethylene by Soil Mixing with Zero Valent Iron and Clay

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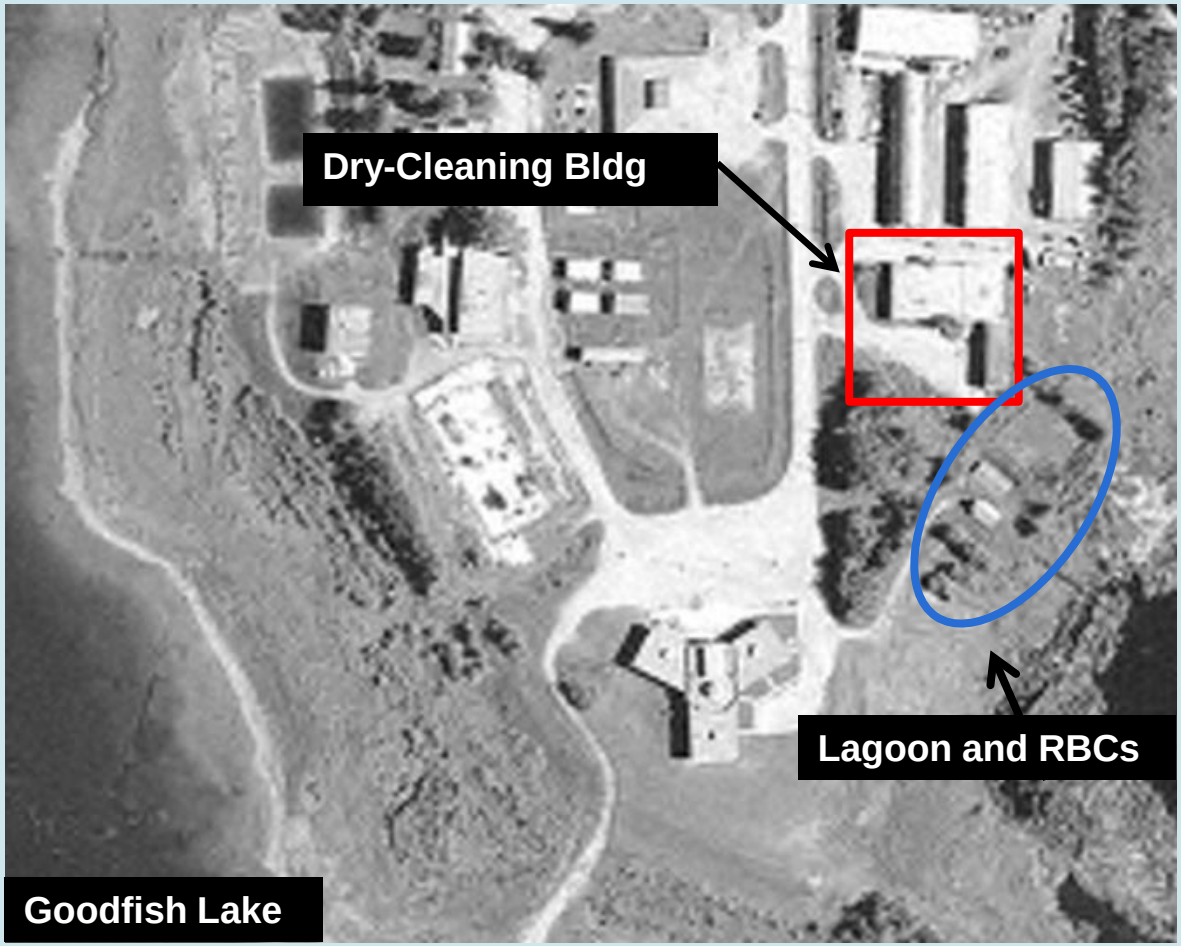
Outline

- Site Setting & History
- Conceptual Site Model
- Remedial Action Plan
- Bench Scale Study
- Soil Mixing Program
- 2013 Monitoring Results
- Lessons Learned

Site Setting & History



2007 DTMI Spatial Inc. Imagery, Government of Canada, Natural Resources Canada, Center for Topographic Information

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Site Setting

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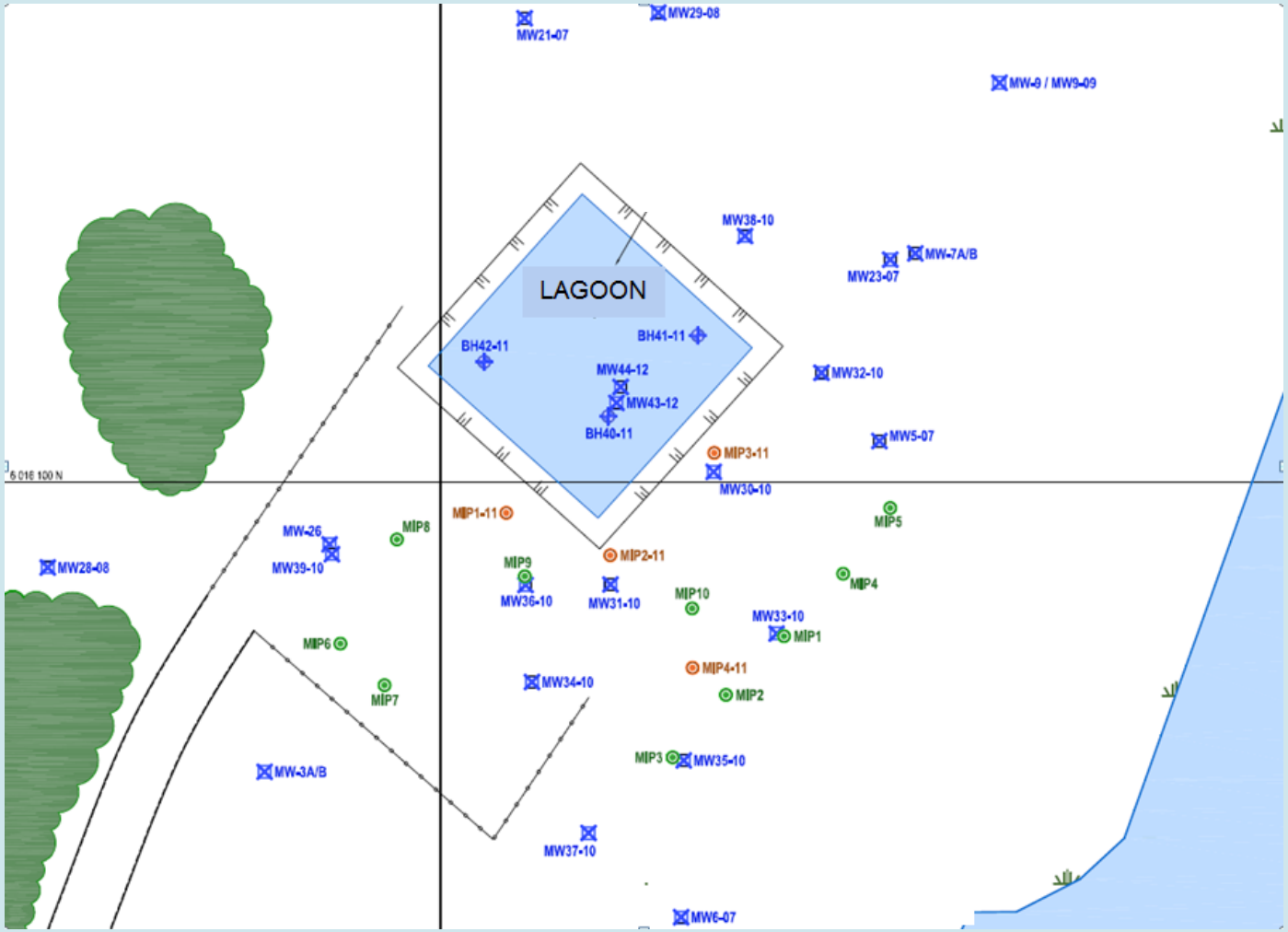
Conceptual Site Model - Investigation



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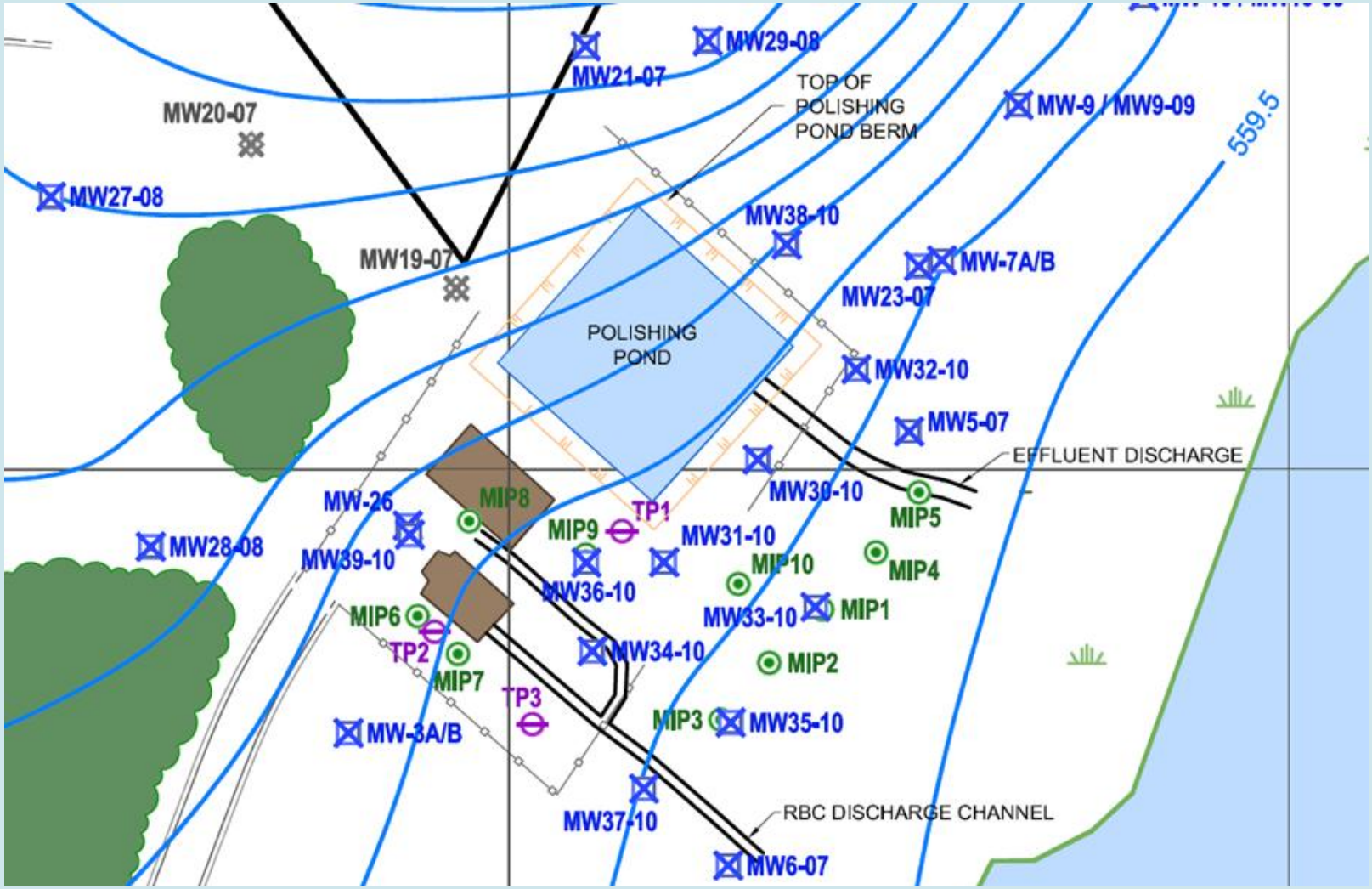
Conceptual Site Model – Groundwater Flow



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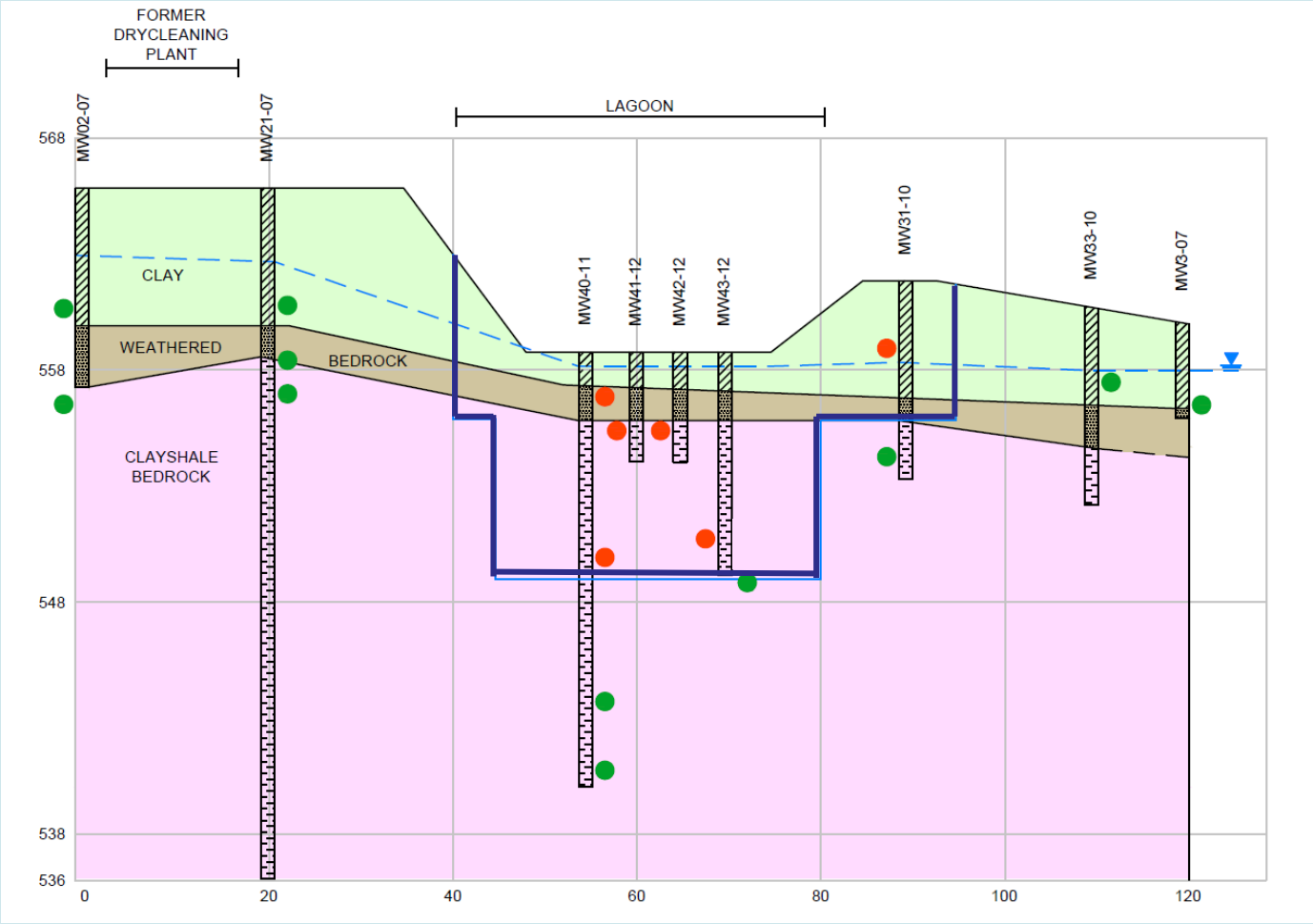
Conceptual Site Model - Soil Stratigraphy

- PCE max conc. of 8,900 mg/kg in soil & 170 mg/L in groundwater
- Daughter products also reported.



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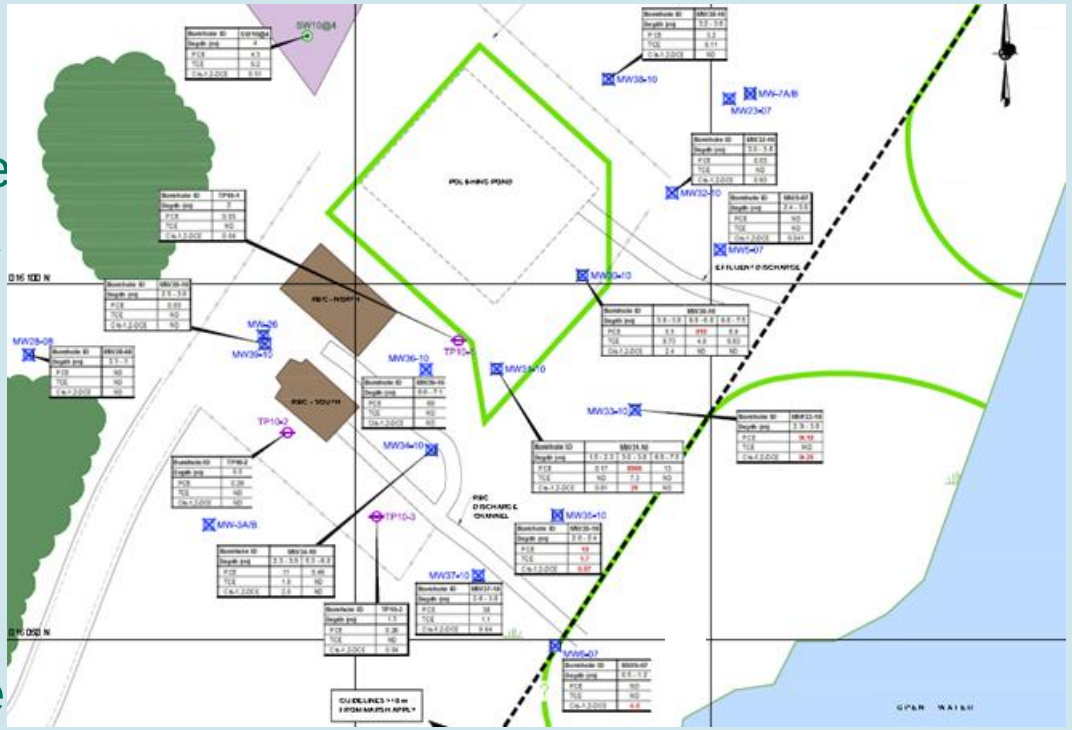
Site Setting – Remediation Target Levels

- In 2008 a Human Health and Ecological Risk Assessment (HHERA) was conducted to help determine appropriate remediation/risk management strategies.
  - Remediation required
  - Site Specific Target Level's (SSTL's) developed
- In 2011 the SSTL's were updated to be specific to the lagoon area



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Remedial Action Plan

STAGE 1

- Bench scale study by Colorado State University

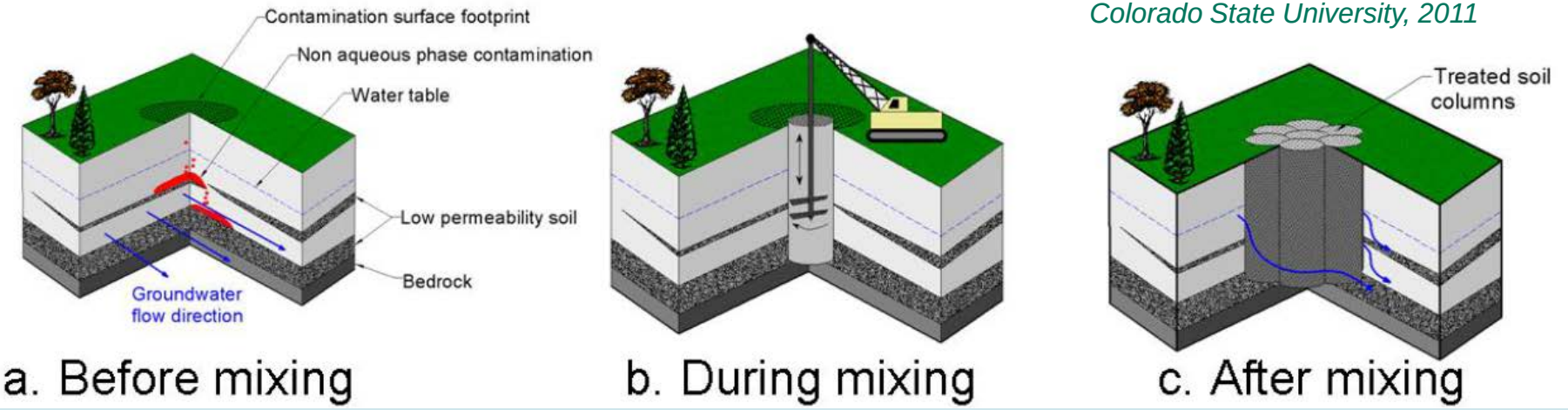
STAGE 2

- Soil mixing ZVI and clay into soil in overlapping columns

STAGE 3

- Post remediation monitoring
- Site restoration
- Annual monitoring

What is Soil Mixing



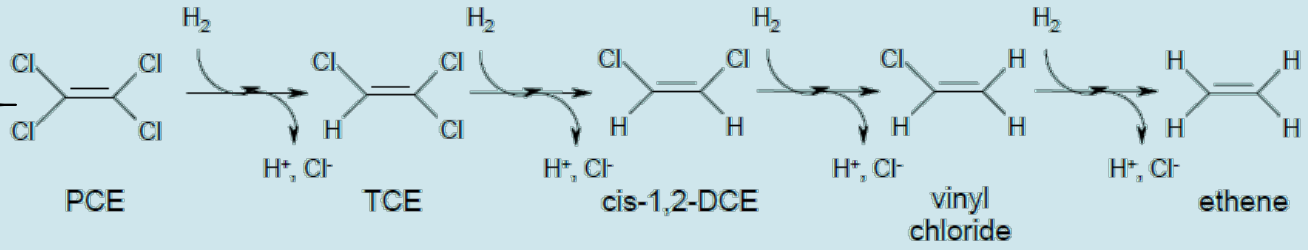
Colorado State University, 2011

- Approach:
  - Mixing tool to create mix zone
  - Delivery of grout containing amendment while mixing.
- Benefits:
  - Uniform delivery
  - Close contact of ZVI with contaminant
  - Reduced hydraulic conductivity with increased residence time.

Theoretical Action

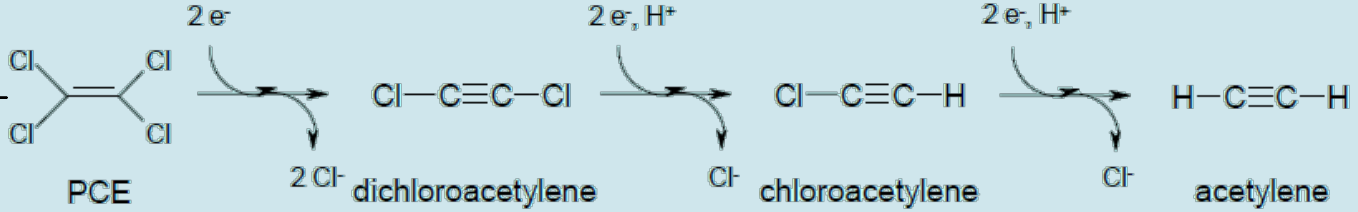
Sequential Dechlorination

- Direct reaction at iron surface (Fe^0 -> Fe^{2+})
- Reduction by Ferrous Iron ($2Fe^{2+}$ -> $2Fe^{3+}$)
- Reduction by Hydrogen formed during corrosion (reaction Fe^0 and H_20)



β-Elimination Pathway

- Abiotic degradation to acetylene and chloride (Fe^0 -> Fe^{2+})



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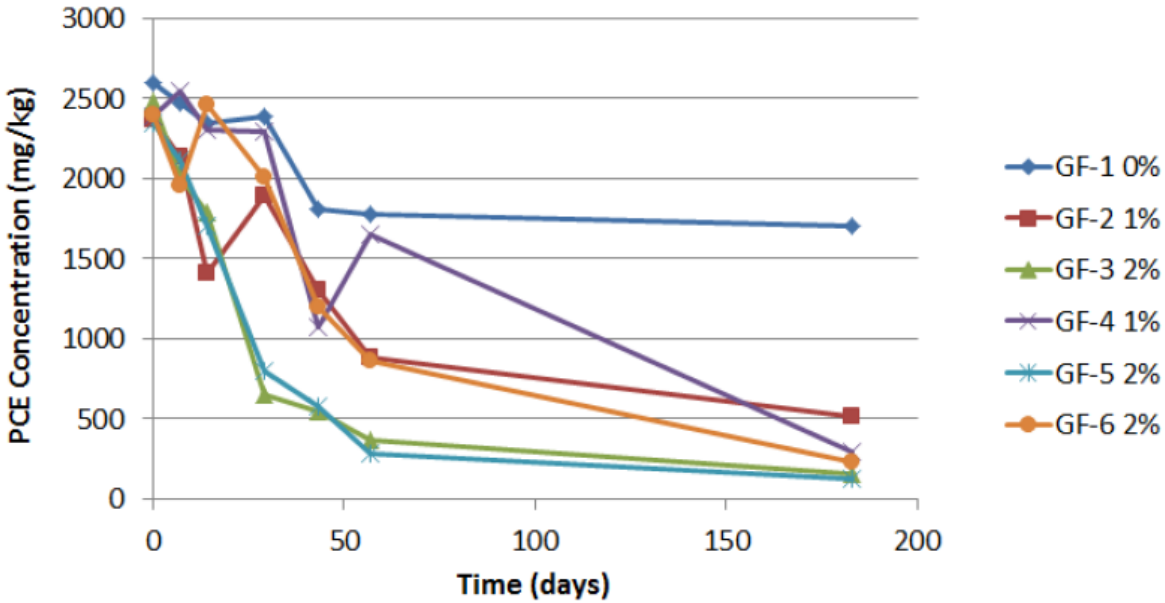
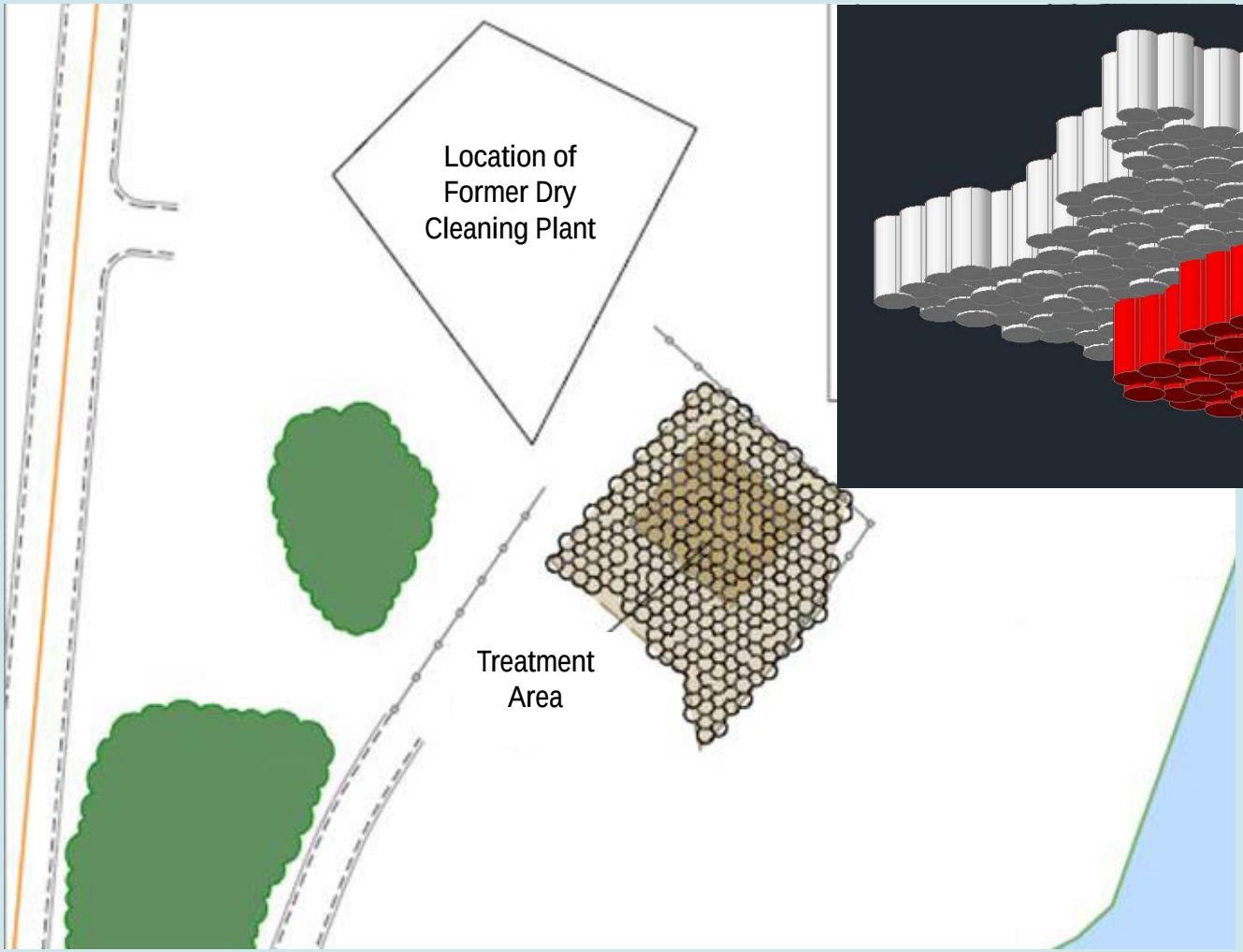
Bench Scale Tests –Column Reactor Study

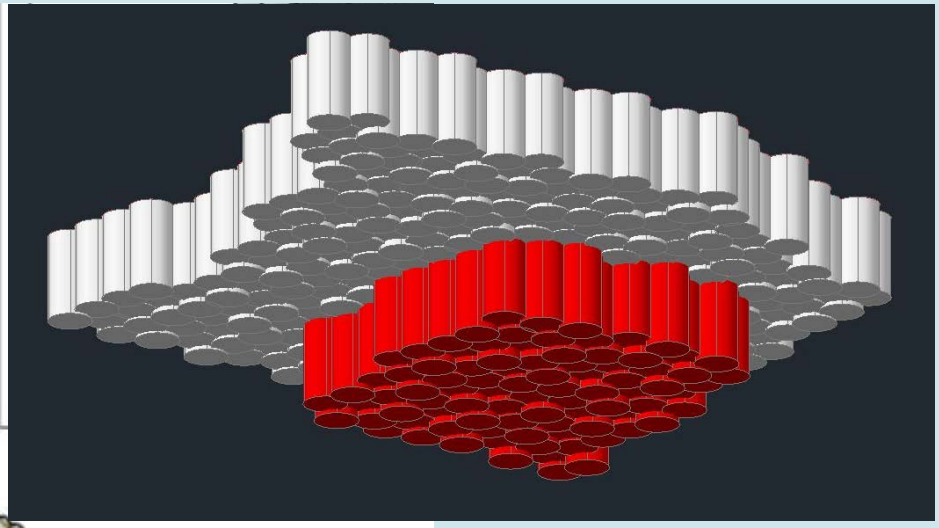
- Batch Column Reactor Study (Site soil spiked with PCE)
  - Ability of ZVI/Clay to deplete PCE and degradation products
  - Treatment effectiveness using varying amounts and different suppliers of granular iron

Colorado State University, 2011



Soil Mixing Program





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Soil Mixing Program

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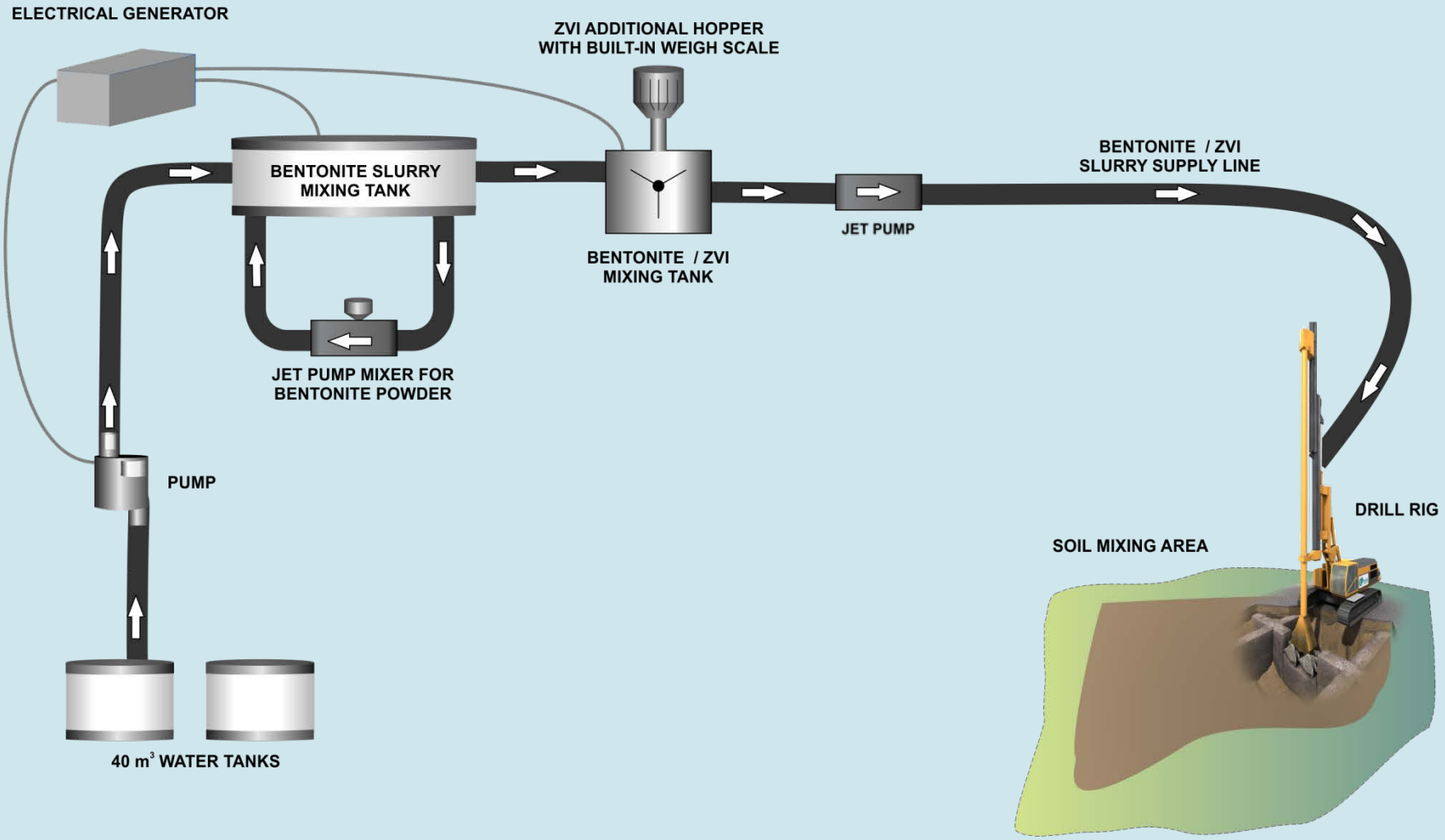
Soil Mixing Program - Process Flow Diagram



Soil Mixing Program - Monitoring

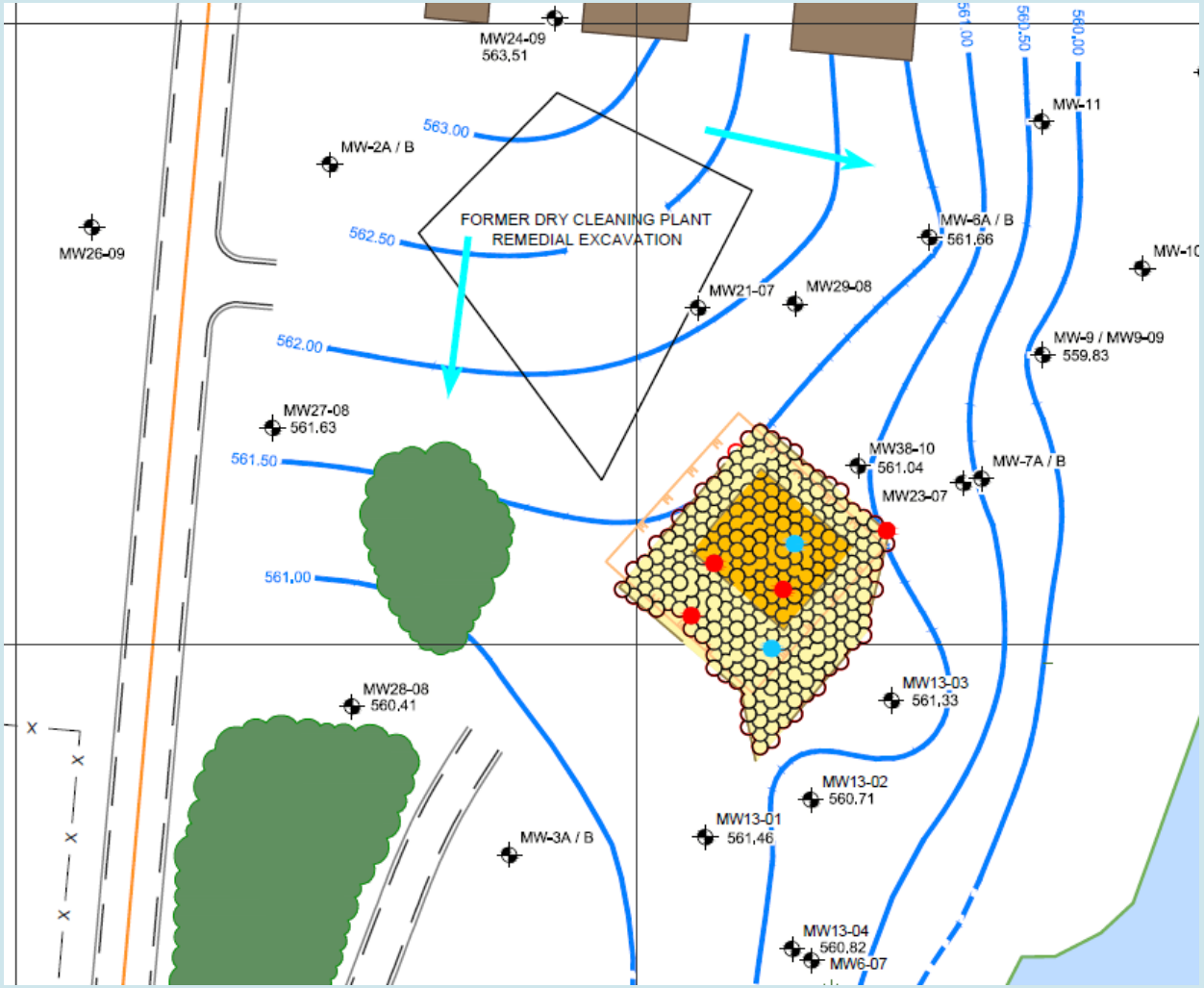
- ZVI Content
  - Collection of 42 samples for field verification of % ZVI from mix columns
  - Collection of 9 samples for field verification of % ZVI from spoils
  - Testing using magnetic separation
  - Results 1.7 to 3.4% ZVI

Soil Mixing Program - Swelling

- Estimate ~35% swell
- Required construction of berm to contain spoils

Soil Mixing Program – Berm Construction

2013 Environmental Monitoring



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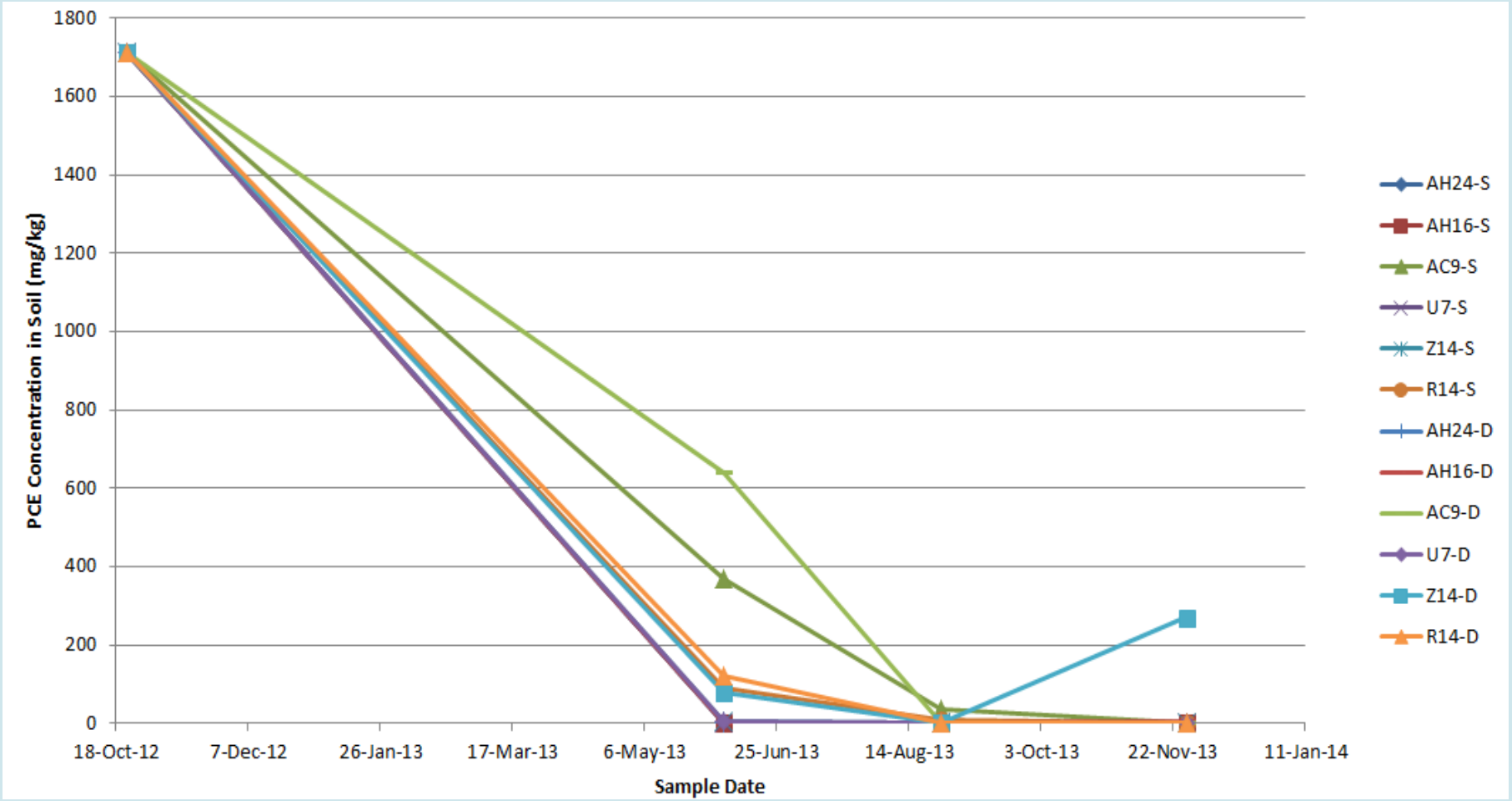
2013 Environmental Monitoring



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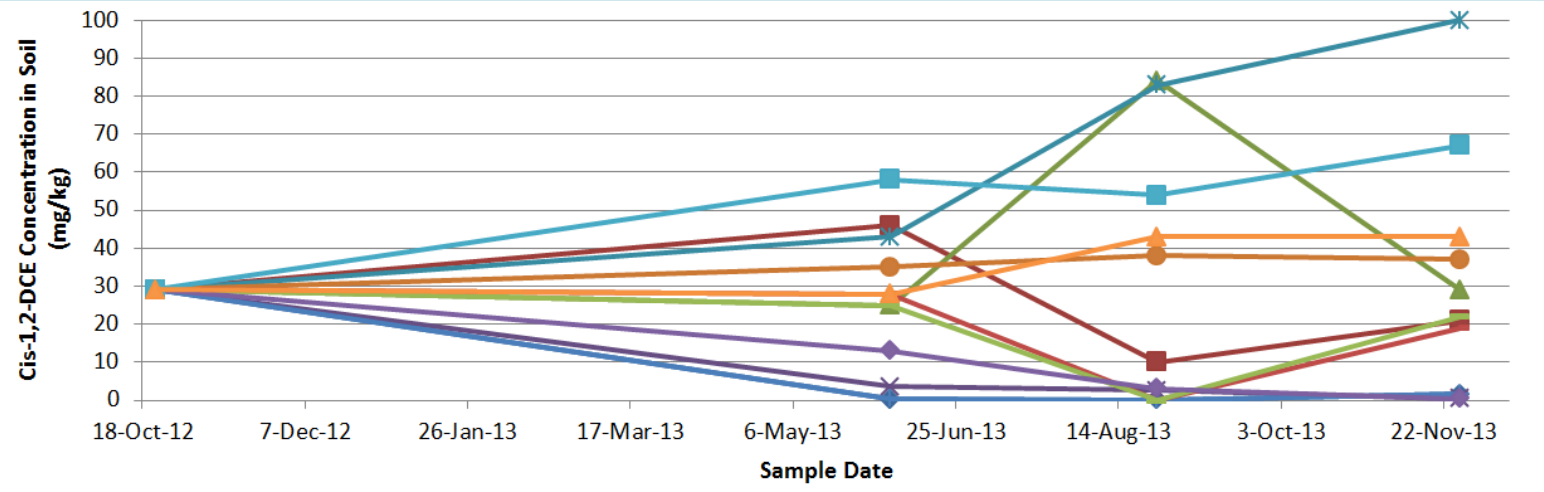
2013 Environmental Monitoring

- Concentrations of cis-1,2, DCE variable in both soil and water. With 8 soil samples exceeding the SSTL in the last sampling program (November 2013).



- Chloride in soil and water observed over 2013 monitoring period.
- Ethylene in water but no trend due to limited sample volume.

LESSONS

- Potential for application of technology elsewhere
  - Limit water
  - Soil strength - consideration for addition of cement or other agent
- Baseline information for chloride
- Availability of equipment
- Availability of iron for continued treatment reactions ...need further monitoring to assess how much further treatment will continue with time.
- Sequence/step wise breakdown of PCE through the degradation reaction chain not as direct as for the lab test
  - PCE and breakdown products in source area soil
  - Consistency of mixing at the field scale

Summary

- Reduction of PCE demonstrated
- Diffusive flux of any remaining contaminants from the mix zone will be very low which serves as an additional risk management control.
- Overall remediation cost approximately half the cost for excavation and landfilling of same volume of soil for this Site and these conditions

Acknowledgements

Quantum Murray

GeoSolutions

Millennium EMS Solutions

References

- Colorado State University, 2011. Final Report ZVI-Clay Treatability Studies Goodfish Lake Site.
- Colorado State University, 2011. Final Report Addendum ZVI-Clay Treatability Studies Goodfish Lake Site.
- Meridian Environmental, 2010. Site-Specific Target Levels for Polishing Pond Area Former Drycleaning Facility, Goodfish Lake, Alberta

Questions