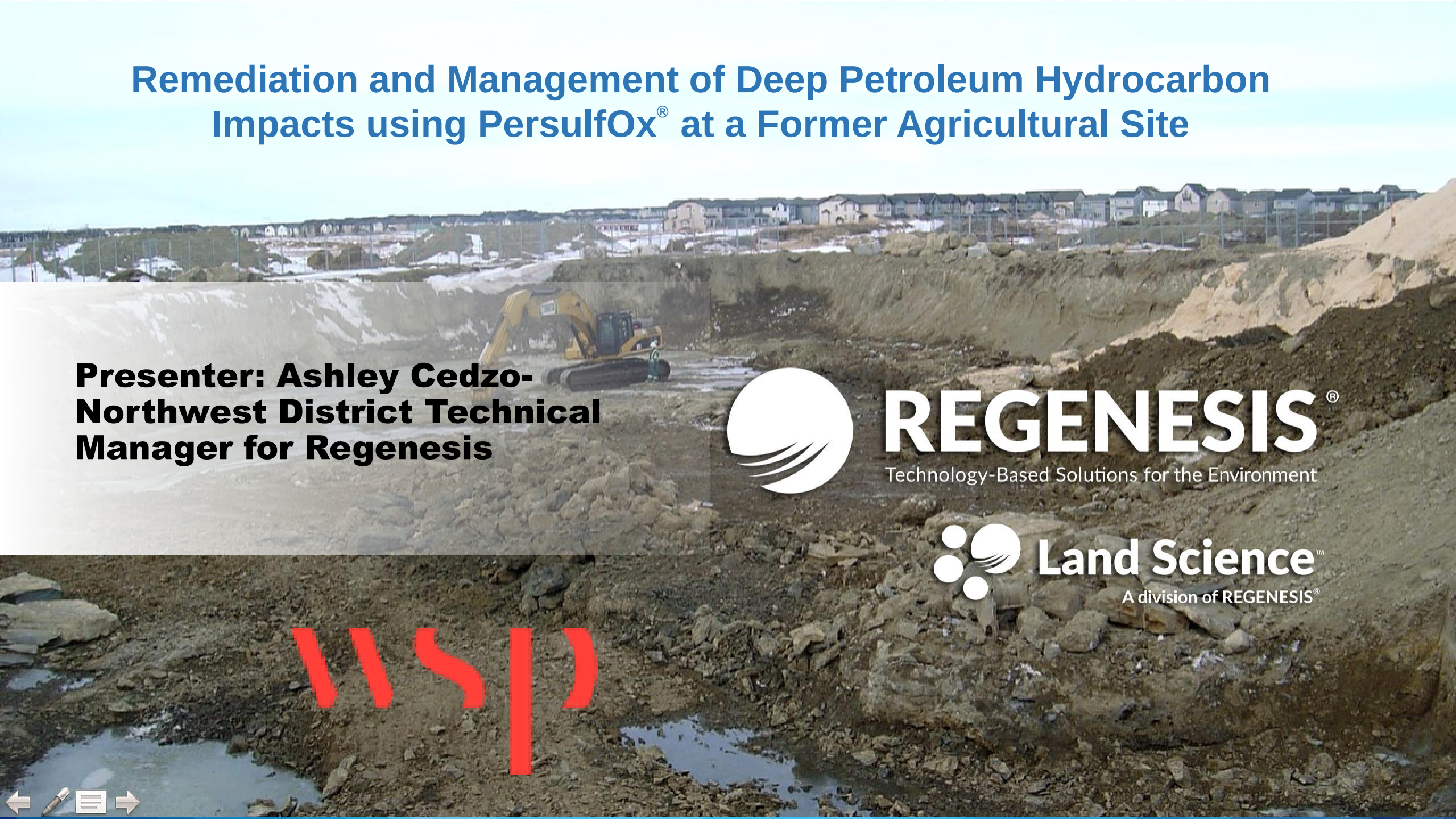
Remediation and Management of Deep Petroleum Hydrocarbon Impacts using PersulfOx® at a Former Agricultural Site



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CREDITS

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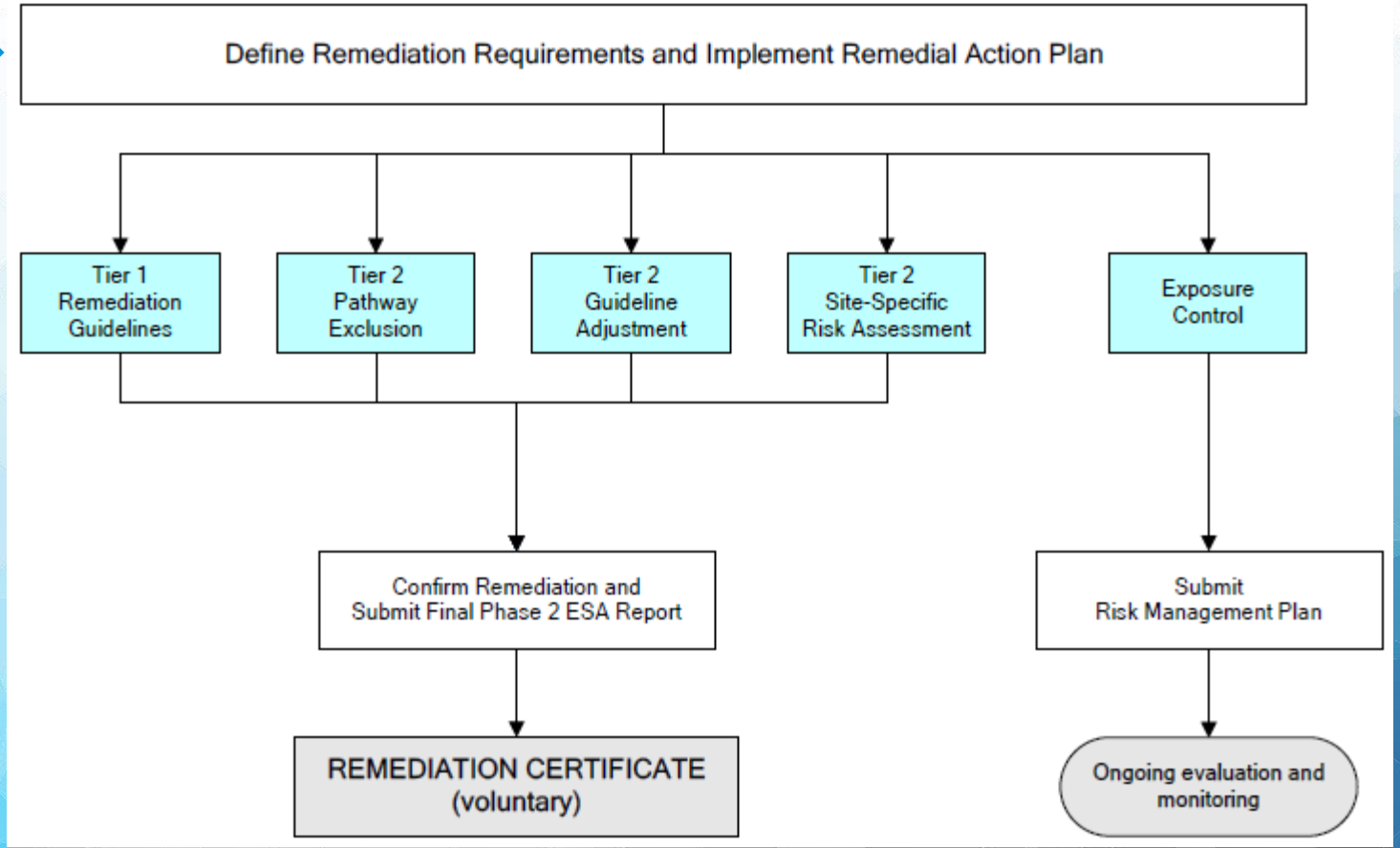
PRESENTATION OUTLINE

- Regulatory Process Overview
- Project Background
- Conceptual Site Model
- Remedial Excavation (Process and Results)
- *In-situ* Technology – PersulfOx®
- Chemical Application (Process and Results)
- Conclusions

AEP – COMPLIANCE PROCESS

Phase I ESA (Identify potential sources of contamination)

Phase II ESA (Confirm Contamination)



Project Timeline

PHC plume delineation and remediation required to support the future proposed urban development.

~~se I ESA~~

~~2006~~

~~Detailed Site Investigations~~

~~2007 - 2009~~

~~Excavation Monitoring and Delineation~~

DUA Pathway Elimination Investigation

CHALLENGE 1: Unable to rule out DUA= strictest T1 standards apply

June – Sept. 2013

Additional Delineation Subsurface Investigations in Bedrock

November 2013

Remediation Plan Development

December 2013

Site Excavation / Product Removal

CHALLENGE 2:
Free product and bedrock contamination= rezoning

December 2013-February 2014

Final Excavation/ Confirmatory Sampling within Excavation

CHALLENGE 3:
PHCs still above vapor inhalation guidelines

February 2014

Groundwater Testing within Excavation and then introduction of PersulfOx® into groundwater

April - May 2014

Post-Remediation Groundwater Monitoring in open excavation

June, July, August 2014

Excavation Backfilling

November 2014

Post-Remediation Monitoring
December 2014

Exposure Control Plan/Risk Management Plan

January-March 2015

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Background

Historical site use:

- Farming Facility since ~1962
- Three ASTs containing diesel and gasoline (removed ~2010) without secondary containment
- Two former pump islands without catch trays
- Stressed vegetation at the fuel dispensing area
- A number of drums and smaller containers of oil stored in one of the Quonsets without secondary containment
- Numerous outbuildings, silos, old corrals and a residence up to October of 2013.

Conceptual Site Model

- Clay underlain by fractured sandstone and shale
- Fine and coarse-textured soil

- Groundwater
  - Seasonal depth between 3 and 10 mbgs (10-33 ft)
  - Direction: SE (prior to Excavation); NW and NE (after remediation)

- High conductivity in sandstone
  - Domestic Use Aquifer pathway could not be eliminated
  - Most stringent Alberta Tier 1 Guidelines are used

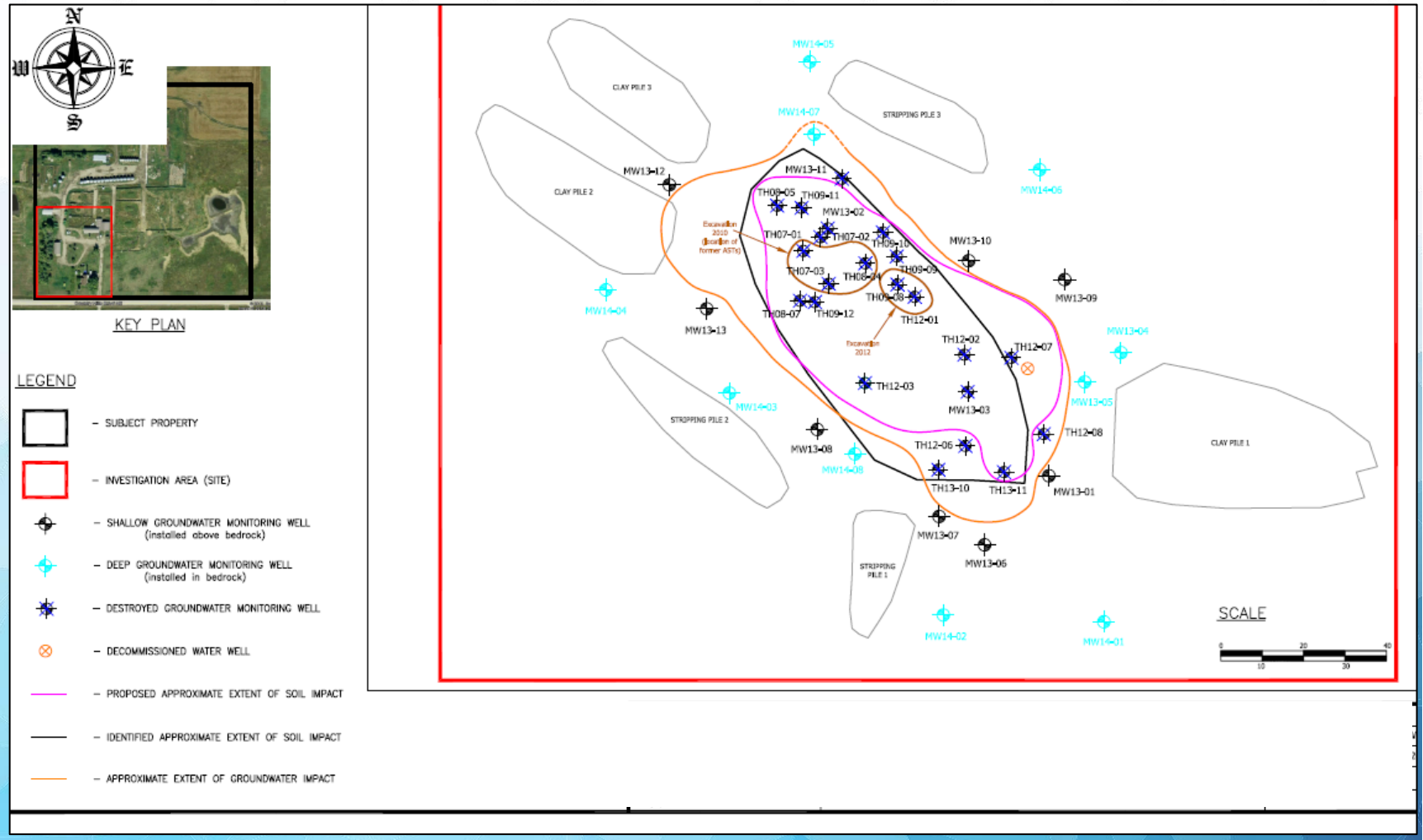
Conceptual Site Model (contd.)

Soil :

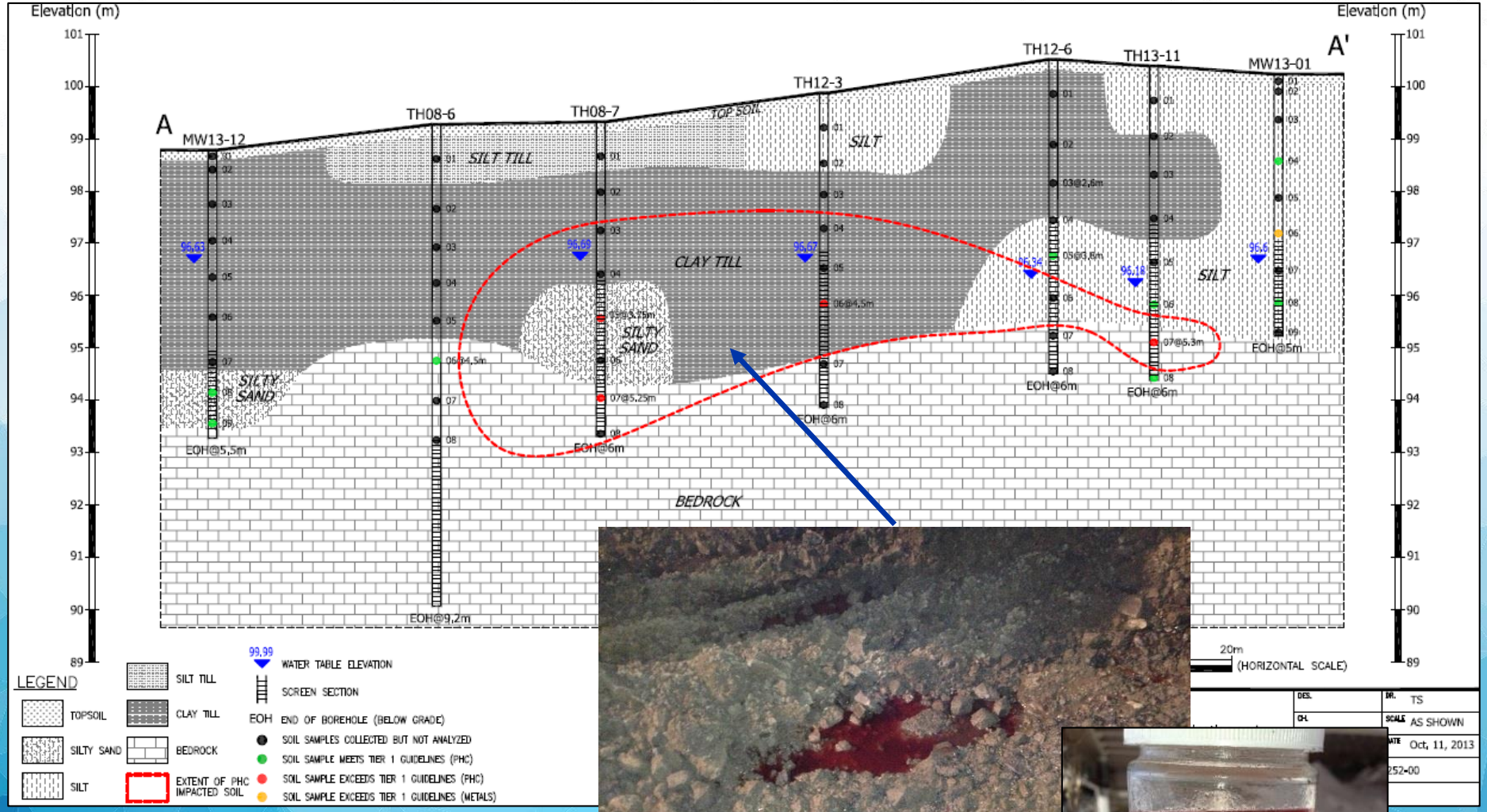
Benzene = 8.1 mg/kg
Toluene = 67.2 mg/kg
Ethylbenzene = 27.4 mg/kg
Xylenes = 107 mg/kg
F1 = 887 mg/kg
F2 = 673 mg/kg
Naphthalene = 1.74 mg/kg
Arsenic = 17.6 mg/kg

Groundwater:

Benzene = 11.2 mg/L
Ethylbenzene = 14.6 mg/L
Toluene = 7.55 mg/L
Xylenes = 67.8 mg/L
F1 = 507 mg/L
F2 = 8.3 mg/L
Dissolved metals



Conceptual Site Model (contd.) and Remedial Excavation



During Excavation, dyed free-floating product was identified within clay soil at ~ 5 mbgs

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Why the need for a large excavation?

- Site land use (initially from agricultural to residential, then rezoned to commercial)

- No Risk Management Plan is allowed for new single residential homes
  - PHC concentrations still above vapour inhalation pathway

REMEDIAL EXCAVATION (contd.)

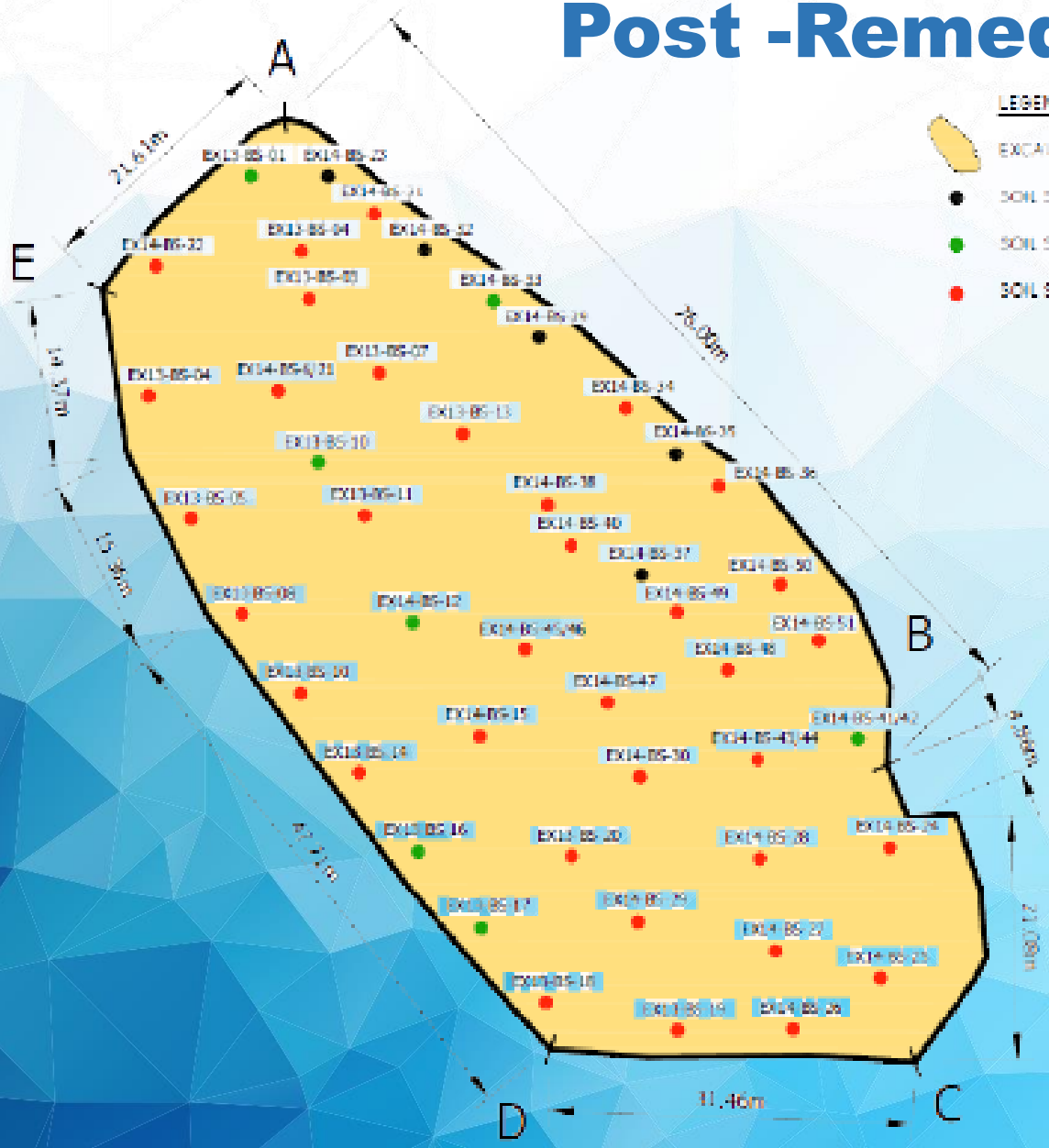
Final Excavation Extent: 95 m x 40 m with depths ranging 6 to 7 mbgs

Clean soil excavated, tested and used for backfilling:

- 1,462 m^3 of topsoil
- 7,468 m^3 of overburden clay material

- 18,160 tonnes of PHC impacted material excavated and disposed off-site.

Soil and Groundwater Results
Post -Remedial Excavation



- Soil concentrations at all final excavation walls met the Commercial AB Tier 1 Guidelines (AT1)
- Soil and groundwater concentration at the base of the excavation were above the Commercial AT1 and vapour inhalation guidelines
- Maximum Concentrations of PHCs:
  - Soil [Benzene] ranged 1.53 mg/kg (AT1: 0.046 mg/kg)
  - Groundwater [Benzene] 0.4 mg/L (AT1: 0.005 mg/L)
  - Groundwater [F1-F2] 2.7 and 1.7 mg/L (AT1: 2.2/1.1 mg/L)

Technology – Why Active Treatment???

- Site sub-surface conditions (fractured bedrock and depth of impacts) – **remedial excavation was no longer feasible**
- Presence of contaminants still in groundwater and soil beneath the water table at the site indicated that *in-situ* treatment should be considered
- Overall goal was to close the site to allow for redevelopment to occur as quickly as possible
- Despite concentrations being fairly low for *in-situ* technologies, ISCO was chosen based on:
  - Short treatment timeframe available (impending site redevelopment)
  - Unknown contaminant concentrations in bedrock
- Open excavation easier for necessary contact within 1 application

Challenges

- Large extent of remaining post-excavation onsite contamination above the vapour inhalation pathway
- Limited time available to remediate
- Limited budget available to remediate
- Low groundwater temperatures

The objective was to aggressively reduce contaminant mass through abiotic oxidation reactions

Why catalyzed persulfate?

- All-in-one product. Easily mixes with water and is applied using subsurface injection or soil mixing tools
- 90% sodium persulfate and 10% blended silica/silicate catalyst
- Can be safely mixed without the risks and potential hazards associated with other persulfate activation methods

PERSULF Ox
Catalyzed Persulfate

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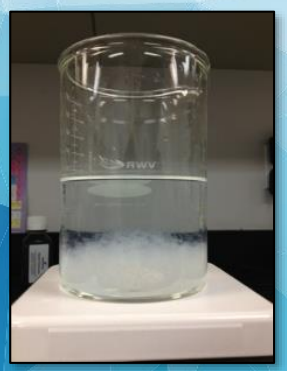
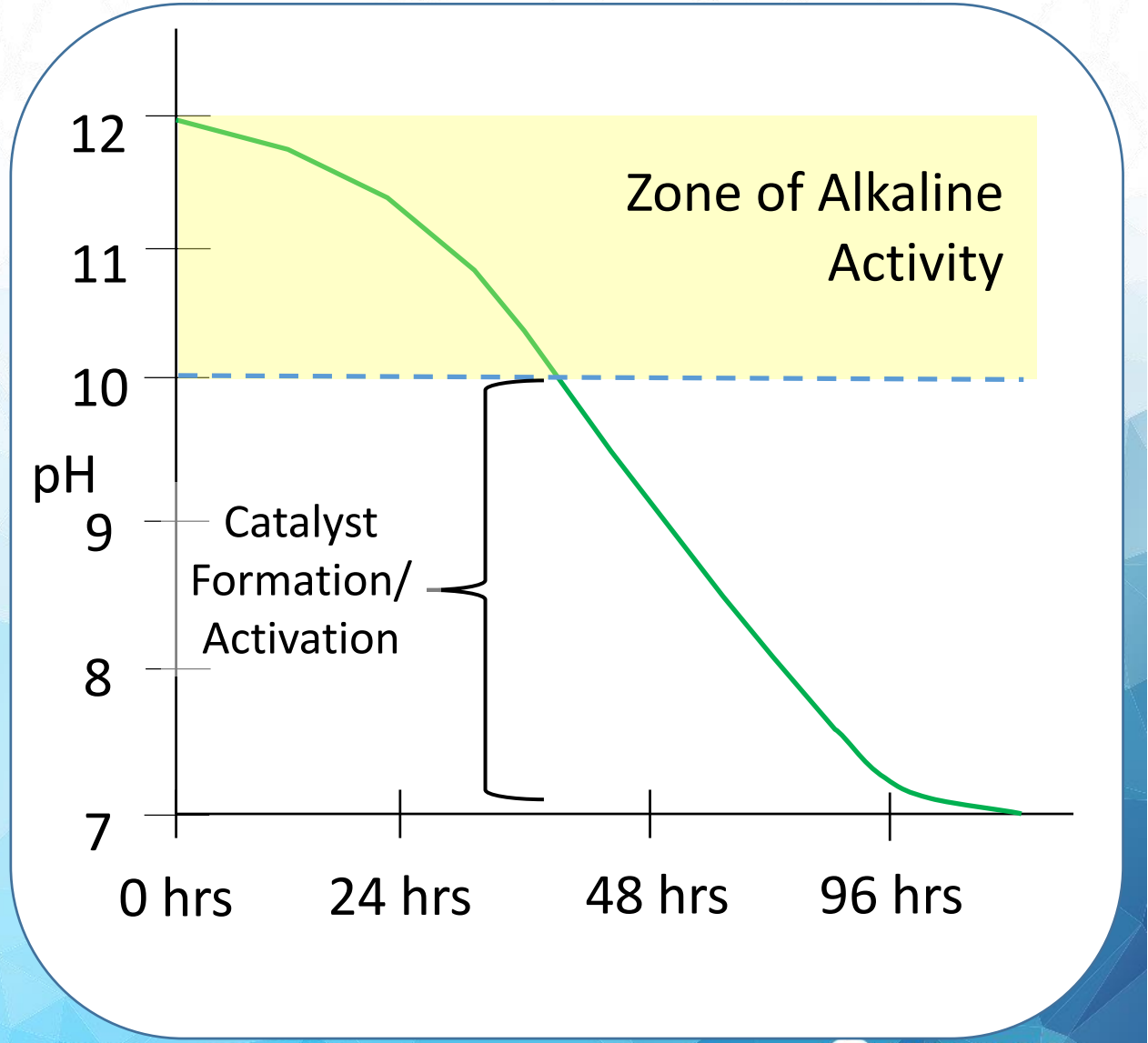
The catalyst in action

Completely soluble Easy to inject
Wide distribution
Initial pH activation



Catalyst forms as pH↓
Solid remains in place
Oxidation is catalyzed
Catalyst regenerates
Contaminants actually sorbed



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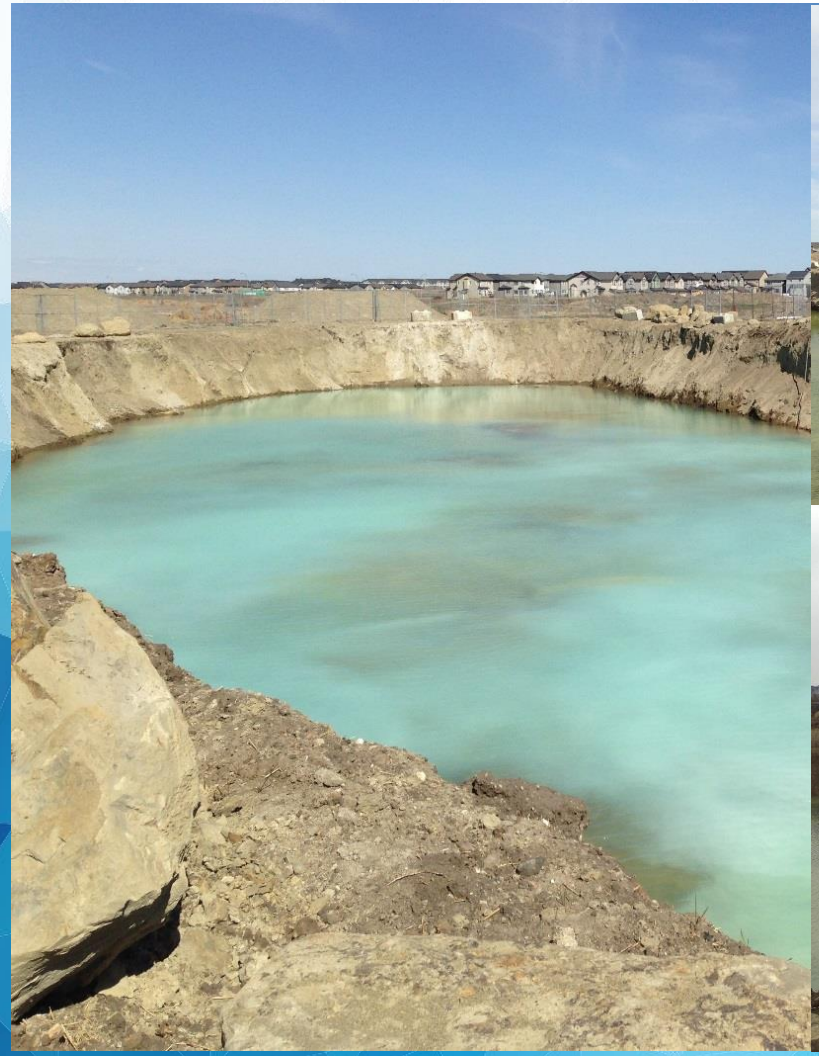
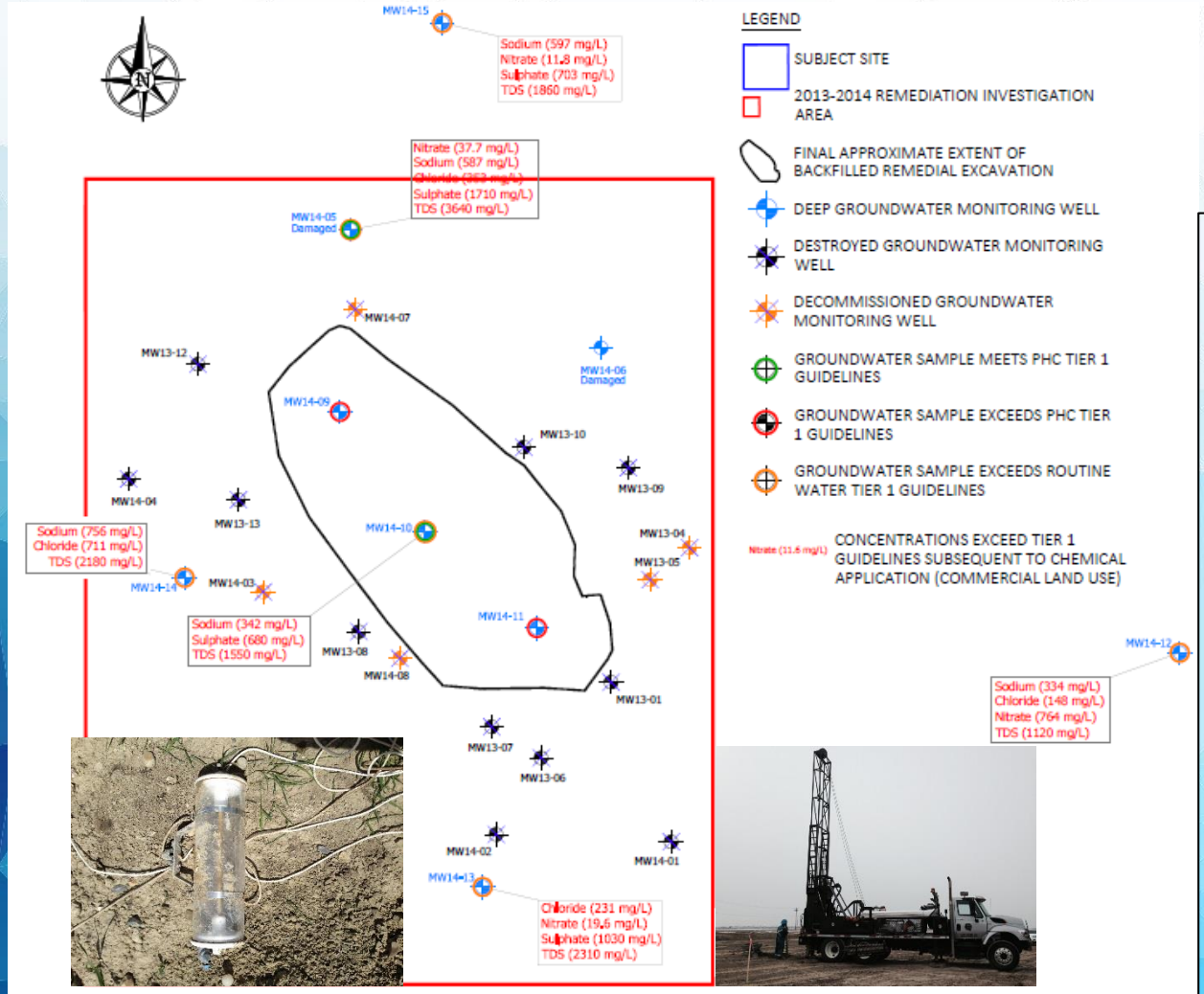
Chemical Application to Groundwater in Open Excavation



PersulfOx® application –

- 5,000 m3 of groundwater within excavation treated with 18,700 kg PersulfOx®
- PersulfOx® mixed with warm water (between 13 and 25°C)
- The mixed solution was sprayed evenly over the groundwater in the excavation with the high pressure hoses (over 3 days)

2014 Soil and Groundwater Results
Post-PersulfOx® Application



- All soil and Groundwater concentration below vapour inhalation guidelines
- Soil and groundwater PHC concentrations above the Commercial AT1 **BUT** below vapour inhalation guidelines

  - Soil [Benzene] 0.047 - 0.172 mg/kg = 97% reduction
    - (AT1: 0.046 mg/kg; VI: 1.2 mg/kg)
  - Groundwater
  - [Benzene] 0.038 - 0.282 mg/L = 91% reduction
    - (AT1: 0.005 mg/L; VI: 1.8 mg/kg)
  - [F1-F2] <0.1- 0.3 mg/L = 89% reduction
    - (below AT1 of 2.2/1.1mg/L and below RDL of <0.1 and <0.2 mg/L)
  - [Sulfate] 5,290- 3,160 mg/L
    - (AT: 500 mg/L)
    - lowered to 1710 and 703 mg/L
  - Other dissolved metals and routine water parameters, PAHs

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2016 Groundwater Results

Monitoring completed by others (publicly available information):

- Groundwater PHC concentrations below the Commercial AT1 (still below vapor inhalation guidelines)
- Sulfate decreased within the excavation since 2014 but increased down-gradient of the former excavation

Sulfate Concentrations in Remedial Footprint

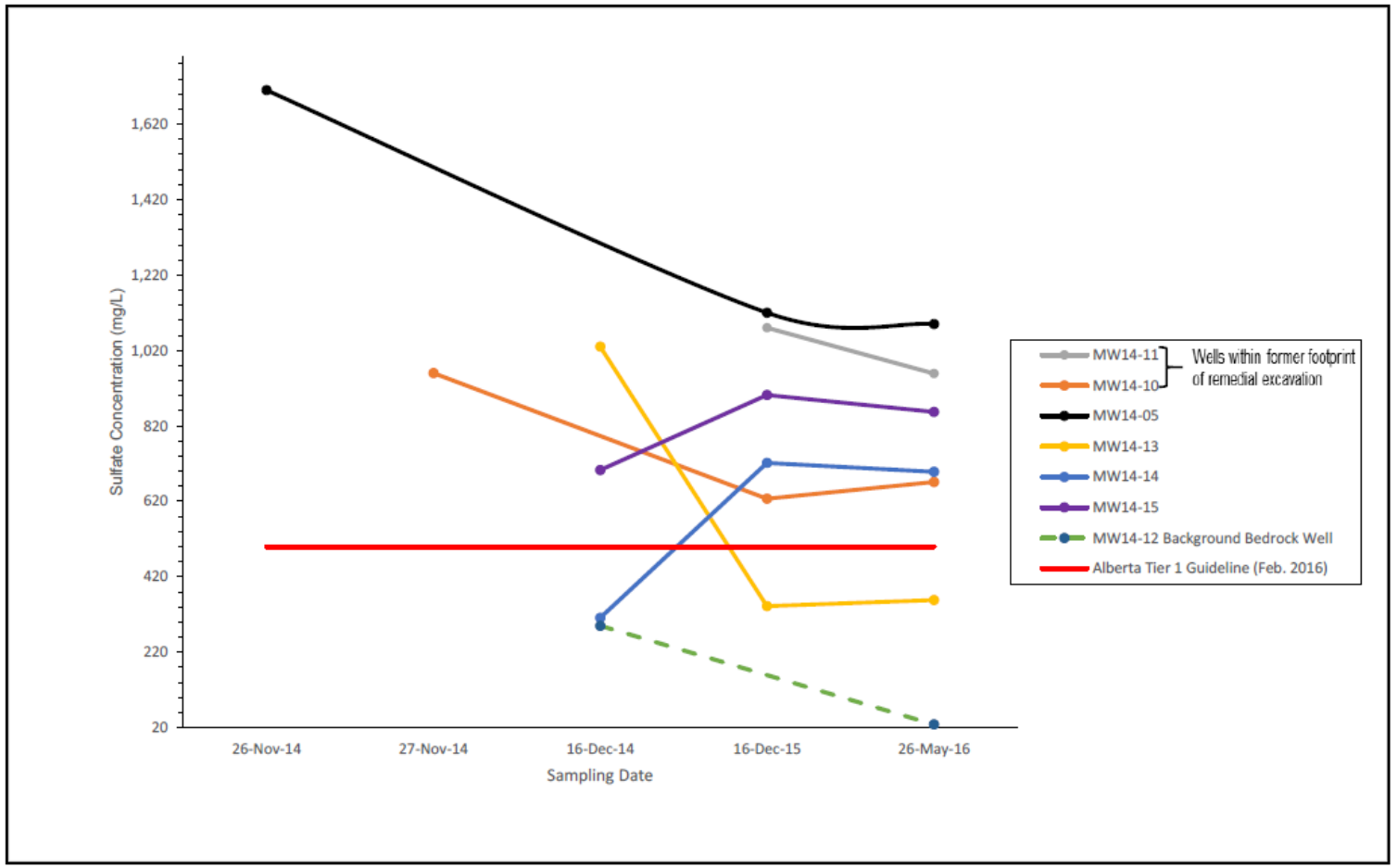

Figure 1: Concentration of Sulphate in Bedrock Monitoring Wells versus Time from 2014 to 2016

- BART used in 7 wells in 2016
  - Indicated active Sulfate reducing bacteria population
- Sulfate in wells exceeds guidelines however, concentrations are stable or decreasing
  - Background well while below guideline has had a ten-fold reduction in Sulfate since 2014- suggesting natural attenuation

Source: 2016 Groundwater Monitoring- Groundwater Information Technologies Ltd.

Conclusions

1. All post-treatment soil and groundwater PHC concentrations were below the vapour inhalation pathway guidelines for commercial use.
2. Introduction of PersulfOx resulted in the absence or reduction of PHC impacts within the fractured bedrock in an open excavation, within a short period of time and under the low groundwater temperatures.
3. High Sulfate concentrations were identified as a result of this chemical application which over the long term would assist in the natural attenuation of any residual.

   The high Sulfate concentrations are expected to attenuate to background concentrations with time as Sulfate is an electron acceptor in the natural attenuation process of PHCs.
4. Exposure Control Plan/Risk Management Plan developed for the Site to manage residual impacts.

Questions

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