

Electrokinetics - Insitu Remediation of Salt Impacted Fine-Grained Soil and Groundwater at a Former Battery Site

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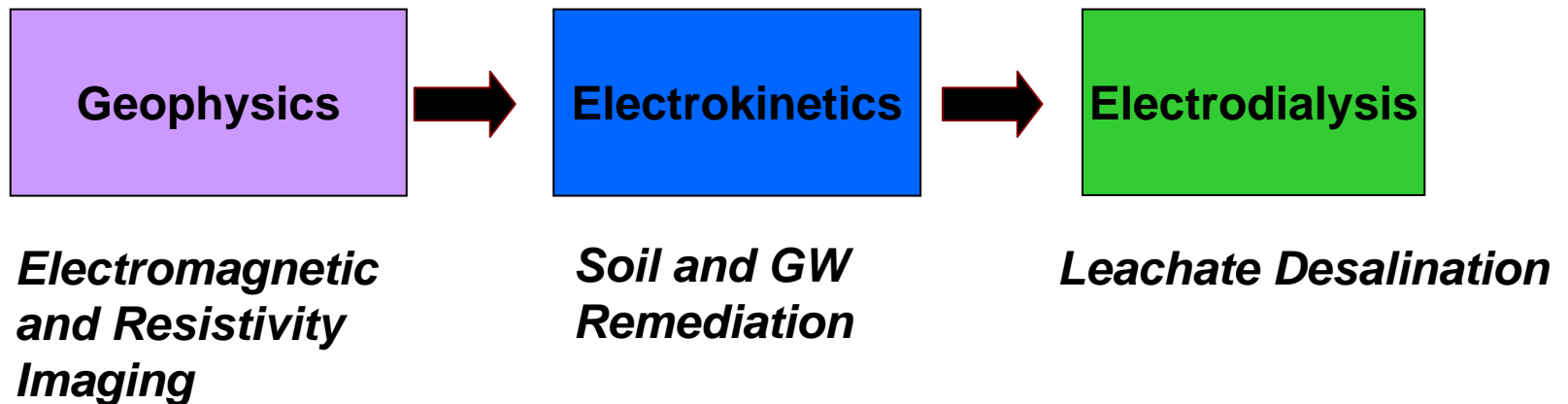
Project Collaborators

Collaborators	Role
1) Shell Energy Canada Ltd.	Project Sponsor/Provided Site
2) National Research Council	Federal Funding/Industry Technology Advice
3) Ground Effects Environmental Services	Electrokinetics Technology/Field Demonstration
4) Volker Stevin Contracting Ltd.	Electrodialysis/Field Demonstration
5) Southern Alberta Institute of Technology	Electrodialysis – Applied Research and Innovation Services (ARIS)



Project Description

- **Pioneer's Goal:** To develop a patented sustainable remedial process for salt impacted sites with a view to reduce the need for land filling.
- **Project Purpose:**
 - To determine technology viability for salinity impacted fine-grained soils and groundwater; and
 - Examine potential impacts to the condition of soils and groundwater as a result of electrokinetics application.
- The project involved the combination of technologies:



Objectives

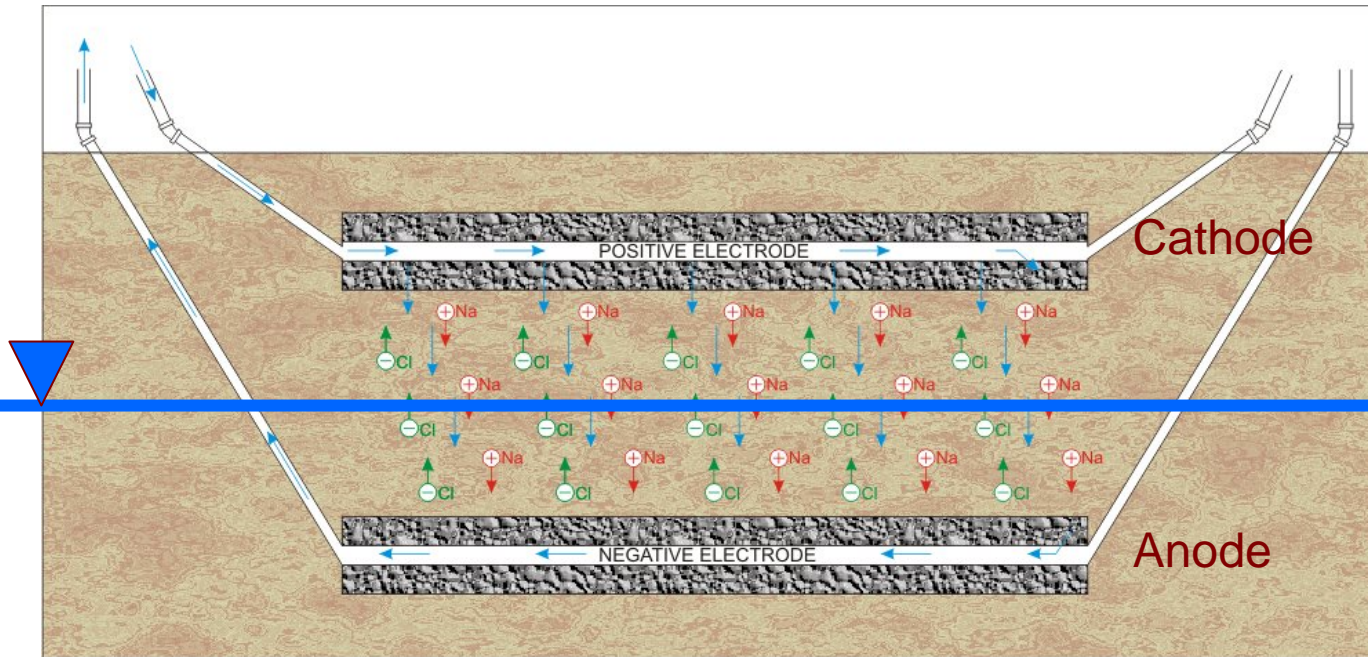
- Determine how well electrokinetics works under;
 - unsaturated
 - saturated conditions
- Determine if electrokinetics remediation affects;
 - microbes in soils
 - electro-migration of dissolved metals (following pH changes)
- Explore the use of electrodialysis to treat salt affected extracted water; and
- Develop design objectives for full-scale remediation.

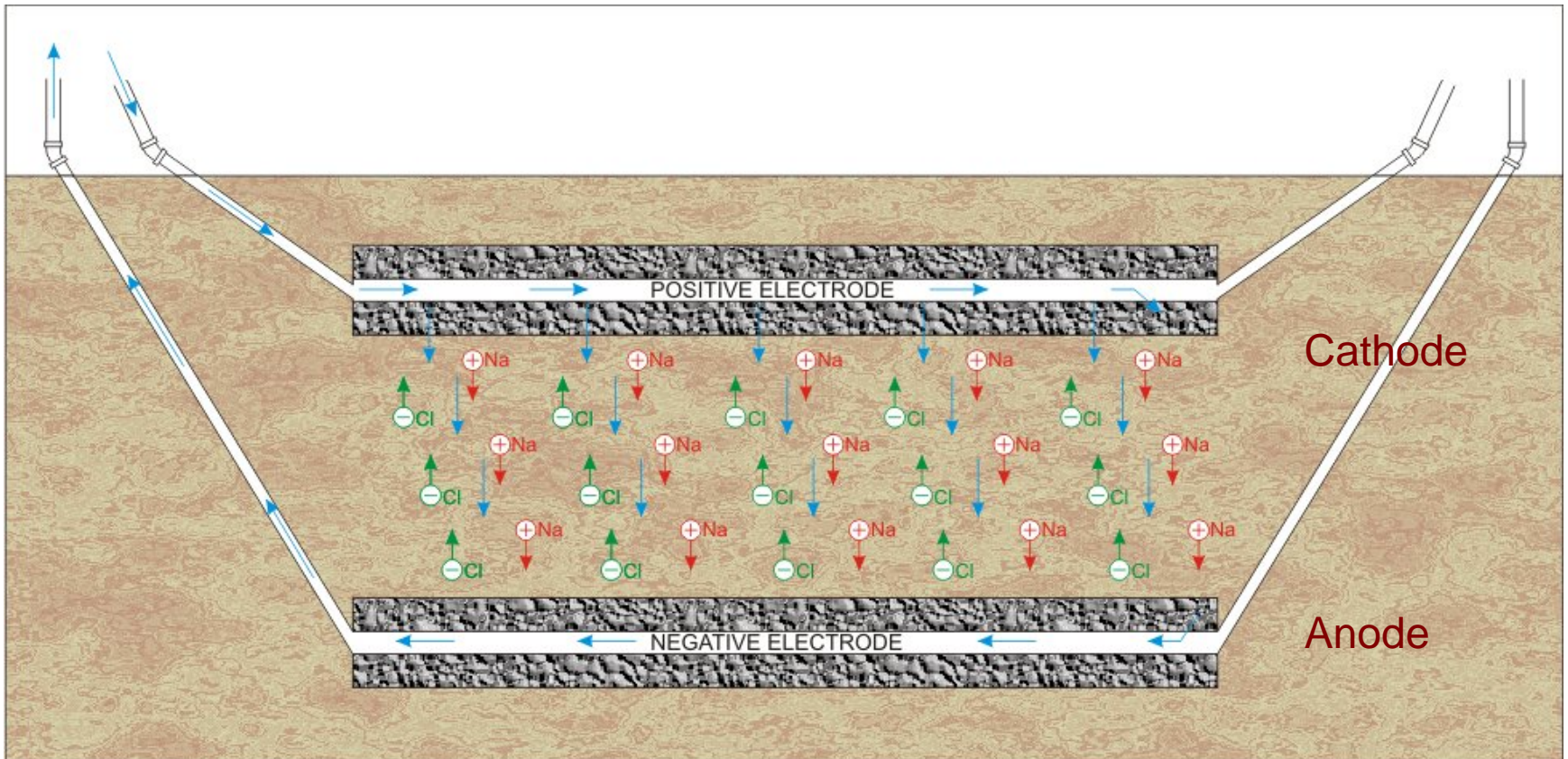
Technology Introduction

- Electrokinetics,
- Electrodialysis,
- Electromagnetics, and
- Electrical resistivity tomography.

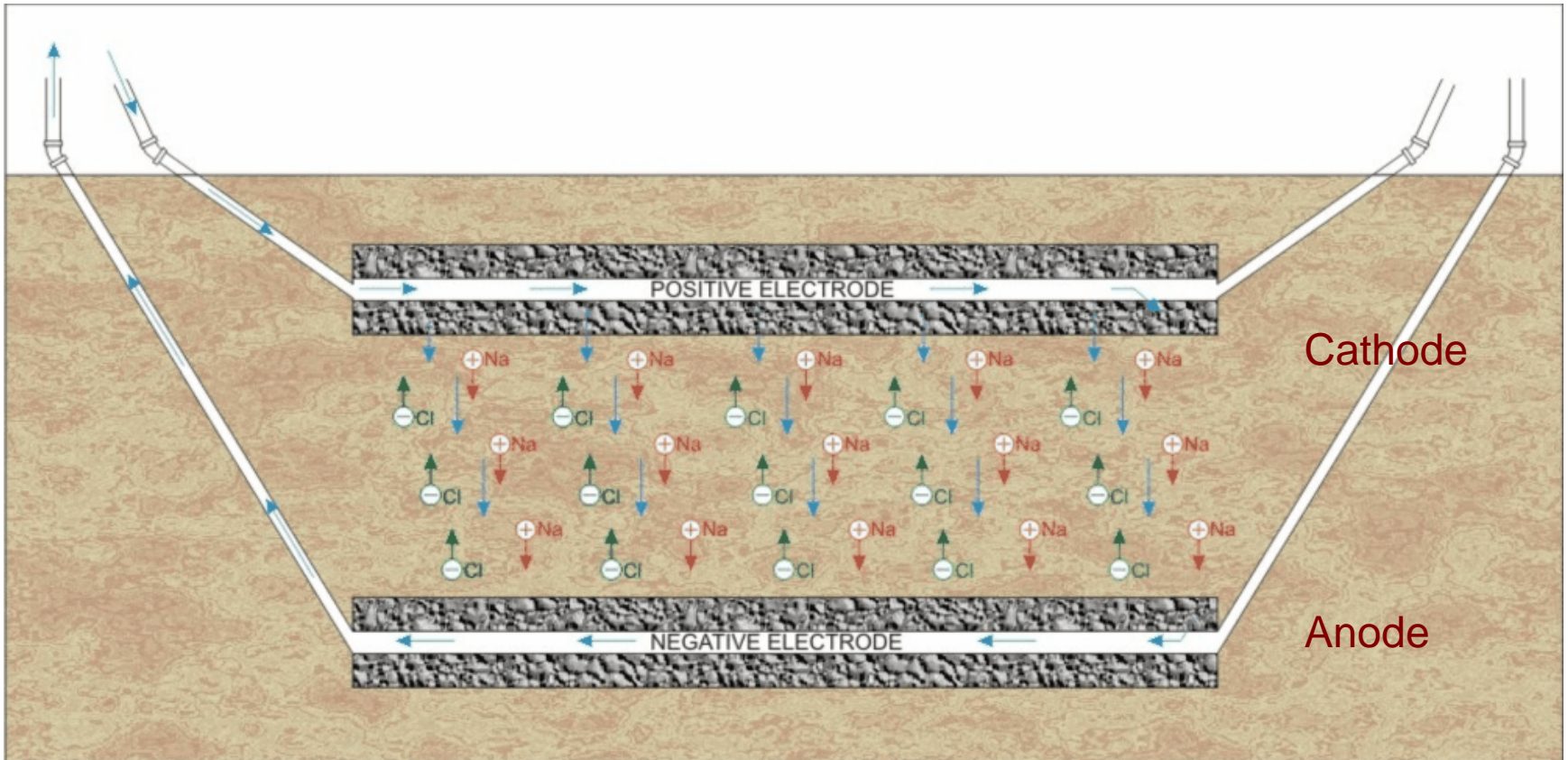
The Electrokinetics Process (treat soil and groundwater)

- Ground Effects researching use of electrokinetics EK3 (patent pending) to remediate sites

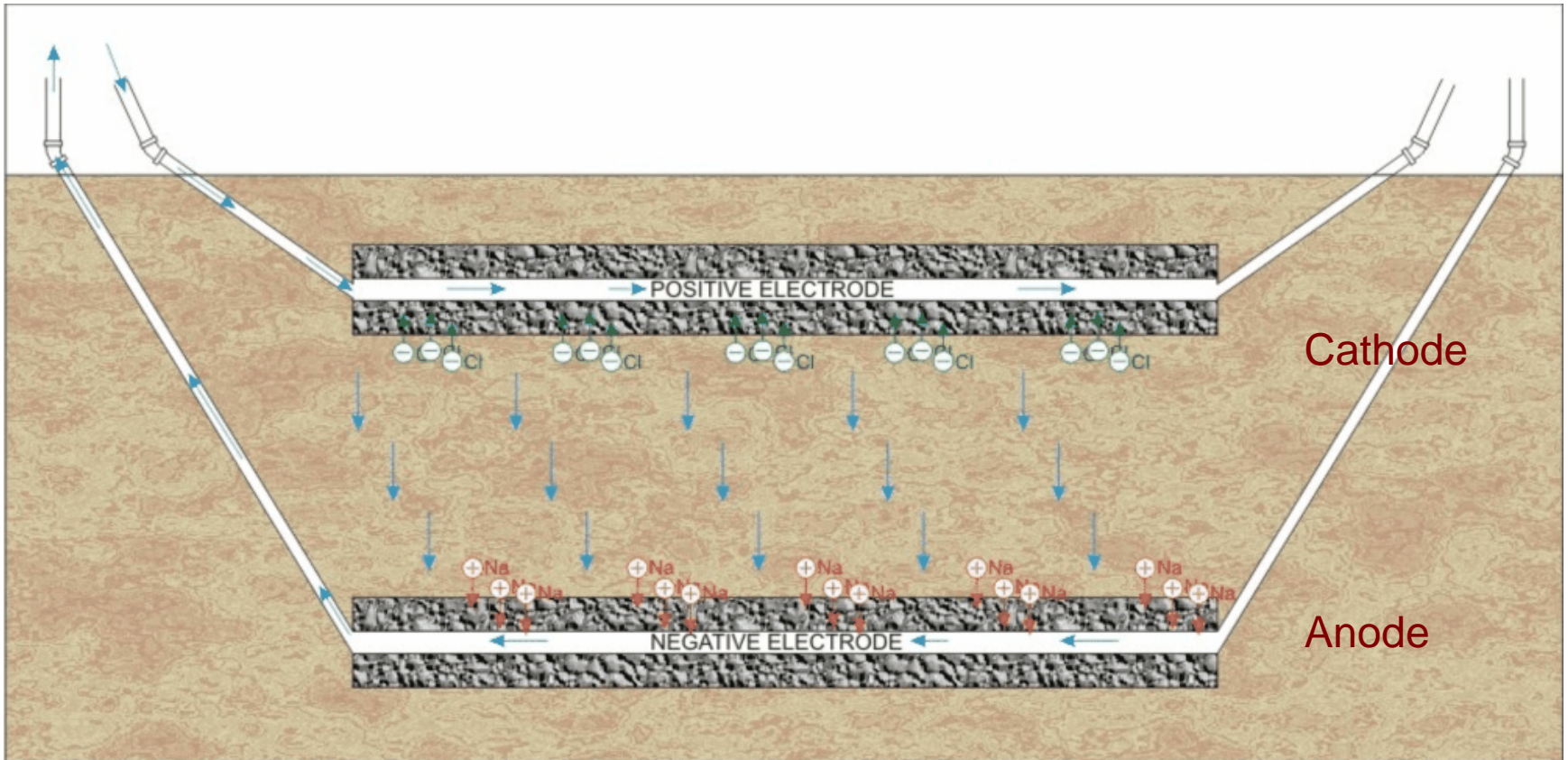




Electrical field is imposed on a volume of contaminated soils



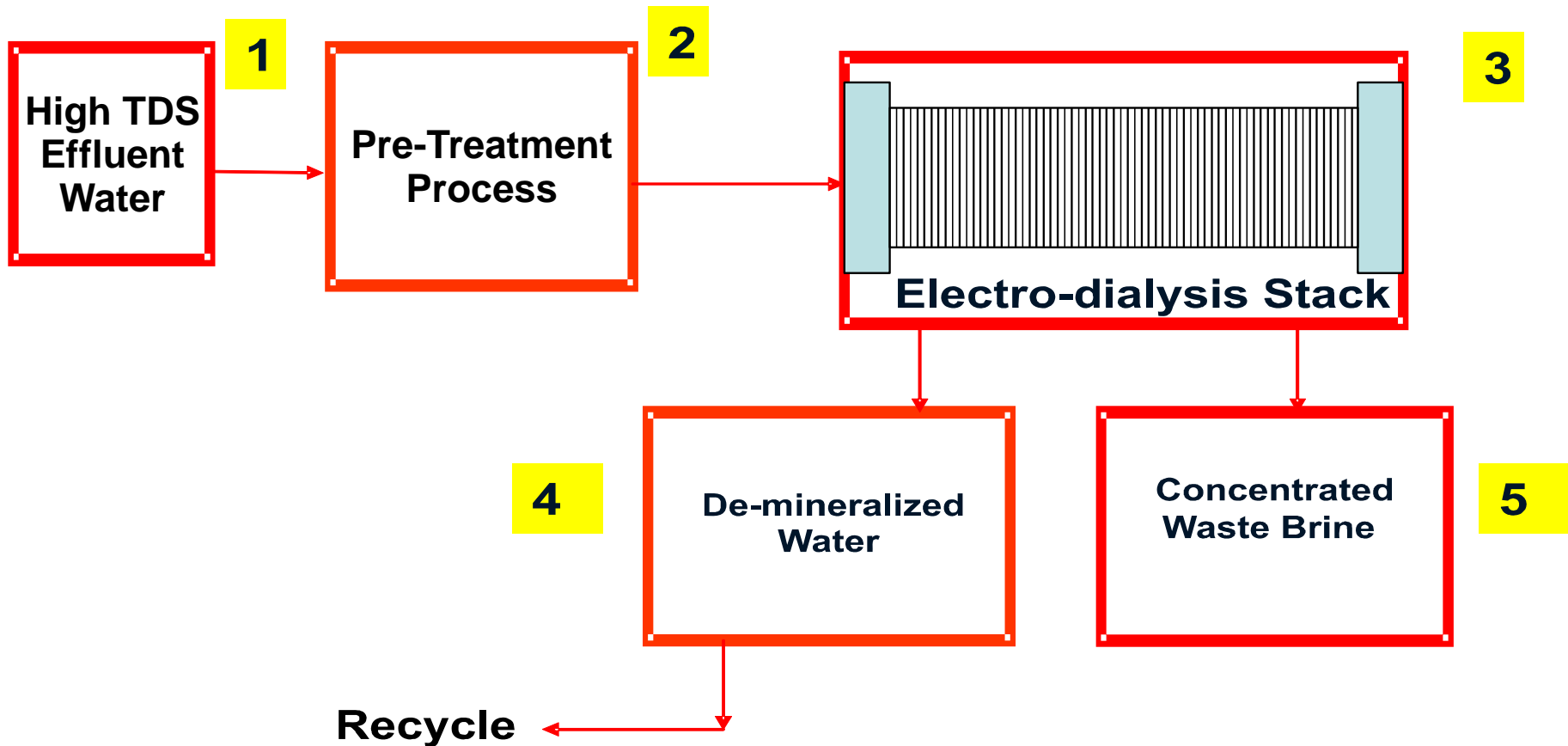
Charged anions and cations migrate under the influence of an electric field to the respective opposite electrodes



Unsaturated zone is flushed and water is extracted from electrodes for potential disposal or exsitu treatment

Electrodialysis Description

(treat effluent water)

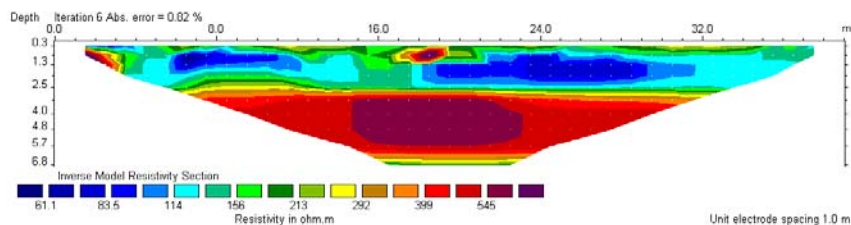
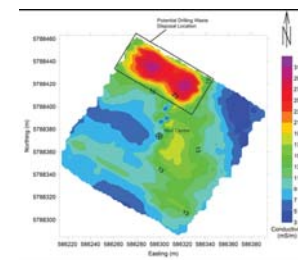


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■ Electrodialysis (Volker Stevin and SAIT)

Electromagnetics (EM) and Electrical Resistivity Tomography (ERT)

- Geophysical investigation methods used for project include:
 - Electromagnetic (EM31) – provides 2-D horizontal image of bulk electrical conductivity; and
 - ERT – provides 2-D vertical image of subsurface materials.



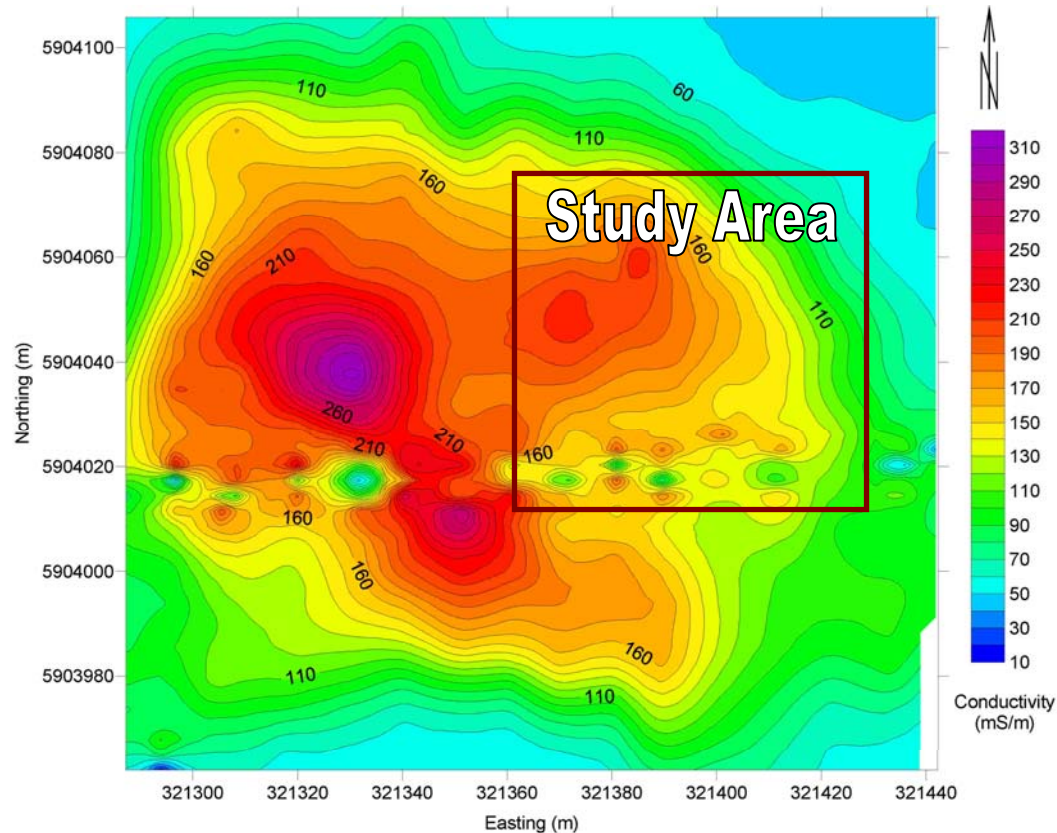
Project Site Selection/History

- Former tank farm and spill area resulted in salinity and metal impacted soils and groundwater.
- Soils:
 - 20,000 m³ impacted from surface to 5 m below grade; and
 - Silty clay till with trace sand and gravel lenses.
- Groundwater:
 - 1.2 and 2.3 m below grade; and
 - Hydraulic conductivity 1.6 E-8 and 1.9 E-6 m/s.

Project Phases

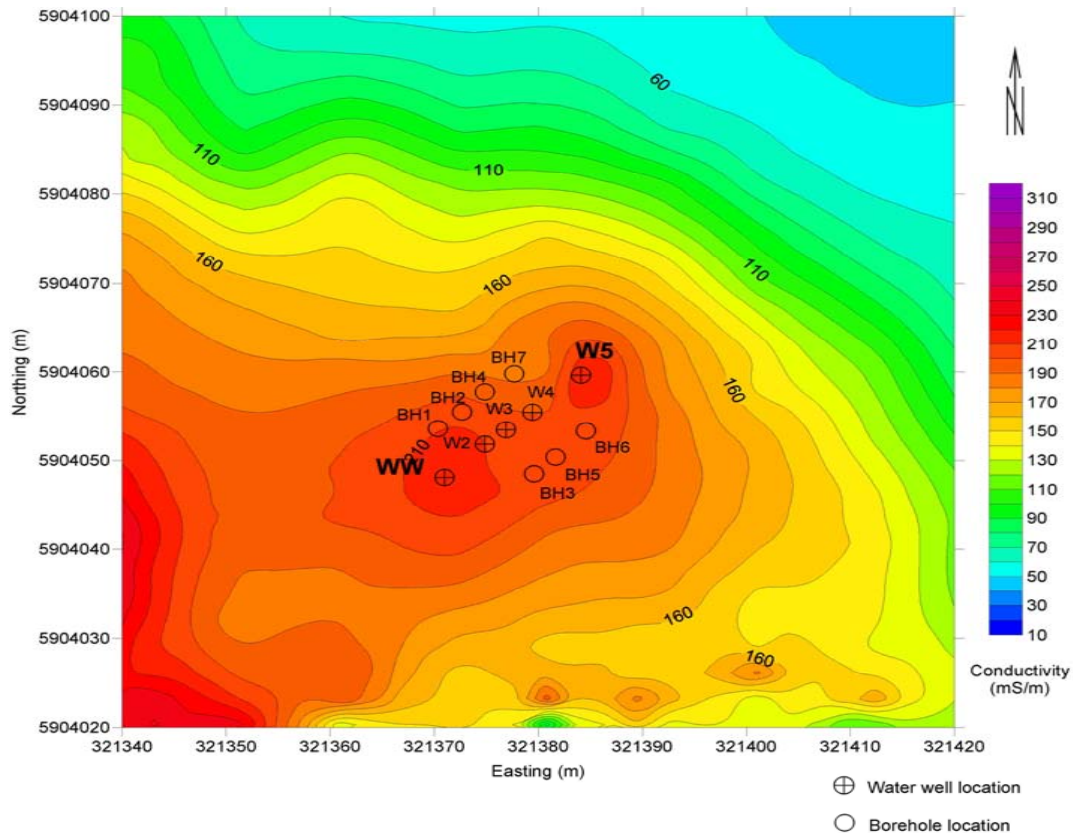
- Baseline soil and groundwater testing
- Bench scale study
- Remedial system installation and operation
- Groundwater and system monitoring
- Post soil and groundwater testing
- Analyze Results → Full-scale design

Baseline EM Survey (June 2006)



An isolated finger of the plume, identified by an EM31 survey, was chosen as the Pilot project study area.

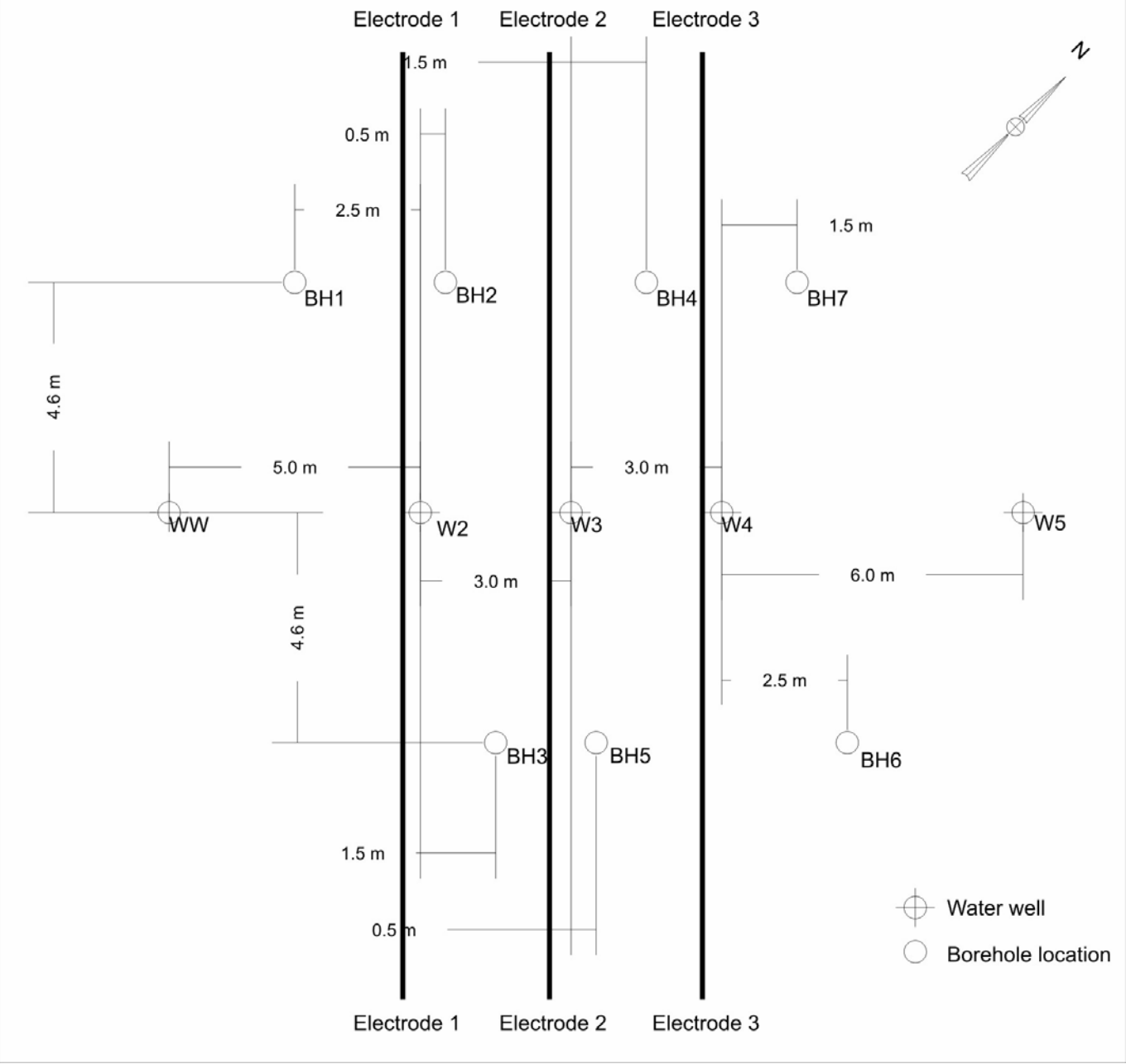
EM Survey (June 2006) Study Area



EM31 – used to establish location of monitoring wells and soil testing

Sampling Locations

- 12 boreholes and 8 gw monitoring wells within pilot area placed at varying distances from electrodes to determine electrode influence.
- Soil sample depths based on electrode placement in:
 - Unsaturated (0.9 m below grade); and
 - Saturated conditions (3.0 m below grade).



Baseline Testing: Groundwater

- The baseline groundwater results used for comparison to results obtained during and after the operation of the system.
- Baseline groundwater data indicated elevated levels of salinity and metal parameters that exceed guidelines:
 - Salinity parameters exceeding include Cl, Na and Ca; and
 - Metal parameters exceeding guidelines in groundwater include: As, Ba, Cd, Li, Mn, Se, S, Tl and V.

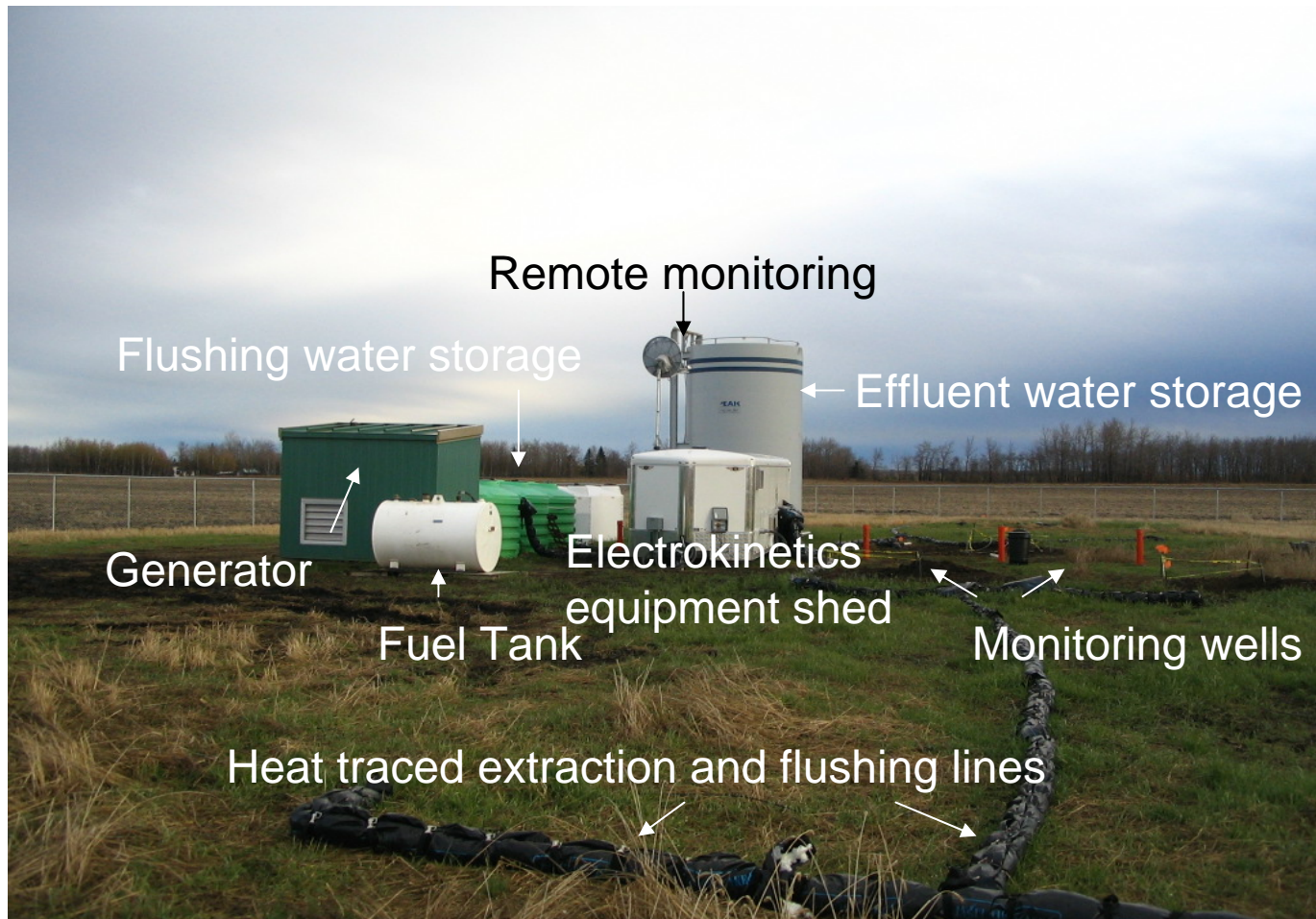
Baseline Testing: Soils

- The baseline soil analytical results were compared to the results obtained after the system has been shut down.
- Baseline soil data indicated:
 - Salinity parameter exceeded guidelines at depths of near surface to > 5.0 m below grade;
 - Metals and hydrocarbons do not exceed in the soil samples collected; and
 - Microbes were present in the topsoil, 0.9 m and 3.0 m.

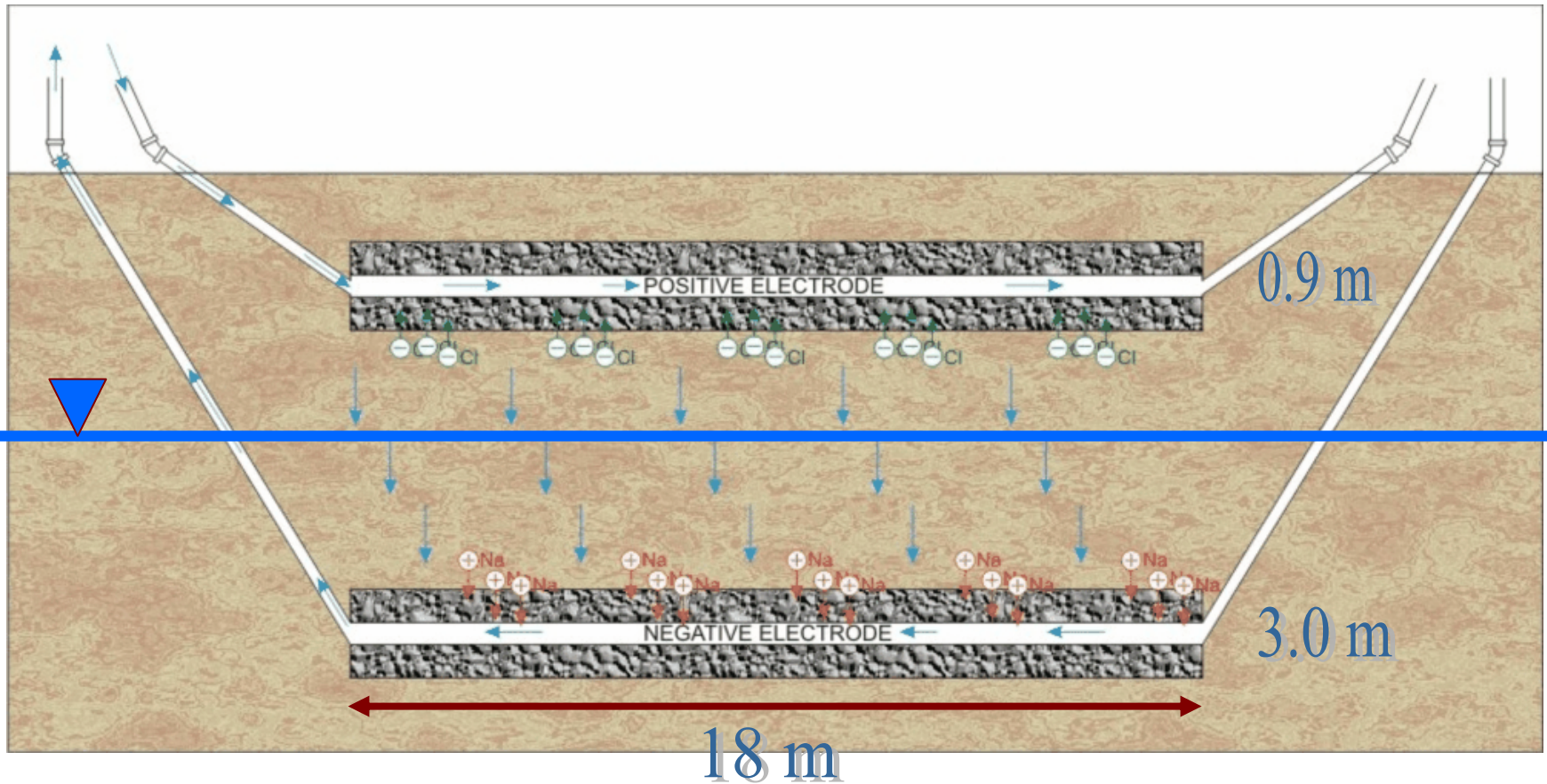
Bench Scale Study

- 1 month bench scale trial conducted by Ground Effects on soils excavated from pilot project area.
- Test procedures:
 - Varied applied amps and distance between electrodes; and
 - Soil and water collected before and after tests.
- Results - salinity in the soils can move under the influence of the electrokinetics and salinity concentrations declined to promising levels.
- H₂S and chlorine gas not detected.

Remedial System Infrastructure



Remedial System Infrastructure



System and Groundwater Monitoring

- Groundwater monitoring and sampling events:
 - Every two weeks after system operation commenced; and
 - Post testing following system shut down.
- Routine and dissolved metal parameters tested. Select samples tested for vinyl chloride and trihalomethanes.
- System testing: influent/effluent water from electrodes – tested for routine water parameters.
- Remote monitoring – pH and temperature.

Operational Issues Encountered (Aug – Nov ' 06)

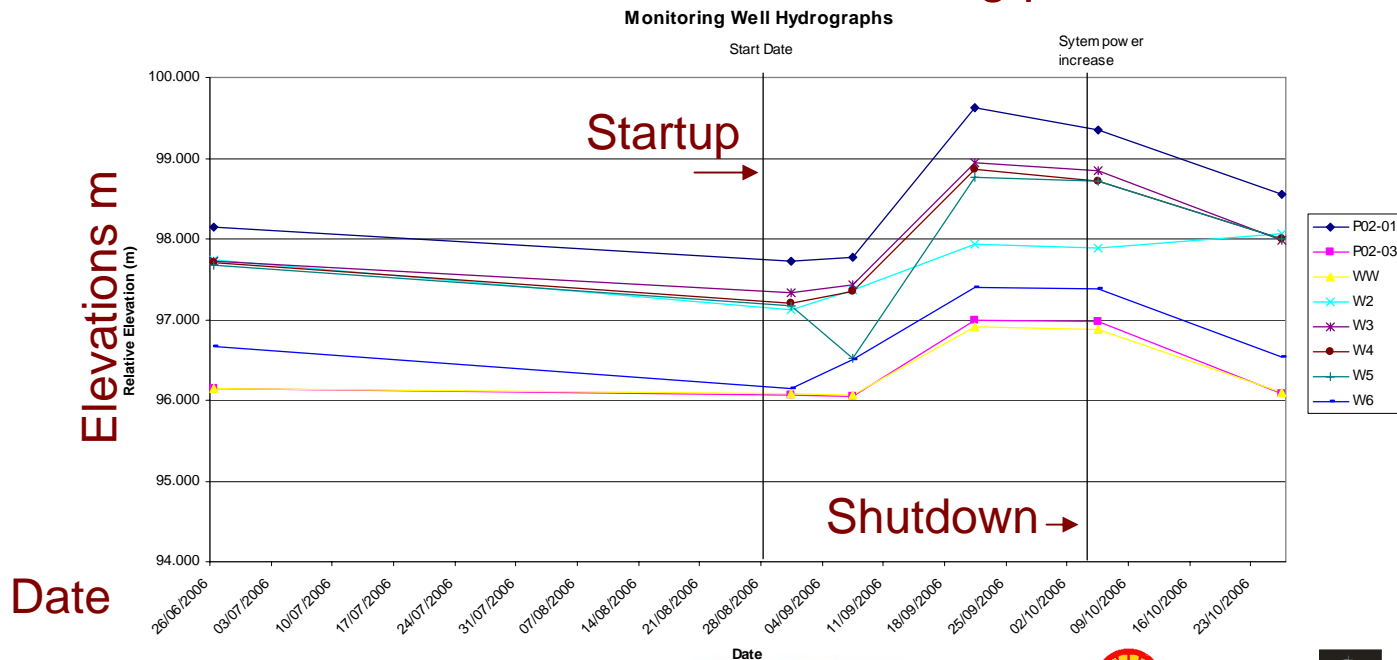
- **Electrodes:**
 - Approximately 68% run time; and
 - Electrical connection failure due to corrosion → electrode exposed to air.
- **Weather**
 - Winter weather caused freeze up of lines (injection water) and storage tanks → lines heat traced.
- **Effluent water**
 - Unanticipated water hardness → pretreatment before electro dialysis.

Results of Pilot Study

- Hydrogeology
- Microbes
- pH and Metals
- Salinity
- Geophysics
- Electrodialysis

Hydrogeology

- Groundwater levels increased during the trial in background wells and wells in the pilot area.
- Groundwater flow direction not affected during trial as water added and extracted during process.



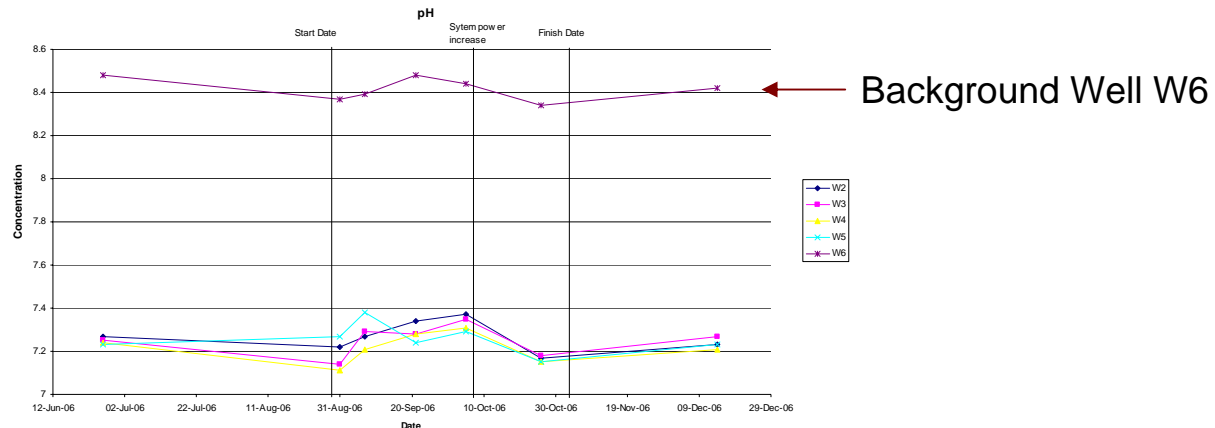
Results:

Heterotrophic Microbes in Soils

- Are microbes affected by electrokinetic processes?
- No apparent affect of electrokinetics on microbe populations with:
 - distance from electrodes, and
 - at depths of 0.9 m (unsaturated zone) and 3.0 m (saturated zone).

Results: pH

- pH: not affected by electrokinetics operation.
- Groundwater trends in wells are consistent with background trends; and



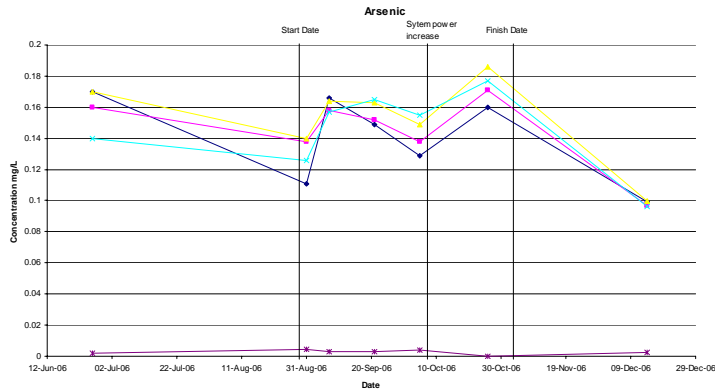
- Negligible changes in the soils.

Results: Metals

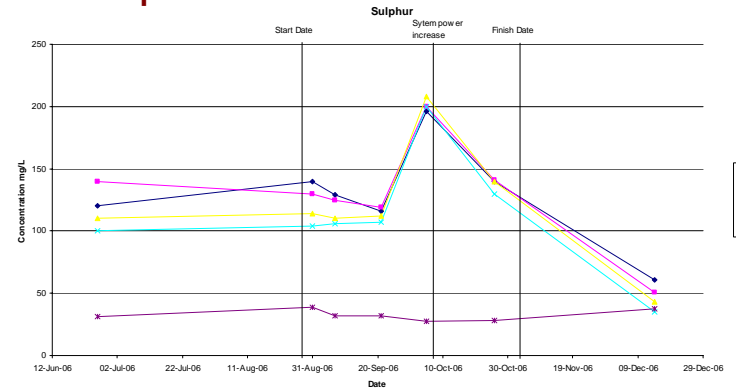
- Metals in soils: no exceeding metals (except for barium)
 - Negligible metal changes in soils overall.
 - Minor increases: Ba.
 - Minor decreases: Cr, V, Zn.
- Metals (of those exceeding) in Groundwater wells:
 - Increase due to system (dissolution from soils): As, Li, Se;
 - Decrease due to system: Ba, Mn, S (spike on Oct 5-06); and
 - Not affected by system: Cd, Cr.

Metals in Groundwater

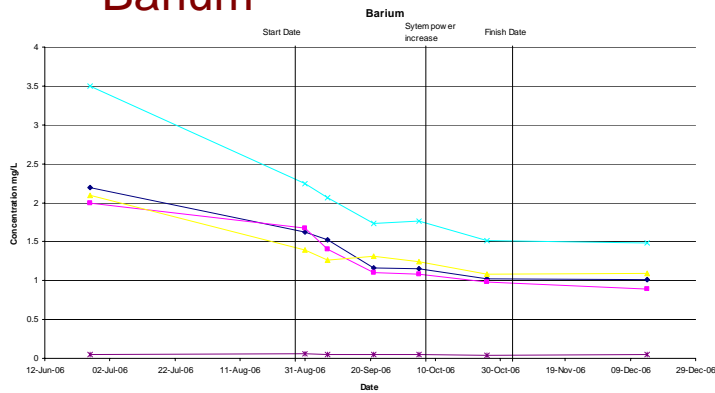
Arsenic



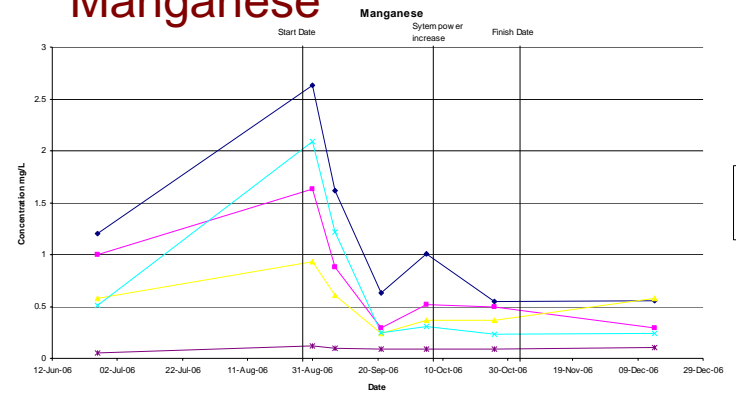
Sulphur



Barium



Manganese

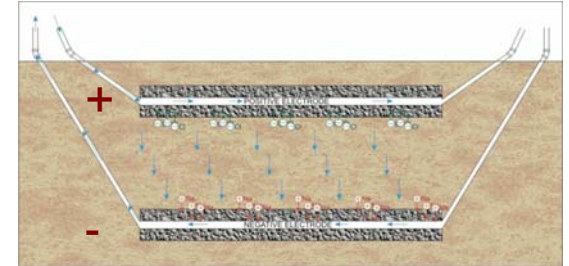


Results: Salinity

- Electrical conductivity (EC);
- Sodium adsorption ratio (SAR);
- Chlorides; and
- Sodium.

Electrical Conductivity (EC)
Sodium Adsorption Ratio (SAR)
Sodium (Na)

$$\text{SAR} = \frac{[\text{Na}]}{\sqrt{\frac{[\text{Ca}] + [\text{Mg}]}{2}}}$$

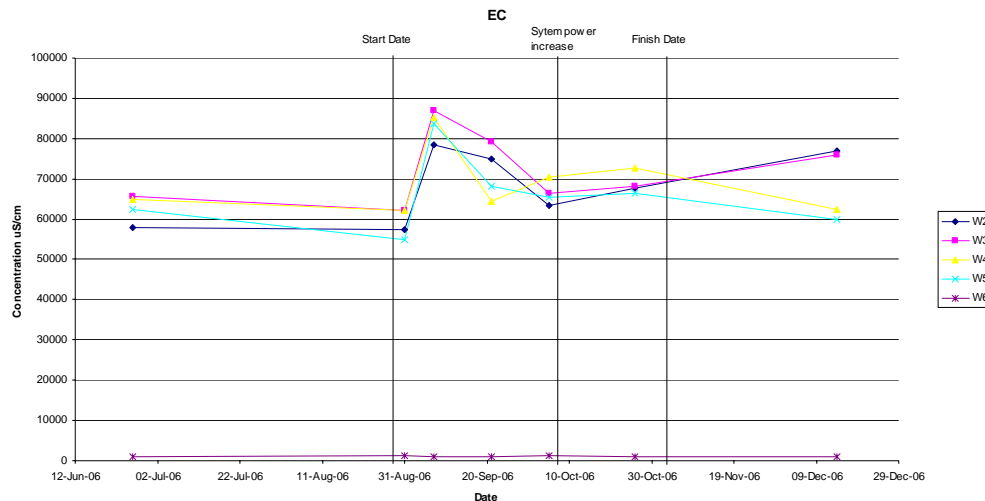


■ Soils:

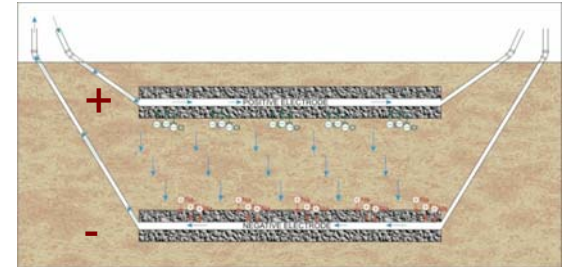
- Regardless of distance of soils from electrodes:
 - EC/SAR/Na generally decreased at a depth of 0.9 m; and
 - EC/SAR/Na generally increased at a depth of 3.0 m.
- Migration of positive ions towards negative electrode.

Electrical Conductivity (EC)

- Groundwater:
 - Dissolution of salinity parameters from soils to groundwater after operation began and then overall decrease in EC was observed during operation; and
 - EC moved toward equilibrium during cold weather mechanical issues and after system shut down.



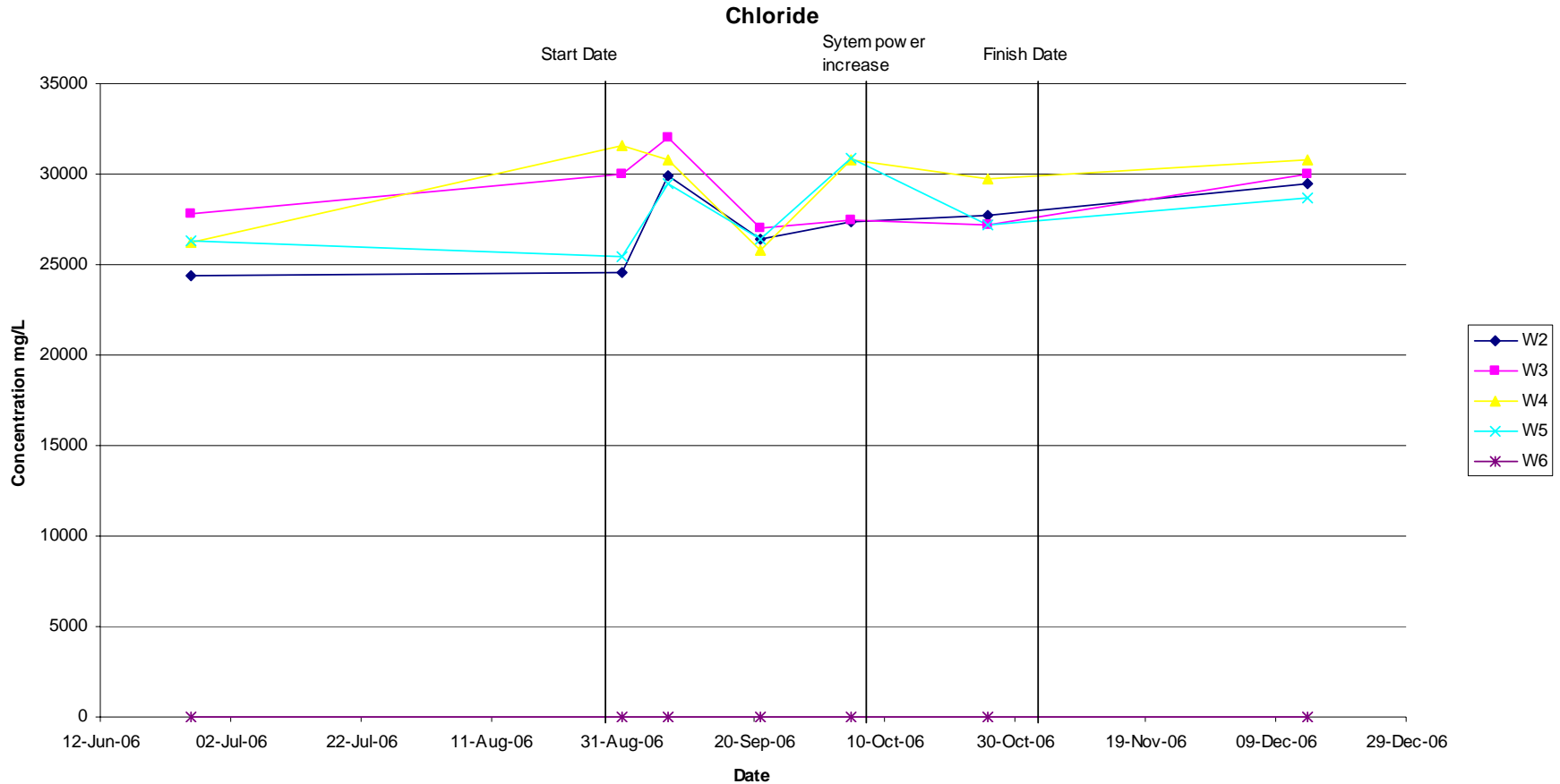
Chlorides



■ Soils:

- At a depth of 0.9 m the chloride (Cl^-) concentrations increased approaching positive electrodes (close to electrodes);
- At a depth of 3.0 m (negative electrode depth) the chloride (Cl^-) concentration generally increased regardless of soils distance from electrodes; and
 - Concentrations expected to decrease if system operational time increased.

Chlorides/ Sodium in Groundwater

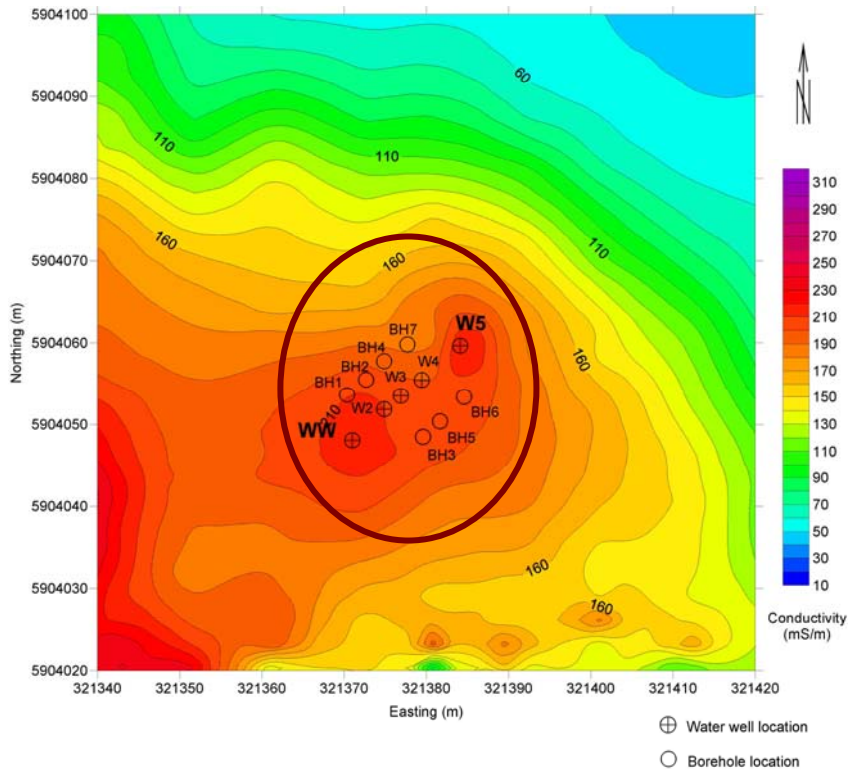


Vinyl chloride and trihalomethanes not detected in water samples

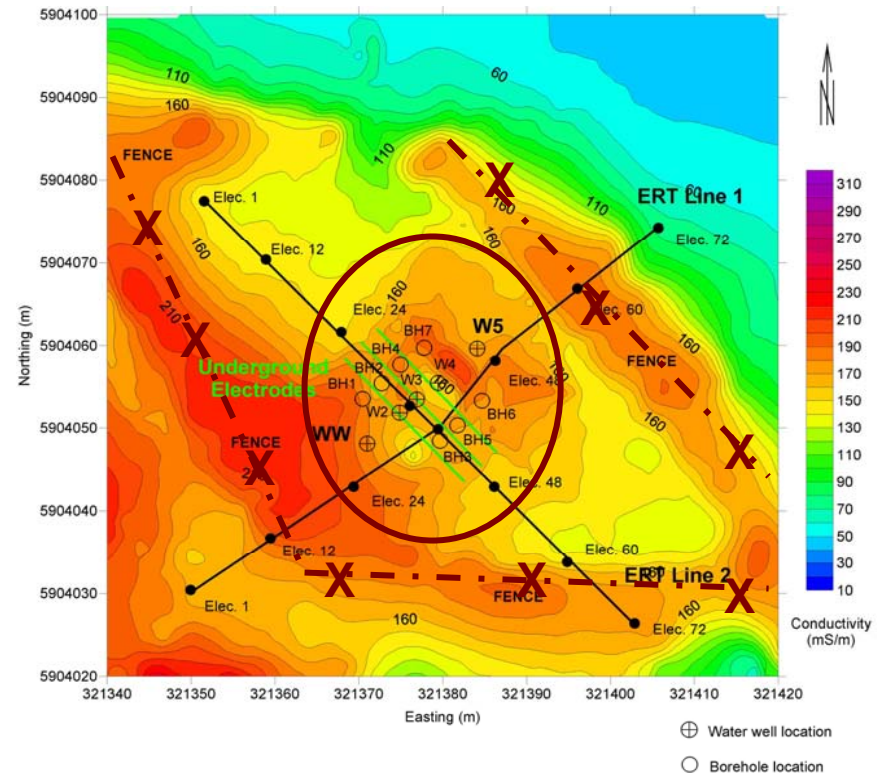
Results: Geophysics

- Post EM survey was conducted in October 2006 with chain link fence still installed; and
- Two Electrical Resistivity Tomography (ERT) lines were completed in March 2007 to delineate the conductivity at depth in the subject area.

EM Surveys: Baseline and Post

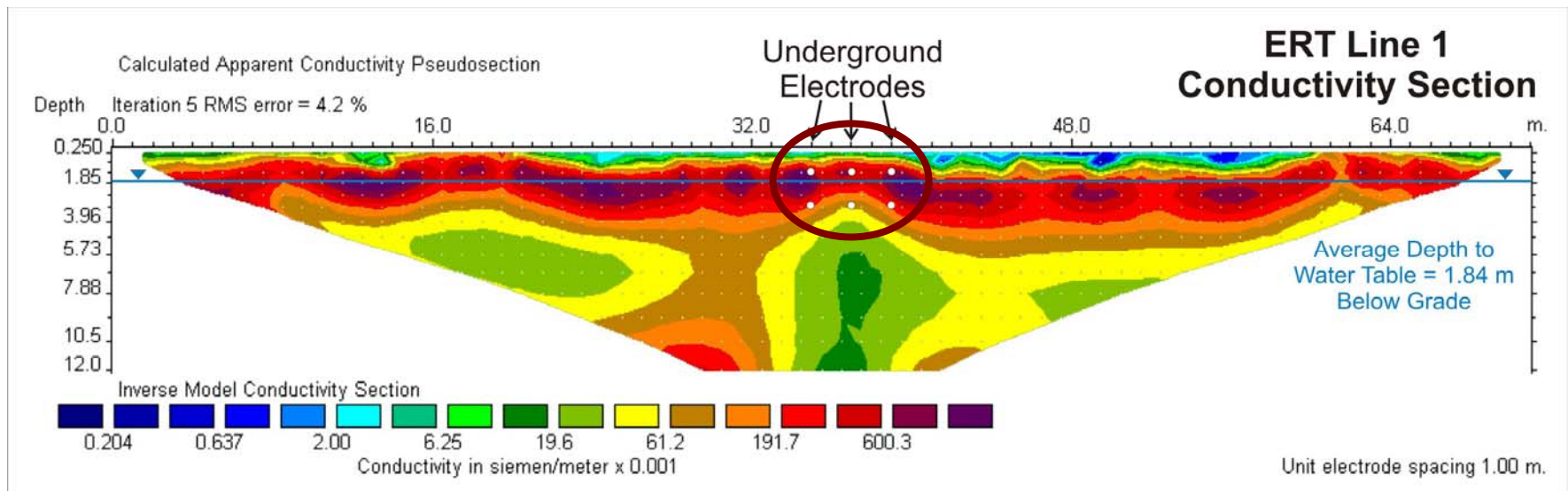


June 2006



October 2006

Post ERT Survey (2007)



- Lower conductivity in vicinity of electrodes

Effluent Water

- Effluent water collected from electrodes and stored in tanks
- Project objective: Advanced treatment (Eco-responsible) (SAIT/Volker Stevin) of effluent water:
 1. Multi-stage pre-treatment process
 2. Electrodialysis for desalination
 3. Product water recycled or re-used (e.g. to flush electrodes/reinject groundwater)



Effluent Water Post Electrokinetics Treatment

- Chemistry (effluent):
 - pH: 2.95 (effluent) vs 7.1 to 8.5 (gw wells)
 - EC up to 15,000 uS/cm
 - Hardness up to 25,000 mg/L
 - Chloride up to 5,000 mg/L
 - TDS up to 35,000 ppm (sea water)
- Pre-treatment required for removal of multi-component impurities in effluent water.
- Desalination required for high salinity in effluent water.
- Treatment/research ongoing...

Outcome of Objectives...

- Determine how well Electrokinetics works under:
 - **Unsaturated conditions** – salinity ions (except Cl) decreased at positive electrode located in unsaturated zone.
 - **Saturated conditions** – salinity ions increased at negative electrode.
 - It will be beneficial to see if a longer operational runtime of electrokinetics will reduce the ions at the negative electrode.

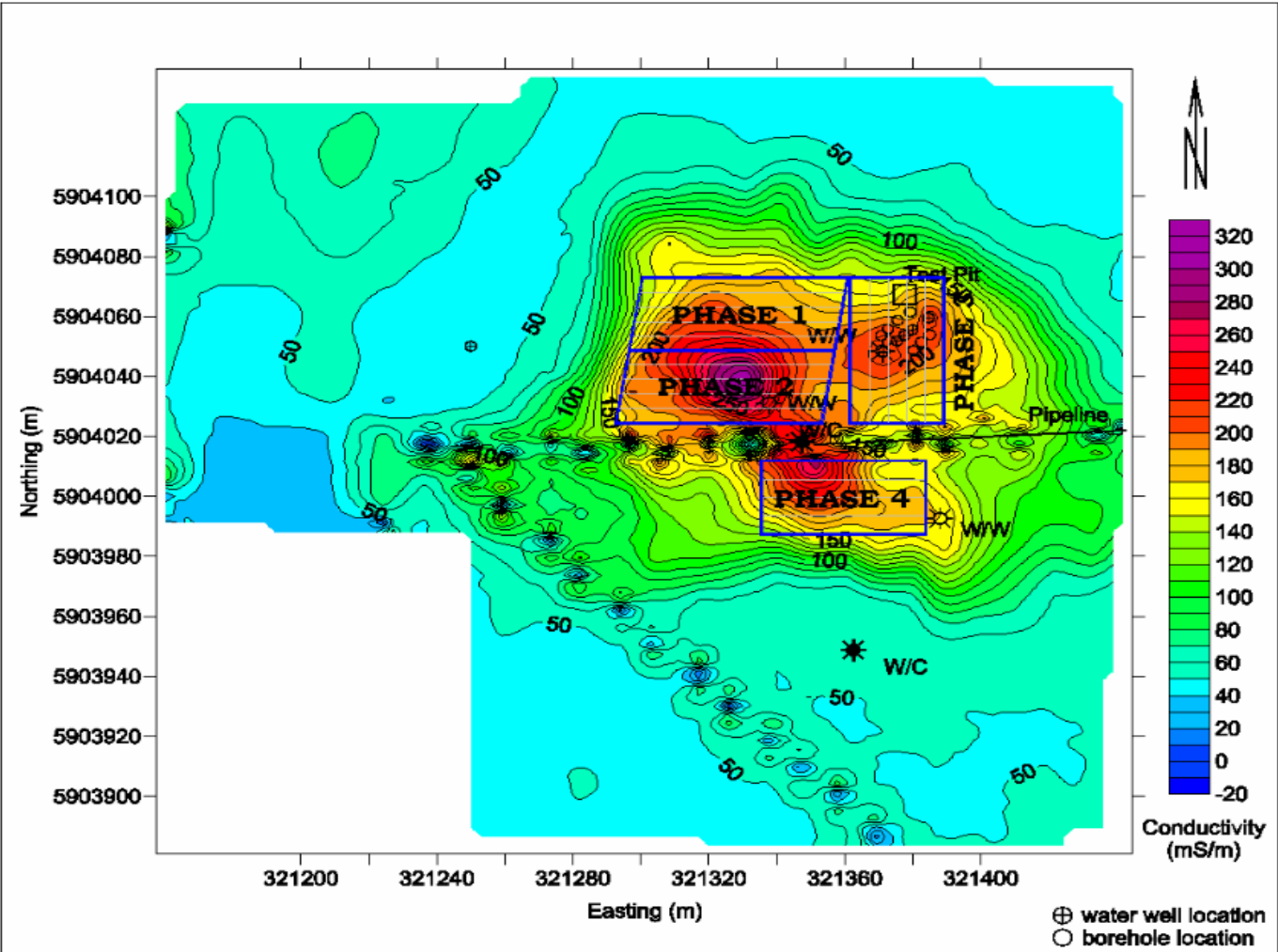
...Outcome of Objectives

- Determine if Electrokinetics remediation affects:
 - **Microbes in soils** – not affected;
 - **pH** in soils/groundwater not affected; and
 - **Metals:**
 - Insignificant metal changes in soils overall; and
 - Groundwater wells: changes in some metal concentrations.

...Outcome of Objectives

- Assess treatment option for effluent water (in process).
- Full-scale remediation (in progress).

Proposed 4 Year Approach



Questions?



- Thanks to:
 - Shell – Carol Elliot, Randall Warren
 - NRC-IRAP – Rolf Stokhuyzen
 - GE – Sean Frisky, Joel Wolensky
 - Pioneer – Dr. Janan Sallomy, Dennis Twerdoff, Bryce Peterson, Burton Cosgrove
 - (ARIS) SAIT – Vita Martez
 - Volker Stevin – Fred Desjarlais, Jack Brown, Cliff Damour
 - AGAT Labs

