The Use of In-Situ Electrokinetics to Remediate Salt-Impacted Soil and Groundwater

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Ground Effects

Environmental Services Inc.

Partners

- Komex International Ltd.
- Ground Effects Environmental
- Alberta Infrastructure/Transportation
- Industrial Research Assistance Program (IRAP)

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Presentation Outline

- Background
- Principles of Electrokinetics
- Laboratory Study
- Pilot Study
- Conclusions and Future Studies

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Salt Contamination

- Sources of Salt Contamination:
  - Oil and gas production (produced water)
  - Salt/sand processing and storage facilities at highway maintenance yards
  - Rendering plants
  - Run-off from snow-removal dumps
- What is liability?
  - Millions of dollars? Billions?

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Salt Contamination

IMPACTS:

- **Limited or no plant growth**
- **Destroy topsoil (dispersion of clay)**
- **Impact groundwater**

REMEDIATION:

- **Excavate and landfill disposal**
- **Groundwater extraction**
- **Soil amendments**
- **Risk Management**

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Background

- Past research focus on heavy metal contaminants; some chlorinated solvent and radionuclide research
- Limited research to date for salt contaminated soil and groundwater
- Electrokinetic remediation…take with a grain of salt!

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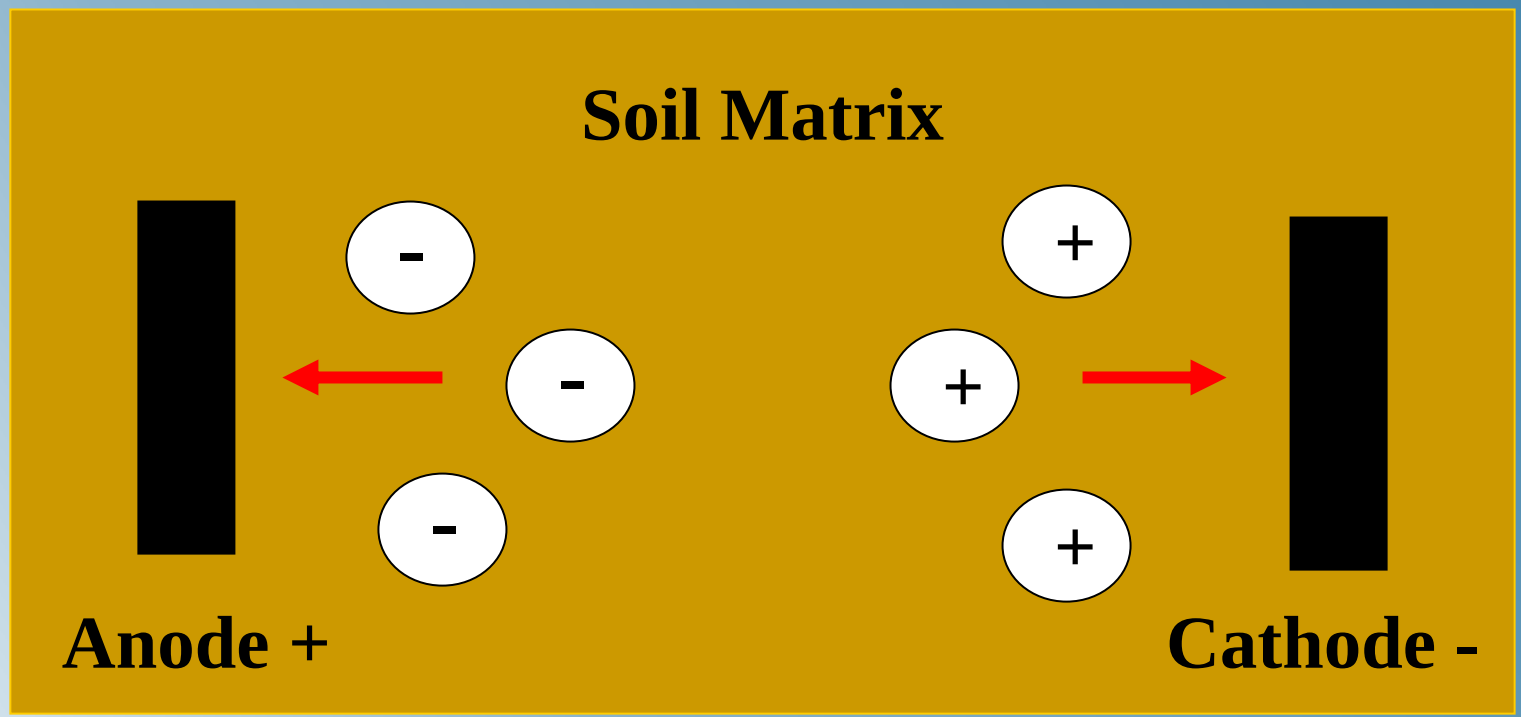
Principles of Electrokinetics

- In-situ process
- Electric field created in soil by electrodes



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Principles of Electrokinetics

- Creating an electric field causes:
  - Electromigration
  - Electroosmosis
  - Electrophoresis
  - Electrolysis of water

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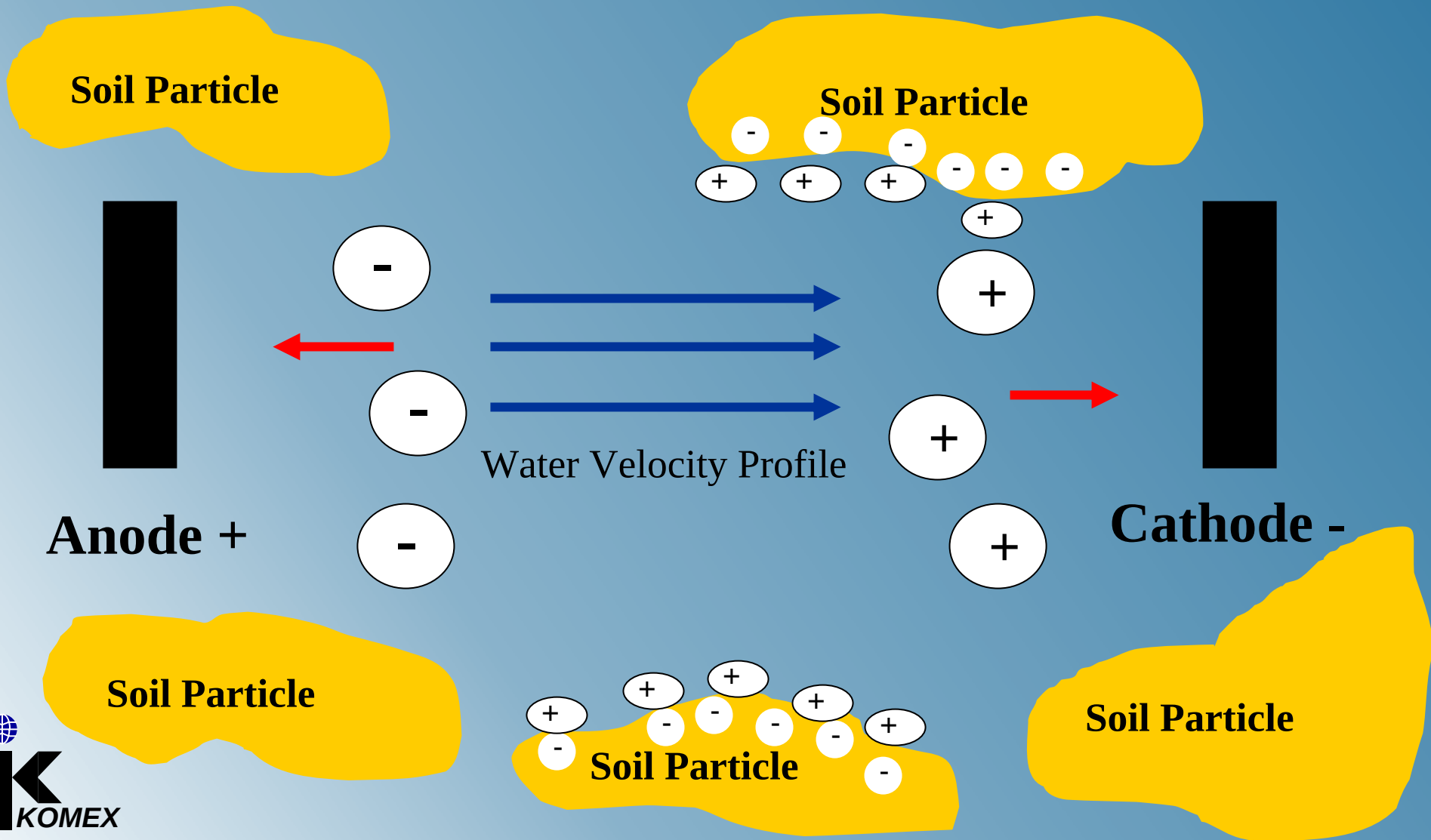
Principles of Electrokinetics



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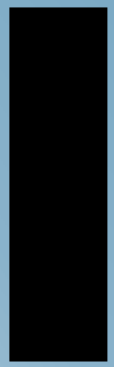
Principles of Electrokinetics

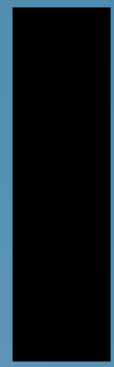


Anode +

$2H_2O \rightarrow 4e^- + O_{2(g)} + 4H^+$

Oxidation

pH ↓



Cathode -

$2H_2O + 2e^- \rightarrow H_{2(g)} + OH^-$

Reduction

pH ↑

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NaCl Chemistry

ANODE (+)

Negative ions migrate to anode (ie. increase in Cl^- concentration)

$2H_2O \rightarrow 4e^- + O_{2(g)} + 4H^+$ Oxidation, pH decrease

$Cl^- \rightarrow Cl\cdot + e^-$ Chlorine free radical

$Cl\cdot + Cl\cdot \rightarrow Cl_{2(g)}$ Chlorine gas

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NaCl Chemistry

CATHODE (-)

Positive ions migrate to cathode (ie. increase in Na^+ concentration)

$2H_2O + 2e^- \rightarrow H_{2(g)} + OH^-$ Reduction, pH increase

$Na^+ + e^- \rightarrow Na$ Sodium metal

$Na^+ + H_2O \rightarrow NaOH + H_{2(g)}$ Hydrogen gas

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Overall Concept

- Test site was a transportation yard with some assessment work completed
- Create an electrical field in a limited treatment zone (pilot study)
- Electrokinetics results in concentration of Na^+ and Cl^- near the electrodes
- Electrokinetics and electrolysis result in an acid/base front propagating from the electrodes

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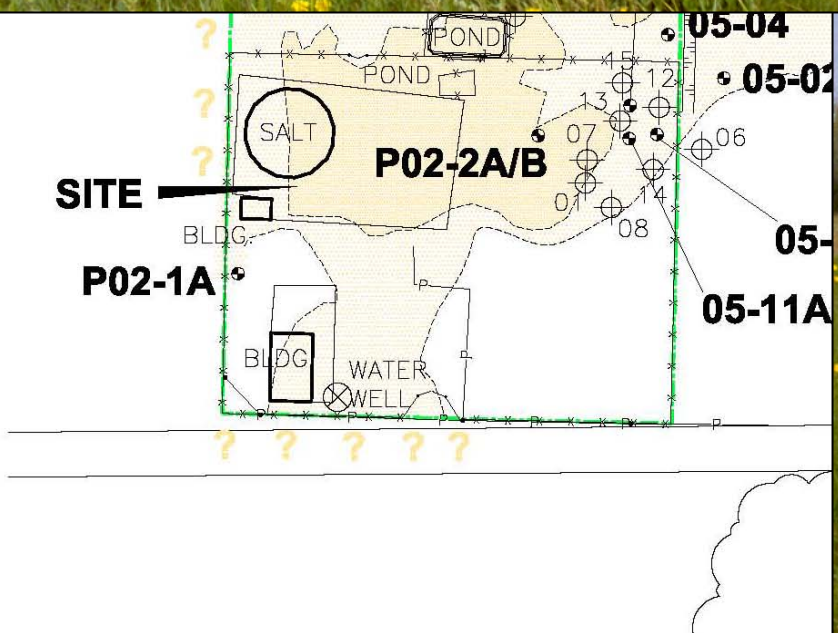

P02-5A/B

CULTIVATED FIELD

EPHEMERAL
STREAM

Laboratory Study

- Series of soil cores ~ 60 cm long
- Soil collected from geophysical Zones A and B
  - Silty Sand, trace clay
- Saturated with NaCl solution
  - pH = 7.5
  - Cl^- = 4,800 mg/L
  - Na^+ = 3,400 mg/L
  - EC = 14 dS/m
- Created different electrical fields
  - Voltage of 80, 160 and 300 volts
  - Initial current ~ 2 amperes

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Laboratory Test Samples

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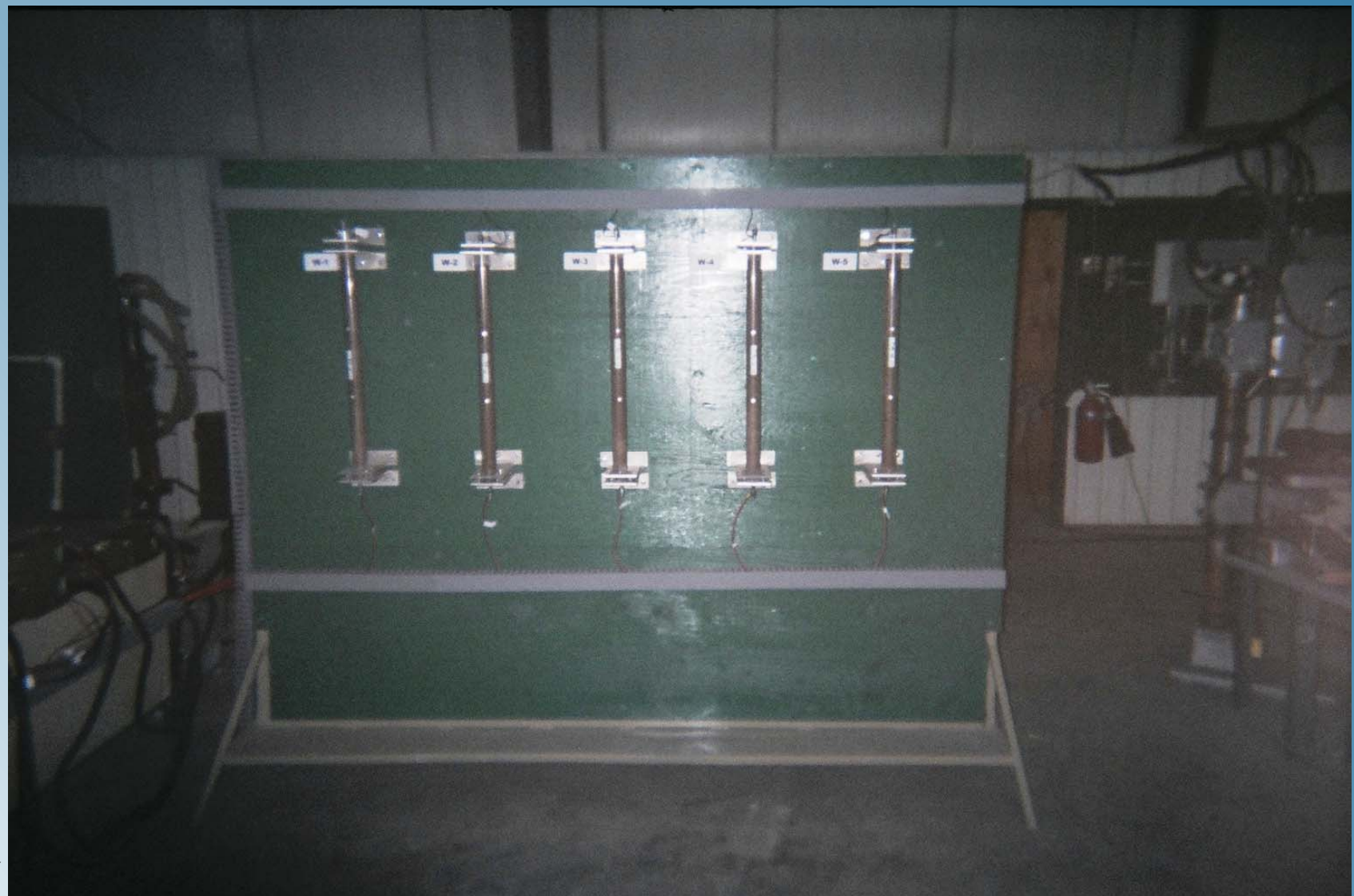
Laboratory Test Layout



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Laboratory Soil Results – 80 Volts

Time (hours)	Electrode	pH	EC (dS/m)	Cl (mg/L)	Na (mg/L)
Initial Soil Conditions		7.6	10.0	3340	2310
ZONE A					
24	Anode	6.4	9.6	3500	1430
120	Anode	5.7	14.1	5900	60
240	Anode	5.4	16.5	7380	54
24	Cathode	8.7	3.6	1080	765
120	Cathode	10.1	4.0	229	52
240	Cathode	9.9	3.3	929	283
ZONE B					
24	Anode	6.8	11.8	4250	2090
120	Anode	4.2	13.6	5560	93
240	Anode	5.5	13.4	5400	150
24	Cathode	9.7	14.5	3020	3520
120	Cathode	10.1	23.3	2990	7920
240	Cathode	10.1	7.9	208	2530

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Laboratory Soil Results – 160 Volts

Time (hours)	Electrode	pH	EC (dS/m)	Cl (mg/L)	Na (mg/L)
Initial Soil Conditions		7.6	10.0	3340	2310
ZONE A					
24	Anode	6.2	9.6	3700	113
120	Anode	5.1	16.5	7850	167
240	Anode	5.9	15.2	6280	129
24	Cathode	9.9	7.9	524	2420
120	Cathode	10.0	4.8	690	1290
240	Cathode	10.1	3.4	781	978
ZONE B					
24	Anode	5.5	11.2	4430	1760
120	Anode	4.1	10.0	3990	111
240	Anode	3.9	21.6	9500	150
24	Cathode	9.6	9.9	2250	2640
120	Cathode	10.0	10.7	1590	3140
240	Cathode	10.4	21.1	465	8070

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Laboratory Study Conclusions

- Migration of ions as expected (somewhat)
- Shift in pH as expected
- Increase in SAR at cathode, visible precipitate and/or dispersed clay
- Over time decrease in current (increase in measured electrical resistance V=IR)
- Higher voltage
  - soil heating (PVC melting)
  - measurable and visible gas formation
  - rapid increase in soil resistance

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Considerations for Pilot Study

- Operate at lower voltage (< 100 volts)
- Measure for shift in pH and concentration in ions
- Extract concentrated water
- May require “clean” water flush and/or acid treatment
- Down- gradient pumping wells for potential mobilization of metals
- Vapour extraction for $H_{2(g)}$ and $Cl_{(g)}$
- Install cathode (SAR problem) at depth

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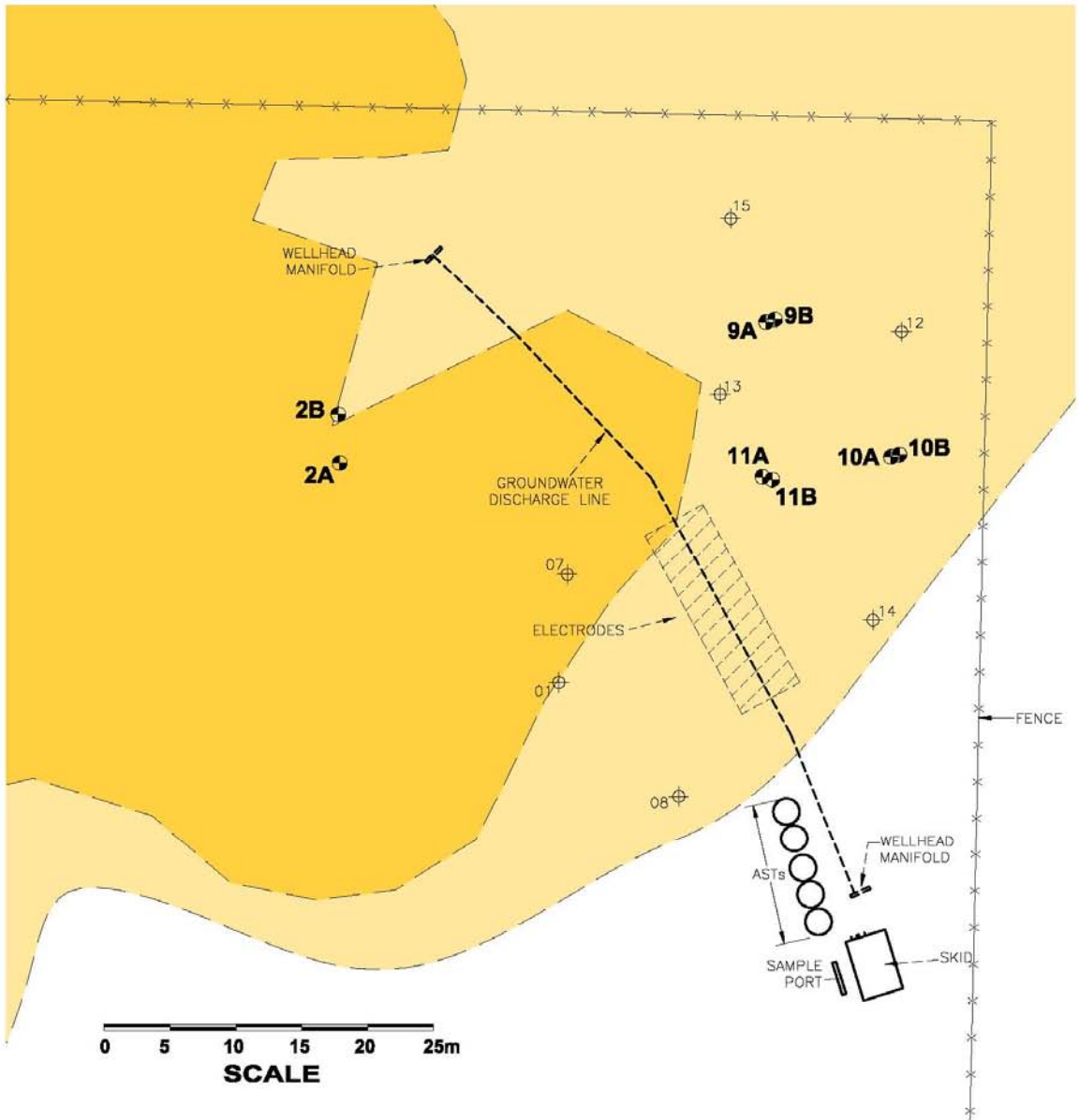
Pilot Study



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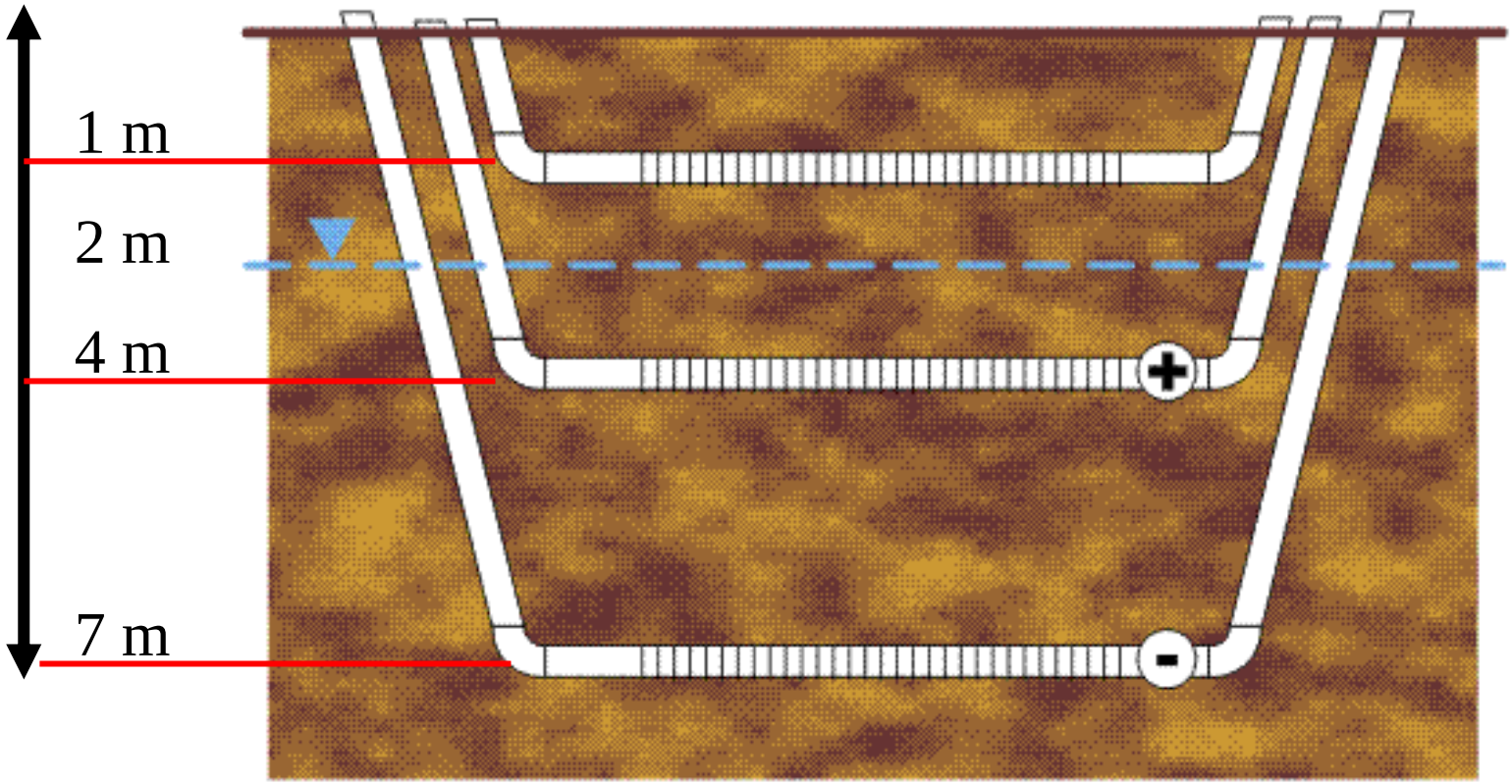
Pilot Installation



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Pilot Installation - Overview

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Pilot Study - Sampling

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Pilot Study - Sampling

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Pilot Study – Interim Results

"Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns -- the ones we don't know we don't know."

Donald Rumsfeld

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Conclusions and Future Studies

- Highly complicated chemistry, coupled with variable soil and groundwater conditions
- Electrokinetics shows promise in the remediation of salt impacted soil and groundwater
- Must manage precipitate formation and dispersion of clay (decrease current and soil permeability)
- System must have mitigative measures to control potential dissolved metals migration

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Conclusions and Future Studies

- System must have health and safety measures for $Cl_{2(g)}$, $H_{2(g)}$, pH and voltage
- Studies to determine optimal water flushing rate
- Post-pilot soil sampling
- Geochemical modelling

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Pilot Study - Electrical

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Pilot Study - Equipment

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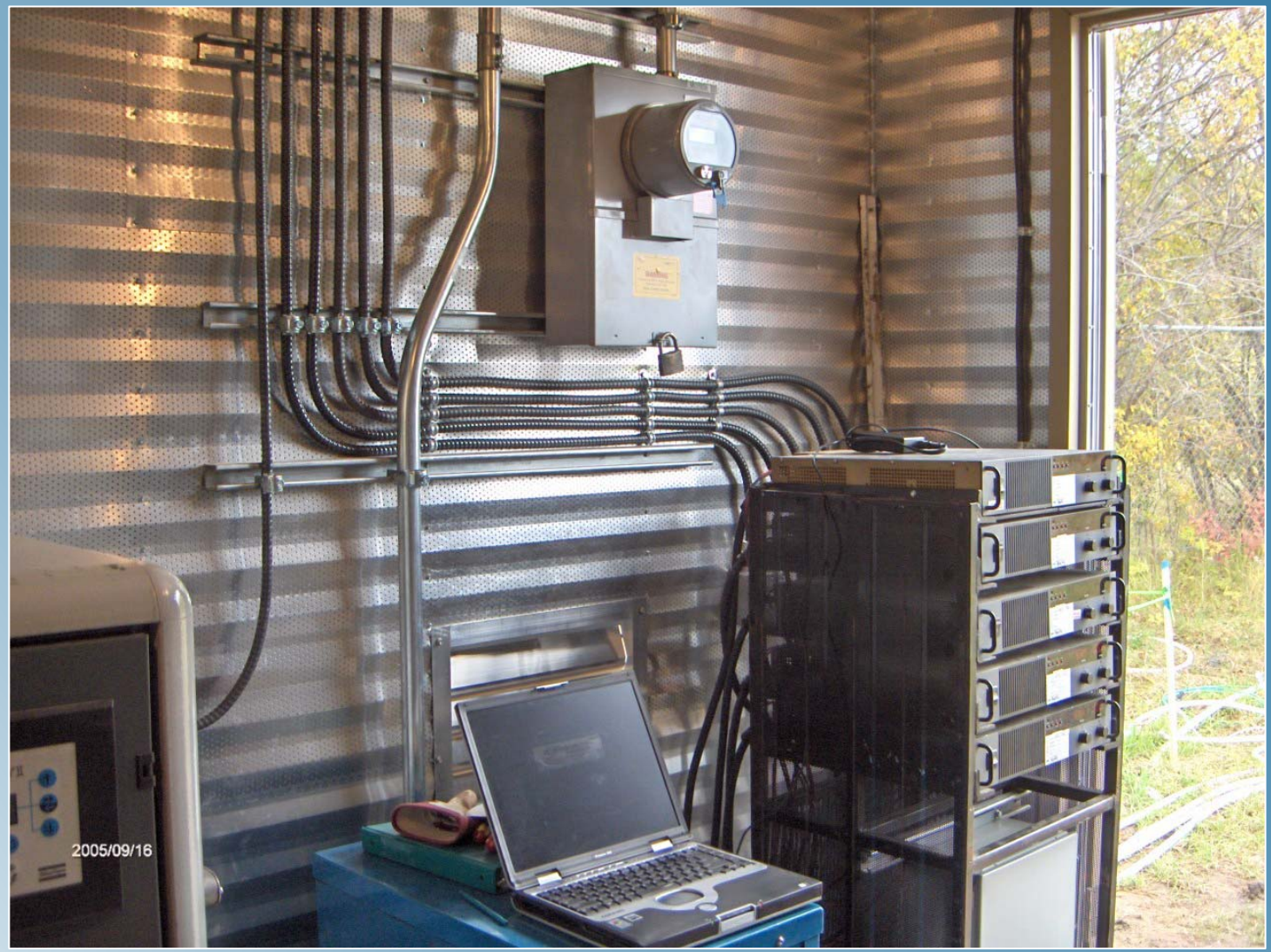
Pilot Study - Power



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