Effluent Treatment: Pre-treatment Train Integrated with Electrodialysis for Use in Electrokinetic Remediation

Back to previous page

Bonnie Swift & Tanya Michailuck - Pioneer Group; and
Vita Martez - Southern Alberta Institute of Technology.

Typical Remediation Practices

- As your are aware salt impacted soils and groundwater, generated from produced water spills, persistently plague the oil and gas industry.

- Unsustainable:
  - Digging and dumping;
  - Disposal with deep well injection / retention ponds.

- Sustainable:
  - Our goal was to remediate soil and groundwater in a way that would allow us to reuse the effluent waters produced.

Introduction: Project Description

- Our project involved electrokinetic bench scale studies and pilot studies followed by effluent treatment.
- **Project Purpose**:
  - To demonstrate the viability of electrokinetics for salt impacted sites.
  - Examine potential impacts to the condition of soils and groundwater as a result of electrokinetics.
  - Determine appropriate water treatment train for effluent water.

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Project Consortium

Consortium Members	Role/Responsibility
Shell Energy Canada Ltd.	Project Sponsor/Provided Site
National Research Council	Federal Funding/Industry Technology
Ground Effects Environmental Services	Electrokinetics Technology/Field Demonstration
Volker Stevin Contracting Ltd.	Electrodialysis/Field Demonstration
Southern Alberta Institute of Technology	Electrodialysis – Applied Research and Innovation Services (ARIS)
Pioneer Professional Group	Project Management and Environmental Engineering

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Presentation Outline

- Part 1: Overall description of pilot project – environmental assessments and electrokinetic remediation
- Part 2: Effluent water treatment update

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Part 1: Field Study

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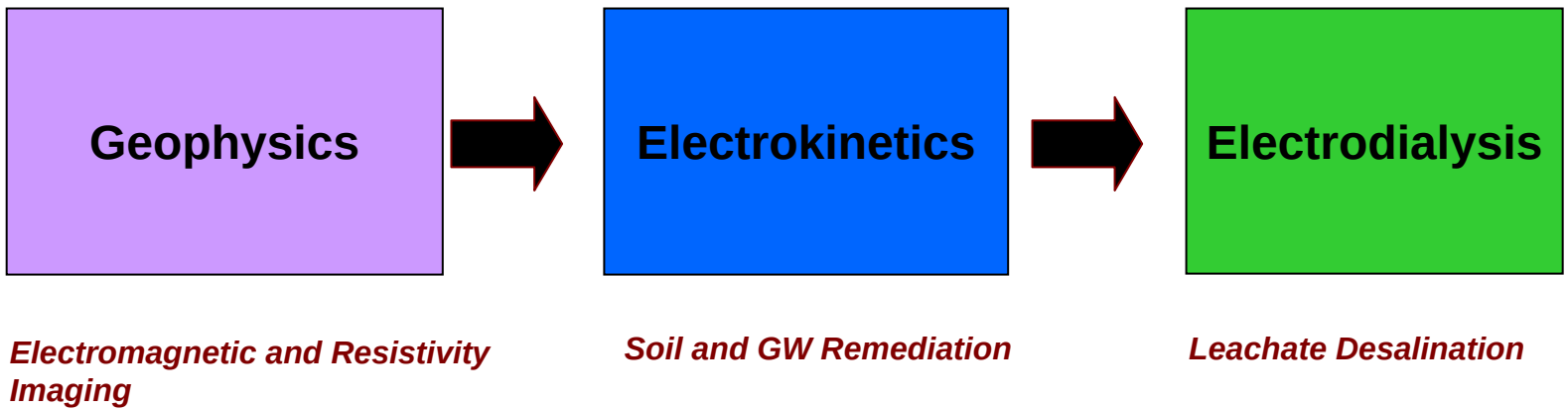
Site Description

- Site description:
  - Former oil battery site with tank farm and spill area which have salinity and metal impacted soils and groundwater.
  - Approximately 20,000 m^3 of fine-grained soil impacted from surface to 5 m below grade.

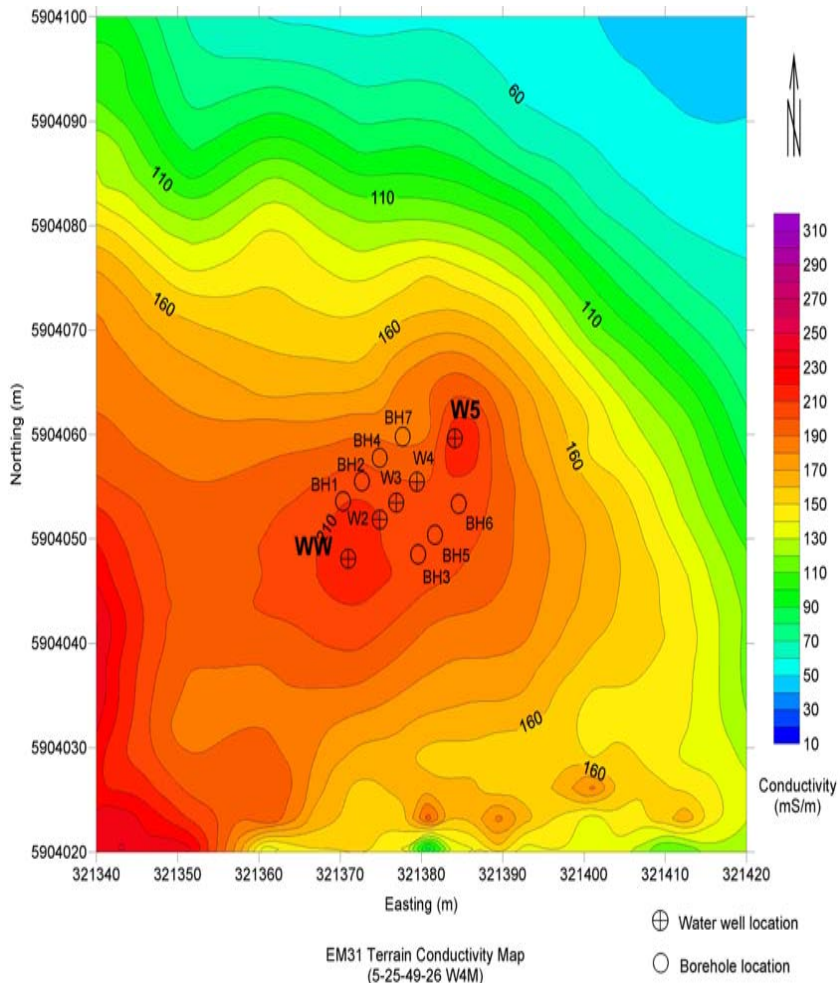
Technology Introduction

- 1 - Electromagnetics,
- 2 - Electrical resistivity tomography,
- 3 - Electrokinetics (EK3), and
- 4 - Electrodialysis (part 2 of presentation).



1 - Electromagnetics (EM)

- Electromagnetic (EM31) – provides 2-D horizontal image of bulk electrical conductivity



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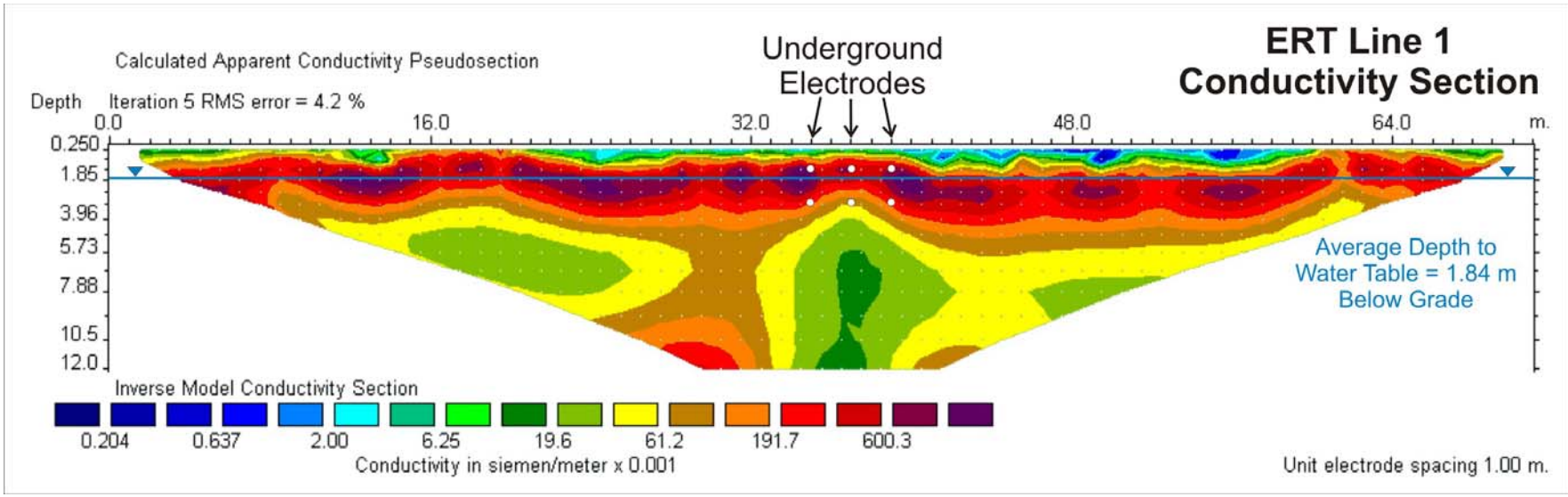
2 - Electrical Resistivity Tomography (ERT)

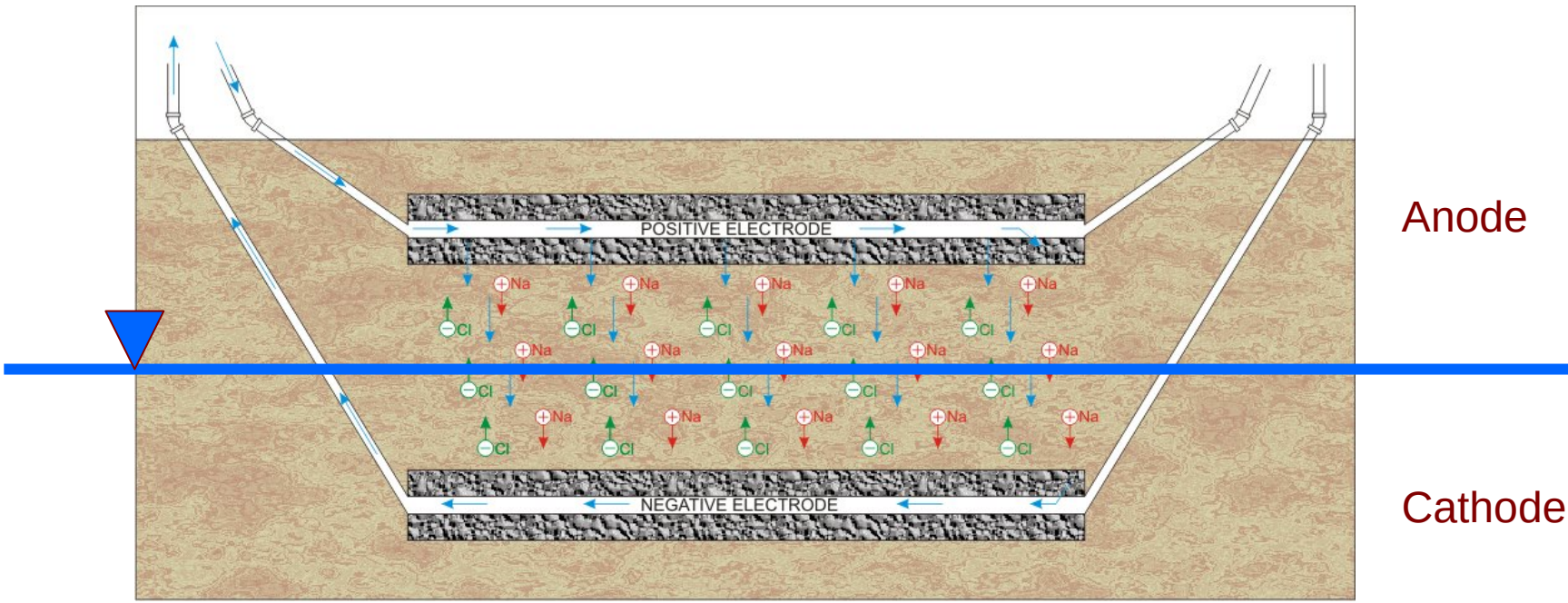
- ERT – provides 2-D vertical image of subsurface materials.



3 - The Electrokinetics Process

(treat soil and groundwater)

- Ground Effects applying the use of electrokinetics EK3 to remediate salt impacted sites



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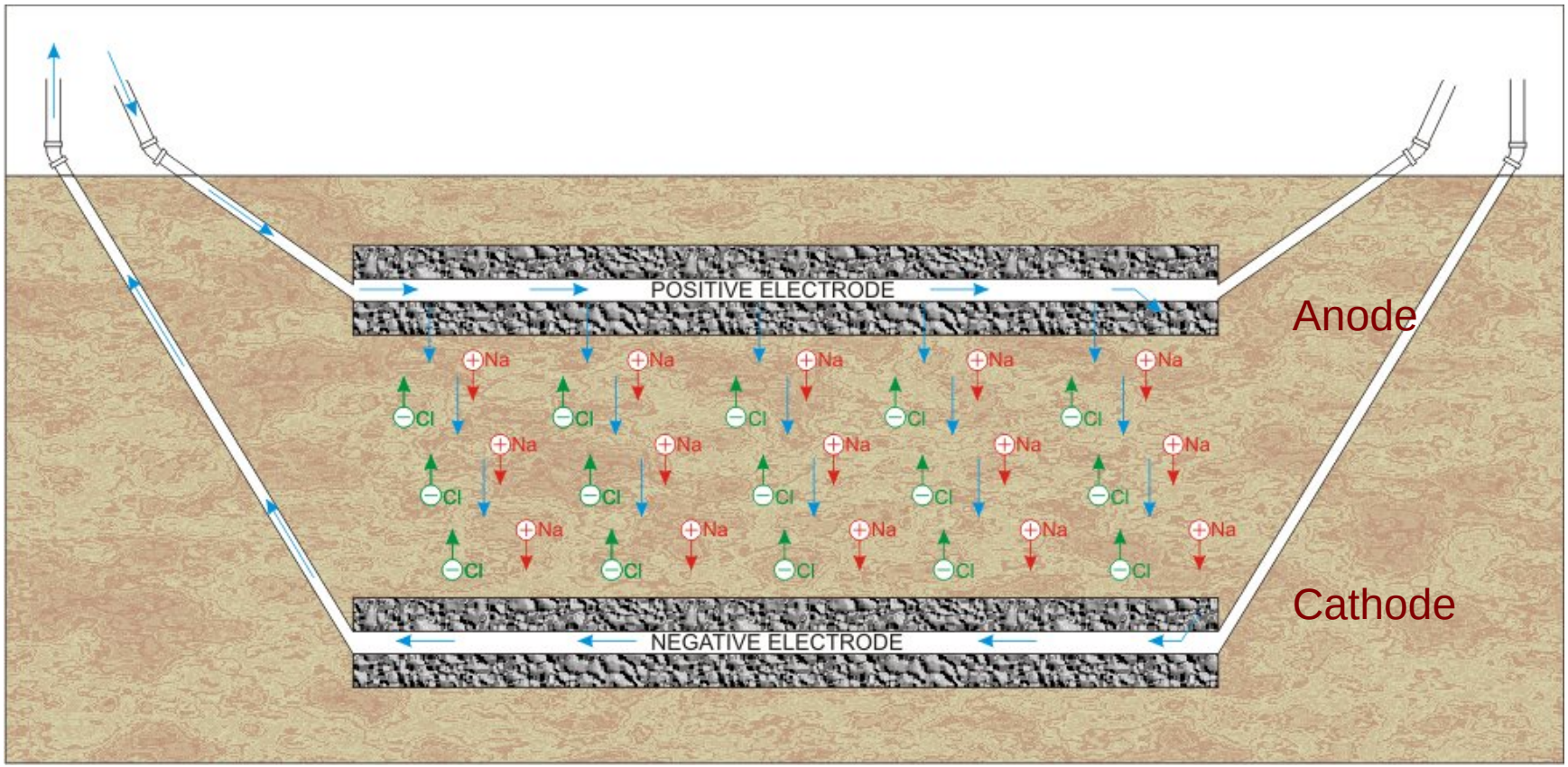
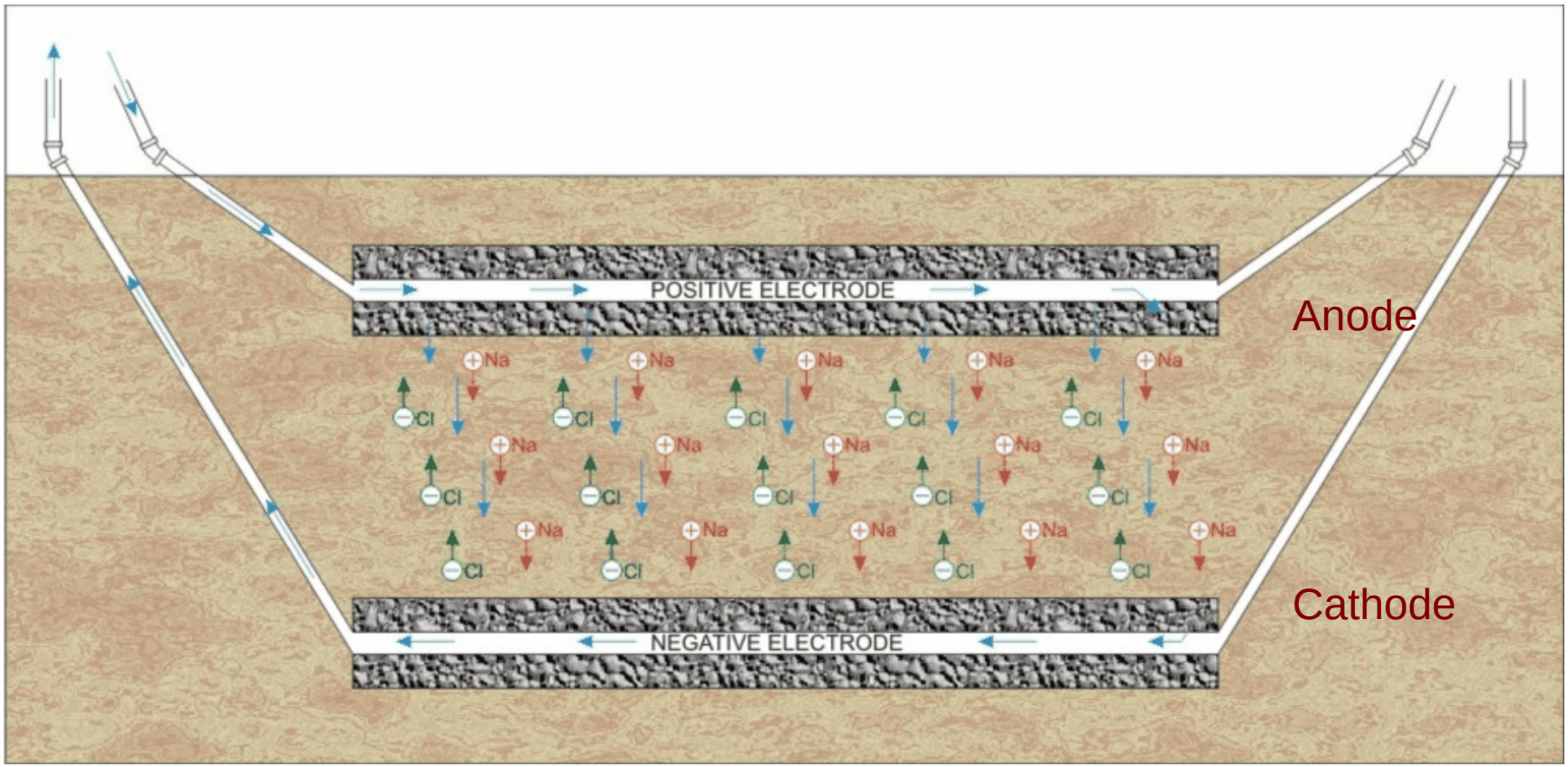
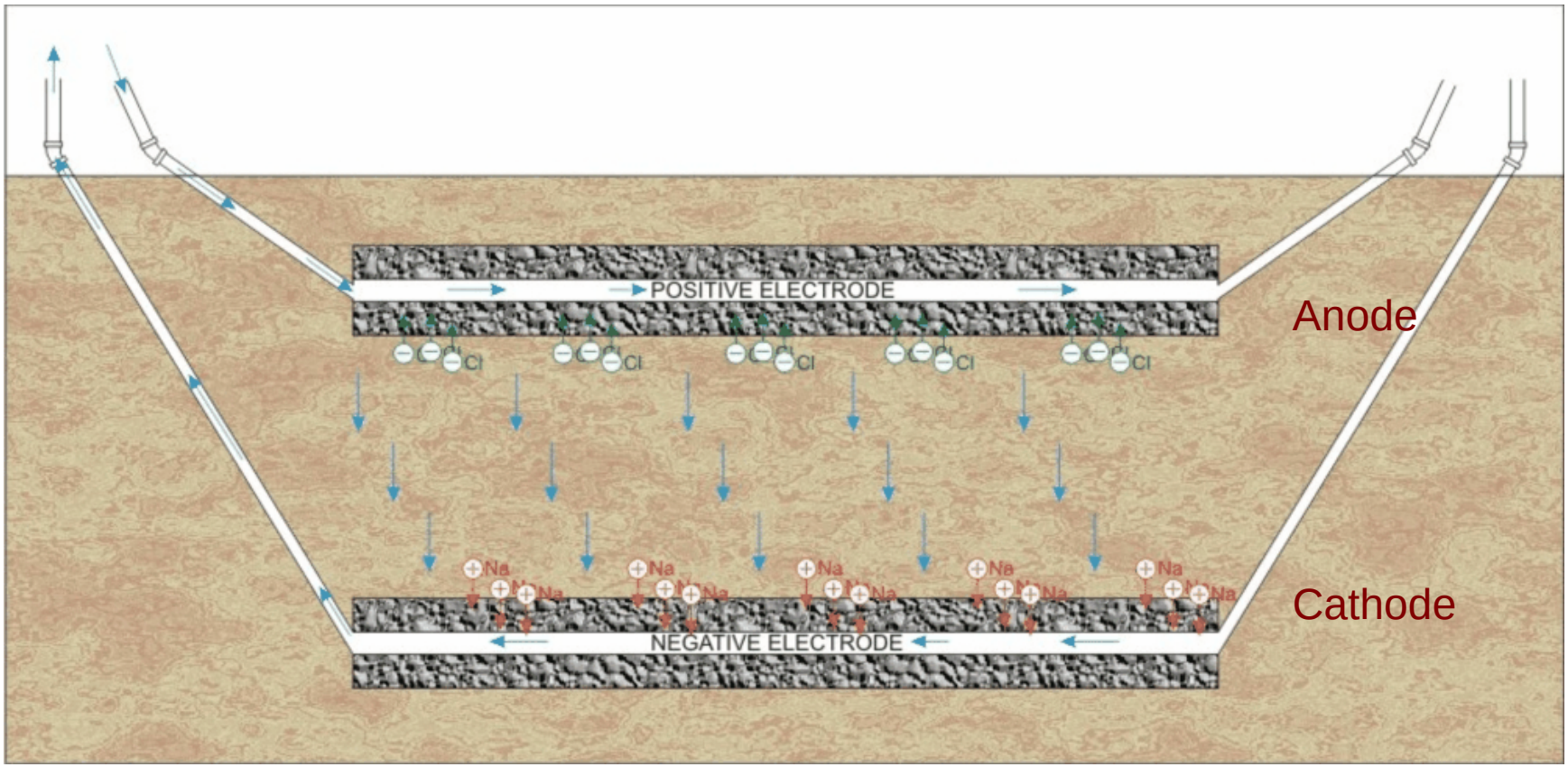


Electrical field is imposed on a volume of contaminated soils



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

Project Stages 2006-2008

1. Baseline soil and groundwater testing/ EM scans
2. Bench scale study (EK3)
3. Pilot (EK3) remedial study - installation and operation
4. Groundwater and EK3 effluent sampling
5. Post soil and groundwater testing/EM scans
6. Water Treatment (Part 2 of presentation)

Baseline Assessments

- Required to establish existing conditions of soils and groundwater

- Assessment activities:
  - Conduct EM/ERT scans
  - Test soils and groundwater for salinity, pH, and metal parameters
  - Monitor groundwater levels and conduct hydraulic conductivity testing

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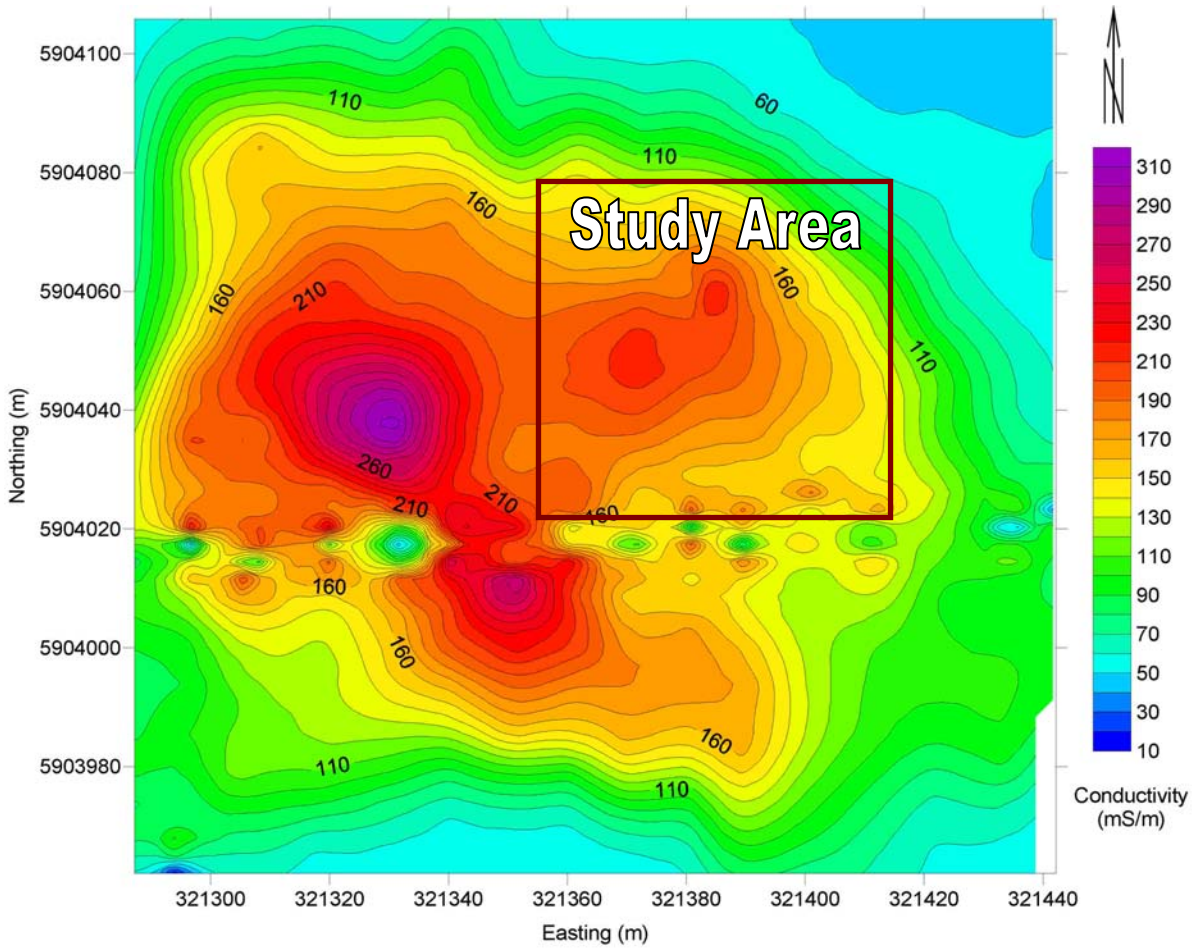
Baseline EM Survey (June 2006)



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EK3 Bench Scale Studies

- 2 month bench scale trial conducted at Ground Effects.
- 2 m^3 of representative soil was excavated from pilot study area.
- During the study amps and electrode distances were optimized.
- Salt ions movement was monitored.
- Effluent water analyzed.

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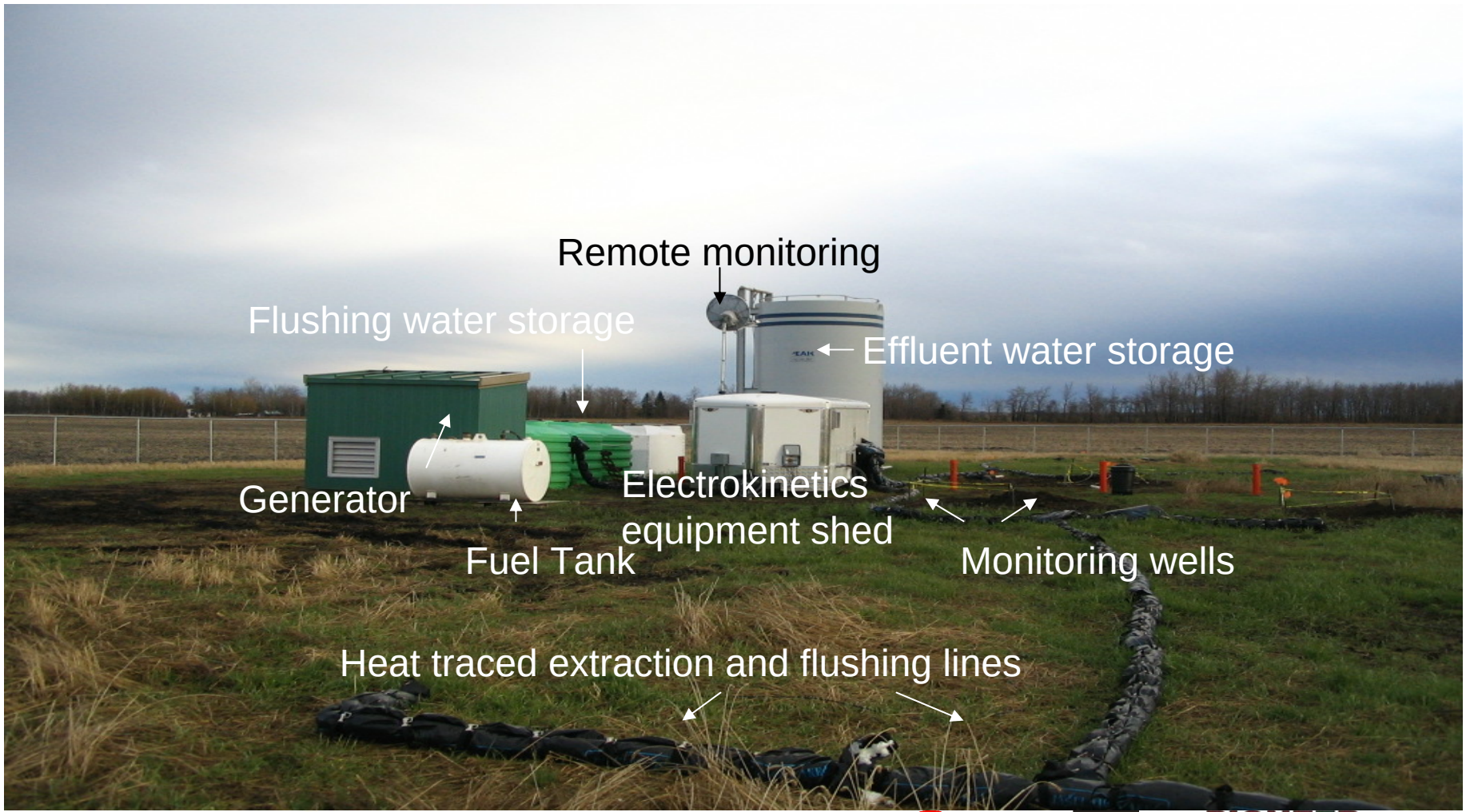
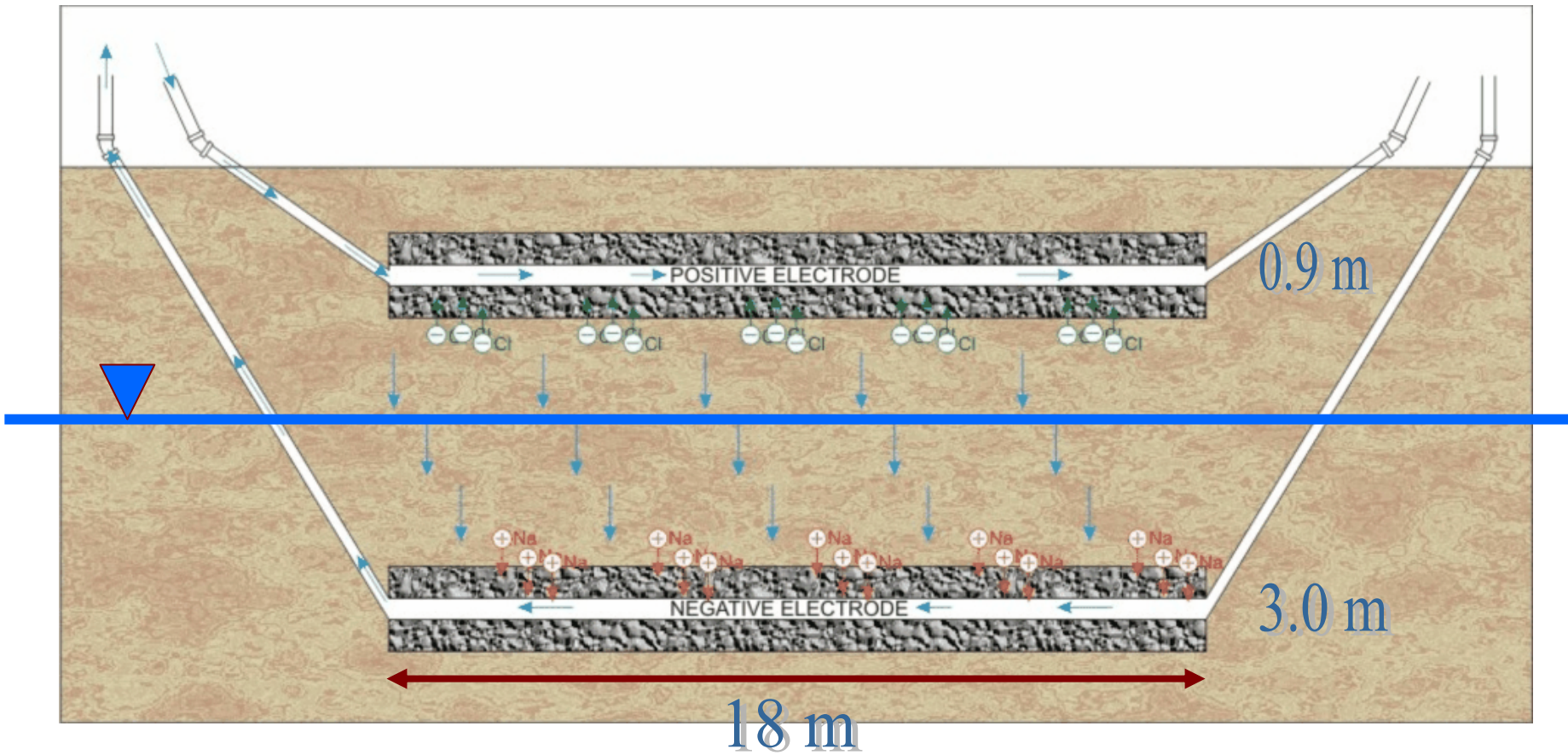
EK3 Pilot Remedial Study Infrastructure



EK3 Remedial System Infrastructure (Cross-section)



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Pilot Involved : Soil, Groundwater and EK3 Effluent Sampling

- Soil sampling was conducted at regular intervals and at the electrode depths.

- Groundwater monitoring and sampling events occurred during:
  - Baseline testing, remediation and post remediation testing. This was done to establish trends in relation to electrokinetics operation.
- Testing of the effluent water from electrodes was conducted to establishing effective removal of salinity.
- Remote monitoring was also conducted to monitor operations.

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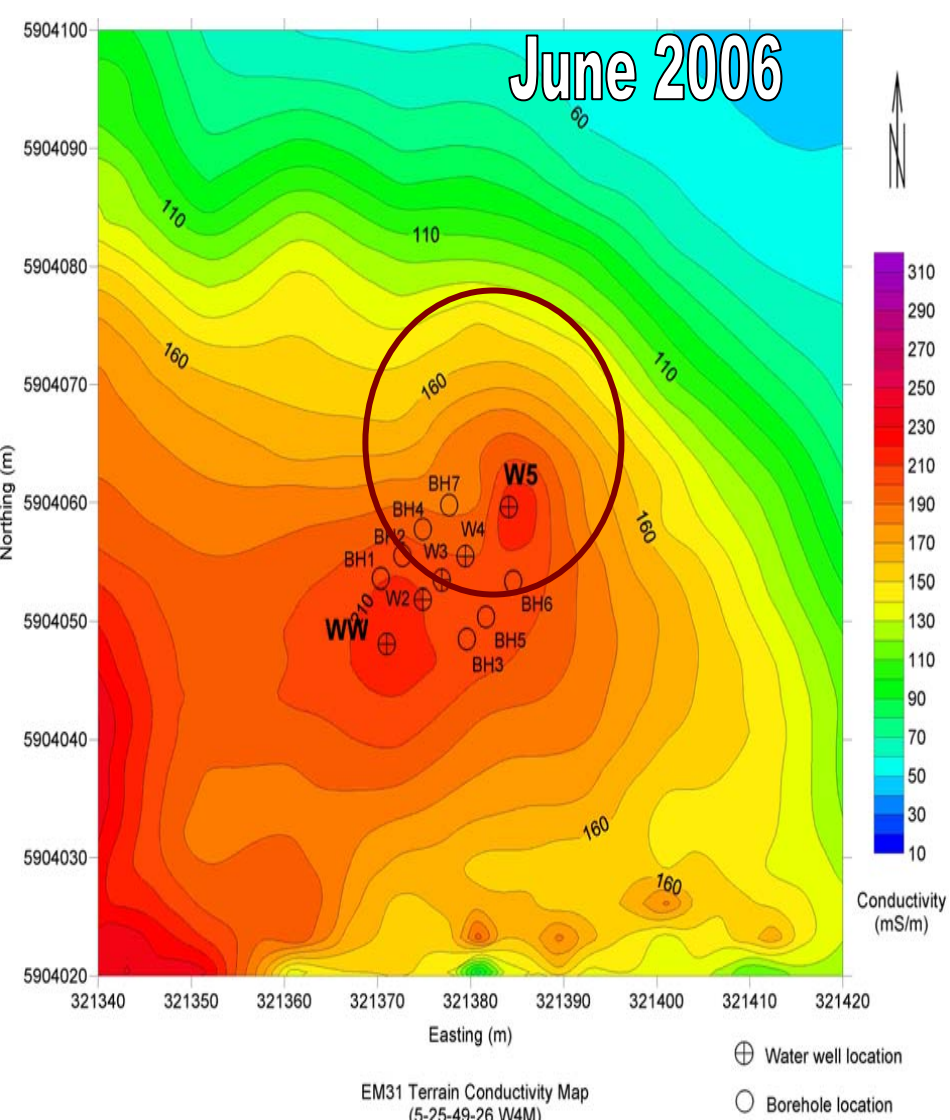
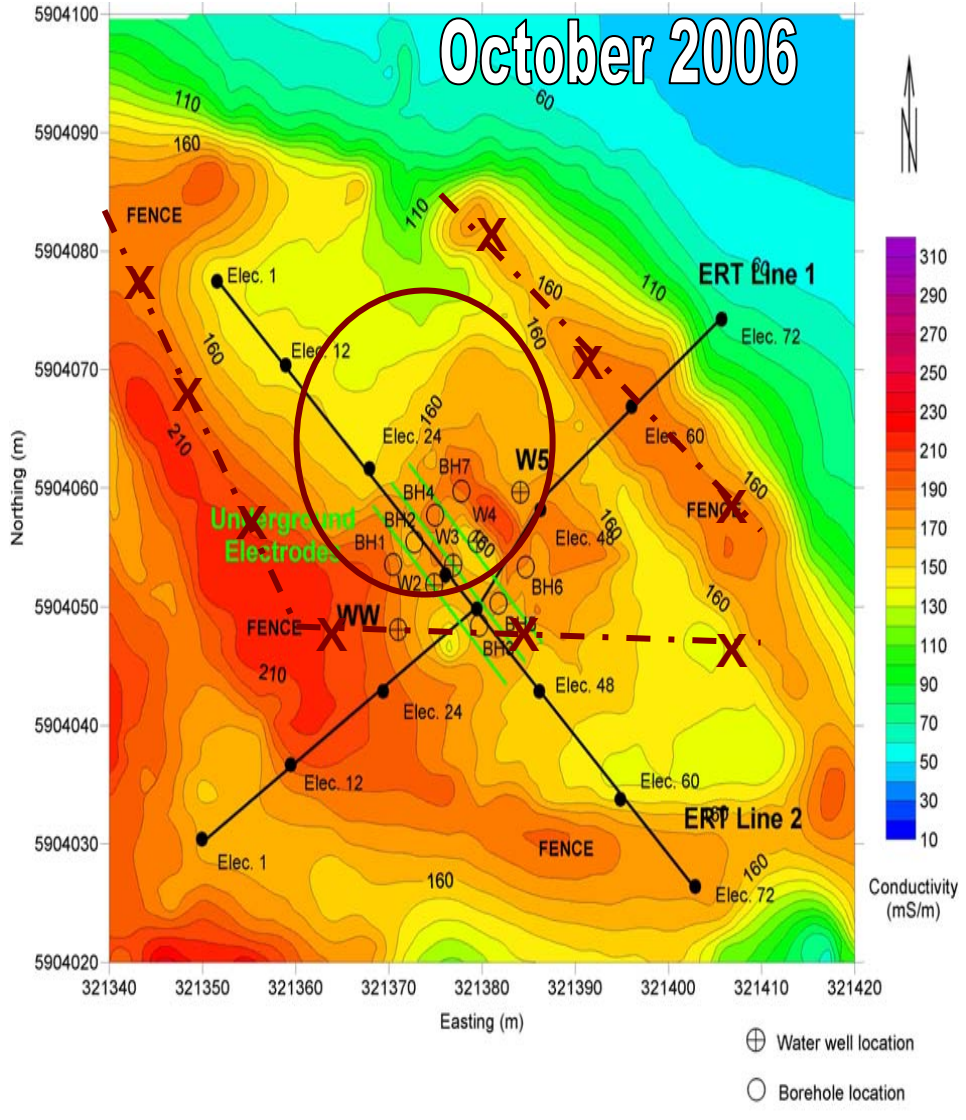
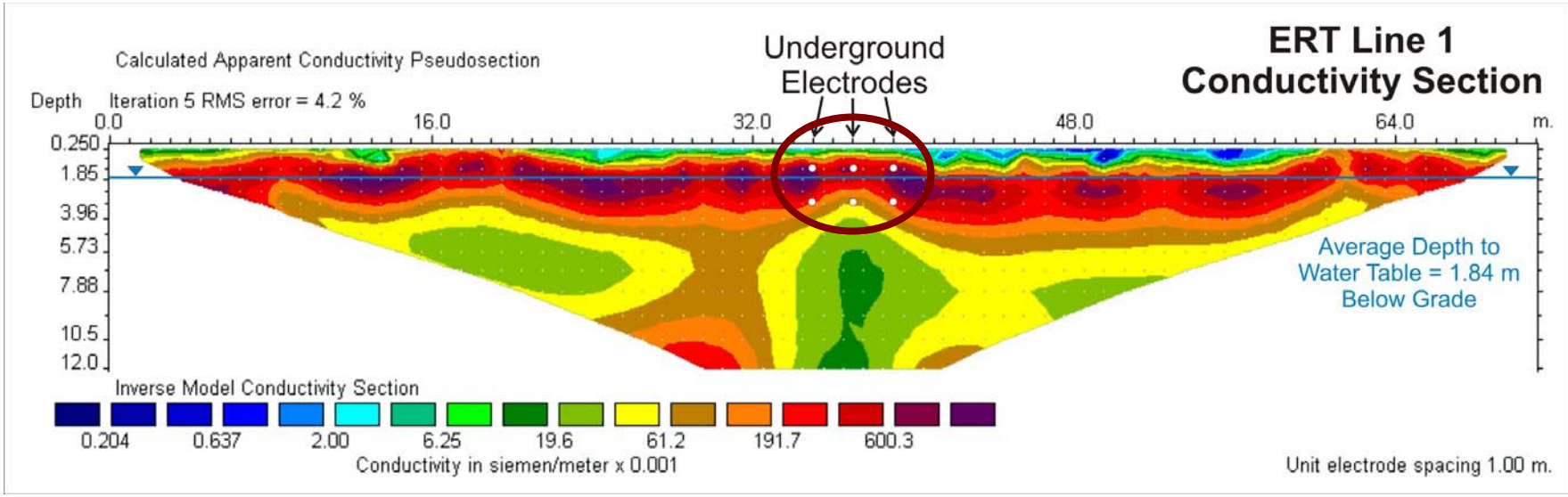
EK3 Pilot EM Surveys: Baseline and Post





EK3: Post Confirmatory ERT Survey (2007)



- Lower conductivity in vicinity of electrodes

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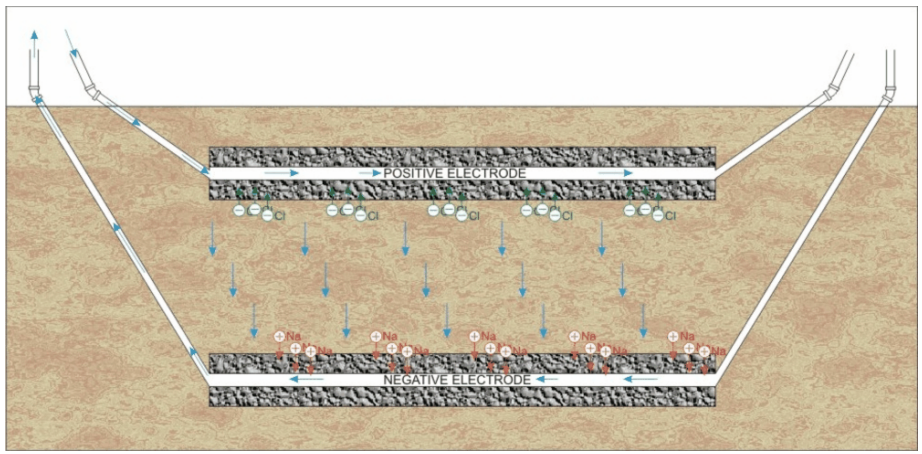
EK3 Pilot: Soil Results

- Salinity ions migrated due to electric field and flushing water.
- We anticipate based on previous applications of EK3 and this pilot that ions will be reduced to meet guidelines during the full scale operation.



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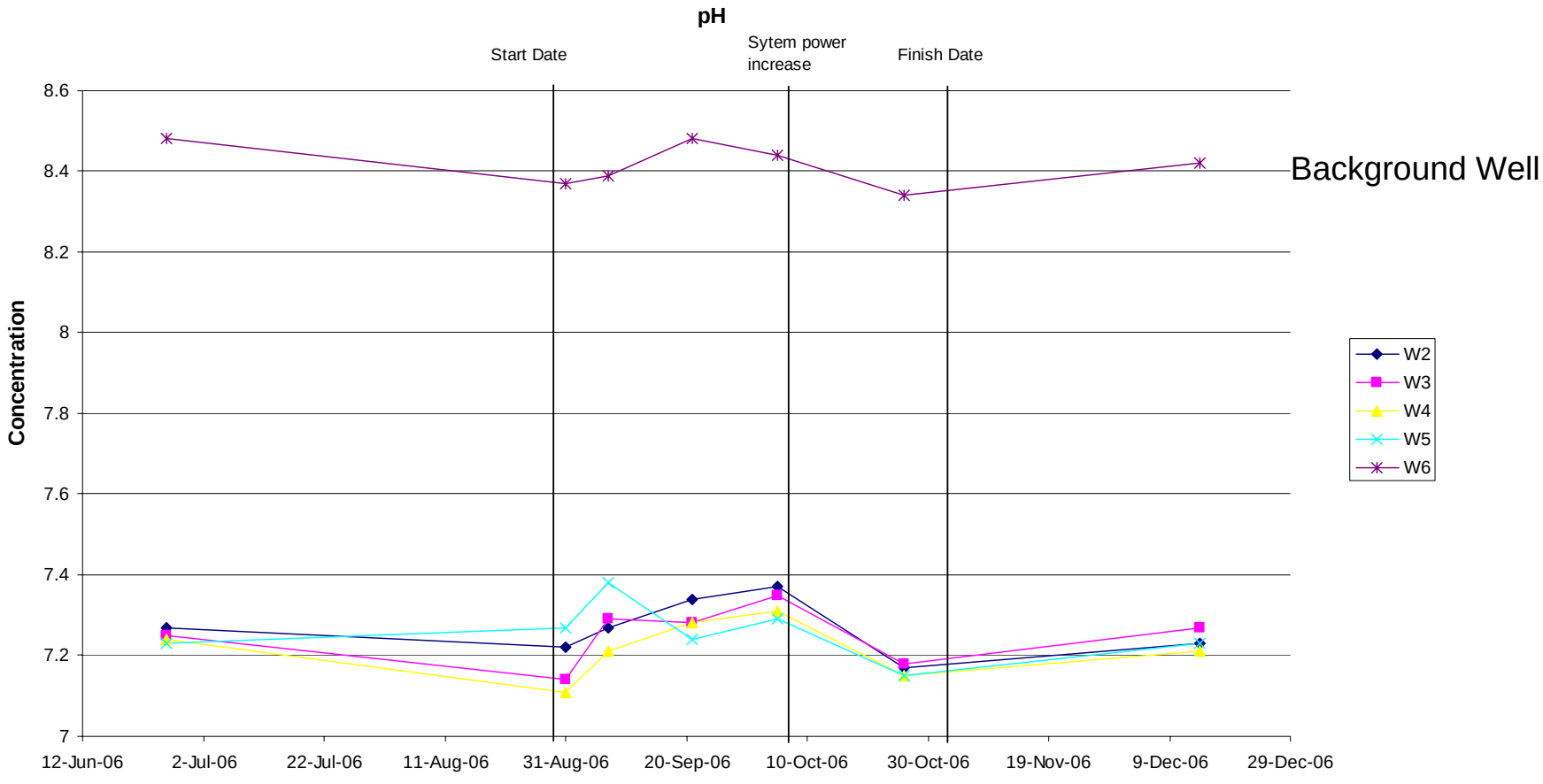
EK3 Pilot Results: pH (Groundwater)

Groundwater trends in pilot area wells are consistent with background trends



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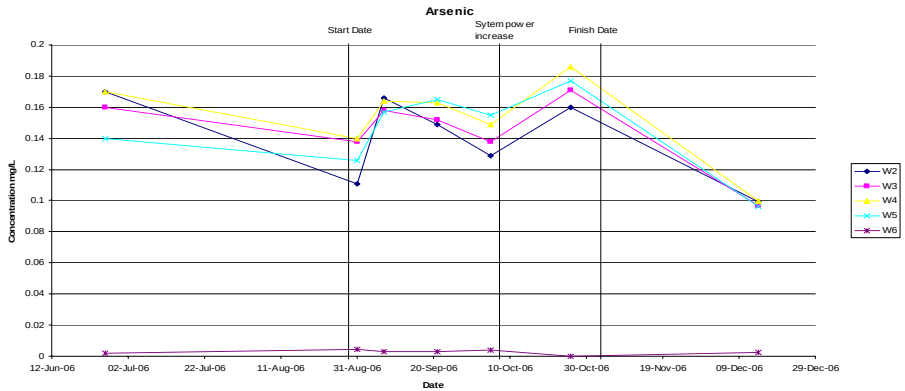
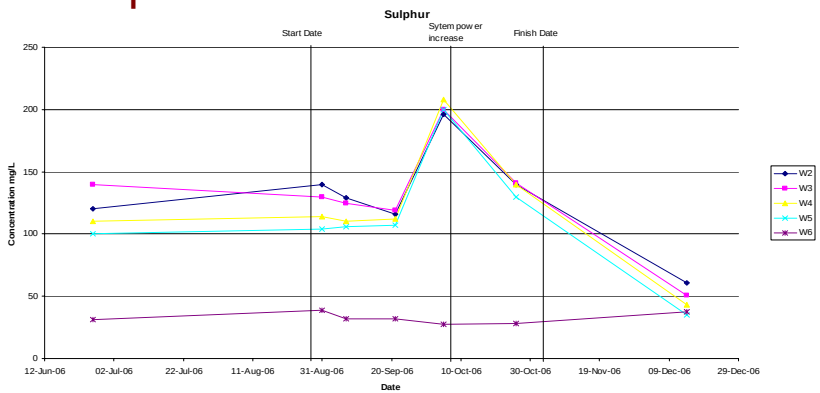
EK3 Pilot Results: Metals (Groundwater)

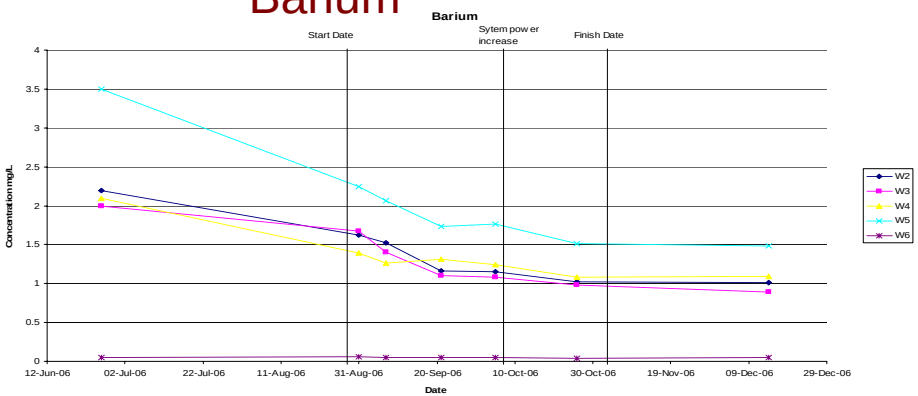
Arsenic



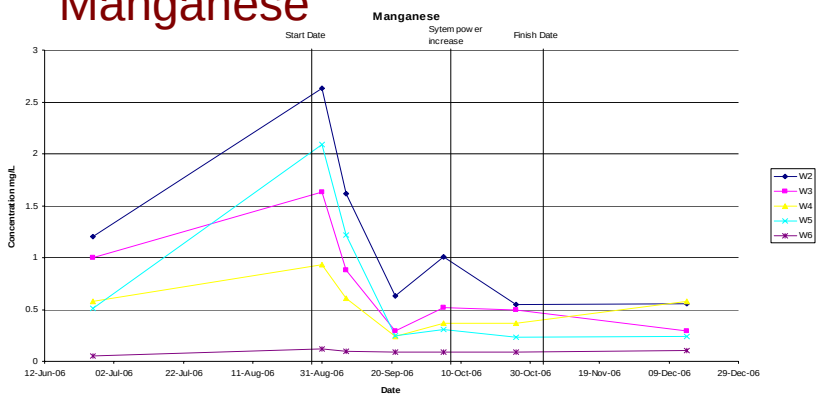
Sulphur



Barium



Manganese



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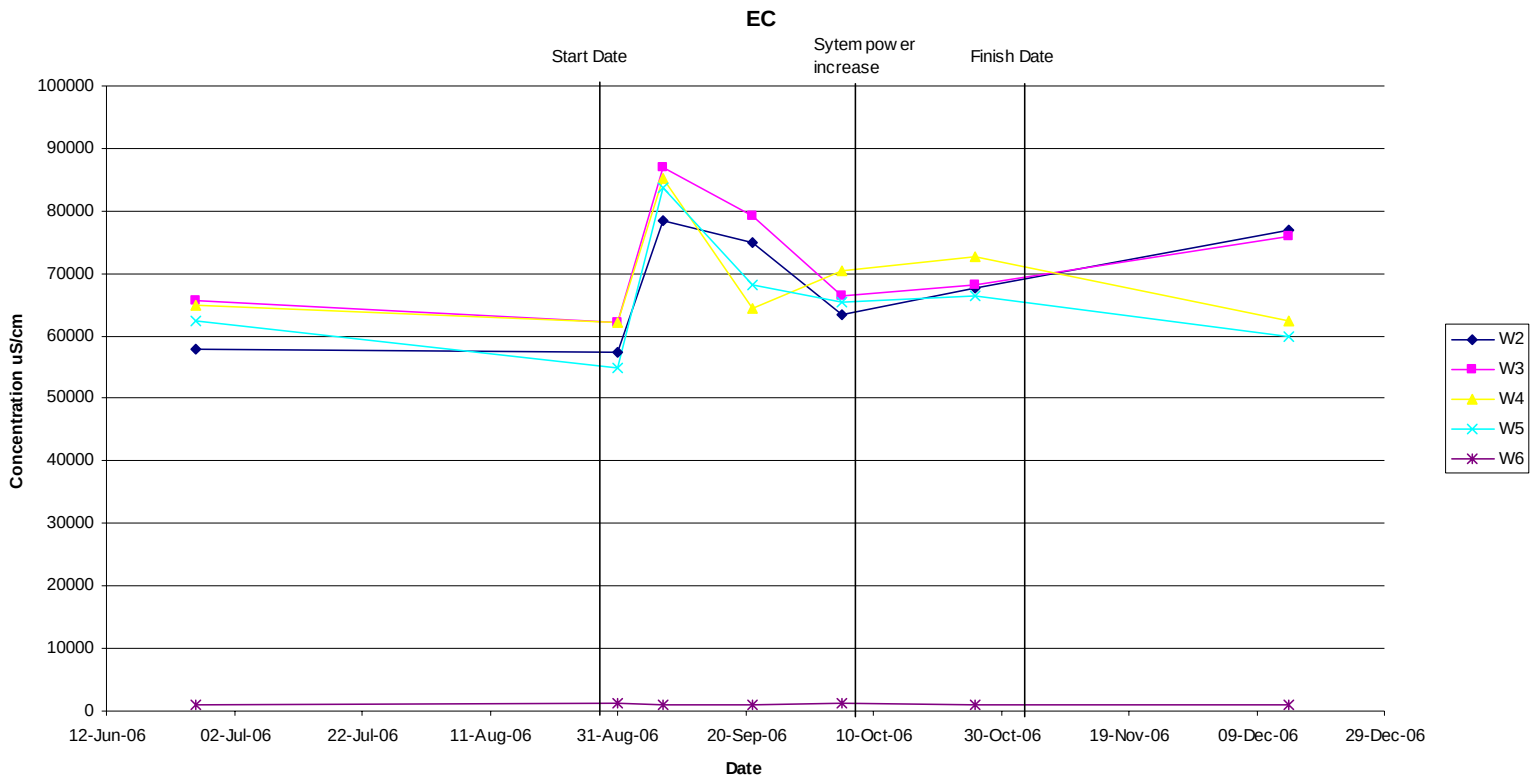
EK3 Pilot: Electrical Conductivity (EC) (Groundwater)



EK3 Bench Scale Results

	pH	EC	SAR	Ca	Na	K	Cl
		dS/m		mg/L	mg/L	mg/L	mg/L
Positive electrode	2	12.6	1.2	193	75	8	3370
Negative electrode	12.6	14.2	160	10	2050	29	25.9
Tap water	7.4			92	54	7	<1

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EK3 Pilot: Effluent Results (< 30 days)

	pH	EC	SAR	Ca	Na	K	Cl
		dS/m		mg/L	mg/L	mg/L	mg/L
Positive electrode	2.8	1840	nd	180	35	1.1	504
Negative electrode	10.6	7530	nd	720	1340	25.6	3590

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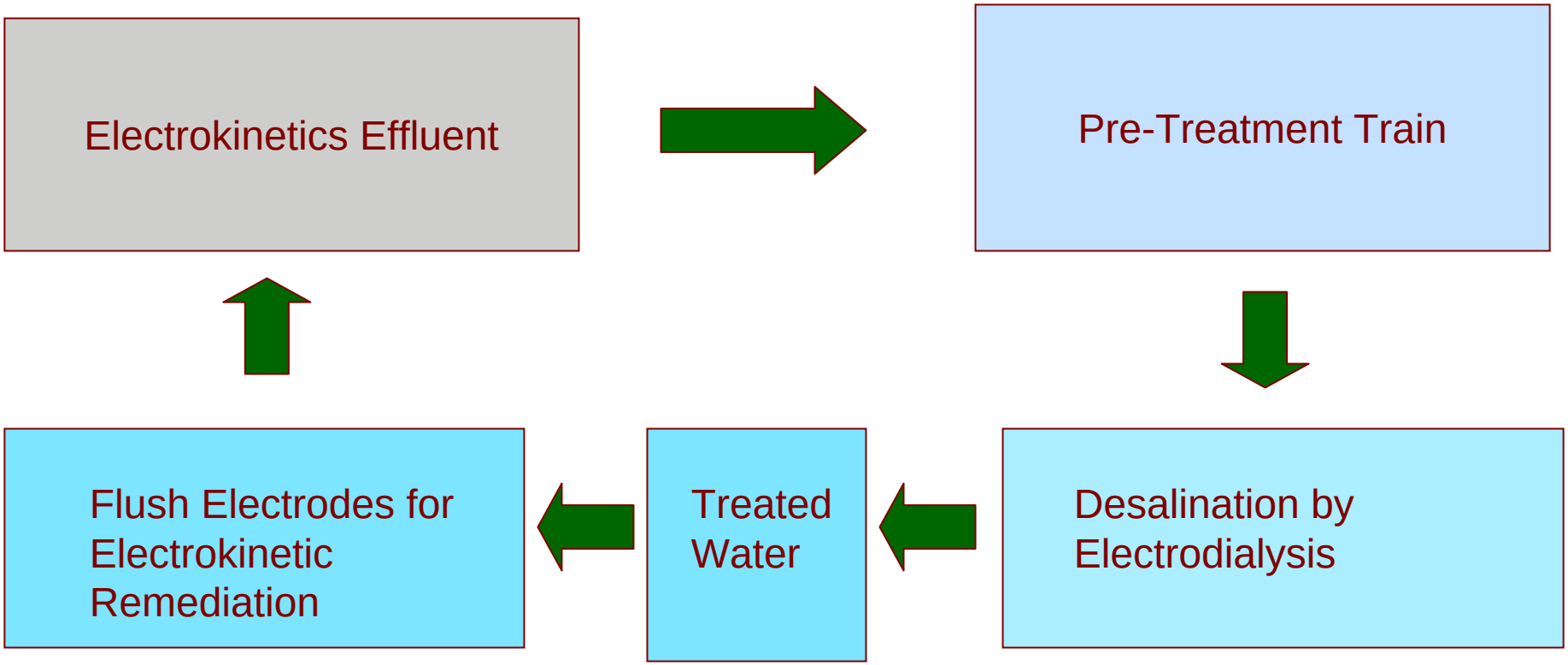
PART 2: Effluent Water Pre-treatment Update



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EK3 Effluent Water Treatment/Recycle

Project objectives:

1. **Determine if treating effluent was a problem or opportunity?**
2. **Determine requirements for the electrokinetic effluent pre-treatment train and conduct pre-treatment.**
3. **Conduct desalination using electrodialysis.**
4. **Use treated water to flush electrodes (recycle).**

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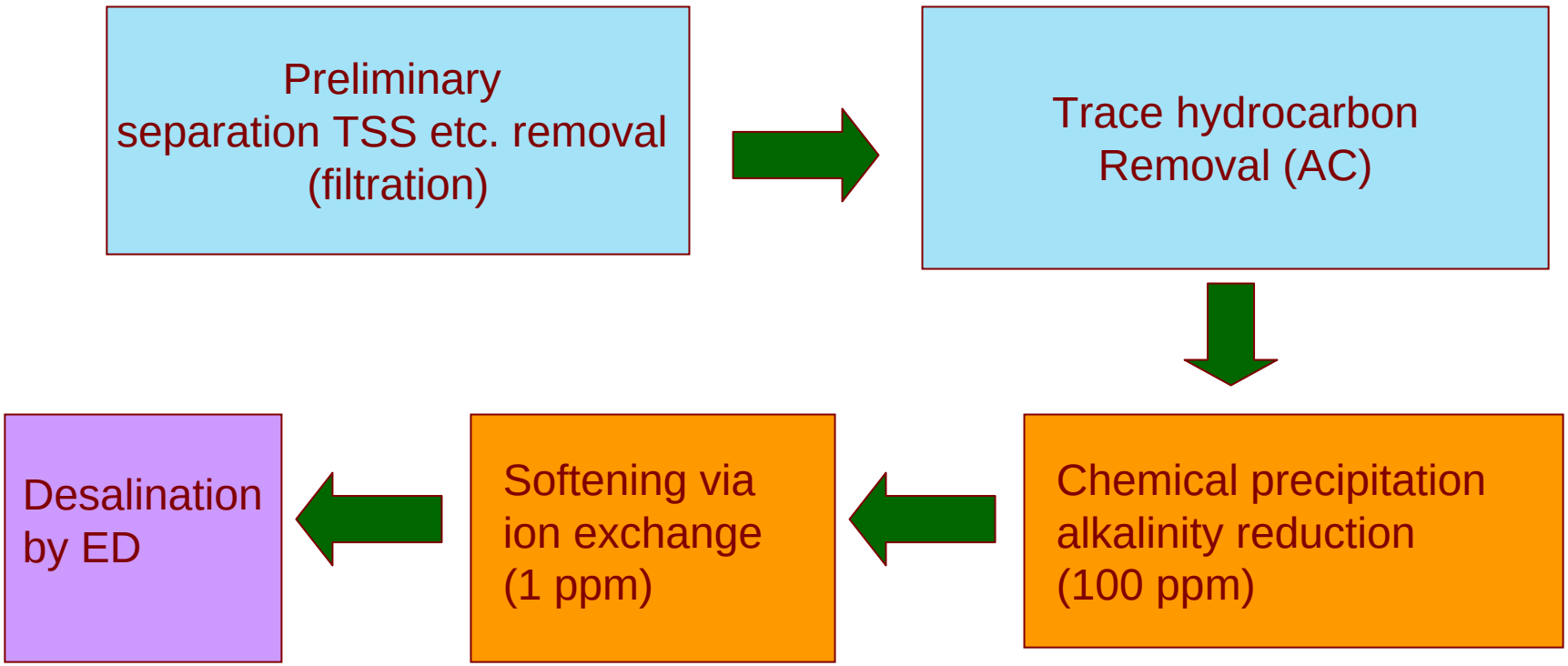
Determine if Effluent Treatment – Problem or Opportunity?

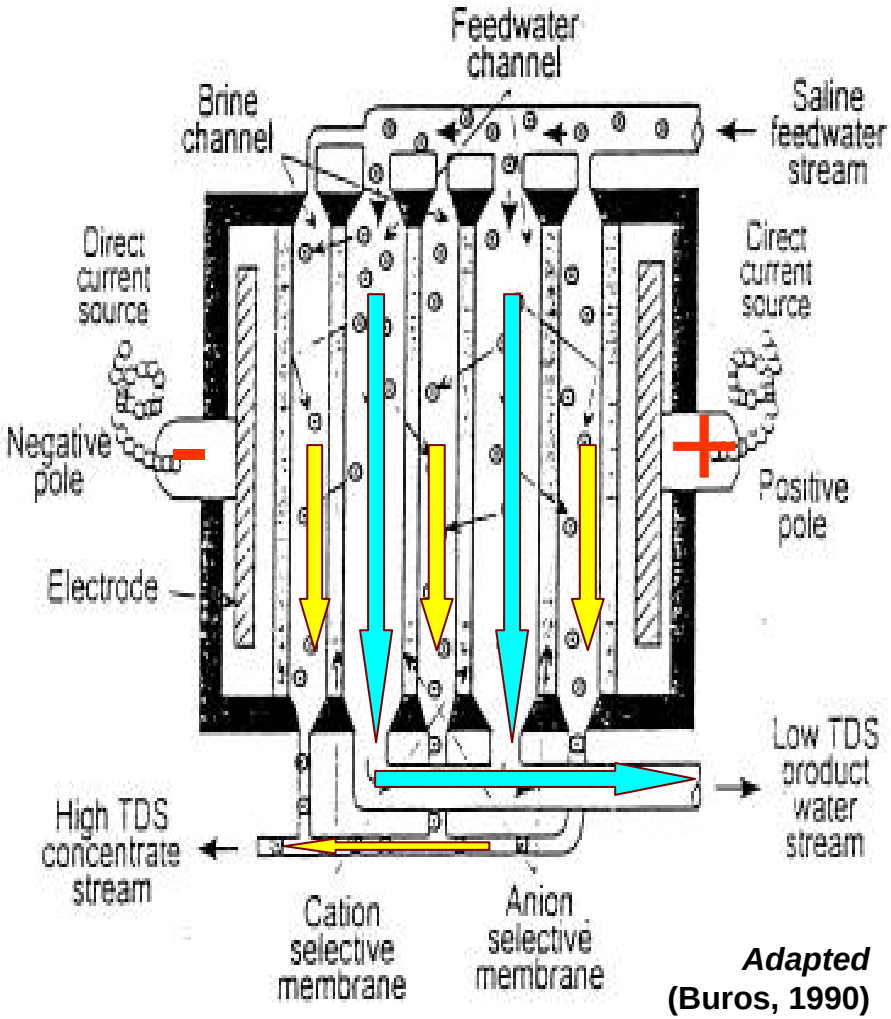
- **Post electrokinetics challenges:**
  - **EC up to 26,000 uS/cm**
  - **Chloride up to 12,000 mg/L**
  - **Hardness up to 10,000 mg/L**
  - **TDS up to 20,000 ppm**
  - **Potential dissolved metals and trace hydrocarbons**

Effluent Pre-treatment Train

Overview



Desalination by Electrodialysis (ED)



Adapted
(Buros, 1990)

Electrodialysis: The dissolved ionic species (e.g. sodium chloride) from saline water are transported through ion selective cation and anion membranes under the influence of an electrical potential to form a low TDS product water stream and a high TDS concentrated brine

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Electrodialysis Mobile System

The Mobile ED desalination system combines a series of pre-treatment filtration units, with a proprietary Electro-dialysis (ED) stack, to produce de-mineralized (NaCl salt free) water for EK3 recycle.

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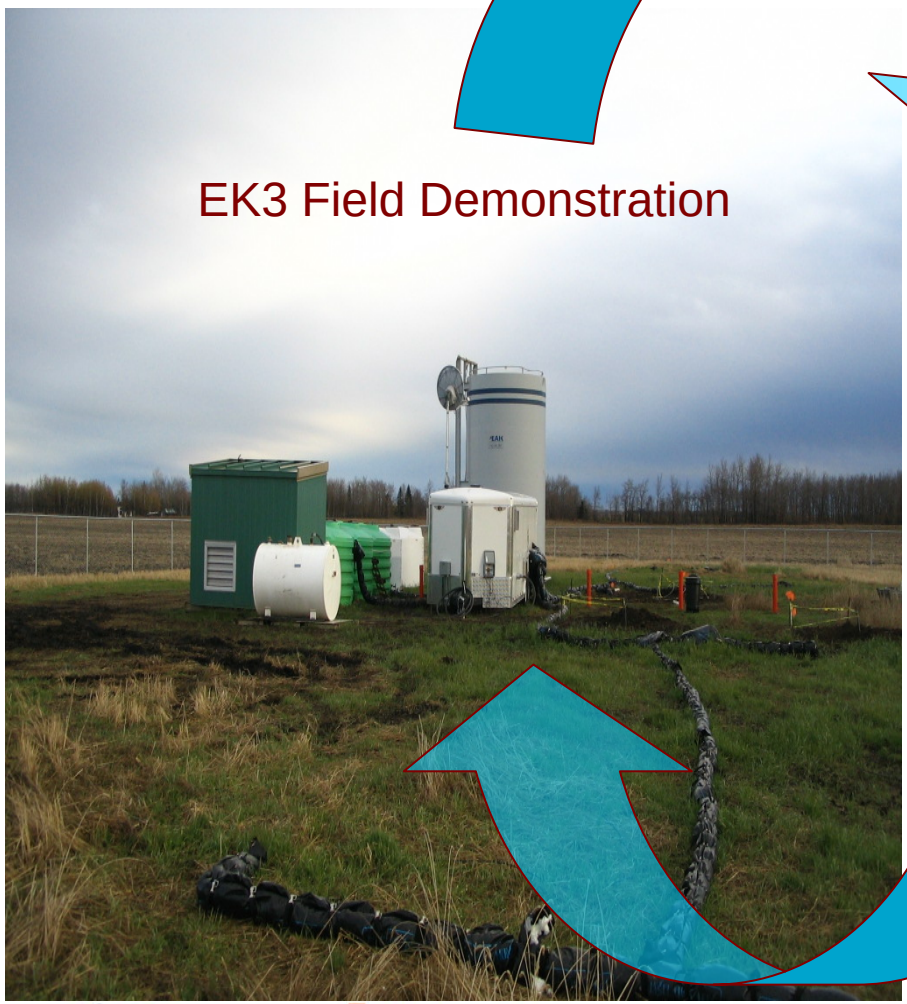
Field Application Concept



EK3 Field Demonstration

Desalination by ED and recycle to EK3

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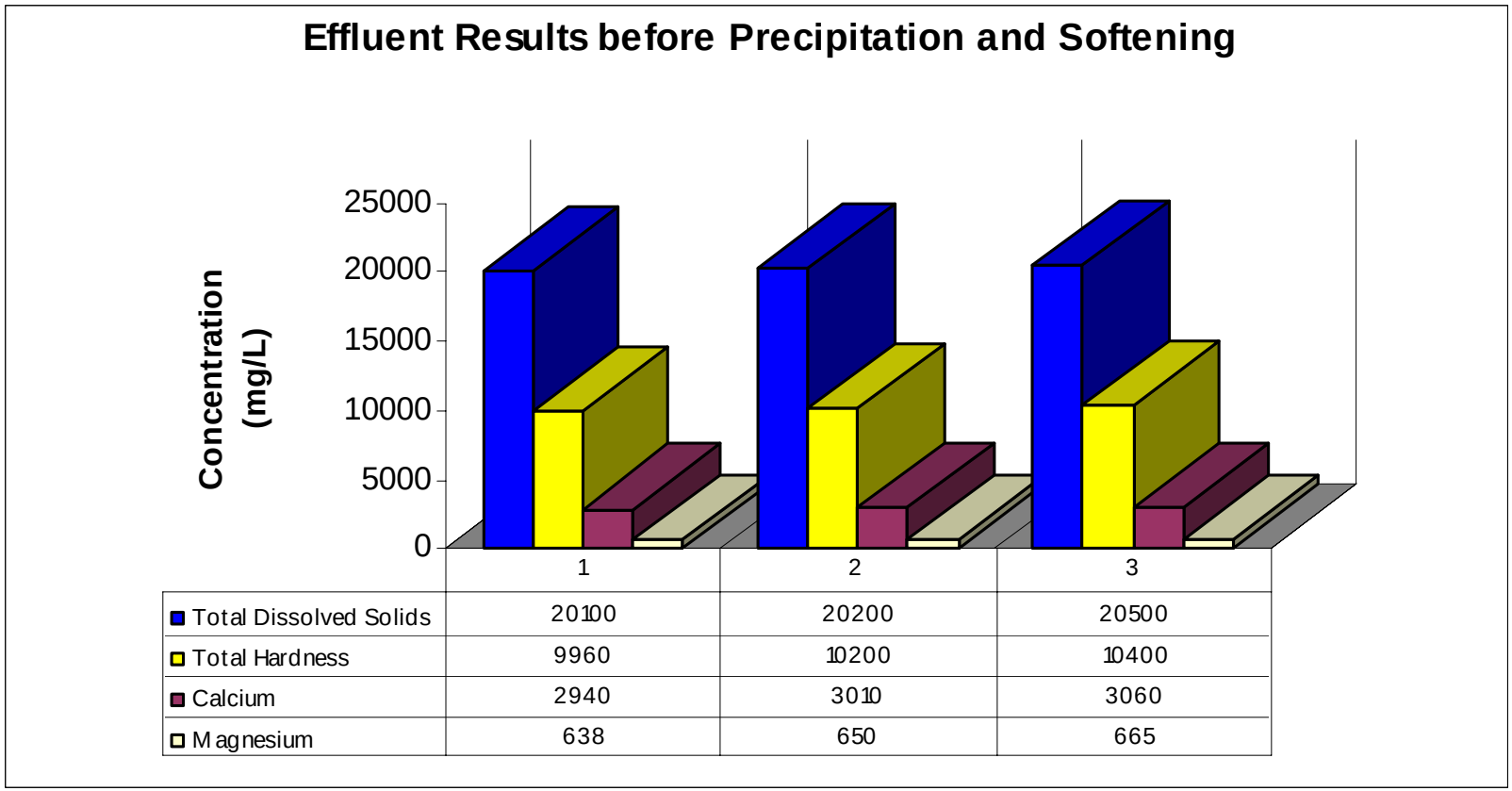
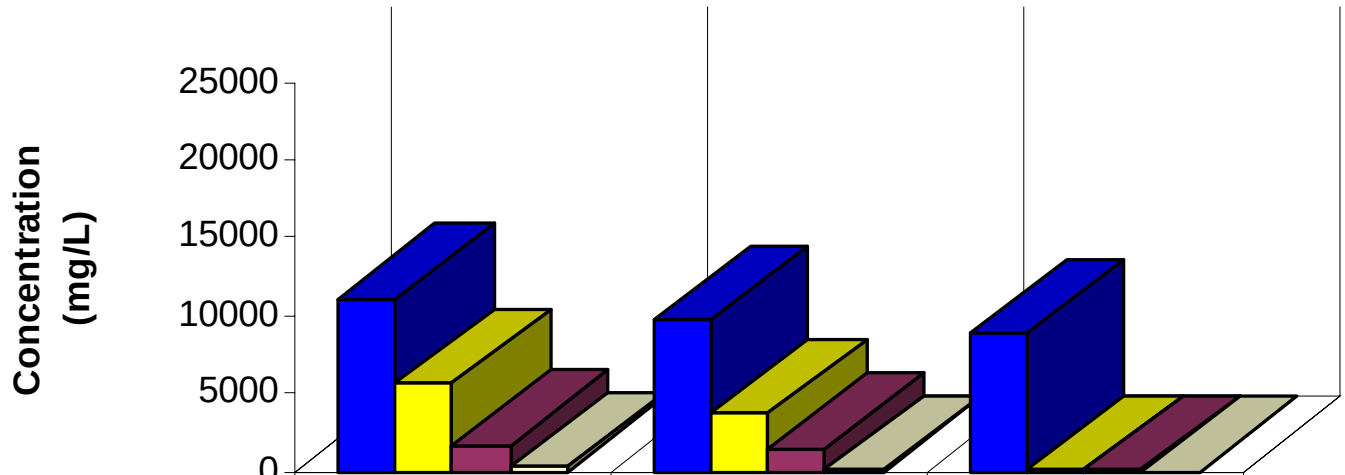
Effluent Pretreatment Results



Effluent Pretreatment Results

Effluent Results after Precipitation and Softening (Ion Exchange)



	Effluent Composite	S# 2 PPT	S# 3 WAC
Total Dissolved Solids mg/L	11100	9720	8890
Total Hardness mg/L	5660	3700	3.2
Calcium mg/L	1690	1450	0.8
Magnesium mg/L	351	19.1	0.3

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Groundwater Effluent Pre-treatment Summary

	Reduction of Significant Parameters		
	GW Before Treatment	**GW Extracted in 1st Flush Waters After Initial EK3 Treatment**	**GW After Pre-treatment**
EC (uS/cm)	57,800 to 65,600	26,000 to 26,500	21,600
Cl (mg/L)	24,400 to 27,900	10,400 to 12,600	5,220
Hardness (CaCO3) mg/L	21,200 to 27,900	9,960 to 10,400	3.23
TDS mg/L	42,200 to 44,700	20,100 to 20,500	8,890
Na mg/L	5,680 to 7,930	2,960 to 3,050	3,510

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ED Desalination Performance Summary Example from a Salt Storage Pond

Parameters	Units	Before Start-up Feed-water @ 0 hrs	During Process At @ 48 hrs	After End of Process @ 55 hrs	Regulatory Criteria	Percent Removal @ 55 hrs
Chloride	mg/L	21067	175	71.2	250*	100%
Sodium	mg/L	12733	145	84	200*	99%
Calcium	mg/L	184	1.0	0.9	NG	100%
Potassium	mg/L	481	1.2	0.9	NG	100%
Magnesium	mg/L	54	0.4	0.3	NG	99%
Sulphate	mg/L	547	90.5	80.3	500*	85%
TDS	mg/L	28533	482	273	500*	99%

Green Font: Summary of Guidelines for Canadian Drinking Water Quality, 2001 and *Aesthetic Objective; NG- No Guideline **Red Font:** Exceeds Guidelines.

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What Did We Learn...

- Isolate the first electrode flush waters and treat separately from subsequent flushes.
- Pre-treatment equipment, materials and processes needs to be customized for site contaminants.
- Standard engineered equipment may not be suitable depending on water chemistry.

Conclusions: Outcome of Project / Projected Work

- Bulk conductivity of the subsurface was reduced by approx. 30% based on EM results during pilot.
- 10,000 gallons of pilot effluent water are to be treated in pilot scale.
- Remainder was deep well injected as unprecedented water hardness required pre-treatment and long term storage not available during the development of the pre-treatment systems.
- Moving forward:
  - Effluent waters will be treated with pre-treatment and ED systems. This pilot study is on going.
  - Future studies will involve hybrid integration of EK3, pretreatment and ED for reproducible field demonstration.
  - Demonstrate sustainable practices by recycling effluent and reusing concentrated brine (i.e. de-icing).

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Benefits of the Integrated EM+EK3+ED Approach

- EK3 insitu treatment of soil and treatment of salinity impacted groundwater
  - No excavation.
  - Lowered costs to remediate vs landfill.
  - No offsite fill and weed control requirements.
- Sustainable approach
  - Limiting fresh water usage needed for EK3 operations.
  - Reusing of concentrated brine for road maintenance.
  - Conducting less hauling, transportation and disposal of waste.
  - Avoiding spills due to transportation.

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Questions?

THANK YOU

Acknowledgement:

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Pioneer – Dr. Janan Sallomy, Dennis Twerdoff, Bryce Peterson and Burton Cosgrove
AGAT and ALS Laboratories