In-Situ Remediation of Brine Impacted Soils and Groundwater Using Hydraulic Fracturing, Desalinization and Recharge Wells

Presented by

Craig Robertson, M.Sc., P.Geol.

Senior Technical Manager

October 12, 2006

Wiebe Environmental Services Inc.

"Practical Solutions for Environmental Management"

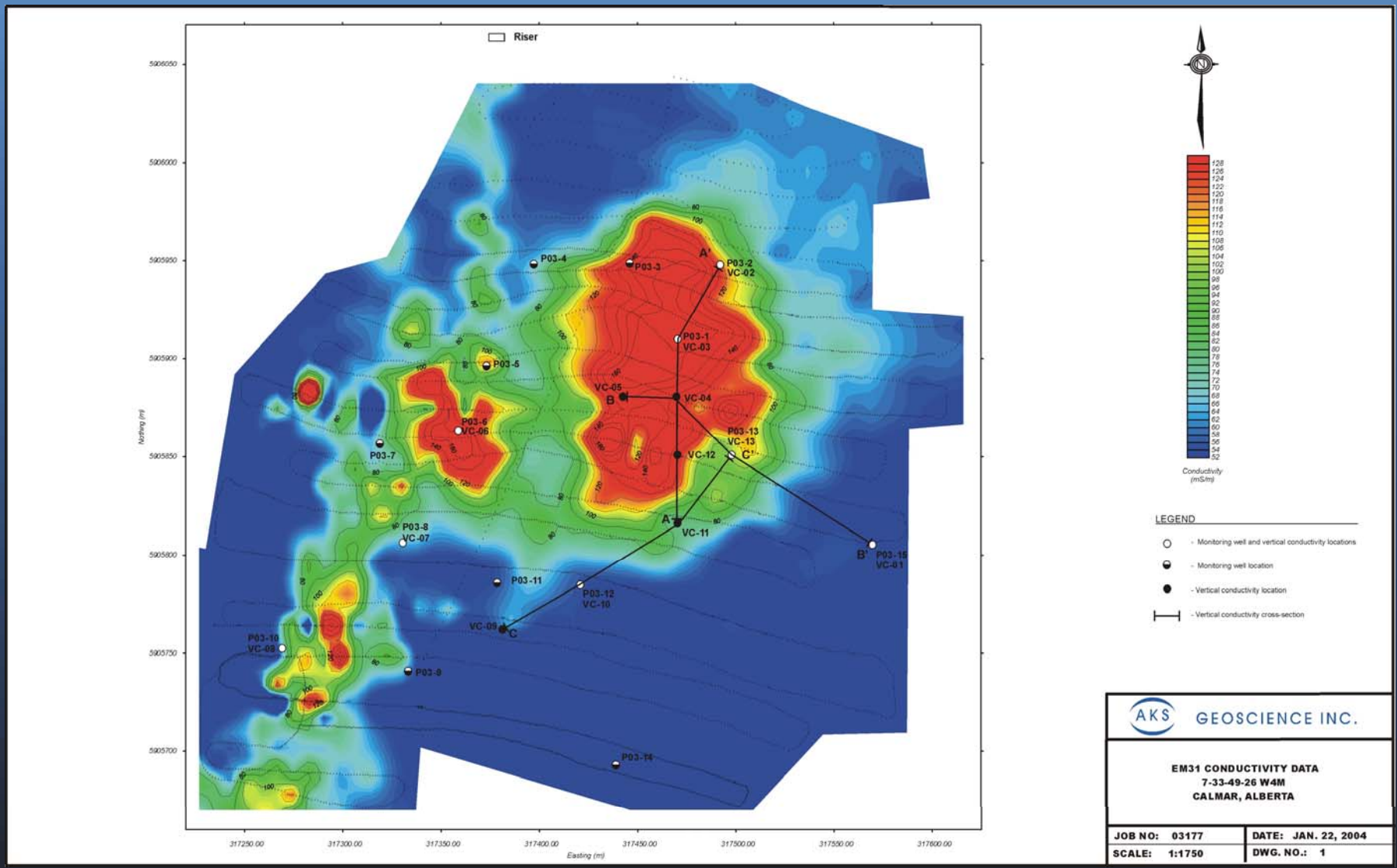
The Problem

- Former oil battery established in 1940's, decommissioned in late 1960's with reclamation certificate issued in 1972
- Land owner reports poor vegetative growth in former Battery area
- Investigate cause of poor growth and delineate contaminants of concern
- Remediation of impacted soil and groundwater associated with a former Battery site

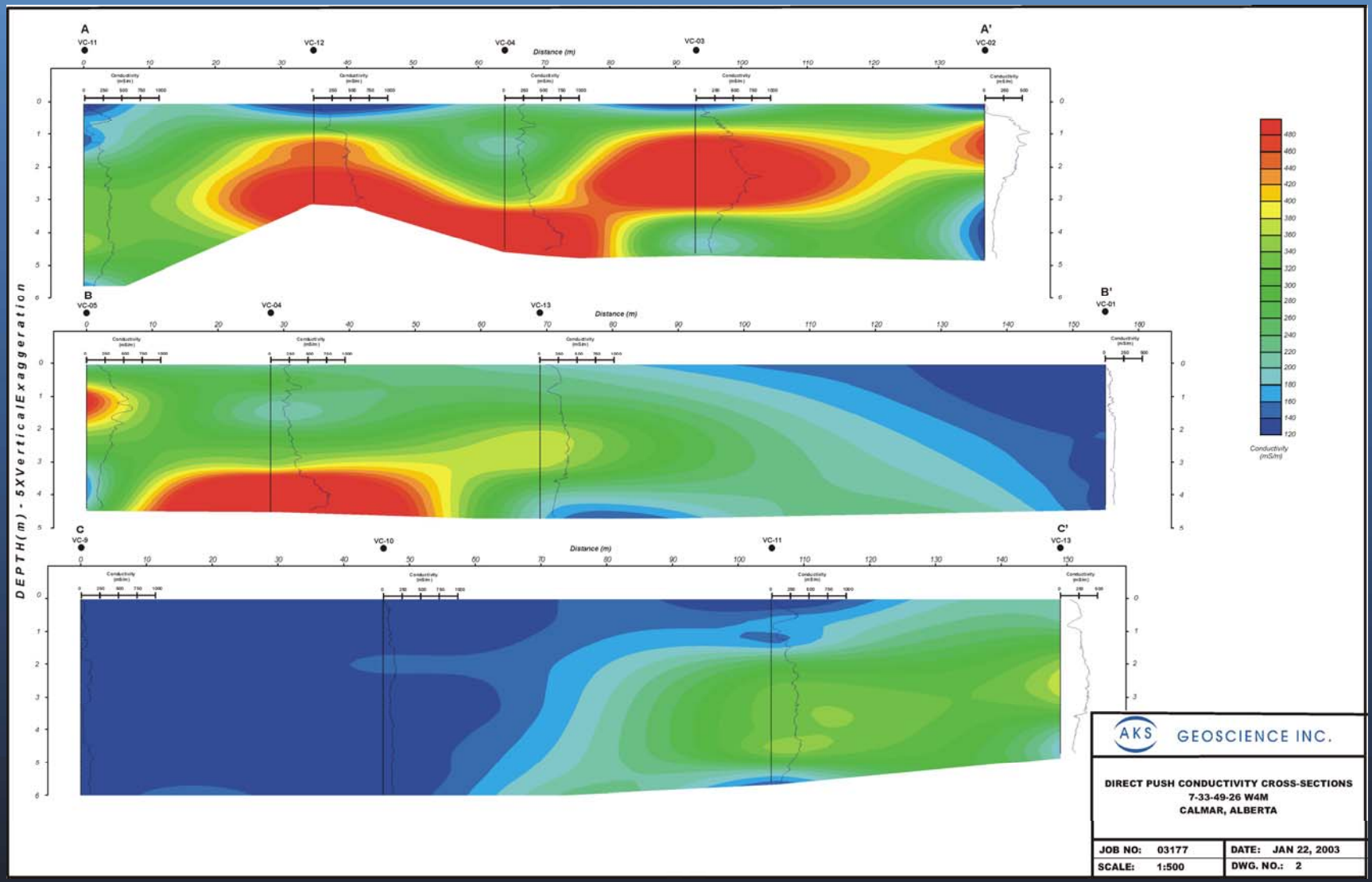
Former Battery Site 1962

The Investigation

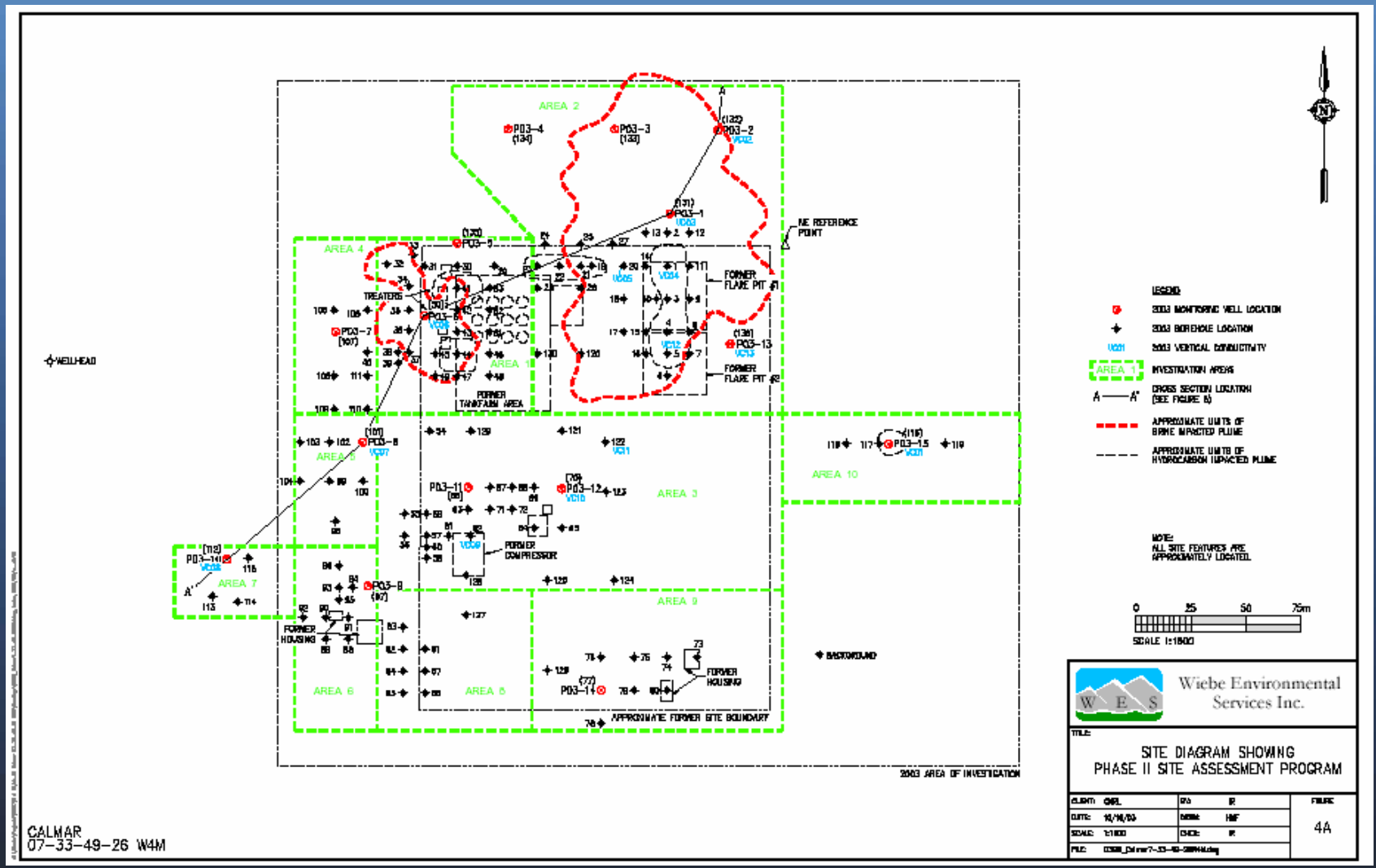
- Agrological, Geophysical and Hydrogeological investigation into extent of anthropogenic impacts
- Develop remediation options and plans to deal with issues of concern



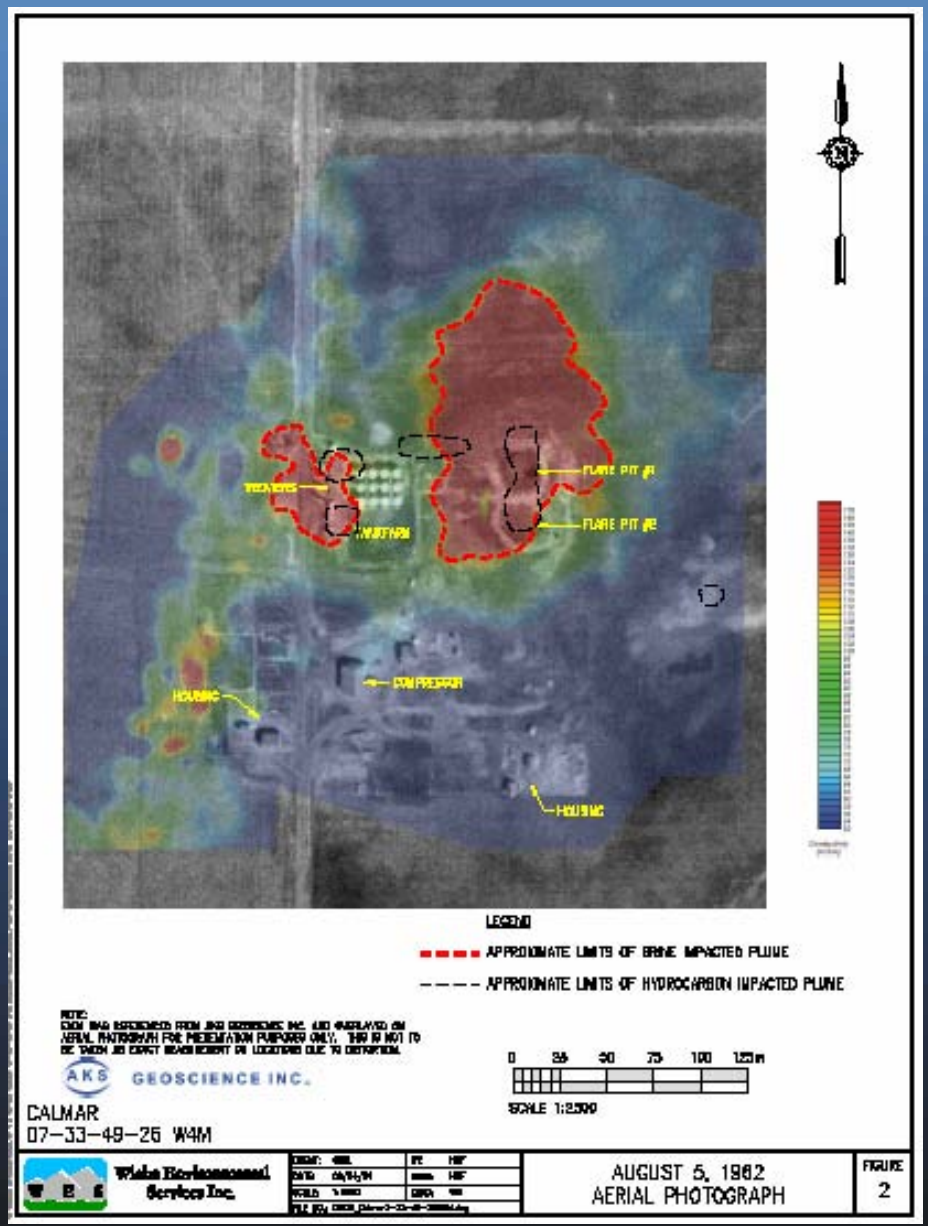
EM31 Survey Results



Vertical Conductivity Survey Results



Phase II Site Assessment Program



Impacted Areas

Results

- 137 boreholes and 100 test holes to a maximum depth of 7.5 m
- Approximately 8,000 m^3 of heavy end hydrocarbons, trace elements (metals), and heavily brine impacted materials was identified in the former tank farm and the buried flare pit areas
- Approximately 62,000 m^3 of brine impacted materials
- Approximately 1,000 m^3 of medium to light end hydrocarbon impacted materials
- groundwater flow is to the northwest at an average linear velocity of 3 mm/year to 6 mm/year

W E S

Canadian Natural

The Options

- In-situ or on site treatment of heavy end hydrocarbons difficult and cost prohibitive. Best option to remove heavy hydrocarbons for off-lease disposal
- Light end hydrocarbons can be treated in-situ, on site or can be removed for treatment or disposal. Off site disposal was selected because the volumes were relatively small, other material was being shipped off lease and on site options would restrict reclamation efforts
- The large volume of salt impacted material made removal cost prohibitive. Other option was in-situ treatment

Limitations on Salt Remediation

- Saline impacts cannot be reclaimed by chemical amendments, conditioners or fertilizers
- Salts cannot be volatilized or degraded
- Soils and groundwater can only be reclaimed by removing salt
- Volumes are too great to dig and dump and natural leaching, if feasible will take decades, especially in semiarid regions

Treatment of Saline Soils

- Leaching Requirement
  - The amount of water needed to leach salts out of the soil profile
- Artificial Drainage
  - Enhanced removal of salty groundwater
- Artificial Recharge
  - Application of water to enhance leaching

Solution

- Multi tasking approach to flush salts through the system and dispose off site
  - Sufficient recharge to move salts out of soil zone to water table
  - Sufficient drainage to move salts to collection point
  - Removal and Disposal of Waste Water

How?

- Install artificial drainage and pump system to remove saline water, create a hydraulic gradient and lower water table
- Desalination of leachate water
- Blend treated water to meet soil chemistry requirements
- Leach salts from soil profile by applying treated water
- Dispose of process waste water

The Plan

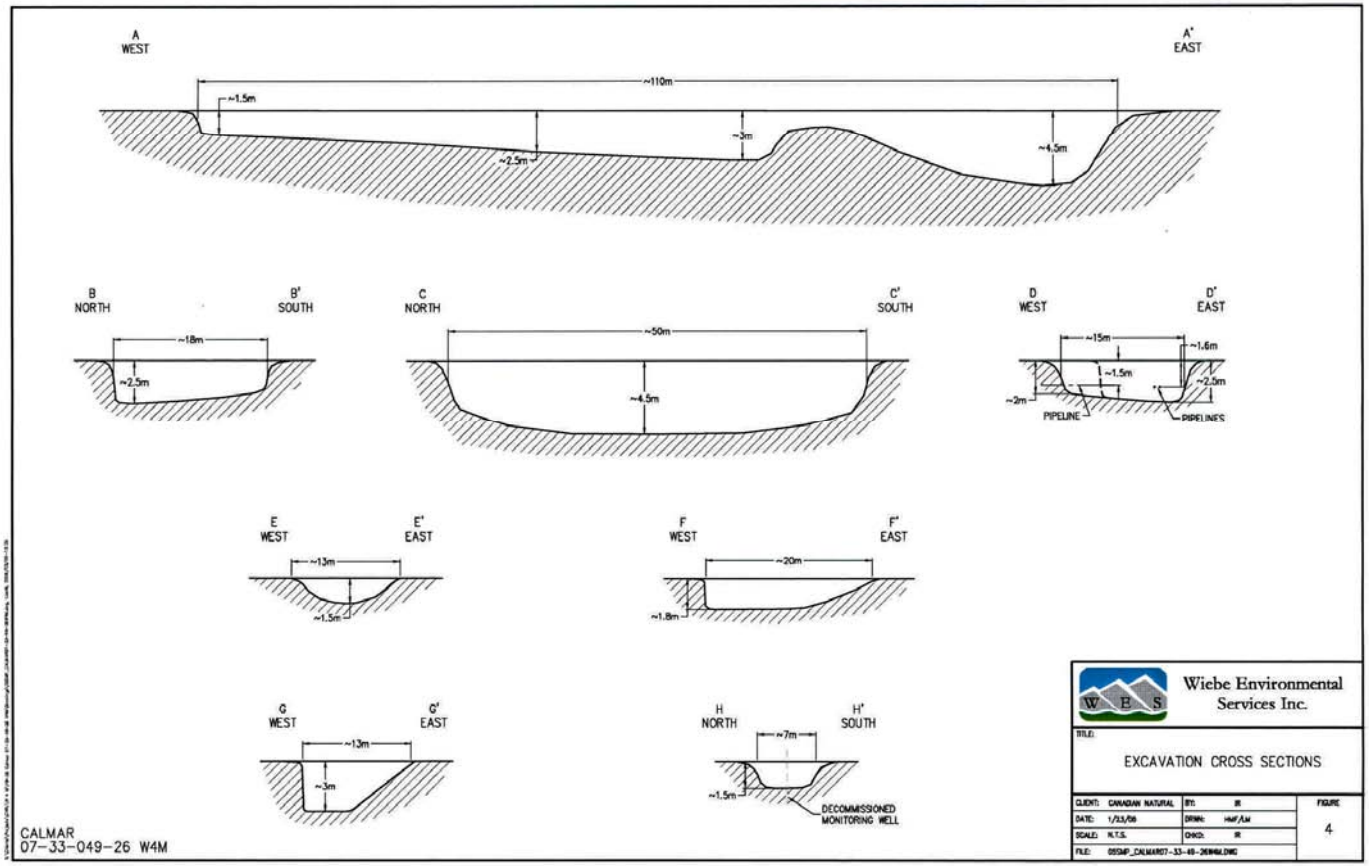
- Removal of remaining infrastructure including pipelines
- Excavation and off-lease disposal of hydrocarbon and major salt impacted soils
- Creation of buried sump for leachate recovery
- Hydraulic fracturing of brine impacted soils
- Installation of injection wells
- Operation of desalinization unit to treat water with injection of processed water

W E S

Canadian Natural

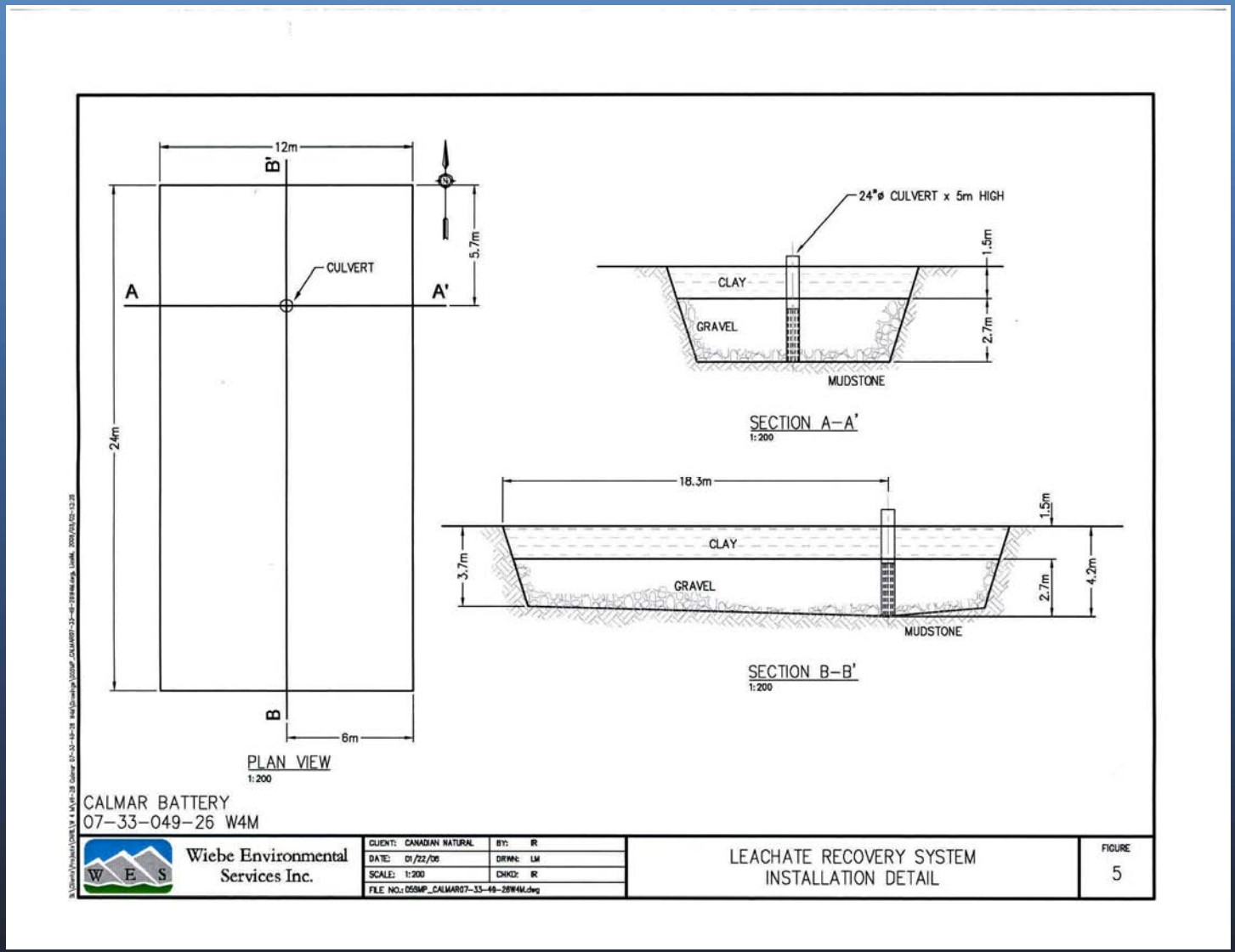
Excavated Pipelines

Former Flare Pit Excavation



Excavation Profiles

Leachate Recovery System

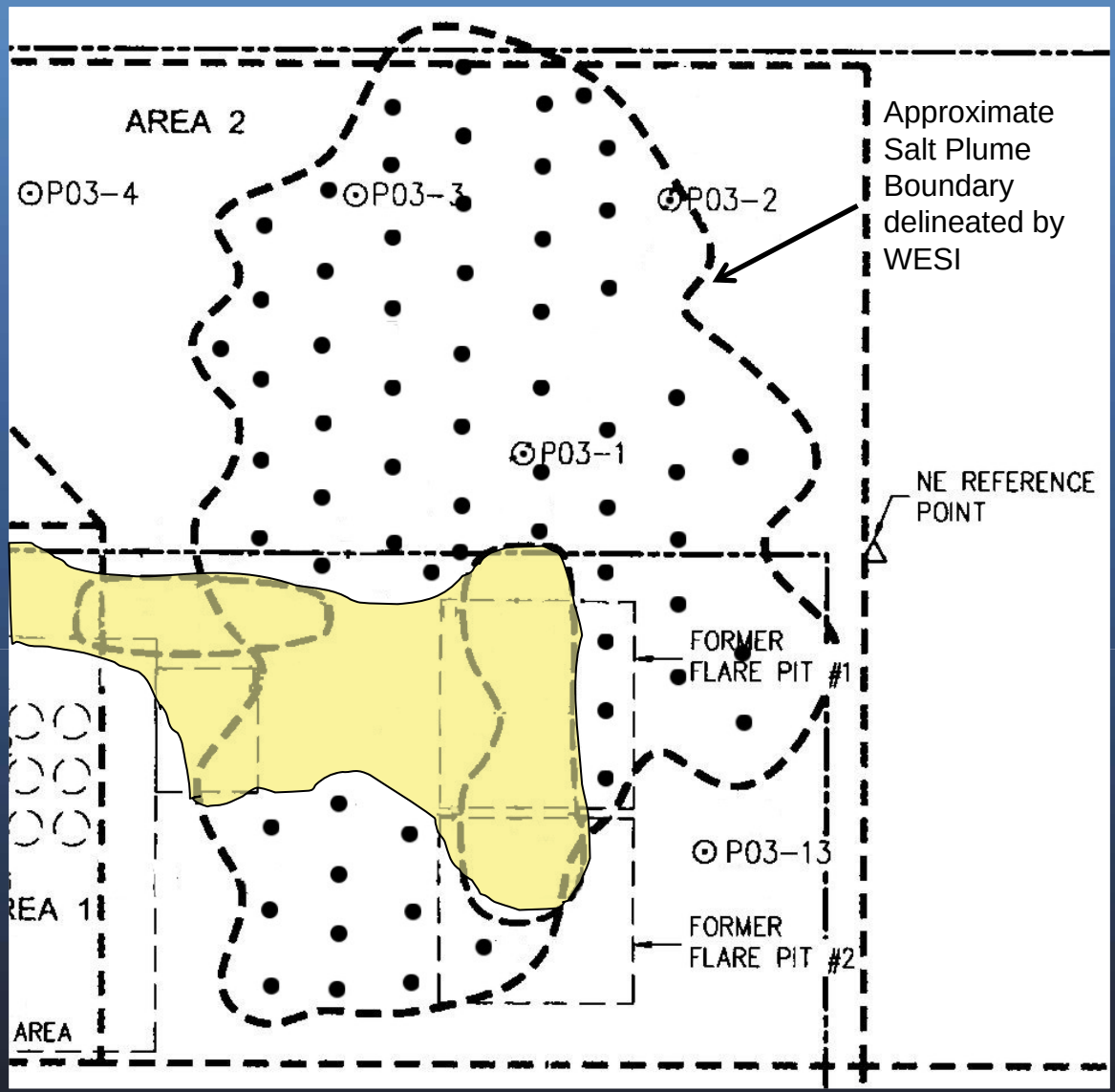


Leachate Recovery System Profiles

After Backfilling and Leveling

Hydraulic Fracturing

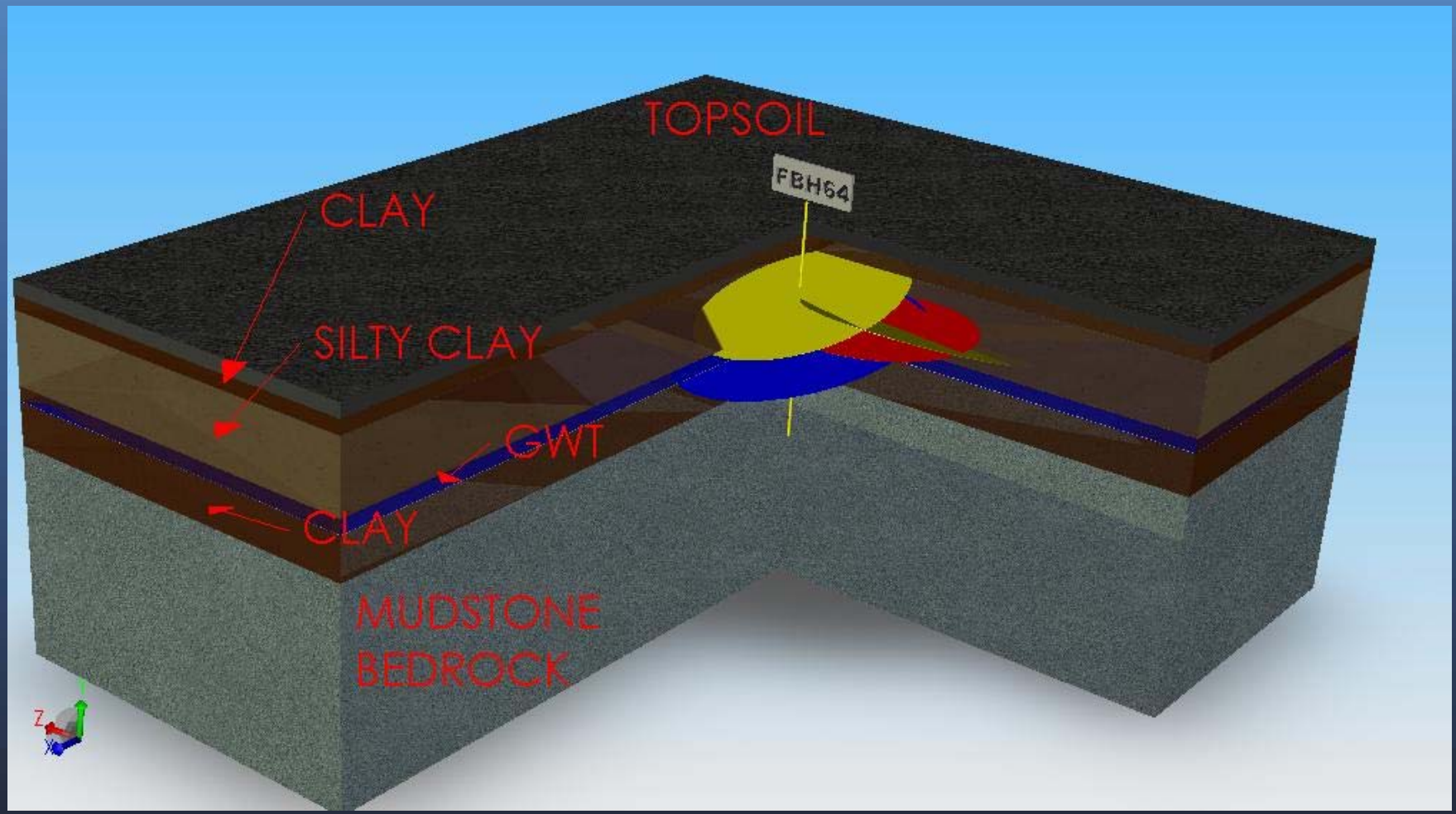
- Fractures initiated using Direct Push Fractool and drilling string
- Fracture mapping with surface mounted tilt meters
- 65 fracture boreholes within the salt plume emplaced 221 drainage fractures containing 207.1 tonnes of sand
- Theoretical fracture radius was 6 m with fractures up to 11 m observed in the field
- Fracture break pressures ranged from 1,000 kPa to 1,500 kPa
- Fracture mapping conducted on 47 fractures to confirm placement and connectivity



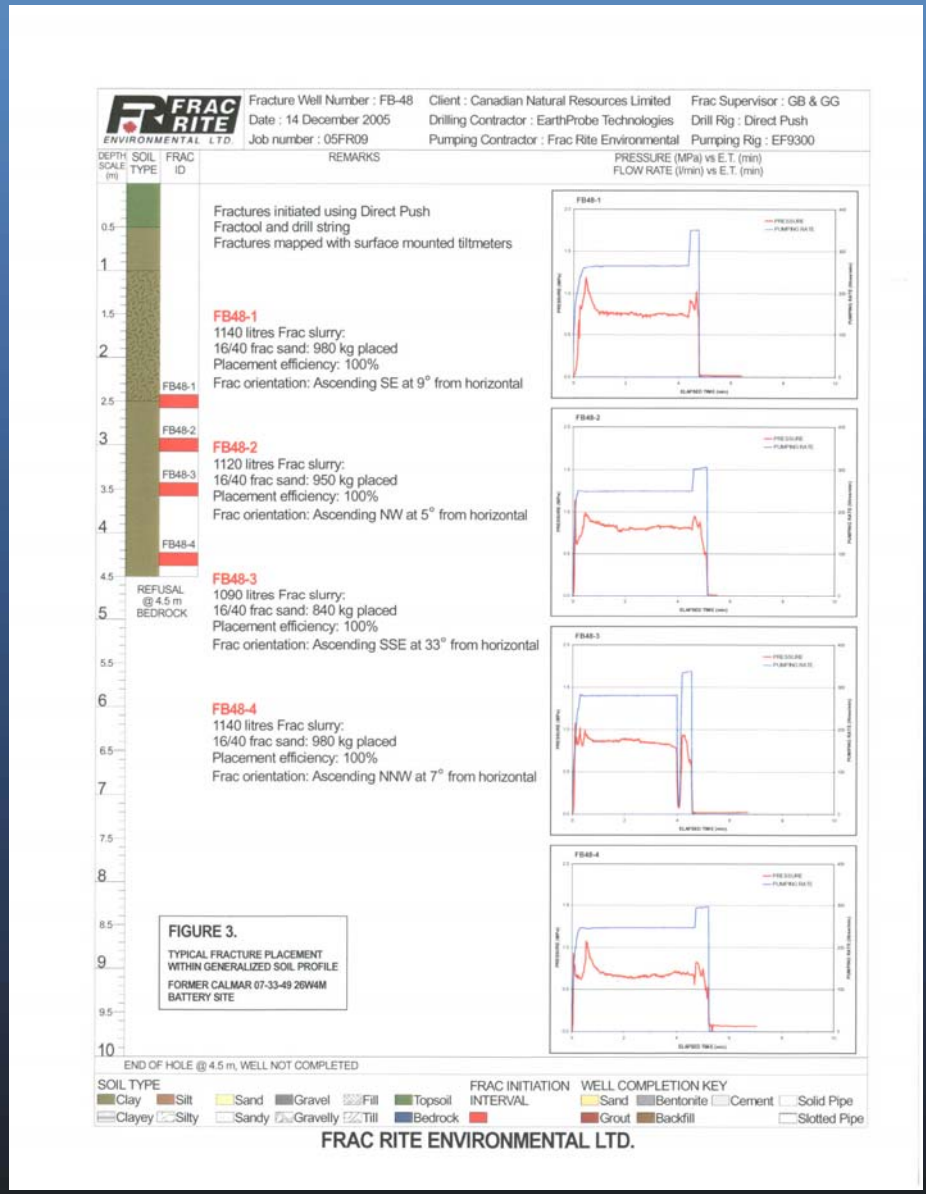
Hydraulic Fracturing Injection Locations

Fracture Emplacement of Sand Slurry

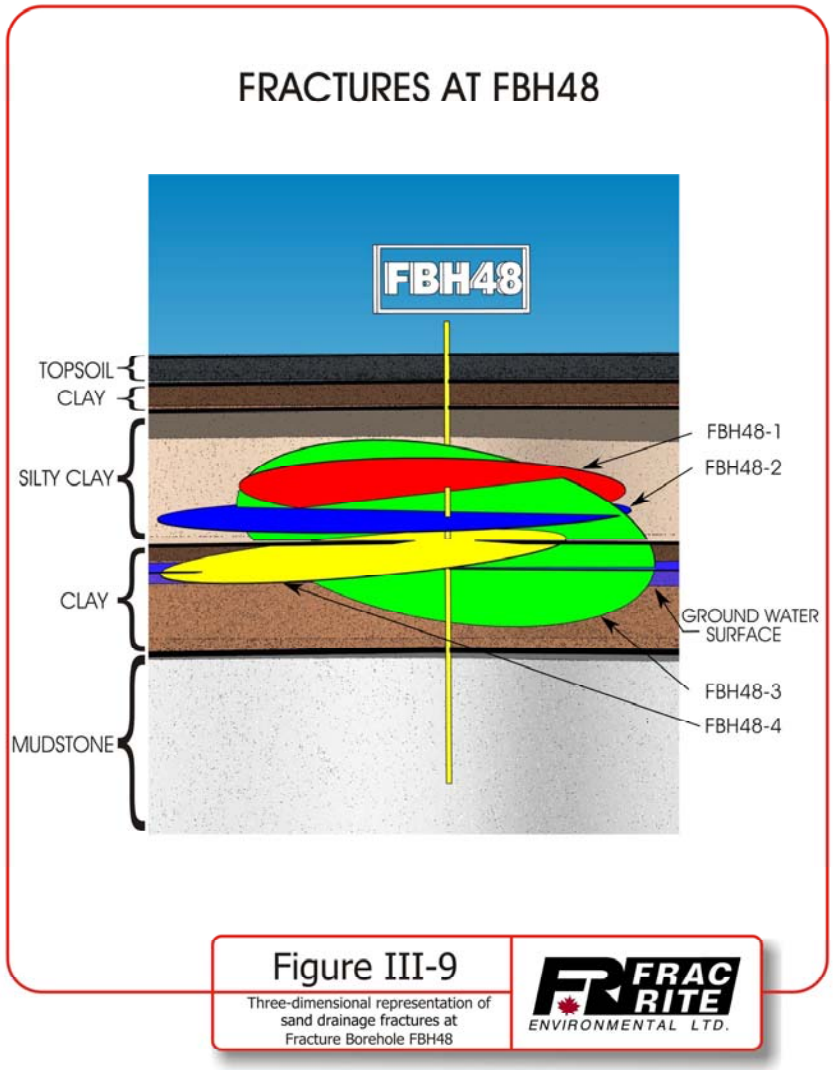
Environmental Fracturing Unit



Conceptual Model of Hydraulic Fracturing



Fracture Placement

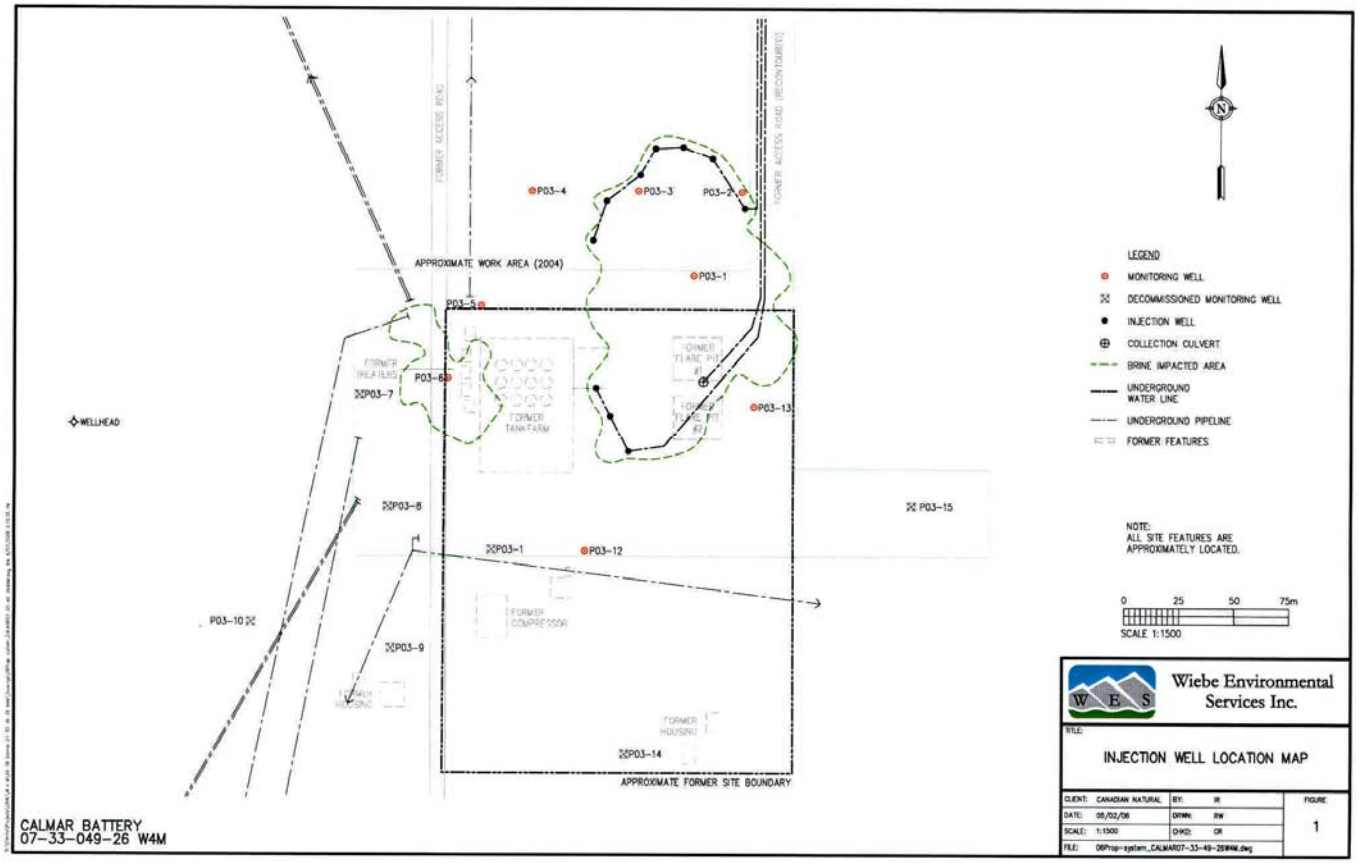


Sand Drainage Fractures

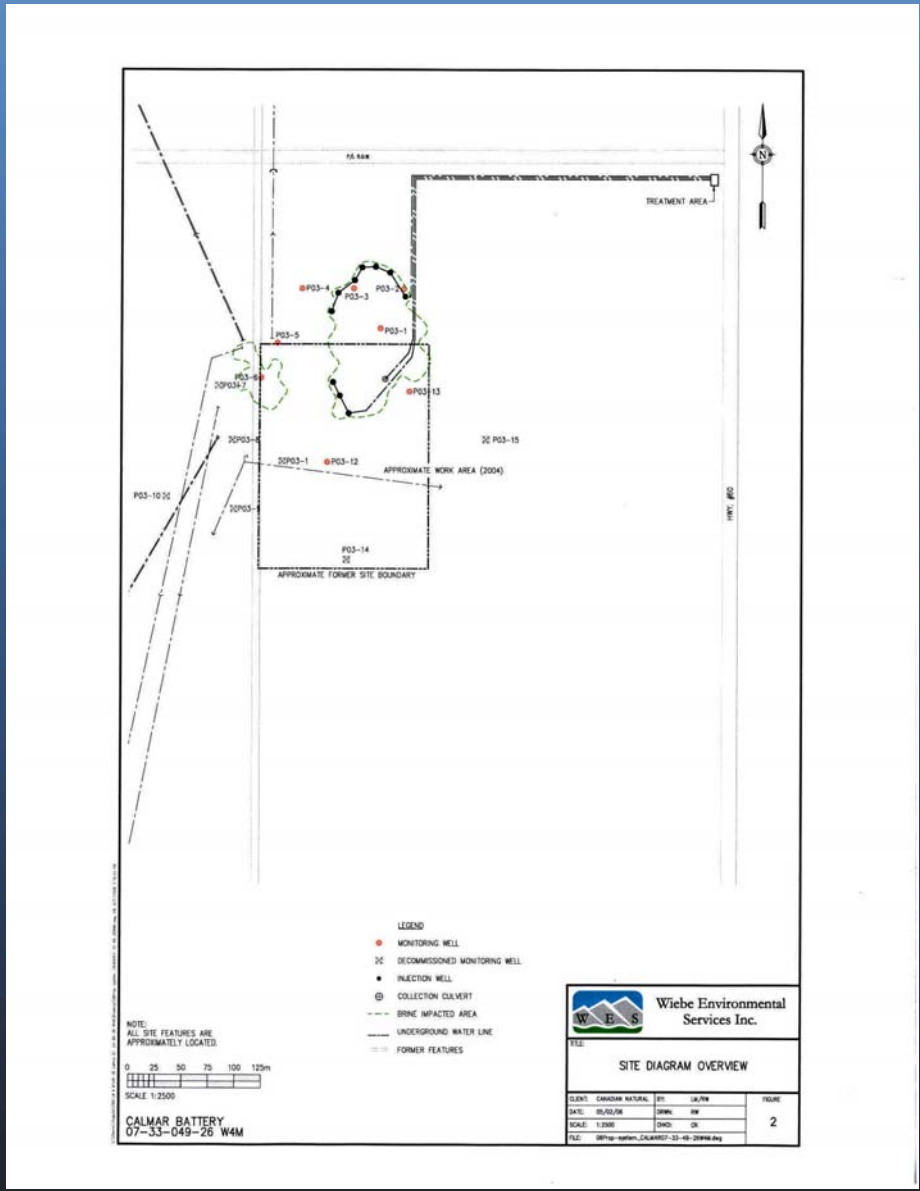
Fracturing Locations

Injection Wells

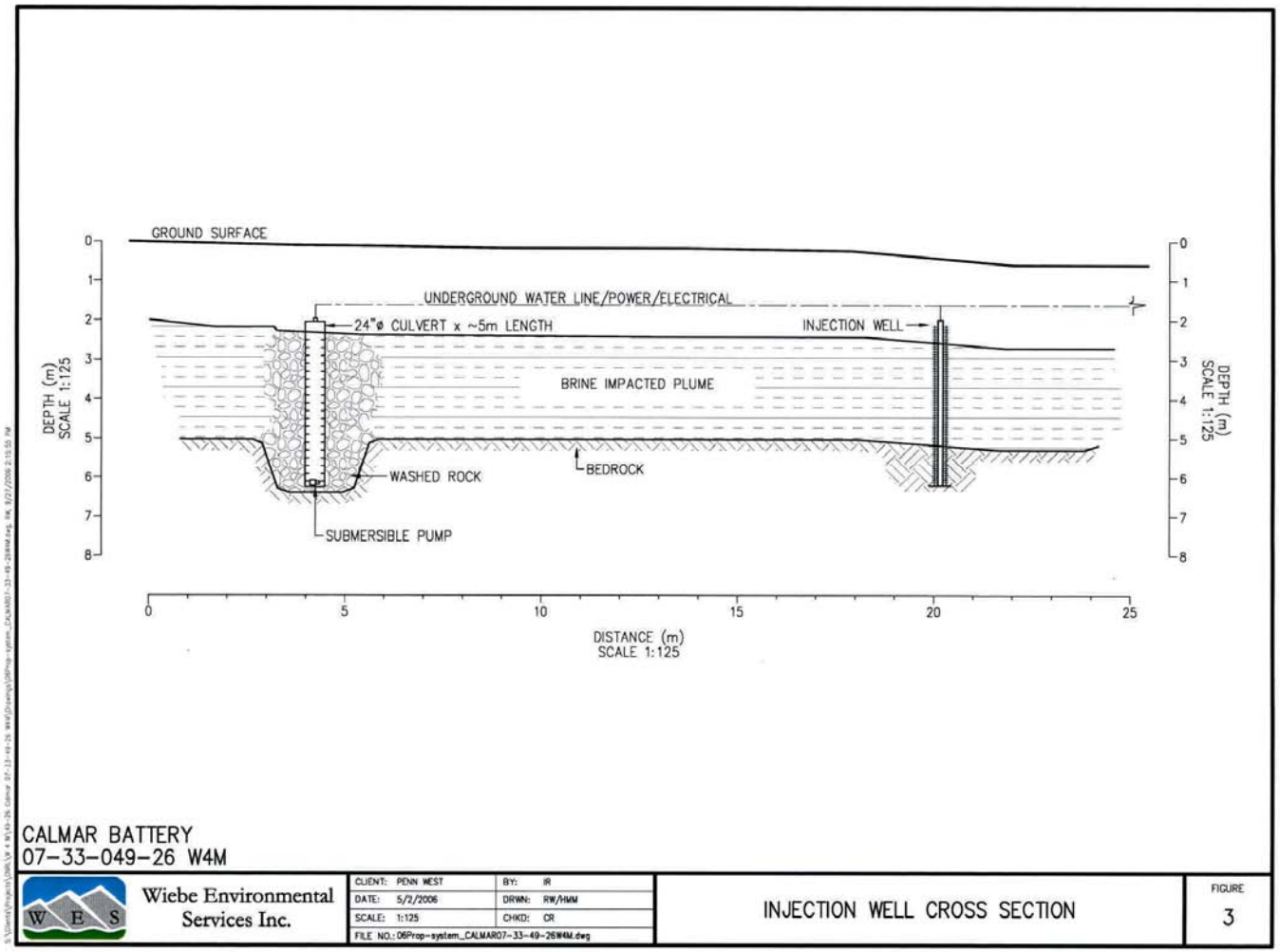
- Injection wells installed to re-circulate treated groundwater though the salt plume
- Wells placed to bypass the non impacted upper 1.5 m of the soil profile
- Wells completed within fracture boreholes for maximum effect
- Injection wells placed at upgradient perimeter of salt plume to maximize head differential and promote flow towards the leachate collection sump



Injection Well Location Map



Treatment Site Overview



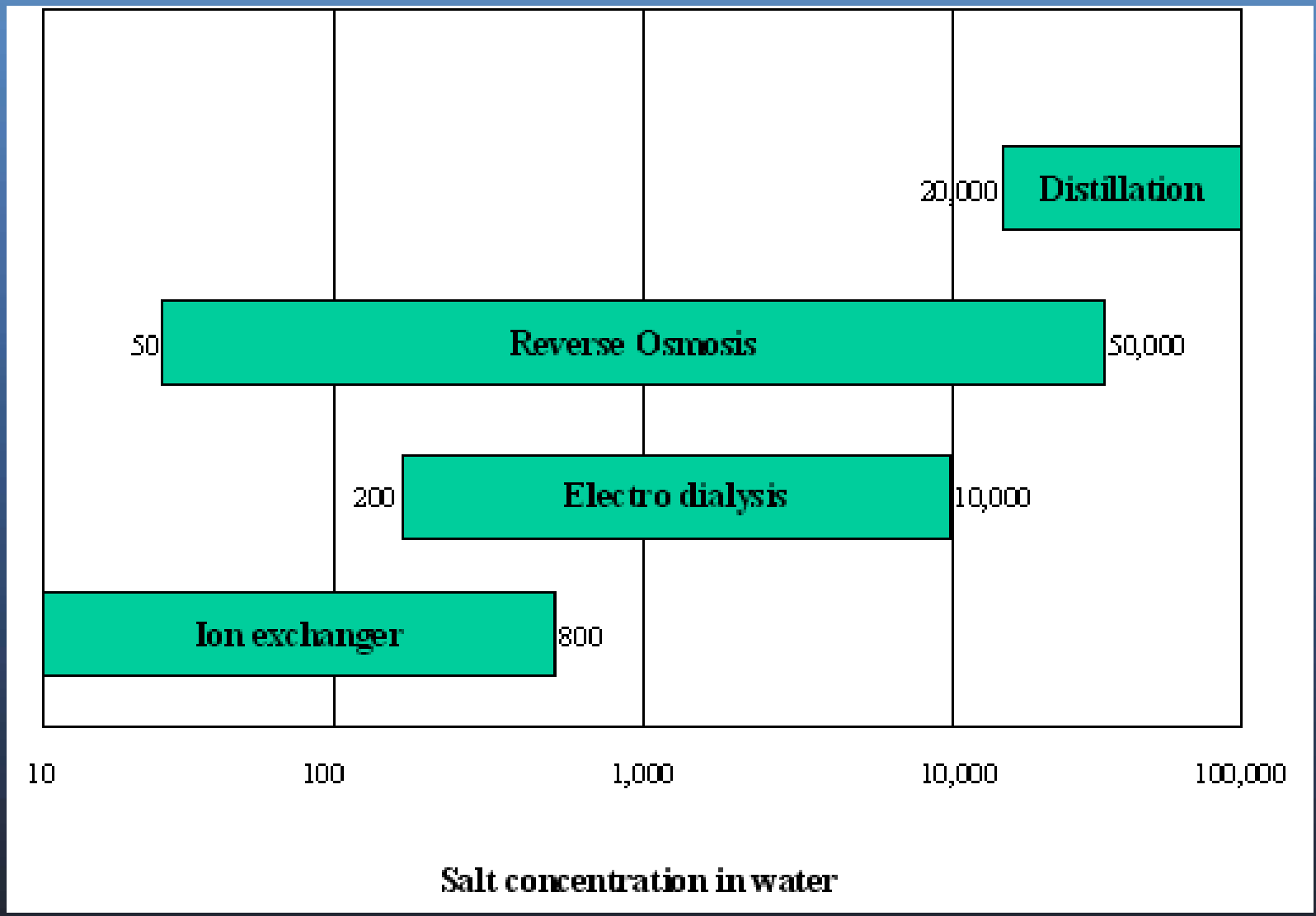
Injection Well Installation Profile

Feed Lines for Injection Wells

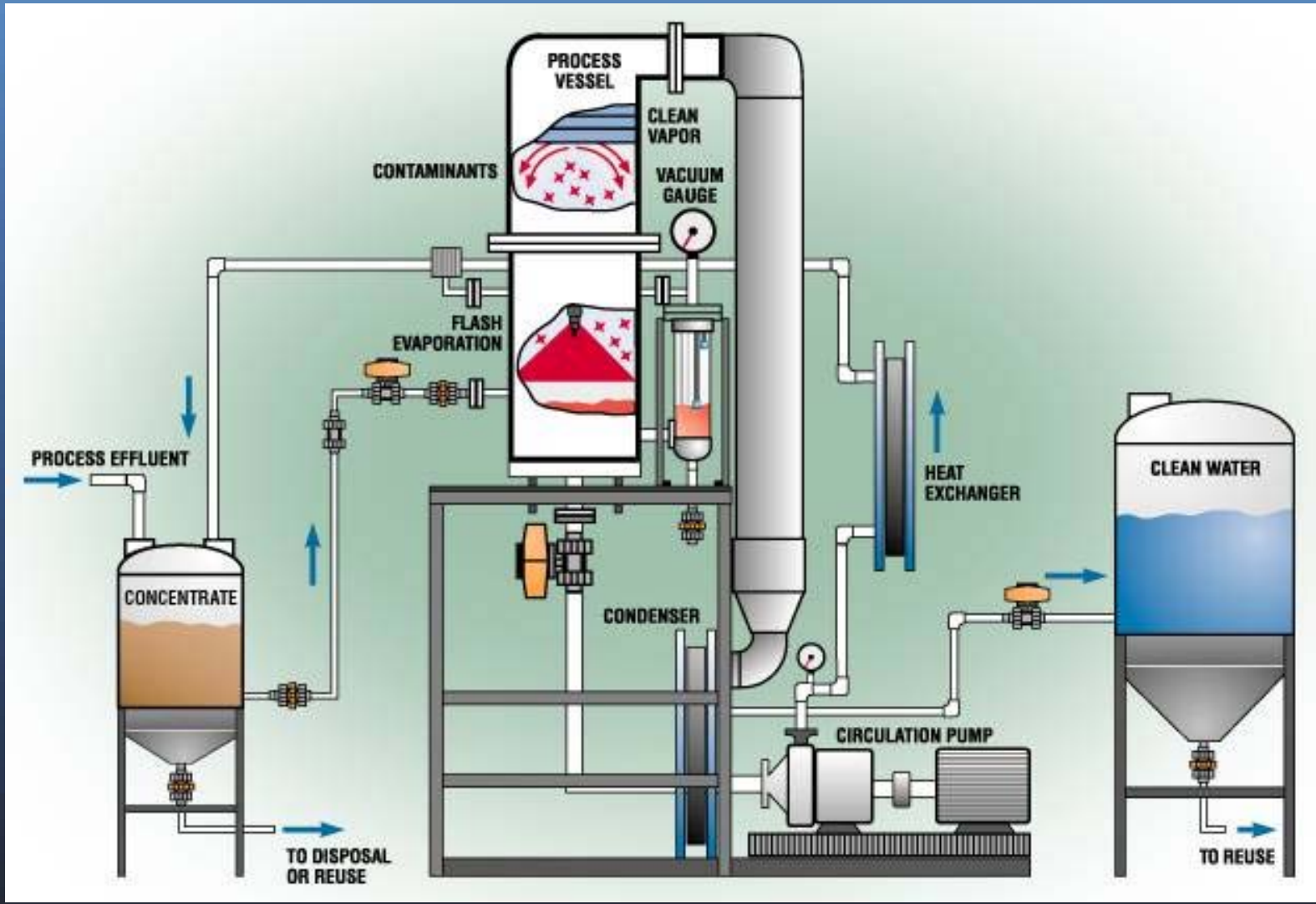
Pad Preparation

Desalination Processes

- Thermal
  - Multi-Stage Flash Distillation
  - Multi Effect Distillation
  - Vapour Compression Distillation
- Membrane
  - Electrodialysis
  - Reverse Osmosis



Concentration Range of Effective Technologies



Flash Distillation Process

Some Assembly Required

Getting the Bugs Out

Canadian Natural

What Next

- Optimise system to improve efficiency and track remediation results
- Track volumes and costs to determine cost effectiveness and break even threshold
- Develop site specific remediation alternatives for other sites
  - Flood irrigation
  - Surface water treatment


W E S