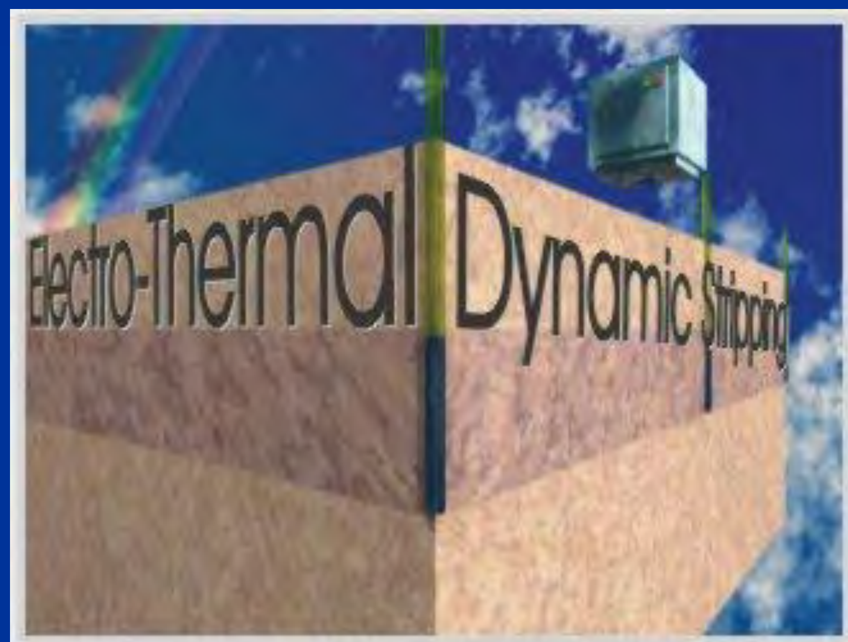
McMillan-McGee Corp.

ET-DSP™ for In-Situ Thermal Remediation



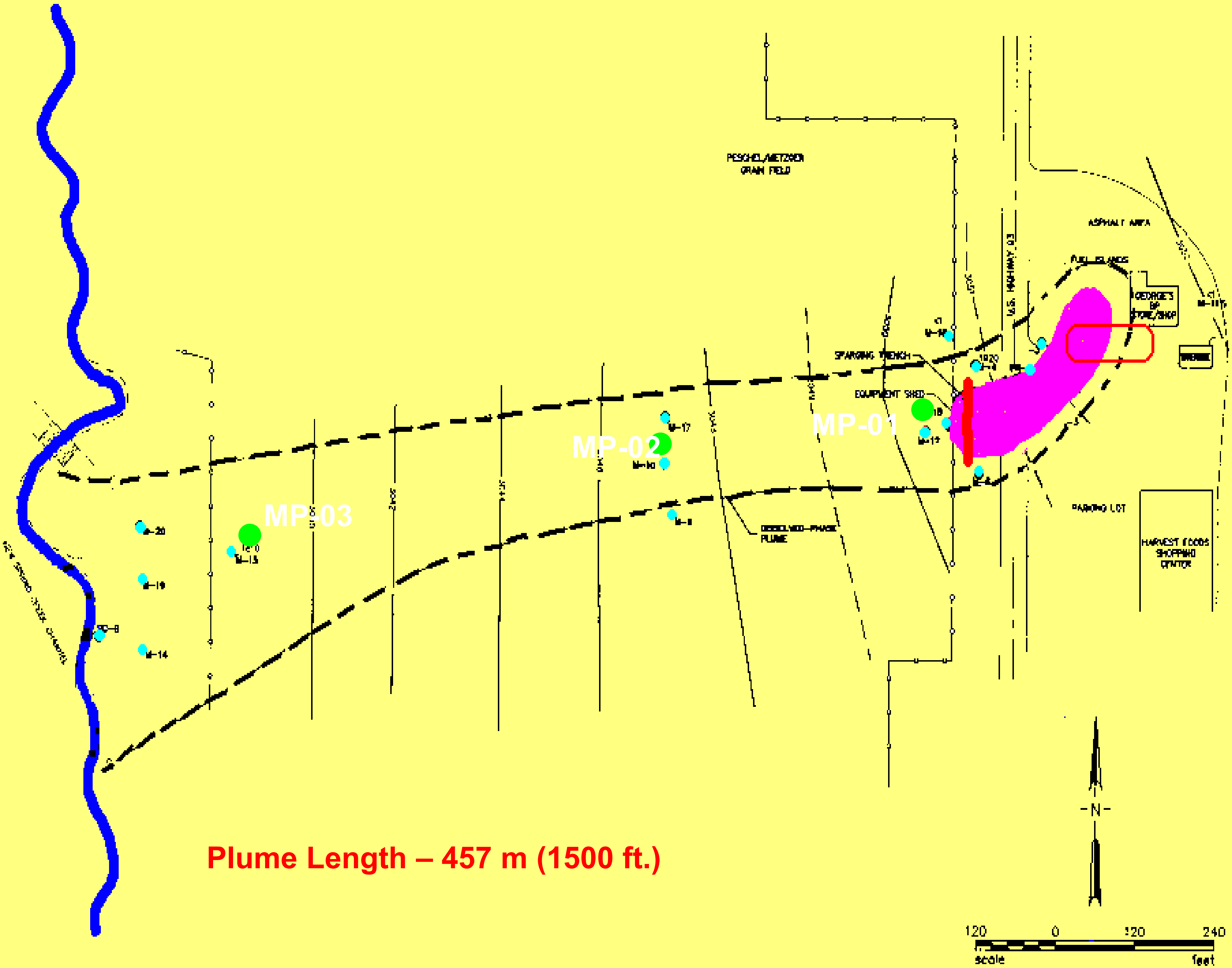
Edward Tung, P.E.

MK Environmental Inc.

McMillan-McGee - Company

- 50 Employees:
  - 2 Ph.D. Electrical Engineers
  - 5 Chemical & Civil/Environmental Engineers
  - 6 technologists/electricians/tradesman
- 15,000 sq ft manufacturing and testing facility
- Thermal laboratory
- Management team has more than 80 years of project experience in thermal remediation
- Fleet of 50 PDS Units with a total power capacity of 40,000 kVA
- Manufacture 25 ET-DSP™ electrodes per day.

George’s Conoco – Ronan, MT



Plume Length – 457 m (1500 ft.)

The Problem with Glacial Lacustrine Sediments

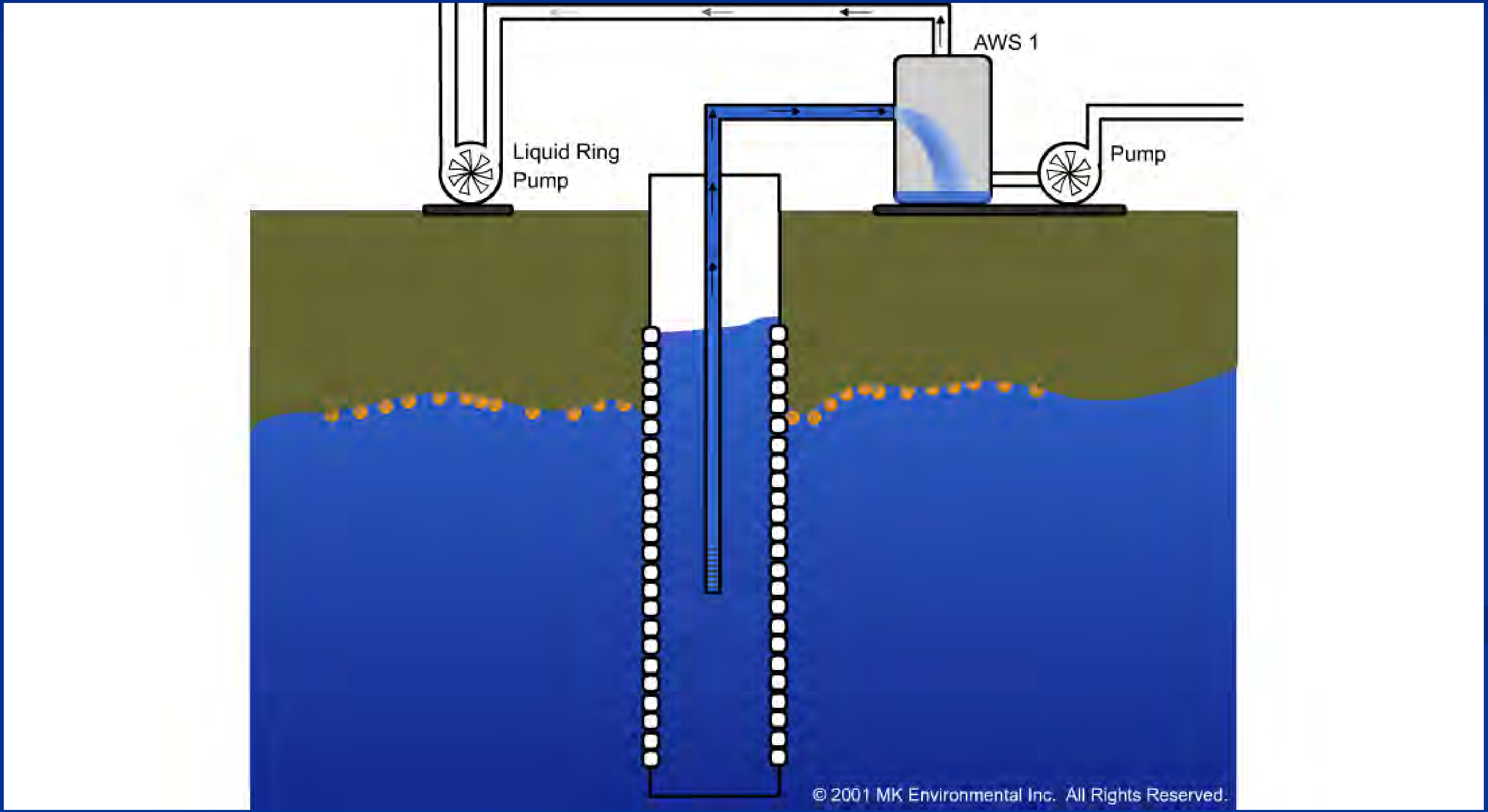
- Traditional technologies such as SVE and AS sparging have limited success
- Plumes have extremely long lives
- Remediation very expensive due to presence of residual LNAPL in vadose zone
- Difficult to characterize
- Easy to miss parts of the plume due to heterogeneities


United Rentals
Bobcat

High Vacuum Dry Blower

- Can achieve over 25” hg
- Expensive
- Very noisy
- High maintenance
- Susceptible to water carry-over

Dual Phase - Principle of Operation



Remediation Efforts

- Approx. 2,000 cubic yards soil excavated and landfarmed
- Approx. 3,500 gallons of gasoline removed through free product skimming, Soil Vapor Extraction (SVE), and Air Sparging (AS)
- Cost approx. $900,000 through 2002

Application of ET-DSP™

- Can be used on virtually all VOC's
- MTBE
- To mobilize heavy LNAPL
- No minimum depth
- No maximum depth
- No lower permeability limit

Where is ET-DSP™ Most Effective?

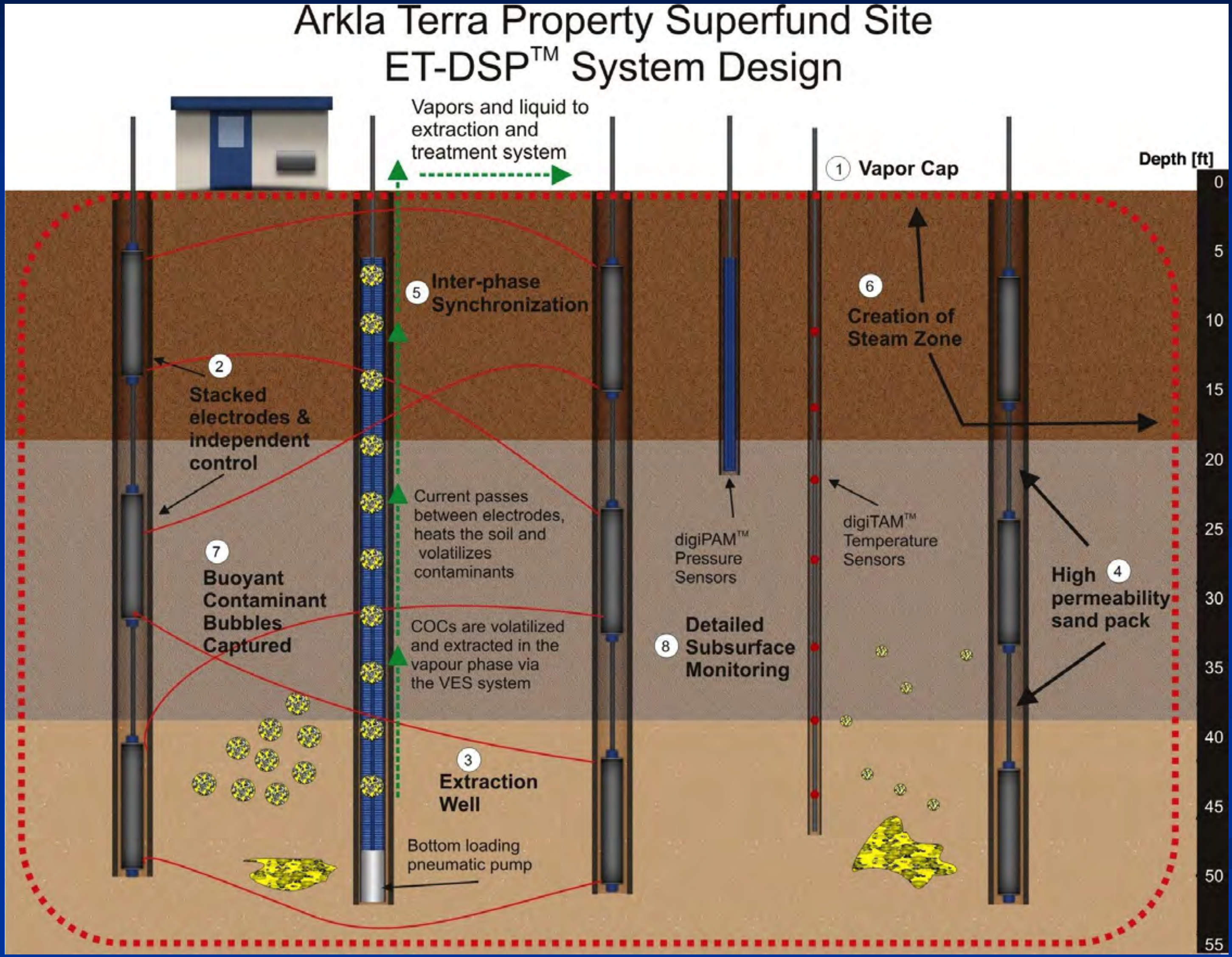
- Soil with hydraulic conductivity less than 10e-3cm/sec
- Layered stratigraphy; clay layers and lenses
- NAPL and source area remediation
- Where other technologies have no chance of meeting a remediation goal or timeline

Application of ET-DSP™

- Need a performance GUARANTEE?
- Fixed cost
- Subject to adequate site characterization and site parameters

- Whatever is “In The Box” gets heated

Typical Subsurface Design



Where is ET-DSP™ Not Used?

- Operating facilities
- Bedrock. Needs to conduct electricity
- Non volatile, PCBs
- High uncontrolled groundwater gradient
- Excessively high conductivity

In-Situ Thermal Remediation

Will Heat Help?

Thermally Enhanced Remediation Mechanisms

Primary Removal Techniques:

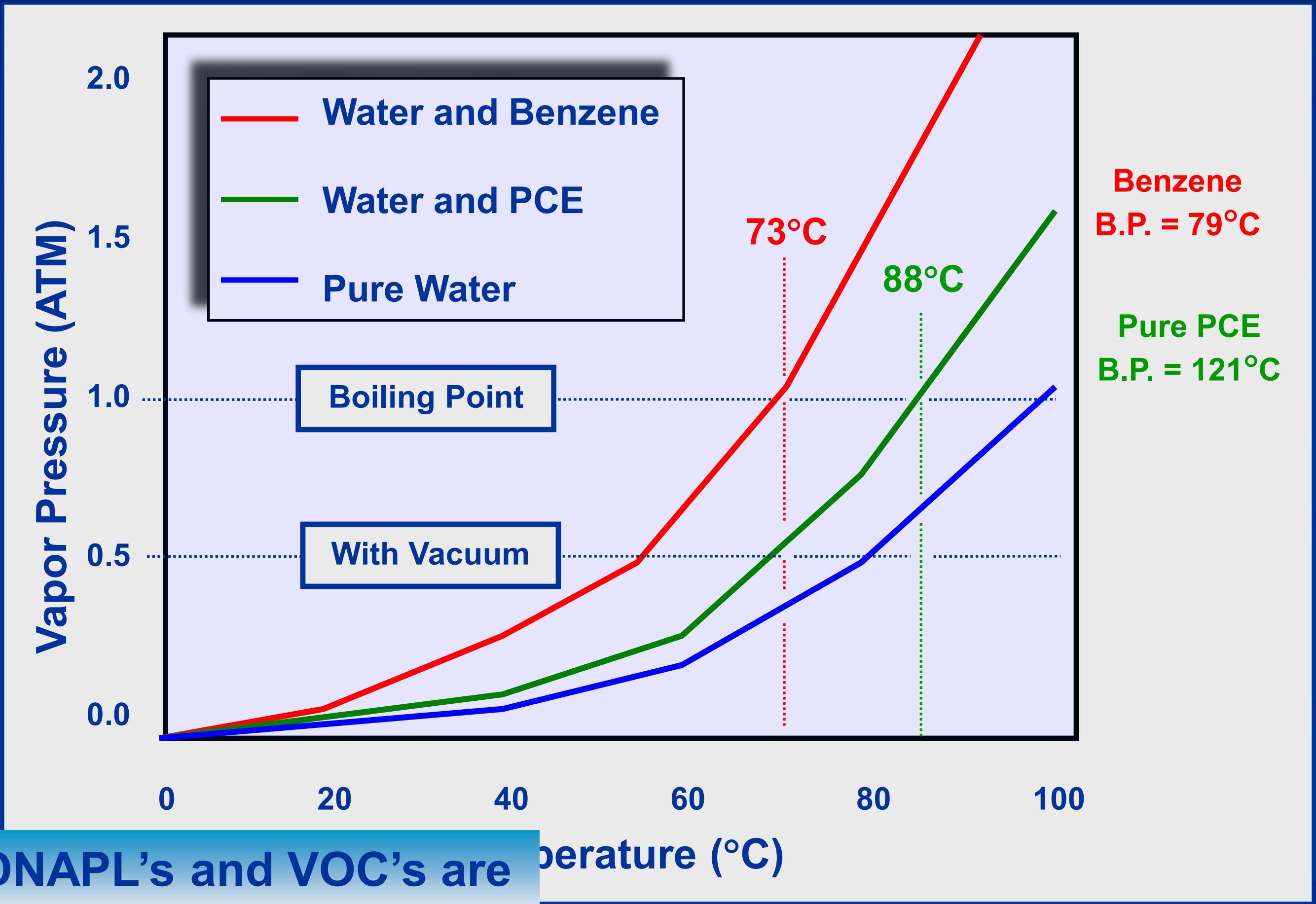
- ***V*****aporization** of volatile and semi-volatile organic compounds (*Dalton's Law of partial pressures*)
- ***Dynamic Stripping*** (*Henry's Law Constant*)
- ***Mobility Improvement*** (*Viscosity reduction and thermally enhanced permeability*)

Additional Considerations:

- ***Thermal Hydrolysis*** (*Arrhenius temperature rate dependence*)
- ***Accelerated Bioremediation*** (*Thermophilic and Extremophilic metabolism*).

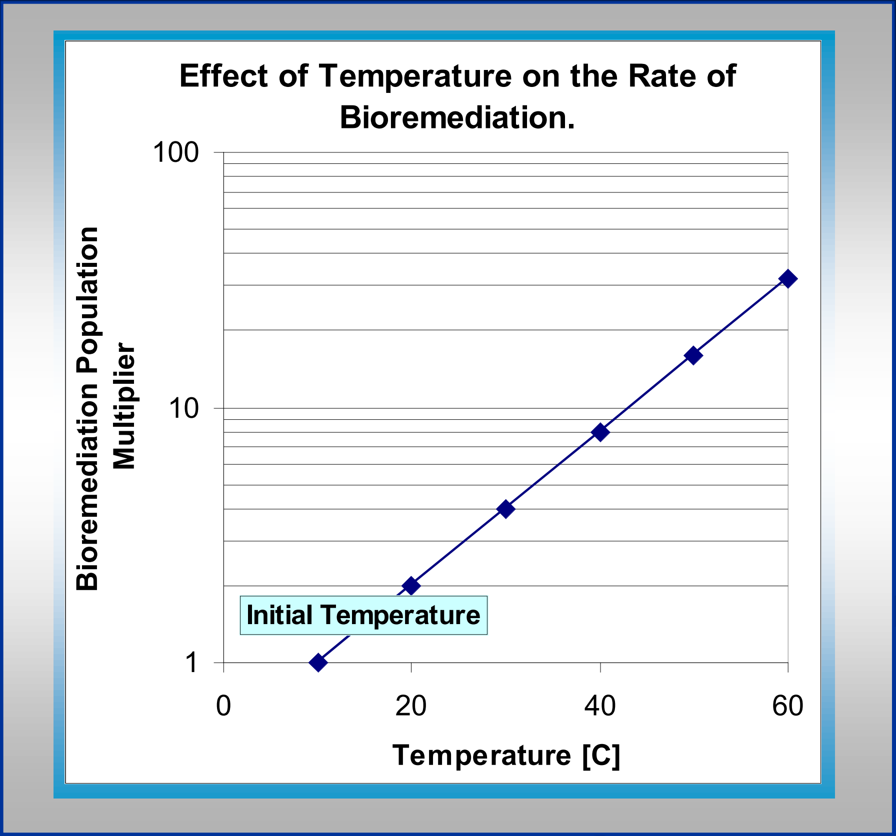
Why Heat Helps

Vapor Pressure-Temperature Relationship



Once the DNAPL's and VOC's are volatilized they can be easily and rapidly recovered from the soil at multi-phase extraction wells.

Heat and Bioremediation



Once the soil is heated the rate of temperature decline is about ¼ ° C per day resulting in a long duration of accelerated natural attenuation.

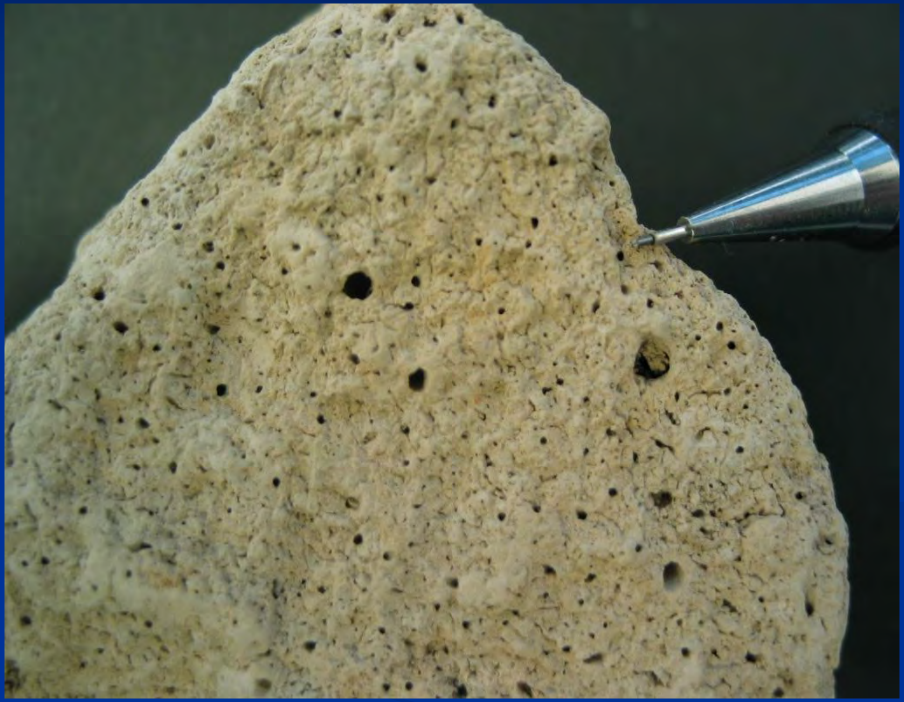
Source: "Analysis of Selected Enhancements for Soil Vapor Extraction", EPA Report EPA-542-R-97-007

Target Temperature for Treatment Zone was 80 Degrees C

- Boiling Point of MTBE = 55.2 Degrees C
- Boiling Point of Benzene = 80.1 Degrees C

Creating Permeability

- Clay/Silt soils heat first
- Steam generated in-situ
- Steam pressure generates secondary porosity
- Contaminants mobilized for capture

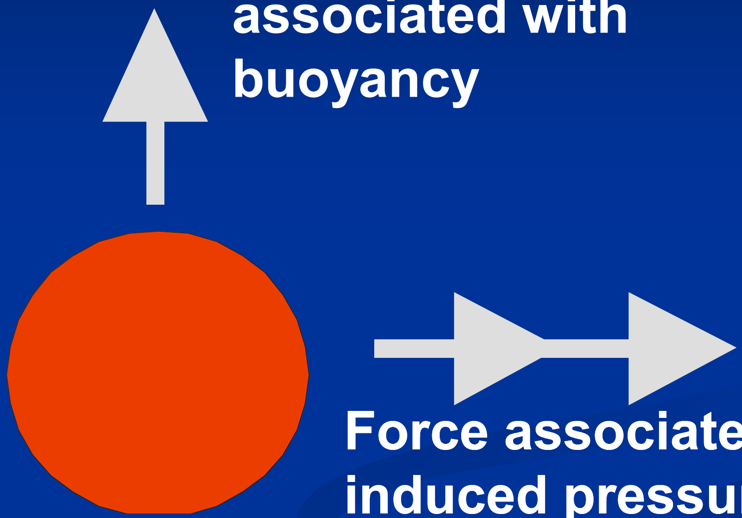


Heat and Mass Transfer

A molecule of hydrocarbon vapor

After Heating

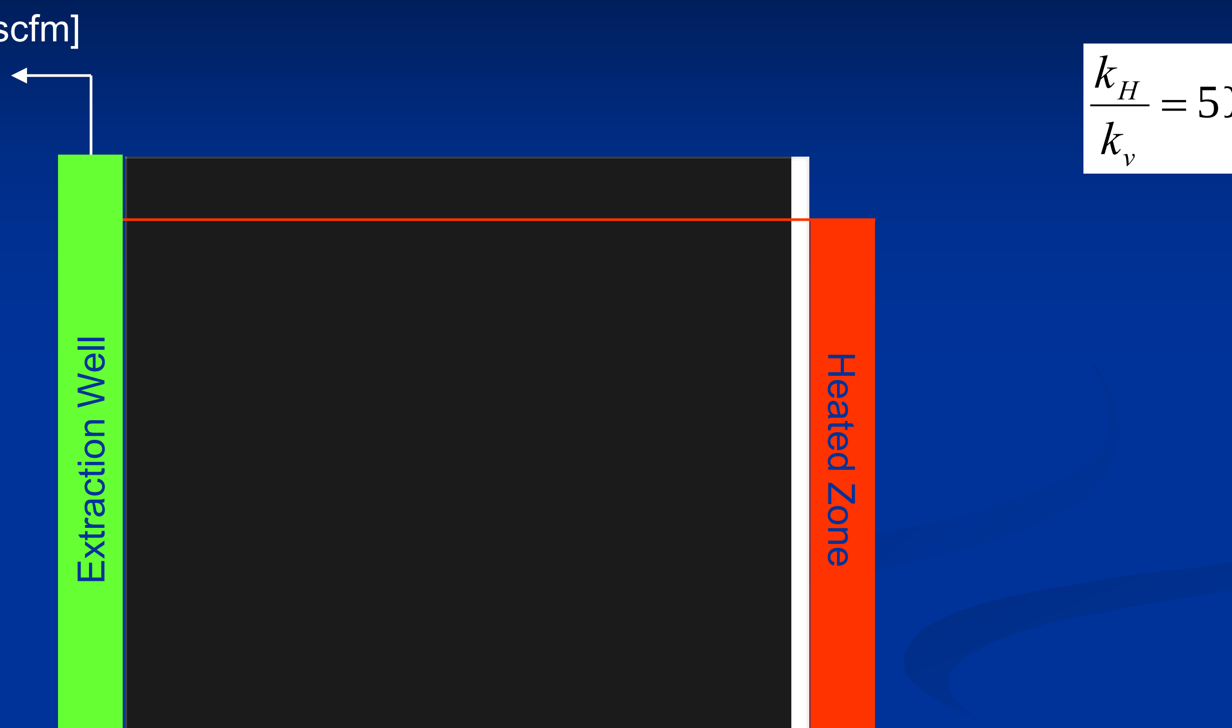
Upward force associated with buoyancy

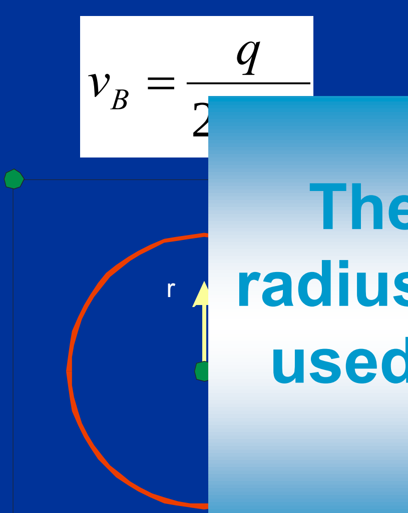


Force associated with induced pressure gradients that fall within the radius of influence.

gradients now must fall within the radius of capture.

Flow Dynamics

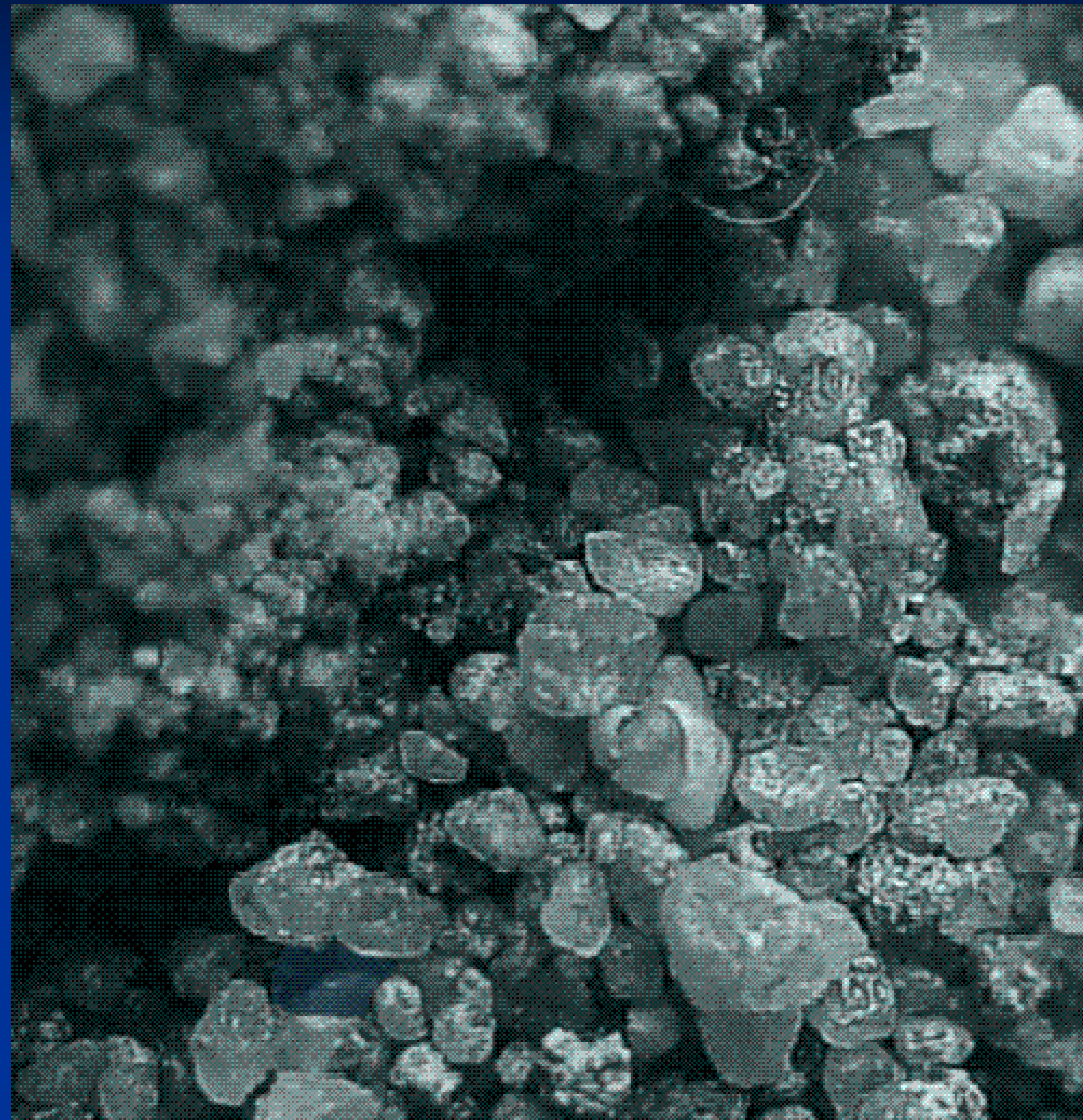




The radius of capture is usually less than the radius of influence and therefore a HVE System is used to prevent vertical migration of the vapors and redistribution of contaminants.

Vapor Transport in the Soil

Much of the vapour phase created by in-situ thermal remediation methods flow throughout the soil as entrained bubbles.



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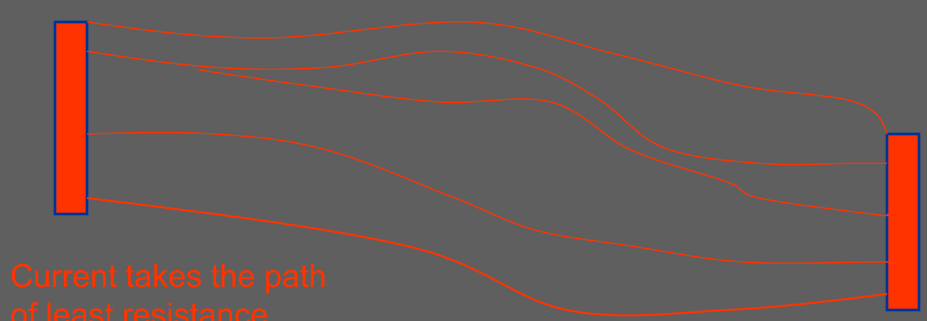
Why Electrical Heating

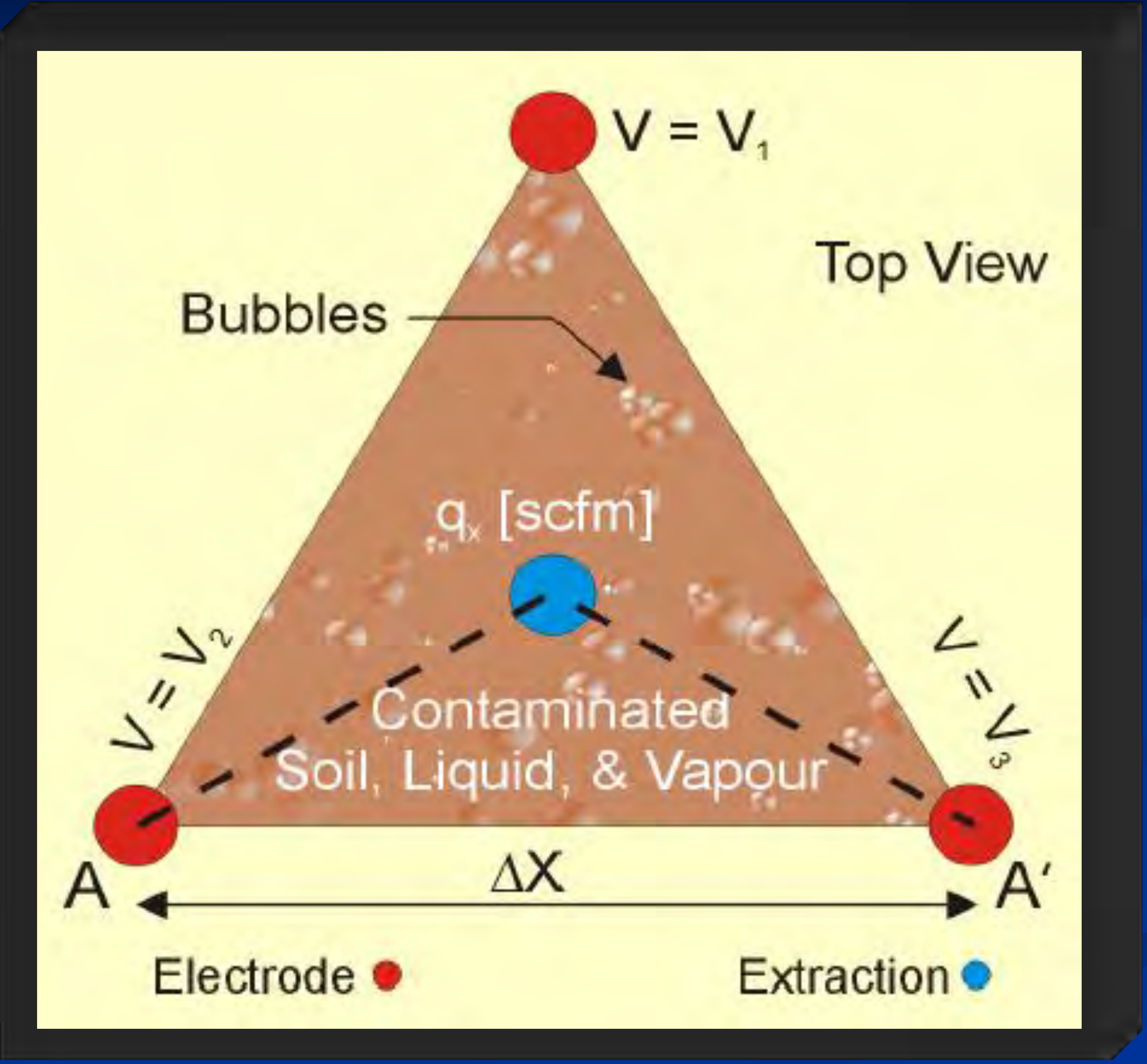
- ***C***urrent can be focused in the soils so little of the energy is wasted. The conduction path is the soil and is where energy dissipation occurs.
- ***G***etting heat into the formation is not limited by depth or the permeability of the soil and during heating permeability is created through a process of micro-fracturing (thermal expansion and high pore pressure release).
- ***S***afe and simply technology to operate and integrates seamlessly with other conventional in-situ remediation technologies such as SVE and bioremediation.
- ***F***or NAPLS, the success of the remediation of the immiscible DNAPL does not depend on knowing the detailed distribution in-situ.



Example animation of a DNAPL spill in a heterogeneous porous medium. Source: Queen's University.
civil.queensu.ca/environ/groundwater/p16_2b.htm

Heat Transfer

1. Conduction- Hot electrode
2. Electrical Resistance – Clay
3. Convection- Hot water flow



V = V1
Top View
Bubbles
qx [scfm]
V = V2
V = V3
Contaminated
Soil, Liquid, & Vapour
A
ΔX
A'
Electrode
Extraction

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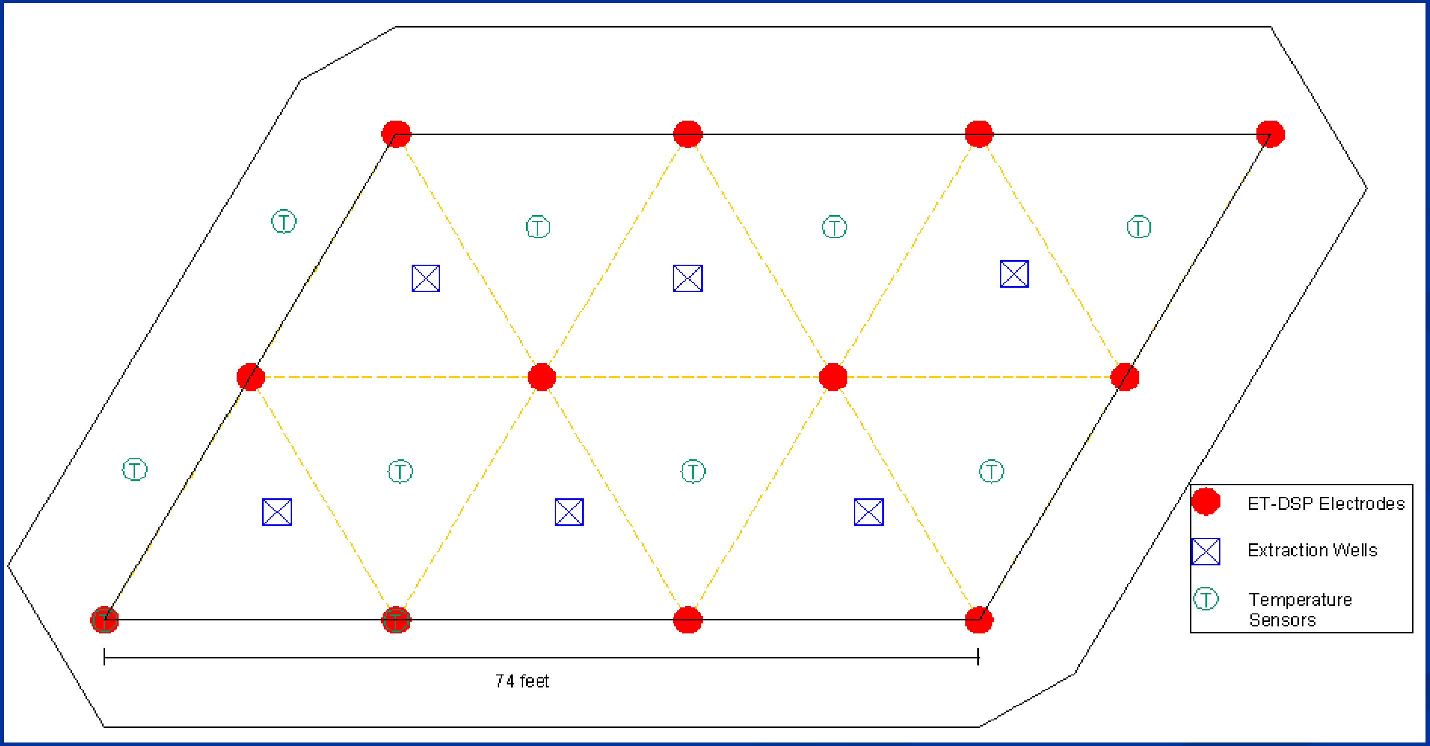
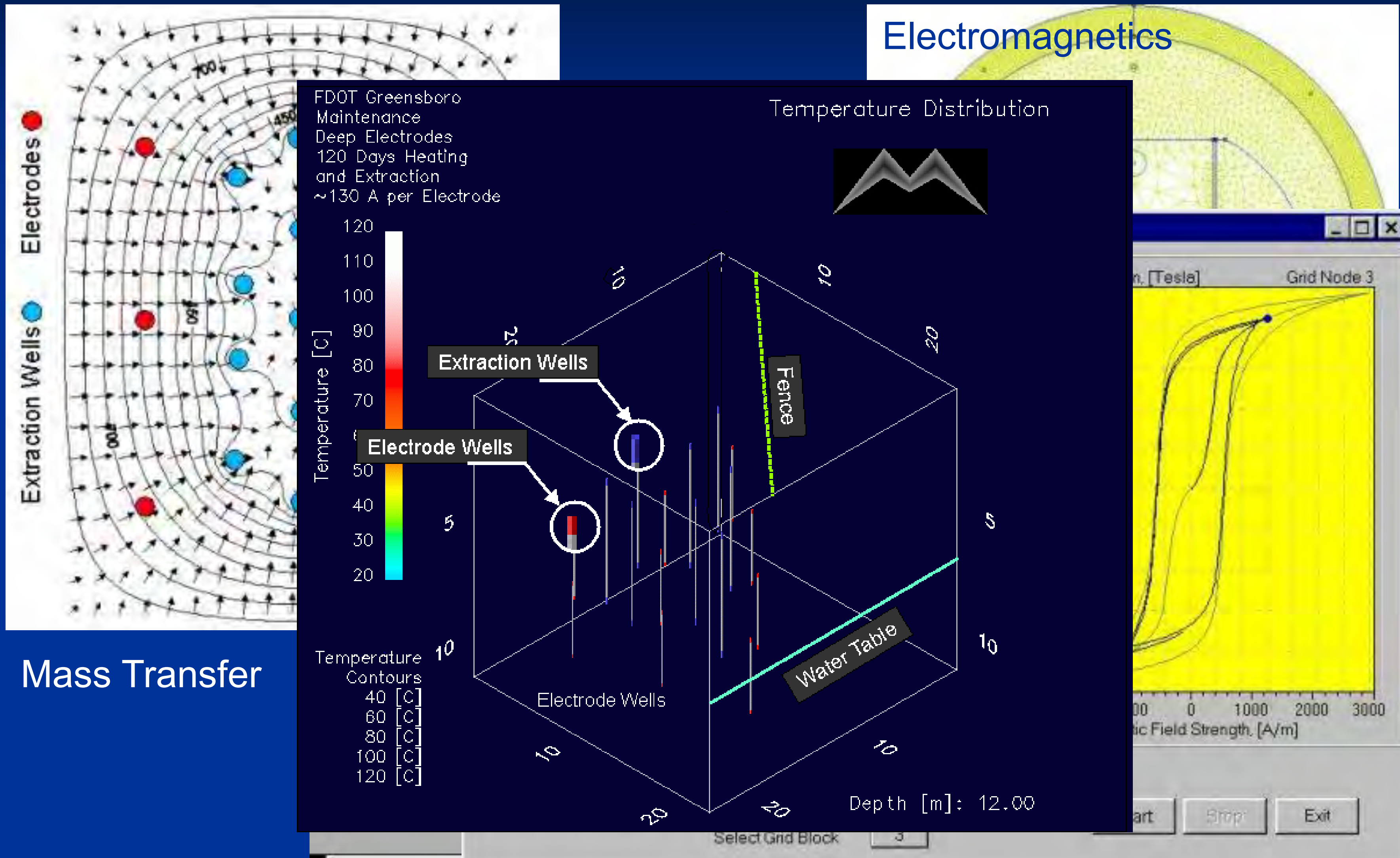
…Examples Cont.

One PDS with 12 electrodes = 5,400 ft^2 and 3,200 yds^3

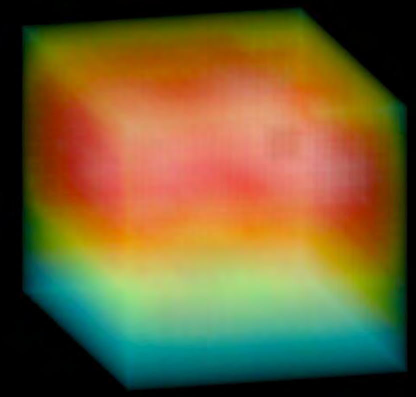


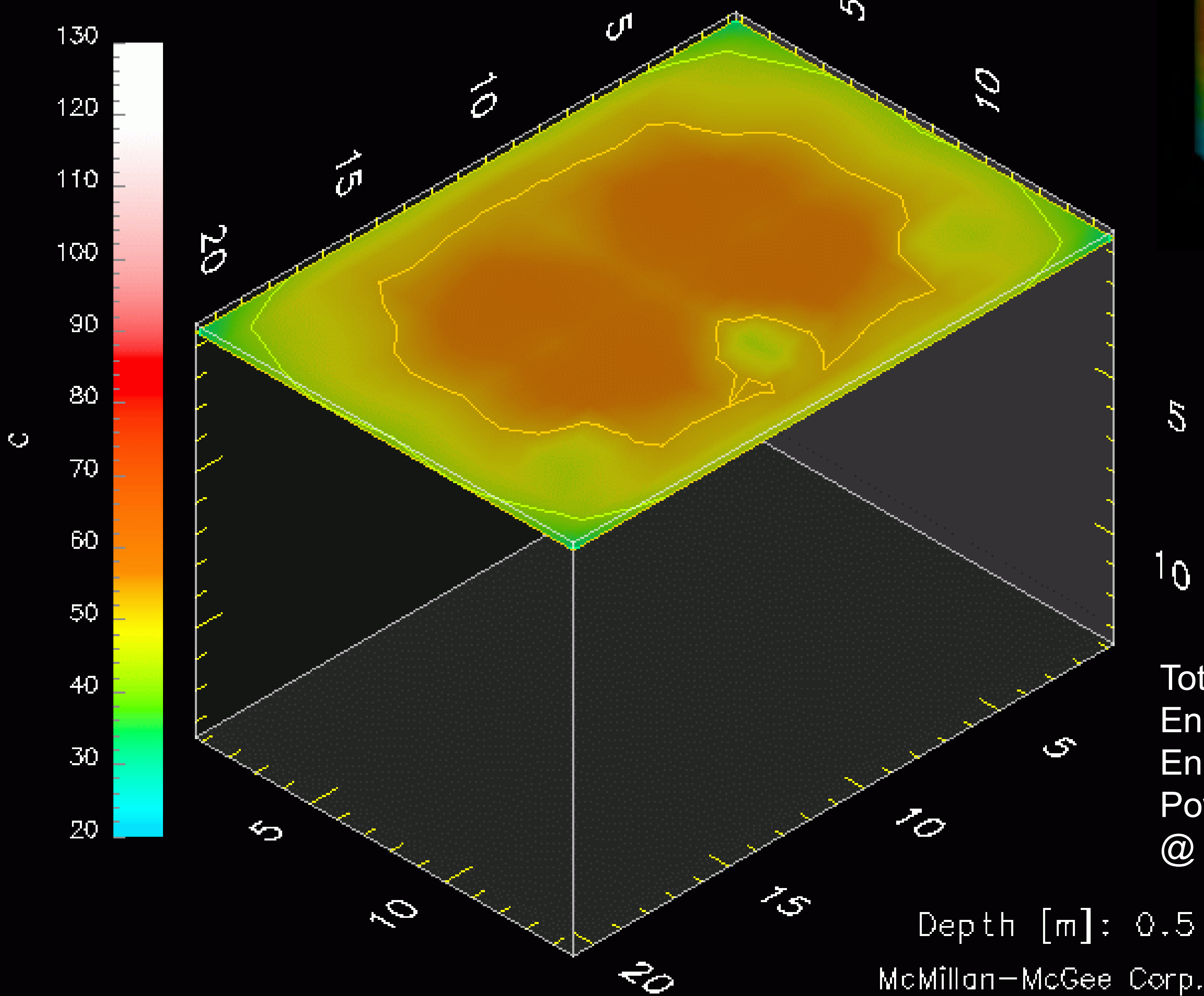
Numerical Modeling



Mass Transfer

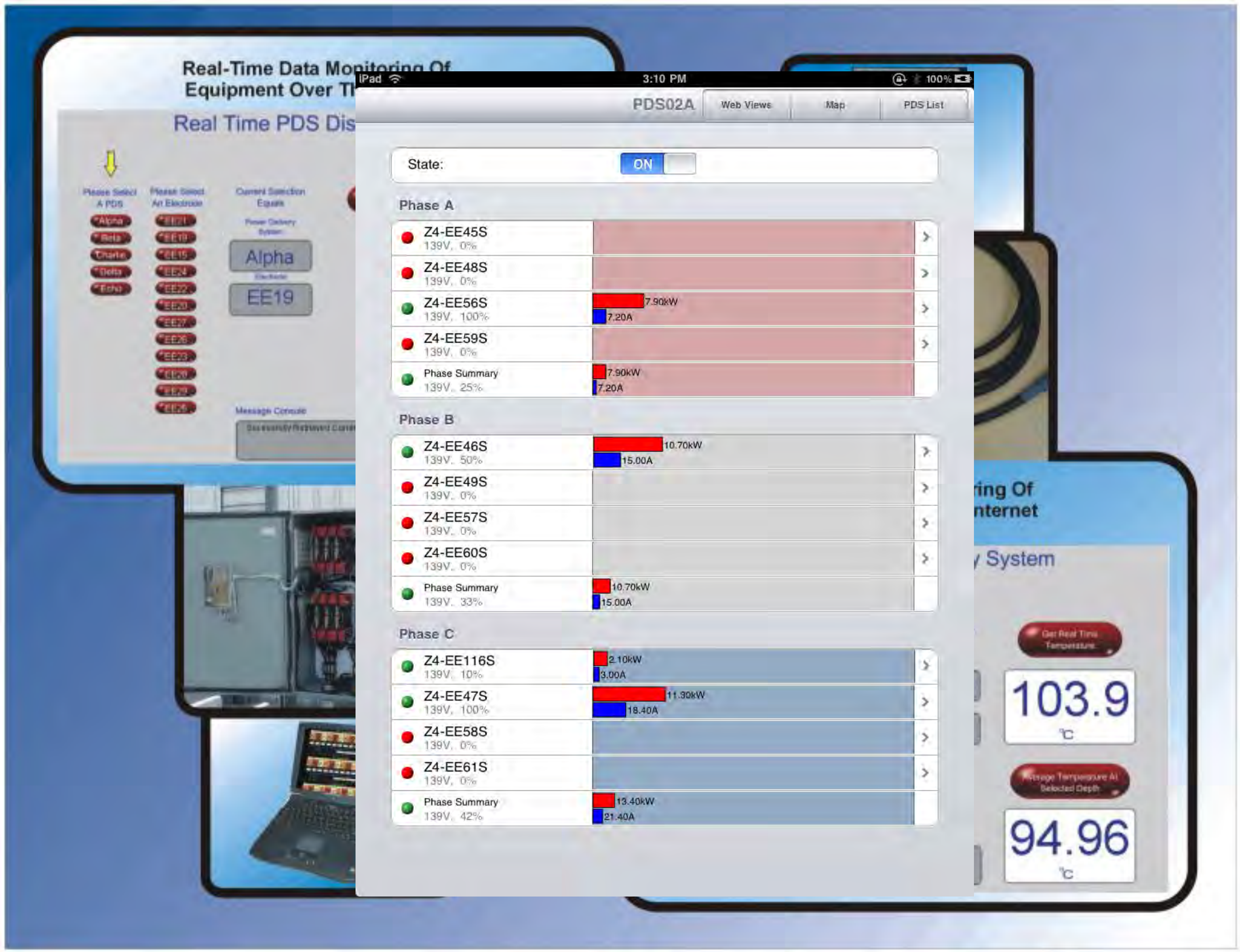
Heat Transfer





Total Volume: 4,150 m3
Energy: 547,000 kWhr
Energy: 132 kWhr/m3
Power Cost: $7.91/m3
@ $US0.06 per kWhr

Real Time Internet Based Data Monitoring



ET-DSP™ Components

Electrodes

- up to 10-feet long
- 8 to 10-inches in diameter
- Installed in a 10 to 12-inch borehole to the appropriate depth
- The effective length of a single electrode is 16-18 feet
- Designed to be abandoned in place

Power Delivery System

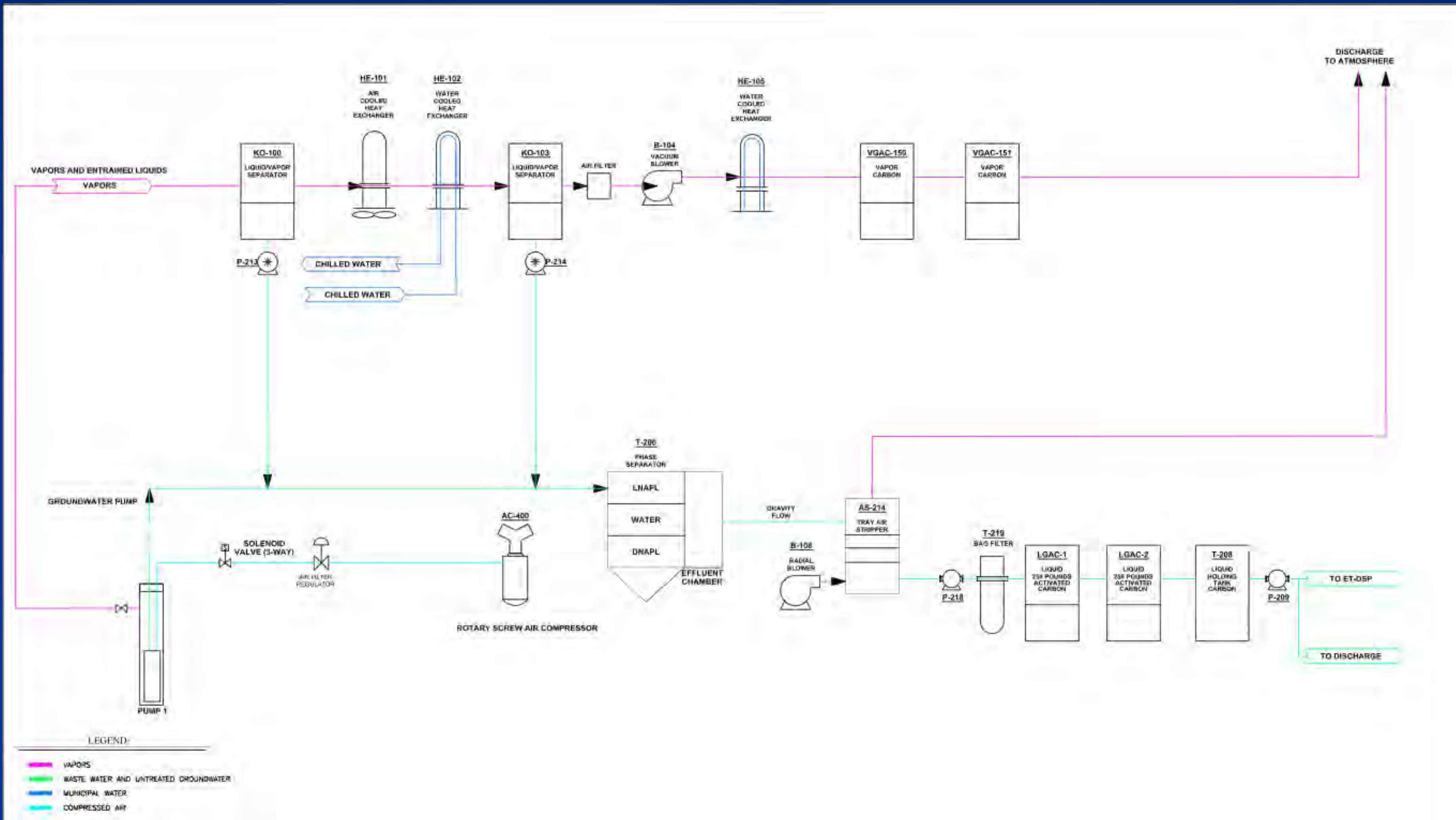
- 600/480 Volt primary
- Multi-tap secondary
- ET-DSP™ control logic
- Web-ready with complete internet connectivity

Water Circulation Systems

- Each WCS is mated to a PDS in a master/slave configuration
- Independent control for each electrode
- ET-DSP™ control logic
- Fully web enabled and controlled via Internet

Treatment System

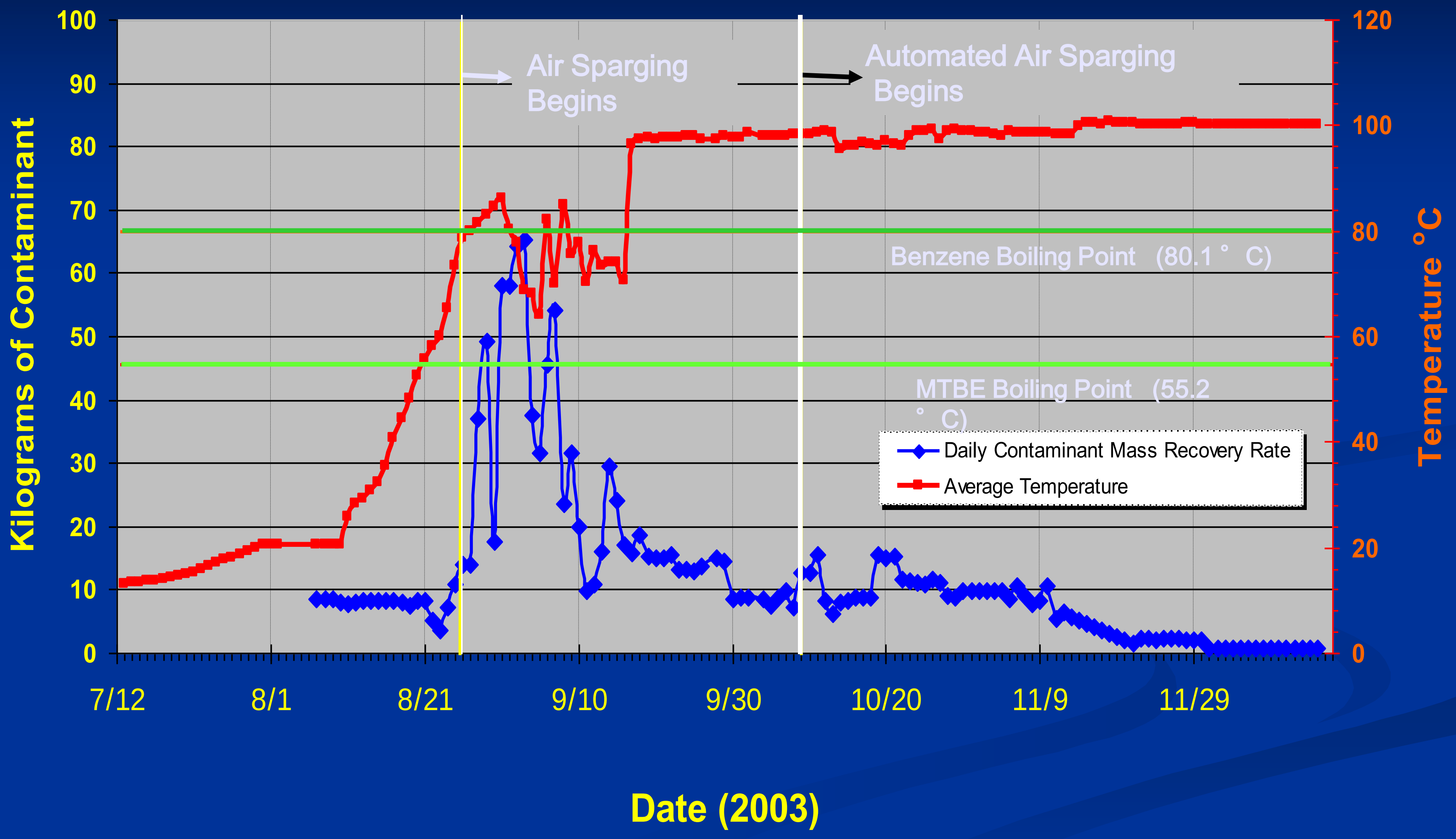
Simple Process Flow Diagram



Preparing to lower an electrode

Electrode/AS/SVE Layout

Daily Contaminant Mass Recovery Rate and Temperature



Groundwater Samples - Pre ERH (red), Post ERH (black)

SAMPLE ID	Sample Date	MTBE	Benzene	Toluene	Ethylbenzene	Total Xylenes	Naphthalene	C9-C10 Aromatics	C5-C8 Aliphatics	C9-C12 Aliphatics	Total Purgeable Hydrocarbons
WQB-7 Human Health Standard	------	30	5	1,000	700	10,000	28	None	None	None	None
Proposed RBSL for Groundwater	------	30	5	1,000	700	10,000	28	100	350	1,000	1,000
HW-93-2	4/23/03	980	28,500	36,400	2,950	18,900	529	21,100	112,000	31,500	165,000
HW-93-2	12/19/03	Not enough water present in new slant well to sample.									
DT-01@23’	6/25/03	58,700	3,050	1,980	156	776	31	338	60,200	488	55,000
DT-01 @ 23’	12/19/03	ND	ND	ND	ND	ND	ND	ND	21	ND	25
DT-01 @ 23’ (duplicate)	12/19/03	ND	ND	ND	ND	1.4	ND	ND	22	24	35
DT-05@ 23’	7/02/03	22,200	3,280	7,110	382	1,950	51	950	89,000	662	85,400
DT-05 @ 23’	12/19/03	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DT-07@ 23’	7/02/03	8,570	1,470	2,410	148	798	40	431	10,500	386	13,400
DT-07@ 23’	12/23/03	ND	ND	ND	ND	ND	ND	ND	23	ND	24

ET-DSP Highlights

- Total run time – 180 days
- Complete removal of BTEX and MTBE in the target zone.
- <u>Total Cost: $500,000 +</u>
- Includes drilling, electricity, equipment rental etc.

Orlando

Tampa Wellfield

Tampa

Select Projects & Site Photos

- Private Site - Atlanta
  - Area:~1,200 m^2
  - Volume: ~42,000m^3
  - Duration: 9 months
  - Mass Removal: ~200,000 kg

Select Projects & Site Photos

- Grants Superfund Site
  - Area:~3,000 m^2
  - Volume: ~25,000m^3
  - Duration: 6 months
  - Most confirmatory samples non-detect
  - Mass Reduction: >99%

Questions?

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