PUMP-AND-TREAT CONVERSION TO IN SITU *BIOREMEDIATION FOR TREATMENT OF PERCHLORATE IN GROUNDWATER*

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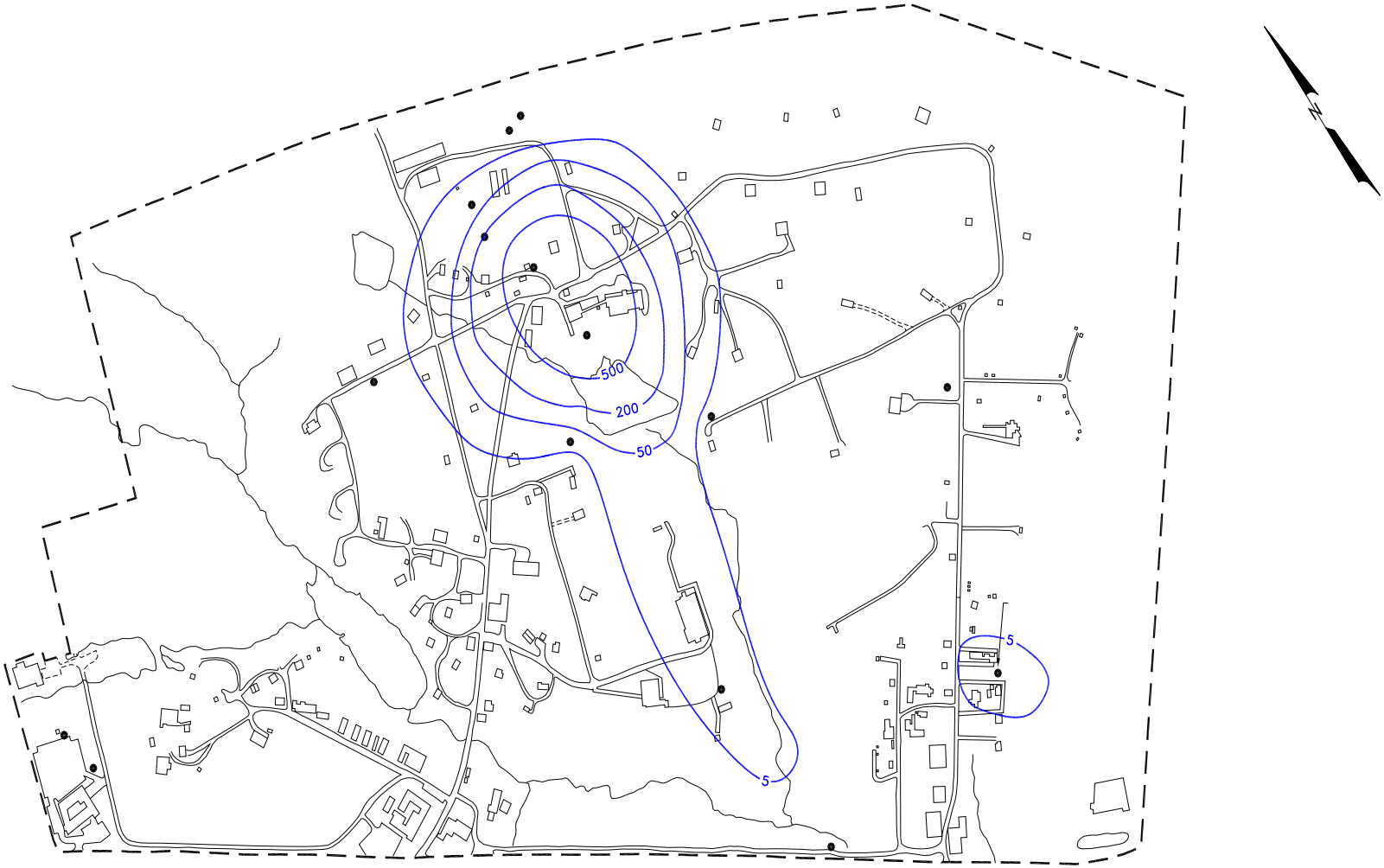
Background

- Former 450-acre RCRA facility
- 220 buildings on site
- Conducted RFI for VOCs in late 1980s
- Implemented Corrective Actions for VOCs:
  - Soil excavation for on-site treatment
  - Initiation of long-term pump & treat for deep groundwater impacts



TOTAL VOCS (PPB) NOVEMBER 1993

ND: NON-DETECT

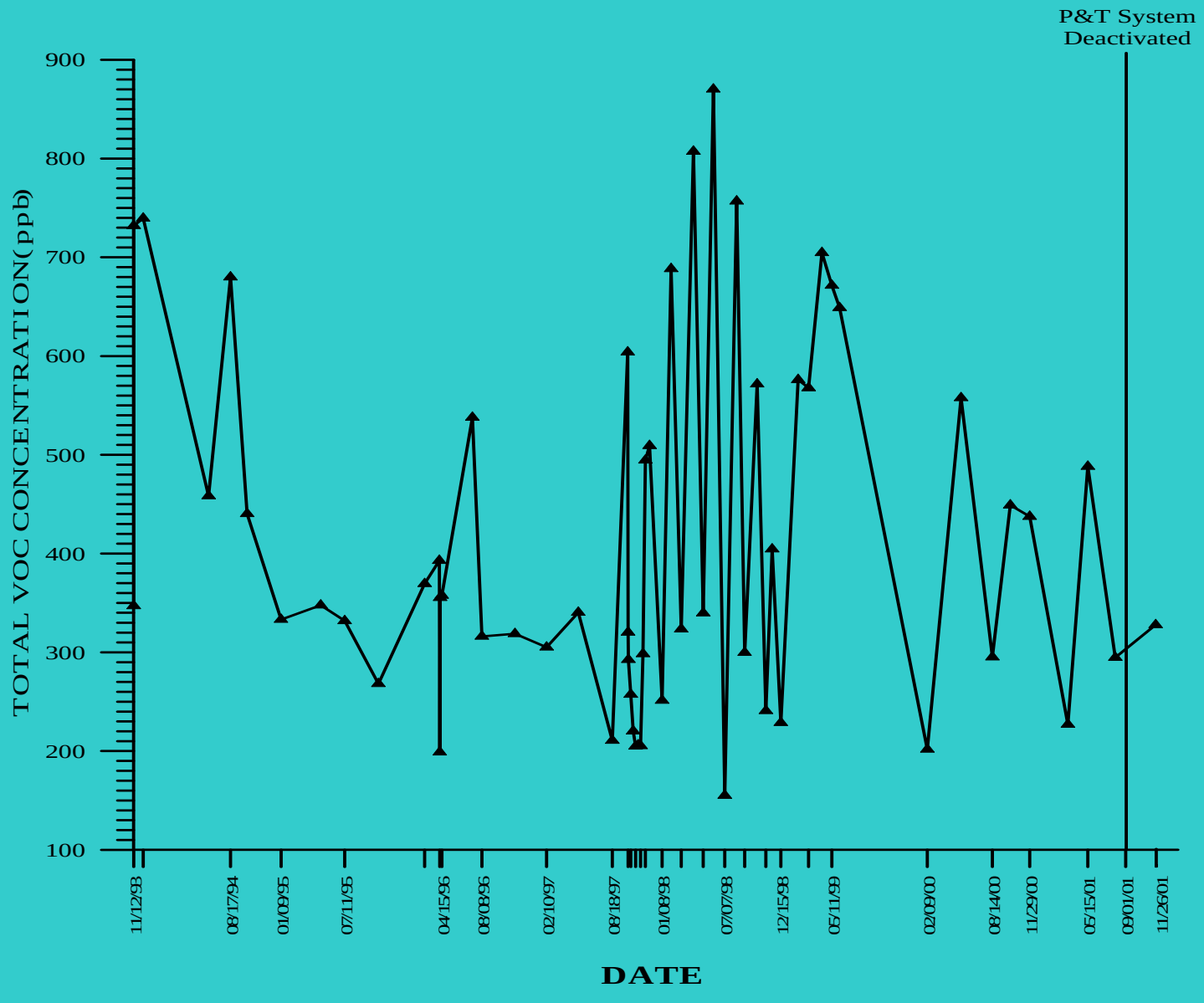
——— ISOCONCENTRATION LINE IN PARTS PER BILLION (ppb)

NOTE: ISOCONCENTRATION LINES ARE INRERRAL BASED ON AVAILABLE DATA

0' 700'

FEET
(APPROXIMATE SCALE)

TOTAL VOLATILE ORGANIC COMPOUNDS (VOCs) CONCENTRATION OVER TIME AT EXTRACTION WELL FORMER P&T SYSTEM



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Background (cont.)

- Pump & treat system effective:
  - Hydraulic control of VOCs plume
- In 2001, perchlorate detected in deep groundwater pump effluent
- Consequently, initiated Supplemental RFI to investigate presence of perchlorate
- Facility closed/relocated operations
- Property preparing for redevelopment

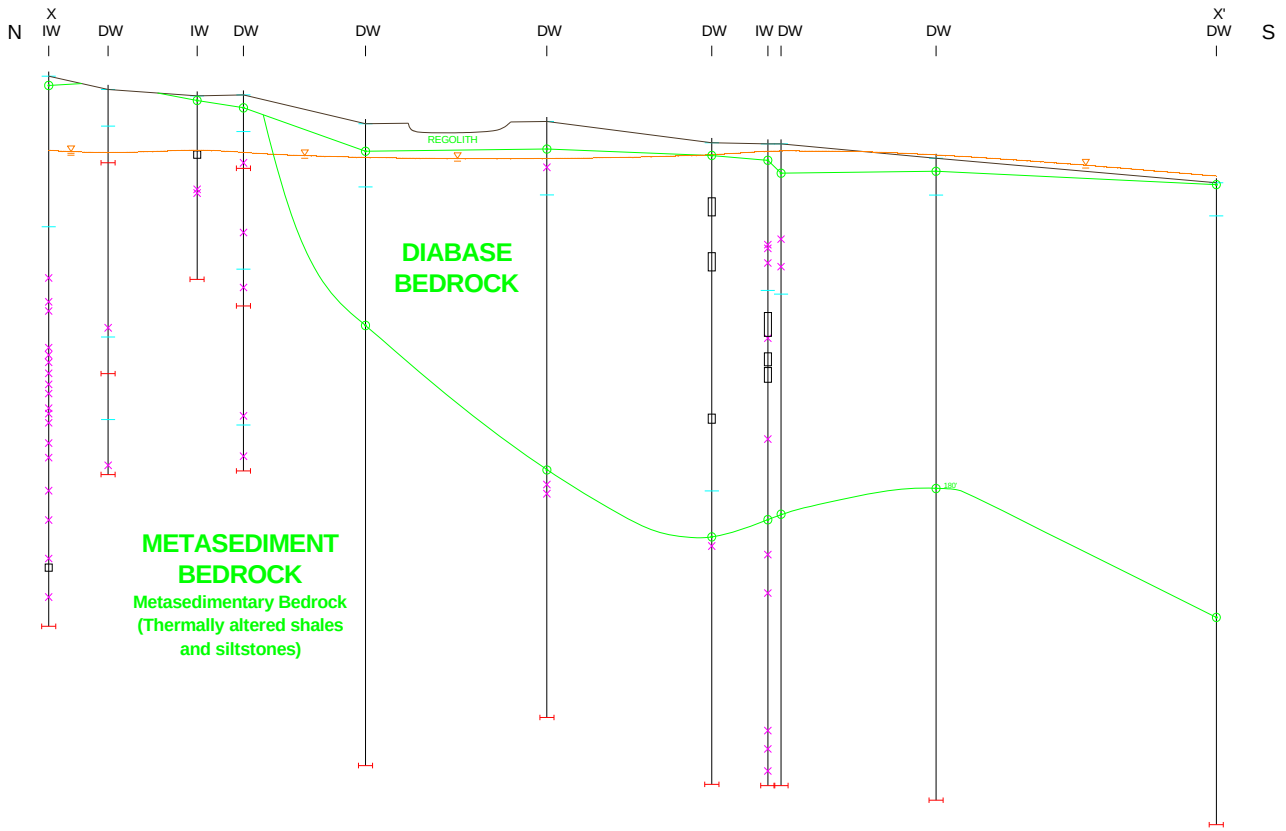
Perchlorate

- Anion of ammonium perchlorate (AP) – major component of solid rocket fuel
- Highly soluble, generally non-reactive under environmental conditions
- Toxicological studies have linked perchlorate to thyroid disfunction
- Currently only 2 states have drinking water standard (CA, MA)

Geologic Conditions

- Jurassic diabase:
  - Up to 300-feet thick
  - Absent of fractures/water-bearing zones
- Triassic metamorphosed siltstone / sandstone (metasediments):
  - Outcrops in north-central portion of site
  - Overlain by diabase over 2/3 of site
  - Highly-fractured and water-bearing
- Regolith:
  - Thin alluvial/saprolitic layer
  - Creates shallow (perched) groundwater zone

Geologic Cross-Section



HORIZONTAL SCALE: 1"=300'
VERTICAL SCALE: 1"=60'
VERTICAL EXAGGERATION: 5x

LEGEND

- Interpreted Lithology Contact
- Potentiometric Surface DGW 11/29/05
- Above Grade Potentiometric Surface DGW 11/29/05
- Top of open borehole/screen interval
- Bottom of open borehole/screen interval
- Fracture

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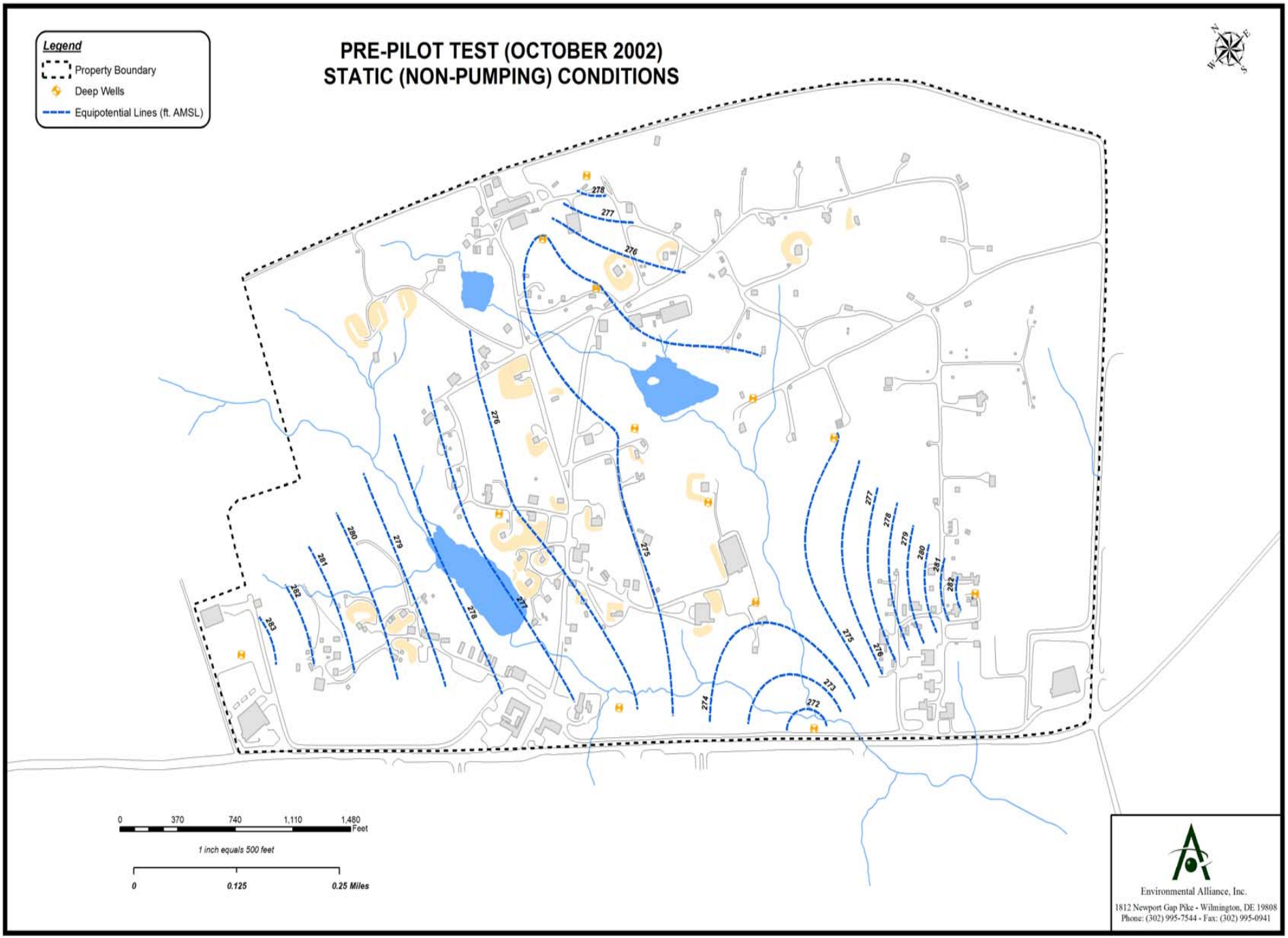
Supplemental RFI – Initial Results

- Installed 37 deep groundwater monitoring wells to depths of 300 to 350 feet
- Installed 224 shallow groundwater monitoring wells to top of bedrock (~10 to 15 feet bgs)
- Identified deep groundwater perchlorate plume:
  - Generally same extent as VOCs plume
  - Perchlorate concentrations exceeded 8,000 ppb
- Implemented phased pilot testing of deep groundwater recirculation system:
  - Maintain hydraulic control of perchlorate & VOC plumes
  - Extract groundwater, treat for VOCs, amend treated water with electron donor substrate, reinject upgradient
  - Electron donor to stimulate biologically-mediated anaerobic reduction of both perchlorate and VOCs

Pilot Test Phase 1

- Converted 2 former P&T wells to extraction and injection wells (IWs)
- Existing air-stripper for VOCs treatment
- CMA salt substrate
- Installed downhole inflatable packer in injection well
- Identified issues with reinjection:
  - Bio-fouling
  - Mineral fouling (result of air-stripper and CMA)
  - High backpressure at injection well
  - Need for system interlock


Legend
Property Boundary
Deep Wells
Equipotential Lines (ft. AMSL)
PRE-PILOT TEST (OCTOBER 2002)
STATIC (NON-PUMPING) CONDITIONS
278
277
276
276
275
277
278
279
280
281
282
280
279
281
282
283
278
277
275
276
273
274
272
0
370
740
1,110
1,480
Feet
1 inch equals 500 feet
0
0.125
0.25 Miles
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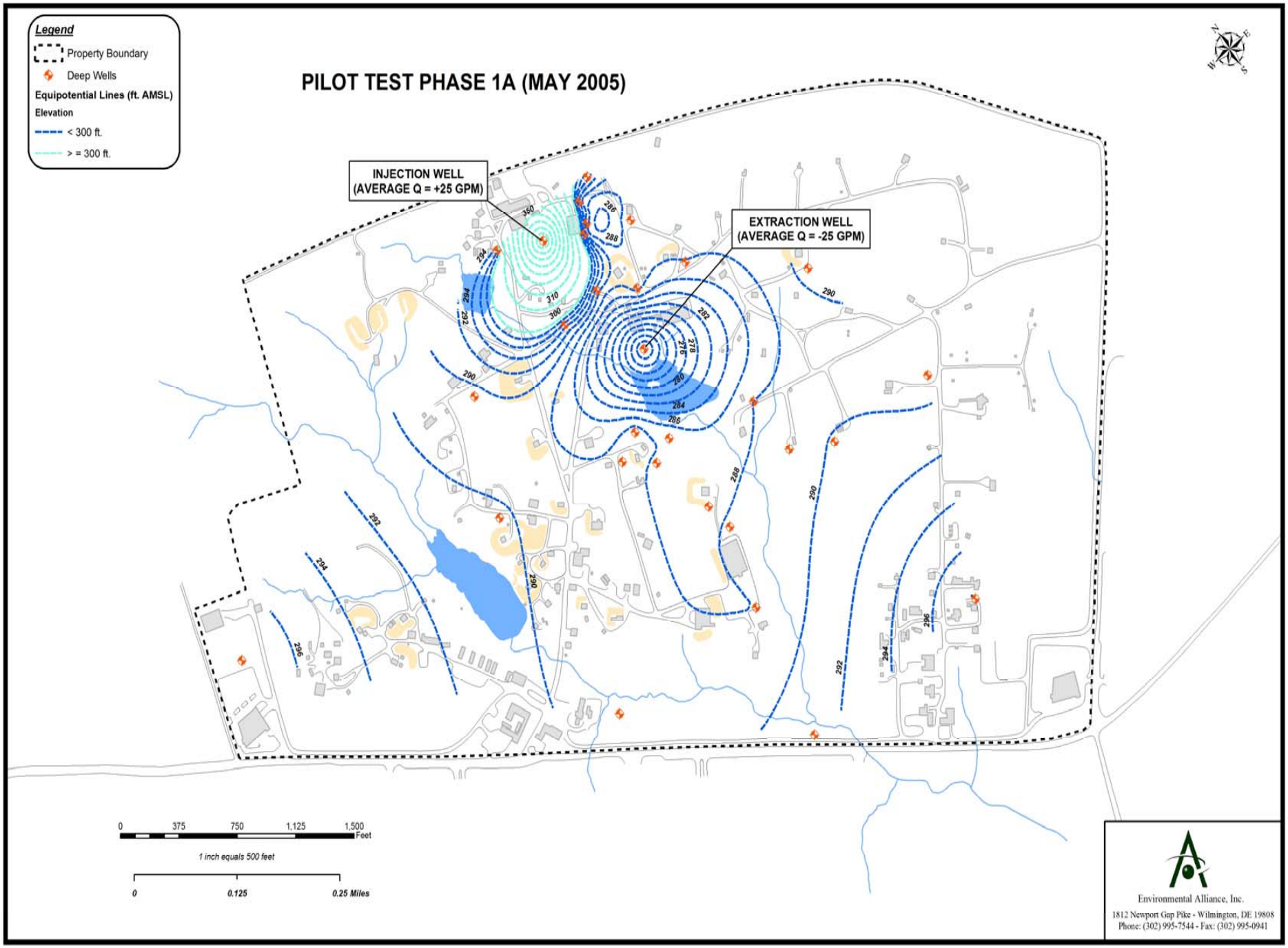
Pilot Test Phase 1A

- Installed interlock system
- Change to methanol substrate
- Change to GAC for VOCs treatment
- Install automated control unit to regulate flow and telemetary to allow remote operation and monitoring
- Batch injections to 5 southern (passive) IWs along downgradient plume edge
- Installed 3 additional IWs and injection gallery:
  - Target high-concentration source areas in north of facility identified through ongoing SRF Investigation
  - Deep and upper zones subjected to substrate addition

PILOT TEST PHASE 1A (MAY 2005)



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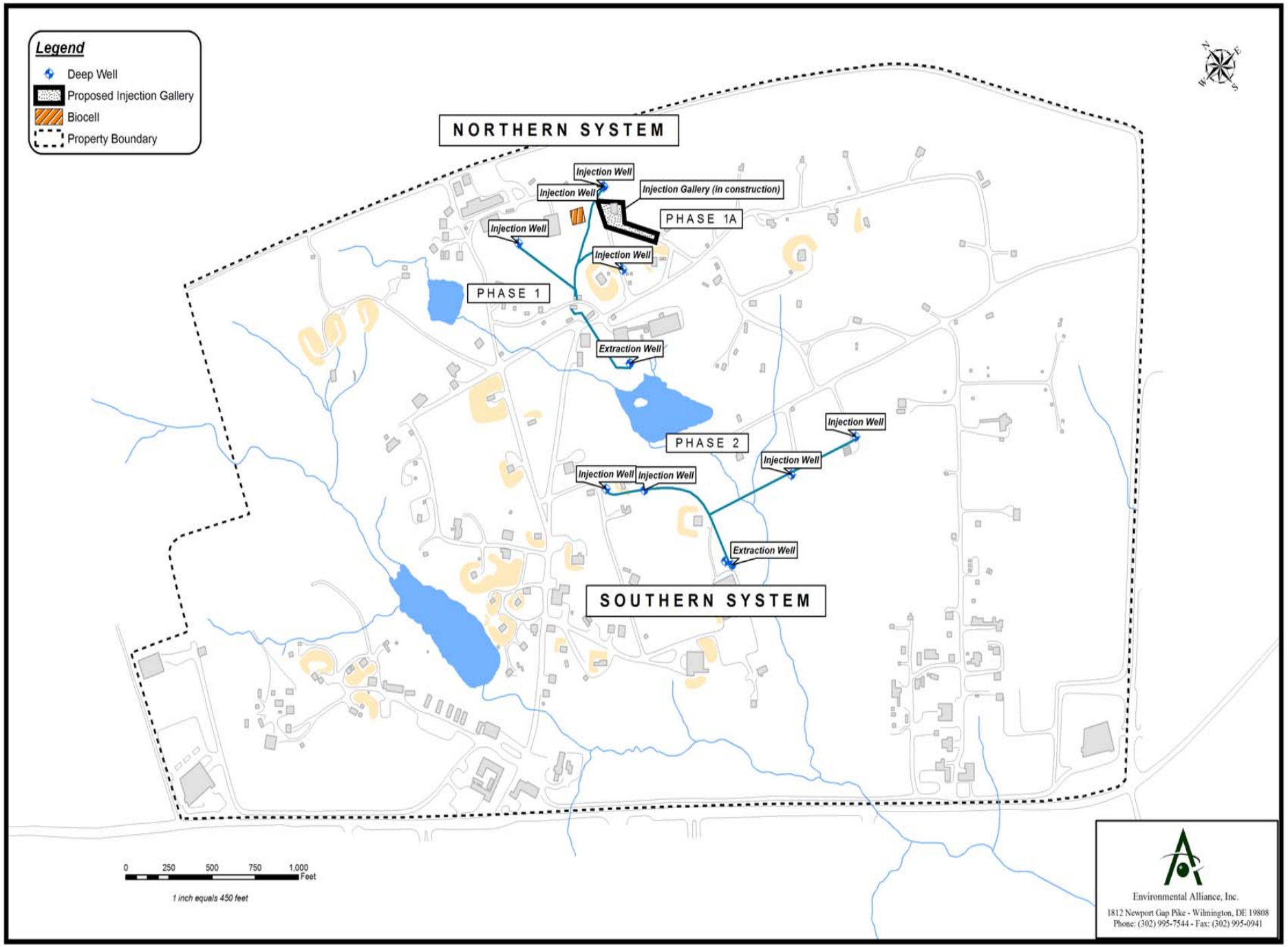
Injection
Gallery
DW-72B
CAUTION

Pilot System Phase 2

- Expand to include southern recirculation system:
  - Target southern downgradient edge of perchlorate plume
  - Reduce substrate travel/distribution times
  - Low extraction rate, low injection rate
  - Reduce labor cost
- Southern system design:
  - 1 new extraction well
  - Convert 4 former passive IWs to active IWs
  - Methanol substrate
  - Set up southern remediation compound
- Final system consists of:
  - 2 separate control units
  - 2 extraction wells
  - Over 6,200 feet of below ground piping


Legend
Deep Well
Proposed Injection Gallery
Biocell
Property Boundary
NORTHERN SYSTEM
Injection Well
Injection Well
Injection Gallery (in construction)
PHASE 1A
Injection Well
Injection Well
PHASE 1
Extraction Well
PHASE 2
Injection Well
Injection Well
Injection Well
Injection Well
Extraction Well
SOUTHERN SYSTEM
0 250 500 750 1,000 Feet
1 inch equals 450 feet
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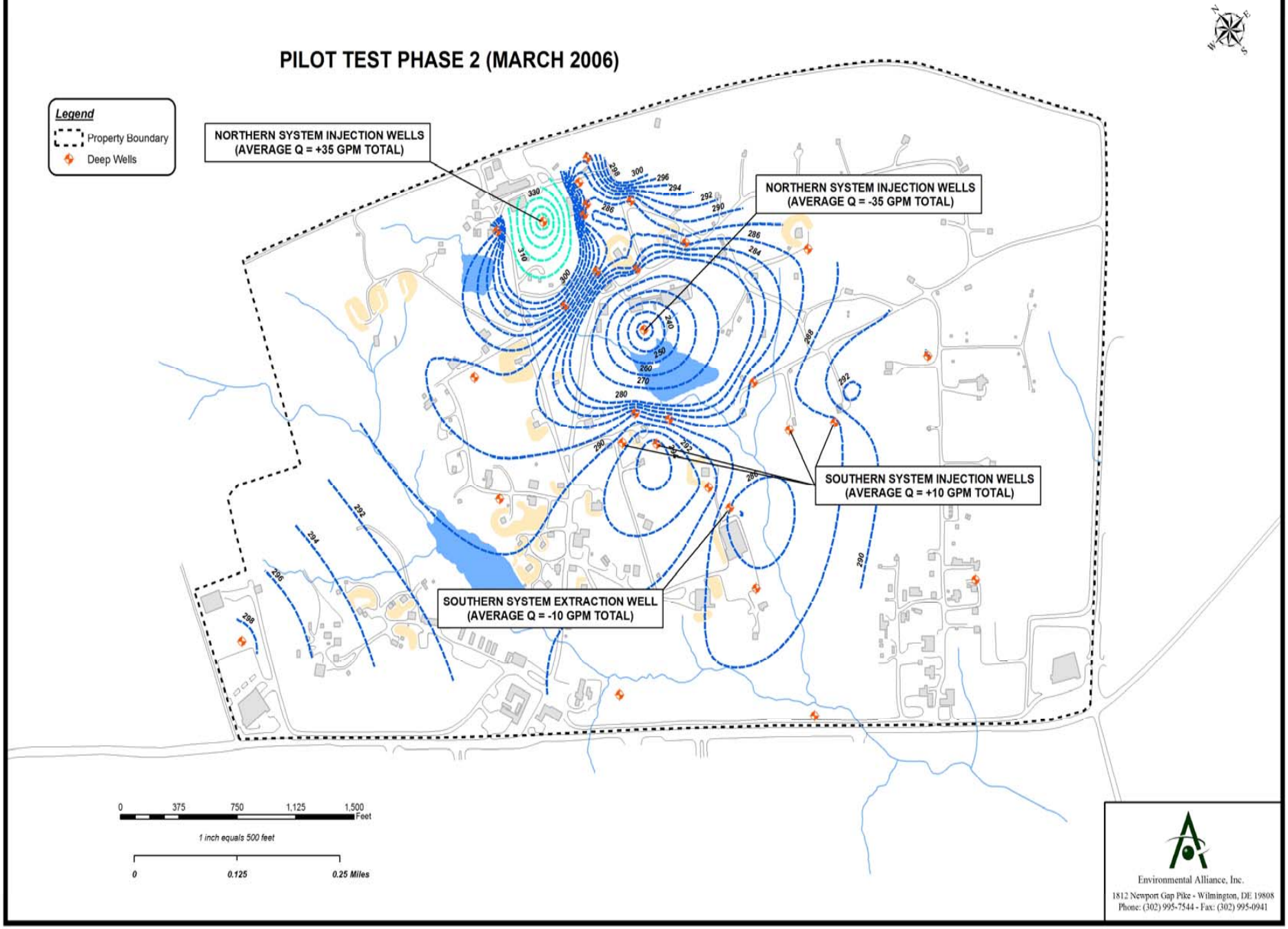
PILOT TEST PHASE 2 (MARCH 2006)



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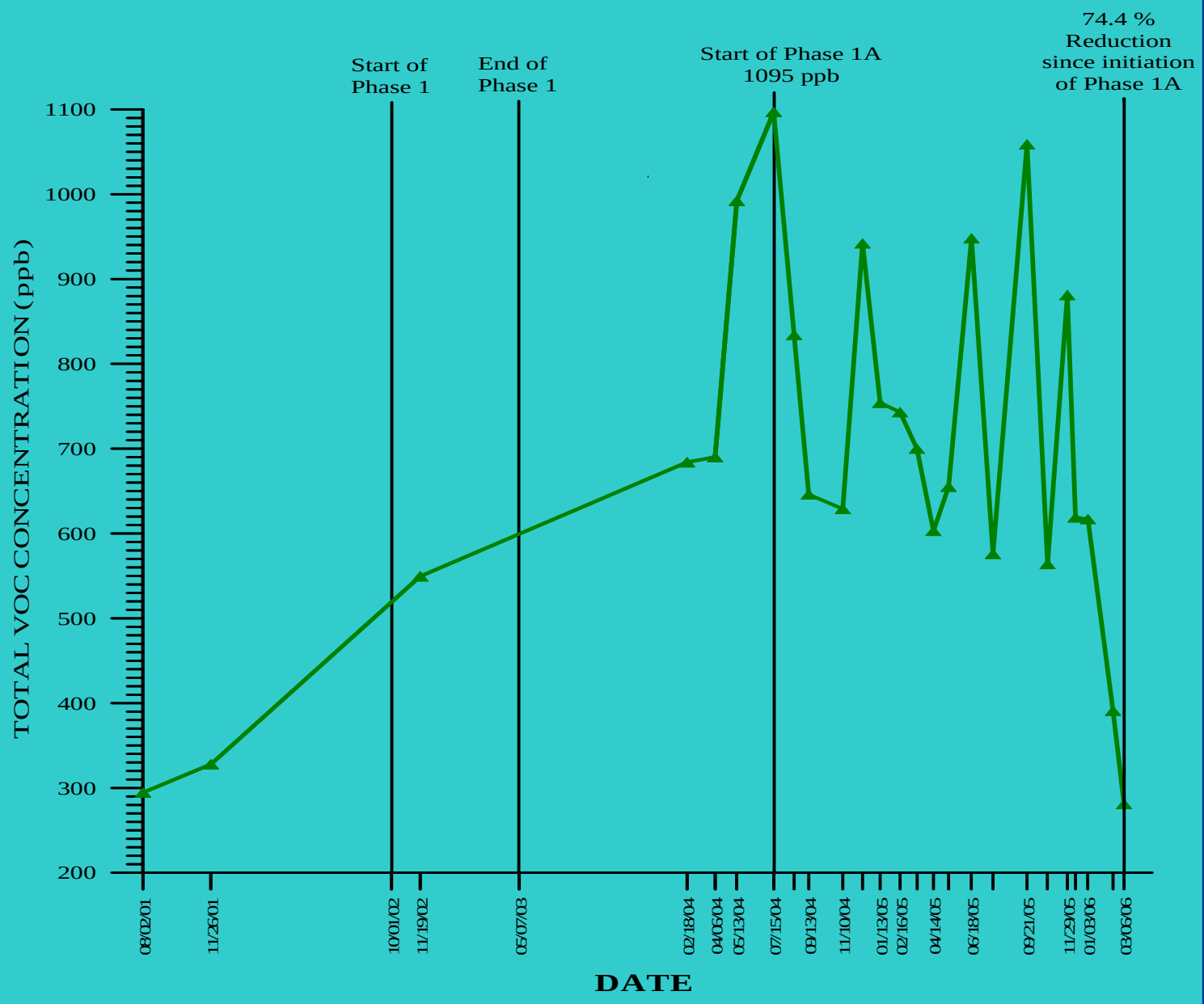
TOTAL VOLATILE ORGANIC COMPOUNDS (VOCs) CONCENTRATION OVER TIME AT EXTRACTION WELL



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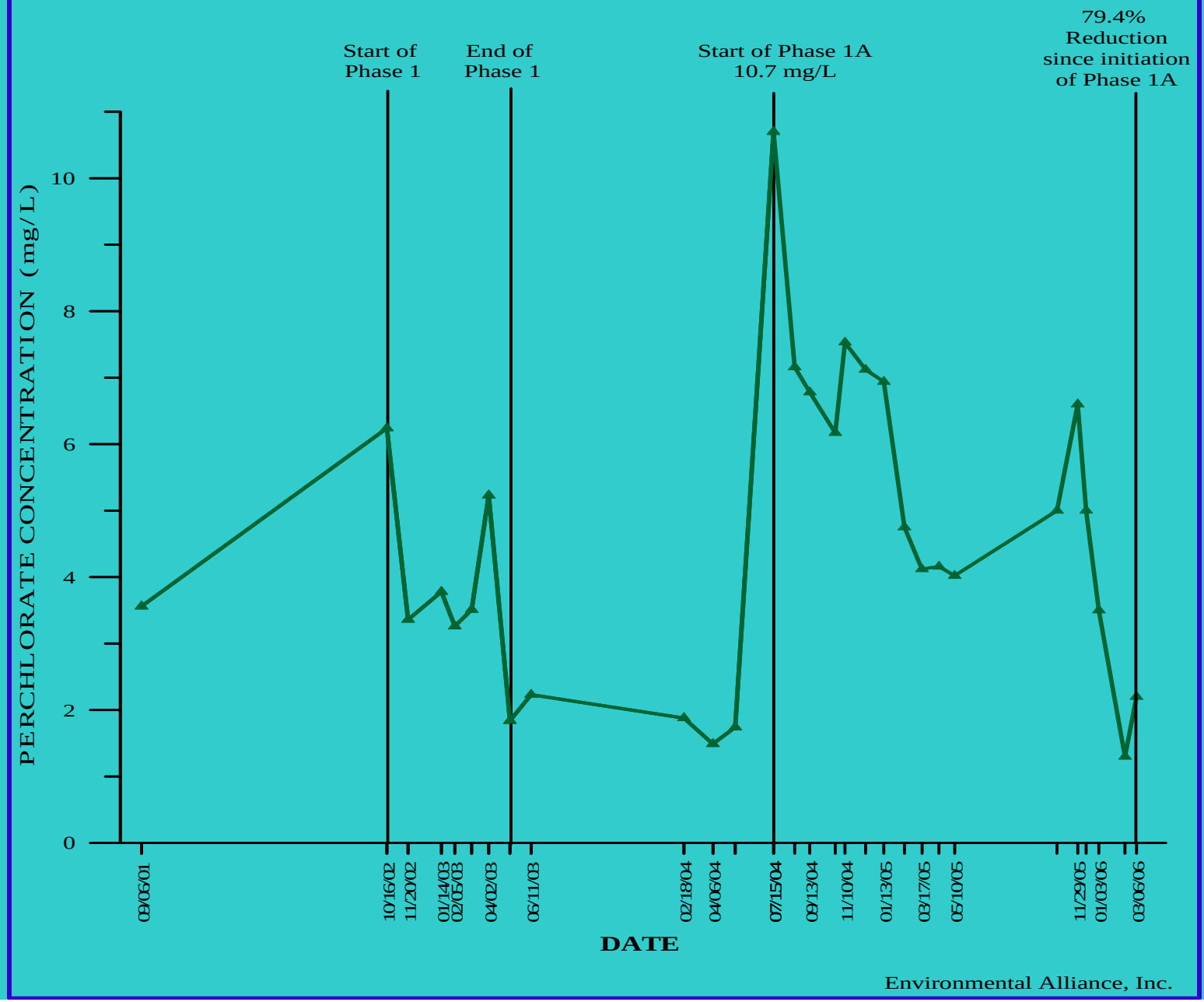
PERCHLORATE CONCENTRATION OVER TIME AT EXTRACTION WELL



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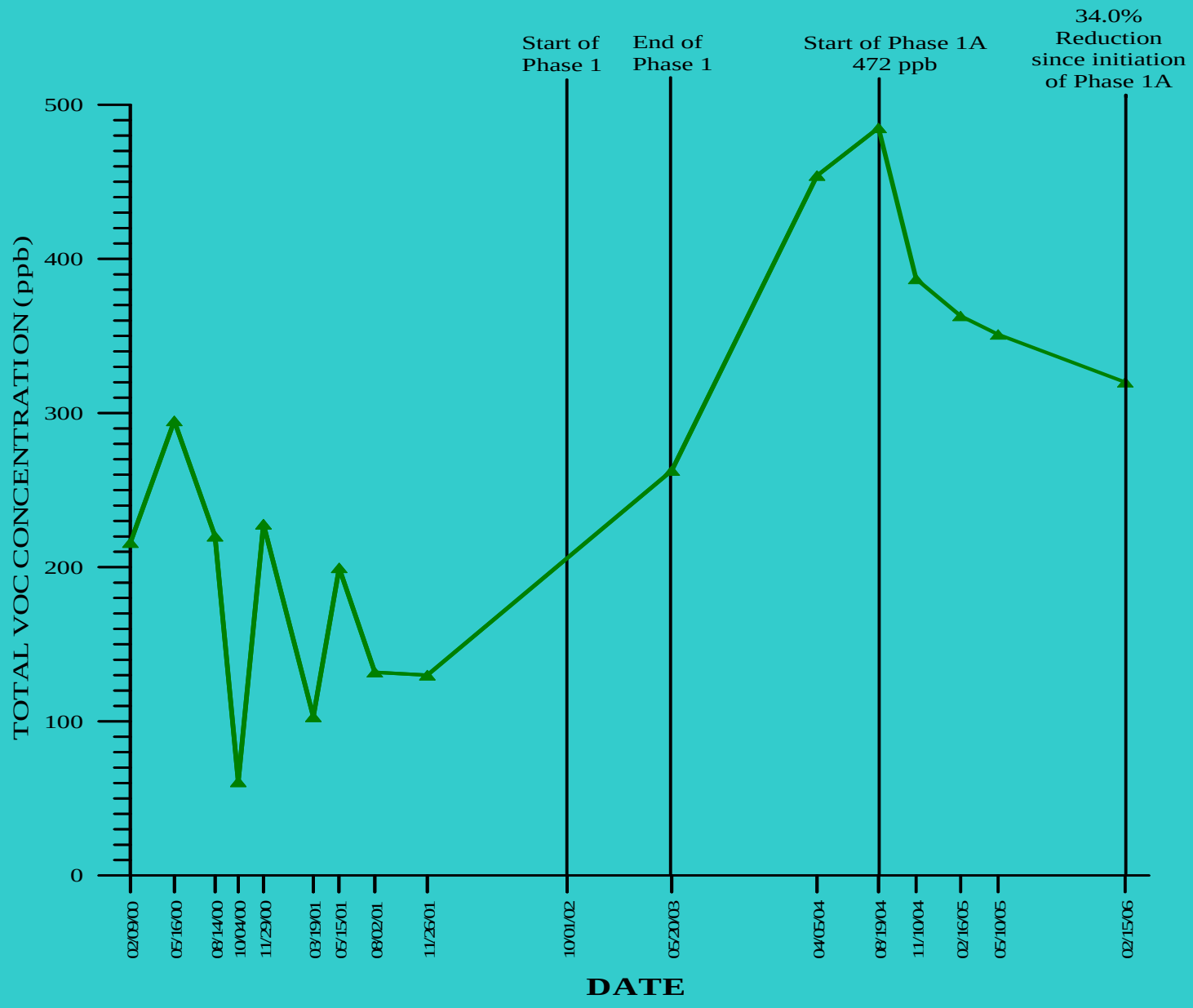
TOTAL VOLATILE ORGANIC COMPOUNDS (VOCs) CONCENTRATION OVER TIME AT UPGRADIENT WELL



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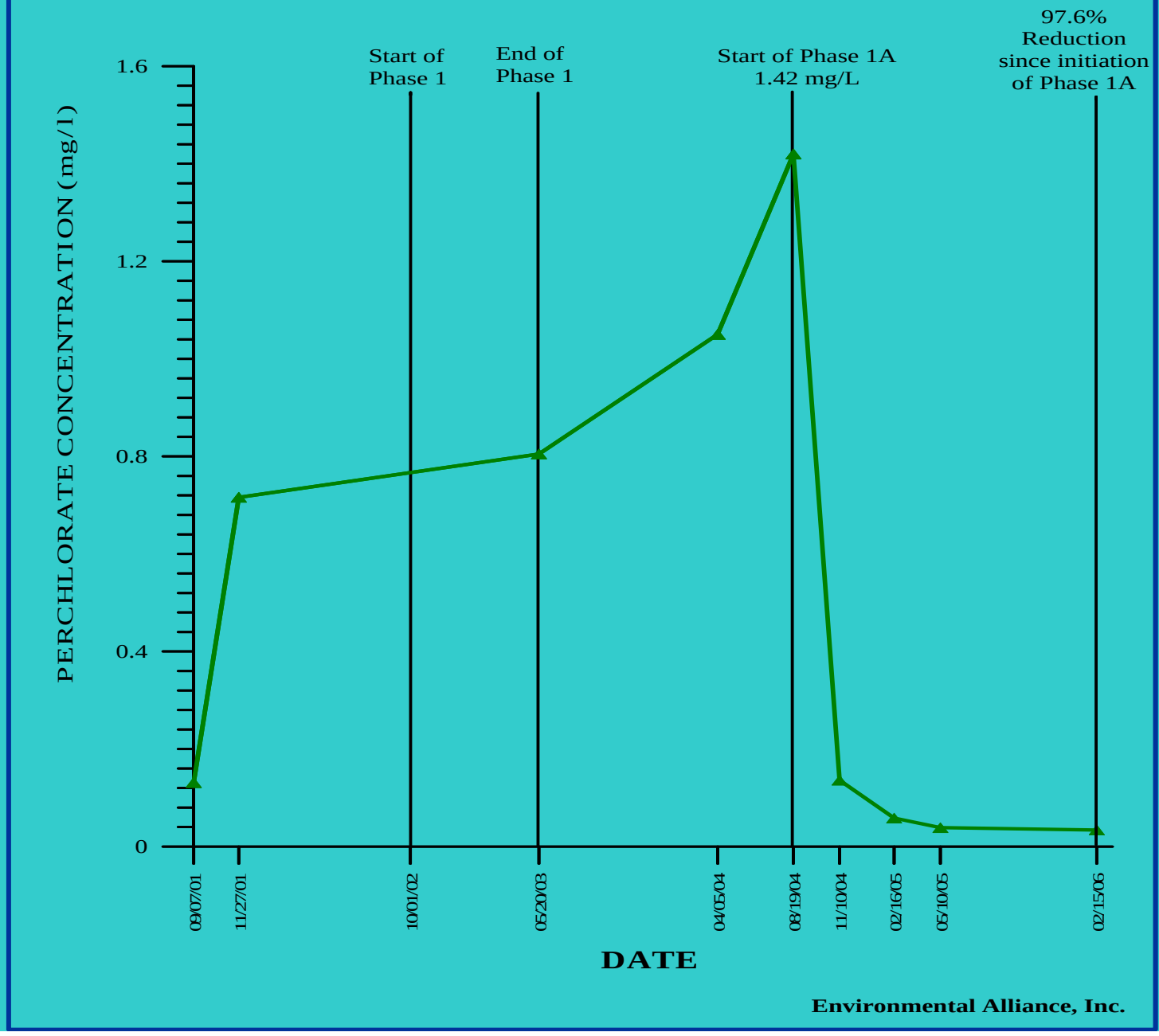
PERCHLORATE CONCENTRATION OVER TIME AT UPGRADIENT WELL



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Pilot Test Results to Date

- Maintained hydraulic control of perchlorate and VOC plumes
- Significant reductions in perchlorate:
  - Decrease in extent of plume
  - 88% in plume core/pumping well
- Significant reductions in VOCs:
  - Decrease in extent of plume
  - 62% in plume core/pumping well

Conclusions & Future Studies

- Phased pilot test approach appropriate for large, complex sites:
  - Evaluate small area, then expand to include additional areas or target specific zones
  - Minimize capital costs by reuse of existing remedial equipment (P&T to recirculation system)
  - Final CMI design better after long-term pilot testing
- Future studies:
  - Evaluation of mixed soluble substrates
  - Ongoing SRF Investigation to improve source area delineation