IN SITU ANAEROBIC BIOREMEDIATION OF A FORMER DRY CLEANING FACILITY AT NAVAL STATION TREASURE ISLAND

Dan Leigh

Lessons Learned – Dry Cleaner
Site Assessment and Mitigation Program (SAM)
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Site 24 - Conditions

- Former dry cleaning facility (1942–1977)
- PCE - >20 ppm in dissolved phase
- Lower concentration of TCE, DCE & VC
- Very low concentrations of ethene detected
- DNAPL possible in source area
- Plume Extends Eastward Toward SF Bay - ~1,000 Feet long, 300 feet wide, 30 feet deep

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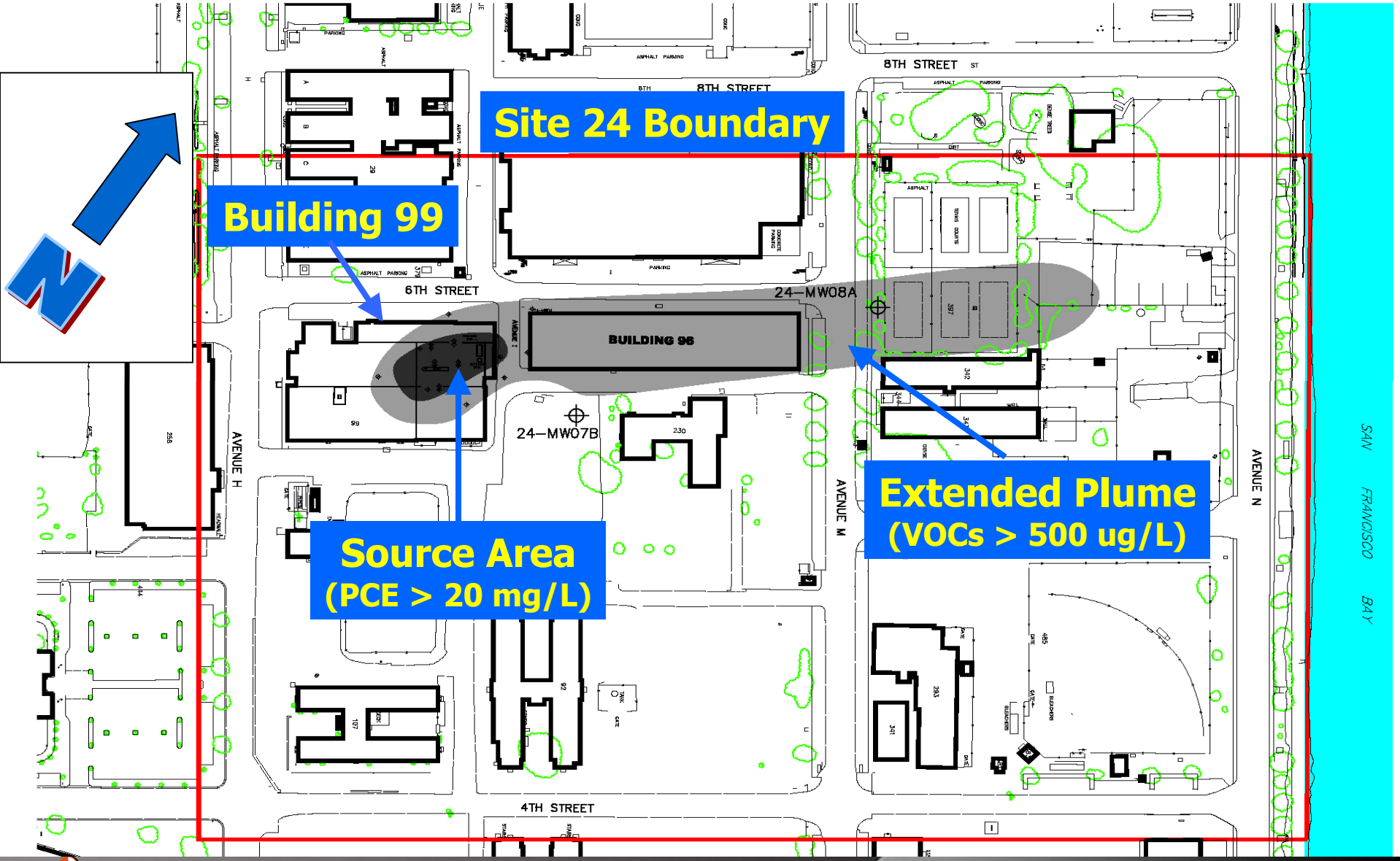
FORMER NAVAL STATION TREASURE ISLAND SITE VICINITY MAP

Site 24 Facility Layout & VOC Plume Extent



Site 24 - Building 99

Hydraulic Fill

A- Zone (K~5ft/day)

B- Zone (K ~ 0.5ft/day)

Bay Mud

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Remediation Strategy

Site conditions indicate In Situ Bioremediation could be applicable remedial technology

- Ethene present
- Low ORP
- Permeable aquifer

- **Conduct Bench Scale Test**
  - Determine presence of dechlorinating bacteria (Dehalococcoides, *sp*)
  - Evaluate biostimulation
  - Evaluate bioaugmentation

- **Conduct Field Test**
  - Evaluate Biostimulation
  - Evaluate Bioaugmentation

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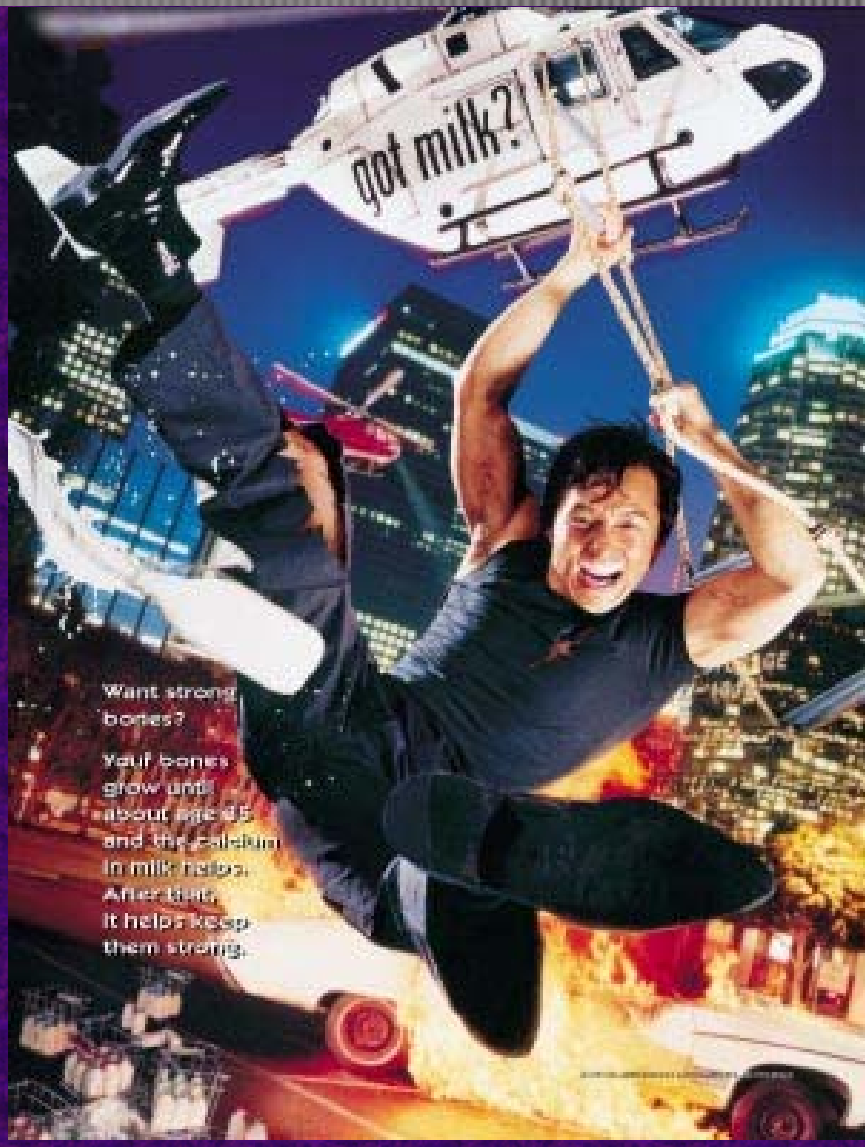
Anaerobic Bioremediation Process - Got Milk?



- Inject easily fermentable food (food grade sodium lactate)
- Bacteria ferment lactate –
  - to acetate and propionate
  - to methane – carbon dioxide and water
- Fermentation generates hydrogen
- Bacteria use hydrogen to sequentially dechlorinate PCE to non toxic end product (ethene)

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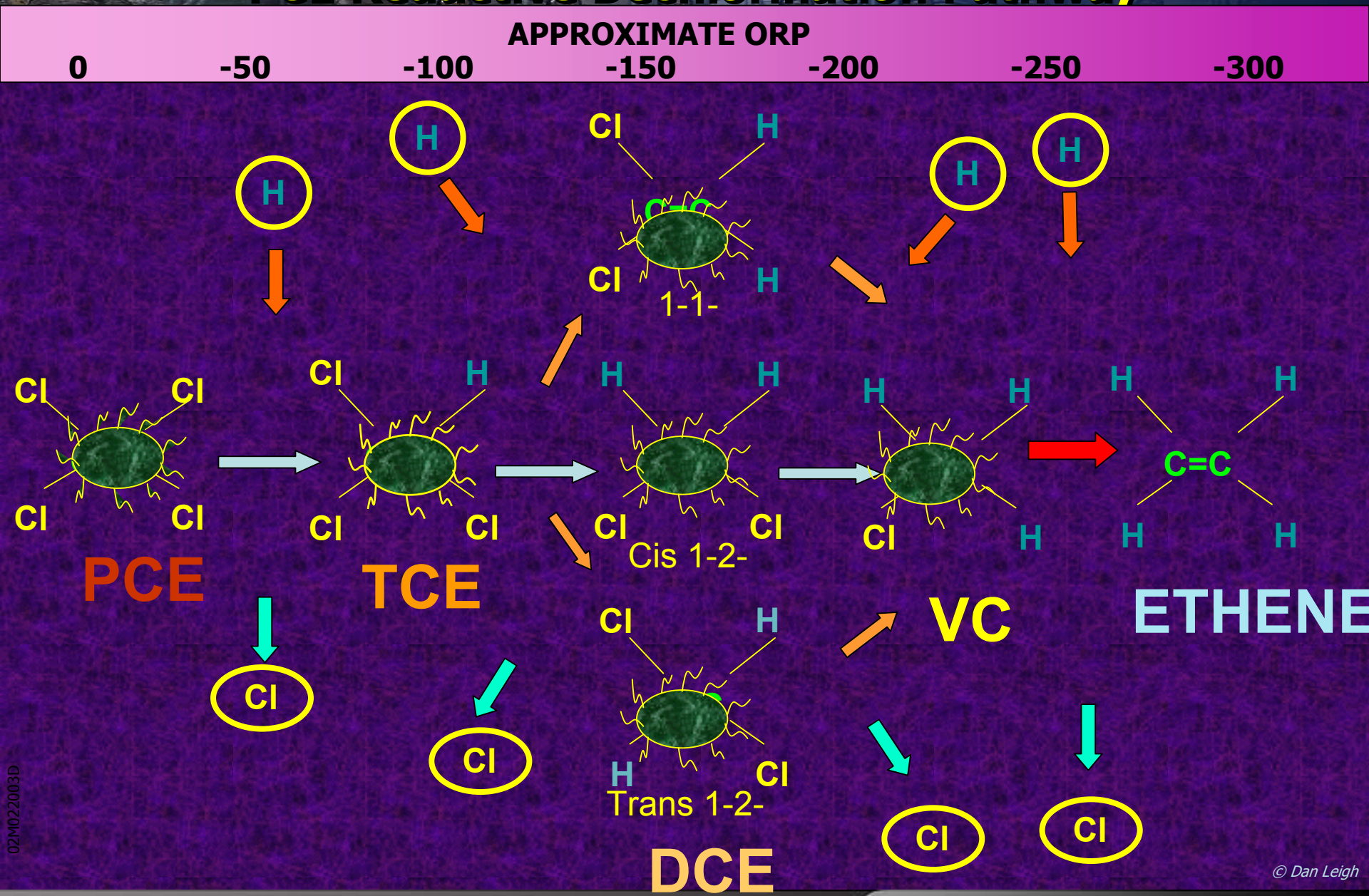
PCE Reductive Dechlorination Pathway



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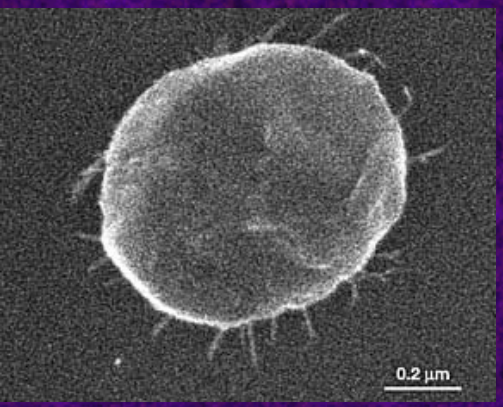
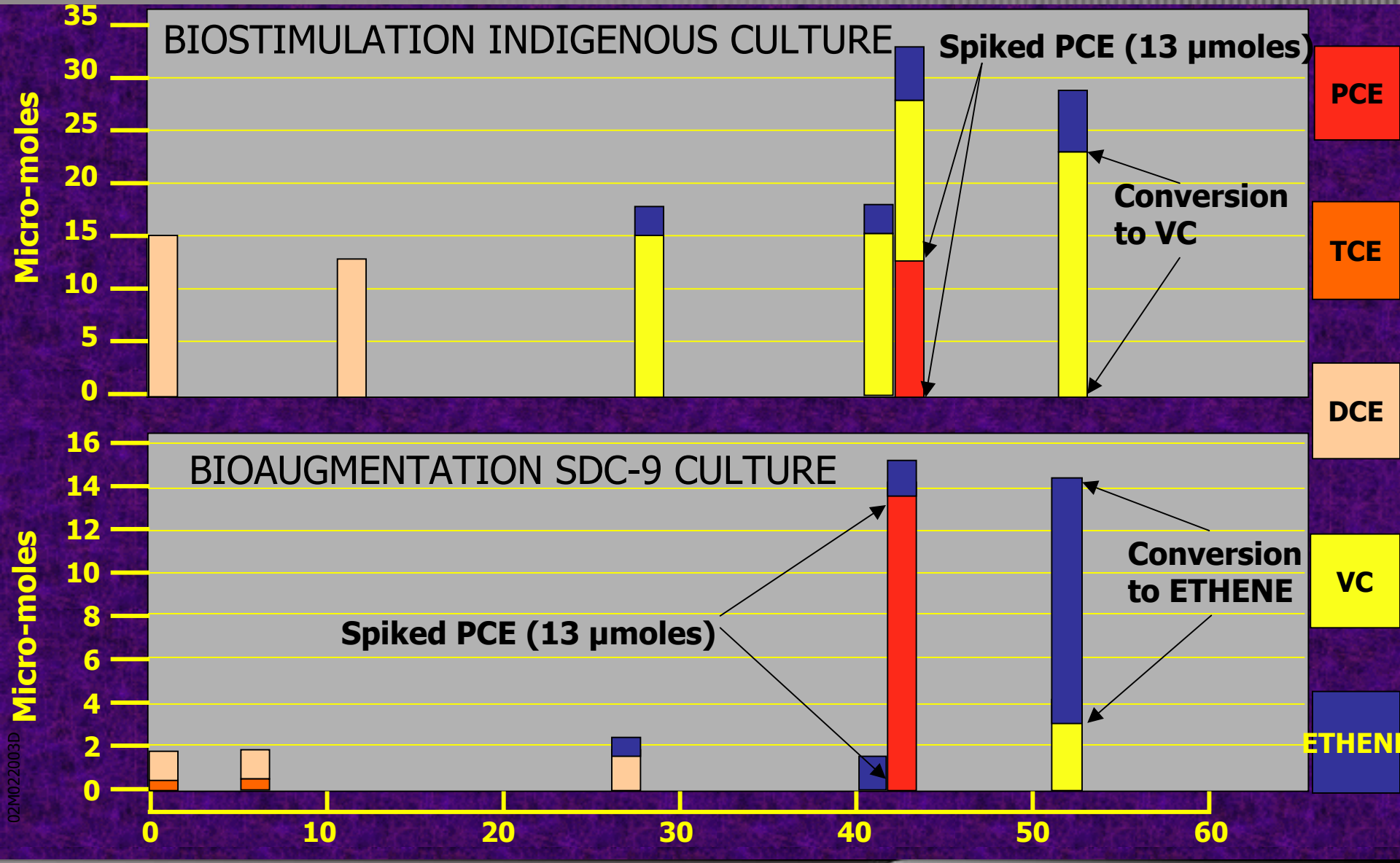
Evaluation of Indigenous Dechlorinating Microorganisms

Microcosm studies conducted to determine biodegradation capacity of indigenous and cultured microorganisms (Dehalococcoides *sp*, (DHC))



Photos of BAV1 – courtesy of Dr. Frank Loeffler

BENCH SCALE TESTING RESULTS



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In Situ Anaerobic Bioremediation Field Test

- **Three Recirculation Loops (~ 100 feet long)**
  - Extraction well
  - Injection well
  - 2 co-located shallow (20′) and deep (30′) monitor well pairs (15′ & 40′ from IW)
- **Groundwater recirculation - 3 to 4.5 gpm/Loop**
- **Two Biostimulation Loops**
  - Loop 3 – Lactate only
  - Loop 1 – Low lactate (~1/4 Loop 2 & 3) + hydrogen gas
- **One Bioaugmentation Loop**
  - Loop 2 – Lactate and SDC-9 culture
- **Three Phases**
  - Phase 1 – Abiotic Recirculation (Day 0 to 14)
  - Phase 2 – Nutrient Injection (Day 14 to 44)
  - Phase 3 – Biodegradation Monitoring (Day 44 to 180)

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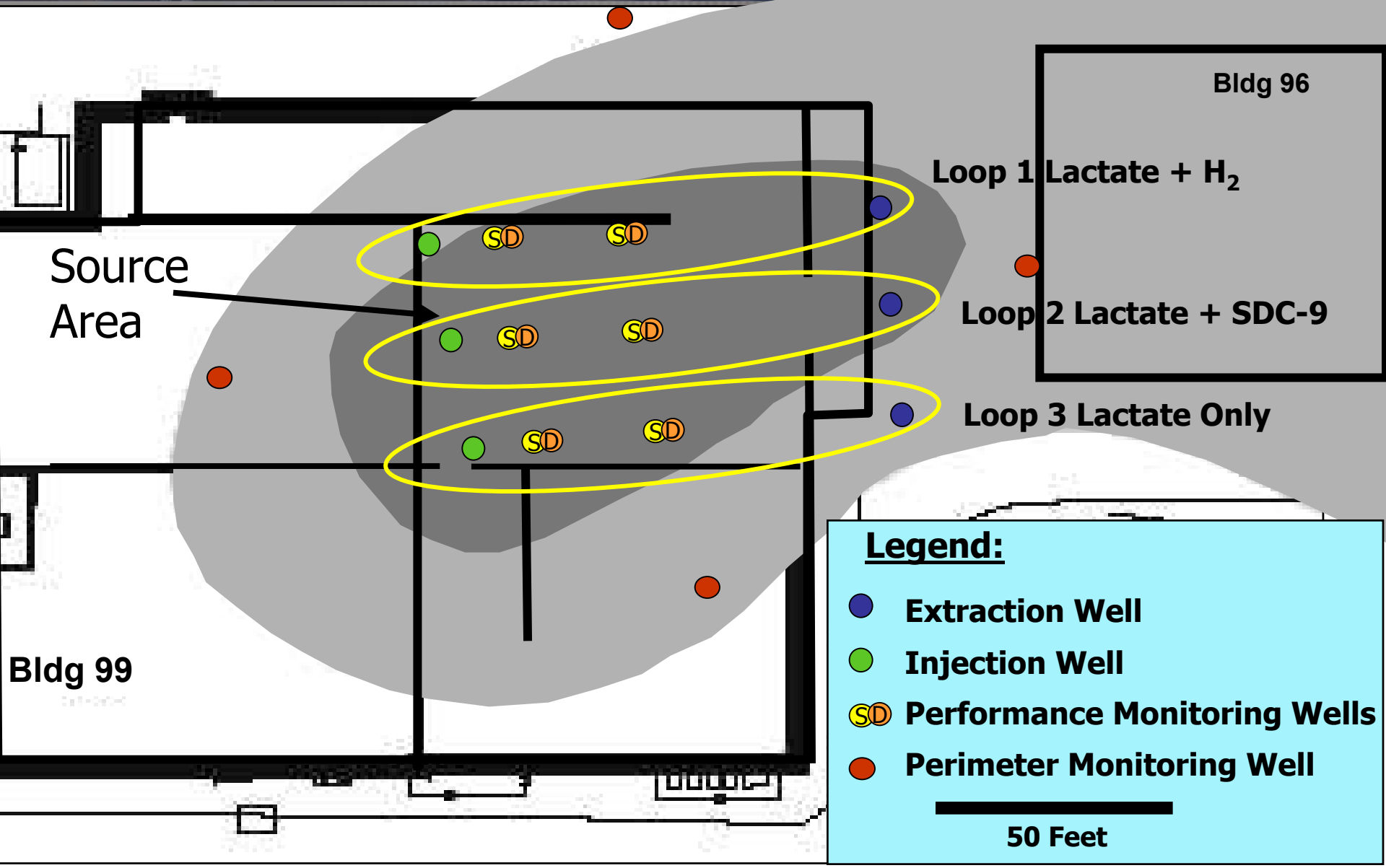
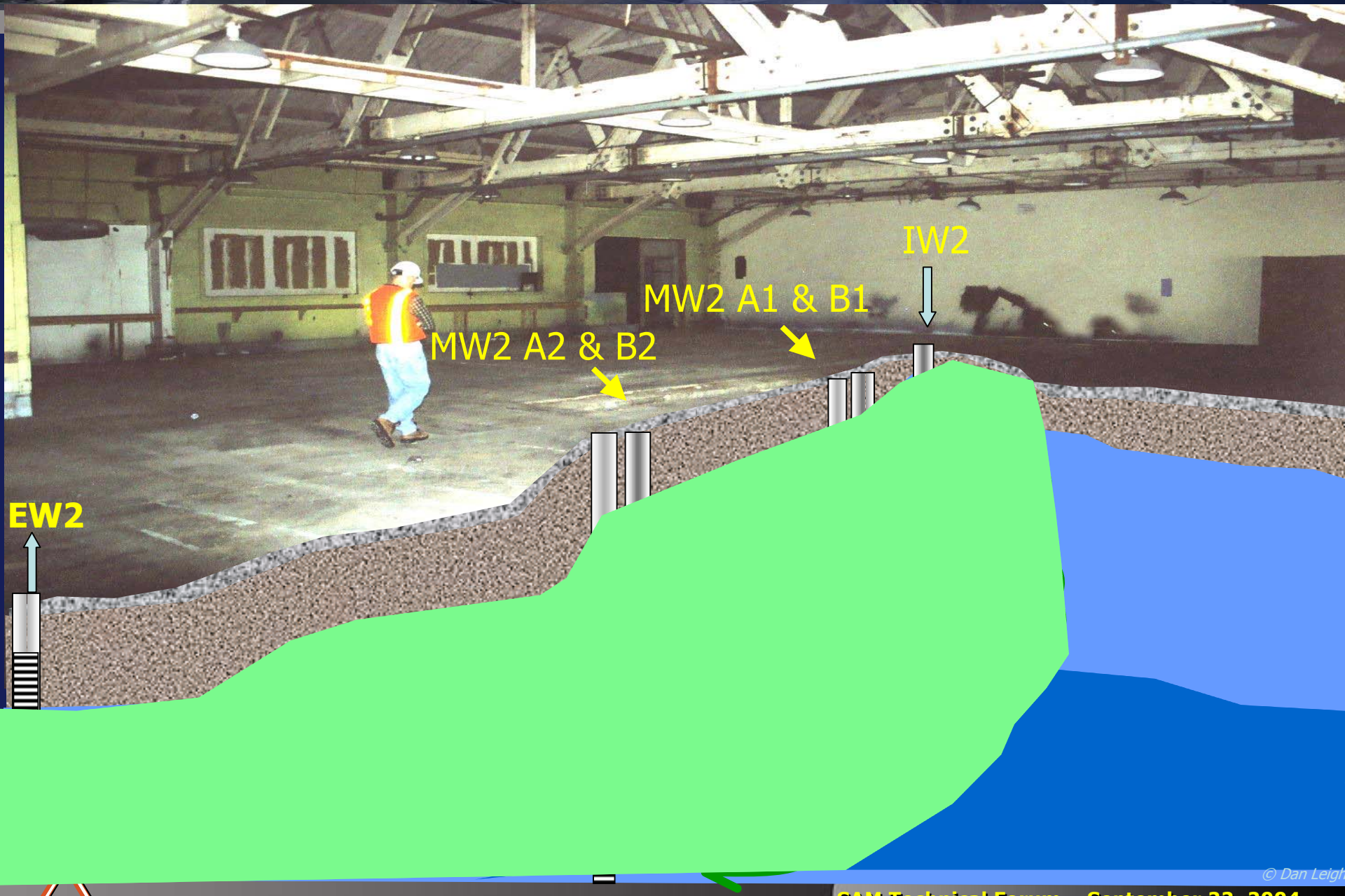
Recirculation – Monitoring System Layout



Conceptual Cross Section of Loop 2



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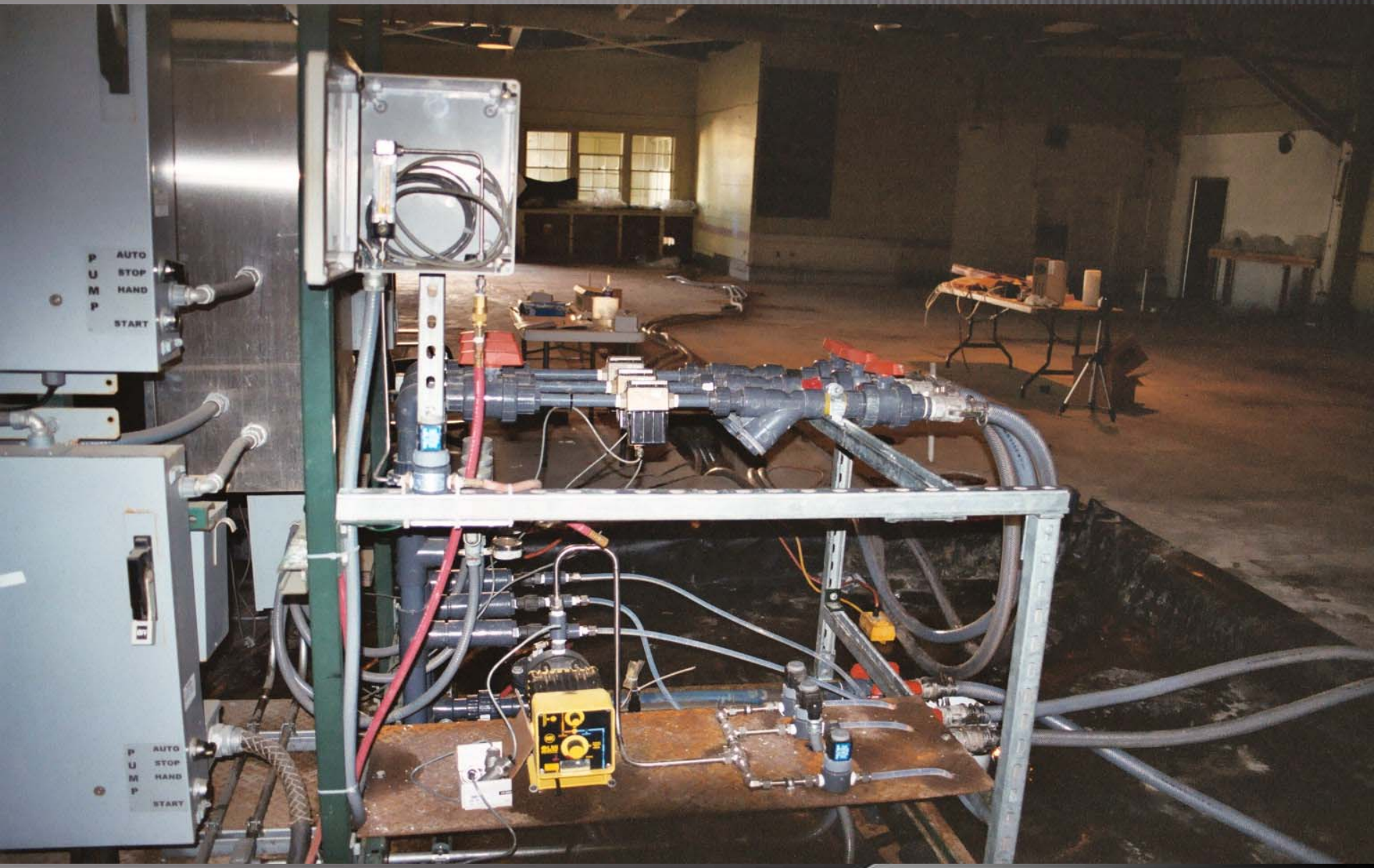
Control and Power Distribution Panels

Chemical Injection Point

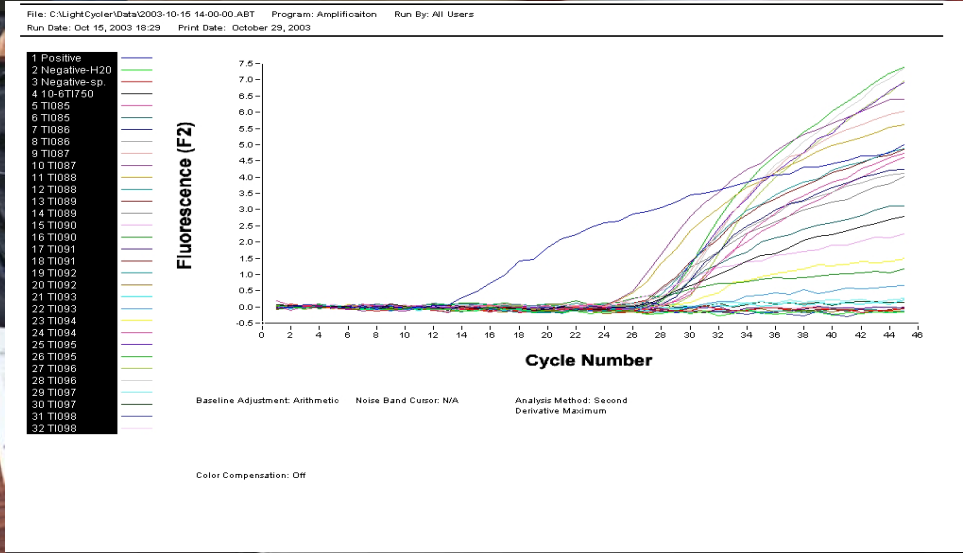


Bioaugmentation

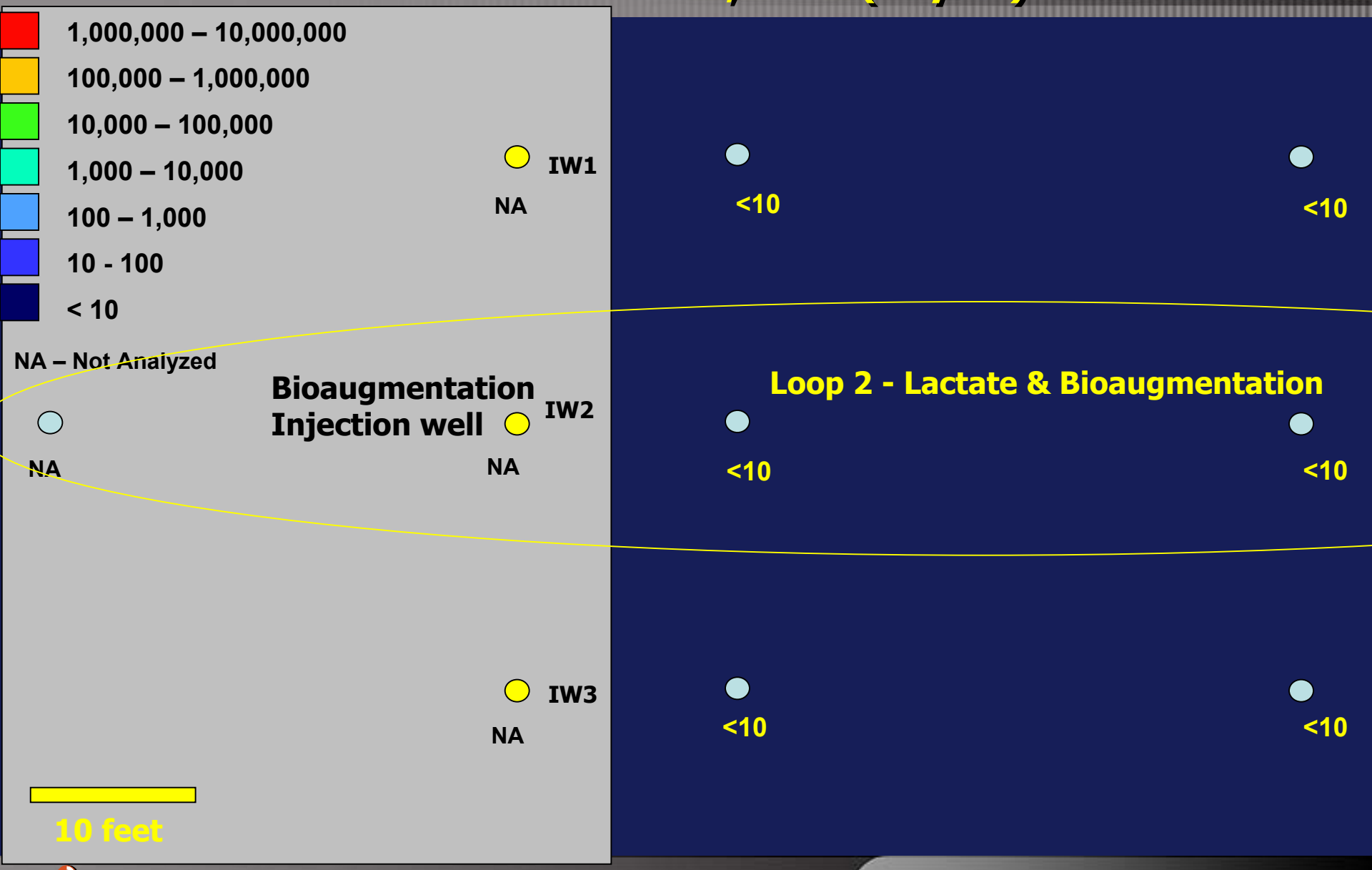
- Used SDC-9 culture (Dehalococcoides *sp*)
- Injected into IW2 and distributed in Loop 2
- Two injections – 60 liters of enriched SDC-9 solution (10^8 cells/mL)
  - Injection 1 – During tracer test & abiotic recirculation phase (Phase 1)
  - Injection 2 – During substrate (lactate) injection phase (Phase 2)
- Monitored migration on-site using real-time quantitative Polymerase Chain Reaction (PCR) analysis
- Monitored DHC growth after recirculation halted (Monitoring Phase - Phase 3)

DHC analysis by real time PCR

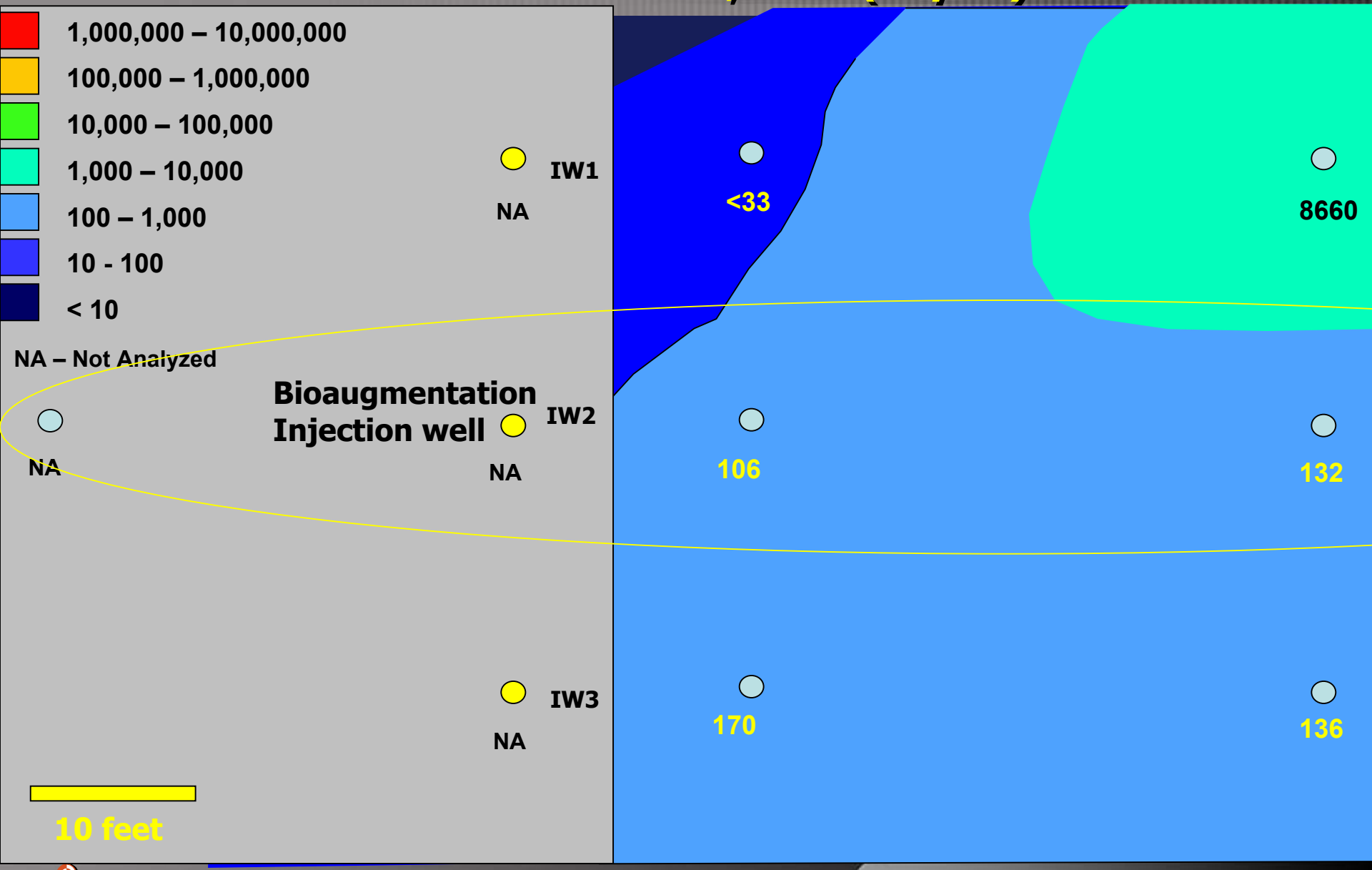
- Developed from Anthrax Remediation
- Analyzes organism (DHC) specific DNA
- Analyses were performed on-site and at Shaw Bioremediation Laboratory



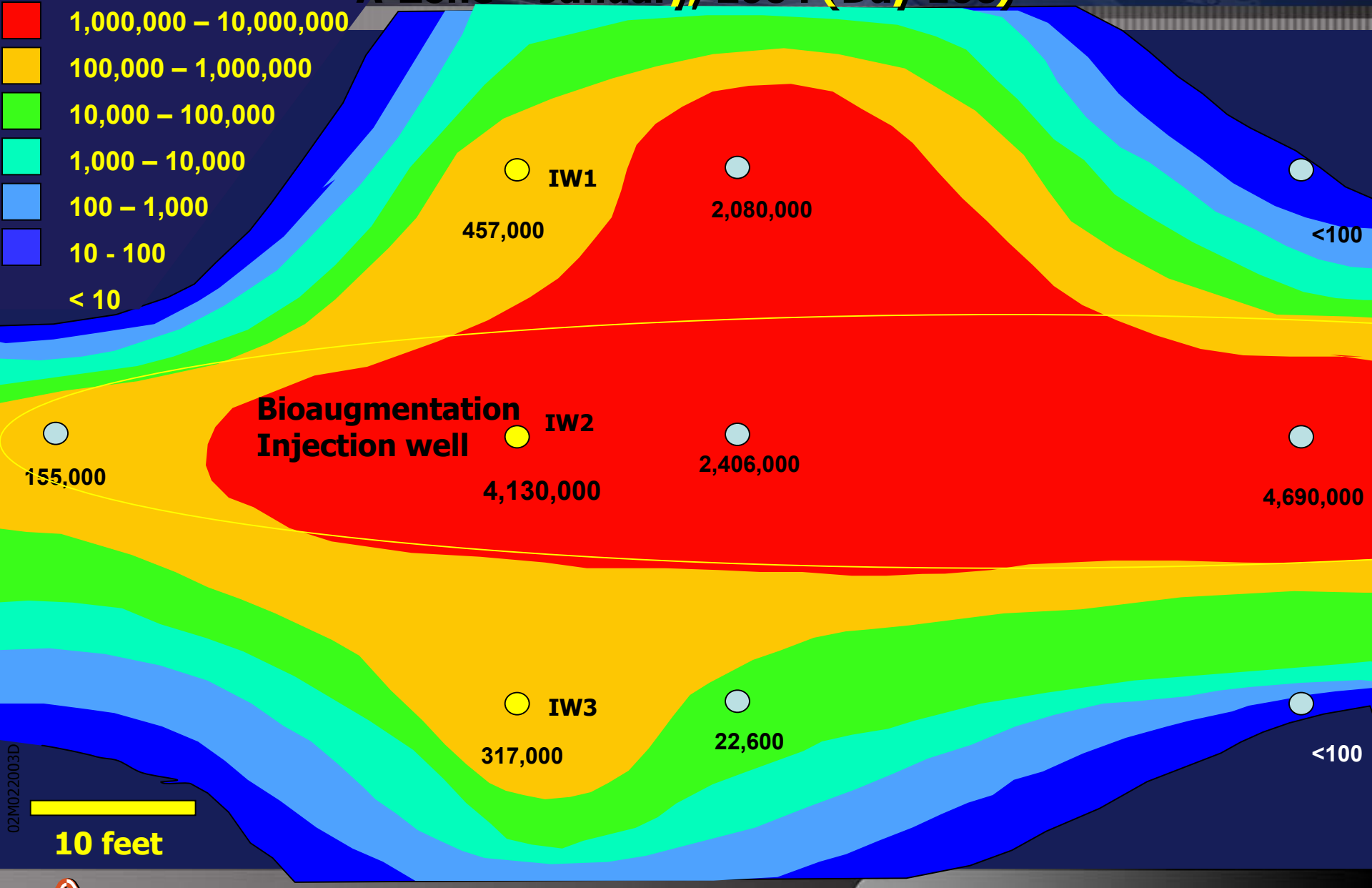
DHC Concentration (cells/ml) in Treatment Zone
A-Zone – November, 2003 (Day 44)



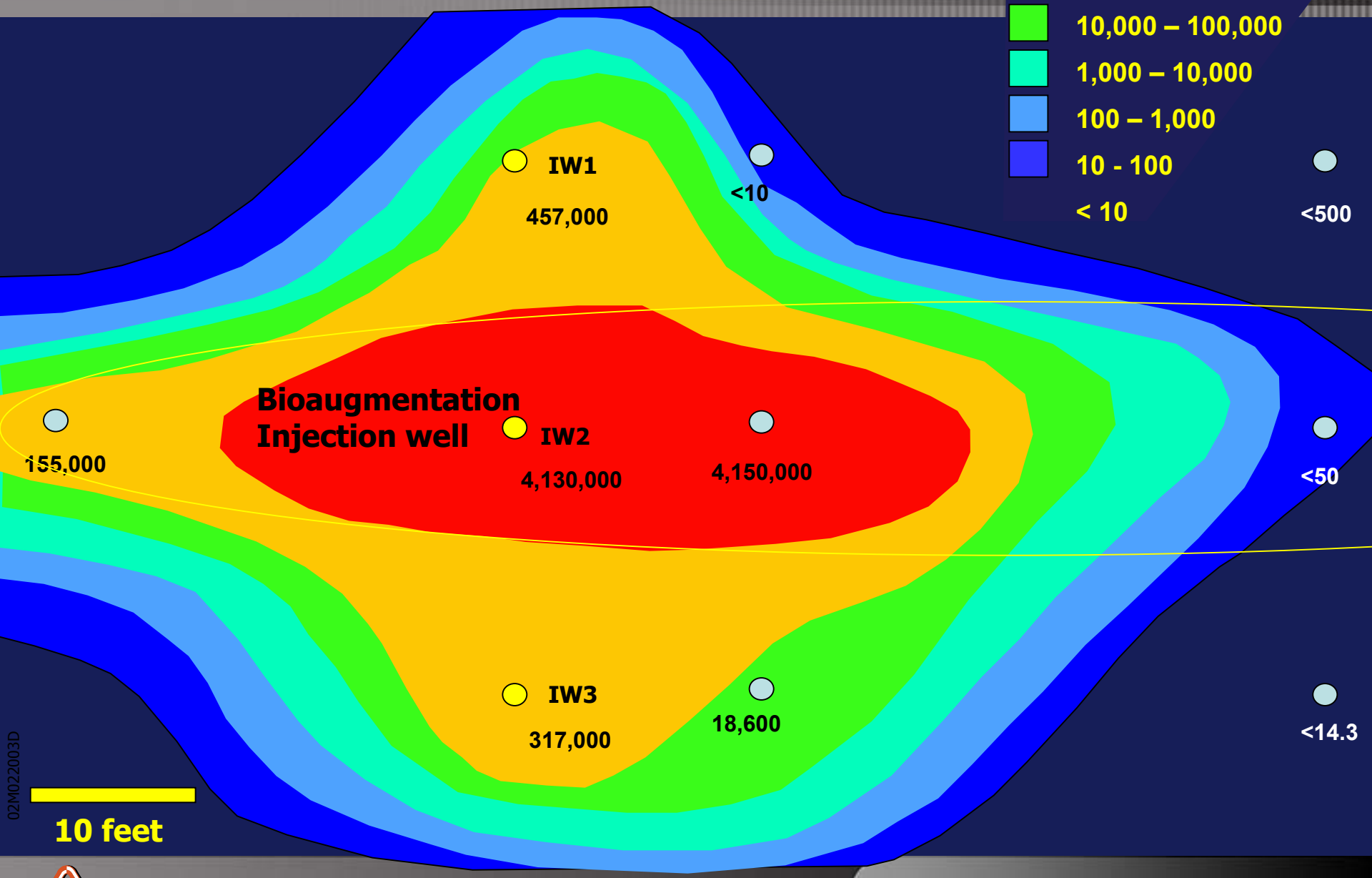
DHC Concentration (cells/ml) in Treatment Zone
B-Zone – November, 2003 (Day 44)



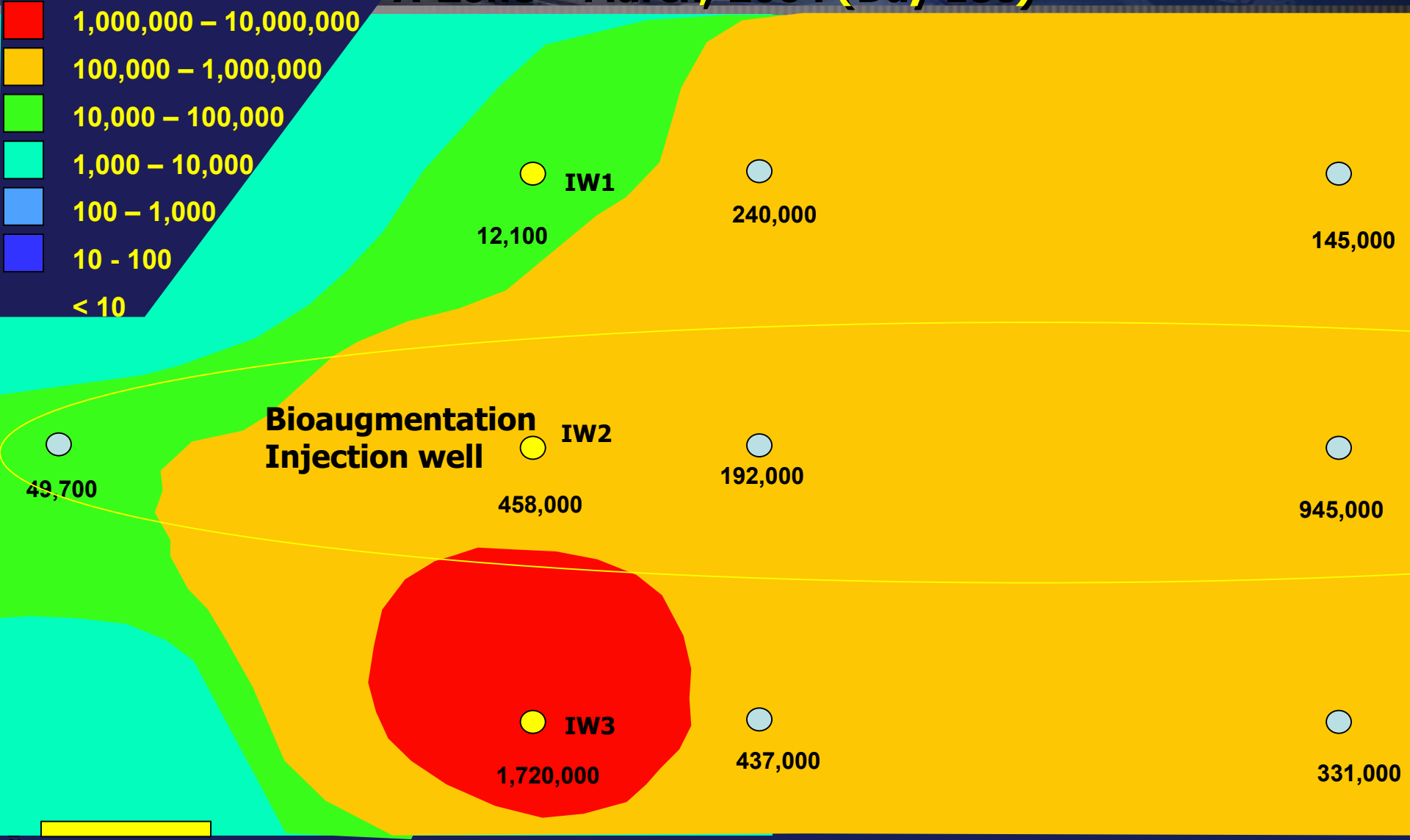
DHC Concentration (cells/ml) in Treatment Zone
A-Zone – January, 2004 (Day 100)



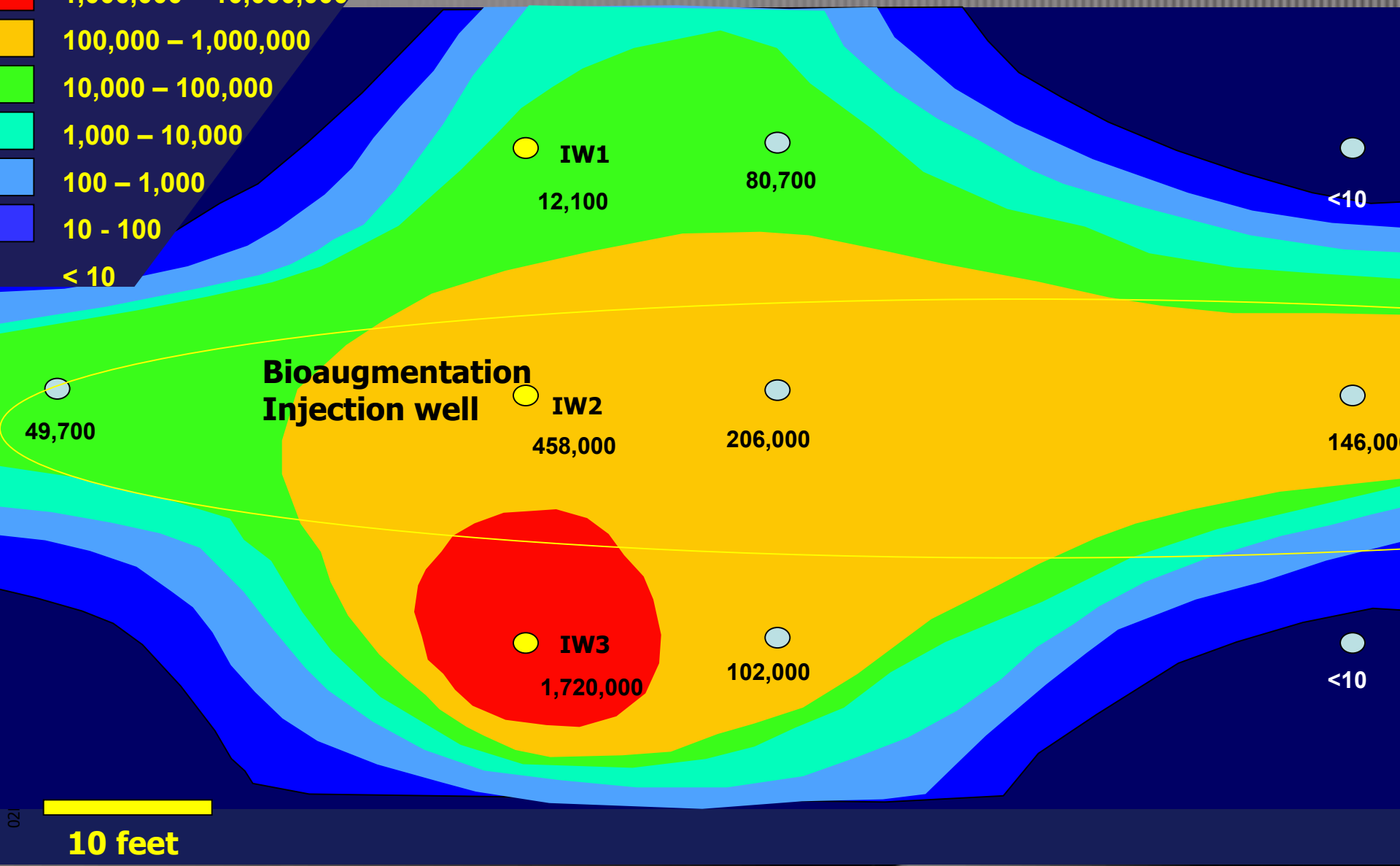
DHC Concentration (cells/ml) in Treatment Zone B-Zone – January, 2004 (Day 100)



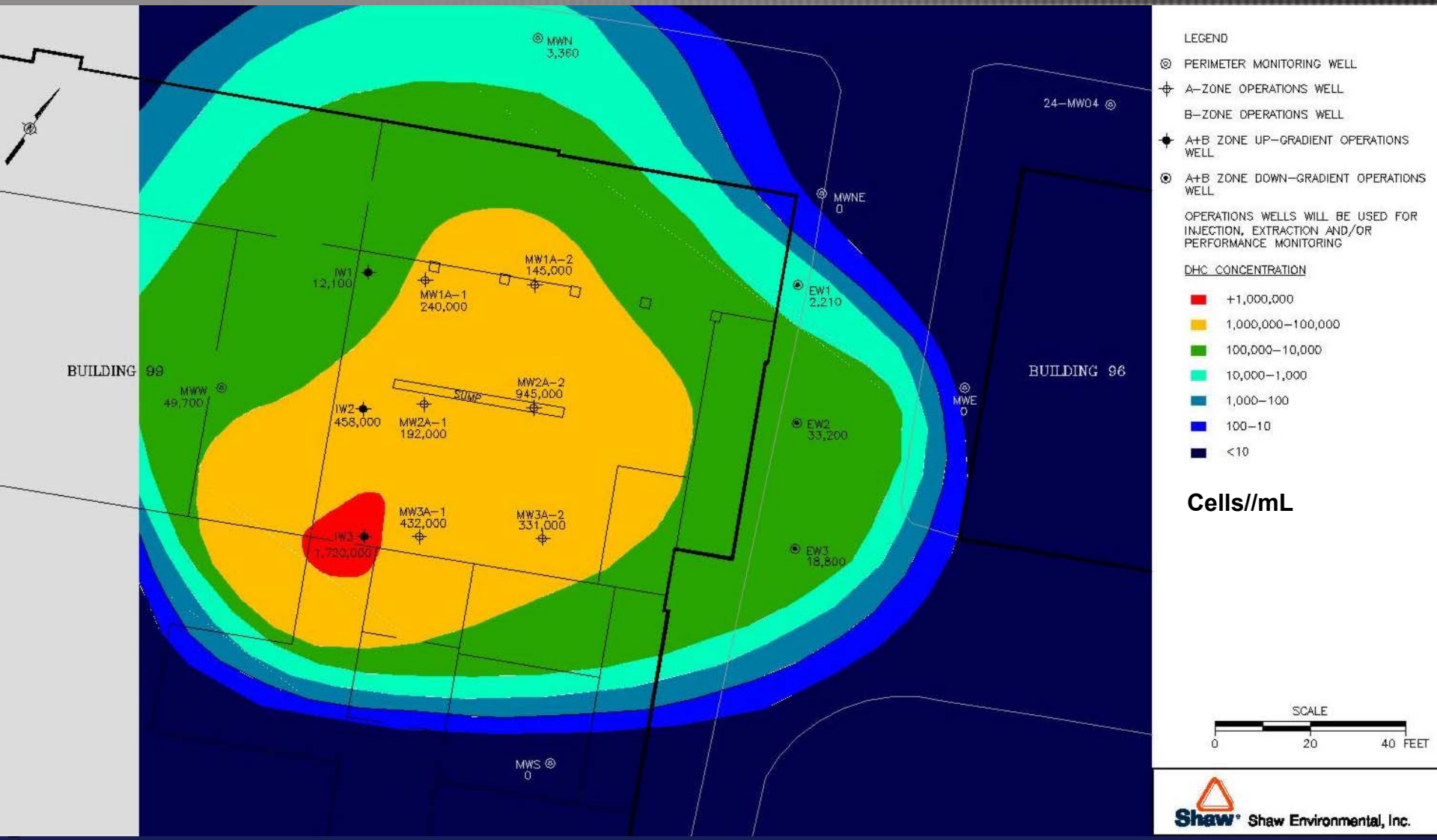
DHC Concentration (cells/ml) in Treatment Zone
A-Zone – March, 2004 (Day 180)



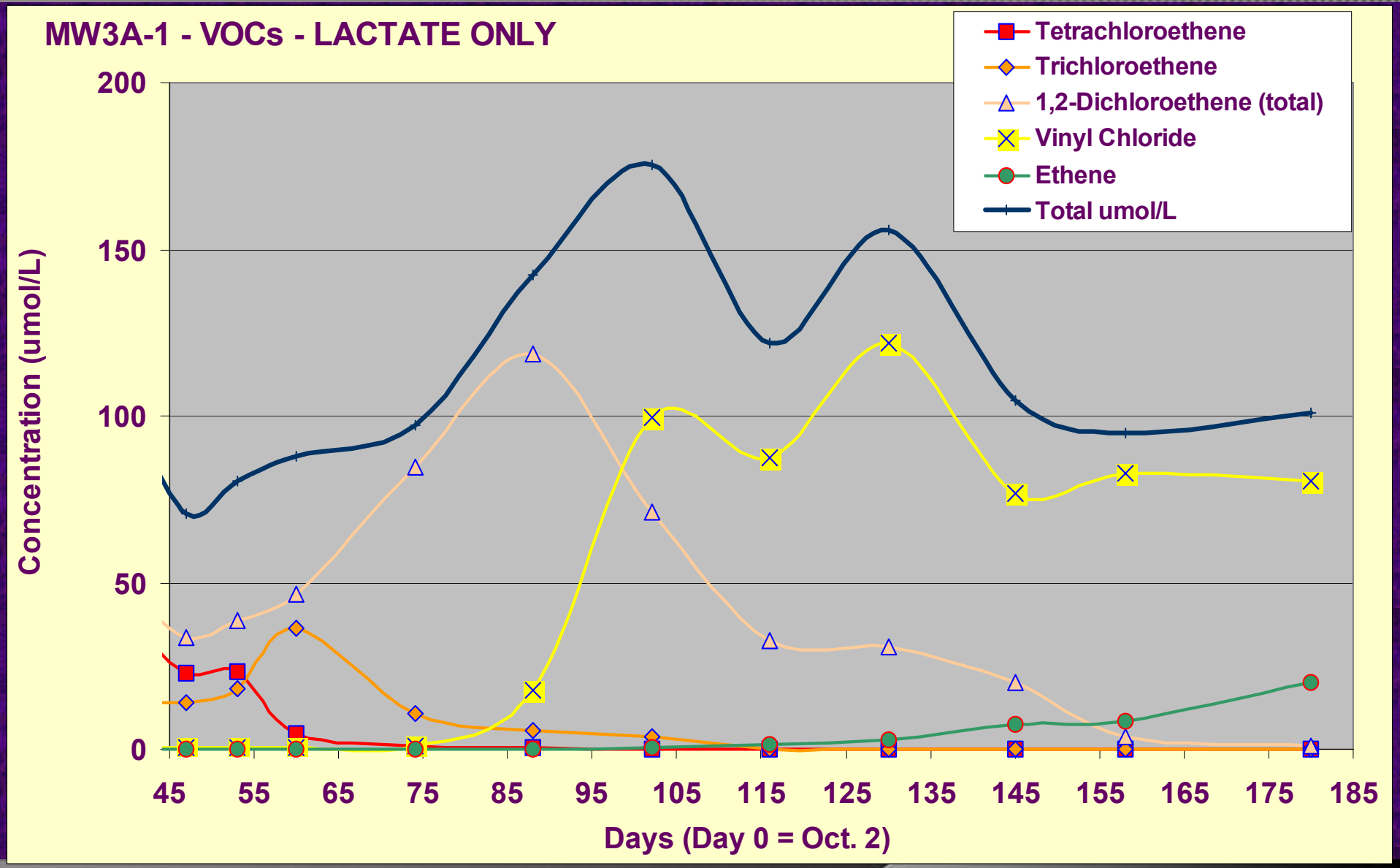
DHC Concentration (cells/ml) in Treatment Zone
B-Zone – March, 2004 (Day 180)



DHC Distribution at Building 99 – March, 2004 (Day 180)



CHANGE IN VOC CONCENTRATION DURING MONITORING PHASE



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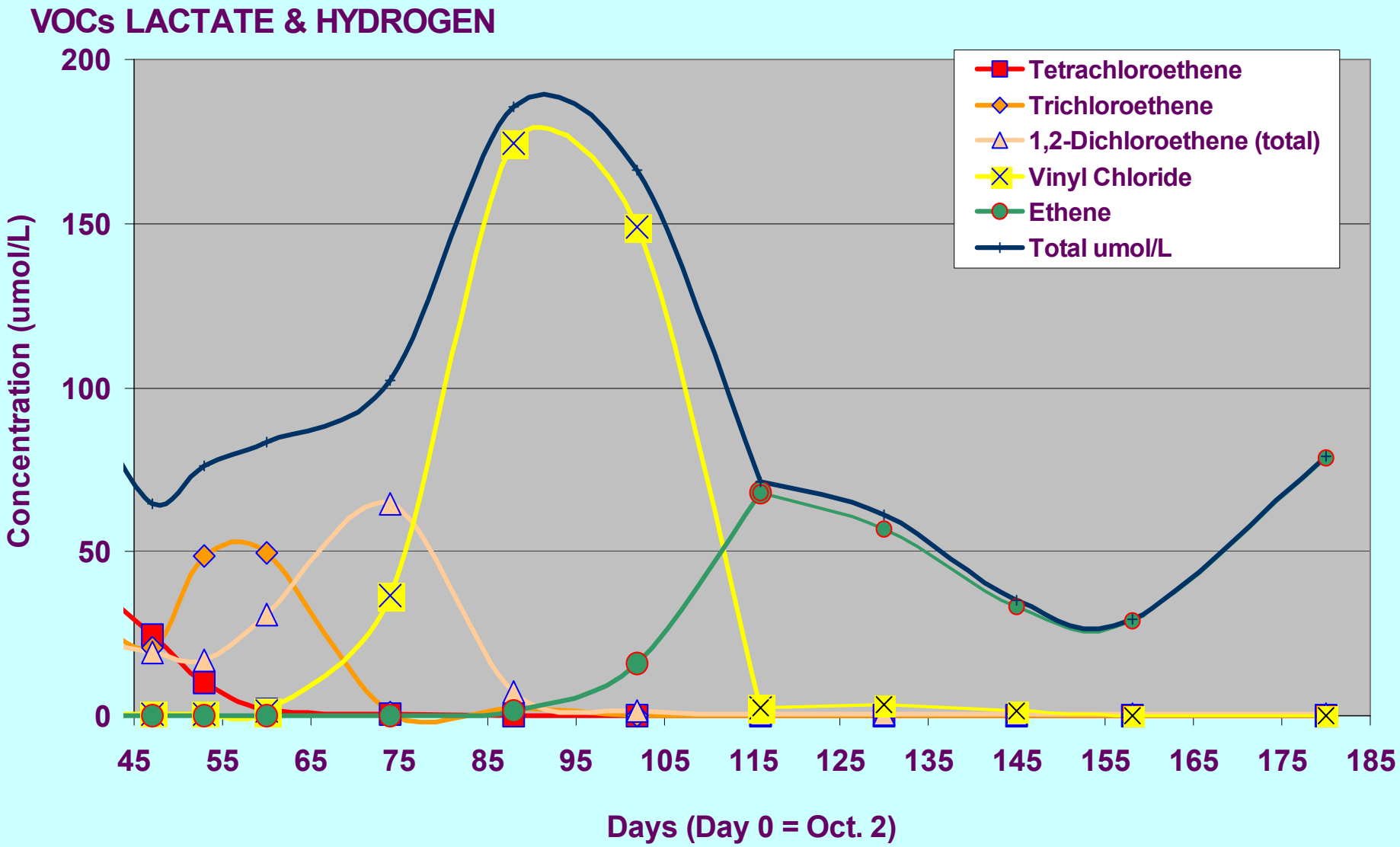

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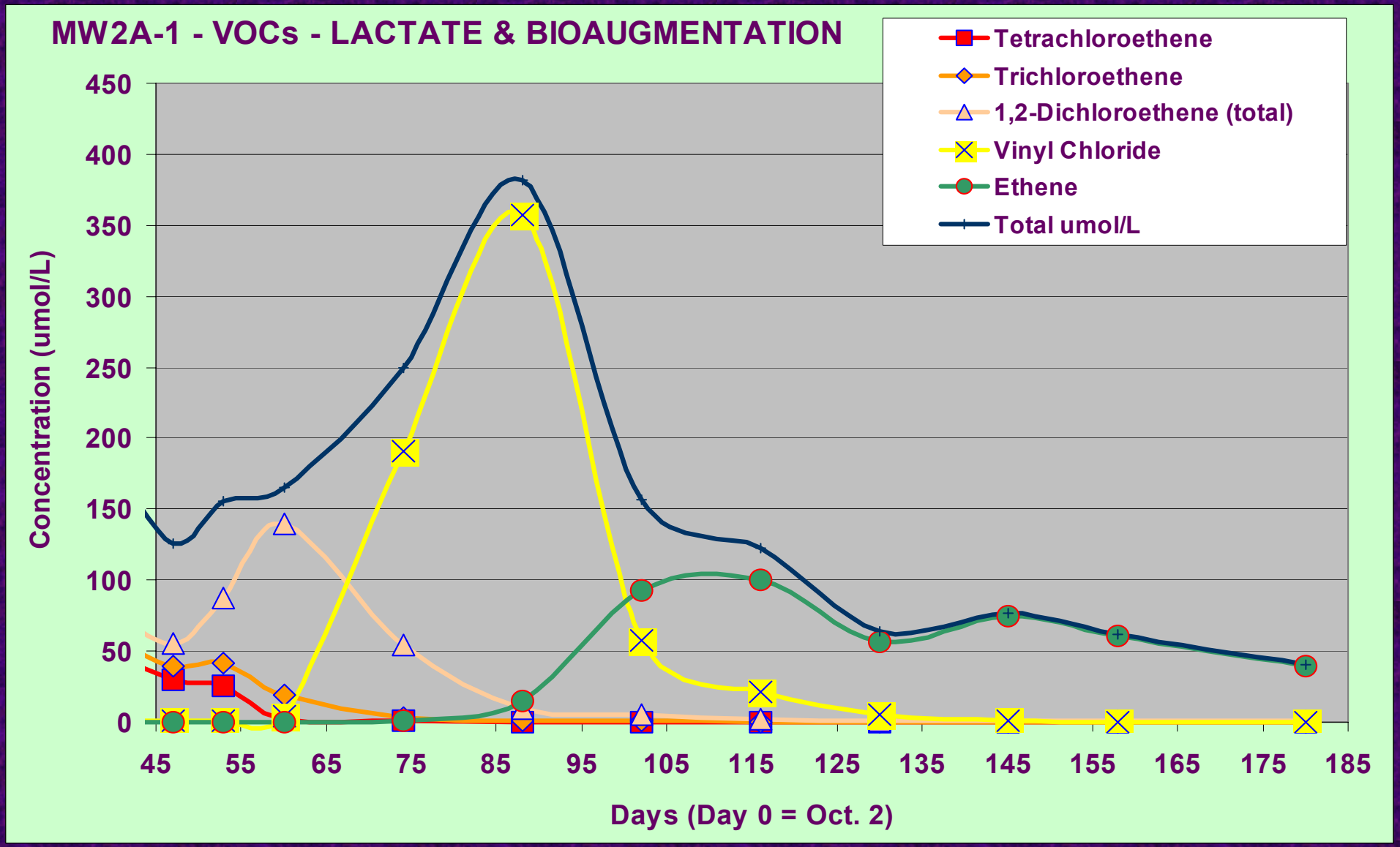
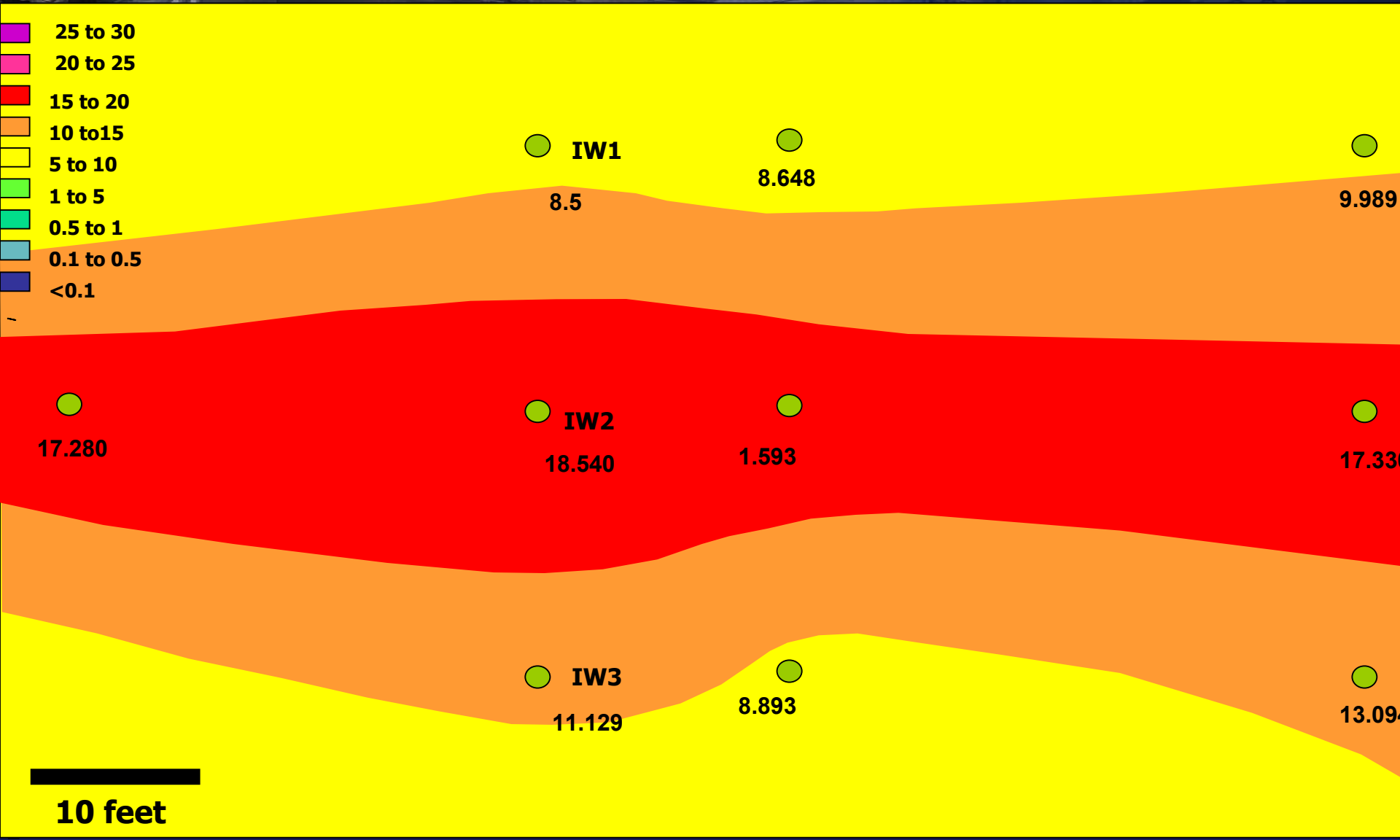
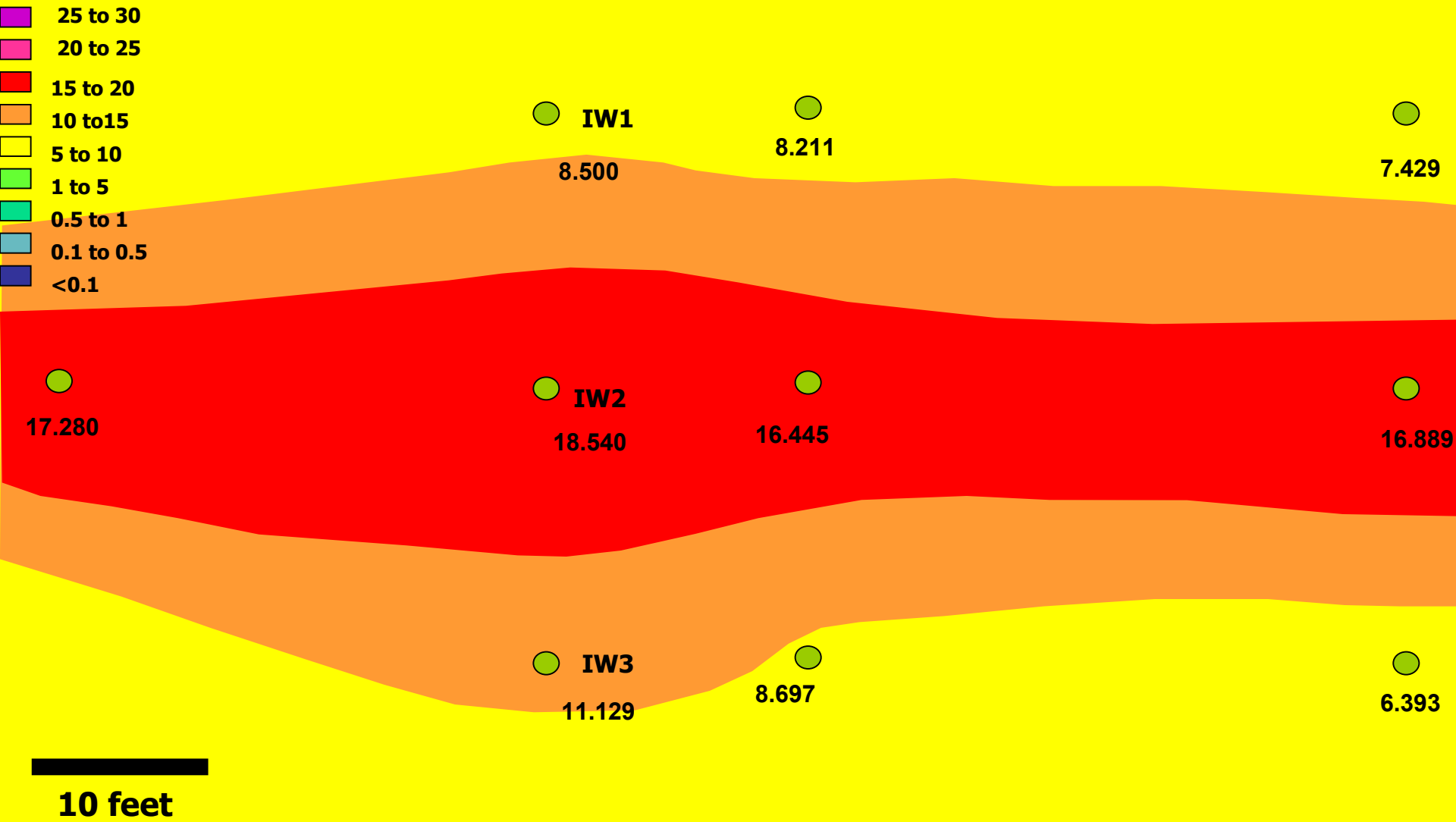


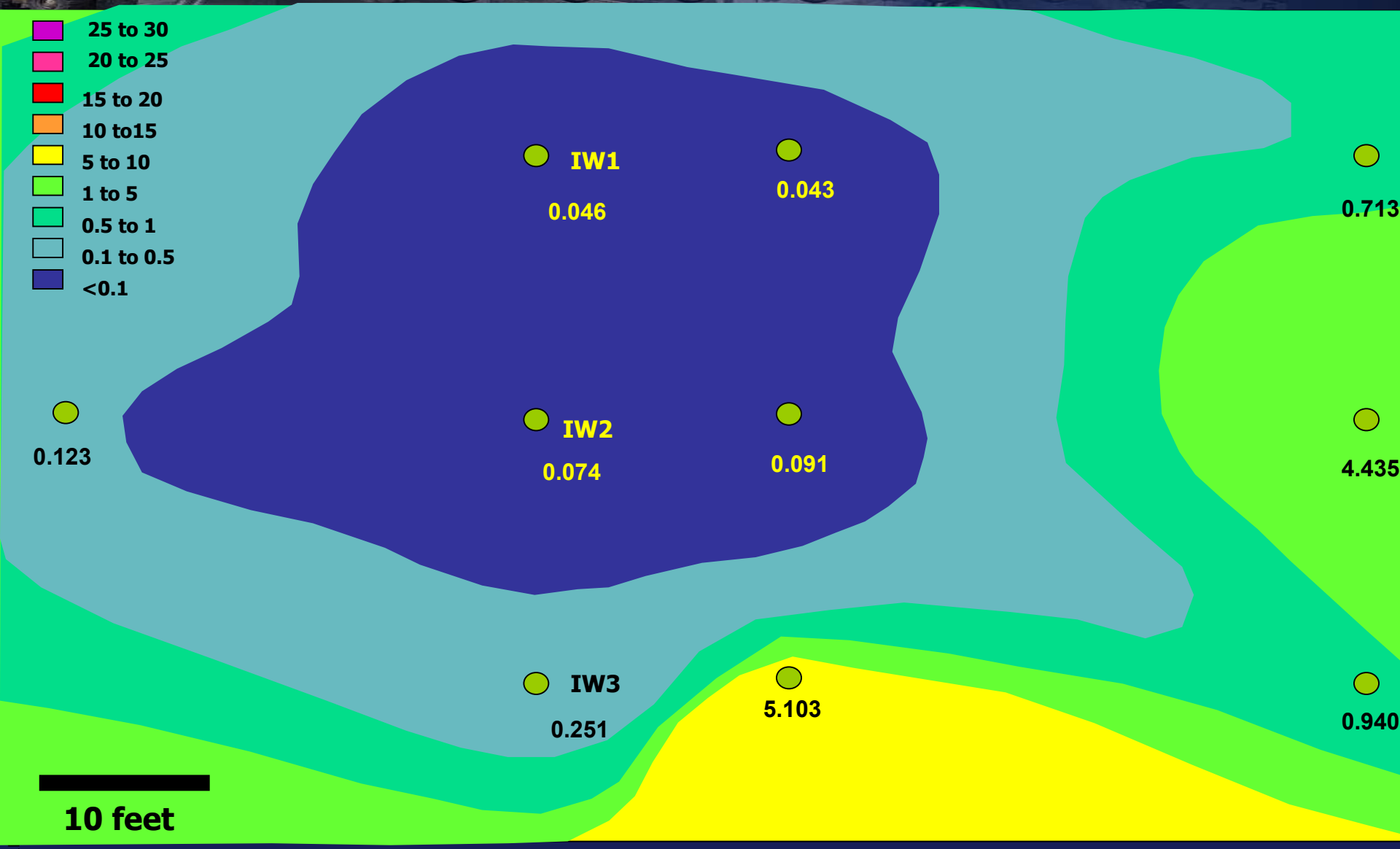
Total VOCs (mg/L) – A-Zone - November, 2003 (Day 44)



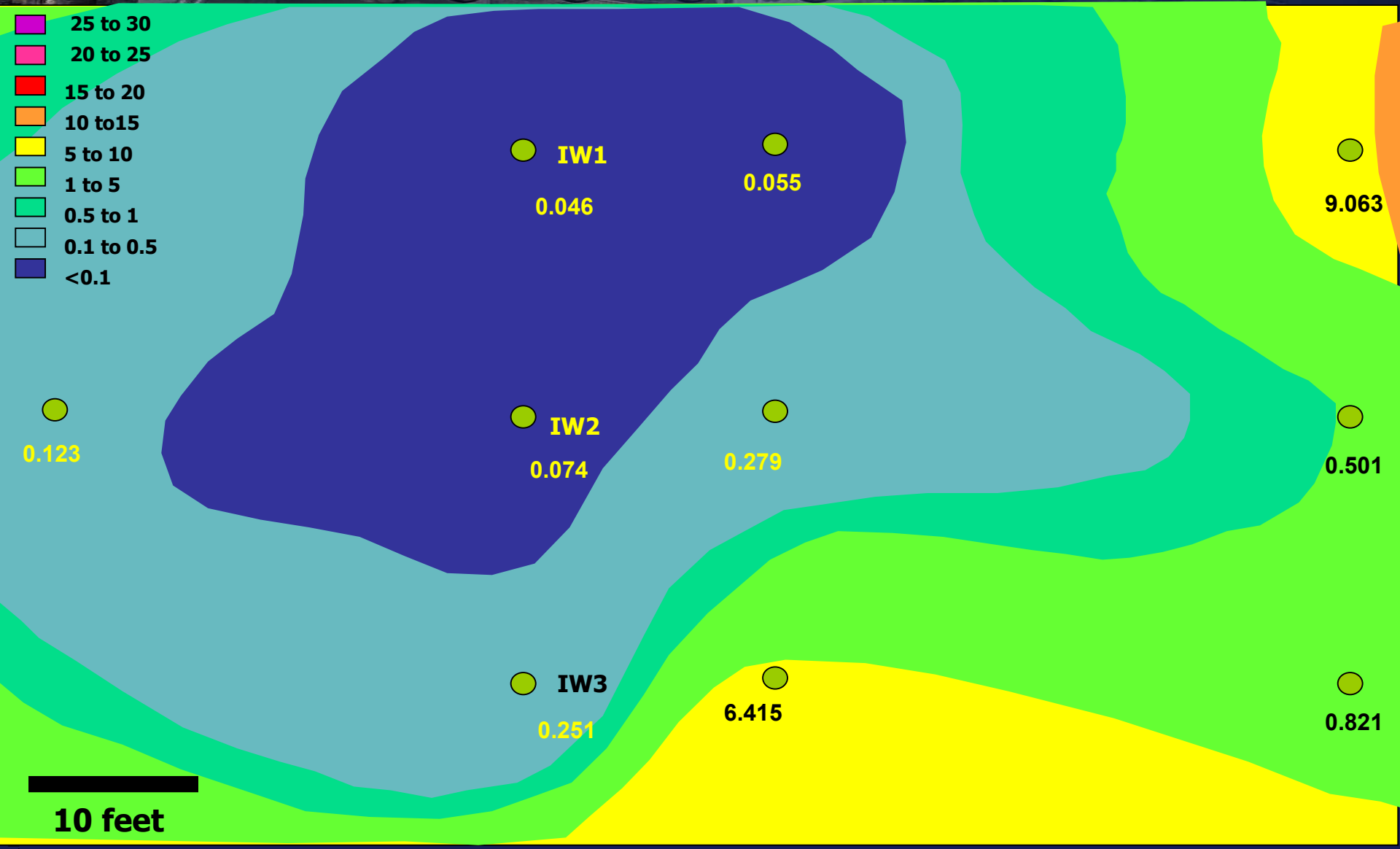
Total VOCs (mg/L) – B-Zone - November, 2003 (Day 44)



Total VOCs (mg/L) – A-Zone – March 2004, Day 180

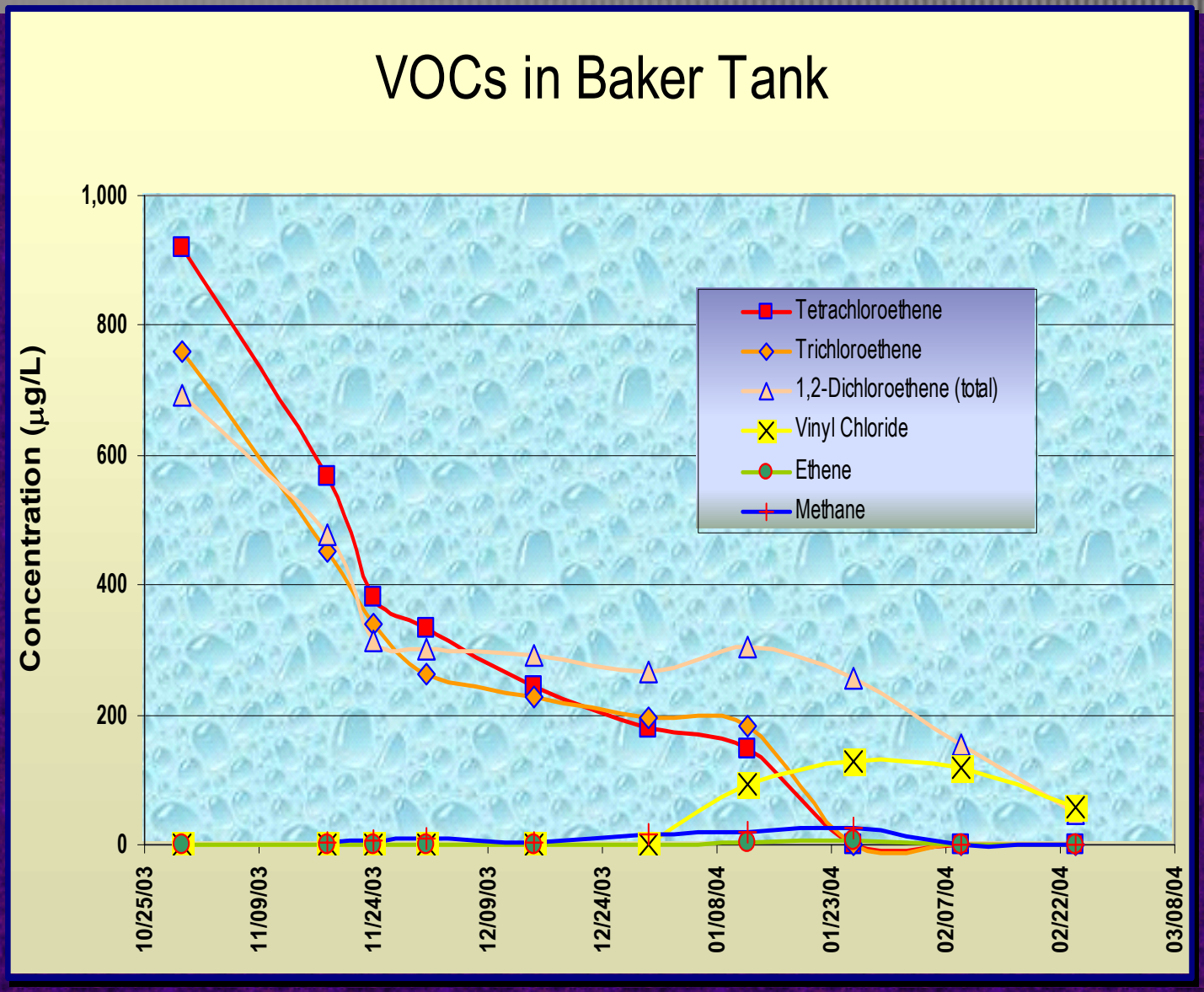


Total VOCs (mg/L) – B-Zone – March 2004, Day 180



Wastewater

- Added: sodium lactate, bacteria, and hydrogen
- Achieved: complete dechlorination of PCE
- DHC concentration 2.5×10^5 cells/mL
- Approved for disposal in POTW



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Conclusions:

Bench-scale test accurately predicted biostimulation rates

Hydrogen addition can increase biodegradation rates.

Bioaugmentation can increase biodegradation rates.

DHC can be effectively distributed through aquifer.

DHC population decreases upon depletion of VOCs.

In Situ bioremediation is an effective remedial technology for dry cleaner sites.

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