Combining Remedies/ Treatment Trains for NAPL Site Remediation

Exploiting Synergies to Reduce Costs/Improve Performance/Increase Certainty

Federal Remediation Technologies Roundtable
May 2007

Jim Cummings
TIFSD/OSWER/USEPA

Historical Perspective on Combining Remedies

- **Earliest – Some talk, little action (like the weather, everyone talked about 'treatment trains…')**

- **Early – Limited use, mostly *ad hoc***
  - **Practitioners noticed something 'interesting' during/after remedy implementation**

  - **EXAMPLE: Electrical Resistance Heating (ERH) to treat methylene chloride**
    - **Contaminants went away but not recovered, - ?????**
    - **Explanation: Greatly increased hydrolysis rates at 70 C**

- **More Recently (post 2003)- (Somewhat) More upfront/purposeful**

- **Practice Still WAY out ahead of the Research (SERDP/ESTCP to the rescue…)**

Combinations

- **Temporal – Adjust/change technologies at appropriate changeover points**
- **Spatial – Treat different zones with different technology(s)**
  - **'Hot Spots'/'Warm Spots'/Dissolved Phase**
- **'Misc.' - E.G., Maximize in-situ destruction (hydrolysis) to reduce/eliminate need for off-gas treatment systems**

Concepts

‘Priming’(Front-end)

and/or

‘Polishing’
(Back-end)

‘Priming’ - Zappi et al

- **‘Chemical Oxidation *Priming* for Enhancing Pollutant Removal in Soils by Biological Treatment’** – *ACS Nat’l Meeting, 2002*

- **‘Chemical *Primed* Enhanced Bioremediation of Petroleum Hydrocarbon Contaminated Sediments’** – *MS-AL SeaGrant Program Review Meeting U of Miss, 2002*

- **‘Integration of Chemical-Oxidation and Biotreatment for Removal of TNT’** – *Final Report to Army Research Office, 2003*

IMPORTANT NOTE: 'Polishing' Doesn't Have to Come Last

- **Michigan PHC site**
  - **Combination of Chemox+Bio implemented following 12 years of MNA**
    - **BTEX plume shrank, but zone still > RAO's**
    - **Trimethylbenzene recalitrant to Bio alone**

Possible In Situ Technology Combinations

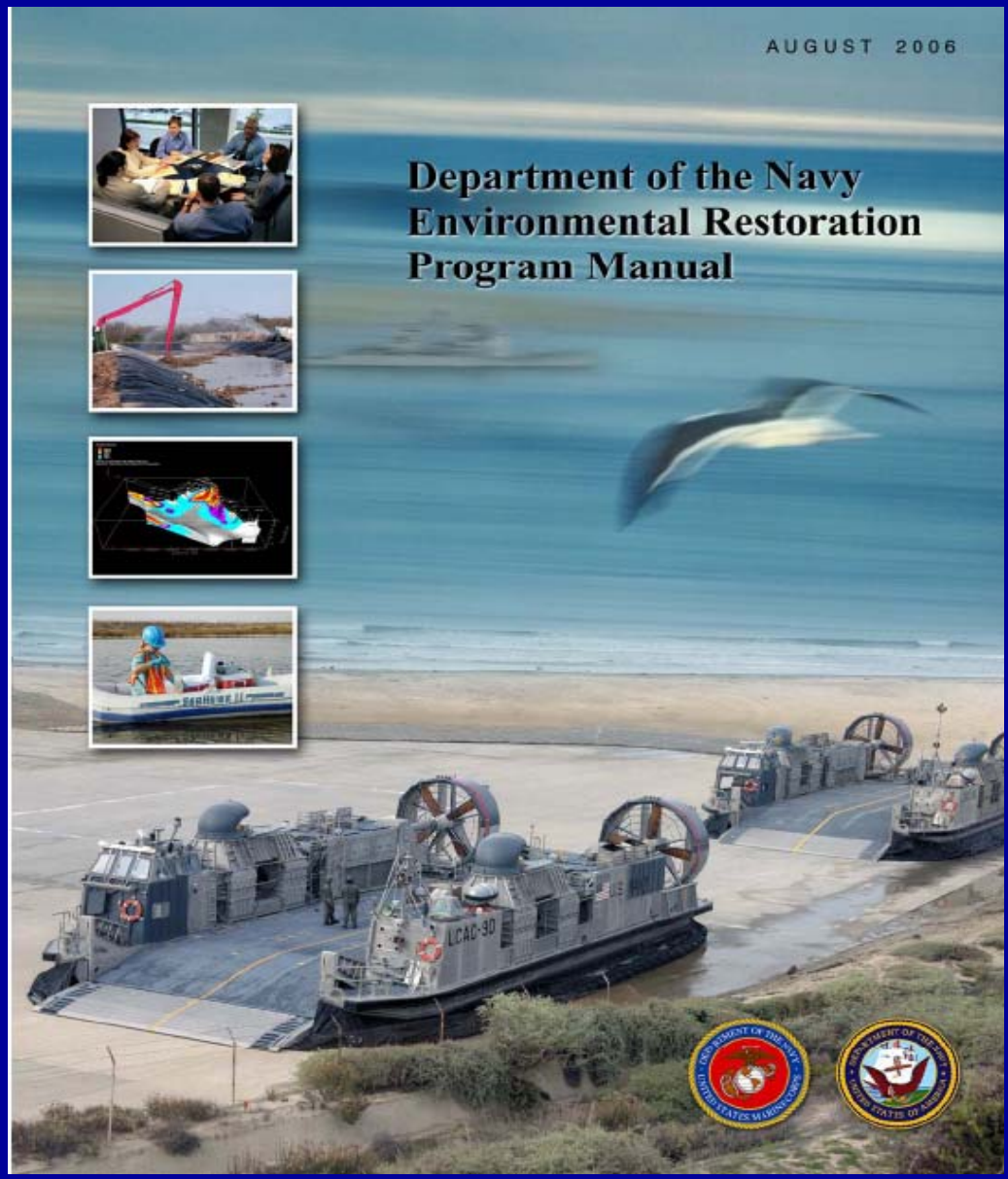
- Thermal + Chemical
- Thermal + Bio
- ChemOx + Bio
- Chemox + Chemox
- Surfactant/Cosolvent + Bio
- Surfactant + ChemOx
- Abiotic (Nano-Fe/ZVI) + ????
- ?
- ?

Seers…(?)

- **‘…it is now clear to many that chemical oxidation is best coupled with accelerated bioremediation for more successful site management.’**

  – *Regenesis ReGenOx Product and Design Manual*

Seers… (cont..)


AUGUST 2006
Department of the Navy
Environmental Restoration
Program Manual
LCAC-90

Navy ERP Manual

- **9.2.3 Flexible ROD**

- The goal of a flexible ROD…is to allow modifications in the remedial approach… These are often required to address ***uncertainties and changing site conditions that typically are encountered during implementation of a remedy as additional site and performance data are collected***

Navy ERP Manual (cont.)

- It is important that the language used in the remedy description allows for ***flexibility in technology transition and unit process selection***

- The remedy should also address the treatment train planned for remedial technologies, such as a transition from contaminant source area treatment to MNA for the dissolved phase plume

NAVFAC
Naval Facilities Engineering Command

ENGINEERING SERVICE CENTER
Port Hueneme, California 93043-4370

TECHNICAL REPORT
TR-2279-ENV

FINAL REPORT – COST AND PERFORMANCE REVIEW OF ELECTRICAL RESISTANCE HEATING (ERH) FOR SOURCE TREATMENT

Prepared by
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Prepared for
Naval Facilities Engineering Service Center

March 2007

Excerpt from NAVFAC Report Executive Summary

- **“In addition to volatilization and steam stripping, enhanced biodegradation and other abiotic reactions at elevated temperatures were an active mechanism at all five sites.**

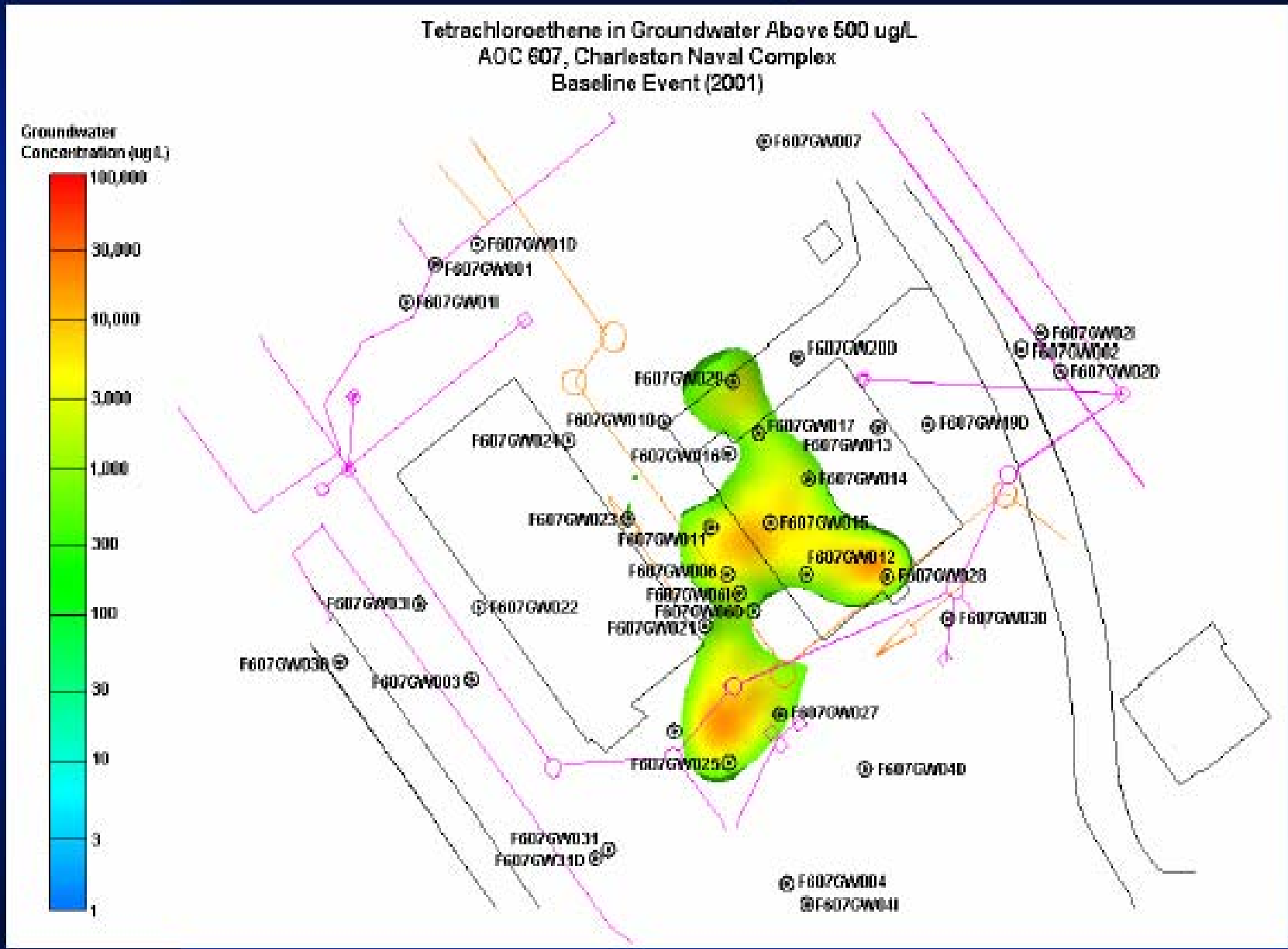
- **Degradation of some components of organic matter at elevated temperatures and the consequent increase in the availability of a carbon source is advantageous for bioremediation.” (i.e., beneficial downgradient effects)**

Charleston Navy Facility ERH Performance

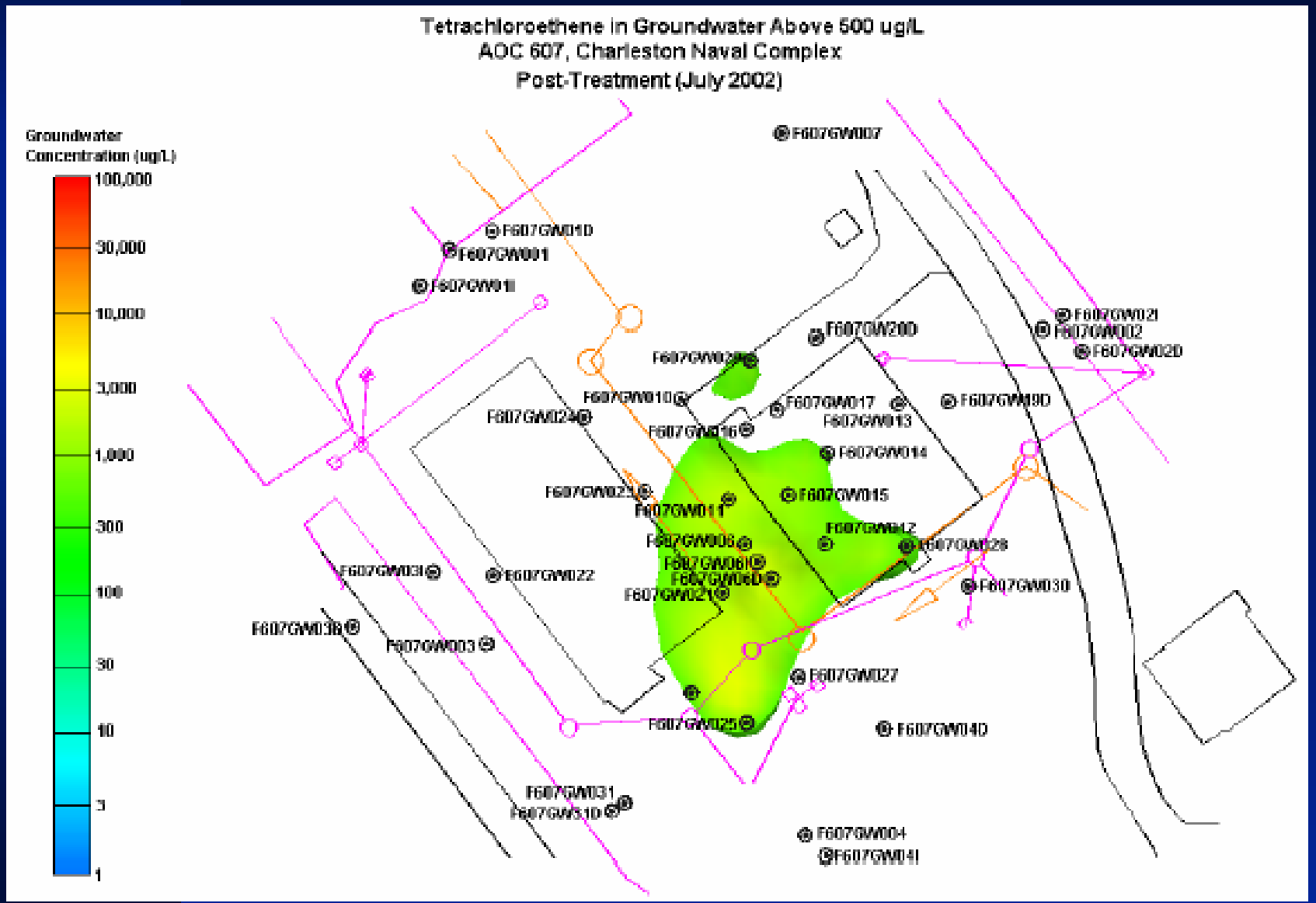
- **Initial Results - 79% VOC reduction (dissolved phase) versus 95% target**
  - **Electrode spacing an issue, also soil drying, acetone generation**
- **Subsequent monitoring data shows continued reduction in contaminant levels**

(Courtesy Dean Williamson, CH2M Hill)

Baseline PCE > 500 ug/L at AOC 607

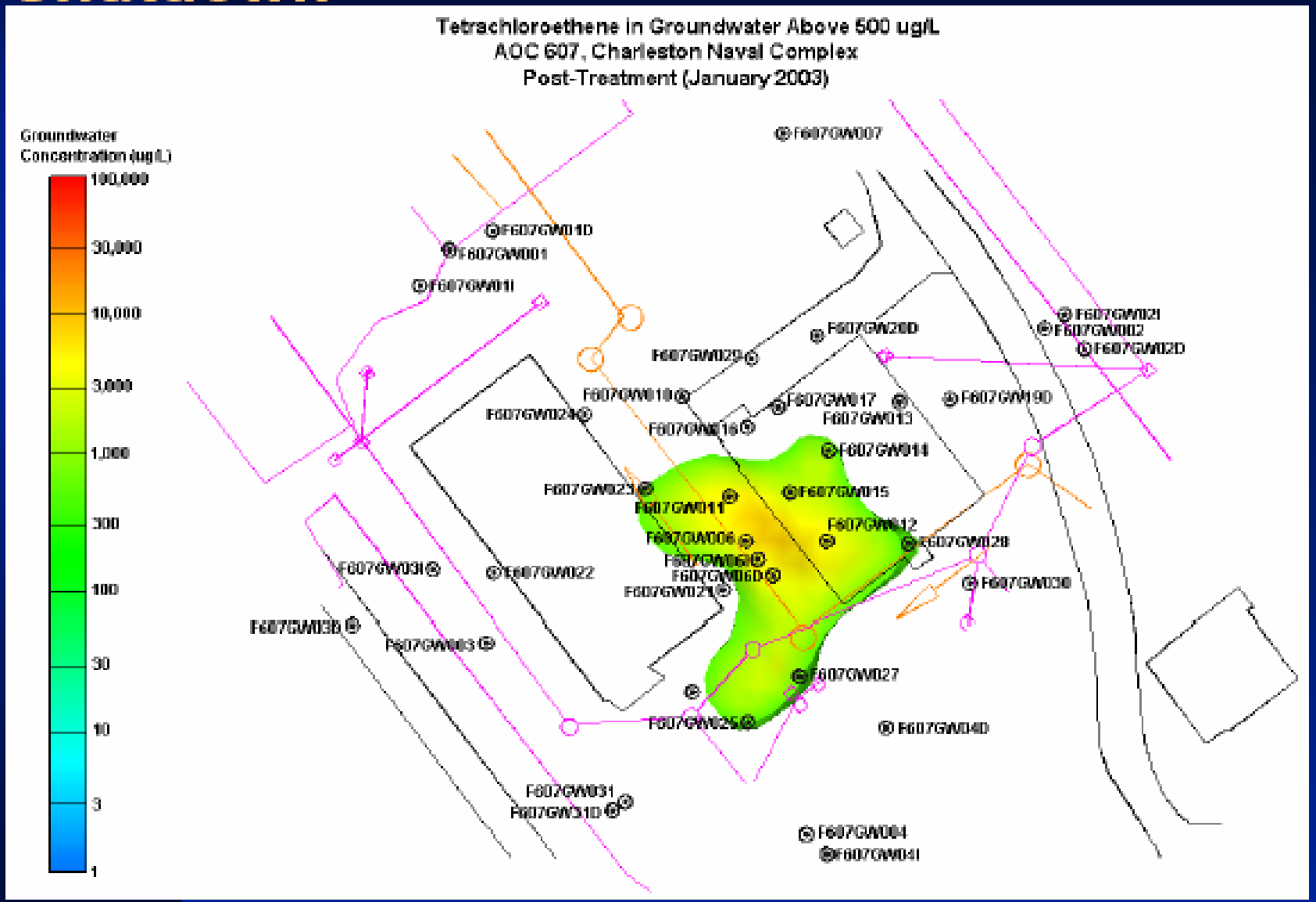


PCE > 500 ug/L at ERH Shutdown



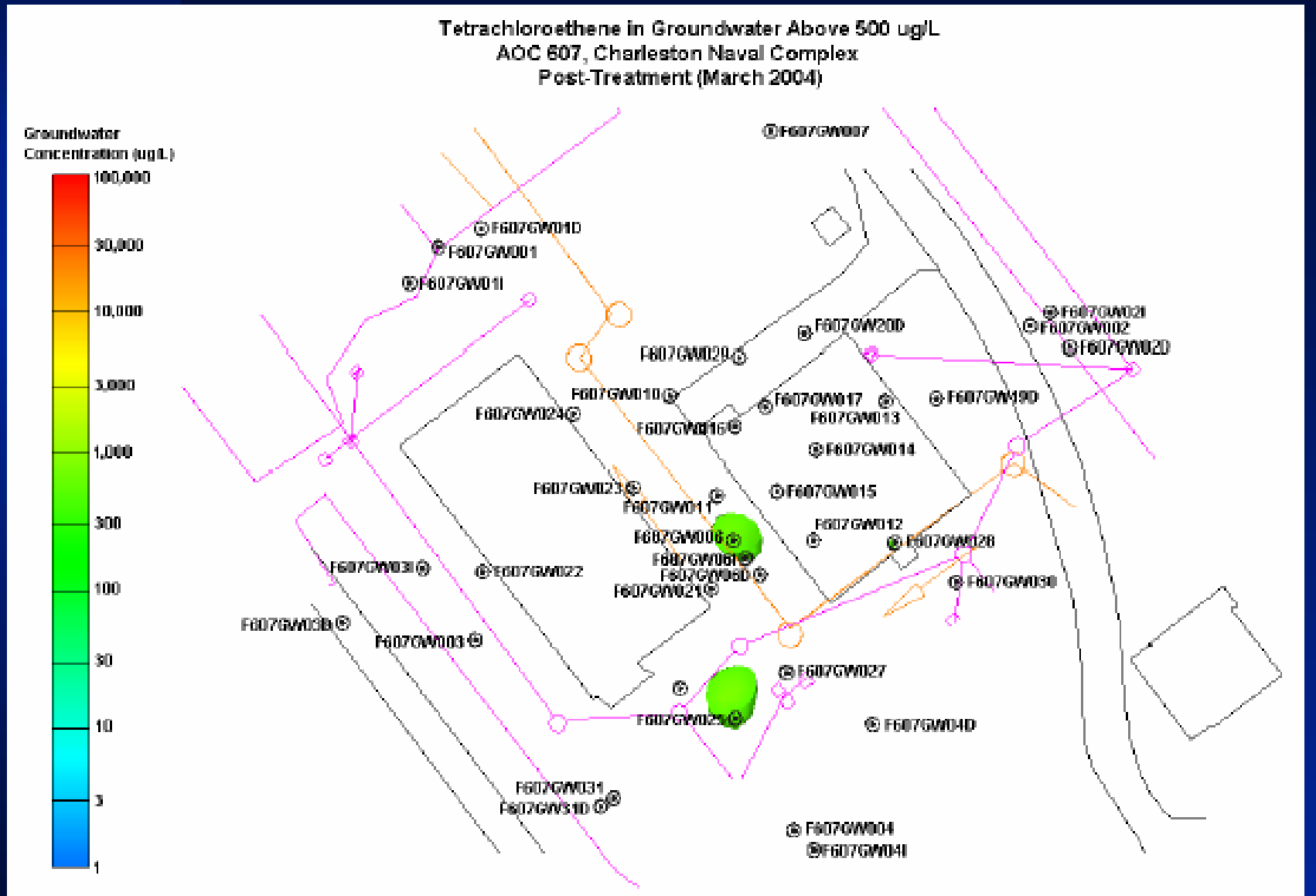
CH2MHILL

PCE > 500 ug/L 6 Months After ERH Shutdown



CH2MHILL

PCE > 500 ug/L 22 Months After ERH Shutdown



CH2MHILL

Thermal + Bio

- **Evidence of biodegradation following Electrical Resistance Heating (ERH) at Charleston Navy Facility Dry Cleaner**
- **Downgradient reduction trends also partly attributable to (slow) flow of clean groundwater through treated zone**

Thermal + Chemical

- ***Dozens of Steam-activated Persulfate Cleanups***
- **Cost Information:**
  - steam subsurface to 65 deg C = $22/cu yd
  - steam subsurface to 45 deg C = $13/ cu yd
  - persulfate @ 1g/kg ox demand = $19/cu yd
  - persulfate @ 2 g/kg ox demand = $28/ cu yd

Steam-ActivatedPersulfate Field Results

Chlorinated Solvents

Location	1,1 DCE (ug/l)	1,1,1 TCA (ug/l)
Scotland Neck, NC	230,000/460	390,000/68,000
Garner, NC	81,700/0.8	73,000/987

Location	PCE (mg/kg)	TCE (mg/kg)
Cobb County, GA	5,100/<2.6	3.2/<0.05

Combined Surfactant/Chemical Oxidation

LNAPL Contamination (Petroleum Hydrocarbons)

Bixby Underground Storage Tank Site, Bixby, OK (LNAPL)

- NAPL: mixed gasoline and kerosene
- Geology: fine sand
- Free product: 0.5 to 2.2 ft, extent 120 ft x 85 ft

- **Surfactant flushing: Mobilization**, 0.94 wt%, 120,000 gallons (1.5 PV) over 13 days

- **Polishing: 0.4 wt% Fenton's Reagent,** 130,000 gallons over 6 days

Bixby UST Site

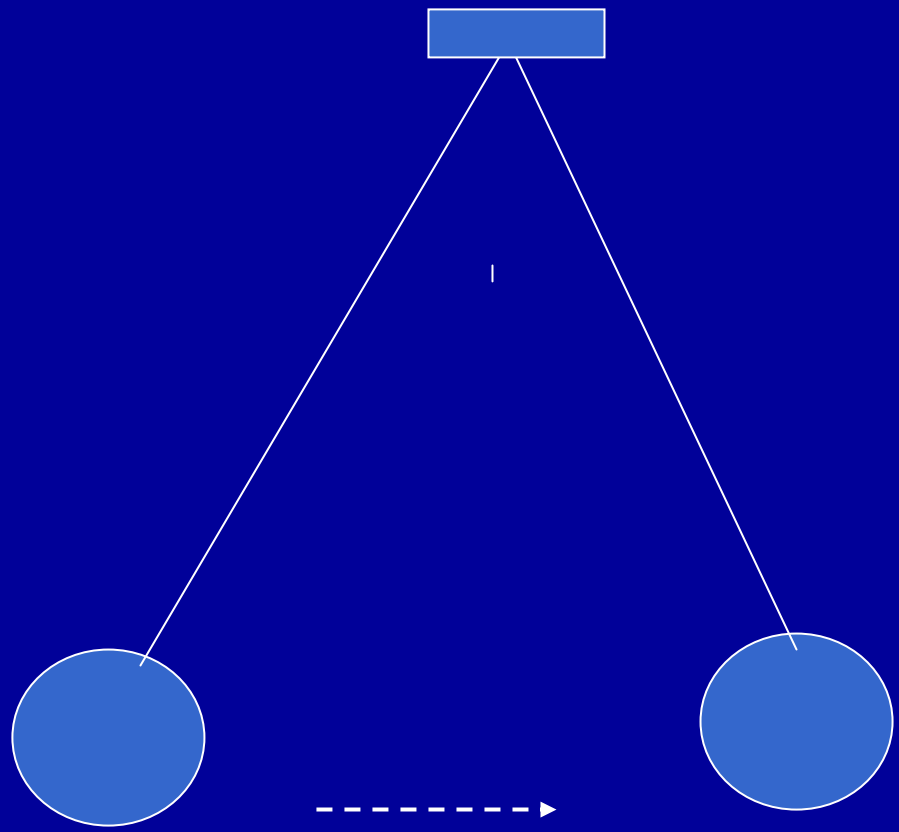
SURBEC ENVIRONMENTAL LLC

Bixby UST Site (cont.)

- No free product observed after surfactant flushing
- Post surfactant flushing: GW Benzene conc. 50 ug/L to 20 mg/L
- Post chem ox polishing: GW Benzene conc. ND to 1.8 mg/L (SSTL 5.6 mg/L)
- Project completed in 2.5 months

SURBEC ENVIRONMENTAL LLC

The Bio-Augmentation Pendulum



1995 – No Way …

- **Predation, etc, etc.**

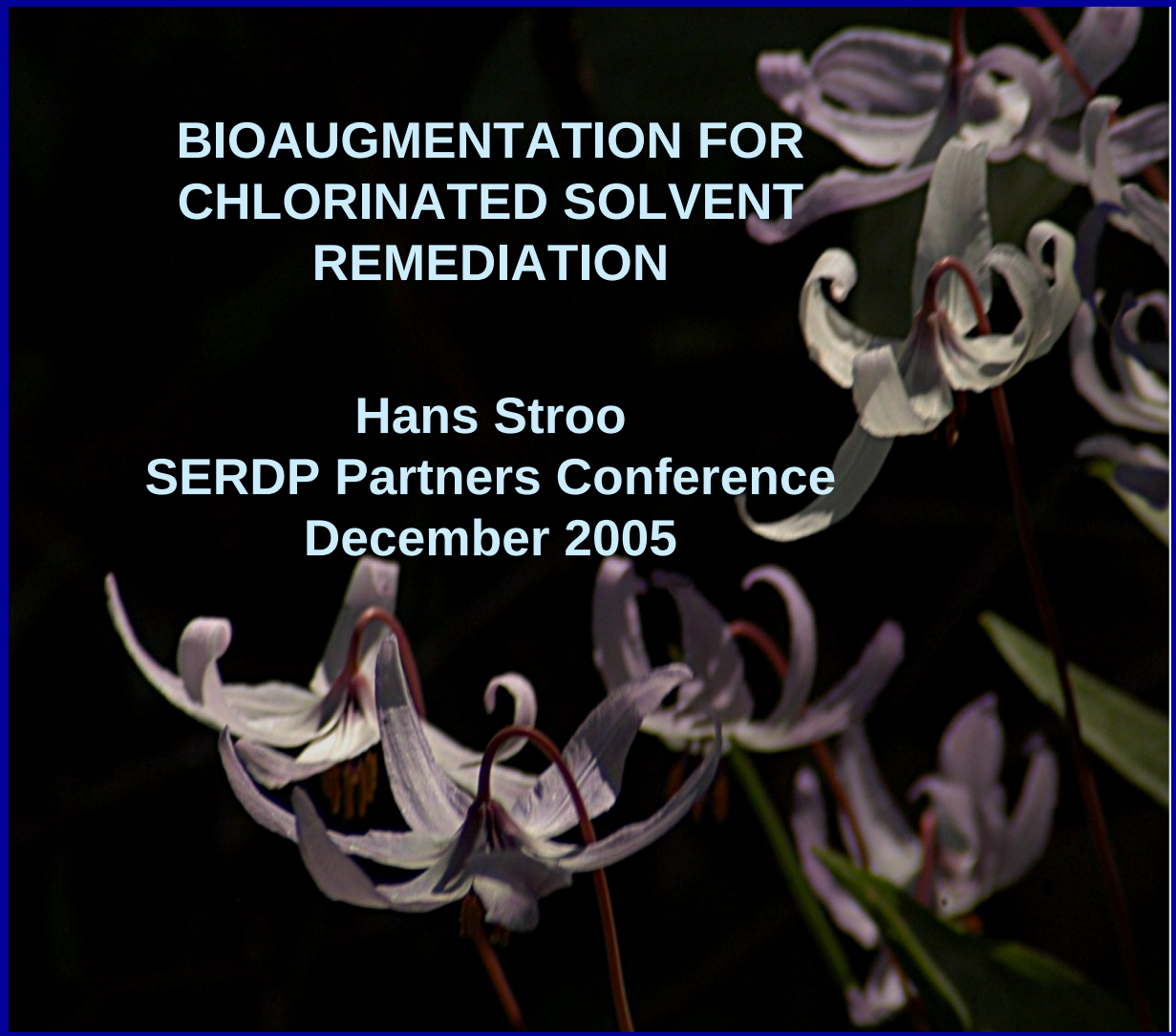
2005 – Why Not?

- **“It’s so cheap…”**

Bioaugmentation

- **Some vendors report bio-augmenting as a matter of course – i.e., without even looking for *Dehallococides Ethogenes (DHE)***

(Highly) ‘Recommended Reading’:



Enhanced Reductive Dechlorination

- **There are a variety of possible electron donors – vegetable oil, molasses, whey, beer wastes, chitin, HRC**

- **Electron Donor appropriateness appears to be site specific**

DESIGN CONSIDERATIONS FOR REMEDIATION BY STEAM AND IRON ENHANCED IN-SITU SOIL MIXING

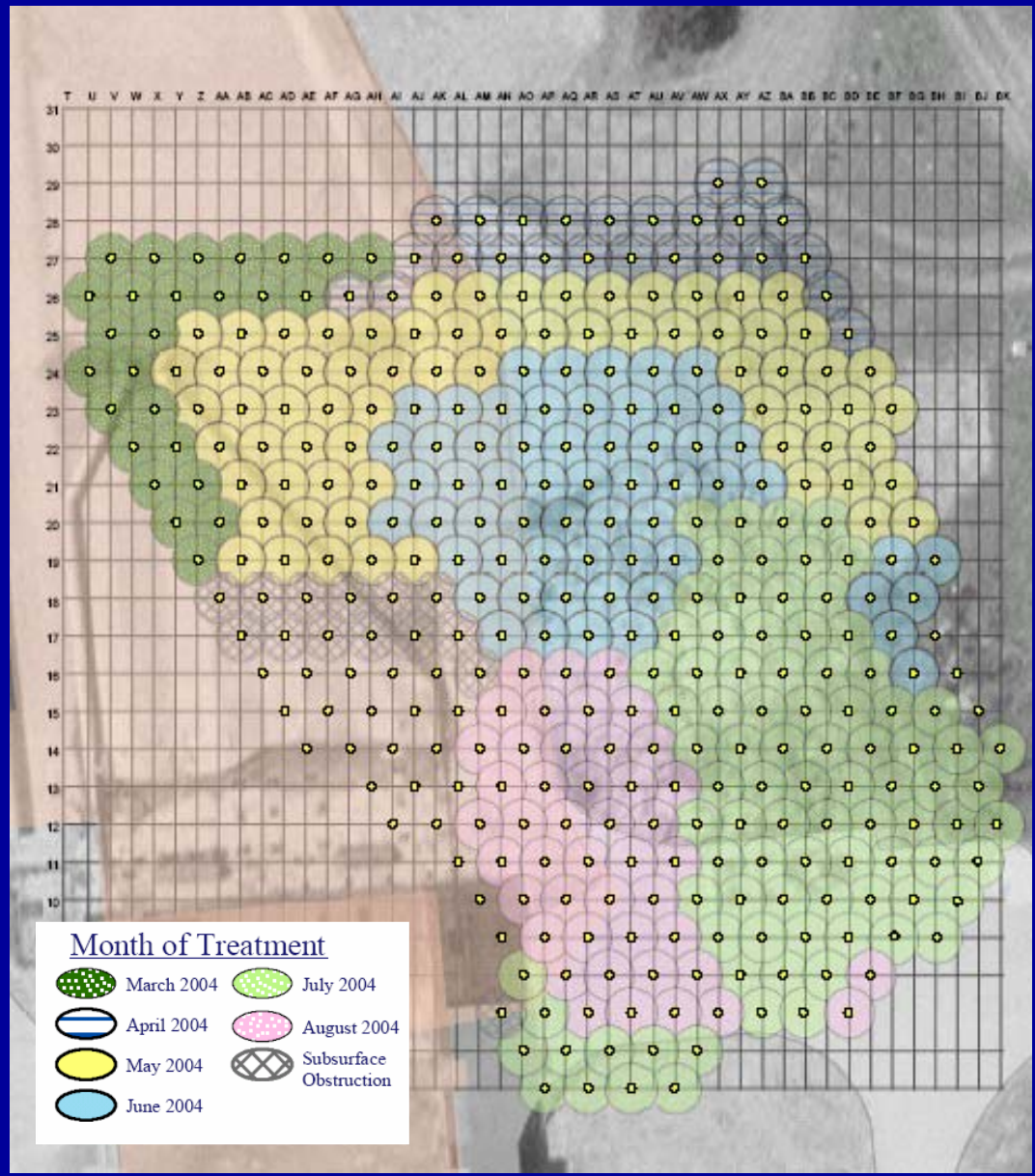
The 5th International Conference on Remediation of Chlorinated and Recalcitrant Compounds

25 May 2006
Monterey, CA

John P. Matthews
Patrick AFB, FL

SPACE LAUNCH COMPLEX 15

- **Launch Stand Treatment**
  - 313 treatment cells
  - 20 ft to 55 ft bgs
  - 1 March – 3 October 2004
  - Estimated TCE Mass Removed: 3,800 – 6,100 lb
  - Estimated VOC Mass Removed: 9,700 – 12,600 lb
  - Does not include in-situ breakdown with ZVI
  - Estimated Treatment Volume: 26,500 cubic yards (minus overlap)



LESSONS LEARNED & FUTURE SITES

- **Lessons Learned from Space Launch Complex 15**
  - Change from 10 foot auger to 8 foot auger
  - Upgrade data acquisition system
  - Increase number of gas chromatographs – run continuously
  - Work outer ring first – then step out from “hot” cells
  - Mix zero-valent iron slurry to lowest depth along outer ring
  - Tweaked treatment protocol to spend more time on high-contaminated cells and less time on low-concentration cells

- **Future Cape Canaveral AFS Sites**
  - Security Police Confidence Course (145 cells)
  - Facility 1381 (892 cells)

Issues

- **Impact of Active Agents – Heat/Oxidants on Mico-organisms**
  - **Within limits, effects seem tolerable/reversible**
  - **Downgradient zones are not affected – In fact, appear to benefit (e.g, Ft Lewis, Wash.)**
- **Effects of Oxidants on Thermal System Components**
  - **May require corrosion resistant materials**
- **Whether costs will be synergistic or additive? – especially with multiple vendors**

Issues

- **Presumption of Certainty in Decision Documents for Sites Subject to Fed'l/State Oversight**
  - **But NOTE: Trend toward more flexible, adaptive approaches and combined remedy specifications in RODs**

Issues (cont.)

- **Combined Remedies may be particularly suitable for early-/mid-90's RODs specifying Pump and Treat at site w/ likely NAPL contamination**

Combined Remedy RODs

- **Pemaco NPL (solvent) site, Maywood, Ca – STATUS; Installation underway**
  - Electrical Resistance Heating (ERH) in hot spot at 35-95’ bgs
  - Enhanced vacuum extraction in vadose zone
  - Possible use of In Situ ChemOx, Enhanced Bio, MNA in downgradient zones

Addtl Recent NPL Site Combined Remedy RODs

- **Brunswick Wood site ROD**
  - Stabilization/Solidification, Slurry Walls, and In-situ Chemical Oxidation
- **TEXWOOD site ROD**
  - insitu S/S, open slurry walls, In-situ Chemical Oxidation, and MNA

Grants, NM Solvent NPL site ROD

PROBLEM COMPONENT	REMEDY
Vapor Intrusion	Mitigation
Source Areas	In Situ Thermal Treatment
Shallow Plume Core and Hot Spot	ISCO + followon ERD
Shallow GW Plume periphery	ERD Bio-Barrier
Deeper GW Plume	ERD Bio-barrier

Grants NM ROD (cont.)

- Remedial Flexibility
  - "EPA will evaluate the site conditions to determine if MNA is a viable remedial alternative after the first 5-year review and after source control has been established in the source area and the shallow GW plume…"

Challenges

- **Convincing decision-makers that 'combined remedies' is not a euphemism for 'blank check'**

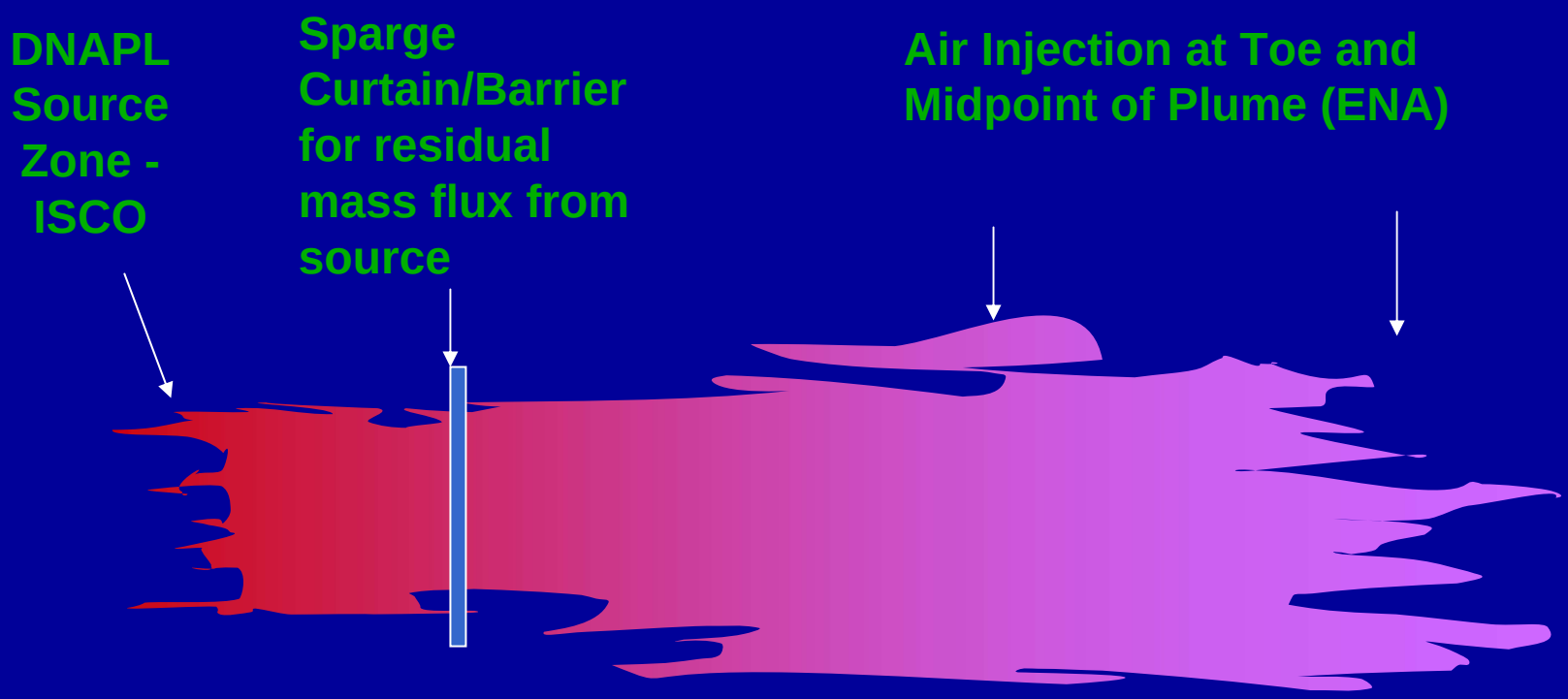
- **Whether single technologies or combinations, we still have work to do in the area of in situ process control**

Desired End State/Least Cost Solutions

- Adequate Use of Robust Source Term Removal Technologies
- Timely transition to cost-effective 'polishing' step(s)
- Reduce/Eliminate Need for Pump and Treat
- Appropriate Reliance on Monitored Natural Attenuation (MNA)

‘Holistic’ Remedy: Partial Mass Removal via In Situ ChemOx (ISCO) + Enhanced Natural Attenuation

Northeast US former Manufactured Gas Plant(MGP)



NOTES: 1) Plume mgmt necessary because contamination has reached residential wells

2) ISCO pilot completed. Consultant analyzing results

Combined Remedies - Closing Thoughts

- **Flexible, Adaptive Implementation is a Crucial Component of Combining Remedies For NAPL Sites**

Combined Remedies - Closing Thoughts (Cont.)

- **System installation and operation can provide valuable information on actual subsurface conditions and contaminant distribution**
  - **"RD/RA - Just the next phase of Site Characterization…"**
  - **"NAPL sources begin to reveal themselves as the remediation progresses…"**
    - ***Consultant at Pittsburgh Envl Restoration Conference***

Another Way of Thinking About 'Performance-Based' …

- **What would a regulatory framework look like that put a number on 'reasonable time frame…' as envisioned by the NCP (e.g. 30 years), and allowed consultants to design treatment trains to meet that timeframe?**

- **Hint: Tools like 'Natural Attenuation Software' will be part of the package**