Flexible, Adaptive, Attentive Use of Combined Remedies

Jim Cummings –
OSRTI/TAB/USEPA

Webinar – May 2018

Bottom Line

- *Yes You Can*
- *Yes You Should*

Sea Changes (Whether one tool or several)

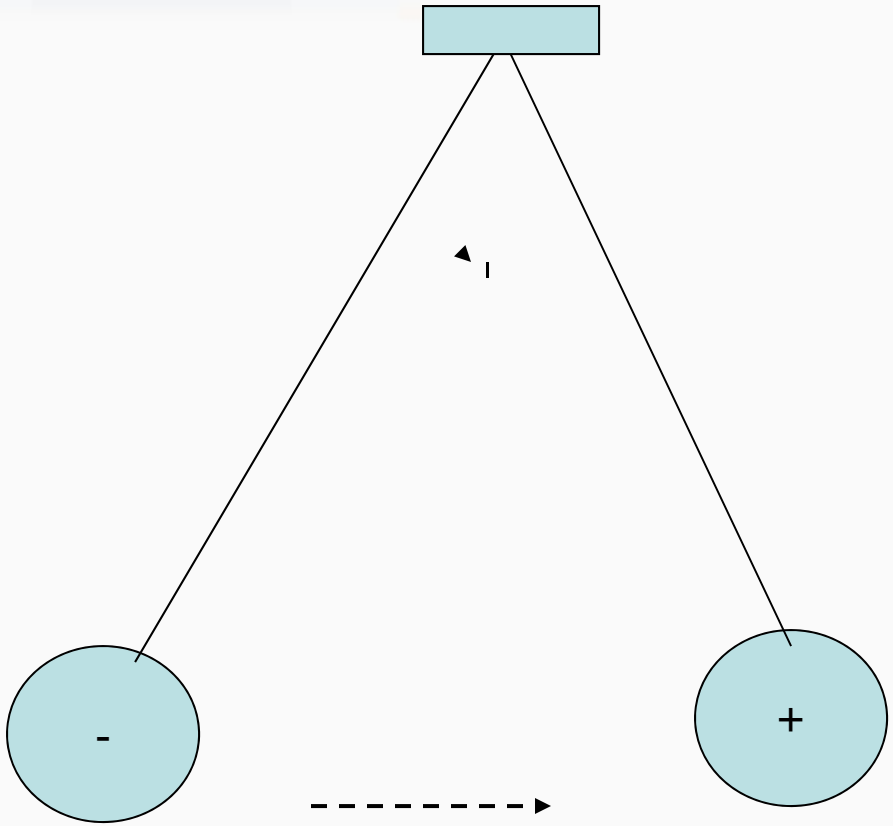
- **Larger tool box of remedial alternatives (especially *In Situ*)**
  - (Much) Better Process Control

- **Better understanding of subsurface compartments and contaminant phases**
  - **Heterogeneity** is the Norm
  - Investment in developing 'better' CSMs can pay dividends
    - 'Return on Investigation (ROI)' – *Joe Quinnan, Arcadis*
  - The Subsurface is NOT static before or during remediation

- **Flexible, Adaptive, Attentive Deployment**

- **High(er) Resolution Site Characterization**
  - But, still making too many simplifying assumptions

The Bio-Augmentation Pendulum



1995 – No Way, Jose…

- Predation, etc, etc.

2005 – Why Not?

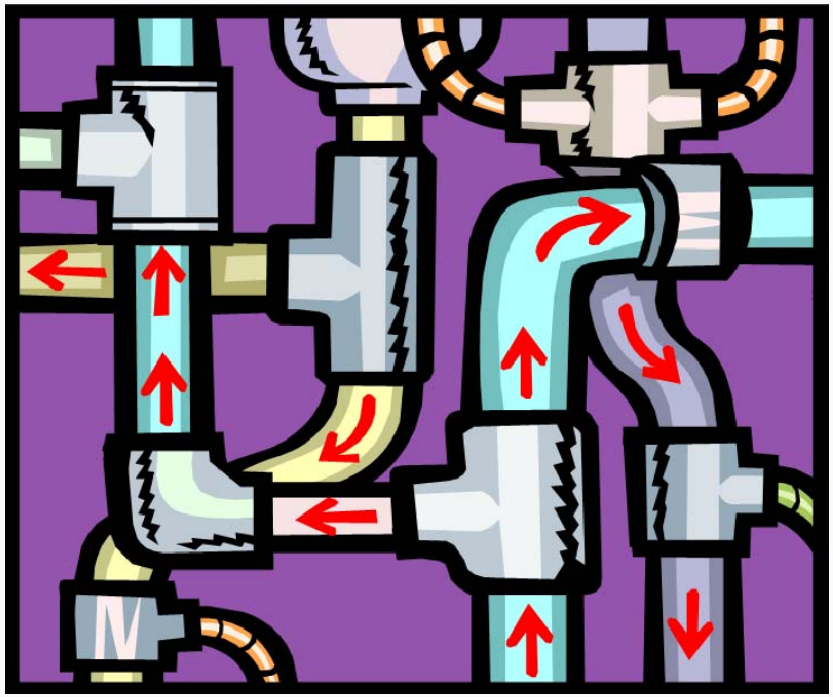
- “It’s so cheap…”

Sea Changes (cont.)

- Increasing Awareness of the Importance of Geology

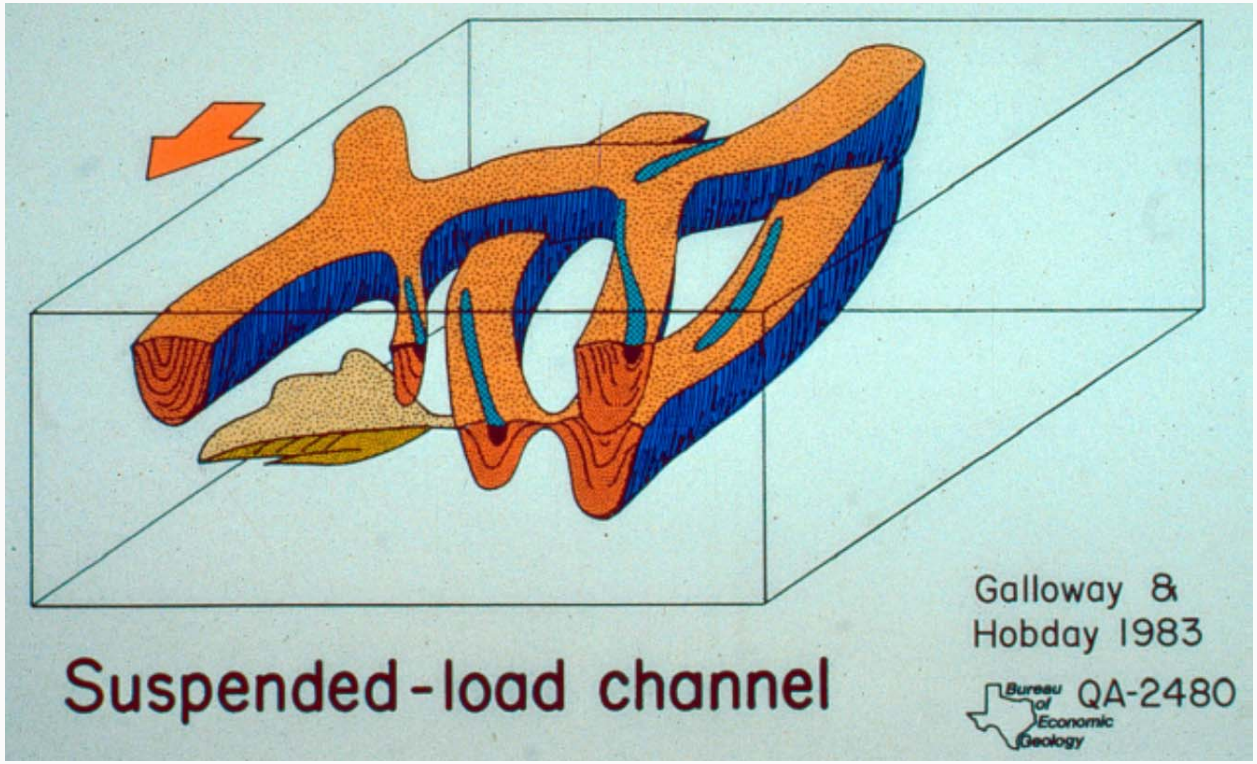
Geology – Connecting the Dots...

- The Plumbing...



Geology – Connecting the Dots...

- The Plumbing...



Geology – Connecting the Dots...

EPA/600/R-17/293
September 2017

EPA United States Environmental Protection Agency

Groundwater Issue

Best Practices for Environmental Site Management:
A Practical Guide for Applying Environmental Sequence Stratigraphy to Improve Conceptual Site Models

Michael R. Shultz[1], Richard S. Cramer[1], Colin Plank[1], Herb Levine[2], Kenneth D. Ehman[3]

Combined Remedies – The 'New Normal'

- Growing awareness that different tools may be most suitable to address:
  - Different contaminant phases/ concentrations
  - In different site 'compartments'

- Not just for larger or more complex sites

Compartments

- **'New, Improved' 3-Domain Model**
  - Transmissive
  - Slightly Transmissive/Slow Advection
  - Storage

- **(Dreaded) 'Back Diffusion'**
  - An engineering speed bump, generally not a road block to site remediation

Examples (Not Exhaustive)

- Thermal + Thermal
- Thermal + Bio
- Thermal + ISCO + Bio
- ISCO + ISCO
- ISCO + Bio
- ISCO + ISCR... (Say What??)
- Surfactant + ISCO
- ISS + ISCO//ISS + Ex Situ Thermal Desorption
- Ex Situ + In Situ

Pioneers - Giving Credit Where Credit is Due…

- **Biodegradation of PCP enhanced by chemical oxidation pretreatment**
  - Lee and Carberry, *Water Env Research,* vol. 64, no. 5 pp 682-690, **1992 !!!!**
- ***Sequential Biological/ Chemical/Biological Treatment of Organic Chemicals - Patent No. 5,955,305***
  - Soni, Kayser, Kelley, Srivastava, Institute of Gas Technology, 1997
- **'Chemical Oxidation Priming for Enhancing Pollutant Removal in Soils by Biological Treatment'**
  - Mark Zappi (now at U of Louisiana Lafayette) *ACS Nat'l Meeting, 2002*

Approaches

- **Temporal – Adjust/change technologies at appropriate changeover points**
- **Spatial – Treat different zones with different technologies**
- **'Package Deals' – Some tools have more than one mechanism of action ('two-fers' and 'three-fers'...)**

PACKAGE DEALS

IN SITU CHEMICAL OXIDATION VENDORS ARE MORPHING INTO CHEM+BIO FIRMS

In Situ Chemical Oxidation (ISCO) + Bio

- **"…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*

FMC Corp**. - *11 Apr 2008 Press Release*

- **FMC Launches *Klozur® CR*, A Combined Remedy Product That Couples Chemical Oxidation Plus Enhanced Aerobic Bioremediation**

- **** - Now Peroxychem**

SRS®-EZVI Emulsified Zero Valent Iron Substrate

- Combination of Biotic and Abiotic Reductive Dechlorination Mechanisms
- Licensed from NASA
- For DNAPL, Freon 113, and Biobarrier Applications

Terra Systems

Redox-Tech Anaerobic BioChem Plus (ABC®+) and Peroxychem EHC

- Promote both reductive dechlorination and anaerobic biodegradation of halogenated solvents in groundwater

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
Arun Gavaskar, Battelle
Mohit Bhargava, Battelle
Wendy Condit, Battelle

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*.”**

- SIDE NOTE: See Hydrolysis

Monitored Natural Attenuation (MNA)

- Frequently used ‘polishing’ component of remedies
  - Concerns regarding DCE/VC ‘stall’
- EPA MNA Guidance***:*** ***MNA is most suitable when used in conjunction with source treatment***
- Increasing use of quantitative ‘lines of evidence’
  - Traditional – Stable or shrinking plume/declining concentrations
  - Newer – QPCR, PLFA, Qantarray to determine micro-organisms and activity

MNA – A 'Natural' Combo (?)

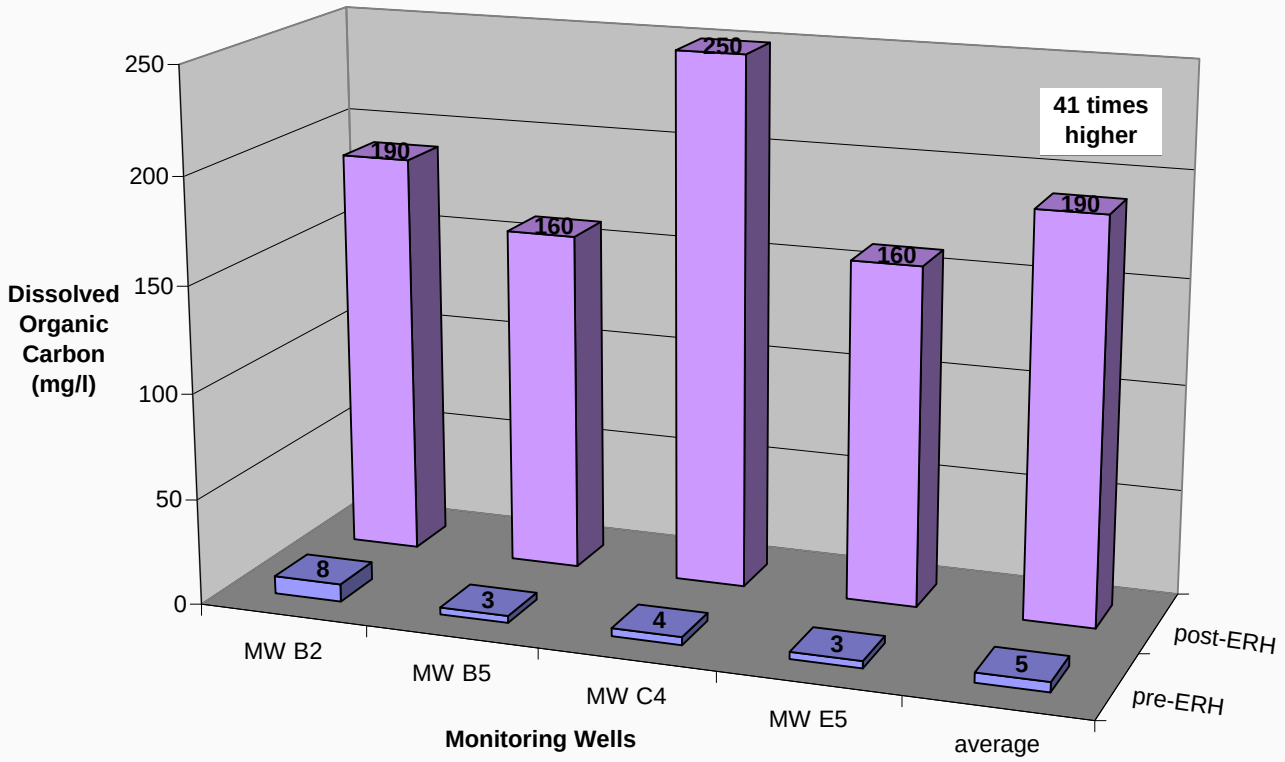
- Biotic AND Abiotic Mechanisms
  - Investigation of Magnetic Susceptibility (magnetite) at the Hopewell Precision NPL site in NY – *John Wilson, EPA, Ada/ORD(ret.)*

- *See also 'Biogeochemical Transformation'*
  - Micro-organisms potentiate metallic species

‘Synergies’ – A/The Holy Grail of Combining Remedies

- Thermal and ISCO Source Zone remedies can release bioavailable dissolved phase carbon

Effect of ERH on Groundwater Dissolved Organic Carbon



Courtesy Thermal RS

Synergies (Cont.)

- **Dechlorinating micro-organisms thrive at 30-35°C**

- **Why not consider implementing bio for dissolved phase contamination while the 'free' carbon is arriving and migrating water is in the right temp range?**

Approaches (cont.)

- **'Type 1' - Anticipatory/Intentional (Newer sites)**
  - Inclusion in original decision documents
  - 'Mid-course corrections' the norm
    - *Even then, 'No plan survives the first encounter with the enemy'*
- **'Type 2' - Ad Hoc/Post Hoc (esp. Older/ Legacy sites)**
  - (Scrambling to) Try something else when 'Plan A' falters

Approaches (cont.)

- **Phased/Progressive/Contingent**
  - *"If, then..."*
- **See Grants NM Drycleaner '*ERH* +' ROD**
  - ISCO or ERD depending on outcome of pilot

IMPORTANT NOTE: How You Do It Is As Important as What You Do

- **"Remedy implementation is just the next phase of site characterization"**
- **"Sources begin to reveal themselves as the remedy progresses"**
  - Many/Most ISCO remedies have a smaller footprint for subsequent injections
- **Therefore: *Flexible*, *Adaptive*, *Attentive…***

Attentive…

- **Even system <u>installation</u> can be informative**
  - AECOM webinar discussed ERH installation found top of confining unit topology which resulted in completely different GW flow regime

- **Process Control!!!!**
  - Initially an advantage for In Situ Thermal
  - ISCO vendors now monitoring reagent presence, DO, ORP, conductivity, color, etc on a frequent basis
    - At least one vendor reports doing MIP probes between ISCO injections

Attentive… (Especially Bio)

- ‘It has become standard practice on our projects to do microbial evaluation throughout the remedial process.“

Jack Sheldon, Antea Group

Presentation at EPA/NGWA Workshop

ENVIRONMENTAL Science & Technology

Feature

pubs.acs.org/est

Biodegradation: Updating the Concepts of Control for Microbial Cleanup in Contaminated Aquifers

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CASE STUDIES

Flexible Adaptive Decision Document and Attentive Implementation of Combined Remedies

Grants Chlorinated Solvent Plume Site, Grants, New Mexico

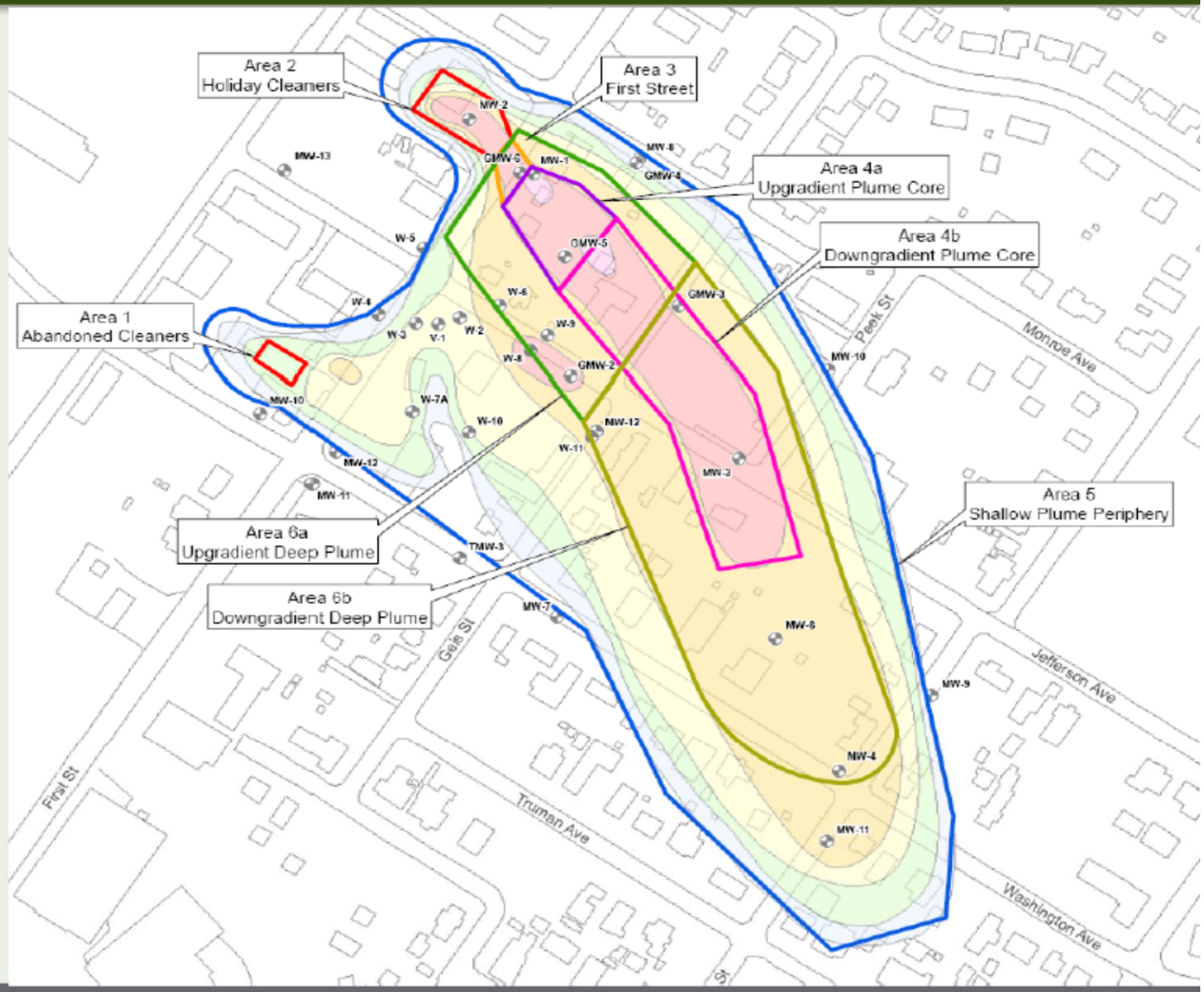
NGWA Symposium
Arlington, VA

By Sai Appaji – Region 6
Dallas, TX
August 8, 2017

EPA
United States
Environmental Protection
Agency

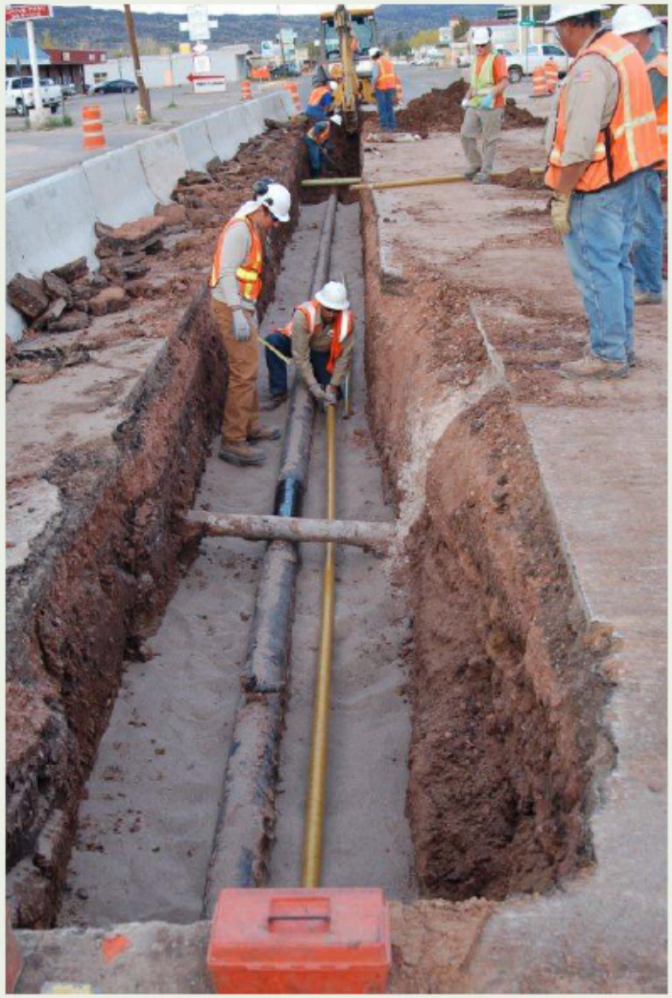
Record of Decision Remedy

Area	Approach
1	In situ thermal treatment (ISTT)
2	ISTT
3	ISTT and in situ chemical oxidation (ISCO)
4a	ISCO
4b	ISCO with follow-on enhanced reductive dechlorination (ERD)
5	ERD
6a	ERD
6b	ERD and long-term monitoring (LTM)
All	Vapor intrusion mitigation systems (VIMS) at residences within plume footprint



ISTT Remedy – Inside Dry Cleaner Building

ISTT Remedy – Under Street and Private Property



Summary/Conclusions

- **Optimization process continuously implemented since Preliminary Remedial Design**
- **Monitoring optimization**
  - » Up to 30% of monitoring wells shifted to biennial sampling
  - » Remainder sampled annually
- **Substrate quantity optimization**
  - » Fourth injection event used 60% less than first
    - › Includes 365 injection wells; down from nearly 700
  - » Fifth injection event expected to by 80% less than first
- **Performance maximized: VOC mass reduction**
  - » From ERD = >80%
  - » From total system implementation: >95%
- **Ahead of schedule presented in Final Remedial Design**

ISCO+ISCO+Removal

- **Site - Future Home of Orlando Magic**
  - **Guaranteed, Fixed Price (50% at risk if MCL's not achieved)**
  - **MCL's achieved**

Courtesy GeoCleanse

Phased Remediation

- **Catalyzed peroxide**
  - Primary Source Reduction
- **Permanganate**
  - Polish to MCLs
  - Prevent back-diffusion
- **Soil Removal**
  - 2 areas x 900 cu ft each
  - Remember the ‘attentive’ admonition?

Courtesy GeoCleanse

Floor Drain Pipe – Likely Source

(Continued Attentiveness since there was $$ on the table)

Courtesy GeoCleanse

Commerce City – Non-NPL Solvent Site

- **Excavation**
- **ISCO** – Potassium AND Sodium Permanganate
- **ISCR**- ZVI Permeable Reactive Barrier

Courtesy GeoCleanse

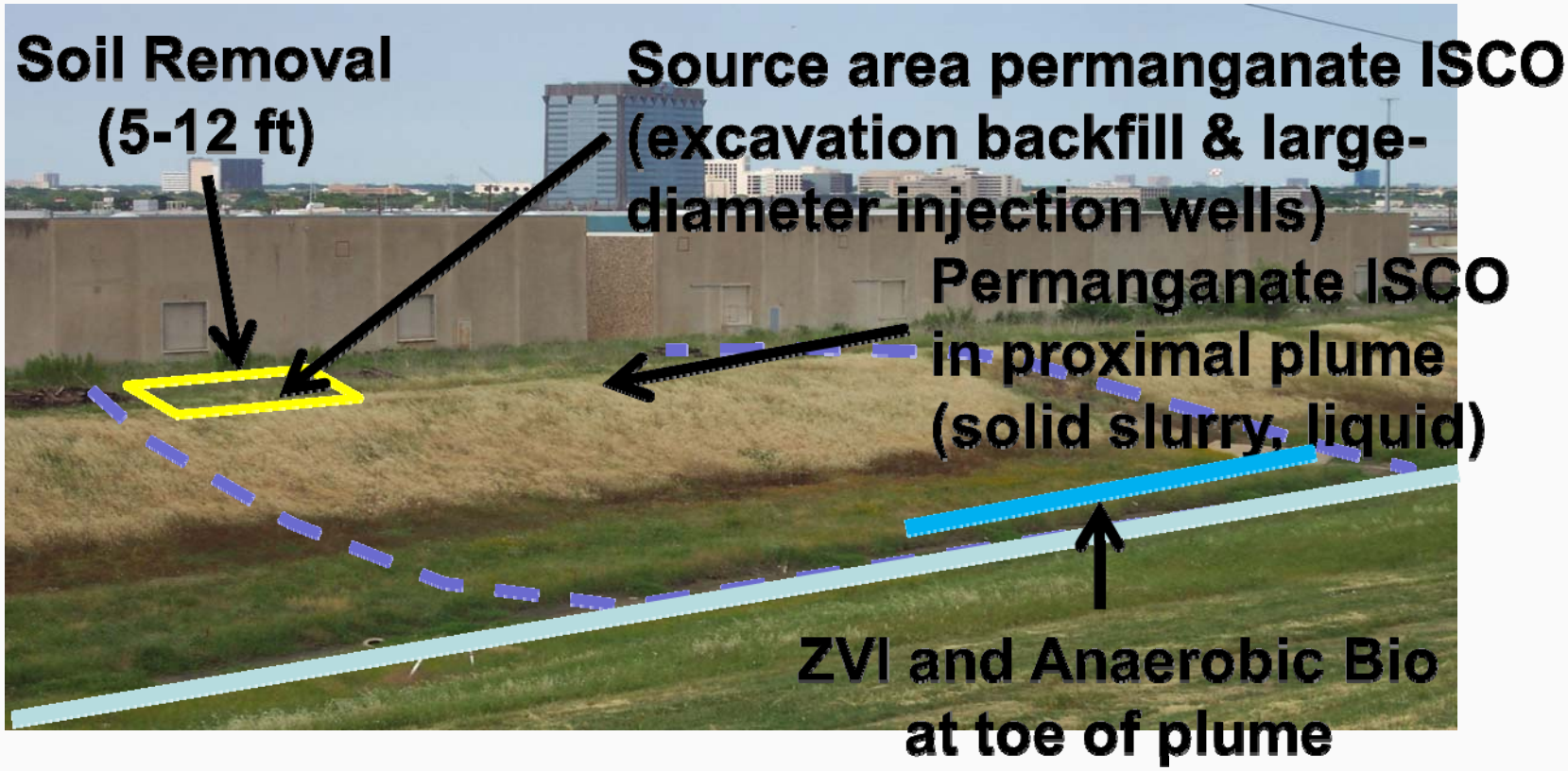
Commerce City - High Points

- **ISCO** – Source Zone, Hot Spots, Recalcitrant Areas of Plume

- **ISCR and Bioremediation** downgradient to protect Surface Water
  - ISCO N/A due to concerns about surface water impacts

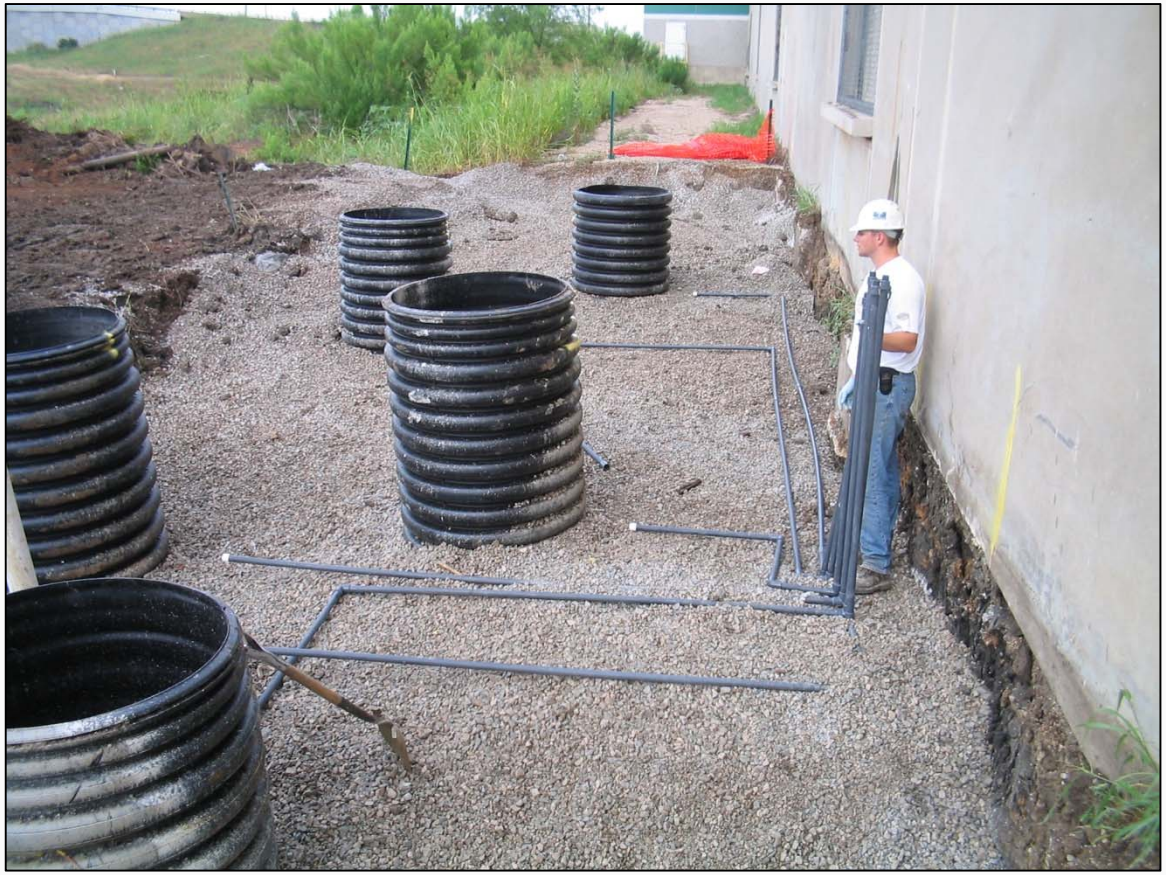
Courtesy GeoCleanse

Remedy Overview



Courtesy GeoCleanse

Remediation Design



Courtesy GeoCleanse

Details

- Solid ISCO reagents backfilled into excavation and boreholes
  - Flooding to dissolve reagents
- Hydraulic fracturing delivery of ISCO, ISCR and slurry of ZVI and Carbon substrate

Courtesy GeoCleanse

Remaining Challenges

- **Tools to Predict Resource Restoration Timeframes**
  - And tools to QA/QC calculations

- **Decision Rules to delineate boundaries/temporal transition points among remedial components**
  - 'How much to heat/how much to eat…'
  - Asymptotic results currently prevalent metric

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)**

Contact Information

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- www.cluin.org

SOME NEW(ER) TOOLS WE ARE TRACKING

Injection of Activated Carbon

- After decades of pumping gazillions of gallons to the surface for carbon treatment…
- Sequester and Treat contaminants

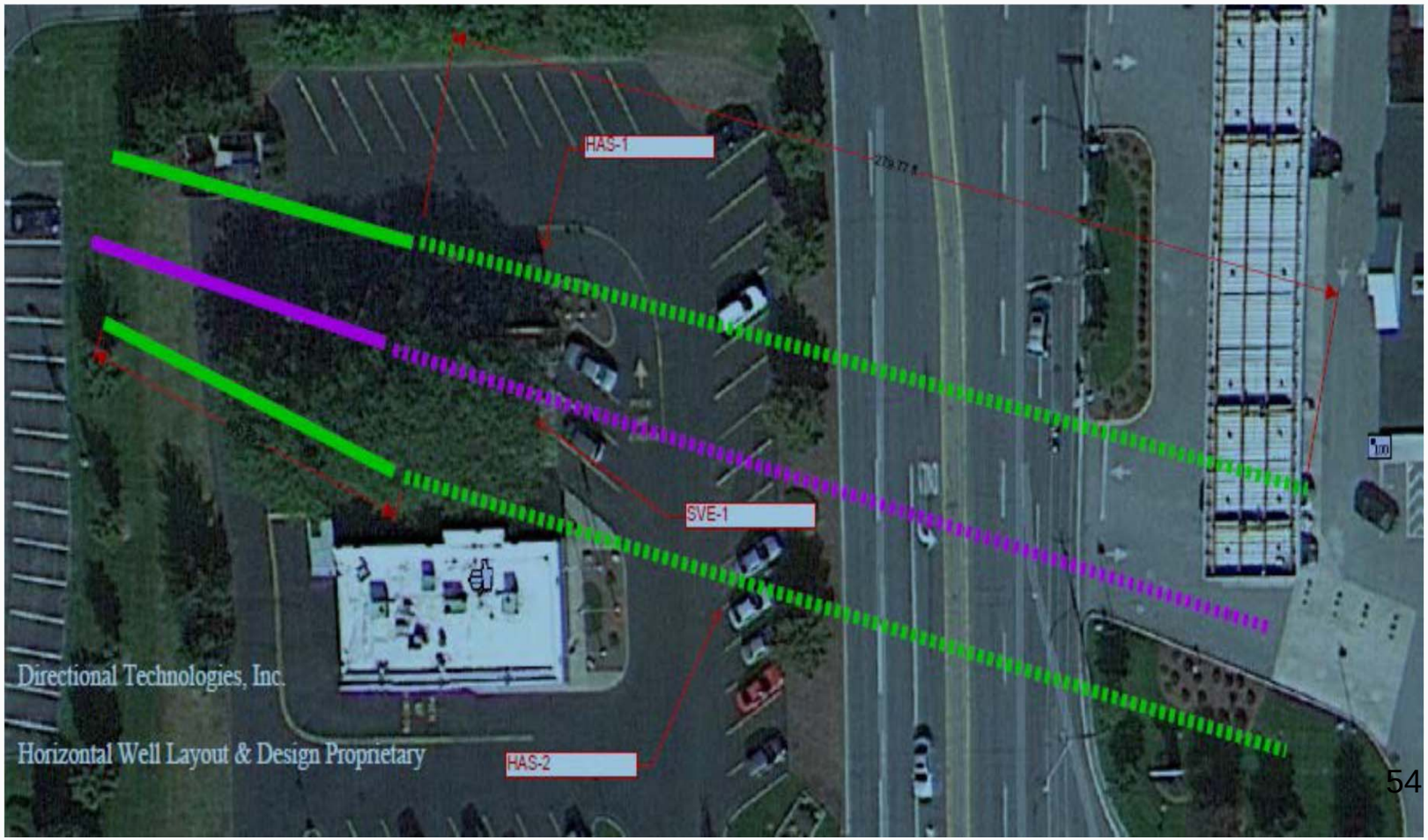
Carbon Injection - State of Practice

- >1000 full-scale UST applications
- Dozen(s) of CVOC applications (including Fractured Rock)
- Several NPL applications

Horizontal Wells

- Improved emplacement accuracy
- Helpful where accessibility is an issue
- Can be used to inject reagents or extract contaminants

Horizontal Wells at a Gas Station



Horizontal Electrodes

Courtesy ThermalRS

Dynamic GW Recirculation (DGR)

- Vary injection/extraction patterns
- Maximize contaminant mass extraction for traditional Pump and Treat systems
- Improve reagent delivery and contact with contaminants

Electro-Kinetics

- **Promising DC-current technology for low permeability/back diffusion situations**

- **E-K Version 2.0**
  - Original - E-K tried to move/recover contaminants
  - ‘New, Improved’ – Move reagents, nutrients, bugs

- **Bio and ISCO variants**

Real-Time Process Control (?)

- Cheap Sensors
- Telemetry
- Cheap/Powerful Computation Capability
- Data Management/Visualization (done properly)