XDD ENVIRONMENTAL

Do it Right, Do it once

***Combining Technologies to Improve Remedial Outcomes* Workshop**

November 2017

State of the Art vs. State of the Practice

The Lost Art of Remedial Design

You Needed This:

But What You Got Was....

State of the Art vs. State of the Practice

State of the Practice		State of the Art
	Short-Term Cost Pressures	
❑ Initial low cost ❑ Limited or "rule of thumb" design ❑ Lower certainty of success ❑ Ultimately higher cost?		❑ Potentially initial higher cost ❑ Appropriate testing and design ❑ Higher certainty of success ❑ Ultimately lower cost?

Complex Remediation Concepts are Being Packaged in Easy to Use Products

Case Study #1 : Early in ISCO Applications

- Are ISCO and Bioremediation Compatible?

- Manufacturing facility – historically used TCE
- Water bearing strata: gravely-sand, semi-confined, 8-10 ft thick, 5 ft/day velocity
- Residual DNAPL in silt lenses and at the aquitard interface
- Main contaminants: TCE, cis-DCE, VC
- Generally reducing groundwater conditions (ORP: 0 to –150 mV)

- Laboratory treatability studies
- Source area characterization: 3-D, high resolution
- Pilot test design:
  - Two treatment zones ~160 ft x 175 ft x 10 ft each
  - Two rows of injection wells (total of 12 locations and 16 wells)
  - Eight rows of nested monitoring points (total of 36 locations and 80 points)

INJECTION	Persulfate	Permanganate
Injection Duration, days	64	172
Monitoring Duration	7 post-injection quarterly events	
Oxidant Quantity, Kg	8,200	45,000
Volume of Water, L	4,300,000	4,400,000
Flow Rate/Location, Lpm	4.3	1.6, 1.9 and 3.8
Injection Conc., g/L	2	5 and 10
Geochemistry Monitoring	pH, ORP, Conductivity and Temperature	
Chemical Parameter Monitoring	VOCs, Cl^-, persulfate, permanganate, Na^+, SO_4^{2-}, K^+ and Mn (dissolved and total)	

Post Injection Monitoring

- 7 quarterly events: august 1999 - December 2000 + June 2001
- Significant increase in daughter products
- Increased daughter product:parent compound ratios: cis-DCE:TCE, VC:cis-DCE
- PFLA analysis
  - Gram Negative type of bacteria (including sulfate-reducing bacteria) present
  - Sulfate-reducing bacteria biomarkers present

Case Study Conclusions

- CVOCs made more bioavailable by reducing sorption sites
- ISCO provided simple organic carbon (a food source) for bacteria by degrading naturally occurring complex organic carbon
- Enhanced CVOCs reducing bacteria growth
- Approximately 50% reduction by ISCO and ERD

Case Study #2 : Thermal Enhancement

(CHA / TERRATHERM/ XDD)

- Question was: Is thermal enhancement beneficial?

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Site History (CHA)

- Manufacturing operations: approximately 1910 to 1997
- Production included wire insulation, industrial enamels, resins for coatings, etc.
- 1994/1995: RI/FS
- 2004: All operations cease, buildings razed
- Low permeability layer that varies in thickness and depth across the Site
- VOC and SVOC impacts

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ADVISE | DESIGN | BUILD | OPERATE

Overview: Questions to Address

- What temperature is needed for site remediation using thermally enhanced soil vapor extraction
  - Flow-through column experiments
  - Three soils: Test Area A, Test Area B, and Test Area C
  - Three temperatures: 35 °C, 50 °C, 70 °C
- To what extent does bioventing assist in site remediation
  - Flow-through column experiments
  - Transition several columns to bioventing phase through decreasing flow rates and measuring oxygen utilization with time
  - Add nutrients to half of the conditions to determine if needed

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Thermally Enhanced Biodegradation

At an ISTR Site, heat accelerates dissolution/desorption but also accelerates biodegradation rates of petroleum hydrocarbons and chlorinated solvents.

Petroleum - BTEX biodegradation has been shown to triple (3X) from 10 to 20°C and petroleum hydrocarbon biodegradation rates have shown peak degradation rates between 30 and 40°C.

Chlorinated Solvents - Up to approximately 40°C, dechlorination rates are expected to double with every 10°C increase in subsurface temperature. Due to:

- Population Growth
- Electron Availability (release from organic material)
- Metabolic Rates/Degradation Rate

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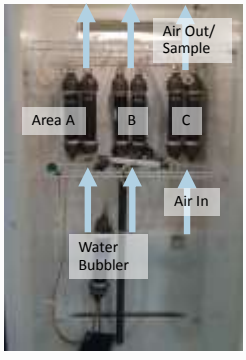
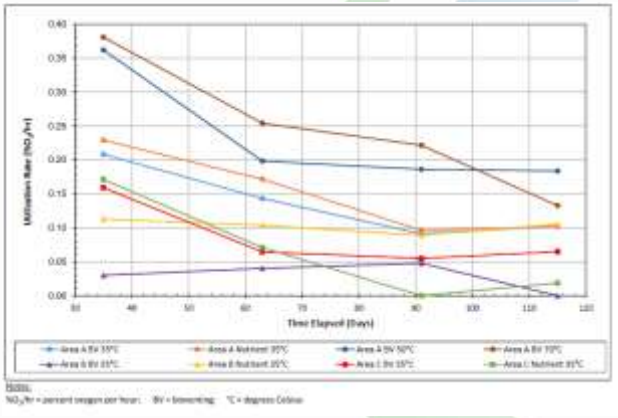
Lab: TSVE/Bioventing

35 °C Incubator



Oxygen Utilization During Bioventing



Primary Treatability Observations

- Higher impacted soils were very tight / silts
- The majority of the treatment occurred during the bioventing phase
  - There was high oxygen utilization in the columns and growth in the biological population.
  - Oxygen utilization decreased with time due to decreased contaminant concentration (carbon source).
- Increased temperature increased contaminant reductions but not significantly over 35 °C.

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Overview: Questions to Address

- What is the site air permeability
  - Point permeability field measurements
  - Using results from the field point permeability, the site-specific soil air permeability was calculated using an air-based three-dimensional computer model.
- What is the well spacing and flow rates needed to optimize thermally enhanced SVE
  - Three dimensional modeling of Site conditions based on field measurements to determine well spacing
  - Spacings determined by outer radius pore velocities for a given series of wells necessary to achieve sufficient pore volume exchanges
- System optimization
  - Comparing site operational data to identify areas where optimization could occur

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- Shallow SVE and AIW well screens designed to target the low permeability layer to ensure contamination in that layer is removed.
- Waterloo^{APS} profiling used to locate the low permeability layer and determine screen locations in the subsurface for all shallow screened wells

Thermal Treatment Zone (TTZ)

Screen Locations Summary

Top of Screen [ft bgs]	Bottom of Screen [ft bgs]	SVES	AIWs (shallow)	Total
3.0	5.0	7	10	17
3.5	5.5	6	14	20
4.0	6.0	18	22	40
4.5	6.5	8	18	26
5.0	7.0	11	17	28
5.5	7.5	22	27	49
6.0	8.0	24	35	59
	Total	96	143	239

Minimum of 7 different well designs for SVE and shallow AIW wells*

*doesn't capture differences in design due to extended sand packs

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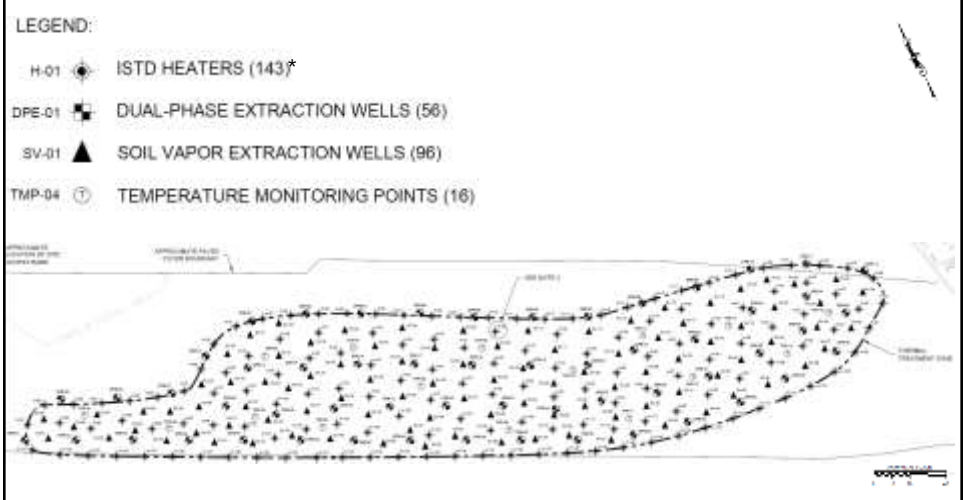
Wellfield Layout



*The wellfield includes 143 Air Injection Wells (AIWs) Located within 3ft of the Heaters

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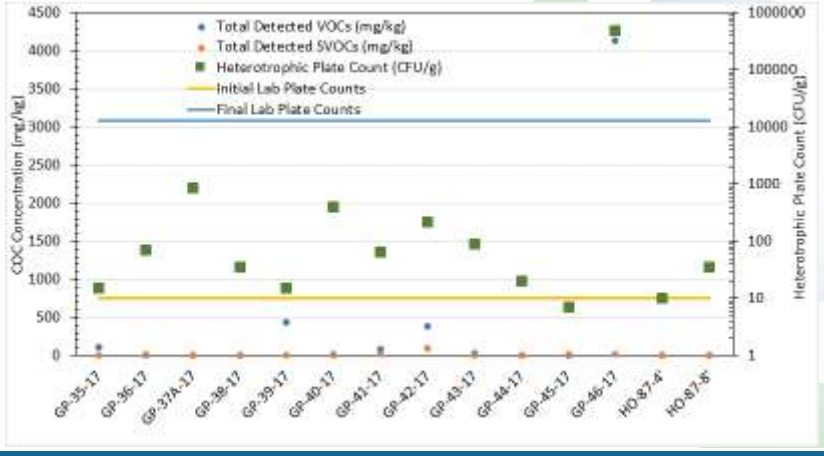
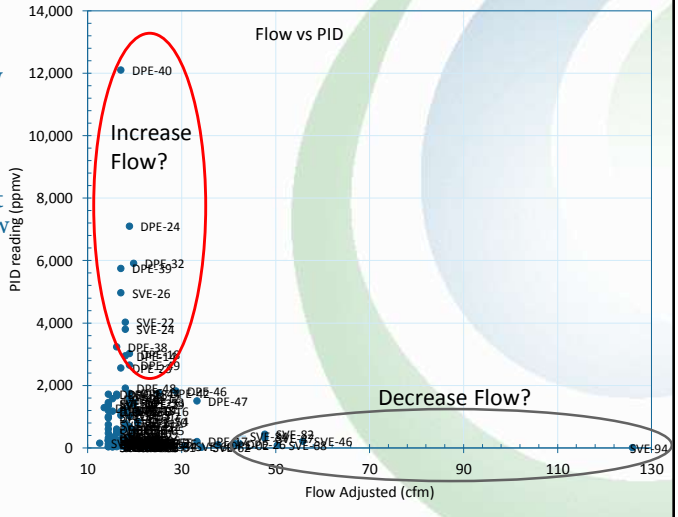
System Operation (1)

- The treatment system has been in operation for approximately 8 months.
- A estimated 3,370 pounds of contaminant mass was removed through SVE



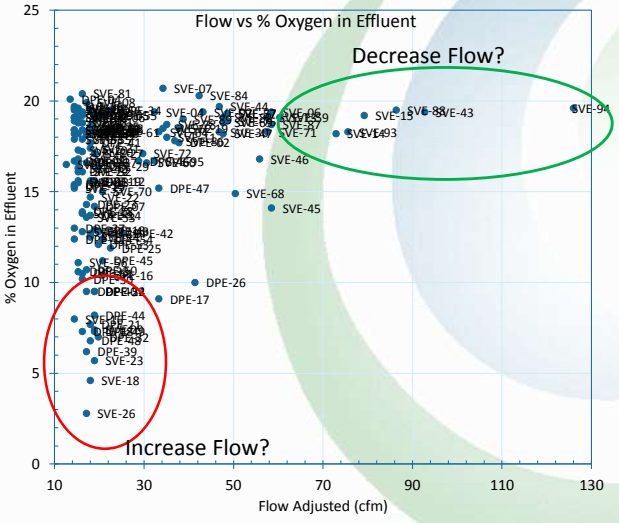
Operation Optimization

- Decrease flows in area with high flow and low contaminant concentration
- Increase flow in wells with high contaminant concentrations and low flows



Operation Optimization

- Decrease flow in areas where oxygen effluent equals ambient oxygen
- Increase flow in wells with low effluent oxygen concentrations



System Operation (2)

- Based on average soil concentrations from samples collected in 2007 and 2017, the soil mass of VOCs have decreased by 58% and the SVOCs have decreased by 73%.

	VOC (lb)	SVOC (lb)	Total (lb)
2007	39,500	2,100	41,600
2017	16,600	550	17,150
% Reduction	58%	73%	59%

- Approximately 24,450 – 3,370 = 21,080 lb. by biodegradation (86%)
  - validated through oxygen utilization / COD measurements

Case Study #3 : Chemical Oxidation and Reduction

- Is ISCO and ISCR compatible?

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- Soil and groundwater chlorinated solvent contamination inside a distribution and transmission substation.
- USEPA decided that Client was going to be solely responsible for a groundwater plume north of our substation that was surrounding City Drinking Water Well and heading towards other City Drinking Water Wells - one being their main supply well.
- City was demanding Client supply them with 3 new drinking water wells.

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- ISCO source treatment in the groundwater near City Well #5 (with USEPA oversite - no UIC permit required)- need rapid treatment
- ISCR permeable barriers to treat the groundwater migrating north to the main City Well - more long term treatment needed – projected life 3-5 years

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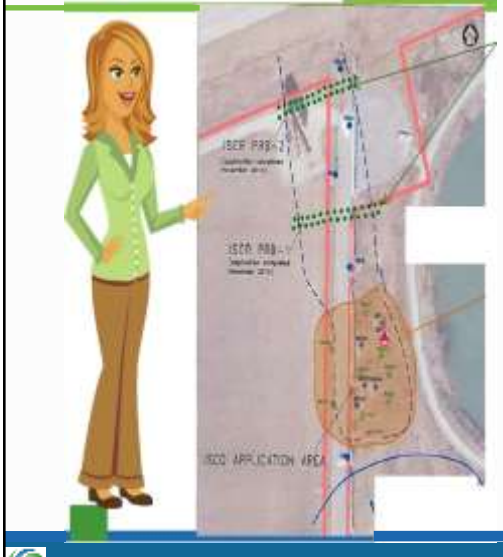

ISCR - Enhanced reductive dechlorination process

- used EHC - a product that combines ZVI with controlled-release carbon & nutrients

ISCO - aggressive oxidation of COCs - short duration time

- Alkaline Activated Sodium Persulfate
  - 2 applications

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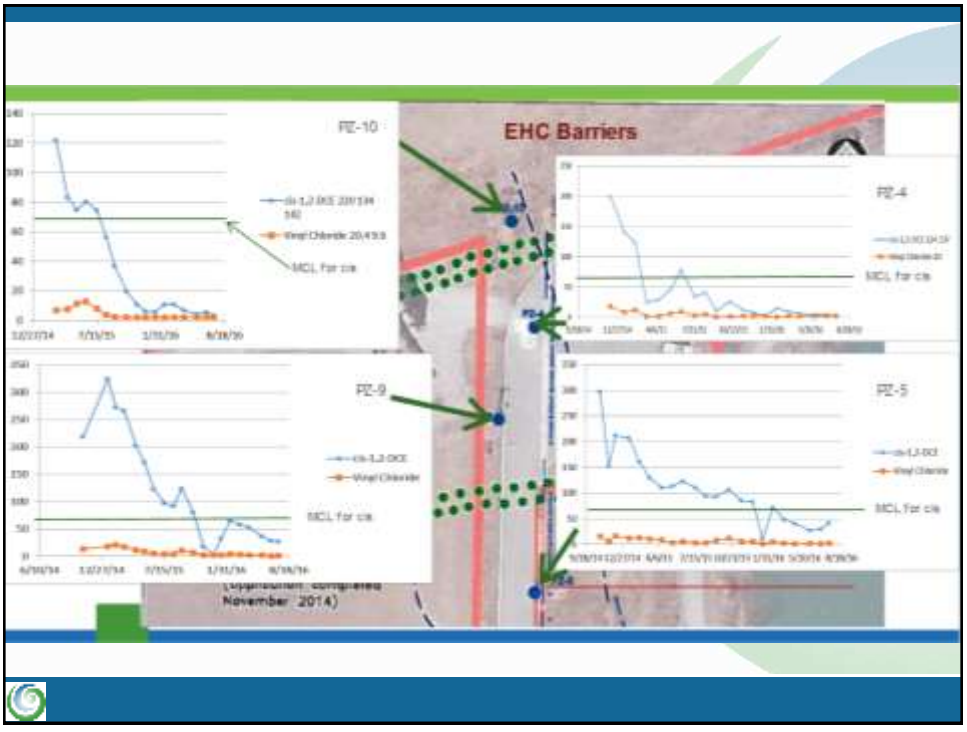
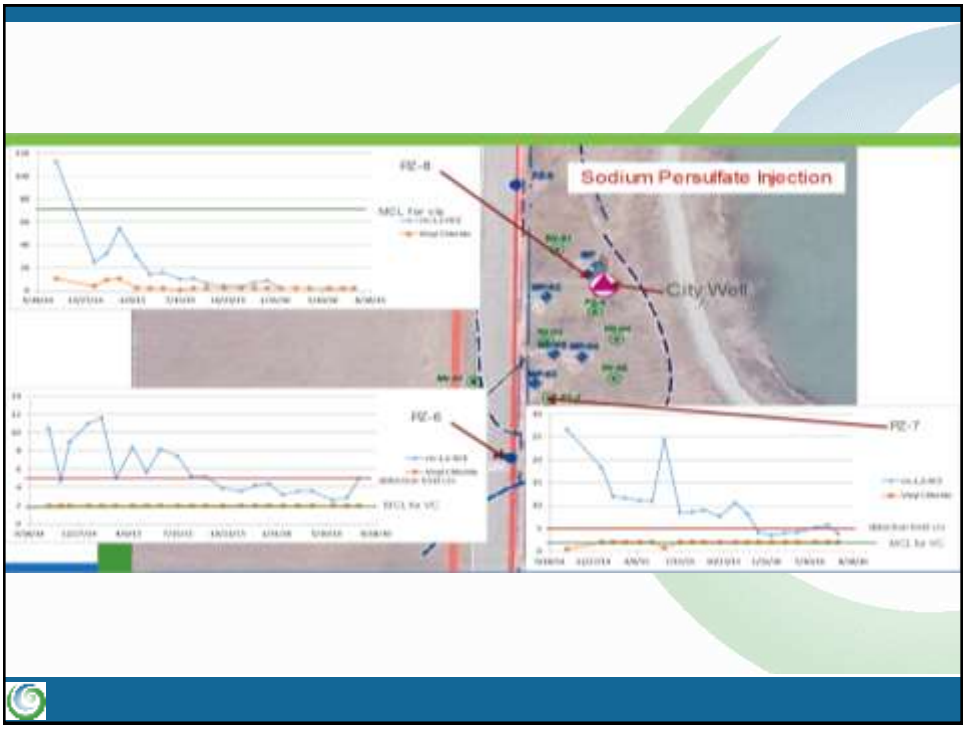

EHC Barriers
PZ-10
PZ-4
PZ-9
PZ-5
MCL for cis
November 2014)


Sodium Persulfate Injection
PZ-8
City Well
PZ-6
PZ-7
MCL for VC

- Of 7 monitoring wells - south of the interstate:
  - 5 wells are below detection limits for all COCs.
  - 2 are below MCLs for all COCs
- USEPA sees no reason to perform any more treatment in this area, as long as the numbers do not increase.

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DISCUSSION

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States in which we had Projects

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