NASA Remediation Technology Collaboration Development Task

Overview and Project Summaries

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ITB, Inc.
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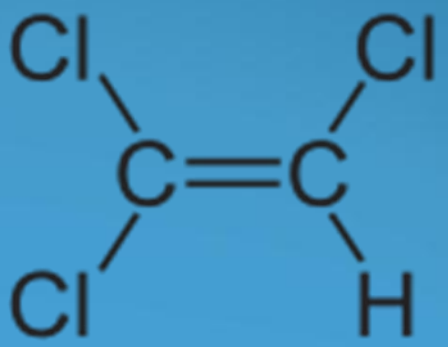
Outline

RTCD Overview

Project Summaries

- In Situ Real Time Groundwater Monitor
- In Situ Chemical Oxidation
- In Situ Bioremediation
- Horizontal Multiport Sampling and Injection Well
- High Resolution Site Characterization



Overview

RTCD has been active since May 2010

Purpose:

"…establish and maintain the capability to specifically target reductions in the long-term liability associated with NASA's most challenging remediation sites."

Accomplished by:

- Maintaining a database of deployed site remediation processes and conditions
- Researching potential emerging technologies while simultaneously looking for similar situations where these emerging technologies could be used
- Pursuing the most promising technologies with directed research, bench studies, pilot studies and demonstration projects

Overview

Provides independent, unbiased assessment of the current conditions and technologies.

- Independent from the viewpoint that we are not tasked with any remediation implementation.

Risks addressed are associated with the long-term environmental liability which includes:

- Cost
- Schedule
- Demonstration of support for technical impracticability (TI) waivers where warranted

Overview

Step I Opportunity Assessment

- Obtain data from HQ Center & Component Facilities Remediation Project Managers (RPMs)
- Standardize and compile data in centralized location (NETS Module)
- Conduct comprehensive evaluation of remedies based on analysis of data
- Identify sites/remedies of interest based on communicated need and/or exceptional remedy success or failure

Step II Planning

Successful remedies:

- Facilitate implementation at additional sites throughout NASA (tech transfer)

Failed remedies and communicated needs:

- Research alternative/innovative technologies/processes (unbiased screening)
- Develop field demonstrations, pilot tests, and bench tests of viable alternative/innovative technologies/processes

Step III Partner Commitments

- Disseminate documents, data, ideas, etc. to HQ and RPMs and obtain stakeholder buy-in
- If buy-in is not obtained then return to Step II and develop revised strategy

Step IV Execute

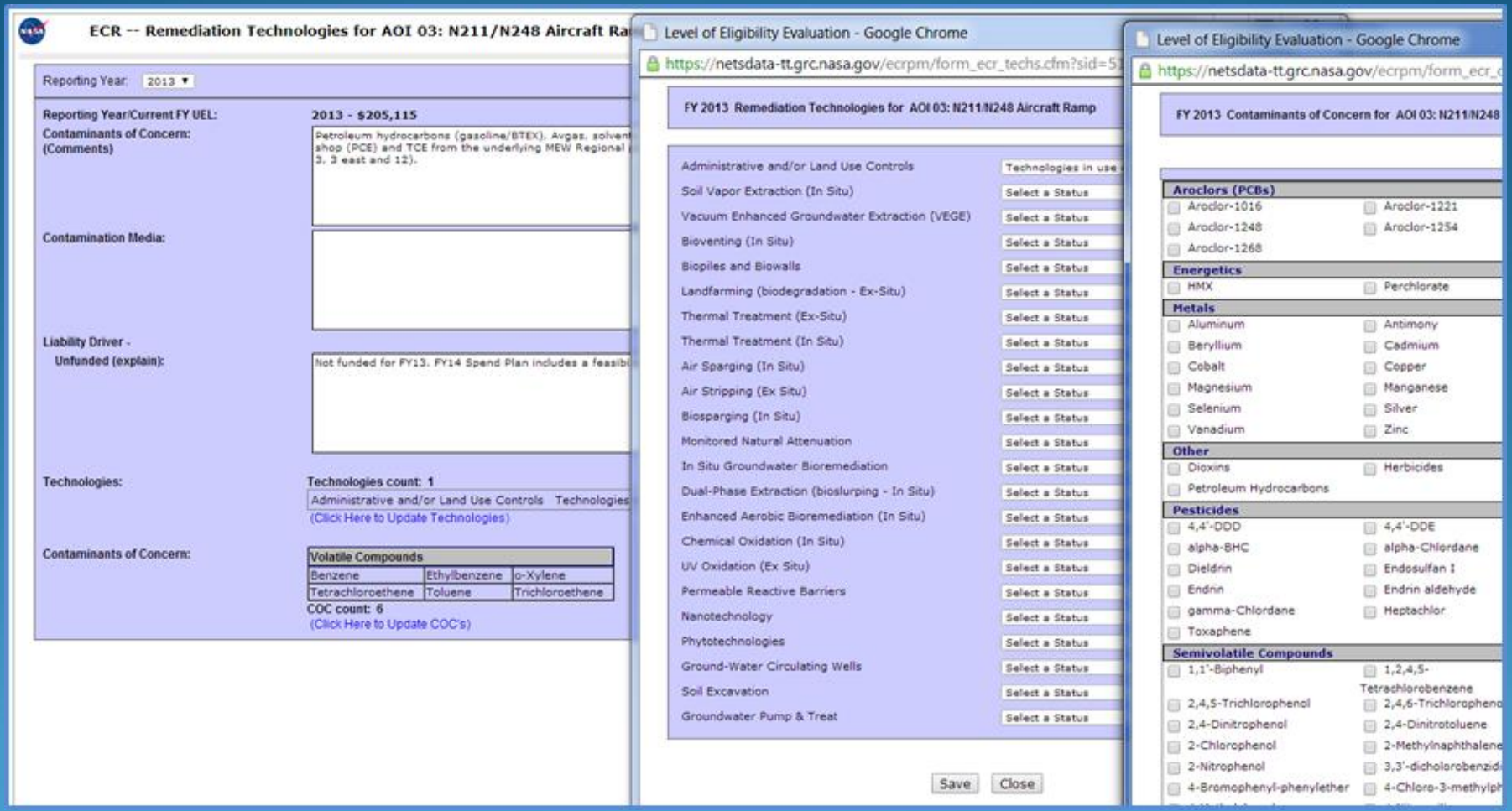
- Coordinate & document the execution of field demonstrations, pilot tests, and bench tests.
- Conduct comprehensive evaluation of new technology/process performance
- Return to Step II

Opportunities to implement innovative site characterization technologies/processes and Green and Sustainable Remediation designs are considered at every step

ITB's Remediation Technology Collaboration Development (RTCD) process leads to in-depth understanding of remediation technology applicability to NASA's most challenging cleanup sites.

Overview

- Screen Shot from the NETS Express RTCD Module



Overview

- RTCD payback is seen immediately in donated engineering services and product vendor materials.

Demonstration / Pilot Test	POP	Direct Cost	Cost to NASA	In-Kind Reduction
In situ real-time measurement of TCE in groundwater (Area D)	9/11 - 11/11	$28,000	$0	($28,000)
In situ chemical oxidation of TCE in groundwater (Area G)	3/12 - 12/12	$184,300	$112,425	($71,875)
In situ bioremediation of TCE in groundwater (Area D)	8/13 - 6/14	$17,974	$0	($17,974)
HDD Installation of Multiport Sampling & Injection Well (Area B)	7/14 - 7/14	$32,500	$24,500	($8,000)
In situ chemical oxidation of TCE in groundwater using horizontal multiport injection well (Area B)	9/14 – present	$64,750	$0	($64,750)
TOTAL		$327,524	$136,925	($190,599)

- Long term payback will be seen in reduced cleanup times and cost.

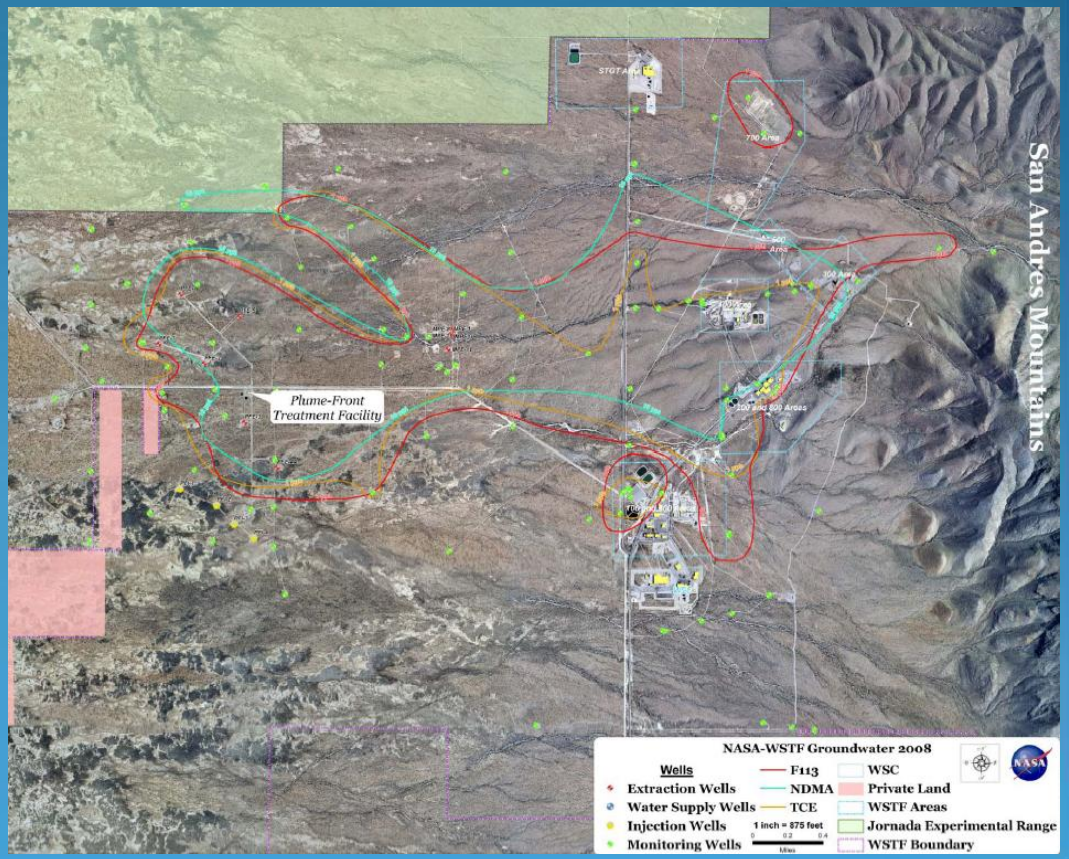
Project Summary

In Situ Real Time Groundwater Monitor (September 2011)

- Development and implementation of monitor that combines sampling and detection of contaminants in a single step with high sensitivity could reduce NASA's site characterization and groundwater monitoring costs across all Centers and Component Facilities.

White Sands Test Facility:

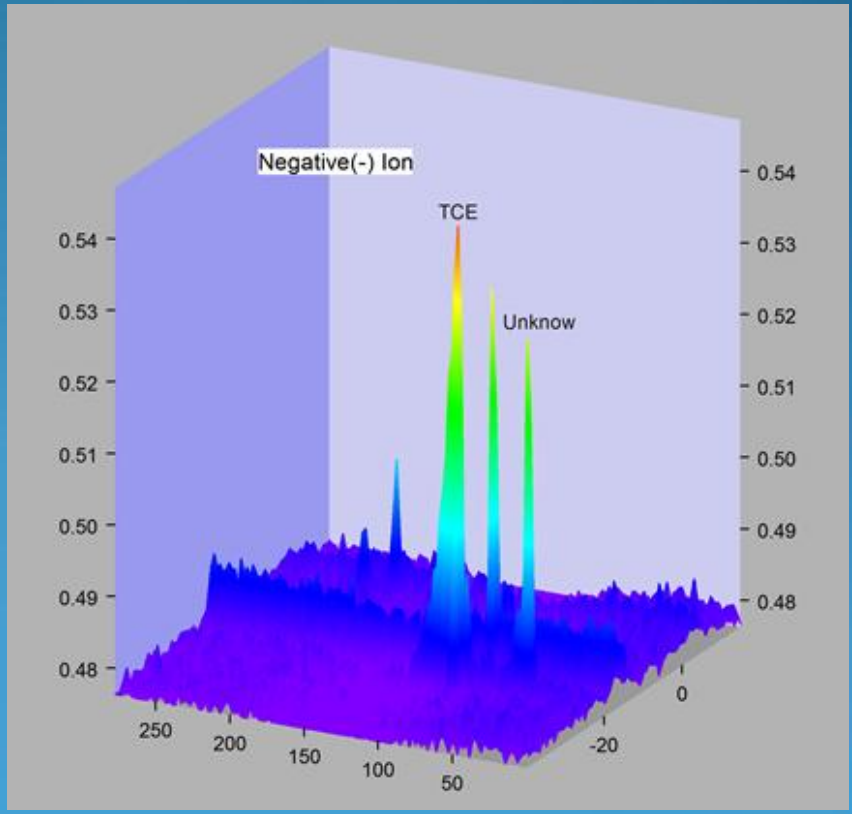
- Plume is ~ 4 miles long, 2 miles wide, and up to 800 feet thick
- Over 100 active monitoring wells with 222 discrete zones being used to define the plume
- Cost is $1.6 million per year
- Expected to take at least several decades to a century achieve to cleanup



Project Summary

In Situ Real Time Groundwater Monitor

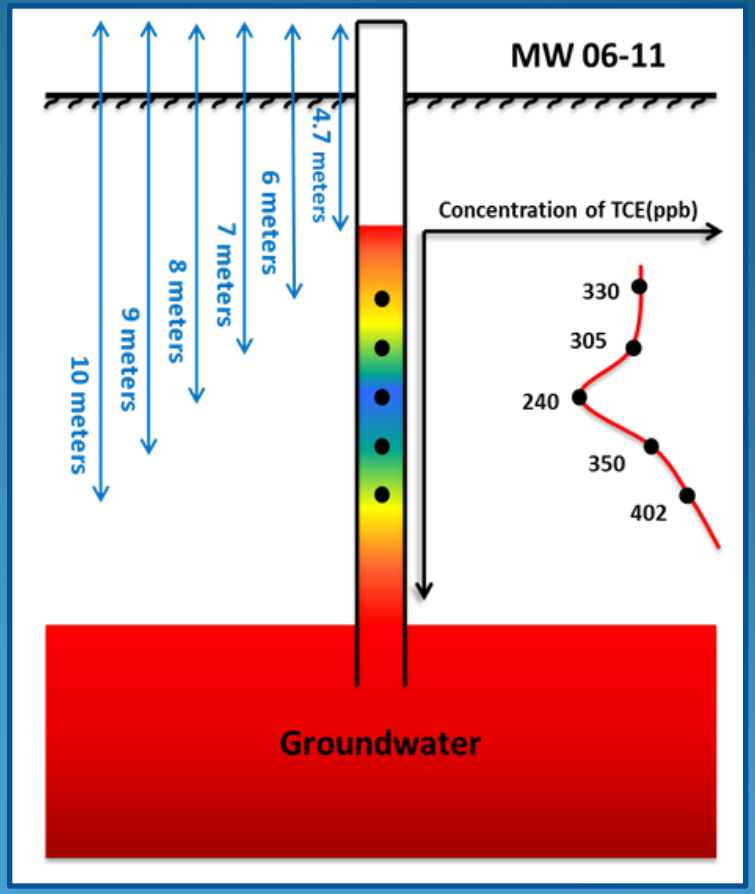
- Membrane-Extraction Ion-Mobility Groundwater Monitor was being developed by Oak Ridge National Laboratory under SERDP funding (ER1603) – currently unfunded
- Two wells at SSC, including one with low trichloroethylene (TCE) concentration/slow recharge rate (06-11 MW) and one with high TCE concentration/fast recharge rate (06-12 MW) were tested at various water depths and durations
- The monitor demonstrated a clear identification of chlorinated hydrocarbons in the wells and reasonably accurate quantification
- More development is needed to be reliable and completely usable in the field



Project Summary

In Situ Real Time Groundwater Monitor

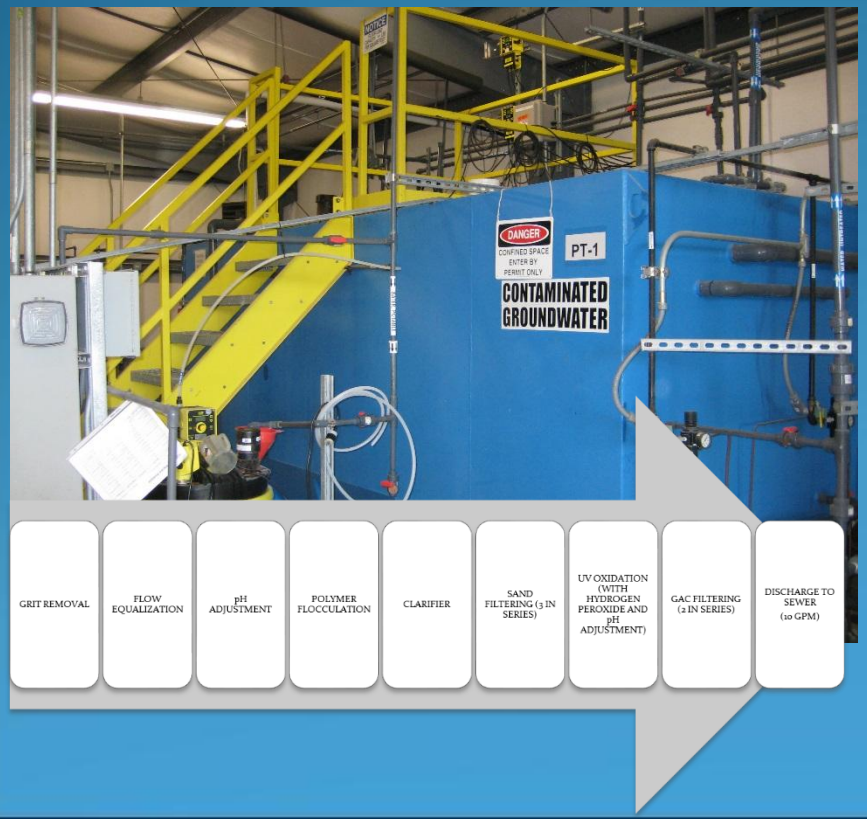
- The analysis at various water depths suggested three TCE-concentration zones within the well
- Sample results can vary significantly over short distances

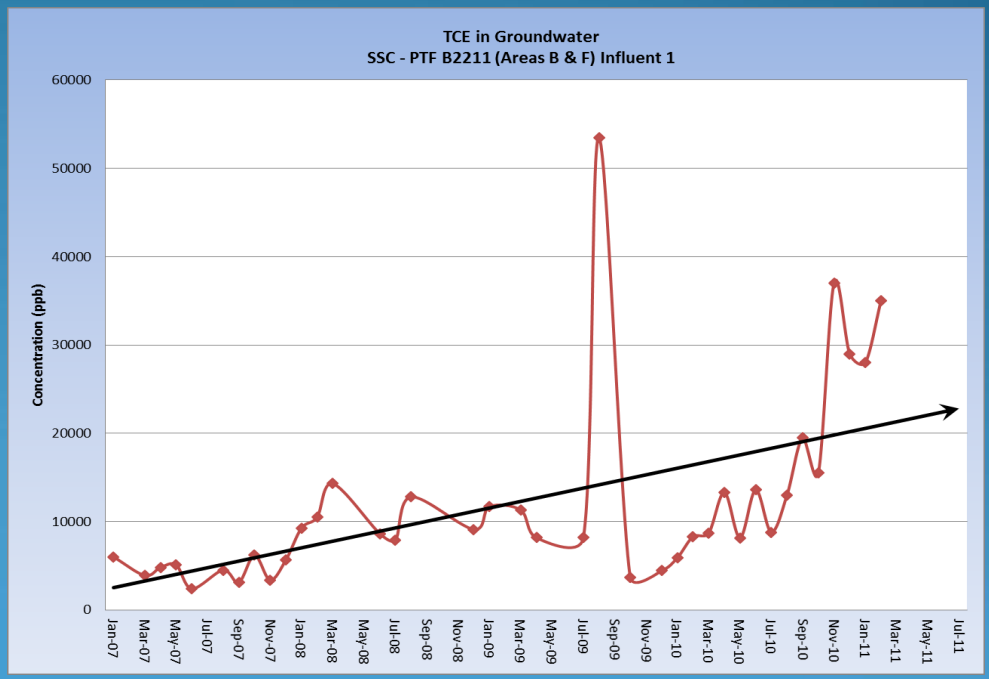


Project Summary

In Situ Chemical Oxidation (March 2012 – December 2012)

- Some P&T systems have been operating for years and based on recent influent concentration data they have reached asymptotic conditions (cannot remove remaining residual contamination to achieve cleanup goals - a.k.a. “flat-lined”) or worse; influent concentrations are still increasing.

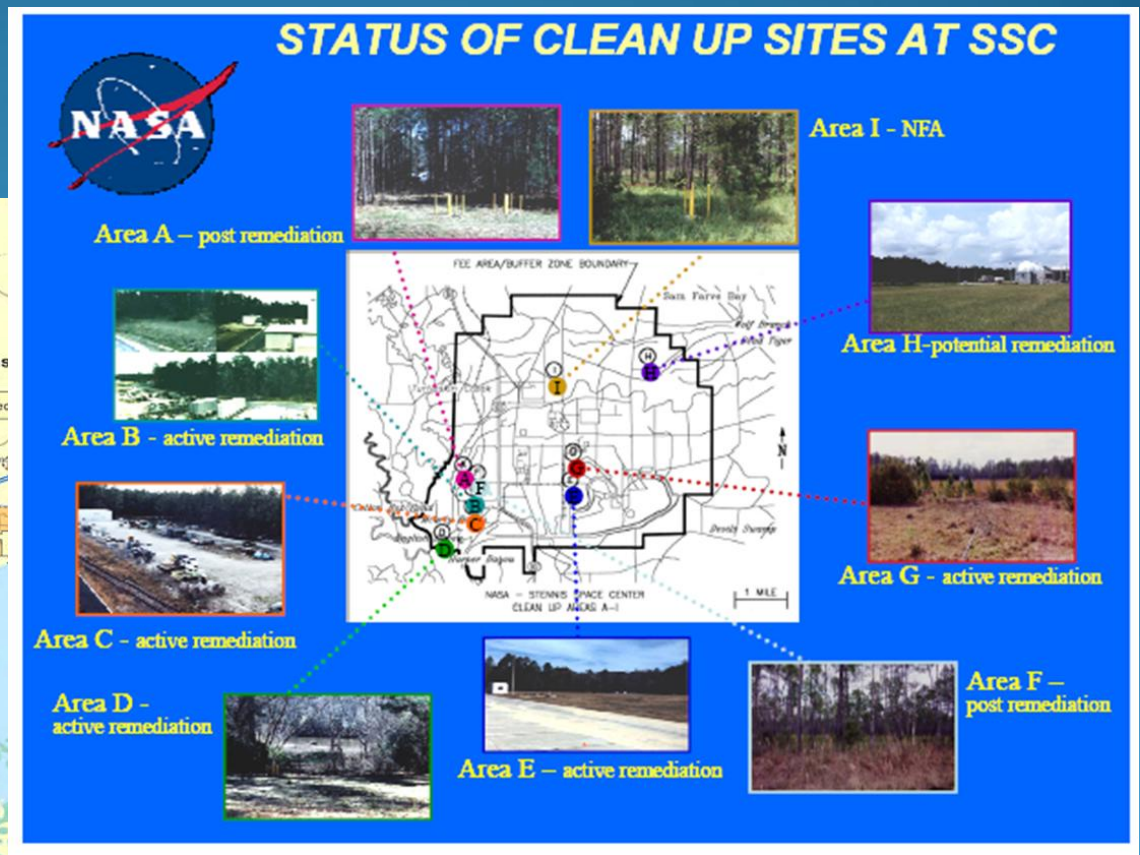




Project Summary

In Situ Chemical Oxidation

- Demonstrate and evaluate a commercially-available chemical oxidation system to treat TCE in situ and augment an existing P&T system at Stennis Space Center's Area G.



Project Summary

In Situ Chemical Oxidation

Why EN Rx?

- EN Rx uses a proprietary sodium-based catalyst with peroxide – "modified Fenton's system" to generate hydroxyl radicals (strongest oxidizer)
- Slow, long-lasting reaction (match mass flux)
- Safe for workers and utilities (little heat generated)
- Works in all subsurface conditions (any pH)
- "Complete package" (consultant and contractor in one - assessment , design, injection, reporting)
- Innovative low-energy delivery process (Continuous Injection System [CIS])
- Very eager and responsive
- Willing to donate in-kind services, materials, and equipment rental for a chance to work with NASA

Table 1-1. Oxidant strengths

Chemical species	Standard oxidation potential (volts)	Relative strength (chlorine = 1)
Hydroxyl radical ($OH^{-\bullet}$)*	2.8	2.0
Sulfate radical ($SO_4^{-\bullet}$)	2.5	1.8
Ozone	2.1	1.5
Sodium persulfate	2.0	1.5
Hydrogen peroxide	1.8	1.3
Permanganate (Na/K)	1.7	1.2
Chlorine	1.4	1.0
Oxygen	1.2	0.9
Superoxide ion ($O^{-\bullet}$)*	-2.4	-1.8

*These radicals can be formed when ozone and H_2O_2 decompose.

Source: Siegrist et al. 2001

Project Summary

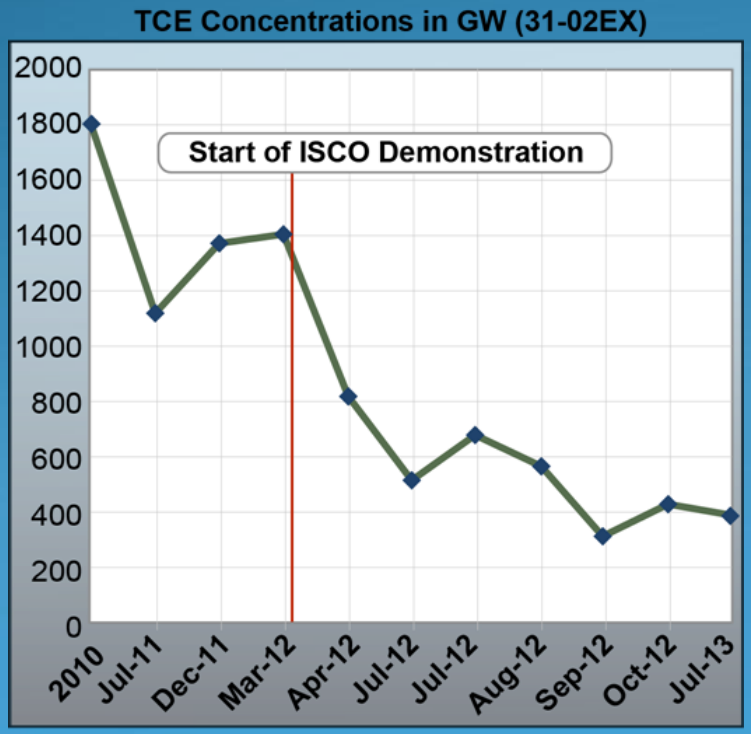
In Situ Chemical Oxidation

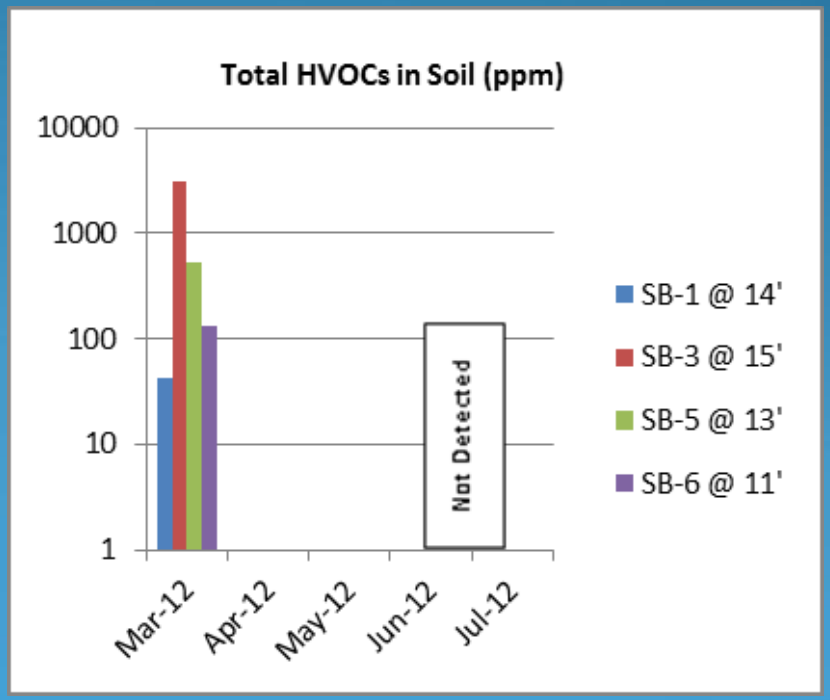
- Innovative low-energy delivery process – Continuous Injection System (CIS)

Project Summary

In Situ Chemical Oxidation

- At the conclusion of the nine month study, levels of TCE and associated daughter products had dropped by more than 70 percent in ground water samples and were non-detect in the treated soils.
- SSC has deemed the demonstration successful and are assessing where the technology may be deployed next.

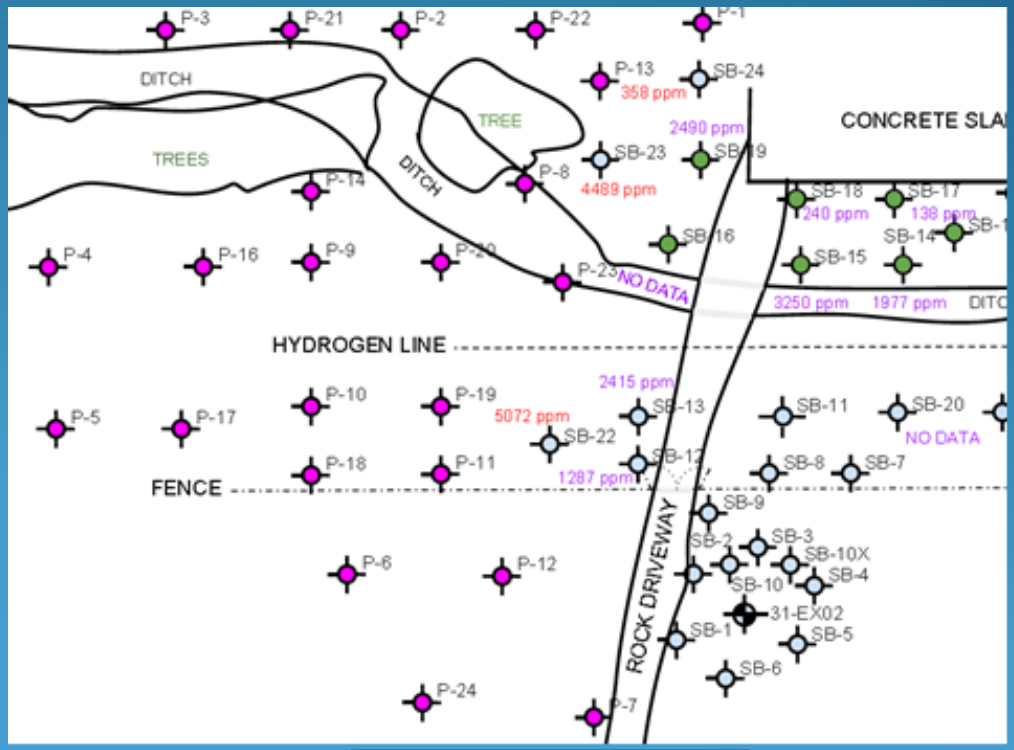




Project Summary

In Situ Chemical Oxidation

- Limited assessment of the area hydraulically up gradient of the initial pilot test location revealed that the contaminant mass has not been delineated.
- All parties agree that a complete delineation is required before injections resume.
- EN Rx has proposed a Performance Based Remediation (PBR) contract to achieve the project goal of closure levels throughout Area G (TCE to 5 µg/L in groundwater).
- A cost ceiling for the remediation phase will be proposed after the complete delineation of contaminant mass (April 2014).

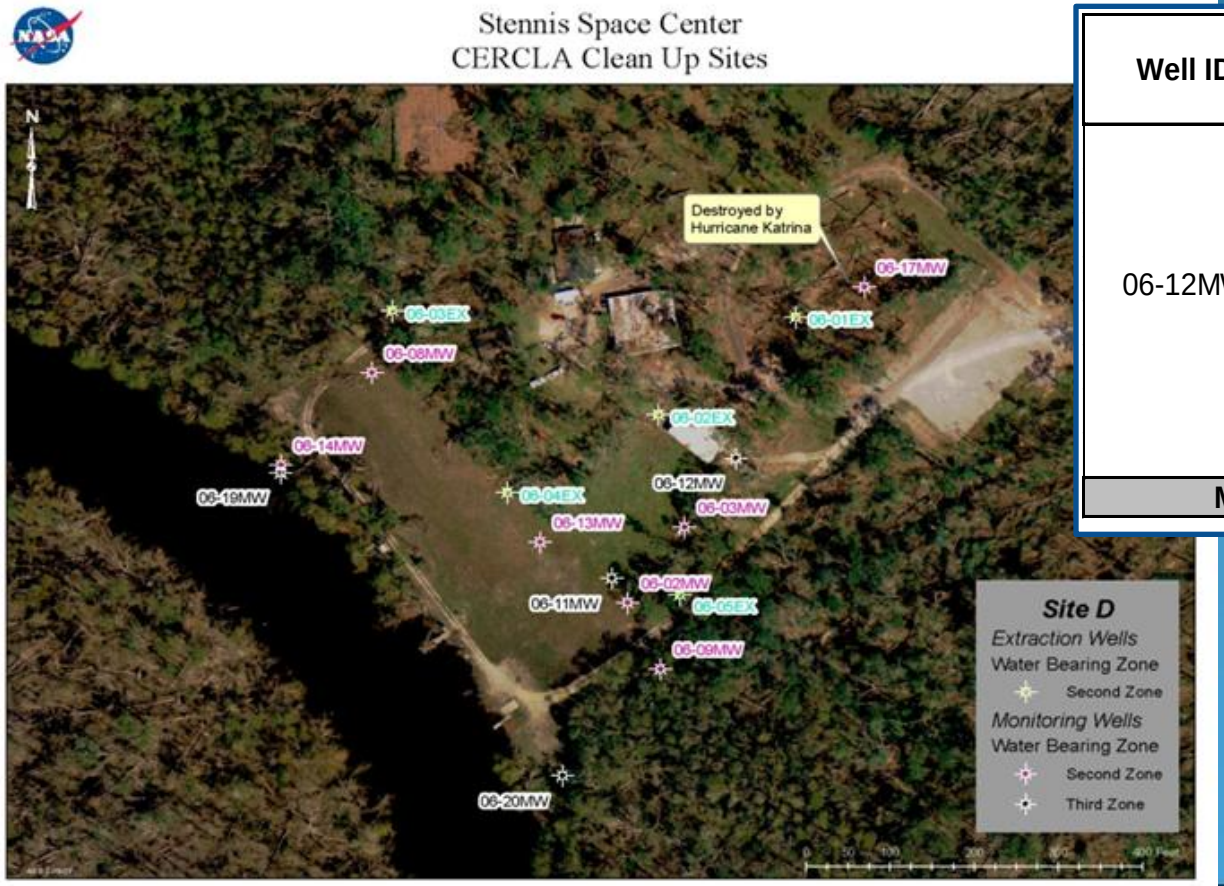


The Area G Assessment Plan

Project Summary

In Situ Bioremediation (August 2013 – present)

- Some P&T systems have been operating for years and based on historical groundwater monitoring data, they have lost (or never had) containment and control of the contaminated groundwater plume.



Well ID	Date	TCE	Cis-1,2 DCE	VC
06-12MW	2007	**69**	12	ND
	2008	**1201**	**233**	ND
	2009	**186**	16	ND
	2010	**1259**	**177**	ND
	2011	**1893**	**331**	ND
	10/2012	**1017**	**99**	ND
	5/2013	**154**	13	ND
	7/2013	**690**	**198**	ND
MCL (ppb)		**5**	**70**	**2**

Monitoring well 06-12MW , screened at 83 to 93 feet below ground surface, in WBZ 3, is not impacted by the extraction system.

Project Summary

In Situ Bioremediation

- Conduct a field demonstration (pilot test) and laboratory treatability study on groundwater from Water Bearing Zone (WBZ) 3 at Area D of SSC (monitoring well 06-12 MW) using bioremediation techniques.

Pilot test site characteristics:

- Anaerobic deep aquifer with dissolved phase TCE
- No significant source mass believed present
- Not impacted by P&T system

Pilot test strategy:

- Biostimulation of native microbes
- Substrate (proprietary blend of nutrients) in fabric socks lowered into well
- Sampling / replacement about every 45 days

BioStryker Remediation

Project Summary

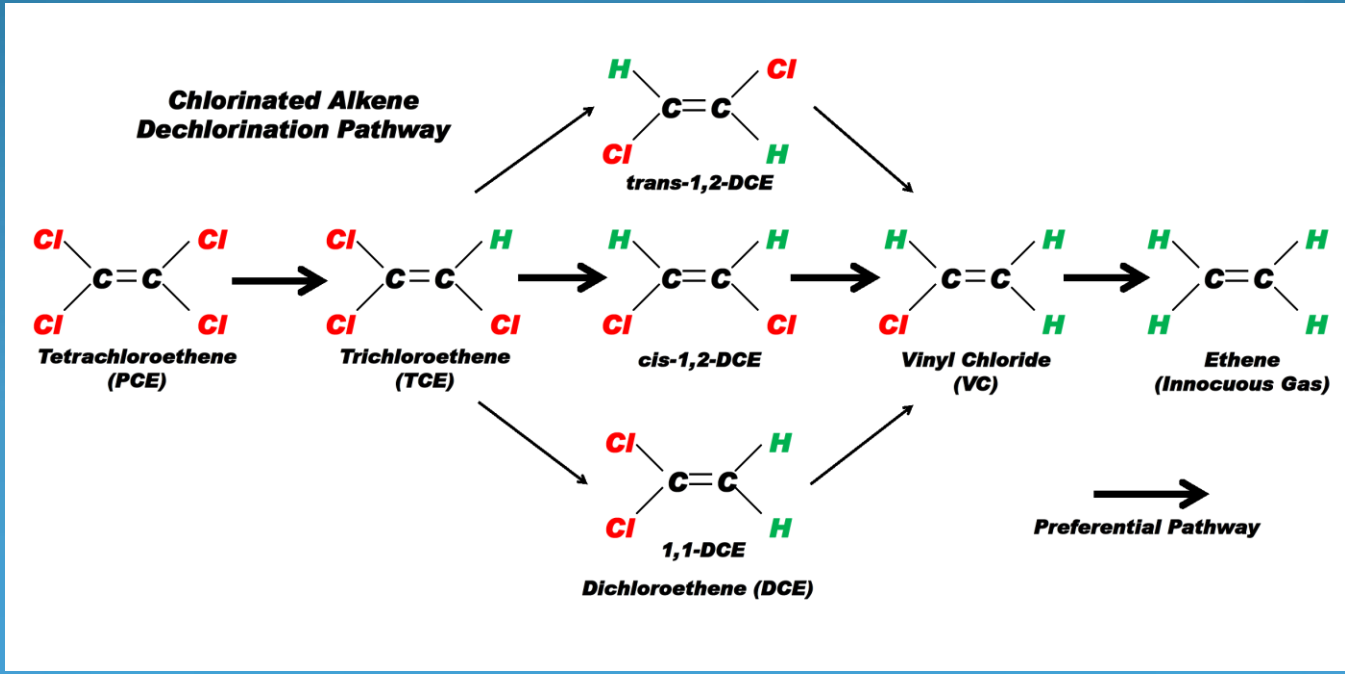
In Situ Bioremediation

- *Microbial reductive dechlorination of trichloroethene (TCE) in groundwater often results in the accumulation of dichloroethenes (DCEs). Dehalococcoides mccartyi (Dhc) are the only known bacteria capable of dechlorination beyond DCE to non-toxic ethene.*

Environ Microbiol. 2013 Aug;15(8):2293-305. doi: 10.1111/1462-2920.12099. Epub 2013 Mar 11.

Isolation of two new Dehalococcoides mccartyi strains with dissimilar dechlorination functions and their characterization by comparative genomics via microarray analysis.

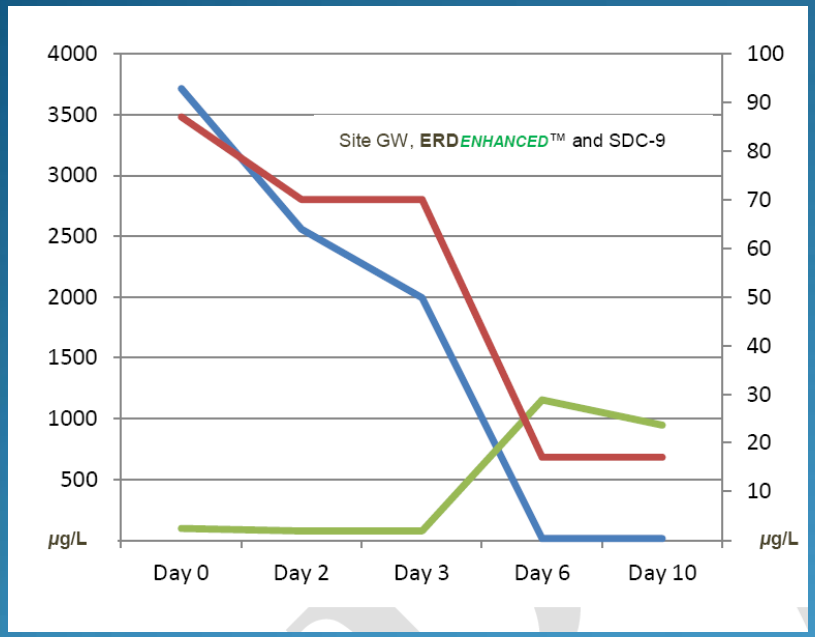
Lee PK[1], Cheng D, West KA, Alvarez-Cohen L, He J. http://www.ncbi.nlm.nih.gov/pubmed/23480482 The National Center for Biotechnology Information advances science and health by providing access to biomedical and genomic information.

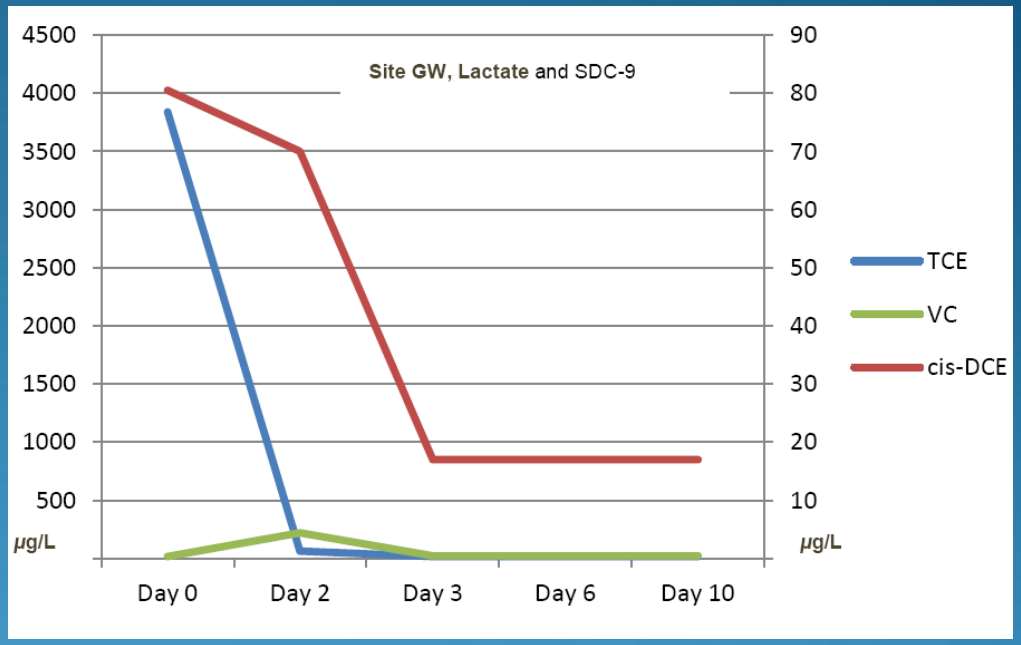


Project Summary

In Situ Bioremediation

- Laboratory treatability study results (in-kind by CB&I, augmented with SDC-9™)



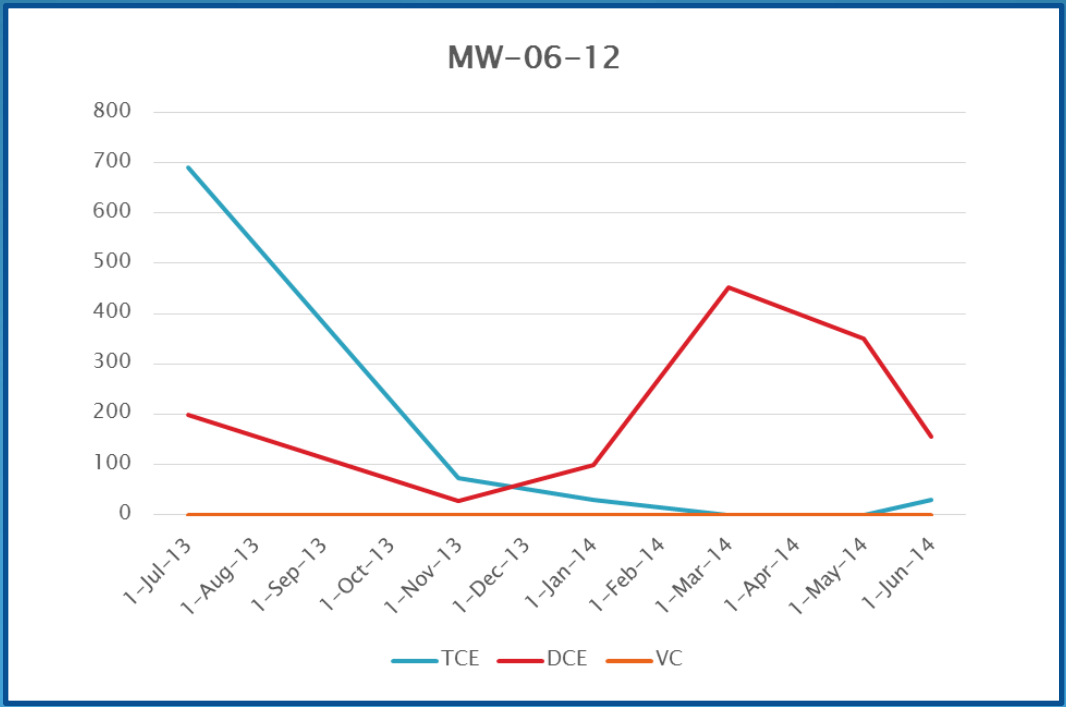


"…greater amounts of total cVOCs appear to have been biotransformed in the ERDENHANCED™ microcosm; indicating, once acclimated SDC-9 microbial populations performed better with ERDENHANCED™ than with their 'host' donor source (lactate)…although Vinyl chloride had not been fully biotransformed by the end of the evaluation (Day 10), the initiation of a downward trend on Day 10 supports lab inoculated microcosm observations that complete biotransformation would be realized in very short order."

Project Summary

In Situ Bioremediation

- Field demonstration (no SDC-9) resulted in 95% reduction in TCE
- Initial 85% decrease in cis-DCE; followed by 16x increase, confirming TCE biotransformation
- cis-DCE has since decreased 65%
- Vinyl Chloride and/or Ethene yet to be detected
- A larger scale pilot is being considered at Area E



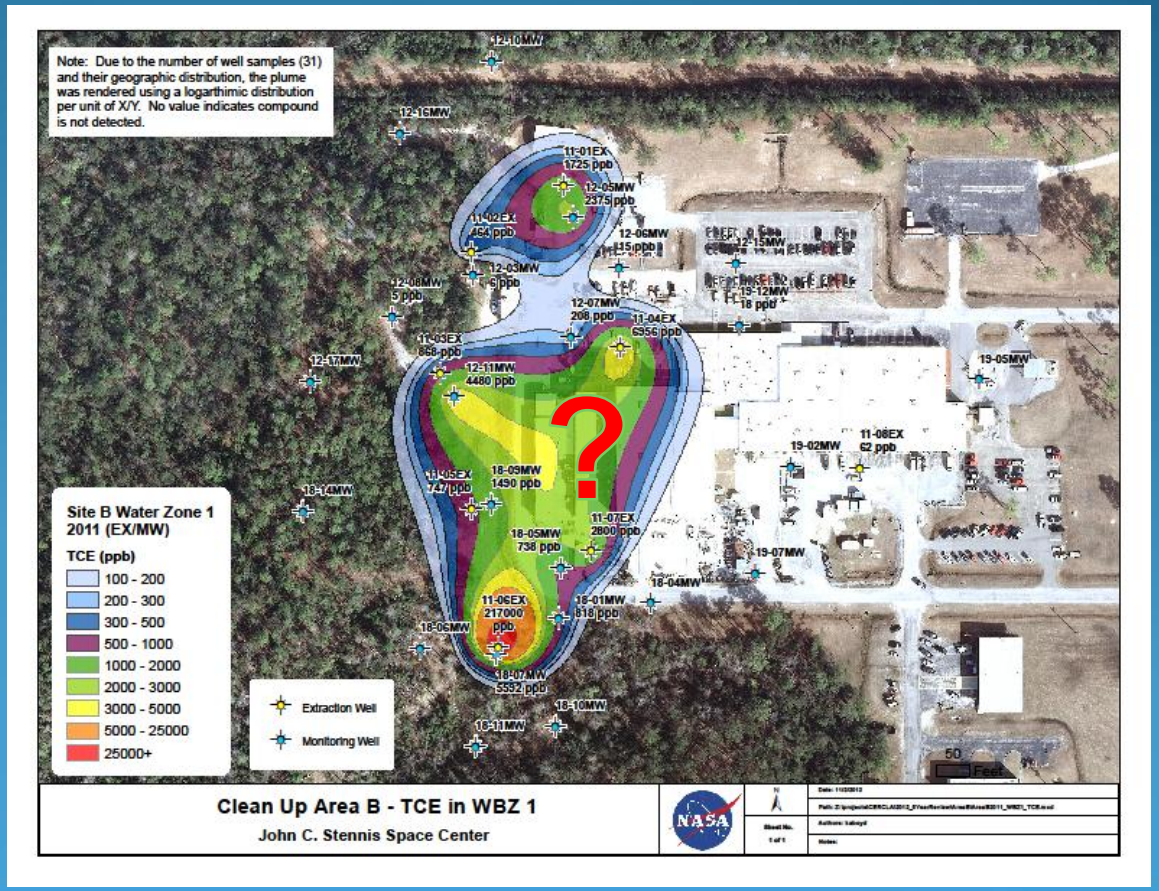
Project Summary

Horizontal Multiport Sampling and Injection Well (July 2014 – present)

- ITB has observed a recurring theme at many of NASA's cleanup sites; more site assessment/re-assessment is required before realistic expectations of remediation effectiveness can be determined.

Horizontal Directional Drilling (HDD)

- Offers the capability to characterize and treat contaminated soil and groundwater under existing structures with minimal interference to facility operations.



Project Summary

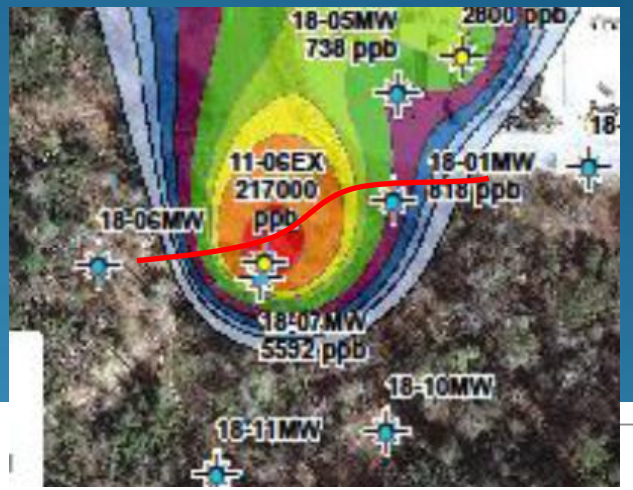
Horizontal Multiport Sampling and Injection Well

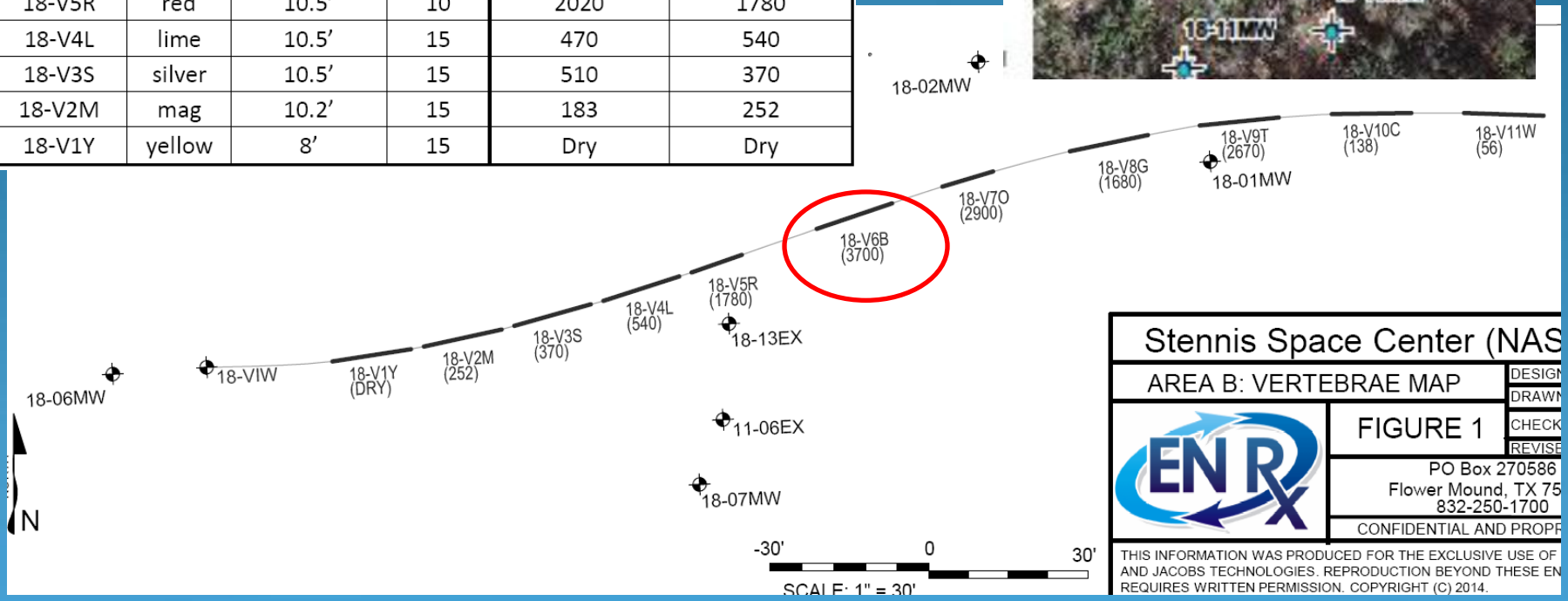
- An HDD well is installed congruent to typical horizontal lithology (e.g., installed just above a clay confining layer). Therefore they are far more useful than traditional monitoring wells or vertical injectors.
- EN Rx is developing a multiport groundwater sampling and injection well called Vertebrae™ and proposed a demonstration to fill in data gaps and potentially treat contamination under a building at SSC Area B.

Project Summary

Horizontal Multiport Sampling and Injection Well

Well Construction Details 18-VIW				Analytical Results (in ug/L)	
ID	Color	Ave. Depth	Length	Freon	TCE
18-V11W	white	8’	15	134	56
18-V10C	cyan	10.1’	15	2340	138
18-V9T	tang	10.5’	15	14900	2670
18-V8G	green	10.4	15	9020	1680
18-V7O	orange	10.2’	10	10100	2900
18-V6B	blue	10.3’	15	6300	3700
18-V5R	red	10.5’	10	2020	1780
18-V4L	lime	10.5’	15	470	540
18-V3S	silver	10.5’	15	510	370
18-V2M	mag	10.2’	15	183	252
18-V1Y	yellow	8’	15	Dry	Dry





Project Summary

Horizontal Multiport Sampling and Injection Well

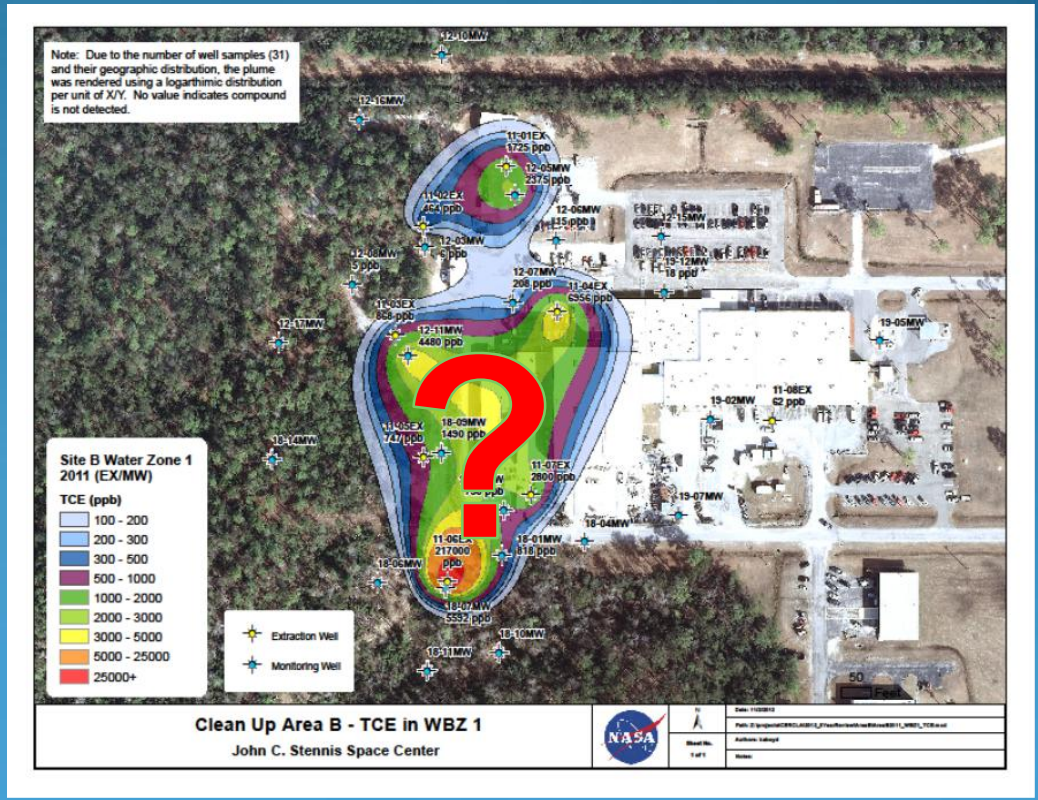
Project Summary

High Resolution Site Characterization

- ITB has observed a recurring theme at many of NASA's cleanup sites; more site assessment/re-assessment is required before realistic expectations of remediation effectiveness can be determined.

EPA Definition:

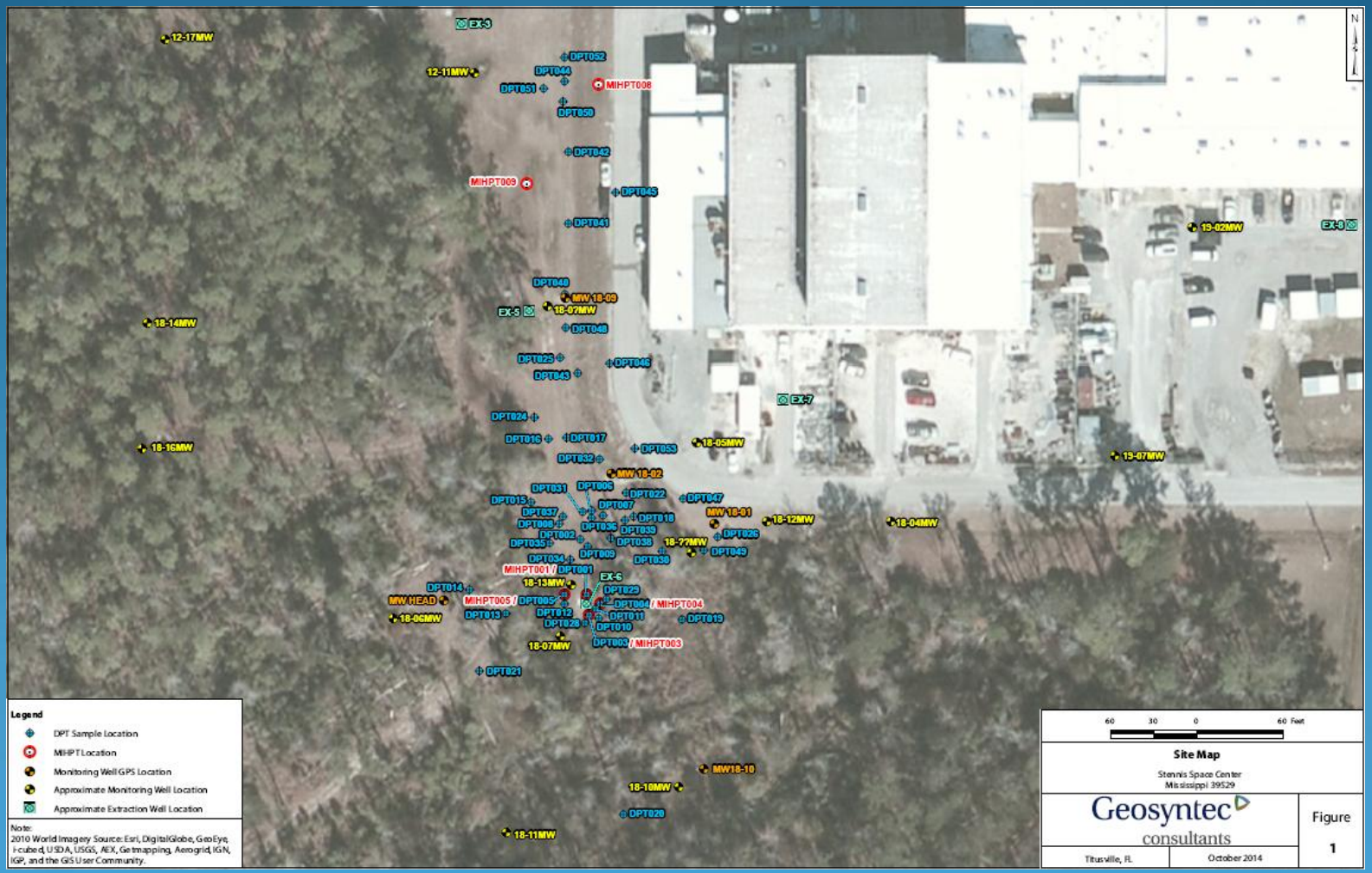
- Strategies and techniques use scale-appropriate measurement and sample density to define contaminant distributions, and the physical context in which they reside, with greater certainty, supporting faster and more effective site cleanup



Project Summary

High Resolution Site Characterization

- Sample Density (one mobilization)

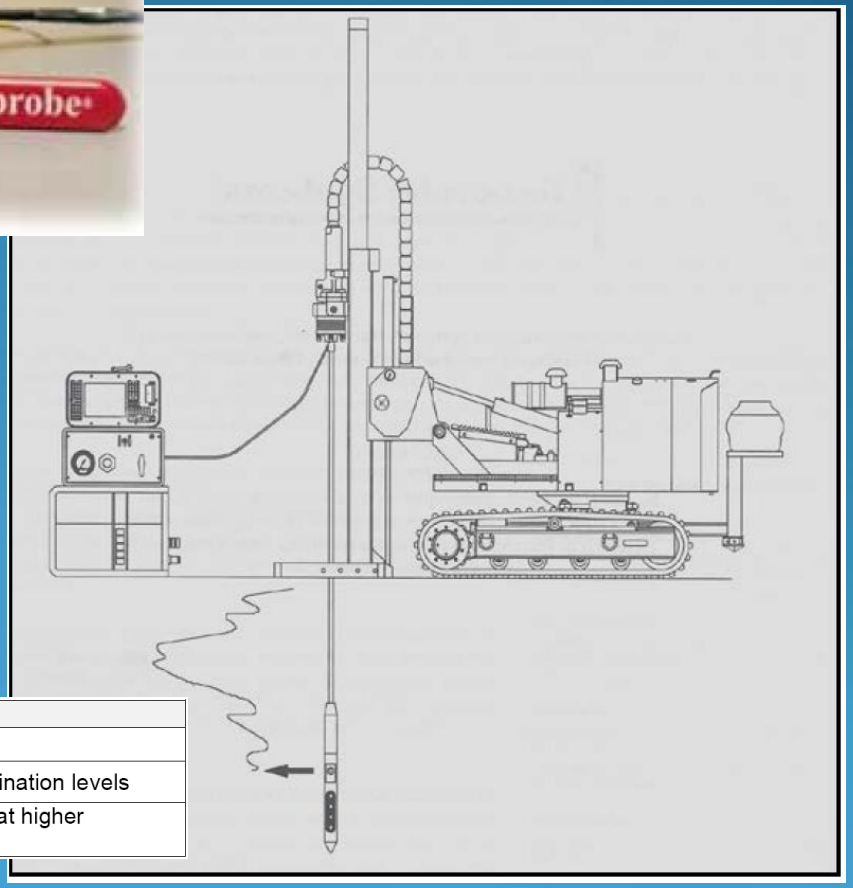


Project Summary

High Resolution Site Characterization

Membrane Interface Probe (MIP)

- Percussion-tolerant down-hole VOC sensor
- Continuously logs VOCs vs. depth
- Photoionization Detector (PID)
- Flame Ionization Detector (FID)
- Electron Capture Detector (ECD)

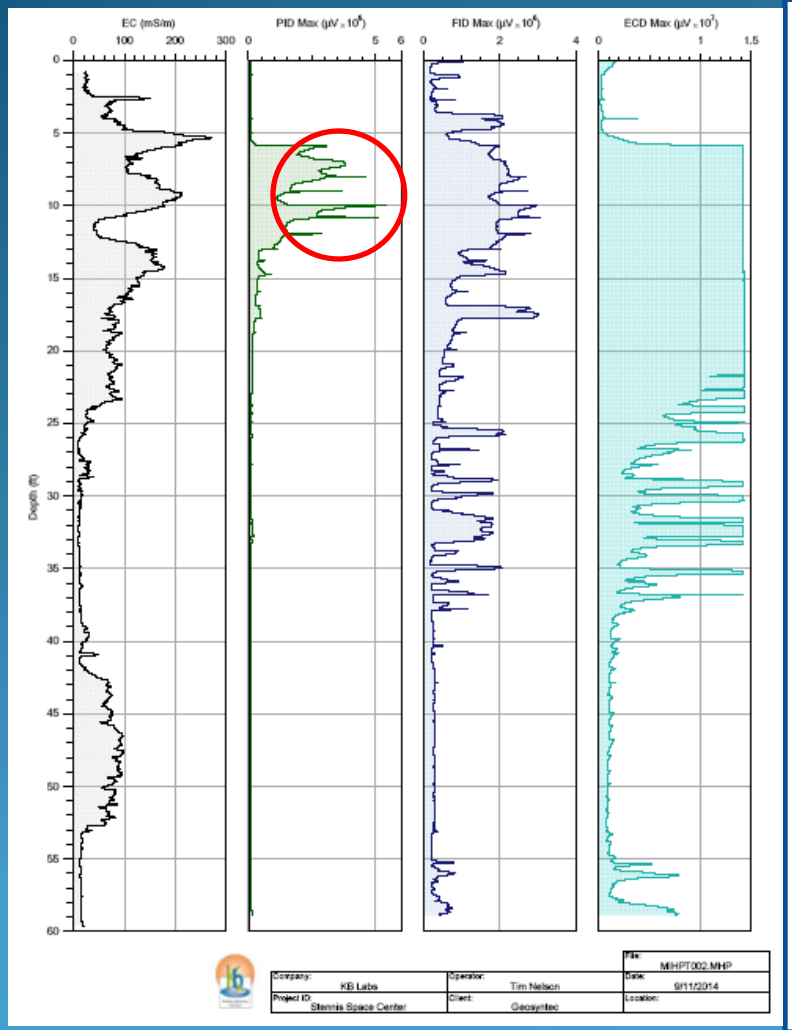


Detector	Sensitivity
ECD	Primary: Total CVOCs (including TCE, PCE)
PID	Primary: Aromatic Compounds (e.g.BTEX); Secondary: CVOCs at higher contamination levels
FID	Primary: Ethane, Methane, Ethene; Secondary: CVOCs & Aromatic Compounds at higher contamination levels

Project Summary

High Resolution Site Characterization

- MIP Results lead to more useful lab sample locations, less mobilizations

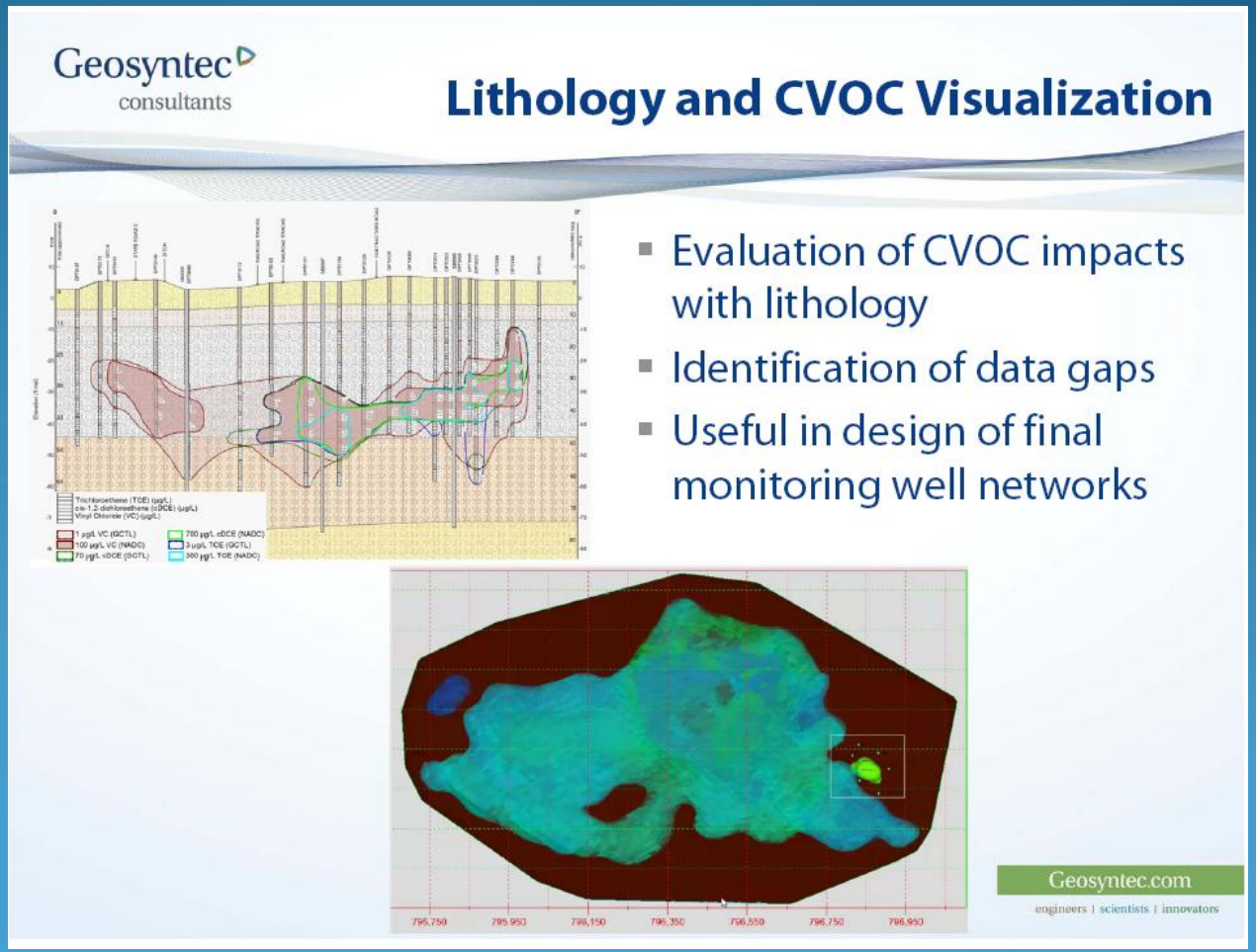


Sample ID	Analysis Date	Sample Time	Matrix	Dilution Factor	Vinyl chloride	Freon113	1,1-Dichloroethene	trans-1,2-Dichloroethene	cis-1,2-Dichloroethene	Trichloroethene	Tetrachloroethene
Method Blank	9/16/2014	00:00	Water	1	0.16 U	1.0 U	0.15 U	0.16 U	0.16 U	0.17 U	0.23 U
DPT002 8-12'	9/16/2014	08:10	Water	5000	1400 J	62000	750 U	800 U	18000	180000	1200 U
Method Blank	9/17/2014	00:00	Water	1	0.16 U	1.0 U	0.15 U	0.16 U	0.16 U	0.17 U	0.23 U
DPT001 10-14'	9/17/2014	07:57	Water	10000	1600 U	14000	1500 U	1600 U	1600 U	41000	2300 U
DPT003 8-12'	9/17/2014	12:25	Water	2000	320 U	95000	300 U	320 U	3300	100000	460 U
DPT004 10-14'	9/17/2014	12:35	Water	500	80 U	34000	75 U	80 U	770	33000	120 U
DPT005 12-16'	9/17/2014	12:45	Water	500	1200	4100	75 U	80 U	14000	6000	120 U
DPT007 10-14'	9/17/2014	14:05	Water	200	46 J	15000	30 U	32 U	3900	13000	46 U
DPT006 12-16'	9/17/2014	14:10	Water	1000	160 U	72000	150 U	160 U	5300	60000	120 U
DPT008 10-14'	9/17/2014	14:10	Water	5000	800 U	130000	750 U	800 U	5000 J	210000	1200 U
DPT009 8-12'	9/17/2014	16:05	Water	20000	3200 U	750000	3000 U	3200 U	3200 J	760000	4600 U
Method Blank	9/18/2014	00:00	Water	1	0.16 U	1.0 U	0.15 U	0.16 U	0.16 U	0.17 U	0.23 U
DPT012 8-12'	9/18/2014	08:43	Water	2000	320 U	69000	300 U	320 U	5900	140000	460 U
DPT011 8-12'	9/18/2014	08:48	Water	500, 1000	80 U	25000	75 U	80 U	1700	59000	120 U
DPT010 8-12'	9/18/2014	08:52	Water	1000	160 U	26000	150 U	160 U	160 U	59000	120 U
DPT013 10-14'	9/18/2014	10:53	Water	10	1.6 U	120	1.5 U	1.6 U	35	280	2.3 U
DPT014 10-14'	9/18/2014	11:00	Water	50	8.0 U	520	7.5 U	8.0 U	75	1400	12 U
DPT015 10-14'	9/18/2014	11:05	Water	10	1.6 U	20	1.5 U	1.6 U	54	71	2.3 U
DPT016 10-14'	9/18/2014	11:13	Water	100	16 U	2000	15 U	16 U	2000	5200	23 U
DPT017 12-16'	9/18/2014	12:44	Water	50	8.0 U	1000	7.5 U	8.0 U	1300	3300	12 U
DPT018 10-14'	9/18/2014	12:54	Water	1000	160 U	53000	150 U	160 U	160 U	39000	120 U

Project Summary

High Resolution Site Characterization

- Result is more accurate and useful Conceptual Site Models (CSMs), less data gaps



Project Summary

Path to NFA at SSC

CERCLA AREA	2013/14	2014	2015	2016	2017	2018	2019
C	Requested funding for Assessment	Conducted Assessment	Request funding for PBR	Implement PBR Request funding for continued PBR	Complete PBR	SHUT DOWN PTF Monitor one year per MDEQ	Request NFA
E PTF treats E&G	Active Remediation	Active Remediation	Request funding for Assessment	Conduct Assessment	Review enhanced remediation options and request funding	Consider BioStryke technology Requires turning off extraction pumps Timeline to be determined	
F	Requested funding for Assessment	Conducted Assessment	Request funding for PBR	Implement and complete PBR	Monitor one year per MDEQ	Request NFA	
G PTF treats E&G	Requested funding for Assessment	Conducted Assessment	Request funding for PBR	Implement PBR Request funding for continued PBR	Complete PBR	SHUT DOWN PTF Monitor one year per MDEQ	Request NFA
Action	**Requested $100K**	**Spent $100K**	**Request $400K** **Request $150K**	**Request $275K** **Spend $550K**	**Request funding for Area E remediation** **Spend $275K**	**Spend to remediate Area E**	

Acknowledgements:

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