



## *Highly Successful ERD Pilot Evaluation Utilizing a Simple Additive Delivery Approach*

# BioStryke

Remediation



Kent C. Armstrong – *BioStryke*® Remediation Products, LLC  
P.O. Box 254, Andover, NH USA; Brampton, Ontario CDN

James Romeo PG – Partner Engineering & Science, Inc.  
Altamonte Springs, Florida

International Petroleum Environmental Conference  
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*BioStryke*  
Remediation

**PARTNER**  
Engineering and Science, Inc.

Engineering and Science, Inc.



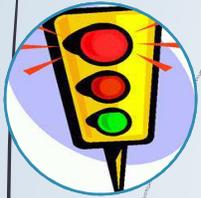
## Project Background

- ▶ Stennis Space Center (SSC), Hancock County, Mississippi
  - ▶ Southern Edge of the Gulf Coastal Plain
  - ▶ Approximately 55 miles NE of New Orleans, Louisiana
  - ▶ Approximately 36 miles West of Biloxi, Mississippi
- ▶ Historical equipment cleaning and disposal practices contributed to groundwater contamination at SSC
- ▶ 1<sup>o</sup> Contaminant-of-Concern (COC) Trichloroethylene (TCE)
- ▶ Concentrations of [TCE] exceeding compliance standards detected at 5-separate locations
- ▶ Performed on-site PRS Based and microcosm evaluations



## Project Background

- Evaluations to determine efficacy and feasibility of biostimulation as a residual source mass site strategy
  - [TCE] at depths ranging from 7 to over 90-ft bgs
  - Four Pump-and-Treat (P&T) systems currently operating
  - NASA estimates cleanup timelines to exceed 20-years
- P&T systems currently reaching asymptotic conditions
- Unable to remove remaining residual contaminant mass effectively
- Recent independent evaluations determined little to no-effect over last 5-years of operations
- NASA and independent consultant believe *both* cleanup duration and costs of current P&T grossly underestimated



- **Inappropriate without Physical Removal**

- Pooled DNAPL Source Zone
- Time is of the essence



- **Appropriate with Remedial Design Considerations**

- Heterogeneous matrix, silty/clay soil, fractured bedrock
- Residual DNAPL, cVOC and non-cVOC mixture
- Highly aerobic overburden



- **Ideal Situation**

- Accessible impact zone
- Time constraints minimal
- Homogeneous stratigraphic conditions

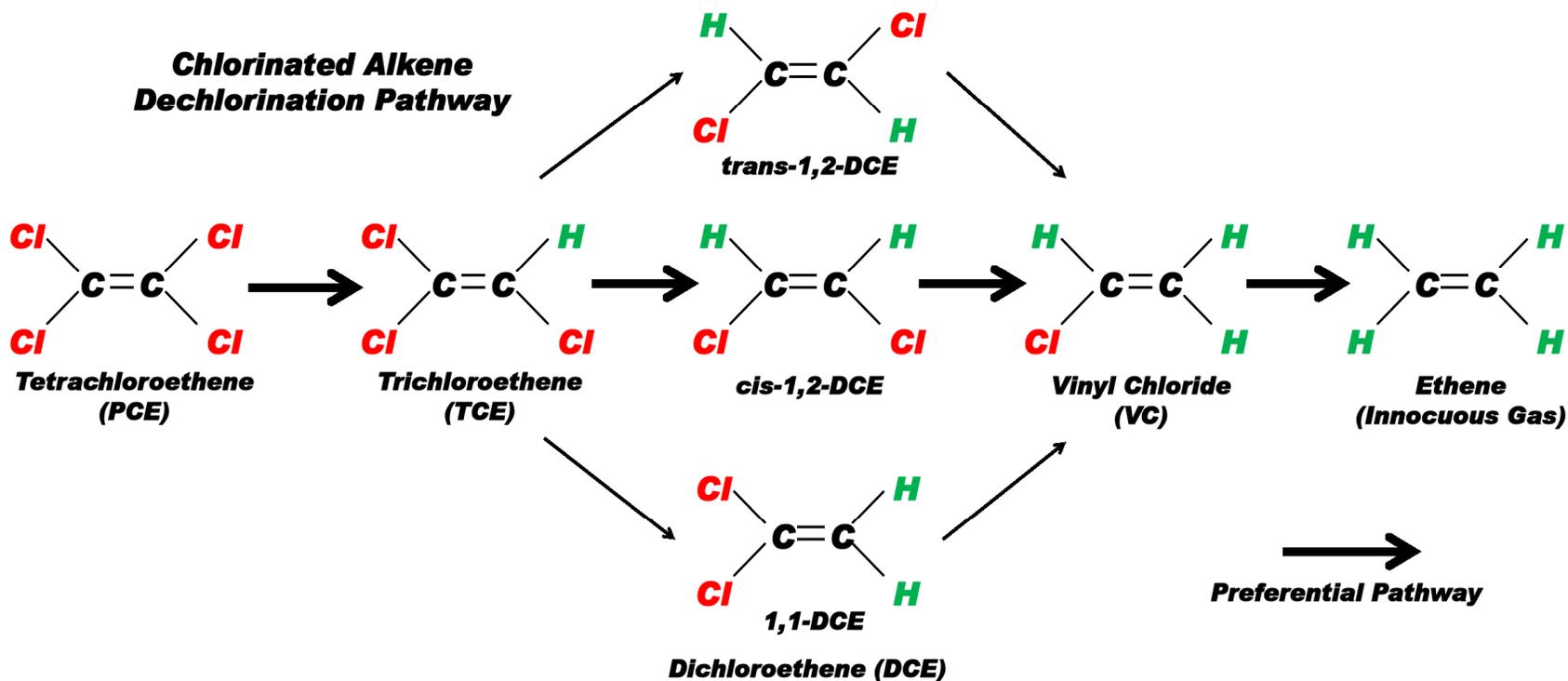


## Benefits to Biostimulation

minimize the impact of remediation

- ▶ Nourishes, stimulates native microbial populations
- ▶ Eliminates above ground support equipment
- ▶ Minimizes off-site removal, fuel and energy costs
- ▶ Eliminates nuisance noise, emissions and vapors
- ▶ Expedites residual source mass solubilization
- ▶ Increases contaminant bioavailability
- ▶ Facilitates cost-effective Long-Term Compliance

# cVOC Biotransformation Pathway

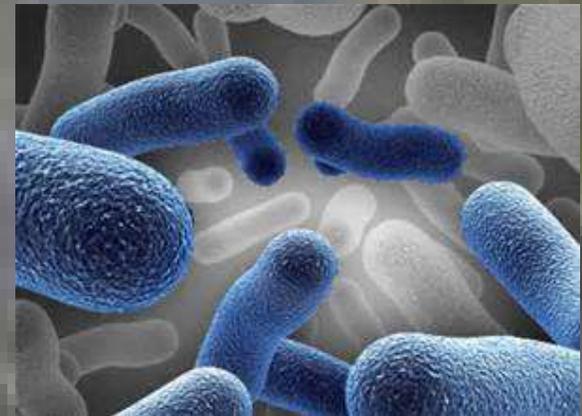




## Evaluation Objectives

### Microcosm Evaluation

- ▶ Performed independent microcosm evaluation (CB&I)
  - ▶ Confirm field results supported by laboratory results
  - ▶ Compare two additives efficacy as sole electron donor
  - ▶ Included augmentation and amendment addition
- ✓ Compared **ERDENHANCED™** to Lactate
- ✓ Each microcosm started with additive concentration of 1.35 g/L
- ✓ Augmented with SDC-9 *Dehalococcoides sp.* at  $1 \times 10^7$  cells/ml
- ✓ Site groundwater spiked with  $\approx 45$  mg/L [TCE]
- ✓ 10-day evaluation period



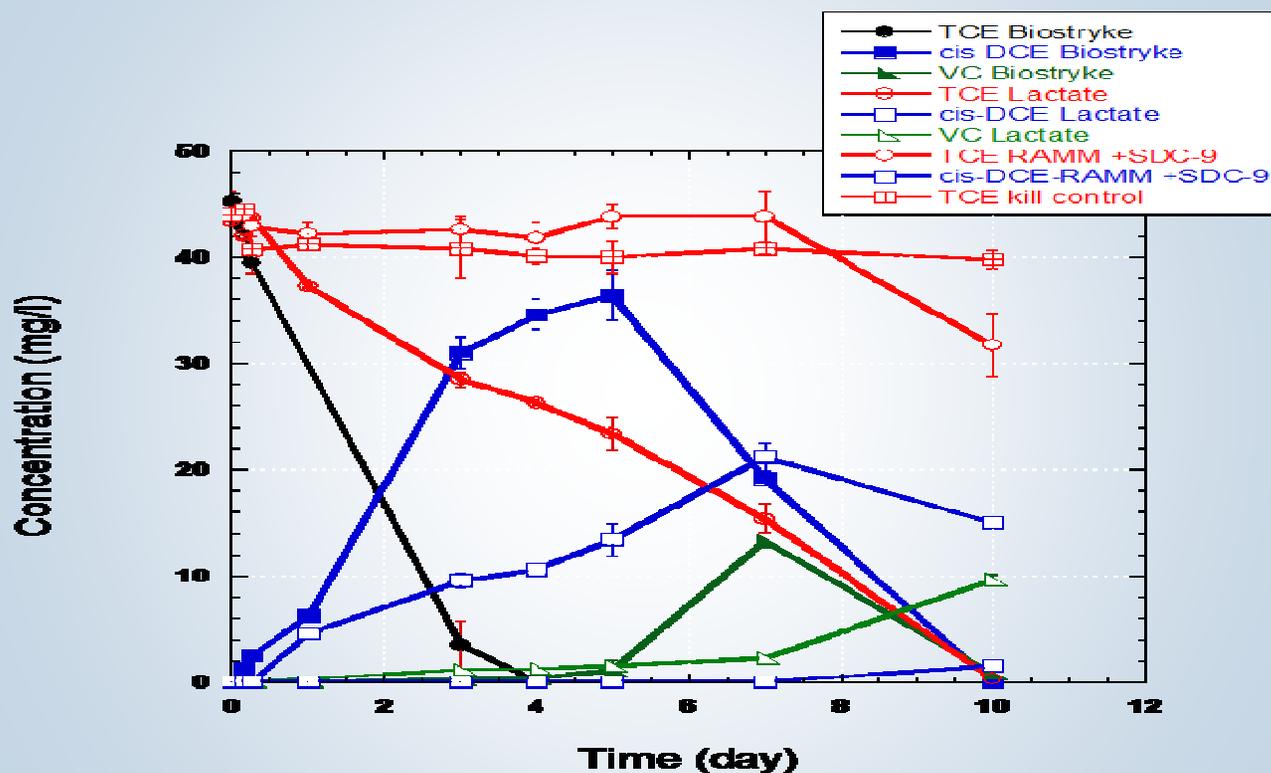


## Pilot Study Microcosm Evaluation

**ERDENHANCED<sup>®</sup>**

**NASA Stennis Space Station - Mississippi**

- Evaluation performed by CB&I, Lawrenceville, NJ



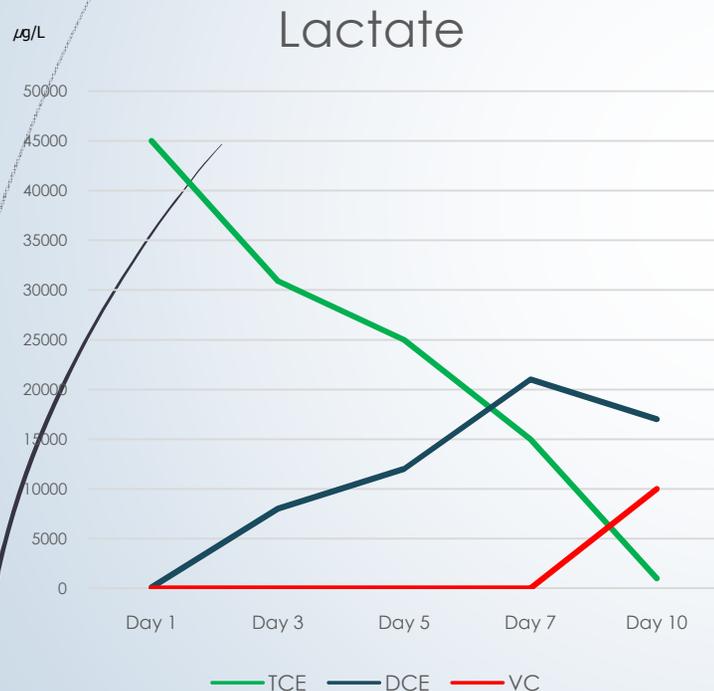


## Pilot Study Microcosm Evaluation One

**ERDENHANCED™**

**NASA Stennis Space Station - Mississippi**

Lactate amended microcosm realized:



Lactate *did not* yield complete biotransformation during evaluation period

- ≈97.8%REDUCTION by day-10
- An increase to 17,000 ug/L [cis-DCE] by day-7; followed by,
- 19.0%REDUCTION [cis-DCE] from peak bioavailability at evaluation end
- Increases in [VC] start at day-7 with continued upward trend at evaluation end
- Increases in [VC] without reduction may result in 2<sup>0</sup> contaminant and compliance issues

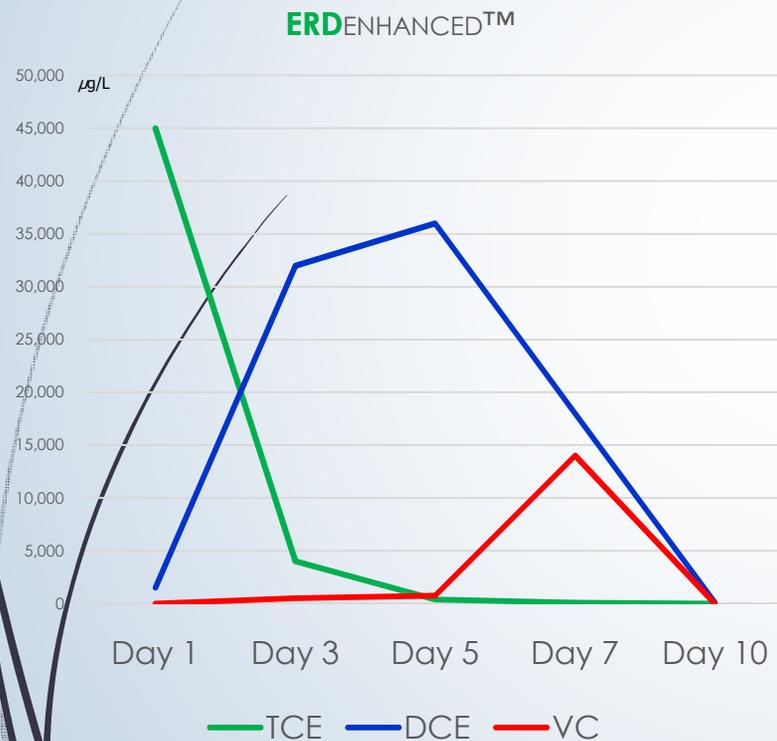


## Pilot Study Microcosm Evaluation

**ERDENHANCED™**

**NASA Stennis Space Station - Mississippi**

Over 10-day microcosm study



BioStryke® Faster, Safer Biotransformation of cVOC contaminants

- BioStryke® ERDENHANCED® realized:
- >99.99% REDUCTION [TCE] by day 5
- Overall >93.3% reduction in [cis-DCE]
  - Initial 2,300% increase at day 5
  - >71% than lactate microcosm
  - >99.7% reduction from peak bioavailability at evaluation end
- A four order-of-magnitude increase [VC] at day-7 of the evaluation
- >99.99% reduction in [VC] at day-10
- Complete parent destruction with twice the daughter production and subsequent complete destruction



# Stennis Space Center ERCLA Clean Up Sites

Natural Resource  
Management  
Team



## Evaluation Objectives Field Evaluation

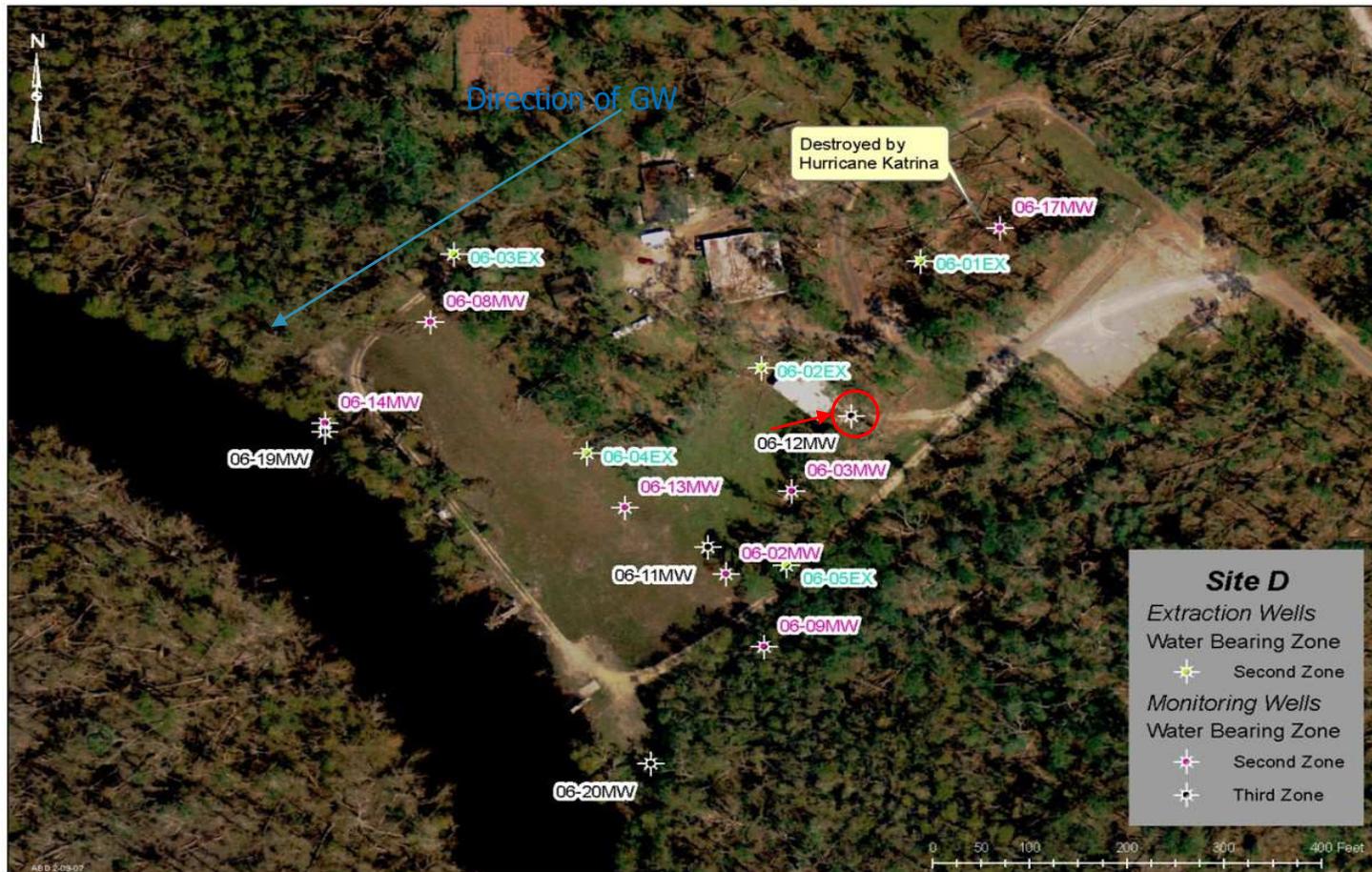
- ▶ NASA and independent consultant (ITB, Inc.) desire alternative remedial strategy to optimize current cleanup strategies at SSC
  - ▶ Conduct field based biostimulation demonstration
  - ▶ Innovative filled Passive Release Sock (PRS) deployment units
  - ▶ Filled Area D Water Bearing Unit 3 (WBZ 3)
    - ✓ 100-gal. storing Well 06-12MW
    - ✓ 4-inch diameter well; depth to water ≈27ft
    - ✓ Total depth ≈92-ft w/10-ft screened section at bottom
    - ✓ Determine potential for native microbial populations to degrade TCE effectively
    - ✓ Data gathered for other NASA sites





Stennis Space Center  
CERCLA Clean Up Sites

Natural Resource  
Management  
Team





# Stennis Space Center ERCLA Clean Up Sites

Natural Resource  
Management  
Team



## Background Conditions Stennis Space Station Area D: 06-12MW

Destroyed by  
Hurricane Katrina

- Deep Groundwater Bearing Unit
- Historical non-compliant [TCE]
  - Ranging from >50 ug/L to ~2,000 ug/L
  - Asymptotic over time
  - Indicative of residual source mass
- Limited daughter production
- No [Vinyl chloride] or [Ethene] recorded over entire period
- P&T systems effectiveness limited
  - In terms of performance
  - In terms of long-term cost

Well-ID	Date	[TCE]	[cis-DCE]	[VC]
06-12MW	2007	69	12	ND
	2008	1,201	233	ND
	2009	186	16	ND
	2010	1,259	177	ND
	2011	1,893	331	ND
	2012	1,017	99	ND
	2013	154	13	ND
MCL (µg/L)		5	70	2



## PRS Evaluation Process

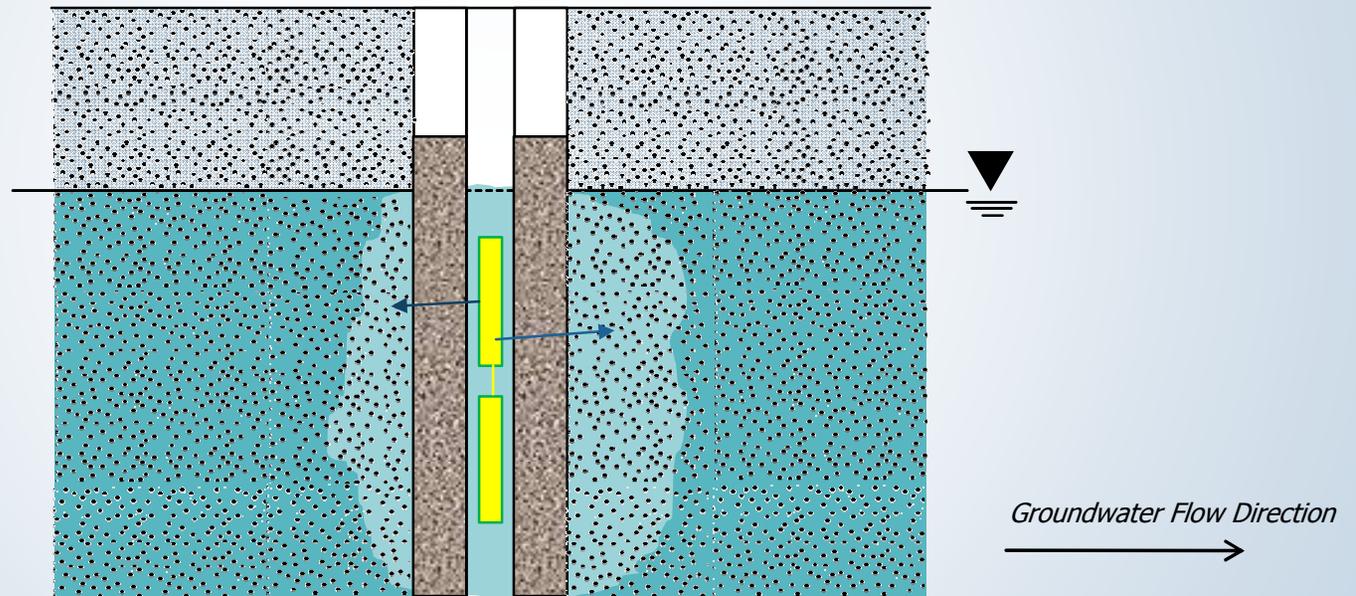
*Determine Additive Efficacy Under Real Biogeochemical Conditions*

- **Low-Risk, Low-Cost alternative to lab based evaluations**
- **Performed under actual Site biogeochemical conditions**
- **Utilize Passive Release Sock (PRS) deployment units**
- **Provides Representative 'Go-no-Go' on-Site Evaluation**
- **Baseline & Performance Monitoring/Sampling**
  - *PRS replacement events every 6-8 weeks*
  - *7 replacement events over 15 month evaluation*
  - *Performance sample collection/analysis each event*
- **Non-purge, low-flow sampling protocols**
  - **Field indicator parameters monitored and recorded each replacement event**
  - **ORP, DO, pH, Temp, Cond; NO<sub>3</sub>, SO<sub>4</sub>, diss. Mn/Fe Ethane, Methane, Ethene, and Contaminants of Concern**



Ground  
surface

Well with  
deployed PRS



Additive slowly dissolves into casing volume of test well

PRS unit acts as a wicking agent to manage additive delivery



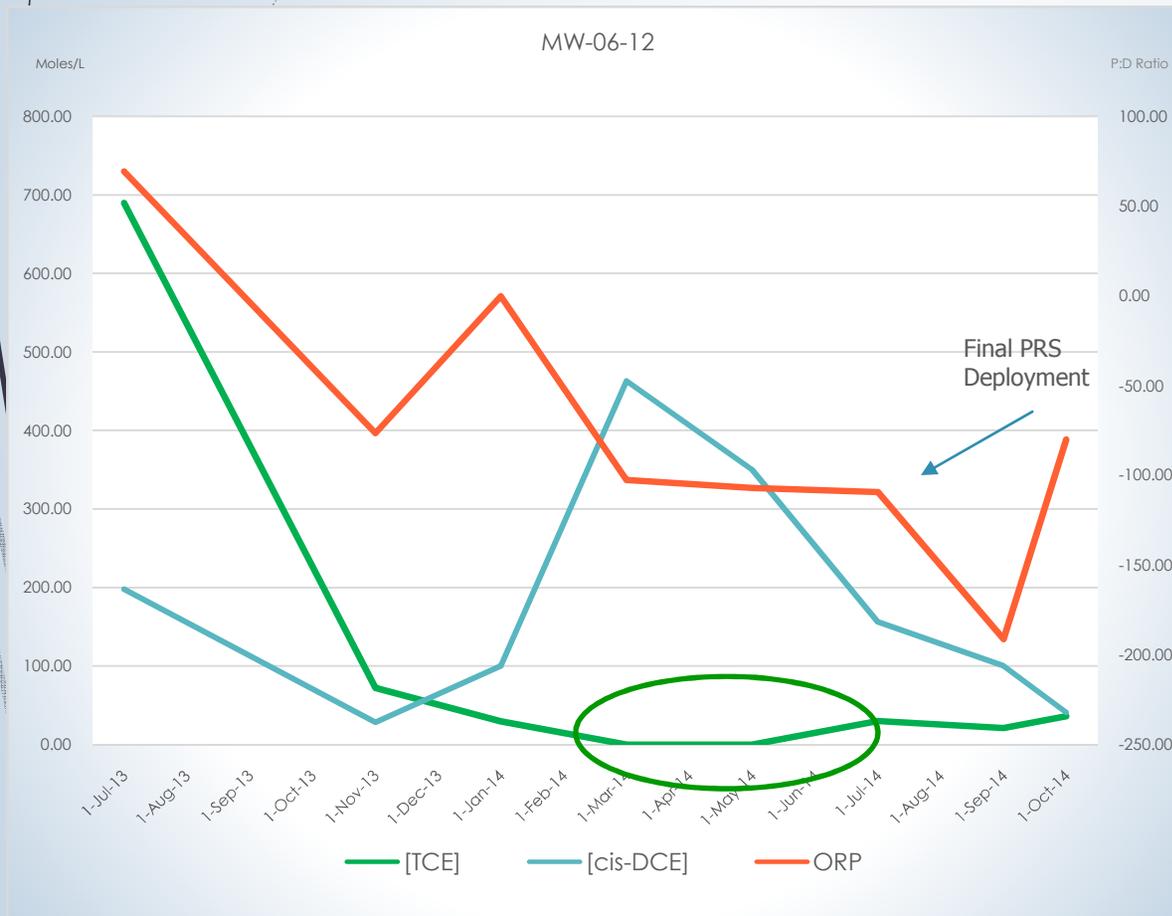
## Pilot Study Program

Benefits - Limitations

- **Confirm Additive Efficacy prior to Full-Scale Commitment**
- **Non-Scalable, PRS Pilot Study Generates Limited AOI**
  - *Typically < 2 meters*
- **Confirms presence/absence dehalorespiring bacteria**
  - *Easily combined with BioTrap® and/or other evaluation tools*
- **Utilizes casing volume of well as 'laboratory microsm'**
  - **Non-purge sampling otherwise skews results**
    - *Removes amended groundwater*
    - *Removes enhanced microbial populations*
  - **Helps identify presence/absence of residual mass and, provides go no-go based results**

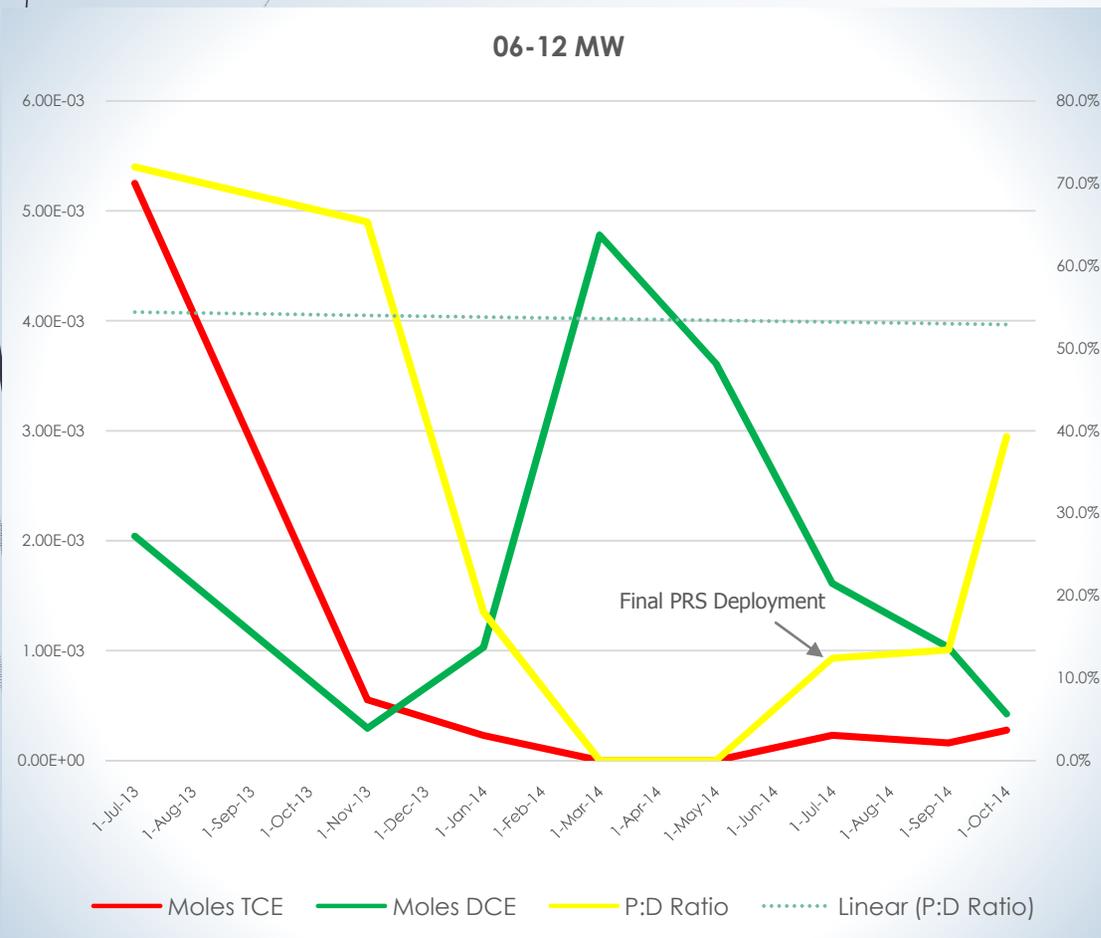


**Changes in concentrations of cVOC contaminants**



- Overall 94.8%<sup>REDUCTION</sup> [TCE] over 15-month evaluation
- >99.99% continuous reductions in [TCE] from months T7-T10
- Overall 79.3%<sup>REDUCTION</sup> [cis-DCE] over 15-month evaluation
  - Initial 85.7% reduction at month 4
  - >1,530% increase by month 8
- >91.1%<sup>REDUCTION</sup> [CIS-DCE] from peak bioavailability at end
- Consistent decrease in ORP values (from +69 to -191mV)
- No [VC] or [Ethene] recorded

### NASA ERDenhanced™ Field Evaluation Results



- As TCE molecules are respired, moles TCE drop 100% in  $\approx$ 8 mos.

- Similarly, moles DCE drop 86% in  $\approx$ 4 months; afterwards,

- >1,500% increase moles DCE next 4 months

- Moles DCE decrease 91% from peak bioavailability

- Overall molar decrease

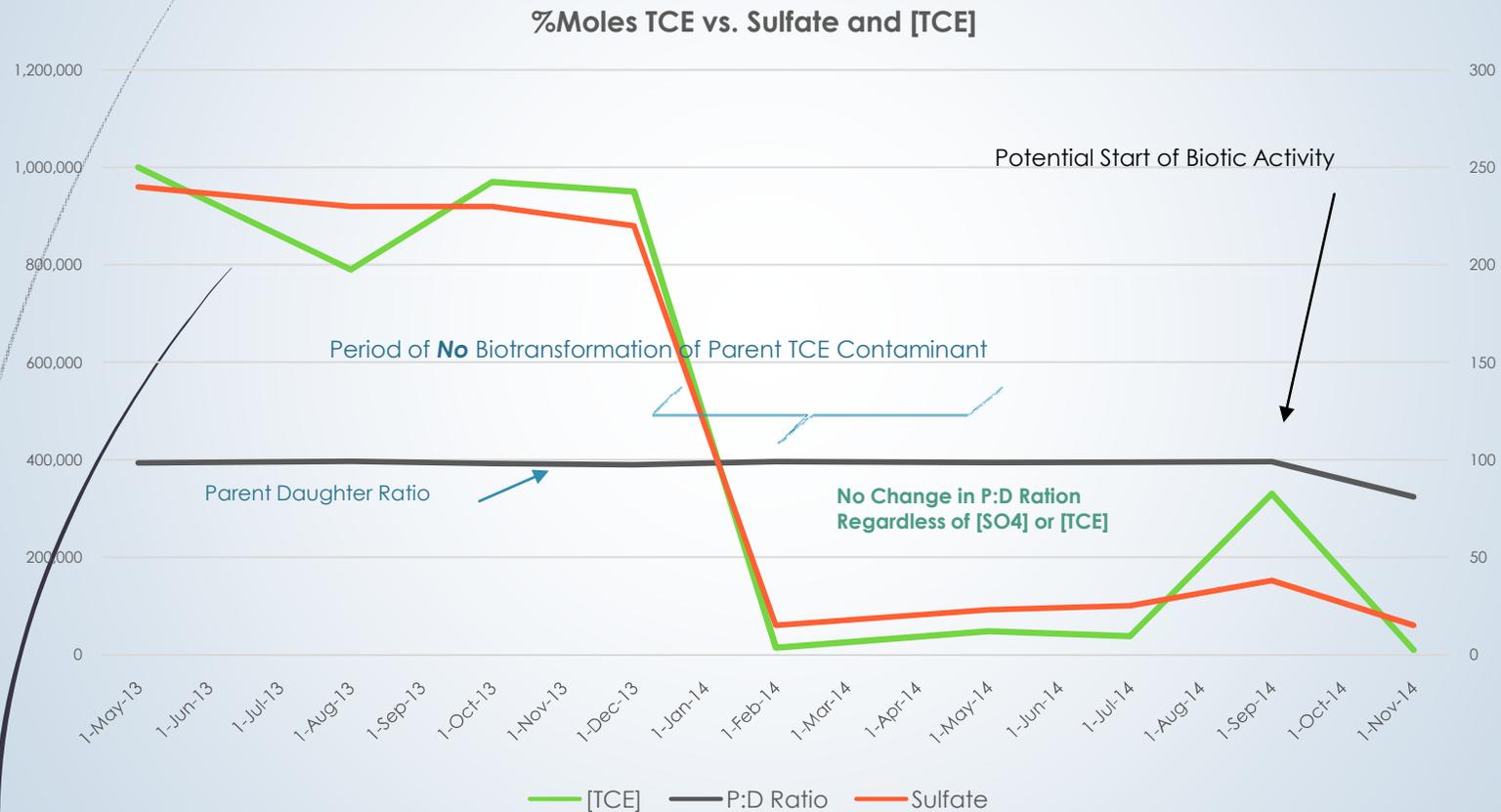
- TCE 94.8%

- DCE 79.3%

- Parent Daughter Ratio Confirms biotransformation of cVOC contaminants

# Contaminant Reduction but *NO* Destruction?

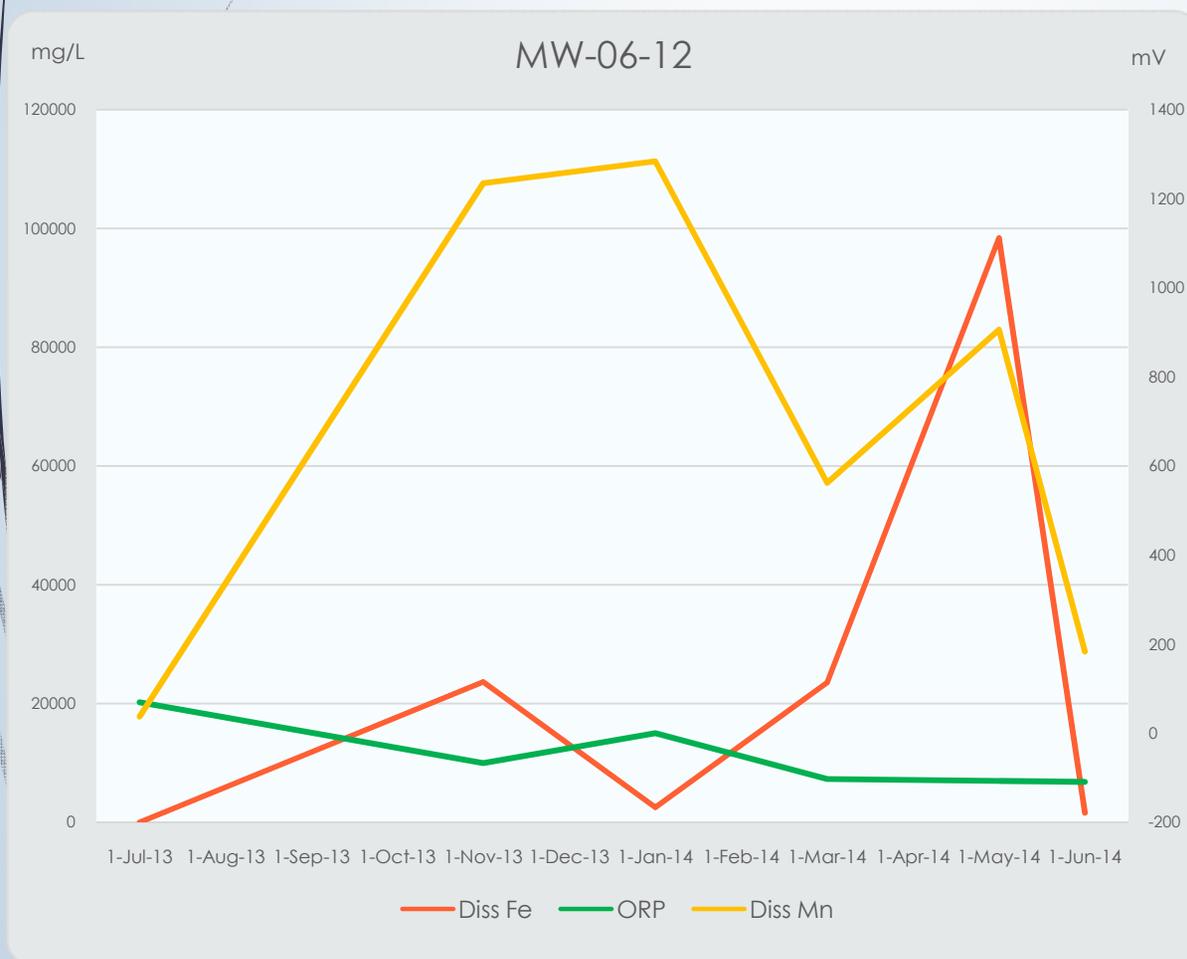
## The importance of molar comparisons





## ERDENHANCED™ PRS Pilot Study NASA Stennis Space Station - Mississippi

Geochemistry; 2<sup>o</sup> lines of evidence supporting biotic reductive dechlorination



- 4 Order-of-Magnitude increase in [dissolved Fe]
- >98.3% decrease [diss. Fe] from peak availability
- >3,000% increase [dissolved Manganese] at month
- >85.7% decrease [diss. Mn] by evaluation end
- 30,000% increase [Sulfate] by month 6; complete depletion by end of evaluation period
- Sustained decrease in ORP, general increases [Methane]

- **ERDENHANCED®** amended microcosm superior performance
- Field evaluation data supported complete cVOC biotransformation
- Demonstrated biostimulation cost-effective strategy
- PRS study proved effective as 'Go no-Go' evaluation process
- Site currently undergoing additional characterization
- 2016 proposed on-site treatability evaluation
  - *DPT injection of ERDenhanced about performance well*
  - *Confirm subsurface distribution capabilities*
  - *Determine transferability of PRS and Microcosm studies*
- From results of Treatability evaluation determine full-scale loading and site requirements
- Current estimations place biostimulation capable of obtaining sustainable reducing conditions and 3-5 year compliance timeline



Thank You

?? Questions ??



**BioStryke Remediation Products, LLC**  
**P.O. Box 254, Andover NH**  
**[www.biostryke.com](http://www.biostryke.com)**  
**603.731.3159      [karmstrong@biostryke.net](mailto:karmstrong@biostryke.net)**