Results From Two Direct Hydrogen Delivery Field Tests For Enhanced Dechlorination

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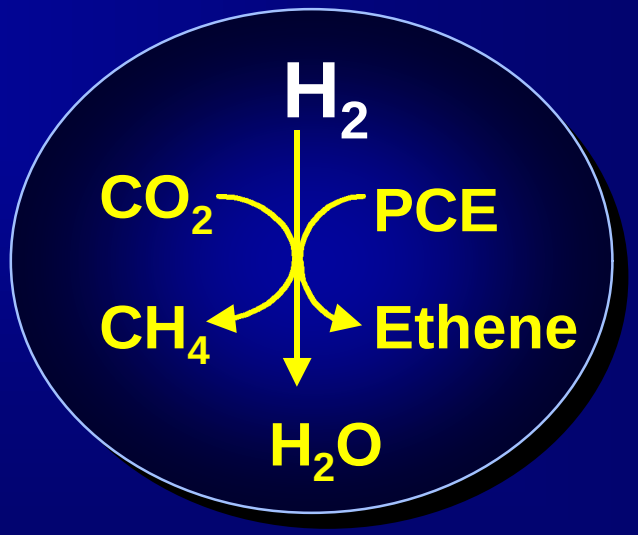


Two Methods to Deliver Hydrogen To Dechlorinators

1.

Deliver Carbon Substrate

↓

Fermenters Produce H_2

↓

Dechlorinators Use H_2

2.

Deliver H_2 Directly

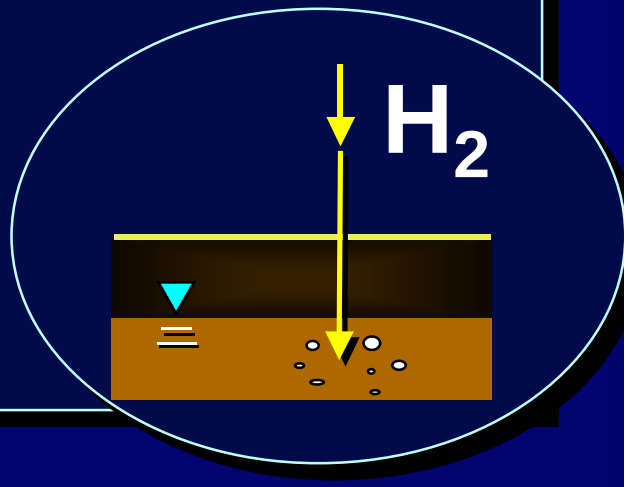
↓

Dechlorinators Use H_2

Multiple Ways to Deliver Hydrogen Directly

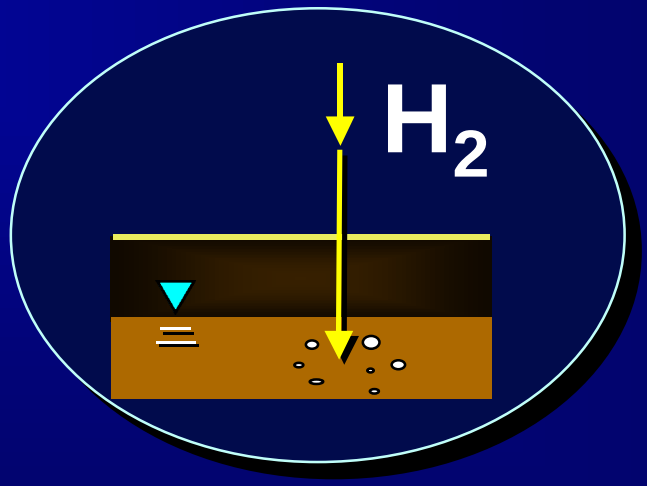
(Hughes, Newell, and Fisher, 1997)

- Low Volume Pulsed Biosparging (P. Johnson)
- Closed-Loop Pumping Systems
- Electrolysis
- Metal Addition
- Foams (Hirasawki and Miller)



Why Direct Delivery of H_2 Won't Work

- Methanogens Will Steal H_2 (competition); Only "Slow Burn" Works
- H_2 has Low Solubility
- H_2 is Unsafe
- Can't Mix H_2



Direct Hydrogen Addition:

Supporting Laboratory Studies

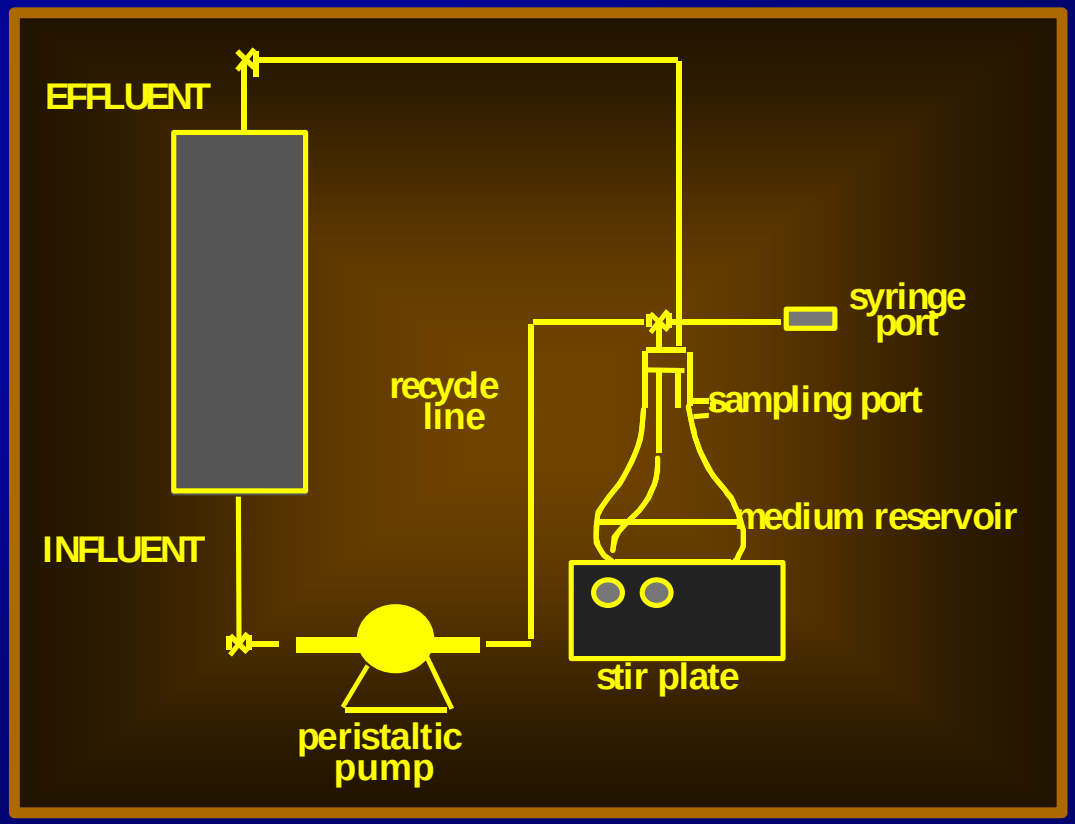
C. D. Carr &

J. B. Hughes

Rice University

ES&T, June 15,1998

Vol 30, No. 12



Conclusions: PCE HALF-Lives:

98 Days Adaptation: 5-16 hours

474 Days Adaptation: < 2 hours

Conclusions: STOICHIOMETRY

1 mg H_2 degrades 23 mg PCE

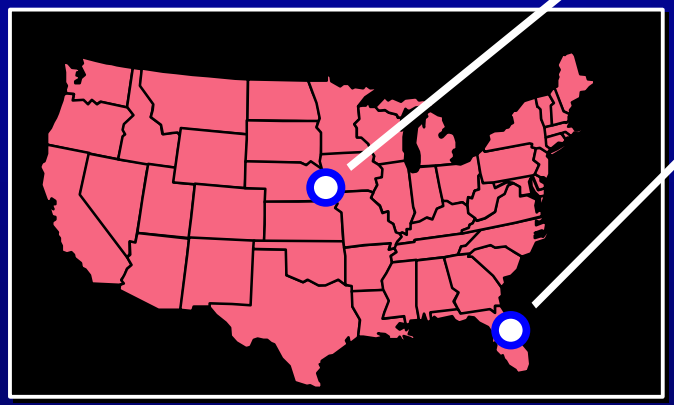
Conclusions: COMPETITION

" Dechlorination not impacted by competition for electron donor, even at high H_2 partial pressures."

" Cost and method of delivery may dictate the electron donor (i.e., fermentation substrates vs. H_2)"

TWO FIELD TESTS

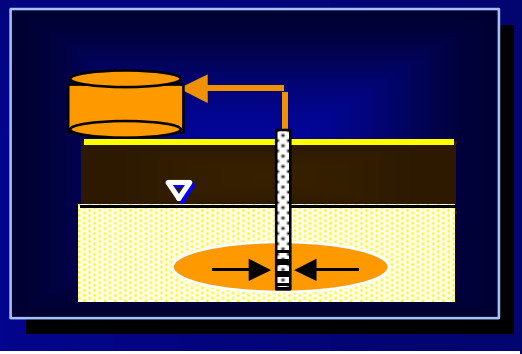
TEST	TYPE	DURATION	LOCATION
Pull-Push-Pull	Treatability	42 Hours	Offutt AFB, Nebraska
Low-Volume Pulsed Biosparge	Pilot	18 Months	Cape Canaveral, Florida



OFFUTT AFB TREATABILITY TEST: APPROACH

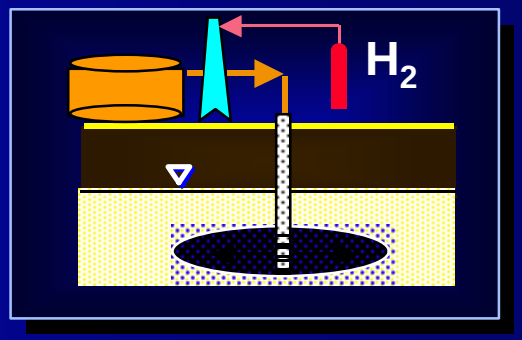
PULL

1. **EXTRACT** 1000 L contaminated groundwater
2. **ANALYZE**



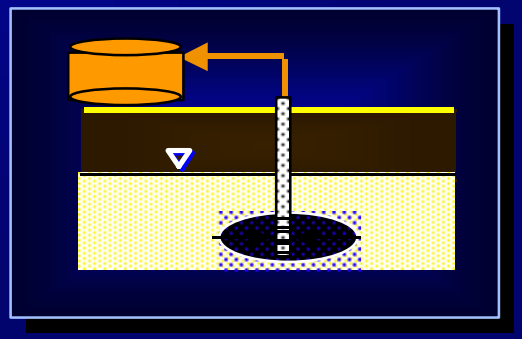
PUSH

3. **ADD** Hydrogen and tracers (He, SF6, Br)
4. **PUMP** back into formation
5. **WAIT** 48 hrs



PULL

6. **EXTRACT** test fluid out
7. **ANALYZE**



OFFUTT AFB TREATABILITY TEST: RESULTS

Before **cis-DCE: 430 ug/L**

VC, ethane, ethene: ND

After **cis-DCE: < 5 ug/L**

< 1% hydrogen recovered

40% helium recovered (volatilization)
67% SF6 recovered
93% Br recovered

Conclusion: ***Complete cis-DCE removal***

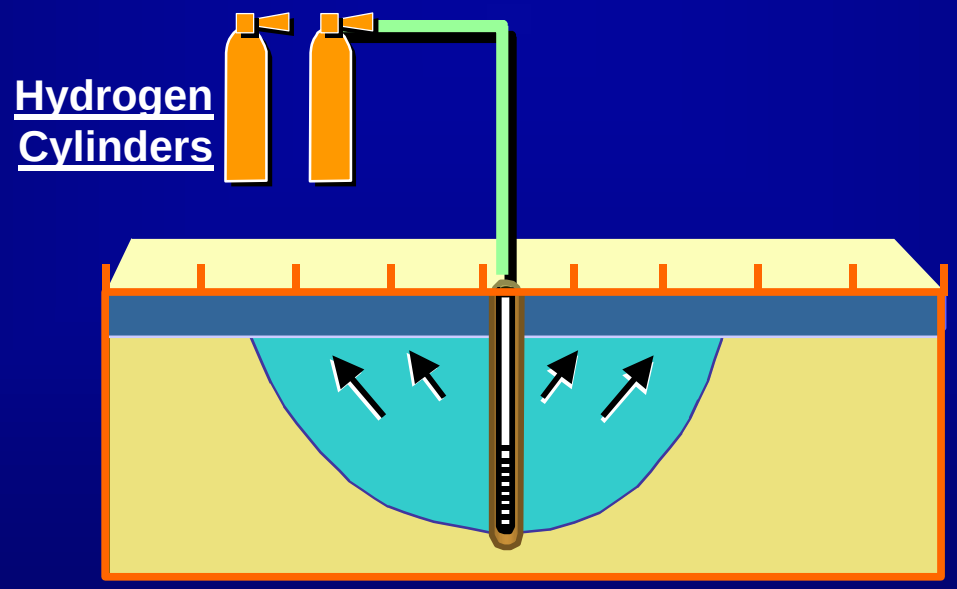
OFFUTT AFB TREATABILITY TEST: RESULTS

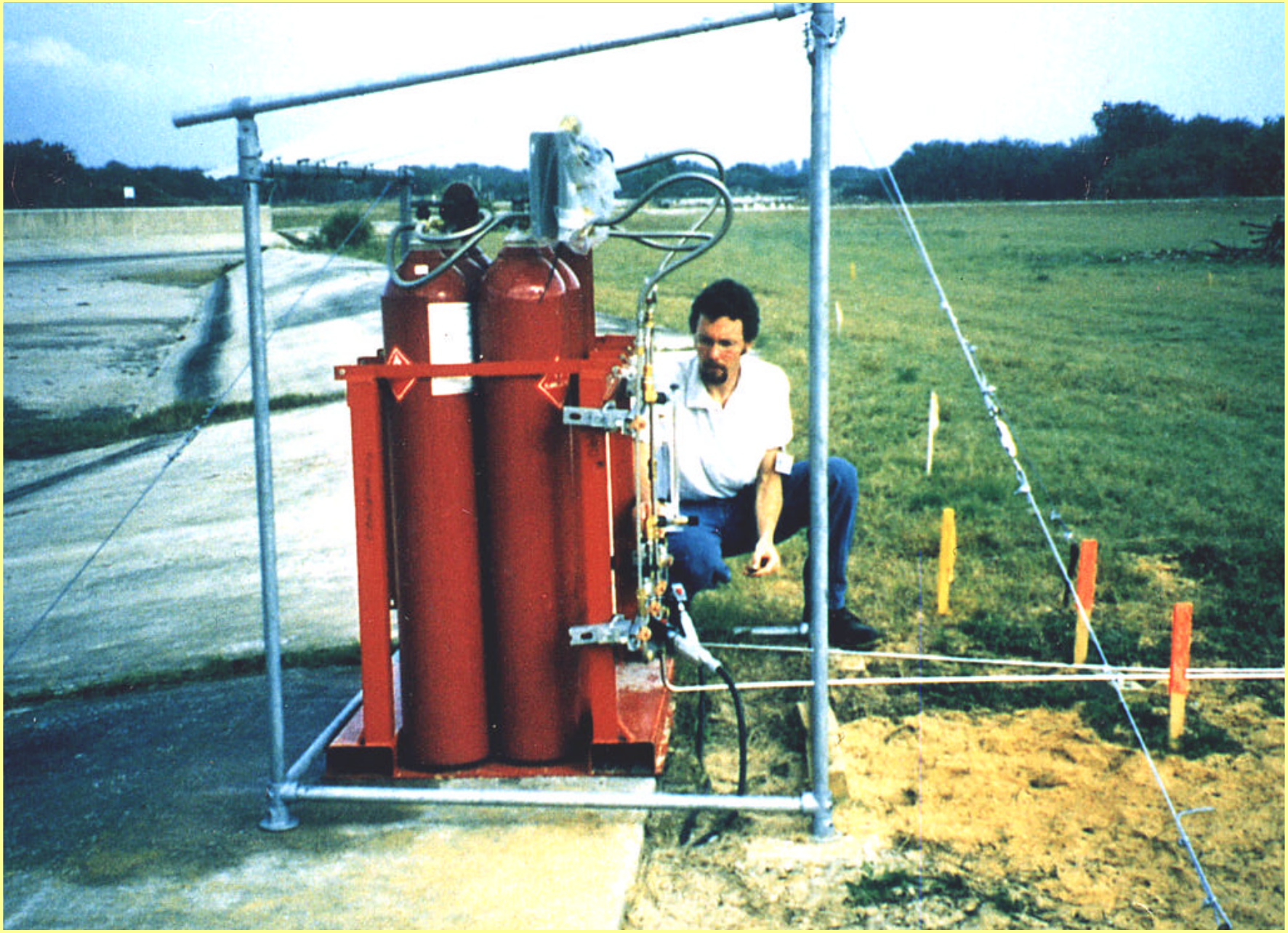
Before **benzene: 88 ug/L**

After **benzene: 81 ug/L (little change)**

Conclusion: ***Benzene data suggests cis-DCE loss from anaerobic biodegradation***

TECHNICAL APPROACH: LOW-VOLUME PULSED BIOSPARGING



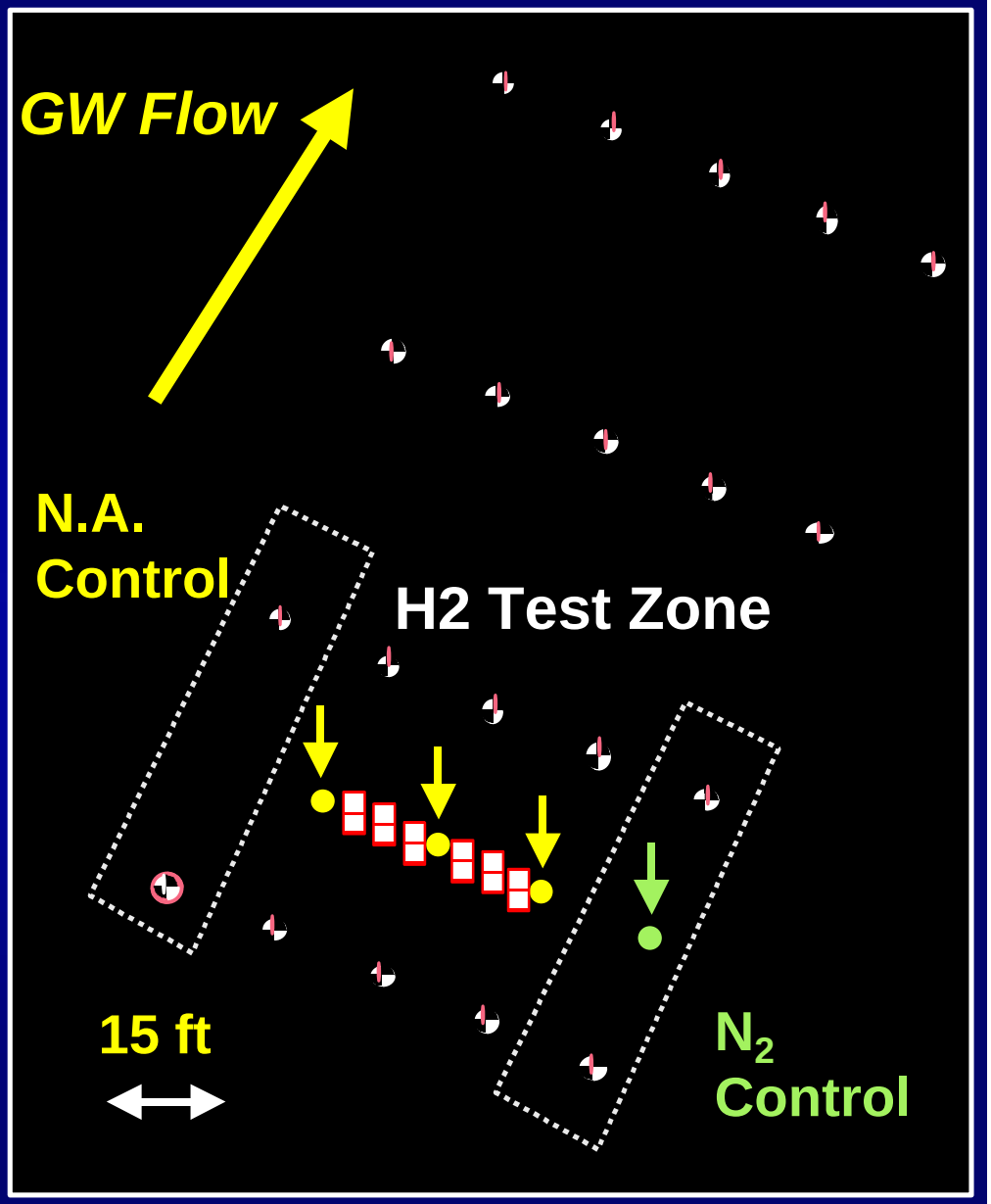


Cape Canaveral Low-Volume Pulsed Biosparge

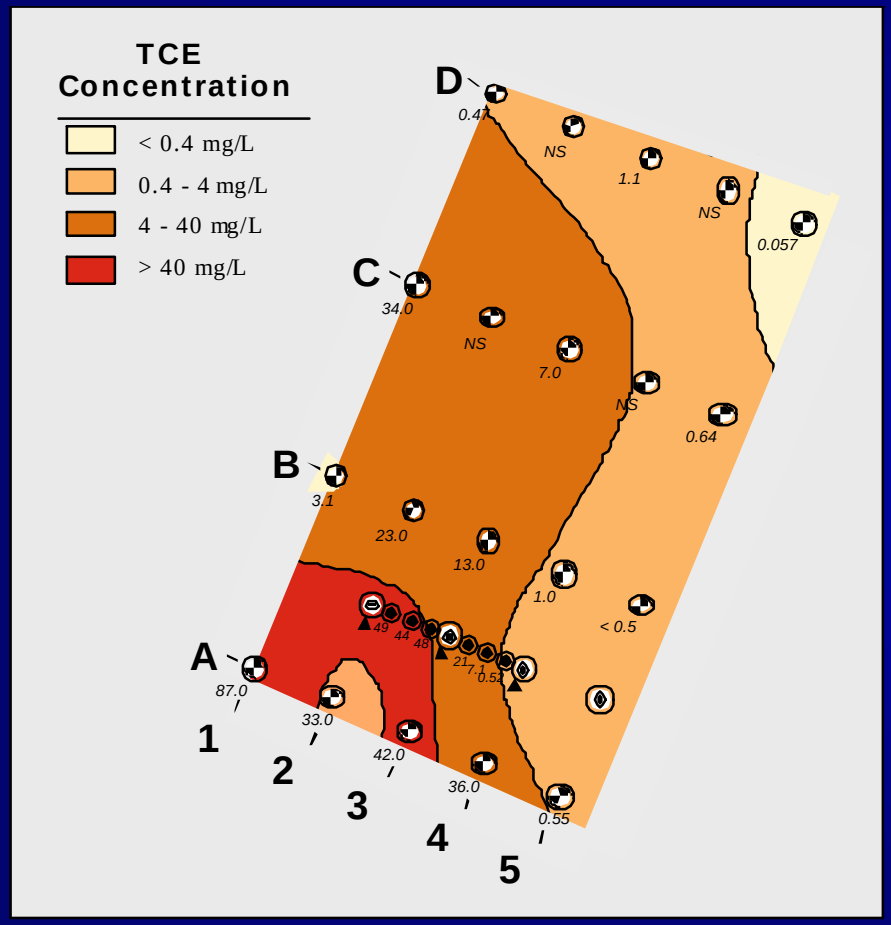
- 4 Sparge Wells
- 6 Multi-Level Points
- 20 Other Monitoring Points

- Sparging For Each Well:
  - 130 ft^3 on Day 1
  - 10 ft^3 per day (Days 0-120)
  - 200 ft^3 per week (Days 120+)

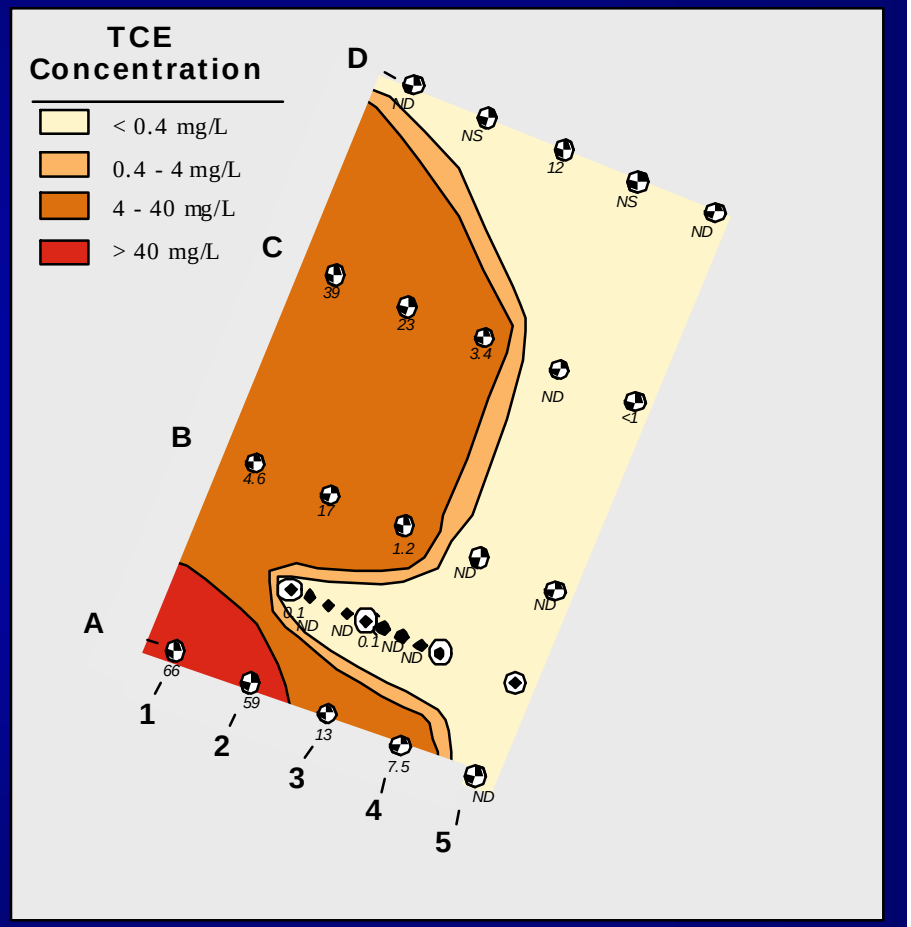
PLAN VIEW



18 Month Change in TCE

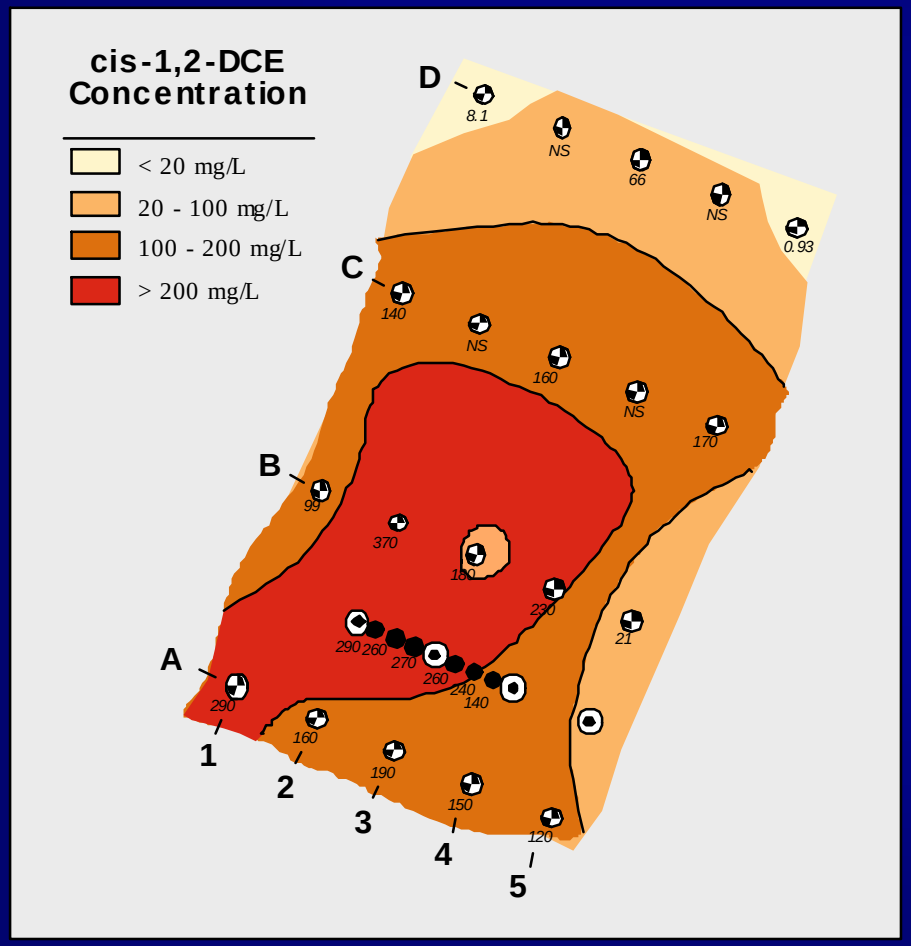


BASELINE

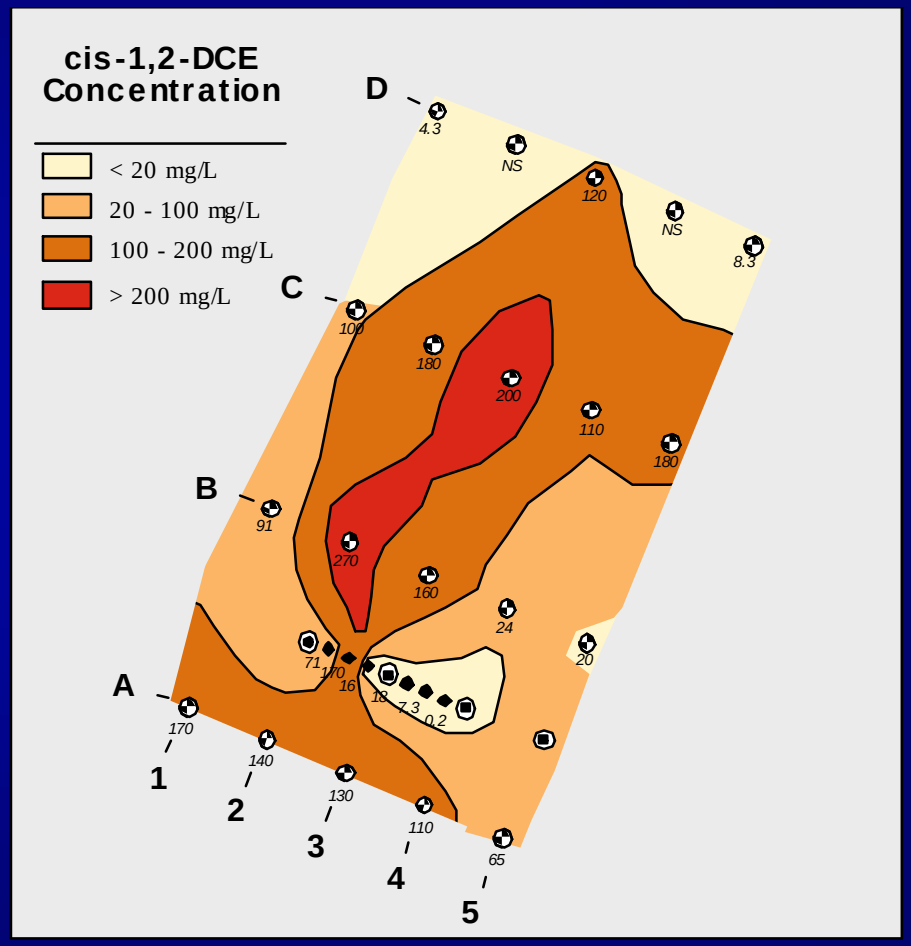


18 Months

18 Month Change in cis-1,2-DCE

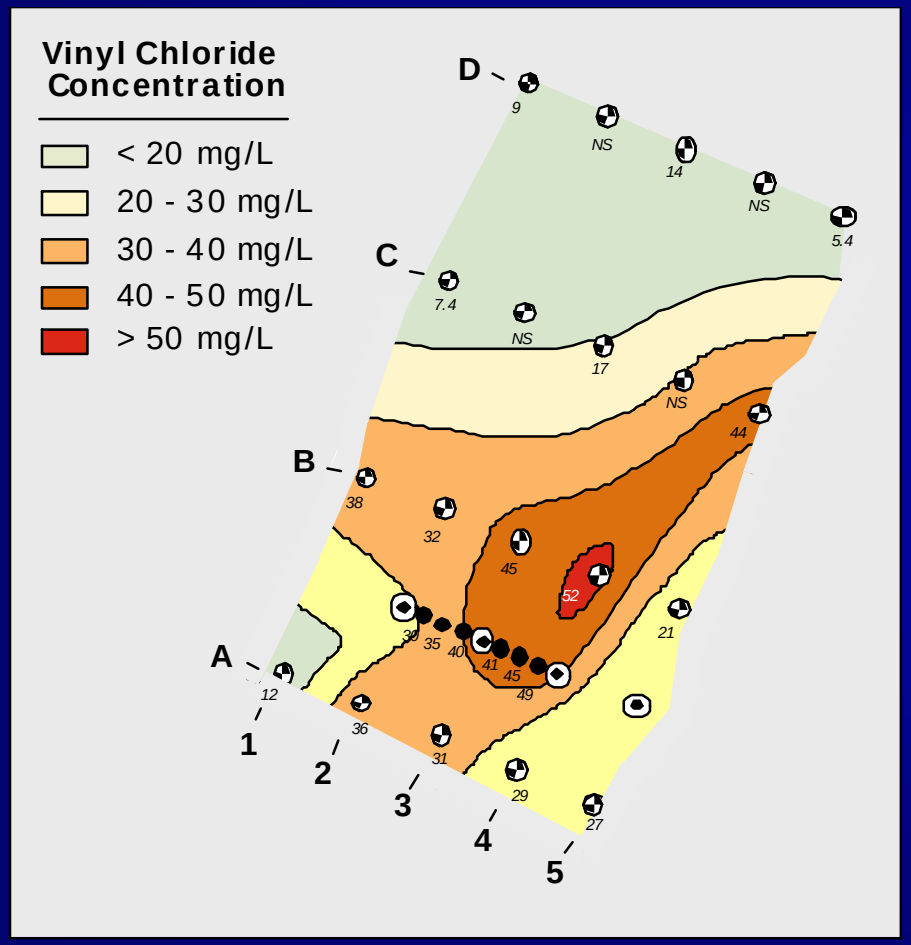


BASELINE



18 Months

18 Month Change in Vinyl Chloride



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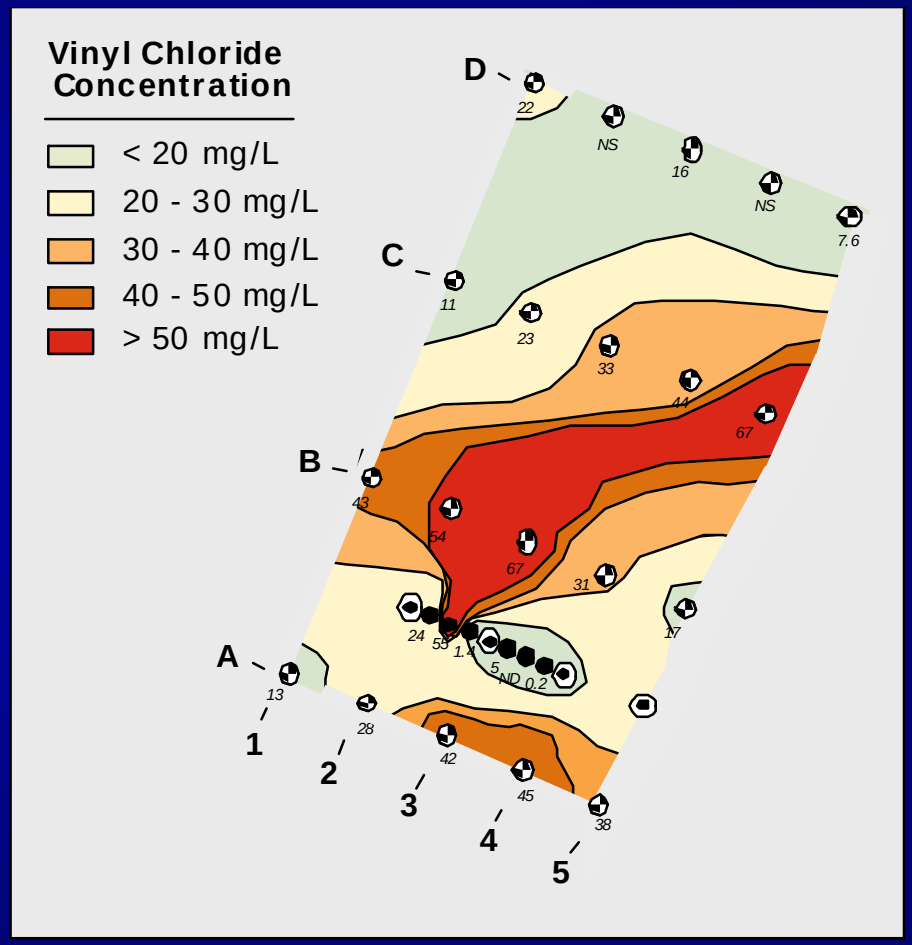
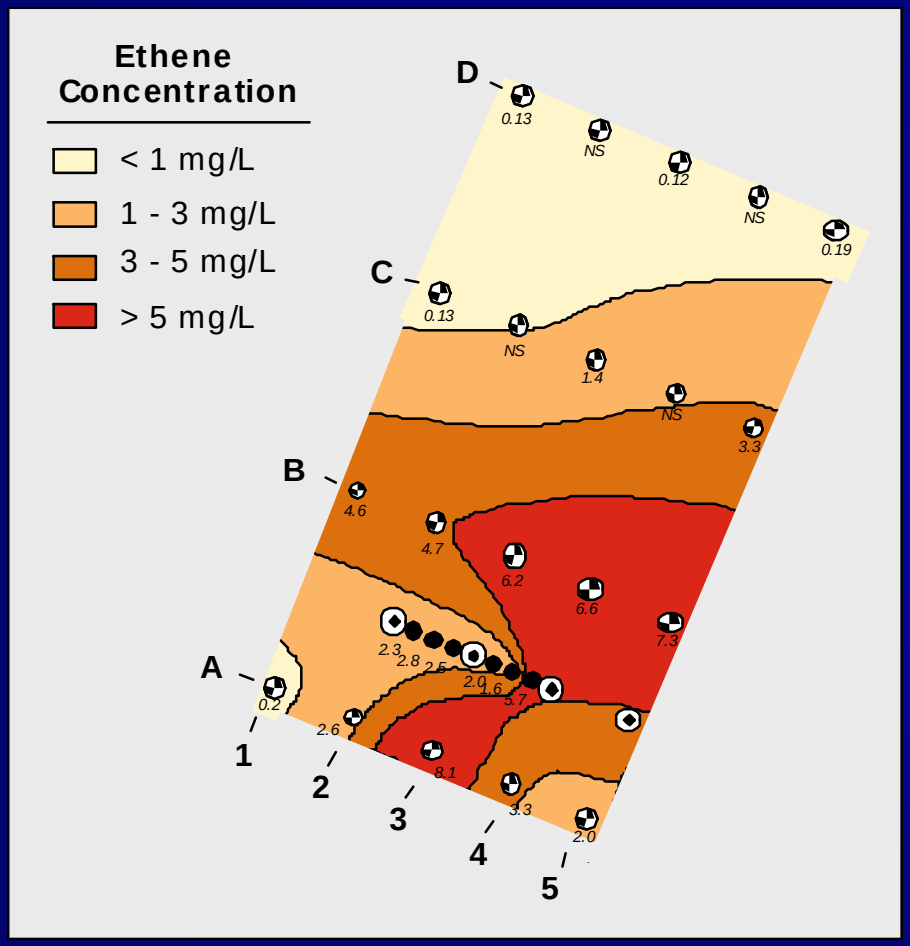


18 Months

18 Month Change in Ethene



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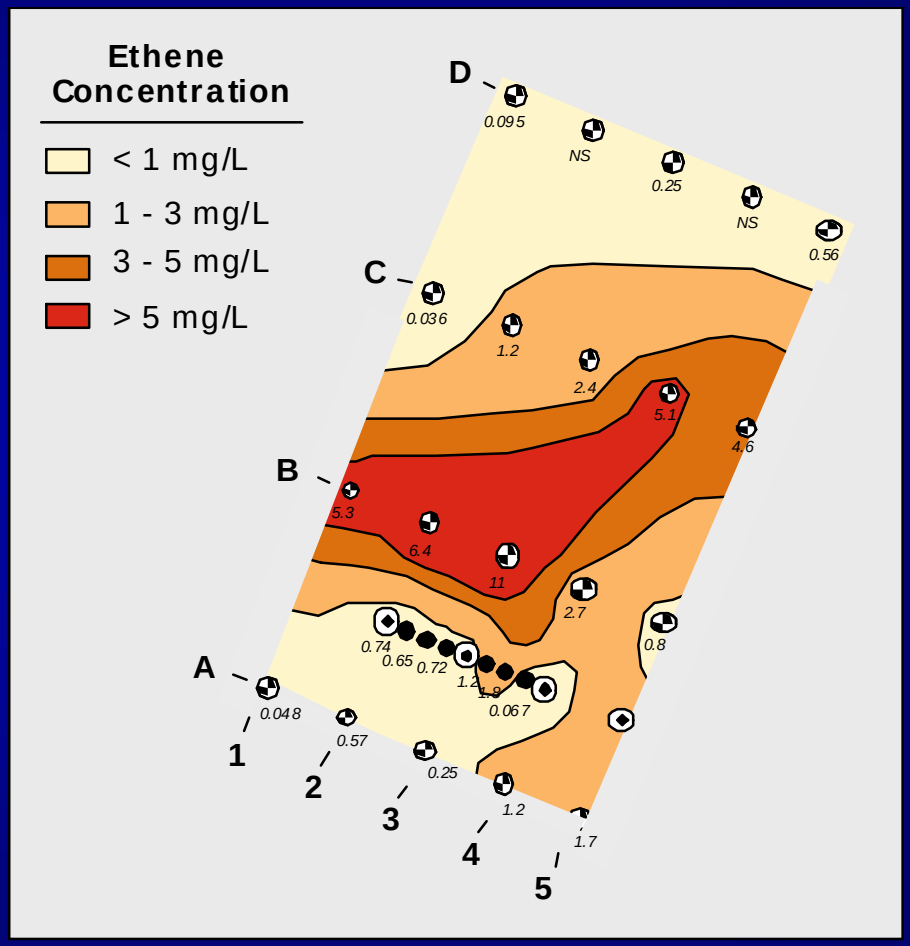
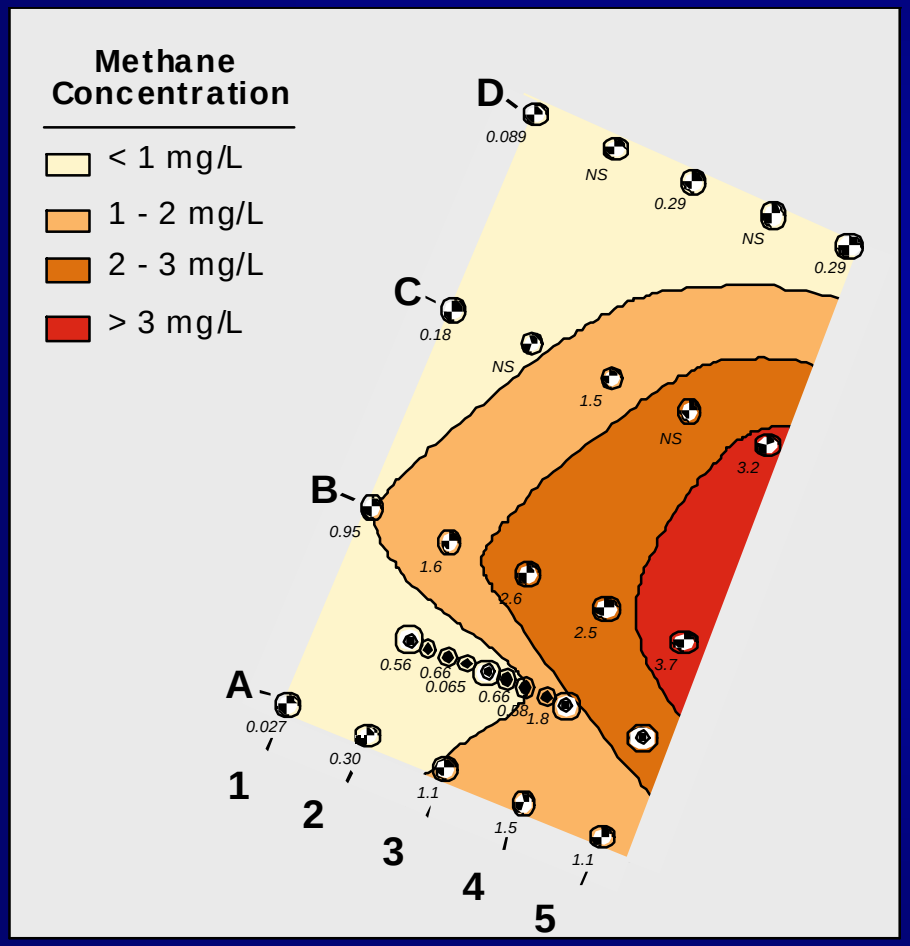
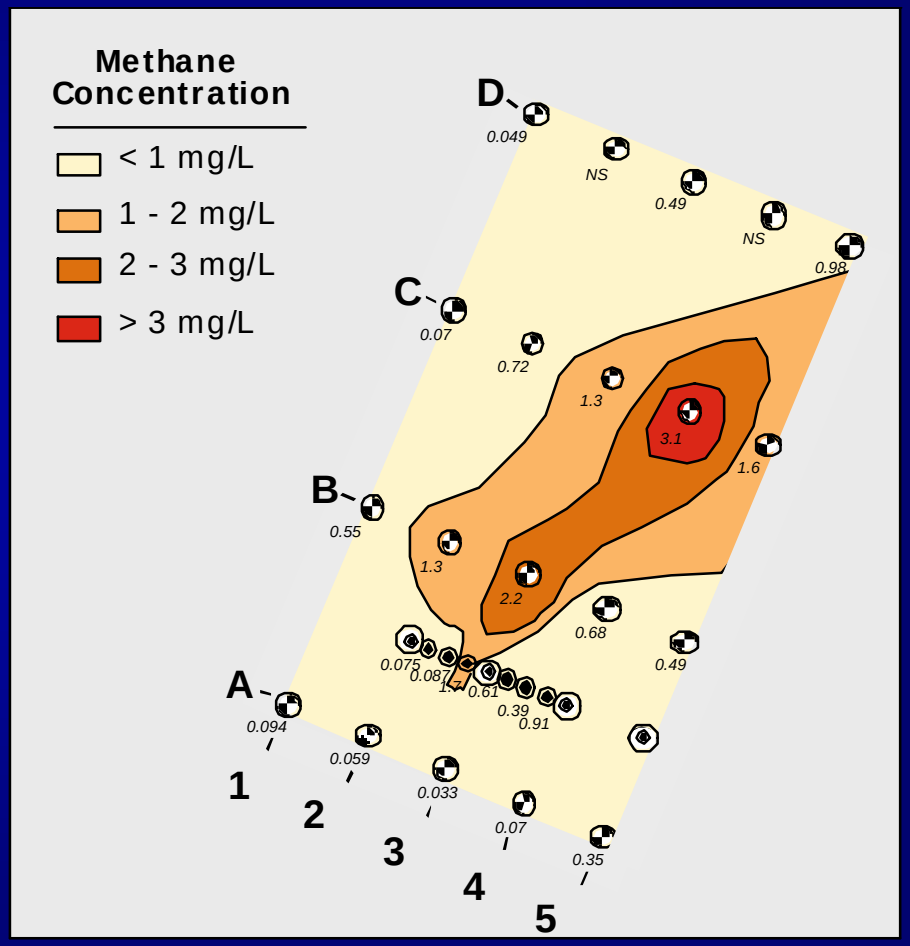


18 Months

18 Month Change in Methane



BASELINE



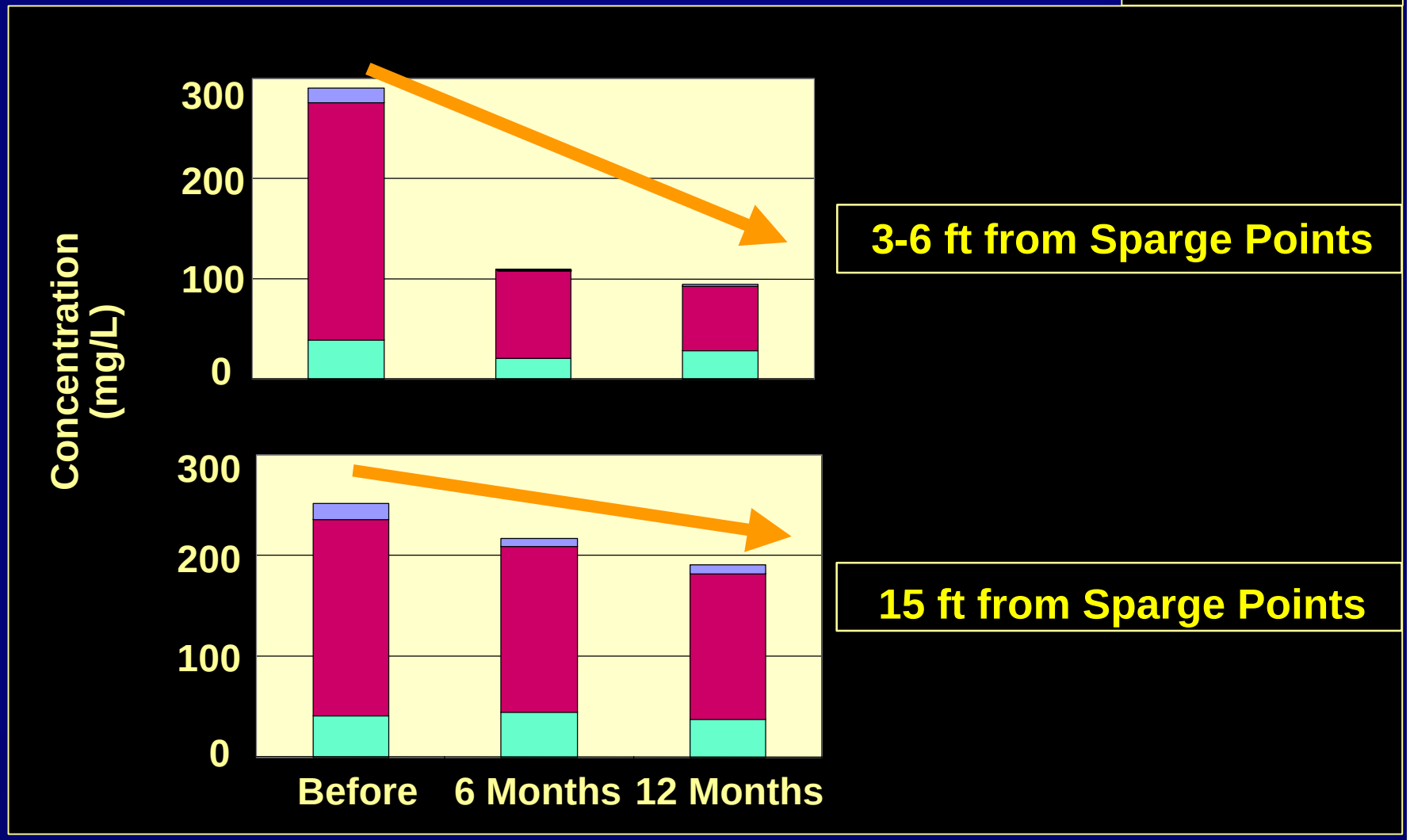
18 Months

Cape Canaveral Hydrogen Biosparge

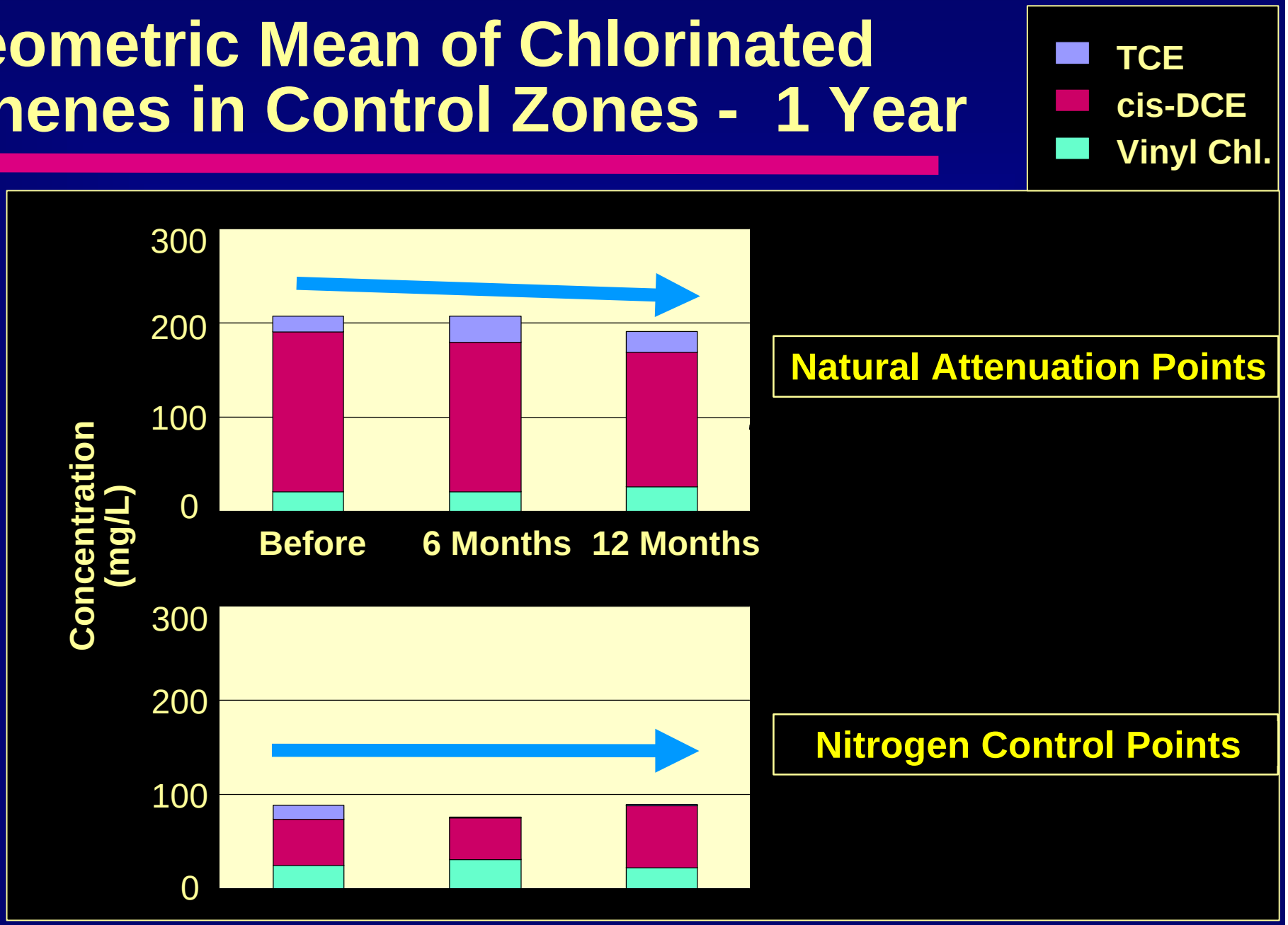
Concentration Change Over 18 Months (mg/L)

	change in conc. (mg/L)			
	Test Zone		Control Zones	
Distance from Sparge	(H_2: 3-6 ft)	(H_2: 15 ft)	(N_2: 15 ft)	(N.A.: 25 ft)
Chlorinated Ethenes	- 274	-142	-13	-42
	(-95%)	(-49%)	(-17%)	(-20%)

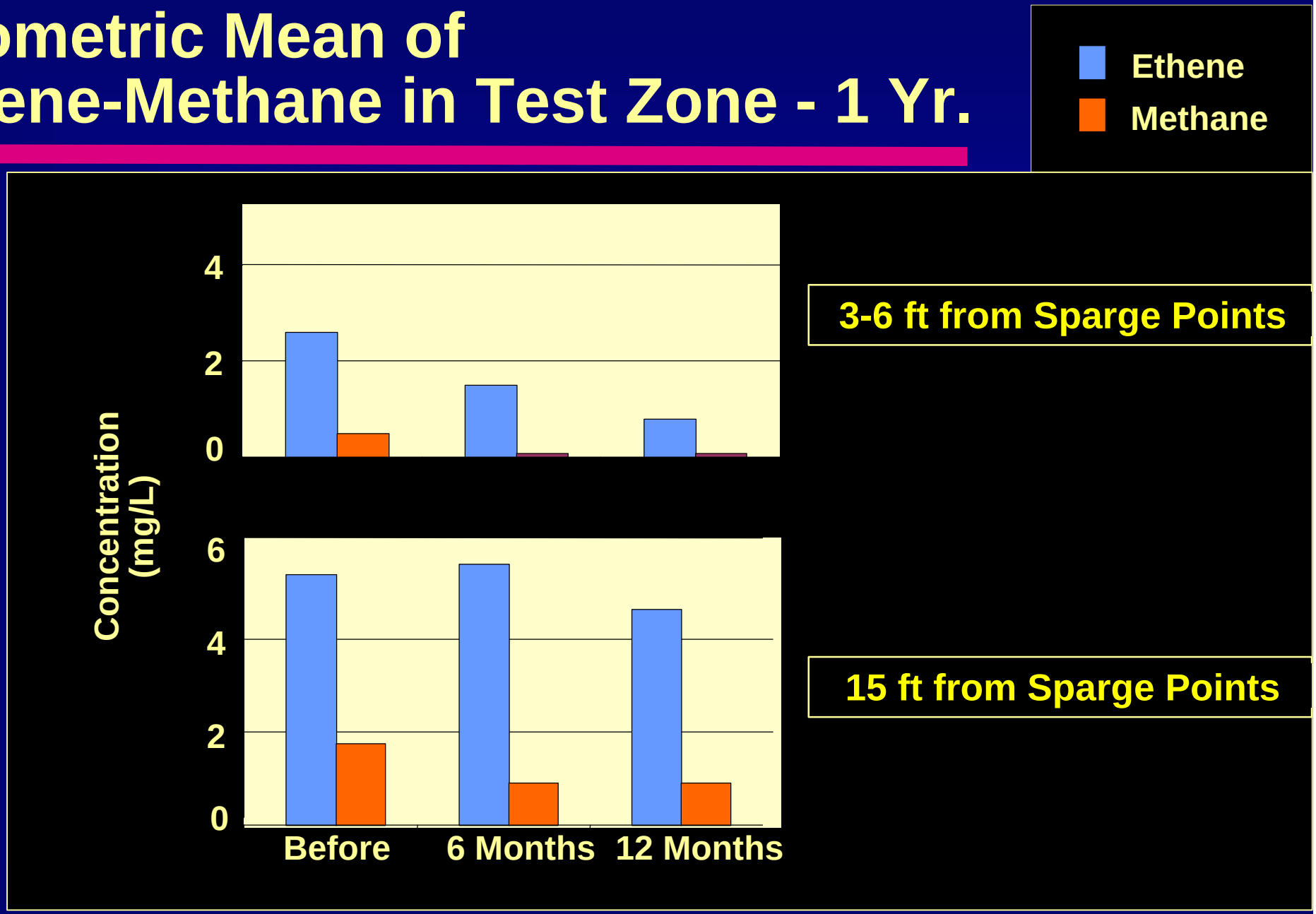
Geometric Mean of Chlorinated Ethenes in Test Zone - 1 Year Data



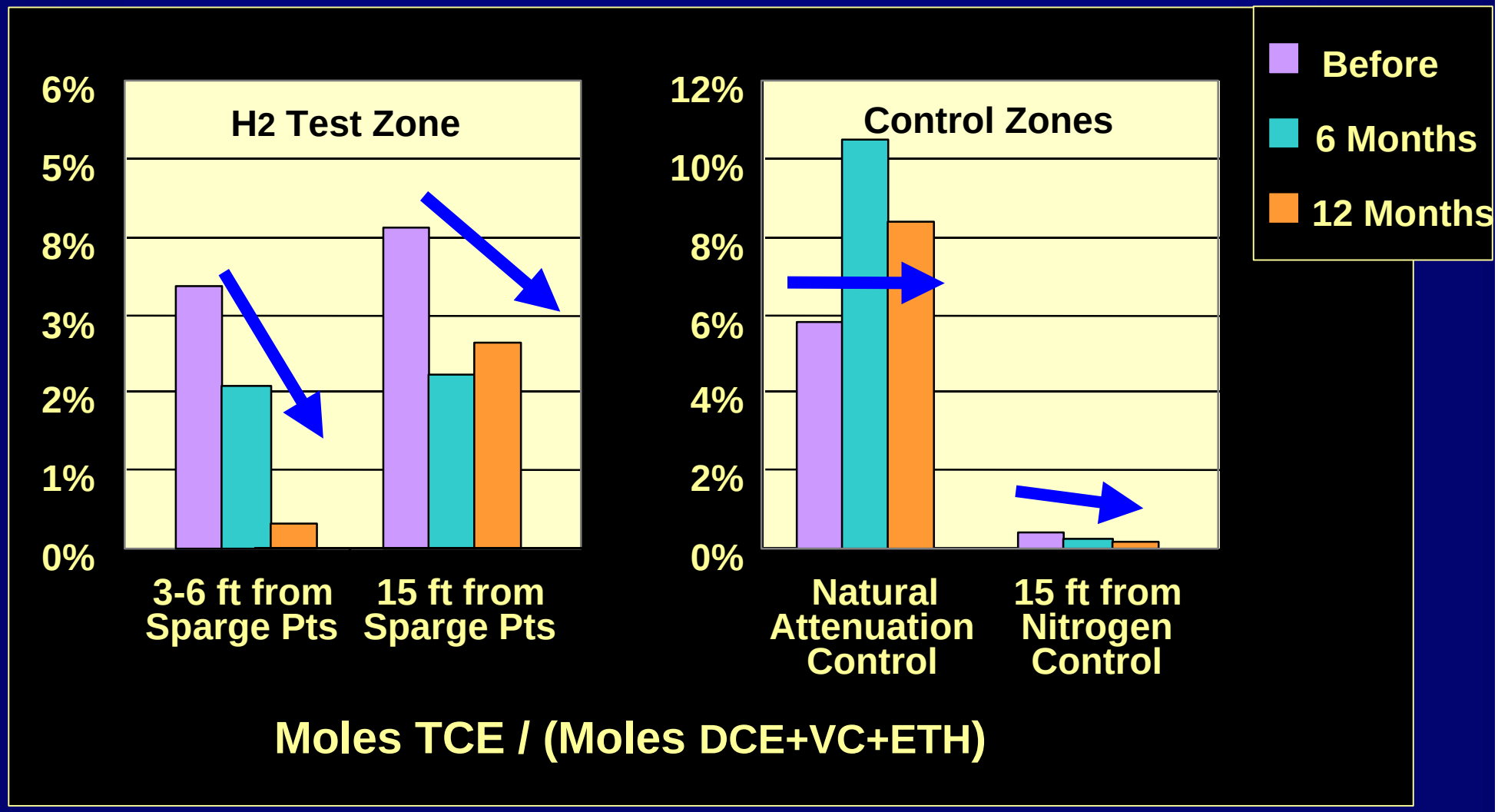
Geometric Mean of Chlorinated Ethenes in Control Zones - 1 Year



Geometric Mean of Ethene-Methane in Test Zone - 1 Yr.



Parent/Daughter Ratio Over Time - 1 Yr



Why No Methane Competition Observed?

- **Volatilized** excess methane?
- **Toxicity** effects from chlorinated solvents?
- Too **cold** (Pietari and Ferguson, 1999)?
- Dechlorinators **more competitive** -
  K_S less important than yield?

CONCLUSION:

"Slow Burn" hypothesis not applicable at this site.

Cape Canaveral Hydrogen Biosparge

CONCLUSIONS

- Tracers show biological consumption of hydrogen
- Significant reduction in TCE, DCE, VC over 1 year
- P/D ratios indicates biodegradation, not volatilization
- Methane competition not observed
- Direct radius of influence: 5 - 10 ft; indirect 15 ft+