Enhanced Bioremediation Field Experience: Using Observed Half Lives in Design and Prediction

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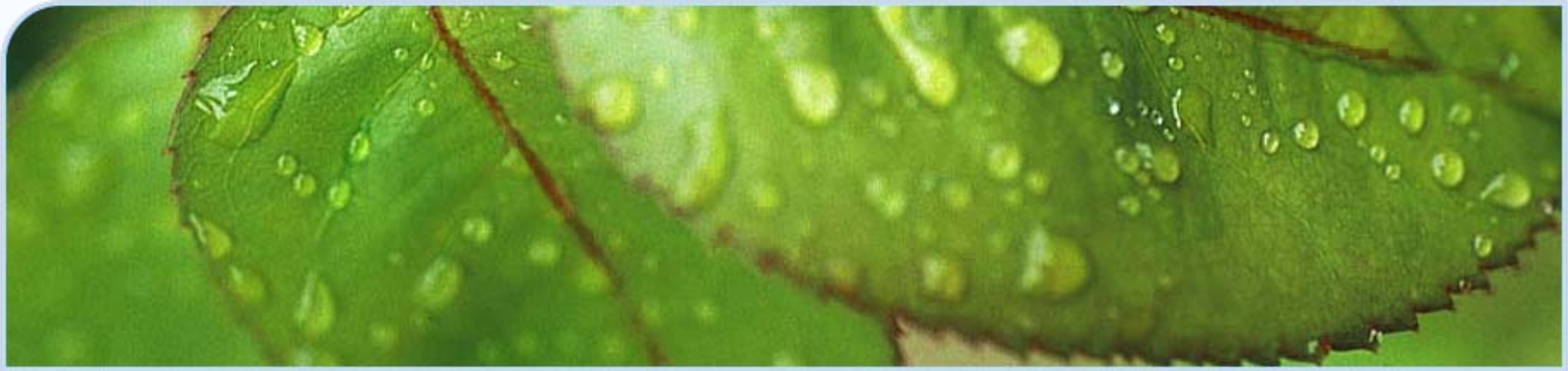
ADVENTUS

Proven Remediation Technologies for Soil, Sediment, and Groundwater



Questions

- What treatment results do we expect?
- How can we use lab and field data for realistic design and prediction?

Outline of Presentation

- Lab Half Lives
- Field Half Lives
- Half Life Trends over Time
- Comparison between Lab and Field Data
- Extrapolation of Data to Design
- Use of Data in Prediction of Cleanup Time
- Conclusions
- Future Work

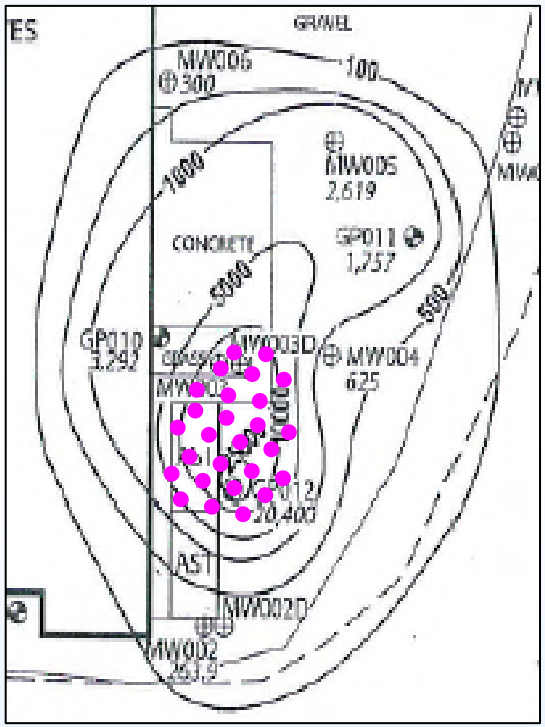
Substrate Composition

EHC is composed of:

- Controlled-release, food grade, complex carbon
- Micro-scale zero valent iron (5 - 10 µm)
- Major, minor, and micronutrients
- Food grade organic binding agent

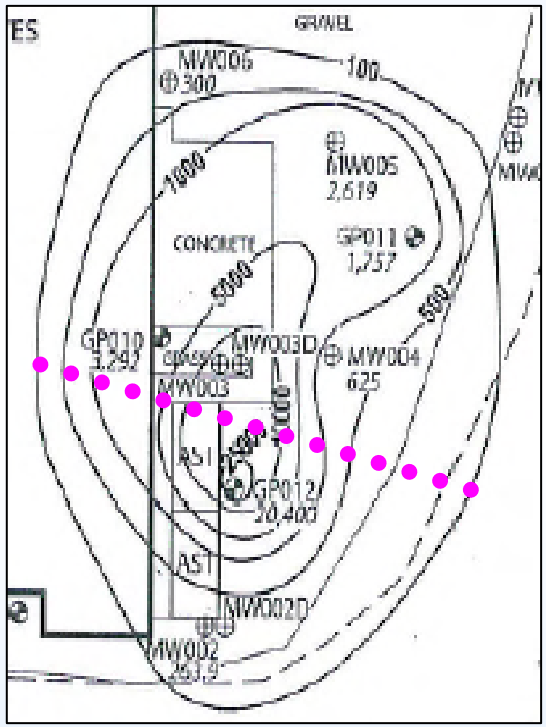
EHC Conceptual Designs

Source Area/ Hotspot Treatment



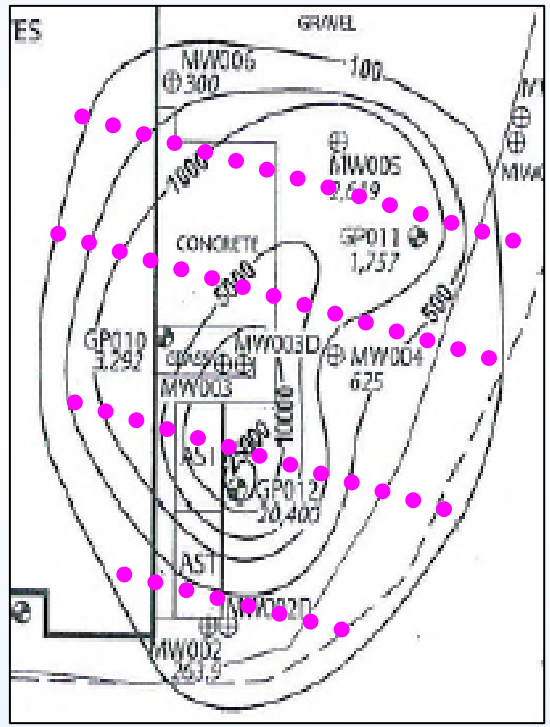
- Dosing: 0.15 to 1% wt/wt
- Spacing: 5 to 15 ft (DPT)

Injection PRB for Plume Control



- Dosing: 0.4 to 1% wt/wt
- Spacing: 5 to 10 ft (DPT)

Plume Treatment



- Dosing: 0.05 to 0.2% wt/wt
- Line Spacing: 100 ft / 1 year gw travel distance

Laboratory Column Approach

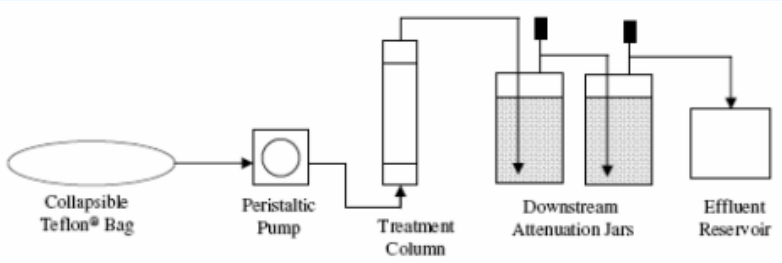


Figure 1. Schematic of EHC treatment column apparatus.

Photograph 1. EHC treatment columns with downstream attenuation jars.

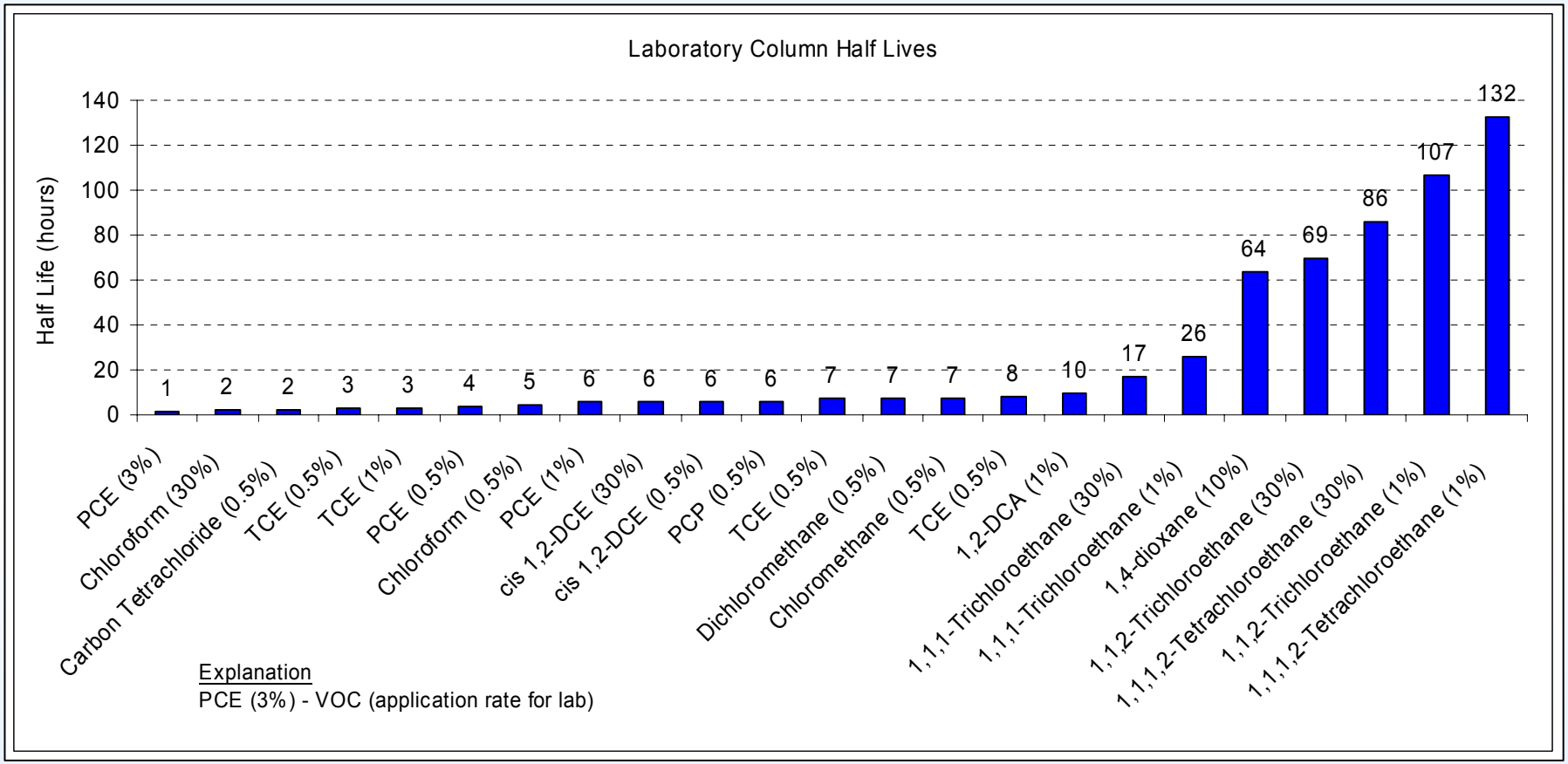
Column test results analyzed using 1D equation (first order decay), appropriate for anaerobic biodegradation of VOCs in aquifers (Alvarez and Illman, 2006) and abiotic degradation with ZVI (Gillham and O'Hannesin, 1994) :

$$C = C_0 e^{-kt}$$

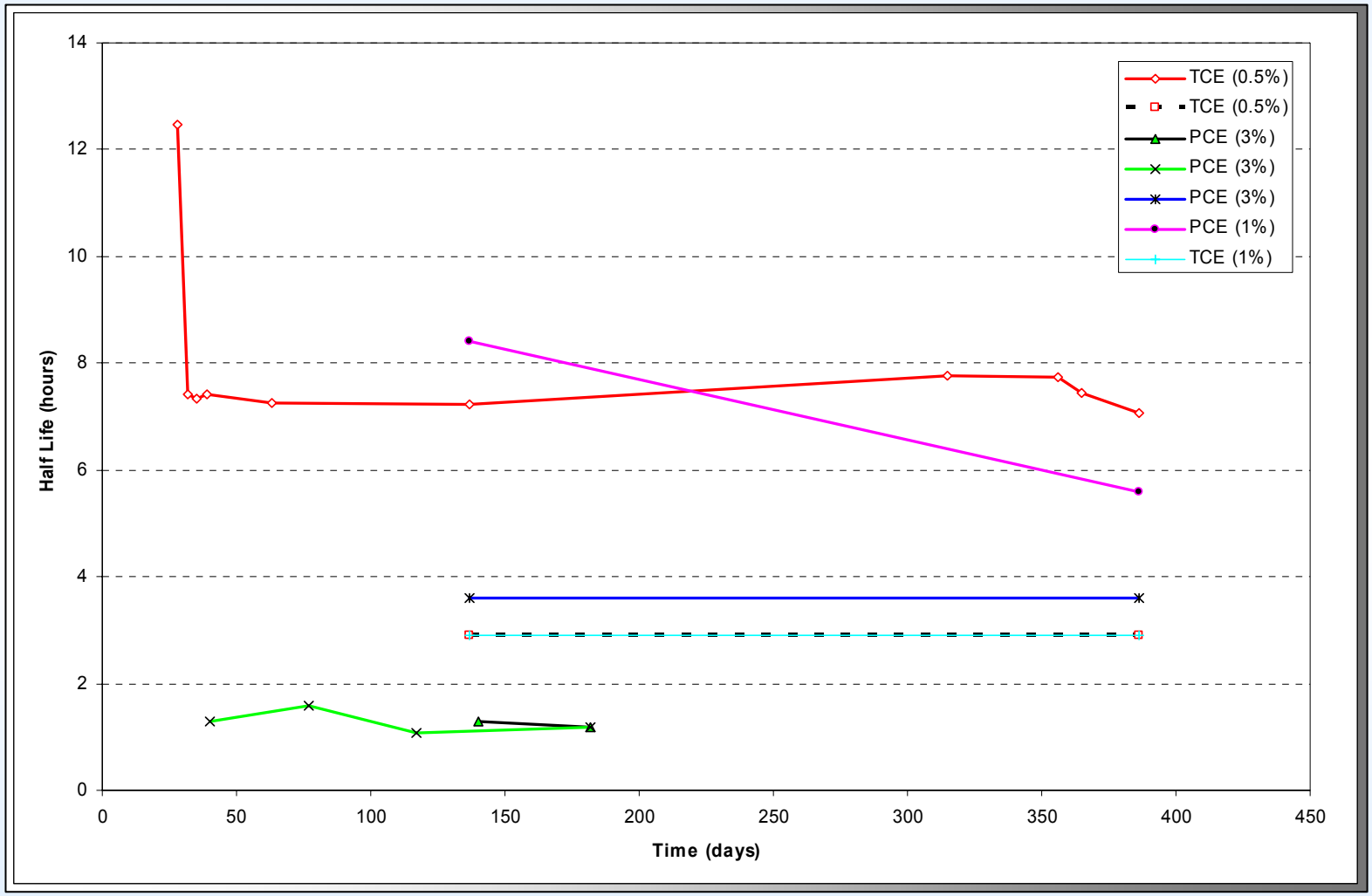
Where:

t = residence time [T]
C = effluent concentration [M/L^3]
C_0 = inflowing concentration [M/ L^3]
k = decay constant [1/T]

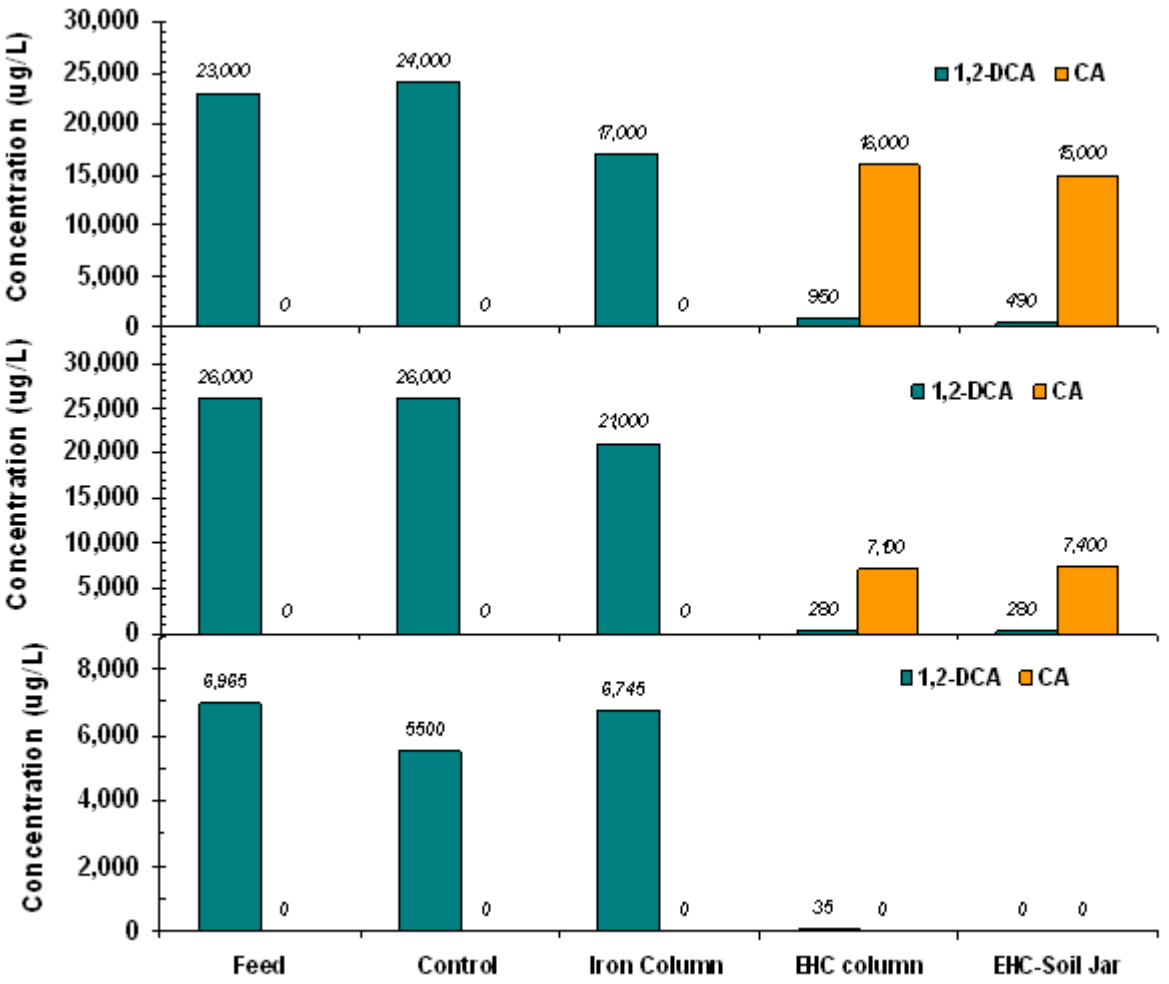
Laboratory Column Half Lives



Laboratory Column Half Lives vs. Time



Degradation Kinetics and Yield Rates



35 days

1,2-DCA CA
100%(mol)

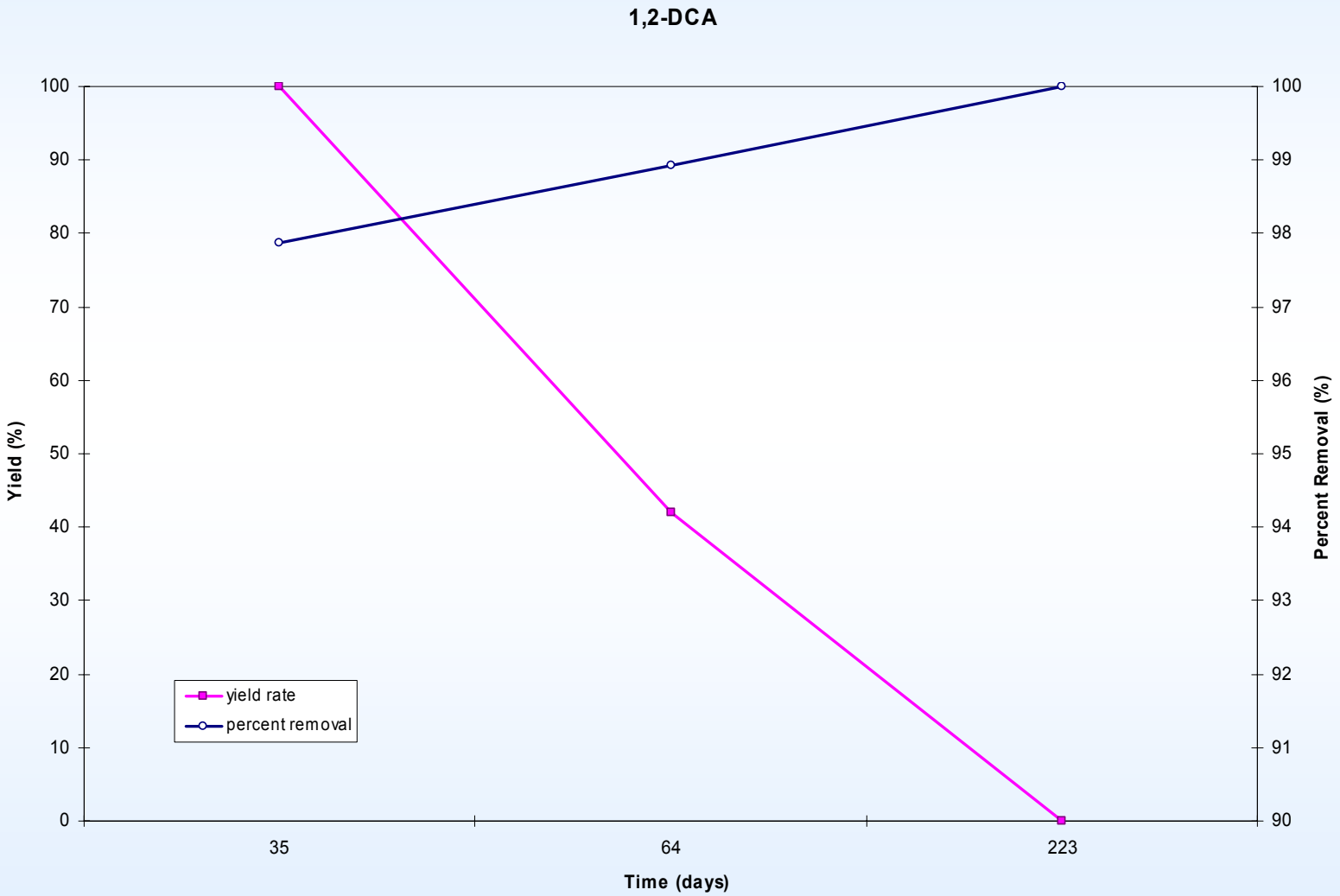
64 days

1,2-DCA CA
42%(mol)

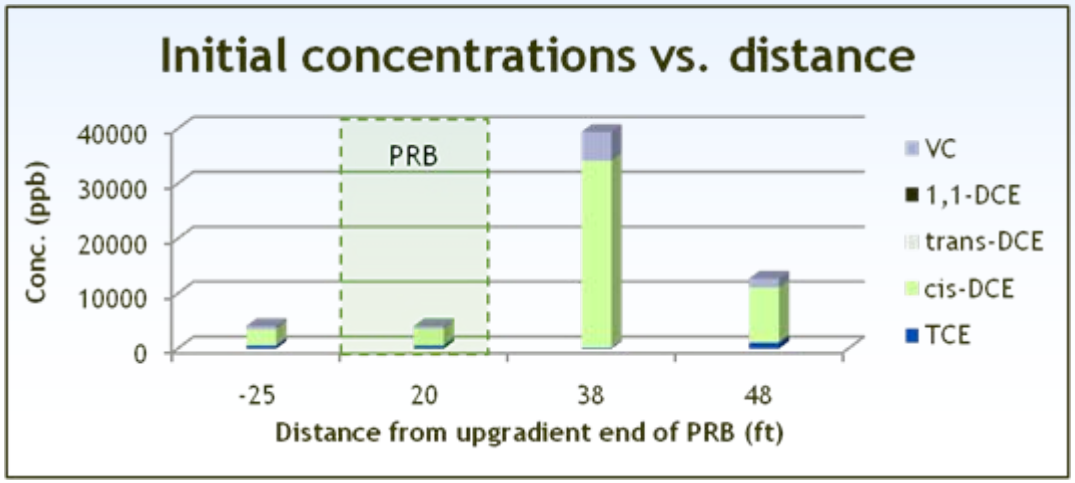
223 days

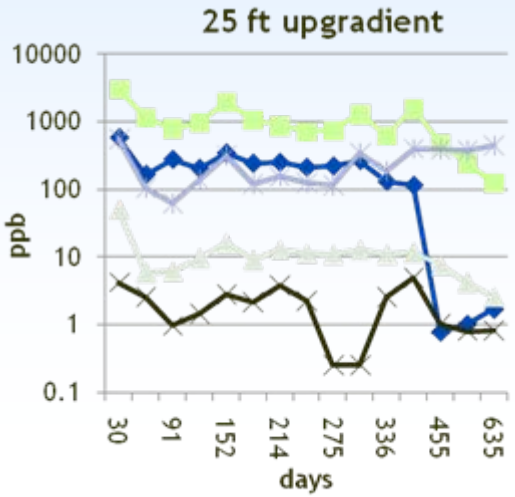
1,2-DCA CA
0%

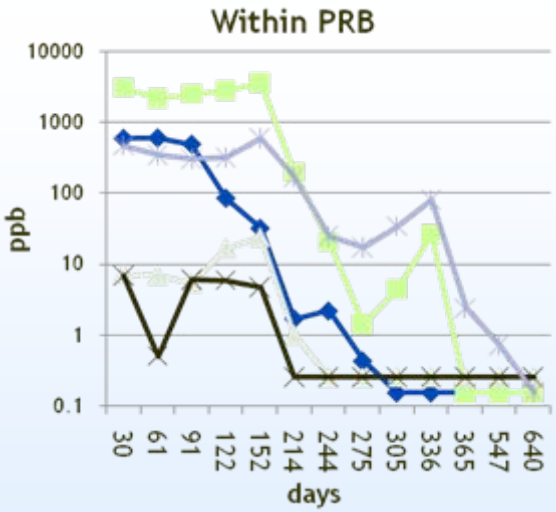
Degradation Kinetics and Yield Rates

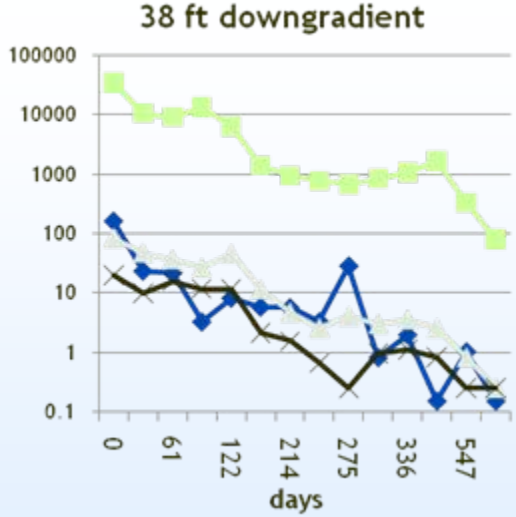


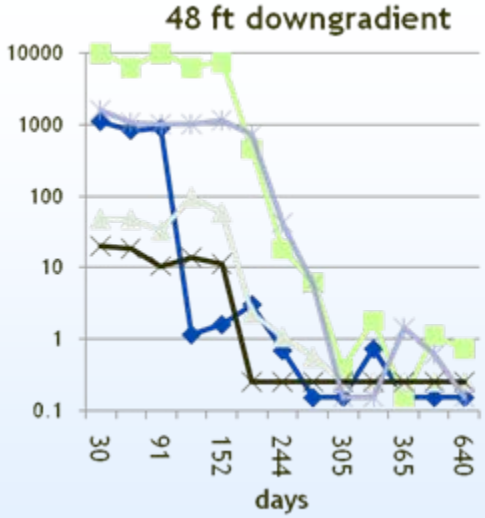
Example Field Data

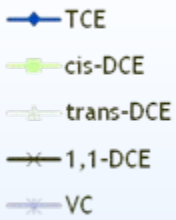












Analytical Assessment of Field Data
– Evaluating Degradation Rates along the Flow Path

- Data collected at multiple points up and downgradient of the PRB analyzed using Buschek and Alcantar relationship (Buschek and Alcantar, 1995), as modified by Carey and Wiedemeier (2000):

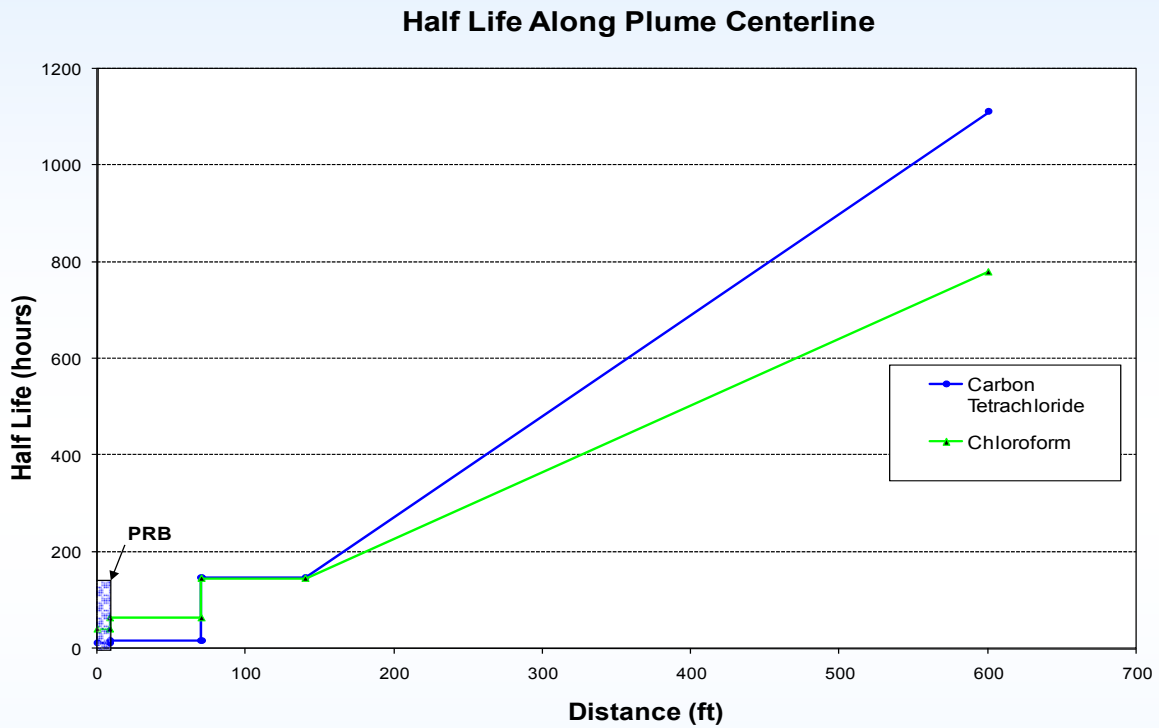
$$\lambda = v/(4\alpha_x R)*((1-2\ \alpha_x m)^2 - 1)$$

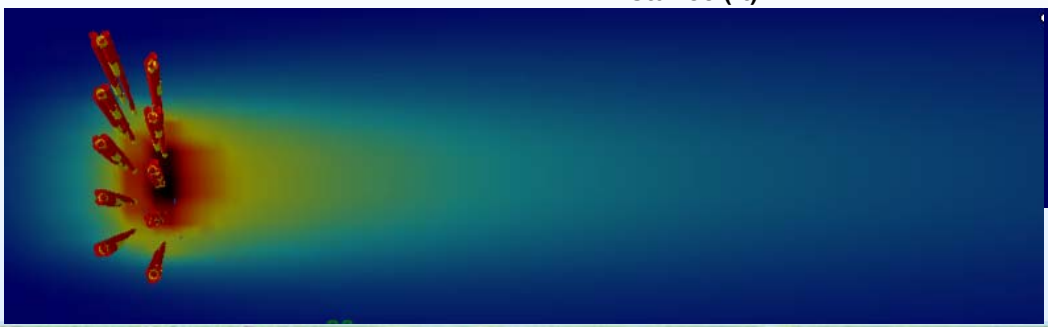
Where:

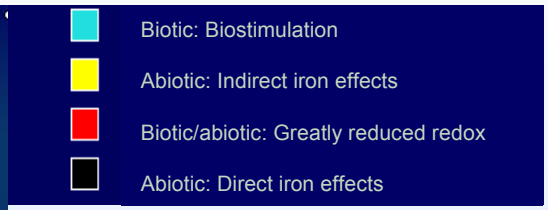
- λ = decay constant [1/T]
- v = average linear groundwater velocity [L/T]
- α_x = hydrodynamic dispersion coefficient along flow path [L]
- R = retardation factor [1]
- m = slope of ln-linear concentration versus distance [1/L]

- This approach analyses 1D, steady-state sorbed & dissolved phase biodegradation & dispersion, but results in conservative (high) estimates of half life because no daughter-production assumed. Desorption and transient effects not considered.

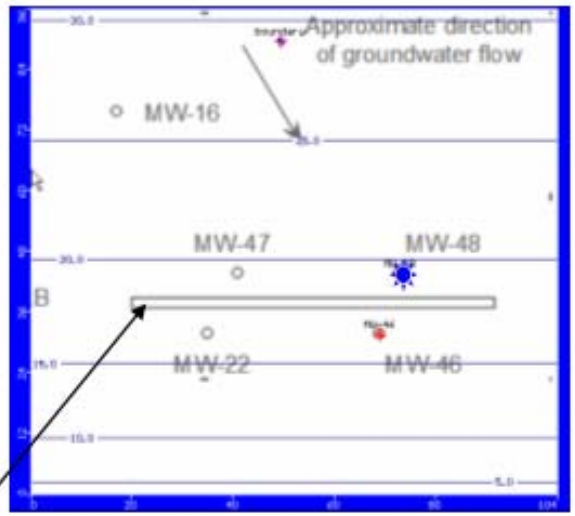
Analytical Assessment of Field Data vs. Distance



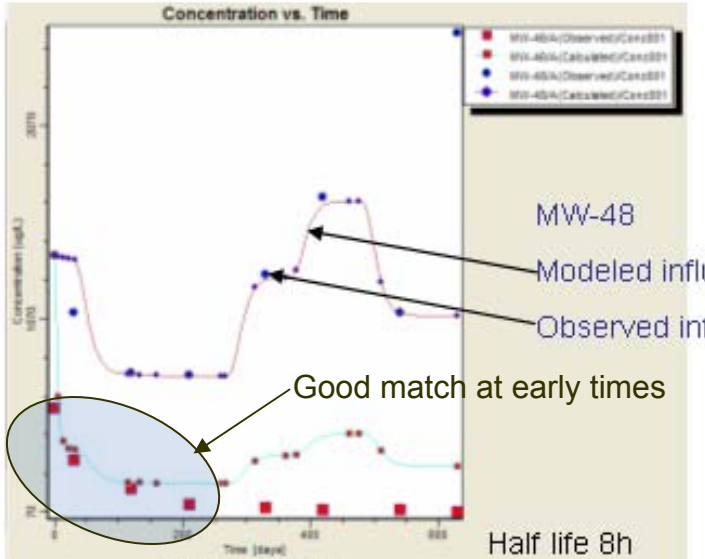


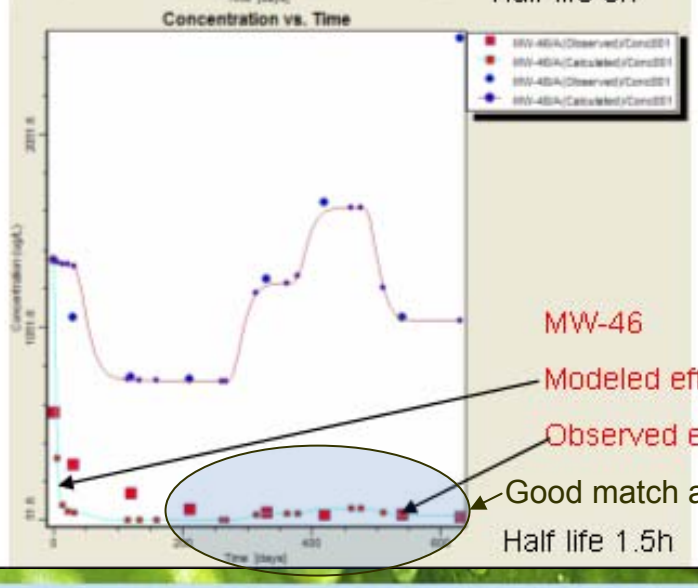


Modeling Assessment of Field Data (Ethenes)

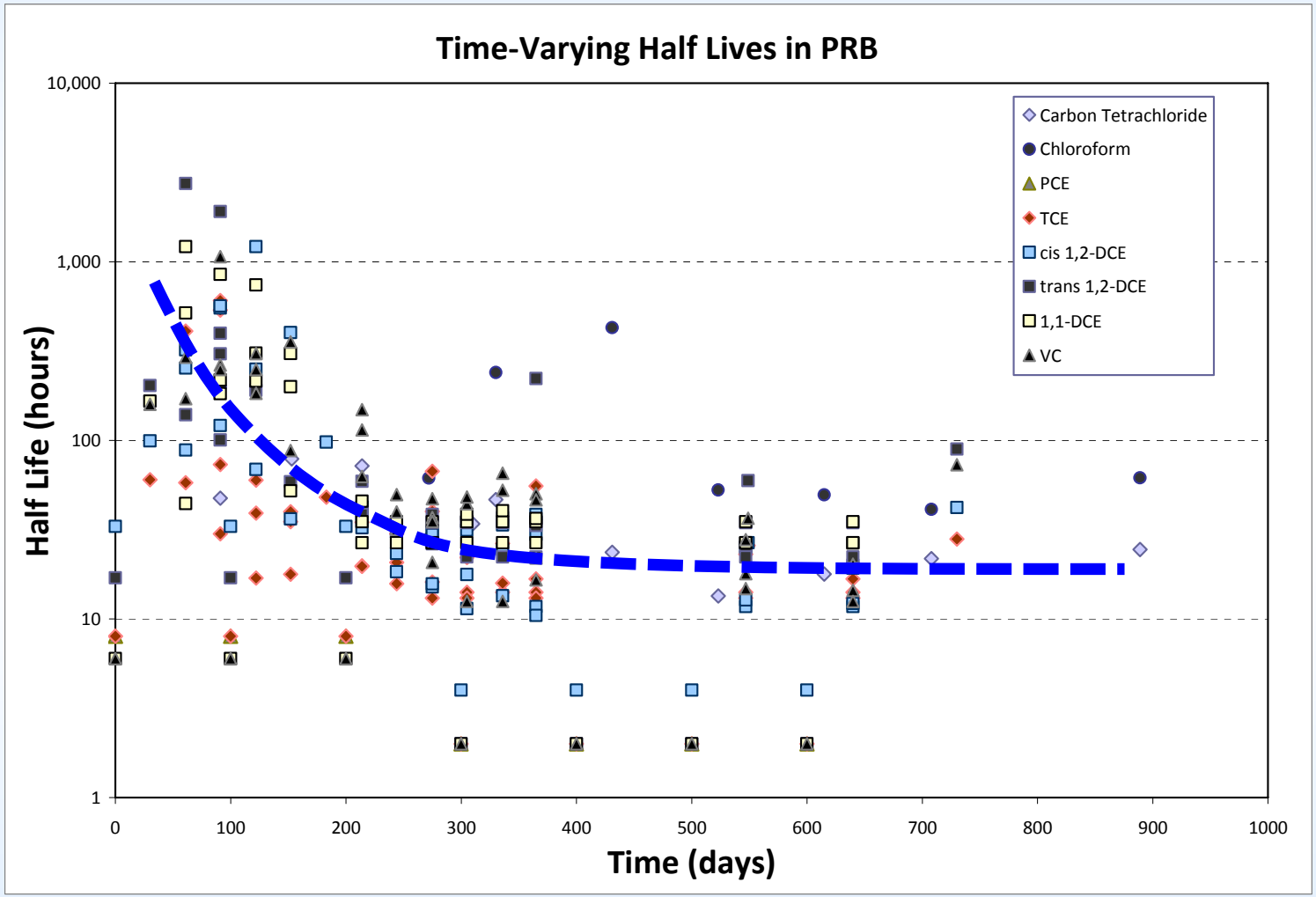


Half life (1.5 or 8.h) based on lab data

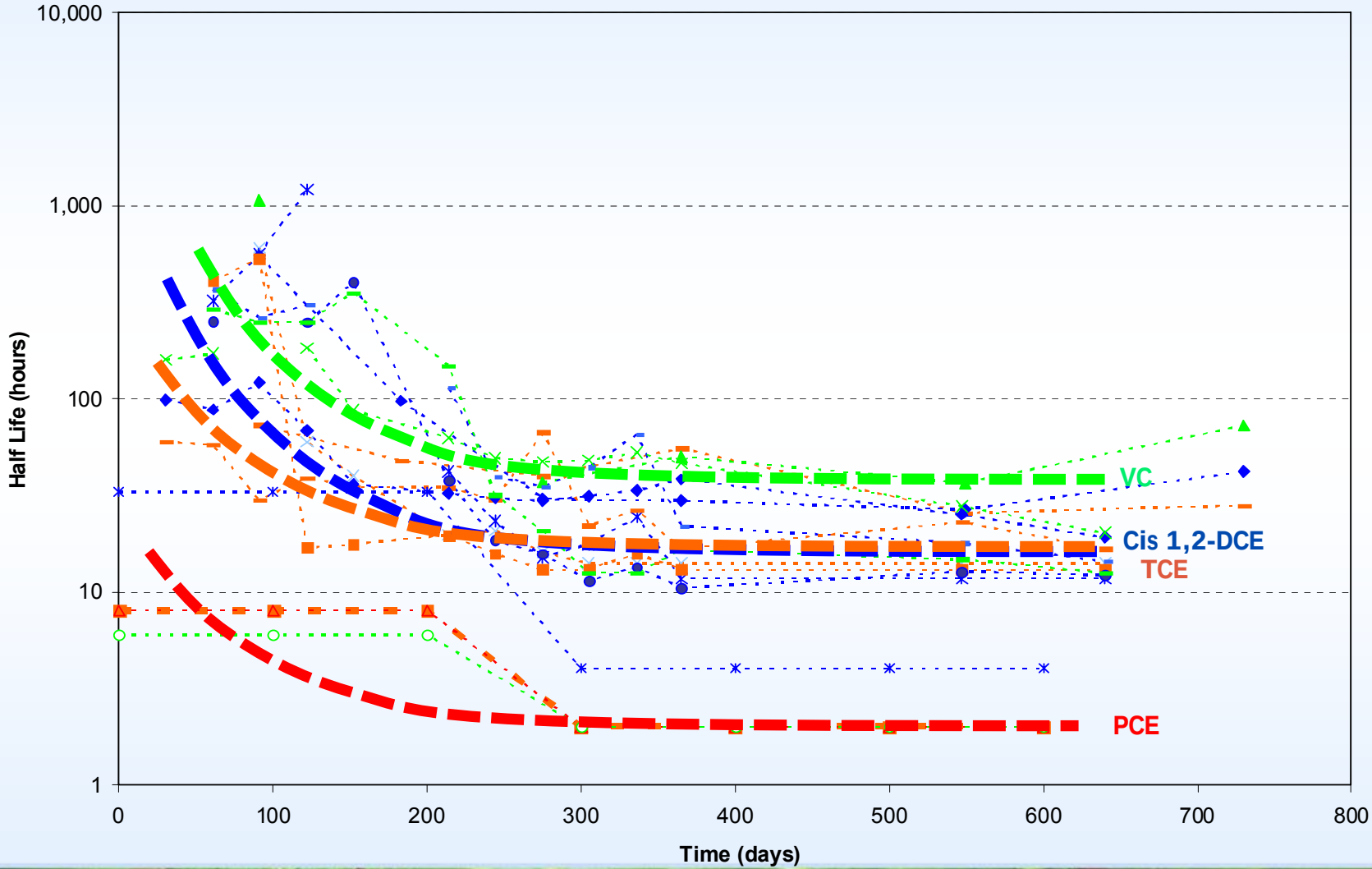




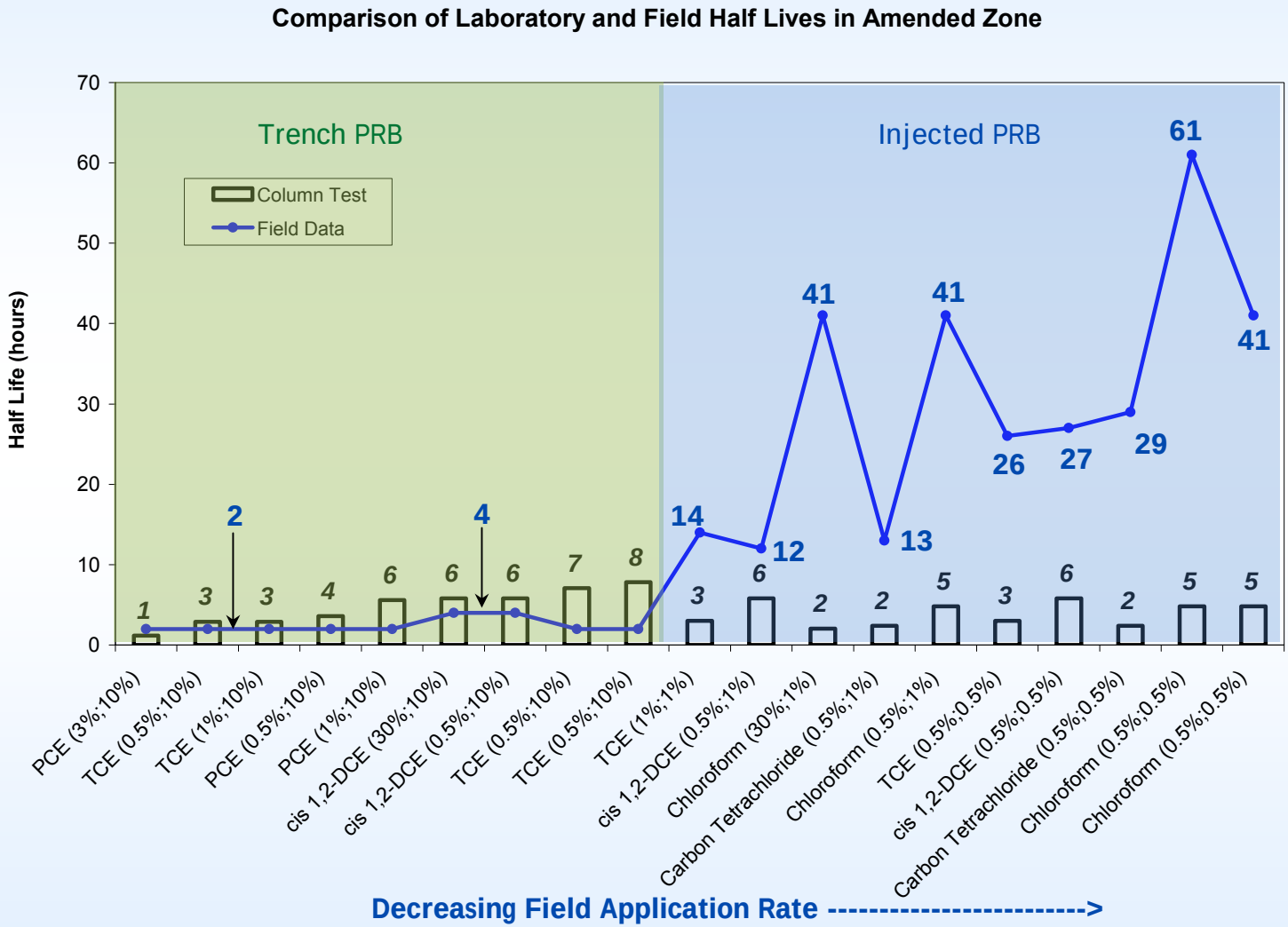
Field Data vs. Time



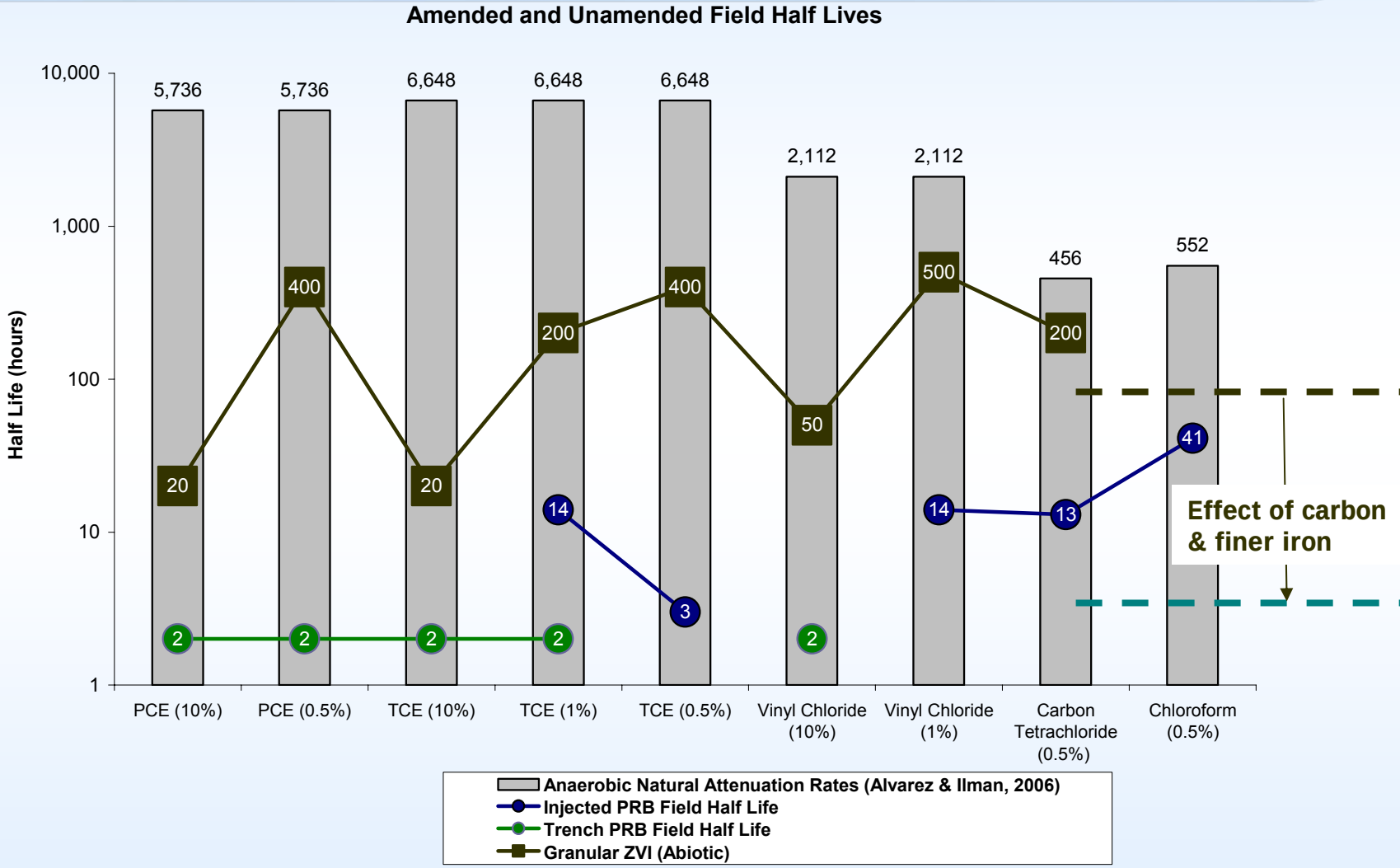
Field Data vs. Time – Ethenes



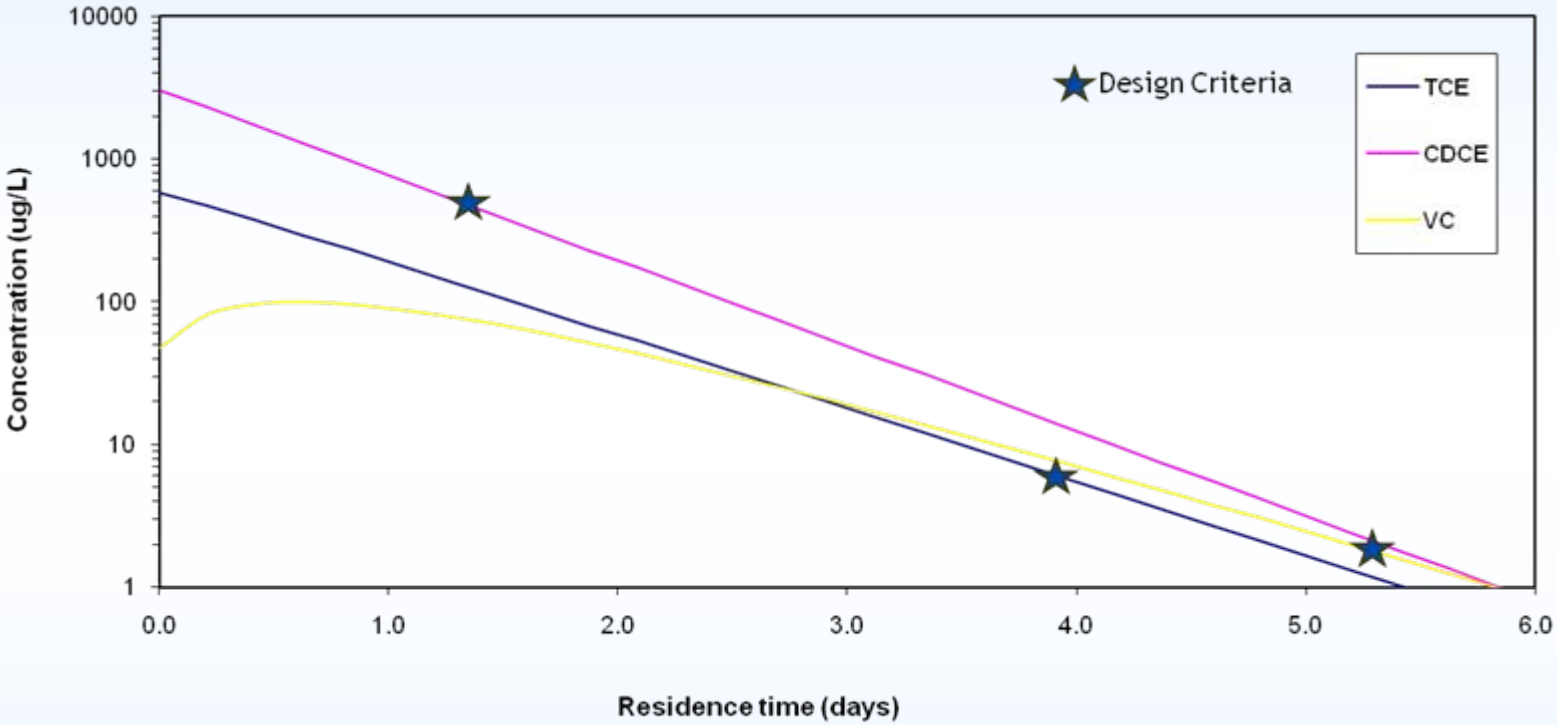
Lab and Field Half Lives vs. Application Rate & Method



Comparison of Amended and Unamended Half Lives

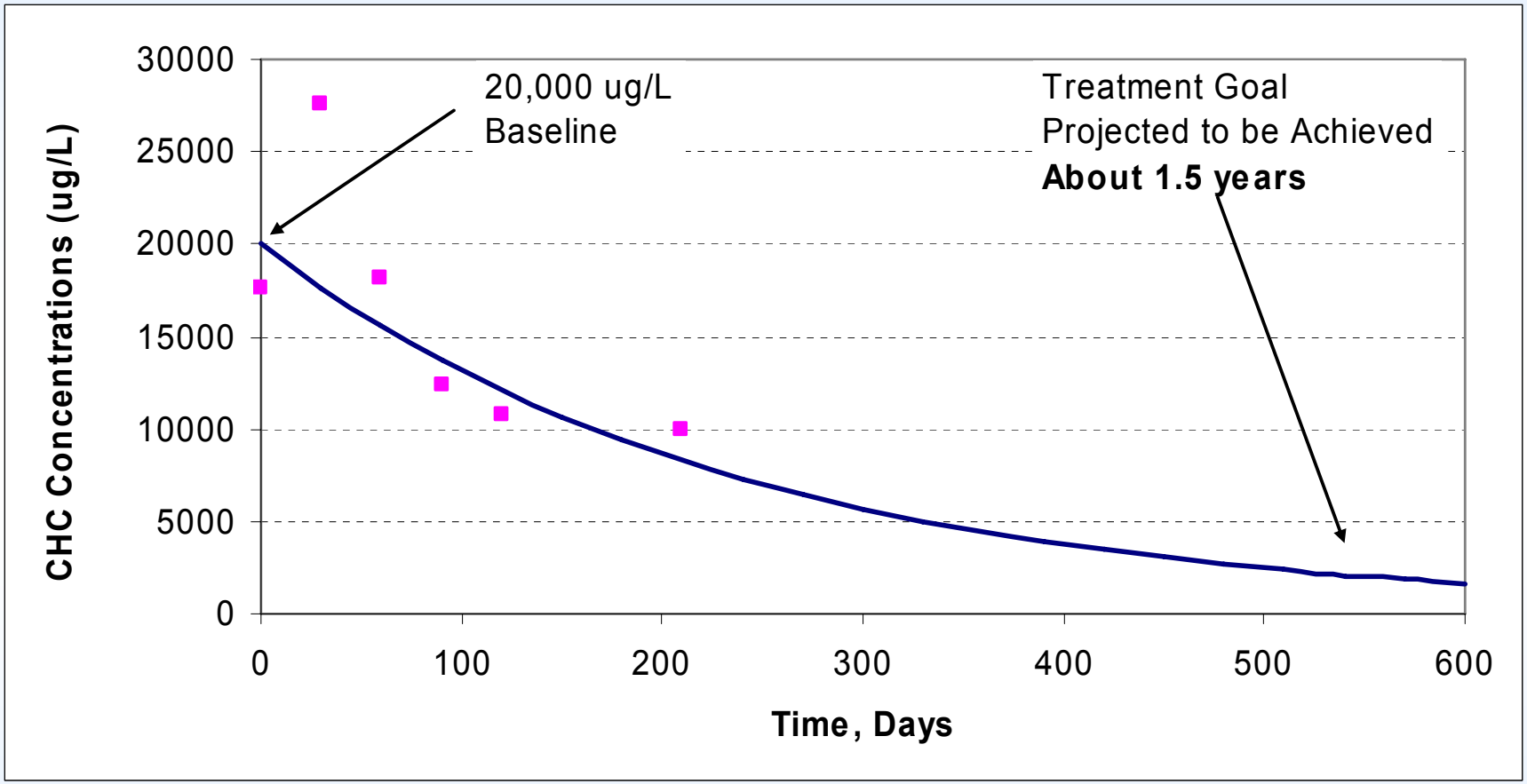


PRB Design Based on Half Lives - Residence Time Requirement



- Residence requirements – ca 5.5 days
- Linear groundwater velocity – 4 ft/day
- Treatment zone width – 5.5 days * 4 ft/day = 22 ft

Extrapolation of Field Data to Calculate Time to Reach Remedial Goal (NAPL Affected Source Area)



Considering source feed and degradation
Net half life ~ 160 days

Model Prediction of Plume Cleanup (Carbon Tetrachloride and Daughters)

- Plume extends 800 m from grain elevators.
- Discharges into small creek.
- Bedrock rises to an elevation of ~ 3 m above present day water table at presumed source area.
- PRB installed down-gradient of suspected source area.
- PRB installed as a line of injection points spaced ~ 3 m apart.
- PRB extends across width of the plume and measures ~ 90 m long.

Model Prediction of Plume Cleanup (Carbon Tetrachloride and Daughters)

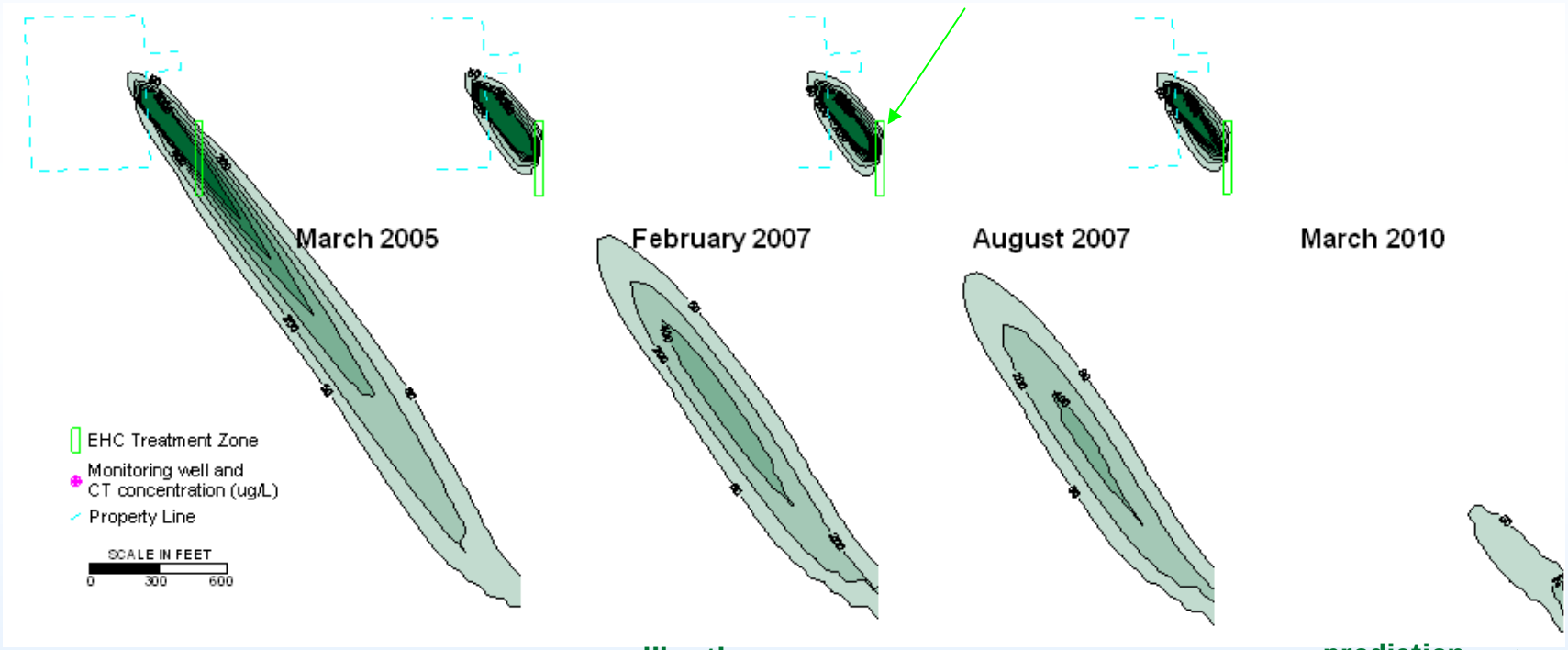
Calibrated half lives:
carbon tetrachloride: 7 hours
chloroform: 20 hours

Model calibrated ½ life		Analytical half lives
Feb 07		
RMS(ug/L)	105.7	94.45
NRMS	17.35%	15.5%
Correlation	0.858	0.873
Residual mean (ug/L)	+23	-2.03
Aug 07		
RMS(ug/L)	99.2	130.6
NRMS (%)	16.28%	21.4%
Correlation	0.859	0.765
Residual mean (ug/L)	-5.32	-33.56

Calibrated half lives:
carbon tetrachloride:
13 hours
18 hours
148 hours

Model Prediction of Plume Cleanup (Carbon Tetrachloride and Daughters)

Calibrated half lives:
carbon tetrachloride: 7 hours
chloroform: 20 hours



Conclusions – Factors Affecting Field Decay rates (Using EHC)

- Decay observed 100s of ft downgradient from PRB (multiple decay mechanisms)
- Half lives decrease with time
- Parents decay faster than daughters (but minimal daughter production)
- Half lives decrease with uniformity of application
- Half lives decrease with application rate (to a point)
- Carbon + iron more effective than carbon alone or iron alone
- Database of half lives can be used in design, extrapolation, prediction

Conclusions – Factors Affecting Field Decay rates (other amendments)

- Decay observed 100s of ft downgradient from PRB ~~(multiple decay mechanisms)~~
- Half lives decrease with time
- Parents decay faster than daughters (~~but minimal daughter production~~)
- Half lives decrease with uniformity of application
- Half lives decrease with application rate (to a point)
- ~~Carbon + iron more effective than carbon alone or iron alone~~
- Database of half lives can be used in design, extrapolation, prediction

Future Work

- Effect of the following on effective degradation rates:
  - Desorption and back diffusion
  - pH
  - Eh