Bioremediation of Chlorinated Solvents via Vegetable Oil Injection

Todd H. Wiedemeier
Parsons Engineering Science, Inc.
Denver, Colorado 80290
(303) 831-8100

Introduction

- **Chlorinated Solvents are one of the most Prevalent Contaminants at Department of Defense Bases**
- **One of the Most Promising Remediation Techniques for these Compounds is Bioremediation**
- **Bioremediation is the Focus of this Talk**

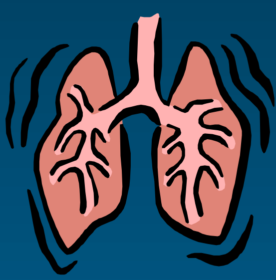
Biological Fate of Organic Contaminants

Two Broad Mechanisms

- **Use as a Primary Growth Substrate**
  - **Growth-Promoting Biological Oxidation (Electron Donor)**
  - **Growth-Promoting Biological Reduction - Halorespiration (Electron Acceptor)**
  - **Fermentation**
- **Cometabolism**

Use as Primary Growth Substrate

+



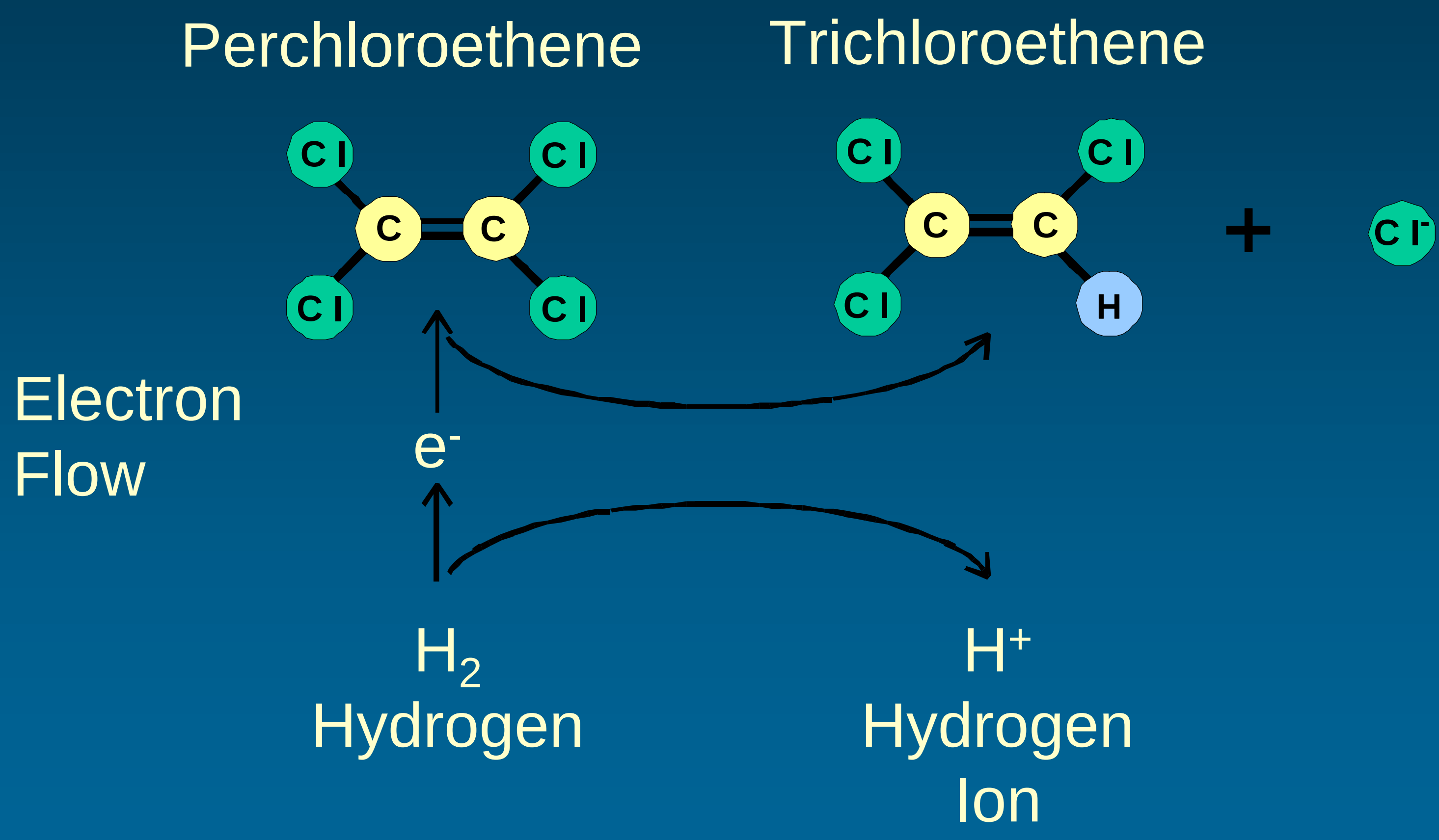
+

Electron Donor (food) + Electron Acceptor (something to breath) [O_2, NO_3^-, SO_4^{2-}, Fe(III), CO_2, Solvents] → Metabolic Byproducts [Fe(II), CH_4] + Energy

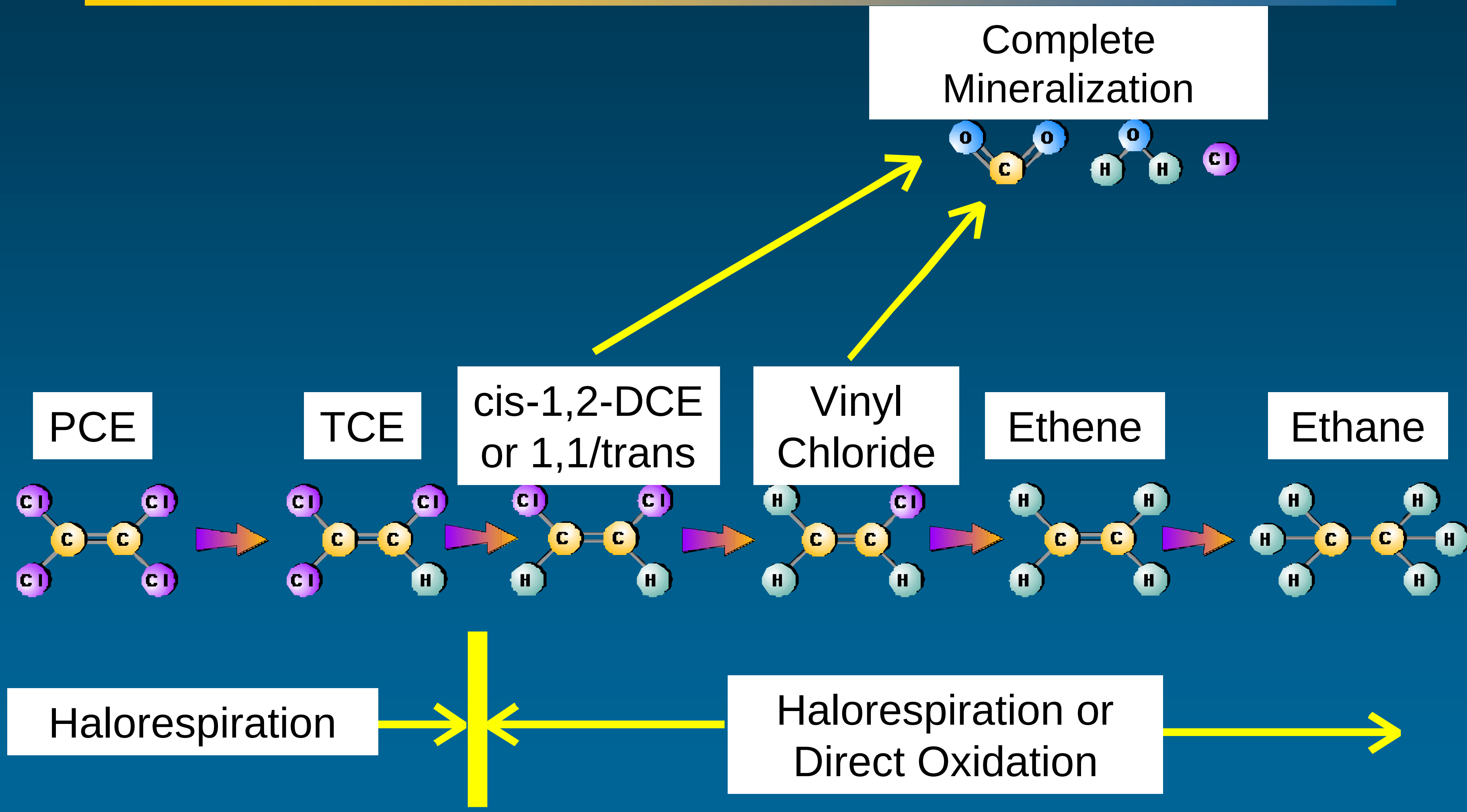
Reductive Dechlorination - Halorespiration

- **Reductive Dechlorination is the Only Biological Mechanism Known to Degrade the Common Chlorinated Solvents (PCE, TCE, TCA, and CT) in Most Groundwater Systems**

Reductive Dechlorination



Chlorinated Ethene Degradation



Requirements for Reductive Dechlorination

- **Halorespiring Bacteria**
- **Electron Donor (for Carbon and Hydrogen)**
- **Strongly Reducing Conditions (Sulfate Reducing or Methanogenic)**
- **Hydrogen Concentrations > 1 nM**

Engineered Bioremediation of Chlorinated Solvents

- **The Limiting Factor at Many Sites Contaminated with Chlorinated Solvents is the Lack of Suitable Electron Donors**
- **i.e., Lack of Hydrogen**

Engineered Bioremediation of Chlorinated Solvents

- **Many Types of Organic Substrate Have Been Added to Groundwater to Stimulate Biodegradation of Solvents Including:**
  - **Propionate**
  - **Lactate**
  - **Butyrate**
  - **Molasses**
  - **Hydrogen Releasing Compound®**
  - **Hydrogen (“Hindenberg Experiment”)**

Engineered Bioremediation of Chlorinated Solvents

- **All of These Materials are Added to Stimulate the Production of Hydrogen for Reductive Dechlorination**
- **All are Soluble to Some Extent in Water and Many are Miscible**
- **This Means Continuous Injection or at a Minimum, Multiple Injections (With the Exception of HRC®)**

Engineered Bioremediation of Chlorinated Solvents

- **Involves Injection of Food-Grade Vegetable Oil Which is Only Slightly Soluble in Groundwater (~1,000ppm)**
- **Costs $0.20 to $0.50/pound**
- **Should Allow a One-Time Injection Scenario – Big Benefit/Cost Savings**
- **Soybean Oil is Being Tested at Six Sites in FL, UT, CA, and TN**

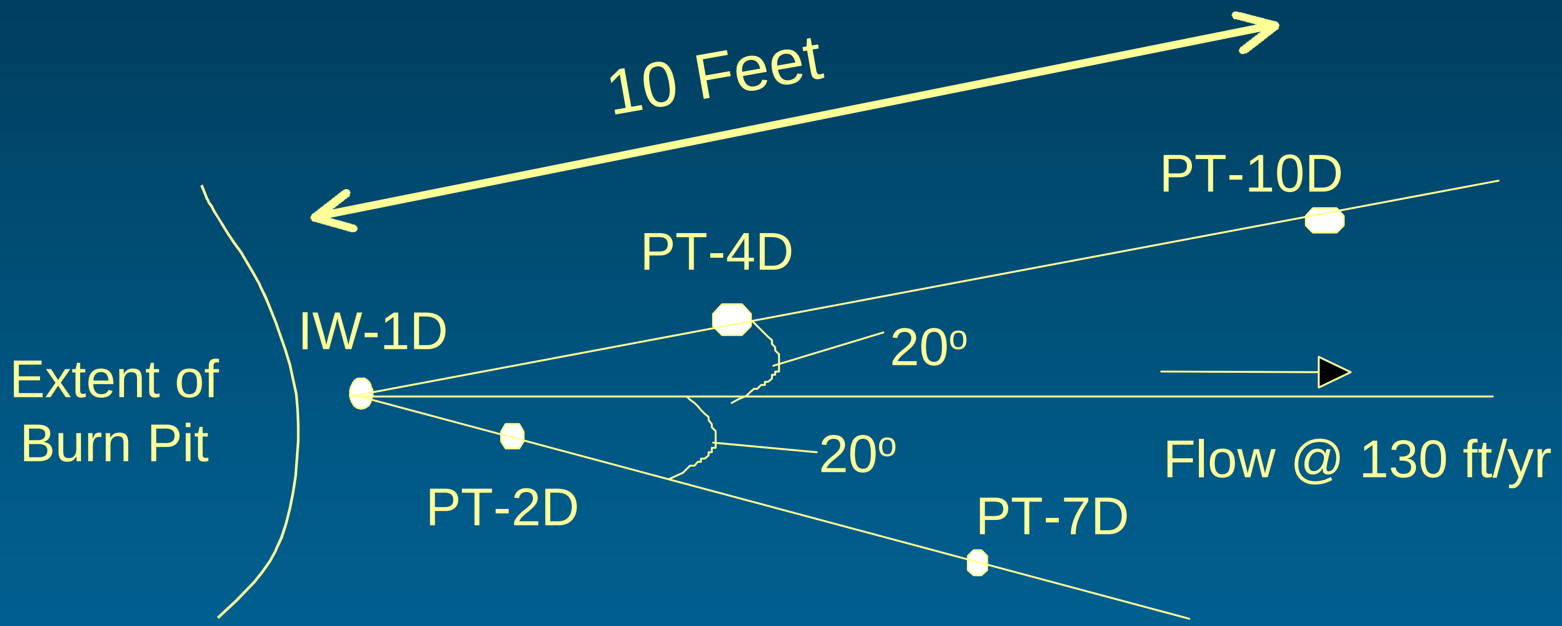
Defense Depot Hill Utah

- **Former Burn Pit**
- **Coarse Sand – Seepage Velocity 130 ft/year**
- **Water Table at 10 feet**
- **One Foot Injection Interval From 22-23 ft bgs**
- **Monitoring Wells Screened From 21-23 ft bgs**

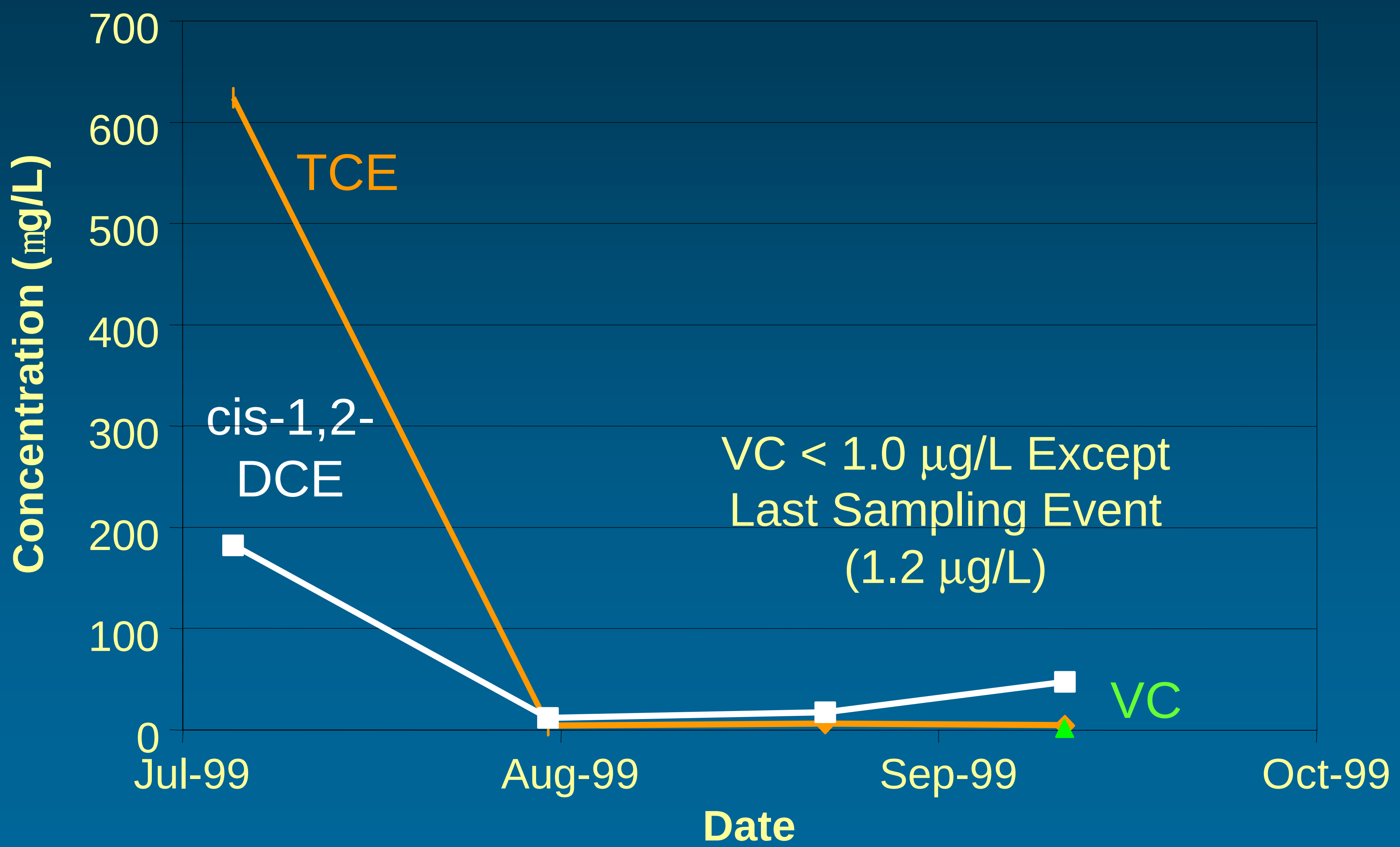
Defense Depot Hill Utah

- **Oil Injected June 30, 1999 and Monitored Until End of September**
- **185 Gallons of Oil Injected at 8psi**
- **Oil was Then Removed until no Oil Remained in the Well - 40 Gallons of Oil Recovered**
- **Very Easy to Inject**

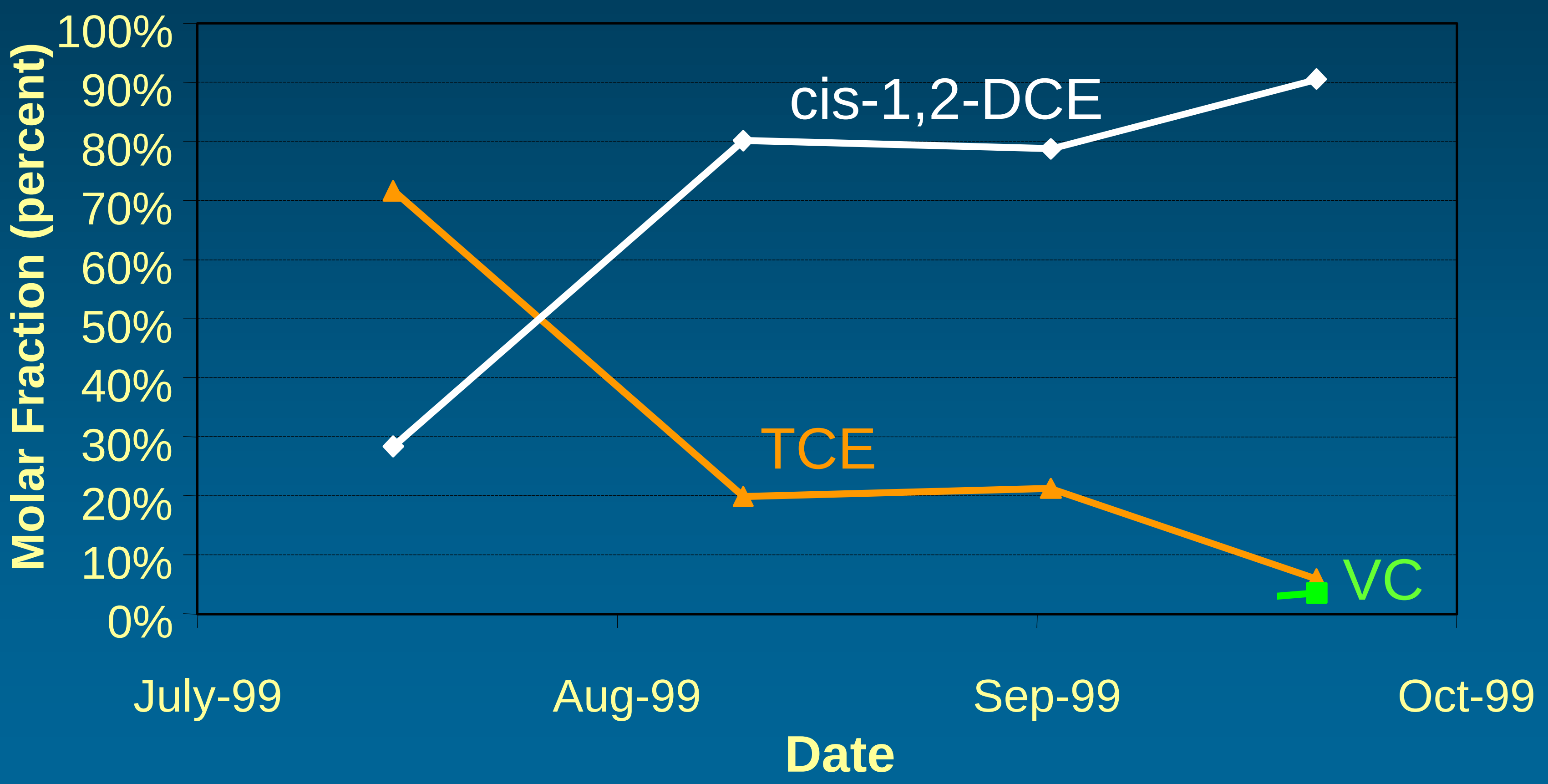
DDHU Site


10 Feet
PT-10D
PT-4D
IW-1D
20o
Extent of
Burn Pit
20o
Flow @ 130 ft/yr
PT-2D
PT-7D

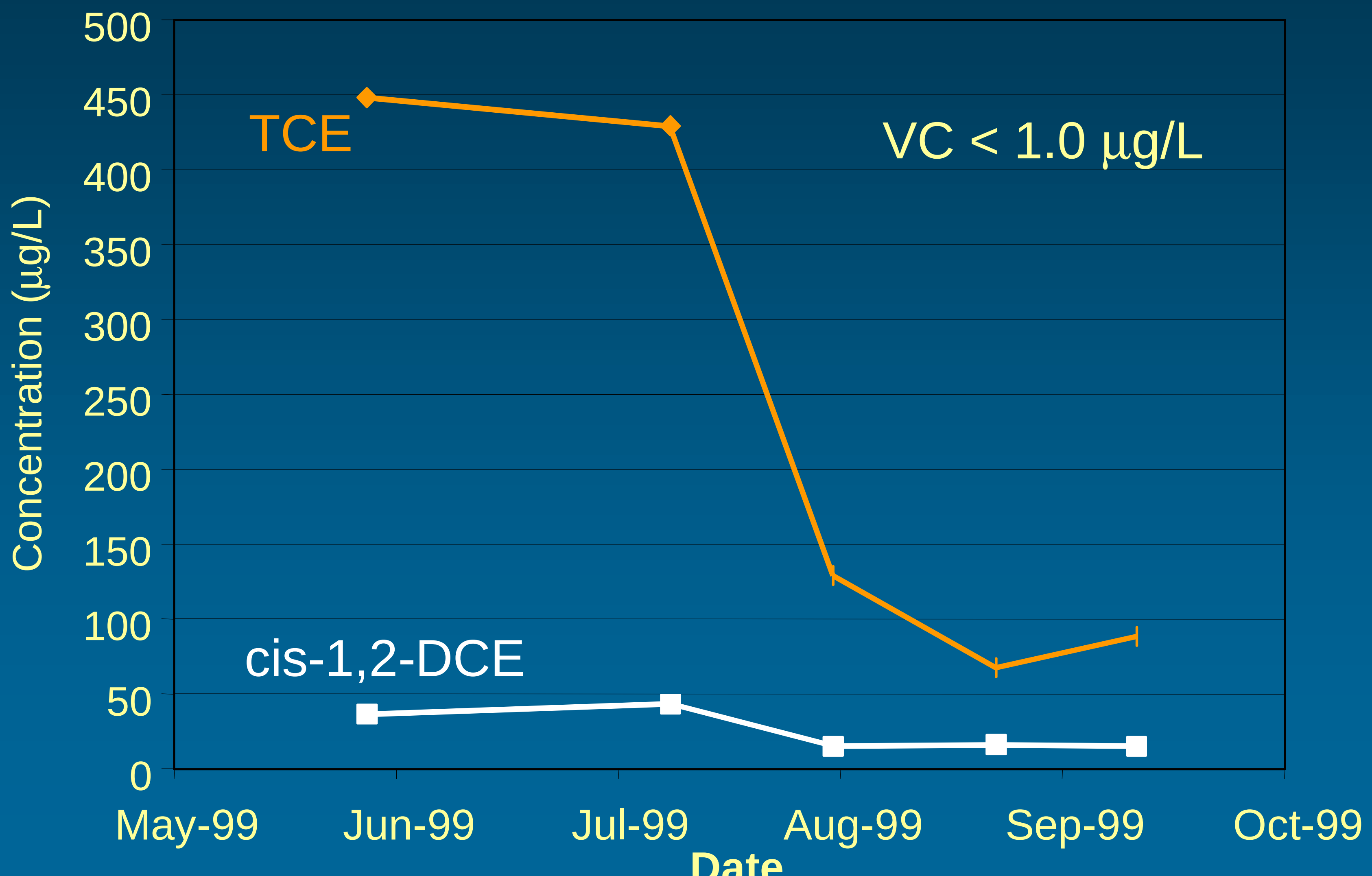
Chlorinated Ethene Concentrations – IW-D



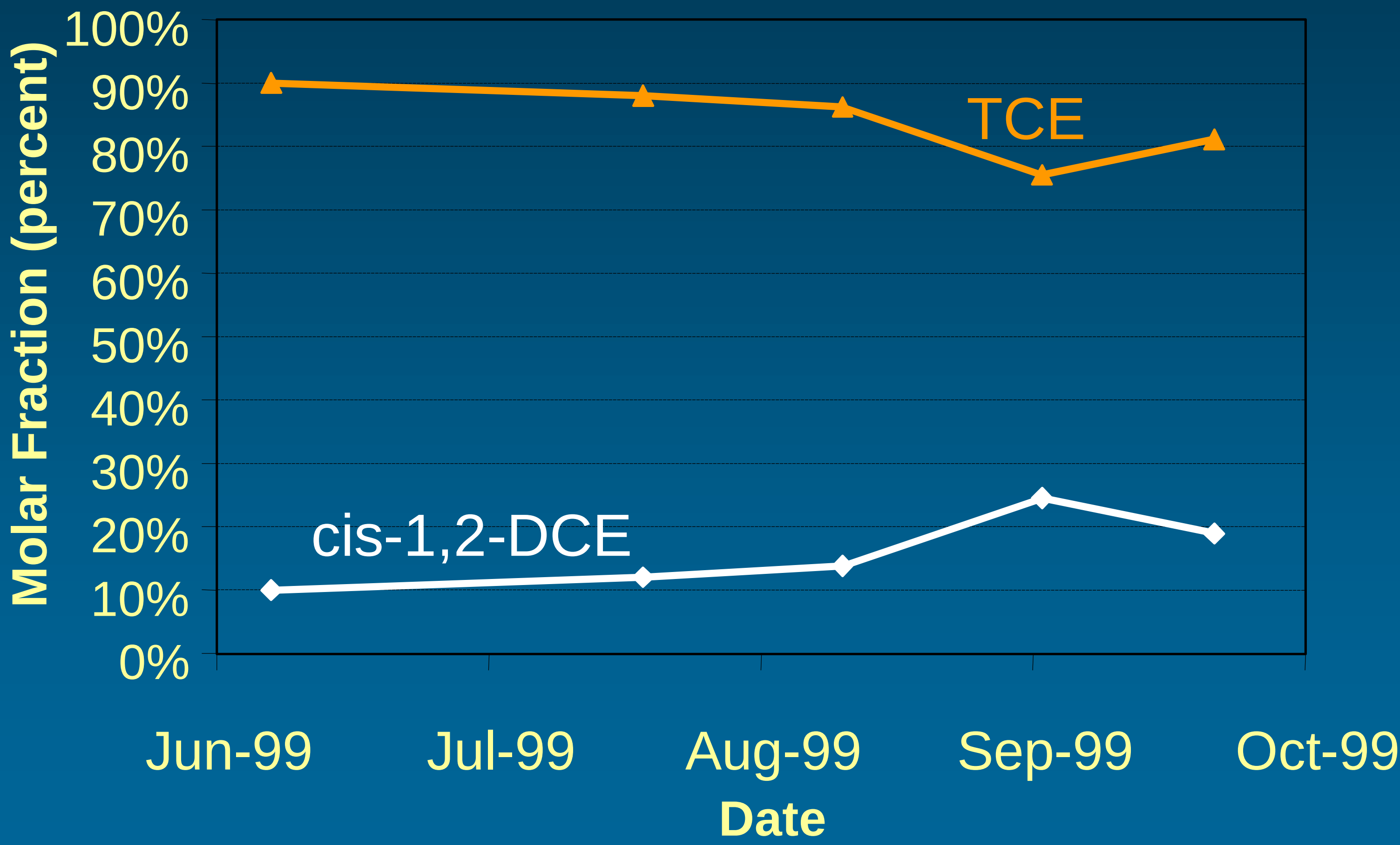
Molar Fraction of Chlorinated Ethenes – Well IW-D



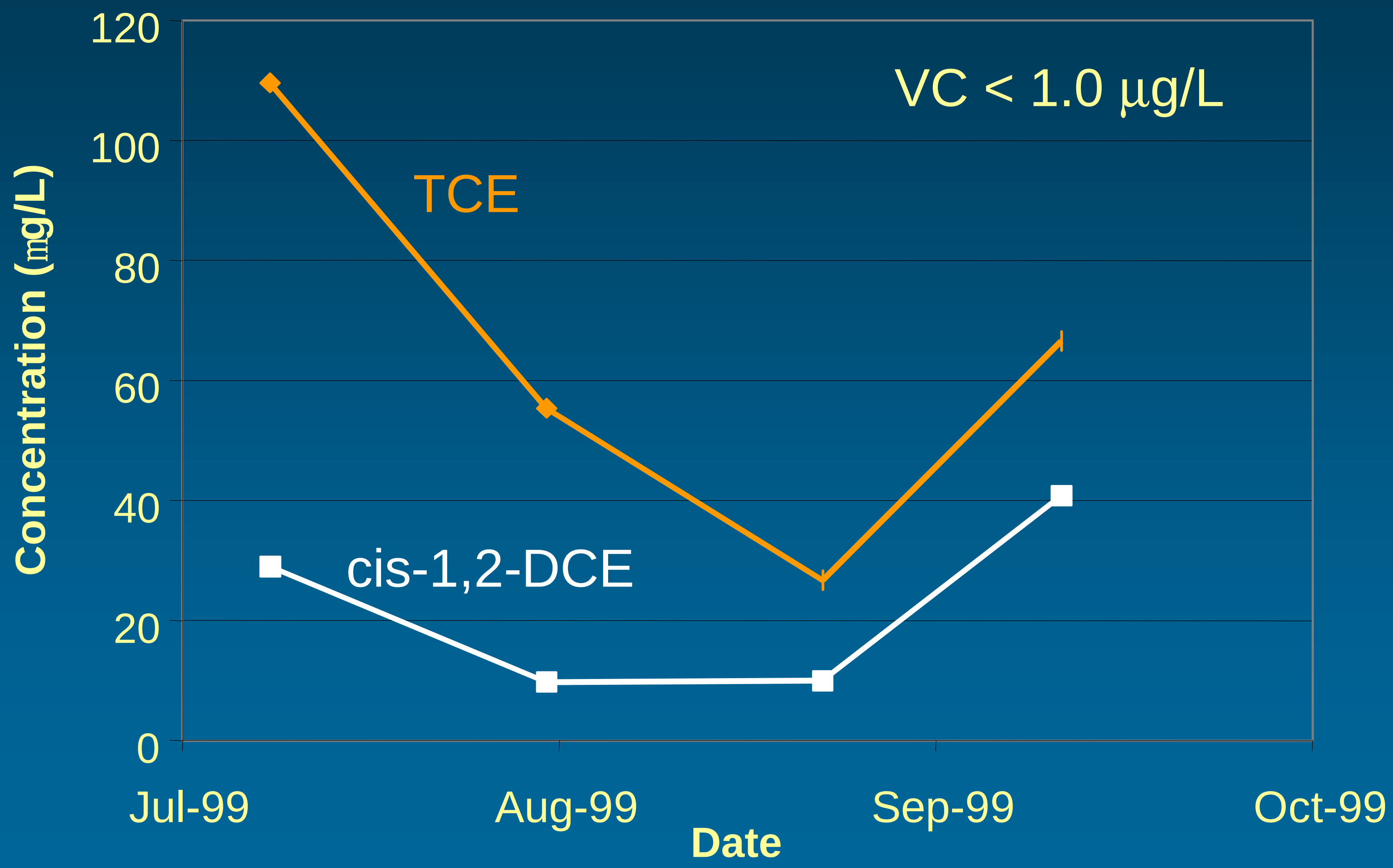
Chlorinated Ethene Concentrations – PT2-D/MCW11



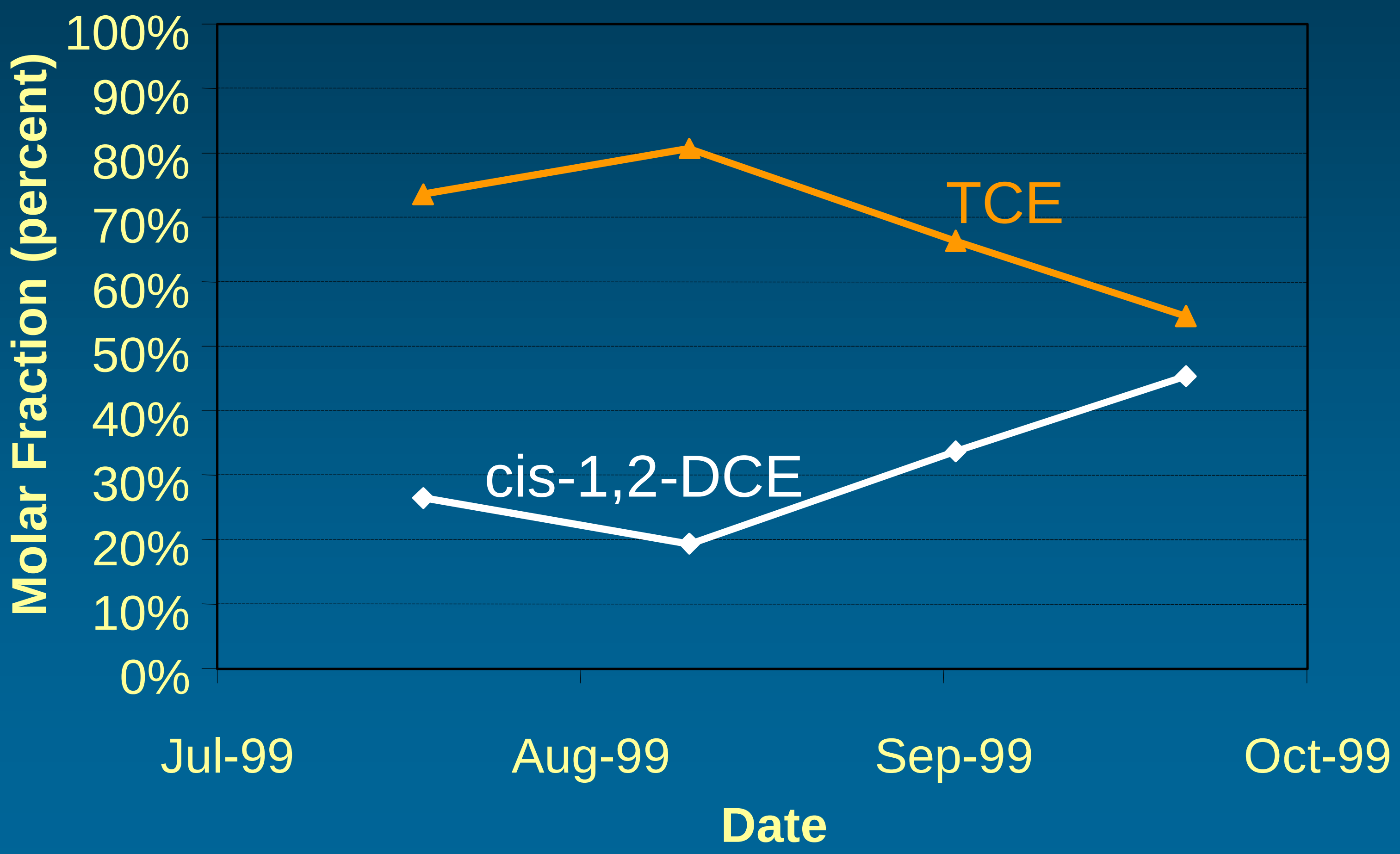
Molar Fraction of Chlorinated Ethenes – Well PT2-D/MCW11



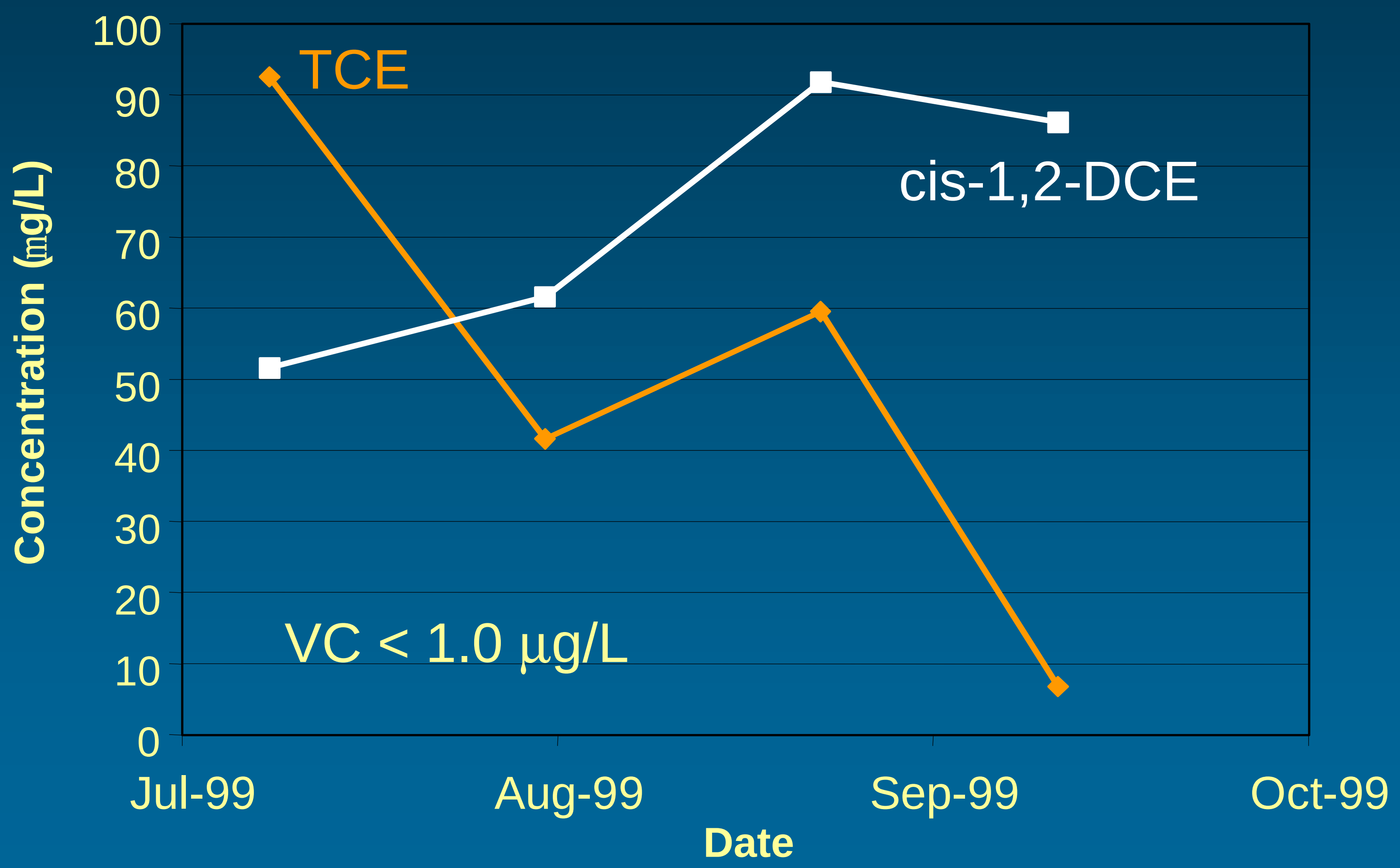
Chlorinated Ethene Concentrations – PT4-D



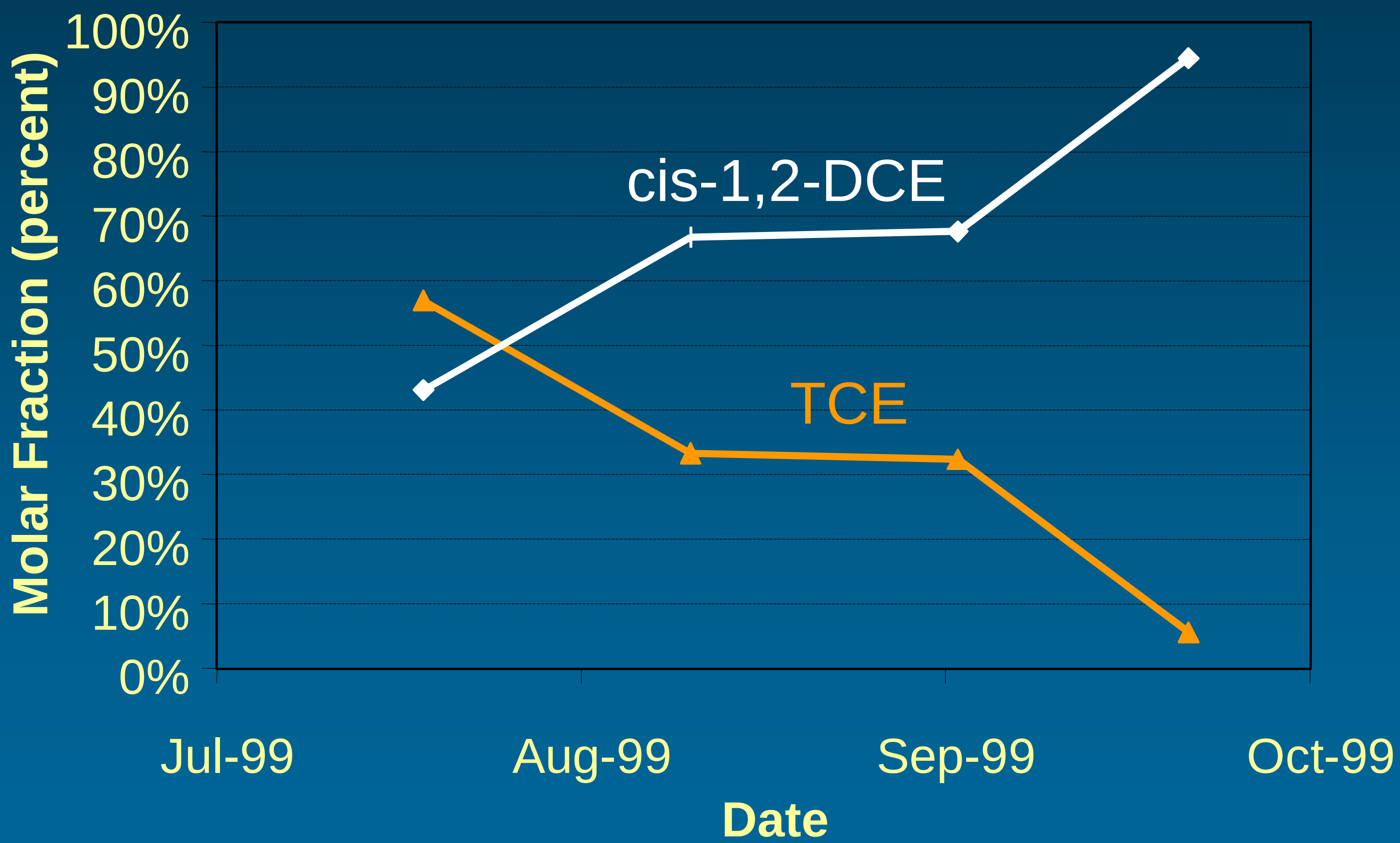
Molar Fraction of Chlorinated Ethenes – Well PT4-D



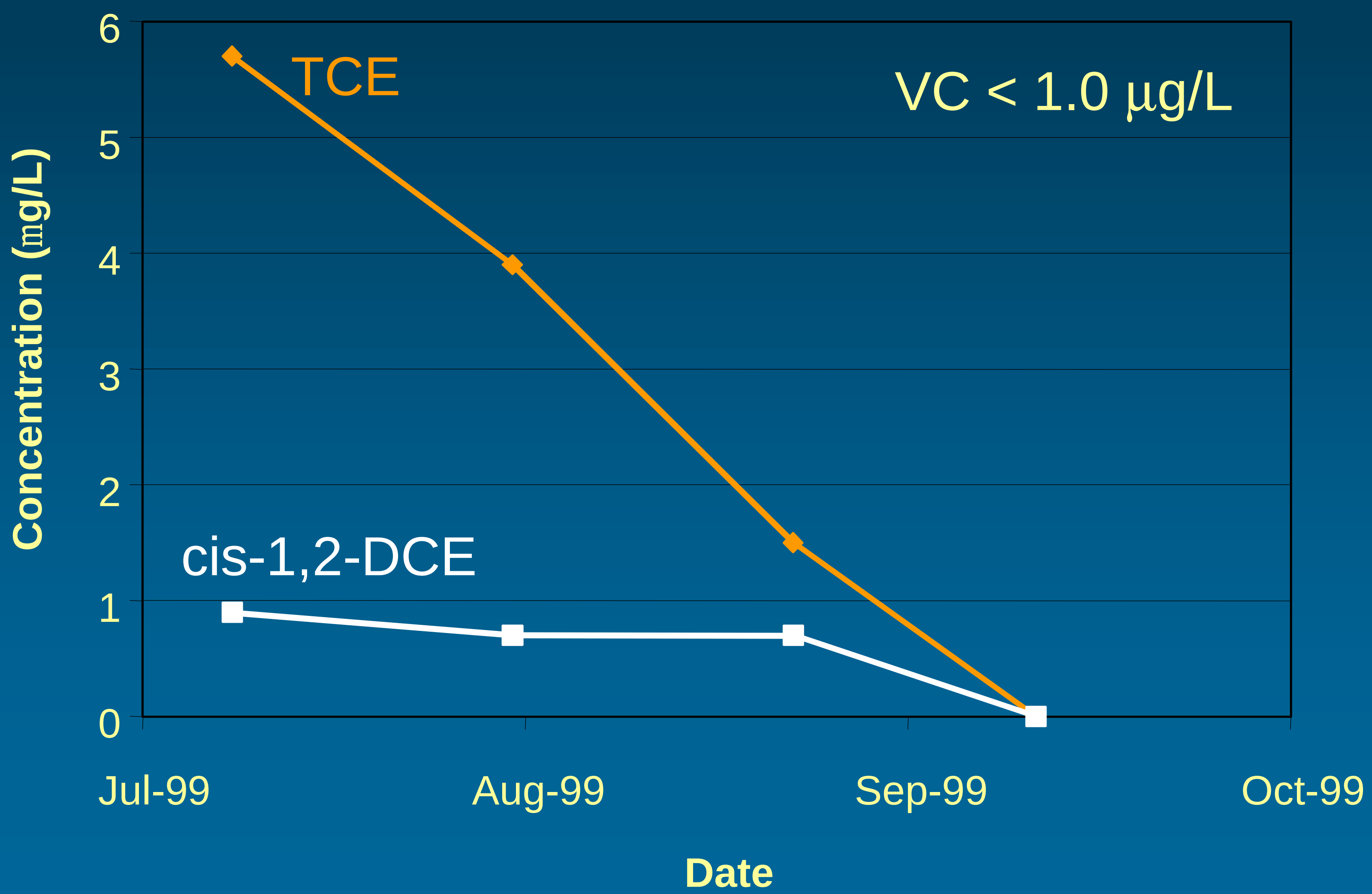
Chlorinated Ethene Concentrations – PT7-D



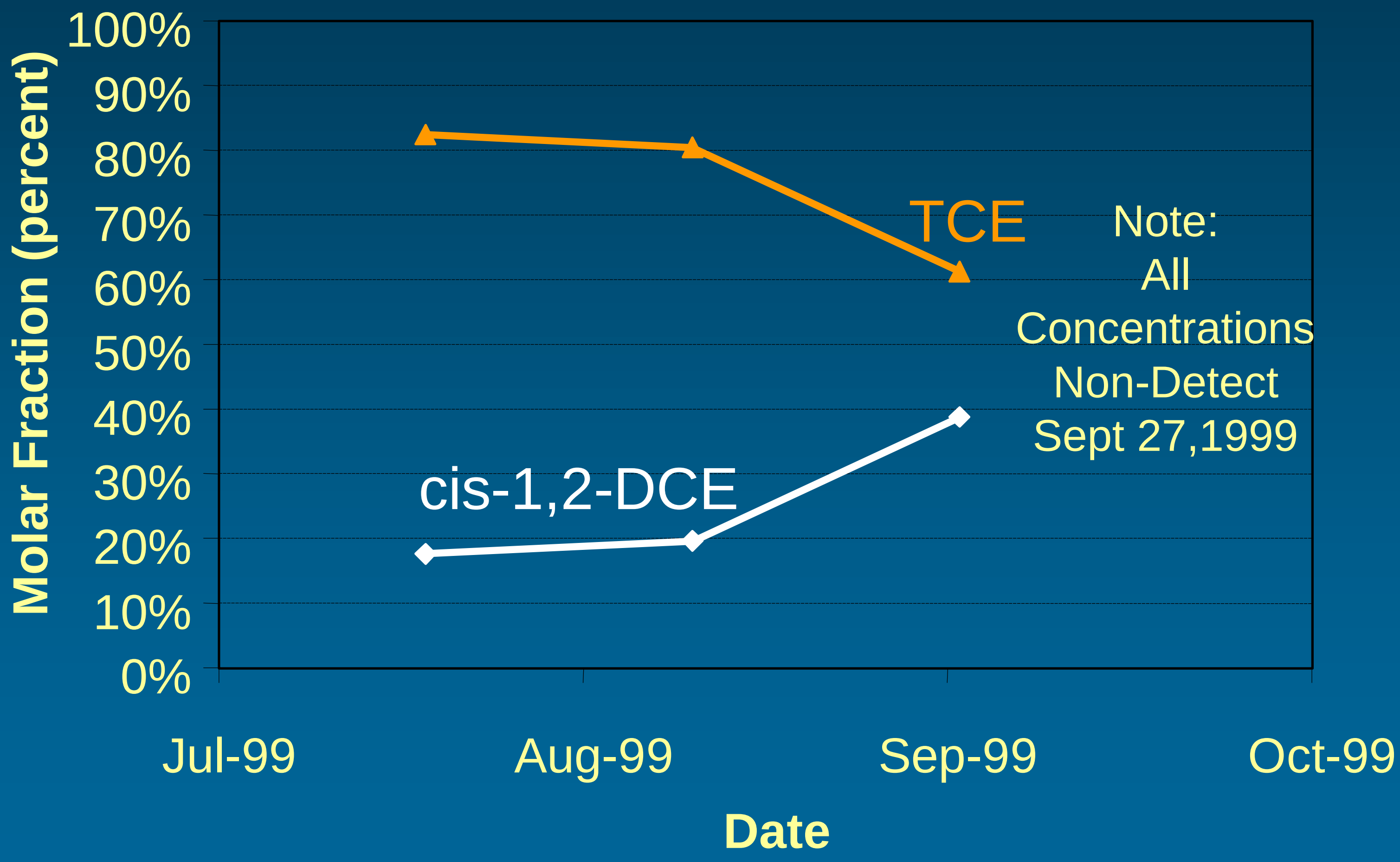
Molar Fraction of Chlorinated Ethenes – Well PT7-D



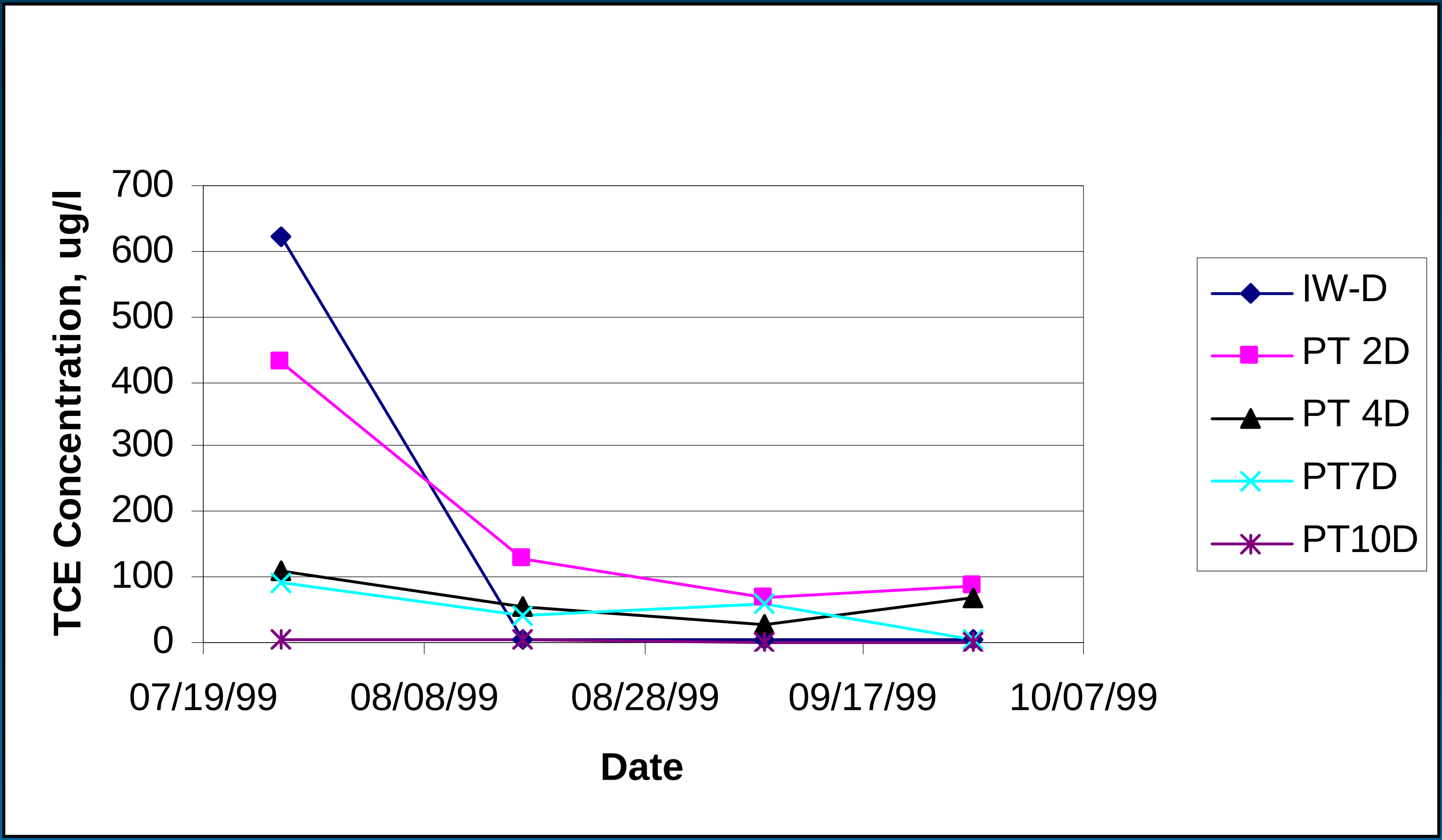
Chlorinated Ethene Concentrations – PT10-D



Molar Fraction of Chlorinated Ethenes – Well PT10-D



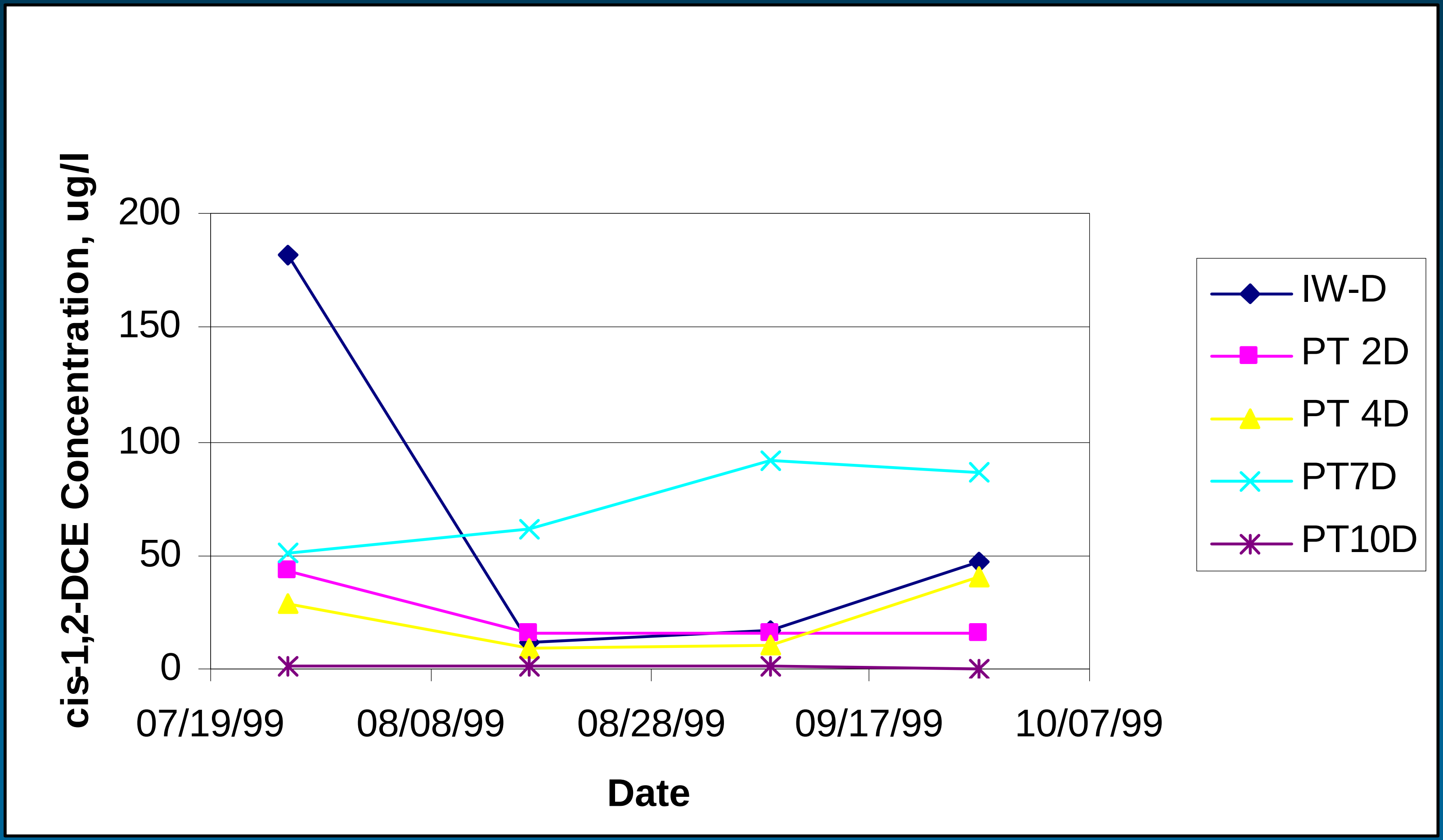
DDHU - Trichloroethene



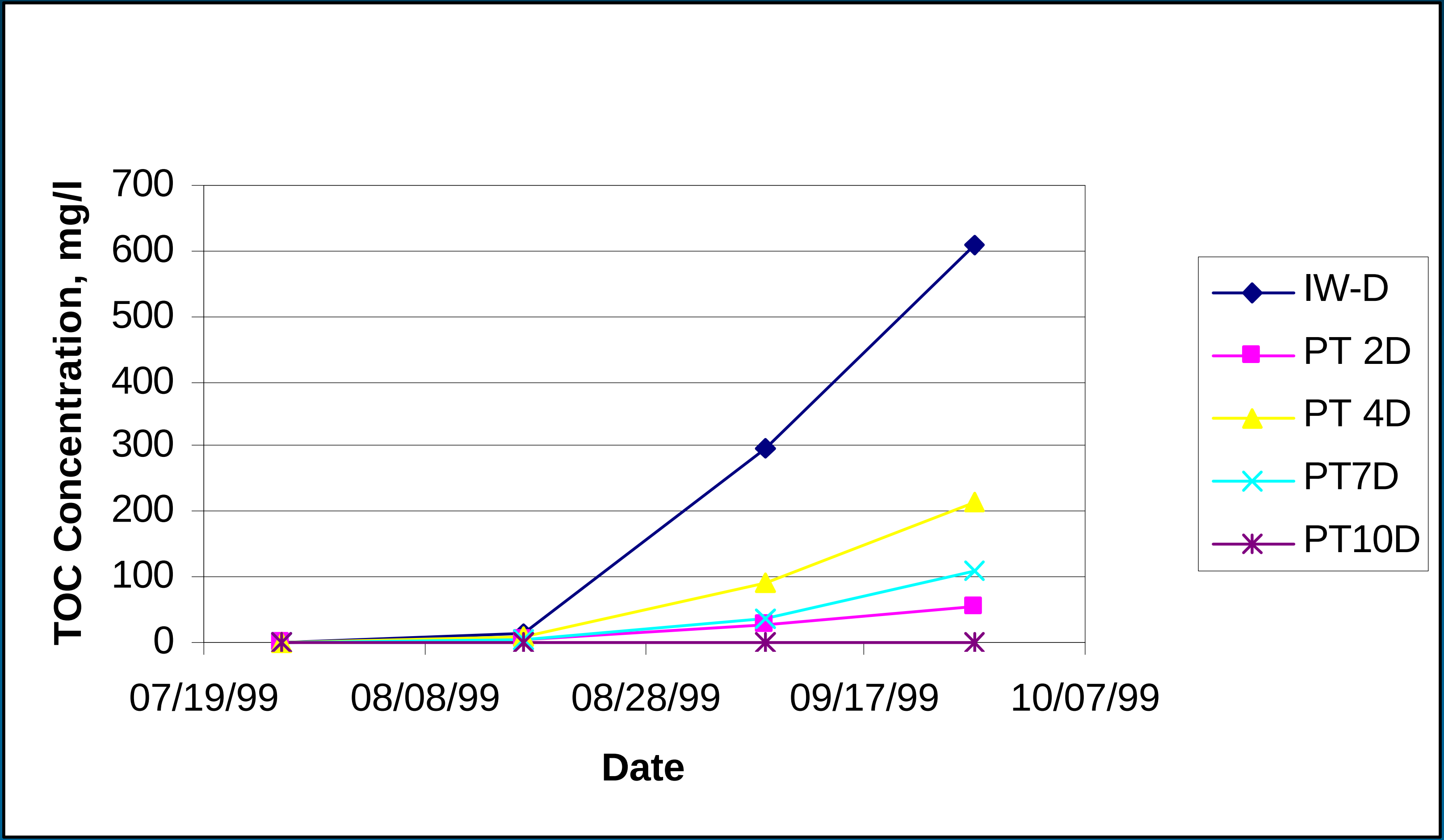
TCE Attenuation Rates

- **PT-2D = 4.9/year ($t_{1/2}$ = 0.14 year)**
- **PT-4D = 2.97/year ($t_{1/2}$ = 0.23 year)**
- **PT-7D = 15.5/year ($t_{1/2}$ = 0.05 year)**
- **PT10-D = 10.75/year ($t_{1/2}$ = 0.06 year)**

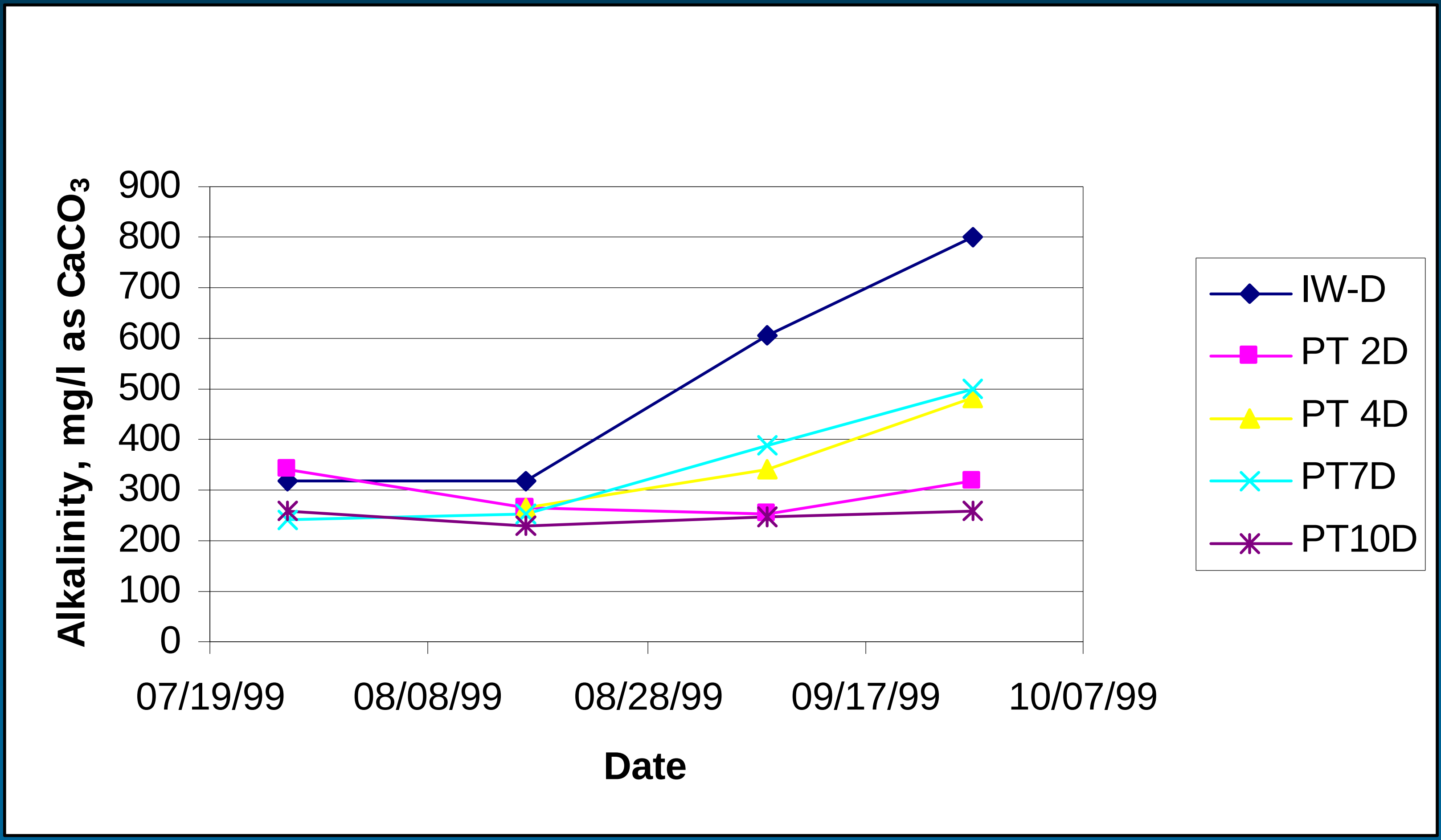
DDHU – cis-1,2-DCE



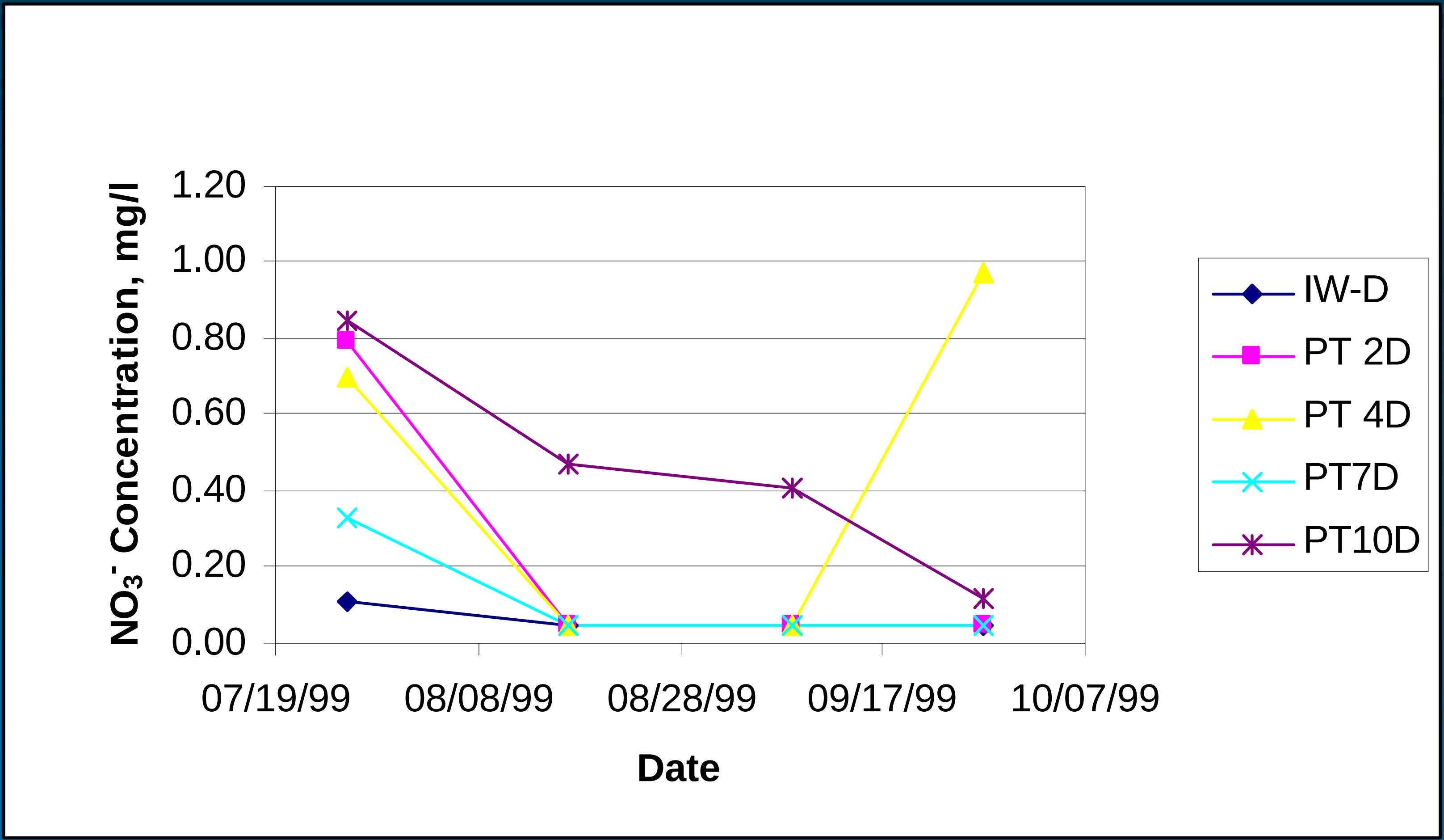
DDHU – Total Organic Carbon



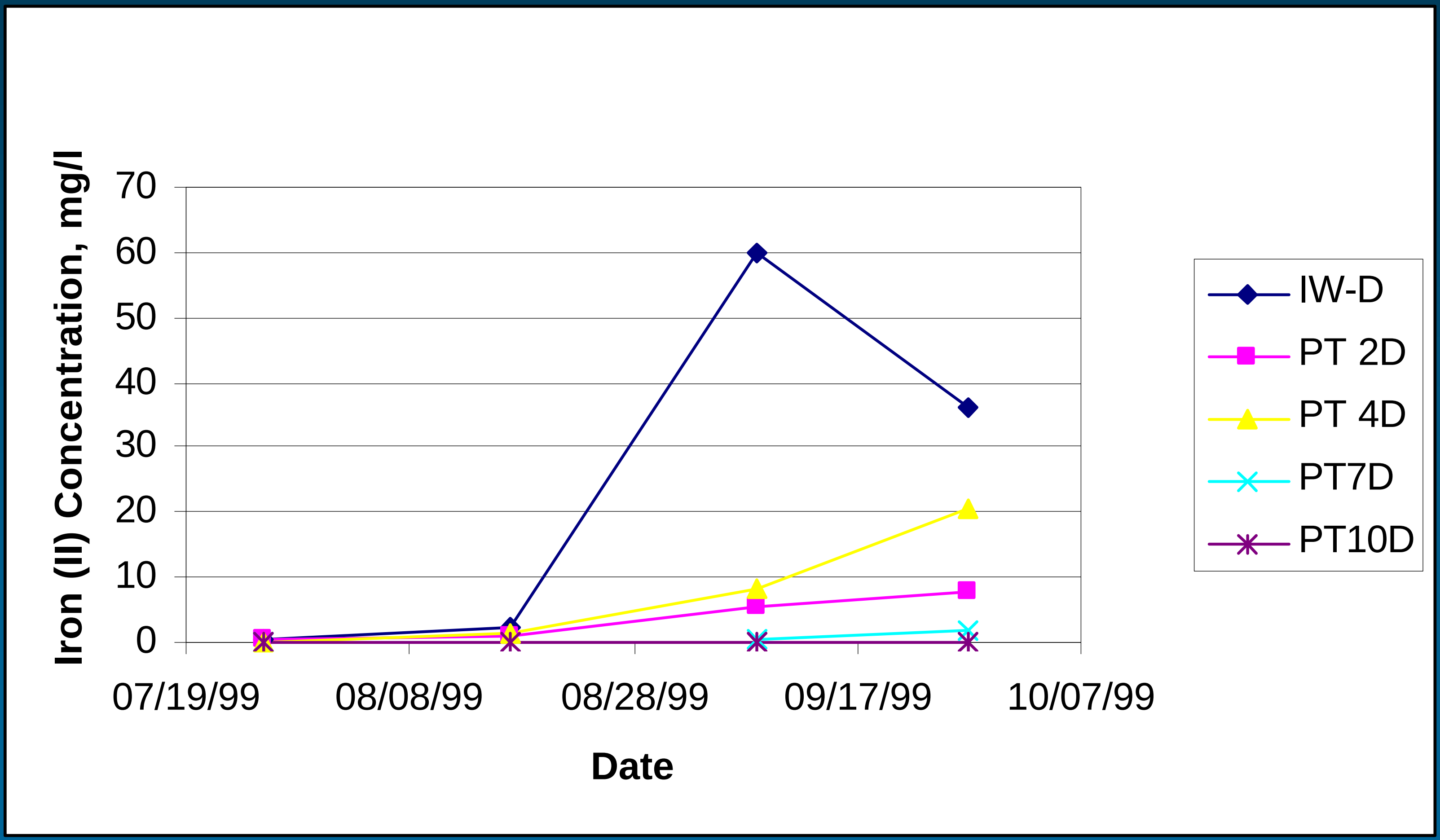
DDHU - Alkalinity



DDHU - Nitrate

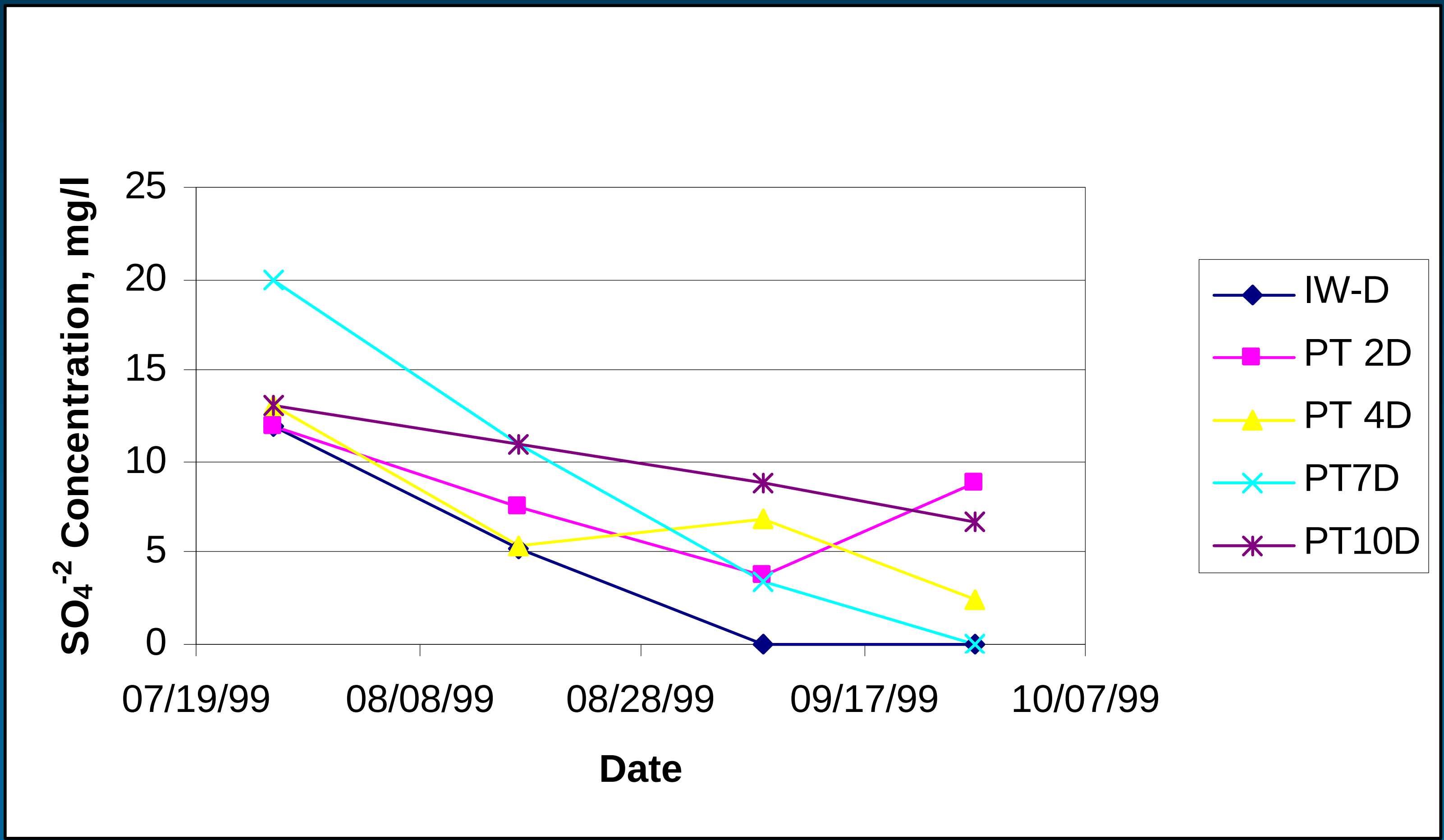


DDHU – Iron (II)



Iron (II) Concentration, mg/l
70
60
50
40
30
20
10
0
07/19/99
08/08/99
08/28/99
09/17/99
10/07/99
Date
IW-D
PT 2D
PT 4D
PT7D
PT10D

DDHU - Sulfate



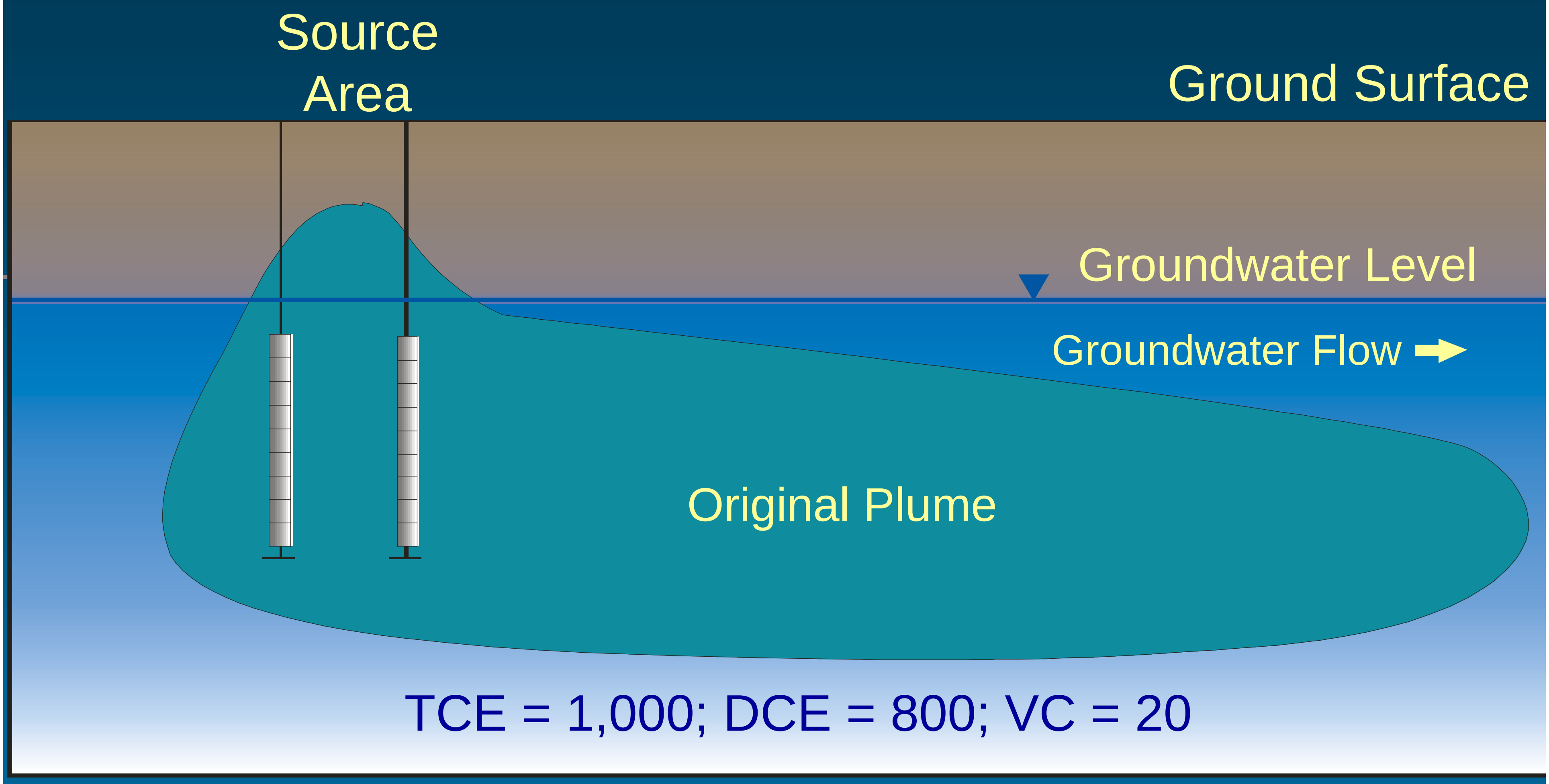
DDHU Results

- Looks very Promising
- Different Geochemistry/Maximum Contaminant Concentrations Means no VC production Compared to the Cape Site
- TCE Almost Gone
- Plume Collapsing
- All this in Three Months

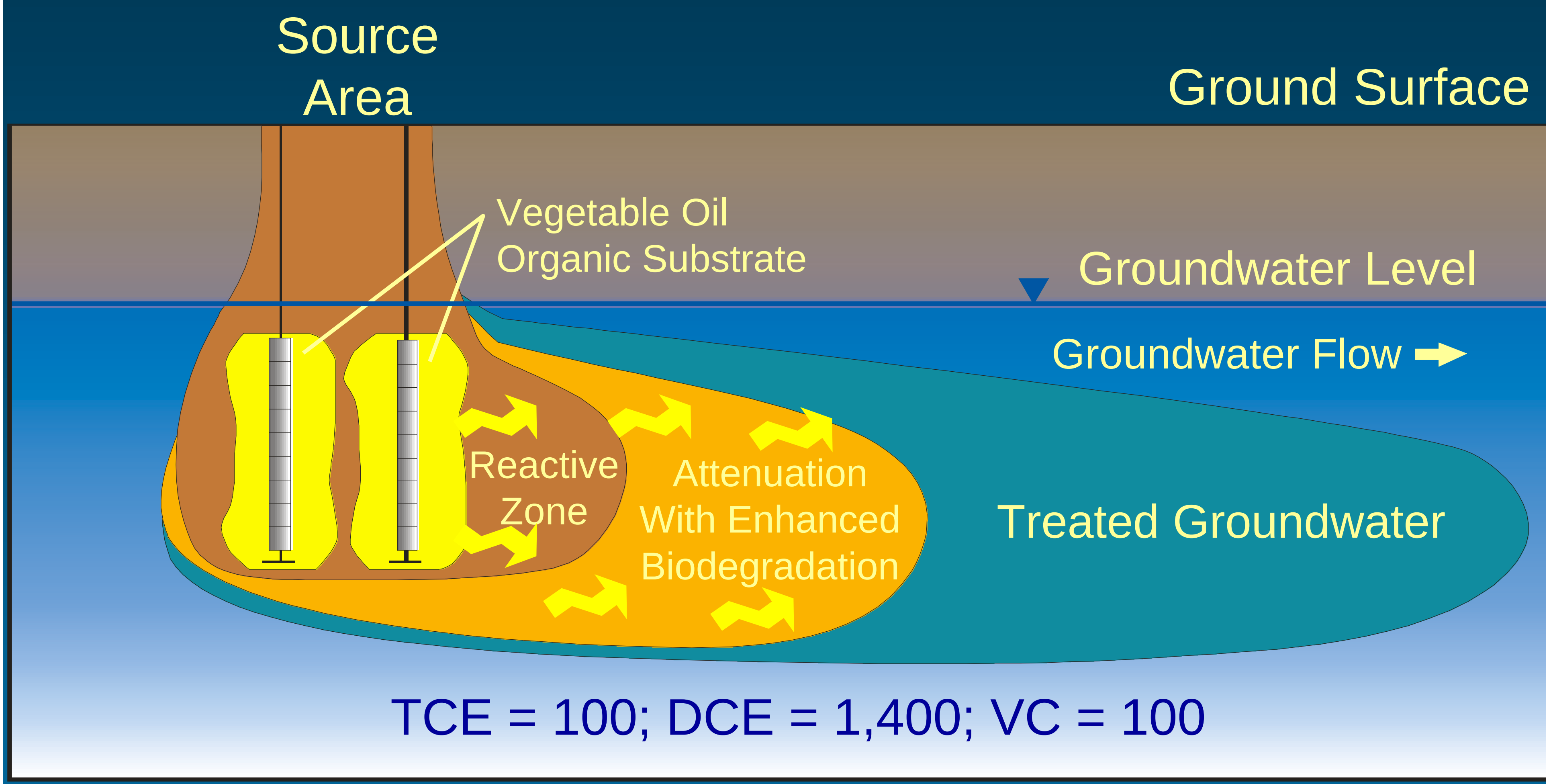
VegOil Conceptual Model

- Rapid Initial Decrease in TCE Concentrations due to Partitioning into Oil + Biodegradation
- Rapid Initial Increase in DCE +/- VC Concentrations due to Biodegradation of TCE
- Over Time Decreasing DCE +/- VC Concentrations due to Partitioning of TCE into Oil and Biodegradation

The VegOil Process – Time 1



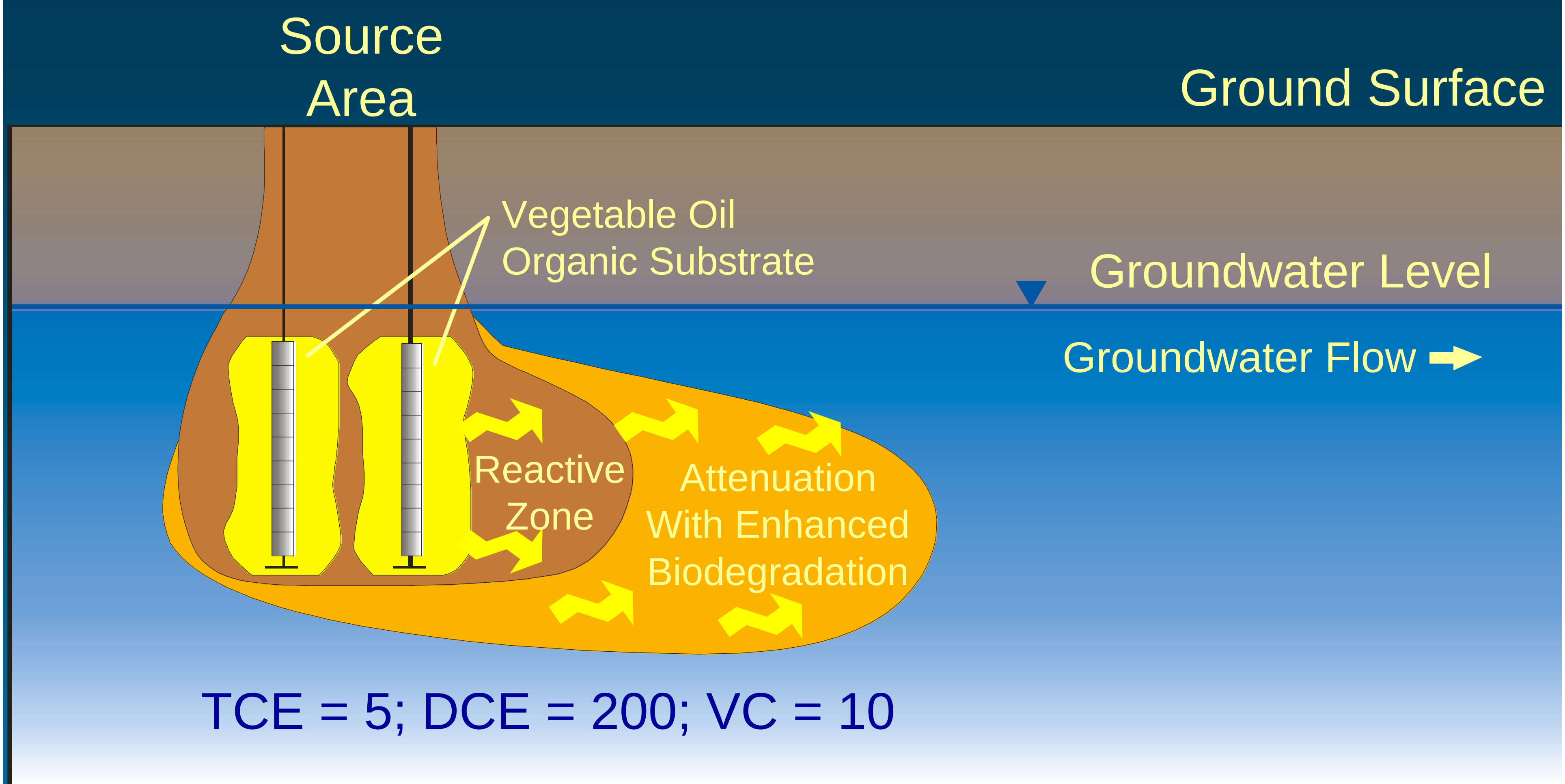
The VegOil Process – Time 2



VegOil Conceptual Model

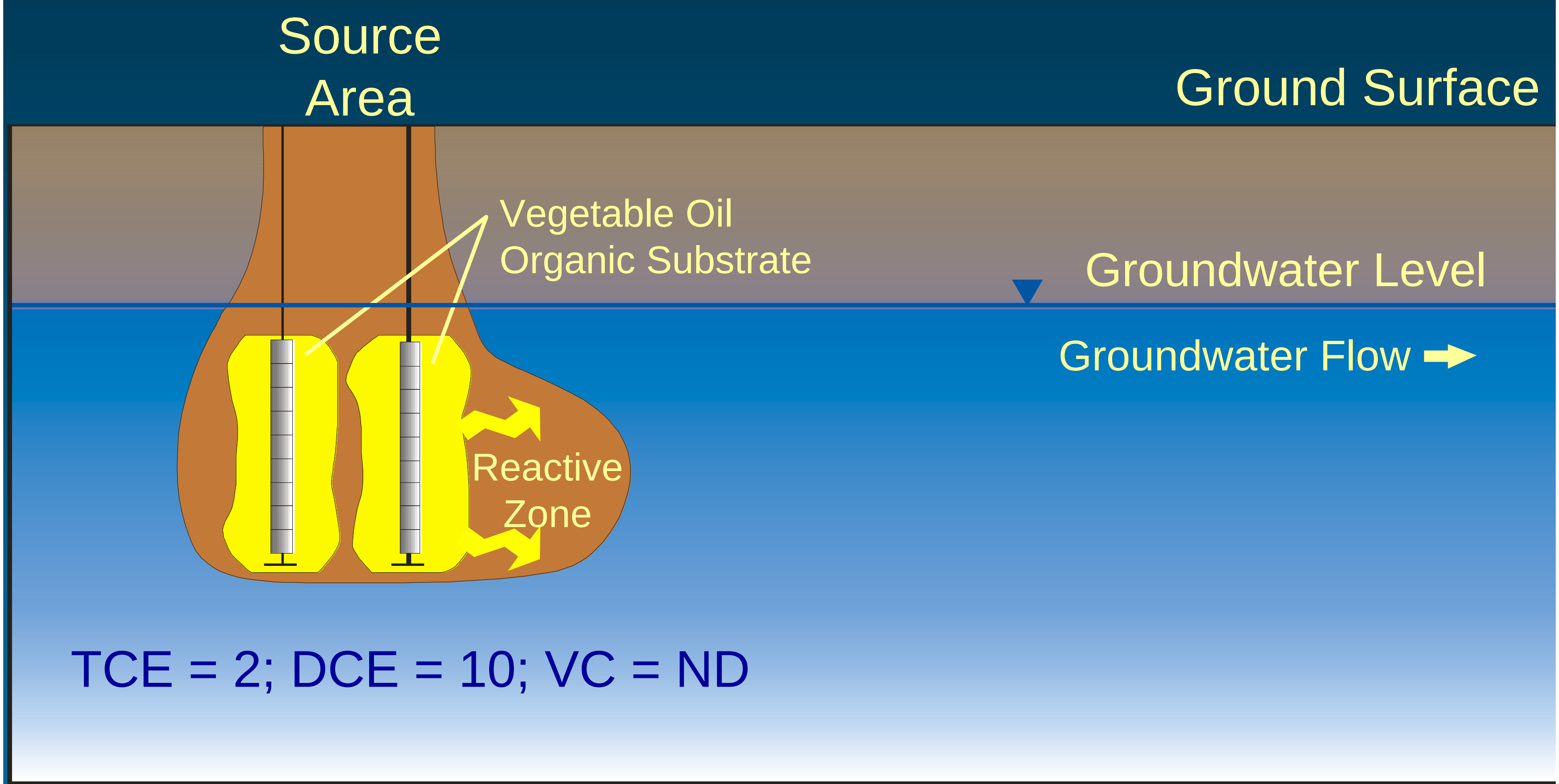
- **Relatively Rapid Collapse of TCE Plume**
- **Collapse of DCE +/- VC Plume over Time**

The VegOil Process – Time 3

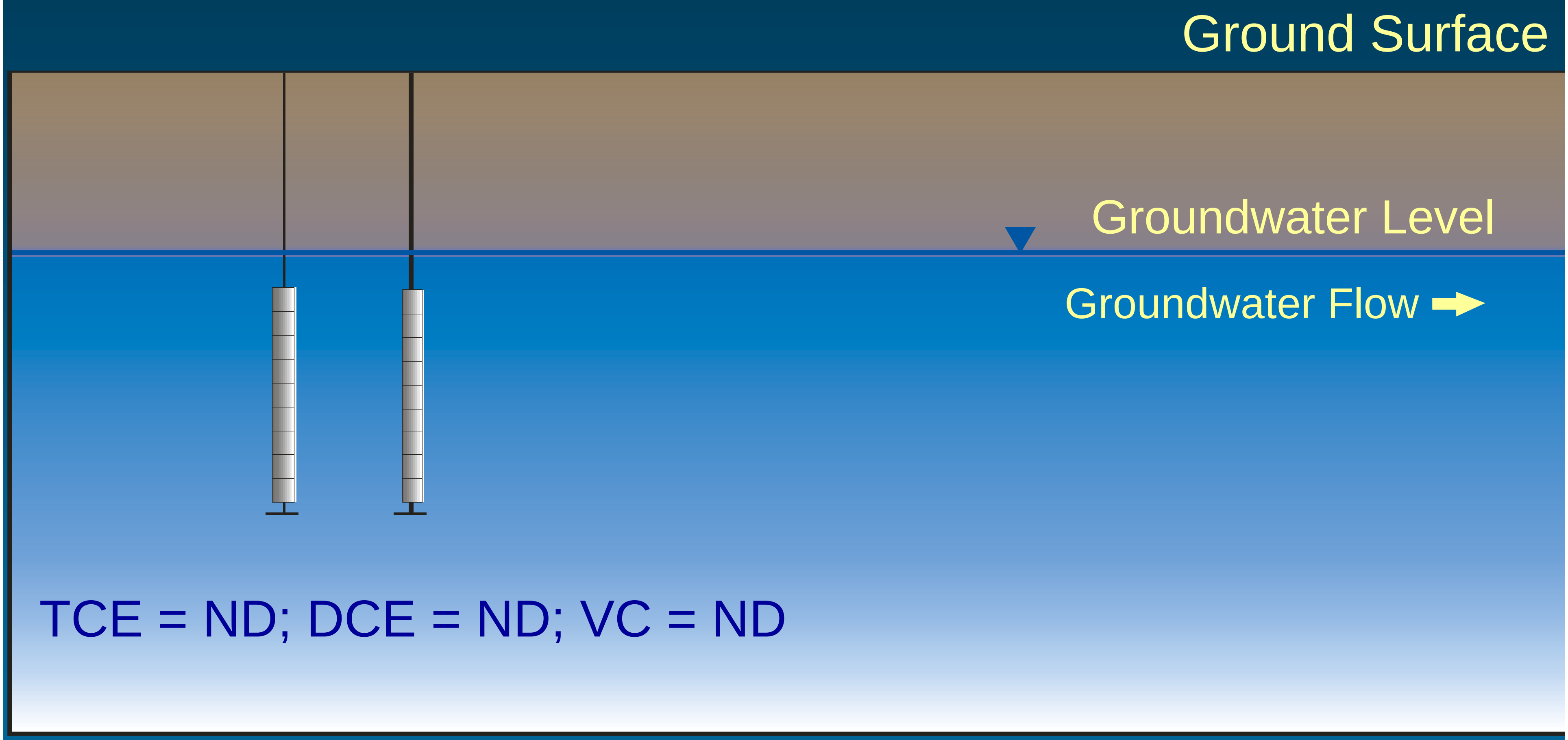


TCE = 5; DCE = 200; VC = 10

The VegOil Process – Time 4



The VegOil Process – Time 5



The VegOil Process

- **Looks Promising!**