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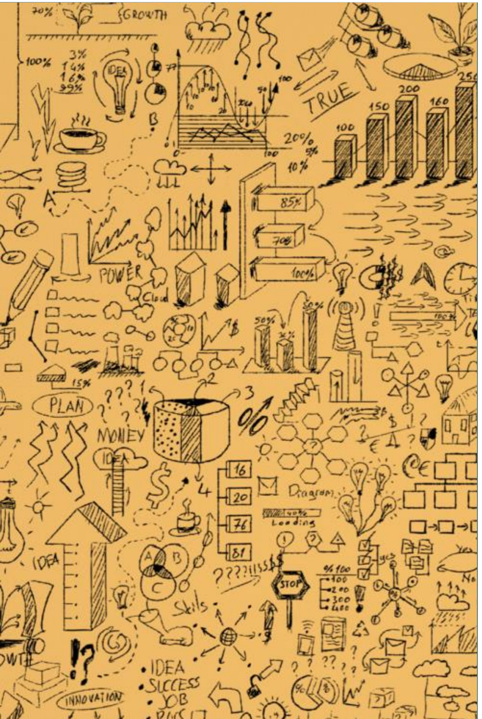

Evaluation of Trichloroethylene Attenuation Rates and Mechanisms in Support of MNA as a Alternative Remedial Approach

Jaana Pietari, Ph.D., P.E.
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Todd Muelhoefer

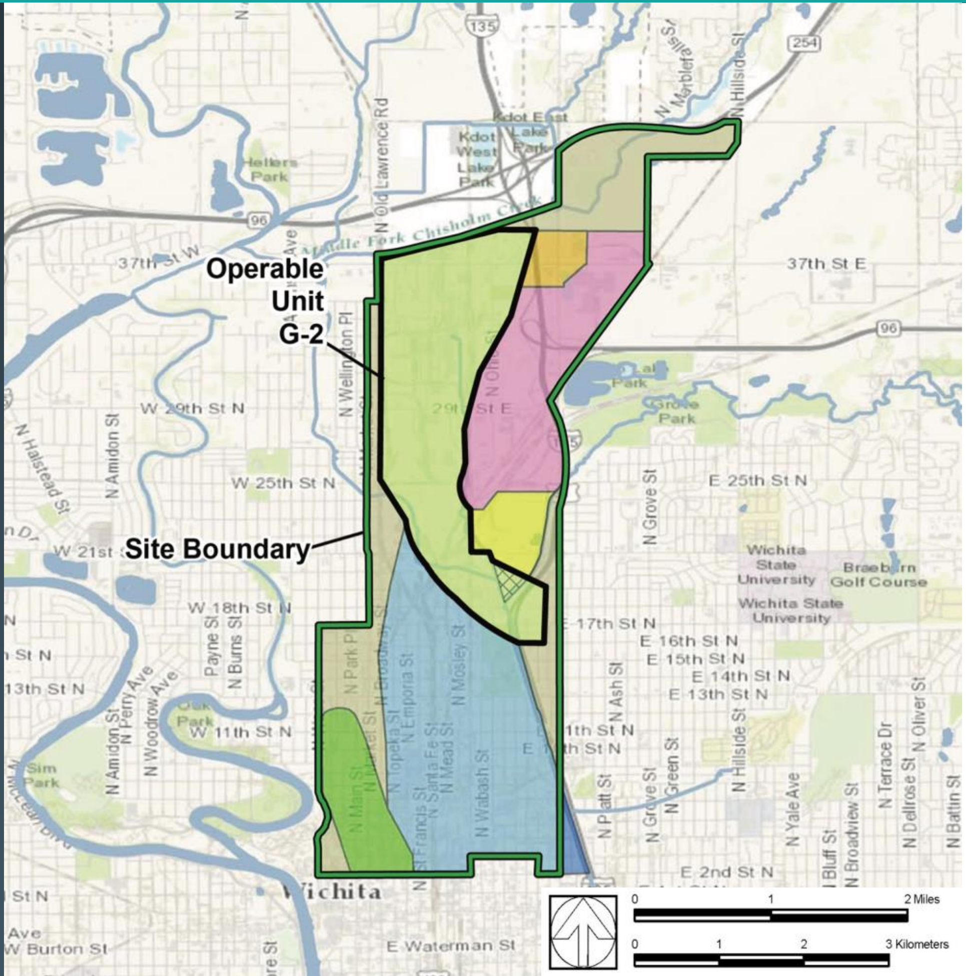
May 25, 2017

Outline

- Introduction
  - Site Background
  - Selected Remedy
- Objective
- Key Questions
- Approach
- Evaluation
- Findings

Introduction: Site Background

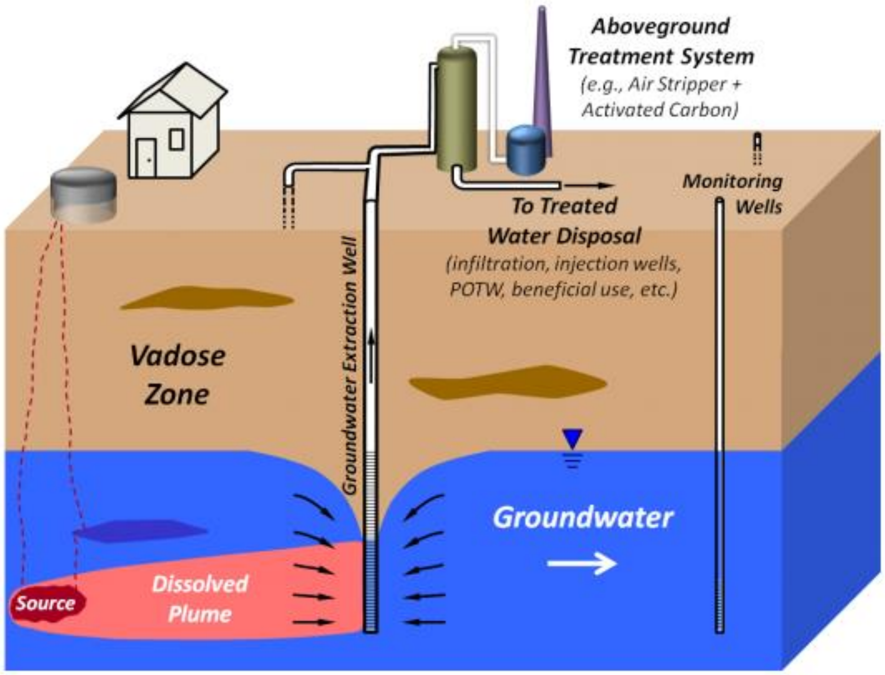
- Approximately 4,000 acres of urban industrial, commercial, recreational, residential, and agricultural property
- Principal contaminants of interest are TCE and locally petroleum hydrocarbons
- Many source areas and potentially responsible parties
- Two groundwater zones
  - Shallow (depth < 21 ft bgs)
  - Deep (depth > 25 ft bgs)



TCE, trichloroethylene
bgs, below ground surface

Introduction: Selected Remedy

- Corrective Action Decision in 2012 for the large, commingled "off-site" plumes
- Source abatement and groundwater extraction and treatment alternative selected by the oversight agency for G-2
- Costs approx. $27M for G-2
- Remediation of source areas addressed by individual parties

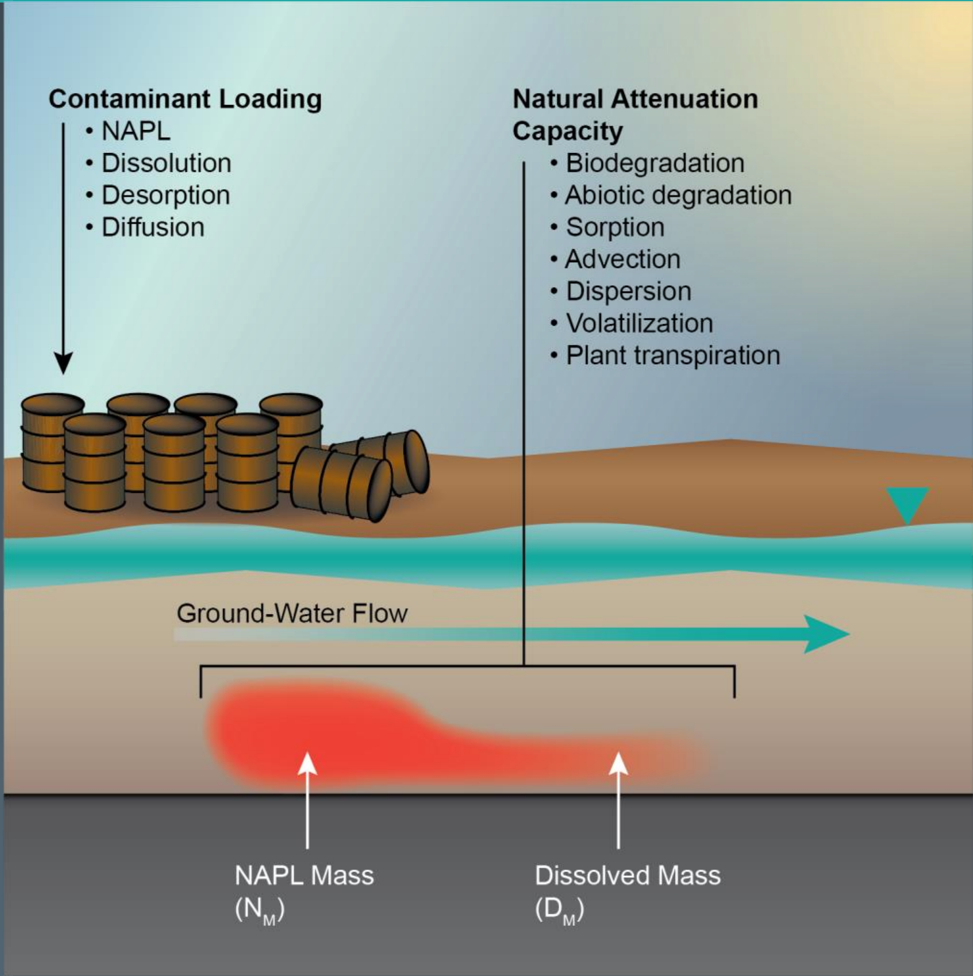


http://bioprocess.pnnl.gov/publictn/PNNL-24696__Performance_Assessment_for_P&T.pdf

MNA, monitored natural attenuation

Introduction: Alternative to Selected Remedy

- MNA screenings during RI/FS indicated that conditions for reductive dechlorination suitable in limited locations
- Recent data collected from G-2 and other units, indicated decrease in TCE concentrations



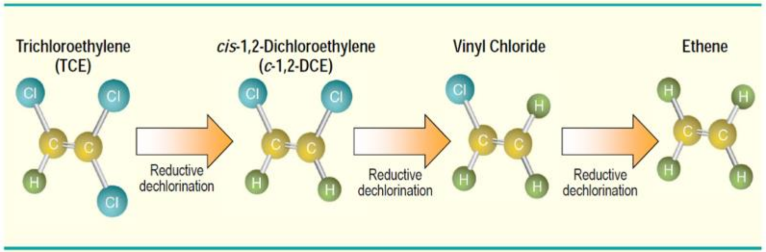
RI/FS, remedial investigation/feasibility study

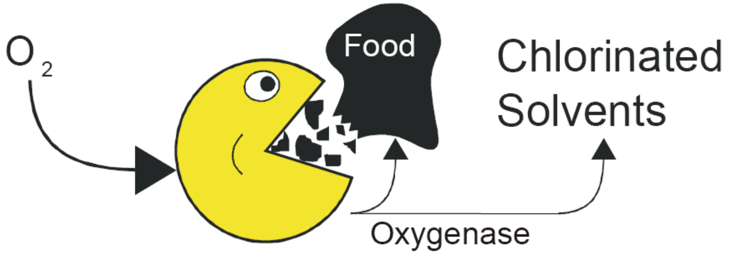
Objective

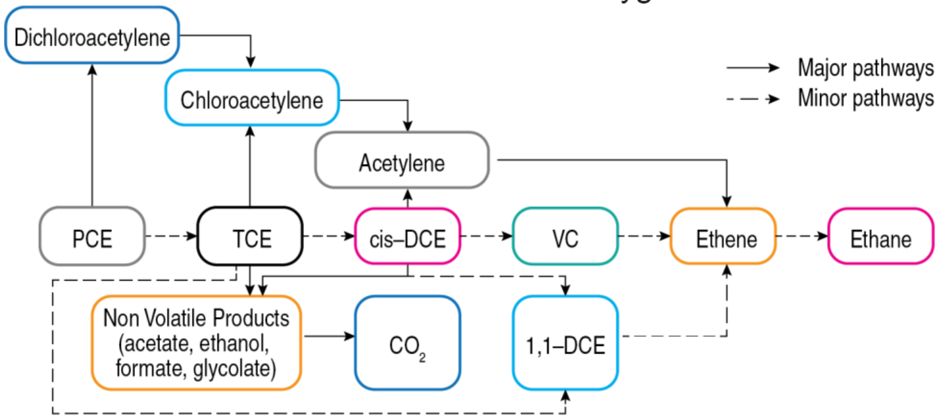
- Perform technical evaluation of TCE attenuation in groundwater that would support a decision that MNA should be adopted as a superior remedial alternative to groundwater extraction and treatment in G-2

Key Questions

- What potential natural attenuation mechanisms may be occurring?
- Anaerobic reductive dechlorination
- Aerobic co-metabolism and/or aerobic oxidation
- Biogeochemical reduction
- Other mechanisms
  - Dispersion
  - Volatilization
  - Sorption







Key Questions

- Is MNA an alternative treatment to groundwater pump and treat in G-2?
- If so, what are the MNA mechanisms?
- What are the approximate attenuation rates for TCE?
- What is the approximate duration to achieve the TCE Alternate Treatment Goal (ATG) of 21 µg/L?

EPA United States Environmental Protection Agency

Ground Water Issue

Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies

Charles J. Newell[1], Hanadi S. Rifai[2], John T. Wilson[3], John A. Connor[1], Julia A. Aziz[1], and Monica P. Suarez[2]

Introduction

This issue paper explains when and how to apply first-order attenuation rate constant calculations in monitored natural attenuation (MNA) studies. First-order attenuation rate constant calculations can be an important tool for evaluating natural attenuation processes at ground-water contamination sites. Specific applications identified in U.S. EPA guidelines (U.S. EPA, 1999) include use in characterization of plume trends (shrinking, expanding, or showing relatively little change), as well as estimation of the time required for achieving remediation goals. However, the use of the attenuation rate data for these purposes

Concentration vs. Time Attenuation Rate Constant, where a rate constant, in units of inverse time (e.g., per day), is derived as the slope of the natural log concentration vs. time curve measured at a selected monitoring location (Figure 1).

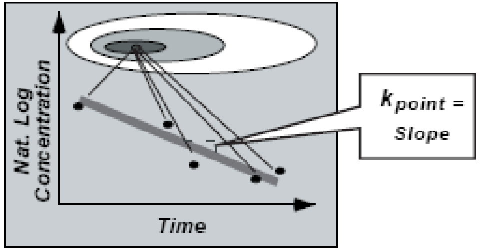


Figure 1. Determining concentration vs. time rate constant (k_{point}).

Development, National Risk Management Research Laboratory, Subsurface Protection and Remediation Division, Ada, Oklahoma

or concentration of contaminants in soil and ground water. These in-situ processes include biodegradation, dispersion, dilution, sorption, volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants (U.S. EPA, 1999).

The overall impact of natural attenuation processes at a given site can be assessed by evaluating the rate at which contaminant concentrations are decreasing either spatially or temporally. Recent guidelines issued by the U.S. EPA (U.S. EPA, 1999) and the American Society for Testing and Materials (ASTM, 1998) have endorsed the use of site-specific attenuation rate constants for ...tural attenuation processes in ground water. The ...ctive on the use of Monitored Natural Attenuation ...perfund, RCRA, and UST sites (U.S. EPA, 1999) ...al references to the application of attenuation rates:

...characterization data have been collected and ...al model developed, the next step is to evaluate ...ial efficacy of MNA as a remedial alternative. ...ves collection of site-specific data sufficient to ...ith an acceptable level of confidence both the ...enuation processes and the anticipated time ...achieve remediation objectives.

...um, the monitoring program should be sufficient ...a determination of the rate(s) of attenuation and ...ate is changing with time.

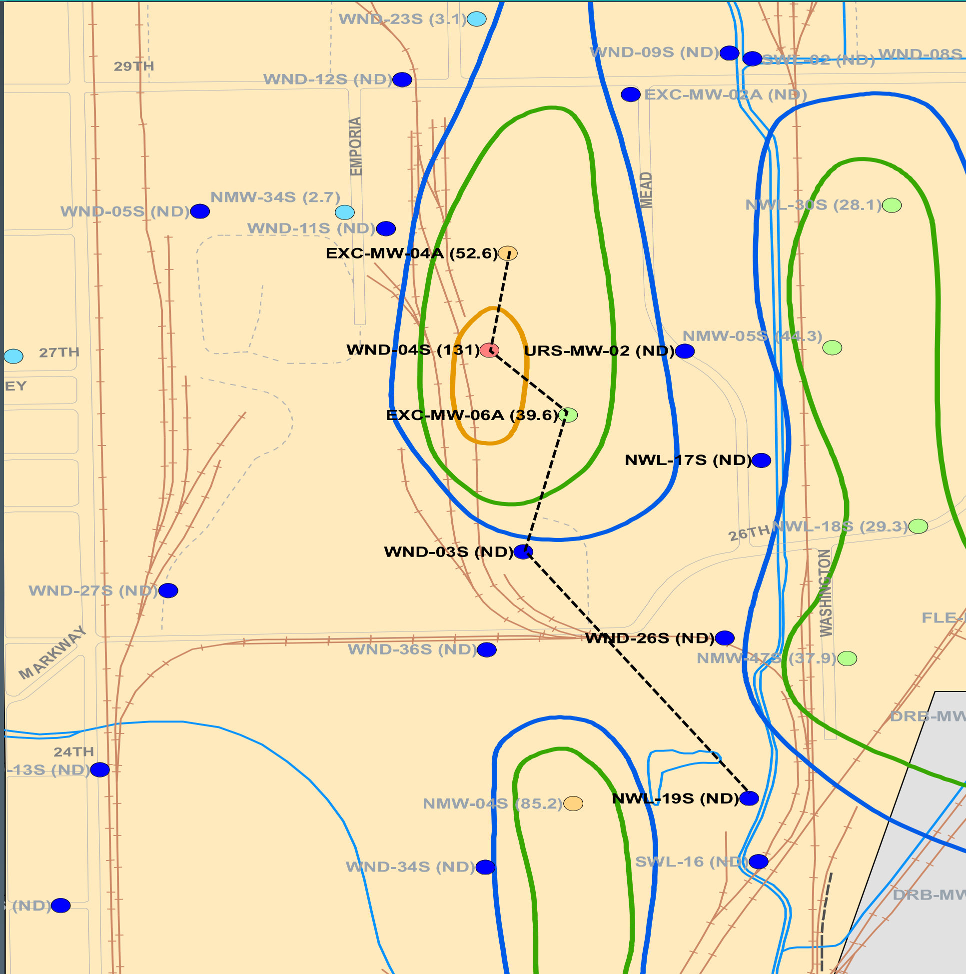
...cterization (and monitoring) data are typically ...stimating attenuation rates.

...andard Guide for Remediation of Groundwater by ...uation at Petroleum Release Sites (ASTM, 1998) ...site-specific attenuation rates as a secondary line ...the occurrence and rate of natural attenuation. In ...chnical guidelines issued by various state ...regulatory agencies recommend estimation of rate ...valuate contaminant plume trends and duration (New ...1998; Wisconsin DNR, 1999). For example, the ...epartment of Environmental Protection (DEP) now ...h calculations for establishing "Classification ...eas (CEAs)" at sites where ground-water quality ...or will be exceeded for an extended time period.

...literature contains numerous guidelines regarding ...erivation of site-specific attenuation rate constants based upon observed plume concentration trends (e.g., ASTM, 1998; U.S. EPA, 1998a; 1998b; Wiedemeier et al. 1995; 1999; Wilson and Kolhatkar, 2002). Other resources, such as the

Approach

- Compile and review of all available HVOC data for G-2
  - Approx. 1984 through 2014
  - Limited wells sampled in 2015
- Construct "cross sections" along the axes of the TCE plumes
- Evaluate well-specific trends for chlorinated ethenes (total and individual compounds) from wells sampled in 2014
  - Estimate well-specific TCE attenuation rates



HVOC, halogenated volatile organic compound

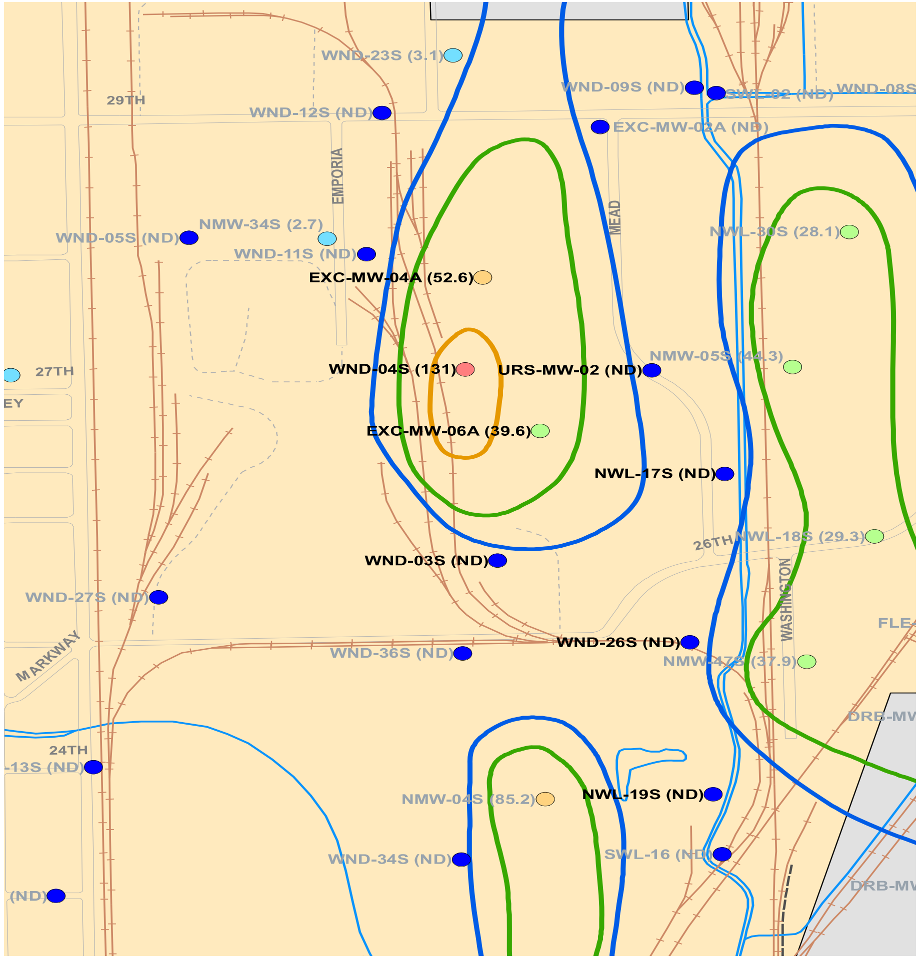
2014 G-2 Groundwater Data Indicates TCE Concentrations are Currently Below the ATG for Most Shallow Wells

- Observation supported the hypothesis that MNA may be occurring

Groundwater Zone	Number of Geoprobes and Wells	TCE Range (µg/L)	Wells Above TCE ATG of 21 µg/L [a]
Shallow zone (< 21 ft bgs)	46	ND–52.4	6
Deep zone (> 25 ft bgs)	42	0.5–76.7	16

Comparison of 2014 and 2007 G-2 TCE Data Indicates TCE Levels Decreased Overall

Zone	TCE Concentrations (µg/L)			
	2007		2014	
	Range	Wells with TCE above ATG/ Total Wells	Range	Wells with TCE above ATG/ Total Wells
Shallow	ND–131	8 / 21	ND–52.4	2 / 21
Deep	ND–202	15 / 18	0.56–76.7	7 / 18
Total	ND–202	23 / 39	ND–76.7	9 / 39



Legend

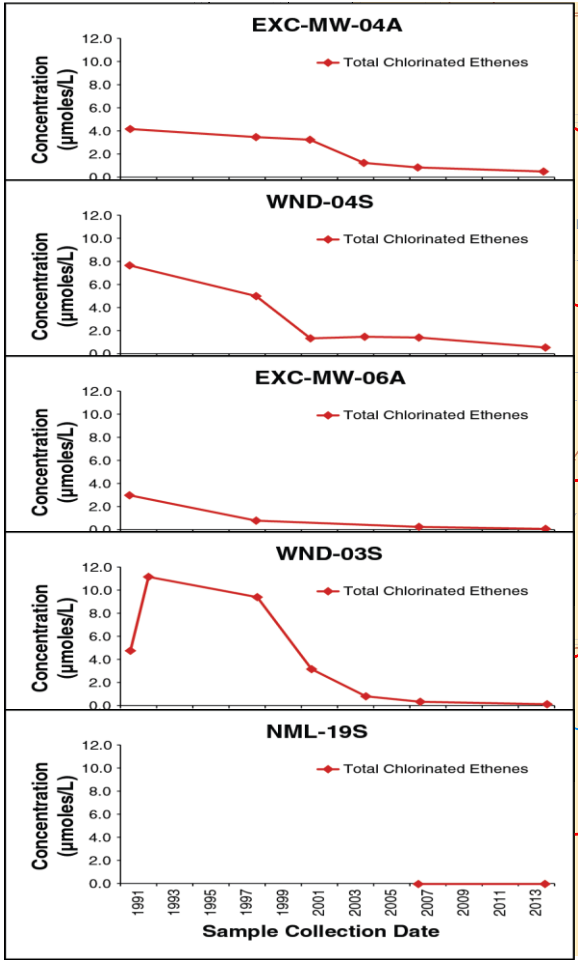
TCE (µg/L)

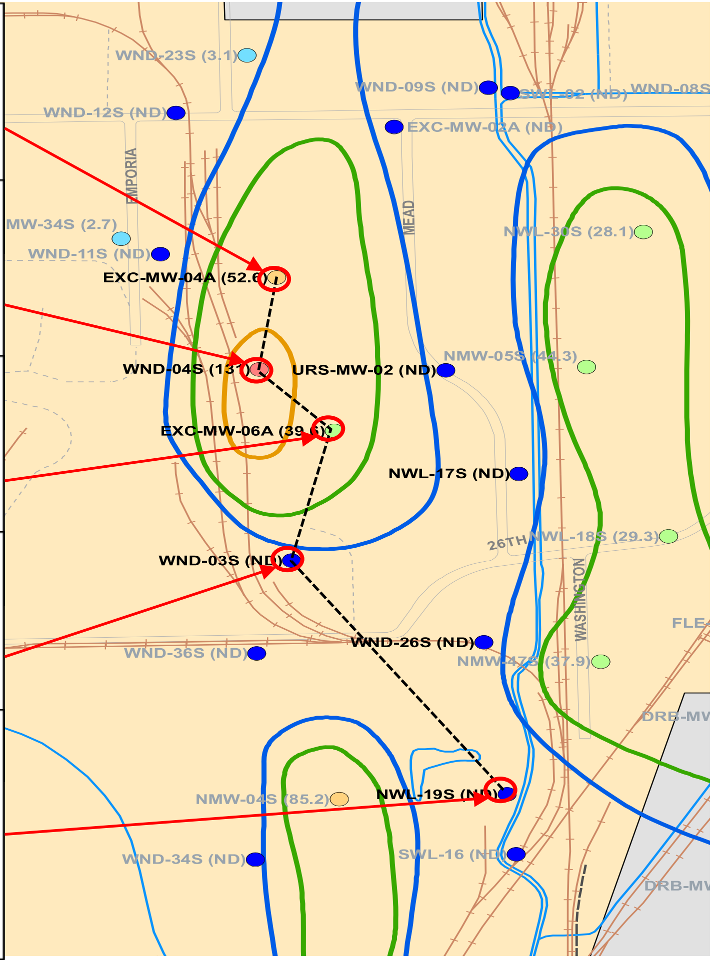
- >200
- 100.01 - 200.00
- 50.01 - 100.00
- 20.01 - 50.00
- 5.01 - 20.00
- 1.01 - 5.00
- 0.00 - 1.00

Trichloroethene (TCE) Contours*

- 500 µg/L
- 100 µg/L
- 20 µg/L
- 5 µg/L

Note: Dashed lines indicate inferred contours.
Some or all data in gray shaded areas were supplied by PRPs.
** = Anomalous or localized data point- not used for contouring*





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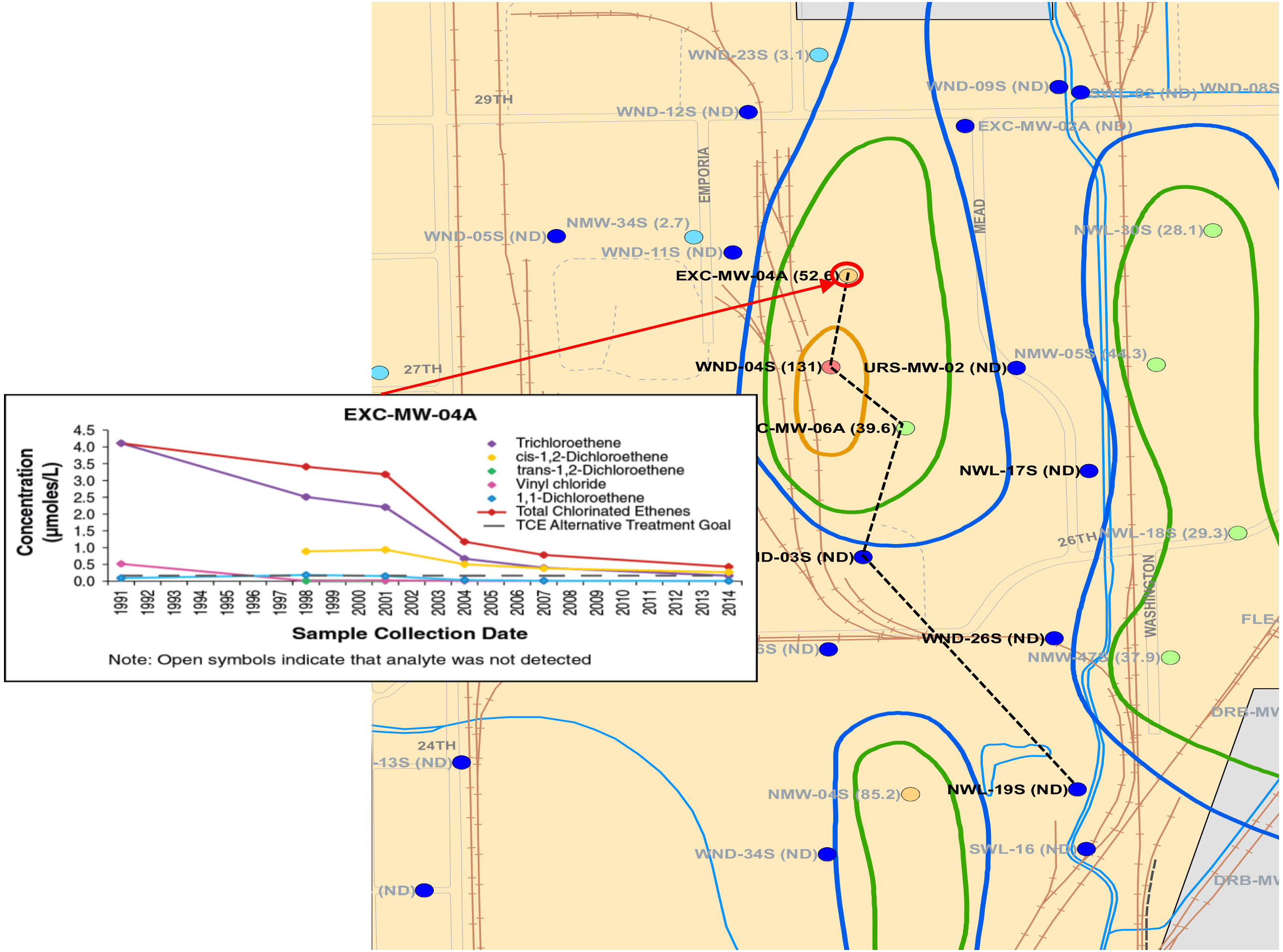

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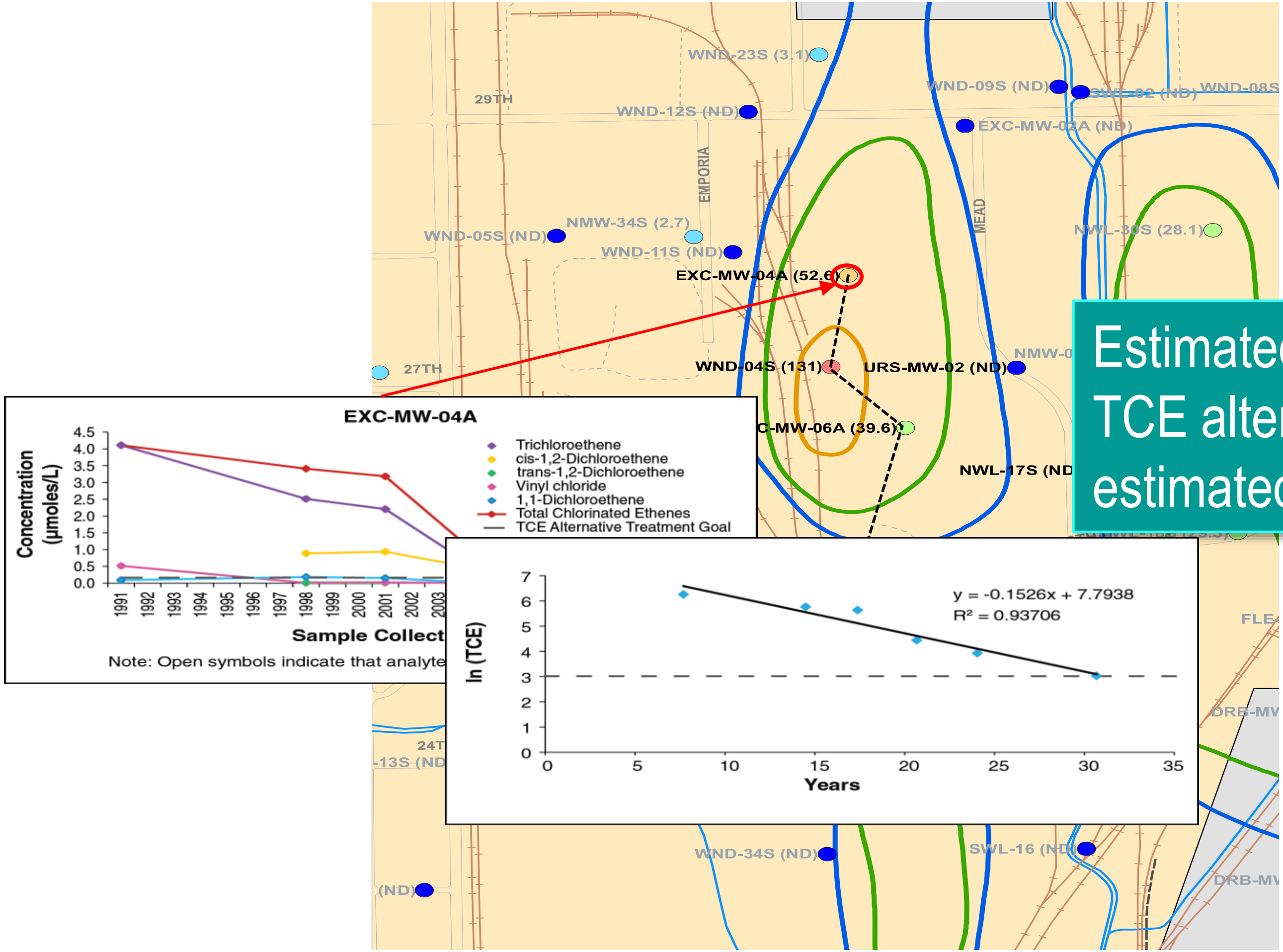
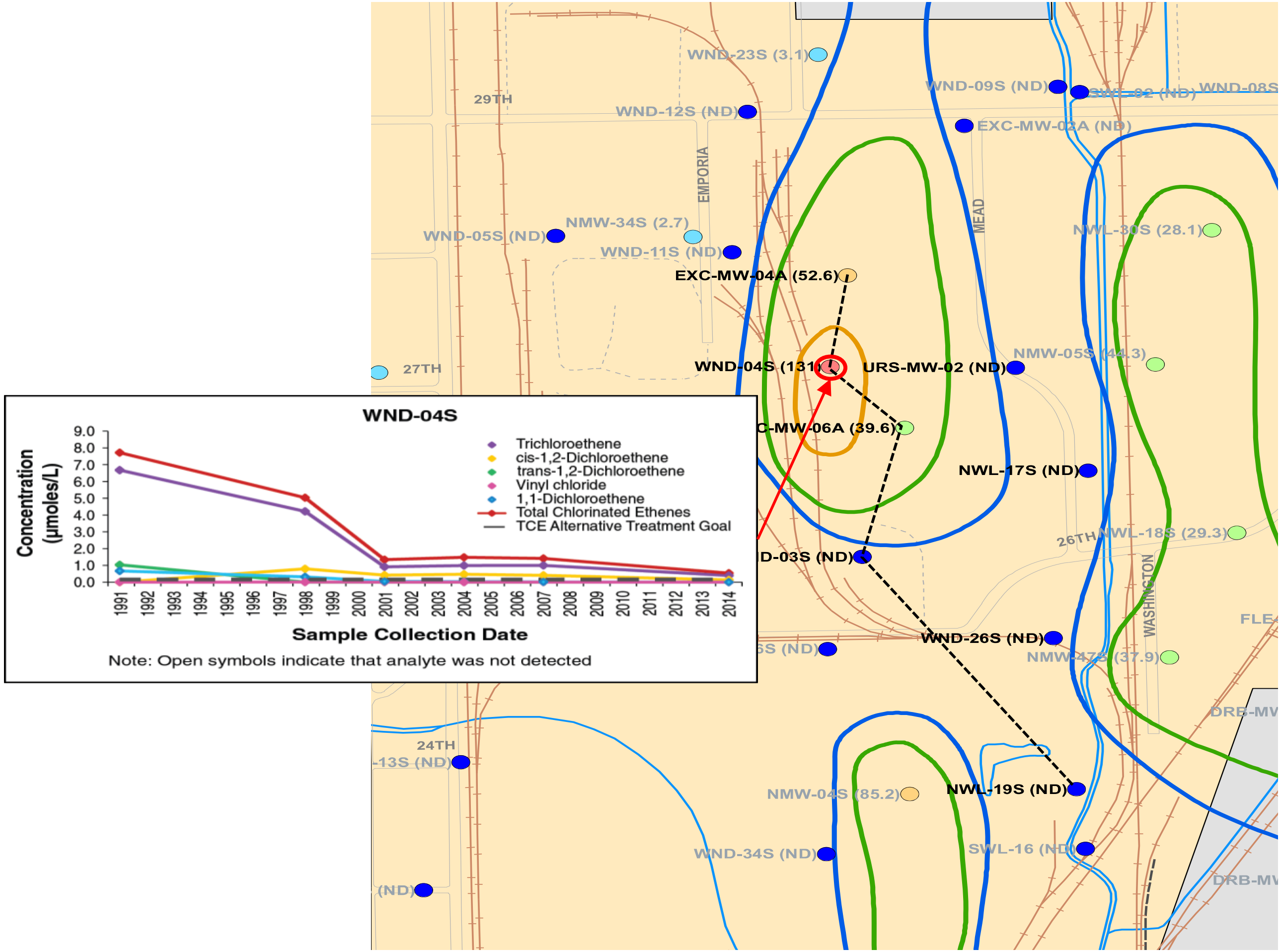


Estimated half-life 5 years;
TCE alternative treatment goal estimated to be reached in 2015



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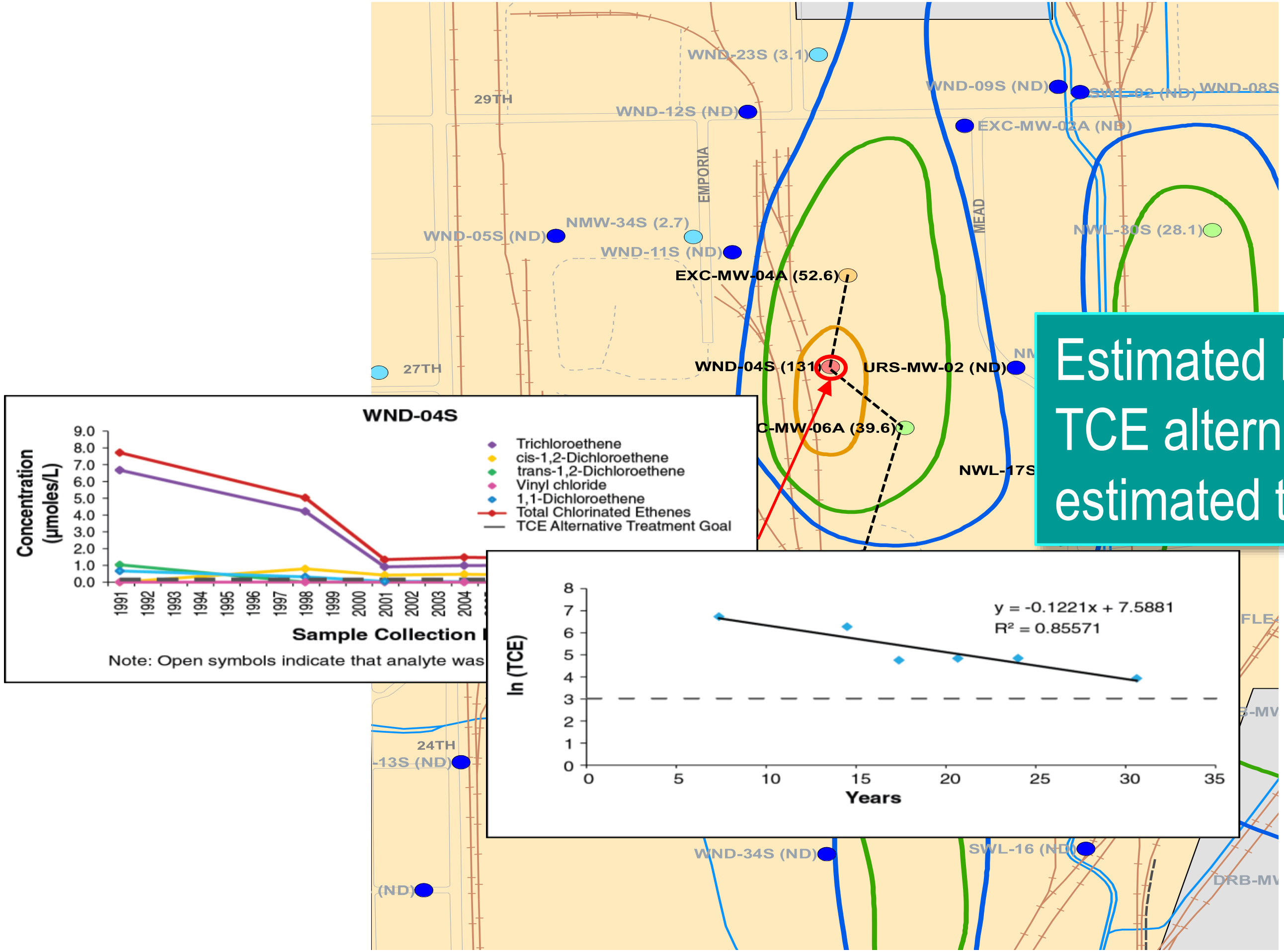


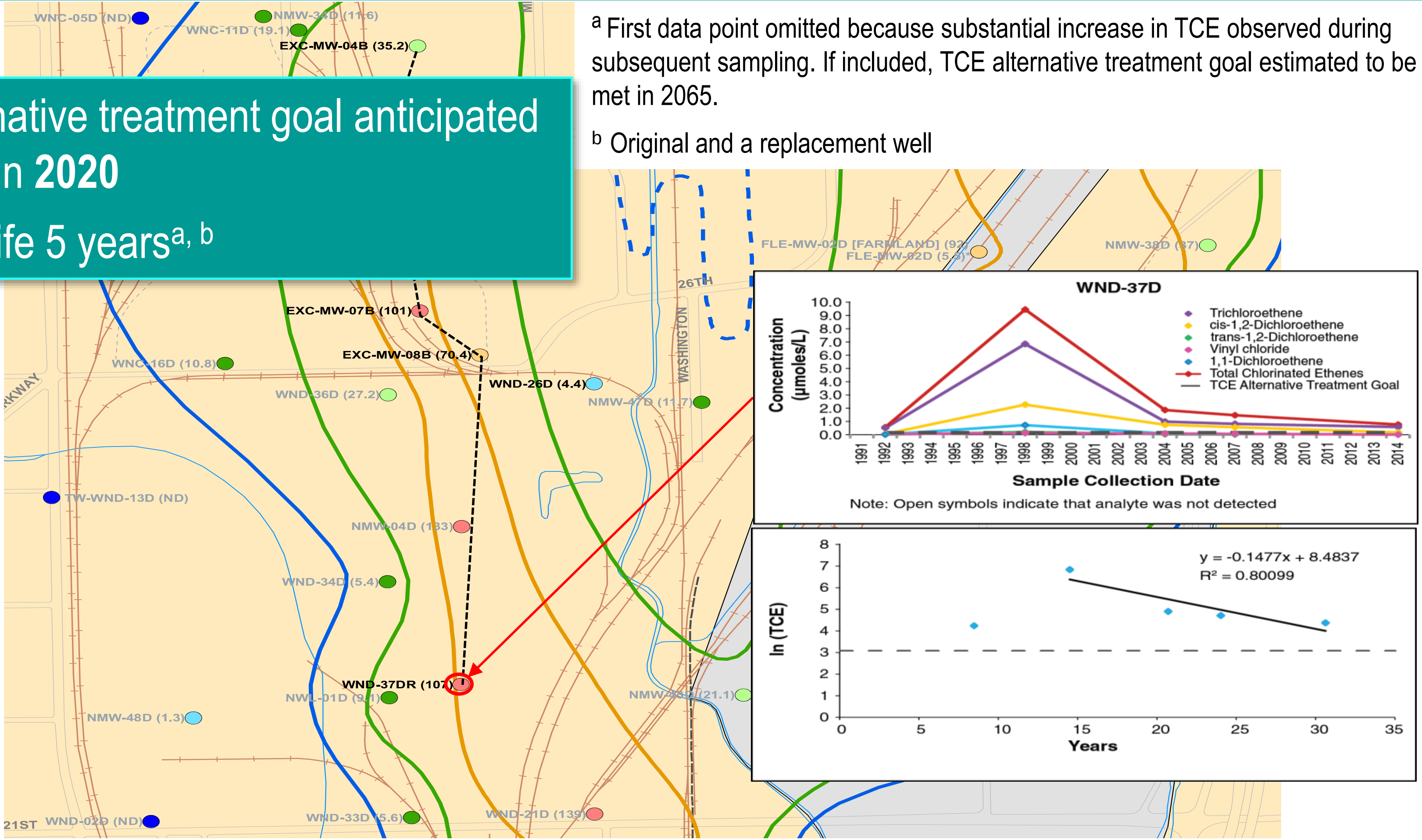
Estimated half-life 6 years;
TCE alternative treatment goal estimated to be reached in 2021

TCE alternative treatment goal anticipated to be met in **2020**

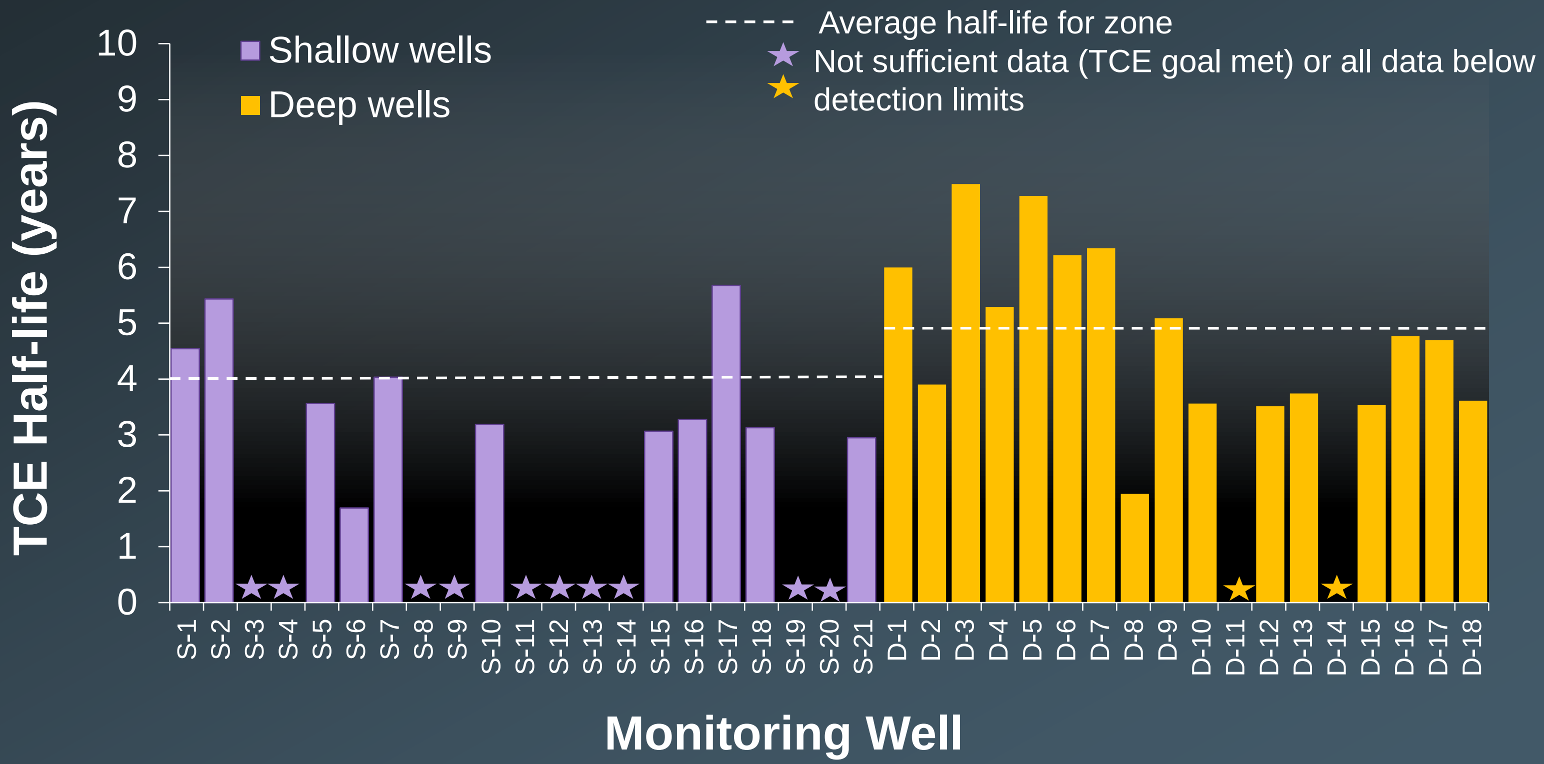
TCE half-life 5 years[a, b]

[a] First data point omitted because substantial increase in TCE observed during subsequent sampling. If included, TCE alternative treatment goal estimated to be met in 2065.

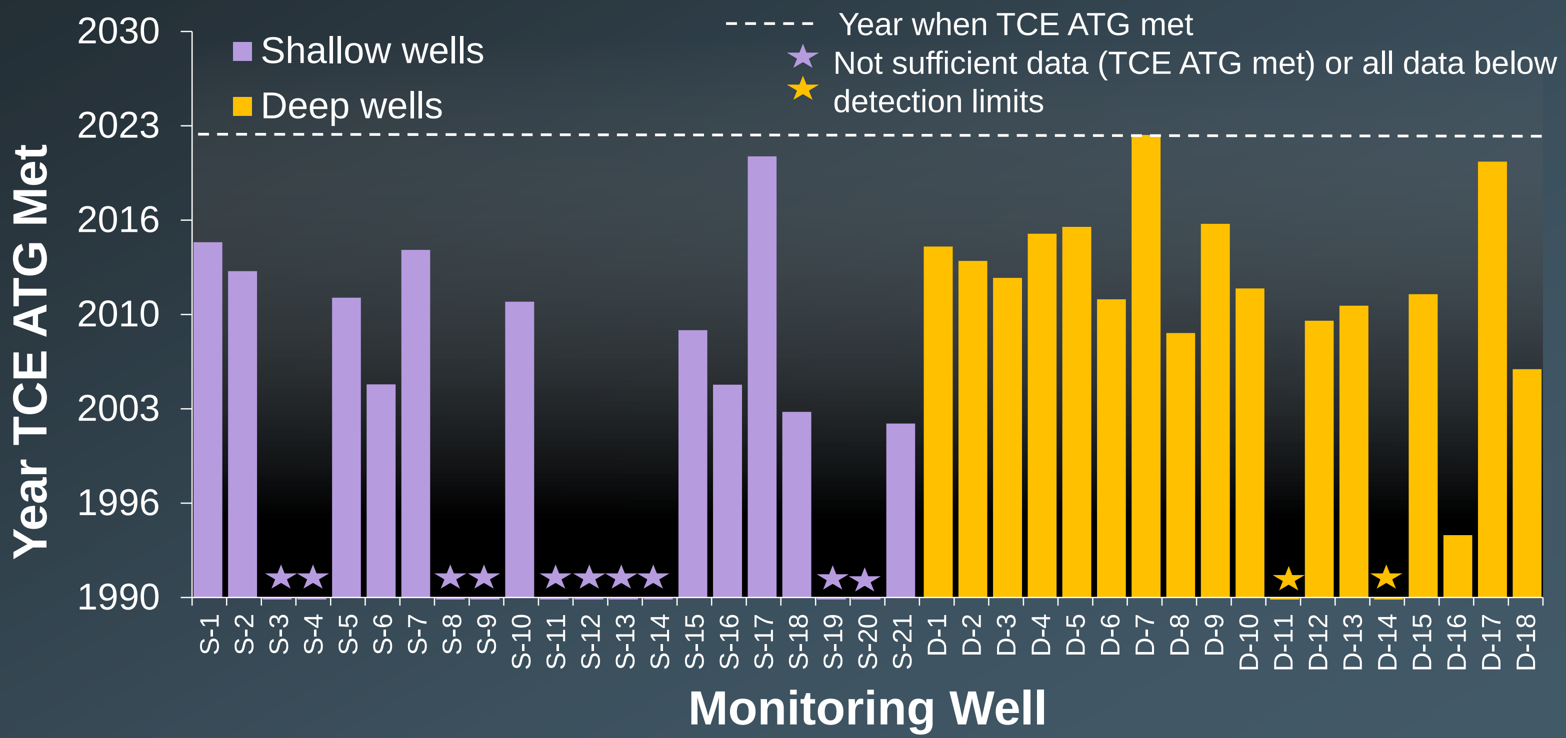
[b] Original and a replacement well



Average TCE Half-Lives 4 and 5 Years for Shallow and Deep Zones, Respectively



TCE Goal in All Wells Predicted to Be Met by 2022



MNA Assessment for G-2

- Evidence of reductive dechlorination observed locally
  - cDCE and VC detected in most wells, at least historically
  - Historically significant levels of cDCE detected in some wells
  - TCE and cDCE attenuates without accumulation of VC
- Observed TCE attenuation rates indicate TCE removal
  - TCE ATG goal predicted to be met around 2022 (based on available site data)
- Multiple mechanisms contribute to the observed attenuation
  - Using the available data, unable to tell which attenuation mechanisms are operable

Summary of Evaluation

- TCE concentrations in G-2 attenuated significantly between 2007 and 2014
- Number of wells above TCE goal reduced from 23 in 2007 to 9 in 2014
- Attenuation of total chlorinated ethenes (TCE, cDCE, tDCE, VC) observed in all wells
- Average TCE half-lives are 4 and 5 years for shallow and deep zones, respectively
- Regardless of the attenuation mechanism, and their relative contributions, natural attenuation is demonstrably occurring in G-2
- Trends predict that TCE ATG will be met by 2022 in G-2

Findings

- MNA is likely to be more readily and efficiently implemented, on a shorter schedule, at a significantly lower cost than groundwater extraction and treatment to meet TCE cleanup goals for G-2
- As compared to pump and treat, MNA has smaller carbon footprint, does not consume power, require treatment, nor produce effluent

Thank You!

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