Innovative Approach to Determine the Rate of Abiotic Degradation of TCE in a Large Diffuse Plume

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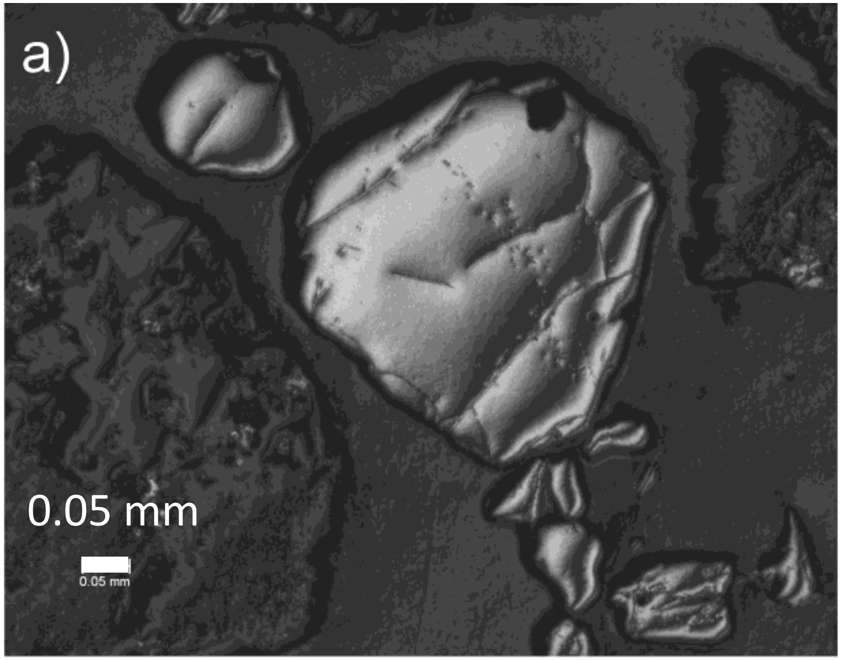
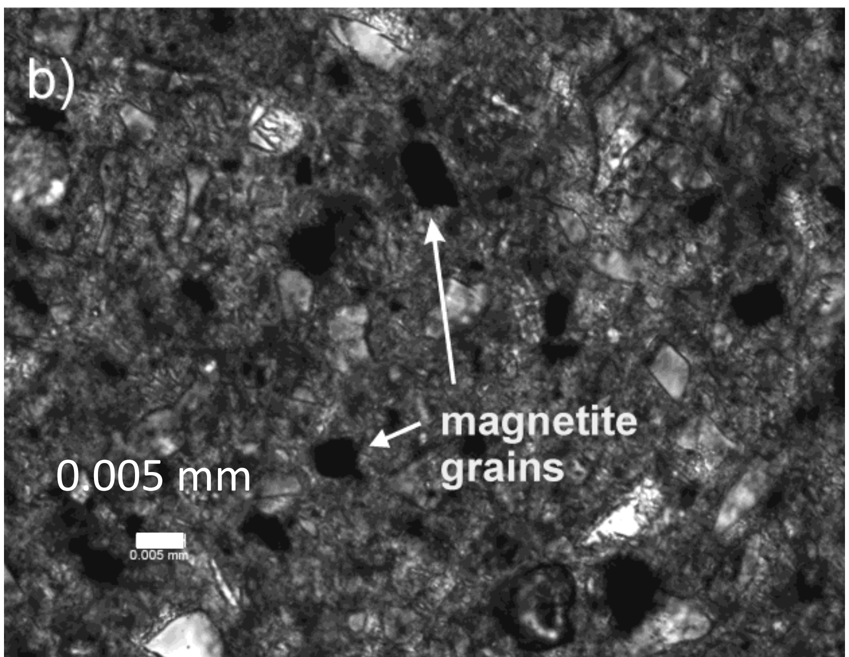
The Fourth International Symposium on Bioremediation and Sustainable Environmental Technologies (Miami, Florida; May 24 2017).

Magnetite in Aquifer Sediment can Degrade TCE

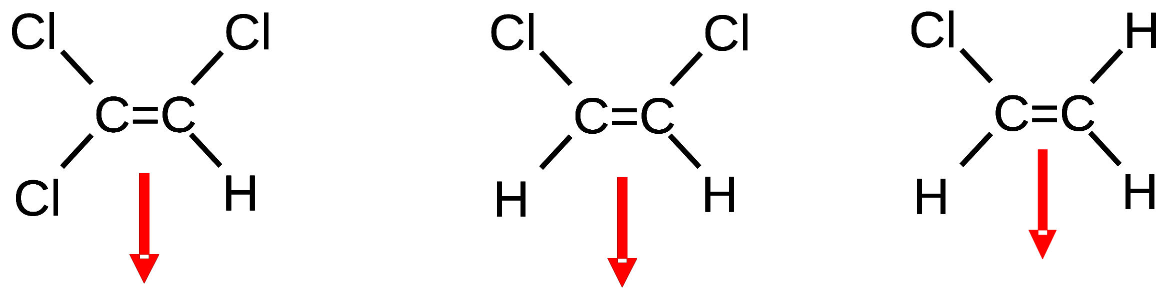




Much of the magnetite is of clay size.

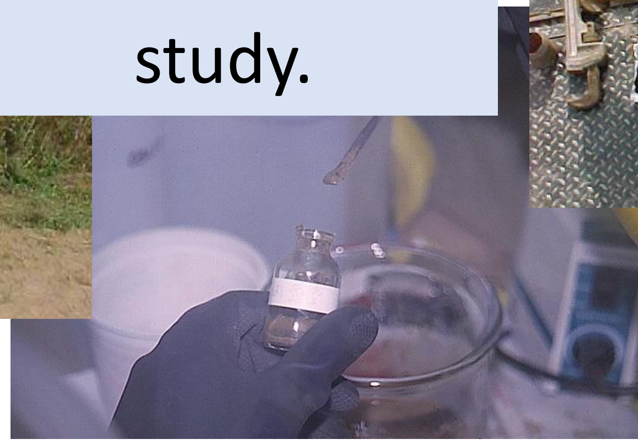
Has high specific surface area.

Abiotic Degradation Carried out by Magnetite



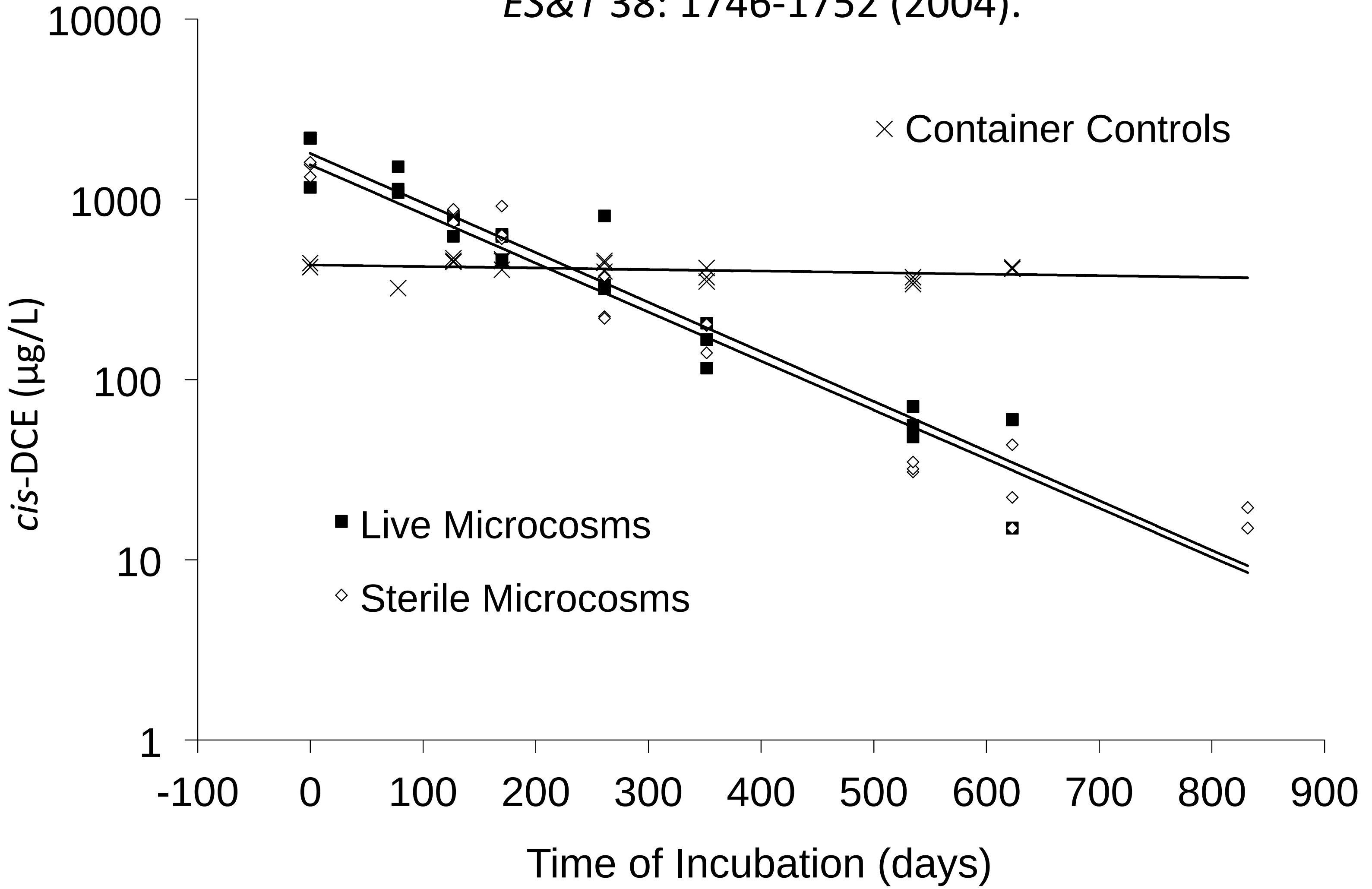
CO_2 and other oxidized products

How fast is this happening?
Do a microcosm study.



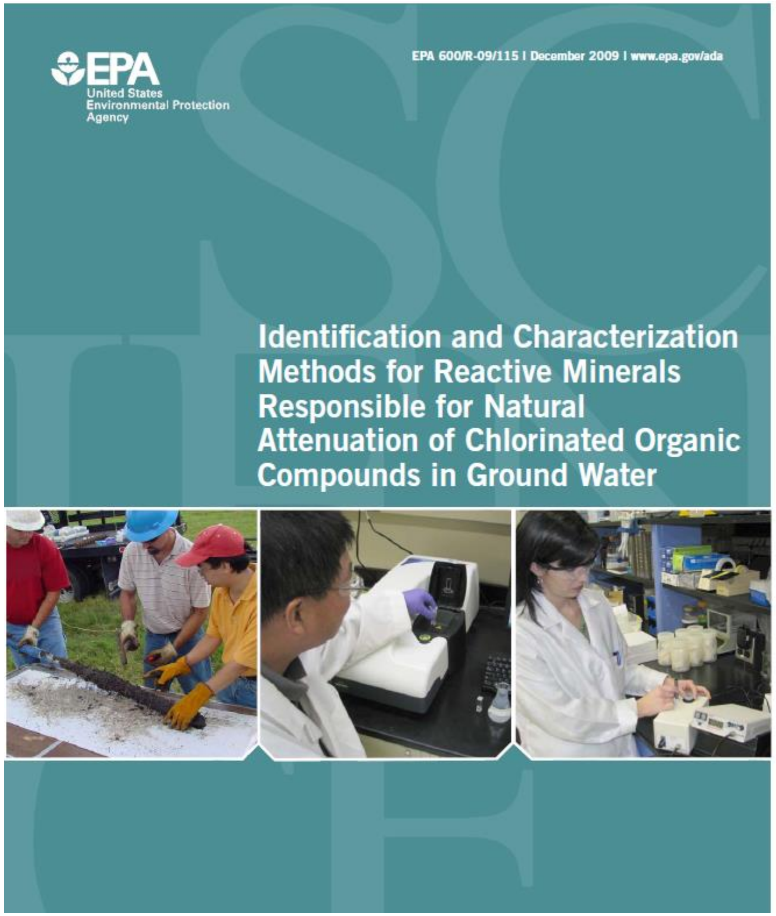
Removal of *cis*-DCE in Sediment from TCAAP Intermediate Depth

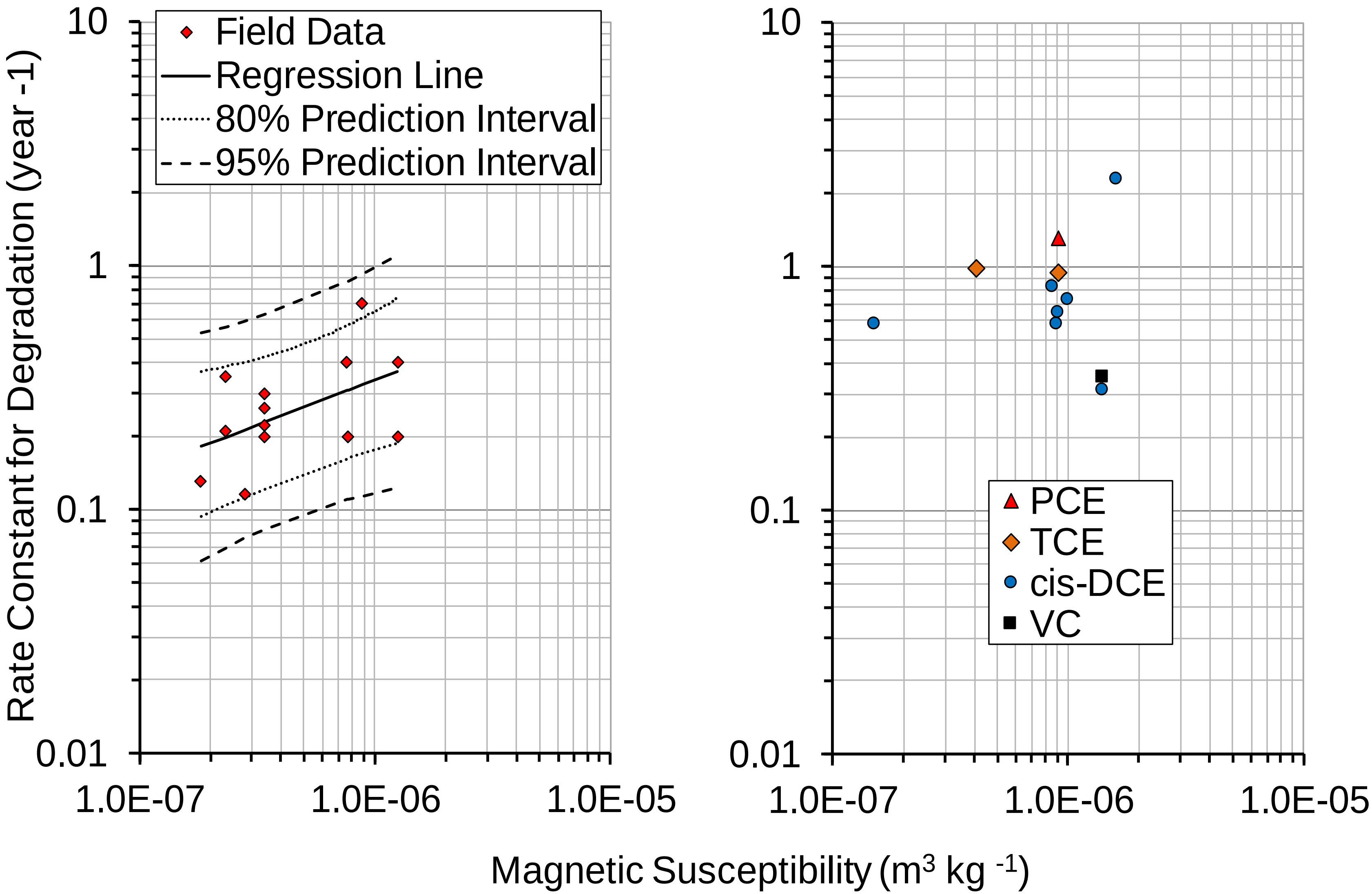
ES&T 38: 1746-1752 (2004).



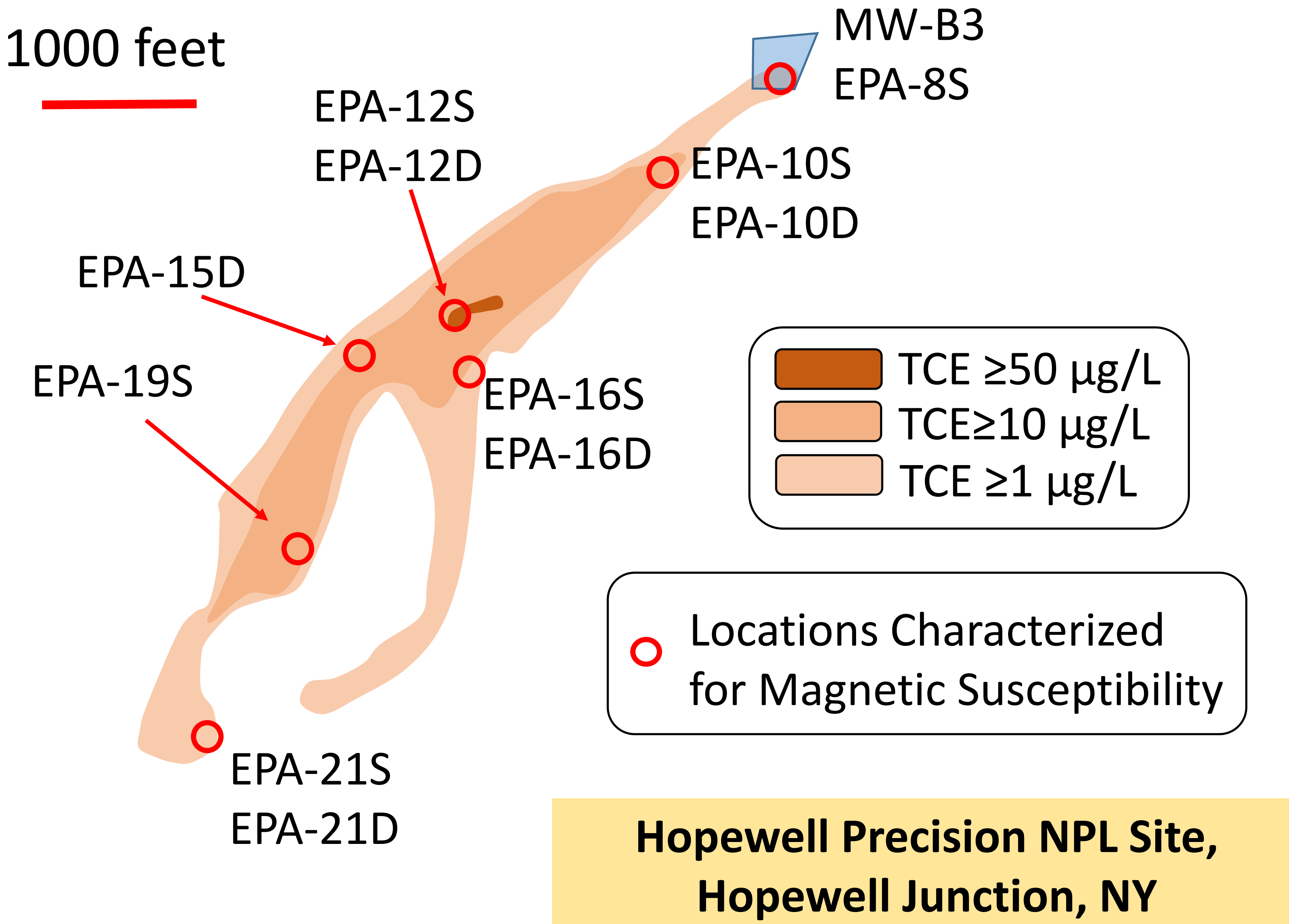
http://www.epa.gov/nrmrl/pubs/600r09115.html

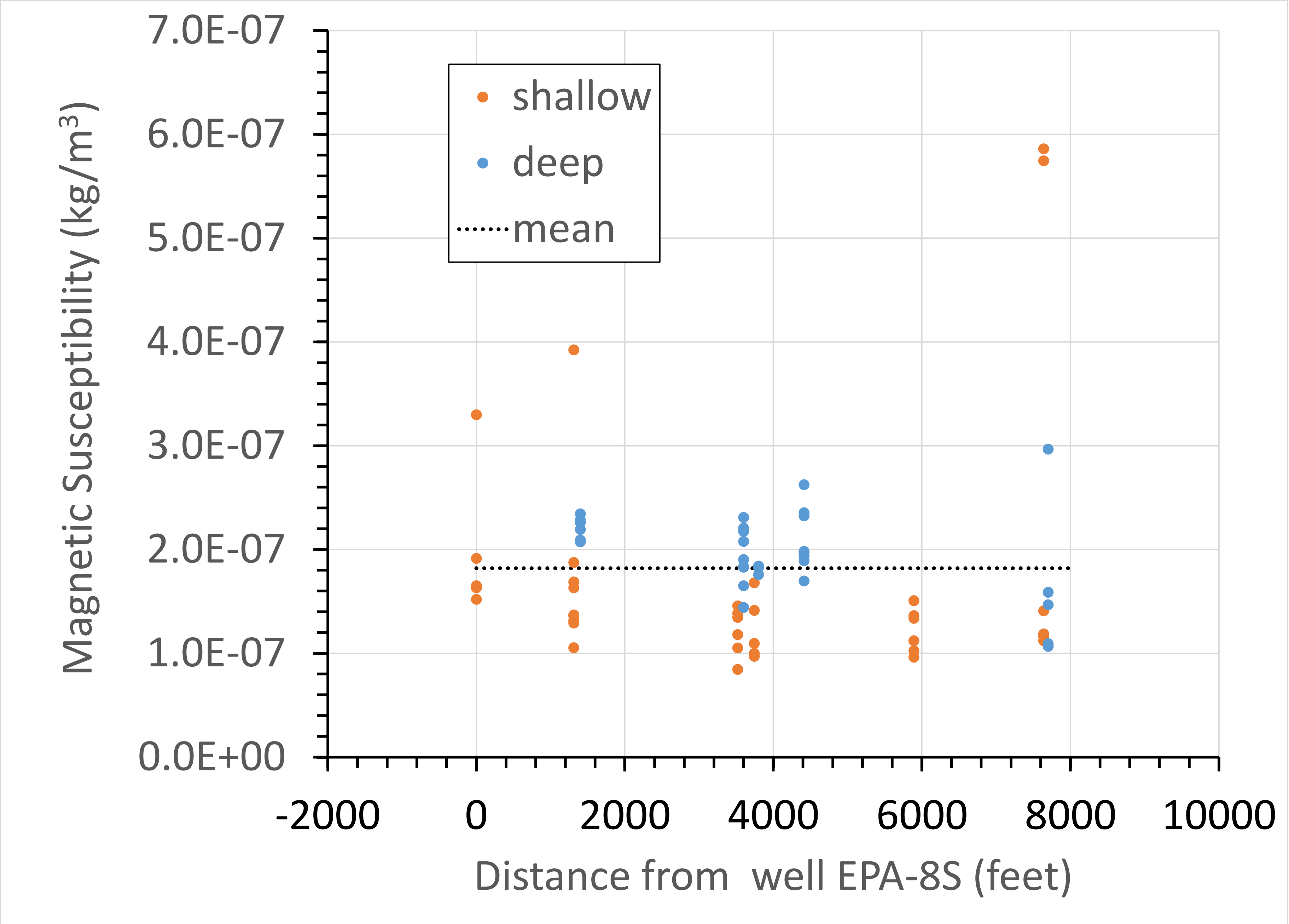
Or Search EPA 600/R-09/115



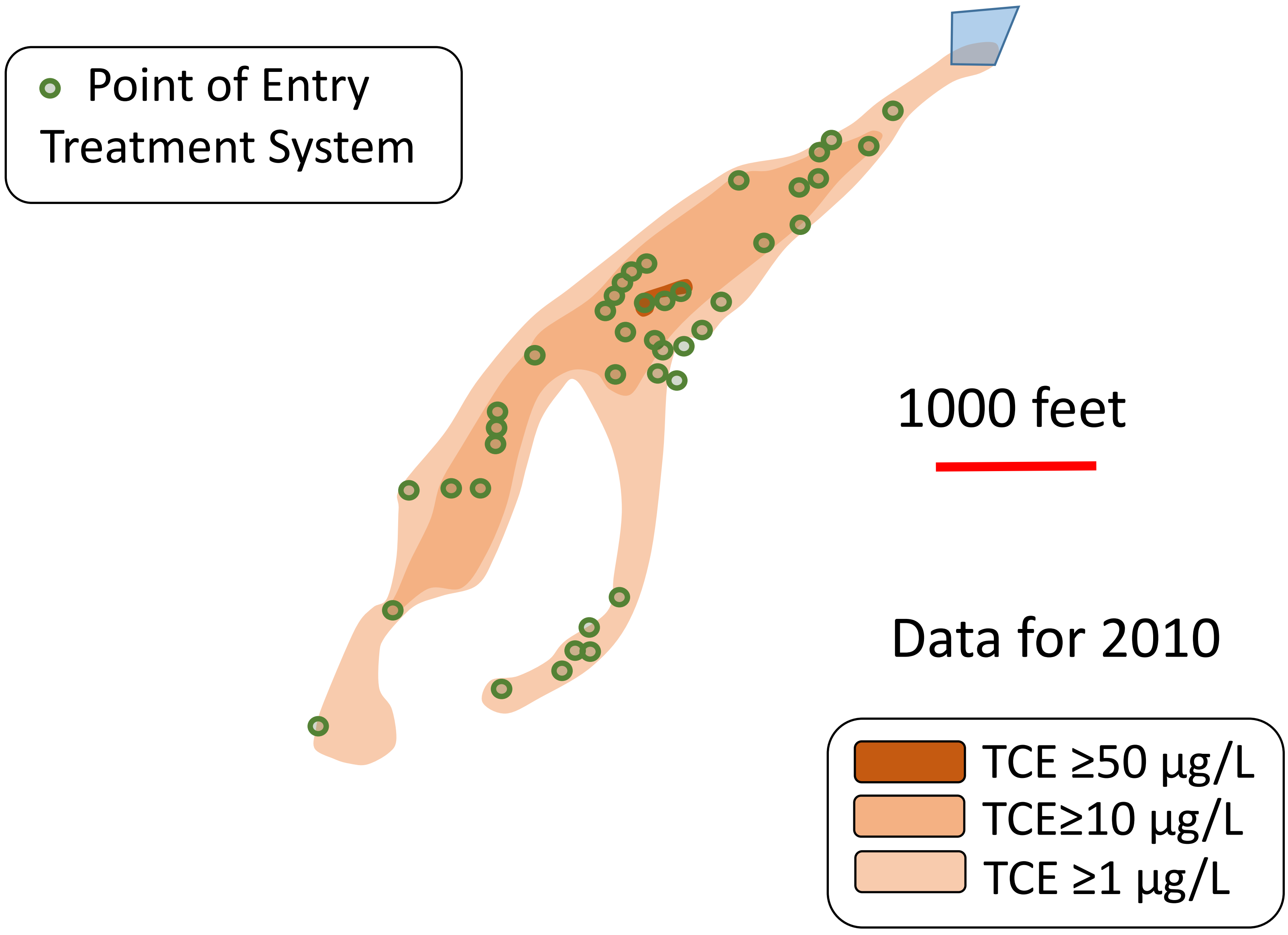


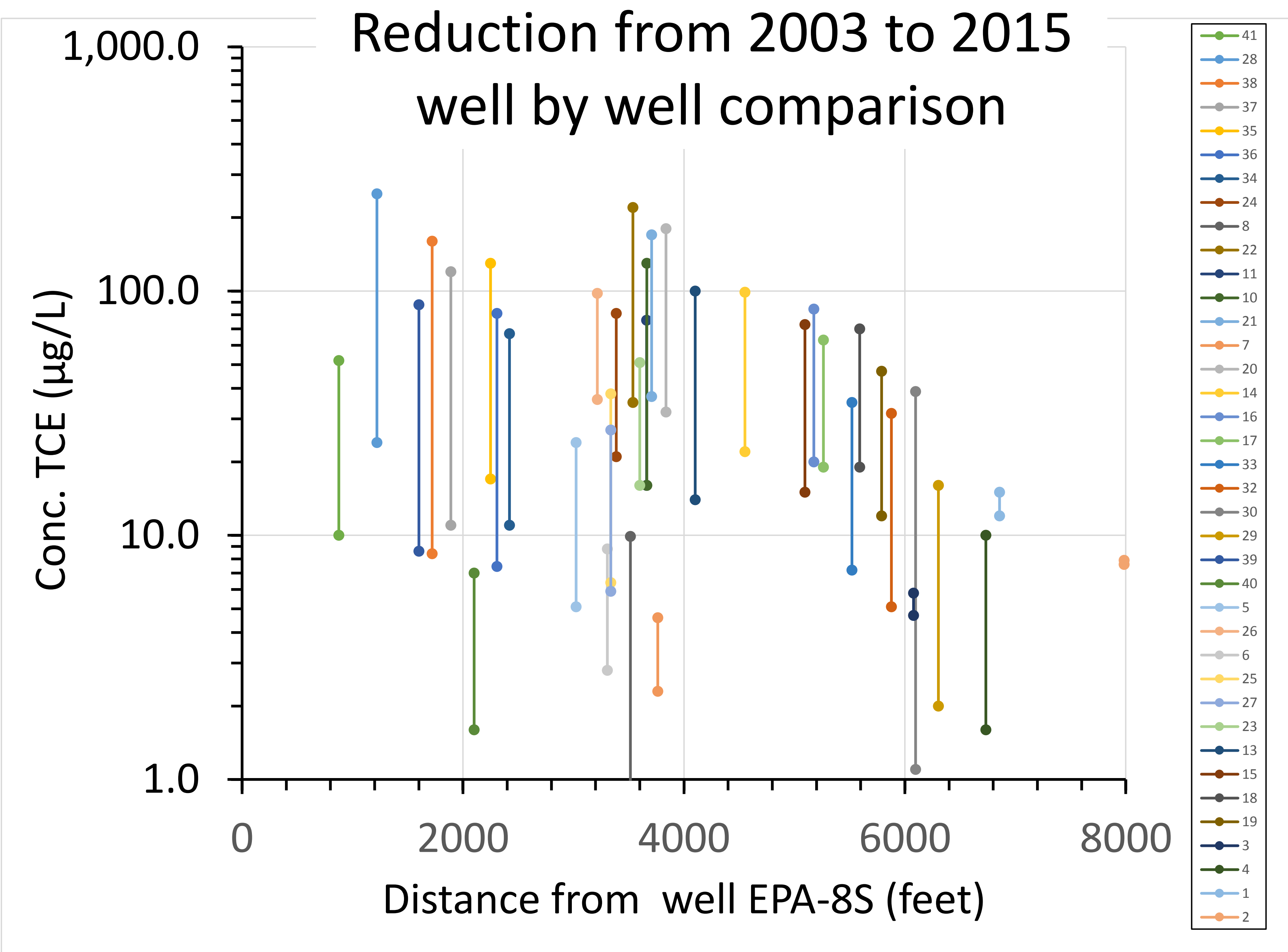
Groundwater Monitoring & Remediation 2017 doi: 10.1111/gwmr.12197


1000 feet
MW-B3
EPA-8S
EPA-12S
EPA-12D
EPA-10S
EPA-10D
EPA-15D
EPA-19S
EPA-16S
EPA-16D
EPA-21S
EPA-21D
TCE ≥50 µg/L
TCE≥10 µg/L
TCE ≥1 µg/L
Locations Characterized for Magnetic Susceptibility
Hopewell Precision NPL Site,
Hopewell Junction, NY



7.0E-07
6.0E-07
5.0E-07
4.0E-07
3.0E-07
2.0E-07
1.0E-07
0.0E+00
Magnetic Susceptibility (kg/m³)
shallow
deep
mean
-2000
0
2000
4000
6000
8000
10000
Distance from well EPA-8S (feet)


Point of Entry
Treatment System
1000 feet
Data for 2010
TCE ≥50 µg/L
TCE≥10 µg/L
TCE ≥1 µg/L

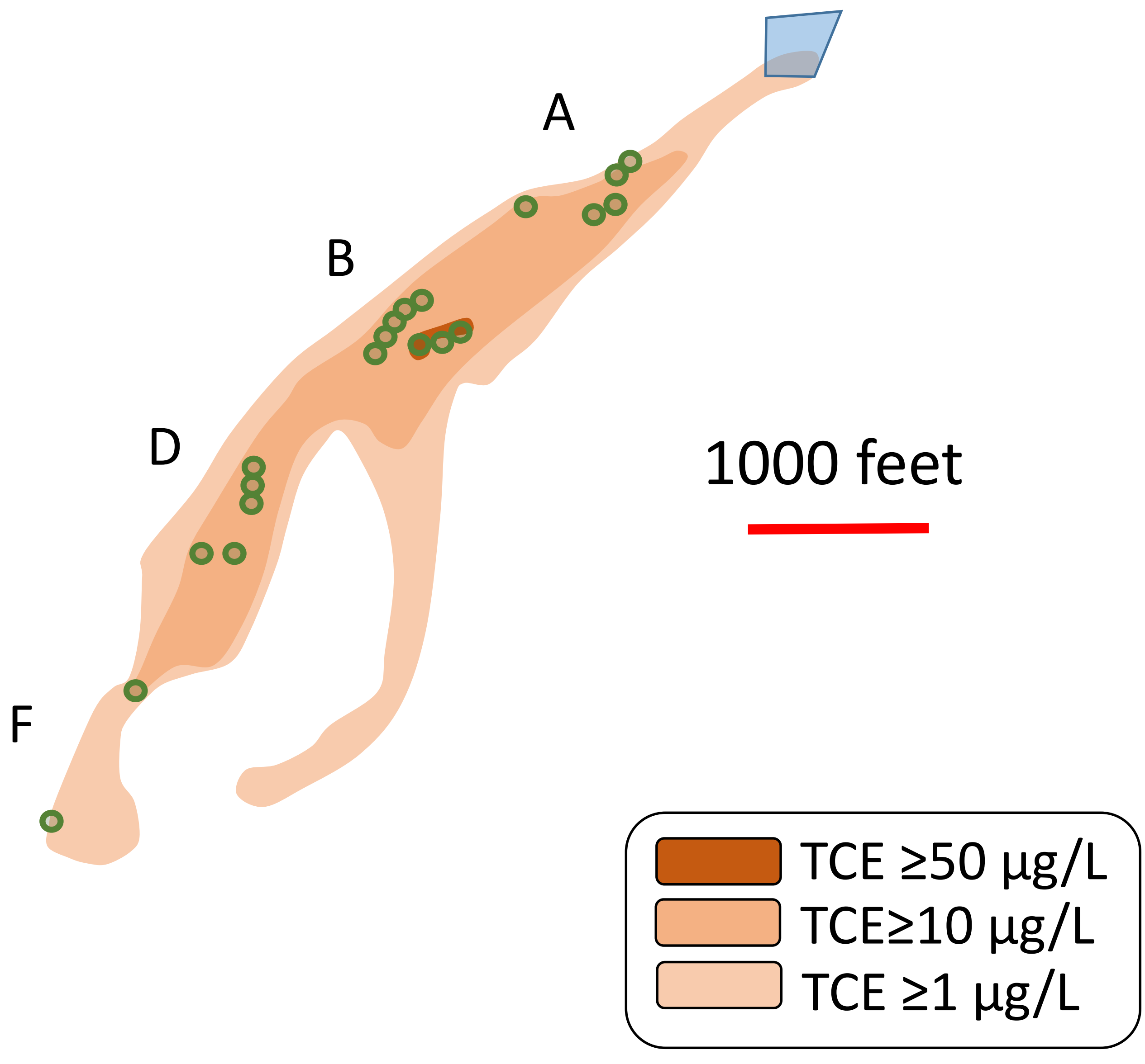


Reduction from 2003 to 2015
well by well comparison
Conc. TCE (µg/L)
1,000.0
100.0
10.0
1.0
0
2000
4000
6000
8000
Distance from well EPA-8S (feet)
41
28
38
37
35
36
34
24
8
22
11
10
21
7
20
14
16
17
33
32
30
29
39
40
5
26
6
25
27
23
13
15
18
19
3
4
1
2

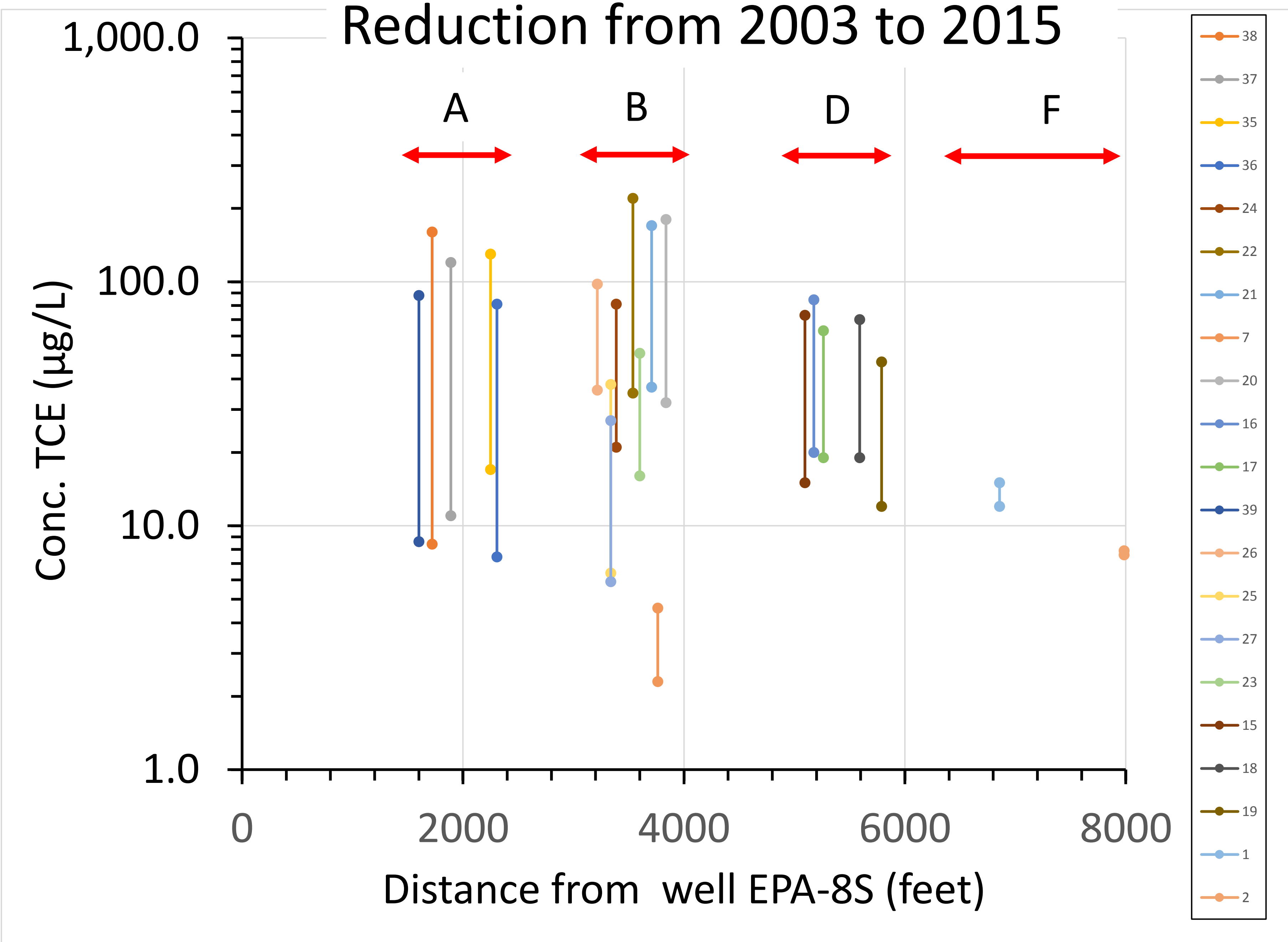
The average first order rate constant for attenuation over time in the POET wells is-

0.17 per year, ± 0.027 per year at 95% confidence.

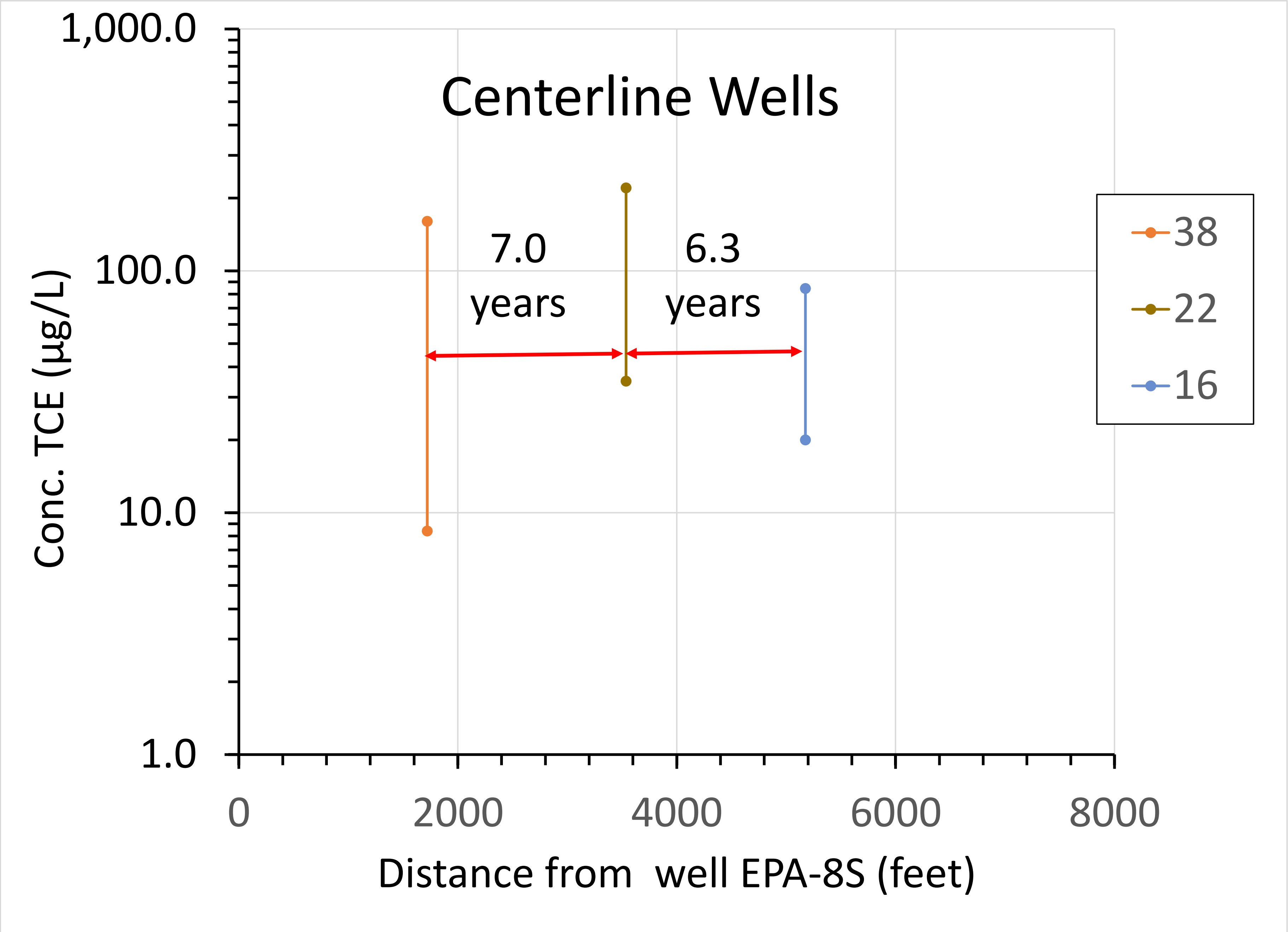
This rate constant is most sensitive to the rate of attenuation of the source.



A
B
D
F
1000 feet
TCE ≥50 µg/L
TCE≥10 µg/L
TCE ≥1 µg/L



Reduction from 2003 to 2015
1,000.0
100.0
10.0
1.0
Conc. TCE (µg/L)
A
B
D
F
0
2000
4000
6000
8000
Distance from well EPA-8S (feet)
38
37
35
36
24
22
21
7
20
16
17
39
26
25
27
23
15
18
19
1
2

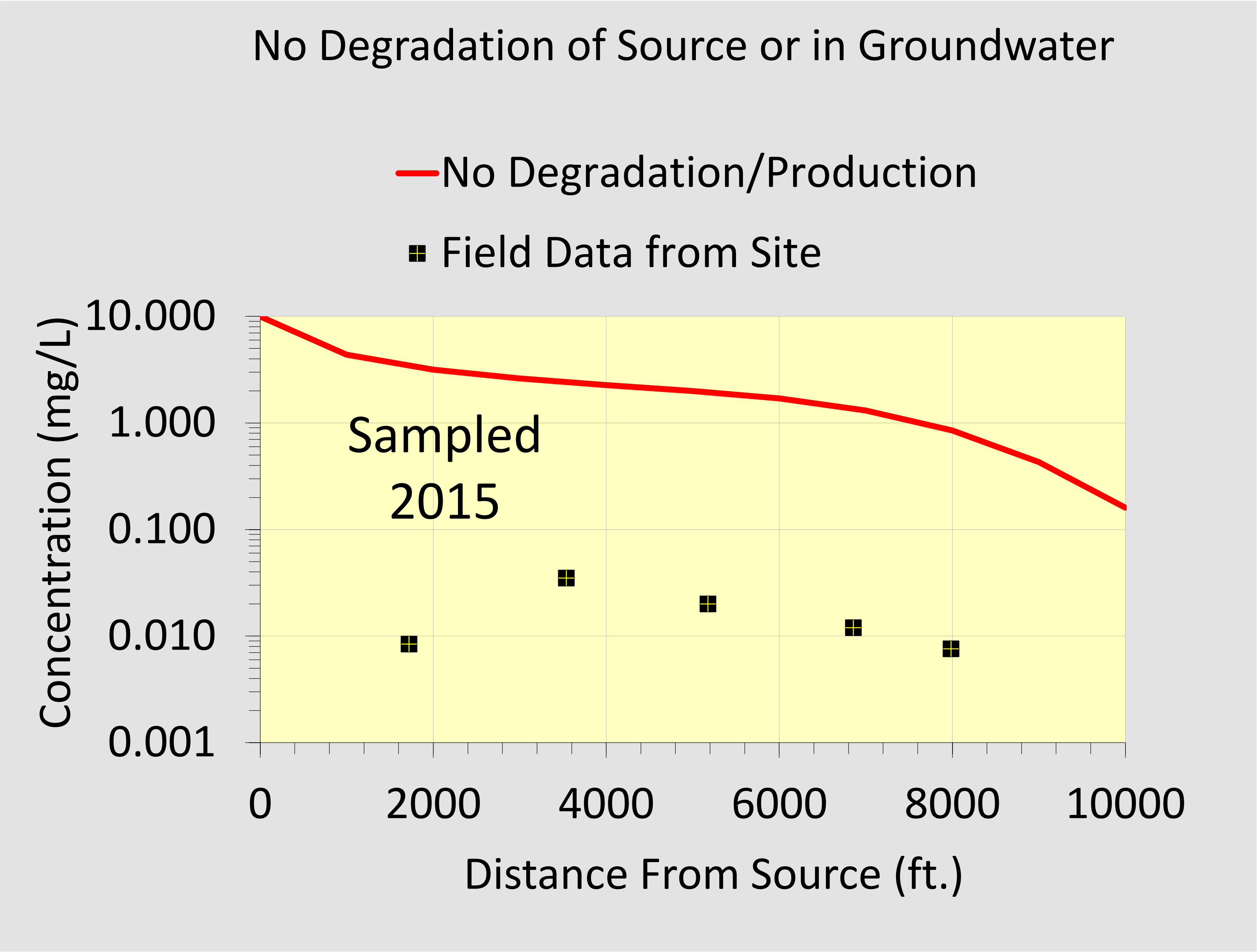

Centerline Wells
1,000.0
100.0
10.0
1.0
Conc. TCE (µg/L)
7.0
years
6.3
years
38
22
16
0
2000
4000
6000
8000
Distance from well EPA-8S (feet)

Up Gradient			Down Gradient			Travel Time	Rate Constant
Well	Date	(µg/L)	Well	Date	(µg/L)	years	per year
38	Jun-03	94.7	22	Jun-10	46.0	7.0	-0.103
38	Jun-04	52.7	22	Jun-11	38.5	7.0	-0.045
38	Jun-05	56.0	22	Jun-12	35.0	7.0	-0.067
38	Jun-06	48.3	22	Jun-13	42.0	7.0	-0.020
38	Jun-07	31.3	22	Jun-14	33.5	7.0	0.010
38	Jun-08	30.7	22	Mar-15	35.0	7.0	0.019
22	Jun-03	166.7	16	Jun-09	31.0	6.3	-0.267
22	Jun-04	101.3	16	Jun-10	31.0	6.3	-0.188
22	Jun-05	96.0	16	Jun-11	24.5	6.3	-0.217
22	Jun-06	81.8	16	Jun-12	20.0	6.3	-0.224
22	Jun-07	73.3	16	Jun-13	23.0	6.3	-0.184
22	Jun-08	69.0	16	Jun-14	18.0	6.3	-0.213
22	Jun-09	64.0	16	Mar-15	20.0	6.3	-0.185

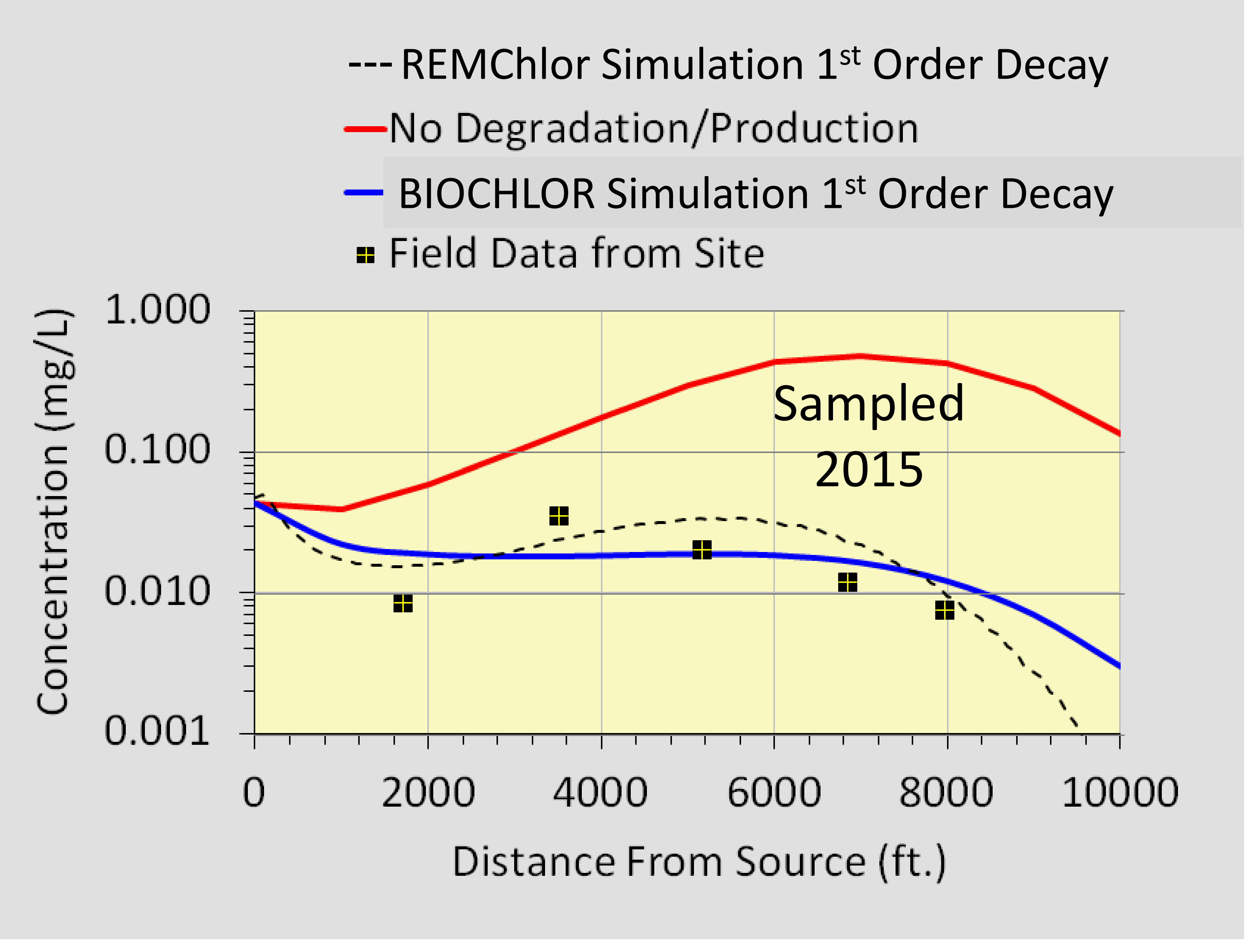
The first order rate constant for attenuation along the flow path is-

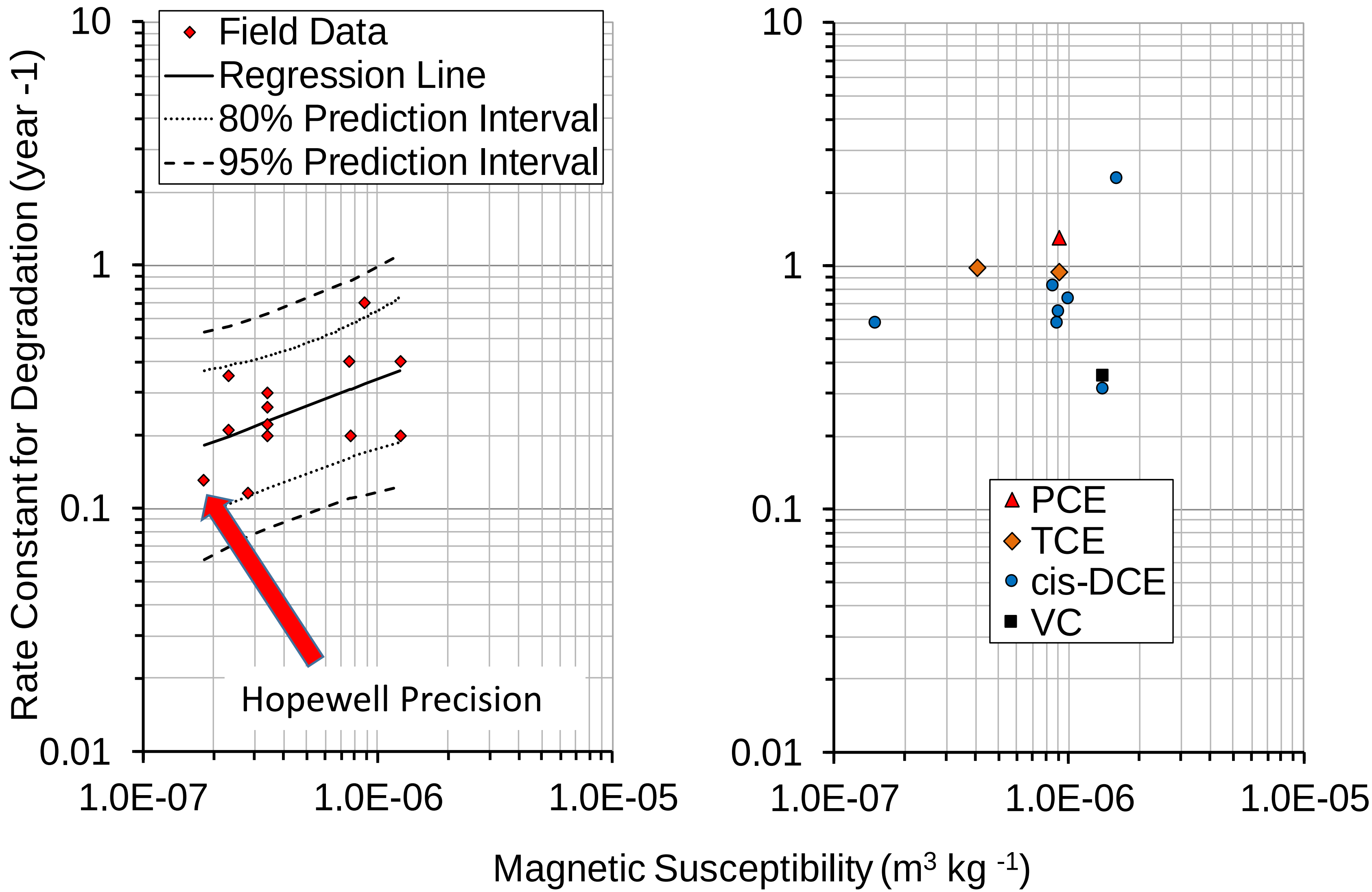
0.13 per year, ± 0.060 per year at 95% confidence.

This rate constant is sensitive to natural degradation processes in the ground water.



No Degradation of Source or in Groundwater
No Degradation/Production
Field Data from Site
Concentration (mg/L)
10.000
1.000
0.100
0.010
0.001
Sampled 2015
0
2000
4000
6000
8000
10000
Distance From Source (ft.)


--- REMChlor Simulation 1st Order Decay
No Degradation/Production
BIOCHLOR Simulation 1st Order Decay
Field Data from Site
Sampled 2015
Concentration (mg/L)
1.000
0.100
0.010
0.001
0
2000
4000
6000
8000
10000
Distance From Source (ft.)



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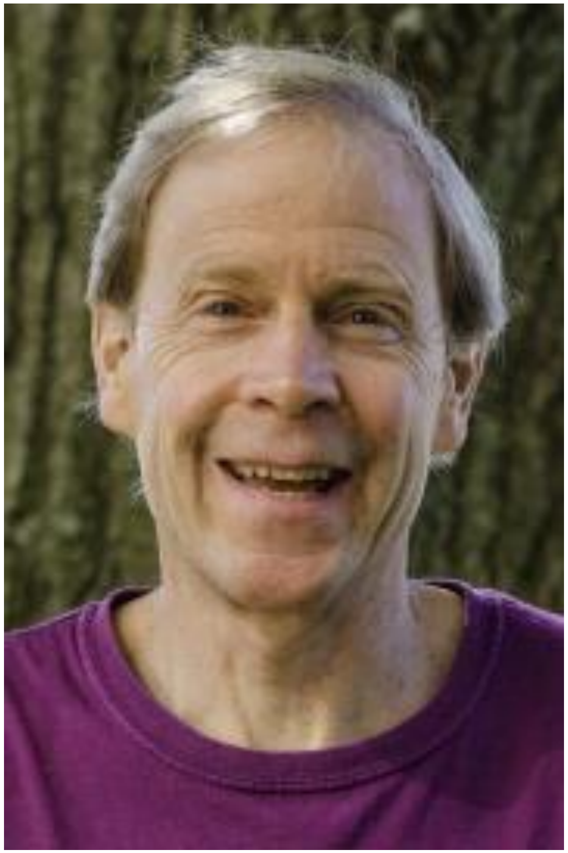
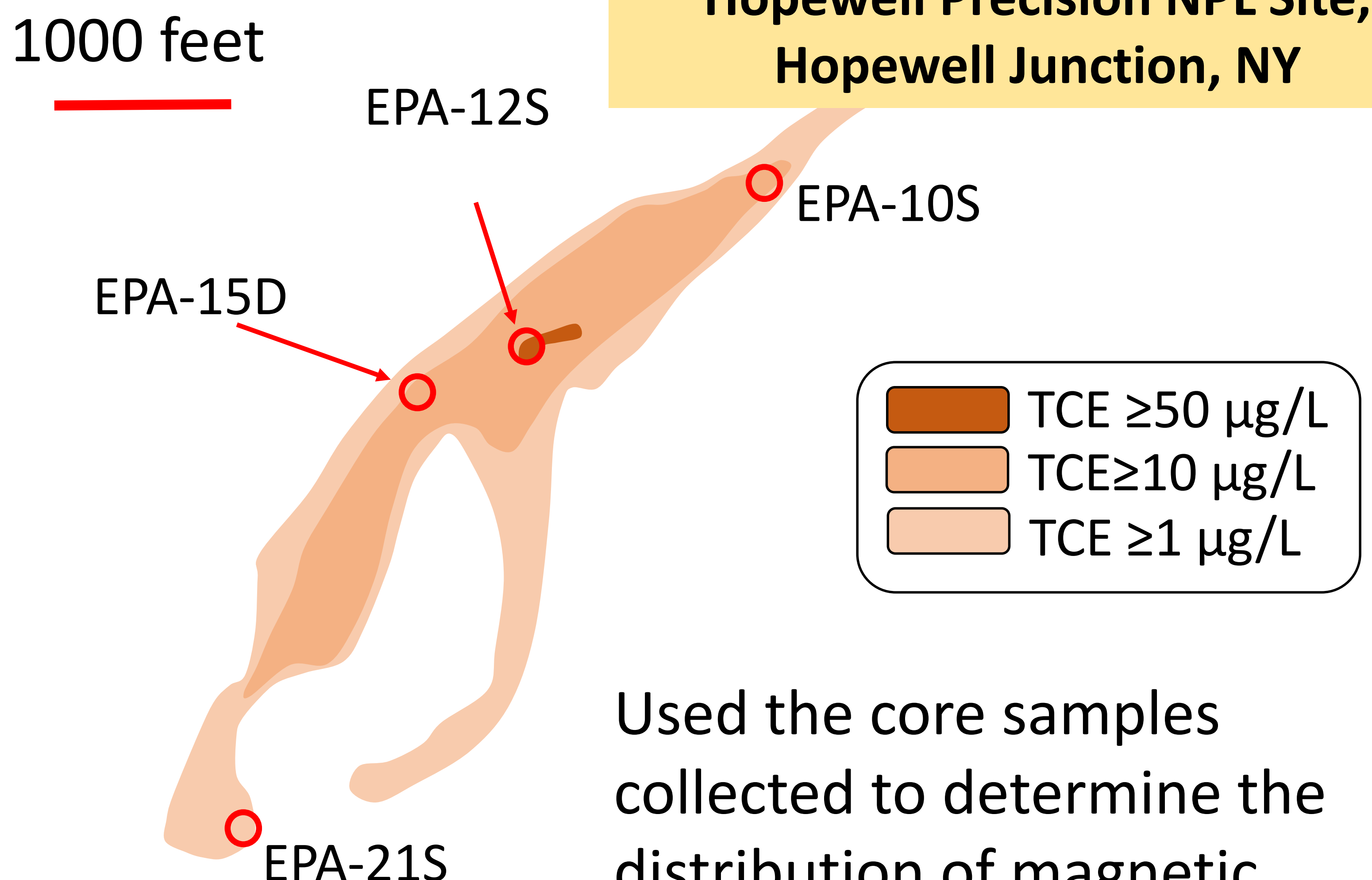


Eugene Madsen
Department of Microbiology
Cornell University-

pointed out that all we had was calibrations with models.

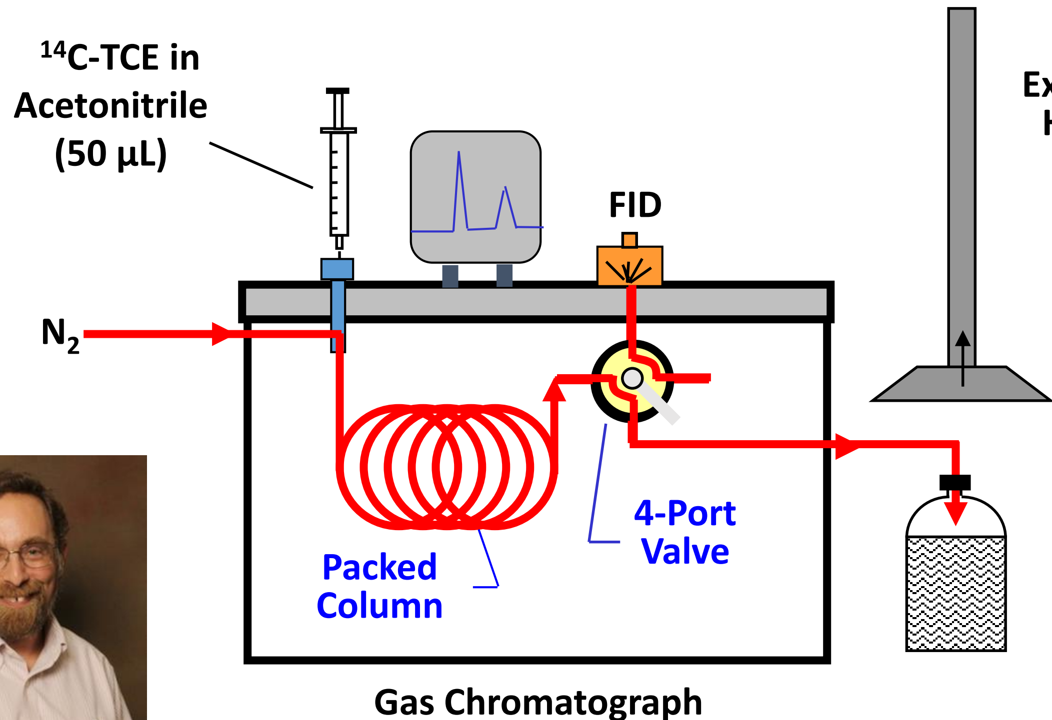
There was no direct information to show that TCE was actually being degraded.

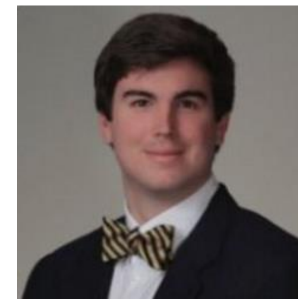
Hopewell Precision NPL Site, Hopewell Junction, NY



Used the core samples collected to determine the distribution of magnetic susceptibility to conduct a ^{14}C assay of TCE degradation.

Clemson Approach: Abiotic Degradation Using ^{14}C-TCE





Serum bottle with FSGW control or FSGW plus sediment

~315 µg/L TCE added along with ~1.1 x 10^6 dpm ^{14}C

Periodically, a small aliquot (3 mL) is taken from the microcosm containing 92 mL of liquid.

The pH of the aliquot is adjusted with base.

The TCE is purged out of the water with a stream of nitrogen.

Then the remaining ^{14}C activity is determined using liquid scintillation counting.

The accumulation of ^{14}C over time is assumed to be degradation products of the TCE.

Lessons Learned

The decay of ^{14}C TCE produces ionizing radiation that causes radiolysis of TCE in addition to the abiotic degradation.

Do a control with groundwater from the site. The control should be filter sterilized to preclude biological cooxididation.

Calculate a net rate of abiotic degradation corrected for radiolysis.

Lessons Learned

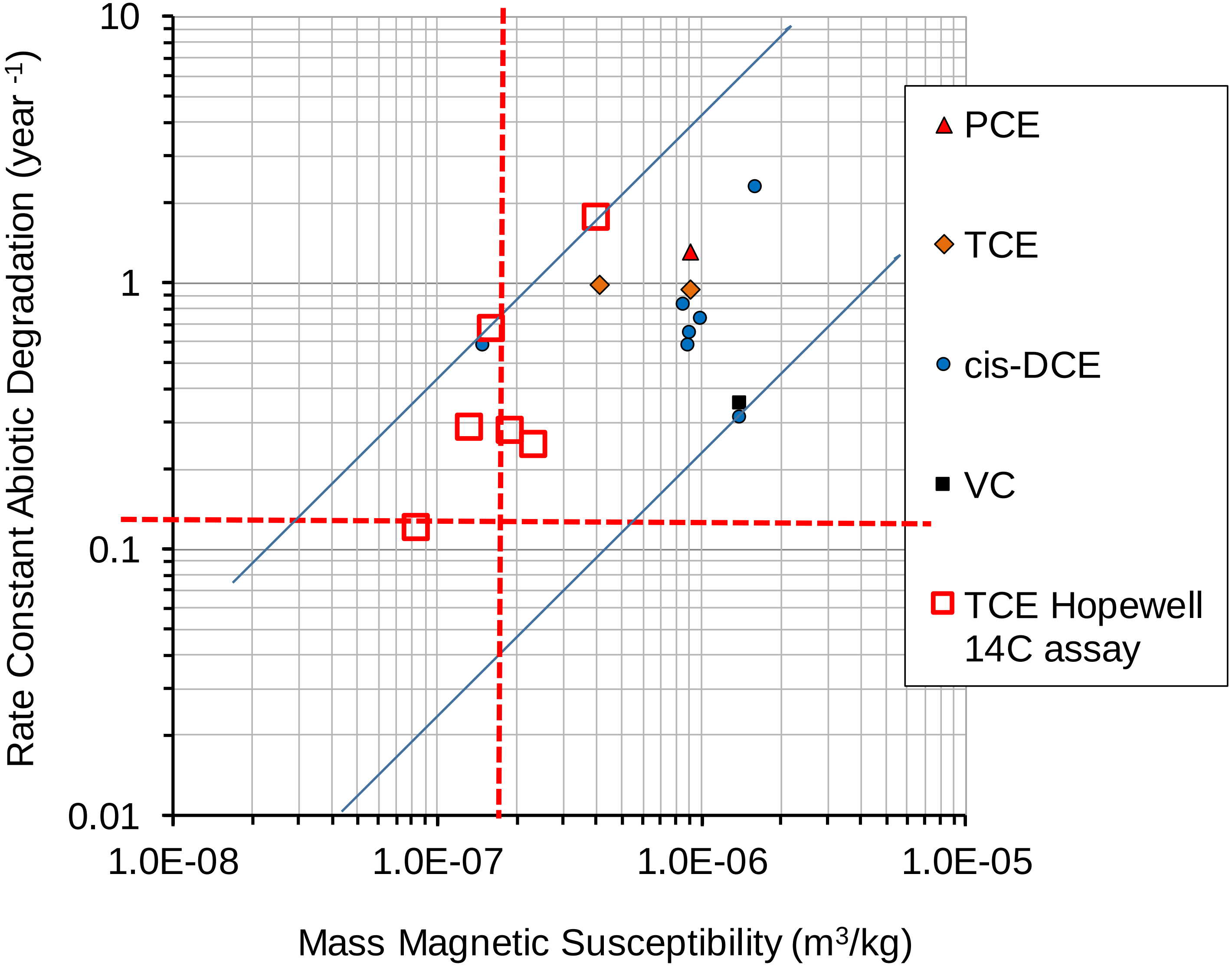
TCE can sorb to suspended solids, and the sorbed TCE is not purged and is interpreted as degradation products.

Count the ^{14}C label after purging a alkaline solution.

Then acidify, purge, and count the label again.

The difference is $^{14}C\text{-}CO_2$ produced from abiotic degradation of TCE.

Use the accumulation of label in $^{14}C\text{-}CO_2$ to calculate the rate of abiotic degradation.


10
1
0.1
0.01
1.0E-08
1.0E-07
1.0E-06
1.0E-05
Rate Constant Abiotic Degradation (year -1)
Mass Magnetic Susceptibility (m3/kg)
PCE
TCE
cis-DCE
VC
TCE Hopewell
14C assay

	k	MMS	k/MMS
	yr^{-1}	$m^3\ kg^{-1}$	$kg\ m^{-3}\ yr^{-1}$
EPA-12S_25-30'_8-19"	0.12	8.4E-08	1.4E+06
EPA-12S_25-30'_19-32"	0.68	1.6E-07	4.2E+06
EPA-21S_15-20'_10-15"	0.29	1.3E-07	2.2E+06
EPA-15D_35-36.5'_0-12"	0.25	2.3E-07	1.1E+06
EPA-15D_27-30'_19-28"	0.28	1.9E-07	1.5E+06
EPA-10S_30-35'_0-1"	1.75	4.0E-07	4.4E+06
Microcosm mean			**2.5E+06**
Microcosm geomean			**2.1E+06**
Field Scale	0.13	1.8E-07	**7.2E+05**