

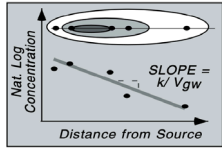
This appendix documents the data and method used to calculate bulk attenuation rate constants consistent with EPA guidance (EPA 2002). The method used is the Concentration versus Distance calculation, relying on 2024 data from wells located at increasing distances away from the highest concentration well in the monitoring network (MW-05), along the general flow path downgradient.

Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies (EPA 2002)

Plot natural log of conc. vs. distance. If the data appear to be first-order, determine the slope of the natural log-transformed data by:

1. Transforming the data by taking natural logs and performing a linear regression on the transformed data, or
2. Plotting the data on a semi-log plot, taking the natural log of the y intercept minus the natural log of the x intercept and dividing by the distance between the two points.

Multiply this slope by the contaminant velocity (seepage velocity divided by the retardation factor R) to get *k*.



Well	Distance along flow path	Average of 2023 Concentrations			
		PCE	TCE	cis-1,2-DCE	vinyl chloride
MW-05	76	240	36	920	130
MW-06	248	150	23	45	0
MW-03	483	4	6	57	4
MW-11	808	0.6	0.5	26.0	7.6
T451MW-035	1320	0.0330	0.0300	0.0200	0.0200
Slope of linear trendline (per foot)		-0.0075	-0.006	-0.0075	-0.0048
Groundwater seepage velocity (ft/day)		0.31	0.31	0.31	0.31
Retardation factor		4.05	1.93	1.90	1.21
Contaminant seepage velocity (ft/day)		0.077	0.162	0.165	0.258
Bulk Attenuation Rate (per day)		0.0006	0.0005	0.0006	0.0004
Bulk Attenuation Rate (per year)		<b>0.21</b>	<b>0.17</b>	<b>0.21</b>	<b>0.14</b>

Calculation of groundwater velocity:  $v = K \times \frac{i}{n}$

Hydraulic Conductivity, K	12.5	ft/day	Jacobs, 2021
Hydraulic Gradient, i	0.005	ft/ft	Jacobs, 2021
Effective Porosity, n	0.2	(-)	Jacobs, 2021
Groundwater Velocity, v	0.31	ft/day	

Calculation of Retardation Factors:  $Retardation\ Factor = 1 + \frac{\rho_{soil} \times K_{oc} \times f_{oc}}{n}$

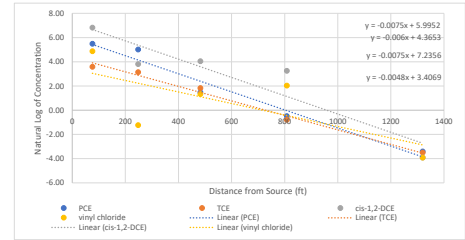
Effective Porosity, n	0.2	(-)	Jacobs, 2021
Soil Bulk Density, $\rho_{soil}$	1.7	(kg/L)	CH2M HILL, 2005
Fraction Organic Carbon, $f_{oc}$	0.000843	(-)	CH2M HILL, 2005

Partition Coefficient (K <sub>oc</sub> )		
PCE	426	(L/kg)
TCE	130	(L/kg)
DCE	125	(L/kg)
VC	30	(L/kg)

Retardation Factor		
PCE	4.05	(-)
TCE	1.93	(-)
DCE	1.90	(-)
VC	1.21	(-)

CH2M HILL, 2005, Remedial Investigation/Source Control Evaluation Report, Northwest Pipe Company Site, December.  
 Jacobs, 2021, Remedial Investigation and Source Control Evaluation - Revised, Prepared for Northwest Pipe Company, ECS1 #138, Portland, Oregon, October.

Well	Distance along flow path	Natural Log of Concentration			
		PCE	TCE	cis-1,2-DCE	vinyl chloride
MW-05	76	5.48	3.58	6.82	4.87
MW-06	248	5.01	3.14	3.81	-1.24
MW-03	483	1.48	1.82	4.04	1.34
MW-11	808	-0.49	-0.80	3.26	2.03
T451MW-035	1320	-3.41	-3.51	-3.91	-3.91



Concentrations in ug/L

Well	Date	PCE	TCE	cis-1,2-DCE	VC
MW-05	8/16/2004	52	5.6	160	0.54
	1/11/2005	190	38	27	72
	6/21/2005	110	18	53	0.5
	9/21/2005	1200	72	160	0.5
	9/24/2007	1400	78	337	0.28
	10/26/2016	3510	195	1160	40.4
	2/1/2017	4150	208	1240	39.5
	5/1/2017	949	92	634	70.7
	7/27/2017	3640	170	1730	7.58
	12/7/2018	1200	85	1600	77
	5/9/2019	4400	240	1700	14
	10/9/2019	2300	140	2200	120
	4/23/2020	3600	170	1900	34
	10/22/2020	2400	150	1200	87
	4/15/2021	3700	170	1800	26
	10/28/2021	2200	180	760	56
	4/14/2022	1900	110	960	170
	9/15/2022	2600	180	1200	61
	3/23/2023	850	100	680	72
	8/24/2023	1900	160	810	94
	5/16/2024	240	36	920	130

Well	Date	PCE	TCE	cis-1,2-DCE	VC
MW-06	1/11/2005	2000	1000	740	0.93
	6/21/2005	2100	1500	1300	5.7
	9/21/2005	2800	1900	1700	6.7
	9/24/2007	1200	470	638	3.1
	10/26/2016	287	60.4	1160	170
	2/1/2017	805	147	1590	51
	5/1/2017	1280	225	1530	21.9
	7/27/2017	810	128	1080	18.3
	12/7/2018	430	110	1300	130
	5/9/2019	980	210	1900	40
	10/9/2019	520	110	1700	110
	4/23/2020	920	160	2000	55
	10/22/2020	560	110	1,700	150
	4/15/2021	810	210	2,100	71
	10/28/2021	590	120	1,500	92
	4/14/2022	360	91	1,100	30
	9/15/2022	230	48	190	0.65
	3/23/2023	180	50	180	1.5
	8/24/2023	170	30	68	5
	5/16/2024	150	23	45	0.29

Well	Date	PCE	TCE	cis-1,2-DCE	VC
MW-03	8/29/2003	19	1	1	1
	8/16/2004	21	2	1	1
	1/11/2005	20	1.9	0.88	0.5
	6/21/2005	12	2.1	1	0.5
	9/21/2005	9.7	1.8	0.79	0.5
	9/24/2007	16	3	1.7	0.001
	10/26/2016	630	221	428	22.8
	2/1/2017	483	178	502	20.8
	5/1/2017	657	283	847	26.1
	7/27/2017	550	209	670	29.9
	12/7/2018	490	160	850	46
	5/9/2019	370	100	890	46
	10/9/2019	530	160	990	62
	4/23/2020	170	58	730	42
	10/22/2020	250	54	360	36
	4/15/2021	160	42	510	43.0
	10/28/2021	130	26	300	57.0
	4/14/2022	130	34	410	70.0
	9/14/2022	68	16	200	53
	3/22/2023	27	11	300	44
	8/23/2023	36	8.3	140	30
	5/15/2024	4.4	6.2	57	3.8

Well	Date	PCE	TCE	cis-1,2-DCE	VC
T451MW22	9/2/2004	12	36	23	0.23
	2/4/2005	27	64	36	0.97
	5/6/2005	34	83	49	0.88
	10/26/2016	1.46	4.6	2.77	0.0499
	2/1/2017	1.28	4.29	5.36	0.106
	4/27/2017	1.43	3.56	2.11	0.022
	7/26/2017	1.71	3	3.78	0.0638
	12/6/2018	1.4	4.6	5.8	0.076
	5/8/2019	1.8	4.4	7.5	0.33
	10/8/2019	1.3	3.4	7.4	0.18
	4/22/2020	1.1	3.3	7	0.32
	10/21/2020	0.94	2.8	7.9	0.17
	4/14/2021	1.70	2.70	5.00	0.140
	10/27/2021	1.10	2.70	4.80	0.200
	3/21/2023	1.2	2.5	3.3	0.057
	8/22/2023	1.4	2.1	1.7	0.031
	5/13/2024	1.7	1.7	2.4	0.059

MW-11 (670)	4/12/2022	1.6	0.8	46	26
	6/29/2022	1.2	1.1	64	52
	9/13/2022	2.1	1.1	32	32
	12/6/2022	1.8	0.7	19	19
	3/21/2023	1.1	0.48	21	13
	6/6/2023	0.77	0.44	37	7.7
	8/23/2023	1.8	0.66	19	4.6
	11/14/2023	2.9	0.63	21	36
	5/14/2024	0.61	0.45	26	7.6

Well	Date	PCE	TCE	cis-1,2-DCE	VC
T451MW035	4/21/2004	0.77	0.29	2.3	0.5
	8/30/2004	1.8	1.3	89	5.4
	1/31/2005	14	3.5	15	1.3
	5/5/2005	1.9	0.42	7.6	0.5
	10/26/2016	0.112	0.15	0.15	0.008
	2/1/2017	0.23	0.15	0.15	0.008
	4/26/2017	0.117	0.15	0.15	0.008
	7/25/2017	0.0508	0.15	0.15	0.008
	12/5/2018	0.1	0.1	0.1	0.02
	5/8/2019	0.1	0.1	0.1	0.02
	10/7/2019	0.1	0.1	0.1	0.02
	4/21/2020	0.1	0.1	0.1	0.02
	10/20/2020	0.1	0.1	0.1	0.02
	4/13/2021	0.1	0.1	0.1	0.02
	10/26/2021	0.1	0.1	0.1	0.02
	4/11/2022	0.084	0.066	0.055	0.013
	9/14/2022	0.084	0.066	0.055	0.013
	3/20/2023	0.027	0.03	0.02	0.02
	8/21/2023	0.03	0.03	0.02	0.02
	5/14/2024	0.033	0.03	0.02	0.02

Well	Date	PCE	TCE	cis-1,2-DCE	VC
T451MW09	4/20/2004	0.15	0.5	0.5	0.5
	9/1/2004	0.5	0.5	0.5	0.5
	2/9/2005	0.5	0.5	0.5	0.5
	5/9/2005	0.13	0.14	0.12	0.22
	10/26/2016	0.0191	0.15	0.15	0.0197
	2/1/2017	0.0177	0.15	0.15	0.0113
	4/26/2017	0.005	0.15	0.15	0.008
	7/25/2017	0.0139	0.15	0.15	0.008
	12/5/2018	0.1	0.1	0.1	0.02
	5/8/2019	0.1	0.1	0.1	0.02
	10/8/2019	0.1	0.1	0.1	0.02
	4/22/2020	0.1	0.1	0.1	0.02
	10/20/2020	0.1	0.1	0.1	0.02
	4/13/2021	0.1	0.1	0.1	0.02
	10/26/2021	0.1	0.1	0.1	0.02
	3/20/2023	0.02	0.03	0.02	0.02
	8/22/2023	0.02	0.03	0.02	0.02
	5/14/2024	0.02	0.03	0.02	0.02