Are Your Soil Remediation Guideline Realistic?

Challenging Conservative Assumptions and Advocating for Realistic Remediation Guidelines

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Introduction

- Guidelines
  - Needed for risk management or remediation decisions
  - Risk based development, but conservative leaning when facing uncertainties
  - Simple to develop and practically apply
- Issues
  - Conservative approach compounds to produce unrealistic values
  - Unrealistic values lead to questionable decisions
  - Continuous Source - Who Spills Forever?
  - Does the assumed guideline model fit your situation?
  - Guidelines provide framework for adjustment - limited guidance for adjustment or site specific guideline development

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Presentation Outline

- Tier 1 and 2 Processes and Assumptions
- Contaminants
- Setting
- Modelling
- Interpretation and Review

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Tier 1 and 2 Processes

- 4.2.2 Guideline Adjustment (ESRD, 2014)
  - "The Tier 1 guidelines that are derived on the basis of fate and transport modeling may be modified where appropriate by the substitution of site-specific values for certain measurable and stable parameters (referred to as Tier 2 Guideline Adjustment). "
  - "The decision to undertake Tier 2 adjustments is a commitment to increase the “realism” or accuracy of the modeling."
- 5.2.4 Alternative Fate & Transport and Exposure Models
  - "There may be cases where there is a requirement to employ chemical fate and transport or exposure models that are different from Tier 1 due to situations where Tier 1 generic guidelines may not apply. Here, it may be possible to develop a site-specific remediation guideline based on alternative modeling protocols."

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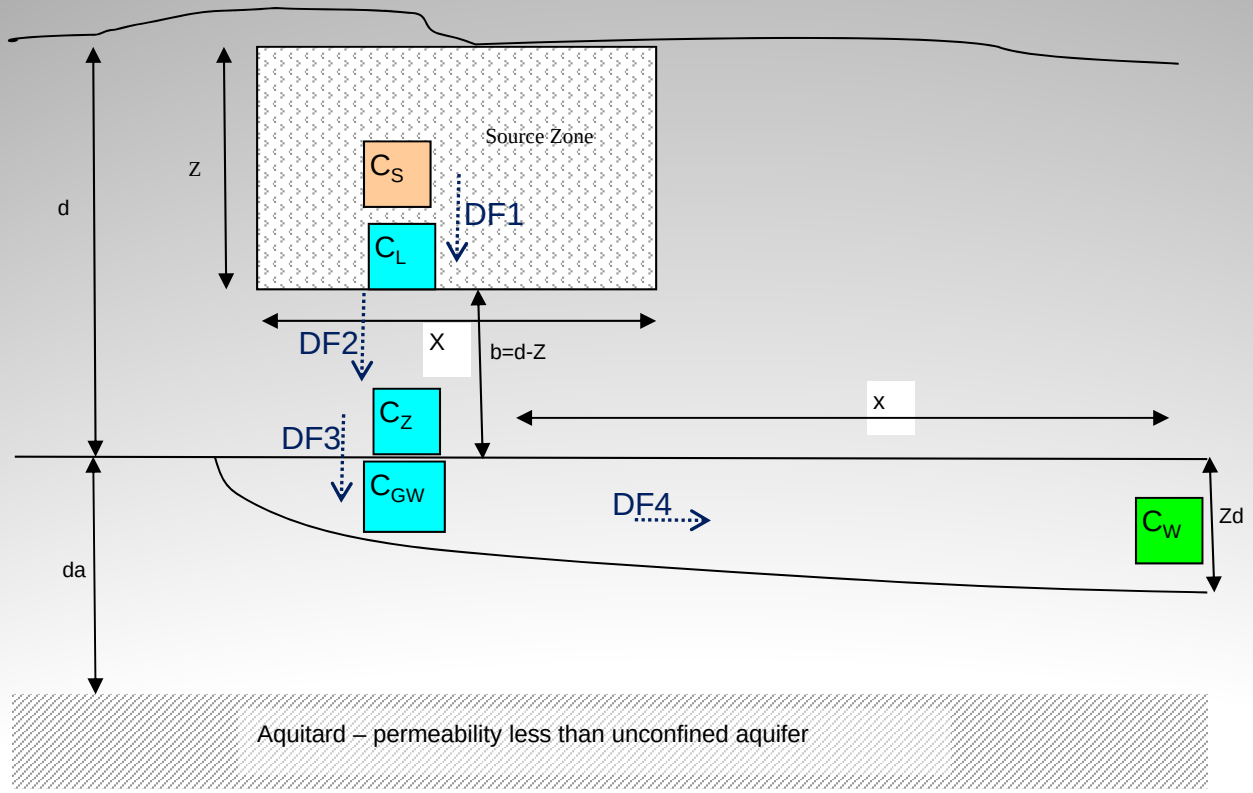
Tier 1 Approach



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Tier 1 Approach

- DF1. partitioning from soil source to pore water (leachate)
- DF2. leachate transport from the source to the water table
- DF3. leachate mixing with groundwater
  - for the potable groundwater pathway only, the average thickness of the mixing zone (Zd) takes the fixed value of 2 m
- DF4. transport in groundwater downgradient to a discharge (receptor)
  - lateral offset (x) between the source and the surface water body is an assumed 10 m for aquatic life and wildlife watering, and zero for other water uses; DF4 is only active for aquatic life and wildlife watering and cannot be applied for other pathways

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Contaminants

- Typical Western Canada contaminants
  - Hydrocarbons: Benzene, F1, F2, Napthalene
  - Inorganics: Chloride, Sodium, Sulphate
  - Other Organics: Sulfolane, DIPA

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Tier 1 - Soil Guidelines

	Tier 1		Tier 1 Receptor Pathway Specific Values												
Receptor Type			Human		Eco									Other	
Soil Receptor / Pathway			Protection of Domestic Use Aquifer		Direct Soil Contact		Nutrient Energy Cycling	Livestock Soil and Food Ingestion	Wildlife Soil and Food Ingestion	Protection of Freshwater Aquatic Life		Protection of Wildlife Water		Mgmt Limit	
Soil Type	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	All	Fine	Coarse	Fine	Coarse	Fine	Coarse
Building Type	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Table A-1. Surface Soil Remediation Guideline Values for Natural Area Land Use															
Hydrocarbons															
Benzene	0.046	0.078	**0.046**	**0.078**	60	31	-	44	18	7.9	0.17	15	0.33	-	-
F1	210	210	1100	2200	**210**	**210**	-	27000	11000	30000	1300	30000	30000	800	700
F2	150	150	1500	2900	**150**	**150**	-	25000	9800	30000	520	30000	30000	1000	1000
Naphthalene	0.014	0.017	28	53	-	-	-	8.8	8.8	**0.014**	**0.017**	NGR	NGR	-	-
Other Organics															
DIPA	14	17	130	250	360	360	-	-	-	**14**	**17**	-	-	-	-
Sulfolane	0.18	0.21	**0.18**	**0.21**	210	210	-	-	-	24	18	-	-	-	-
Table A-6. Subsoil Remediation Guideline Values for Natural Area Land Use - BTEX and PHC Only															
Benzene	0.046	0.078	**0.046**	**0.078**	120	62	-	na	na	7.9	0.17	15	0.33	-	-
F1	420	420	1100	2200	**420**	**420**	-	na	na	30000	1300	NGR	30000	**800**	**700**
F2	300	300	1500	2900	**300**	**300**	-	na	na	30000	**520**	NGR	30000	**1000**	1000

	Tier 1		Tier 1 Receptor Pathway Specific Values																							
Receptor Type			Human							Eco														Other	
Soil Receptor / Pathway			Protection of Domestic Use Aquifer		Direct Soil Contact	Vapour Inhalation				Direct Soil Contact		Nutrient Energy Cycling	Livestock Soil and Food Ingestion	Wildlife Soil and Food Ingestion	Protection of Freshwater Aquatic Life		Protection of Livestock Water		Protection of Wildlife Water		Protection of Irrigation Water		Mgmt Limit	
Soil Type	Fine	Coarse	Fine	Coarse	All	Fine	Fine	Coarse	Coarse	Fine	Coarse	All	All	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse
Building Type	-	-	-	-	-	Basement	Slab	Basement	Slab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Table A-2. Surface Soil Remediation Guideline Values for Agricultural Land Use																										
Hydrocarbons																										
Benzene	0.046	0.073	**0.046**	**0.078**	78	1.7	1.6	0.1	0.073	60	31	-	44	18	7.9	0.17	0.2	0.21	15	0.33	-	-	-	-		
F1	210	24	1100	2200	12000	710	610	30	**24**	**210**	210	-	27000	11000	30000	1300	6600	7400	30000	30000	-	-	800	700		
F2	150	130	1500	2900	6800	3600	3100	160	**130**	**150**	150	-	25000	9800	30000	520	16000	19000	30000	30000	-	-	1000	1000		
Naphthalene	0.014	0.017	28	53	1800	58	51	2.9	2.2	-	-	-	8.8	8.8	**0.014**	**0.017**	NGR	NGR	NGR	NGR	-	-	-	-		
Other Organics																										
DIPA	14	17	130	250	22000	-	-	-	-	360	360	-	-	-	**14**	**17**	-	-	-	-	29	34	-	-		
Sulfolane	0.18	0.21	**0.18**	**0.21**	350	-	-	-	-	210	210	-	-	-	24	18	-	-	-	-	0.39	0.28	-	-		
Table A-7. Subsoil Remediation Guideline Values for Agricultural Land Use - BTEX and PHC Only																										
Benzene	0.046	0.078	**0.046**	**0.078**	78	1.7	1.6	0.1	0.14	120	62	-	na	na	7.9	0.17	0.2	0.21	15	0.33	-	-	-	-		
F1	420	30	1100	2200	12000	710	**630**	**30**	55	**420**	420	-	na	na	30000	1300	6600	7300	NGR	30000	-	-	800	700		
F2	300	160	1500	2900	6800	3600	3300	**160**	290	**300**	300	-	na	na	30000	520	16000	19000	NGR	30000	-	-	**1000**	1000		

Notes:

NGR - no guideline required, calculated value >1,000,000 mg/kg; or for PAH groundwater protection, calculated value results in groundwater concentration greater than solubility; na = exposure pathway not applicable to subsoil

Subsoil guidelines for petroleum hydrocarbons (i.e. Tables A-6 and A-7) apply to soils >1.5 mbgl within 5 m of an oilfield wellhead, or >3 mbgl anywhere else.
Under Tier 1, the soil and groundwater Direct Ecological Contact pathway for F1-F4 can be excluded for depths >3 m, where Management Limits are applied.

Indicates guideline controlled by water receptor pathway

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Tier 1 - Groundwater Guidelines

Table B-1. Natural Areas

Tier 1 or 2	Tier 1		Tier 1 Receptor Specific Values						
Water Receptor / Pathway			Potable GW	Eco Soil Contact		Aquatic Life		Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
General and Inorganic Parameters									
Chloride	120	120	250	-	-	**120**	**120**	-	-
Sodium	200	200	**200**	-	-	-	-	-	-
Sulphate	128	128	500	-	-	***128***	***128***	-	-
Hydrocarbons									
Benzene	0.005	0.005	**0.005**	100	61	3.6	0.074	6.8	0.14
F1	2.2	2.2	**2.2**	6.5	7.1	NGR	9.8	NGR	NGR
F2	1.1	1.1	**1.1**	1.8	1.8	NGR	1.3	NGR	NGR
Naphthalene	0.001	0.001	0.47	-	-	**0.001**	**0.001**	NGR	NGR
Other Organics									
Diisopropanolamine	1.6	1.6	3.6	160	160	**1.6**	**1.6**	-	-
Sulfolane	0.09	0.09	**0.09**	1700	2800	50	50	-	-

Table B-2. Agricultural Land

Tier 1 or 2	Tier 1		Tier 1 Receptor Specific Values, or Active Tier 2 Receptors										
Water Receptor / Pathway			Potable GW	Vapour Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock Water	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
General and Inorganic Parameters													
Chloride	100	100	250	-	-	-	-	120	120	**100**	-	-	-
Sodium	200	200	**200**	-	-	-	-	-	-	-	-	-	-
Sulphate	128	128	500	-	-	-	-	***128***	***128***	-	1000	-	-
Hydrocarbons													
Benzene	0.005	0.005	**0.005**	2.8	0.14	100	61	3.6	0.074	-	0.088	6.8	0.14
F1	2.2	0.81	**2.2**	19	**0.81**	6.5	7.1	NGR	9.8	-	53	NGR	NGR
F2	1.1	1.1	**1.1**	NGR	1.5	1.8	1.8	NGR	1.3	-	NGR	NGR	NGR
Naphthalene	0.001	0.001	0.47	14	0.6	-	-	**0.001**	**0.001**	-	NGR	NGR	NGR
Other Organics													
Diisopropanolamine	1.6	1.6	3.6	-	-	160	160	**1.6**	**1.6**	3.2	-	-	-
Sulfolane	0.09	0.09	**0.09**	-	-	1700	2800	50	50	0.8	-	-	-

Notes:

NGR - no guideline required, calculated value > solubility or >1,000,000 mg/L

Eco Soil Contact = protection of terrestrial plants and soil invertebrates in areas with shallow groundwater

Wildlife Watering = protection of groundwater discharging to a surface water body from which wildlife may drink

Sulphate Aquatic Life guideline from AB Surface Water Guidelines (ESRD, 2014), with an assumed 10 mg/L receiving environment hardness.

Under Tier 1, the soil and groundwater Direct Ecological Contact pathway for F1-F4 can be excluded for depths >3 m, where Management Limits are applied.

Indicates guideline controlled by water receptor pathway

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Tier 1 Guideline Controlling Pathways

	Natural Area Land Use						Agricultural Land Use					
	Surface Soil		Subsoil		Groundwater		Surface Soil		Subsoil		Groundwater	
Soil Type	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse
Inorganics												
Chloride	-	-	-	-	Eco FWAL	Eco FWAL	-	-	-	-	Eco Irrigation	Eco Irrigation
Sodium	-	-	-	-	Human DUA	Human DUA	-	-	-	-	Human DUA	Human DUA
Sulphate	-	-	-	-	Eco FWAL	Eco FWAL	-	-	-	-	Eco FWAL	Eco FWAL
Hydrocarbons												
Benzene	Human DUA	Human DUA	Human DUA	Human DUA	Human DUA	Human DUA	Human DUA	Human DUA	Human DUA	Human DUA	Human DUA	Human DUA
F1	Eco Direct Soil Cont.	Eco Direct Soil Cont.	Mgmt Limit	Mgmt Limit	Human DUA	Human DUA	Eco Direct Soil Cont.	Human Vap. Inh.	Human Vap. Inh.	Human Vap. Inh.	Human DUA	Human Vap. Inh.
F2	Eco Direct Soil Cont.	Eco Direct Soil Cont.	Mgmt Limit	Human DUA	Human DUA	Human DUA	Eco Direct Soil Cont.	Human Vap. Inh.	Mgmt Limit	Human Vap. Inh.	Human DUA	Human DUA
Naphthalene	Eco FWAL	Eco FWAL	-	-	Eco FWAL	Eco FWAL	Eco FWAL	Eco FWAL	-	-	Eco FWAL	Eco FWAL
Other Organics												
DIPA	Eco FWAL	Eco FWAL	-	-	Eco FWAL	Eco FWAL	Eco FWAL	Eco FWAL	-	-	Eco FWAL	Eco FWAL
Sulfolane	Human DUA	Human DUA	-	-	Human DUA	Human DUA	Human DUA	Human DUA	-	-	Human DUA	Human DUA

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Setting

- Selected scenarios to represent a variety of conditions (e.g. impacts and groundwater restricted to soil vs. rock; or higher and lower K, etc.)

Site	Media	K (m/s)	i	Contaminants
A	Bedrock	$3x10^{-4}$	0.005	F2, Naphthalene
B	Bedrock/ Overburden	$7x10^{-7}$	0.05 - 0.01	Sulfolane, DIPA Chloride, Sodium Sulphate
C	Bedrock/ Overburden	$3x10^{-7}$	0.02	Sulfolane, DIPA Chloride, Sodium Sulphate
D	Overburden	$2x10^{-6}$	0.003	Benzene, F1
E	Bedrock/ Overburden	$1x10^{-7}$	0.06	Benzene, F1

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Modelling – Tier 1 Approach

- DF1. partitioning from soil source to pore water (leachate)
- DF2. leachate transport from the source to the water table
- DF3. leachate mixing with groundwater
  - for the potable groundwater pathway only, the average thickness of the mixing zone (Zd) takes the fixed value of 2 m
- DF4. transport in groundwater downgradient to a discharge (receptor)
  - lateral offset (x) between the source and the surface water body is an assumed 10 m for aquatic life and wildlife watering, and zero for other water uses; DF4 is only active for aquatic life and wildlife watering and cannot be applied for other pathways

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Modelling – Non-Constant Source

- Ideal Realistic Goal - Conservation of Mass
  - Simple Non-Ideal Alternative
    - Model existing situation forward only from DF4 alternative
    - Analytical solution relying on reducing source term at the water table

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Chemical Properties

Chemical	Molecular Weight	Aqueous Solubility	Organic Carbon-Water Distribution Coefficient [K_{oc}]	Henry's Constant (Dimensionless)	Biodegradation Half-Life	Diffusion Coefficient in Air	FWAL Surface Water Guideline
Units	**g/mol**	**mg/L**	**L/kg**	**-**	**days**	**cm^2/s**	**mg/L**
Chloride	35.453	42370	1	-	1.E+99	1.E-99	120
Sodium	22.987	4.45E+05	1	-	1.E+99	1.E-99	-
Sulphate	96.036	1.00E+07	1	-	1.E+99	1.E-99	128
Sulfolane	120.17	1.00E+06	1.2	3.60E-08	30	0.06894	50
DIPA	101.19	870000	2.21	7.00E-06	30	0.07709	1.6
Benzene	78.11	1780	81	0.225	365	8.8E-02	0.04
Naphthalene	128.18	31.7	708	0.013	0.9	5.9E-02	0.001
F1	112.6	8.97	13716.48	56.3	712	0.05	0.15
F2	173.8	2.90	2295605	272.0	1748	0.05	0.11

Notes:

If not indicated otherwise, data generally taken from AB Tier 2 Soil and Groundwater Remediation Guidelines (ESRD, March 2014).

Chemical Property Values from EPI Suite™ (USEPA, 2012).

Values from CCME Canada Wide Standard for Petroleum Hydrocarbons in Soil: Scientific Rationale Supporting Document (CCME, Jan. 2008).

Value approximated from relative proportion of each subfraction defined in CCME (2008).

Assumed values.

Value presented is a mean K_d, rather than K_{oc} since DIPA sorbs to clays in preference to organic carbon.

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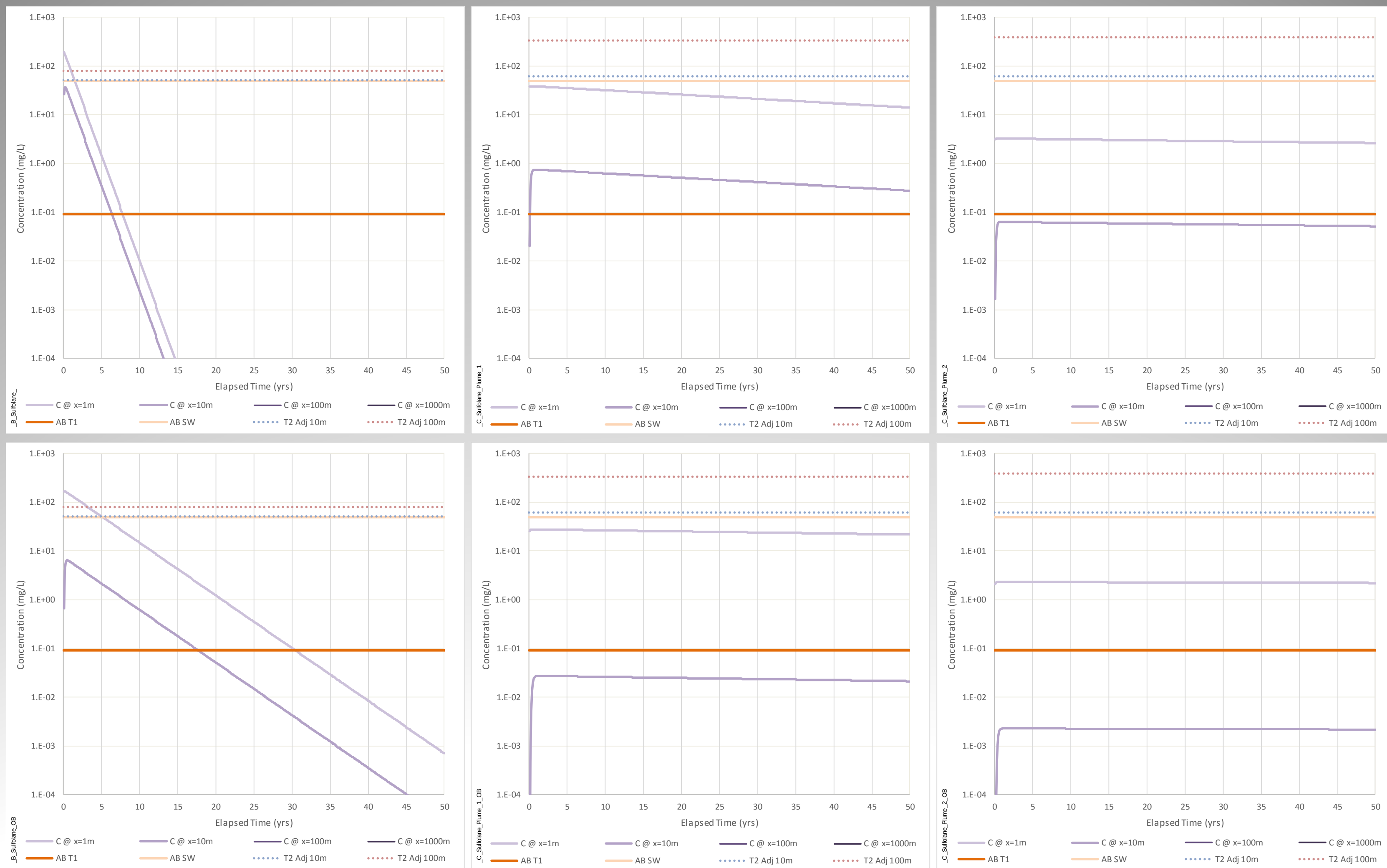
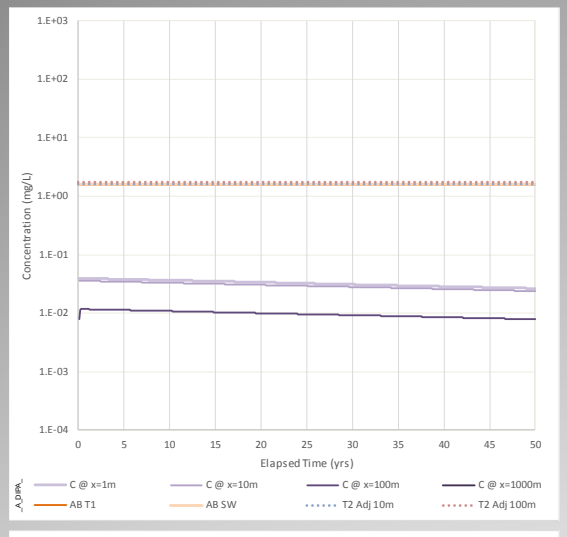
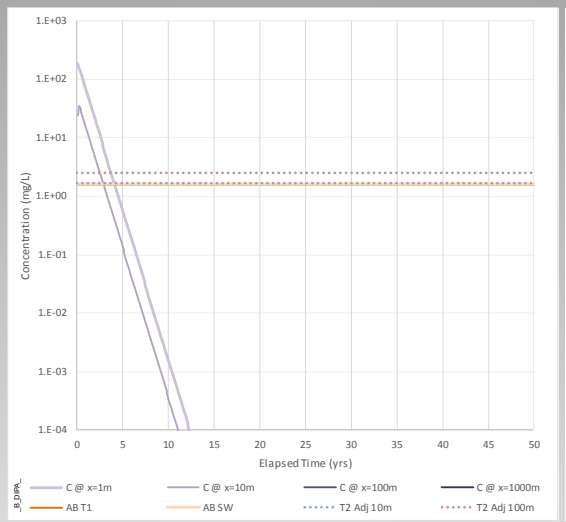
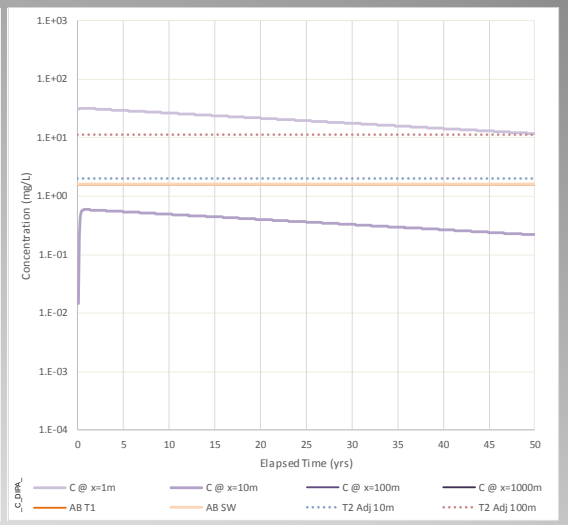
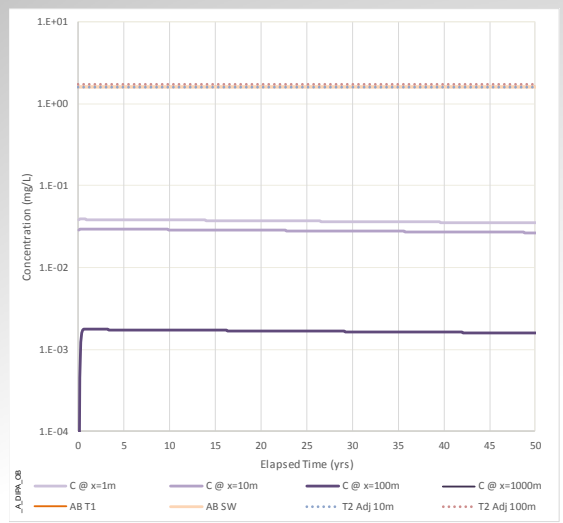

Concentration (mg/L)
Elapsed Time (yrs)
C @ x=1m
C @ x=10m
C @ x=100m
C @ x=1000m
AB T1
AB SW
T2 Adj 10m
T2 Adj 100m

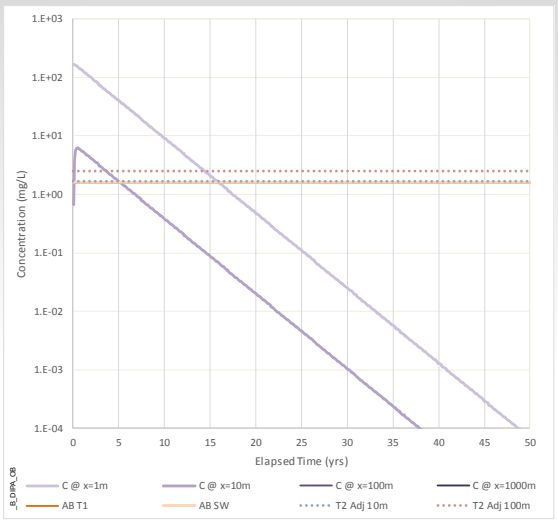
Sulfolane

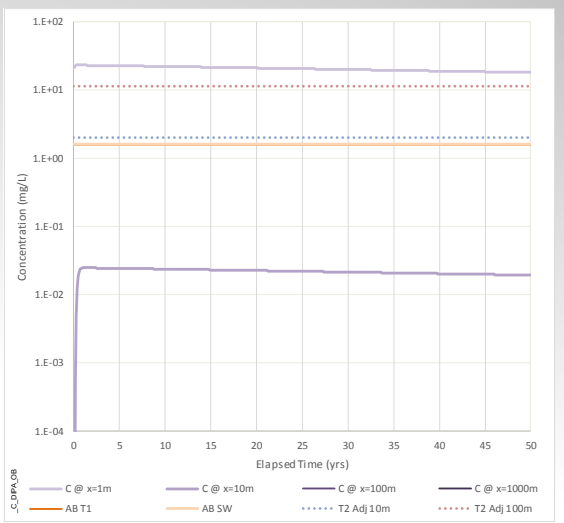












DIPA

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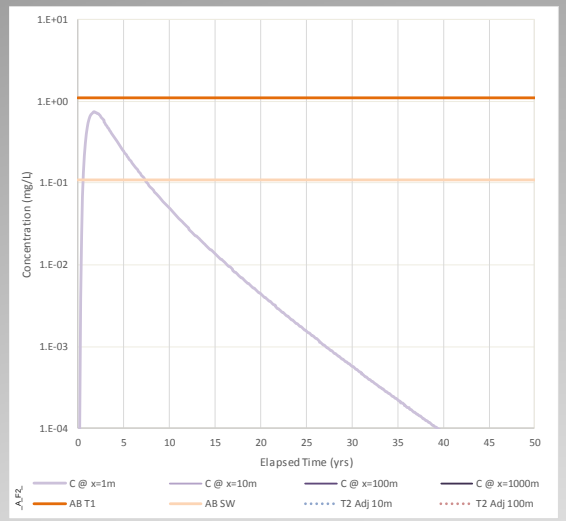

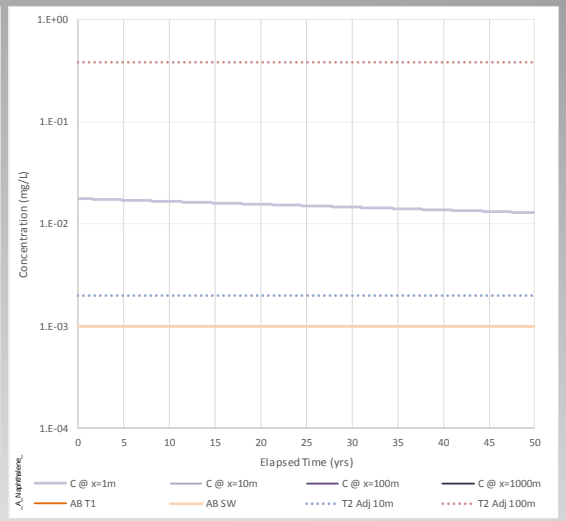

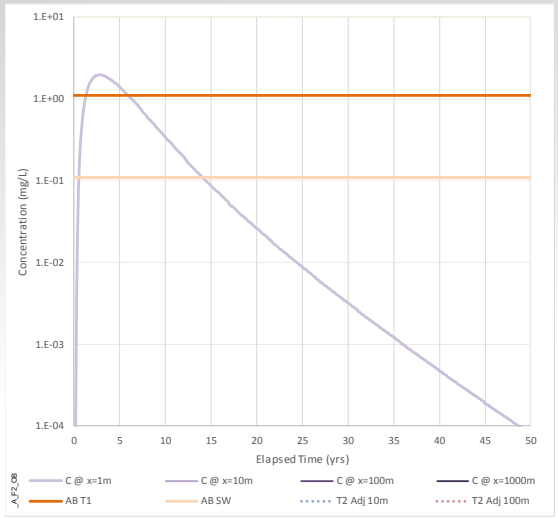

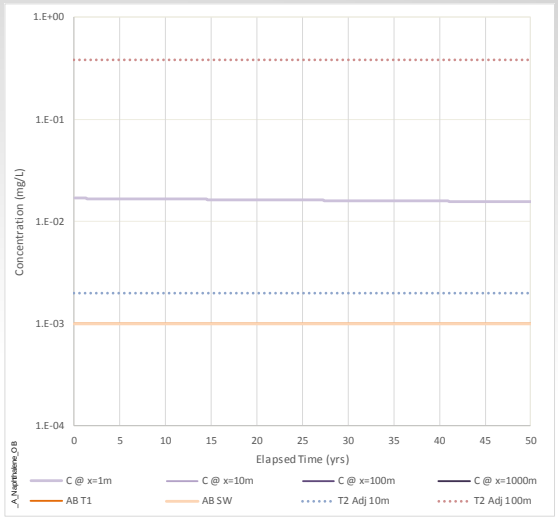

F2 and Naphthalene

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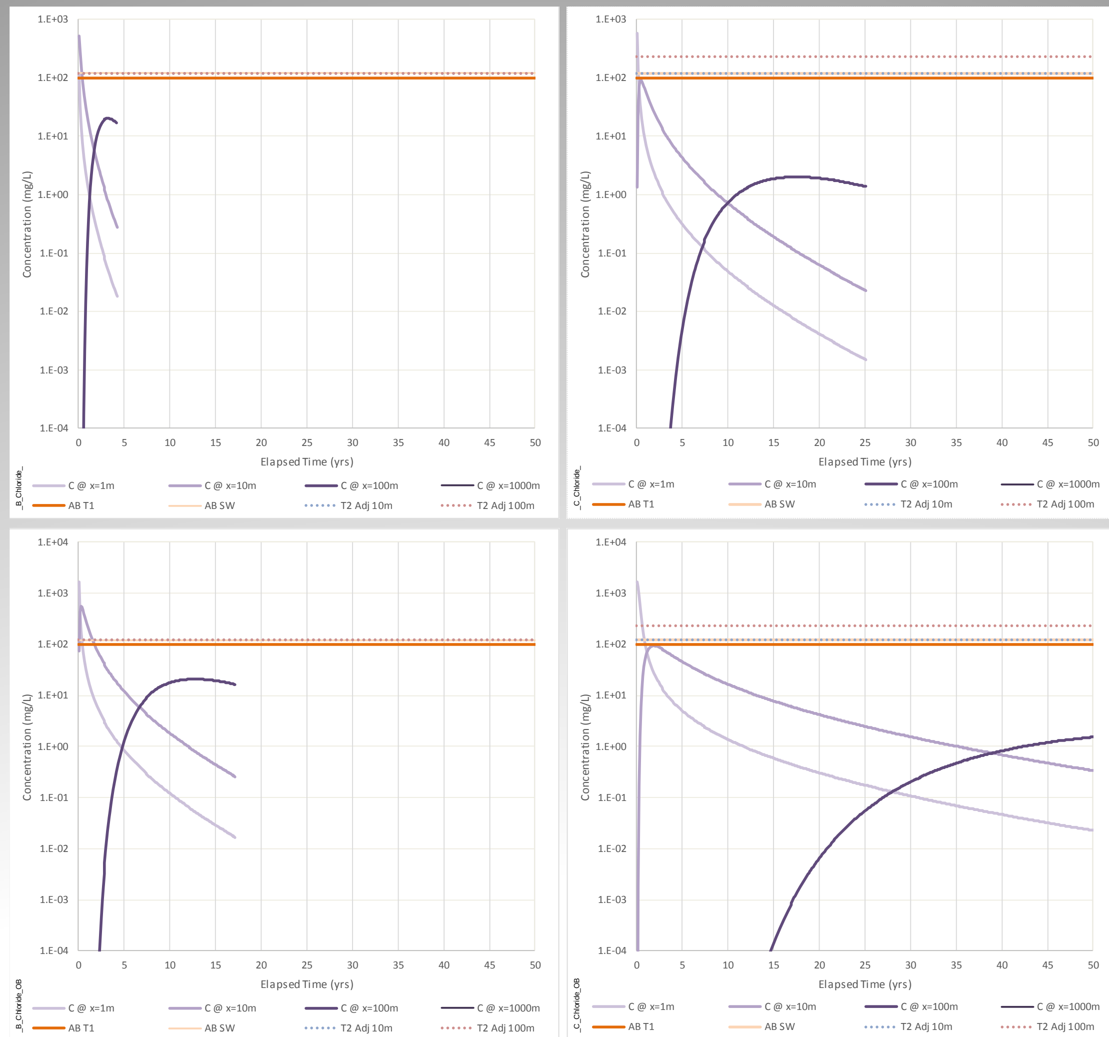

Chloride

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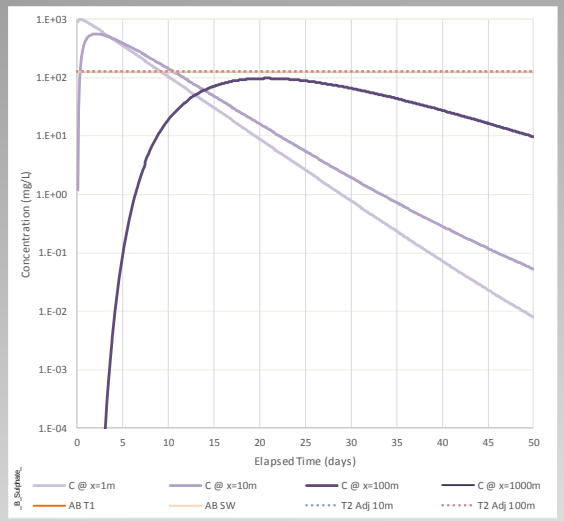

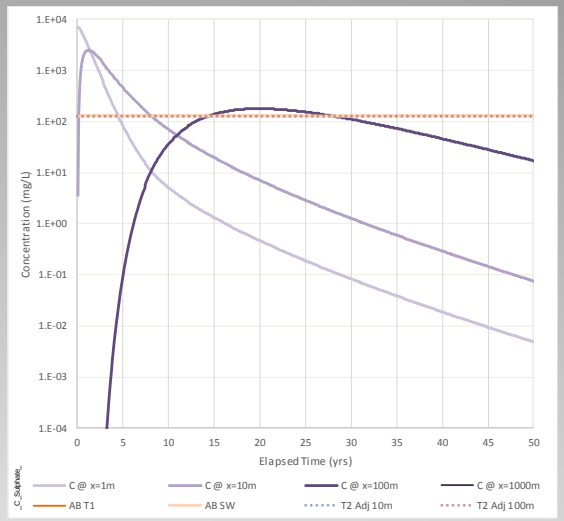

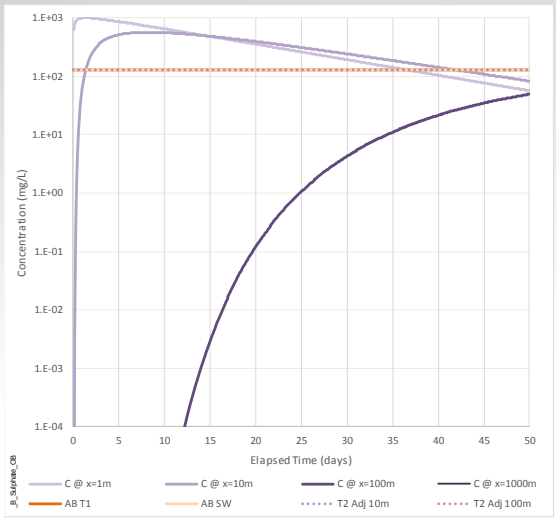

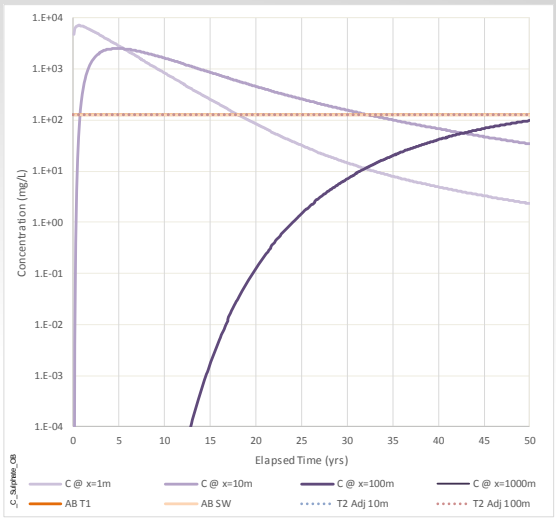

Sulphate

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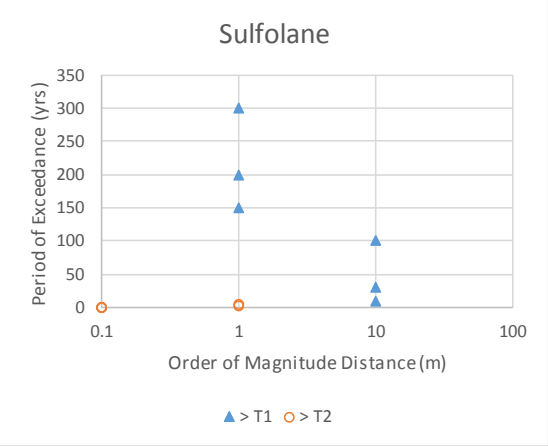
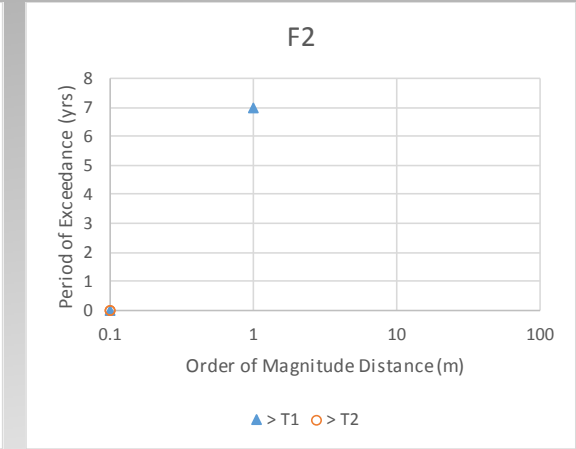
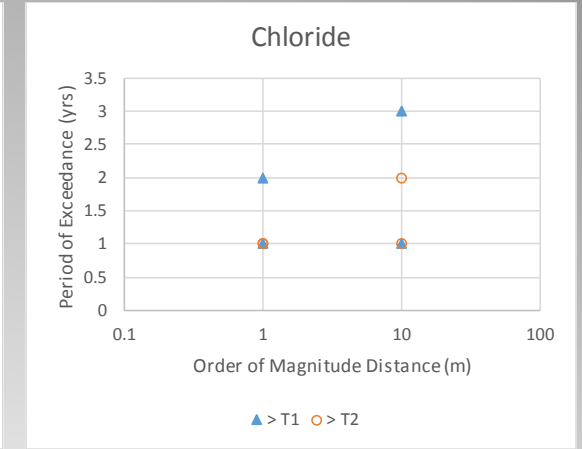
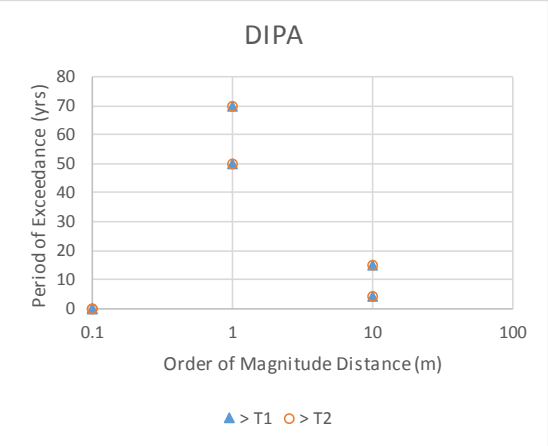
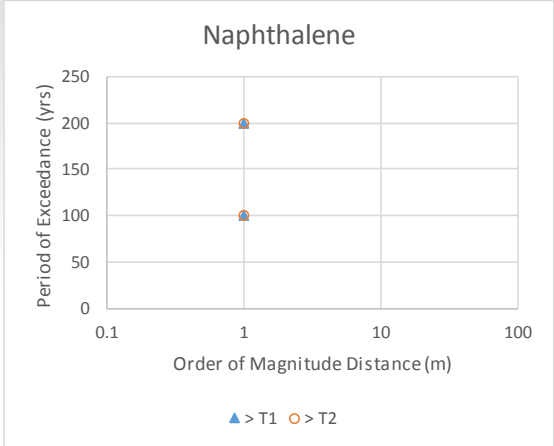
Summary

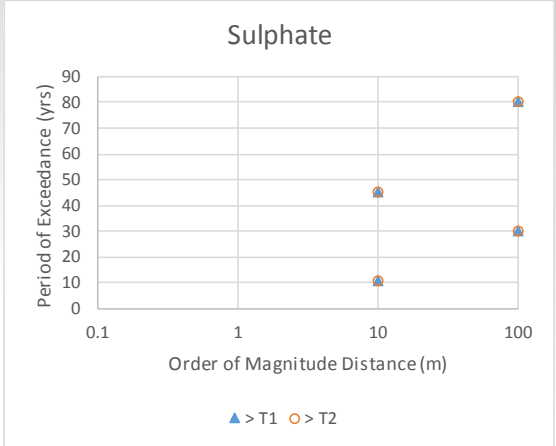












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Conclusions

- Thinking critically about your guidelines can change important decision points and have a significant influence on remedial costs
- Strong potential for dramatic changes to guidelines for reactive, degradable species (i.e. organics such as sulfolane)
- Lower potential for conservative species (i.e. dispersion influences only)

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What Next?

- Other scenarios to consider relative site sensitivity (i.e. is it worth looking at this for site X?)
- Approach DF1 - DF3 solution alternatives to revisit guidelines controlled by other pathways such as potable or irrigation water uses
- A regulators perspective, any guidance?

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Questions?

Thank You

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