Addressing Low Levels of PFAS in Soil: A Local Case Study

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Introduction

During the removal of an underground storage tank that had been associated with an aqueous film-forming foam (AFFF) fire suppression system, levels of PFAS substances in the surrounding soil exceeded the Washington State Model Toxics Control Act (MTCA) soil concentrations criteria for the protection of groundwater (GW) . This case study discusses the efforts to develop data quality objectives (decision flow process) and sampling and analysis plans to address low levels of detection to meet regulatory requirements for PFAS in soil. Consultation with the Washington State Department of Ecology defined the path forward to provide additional data to demonstrate "enough information to show PFAS is unlikely to have leached into groundwater." Protection of groundwater was evaluated based on 1-D STOMP modeling to demonstrate transport of PFAS chemicals (PFOS, PFOA, PFNA, PFHxS, PFDA and PFBA) through the subsurface to the top of the groundwater aquifer. The case study demonstrates the complexity of sampling, modeling, and decision making involved regarding this tank and associated surrounding soil, and the value of working closely with state regulators.

Sampling

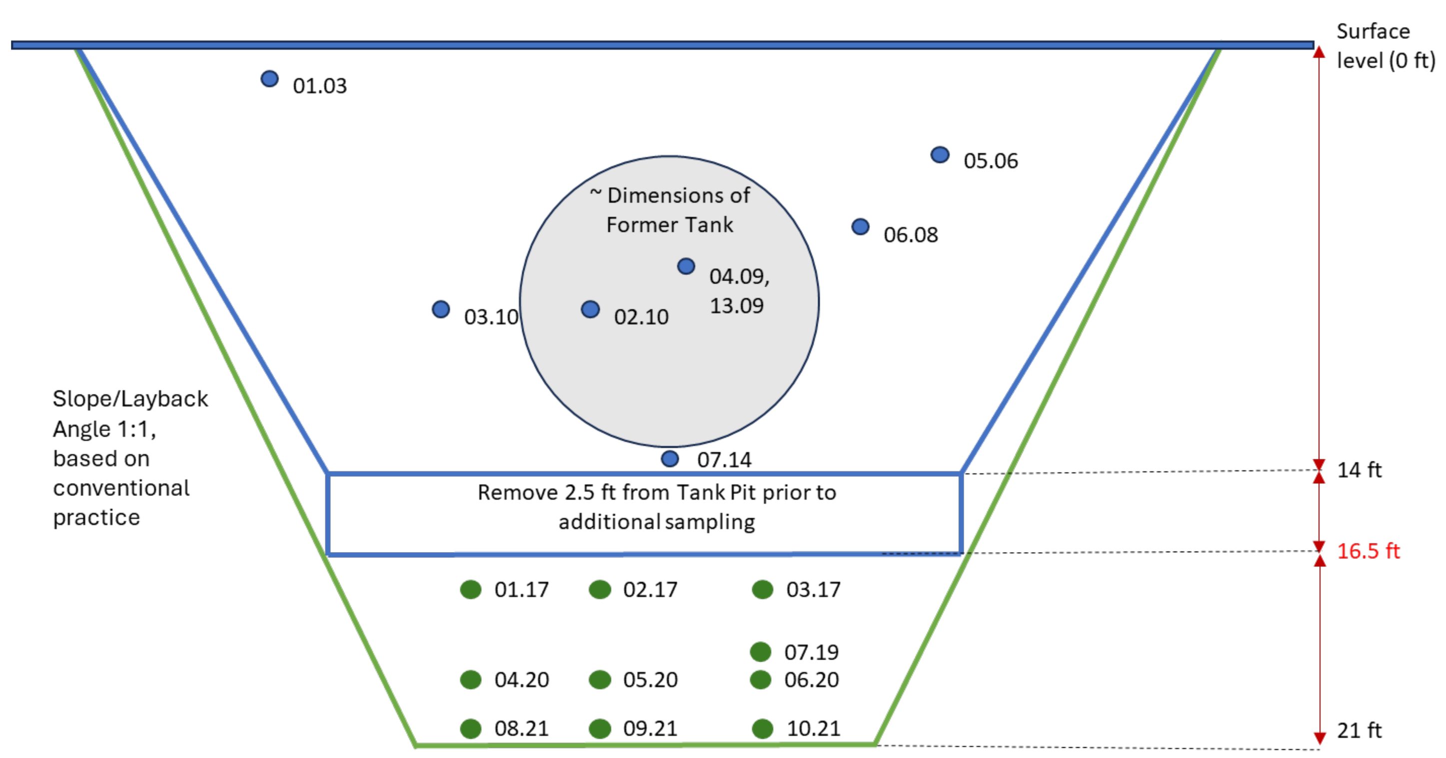
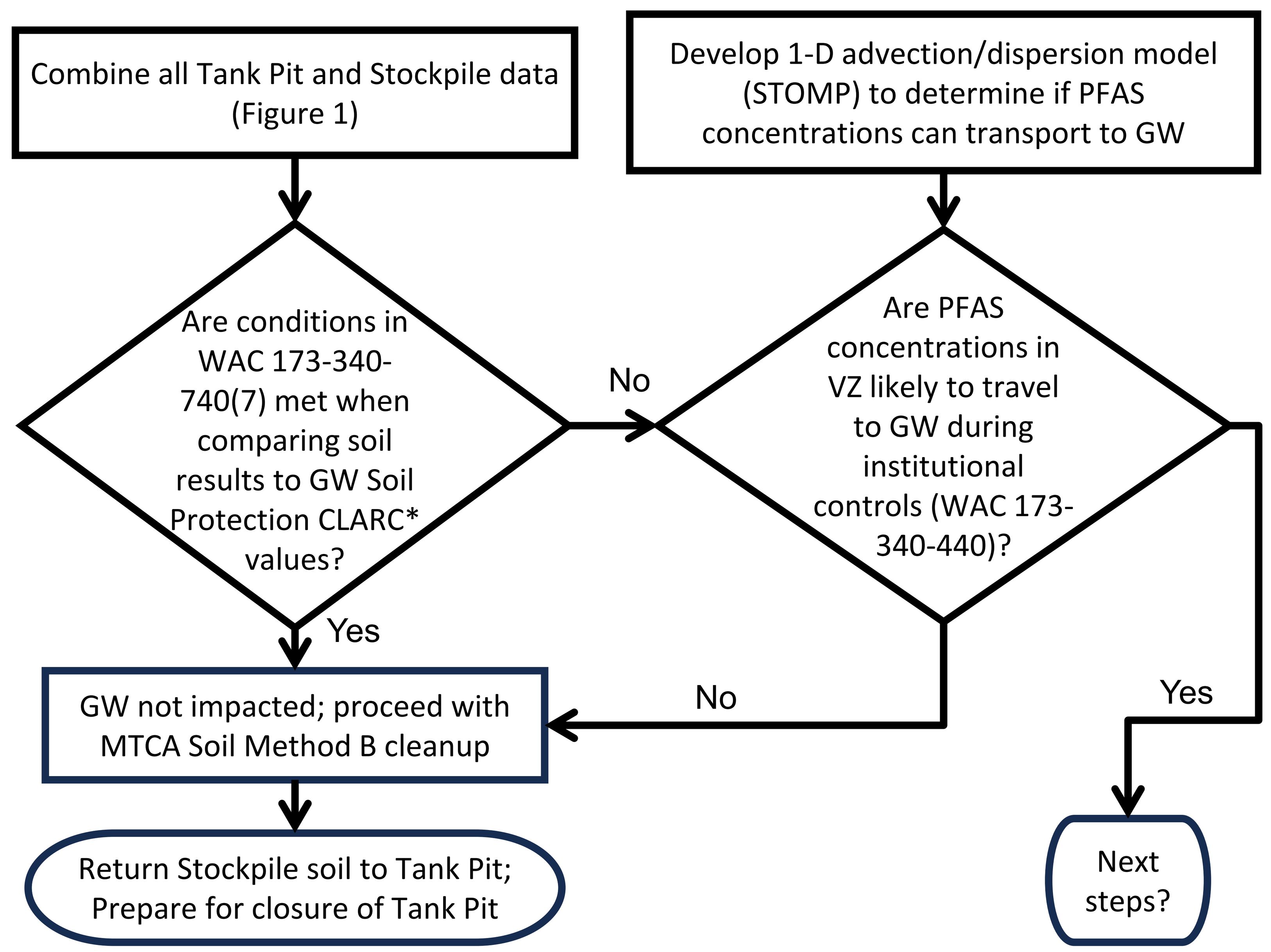


Figure 1. Cross-section of the excavation area and approximate sampling locations for two sampling campaigns (blue and green). The sample ID next to location indicates the sequence of the sample followed by the depth (e.g., 04.20 = 4th sample of the day, removed at 20 ft. below surface). Results are shown in Table 1.

Decision Flow Process



* CLARC: Cleanup Levels and Risk Calculation (https://fortress.wa.gov/ecy/ezshare/tcp/CLARC/CLARC_Master.PDF)

Soil Results

Table 1. Soil Results and Selection of maximum concentration of PFAS priority substance for consideration in modeling. All units in µg/kg.

Sample ID	Depth (ft)	Location	Duplicate?	PFBA	Qualifier	PFNA	Qualifier	PFOS	Qualifier	PFOA	Qualifier	PFDA	Qualifier	PFHxS	Qualifier	HFPO-DA	Qualifier
101823-UT-01.03	3	Tank Pit	NA	0.14	U	0.044	U	0.14	D	0.15	D	0.038	U	0.033	U	0.1	U
101923-UT-02.10	10	Tank Pit	NA	0.14	U	0.044	U	0.051	U	0.036	U	0.038	U	0.033	U	0.1	U
101923-UT-03.10	10	Tank Pit	NA	0.14	U	0.12	D	0.33	D	0.12	D	0.039	U	0.033	U	0.1	U
101923-UT-04.09	9	Tank Pit	NA	0.14	U	0.044	U	0.051	U	0.083	D	0.038	U	0.033	U	0.1	U
101923-UT-13.09	9	Tank Pit	04.09	0.14	U	0.044	U	0.047	U	0.068	D	0.038	U	0.033	U	0.1	U
101923-UT-05.06	6	Tank Pit	NA	0.91	D	0.044	U	0.052	U	0.067	D	0.039	U	0.033	U	0.1	U
102323-UT-06.08	8	Tank Pit	NA	0.14	U	0.044	U	0.051	U	0.04	D	0.038	U	0.033	U	0.1	U
102323-UT-07.14	14	Tank Pit	NA	0.14	U	0.044	U	0.052	U	0.036	U	0.038	U	0.033	U	0.099	U
102323-UT-08	14	Stockpile	NA	0.14	U	0.044	U	0.1	D	0.059	D	0.038	U	0.032	U	0.099	U
102323-UT-09	14	Stockpile	NA	0.14	U	0.044	U	0.12	D	0.073	D	0.038	U	0.033	U	0.1	U
102323-UT-10	14	Stockpile	NA	0.14	U	0.044	U	0.11	D	0.064	D	0.039	U	0.033	U	0.1	U
102323-UT-11	14	Stockpile	NA	0.14	U	0.044	U	0.072	D	0.059	D	0.045	D	0.033	U	0.099	U
102323-UT-12	14	Stockpile	NA	0.3	D	0.044	U	0.067	D	0.036	U	0.038	U	0.033	U	0.099	U
121824-UTA-01.17	17	Tank Pit	02.17	0.79	U	0.2	U	0.31	D	0.2	U	0.12	U	0.18	U	0.79	U
121824-UTA-02.17	17	Tank Pit	NA	0.81	U	0.2	U	0.24	D	0.2	U	0.12	U	0.18	U	0.81	U
121824-UTA-03.17	17	Tank Pit	NA	0.79	U	0.2	U	0.18	U	0.2	U	0.12	U	0.18	U	0.79	U
121824-UTA-04.20	20	Tank Pit	NA	0.79	U	0.2	U	0.18	U	0.2	U	0.12	U	0.18	U	0.79	U
121824-UTA-05.20	20	Tank Pit	NA	0.8	U	0.2	U	0.19	U	0.2	U	0.12	U	0.18	U	0.8	U
121824-UTA-06.20	20	Tank Pit	NA	0.8	U	0.2	U	0.19	U	0.2	U	0.12	U	0.18	U	0.8	U
121824-UTA-07.19	19	Tank Pit	NA	0.8	U	0.2	U	0.18	U	0.2	U	0.12	U	0.18	U	0.8	U
121824-UTA-08.21	21	Tank Pit	NA	0.8	U	0.2	U	0.19	U	0.2	U	0.12	U	0.18	U	0.8	U
121824-UTA-09.21	21	Tank Pit	10.21	0.79	U	0.2	U	0.18	U	0.2	U	0.12	U	0.18	U	0.79	U
121824-UTA-10.21	21	Tank Pit	NA	0.79	U	0.2	U	0.18	U	0.2	U	0.12	U	0.18	U	0.79	U

Highlighted field is the value selected for modeling
U = Not Detected, reporting the MDL of the analytical method
D = Detected, reporting detected value in blue

1-D STOMP Modeling

The STOMP (https://www.pnnl.gov/projects/stomp) 1-D modeling simulated concentrations at the bottom of the vadose zone (VZ), 10 cm above water table. Assumptions for assessing transport time for PFAS substance to reach groundwater:

- Uniform distribution of maximum sampled concentrations of soil (Table 1) over depth range (0-21 ft).
- Physical and hydraulic parameters for Hanford 300 Area sediments (Rockhold et al. 2018) and K_d parameters (Table 2).
- Recharge scenarios: Scenario 1 (worst case), high recharge, is shown with a **black** line.
  Scenario 2 (best case), low recharge, is shown with a **red** line.
- Perform 1-D STOMP (White and Oostrom, 2006) model simulations to generate solute curves at the water table.
  [Additional results for the other PFAS substance and all references available upon request.]

Table 2. Parameters for 1-D STOMP modeling.

Parameter	Value	Units	Reference
Dry bulk density, ρ_b	2.09	g cm^{-3}	Rockhold et al. 2018
Porosity, θ_s	0.228	-	Rockhold et al. 2018
Saturated hydraulic conductivity, K_s	5.08e-2	cm s^{-1}	Rockhold et al. 2018
van Genuchten model parameter, α	0.378	cm^{-1}	Rockhold et al. 2018
van Genuchten model parameter, n	1.3194	-	Rockhold et al. 2018
Residual saturation, S_r	0.0	-	Rockhold et al. 2018
Dispersivity, δ_L	10	cm	Rockhold et al. 2015
PFOS Partition coefficient 1, $K_{d\text{-}PFOS}$ **(Figure 2)**	28.2	cm^3 g^{-1}	Rovero et al. 2021
PFOS Partition coefficient 2, $K_{d\text{-}PFOS}$ **(Figure 3)**	0.64	cm^3 g^{-1}	Wang et al. 2021
PFOA Partition coefficient, $K_{d\text{-}PFOA}$	3.49	cm^3 g^{-1}	Rovero et al. 2021
PFNA Partition coefficient, $K_{d\text{-}PFNA}$	9.12	cm^3 g^{-1}	Rovero et al. 2021
PFHxS Partition coefficient, $K_{d\text{-}PFHxS}$	1.47	cm^3 g^{-1}	Rovero et al. 2021
PFDA Partition coefficient, $K_{d\text{-}PFDA}$	28.2	cm^3 g^{-1}	Rovero et al. 2021
PFBA Partition coefficient, $K_{d\text{-}PFBA}$	21.9	cm^3 g^{-1}	Rovero et al. 2021

Scenario 1 (worst case):
- **High recharge** rate of 46 mm/yr (Allena et al. 2022), representing disturbed, uncovered sediment (exposed, non-vegetated, no asphalt cover).
- PFAS concentrations within excavated pit volume at maximum sampled concentration

Scenario 2 (best case):
- **Low recharge** rate of 1 mm/yr for long-term average percolation rate through cracked asphalt parking lot (DOE/RL 2016; Meyer et al. 1994).
- PFAS concentrations within excavated pit volume at maximum sampled concentration.

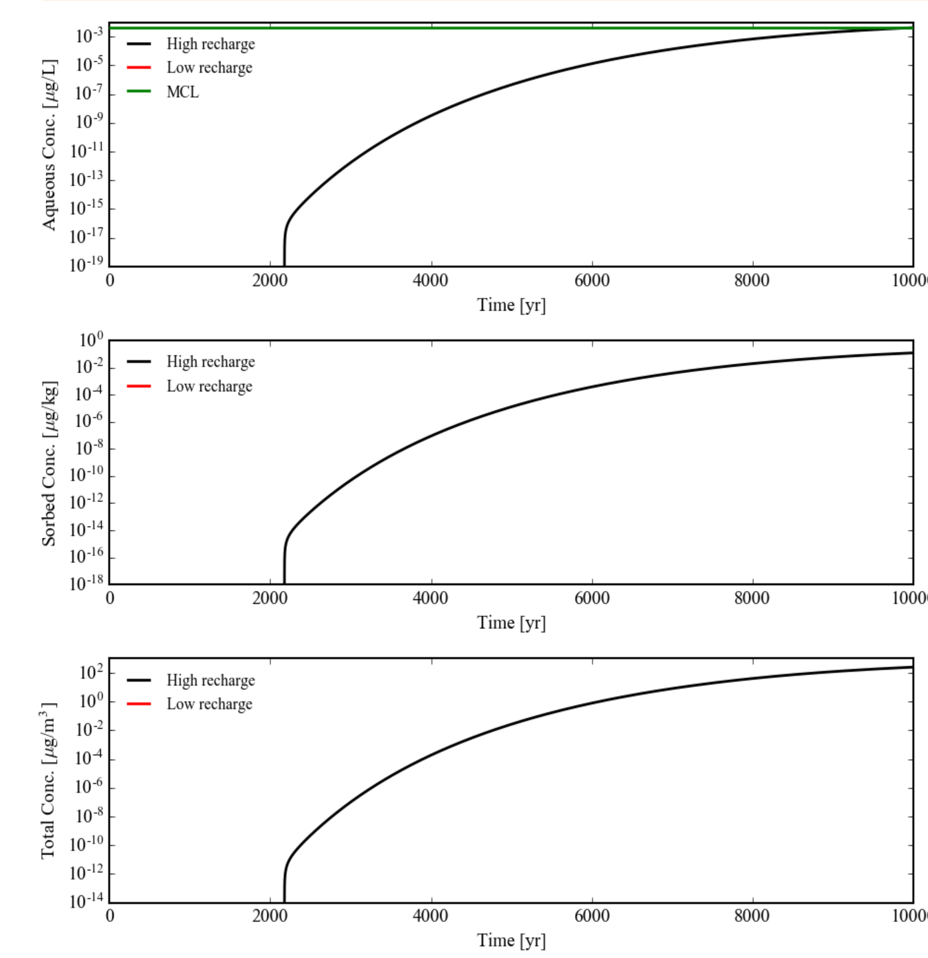


Figure 2. PFOS transport modeling results for median K_d values based on Rovero et al. 2021.

Note: Hanford sediment-specific K_d value is (Wang et al. 2021) is a factor of 44 lower than median K_d (Rovero et al. 2021).

Hanford sediment-specific K_d only available for PFOS (Wang et al. 2021).

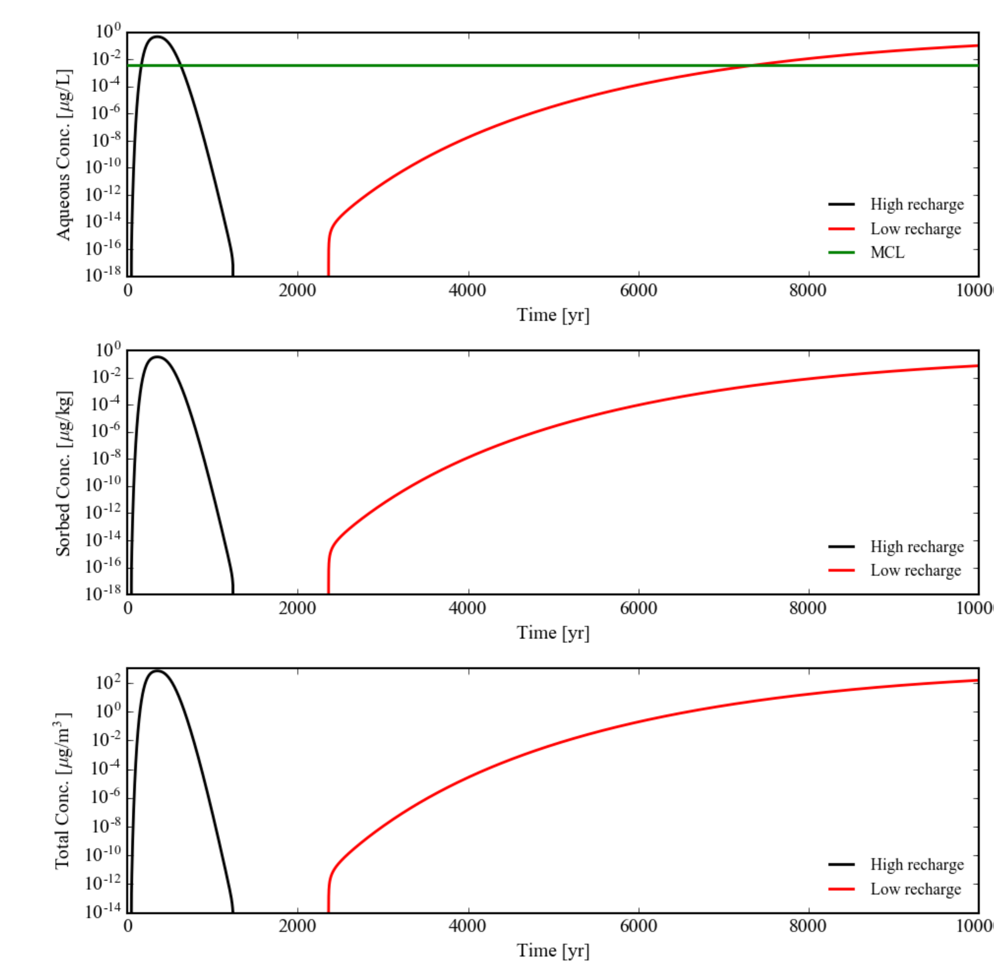


Figure 3. PFOS transport modeling results for Hanford Formation K_d values based on Wang et al. 2021.

Decision

Stockpiled soil was returned to excavated tank pit, asphalt parking lot was re-established (limiting recharge to the soil), and no further MTCA actions are required. The decision was based on lack of detected PFAS substances at the greatest depth sampled, and transport modeling demonstrated that highest detected levels evaluated in the soil will not reach groundwater.

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