December 4, 2024

Mary Camarata
Regional Solutions Coordinator
165 East 7th Avenue, Suite 100
Eugene, Oregon 97401

Dear Mary:

Enclosed, please find a technical memorandum (TM), prepared by GeoSystems Analysis, Inc. (GSA), that documents an analysis of the fate and transport of residual toluene and di(2-ethylhexyl)phthalate (DEHP) in treated wastewater discharges from a proposed wastewater infiltration system in Mill City, Oregon. The TM was prepared to address the Oregon Department of Environmental Quality's (DEQ's) January 16, 2024, comments on a screening-level fate and transport analysis of toluene and DEHP by GSI Water Solutions, Inc. (GSI) [1]. Specifically, the GSA TM addresses DEQ Comment No. 1.

GSA's fate and transport analysis concludes that residual toluene and DEHP in treated wastewater do not reach the Santiam River because they are attenuated by dilution, dispersion, biodegradation, and sorption. This conclusion, in conjunction with nitrate fate and transport modeling[2] and geochemical modeling[3], may be used to inform the permitting framework for the proposed wastewater infiltration system.

The table below summarizes the seven factors established by DEQ for evaluating functional equivalency, and how the factors are addressed by the toluene and DEHP transport model. Note that the toluene and DEHP transport model does not address Factor 2, Factor 3, or Factor 6.

Functional Equivalency Factors Addressed by the Toluene/DEHP Transport Model

Factor	Description	Toluene and DEHP Model Result	Factor Classification
1	Transit Time of Toluene/DEHP	Do Not Reach River	Unlikely Factor
2	Travel Distance of Toluene/DEHP	—	—
3	Nature of Material	—	—
4	Chemical Change of Toluene/DEHP	100% Reduction	Unlikely Factor
5	Amount Toluene/DEHP Entering Navigable Water	0% of Initial Concentration	Unlikely Factor
6	Manner or Area of Toluene/DEHP Discharge	--	--
7	Identity of Toluene/DEHP at Discharge Point	100% reduction	Unlikely Factor

Notes

— = not applicable, nitrate model does not provide information about the factor

[1] GSI. 2023. Evaluation of the Environmental Fate of Residual Pollutants from an Advance (Class A) Treated Wastewater Infiltration System, Mill City, Oregon. Prepared by: GSI Water Solutions, Inc. Prepared for: Marion County. November 16.
[2] GSI. 2024. Evaluation of the Environmental Fate of Residual Nitrate from an Advance (Class A) Treated Wastewater Infiltration Facility, Mill City, Oregon. Prepared by: GSI Water Solutions, Inc. Prepared for: Marion County. November 26.
[3] LCG. 2024. Geochemical Assessment to Support Evaluation of Treated Wastewater Infiltration, Gates and Mill City, Marion and Linn Counties, Oregon. Prepared by: LifeCycleGeo. Prepared for: GSI Water Solutions, Inc. October 29.

The table above applies DEQ's guidance related to the U.S. Supreme Court's "functional equivalence test" in the *County of Maui v. Hawaii Wildlife Fund* decision. We make no opinion as to DEQ's guidance's consistency with that decision or related EPA guidance.

Sincerely,
GSI Water Solutions, Inc.

Matt Kohlbecker, RG
Principal Hydrogeologist

GeoSystems Analysis, Inc.
Innovations in Hydrology

MEMORANDUM

REGISTERED OREGON JASON M. KELLER No. G2301 GEOLOGIST

Expires 2/1/25

December 4, 2024

TO: Matt Kohlbecker, RG, GSI Water Solutions, Inc.

FROM: Quinn Hull, GeoSystems Analysis, Inc.

Jason Keller, RG, GeoSystems Analysis, Inc.

RE: Subsurface Fate and Transport of Residual Discharges of Toluene and Di(2-ethylhexyl)phthalate from a Treated Wastewater Infiltration System, Mill City, Oregon

1.0 INTRODUCTION

This technical memorandum (TM), prepared by GeoSystems Analysis, Inc (GSA) on behalf of GSI Water Solutions, Inc. (GSI), summarizes an evaluation of the subsurface environmental fate and transport of residual discharges of toluene and Di(2-ethylhexyl)phthalate (DEHP) from a proposed treated wastewater infiltration system in Mill City, Oregon. The purpose of this TM is to inform the permitting framework for the proposed system by updating a screening-level evaluation conducted by GSI as part of the Gates/Mill City Oregon Wastewater Infiltration Feasibility Assessment (GSI, 2024a).

2.0 Project Background

The proposed wastewater treatment system will infiltrate treated wastewater into the groundwater system using a series of Rapid Infiltration Basins (RIBs) at site GM1 in Mill City (Figure 1). GSI previously evaluated the impact of the proposed RIBs on the downgradient groundwater and the Santiam River using a set of screening-level analytical groundwater pollutant fate and transport models (GSI, 2024a). Toluene and DEHP were selected for fate and transport modeling as they are organic compounds that have been detected in untreated wastewater. Based on the screening-level model simulations, both toluene and DEHP are predicted to attenuate to below their respective detection limits before reaching the downgradient property boundary.

However, changes to the RIB design and revisions to subsurface physical, hydrologic, and geochemical properties as supported by ongoing characterization activities have necessitated that the screening-level models be re-run to develop final conclusions about toluene and DEHP transport at the site. Additionally, in comments provided to GSI in an email from January 16, 2024, the Oregon Department of Environmental Quality (DEQ) has asked for a sensitivity analysis of the model methodology to evaluate the impact of different plausible operational and groundwater conditions on pollutant concentrations (DEQ, 2024a). GSA has been tasked with updating the modeling evaluation.

2.1 Objectives

The objectives of the updated modeling evaluation presented herein are as follows:

- Update the physical, hydrologic, and transport properties of the analytical models for consistency with current site understanding.
- Analyze the model sensitivity to a range of plausible values for the aquifer hydraulic conductivity and wastewater recharge volume.
- Present resulting groundwater concentrations of toluene and DEHP at the downgradient property boundary and Santiam River.

2.2 Organization

The remainder of the TM is organized as follows:

- Section 3.0 Fate and Transport Modeling Methods
- Section 4.0 Fate and Transport Modeling Results
- Section 5.0 Conclusions

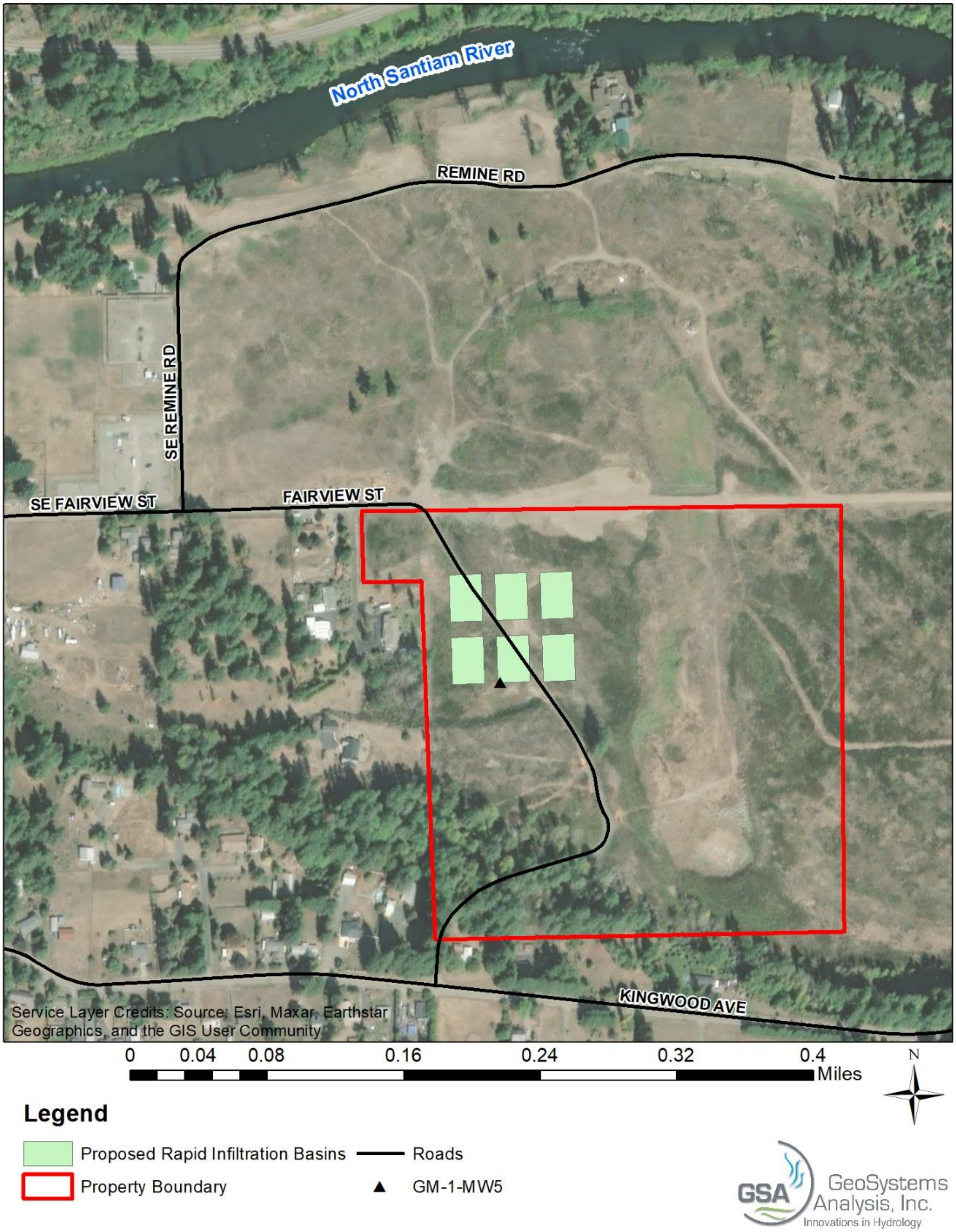


Figure 1. Site GM1 and rapid infiltration basins

3.0 METHODS

3.1 Modeling Approach

The modeling methods comprise two steps:

- Use the Washington State Department of Health's Large Onsite Septic System (LOSS) model (DOH, 2021) to calculate pollutant attenuation beneath the RIBs by dilution when wastewater, precipitation and groundwater are mixed.
- Use the United State Environmental Protection Agency (US EPA) BIOSCREEN model (US EPA, 1996) to calculate pollutant attenuation by dispersion, biodegradation, and sorption as groundwater is transported downgradient through the aquifer.

Output from the LOSS model is the initial pollutant concentration used in the BIOSCREEN model, based on the wastewater discharge volumes and pollutant concentration from the RIB system. Output from the BIOSCREEN model is the pollutant concentration at the property boundary (transport distance of 120 feet from the RIB edge).

This modeling approach is considered reasonably conservative, due to several simplifying assumptions that were reviewed by Oregon DEQ in the original GSI memorandum (2024a). Detailed technical documentation of the modeling approach is provided in the supporting appendices:

- Appendix A –The LOSS model.
- Appendix B – The BIOSCREEN model.

3.2 Sensitivity Analysis

To evaluate pollutant concentrations in groundwater at the downgradient property boundary in response to a range of plausible hydrogeologic and operating conditions, a sensitivity analysis was conducted. The range of pollutant concentrations from the sensitivity analysis is a representation of uncertainty from the combined LOSS and BIOSCREEN model predictions.

The input parameters evaluated for the sensitivity analysis, which were identified by DEQ (2024a), include:

- Wastewater volume
- Horizontal aquifer hydraulic conductivity (K)

The values of the input parameters for wastewater volume and horizontal hydraulic conductivity used in the assessment are provided in Table 1. The wastewater volumes used in the LOSS model are derived from the projected effluent generation volumes of the RIBs representing year 2045 average wet weather flow (base scenario) and maximum month wet weather flow (high scenario) (Keller, 2024). The K values evaluated are the low and high slug tests measured K values from monitoring wells at site GM1 (GSI, 2023b) and the groundwater numerical model calibrated K value for the aquifer beneath GM1 (GSI, 2024b).

Table 1. Model input parameters for sensitivity analysis

Model Input Parameter	Value			Units
	Low	Base	High	
Horizontal Aquifer Hydraulic Conductivity	37.0	95.0	163.3	feet/day
Wastewater Volume	-	237,000	262,000	gpd

gpd = gallons per day

4.0 RESULTS

Model results are provided in Table 2. The range of predicted values from the sensitivity analysis are presented. A detailed discussion of modeling results is provided in Appendix A (LOSS model) and Appendix B (BIOSCREEN model). Values reported as "< X" indicate that the predicted concentration is less than the detection limit for the pollutant, with the value of "X" indicating the detection limit. Detection limits were selected based on laboratory detection limits for groundwater samples collected during the Phase II Subsurface Characterization (GSI, 2023a).

Table 2. Model predicted Toluene and DEHP concentrations

Pollutant	Concentration in Untreated Wastewater	Concentration at Basin Edge (LOSS Model)	Concentration at Property Boundary (BIOSCREEN)	Concentration at Santiam River (BIOSCREEN)
	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Toluene	0.0496	0.0402 to 0.0466	< 0.0005	< 0.0005
DEHP	0.00901	0.00730 to 0.00846	< 0.0001	< 0.0001

mg/L = milligrams per liter

5.0 CONCLUSIONS

The fate and transport modeling evaluation demonstrates that both toluene and DEHP are predicted to attenuate to below their respective detection limits before reaching the downgradient property boundary. The concentrations at the property boundary were below detection for all values of K and wastewater recharge volumes evaluated.

The model results can be used to determine whether treated wastewater infiltration and discharge of groundwater to the Santiam River is functionally equivalent to a direct discharge to the Santiam River. The following analysis is based on the DEQ guidance "Determining if a WPCF permit should be a NPDES permit under the Maui Supreme Court Decision" (DEQ, 2024b). DEQ (2024b) identifies seven factors upon which to base a determination of functional equivalency. The fate and transport evaluation of toluene and DEHP addresses factors 4 and 5 described below:

Factor 4: the extent to which the pollutant is diluted or chemically changed as it travels. DEQ guidance states that "(o)nce the effluent reaches groundwater, it can be diluted or chemically changed by the groundwater, aquifer material, or aquifer sediments" (DEQ, pg. 9, 2024b). The guidance does not establish thresholds for evaluating the extent of pollutant dilution. However, the guidance states that ". . . the permit writer, in consult with a DEQ hydrogeologist, should consider the extent to which the pollutants in question are diluted or chemically changed as they travel, however this factor will not, on its own, support a finding of a functional equivalent of a direct discharge" (DEQ, pg. 9, 2024b).

The toluene and DEHP attenuation model results demonstrate that concentrations of both pollutants are below detectable limits at the property boundary. The simulated initial concentrations at the point of discharge for toluene and DEHP are 0.0496 and 0.00901 mg/L, respectively. The concentrations are measured, existing treatment plant influent concentrations. Toluene and DEHP will likely be removed through the wastewater treatment process, though how much removal is not known. Thus, using measured treatment plant influent concentrations at the point of discharge is a conservative assumption. <u>Both pollutants experience complete detectable reduction in concentration by the time they reach the Santiam River, indicating significant dilution and chemical change.</u>

Factor 5: the amount of pollutant entering the navigable waters relative to the amount of the pollutant that leaves the point source. DEQ guidance indicates that this factor requires an assessment of the proportion of pollutants reaching navigable waters compared to the amount discharged (DEQ, pg. 10, 2024b). The guidance emphasizes that the higher the percentage of pollutants entering navigable waters, the more likely the discharge is functionally equivalent to a direct discharge.

Modeling results for toluene and DEHP show that while simulated initial concentrations of 0.0496 mg/L and 0.00901 mg/L are present at the point source, detectable levels are not observed at the Santiam River boundary. This supports the conclusion that the mass of both pollutants are largely attenuated before entering navigable waters.

6.0 REFERENCES

Washington State Department of Health (DOH), 2021. Level 1 Nitrate Balance Instructions for Large On-Site Sewage Systems. DOH 337-069.

GSI Water Solutions, Inc. (GSI), 2023a. Phase II Subsurface Characterization to Support and Evaluation of Treated Wastewater Infiltration in Gates and Mill City, Marion and Linn Counties, Oregon. September 12, 2023.

GSI Water Solutions, Inc. (GSI), 2023b. Phase III Subsurface Characterization to Support and Evaluation of Treated Wastewater Infiltration in Gaes and Mill City, Marion and Linn Counties, Oregon. Memorandum to Chris Einmo, PE, Marion County. November 15, 2023

GSI Water Solutions, Inc. (GSI), 2024a. Evaluation of the Environmental Fate and Residual Pollutants from an Advance (Class A) Treated Wastewater Infiltration System, Mill City, Oregon. Memorandum to Chris Einmo, PE, Marion County. April 22, 2024

GSI Water Solutions, Inc. (GSI), 2024b. Evaluation of the Environmental Fate of Residual Nitrate from an Advance (Class A) Treated Wastewater Infiltration System, Mill City, Oregon. November 26, 2024.

Keller and Associates, 2024. Preliminary Engineering Report - Volume 1. City of Mill City. Water Pollution Control Facility Predesign. Prepared For Marion County, Oregon. September 30, 2024.

Oregon Department of Environmental Quality (DEQ), 2024a. Email from Mary Camarata (DEQ) to Chris Einmo (Marion County) RE: Comments on the Groundwater Model Report. January 16, 2024.

DEQ. 2024b. Determining if a WPCF permit should be a NPDES permit under the Maui Supreme Court Decision. May 9.

US Environmental Protection Agency (EPA), 1996. BIOSCREEN, Natural Attenuation Decision Support System - User's Manual, Version 1.3 (PDF). Publication No. EPA/600/R-96/087. August 1996

APPENDIX A: Technical Documentation for LOSS Model Simulations

1.0 BACKGROUND

This attachment provides technical documentation for application of the Washington State Department of Health's Large Onsite Septic System (LOSS) model to a proposed treated wastewater infiltration system at Site GM1 in Mill City, Oregon. The model is used to evaluate dilution of the residual wastewater pollutants toluene and Di(2-ethylhexyl)phthalate (DEHP) when they mix with infiltrating precipitation and groundwater at the site.

A screening-level version of the LOSS model was used by GSI Water Solutions, Inc. (GSI) to evaluate the dilution of toluene and DEHP in the technical memorandum titled "Evaluation of the Environmental Fate of Residual Pollutants from an Advance (Class A) Treated Wastewater Infiltration System, Mill City, Oregon" (GSI, 2024a). The Oregon Department of Environmental Quality (DEQ) has asked that the LOSS model be updated to reflect current site understanding and that a sensitivity analysis of model parameters be conducted (DEQ, 2024).

This section provides an overview of the governing equations used by the LOSS model to calculate toluene and DEHP concentrations in groundwater (Section 1.1), the sensitivity analysis (Section 1.2), and the purpose of the model simulations (Section 1.3).

1.1 LOSS Model Governing Equation

The equation used by the LOSS model to calculate the concentrations of pollutants in groundwater is:

$$C_{GW} = \frac{(Q \cdot C_B) + \left(V_W \cdot C_W(1-d)\right) + (V_R \cdot C_R)}{Q + V_W + V_R} \qquad \text{Equation A.1}$$

Where:

- C_{GW} is the pollutant concentration in groundwater at the downgradient edge of the RIBs (milligrams per liter, or mg/L),
- Q is the aquifer flow (gallons per day), calculated as $Q = (K)(i)(b)(W_A)$, where:
    - K is horizontal hydraulic conductivity (feet per day)
    - i is horizontal hydraulic gradient (feet per foot)
    - b is depth of mixing in the aquifer (feet)

  - W_A is width of the aquifer (feet)
- C_B is the background or upgradient pollutant concentration (mg/L)
- V_W is the volume of wastewater (gallons per day)
- C_W is the pollutant concentration in wastewater (mg/L)
- d is the pollutant percentage removed by denitrification in soil (dimensionless)
- V_R is the volume of precipitation recharge over the facility (gallons per day), calculated as
  - $V_R – (A_D)(R)(0.0017)$, where:
    - A_D is the area of the wastewater infiltration facility (square feet)
    - R is recharge (inches per year)
    - 0.0017 is a unit conversion to express V_R in units of gallons per day
- C_R is the pollutant concentration in precipitation (mg/L)

In the application of the LOSS model to concentrations of toluene and DEHP at site GM1 in Mill City, the following input parameter values can be set to zero[1]:

- Denitrification (d)
- Concentration of pollutant in background groundwater (C_B)
- Concentration of pollutant in precipitation (C_R)

Making these changes, Equation A-1 becomes:

$$C_{GW} = \frac{(V_W \cdot C_W)}{Q + V_W + V_R} \qquad \text{Equation A.2}$$

In Equation A.2, the pollutant concentration in effluent is represented by the quantity [(V_W)(C_W)].

The LOSS model's output (C_{GW}, the concentration of the pollutant in the aquifer adjacent and downgradient to the RIBs) represents pollutant attenuation only due to dilution (specifically,

[1] Background groundwater samples from Site GM1 did not have detectable levels of toluene and DEHP (GSI, 2023a). The concentration of the pollutants in precipitation can reasonably be assumed to be zero.

by mixing between precipitation, treated wastewater, and groundwater entering the site from upgradient). This concentration can be used as input to an aquifer pollutant fate and transport model that simulates other pollutant attenuation mechanisms (for example, dispersion, sorption, and biodegradation).

1.2 Sensitivity Analysis

To evaluate how pollutant concentrations in groundwater respond to a range of plausible hydrogeologic and operating conditions, a sensitivity analysis was conducted. The input parameters evaluated for the sensitivity analysis, which were identified by DEQ (2024) include:

- Wastewater volume (V_W)
- Horizontal aquifer hydraulic conductivity (K)

The range of pollutant concentrations C_{GW} from the sensitivity analysis is a representation of the uncertainty of the LOSS model predictions.

1.3 Purpose

The purpose of the LOSS modeling is to predict concentrations of the pollutants toluene and DEHP in groundwater at the downgradient edge of the proposed wastewater Rapid Infiltration Basins (RIBs) at Site GM1. A secondary purpose is to represent the uncertainty of the predictions with a sensitivity analysis of the model output to a range of plausible values for input concentrations for a separate model (i.e., BIOSCREEN) to predict pollutant attenuation by dispersion, sorption, and biodegradation that occurs during transport from the downgradient edge of the infiltration basin to the downgradient property boundary.

2.0 MODEL INPUT PARAMETERS

Model input parameters for using Equation A.2 to calculate the concentration of pollutants toluene and DEHP in groundwater (C_{GW}) adjacent to the infiltration basin are summarized in Table A-1. The following subsections describe the methods that were used to develop the model input parameters. The V_W and K values are varied for the purpose of the sensitivity analysis, and are described in Section 2.7. The remaining input parameter values from Equation A.2 are fixed in the sensitivity analysis, and are described in Sections 2.1 through 2.6.

Table A-1. LOSS Model Input Parameters for Calculation of C_{GW}

Model Input Parameter	Symbol	Value	Units	Subsection in the Text
Aquifer Thickness	b	20	feet	2.1
Wastewater Infiltration Facility Area	A_D	89,000	ft^2	2.2
Aquifer Width	W_A	510	feet	2.3
Hydraulic Gradient	i	0.004	feet/feet	2.4
Recharge	R	35	inches/year	2.5
Concentration in Untreated Wastewater	C_W	0.0496 (Toluene) 0.00901 (DEHP)	mg/L	2.6
Horizontal Hydraulic Conductivity	K	Variable[1]	feet/day	2.7.1
Wastewater Volume	V_W		gpd	2.7.2

1. Evaluated in sensitivity analysis
mg/L = milligrams per liter
gpd = gallons per day
ft^2 = square feet

2.1 Aquifer Thickness (*b*)

Data from temporary borings and monitoring wells indicate that the aquifer thickness at Site GM1 is about 45 feet. Specifically, the bottom of the aquifer coincided with a greater than 20 foot thick layer of silt at 65 feet below ground surface (bgs) in temporary boring TB-2, and the depth to groundwater was approximately 20 feet bgs (GSI, 2023b). However, the DOH (2021) guidance requires that the maximum aquifer thickness used for modeling purposes is 20 feet. Therefore, a value for *b* of 20 feet was used in the LOSS model.

2.2 Wastewater Infiltration Facility Area (A_D)

The wastewater infiltration facility will consist of six basins with a total area of 89,000 square feet (ft^2) (i.e., about 2 acres total) (Keller, 2024). The locations of the infiltration basins are shown in Figure A-1.

2.3 Aquifer Width (W_A)

As shown in Figure A-1, groundwater at Site GM1 flows towards the northwest. The aquifer width, which is equivalent to the width of the infiltration facility perpendicular to the groundwater flow direction, is estimated to be 510 feet.

2.4 Upgradient Hydraulic Gradient (i)

The hydraulic gradient (i) is the slope of the water table near the infiltration basins. Modeling of the effect of wastewater infiltration on groundwater levels demonstrates that i will be lower to the southeast (i.e. upgradient) than to the northwest (i.e. downgradient) of the infiltration basins (GSA, 2024). For the LOSS model, the upgradient i is used to calculate the aquifer flow, Q (Equation A.2). Note that using upgradient i for the purposes of the LOSS model is reasonable, as the downgradient i may overestimate the degree of mixing between infiltrated wastewater and the aquifer. The upgradient hydraulic gradient at site GM1 is 0.004 feet per foot, which is based on the observed groundwater elevations at monitor well locations MW4 and GM1-MW2 on June 20, 2024 (GSI, 2024b). The estimated groundwater elevation contours are shown in Figure A-1.

2.5 Recharge (R)

Recharge is the amount of precipitation that infiltrates into the aquifer. Recharge at Site GM1 was evaluated using two methods.

1) PRISM (https://prism.oregonstate.edu/) estimated 10-year average water year (October through September) precipitation at Site GM1 is 60.8 inches per year. Through an analysis of seasonal changes in measured groundwater elevation at Site GM1, GSI estimated groundwater recharge at the site to be 59.4% of precipitation (GSI, 2024b). This equates to a recharge rate of 36.1 inches per year when applying to the PRISM estimated precipitation.

2) OpenET (https://etdata.org/) estimated potential evapotranspiration for Site GM1 is 27.4 inches per yr. Assuming the PRISM estimated average water year precipitation (60.8 inches per year) minus potential evapotranspiration is equal to the recharge rate, the estimated recharge using this method is 33.4 inches per year.

The average of the two estimation methods (35 inches per year) was used in the LOSS model.

2.6 Toluene and DEHP Concentration in Wastewater (C_W)

The concentrations of toluene and DEHP in wastewater were determined based on samples of untreated wastewater from Mill City's existing wastewater treatment system collected on May 2, 2023. Note that the values of C_W are conservative because they represent concentrations prior to treatment.

2.7 Parameters for Sensitivity Analysis

Model input parameters that were varied for the purposes of the sensitivity analysis are summarized in Table A-2. The sensitivity analysis was conducted for low, baseline, and high values for K, and baseline and high values for V_W.

Table A-2. LOSS Model Input Parameters for Sensitivity Analysis of C_{GW}

Model Input Parameter	Symbol	Value			Units	Subsection in the Text
		Low	Baseline	High		
Horizontal Aquifer Hydraulic Conductivity	K	37.0	95.0	163.3	feet/day	2.7.1
Wastewater Volume	V_W	-	237,000	262,000	gpd	2.7.2

gpd = gallons per day

2.7.1 Horizontal Hydraulic Conductivity (K)

Hydraulic conductivity is a property of porous materials that describes how easily fluid moves through the pore space, and is correlated with soil type in the aquifer (e.g., clay, silt, sand, or gravel). A baseline hydraulic conductivity of 95 feet per day was used in the LOSS model; the low- and high-end values are based on low and high slug test measured K at the site GM1 monitoring wells. The baseline K value was assigned to be equal to the groundwater numerical model calibrated K value for the aquifer beneath GM1 (GSI, 2024c).

2.7.2 Wastewater Volume (V_W)

The wastewater volumes used in the LOSS model are derived from the projected effluent generation volumes (Keller, 2024). The baseline wastewater volume is 237,000 gallons per day, which is the projected year 2045 average wet weather flow. The high-end wastewater volume is 262,000 gallons per day, which is the projected 2045 maximum month wet weather flow.

3.0 RESULTS

This section provides an overview of the concentration of toluene (Section 3.1) and DEHP (Section 3.2) in groundwater after dilution, C_{GW}. For each pollutant, concentrations are presented for six sensitivity analysis scenarios with all possible combinations of the K and V_W input parameters.

3.1 Toluene Concentration in Groundwater

LOSS model output concentrations of toluene in groundwater adjacent to the RIBs (C_{GW}) are summarized in Table A-3. C_{GW} of toluene ranges between 0.0402 and 0.0466 mg/L. The LOSS model calculations are presented from Figure A-2 to Figure A-7 for each sensitivity analysis scenario (scenarios 1 through 5) and the base scenario (scenario 6). C_{GW} of toluene for the base scenario is 0.0433 mg/L.

Table A-3. LOSS Model Output for Toluene

Analysis Scenario	Model Input Parameter			Model Output	Figure Reference
	Concentration in Untreated Wastewater, C_W (mg/L)	Horizontal Hydraulic Conductivity, K (feet /day)	Wastewater Volume, V_W (gpd)	Concentration in Groundwater, C_{GW} (mg/L)	
1	0.0496	37.0	262,000	0.0466	A-2
2		163.3	262,000	0.0410	A-3
3		37.0	237,000	0.0464	A-4
4		163.3	237,000	0.0402	A-5
5		95.0	262,000	0.0439	A-6
6 (base)		95.0	237,000	0.0433	A-7

mg/L = milligrams per liter

gpd = gallons per day

3.2 DEHP Concentration in Groundwater

LOSS model output concentrations of DEHP in groundwater adjacent to the RIBs (C_{GW}) are summarized in Table A-4. C_{GW} of DEHP ranges between 0.00730 and 0.00846 mg/L. The LOSS model calculations are presented from Figure A-8 to Figure A-13 for each sensitivity analysis scenario (scenarios 1 through 5) and the base scenario (scenario 6). C_{GW} of DEHP for the base scenario is 0.0786 mg/L.

Table A-4. LOSS Model Output for DEHP

Analysis Scenario	Model Input Parameter			Model Output	Figure Reference
	Concentration in Untreated Wastewater, C_W (mg/L)	Horizontal Hydraulic Conductivity, K (feet /day)	Wastewater Volume, V_W (gpd)	Concentration in Groundwater, C_{GW} (mg/L)	
1	0.00901	37.0	262,000	0.00846	A-8
2		163.3	262,000	0.00744	A-9
3		37.0	237,000	0.00841	A-10
4		163.3	237,000	0.00730	A-11
5		95.0	262,000	0.00796	A-12
6 (base)		95.0	237,000	0.00786	A-13

mg/L = milligrams per liter

gpd = gallons per day

4.0 CONCLUSION

The LOSS model results in Table A-3 and Table A-4 are appropriate to use as initial concentrations in BIOSCREEN to evaluate the pollutant attenuation that occurs by dispersion, sorption, and biodegradation during transport in groundwater between the edge of the RIBs and the downgradient property boundary, as presented in Appendix B.

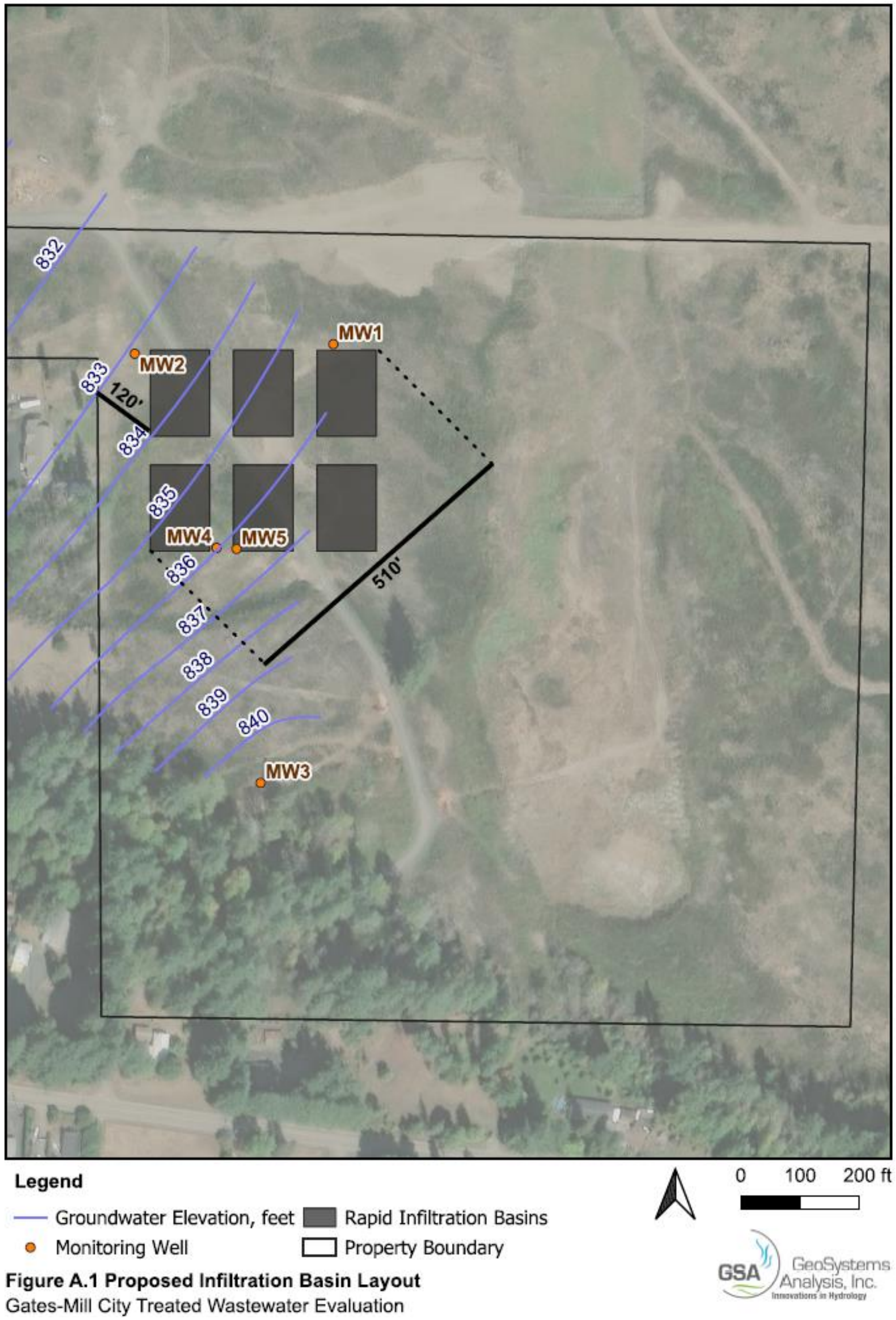


Figure A-1 Proposed Infiltration Basin Layout

Figure A.2, Scenario 1

LOSS Model for Toluene

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infiltration Basin**
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**
Date:	**10/14/2024**

Input Values	Factor	Units	Values
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0496
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	37.0
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	262,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	0.0466
Dilution Factor			1.06

DOH 337-070

Figure A-2 Loss Model for Toluene, Scenario 1

Figure A.3, Scenario 2

LOSS Model for Toluene

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infilitration Basin**
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**
Date:	**10/14/2024**

Input Values	Factor	Units	Values
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0496
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	163.3
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	262,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	0.0410
Dilution Factor			1.21

DOH 337-070

Figure A-3 Loss Model for Toluene, Scenario 2

Figure A.4, Scenario 3

LOSS Model for Toluene

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infiltration Basin**
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**
Date:	**10/14/2024**

Input Values	Factor	Units	Values
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0496
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	37.0
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	237,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	0.0464
Dilution Factor			1.07

DOH 337-070

Figure A-4 Loss Model for Toluene, Scenario 3

Figure A.5, Scenario 4

LOSS Model for Toluene

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infiltration Basin**
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**
Date:	**10/14/2024**

Input Values	**Factor**	**Units**	**Values**
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0496
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	163.3
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	237,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	**0.0402**
Dilution Factor			**1.23**

DOH 337-070

Figure A-5 Loss Model for Toluene, Scenario 4

Figure A.6, Scenario 5

LOSS Model for Toluene

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infiltration Basin**
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**
Date:	**10/14/2024**

Input Values	**Factor**	**Units**	**Values**
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0496
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	95.0
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	262,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	**0.0439**
Dilution Factor			**1.13**

DOH 337-070

Figure A-6 Loss Model for Toluene, Scenario 5

Figure A.7, Scenario 6

LOSS Model for Toluene

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infiltration Basin**
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**
Date:	**10/14/2024**

Input Values	**Factor**	**Units**	**Values**
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0496
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	95.0
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	237,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	**0.0433**
Dilution Factor			**1.14**

DOH 337-070

Figure A-7 Loss Model for Toluene, Scenario 6

Figure A.8, Scenario 1

LOSS Model for DEHP

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infilitration Basin**
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**
Date:	**10/14/2024**

Input Values	**Factor**	**Units**	**Values**
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0090
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	37.0
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	262,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	**0.00846**
Dilution Factor			**1.06**

DOH 337-070

Figure A-8 Loss Model for DEHP, Scenario 1

Figure A.9, Scenario 2

LOSS Model for DEHP

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infiltration Basin**
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**
Date:	**10/14/2024**

Input Values	**Factor**	**Units**	**Values**
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0090
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	163.3
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	262,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	**0.00744**
Dilution Factor			**1.21**

DOH 337-070

Figure A-9 Loss Model for DEHP, Scenario 2

Figure A.10, Scenario 3

LOSS Model for DEHP

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infiltration Basin**		
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**		
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**		
Date:	**10/14/2024**		

Input Values	**Factor**	**Units**	**Values**
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0090
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	37.0
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	237,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	**0.00841**
Dilution Factor			**1.07**

DOH 337-070

Figure A-10 Loss Model for DEHP, Scenario 3

Figure A.11, Scenario 4

LOSS Model for DEHP

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infiltration Basin**
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**
Date:	**10/14/2024**

Input Values	**Factor**	**Units**	**Values**
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0090
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	163.3
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	237,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	**0.00730**
Dilution Factor			**1.23**

DOH 337-070

Figure A-11 Loss Model for DEHP, Scenario 4

Figure A.12, Scenario 5

LOSS Model for DEHP

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infiltration Basin**
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**
Date:	**10/14/2024**

Input Values	**Factor**	**Units**	**Values**
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0090
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	95.0
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	262,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	**0.00796**
Dilution Factor			**1.13**

DOH 337-070

Figure A-12 Loss Model for DEHP, Scenario 5

Figure A.13, Scenario 6

LOSS Model for DEHP

Gates-Mill City Treated Wastewater Infiltration Evaluation

Washington State Department of Health

Project name:	**Gates and Mill City Infilitration Basin**
Address, city and county:	**Gates and Mill City, Marion and Linn Counties, OR**
Completed by (name and title):	**R. Hull (Project Hydrogeologist)**
Date:	**10/14/2024**

Input Values	Factor	Units	Values
Pollutant concentration in precipitation	C_R	mg/l	0
Total pollutant concentration in wastewater	C_W	mg/l	0.0090
Soil denitrification	d	unitless	0
Aquifer thickness	b	ft	20
Drainfield area	A_D	ft^2	88,863
Distance from drainfield to property boundary	D_{pb}	ft	1
Aquifer width	W_A	ft	510
Aquifer hydraulic conductivity	K	ft/day	95.0
Hydraulic gradient	i	ft/ft	0.004
Recharge	R	in/yr	35
Pollutant concentration of upgradient ground water	C_B	mg/l	0
Wastewater volume	V_W	gpd	237,000

Output Values			
Groundwater Concentration	C_{GW}	mg/l	0.00786
Dilution Factor			1.14

DOH 337-070

Figure A-13 Loss Model for DEHP, Scenario 6

5.0 REFERENCES

DOH. 2021. Level 1 Nitrate Balance Instructions for Large One-Site Sewage Systems. DOH 337-069.

GeoSystems Analysis (GSA), 2024. Evaluation of Groundwater Mounding from Site GM1 Treated Wastewater Infiltration, Mill City, Oregon. November 8, 2024.

GSI Water Solutions, Inc. (GSI), 2023a. Phase II Subsurface Characterization to Support and Evaluation of Treated Wastewater Infiltration in Gates and Mill City, Marion and Linn Counties, Oregon. September 12.

GSI Water Solutions, Inc. (GSI), 2023b. Phase III Subsurface Characterization to Support and Evaluation of Treated Wastewater Infiltration in Gaes and Mill City, Marion and Linn Counties, Oregon. Memorandum to Chris Einmo, PE, Marion County. November 15, 2023

GSI Water Solutions, Inc. (GSI), 2024a. Evaluation of the Environmental Fate and Residual Pollutants from an Advance (Class A) Treated Wastewater Infiltration System, Mill City, Oregon. Memorandum to Chris Einmo, PE, Marion County. April 22, 2024

GSI Water Solutions, Inc. (GSI), 2024b. Groundwater Level Monitoring to Support an Evaluation of Treated Wastewater Infiltration in Gates and Mill City, September 2023 to April 2024. Prepared by: GSI Water Solutions, Inc. Prepared for: Marion County. May 24.

GSI Water Solutions, Inc. (GSI), 2024c. Evaluation of the Environmental Fate of Residual Nitrate from an Advance (Class A) Treated Wastewater Infiltration System, Mill City, Oregon. November 26, 2024.

Keller and Associates, 2024. Preliminary Engineering Report - Volume 1. City of Mill City. Water Pollution Control Facility Predesign. Prepared For Marion County, Oregon. September 30, 2024.

Oregon Department of Environmental Quality (DEQ), 2024. Email from Mary Camarata (DEQ) to Chris Einmo (Marion County) RE: Comments on the Groundwater Model Report. January 16, 2024.

APPENDIX B: Technical Documentation for BIOSCREEN Model Simulations

1.0 BACKGROUND

This appendix provides technical documentation for application of the U.S. Environmental Protection Agency's (EPA) BIOSCREEN model to a proposed treated wastewater infiltration system at Site GM1 in Mill City, Oregon. The model is used to simulate the fate and transport of the residual wastewater pollutants toluene and Di(2-ethylhexyl)phthalate (DEHP) in groundwater to the property boundary of Site GM1. The BIOSCREEN model is applied after the evaluation of pollutant dilution using the Washington State Department of Health's Large Onsite Septic System (LOSS) model, as described in Appendix A.

BIOSCREEN is an analytical model developed by EPA to simulate pollutant fate and transport in saturated porous media (EPA, 1996). The model simulates pollutant attenuation by dispersion, biodegradation, and sorption.

An initial screening-level BIOSCREEN model was used by GSI Water Solutions, Inc. (GSI) to simulate the fate and transport of toluene and DEHP at site GM1 (GSI, 2024a). The Oregon Department of Environmental Quality (DEQ) has asked that the BIOSCREEN model be updated to reflect current site understanding and that a sensitivity analysis of model parameters be conducted (DEQ, 2024).

This section provides an overview of the governing equations used by BIOSCREEN to simulate pollutant fate and transport (Section 1.1), the sensitivity analysis (Section 1.2), and the purpose of the model simulations (Section 1.3).

1.1 BIOSCREEN Model Governing Equation

Pollutant attenuation by dispersion, degradation, and sorption can be modeled with the advection dispersion equation (e.g., Bear, 1972). BIOSCREEN uses the Domenico (1987) solution to the three-dimensional advection dispersion equation with first-order decay of the source concentration into the solution. The Domenico (1987) solution for transport in three dimensions with first-order source decay is (EPA, pg. 9, 1996):

$$C(x,y,z,t) = \frac{C_0}{8} e^{-k_l t} f_x f_y f_z \qquad \text{Equation B.1}$$

Where:

$$f_x = \exp\left[\frac{x\left(1-\sqrt{1+\frac{4\lambda\alpha_x}{v}}\right)}{2\alpha_x}\right] \operatorname{erfc}\left[\frac{x-vt\sqrt{\frac{1+4\lambda\alpha_x}{v}}}{\sqrt{2\alpha_x vt}}\right] \quad \text{Equation B.2}$$

$$f_y = \operatorname{erf}\left[\frac{y+\frac{Y}{2}}{2\sqrt{\alpha_y x}}\right] - \operatorname{erf}\left[\frac{y-\frac{Y}{2}}{2\sqrt{\alpha_y x}}\right] \quad \text{Equation B.3}$$

$$f_z = \operatorname{erf}\left[\frac{Z}{2\sqrt{\alpha_z x}}\right] - \operatorname{erf}\left[\frac{-Z}{2\sqrt{\alpha_z x}}\right] \quad \text{Equation B.4}$$

In Equation B.1 through Equation B.4, *erf* is the error function, and *erfc* is the complimentary error function. These functions model pollutant transport according to a normal (Gaussian) probability density function. The variables in Equation B.1 through Equation B.4 are:

- $C(x,y,z,t)$ is the dissolved concentration in units of mass, M, per cubic length, L^3 (M/L^3) at the spatial coordinates x, y, and z and time t (note that x is in the direction of groundwater flow, y is the cross-gradient direction, and z is the vertical direction),
- C_0 is the dissolved concentration in the source zone at time = 0 (M/L^3),
- α_x is dispersivity in the x-direction (longitudinal dispersivity) (L),
- α_y is dispersivity in the y-direction (transverse dispersivity) (L),
- α_z is dispersivity in the z-direction (vertical dispersivity) (L),
- λ is the first-order decay constant for dissolved pollutants, in units of inverse time, T (T^{-1}),
- v is groundwater velocity (L/T),
- Y is the source width (L), and
- Z is the source thickness (L).

Equation B.1 assumes that the initial pollutant concentration in the source is $C = C_0$, and the initial pollutant concentration in groundwater is C = 0. Testing of background groundwater water quality confirms that levels of both toluene and DEHP are not detectable at Site GM1 (GSI, 2023a).

The BIOSCREEN model output $C(x, y, z, t)$ can be evaluated at any location in the aquifer downgradient to the infiltration facility. The simulated pollutant concentration at the downgradient property boundary of GM1 is denoted by C_{DG}.

1.2 Sensitivity Analysis

The sensitivity analysis of LOSS model outputs is extended to the BIOSCREEN model, in order to evaluate how pollutant concentrations at the downgradient property boundary (C_{DG}) respond to a range of plausible hydrogeologic and operating conditions. The sensitivity of C_{DG} to two input parameters is evaluated:

- Initial concentration of the pollutants in groundwater (C_0)
- Groundwater velocity (v)

Of note, C_0 is the model output from the LOSS model. The LOSS sensitivity analysis is further described in Appendix A.

1.3 Purpose

The purpose of the BIOSCREEN modeling summarized in this appendix is to predict pollutant concentrations in groundwater at the downgradient property boundary of Site GM1. The simulations are based on the pollutant attenuation by dispersion, sorption, and biodegradation that is expected to occur during transport from the downgradient edge of the Rapid Infiltration Basins (RIBs) to the downgradient property boundary.

2.0 MODEL INPUT PARAMETERS

Model input parameters are summarized in Table B-1. The following subsections describe the methods that were used to develop the model input parameters. Model input parameters were developed based on scientific literature and site-specific data collected at Site GM1. The initial concentrations in groundwater (C_{GW}) and seepage velocity (V_S) are varied as a function of the sensitivity analysis, and are described in Section 2.8. The remaining input parameter values from Equation A.2 are fixed in the sensitivity analysis, and are described in Sections 2.1through 2.7.

Table B-1. BIOSCREEN Model Input Parameters

Model Input Parameter	Symbol	Value	Units	Subsection in the Text
Dispersivity	α_L α_T α_V	8.0 (Longitudinal) 2.6 (Transverse) 0.40 (Vertical)	feet	2.1
Retardation Factor	R	1.84 (Toluene) 762 (DEHP)	(-)	2.2
Half Life	h	4.7 (Toluene) 3.5 (DEHP)	days	2.3
Source Width	W_S	510	feet	2.4
Source Thickness	T_S	20	feet	
Model Width	W_M	1,000	feet	2.5
Model Length	L_M	120	feet	
Simulation Time	t	10,000	years	2.6
Source Type	-	Constant Concentration	(-)	2.7
Concentration in Wastewater	C_0	Variable[1]	mg/L	2.8.1
Seepage Velocity	V_S		feet/day	2.8.2

1. Evaluated in sensitivity analysis
mg/L = milligrams per liter

2.1 Dispersivity (α_L, α_T, α_V)

Dispersivity is a three-dimensional, scale-dependent variable that describes the amount of pollutant spreading (i.e., dispersion) that occurs during pollutant transport. Dispersivity in the direction of flow is called longitudinal dispersivity. Longitudinal Dispersivity was calculated using the Xu and Eckstein (1995) equation:

$$\alpha_L = 0.83\left[\log\left(L_p\right)\right]^{2.414} \qquad \text{Equation B.5}$$

where:

α_L is longitudinal dispersivity (meters)

L_p is the length of the pollutant plume (meters)

As shown in Figure B-1, the shortest distance between an infiltration basin and the downgradient property boundary along the groundwater flow path is about 120 feet. Using the shortest distance is conservative because it will result in the smallest value for dispersivity and, therefore, least amount of dispersion. Based on a pollutant plume length of 120 feet, the longitudinal dispersivity is 8.0 feet according to Equation B.5.

According to ASTM (1995), transverse dispersivity can be assumed to be 33% of longitudinal dispersivity (i.e., 2.6 feet), and vertical dispersivity can be assumed to be 5% of longitudinal dispersivity (i.e., 0.40 feet).

2.2 Retardation (*R*)

Pollutants in porous media partition between the liquid, solid, and gas phases. This modeling evaluation conservatively assumes that pollutants only partition between the liquid phase (i.e., aqueous or dissolved phase) and solid phase (i.e., adhere to soil particles). Partitioning between the liquid and solid phases is called sorption, which is caused primarily by van der Waals forces and electrostatic forces between the contaminant molecule and the ions of the soil particle surface. Some pollutants partition preferentially into the aqueous phase, while other pollutants preferentially partition onto the soil particles.

Due to sorption, a pollutant velocity may be slower than groundwater velocity. A pollutant's velocity relative to groundwater is quantified by the retardation factor (e.g., Freeze and Cherry, 1979):

$$R = 1 + \frac{(\rho_b)(K_{oc})(f_{oc})}{n} \qquad \text{Equation B.6}$$

where:

R is the retardation factor (dimensionless)

ρ_b is the soil bulk density (kilograms per liter)

K_{oc} is the organic carbon water partitioning coefficient (liters per kilogram)

f_{oc} is the fraction of organic carbon in soil

n is total porosity (dimensionless)

Table B-2 summarizes the values that were used to calculate retardation factor for the pollutants modeled with BIOSCREEN. A retardation factor of 2 indicates that a pollutant travels half the speed of groundwater. Note that the retardation factor for toluene indicates that it travels at about half the velocity as groundwater, and the retardation factor for DEHP indicates that it travels at 1/635th the velocity of groundwater.

Table B-2. Retardation Factor Calculation

Model Input Parameter	Symbol	Value	Units
Soil bulk density[1]	ρ_b	1.66	kg/L
Organic carbon water partitioning coefficient[2]	K_{oc}	165 (Toluene) 149,000 (DEHP)	L/kg
Fraction of organic carbon[3]	f_{oc}	0.0012	(-)
Total Porosity[4]	n	0.39	(-)
Retardation Factor	R	1.84 (Toluene) 762 (DEHP)	(-)

1. Average dry bulk density based on soil samples collected from the monitoring well GM1-MW1 boring. See Attachment B of the Phase II Subsurface Characterization (GSI, 2023a).

2. K_{oc} for DEHP and toluene are based on a literature review (GSI, 2024a).

3. f_{oc} value from soil analysis from test pit TP7, which was the lowest observed below Site GM1 (See Attachment B-1).

4. Average total porosity based on soil samples collected from the monitoring well GM1-MW1 boring. See Attachment B of the Phase II Subsurface Characterization (GSI, 2023a).

kg/L = killograms per liter

L/kg = liters per kilogram

2.3 Half Life (*h*) and First Order Decay Constant (*λ*)

Pollutants degrade by photolysis (exposure to sunlight), hydrolysis (interaction with water), and biodegradation (degradation by microbes). We conservatively only include the degradation pathway of biodegradation in the BIOSCREEN modeling analysis. GSI (2024a) conducted an extensive literature review of biodegradation rates for DEHP and toluene, and findings were applied herein, consistent with the previous BIOSCREEN model analysis (GSI, 2024a).

Biodegradation is described by a half life (*h*), which is the time required for a pollutant concentration to decline by 50%, and first order decay constant (λ), which is calculated as:

$$\lambda = \frac{ln(2)}{h} \quad \text{Equation B.7}$$

Because *h* and λ depend on oxygen levels (i.e., whether the subsurface is aerobic or anaerobic), only aerobic-based values of *h* and λ were considered. The *h* and λ used in the fate and transport evaluation are summarized in Table B-3. Because BIOSCREEN requires that *h* and λ to be input in units of years, the values in Table B-3 were converted to from days to years for input into the model.

Table B-3. Biodegradation Rates

Model Input Parameter	Symbol	Value	Units
Half life[1]	*h*	4.67 (Toluene) 3.50 (DEHP)	days
First Order Decay Constant[1]	λ	0.148 (Toluene) 0.198 (DEHP)	$days^{-1}$

1. Half life and first order decay constant values are based on a literature review (See GSI, 2024a)

2.4 Source Width (W_s)and Thickness (T_s)

The width of the source, W_s, is the RIBs width perpendicular to the direction of groundwater flow. As shown in Figure B-1, groundwater flows towards the northwest, and the width of the RIBs perpendicular to the groundwater flow direction is 510 feet. Source thickness T_s in the saturated zone was selected to be 20 feet to align the BIOSCREEN model with the LOSS model. Specifically, the LOSS model guidance (DOH, 2021) assumes that infiltrating wastewater will mix with the upper 20 feet of the saturated zone.

2.5 Model Width (W_m) and Length (L_m)

The width of the area being modeled (W_m) should be larger than the pollutant plume, and was selected to be 1,000 feet in the BIOSCREEN model. The length of the area being modeled (L_m) is equivalent to the length over which concentrations are to be calculated, and was selected to be 120 feet in the BIOSCREEN model. This model length value output pollutant concentrations at 120 feet from the source (i.e., the shortest distance between the downgradient edge of the RIBs and the downgradient property boundary).

2.6 Simulation Time

Simulation time (t) is the time period over which transport occurs. A simulation time of 10,000 years was used for the BIOSCREEN simulations. It was determined empirically that the pollutants plumes reach a steady state condition by this time.

2.7 Source Type

Pollutant fate and transport simulations can be conducted using several different source types. For example, a source can be simulated as continuous with constant concentration, continuous with a concentration that decays over time, or a pulse of known concentration. The infiltration of treated wastewater was conservatively simulated as a continuous source with constant concentration in the BIOSCREEN model by entering a “Source Half Life” of “Infinite” in the model.

2.8 Parameters for Sensitivity Analysis

This section summarizes BIOSCREEN model input parameters that were varied for the purposes of the sensitivity analysis. Section 2.8.1 provides the initial pollutant concentrations in groundwater (C_0), which is calculated from the LOSS model. Section 2.8.2provides calculations for seepage velocity (V_S), which is calculated from low, baseline, and high values for horizontal aquifer hydraulic conductivity (K).

2.8.1 Initial Concentration in Groundwater (C_0)

Initial concentrations in BIOSCREEN for toluene and DEHP are provided in Table B-4. The initial concentrations are calculated outputs from the LOSS model. For both toluene and DEHP, C_0 is calculated for six sensitivity analysis scenarios, each representing a possible combination of the model parameters K and V_W. See Appendix A for a detailed discussion.

Table B-4. Initial concentration in groundwater of toluene and DEHP (from LOSS model)

Sensitivity Analysis Scenario	LOSS Model Inputs		Toluene	DEHP
	Horizontal Hydraulic Conductivity, K (feet /day)	Wastewater Volume, V_W (gpd)	Initial Concentration in BIOSCREEN, C_0 [1] (mg/L)	
1	37.0	262,000	0.0466	0.00846
2	163.3	262,000	0.0410	0.00744
3	37.0	237,000	0.0464	0.00841
4	163.3	237,000	0.0402	0.00730
5	95.0	262,000	0.0439	0.00796
6 (base)	95.0	237,000	0.0433	0.00786

1. Calculated as model output from LOSS model

mg/L = milligrams per liter

gpd = gallons per day

2.8.2 Seepage Velocity (V_S)

Seepage velocity is calculated by the following equation:

$$v_S = \frac{K}{n_e} i \qquad \text{Equation B.8}$$

where:

v_S is the seepage velocity (feet per day)

K is the horizontal aquifer hydraulic conductivity (feet per day)

ne is effective porosity (dimensionless)

i is the downgradient horizontal hydraulic gradient (feet per foot)

Table B-5 summarizes the values used to calculate seepage velocity for input to the BIOSCREEN model. V_S is calculated for the three possible values of K.

Modeling of the effect of wastewater infiltration on groundwater levels demonstrates that i will be lower to the southeast (i.e. upgradient) than to the northwest (i.e. downgradient) of the infiltration basins (GSA, 2024). For the BIOSCREEN model, the downgradient i is used to calculate the seepage velocity, v_S (Equation B.8). Using downgradient i for the purposes of the BIOSCREEN model is reasonable, as the upgradient i may underestimate the rate of lateral transport of water in the aquifer. The downgradient i was estimated from simulated average groundwater mounding at monitor well locations MW4 and GM1-MW2 in response to treated wastewater infiltration at Site GM1, as evaluated by GSI (2024c).

Table B-5. Seepage velocity

Model Input Parameter	Symbol	Value			Units
		Low	Base	High	
Horizontal Hydraulic Conductivity	K	37.0	95.0	163	feet/day
Effective Porosity [1]	n_e	0.20			(-)
Downgradient Hydraulic Gradient	i	0.007			feet/feet
Seepage Velocity [2]	V_S	1.30	3.33	5.72	feet/day
		475	1216	2089	feet/year

1. Effective porosity values assumed to be equal to the numerical groundwater model calibrated specific yield (GSI, 2024b)
2. Calculated from Equation B.8

3.0 RESULTS

This section provides an overview of the concentration of toluene (Section 3.1) and DEHP (Section 3.2) in groundwater at the downgradient property boundary, C_{DG}. For each pollutant, concentrations are presented for six sensitivity analysis scenarios with all possible combinations of the input parameters initial concentration (C_0) and seepage velocity (V_S). Values reported as "< X" indicate that the predicted concentration is less than the detection limit for the pollutant, with the value of "X" indicating the detection limit. Detection limits were selected based on laboratory detection limits for groundwater samples collected during the Phase II Subsurface Characterization (GSI, 2023a).

3.1 Toluene Concentration at Downgradient Property Boundary

BIOSCREEN model output concentrations of toluene in groundwater at the downgradient property boundary (C_{DG}) are summarized in Table B-6. C_{DG} of toluene is below the detection limit (<0.0005 mg/L) for all sensitivity analysis scenarios (scenarios 1 through 5) and the base scenario (scenario 6). The BIOSCREEN model calculations are presented for toluene in Figure B-2 to B-7 for each scenario.

Table B-6. Toluene concentrations at the downgradient property boundary

Analysis Scenario	Concentration in Untreated Wastewater, C_W (mg/L)	BIOSCREEN Input Parameter: Initial Concentration in Groundwater at Basin Edge (from the LOSS Model), C_0 (mg/L)	BIOSCREEN Input Parameter: Seepage Velocity, V_s (feet/year)	BIOSCREEN Output: Concentration in Groundwater at the Downgradient Property Boundary, C_{DG} (mg/L)	Figure Reference
1	0.0496	0.0466	475	< 0.0005	B-2
2		0.0410	2,089	< 0.0005	B-3
3		0.0464	475	< 0.0005	B-4
4		0.0402	2,089	< 0.0005	B-5
5		0.0439	1,216	< 0.0005	B-6
6 (base)		0.0433	1,216	< 0.0005	B-7

mg/L = milligrams per liter

3.2 DEHP Concentration at Downgradient Property Boundary

BIOSCREEN model output concentrations of DEHP in groundwater at the downgradient property boundary (C_{DG}) are summarized in Table B-7. C_{DG} of DEHP is below the detection limit (<0.0001 mg/L) for all sensitivity analysis scenarios (scenarios 1 through 5) and the base scenario (scenario 6). The BIOSCREEN model calculations are presented for DEHP in Figure B-8 to B-13 for each scenario.

Table B-7. DEHP concentrations at the downgradient property boundary

Analysis Scenario	Concentration in Untreated Wastewater, C_W (mg/L)	BIOSCREEN Input Parameter: Initial Concentration in Groundwater at Basin Edge (from the LOSS Model), C_0 (mg/L)	BIOSCREEN Input Parameter: Seepage Velocity, V_s (feet/year)	BIOSCREEN Output: Concentration in Groundwater at the Downgradient Property Boundary, C_{DG} (mg/L)	Figure Reference
1	0.009	0.0085	475	< 0.0001	B-8
2		0.0074	2,089	< 0.0001	B-9
3		0.0084	475	< 0.0001	B-10
4		0.0073	2,089	< 0.0001	B-11
5		0.0080	1,216	< 0.0001	B-12
6 (base)		0.0079	1,216	< 0.0001	B-13

mg/L = milligrams per liter

4.0 CONCLUSION

Based on modeling of dilution, dispersion, biodegradation, and sorption described in Appendix A (LOSS model) and Appendix B (BIOSCREEN model), the pollutants toluene (Table B-6) and DEHP (Table B-7) attenuate to below their respective detection limit within 120 ft of the RIBs. Over distances greater than 120 feet downgradient of the RIBs (i.e. to the Santiam River), toluene and DEHP are expected to remain at undetectable concentrations.

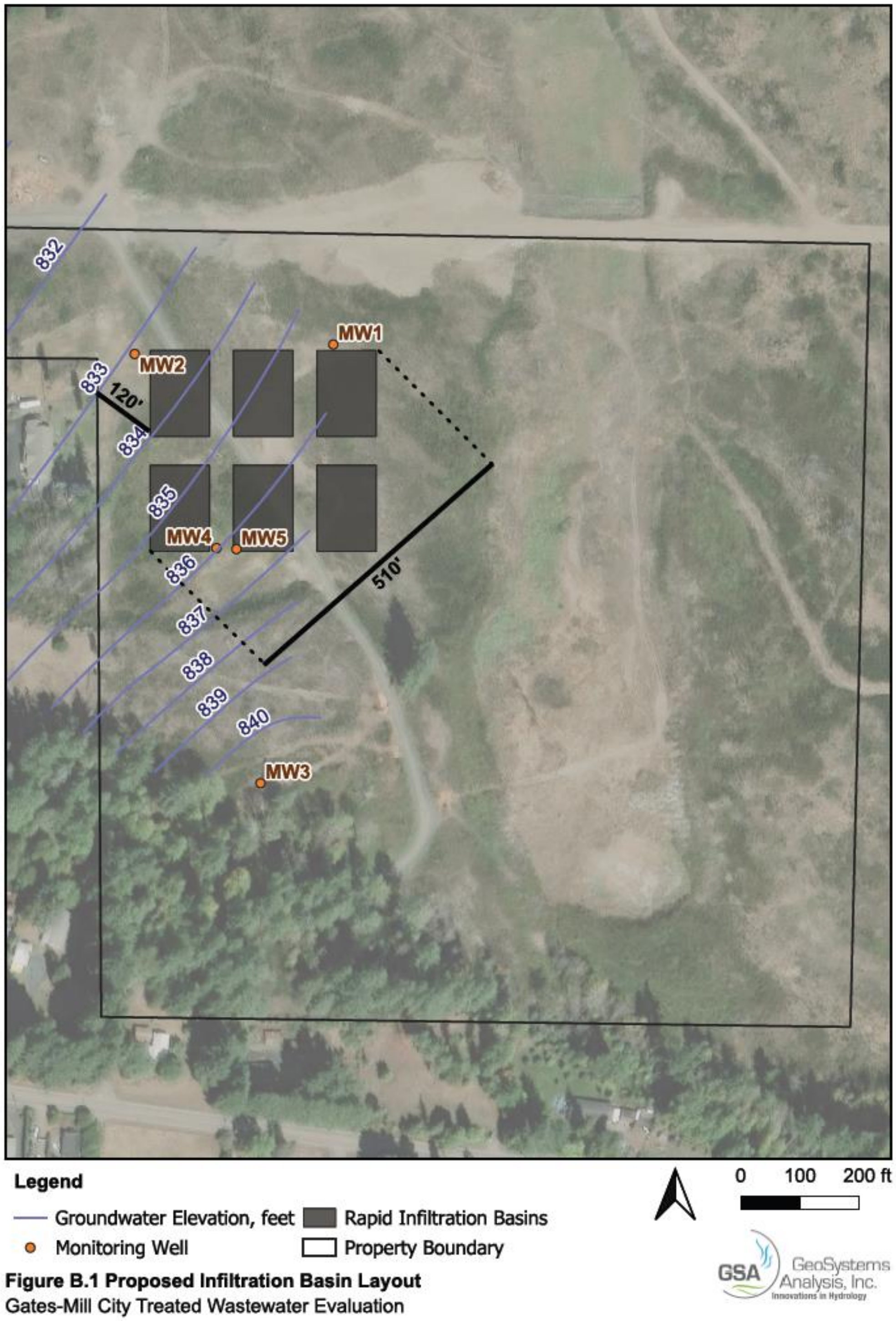


Figure B-1 Proposed infiltration basin layout

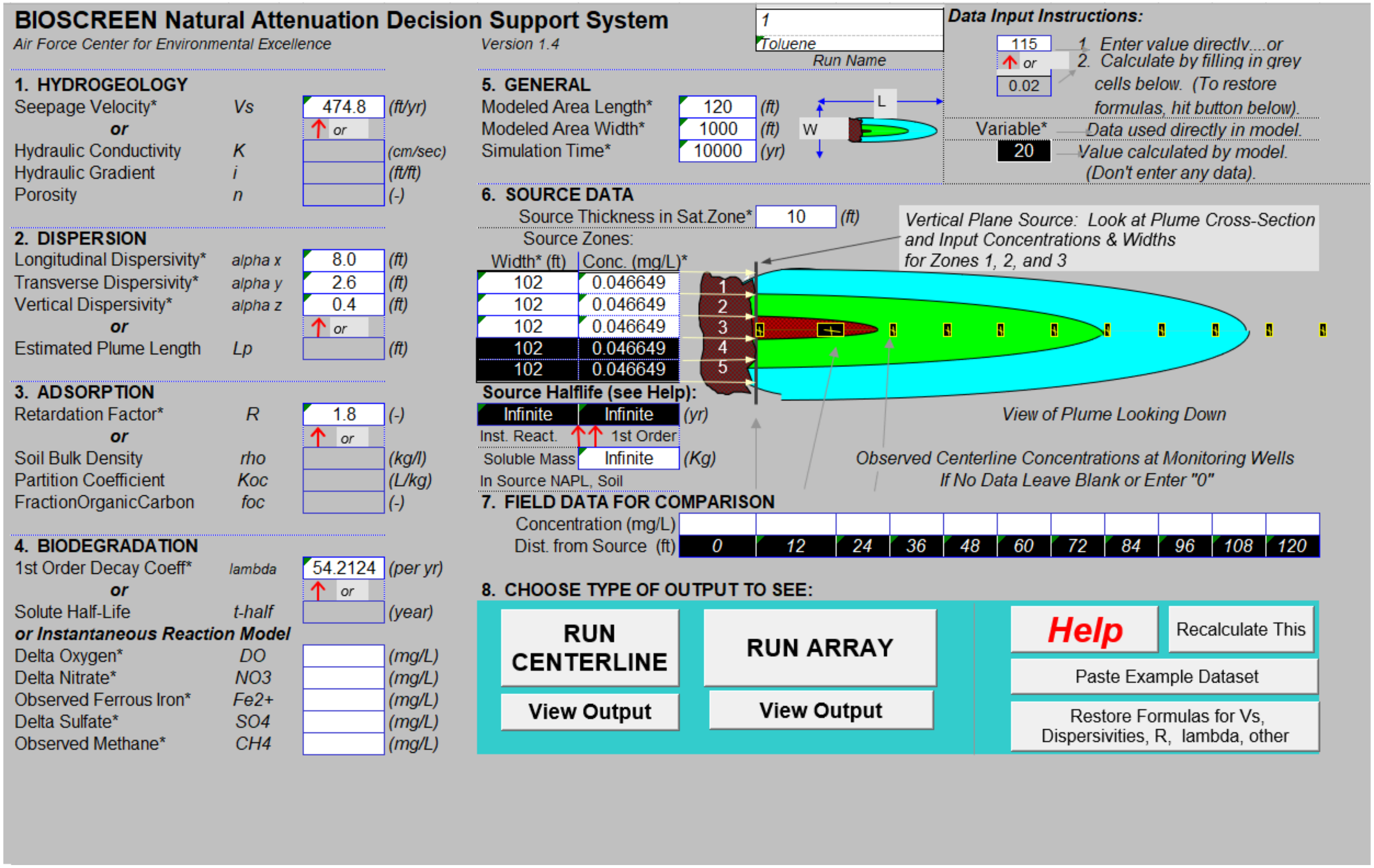
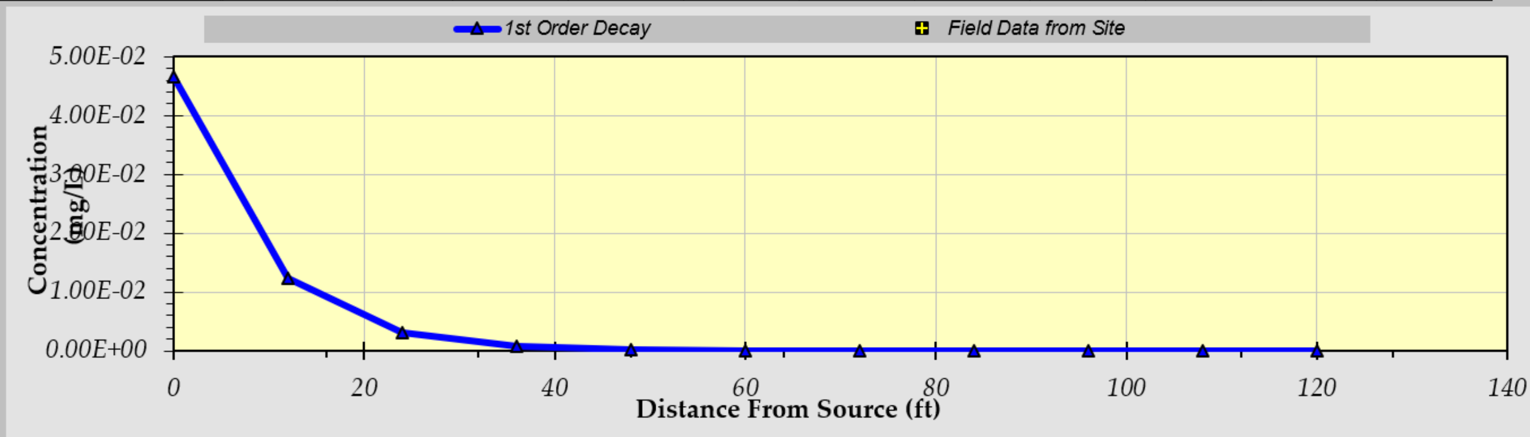


Figure B-2 BIOSCREEN Model for Toluene, Scenario 1

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Distance from Source (ft)

TYPE OF MODEL	0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	4.66E-02	1.23E-02	3.16E-03	7.96E-04	2.00E-04	5.00E-05	1.26E-05	3.16E-06	7.99E-07	2.02E-07	5.13E-08
Field Data from Site											



Calculate Animation

Time: 10,000 Years

Return to Input

Recalculate This Sheet

Figure B-2 BIOSCREEN Model for Toluene, Scenario 1 (cont.)

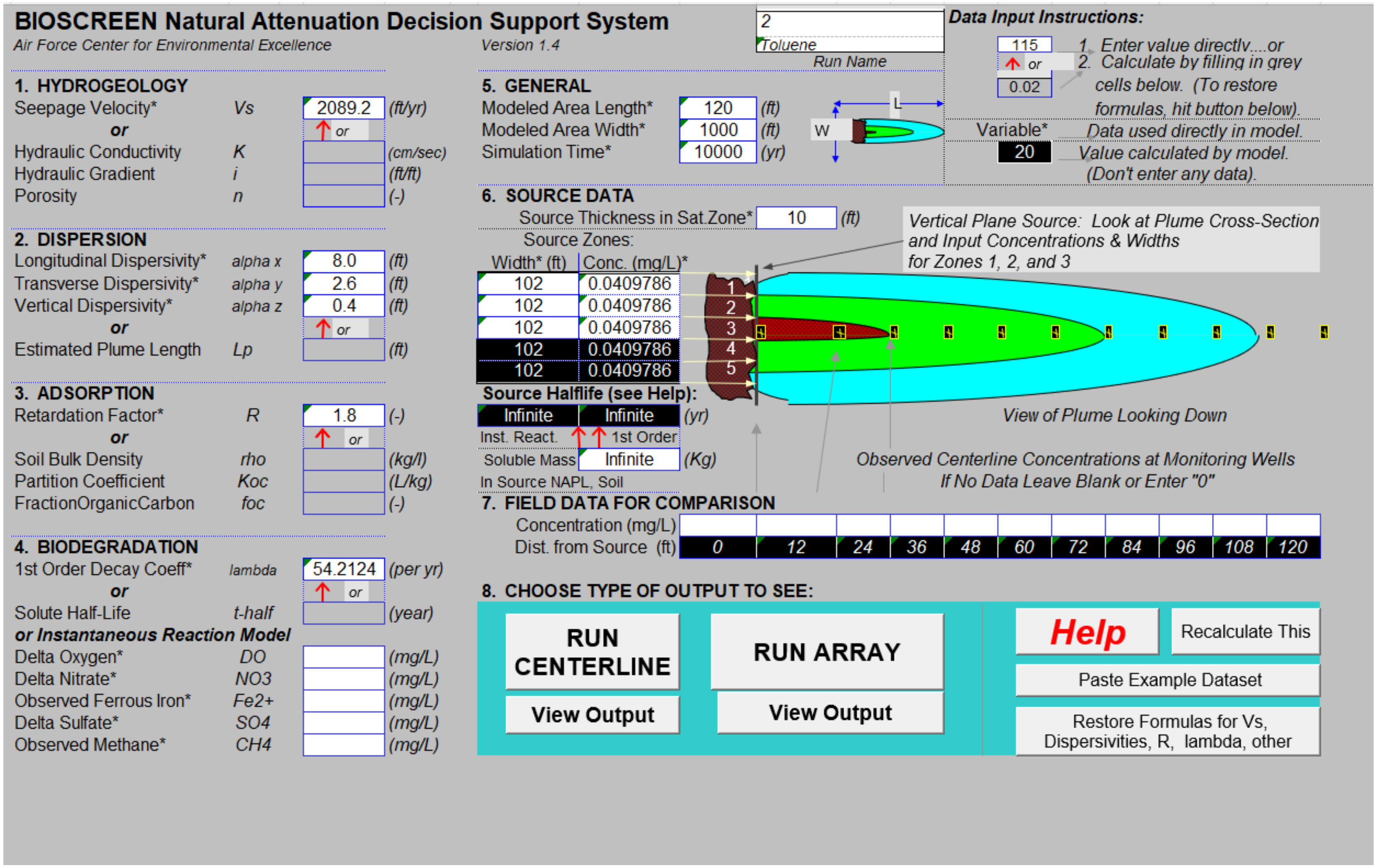


Figure B-3 BIOSCREEN Model for Toluene, Scenario 2

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	4.10E-02	2.63E-02	1.65E-02	1.02E-02	6.22E-03	3.81E-03	2.33E-03	1.43E-03	8.84E-04	5.46E-04	3.38E-04
Field Data from Site											

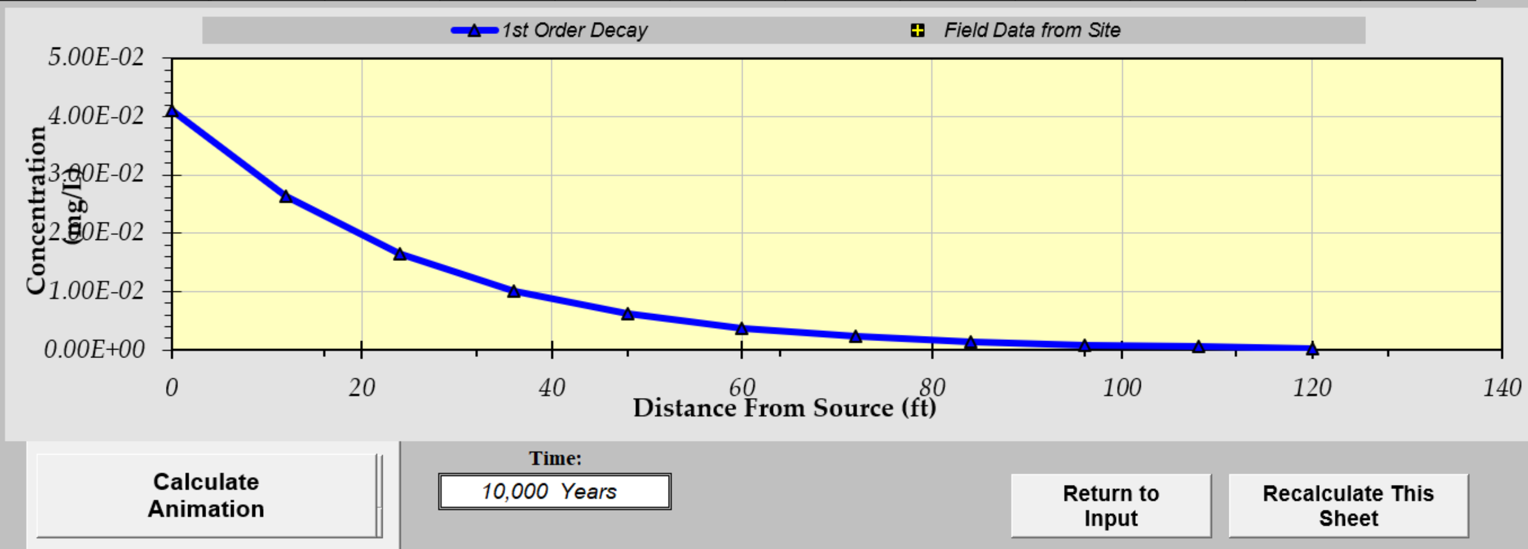


Figure B-3 BIOSCREEN Model for Toluene, Scenario 2 (cont.)

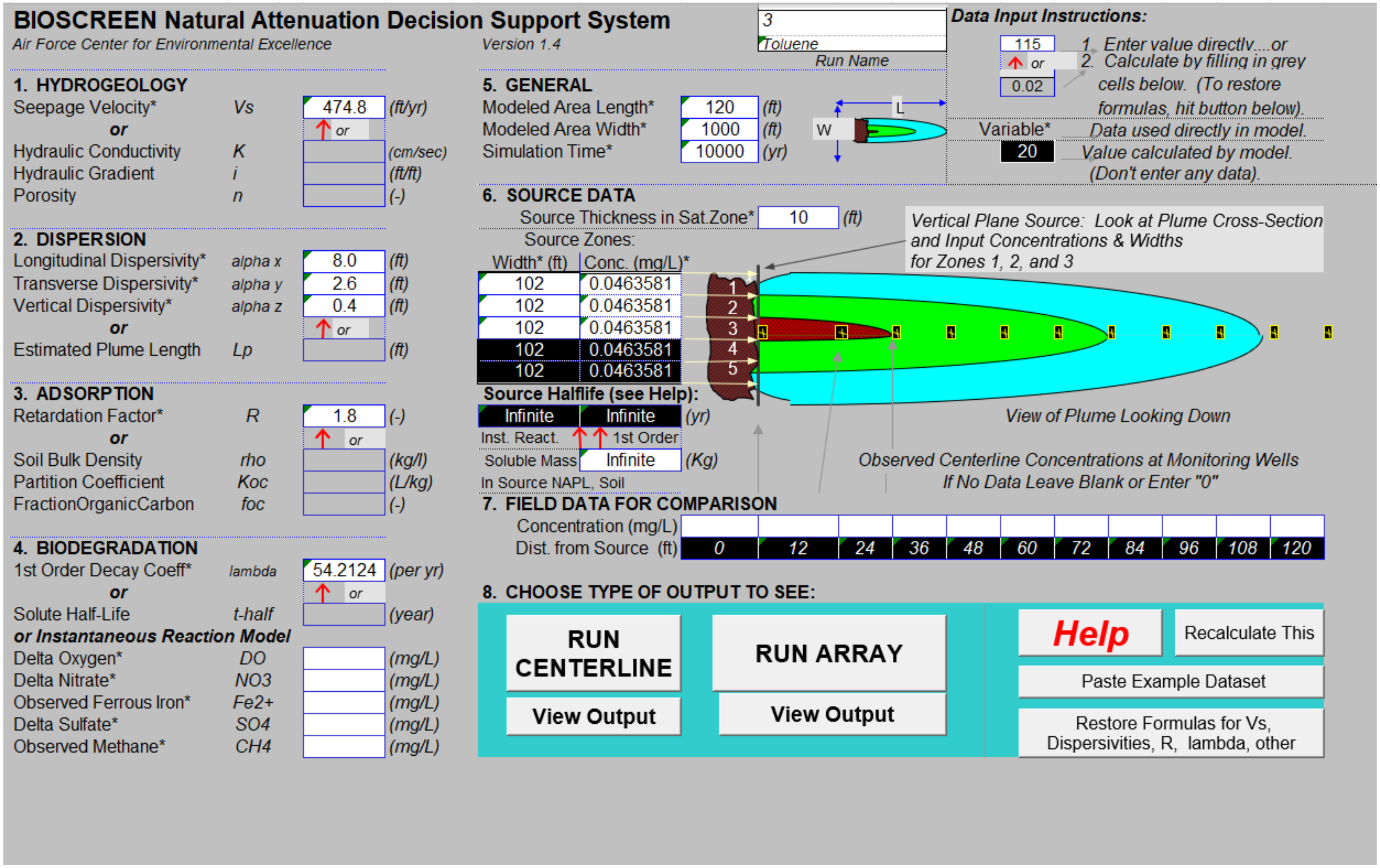
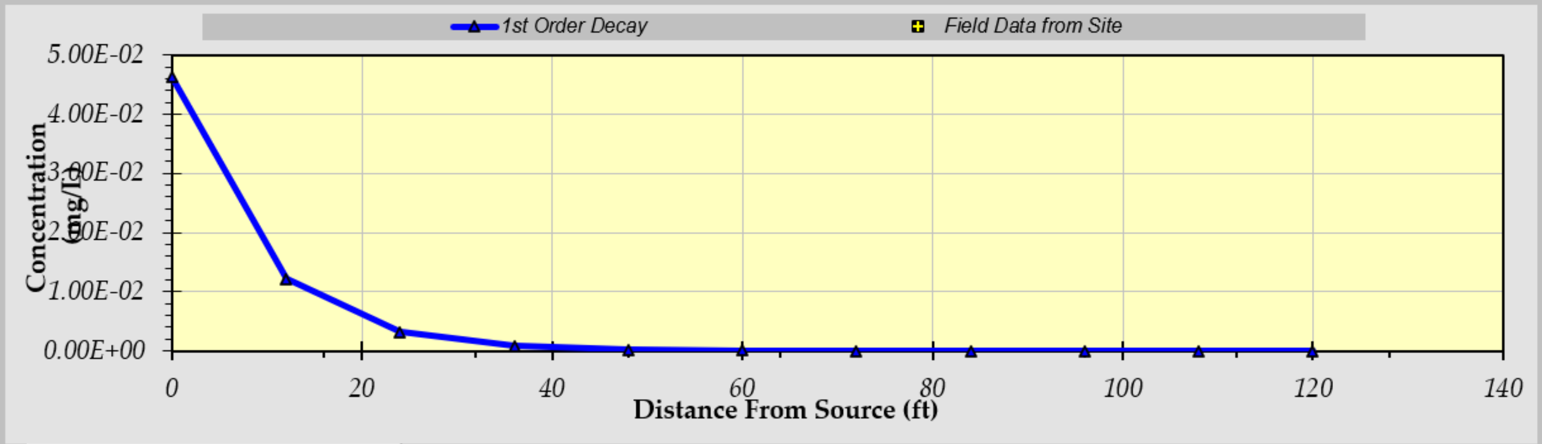


Figure B-4 BIOSCREEN Model for Toluene, Scenario 3

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	4.64E-02	1.22E-02	3.14E-03	7.91E-04	1.98E-04	4.97E-05	1.25E-05	3.14E-06	7.94E-07	2.01E-07	5.10E-08
Field Data from Site											



Calculate Animation

Time: 10,000 Years

Return to Input

Recalculate This Sheet

Figure B-4 BIOSCREEN Model for Toluene, Scenario 3 (cont.)

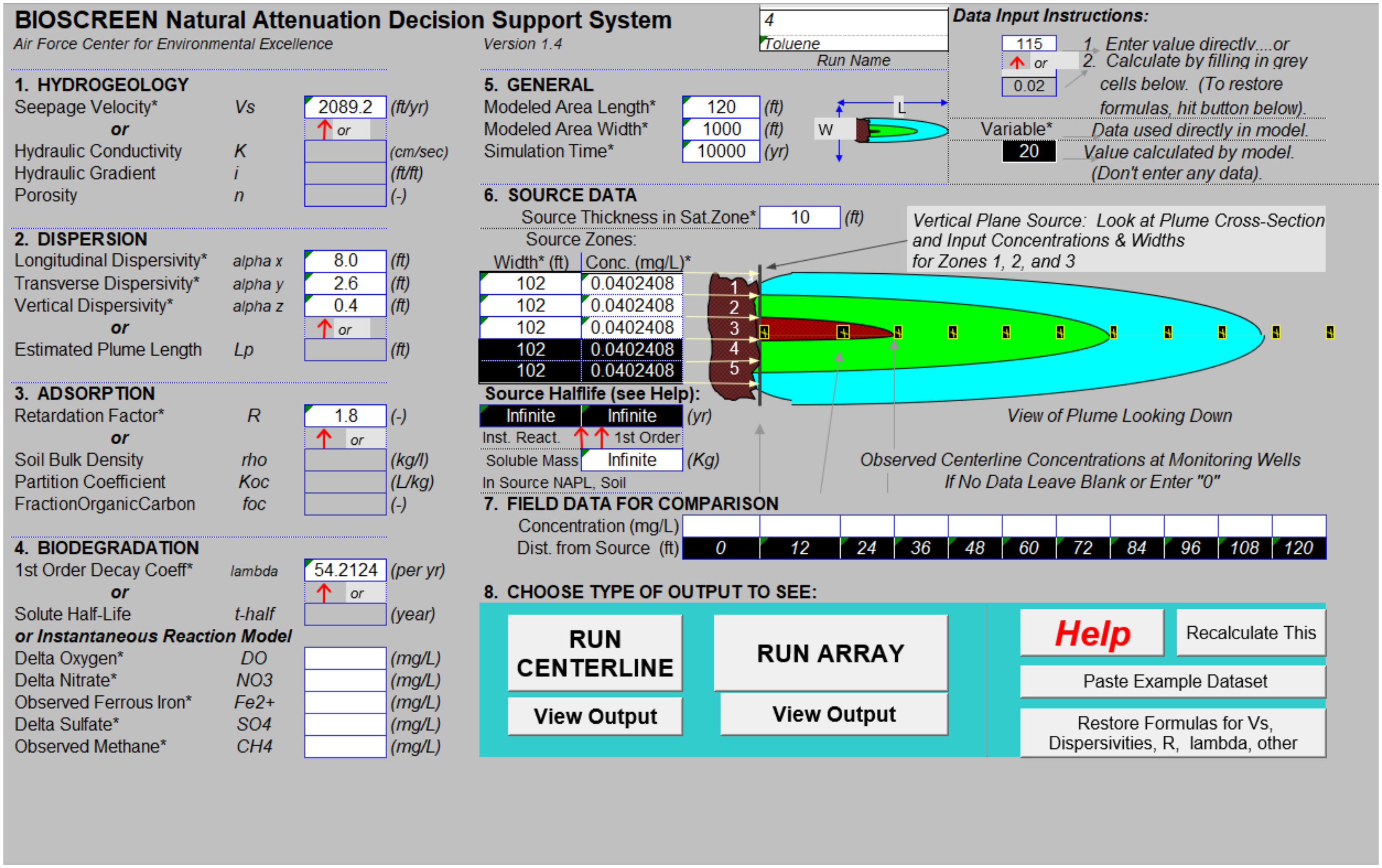
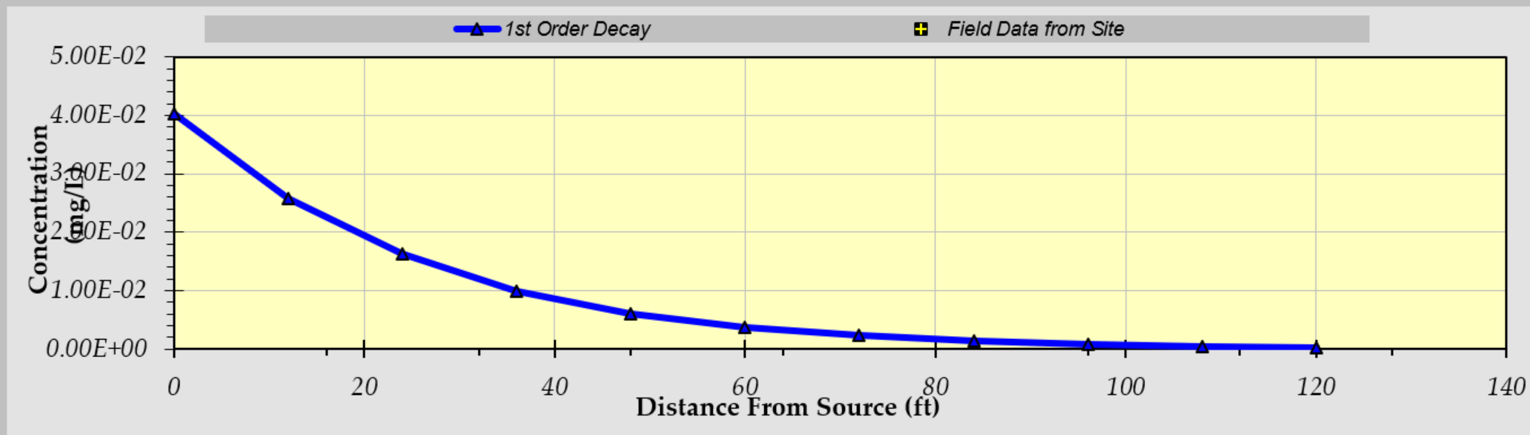


Figure B-5 BIOSCREEN Model for Toluene, Scenario 4

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	4.02E-02	2.58E-02	1.62E-02	9.99E-03	6.11E-03	3.74E-03	2.29E-03	1.41E-03	8.68E-04	5.36E-04	3.32E-04
Field Data from Site											



Calculate Animation

Time: 10,000 Years

Return to Input

Recalculate This Sheet

Figure B-5 BIOSCREEN Model for Toluene, Scenario 4 (cont.)

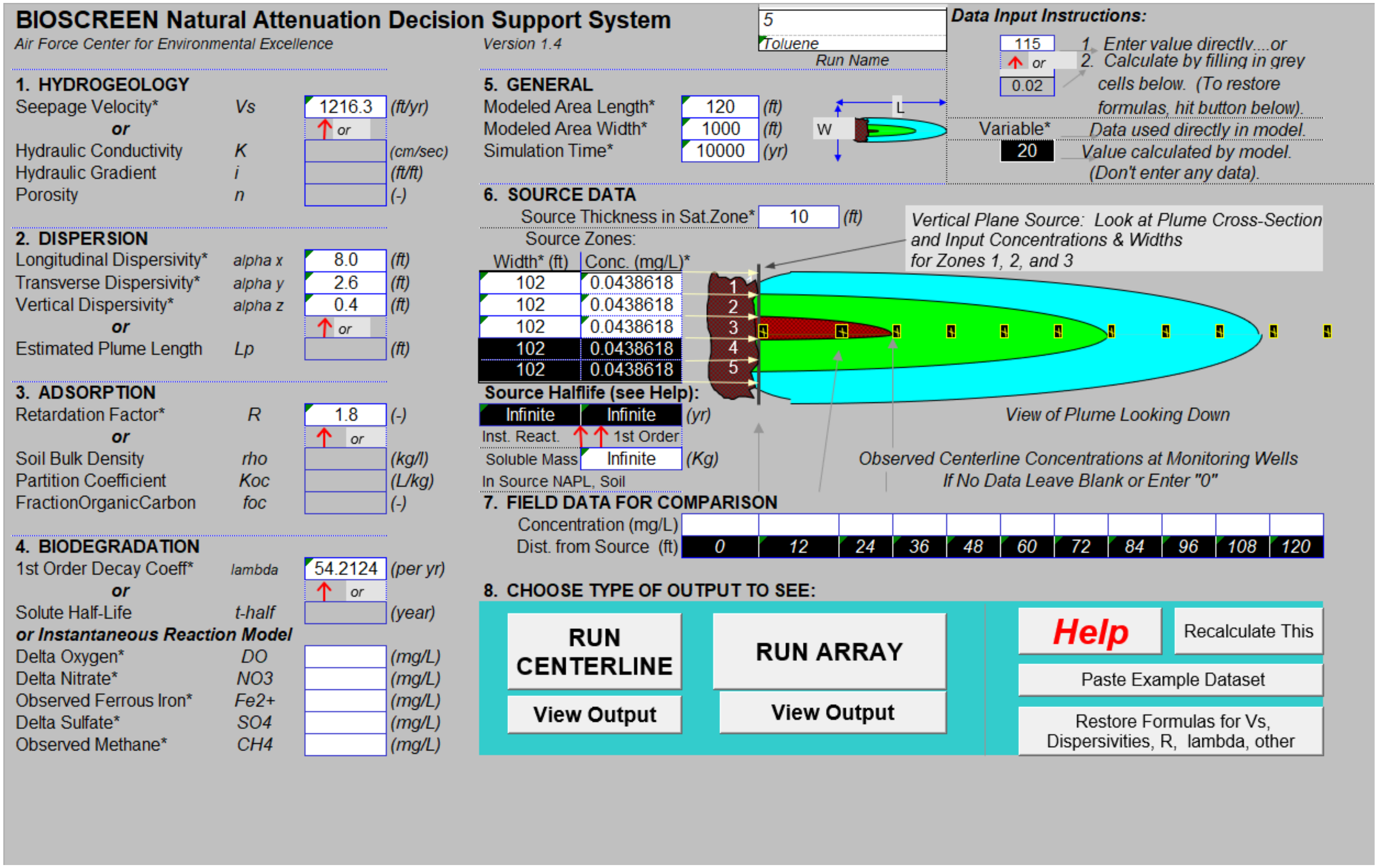
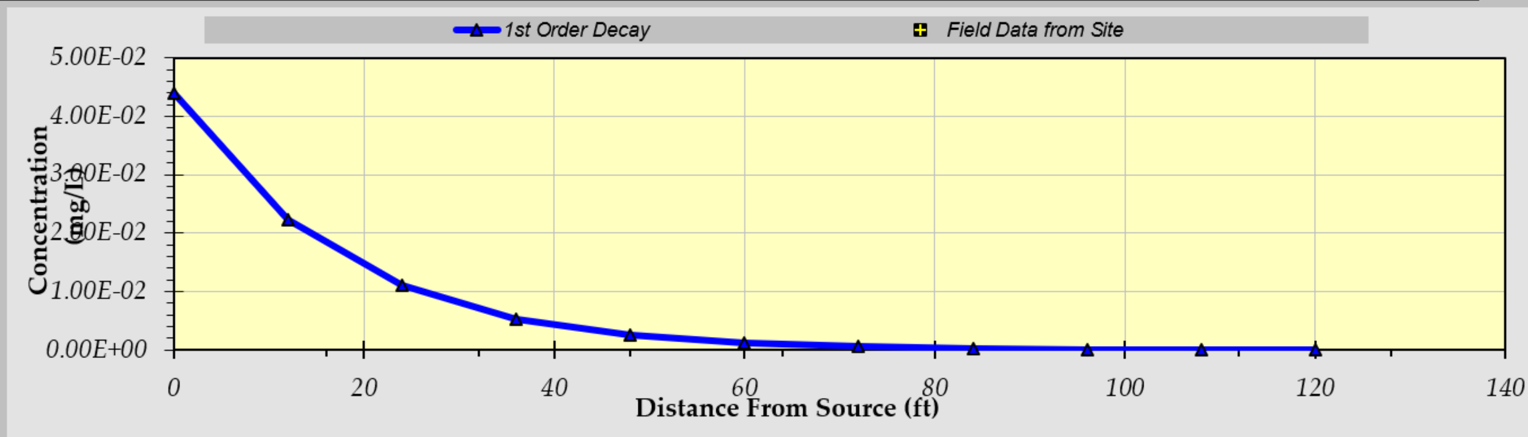


Figure B-6 BIOSCREEN Model for Toluene, Scenario 5

	Distance from Source (ft)										
TYPE OF MODEL	0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	4.39E-02	2.22E-02	1.10E-02	5.37E-03	2.60E-03	1.25E-03	6.08E-04	2.95E-04	1.44E-04	7.02E-05	3.43E-05
Field Data from Site											



Calculate Animation

Time: 10,000 Years

Return to Input

Recalculate This Sheet

Figure B-6 BIOSCREEN Model for Toluene, Scenario 5 (cont.)

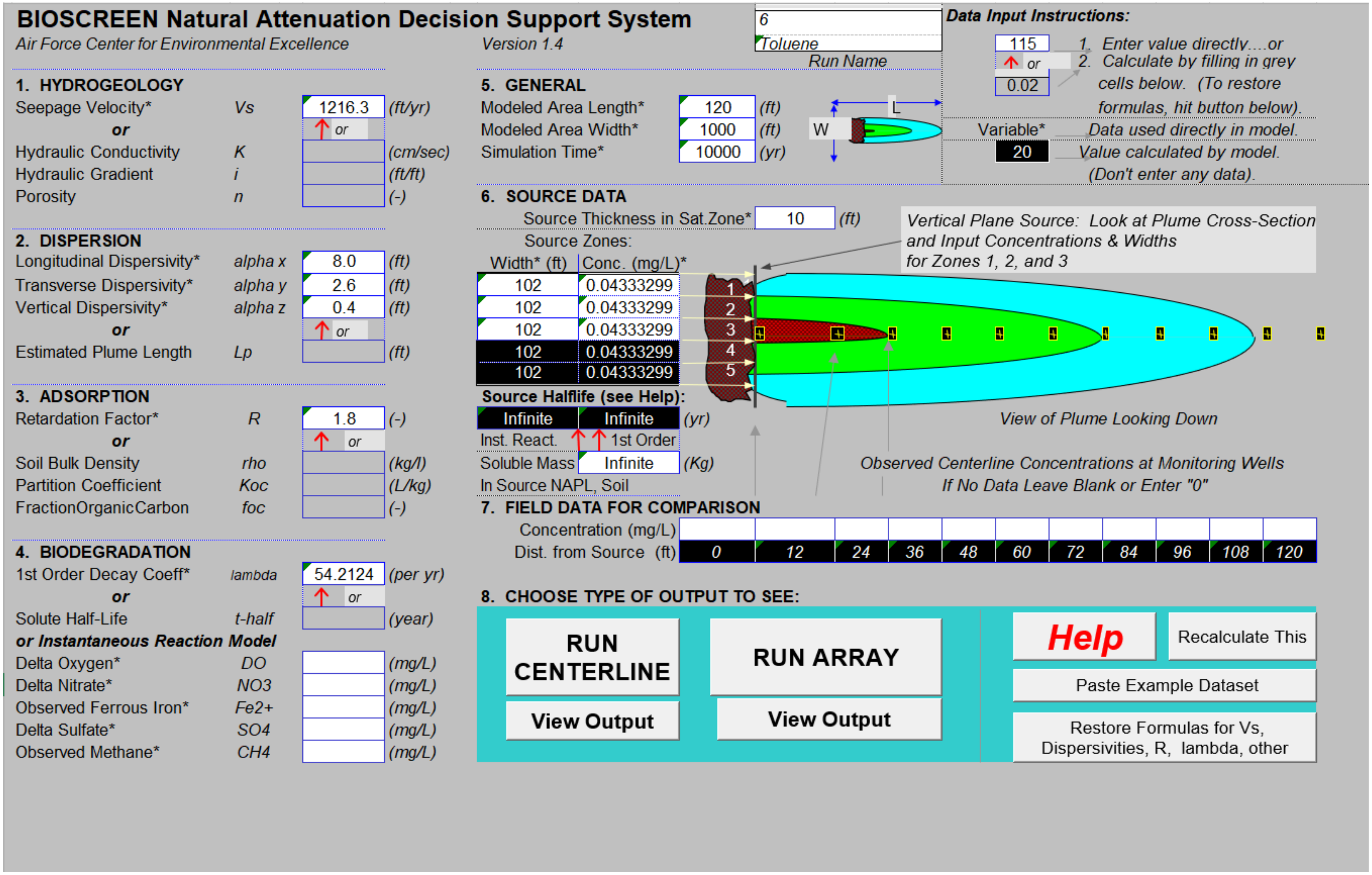
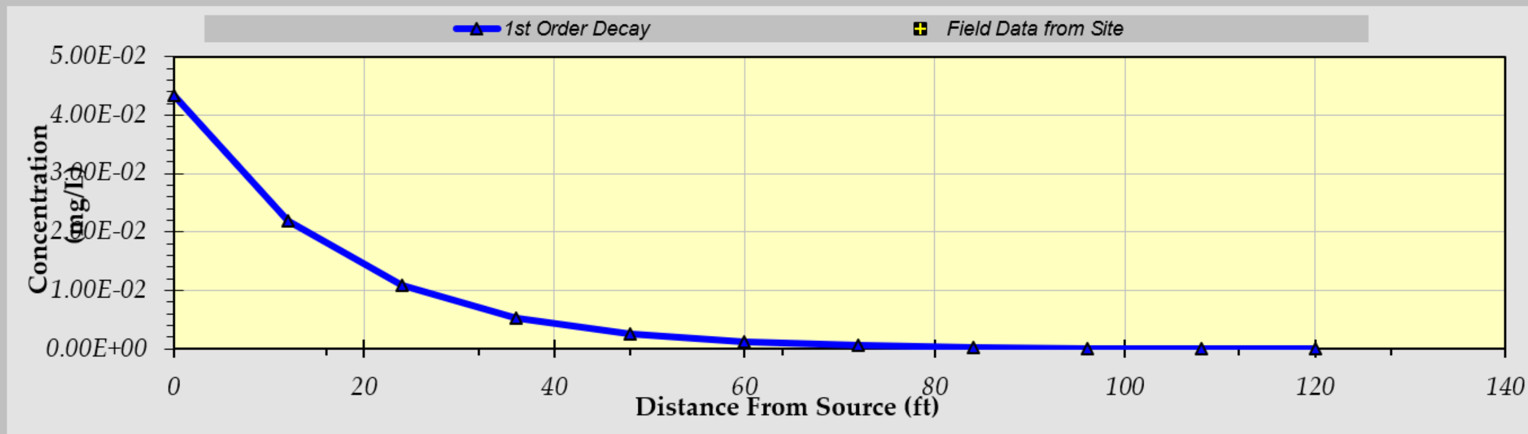


Figure B-7 BIOSCREEN Model for Toluene, Scenario 6

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	4.33E-02	2.20E-02	1.09E-02	5.31E-03	2.57E-03	1.24E-03	6.00E-04	2.92E-04	1.42E-04	6.93E-05	3.39E-05
Field Data from Site											



Calculate Animation

Time:
10,000 Years

Return to Input

Recalculate This Sheet

Figure B-7 BIOSCREEN Model for Toluene, Scenario 6 (cont.)

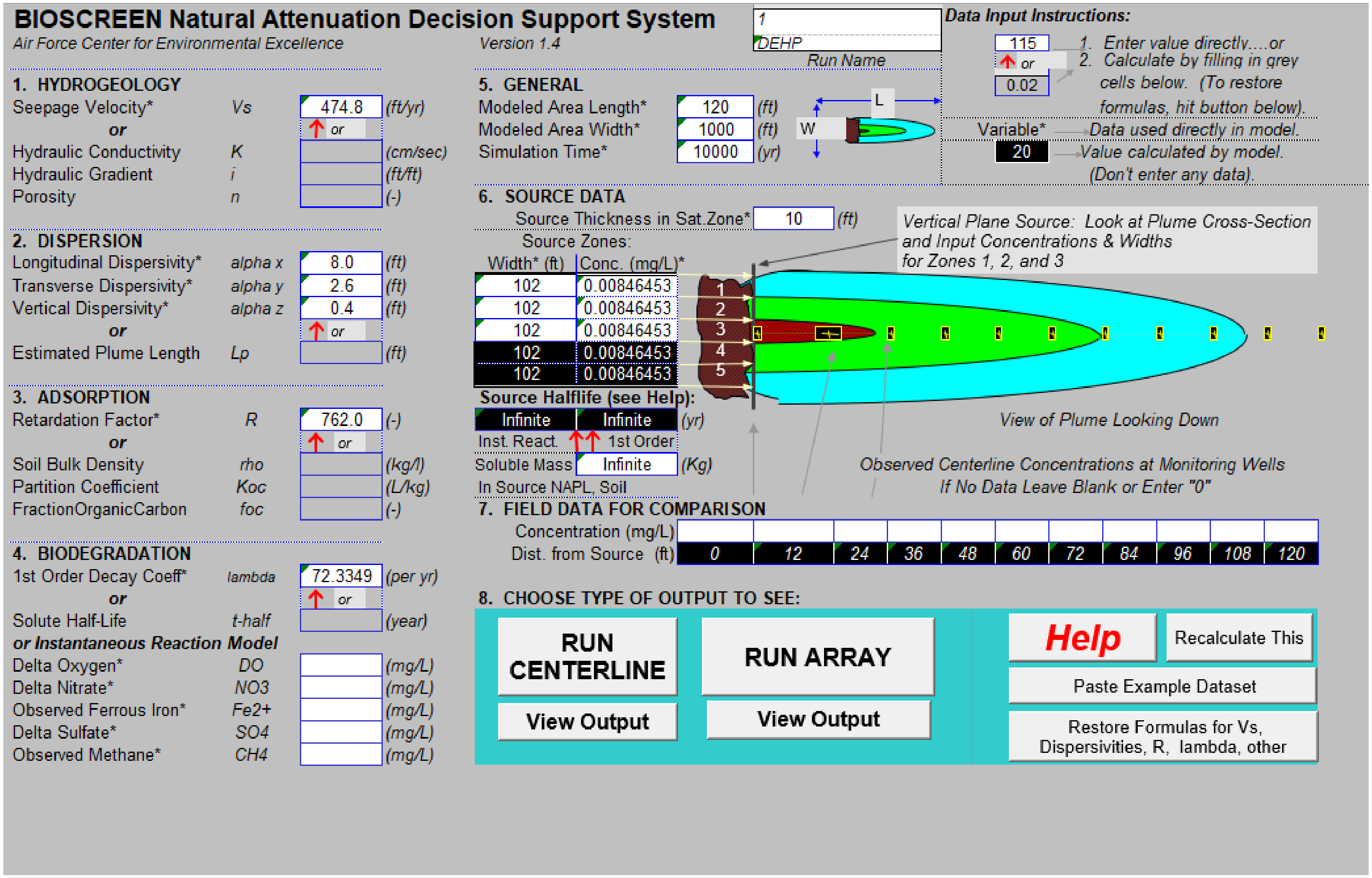
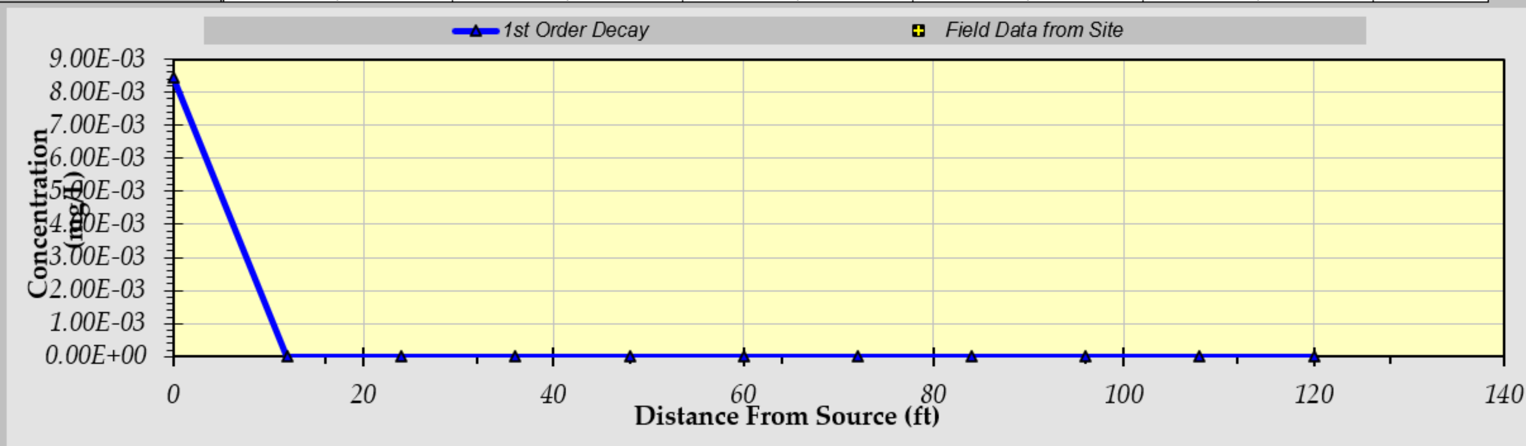


Figure B-8 BIOSCREEN Model for DEHP, Scenario 1

	Distance from Source (ft)										
TYPE OF MODEL	0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	8.46E-03	2.54E-22	7.46E-42	2.15E-61	6.15E-81	1.76E-100	5.04E-120	1.45E-139	4.17E-159	1.21E-178	3.49E-198
Field Data from Site											



Calculate Animation

Time: 10,000 Years

Return to Input

Recalculate This Sheet

Figure B-8 BIOSCREEN Model for DEHP, Scenario 1 (cont.)

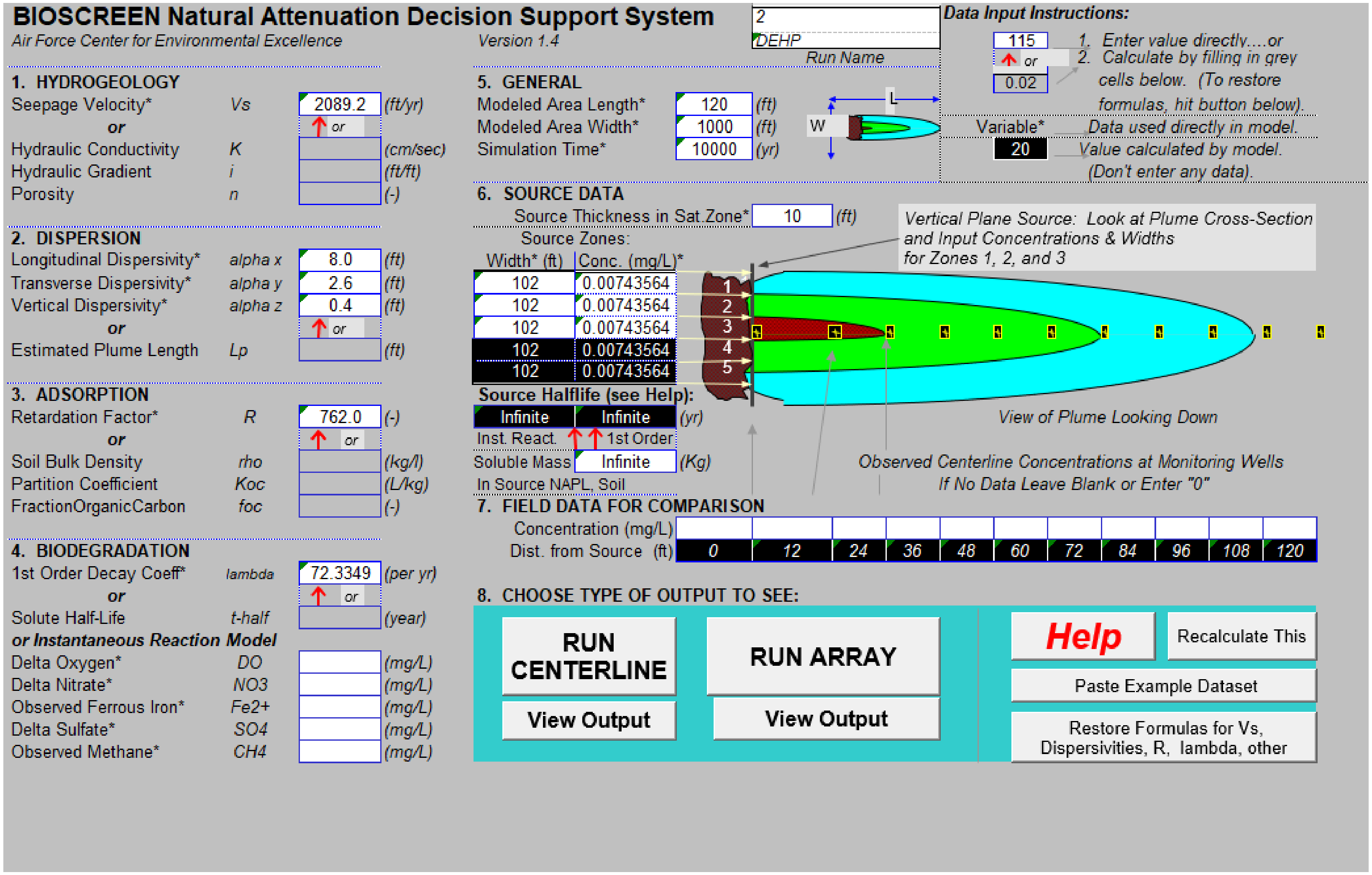
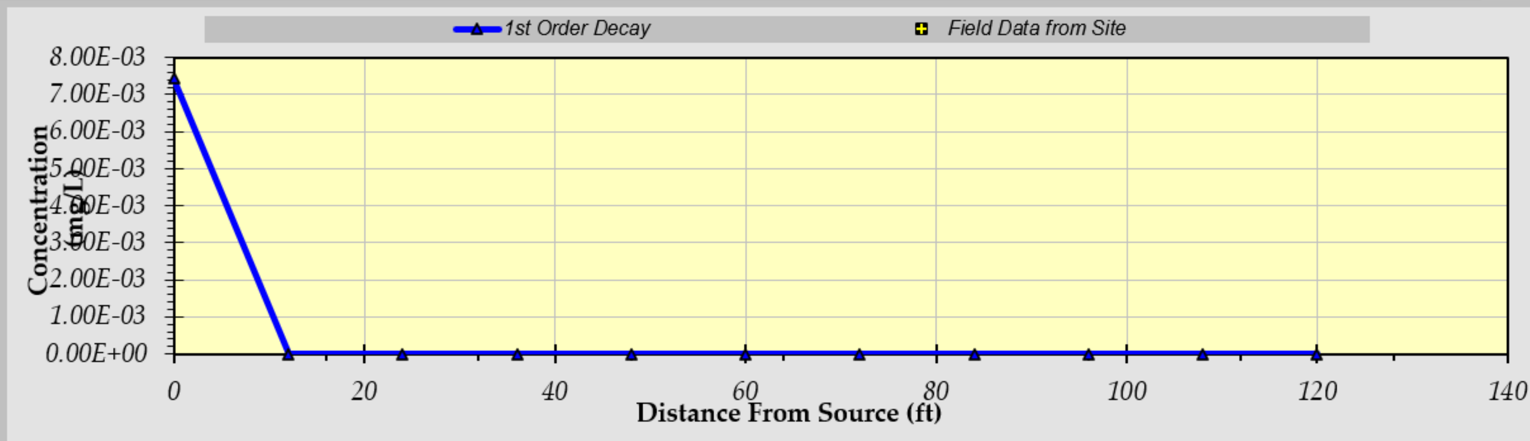


Figure B-9 BIOSCREEN Model for DEHP, Scenario 2

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Distance from Source (ft)

TYPE OF MODEL	0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	7.44E-03	5.37E-12	3.80E-21	2.63E-30	1.81E-39	1.25E-48	8.61E-58	5.96E-67	4.13E-76	2.87E-85	2.00E-94
Field Data from Site											



Calculate Animation

Time: 10,000 Years

Return to Input

Recalculate This Sheet

Figure B-9 BIOSCREEN Model for DEHP, Scenario 2 (cont.)

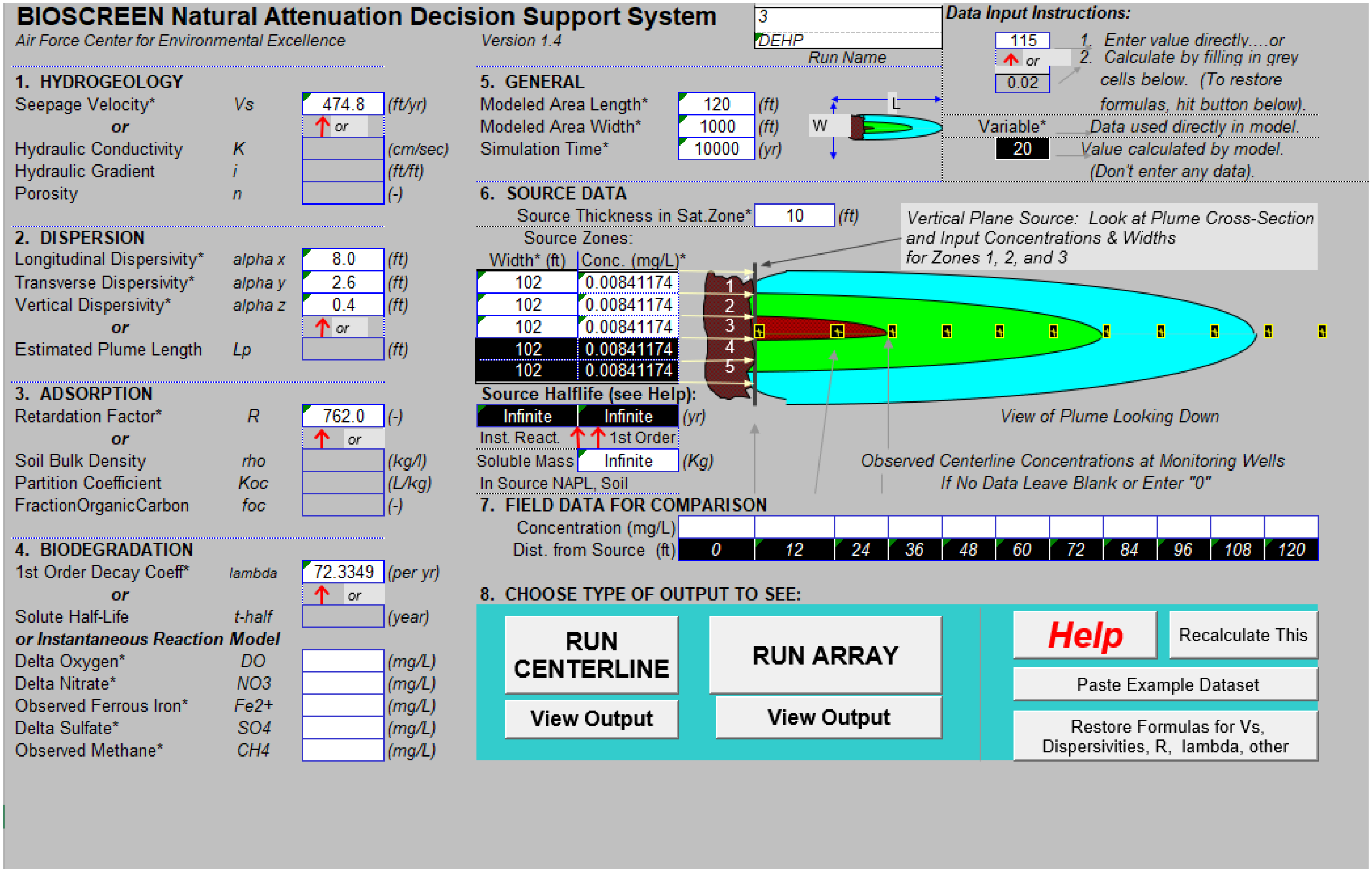
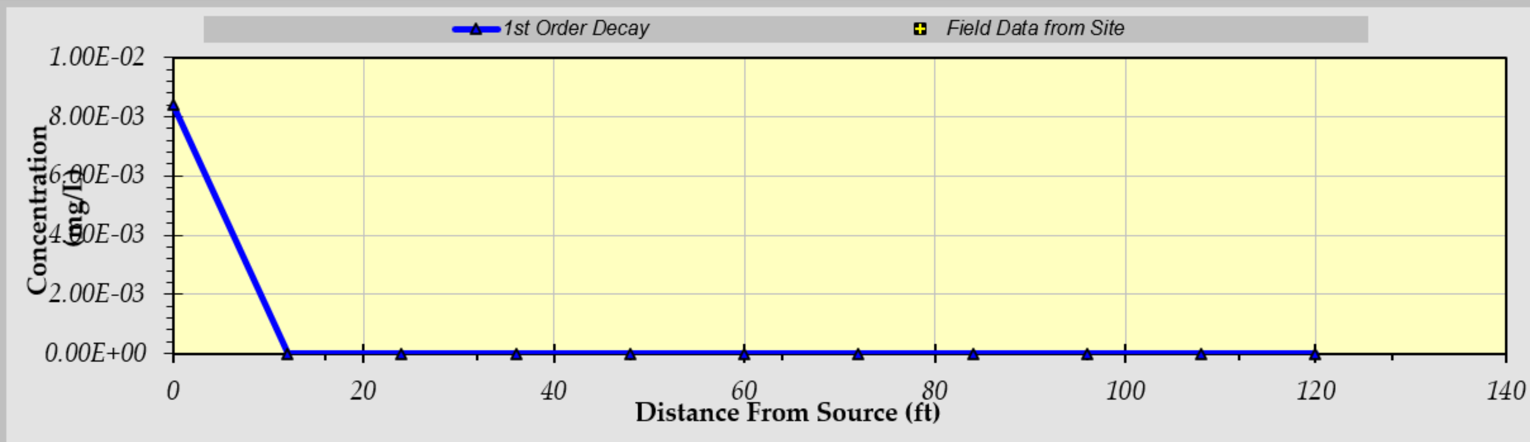


Figure B-10 BIOSCREEN Model for DEHP, Scenario 3

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	8.41E-03	2.52E-22	7.41E-42	2.14E-61	6.11E-81	1.75E-100	5.01E-120	1.44E-139	4.15E-159	1.20E-178	3.47E-198
Field Data from Site											



Calculate Animation

Time:

10,000 Years

Return to Input

Recalculate This Sheet

Figure B-10 BIOSCREEN Model for DEHP, Scenario 3 (cont.)

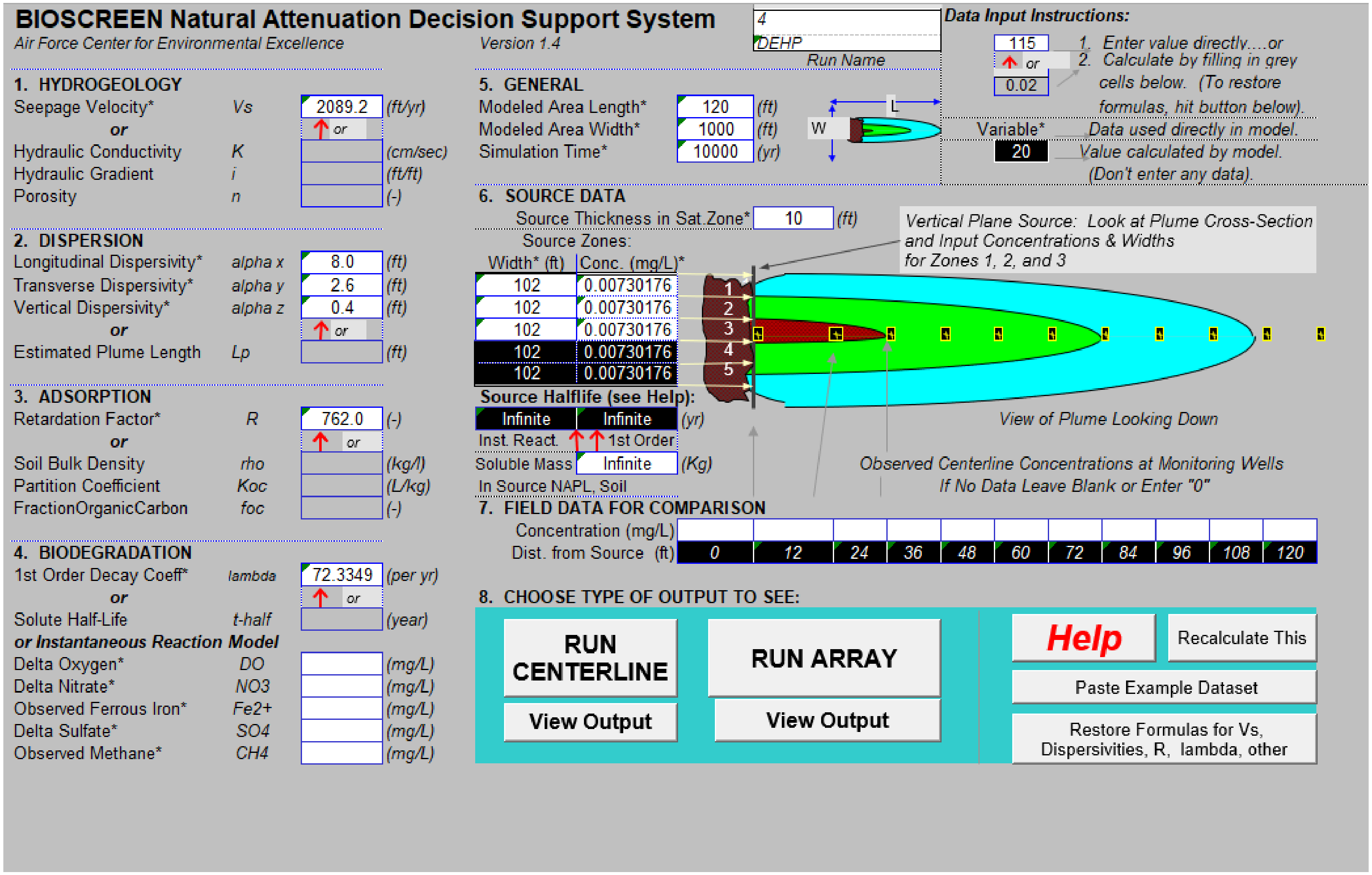
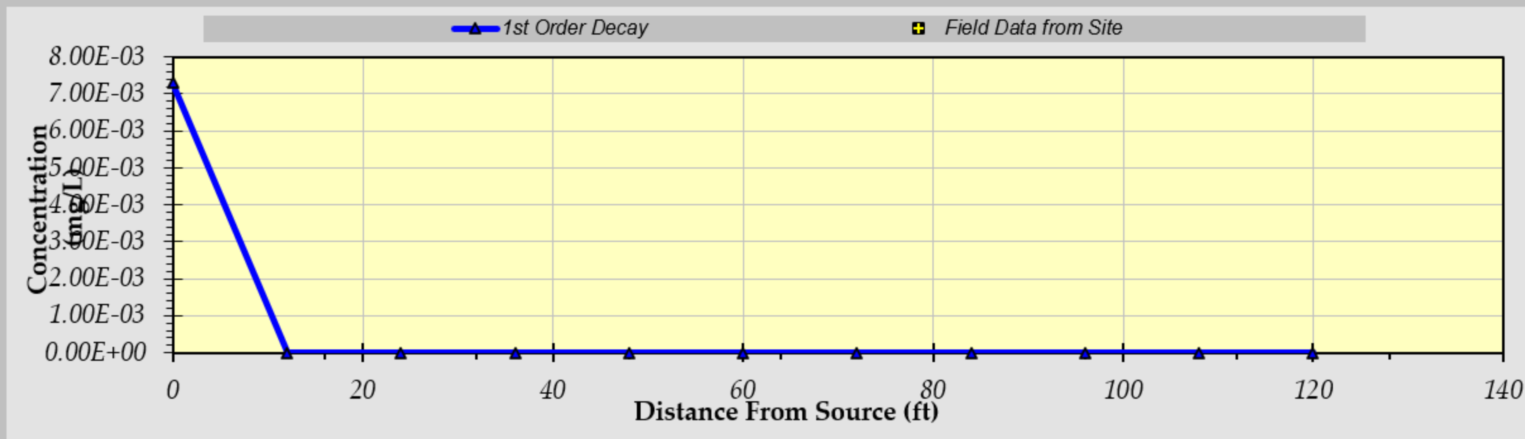


Figure B-11 BIOSCREEN Model for DEHP, Scenario 4

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	7.30E-03	5.27E-12	3.73E-21	2.58E-30	1.78E-39	1.23E-48	8.46E-58	5.85E-67	4.06E-76	2.82E-85	1.97E-94
Field Data from Site											



Calculate Animation

Time: 10,000 Years

Return to Input

Recalculate This Sheet

Figure B-11 BIOSCREEN Model for DEHP, Scenario 4 (cont.)

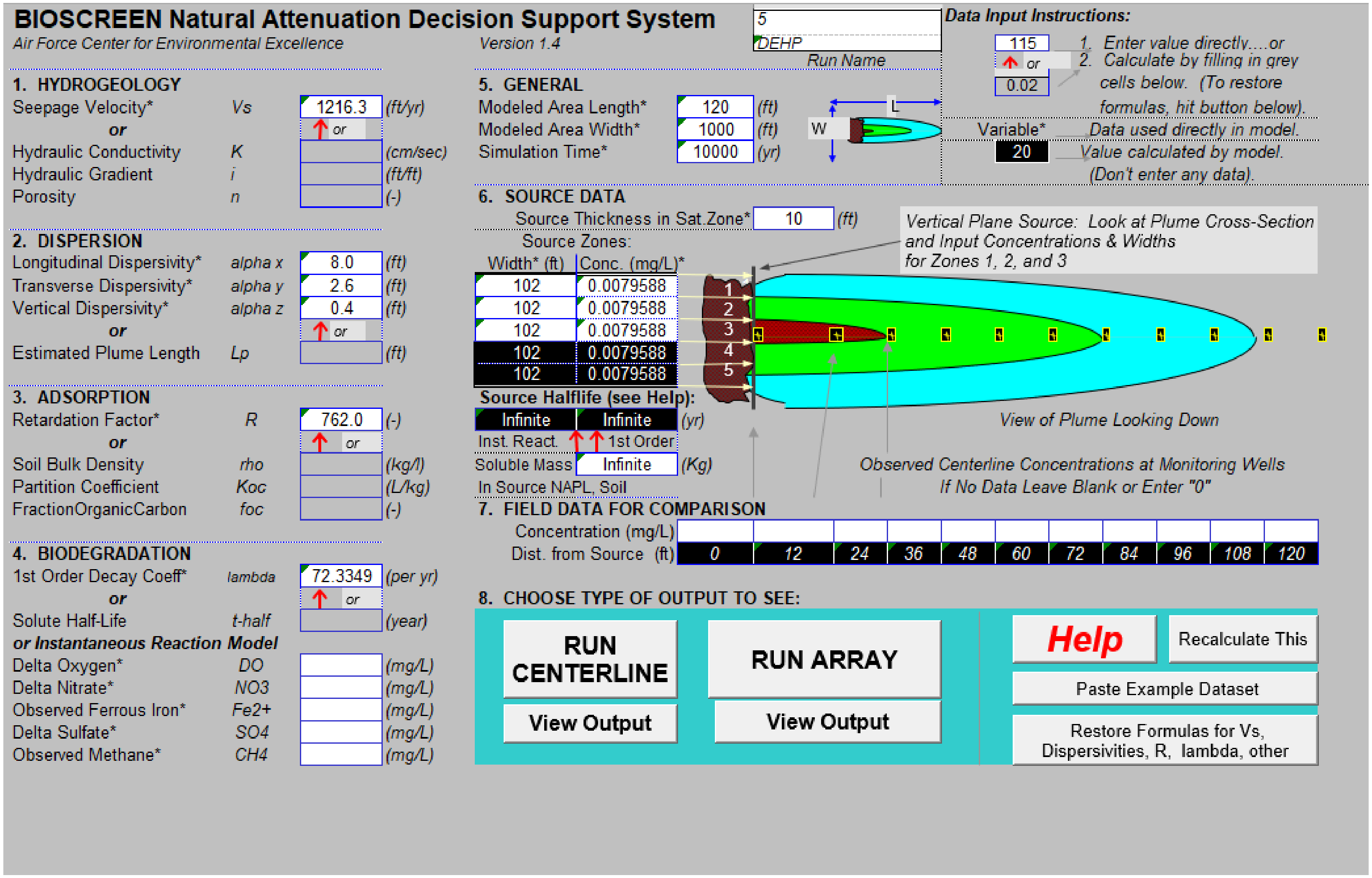
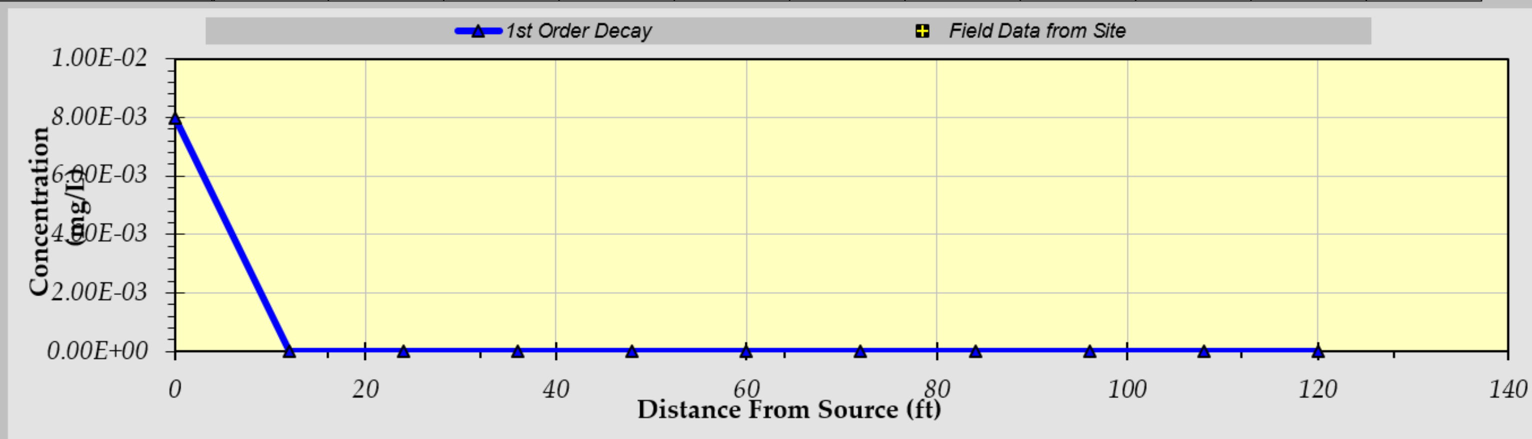


Figure B-12 BIOSCREEN Model for DEHP, Scenario 5

	Distance from Source (ft)										
TYPE OF MODEL	0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	7.96E-03	6.64E-15	5.42E-27	4.34E-39	3.45E-51	2.75E-63	2.19E-75	1.75E-87	1.40E-99	1.13E-111	9.07E-124
Field Data from Site											



Calculate Animation

Time: *10,000 Years*

Return to Input

Recalculate This Sheet

Figure B-12 BIOSCREEN Model for DEHP, Scenario 5 (cont.)

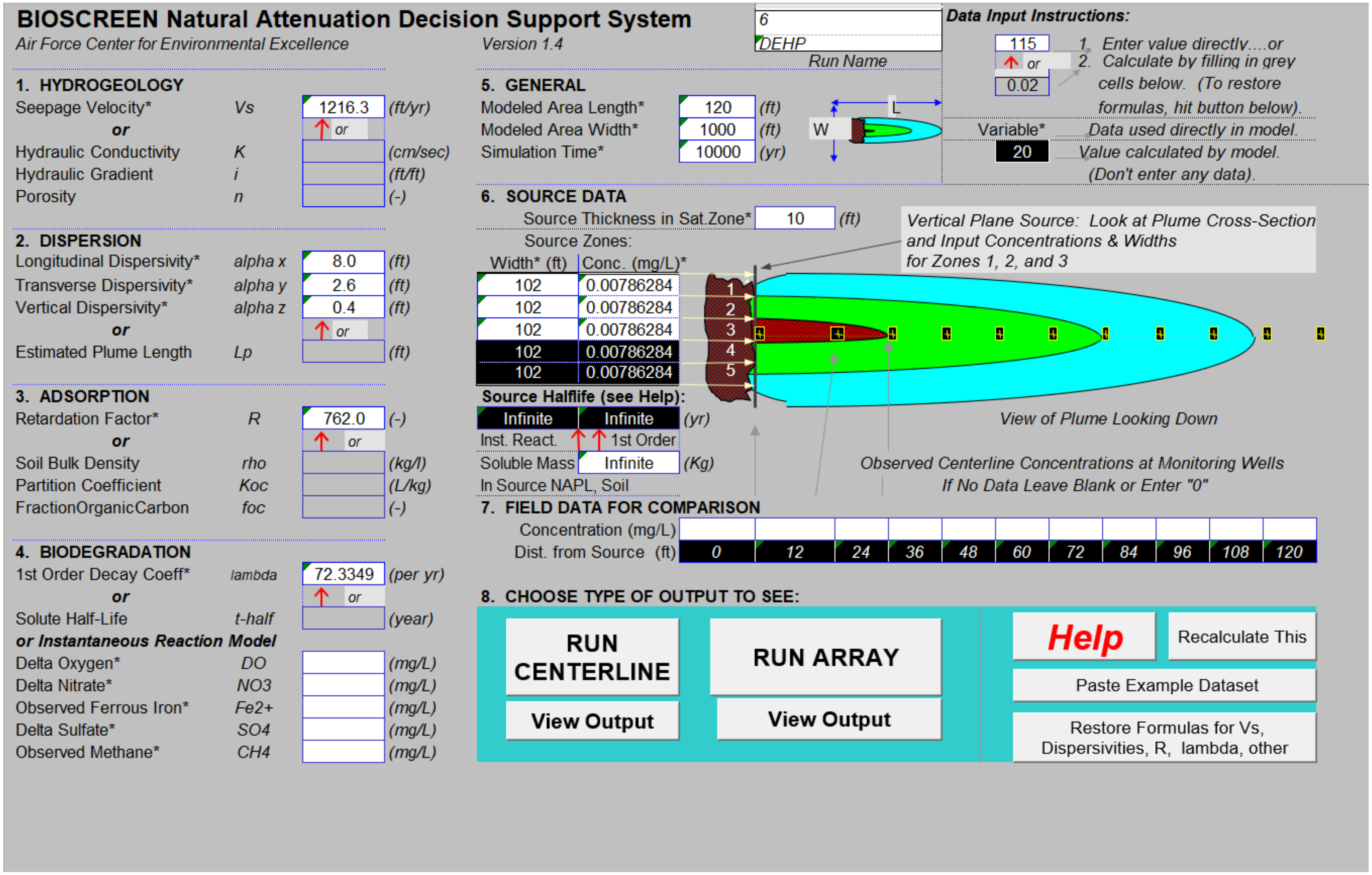
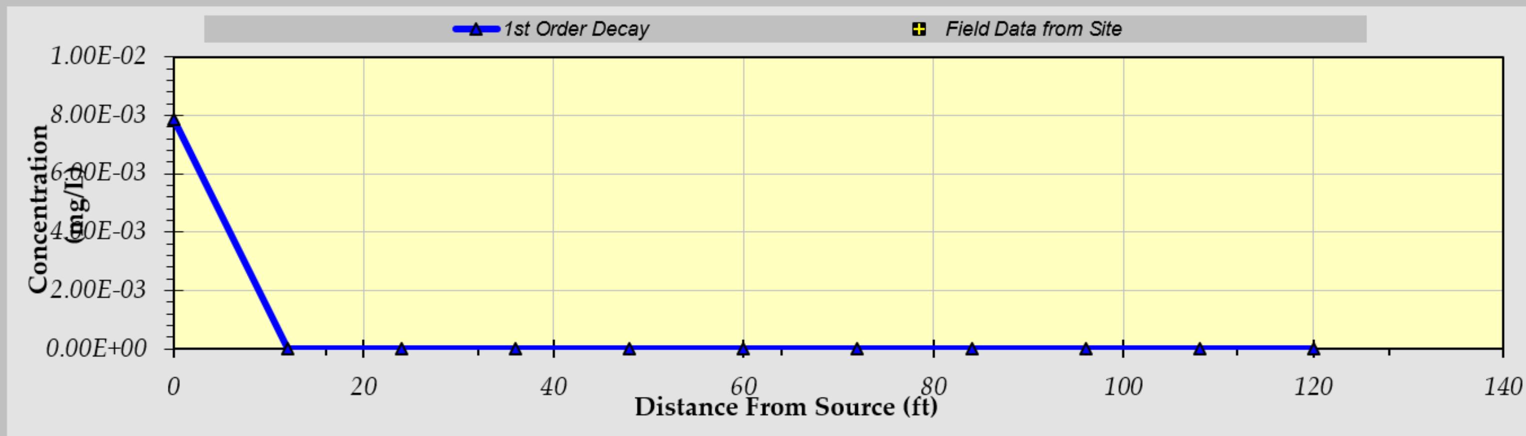


Figure B-13 BIOSCREEN Model for DEHP, Scenario 6

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	12	24	36	48	60	72	84	96	108	120
1st Order Decay	7.86E-03	6.56E-15	5.36E-27	4.29E-39	3.41E-51	2.71E-63	2.16E-75	1.73E-87	1.38E-99	1.11E-111	8.96E-124
Field Data from Site											



Calculate Animation

Time: *10,000 Years*

Return to Input

Recalculate This Sheet

Figure B-13 BIOSCREEN Model for DEHP, Scenario 6 (cont.)

5.0 REFERENCES

ASTM. 1995. Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites. ASTM E-1739-95. Philadelphia, PA.

Bear, J. 1972. Dynamics of Fluids in Porous Media. Dover Publications, Inc., New York: New York, 764 pp.

Domenico, P. A. 1987. An Analytical Model for Multidimensional Transport of a Decaying Contaminant Species. Journal of Hydrology, Vol. 91, pp 49 – 58.

Freeze, R. A. and J. A. Cherry. 1979. Groundwater. 604 pp.

GeoSystems Analysis (GSA), 2024. Evaluation of Groundwater Mounding from Site GM1 Treated Wastewater Infiltration, Mill City, Oregon. November 8, 2024.

GSI Water Solutions, Inc. (GSI), 2023a. Phase II Subsurface Characterization to Support and Evaluation of Treated Wastewater Infiltration in Gates and Mill City, Marion and Linn Counties, Oregon. September 12.

GSI Water Solutions, Inc. (GSI), 2023b. Phase III Subsurface Characterization to Support and Evaluation of Treated Wastewater Infiltration in Gates and Mill City, Marion and Linn Counties, Oregon. Memorandum to Chris Einmo, PE, Marion County. November 15, 2023

GSI Water Solutions, Inc. (GSI), 2024a. Evaluation of the Environmental Fate and Residual Pollutants from an Advance (Class A) Treated Wastewater Infiltration System, Mill City, Oregon. Memorandum to Chris Einmo, PE, Marion County. April 22, 2024

GSI Water Solutions, Inc. (GSI), 2024c. Evaluation of the Environmental Fate of Residual Nitrate from an Advance (Class A) Treated Wastewater Infiltration System, Mill City, Oregon. November 26, 2024.

Oregon Department of Environmental Quality (DEQ), 2024a. Email from Mary Camarata (DEQ) to Chris Einmo (Marion County) RE: Comments on the Groundwater Model Report. January 16, 2024.

US Environmental Protection Agency (EPA), 1996. BIOSCREEN, Natural Attenuation Decision Support System - User's Manual, Version 1.3 (PDF). Publication No. EPA/600/R-96/087. August 1996

Xu, M. and Y. Eckstein. 1995. Use of Weighted Least-Squares Method in Evaluation of the Relationship Between Dispersivity and Scale. Journal of Groundwater (33), No. 6, pp. 905 – 908.

ANALYTICAL REPORT

Apex Laboratories, LLC

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503-718-2323
ORELAP ID: **OR100062**

Friday, August 2, 2024

Erik Hedberg
GSI Water Solutions
650 NE Holladay St, Ste 900
Portland, OR 97232

RE: A4G1556 - Mill City Infiltration Basin - 464.027

Thank you for using Apex Laboratories. We greatly appreciate your business and strive to provide the highest quality services to the environmental industry.

Enclosed are the results of analyses for work order A4G1556, which was received by the laboratory on 7/25/2024 at 6:01:00PM.

If you have any questions concerning this report or the services we offer, please feel free to contact me by email at: pnerenberg@apex-labs.com, or by phone at 503-718-2323.

Please note: All samples will be disposed of within 30 days of sample receipt, unless prior arrangements have been made.

Cooler Receipt Information
Acceptable Receipt Temperature is less than, or equal to, 6 degC (not frozen), or received on ice the same day as sampling.
(See Cooler Receipt Form for details)
Default Cooler 1.1 degC

This Final Report is the official version of the data results for this sample submission, unless superseded by a subsequent, labeled amended report.
All other deliverables derived from this data, including Electronic Data Deliverables (EDDs), CLP-like forms, client requested summary sheets, and all other products are considered secondary to this report.

Apex Laboratories

Philip Nerenberg, Lab Director

The results in this report apply to the samples analyzed in accordance with the chain of custody document(s) and updated by any subsequent written communications. This analytical report must be reproduced in its entirety.

APEX LABORATORIES

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GSI Water Solutions	Project: **Mill City Infiltration Basin**	
650 NE Holladay St, Ste 900	Project Number: **464.027**	**Report ID:**
Portland, OR 97232	Project Manager: **Erik Hedberg**	**A4G1556 - 08 02 24 1640**

ANALYTICAL REPORT FOR SAMPLES

SAMPLE INFORMATION

Client Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
TP 5	A4G1556-01	Soil	07/24/24 00:00	07/25/24 18:01
TP 7	A4G1556-02	Soil	07/24/24 00:00	07/25/24 18:01
TP 8	A4G1556-03	Soil	07/24/24 00:00	07/25/24 18:01

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ANALYTICAL REPORT

GSI Water Solutions
650 NE Holladay St, Ste 900
Portland, OR 97232

Project: **Mill City Infiltration Basin**
Project Number: **464.027**
Project Manager: **Erik Hedberg**

Report ID:
A4G1556 - 08 02 24 1640

ANALYTICAL SAMPLE RESULTS

Demand Parameters

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
TP 5 (A4G1556-01)				**Matrix: Soil**				
Batch: 24G0961								
Total Organic Carbon	**5600**	---	200	mg/kg	1	08/01/24 04:02	EPA 9060Amod	**CONT**
TP 7 (A4G1556-02)				**Matrix: Soil**				
Batch: 24G0961								
Total Organic Carbon	**1200**	---	200	mg/kg	1	08/01/24 04:35	EPA 9060Amod	**CONT**
TP 8 (A4G1556-03)				**Matrix: Soil**				
Batch: 24G0961								
Total Organic Carbon	**5600**	---	200	mg/kg	1	08/01/24 04:46	EPA 9060Amod	**CONT**

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Philip Nerenberg, Lab Director

Apex Laboratories, LLC

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ANALYTICAL REPORT

GSI Water Solutions
650 NE Holladay St, Ste 900
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Project Number: **464.027**
Project Manager: **Erik Hedberg**

Report ID:
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QUALITY CONTROL (QC) SAMPLE RESULTS

Demand Parameters

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch 24G0961 - EPA 9060A							**Soil**					
Blank (24G0961-BLK1)			Prepared: 07/26/24 16:23 Analyzed: 08/01/24 03:40									
EPA 9060Amod												
Total Organic Carbon	ND	---	200	mg/kg	1	---	---	---	---	---	---	
LCS (24G0961-BS1)			Prepared: 07/26/24 16:23 Analyzed: 08/01/24 03:51									
EPA 9060Amod												
Total Organic Carbon	9800	---	200	mg/kg	1	10000	---	98	86-110%	---	---	
Duplicate (24G0961-DUP1)			Prepared: 07/26/24 16:23 Analyzed: 08/01/24 04:13									
QC Source Sample: TP 5 (A4G1556-01)												
EPA 9060Amod												
Total Organic Carbon	**5400**	---	200	mg/kg	1	---	5600	---	---	5	30%	CONT
Duplicate (24G0961-DUP2)			Prepared: 07/26/24 16:23 Analyzed: 08/01/24 04:24									
QC Source Sample: TP 5 (A4G1556-01)												
EPA 9060Amod												
Total Organic Carbon	**6400**	---	200	mg/kg	1	---	5600	---	---	13	30%	CONT

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Portland, OR 97232	Project Manager: **Erik Hedberg**	**A4G1556 - 08 02 24 1640**

SAMPLE PREPARATION INFORMATION

Demand Parameters

Prep: EPA 9060A

Lab Number	Matrix	Method	Sampled	Prepared	Sample Initial/Final	Default Initial/Final	RL Prep Factor
Batch: 24G0961							
A4G1556-01	Soil	EPA 9060Amod	07/24/24 00:00	07/26/24 16:23			NA
A4G1556-02	Soil	EPA 9060Amod	07/24/24 00:00	07/26/24 16:23			NA
A4G1556-03	Soil	EPA 9060Amod	07/24/24 00:00	07/26/24 16:23			NA

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QUALIFIER DEFINITIONS

Client Sample and Quality Control (QC) Sample Qualifier Definitions:

Apex Laboratories

CONT The Sample Container provided for this analysis was not provided by Apex Laboratories, and has not been verified as part of the Apex Quality System.

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REPORTING NOTES AND CONVENTIONS:

Abbreviations:

DET Analyte DETECTED at or above the detection or reporting limit.

ND Analyte NOT DETECTED at or above the detection or reporting limit.

NR Result Not Reported

RPD Relative Percent Difference. RPDs for Matrix Spikes and Matrix Spike Duplicates are based on concentration, not recovery.

Detection Limits: Limit of Detection (LOD)

Limits of Detection (LODs) are normally set at a level of one half the validated Limit of Quantitation (LOQ).
If no value is listed ('-----'), then the data has not been evaluated below the Reporting Limit.

Reporting Limits: Limit of Quantitation (LOQ)

Validated Limits of Quantitation (LOQs) are reported as the Reporting Limits for all analyses where the LOQ, MRL, PQL or CRL are requested. The LOQ represents a level at or above the low point of the calibration curve, that has been validated according to Apex Laboratories' comprehensive LOQ policies and procedures.

Reporting Conventions:

Basis: Results for soil samples are generally reported on a 100% dry weight basis.
The Result Basis is listed following the units as " dry", " wet", or " " (blank) designation.

" dry" Sample results and Reporting Limits are reported on a dry weight basis. (i.e. "ug/kg dry")
See Percent Solids section for details of dry weight analysis.

" wet" Sample results and Reporting Limits for this analysis are normally dry weight corrected, but have not been modified in this case.

" " Results without 'wet' or 'dry' designation are not normally dry weight corrected. These results are considered 'As Received'.

Results for Volatiles analyses on soils and sediments that are reported on a “dry weight” basis include the water miscible solvent (WMS) correction referenced in the EPA 8000 Method guidance documents. Solid and Liquid samples reported on an “As Received” basis do not have the WMS correction applied, as dry weight was not performed.

QC Source:

In cases where there is insufficient sample provided for Sample Duplicates and/or Matrix Spikes, a Lab Control Sample Duplicate (LCS Dup) may be analyzed to demonstrate accuracy and precision of the extraction batch.

Non-Client Batch QC Samples (Duplicates and Matrix Spike/Duplicates) may not be included in this report. Please request a Full QC report if this data is required.

Miscellaneous Notes:

" --- " QC results are not applicable. For example, % Recoveries for Blanks and Duplicates, % RPD for Blanks, Blank Spikes and Matrix Spikes, etc.

" *** " Used to indicate a possible discrepancy with the Sample and Sample Duplicate results when the %RPD is not available. In this case, either the Sample or the Sample Duplicate has a reportable result for this analyte, while the other is Non Detect (ND).

REPORTING NOTES AND CONVENTIONS (Cont.):

Blanks:

Standard practice is to evaluate the results from Blank QC Samples down to a level equal to one half of the Reporting Limit (RL).

Blank results for gravimetric analyses are evaluated to the Reporting Level, not to half of the Reporting Level.

-For Blank hits falling between ½ the RL and the RL (J flagged hits), the associated sample and QC data will receive a 'B-02' qualifier.

-For Blank hits above the RL, the associated sample and QC data will receive a 'B' qualifier, per Apex Laboratories' Blank Policy. For further details, please request a copy of this document.

-Sample results flagged with a 'B' or 'B-02' qualifier are potentially biased high if the sample results are less than ten times the level found in the blank for inorganic analyses, or less than five times the level found in the blank for organic analyses.

'B' and 'B-02' qualifications are only applied to sample results detected above the Reporting Level, if results are not reported to the MDL.

Preparation Notes:

Mixed Matrix Samples:

Water Samples:

Water samples containing significant amounts of sediment are decanted or separated prior to extraction, and only the water portion analyzed, unless otherwise directed by the client.

Soil and Sediment Samples:

Soil and Sediment samples containing significant amounts of water are decanted prior to extraction, and only the solid portion analyzed, unless otherwise directed by the client.

Sampling and Preservation Notes:

Certain regulatory programs, such as National Pollutant Discharge Elimination System (NPDES), require that activities such as sample filtration (for dissolved metals, orthophosphate, hexavalent chromium, etc.) and testing of short hold analytes (pH, Dissolved Oxygen, etc.) be performed in the field (on-site) within a short time window. In addition, sample matrix spikes are required for some analyses, and sufficient volume must be provided, and billable site specific QC requested, if this is required. All regulatory permits should be reviewed to ensure that these requirements are being met.

Data users should be aware of which regulations pertain to the samples they submit for testing. If related sample collection activities are not approved for a particular regulatory program, results should be considered estimates. Apex Laboratories will qualify these analytes according to the most stringent requirements, however results for samples that are for non-regulatory purposes may be acceptable.

Samples that have been filtered and preserved at Apex Laboratories per client request are listed in the preparation section of the report with the date and time of filtration listed.

Apex Laboratories maintains detailed records on sample receipt, including client label verification, cooler temperature, sample preservation, hold time compliance and field filtration. Data is qualified as necessary, and the lack of qualification indicates compliance with required parameters.

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LABORATORY ACCREDITATION INFORMATION

ORELAP Certification ID: OR100062 (Primary Accreditation) -
EPA ID: OR01039

All methods and analytes reported from work performed at Apex Laboratories are included on Apex Laboratories' ORELAP Scope of Certification, with the exception of any analyte(s) listed below:

Apex Laboratories

Matrix	Analysis	TNI_ID	Analyte	TNI_ID	Accreditation
All reported analytes are included in Apex Laboratories' current ORELAP scope.					

Secondary Accreditations

Apex Laboratories also maintains reciprocal accreditation with non-TNI states (Washington DOE), as well as other state specific accreditations not listed here.

Subcontract Laboratory Accreditations

Subcontracted data falls outside of Apex Laboratories' Scope of Accreditation.
Please see the Subcontract Laboratory report for full details, or contact your Project Manager for more information.

Field Testing Parameters

Results for Field Tested data are provded by the client or sampler, and fall outside of Apex Laboratories' Scope of Accreditation.

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APEX LABS
6700 SW Sandburg St., Tigard, OR 97223 Ph: 503-718-2323

CHAIN OF CUSTODY

Lab # A4G1556 COC ___of___

Company: GSI WATER SOLUTIONS | Project Mgr: ERIK HEDBERG | Project Name: MILL CITY INFILTRATION BASIN | Project #: 464.027

Address: 650 NE HOLLADAY #900 PORTLAND, OR | Phone: 512-461-4098 | Email: cdavidson@gsiws.com | PO #

Sampled by: C. DAVIDSON

Site Location: MILL CITY
State OR
County LINN

ANALYSIS REQUEST

SAMPLE ID	DATE	TIME	MATRIX	# OF CONTAINERS	NWTPH-HCID	NWTPH-Dx	NWTPH-Gx	8260 BTEX	8260 RBDM VOCs	8260 Halo VOCs	8260 VOCs Full List	8270 SIM PAHs	8270 Semi-Vols Full List	8082 PCBs	8081 Pesticides	RCRA Metals (8)	Priority Metals (13)	Al, Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Hg, Mg, Mn, Mo, Ni, K, Se, Ag, Na, Tl, V, Zn TOTAL DISS. TCLP	TCLP Metals (8)	TOC							Hold Sample	Frozen Archive
TP 5	7/24			1																✓								
TP 7	7/24			1																✓								
TP 8	7/24			1																✓								

Standard Turn Around Time (TAT) = 10 Business Days

TAT Requested (circle): 1 Day | 2 Day | 3 Day | 5 Day | Standard | Other: OR EARLIER

SPECIAL INSTRUCTIONS: please archive volumes of unused samples

SAMPLES ARE HELD FOR 30 DAYS

RELINQUISHED BY:	RECEIVED BY:	RELINQUISHED BY:	RECEIVED BY:
Signature: [signature] Date: 7/25/24	Signature: [signature] Date: 7/25/24	Signature: Date:	Signature: Date:
Printed Name: Time:	Printed Name: Krystal Norberg Time: 1801	Printed Name: Time:	Printed Name: Time:
Company:	Company: Apex	Company:	Company:

Form Y-002 R-00

APEX LABS COOLER RECEIPT FORM

Client: GSI Water Solutions Element WO#: A4 G1556

Project/Project #: Mill City Infiltration Basin / 464.027

Delivery Info:

Date/time received: 7/25/24 @ 1801 By: KN

Delivered by: Apex__ Client X ESS___ FedEx__ UPS__ Radio___ Morgan ___ SDS___ Evergreen___ Other ___

From USDA Regulated Origin? Yes ______ No ✓

Cooler Inspection Date/time inspected: 7/25/24 @ 1801 By: KN

Chain of Custody included? Yes ✓ No ______

Signed/dated by client? Yes ✓ No ______

Contains USDA Reg. Soils? Yes ______ No ✓ Unsure (email RegSoils) ______

	Cooler #1	Cooler #2	Cooler #3	Cooler #4	Cooler #5	Cooler #6	Cooler #7
Temperature (°C)	1.1						
Custody seals? (Y/N)	N						
Received on ice? (Y/N)	Y						
Temp. blanks? (Y/N)	N						
Ice type: (Gel/Real/Other)	Real						
Condition (In/Out):	In						

Cooler out of temp? (Y/N) Possible reason why: ______

Green dots applied to out of temperature samples? Yes/No

Out of temperature samples form initiated? Yes/No

Sample Inspection: Date/time inspected: 7/25/24 @1832 By: KN

All samples intact? Yes ✓ No ___ Comments: ______

Bottle labels/COCs agree? Yes ~~✓~~ No ✓ Comments: No date or time on bags, no time on COC

COC/container discrepancies form initiated? Yes ___ No ✓

Containers/volumes received appropriate for analysis? Yes ✓ No ___ Comments: received trip blank (3550) not listed on COC

Do VOA vials have visible headspace? Yes ___ No ___ NA ✓

Comments ______

Water samples: pH checked: Yes___No___NA ✓ pH appropriate? Yes___No___NA ✓ pH ID: ______

Comments: ______

Labeled by: KN Witness: [illegible] Cooler Inspected by: KN

Form Y-003 R-02