Feasibility Study
Former Fire Training Area
NASA Wallops Flight Facility

Wallops Island, Virginia

National Aeronautics and Space Administration
Goddard Space Flight Center
Wallops Flight Facility

SEPTEMBER 2005

CERTIFICATION

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Enclosure 1

PHIL-19383

FEASIBILITY STUDY
FORMER FIRE TRAINING AREA
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

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Goddard Space Flight Center
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LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	Microgram(s) per liter
ARAR	Applicable or Relevant and Appropriate Requirement
AS	Air sparging
AS/VE	Air sparging / vapor extraction
AWQC	Ambient Water Quality Criteria (U.S. EPA's)
bgs	Below ground surface
BNP	Bimetallic Nanoscale Particle
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
COC	Chemical of concern
COPC	Chemical of potential concern
CSF	Cancer Slope Factor (U.S. EPA's)
CWA	Clean Water Act
DCE	Dichloroethene
DPT	Direct push technology
FFTA	Former Fire Training Area
FOTW	Federally owned treatment works
FS	Feasibility Study
FUDS	Formerly Utilized Defense Site
GAC	Granular activated carbon
GSFC	Goddard Space Flight Center
GRA	General Response Action
HI	Hazard Index
HRC®	Hydrogen release compound
ICR	Incremental cancer risk
LDRs	Land Disposal Restrictions (U.S. EPA's)
LUC	Land use control
MB	Main Base
MCL	Maximum Contaminant Level (U.S. EPA's)
mg/L	Milligram(s) per liter
MNA	Monitored natural attenuation

MTBE	Methyltert-butyl ether
NAAQS	National Ambient Air Quality Standards (U.S. EPA's)
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NPW	Net present worth
NSPS	New Source Performance Standards (U.S. EPA's)
O&M	Operation and maintenance
ORC®	Oxygen release compound
ORP	Oxidation/Reduction potential
OSHA	Occupational Safety and Health Act
OSWER	Office of Solid Waste and Emergency Response
PA	Preliminary assessment
PCB	Polychlorinated biphenyl
PID	Photoionization detector
POTW	Publicly owned treatment works
PPE	Personal protection equipment
PRG	Preliminary Remediation Goal
RAO	Remedial Action Objective
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose (U.S. EPA's)
RI	Remedial Investigation
SDWA	Safe Drinking Water Act
SI	Site investigation
SMCL	Secondary Maximum Contaminant Level (U.S. EPA's)
SSL	Soil Screening Level
SVOC	Semivolatile organic compound
SWDA	Solid Waste Disposal Act
SWMUs	Solid Waste Management Units
TAL	Target analyte list
TBC	To Be Considered (criterion)
TCA	Trichloroethane
TCL	Target compound list

TSDF	Treatment, storage, disposal facility
TtNUS	Tetra Tech NUS, Inc.
U.S. EPA	United States Environmental Protection Agency
UIC	Underground Injection Control
USFWS	United States Fish and Wildlife Service
VAC	Virginia Administrative Code
VADEQ	Virginia Department of Environmental Quality
VOC	Volatile organic compound
WFF	Wallops Flight Facility
WWTP	Wastewater treatment plant

EXECUTIVE SUMMARY

E.1 PURPOSE OF THE REPORT

The purpose of this Feasibility Study (FS) Report is to develop and evaluate options for the remediation of contaminated groundwater at the Former Fire Training Area (FFTA) at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) Wallops Flight Facility (WFF) located in Accomack County, Virginia.

E.2 SITE DESCRIPTION AND HISTORY

The FFTA is located on the north side of the Main Base, adjacent to a former taxiway immediately north of an active runway. The area is currently an open grass field that gently slopes to the north and northeast. The surface elevation of the site ranges from approximately 27 to 32 feet above mean sea level. Areas of higher elevation surround the FFTA. There are no surface water bodies in or immediately near the FFTA. Surface runoff within the FFTA flows to low-lying areas within the site where it either infiltrates or evaporates.

The FFTA is bordered to the south by an abandoned taxiway. An earthen berm, about 100 feet long and 4 feet high, exists at the edge of the taxiway. The berm is constructed around a discarded airplane fuselage that was used for fire fighting training exercises. NASA began using the FFTA for fire fighting training exercises in 1965 and continued using the area until 1987. It is reported that fire fighting training, conducted twice a week during this time period, consisted of releasing combustible material onto the ground or into an open-top tank, shallow pit, or discarded airplane body, igniting the material, and extinguishing the flames. There are no records identifying the type of materials used during these training exercises.

In 1986, the Commonwealth of Virginia conducted an inspection of the FFTA. The Virginia Department of Waste Management issued a removal order based on the inspection findings. NASA responded to the order by completing a soil removal (approximately 120 cubic yards of impacted soils) in November 1986. A preliminary assessment and site investigation of the FFTA were conducted from 1989 through 1990. Additional studies including a Remedial Investigation (RI) (conducted from 1993 through 1994), supplemental groundwater sampling investigation (conducted in February 2000), and a supplemental RI (conducted in February and March 2003) were performed to characterize the site and define the nature and extent of contamination. These investigations showed that the FFTA groundwater is contaminated with volatile organic compounds (VOCs) (benzene, cis-1,2-dichloroethene [DCE], and vinyl chloride), two semivolatile organic compounds (SVOCs),(naphthalene and 4-methylphenol), and two inorganics (arsenic and manganese) extending from the former fire training pit area in a northerly and easterly direction.

The conclusions of these reports were that past operations at the former fire training area were the likely source of groundwater contamination but the area does not appear to act as a current source of contamination. The past removal action may have removed the primary source material. The contaminant plume is essentially confined to the upper flow unit within the Columbia Aquifer with the presence of a silty clay lens at or near sea level controlling the migration and flow of the contaminants within the upper unit. The detected contaminant concentrations within the plume have decreased and the aerial extent of the plume appears to be less extensive than it was in 1996. No contamination was detected in a monitoring well installed at the projected groundwater discharge point near the closest surface water body, Little Mosquito Creek.

The baseline human health risk assessment performed as part of the Supplemental RI identified that hypothetical future residential exposure to groundwater could potentially result in adverse health effects. The primary constituents in groundwater resulting in this human health risk included arsenic, pentachlorophenol, benzene, vinyl chloride, tetrachloroethene, bis(2-ethylhexyl) phthalate, iron, manganese, 4-methylphenol, cis-1,2-dichloroethene, and naphthalene as chemicals of concern (COCs). The human health risk assessment also indicated that there was considerable uncertainty associated with the source and/or risk attributed to arsenic, pentachlorophenol, tetrachloroethene, bis(2-ethylhexyl) phthalate, iron, and manganese. The groundwater in the vicinity of the FFTA is not used and the current and planned land use of the area is an active runway. Residential development and/or residential land use at the site and immediately downgradient of the FFTA is not anticipated. Also, the use of the shallow aquifer (Columbia aquifer) as a water supply is highly unlikely in that the lower Yorktown aquifer is more productive. In addition, the FTTA is located within a designated Groundwater Management Area. Groundwater use in the area is managed and controlled through a permit application and review process administered by DEQ, the Virginia Department of Health, and the Accomack County Health Department. These agencies operate in consultation with the Accomack-Northampton Planning District Committee and the Eastern Shore of Virginia Groundwater Committee who administer the Groundwater Supply Protection and Management Plan adopted by the county.

The human health risk assessment also evaluated the potential risks associated with FFTA soils. Based on the risk assessment, no actionable risks were identified in the soil and no further action is necessary to protect human health or the environment.

An ecological risk assessment was performed to determine whether adverse ecological impacts are present as a result of exposure to contaminants released to the environment at the FFTA. The FFTA is a terrestrial habitat and the receptors evaluated were plants, soil invertebrates, and herbivorous and insectivorous birds, mammals and reptiles with the potential for contaminant exposure through groundwater discharge to surface water for aquatic receptors. Overall, risks to plants and invertebrates from chemicals detected at the FFTA in surface soils were found to be low to negligible. Similarly, risks to terrestrial wildlife and aquatic receptors were found to be low and similar to background risks.

Based on the RI and risk assessment findings, contaminated groundwater attributable to the FFTA presents an unacceptable potential risk to human health.

E.3 REMEDIAL ACTION OBJECTIVES AND CLEANUP GOALS

The Remedial Action Objectives (RAOs) identified for the FFTA are as follows:

- Prevent the exposure to and use of the FFTA-contaminated groundwater, which presents an unacceptable risk.

- Restore FFTA-impacted groundwater to usable standards and attain cleanup goals established in this FS and the Record of Decision.

In order to be considered for implementation, a remedy must be able to achieve these RAOs. In addition, implementation and maintenance of the remedy must have minimal impact on NASA's mission at WFF.

The cleanup goals for the FFTA groundwater are as follows:

Chemical of Concern (1)	**Frequency of Detection**	**Range of Concentrations**	**Cleanup Goal**
INORGANICS (µg/L)			
Arsenic	3 / 20	5.1 - 25.4	10(2)
Manganese	18 / 18	9 - 4,990	124(3)
SVOCs (µg/L)			
4-Methylphenol	2 / 19	88 - 300	27(3)
Naphthalene	4 / 20	21 - 66	16(3)
VOCs (µg/L)			
Benzene	6 / 21	1 - 28	5(2)
1,2-DCE (cis)	10 / 21	1 - 460	70(2)
Vinyl Chloride	2 / 21	2 - 6	2(2)

NOTES:

1 Future monitoring programs will include these chemicals of concern as well as pentachlorophenol and tetrachloroethene.

2 United States Environmental Protection Agency Drinking Water Maximum Contaminant Levels (U.S. EPA, 2003b).

3 Site-specific risk-based clean-up goal.

Based on analytical results from FFTA groundwater samples, the estimated mass of COCs dissolved in the groundwater is 2 pounds. Although soils at the FFTA do not present a risk to human health or the environment, the presence of petroleum-related contamination in soils below the water table may be contributing to groundwater conditions that could impact the selection of a groundwater remedy. The estimated mass of organic and petroleum related contaminants in the soils are 125 pounds.

E.4 SCREENING OF GENERAL RESPONSE ACTIONS, REMEDIATION TECHNOLOGIES, AND PROCESS OPTIONS

General Response Actions (GRAs) and the remediation technologies and process options associated to these GRAs were screened for effectiveness, implementability, and cost. Remediation technologies that were determined to be ineffective or too difficult to implement were eliminated from further consideration.

The following technologies and process options were retained for the FFTA groundwater:

General Response Action	Technology	Process Options
No Action	None	Not Applicable
Limited Action	Monitoring	Sampling & Analysis
	Institutional Controls	Deed Restrictions/Groundwater Use Restrictions/Facility Master Plan
	Natural Attenuation	Naturally-Occurring Biodegradation and Dilution
In-situ Treatment	Biological - Biostimulation	Aerobic/Anaerobic biological treatment Oxygen and/or Hydrogen release compounds (ORC®/HRC®), Bioventing, Air Diffusion, Bimetallic Nanoscale Particles (BNP)
	Biological - Bioaugmentation	Aerobic/Anaerobic biological treatment microbes, inoculums, and/or bacterium
	Physical	Air Sparging (AS) or Air Sparging/ Vapor Extraction (AS/VE)

E.5 DEVELOPMENT OF REMEDIAL ALTERNATIVES

Based upon the results of the detailed screening of remediation technologies, the following remedial alternatives were developed for the FFTA groundwater:

- **Alternative 1: No Action**. No action would be taken. Retained as a baseline for comparison with other alternatives.

- **Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring**. Natural attenuation would consist of letting concentrations of groundwater VOC and SVOC COCs decrease through naturally-occurring processes such as biodegradation, dilution, and dispersion. The arsenic and manganese contamination is most likely associated with the reducing environment (created by the degradation of the VOC and SVOC contaminants) and will transform to insoluble oxidized compounds when the site returns to an oxic environment. Institutional controls would consist of preventing the use of groundwater for drinking purposes until the cleanup goals have been met. Annual site inspections would be performed to verify implementation of the institutional controls. Monitoring would consist of regularly collecting and analyzing groundwater samples both from within the contaminant plumes to assess natural attenuation and downgradient of the leading edge of the plume to evaluate potential contaminant migration.

- **Alternative 3: In-Situ Biological Treatment (Biostimulation), Institutional Controls, and Monitoring**. In-situ biostimulation treatment would consist of injecting oxygen release compounds (ORC®) in the groundwater to accelerate biodegradation of VOC and SVOC COCs. ORC® would be used to promote the aerobic biodegradation of the benzene, cis-1,2-dichloroethene, and SVOCs in the FFTA plume. The treatment would consist of two ORC® barrier walls that would inject 900 pounds of ORC® through 20 direct push technology (DPT) injection points. The in-situ aerobic biological treatment may also be effective in the treatment of the dissolved arsenic and manganese contamination (most likely associated with the reducing environment created by the degradation of VOC and SVOC contaminants). In-situ aerobic treatment would change the site to an oxic environment that should cause the arsenic and manganese to transform to insoluble oxidized compounds. Institutional controls and monitoring would be similar to those of Alternative 2.

- **Alternative 4: In-Situ Biological Treatment (Bioaugmentation), Institutional Controls, and Monitoring**. In-situ bioaugmentation treatment would consist of injecting a solution of patented aerobic naturally occurring microbes and food sources (CL-Out) to augment natural biodegradation processes in the contaminant plume to accelerate biodegradation of COCs. CL-Out would be used to promote the biodegradation of the benzene, cis-1,2-dichloroethene, and SVOCs in the FFTA plume. The treatment would consist of an initial injection of 76 drums of CL-Out through 80 DPT injection points. The arsenic and manganese contamination is most likely associated with the reducing environment (created by the degradation of the VOC and SVOC contaminants) and will transform to insoluble oxidized compounds when the site returns to an oxic environment. Institutional controls and monitoring would be similar to those of Alternative 2.

- **Alternative 5: In-Situ Air Sparging Treatment, Institutional Controls, and Monitoring**. In-situ Air Sparging (AS) treatment would consist of injecting air in the groundwater to promote the volatilization of benzene, cis-1,2-dichloroethene, and SVOCs. Under this alternative two options were evaluated, one to treat the entire contaminant plume or one to treat the former source area only. The entire contaminant plume would feature 75 sparging wells and two 450 cubic feet per minute (cfm) blowers. The former source area only option would feature 16 sparging wells and one 200 cfm blower. The in-situ AS treatment may also be effective in the treatment of the dissolved arsenic and manganese contamination (most likely associated with the reducing environment created by the degradation of VOC and SVOC contaminants) by changing the site to an oxic environment that should cause the arsenic and manganese to transform to insoluble oxidized compounds. Institutional controls and monitoring (without the monitoring of the natural attenuation parameters) would be similar to those of Alternative 2.

E.6 ANALYSIS OF REMEDIAL ALTERNATIVES

The remedial alternatives were analyzed in detail and compared to each other using seven of the nine criteria provided in the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). These seven criteria are as follows:

- Overall Protection of Human Health and the Environment,
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) and To-Be-Considered (TBCs) guidance criteria,
- Long-term Effectiveness and Permanence,
- Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment,
- Short-term Effectiveness,
- Implementability, and
- Cost

Two other criteria, State and Community Acceptance were not evaluated in this report. They will be evaluated after regulatory and public comments are available.

The following is a summary of these comparisons:

- **Overall Protection of Human Health and Environment**

Alternative 1 would not be protective of human health and the environment because COCs would remain above cleanup goals, no institutional controls would be implemented to prevent unacceptable risk from ingestion of contaminated groundwater, and no monitoring would be performed to evaluate the progress of natural attenuation or the potential migration of COCs.

Alternative 2 would be protective of human health and the environment. Although no active remediation would take place, natural attenuation would dissipate the contaminant plume, institutional controls would prevent unacceptable exposure to contaminated groundwater, and monitoring would evaluate the progress of natural attenuation and verify that unacceptable migration of contaminants is not taking place.

Alternatives 3, 4, and 5 would be slightly more protective of human health and the environment than Alternative 2 because, in addition to institutional controls and monitoring, these alternatives would somewhat accelerate removal of COCs through active treatment processes. Although Alternative 5 could result in fugitive emissions, the operation of the AS system would be controlled so that the rate of these emissions would remain well under Virginia's allowable de minimis of 15 pounds of VOCs per day. Alternative 5 would be more protective than Alternatives 2, 3, and 4 because it would achieve complete protection in a shorter time.

- **Compliance with ARARs and TBCs**

Alternative 1 would not comply with chemical- or location-specific ARARs and TBCs. No action-specific ARARs or TBCs would apply to this alternative. Alternatives 2, 3, 4, and 5 would comply with location- and action-specific ARARs and TBCs and, eventually, with chemical-specific ARARs and TBCs as well. It is anticipated that compliance with chemical-specific ARARs and TBCs would first be achieved by Alternative 5, followed by Alternatives 3 and 4, and then by Alternative 2.

- **Long-term Effectiveness and Permanence**

Alternative 1 would have limited long-term effectiveness and permanence because no action would be taken to reduce contamination, or control exposure to contaminated groundwater, or to monitor the progress of natural attenuation and detect potential migration of contaminants.

Alternative 2 would have long-term effectiveness and permanence because natural attenuation has been demonstrated as effective for the removal of the groundwater COCs. In addition, institutional controls and monitoring would effectively prevent unacceptable exposure to contaminated groundwater until the cleanup goals have been met through natural attenuation.

Alternatives 3, 4, and 5 would be more effective than Alternative 2, because, in addition to the same institutional controls and monitoring components as Alternative 2, they would also include an active treatment component that, compared to natural attenuation, would somewhat accelerate the removal of COCs. Alternative 5 would be most effective because it would use a well-proven treatment technology. Alternatives 3 and 4 would be slightly less effective than Alternative 5 because their application would use an in-situ biological technology that would require treatability testing.

- **Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment**

Alternatives 1 and 2 would not reduce contaminant toxicity, mobility, or volume through treatment. Under these alternatives, contaminant toxicity and volume would be reduced through natural attenuation. The natural attenuation process includes a degradation component that is irreversible but only Alternative 2 would monitor for contaminant reduction.

Alternatives 3, 4, and 5 would significantly reduce contaminant toxicity and volume through treatment. The treatment systems of these alternatives would remove an estimated 2 pounds of COCs and 125 pounds of other contaminants through their operating life. The contaminant removal achieved by these alternatives would be completely irreversible.

- **Short-term Effectiveness**

There would be no short-term effectiveness concerns and no impact to the surrounding community associated with Alternative 1 because no action would be taken.

Alternatives 2, 3, 4, and 5 would also not impact the surrounding community but there would be some short-term effectiveness concerns associated with their implementation because of the risk of workers being exposed to contaminated groundwater. The magnitude of this risk would be proportional to the extent of remedial activities, e.g., it would be lowest for Alternative 2, higher for Alternatives 3 and 4, and highest for Alternative 5. However, regardless of its magnitude, the risk of exposure would be properly mitigated through implementation of proper engineering controls, and adherence to applicable OSHA regulations and to the site-specific health and safety plan (HASP), including the wearing of appropriate personal protection equipment (PPE).

Alternative 1 would not achieve the groundwater RAOs and, although the groundwater cleanup goals would eventually be attained through natural attenuation, there would be no means of determining when this had occurred. Alternatives 2, 3, 4, and 5 would achieve the first RAO immediately upon implementation of institutional controls. Based on the results of experience with similar applications and modeling, it is estimated that the respective timeframes to achieve the second RAO and the groundwater cleanup goals, and achieve site closure would be up to 10 years for Alternative 2, 5 to 10 years for Alternatives 3 and 4, and 4 to 10 years for Alternative 5.

- **Implementability**

Alternative 1 would be easiest to implement since there would be no activities to implement.

Technical implementation of the various components of Alternatives 2, 3, 4, and 5 would be relatively simple.

The technical implementation of the natural attenuation, institutional controls, and monitoring components of Alternative 2 would be very simple. The resources, equipment, and material required for the activities associated with these components are readily available.

The technical implementation of Alternatives 3, 4, and 5 would be more difficult than that of Alternative 2 because each of these alternatives would require the installation and O&M of a groundwater treatment system. Of these three alternatives, Alternatives 3 and 4 would be easiest to implement because they would only require the installation of small diameter DPT injection points and the feeding of chemicals without installation of permanent equipment. Alternative 5 would be technically harder to implement than Alternatives 3 and 4 because it would require construction of an AS system with numerous sparging wells, interconnecting piping, and one or more blower systems. However, the resources, equipment, and material necessary to implement any of these three alternatives are readily available.

Administrative implementation of the various components of Alternatives 2, 3, 4, and 5 would be relatively simple.

Administrative implementation of the institutional controls component of Alternative 2 would be simple because appropriate Land Use Controls (LUCs) or a Facility Master Plan, including land and groundwater use restrictions, would be formulated and implemented to prevent the use of the groundwater from the shallow Columbia aquifer at the FFTA site. Administrative implementability of the monitoring component of Alternative 2 should also be simple and would not require the securing of permits.

The administrative implementation of Alternatives 3, 4, and 5 would be slightly more difficult than that of Alternative 2, because in addition to the same requirements as Alternative 2, these three alternatives would also require the securing of permits for the installation of the injection points. However, these permits should be relatively easy to obtain. Alternatives 3 and 4 may also need underground injection permits for the delivery of the chemicals.

- **Cost**

The cost to implement (capital cost) and operate and maintain (O & M) the remedies were estimated using current dollars. The long-term O & M costs were discounted to calculate the net present worth (NPW) over the life cycle of the remedy. The capital and O&M costs and the NPW of the groundwater remedial alternatives were estimated to be as follows:

Alternative	**Capital**	**NPW of O&M (years)**	**NPW (years)**
1	$0	$0	$0
2	$11,000	$480,000 (10 Years)	$491,000 (10 Years)
3	$133,000	$585,000 (10 Years)	$718,000 (10 Years)
4	$456,000	$580,000 (10 Years)	$1,036,000 (10 Years)
5 (entire plume)	$543,000	$571,000 (10 Years)	$1,114,000 (10 Years)
5 (source area)	$327,000	$483,000 (10 Years)	$810,000 (10 Years)

The above cost figures have been rounded to the nearest $1,000 to reflect the preliminary nature of these estimates.

1.0 INTRODUCTION

This Feasibility Study (FS) report has been prepared for the Former Fire Training Area (FFTA) at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) Wallops Flight Facility (WFF) located in Accomack County, Virginia. The FS has been prepared by Tetra Tech NUS, Inc. (TtNUS) for NASA under Contract Task Order 012 issued by the Engineering Field Activity Northeast of the Naval Facilities Engineering Command under the Comprehensive Long-Term Environmental Action Navy contract number N62472-03-D-0057. This FS report describes the formulation and evaluation of remedial alternatives for contaminated groundwater at the FFTA site. The Supplemental Remedial Investigation (RI) for this site concluded that no further action is required for the soil (TtNUS, 2004b).

This report has been prepared as part of the NASA Environmental Restoration Program in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Guidance for Conducting Remedial Investigations and Feasibility Studies [United States Environmental Protection Agency (U.S. EPA), 1988] and the Virginia Administrative Code (VAC) Hazardous Waste Management Regulations, 9 VAC 20. The FS was conducted to establish Remedial Action Objectives (RAOs) and Cleanup Goals; screen remedial technologies; and assemble, evaluate, and compare remedial alternatives. This FS focuses on the groundwater contaminant plume that has been delineated at the FFTA.

1.1 SITE DESCRIPTION AND BACKGROUND

Figures 1-1 and 1-2 present the location of the NASA WFF and the FFTA site, respectively. Figure 1-3 provides the site layout. The FFTA is located on the north side of the Main Base (MB), adjacent to a former taxiway immediately north of Runway 10-28 (see Figures 1-2 and 1-3). The area is currently an open grass field that gently slopes to the north and northeast. The surface elevation of the site ranges from approximately 27 to 32 feet above mean sea level. Areas of higher elevation surround the FFTA. There are no surface water bodies in or immediately near the FFTA. Surface runoff within the FFTA flows to low-lying areas within the site where it either infiltrates or evaporates.

The FFTA is bordered to the south by an abandoned taxiway. An earthen berm, about 100 feet long and 4 feet high, exists at the edge of the taxiway. The berm is constructed around a discarded airplane fuselage that was used for fire fighting training exercises. The WFF wastewater treatment plant (WWTP) is located west of the FFTA. To the north, separated by an embankment ranging in height from 3 to 12 feet, is the former Navy magazine area. This area is currently used by NASA as a rocket motor storage and preparation area. Access to this area is controlled and restricted. The area east of the FFTA is heavily wooded with conifer trees and contains a former disposal and debris pile area that was used by the Navy prior to NASA's operations. This area is referred to as the Site 14 Debris Pile and is under investigation by the USACE as part of the federal Formerly Utilized Defense Site (FUDS) program.

The geology immediately underlying the site consists of the lithologic unit called the Columbia Group. This lithologic unit predominantly consists of fine- to medium-sand with lesser amounts of silt and clay. The Columbia Group is approximately 50 feet thick beneath the FFTA. A silty clay layer was encountered between 47 and 52 feet below ground surface (bgs). This clay is interpreted as the upper aquitard of the Yorktown Formation based on the agreement between the resultant observed thickness of the Columbia Group (approximately 50 feet) with its estimated regional thickness. A silty clay layer, approximately 3 feet thick, exists within the Columbia Group beneath the FFTA at a subsurface elevation near sea level (25 feet below ground surface). This clay lens functions as a leaky aquitard that hydraulically divides the Columbia aquifer beneath the FFTA into upper and lower units.

The depth to groundwater beneath the FFTA is about 15 feet bgs. Groundwater in the upper unit of the Columbia Aquifer flows in a northeastward direction following the regional topography towards the unnamed tributary to Little Mosquito Creek and from there towards Little Mosquito Creek as shown on Figure 1-4. Groundwater in the lower unit of the Columbia aquifer flows in a generally northward direction and does not appear to be influenced by the unnamed tributary. The measured vertical hydraulic gradient within the Columbia Group at the FFTA and close to the unnamed tributary to Little Mosquito Creek is downward. This downward vertical gradient indicates that the area is a groundwater recharge area. The unnamed tributary is not expected to be a significant groundwater discharge point. The horizontal hydraulic gradient beneath the site was generally very low for the shallow groundwater zone; calculated to be approximately 0.003 feet per foot. The gradient steepened by an order of magnitude further downgradient, near the discharge point to the unnamed tributary to Little Mosquito Creek. Little Mosquito Creek and its associated wetlands are expected to be the significant groundwater discharge point for the study area.

NASA began using the FFTA for fire fighting training exercises in 1965 and continued using the area until 1987. It is reported that fire fighting training, conducted twice a week during this time period, consisted of releasing combustible material onto the ground or into an open-top tank, shallow pit, or discarded airplane body, igniting the material, and extinguishing the flames. There are no records identifying the type of materials used during these training exercises.

The open-top tank was reportedly placed on the edge of the taxiway, and an earthen berm was constructed on the downgradient (northern) side of the tank to contain spilled material. The earthen berm still exists and is shown on Figure 1-3. It is reported that a 500-gallon tank was also installed in the area to collect runoff generated during the training exercises. This tank and the open-top burn tank were reportedly removed in 1990.

A fire training burn pit was reportedly located about 100 feet north of the bermed area. A review of historical photographs and records conducted as part of the 1996 RI (Metcalf & Eddy, Inc., 1996) indicated that the pit was unlined and about 2 to 3 feet deep. The review did not identify the lateral extent of the pit. The fire training pit and the surrounding soil were reportedly excavated and the area was backfilled in 1986.

It is not evident from a review of historical documents when use of an airplane fuselage for training purposes began or where that training occurred. It is likely that multiple airplane bodies were used over the years. An airplane fuselage is currently located on the taxiway within the bermed area. In 1994, 7 years after training exercises at the FFTA were terminated, a similar airplane body was located in the field about 300 feet northwest of this area (Metcalf & Eddy, Inc., 1996).

1.2 SITE INVESTIGATIONS

The following investigations and studies have been conducted at the FFTA site:

- Environmental investigations began at the FFTA in 1986. In 1986, the Commonwealth of Virginia conducted an inspection of the FFTA and identified substances thought to be jet fuel and crank case oil in the unlined burn pit. The Virginia Department of Waste Management issued a removal order based on the inspection findings. NASA responded to the order by completing a soil removal in November 1986. It is reported that approximately 120 cubic yards of impacted soils were removed. The limits of the excavation were determined by visual observations. No sampling or surveying was conducted as part of the removal action (Metcalf & Eddy, Inc., 1996).

- A preliminary assessment (PA) and site investigation (SI) of the FFTA were conducted from 1989 through 1990. The studies included the performance of soil gas surveys, well installation, and surface soil and groundwater sampling. During the initial investigation, 43 soil gas samples were collected from an approximately 1-acre study area consisting of the open field immediately north of the berm and including the suspected location of the training pit. Samples were collected at 100-foot centers and were analyzed using a field organic vapor detection instrument. Samples from three monitoring wells were also collected and analyzed with the field instrument using the headspace technique. The field data indicated the presence of volatile organic compounds (VOCs) in soil gas and groundwater. The highest levels of soil gas contamination were identified in an area about 80 feet directly north of the berm area. A sample from a monitoring well installed east of the elevated soil gas readings and northeast of the berm area also was found to contain VOCs (Ebasco Services, Inc., 1990).

- The PA and SI was followed up with an additional sampling program that included the collection of four surface soil samples and additional groundwater samples from the three existing monitoring wells. The laboratory analytical results indicated that VOCs were not present in the surface soils or an upgradient well, but elevated VOC concentrations were identified in the shallow downgradient well. The analytical data generated from the PA and SI were sufficient to determine the need for additional investigations. However, the exact locations (survey coordinates) of the soil sampling points and the quality of the analytical data were not well defined. For these reasons, the data were used only to guide further investigations but were not considered sufficient to be used for risk assessment or RI purposes (Metcalf & Eddy, Inc., 1996).

- An RI was conducted at the FFTA from 1993 through 1994 (Metcalf & Eddy, Inc., 1996). Field activities included a soil gas survey, advancement of soil borings, installation of monitoring wells, and collection of soil (surface and subsurface) and groundwater samples. The study area included the FFTA and the surrounding features and included the field immediately north of the taxiway. The study area extended about 3,000 feet east-west along the taxiway and about 400 feet to the north to the magazine area embankment. The field investigation included sampling in and around other features adjacent to the FFTA including a reported former temporary drum storage area, WWTP sludge pile, and construction debris pile. The drum storage area was not well defined or confirmed during the RI. Its existence and location were described in an earlier account of site conditions, but the drums were removed prior to the RI. Based on previous accounts, the temporary drum storage area was located immediately south of the WWTP sludge pile. These features are shown on Figure 1-3.

- Soil gas samples collected from throughout the study area were analyzed using a field laboratory equipped with a gas chromatogram for contaminant identification. The most prevalent and highest concentration compounds identified in this survey were 1,1-dichloroethene (1,1-DCE) and 1,1,1-trichloroethane (1,1,1-TCA). The highest level of contamination was identified in the area of the former fire training pit. Eight surface soil samples were collected in the FFTA from around the area that exhibited the elevated soil gas readings. Seventeen subsurface soil samples were collected from six borings advanced in or immediately downgradient of the FFTA and 10 monitoring wells were installed at the site at the conclusion of the soil boring program. The monitoring wells were completed at three depth intervals within the shallow Columbia aquifer and were located based on projected groundwater flow direction (to the north and northeast) and proximity to the suspected source area (fire training pit area). The new and existing monitoring wells were sampled and all soil and groundwater samples were analyzed for target compound list (TCL) organic and target analyte list (TAL) metals. Based on the RI findings it was concluded that a groundwater contaminant plume, consisting primarily of benzene, toluene and cis-1,2-DCE, was emanating from the former fire training pit area and flowing to the northeast (Metcalf & Eddy, Inc., 1996).

- A supplemental groundwater sampling investigation was conducted in February 2000. The objective of the sampling event was to collect groundwater data to assess if site conditions had changed since the RI data were collected. The results of the 2000 sampling were compared to the RI findings and it was concluded that the apparent groundwater plume had diminished in the source area and broadened in the downgradient area. Based on the results of the 1996 RI (soil gas, surface soil, subsurface soil, groundwater) and 2000 (groundwater only) sampling events, it was concluded that past fire fighting training exercises were the source of groundwater contamination identified north of the abandoned taxiway. Based on the analytical data it was suggested that contamination, primarily VOCs, was migrating with the groundwater and possibly being discharged to the area wetlands and creeks (Versar, Inc., 2000).

- A supplemental RI field investigation was conducted in February and March 2003 that included collecting and analyzing surface and subsurface soil samples from within the suspected source area, installing additional monitoring wells, and sampling the new and existing monitoring wells to better define the groundwater flow and contaminant migration pathway. Eighteen surface and 37 subsurface soil samples were collected from the suspected source area and analyzed for VOCs, semi-volatile organic compounds (SVOCs), polychlorinated biphenyl (PCB), and TAL metals. Additionally, surface soil samples were analyzed for dioxin (and furans), pH, total organic carbon, and grain size. Seven new monitoring wells were also installed. The purpose of the new wells was to fill data gaps to provide a more complete delineation of groundwater flow patterns (by providing additional hydraulic head data) and a more complete delineation of the nature and extent of groundwater contamination. Groundwater samples were analyzed for VOCs plus methyl tert-butyl ether (MTBE), SVOCs, PCBs, TAL total and dissolved metals (field-filtered), and monitored natural attenuation parameters (TtNUS, 2004b).

1.3 SUMMARY OF INVESTIGATIONS FINDINGS

1.3.1 Nature and Extent of Soil Contamination

The surface soil samples were collected from 0 to 0.5 feet bgs and the subsurface soil samples were collected above the water table from the center and at 25- and 50-foot intervals along vectors emanating from the suspected location of the former fire training pit. Subsurface soil samples were collected from the 2 to 4 feet depth at all locations and additional samples were collected from each location at depths ranging from 7 to 17 feet [see the Supplemental RI Report Section 4.2 and Figure 4-5 (TtNUS, 2004b)]. Several soil borings for the subsurface samples exhibited elevated photoionization detector (PID) readings and fuel or solvent odors although none of the borings had visual evidence of contamination with the exception of one boring located in the approximate center of the former fire training pit, which contained a 0.5 feet thick layer of black "charred or charcoal-like" material at the water table (16 to 17 feet bgs). The elevated PID readings detected near the water table from the borings located in the downgradient direction of the training pit (coupled with the lack of vadose zone contamination) are interpreted to reflect the significant groundwater contamination detected in this area. Several soil samples at or near the water table contained VOCs and other contaminants that define the nature and extent of the groundwater plume. However, the concentrations of the contaminants were below U.S. EPA Soil Screening Levels (SSLs) that could result in groundwater contamination above drinking water standards (TtNUS, 2004b).

1.3.2 Nature and Extent of Groundwater Contamination

Analytical results for the groundwater samples collected at the FFTA site during the Supplemental RI field investigation are summarized on Tables 1-1 and 1-2 and illustrated on Figures 1-5 through 1-9. Historical VOCs results, primarily benzene, toluene, and cis-1,2-DCE, were used to characterize groundwater contamination at the site. Results from the Supplemental RI show similar contaminants as previous investigations (see Tables 1-1 and 1-2). However, the compounds selected as chemicals of potential concern (COPCs) in 1996 were detected at lower concentrations during the Supplemental RI sampling. In addition, other contaminants (VOCs, SVOCs, and metals) were detected at concentrations that suggest a mixed contaminant plume extending from the former pit area to the north and east. Figure 1-5 shows the concentrations of selected contaminants detected in monitoring well samples collected and analyzed during the Supplemental RI. The contaminants shown were selected based on their historical use to define groundwater contamination, potential human health risks, and frequency of detection.

Figure 1-6 shows the benzene isoconcentrations using the 2003 Supplemental RI data. The highest concentrations of benzene are in the area around monitoring well MW-61I. However, benzene concentrations in that well have decreased from 100 micrograms per liter (ug/L) in 1996 to 31 ug/L in 2000 and to 28 ug/L in 2003. The northern extent of the benzene plume in groundwater, as indicated in the investigation, is in the area of MW-57S, which current data indicate contains benzene at 3 ug/L. The south-southwestern extent, as defined in the current data, is at MW-55S (2 ug/L). A low concentration of benzene was detected at MW-2S (2 ug/L) in 1996, but benzene has not been detected in this well since that event.

Results for the Supplemental RI show toluene present in MW-55S (83 ug/L). Concentrations in MW-55S were substantially less than previously reported (1,400 ug/L). The only other Supplemental RI groundwater sample with a positive detection of toluene was collected from MW-101S (12 ug/L), which is located approximately 50 feet south of MW-55S. There is no indication that toluene has migrated further northeast towards MW-61I, which generally shows the highest concentrations of VOCs detected on site. Although highly interpretive, a projected toluene plume based on these two detections is shown on Figure 1-7.

Results from the Supplemental RI sampling also indicated a decrease in the cis-1,2-DCE contaminant concentrations. Concentrations of cis-1,2-DCE ranged from 1 ug/L to 3,000 ug/L and 1 ug/L to 1,700 ug/L in the 1996 and 2000 RI sampling results, respectively. During the Supplemental RI, cis-1,2-DCE was detected in 10 of 21 samples at concentrations ranging from 1 ug/L to 460 ug/L. A projected cis-1,2-DCE plume, based on the Supplemental RI data is presented in Figure 1-8. The highest concentrations extend from MW-61I northeastward to MW-56D (360 ug/L) and MW-57S (110 ug/L), but was detected at only 1 ug/L in MW-105D screened in the deeper portion of the aquifer at this location.

Results from the Supplemental RI indicate an east-west oriented 1,1,1-TCA plume as shown in Figure 1-9, with the highest concentrations located at MW-58S (340 ug/L) and MW-61I (240 ug/L). The plume extends northeastward from MW-58S and MW-61I toward MW-56D (210 ug/L) and MW-57S (84 ug/L) as well as eastward to MW-103I (19 ug/L). The shallow and deep wells at MW-103 do not show 1,1,1-TCA. Previous sampling results from the 2000 RI sampling effort indicated the possible presence of a 1,1,1-TCA plume with the highest concentration of 510 ug/L extending from MW55S to MW-57S. The data indicate that the plume may be decreasing in concentration and size.

Naphthalene was present in wells at the FFTA site with concentrations ranging from 21 ug/L to 66 ug/L. The naphthalene was present in wells located within and immediately downgradient of the suspected source area. Other SVOCs detected during the Supplemental RI included 4-methylphenol, which was detected at well cluster MW-55S/D at concentrations above human health risk-based screening criteria.

Arsenic and manganese were detected in the FFTA monitoring well samples during the Supplemental RI. Filtered groundwater samples were also collected from all wells during the Supplemental RI to evaluate the presence of dissolved metals. The highest concentrations of total arsenic (25.4 ug/L) and total manganese (4,990 ug/L) were from the samples from monitoring wells MW-55S and MW-61I. Filtered samples from these wells also contained the highest concentrations of dissolved arsenic and manganese.

The conclusions of the Supplemental RI report indicated that the past operations at the former fire training area were likely the source of groundwater contamination but the area does not appear to act as a current source of contamination. Past removal actions may have removed the primary source material and current fire training exercises do not include the use of combustible or waste materials. The dissolved plume of contamination is primarily defined by the presence of VOCs located downgradient of the former fire training pit area, and the contaminant plume is essentially confined to the upper flow unit within the Columbia

Aquifer. The presence of the silty clay lens at or near sea level appears to control the migration of the contaminants as well as influence the flow within the upper unit. The detected contaminant concentrations within the plume have decreased and the areal extent of the plume appears to be less extensive than it was depicted using the 1996 RI sampling data. No contamination was detected in a monitoring well (FTA-MW-104S) installed at the projected groundwater discharge point near the confluence of the unnamed tributary and Little Mosquito Creek (TtNUS, 2004b).

1.3.3 Human Health Risk Assessment

A baseline human health risk assessment for the FFTA site was completed as part of the Supplemental RI (TtNUS, 2004b). The risk assessment evaluated potential risks to current and future industrial workers, future construction workers, and hypothetical future residents and considered soil and groundwater at the site. The future anticipated land use for the FFTA is the continued use of the area as an airfield. Residential development of the area is extremely unlikely. The future residential scenario was developed as a baseline for comparison purposes in accordance with U.S. EPA guidelines. In evaluating this exposure scenario it was assumed that the shallow FFTA groundwater (Columbia aquifer) would be used for residential purposes. The use of the shallow aquifer as a water supply is highly unlikely in that the lower Yorktown aquifer is more productive. In addition, the FFTA is located within a designated Groundwater Management Area and groundwater use in the area is managed and controlled through a permit application and review process administered by DEQ, the Virginia Department of Health, and the Accomack County Health Department. The results of the risk assessment indicated that hypothetical future residential exposure to groundwater could potentially result in adverse health effects. No other unacceptable risks were identified for the other exposure scenarios or other media present at the FFTA.

The incremental cancer risk (ICR) associated with residential exposure to groundwater was calculated as 3.28×10^{-4}. The primary constituents in groundwater resulting in this risk include arsenic, pentachlorophenol, benzene, vinyl chloride, tetrachloroethene, and bis(2-ethylhexyl) phthalate. The evaluation of the domestic use of site groundwater resulted in noncancer health hazards (hazard index [HI]) greater than 1.0 based primarily on potential exposure to arsenic, iron, manganese, 4-methylphenol, cis-1,2-DCE, and naphthalene in untreated drinking water. The contaminants that were identified as risk contributors are provided on Table 1-3 with the occurrence and distribution of these contaminants at the FFTA site and background groundwater samples.

As discussed in the Supplemental RI, there is considerable uncertainty associated with the source and/or risk attributed to some of these compounds. Arsenic was detected in one site background and three site-related monitoring well samples (see Table 1-3). Two of the site-related groundwater samples, MW-55S and MW-61I, contained arsenic at concentrations (25.4 ug/L and 13.7 ug/L, respectively) that appear to be elevated when compared to the other site detection and site-related background concentrations. Arsenic was detected in the other FFTA site sample at a concentration (5.1 ug/L) similar to the background detection (3.88 ug/L). Six base-wide background groundwater samples contained arsenic, three of which contained arsenic at similarly elevated concentrations. However, a review of the base-wide background data indicates that in subsequent sampling of these wells, arsenic was either not detected or was detected at low estimated concentrations. As discussed in the Supplemental RI, it is not known if the elevated concentrations of arsenic detected in two of the site-related wells is directly associated with waste materials handled at the FFTA or if the concentrations are associated with the release of arsenic from native materials as a result of the reducing environment created by the degradation of other FFTA waste-related contaminants. Arsenic has been found to be present in some refined petroleum products and waste oils, and these materials may have been handled at the FFTA. However, the extent of the arsenic present at the FFTA site is not widespread and is found at elevated concentrations only at wells that exhibit highly reducing environments [indicated by low oxidation/reduction potential (ORP) results]. The low frequency and the location of the detections at the site suggest an uncertainty as to the source of the arsenic detected in the FFTA site groundwater samples.

Similarly, manganese, a naturally occurring element, was detected in the site and background groundwater samples. The maximum site-related concentration exceeds the background concentrations. Manganese is not typically associated with the materials handled at the FFTA, but is often detected at elevated concentrations within the active degradation portion of contaminant plumes. The active degradation portion of the plume is typically an anaerobic or reducing environment that exhibits low dissolved oxygen and ORP. This reducing environment is conducive to the dissolution of manganese from the native materials. The elevated manganese concentrations detected at the FFTA match this pattern; they were detected immediately within and adjacent to the central portion of the contaminant plume, where data indicates a reducing environment exists. The nature and extent of the manganese detections within the FFTA groundwater suggest that elevated concentrations of this compound may be related to the highly reducing environment and may not be a component of the actual waste materials released at the site.

Iron, also a naturally occurring element, was detected in the site and background samples. Iron is not typically associated with the materials handled at the FFTA site. Supplemental RI site and site-related background groundwater samples contained iron at concentrations up to 44,200 ug/L and 11,500 ug/L, respectively. Iron has also been detected in historical base-wide background groundwater samples at concentrations up to 55,000 ug/L, (see Table 1-3). Iron was detected in three sites samples (at concentrations ranging from 6,060 to 44,200 ug/L), one site background sample (11,000 ug/L), and eight of the 12 base-wide background samples (at concentrations ranging from 7,370 to 50,000 ug/L) at elevated concentrations that would result in similar unacceptable risk levels. A qualitative review of the site and background data suggests that site concentrations are not greater than base-wide background concentrations and the risk associated with exposure to iron is similar to background risks and is not site-related.

As shown in Table 1-3, bis(2-ethylhexyl) phthalate was detected in one FFTA-related background and six site groundwater samples. The background sample contained 7 ug/L and site concentrations ranged from an estimated value of 1J to 6 ug/L. A common laboratory contaminant, bis(2-ethylhexyl) phthalate, was detected in quality assurance blanks and reported as present in 4 other samples at concentrations that were rejected during the data validation process because of the blank contamination. The concentrations reported in the six site samples and the background sample could not be discounted according to data validation protocol, but the pattern of detection suggests that the reported detection in groundwater samples is related to the laboratory contamination. Considering the evidence that suggests that bis(2-ethylhexyl) phthalate detections may be related to laboratory contamination, the low concentration of the detections, and the fact that the highest concentration was reported in a background sample, the calculated risk associated with bis(2-ethylhexyl) phthalate does not appear to be site related.

Pentachlorophenol was detected (below practical quantitation limits) in one site sample at an estimated concentration of 2J ug/L in monitoring well FTA-MW-61I. Pentachlorophenol was not detected in the other groundwater samples, including downgradient wells, or in the site surface and subsurface soil samples collected during the Supplemental RI. The single low-concentration detection does not constitute a plume and the calculated risk based on this single estimated concentration results in an overestimation of actual site risks.

Similarly, tetrachloroethene was identified as a contributor to the lifetime incremental cancer risk but it was detected in only two samples at 1 ug/L. Because of the low frequency and level of detection, the calculated risk associated with tetrachloroethene may be overestimated.

As indicated above, the human health risk assessment also evaluated the potential risks associated with FFTA soils. The ICRs for potential industrial worker, construction worker, and residential exposure to soils were calculated as 3.5×10^{-6}, 4.9×10^{-7}, and 1.6×10^{-5}, respectively. These risks fall within the U.S. EPA acceptable risk range (10^{-4} to 10^{-6}). There were no contaminants that would contribute to a noncancer health effect greater than unity (HI of 1) under the exposure scenarios. Based on the investigation and the risk assessment, no actionable risks were identified in the soil and no further action is necessary (TtNUS, 2004b).

1.3.4 Ecological Risk Assessment

An ecological risk assessment was performed to determine whether adverse ecological impacts are present as a result of exposure to contaminants released to the environment at the FFTA. The FFTA is a terrestrial habitat and the receptors evaluated were plants, soil invertebrates, and herbivorous and insectivorous birds, mammals and reptiles. In addition, the potential for contaminant exposure through groundwater discharge to surface water and the potential risk to aquatic receptors was evaluated. Overall, risks to plants and invertebrates from chemicals detected at the FFTA in surface soils were found to be low to negligible. Similarly, risks to terrestrial wildlife and aquatic receptors were found to be low and similar to background risks (TtNUS 2004).

1.4 DOCUMENT ORGANIZATION

This FS Report has been organized with the intent of meeting the general format requirements specified in the RI/FS Guidance Document (U.S. EPA, 1988). This report features the following five sections:

- Section 1.0, Introduction, summarizes the purpose of the report, provides site background information, summarizes findings of the RI, and provides the report outline.

- Section 2.0, RAOs and General Response Actions (GRAs), presents the RAO, identifies Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered (TBC) criteria, develops cleanup goals and associated GRAs, and provides an estimate of the volume of contaminated media to be remediated.

- Section 3.0, Screening of Remediation Technologies and Process Options, provides a two-tiered screening of potentially applicable groundwater remediation technologies and identifies the technologies that will be assembled into remedial alternatives.

- Section 4.0, Assembly and Detailed Analysis of Remedial Alternatives, assembles the remedial technologies retained from the Section 3.0 screening process into multiple groundwater remedial alternatives, describes these alternatives, and performs a detailed analysis of these alternatives in accordance with seven CERCLA criteria.

- Section 5.0, Comparative Analysis of Remedial Alternatives, compares the groundwater remedial alternatives on a criterion-by-criterion basis, for each of the seven CERCLA analysis criteria used in Section 4.0

2.0 REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS

This section identifies the media of concern and develops RAOs and derives cleanup or remediation goals for the contaminated media. The regulatory requirements and guidances that may potentially govern remedial activities are presented in this section. In addition, this section presents GRAs that may be suitable to achieve the cleanup goals. Finally, this section presents an estimate of the volumes of contaminated media.

2.1 MEDIA OF CONCERN

Groundwater associated with the FFTA Site is contaminated with VOCs, SVOCs, and metals (see Section 1). The nature and extent of the contamination, as summarized in Section 1 and presented in the Supplemental RI report (TtNUS, 2004b), have been defined. The level of contamination in groundwater exceeds human health-based benchmarks and presents an unacceptable risk to future potential residential groundwater users. The Supplemental RI investigated and evaluated contaminant levels in surface and subsurface soils at the FFTA. Based on the Supplemental RI findings, the level of contamination detected in FFTA soil do not present an unacceptable risk to human health. The ecological risk assessment conducted as part of the Supplemental RI concluded that risks to the environment from contaminants identified in FFTA groundwater and soil were low to negligible and similar to background concentrations. Groundwater is the only medium of concern.

2.2 REMEDIAL ACTION OBJECTIVES

The purpose of this section is to develop RAOs for FFTA site at NASA's WFF in Accomack County, Virginia. Development of RAOs is an important step in the FS process. The RAOs are medium-specific goals that define the objective of conducting remedial actions to protect human health and the environment.

The development of cleanup goals and GRAs to attain the RAOs takes into consideration Federal and state laws that are considered to be ARARs as well as other Federal and state guidelines and criteria TBCs. Section 2.2.1 presents the RAOs, Section 2.2.2 identifies the ARARs and TBCs, and Section 2.2.3 identifies the chemicals of concern (COCs) for remediation.

2.2.1 Statement of Remedial Action Objectives

This FS addresses groundwater contamination at the FFTA site. Contaminated groundwater contributable to the FFTA Site presents an unacceptable human health risk to potential future residential users. To protect the public from potential current and future health risks, the following RAOs have been developed:

- Prevent the exposure to and use of the FFTA-contaminated groundwater, which presents an unacceptable risk.

- Restore FFTA-impacted groundwater to usable standards and attain cleanup goals established in this FS.

In addition to these RAOs, remedial actions must also have minimal impact on NASA’s ability to perform its mission at WFF.

2.2.2 Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria

ARARs consist of the following:

- Any standard, requirement, criterion, or limitation under Federal environmental law.

- Any promulgated standard, requirement, criteria, or limitation under a state environmental or facility-siting law that is more stringent than the associated Federal standard, requirement, criterion, or limitation.

TBCs are nonpromulgated, nonenforceable guidelines or criteria that may be useful for developing a remedial action or are necessary for determining what is protective to human health and/or the environment. Examples of TBCs include U.S. EPA Drinking Water Health Advisories, Reference Doses (RfDs) and Cancer Slope Factors (CSFs).

One of the primary concerns during the development of remedial action alternatives for hazardous waste sites under CERCLA is the degree of human health and environmental protection offered by a given remedy. Section 121 of CERCLA requires that primary consideration be given to remedial alternatives that attain or exceed ARARs. The purpose of this requirement is to make CERCLA response actions consistent with other pertinent Federal and state environmental requirements.

2.2.2.1 Definitions

The definitions of ARARs are given below:

- Applicable Requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

- Relevant and Appropriate Requirements are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law, while not "applicable" to a hazardous substance, pollutant, contaminant, or remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

- TBCs are a category created by the U.S. EPA that includes non-promulgated criteria, advisories, and guidance issued by Federal or state government that are not legally binding and do not have the status of potential ARARs. However, pertinent TBCs will be considered along with the ARARs in determining the necessary level of cleanup or technology requirements.

Under CERCLA Section 121(d)(4), the U.S. EPA may waive compliance with an ARAR if one of the following conditions can be demonstrated:

- The remedial action selected is only part of a total remedial action that will attain the ARAR level or standard of control upon completion;

- Compliance with the requirement will result in greater risk to human health and the environment than other alternatives;

- Compliance with the requirement is technically impracticable from an engineering perspective;

- The remedial action selected will attain a standard of performance that is equivalent to that required by the ARAR through the use of another method or approach;

- With respect to a state requirement, the state has not consistently applied the ARAR in similar circumstances at other remedial actions within the state; or

- Compliance with the ARAR will not provide a balance between protecting public health, welfare, and the environment at the facility with the availability of Superfund money for response at other facilities (fund-balancing). This condition only applies to Superfund-financed actions.

The National Oil and Hazardous Substance Pollution Contingency Plan (NCP) has identified three categories of ARARs [40 Code of Federal Regulations [CFR] Section 300.400 (g)]:

- Chemical-Specific: Health-risk-based numerical values or methodologies that establish concentration or discharge limits for particular contaminants. Examples include Maximum Contaminant Level (MCLs) and Clean Water Act (CWA) Ambient Water Quality Criteria (AWQC).

- Location-Specific: Restrictions on actions or contaminant concentrations in certain environmentally sensitive areas. Examples of these areas regulated under various Federal laws include floodplains, wetlands, and locations where endangered species or historically significant cultural resources are present.

- Action-Specific: Technology- or activity-based requirements, limitations on actions, or conditions involving special substances. Examples of action-specific ARARs include wastewater discharge standards.

The following section discusses contaminant- and location-specific ARARs and TBCs. Action-specific ARARs and TBCs are presented in Section 2.3 along with the discussion of GRAs.

2.2.2.2 Chemical-Specific ARARs and TBCs

Tables 2-1 and 2-2 present summaries of Federal and State of Virginia chemical-specific ARARs and TBCs for this FS. These ARARs and TBCs provide some medium-specific guidance on “acceptable” or “permissible” concentrations of contaminants. These ARARs and TBCs are discussed below.

FEDERAL

The Safe Drinking Water Act (SDWA) promulgated National Primary Drinking Water Standard MCLs (40 CFR Part 141). MCLs are enforceable standards for contaminants in public drinking water supply systems. They consider not only health factors but also the economic and technical feasibility of removing a contaminant from a water supply system. Secondary MCLs (SMCLs) (40 CFR Part 143) are not enforceable but are intended as guidelines for contaminants that may adversely affect the aesthetic quality of drinking water, such as taste, odor, color, and appearance, and may deter public acceptance of drinking water provided by public water systems.

The SDWA also established MCL Goals (MCLGs) for several organic and inorganic compounds in drinking water. MCLGs are set at concentrations of no known or anticipated adverse health effects, with an adequate margin of safety. The NCP [40 CFR Part 300.430(e)(2)(i)] states that MCLGs that are set at concentrations above zero shall be attained by remedial actions for groundwater or surface water that are current or potential sources of drinking water [where the MCLGs are relevant and appropriate under the circumstances of the release based on the factors in Section 300.400(g)(2) of the NCP]. If an MCLG is found not to be relevant and appropriate, the corresponding MCL shall be achieved where relevant and appropriate to the circumstances of the release. For MCLGs that are set at zero, the MCL promulgated for that contaminant under the SDWA shall be attained by the remedial actions. In cases involving multiple contaminants or pathways where attainment of chemical-specific ARARs will result in a cumulative cancer risk in excess of 10^{-4}, criteria in paragraph (e)(2)(i)(A) of Section 300.430 (i.e., risk-based criteria) may be considered when determining the clean-up level to be attained. The NCP explains that clean-up levels set at zero (generally the case for carcinogens) are not appropriate because CERCLA does not require complete elimination of risk and because "true zero" cannot be detected. SDWA requirements may be relevant and appropriate to remedial actions involving groundwater.

U.S. EPA Health Advisories are nonenforceable guidelines (TBCs) developed by the U.S. EPA Office of Drinking Water for chemicals that may be intermittently encountered in public water supply systems. Health advisories are available for short-term, longer-term, and lifetime exposures for a 10-kilogram child and/or a 70-kilogram adult. Health advisories may be pertinent for remedial actions involving groundwater, especially for contaminants that are not regulated under the SDWA.

Cancer Slope Factors (CSFs) are used for estimating the lifetime probability (assumed 70-year lifespan) of human receptors contracting cancer as a result of exposure to known or suspected carcinogens. These factors are generally reported in units of kg-day/mg and are derived through an assumed low-dosage linear relationship and an extrapolation from high to low dose responses determined from human or animal studies. Cancer risk and CSFs are most commonly estimated through the use of a linearized multistage mathematical extrapolation model applied to animal bioassay results. The value used in reporting the slope factor is the upper 95 percent confidence limit. CSFs are TBCs for FFTA groundwater.

Reference Dose (RfD), as defined in the U.S. EPA Integrated Risk Information System, is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs are developed for chronic and/or subchronic human exposure to hazardous chemicals and are based on the assumption that thresholds exist for certain toxic effects. The RfD is usually expressed as an acceptable dose (mg) per unit body weight (kg) per unit time (day). The RfD is derived by dividing the no-observed-adverse effect level or the lowest-observed-adverse effect level by an uncertainty factor times a modifying factor. The use of uncertainty factors and modifying factors is discussed in the U.S. EPA Office of Research and Development Health Effects and Summary Tables (U.S. EPA, 1997). RfDs are TBCs for FFTA groundwater.

The Clean Water Act (CWA) sets U.S. EPA ambient water quality criteria (AWQCs) that are non-enforceable guidelines developed for pollutants in surface waters pursuant to Section 304(a)(1) of the CWA. Although AWQCs are not legally enforceable, they have been used by many states to develop enforceable water quality standards; they should be considered as potential ARARs, as specified by CERCLA. AWQCs are available for the protection of human health from exposure to contaminants in surface water as well as from ingestion of aquatic biota and for the protection of freshwater and saltwater aquatic life. AWQCs may be considered for actions that involve groundwater treatment and/or discharge to nearby surface waters and may be used as a basis for determining cleanup goals in the absence of State water quality standards.

STATE

Virginia Surface Water Antidegradation Policy (9 VAC 25-260-30) has been established to protect surface waters from activities that have the potential to impact existing surface water quality. This policy establishes, at a minimum, that existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected. This policy does not address specific contaminant levels but is potentially relevant and appropriate for a remedial action that includes discharge of extracted groundwater.

Virginia Numerical Criteria for Dissolved Oxygen, pH, and Maximum Temperature (9 VAC 25-260-50) establishes minimum, daily averages, and maximum numeric criteria for various Classes of surface water. These criteria have been established to protect surface water conditions and are also used to calculate loading and are used to establish limits for discharges to surface water. These criteria may be applicable for a remedial action that includes discharge of extracted groundwater.

Virginia Criteria for Surface Water (9 VAC 25-280-140) have been established for pollutants in surface water. Instream water conditions shall not be acutely or chronically toxic, except as allowed in mixing zones. Standards are available for freshwater and saltwater aquatic life and human health (both from drinking water and fish consumption and only fish consumption). These criteria are also used to calculate waste load allocations that are used to establish limits for discharges to surface water. These criteria can be used to determine groundwater remediation goals that are protective of surface water. These criteria may be applicable for remedial action that includes discharge of extracted groundwater.

Virginia Groundwater Standards (9 VAC 25-280, Part IV) contain standards that apply statewide and by physiographic province. The standards apply to the groundwater occurring at or below the uppermost seasonal limits of the water table. The NASA WFF is on the eastern shore of the Delmarva Peninsula in the Atlantic Coastal Plain Physiographic Province. The standards may be applicable for developing groundwater remediation goals.

Virginia Water Quality Criteria for Groundwater (9 VAC 25-280, Part V) contain criteria that apply primarily to constituents that occur naturally by physiographic province. Since natural groundwater quality can vary greatly from area to area for these constituents, enforceable standards were not adopted. These criteria are intended to provide guidance in preventing groundwater pollution and are not mandatory. The groundwater quality criteria may be TBC criteria for developing remediation goals for groundwater.

Virginia Voluntary Remediation Regulations, Remediation Levels (9 VAC 20-160) are applicable for sites that are not being remediated under CERCLA, the Virginia Waste Management Act, or the Virginia State Water Control Law. The remediation levels include general and tier-based criteria. For a site with carcinogenic contaminants, the remediation goal for individual carcinogenic contaminants shall be an incremental upper-bound lifetime cancer risk of 1E-6. The remediation levels for the site shall not result in an incremental upper-bound lifetime cancer risk exceeding 1E-4 considering multiple contaminants and multiple exposure pathways, unless the use of a SDWA MCL results in a cumulative risk of greater than 1E-4. For noncarcinogens, the HI shall not exceed a combined value of 1.0. For unrestricted future use, where a contaminant of concern has an MCL, the MCL for that contaminant shall be the remediation level. For unrestricted use, where a contaminant of concern exists for which a surface water quality standard has been adopted, the concentration in other media shall not result in a concentration that exceeds the water quality standard in adjacent surface water bodies. If the concentration of a contaminant is below the Practical Quantitation Limit, the Practical Quantitation Limit may be considered as the remediation level. Tier-based criteria may be based on background levels, MCLs, Risk-Based Concentration (RBCs), and/or a site-specific risk assessment conducted in accordance with CERCLA guidance. The voluntary remediation levels may be relevant and appropriate for developing remediation goals for groundwater.

Virginia Department of Health Waterworks Regulations (12 VAC 5-590-10) contain both MCLs and SMCLs. Cleanup levels for potential drinking water sources are typically based on MCLs or SMCLs if these are enforceable requirements. In the absence of MCLs/SMCLs, other health-based standards or criteria, or best professional judgment based on risk assessment, may be employed. The standards may be applicable for developing groundwater remediation goals.

2.2.2.3 Location-Specific ARARs and TBCs

Tables 2-3 and 2-4 present a summary of Federal and State of Virginia location-specific ARARs and TBCs for this FS. This section presents a summary of Federal and state location-specific ARARs and TBCs. These ARARs and TBCs place restrictions on concentrations of contaminants or the conduct of activities based upon the site's particular characteristics or location.

FEDERAL

The Endangered Species Act of 1973 provides for consideration of the impacts on endangered and threatened species and their critical habitats. This act requires federal agencies, in consultation with the Secretary of the Interior, to make sure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any endangered or threatened species or adversely affect its critical habitat. A review of the available information indicates that no state or federally listed endangered or threatened species are known to permanently or seasonally reside in the vicinity of the FFTA Site. For this reason, the Endangered Species Act would not be applicable or relevant and appropriate to actions taken at the site.

The Archaeological and Historic Preservation Act (36 CFR Part 62 and 65) establishes requirements relating to potential loss or destruction of significant scientific, historical, or archaeological data as a result of any proposed remedy. The Act also requires Federal agencies to consider the existence and location of landmarks on the National Registry of Natural Landmarks to avoid undesirable impacts on such landmarks. The Secretary of the Interior must be notified if a federal agency finds that its activities, in connection with any federal construction project, might cause loss or destruction of such data. The land surrounding FFTA Site is not classified as a potential significant scientific, historical, archaeological, or Natural Landmark. For this reason, the Archaeological and Historic Preservation Act is not applicable or relevant and appropriate to actions taken at the site.

The Fish and Wildlife Coordination Act (33 CFR Subsection 320.3) was enacted to protect fish and wildlife when federal actions result in the control or structural modification of a natural stream or body of water. The types of actions that would fall under the jurisdiction of this act include (1) discharges of pollutants including industrial, mining, and municipal wastes or dredge and fill material into a body of water or wetlands and (2) projects involving construction of dams, levees, impoundments, stream relocation, and water diversion structures. This act requires the federal agency to consult with the U.S.

FWS or National Marine Fisheries Service and appropriate state agencies if the above actions would occur as a result of off-site remedial alternatives.

Federal Protection of Wetlands Executive Order (E.O. 11990) and National Environmental Policy Act (NEPA) Regulations 40 CFR 6.302 [a] requires federal agencies, in carrying out their responsibilities, to take action to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. According to the published definition of national wetlands, Federal Register 40 CFR Appendix C, wetlands are present at WFF and along its boundaries. Although no wetlands exist at the FFTA, this ARAR has been retained in the event that wetland areas may be affected.

Federal Floodplain Management Executive Order (E.O. 11988) and NEPA Regulations 40 CFR 6 provides consideration of floodplains during remedial actions. E.O. 11988 requires federal agencies to avoid long-term and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid support of floodplain development wherever there is a practicable alternative. If no practicable alternative exists to performing cleanup in a floodplain, potential harm must be mitigated and actions taken to preserve the natural and beneficial values of the floodplain. 40 CFR 6 Appendix A contains EPA policy for implementing the provisions of E.O. 11988. If the treatment system associated with remedial alternatives is constructed, it would be located outside the floodplain.

The Fish and Wildlife Coordination Act (40 CFR Section 6.302) provides for consideration of the impacts on wetlands and protected habitats. The act requires that federal agencies, before issuing a permit or undertaking federal action for the modification of any body of water, consult with the appropriate state agency exercising jurisdiction over wildlife resources to conserve those resources. Consultation with the United States Fish and Wildlife Service is also required. This ARAR has been retained in the event that wetland areas or wildlife resources may be affected.

STATE

Wetlands Mitigation Compensation Policy (4 VAC 20-390-10) regulates activities in wetlands. An activity that impacts a wetland is required to meet the provisions of this act. Wetlands of primary ecological significance must not be altered so that ecological systems in the wetland are unreasonably disturbed. Anticipated public and private benefit resulting from the activities occurring in a wetland should exceed the public and private detriment. Wetlands are present at WFF and along its boundaries. Although no wetlands exist at the FFTA, this ARAR has been retained in the event that wetland areas may be affected. Remedial actions for groundwater would not be expected to adversely affect wetlands.

Chesapeake Bay Preservation Area Designation and Management Regulations (9 VAC 10-20-10) establishes criteria for use by local governments in granting, denying or modifying requests to rezone, subdivide, or to use and develop land in Chesapeake Bay Preservation Areas. The purpose of the criteria is to protect and improve the water quality of the Chesapeake Bay, its tributaries, and other state waters by minimizing the effects of human activity upon these waters and implementing the Act. The location of the FFTA site is along the Atlantic Ocean coast line which is not part of the Chesapeake Bay. These regulations are not applicable or relevant and appropriate to the site.

Virginia Natural Areas Preserves Act (Virginia Code §§ 10.1-209) dedicates sites or portions of sites as natural area preserves through the Department of Conservation and Recreation. Dedication under the Act may restrict certain uses of preserve areas. If no such dedication exists, the Act's provisions regarding natural heritage preservation should be classified as TBC. Since the site has not been dedicated as a preserve area, this regulation is not applicable or relevant and appropriate to the site and the Act's provisions should be classified as TBC.

Virginia Endangered Species Act (4 VAC 15-20-130) provides for the consideration of the impacts on endangered and threatened species and their critical habitats. A review of the available information indicates that no state or federally listed endangered or threatened species are known to permanently or seasonally reside in the vicinity of the FFTA Site. For this reason, this Act is not applicable or relevant and appropriate to actions taken at the site.

Virginia Endangered Plant and Insect Species Act (2 VAC 5-320-10) prohibit the taking of endangered plant and insect species. A review of the available information indicates that no state listed endangered or threatened species are known to permanently or seasonally reside in the vicinity of the FFTA Site. For this reason, this Act is not applicable or relevant and appropriate to actions taken at the site.

Virginia Private Well Regulations (12 VAC 5-630) contain standards and prohibitions on groundwater wells. Private wells are prohibited if a source of contamination could adversely affect the well and preventive measures are not available to protect the groundwater. Wells would not be permitted at the FFTA site until the groundwater has been remediated and is no longer a source of groundwater contamination.

2.2.3 Chemicals of Concern for Remediation

The Supplemental RI human health risk assessment identified potential unacceptable risks for future residential use of FFTA-related groundwater. Section 1 summarizes the results of the risk assessment, identifies the contaminants that contributed to the unacceptable risk, and discusses some of the uncertainties associated with the risk assessment. This section further reviews the FFTA-related contaminants, considers the ARARs discussed above, and identifies the COCs that require remediation in FFTA-related groundwater. Table 2-5 presents a listing of the contaminants identified as contributing to the FFTA groundwater risks, and provides a summary of the primary chemical-specific and location-specific ARARs and TBCs that apply in determining the COCs.

Arsenic was identified in two FFTA monitoring wells at concentrations greater than the MCL of 10 ug/L. As discussed in Section 1, there is uncertainty associated with the source of the arsenic detected at the site. The arsenic contamination is most likely associated with the reduced environment created by the degradation of FFTA-related VOC and SVOC contaminants. The extent of the arsenic contamination is not widespread and is found at the same monitoring wells that exhibit the highly reducing environment. However, since elevated concentrations in FFTA-related groundwater may be related to site activities, arsenic is considered a COC. The MCL should be considered in establishing a remediation goal.

Similarly the source of elevated manganese concentrations at the site is not well defined but may be related to site activities. The manganese contamination is most likely associated with the reduced environment created by the degradation of FFTA-related VOC and SVOC contamination. Elevated manganese concentrations appear to coincide with the presence of FFTA-related organic contaminants. However, because the site maximum concentration exceeds the maximum background concentration, and because of the frequency and pattern of detection, manganese is considered a COC. There is no primary MCL for manganese and the secondary MCL is not health-based. Manganese was identified as a contributor to non-cancer risks. Therefore, the RfD and other appropriate health-based ARARs and TBCs, should be considered in developing a remediation goal for this compound.

Site data does not suggest that iron concentrations present in the FFTA groundwater are related to site activities. Iron concentrations detected in FFTA-related groundwater samples were similar to background concentrations. Therefore the risks associated with the FFTA-related groundwater are similar to those posed by background conditions and iron is not considered to be a COC.

Six site samples contained bis(2-ethylhexyl) phthalate at concentrations of up to 6 ug/L. A background sample contained bis(2-ethylhexyl) phthalate at a concentration of 7 ug/L. The MCL for bis(2-ethylhexyl) phthalate is 6 ug/L. Although bis(2-ethylhexyl) phthalate was identified as a risk contributor, the analytical results, as discussed in Section 1, suggest that its presence in groundwater samples is likely an artifact due to laboratory contamination and is not site-related. In addition, site samples contained lower concentrations than were reported for the background sample. Based on these findings, bis(2-ethylhexyl) phthalate is not considered a COC.

Noncancer risk contributors 4-methylphenol and naphthalene were both identified in FFTA-related groundwater samples and not in background samples. The detections were in groundwater sampled from the suspected source and downgradient plume areas. Both of these contaminants appear to be site related and are considered to be COCs. There is no MCL for either 4-methylphenol or naphthalene. Therefore, the RfD and other appropriate health-based ARARs and TBCs, should be considered in developing remediation goals for these compounds.

Pentachlorophenol was detected in one site related groundwater sample at an estimated concentration (2J ug/L) below the practical quantitation limit. It was not detected in the other groundwater samples nor was it detected in the site surface or subsurface soil samples. The MCL for pentachlorophenol is 1 ug/L. Because of the low frequency, level of detection, and the fact that the one reported detection in the absence of any other site-related detections does not constitute a plume, pentachlorophenol is not considered a COC. However, because the compound was detected in site-related groundwater, future monitoring programs should include this compound.

Benzene, detected in six site wells and suspected as being a component of the types of materials handled at the FFTA, is considered to be a COC. The MCL for benzene is 5 ug/L and three of the site-related detections exceed the MCL. The MCL should be considered in establishing the remediation goal for benzene.

Vinyl chloride was detected in two site samples at concentrations of 2 and 6 ug/L. The MCL for vinyl chloride is 2 ug/L. Although vinyl chloride contamination is not wide-spread at the FFTA site, it is typically found as a daughter-product of the degradation process of higher level chlorinated compounds such as 1,2-DCE. cis-1,2-DCE was detected in 10 of the 21 groundwater samples, and has been identified as a risk contributor. Because vinyl chloride may be a by-product of the degradation of this and other site-related contaminants and it is identified as contributing to the overall cancer risk, it is considered a COC. The MCL should be considered in establishing a remediation goal for this compound.

Tetrachloroethene was identified as a risk contributor. It was detected in two site groundwater samples at 1 ug/L. The MCL for tetrachloroethene is 5 ug/L. The two trace-level FFTA-related detections are below the MCL and therefore tetrachloroethene should not be considered a COC and no remediation goal should be established for this compound. However, because it is a possible mother product of vinyl chloride and 1,2-DCE and it was detected at low concentrations in site soil (less than U.S. EPA SSLs established for the protection of groundwater) this compound should be included in future monitoring programs.

In summary, based on a review of risk assessment and analytical findings and considering chemical- and location-specific ARARs and TBCs, arsenic, manganese, 4-methylphenol, naphthalene, benzene, vinyl chloride, and cis-1,2-DCE are retained as COCs. Although not retained as COCs, pentachlorophenol and tetrachloroethene should be included in future groundwater monitoring programs at the FTTA.

2.3 REMEDIATION GOALS

A remediation or cleanup goal is the target concentration that a COC must be reduced to within a particular medium of concern to achieve one or more of the established RAOs. Cleanup goals are developed to make sure that contaminant concentrations left on site are protective of human and ecological receptors.

For the FFTA site, cleanup goals were established based on the following criteria:

- Protection of human health from residential exposure to contaminated groundwater.
- Compliance with ARARs and TBCs to the extent practicable.

The groundwater cleanup goals can be summarized as follows:

Chemical of Concern (1)	**Frequency of Detection**	**Range of Concentrations**	**Cleanup Goal**
INORGANICS (µg/L)			
Arsenic	3 / 20	5.1 - 25.4	10**(2)**
Manganese	18 / 18	9 - 4,990	124**(3)**
SVOCs (µg/L)			
4-Methylphenol	2 / 19	88 - 300	27**(3)**
Naphthalene	4 / 20	21 - 66	16**(3)**
VOCs (µg/L)			
Benzene	6 / 21	1 - 28	5**(2)**
1,2-DCE (cis)	10 / 21	1 - 460	70**(2)**
Vinyl Chloride	2 / 21	2 - 6	2**(2)**

NOTES:

1 Future monitoring programs will include these chemicals of concern as well as pentachlorophenol and tetrachloroethene.

2 United States Environmental Protection Agency Drinking Water Maximum Contaminant Levels (U.S. EPA, 2003b).

3 Site-specific risk-based clean-up goal.

For development of groundwater remediation goals, a hierarchy was applied to select the most appropriate regulatory or risk-based criteria. The first priority was to consider adopting the MCL if a MCL was available (SMCLs are not generally used) as the remediation goal. If MCLs were not available, the second approach was to consider risk-based values derived from the human health risk assessment for the FFTA.

REMEDIATION GOALS FOR ARSENIC, BENZENE, cis-1,2-DCE, AND VINYL CHLORIDE

MCLs were selected as the remediation goals for arsenic, benzene, cis-1,2-DCE, and vinyl chloride.

REMEDIATION GOALS FOR MANGANESE, NAPHTHALENE, AND 4-METHYLPHENOL

MCLs do not exist for manganese, naphthalene, and 4-methylphenol so the results of the risk assessment were used to calculate the following site-specific remediation goals for each substance. For manganese, naphthalene, and 4-methylphenol, toxicity is measured by non-cancer effects associated with specific target organs, so the remediation goal was calculated based upon making sure that the target organ HI does not exceed 1.0, wherever one chemical was involved, or does not exceed 1/N for each chemical, where N different chemicals affect the same target organ. When the target organs adversely affected by a particular chemical varied according to the route of exposure (for example, different target organs for inhalation versus ingestion), then the most sensitive target organ exposure pathway and most sensitive receptor were used to determine the overall remediation goal for that chemical.

Remediation Goal for Manganese For manganese, a risk based calculation was used to develop a remediation goal because no MCL exists and the SMCL is based on aesthetic properties such as taste or odor which are not relevant for protection of human health. For manganese, the central nervous system is the primary target organ associated with groundwater exposure. However, another groundwater contaminant, 4-methylphenol, also has the potential to adversely affect the central nervous system. Therefore, to develop a conservative remedial goal protective against adverse effects to the central nervous system, the target organ HI for each of these substances should not exceed one-half so that an overall protectiveness is maintained in the case of multiple chemical exposures. Hence, for manganese, the remediation goal of 124 ug/L was calculated by multiplying the exposure point concentration (4090 ug/L) listed in the risk assessment by a target HI of 0.5, then dividing by the hazard quotient value of 16.5 for the residential child, which is the most sensitive human receptor for non-cancer toxicity via ingestion and dermal contact.

Remediation Goal for Naphthalene For naphthalene, a remediation goal was developed by considering only the non-cancer toxicity effects associated with a RfD developed for the most sensitive target organ, which is the respiratory system. At a concentration of naphthalene in groundwater equivalent to the exposure point concentration, the risk assessment found that the most sensitive exposure pathway for naphthalene would be inhalation of vapors by an adult resident during showering (which affects the respiratory system), while a lesser degree of toxicity (smaller hazard quotient) would be associated with naphthalene exposure from tap water ingestion and dermal contact (for which the toxicity effects are decreased weight gain) for the adult resident and the child resident.

Naphthalene and 4-methylphenol both have the potential to adversely affect the respiratory system via inhalation during showering. Therefore, to develop a conservative remediation goal protective against adverse effects to the respiratory system, the target organ HI for each of these substances should not exceed one-half so that an overall protectiveness is maintained in the case of multiple chemical exposures. Hence, for naphthalene, the remediation goal of 16 ug/L was calculated by multiplying the exposure point concentration (32.8 ug/L) listed in the risk assessment by a target HI of 0.5, then dividing by the hazard quotient (1.04) for the residential adult from inhalation during showering, which is the most sensitive receptor exposure pathway for respiratory system toxicity.

Remediation Goal for 4-Methylphenol To develop a remediation goal for 4-methylphenol, a remediation goal was developed by considering only the non-cancer toxicity effects associated with a RfD developed for the most sensitive target organs, which are the respiratory system and the central nervous system for the child resident exposed to groundwater via tap water ingestion and dermal contact. An HI of 0.5 was considered an appropriate chemical-specific target risk level for the respiratory system because there are two chemicals (naphthalene and 4-methylphenol) that affect this target organ. Similarly, an HI of 0.5 was considered an appropriate chemical-specific target risk level for the central nervous system because two chemicals (manganese and 4-methylphenol) also affect this target organ. Therefore, in order to be protective in these situations, the overall remediation goal for 4-methylphenol was developed by finding the more conservative (lowest concentration) of two candidate remediation goals. The first value was obtained by multiplying the 4-methylphenol exposure point concentration by the respiratory system target HI of 0.5, then dividing by the hazard quotient for the child resident exposed via tap water ingestion and dermal contact, while the second candidate value was obtained by multiplying the exposure point concentration by the central nervous system target HI of 0.5, then dividing by the hazard quotient for the child resident exposed via tap water ingestion and dermal contact. Since these two values are equal, the final remediation goal for 4-methylphenol of 27 ug/L was based upon one-half the exposure point concentration (0.5 times 124 ug/L) divided by the child resident hazard quotient of 2.28.

2.4 GENERAL RESPONSE ACTIONS AND ACTION-SPECIFIC ARARs

GRAs are broadly defined remedial approaches that may be used (by themselves or in combination with one or more of the others) to attain the RAO. Action-specific ARARs and TBCs are those regulations, criteria, and guidances that must be complied with or taken into consideration during remedial activities on site.

2.4.1 General Response Actions

GRAs describe categories of actions that could be implemented to satisfy or address a component of the RAOs for the site. Remedial action alternatives will then be assembled by identifying types of treatment technologies and process options associated with these technologies according to these GRAs. The technologies and process options will be screened and evaluated using GRAs individually or in combination to develop the remedial action alternatives to be considered for the FFTA groundwater.

The following GRAs were considered for groundwater remediation at the FFTA site:

- No Action,
- Limited Action (Natural Attenuation, Institutional Controls, Monitoring),
- Containment,
- Removal,
- In-Situ Treatment,
- Ex-Situ (On-Site or Off-Base) Treatment, and
- Disposal.

2.4.2 Action-Specific ARARs

Action-specific ARARs and TBCs are technology- or activity-based regulatory requirements or guidance that would control or restrict remedial action. Tables 2-6 and 2-7 present a list of Federal and state action-specific ARARs and TBCs that may apply to the screening and selection of technologies for addressing the FFTA groundwater.

FEDERAL

Air/Superfund National Technical Guidance (Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-28, EPA/450/1-89/001 to 004) is a TBC that guides the control of air emissions from remedial actions at Superfund sites. For sites located in areas that are not attaining National Ambient Air

Quality Standards (NAAQS) for ozone, add-on emission controls are required for remedial actions with an actual emission rate in excess of 3 pounds per hour, an actual emission rate in excess of 15 pounds per day, or a potential (i.e., calculated) emission rate of 10 tons per year of total VOCs. Generally, the guidelines are suitable for VOC air emissions from other vented extraction techniques (e.g., soil vapor extraction) but not from area sources (e.g., soil excavation). NASA WFF is in a nonattainment area for ozone.

Clean Air Act (CAA) (42 USC 7401) consists of three programs or requirements that may be ARARs: National Ambient Air Quality Standards (NAAQS) (40 CFR Parts 50 and 53), New Source Performance Standards (NSPS) (40 CFR Part 60), and National Emission Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR Part 61). U.S. EPA requires the attainment and maintenance of primary and secondary NAAQS to protect public health and public welfare. These standards are not source specific but rather are national limitations on ambient air quality. States are responsible for assuring compliance with the NAAQS. NSPS are established for new sources of air emissions to make sure that the new stationary sources minimize emissions. These standards are for categories of stationary sources that cause or contribute to air pollution that may endanger public health or welfare. Standards are based upon the best-demonstrated available technology. NESHAPs, which are emission standards for source types (i.e., industrial categories) that emit hazardous air pollutants, are not likely to be applicable or relevant and appropriate for NASA WFF because they were developed for a specific source. These requirements may be applicable for groundwater remediation systems that would emit air pollutants.

Clean Water Act (CWA) governs point source discharges to surface water through the National Pollutant Discharge Elimination System (NPDES), the discharge of dredged or fill material to surface water, and spills of oil and hazardous substances to surface water. NPDES requirements (40 CFR 122 to 125) are potentially applicable if the direct discharge of pollutants into surface water is part of the remedial action. This includes the discharge of stormwater from construction and other industrial activities. Dredge and fill requirements (40 CFR 230) would not be applicable to a remedial action for groundwater because no fill materials would be discharged into surface water.

National Pretreatment Standards (40 CFR Part 403) controls the indirect discharge of pollutants to publicly owned treatment works (POTWs). The goal of the pretreatment program is to protect municipal wastewater treatment plants and the environment from damage that may occur when hazardous, toxic, or other non-domestic wastes are discharged in a sewer system. The regulations include general and specific prohibitions on discharges to POTWs. The regulations are potentially applicable if treated or untreated groundwater is discharged to a local POTW.

Federal Facilities Compliance Act expands the domestic sewage exclusion policy to federally owned treatment works (FOTW). When wastewater is considered a hazardous waste under RCRA, but is mixed with domestic waste as it flows through the sewer system, the system would not be required to meet the additional regulatory requirements for a RCRA facility.

Occupational Health and Safety Act (OSHA) (29 USC Sections 651 through 678) regulates worker health and safety during implementation of remedial actions.

Resource Conservation and Recovery Act (RCRA) Subtitle C regulates the treatment, storage, and disposal of hazardous waste from its generation until its ultimate disposal. In general, RCRA Subtitle C requirements for the treatment, storage, or disposal of hazardous waste will be applicable if:

- The waste is a listed or characteristic waste under RCRA.

- The waste was treated, stored, or disposed (as defined in 40 CFR 260.10) after the effective date of the RCRA requirements under consideration.

- The activity at the site constitutes current treatment, storage, or disposal as defined by RCRA.

Groundwater from the site would not be classified as a hazardous waste because the concentrations are below toxicity characteristic concentrations (40 CFR 261.24) and are not contaminated with known hazardous wastes. However, residuals generated during groundwater treatment activities would need to be tested to determine whether they exhibit the toxicity characteristic. If groundwater treatment residuals were classified as a hazardous waste, the hazardous waste generator (40 CFR 262) and transportation (40 CFR 263) requirements would be applicable.

RCRA Subtitle C requirements may be relevant and appropriate when the waste is sufficiently similar to a hazardous waste and/or the on-site corrective action constitutes treatment, storage, or disposal and the particular RCRA requirement is well suited to the circumstances of the contaminant release and site. RCRA Subtitle C requirements may also be applicable when the corrective action constitutes generation of a hazardous waste.

The following requirements included in the RCRA Subtitle C regulations may pertain to the NASA WFF:

- Hazardous waste identification and listing regulations (40 CFR Part 261).
- Hazardous waste generator requirements (40 CFR Part 262).
- Transportation requirements (40 CFR Part 263).

- Standards for owners and operators of hazardous waste treatment, storage, and disposal facilities (TSDF) (40 CFR Part 264).
- Interim status standards for owners and operators of hazardous waste TSDF (40 CFR Part 265).
- Land disposal restrictions (LDRs) (40 CFR Part 268).

Hazardous Waste Identification and Listing Regulations (40 CFR Part 261) define those solid wastes that are subject to regulation as hazardous waste under 40 CFR Parts 262 to 265 and Parts 124, 270, and 271.

A generator that treats, stores, or disposes of hazardous waste on site must comply with RCRA Standards Applicable to Generators of Hazardous Waste (40 CFR Part 262). These standards include manifest, pre-transport (i.e., packaging, labeling, and placarding), record keeping, and reporting requirements. The standards are applicable if actions taken at the FFTA site constitute generation of a hazardous waste (e.g., generation of treatment residues that may be hazardous).

Standards Applicable to Transporters of Hazardous Waste (40 CFR Part 263) are applicable to off-site transportation of hazardous waste. These regulations include requirements for compliance with the manifest and record keeping systems and requirements for immediate action and cleanup of hazardous waste discharges (spills) during transportation. The standards are potentially applicable if corrective actions involve off-site transportation of hazardous waste from the FFTA site.

Standards and Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR Parts 264 and 265) are applicable to corrective actions that may be taken at the FFTA site and to off-site facilities that receive hazardous waste from the site for treatment and/or disposal. Standards for TSDFs include requirements for preparedness and prevention, corrective action requirements, closure and post-closure care, use and management of containers, and design and operating standards for tank systems, surface impoundments, waste piles, landfills, and incinerators. These standards are potentially applicable if corrective actions involve the on-site treatment or disposal of hazardous waste at the FFTA.

RCRA Land Disposal Restriction (LDR) Requirements (40 CFR Part 268) restrict certain wastes from being placed or disposed on the land unless they meet specific best demonstrated available technology treatment standards (expressed as concentrations, total or in the TCLP extract, or as specified technologies). Removal and treatment of a RCRA hazardous waste or movement of the waste outside of a Corrective Action Management Unit, thereby constituting “placement” would trigger the LDR requirements.

Placement of hazardous waste into underground injection wells constitutes “land disposal” under the LDRs. Furthermore, RCRA Section 3020(a) bans hazardous waste disposal by underground injection into or above an underground source of drinking water. RCRA Section 3020(b), however, exempts from the ban reinjection of treated contaminated groundwater into such formations undertaken as part of a RCRA corrective action. The contaminated groundwater must be treated to substantially reduce hazardous constituents before such injection, and the corrective action must be sufficient to protect human health and the environment upon completion. LDRs would be potentially applicable if corrective actions at the FFTA site include off-site disposal of wastes in a landfill or reinjection of treated groundwater.

RCRA Subtitle D (40 CFR 258) establishes design and operating criteria for solid waste (nonhazardous) landfills. In general, RCRA Subtitle D establishes minimum design and operating criteria for solid waste landfills that meet any of the following:

- Receive municipal solid waste as defined in 40 CFR 258
- Codispose sewage sludge with municipal solid waste
- Receive nonhazardous municipal solid waste combustion
- Are not regulated under RCRA Subtitle C

The closure and post-closure care requirements under RCRA Subtitle D may be relevant and appropriate for the landfill waste. These requirements are intended to minimize the infiltration of water into the landfill and maintain the integrity of the cover during the post-closure care period by minimizing cover erosion. Minimum requirements for a final landfill cover are included; however, states with EPA-approved programs may approve alternate cover designs. Post-closure care must be conducted for 30 years; however, states with EPA-approved programs have the authority to lengthen or shorten the post-closure period.

Solid Waste Disposal Act (SWDA) Underground Injection Control Program (40 CFR Parts 144 to 147 and 1000) contains provisions for the control and prevention of pollutant injection into groundwater. Class IV wells are used to inject hazardous waste into or above a formation that, within 1/4 mile of the well, contains an underground drinking water source. Operation or construction of Class IV wells is prohibited and allowed only for the reinjection of treated wastes as part of a CERCLA or RCRA cleanup. The regulations are potentially applicable if groundwater is removed, treated, and reinjected into the formation from which it was withdrawn.

<u>Department of Defense Interim Policy on Integration of Natural Resource Injury Responsibilities and Environmental Restoration Activities</u> (<u>Department of Defense</u>, 2000). It is Department of Defense policy that Components (e.g., Navy) identify natural resource injury and, whenever practicable, redress it as part of the site assessment, investigation, and remedy selection process for clean-up actions. Components determine what is practicable based on factors including cost and cost-effectiveness, ERA fund availability, risk prioritization, and technical and engineering feasibility.

<u>Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites</u> (OSWER Directive 9200.4-17P) contains guidelines for the use of monitored natural attenuation for the remediation of contaminated soil and groundwater. This guidance is a TBC criterion if monitored natural attenuation is a component of the corrective action at the FFTA site.

<u>STATE</u>

<u>Virginia Solid Waste Management Regulations, Groundwater Protection Levels of Hazardous Constituents</u> (9 VAC 20-80, Appendix 5.3) establish protection levels for groundwater. These levels are used to trigger the need for corrective action for groundwater at solid waste management facilities. The protection levels may be applicable for developing remediation goals for groundwater. However, the state has additional applicable solid waste regulations on action levels (9 VAC 25-80-220) and clean-up standards (9 VAC 25-80-230) and voluntary remediation regulations on remediation levels (9 VAC 20-160-90) that may be more appropriate. These are discussed below.

<u>Virginia Solid Waste Management Regulations, Action Levels</u> (9 VAC 20-80-220) have been established for constituents in groundwater that may have been released from a solid waste management unit. Action levels include SDWA MCLs. For carcinogens for which MCLs have not been promulgated, the action level is a concentration associated with an excess lifetime cancer risk of 1E-6. For systemic toxicants for which MCLs have not been promulgated, the action level is a concentration to which the human population (including sensitive subgroups) could be exposed on a daily basis without an appreciable risk of deleterious effects. The action levels may be applicable for developing remediation goals for groundwater.

<u>Virginia Solid Waste Management Regulations, Cleanup Standards</u> (9 VAC 20-80-230) have been established for contaminated media. The clean-up standards shall be concentration levels that protect human health and the environment. For known or suspected carcinogens, clean-up standards shall be established at concentrations that represent an excess upper-bound lifetime risk to an individual of between 1E-4 and 1E-6. The 1E-6 risk level shall be the point of departure in establishing such clean-up levels. For systemic toxicants, clean-up standards shall represent concentration levels to which human

populations (including sensitive subgroups) could be exposed on a daily basis without appreciable risk of deleterious effects during a lifetime. For groundwater that is a current or potential source of drinking water, SDWA MCLs will be considered in establishing clean-up standards. In establishing clean-up standards, VDEQ may consider the following: multiple contaminants; exposure threats to sensitive environmental receptors; other site-specific exposure or potential exposure to contaminated media; and the reliability, effectiveness, practicability, or other relevant features of the remedy. If a specific concentration is naturally occurring or from another source, a clean-up level that is not below that specific concentration may be established. For groundwater, the clean-up standards or levels shall be achieved throughout the contaminated groundwater, or, at VDEQs discretion, when waste is left in place, up to the boundary of a waste management area encompassing the original source of release. The clean-up standards may be applicable for developing remediation goals for groundwater.

Virginia Hazardous Waste Management Regulations (9 VAC 20-60) regulate the treatment, storage, and disposal of hazardous waste from its generation to its ultimate disposal. The regulations adopt the federal RCRA Subtitle C regulations by reference, with certain additions, modifications, and exceptions. Groundwater from the site would not be classified as a hazardous waste because the concentrations are below toxicity characteristic concentrations (40 CFR 261.24) and are not contaminated with known hazardous wastes. However, residuals generated during groundwater treatment activities would need to be tested to determine whether they exhibit the toxicity characteristic. If groundwater treatment residuals are classified as a hazardous waste additional requirements would be applicable.

Virginia Pollutant Discharge Elimination System Regulations (9 VAC 25-31, Parts I to IV) govern the direct discharges of pollutants to surface water. Discharges must meet the effluent discharge limits established by these regulations. These limits are established on a case-by-case basis and may be based on the following: technology-based effluent limitations, prevention of discharges that would cause a violation of the surface water quality standards, and prevention of discharges of toxic pollutants in amounts that have a reasonable likelihood of adversely affecting human health or the environment. These regulations are potentially applicable for the discharge of groundwater to surface water. These regulations also govern discharges to POTWs. The regulations require POTWs to establish pretreatment requirements of industrial users to prevent pass-through or upset of the POTW and contain specific limitations on discharges to the POTW for various industrial categories.

Virginia Pollution Abatement Permit Regulations (9 VAC 25-32) govern non-point source discharges to surface water from pollutant management activities. These regulations are not potential ARARs. Remedial actions that involve groundwater extraction would have a point source discharge to surface water or would discharge to a POTW or FOTW.

Virginia Stormwater Management Regulations (4 VAC 3-20) establishes requirements for discharges of stormwater to protect the surface water of the state. This regulation also allows local regulatory agencies to adopt management programs in accordance to the regulations. If a local stormwater management program has been adopted and the response action is not exempt under the local program, the project must comply with program requirements. If a local program has not been adopted, the standards contained in these regulations should be considered to be relevant and appropriate requirements.

Virginia Erosion and Sediment Control Regulations (4 VAC 50-30) establishes requirements for erosion control to protect of the surface water of the state. This regulation also allows local regulatory agencies to adopt erosion and sediment control programs in accordance to the regulations. If a local soil and erosion control program has been adopted and the response action is not exempt under the local program, the project must comply with program requirements. If a local program has not been adopted, the standards contained in the regulations should be considered to be relevant and appropriate requirements.

Virginia Water Protection Permit Regulations (9 VAC 25-210) delineate the procedures and requirements for dredging and filling activities in surface water. These regulations are potentially applicable for remedial activities that occur in the river or wetlands adjacent to a site.

Virginia Air Pollution Control Regulations (9 VAC 5) establish ambient air quality standards and regulate the discharge of pollutants into the atmosphere. Remedial actions that involve groundwater treatment would not be expected to result in the discharge of air pollutants. The concentrations of VOCs in groundwater are low enough that treatment, such as air stripping, would not be required prior to discharge. Therefore, these regulations are not potential ARARs.

2.5 ESTIMATED VOLUME OF CONTAMINATED MEDIA

For remedial action purposes, the volume of contaminated groundwater at the FFTA site was estimated based on the location of samples where COCs were detected in excess of cleanup goals. The plume surface area is illustrated on Figure 2-1.

Based on the analytical results of the Supplemental RI, the groundwater plume was delineated as the area of groundwater where concentrations of the COCs are greater than the remediation goals defined in Section 2.2, and is primarily defined by the VOCs, SVOCs, and metals. The plume extends over an area approximately 72,600 ft^2 in size (1.7 acres) and to a depth of up to 15 feet below the water table. Based on a porosity of 0.25, the estimated volume of the plume was computed at approximately 2,050,000 gallons. The extent of the plume is illustrated on Figure 2-1 and volume computations are presented in Appendix A.

The portion of the plume defined by VOC and SVOC contamination extends over an area approximately 55,850 ft^2 in size (1.3 acres) and to a depth of up to 15 feet below the water table. Based on a porosity of 0.25, the estimated volume of the plume was computed at approximately 1,567,000 gallons. Based on the average analytical results from groundwater analysis from the Supplemental RI, the estimated dissolved mass of COCs in the groundwater is 2 pounds. Mass calculations are presented in Appendix A.

Although contaminated soils do not present a risk to human health or the environment, soils below the vadose zone in the area of the former fire training pit contain other organic petroleum-related contaminants that may be contributing to the reduced environment at the FFTA site. The presence of these contaminants must be considered in developing remedies to address the FFTA groundwater. The area and volume of soil containing contaminants that could impact a remedy was delineated using the soil boring data collected during the Supplemental RI. Based on the average analytical results for samples collected from within the former fire training pit area, the estimated mass of organic and petroleum-related contaminants in the soil is 125 pounds. Volume and mass calculations are presented in Appendix A.

3.0 SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

This section identifies, screens, and evaluates the potential technologies and process options that may be applicable to assemble the remedial alternatives for FFTA site at NASA's WFF. The primary objective of this phase of the FS is to develop an appropriate range of remedial technologies and process options that will be used for developing the remedial alternatives.

The basis for technology identification and screening began in Section 2.0 with a series of discussions that included the following:

- Identification of ARARs,
- Development of RAOs,
- Identification of GRAs, and
- Identification of areas and volumes of contaminated groundwater.

Technology screening evaluation is performed in this section with the completion of the following analytical steps:

- Identification and screening of remedial technologies and process options.
- Evaluation and selection of representative process options.

In this section a variety of technologies and process options are identified under each GRA (discussed in Section 2.3.1) and screened. The selection of technologies and process options for initial screening is based on the "Guidance for Conducting Remedial Investigations/Feasibility Studies under CERCLA" (U.S. EPA, 1988). The screening is first conducted at a preliminary level to focus on relevant technologies and process options. Then the screening is conducted at a more detailed level based on certain evaluation criteria. Finally, process options are selected to represent the technologies that have passed the detailed evaluation and screening.

The evaluation criteria for detailed screening of technologies and process options that have been retained after the preliminary screening are effectiveness, implementability, and cost. The following are descriptions of these evaluation criteria:

- Effectiveness
    - Protection of human health and the environment; reduction in toxicity, mobility, or volume; and permanence of solution.
    - Ability of the technology to address the estimated areas or volumes of contaminated media.
    - Ability of the technology to attain the Cleanup Goals required to meet the RAOs.
    - Technical reliability (innovative versus well-proven) with respect to contaminants and site conditions.

- Implementability
    - Overall technical feasibility at the site.
    - Availability of vendors, mobile units, storage and disposal services, etc.
    - Administrative feasibility.
    - Special long-term maintenance and operation requirements.

- Cost (Qualitative)
    - Capital cost.
    - Operation and maintenance (O&M) costs.

Technologies and process options will be identified in the following sections.

3.1 PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

This section identifies and screens groundwater technologies and process options at a preliminary stage based on implementation with respect to site-specific conditions and COCs. Table 3-1 summarizes the results of this preliminary screening process. It presents the GRAs, identifies the technologies and process options, and provides a brief description of each process option followed by the screening comments.

The following are the groundwater technologies and process options retained for detailed screening:

General Response Action	Technology	Process Options
No Action	None	Not Applicable
Limited Action	Monitoring	Sampling & Analysis
	Institutional Controls	Deed Restrictions/Groundwater Use Restrictions/Facility Master Plan
	Natural Attenuation	Naturally-Occurring Biodegradation and Dilution
Containment	Vertical Hydraulic Barrier	Extraction Wells
Removal	Groundwater Extraction	Extraction Wells
In-situ Treatment	Biological – Biostimulation	Aerobic/Anaerobic biological treatment Oxygen and/or Hydrogen release compounds (ORC®/HRC®), Bioventing, Air Diffusion, Bimetallic Nanoscale Particles (BNP)
	Biological – Bioaugmentation	Aerobic/Anaerobic biological treatment microbes, inoculum, and/or bacterium
	Physical	Air Sparging (AS) or Air Sparging/ Vapor Extraction (AS/VE)
Ex-situ Treatment	Biological	Aerobic Biodegradation Treatment
	Physical	Filtration, Air Stripping, Granular Activated Carbon (GAC) Adsorption, Sedimentation, Dewatering, Equalization
	Chemical	Coagulation/Flocculation, Neutralization/pH Adjustment, Chemical Precipitation
Disposal	Surface Discharge	Publicly Owned Treatment Works (POTW) or National Pollutant Discharge Elimination System (NPDES)

3.2 DETAILED SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

3.2.1 No Action

No Action consists of maintaining the status quo at the site. As required under CERCLA regulations, the No Action alternative is carried through the FS to provide a baseline for comparison of alternatives and their effectiveness in mitigating risks posed by site contaminants. Because no remedial actions are conducted under this alternative, there are no costs associated with “walking away from” the site, and there is no reduction in risk through exposure control or treatment.

Effectiveness

No Action would not be effective in meeting the RAOs and remediation goals. No Action would not be effective in evaluating either potential contaminant reduction through natural attenuation or potential contaminant migration off-site because no monitoring would be performed.

Implementability

There would be no implementability concerns because No Action would be implemented.

Cost

There would be no costs associated with No Action.

Conclusion

No Action is retained for comparison to other options.

3.2.2 Limited Action

3.2.2.1 Institutional Controls

Institutional controls would consist of limiting access to groundwater by restricting future land use. Land Use Controls (LUCs) or a Facility Master Plan, including land and groundwater use restrictions, would be formulated and implemented to prevent the use of the groundwater from the shallow Columbia aquifer at the FFTA site. As part of institutional controls, regular site inspections would be conducted to verify and enforce the continued application of these controls.

Effectiveness

Groundwater use restrictions would not reduce the toxicity, mobility, or volume of contaminants in the groundwater. However, these controls would minimize potential human health risks associated with exposure to contaminated groundwater and as such, would achieve one of the two groundwater RAOs for the FFTA site. Groundwater use restrictions would be effective in combination with other remedial activities.

Implementability

Institutional controls would be readily implementable. The Facility Master Plan will document the LUCs while the property is owned by NASA. If the site changes from NASA to private ownership, provisions will be incorporated in property transfer documents (deed restrictions) to make sure the continued implementation of institutional controls. Resources are readily available for the preparation of deed restrictions.

Cost

Costs of institutional controls would be low.

Conclusion

Institutional controls are retained in combination with other process options for the development of groundwater remedial alternatives.

3.2.2.2 Monitoring

Sampling and analysis of groundwater throughout the area of potential groundwater contamination could be used to evaluate migration of contaminants. Monitoring can also be used to monitor potential natural attenuation or the progress of active groundwater remediation.

Effectiveness

Monitoring would not of itself reduce the toxicity, mobility, or volume of contaminants in the groundwater; but it would allow the evaluation of potential off-site migration of contaminants and the potential reduction in contaminant concentrations through natural attenuation. By serving as a warning mechanism, periodic groundwater monitoring would enable NASA to manage the area of contamination if concentrations or the plume area increased. Monitoring would also be helpful in measuring and evaluating the effectiveness of natural attenuation or active remediation technologies.

Implementability

A groundwater monitoring program could be readily implemented at the site under consideration.

Cost

Capital and O&M costs of monitoring would be low.

Conclusion

Monitoring is retained in combination with other process options for the development of groundwater remedial alternatives.

3.2.2.3 Natural Attenuation

Natural attenuation would consist of monitoring groundwater quality to determine the extent to which naturally-occurring processes such as biodegradation, abiotic transformation, dispersion, and dilution would break down chlorinated VOCs and SVOCs over time, thereby reducing concentrations of these chemicals below regulatory or risk-based criteria. For this purpose, new groundwater monitoring wells would be installed as required and samples from these new groundwater monitoring wells and existing wells would be regularly collected and analyzed for natural attenuation parameters and COCs. The natural attenuation parameters that would be analyzed include oxidation/reduction potential (ORP), dissolved oxygen (DO), pH, alkalinity, temperature, conductivity, total organic carbon (TOC), ferrous and total iron, sulfur compounds (sulfides, sulfates), nitrogen compounds (nitrites, nitrates), orthophosphates, chloride, metabolic gases [methane, ethane, ethene, carbon dioxide (CO_2)]. In addition to the natural attenuation parameters (used to evaluate the continued efficiency of this process), the identified COCs (parents and daughter products) would also be collected.

Effectiveness

Naturally occurring processes (physical, chemical and biological) are expected to reduce contaminant concentrations (VOCs and SVOCs) in the aquifer over the long term. For the FFTA site, a natural attenuation evaluation was conducted for the chlorinated VOC contaminants using the two lines of evidence (contaminant concentrations through time and hydrogeologic and geochemical data) (U.S. EPA, 1998 and Navy, 1998); the U. S. EPA Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water scoring table (1998); and the BIOCHLOR analytical screening model (version 2.2, 2002) to determine its effectiveness as a remedial action (see Appendix B). The BIOCHLOR model was used to evaluate contaminant migration and degradation. The analytical model was calibrated to site-specific data and utilized to predict potential impacts to downgradient receptors, as well as cleanup times in the source area and present portions of the contaminant plume where the highest concentrations are observed.

Detailed site geology and hydrogeology is provided in the Supplemental RI report and is summarized in Section 1.1 of this report. In order to assess the effectiveness of natural attenuation at the FFTA, potentiometric maps for both the upper and lower units from 1996, 2000, and 2003 were analyzed. In general, two important features were identified. One, the general flow directions are consistent over time, and two, the downward gradient from the upper to lower units are also consistently present. Therefore, the general flow regime (and site conceptual model) as described in previous reports is mostly accurate. However, close analysis of the 2003 potentiometric surfaces show that the flow regime is more complicated, particularly in the upper unit. This detail was not available until the newly installed 100 series wells were installed as part of the Supplemental RI. Effectively, groundwater in the upper unit flows in two directions from the original source area at the FFTA. From the source area (around monitoring wells FTA-101S and FTA-MW55S), the groundwater in the upper unit flows northeast for approximately 500 feet until the surface elevations increase. At this point (near MW-57S), the flow becomes southeast toward the unnamed tributary (elevation lows). Groundwater flow in the lower unit is primarily northerly and does not bend near MW-57S. Current distribution of the impacted groundwater (contaminant plumes) and historical groundwater elevations confirm that the groundwater flow regimes present at the FFTA have remained relatively constant through time.

The site data was entered into the U.S. EPA natural attenuation scoring table to evaluate the effectiveness of the natural attenuation process at the site (U.S. EPA, 1998). Since limited data is available, the score can be considered negotiable. The score considering the data in the source area is 21. The score considering the data in the source area as well as the plume is 14. These scores indicate natural attenuation is adequate to strong in effectiveness. The scoring tables and further details concerning their data entry are provided in Appendix B.

Contaminant concentrations through time were evaluated as well as the contaminant concentrations plume size and shape. The concentrations of both parents and daughter chemicals were considered for both the ethenes and ethanes pathways for the contaminant plumes. Results from the most recent sampling (Supplemental RI) show similar contaminants as the earlier investigations, however, the contaminants were detected at lower concentrations during the recent sampling. PCE was the most likely parent chemical at the site and was observed in multiple wells in 1990 and 1994. PCE was detected in one well in 2003 at a concentration below the MCL. Concentrations of cis-1,2-DCE (daughter chemical) ranged from 1 ug/L to 3,000 ug/L and 1 ug/L to 1,700 ug/L in the 1996 and 2000 RI sampling results. Results from the Supplemental RI sampling indicated cis-1,2-DCE was detected in 10 of 21 samples at concentrations ranging from 1 ug/L to 460 ug/L, a decrease in the contaminant concentrations compared to the earlier investigations.

Previous sampling results from the 2000 sampling effort indicated a 1,1,1-TCA plume was present at the site with the highest concentration of 510 ug/L. Results from the Supplemental RI showed the highest concentrations of 1,1,1-TCA as 340 ug/L and general decrease in the concentration and size of the plume. Benzene, toluene, ethylbenzene, and xylenes (BTEX) are also present at the site and concentrations have been decreasing with time. Benzene concentrations have decreased from 100 ug/L in 1996 to 31 ug/L in 2000 and to 28 ug/L in 2003. Results for toluene have decreased from 1,400 ug/L in the earlier investigations, to 83 ug/L in the Supplemental RI. In general, contaminant concentrations have decreased significantly, usually by an order of magnitude or more, since 1990 for the COCs at the FFTA.

Additionally, the natural attenuation geochemical data from the Supplemental RI was also evaluated. The results of the natural attenuation field parameter monitoring conducted at the FFTA site is provided on Table 3-2. Special emphasis was placed on DO and ORP since they are driving factors for effective reductive dechlorination of the natural attenuation process. The low DO and ORP in 12 of the 23 groundwater monitoring wells is indicative of an anaerobic environment and was observed in the area where active reductive dechlorination is occurring. This anaerobic reductive dechlorination pathway is the most effective naturally occurring process to reduce chlorinated chemical concentrations. Two groundwater monitoring wells (MW-55S and MW-61I) had both the lowest DO (less than 0.5 milligrams per liter [mg/L]) and negative ORP and also had the complete suite of parent and daughter product concentrations observed. This area shows that reductive dechlorination is actively occurring. For the other 10 groundwater monitoring wells where anaerobic conditions occur, groundwater chemistry does not appear to be as ideal for as efficient reductive dechlorination. For the remaining 11 groundwater monitoring wells, aerobic conditions exist. In general, groundwater within the contaminant plume is anaerobic while groundwater located outside of the plume and in the former source area is aerobic.

Besides DO and ORP, other parameters on Table 3-2 were also analyzed to assist in evaluation of the effectiveness of natural attenuation at the FFTA. Though only one round of data was collected, based on the results of this data and other historical data, it would appear that iron reduction is the dominant reductive dechlorination mechanism. Ferrous iron was detected at several wells where anaerobic reductive dechlorination is occurring. Furthermore, historical concentrations of iron are relatively high at the site. Given the aerobic groundwater present, it is logical to conclude that the ferrous iron is quickly transformed to ferric iron, resulting in the high concentrations of iron observed at the site.

These results (the U.S. EPA scoring table, contaminant concentrations, and geochemical data) show that there is evidence of an environment favorable to biodegradation and reductive biodegradation of chlorinated VOCs in the Columbia Aquifer for both the upper and lower units. The effectiveness of natural attenuation is supported by the fact that the concentrations of the COCs in the plume have decreased since the 1990 sampling event. Based on the limited data that is available for the site since 1990 and the above evaluation, the following conclusions can be made about the natural attenuation processes occurring at the FFTA site and monitored natural attenuation (MNA) as a potential remedial action:

- Hydrogeology has remained consistent over the site history.
- Concentrations of parent compounds (1,1,1-TCA and PCE) were greatest in 1990 or 1994 and have decreased significantly through 2003.
- Reductive dechlorination has been and is currently occurring at the site.

- Reductive dechlorination is occurring in both the upper and lower units of the Columbia Aquifer.

- Anaerobic conditions dominate the contaminant plume where significant concentrations are currently present. Aerobic conditions dominate the edges of the plume and the historical source area.

- Iron reduction appears to be the dominant anaerobic reductive dechlorination mechanism.

Based on the site-specific information, the analytical screening model BIOCHLOR was utilized to simulate remediation by natural attenuation (BIOCHLOR modeling is presented in Appendix B). Based on the site history, the source of contamination to the groundwater resulted from intermittent fluxes/releases rather than a distinct, steady point source. The BIOCHLOR model was calibrated using the 1990, 1994, 2000, and 2003 data from the site. During the calibration process the PCE data matched well, but the actual DCE concentrations at the downgradient locations were higher than the calculated concentrations based on PCE observed between the source area and the midpoint of the plume. This could imply that additional PCE was released historically and had already degraded by reductive dechlorination. The DCE data matched well as a first order decay from the midpoint of the plume to the edge of the plume with a decay rate coefficient determined to be 7.5 per year.

The actual vinyl chloride concentrations in the source area and at the downgradient locations were much lower than the calculated concentrations from the BIOCHLOR model (the vinyl chloride data did not match well). This implies that other processes (aerobic, dispersion, etc.) are reducing the vinyl chloride concentrations. The DCE and vinyl chloride are being removed faster and more efficiently under the aerobic conditions that are present in the plume and fringes of the plume at the FFTA site. In addition, the ethanes and ethenes will also dissipate quickly and efficiently. Therefore, DCE and vinyl chloride are not likely to accumulate as a result of anaerobic dechlorination stalling.

Using the calibrated model and a target cutoff of 70 ug/L (the MCL for DCE), the model was run to estimate the time MNA would remediate the site at the source area and the edge of the plume. The results of the model runs are summarized as follows:

Condition	Time
Time to achieve target cut off at the midpoint using the highest concentration at the source area modeled (source area to midpoint of the plume)	5 years
Time to achieve target cut off at the edge of the plume with the highest concentration at the mid-point (midpoint of the plume to edge of the plume)	5 years
Time to achieve target cut off at the midpoint with the highest concentration modeled (source area to midpoint of the plume) assuming no decay (this is not supported by the calibrated model)	10 to 15 years

The results of the model are approximate. Minor concentrations of DCE could be introduced by simple dispersion, so the time should be considered low. The persistence of DCE to migrate with the plume is mostly due to the presence of PCE. PCE was detected at low concentrations recently (below the MCL), so production of DCE at the site should be minimal while the DCE concentrations will continue to decrease from those currently observed.

It has been assumed that the concentrations of benzene and the SVOCs at the FFTA site will decrease and meet the preliminary remediation goals at the same time as the chlorinated VOCs. The arsenic and manganese contamination is most likely associated with the reducing environment created by the degradation of other FFTA VOC and SVOC contaminants since the extent of the contamination is not widespread and is found at the wells that exhibit the highly reducing environment. It is assumed that the site would return to an oxic environment after the VOCs and SVOCs have been biodegraded and this should cause the arsenic and manganese to transform to insoluble oxidized compounds.

Groundwater monitoring would provide an effective means of evaluating the concentrations of COCs in groundwater and of assessing the rate of decrease of these concentrations. Monitoring of indicator parameters would help to evaluate the effectiveness of natural attenuation in reducing COCs concentrations.

Implementability

Natural attenuation would be easy to implement. Monitoring groundwater quality, restricting groundwater use, and periodic reviewing of site conditions could readily be performed, and the necessary resources are available to provide these services.

Cost

Capital and O&M costs for natural attenuation would be low.

Conclusion

Natural attenuation is retained in combination with other process options for the development of groundwater remedial alternatives.

3.2.3 Containment/Removal

The only technology considered under this GRA is groundwater extraction. Groundwater extraction uses a pumping system composed of a series of wells that are used to capture contaminated groundwater and restrict horizontal migration of groundwater and to treat the contaminated groundwater. The wells used in the capture system would be designed and located to provide optimum efficiency in capturing contaminated groundwater while minimizing the collection of uncontaminated groundwater.

Effectiveness

Groundwater extraction is a well-established technology for the removal of contaminated groundwater and the containment of groundwater contaminant plumes. While the initial effectiveness of this technology for contaminant capture is high, it has often been shown to decrease over time. This decrease is generally due to one or more of several factors including the presence of preferential flow pathways due to aquifer heterogeneity, contaminant adsorption onto aquifer materials, diffusion of contaminants into the pore spaces of low-permeability materials, and creation of stagnation zones due to pumping operations. It should be noted, however, that no such decrease over time is observed in the effectiveness of this technology for containment of contaminant plumes. The effectiveness of an extraction well system depends largely on the extent of contamination and site-specific geology and hydrogeology. The use of wells to extract groundwater should reduce contaminant concentrations and may attain the cleanup goals over the long term. This technology is reliable, and minimal effects on human health and the environment would be expected during implementation.

The findings from the several recent case studies concluded that the systems were generally not making adequate progress for contaminant mass removal, and that optimization efforts based on the life cycle design concept were needed to achieve site close out within a reasonable timeframe, particularly for sites that require aquifer restoration to levels such as MCLs. The long operating timeframe is a common limitation for extraction operations. The result is a slowdown in contaminant mass removal, also referred to as tailing or asymptotic conditions. This phenomenon strongly limits the extraction system's ability to achieve remediation goals for aquifer restoration in a reasonable timeframe.

Extraction has been unable to achieve "restoration" (i.e., reduction of contaminants to levels required by health-based standards) as anticipated in the design phase of projects because of a variety of factors (tailing and rebound). Extraction is useful for providing hydraulic containment (control the movement of contaminated groundwater and prevent the continued expansion of the contaminated zone) of those portions of the plume where contaminant sources are present, or for containing or restoring those plume areas with relatively high concentrations of dissolved contamination (“hot spots”). However, extraction followed by treatment may not be the best method for restoring large areas of the plume with low contaminant concentrations (U.S. EPA, 1996a and 1996b, and Navy, 2003).

Implementability

Groundwater extraction through a pumping well system could be readily implemented at the FFTA site. This technology uses readily available equipment and techniques and has been widely used in similar situations. Implementation of this technology would require long term O&M. Maintenance may require periodic replacement of mechanical components and well flushing to remove fine-grained material that may clog the wells.

Cost

The extraction systems require long remediation time, perhaps decades, to achieve cleanup goals. Therefore, site closeout costs for these sites are expected to be very high as these systems are O&M cost intensive.

Conclusion

A pumping well system is eliminated from further consideration and evaluation due to effectiveness and cost concerns.

3.2.4 In-Situ Treatment

3.2.4.1 In-Situ Aerobic/Anaerobic Biological Treatment - Biostimulation

Biological treatment involves the use of microorganisms, primarily bacteria, actinomycetes, and fungi to breakdown hazardous organic compounds into nontoxic or less toxic forms. This technology would enhance natural attenuation of organic COCs by the injection of an electron donor (food source) to promote degradation activity in the subsurface (biostimulation).

This option would consist of using an oxygen-release compound (ORC®), a hydrogen-release compound (HRC®), and/or bimetallic nanoscale particles (BNP) to enhance the growth of indigenous microorganisms and natural biodegradation processes, while monitoring groundwater quality to determine the extent to which these microorganisms and processes would break down contaminants over time. ORC®s such as hydrogen or magnesium peroxide could be used to enhance the aerobic biodegradation. An HRC® such as lactic acid could be used to enhance the anaerobic biodegradation of the FFTA site. BNP, such as zero valent iron (Fe0), could be used to provide rapid destruction of the contaminants based on a surface-catalyzed redox process where the contaminant serves as an electron acceptor and BNP as the electron donor that stimulates anaerobic bacteria known to degrade chlorinated solvents. These compounds would initially be injected into the contaminant plume using direct push technology (DPT), after which a maintenance dosage would be periodically fed into monitoring wells if needed. New monitoring wells would be installed as required, and samples from these new wells and existing wells would be regularly collected and analyzed.

This option could also consist of bioventing or air diffusion (ISOC®) to enhance the growth of indigenous microorganisms and natural biodegradation processes, while monitoring groundwater quality to determine the extent to which these microorganisms and processes would break down contaminants over time. Bioventing and air diffusion are similar to AS described in Section 3.2.4.2 below but they use low air flow rates to provide only enough oxygen to sustain microbial activity. Bioventing generically involves the delivery of oxygen to the subsurface soils either through injection or extraction of air with blowers and wells to increase oxygen concentrations and stimulate biodegradation. A blower and new monitoring wells would be installed as required, and samples from these new wells and existing wells would be regularly collected and analyzed.

Effectiveness

In-situ aerobic biological treatment with ORC® or by bioventing or air diffusion is a well-proven technology that would be effective for the removal of COCs from the FFTA site, such as the benzene, cis-1,2-DCE, vinyl chloride, and SVOCs. In-situ aerobic biological treatment may also be effective in the treatment of the dissolved arsenic and manganese contamination. The arsenic and manganese contamination is most likely associated with the reducing environment created by the degradation of other FFTA VOC and SVOC contaminants since the extent of the contamination is not widespread and is found at the wells that exhibit the highly reducing environment. In-situ aerobic treatment would change the site to an oxic environment that should cause the arsenic and manganese to transform to insoluble oxidized compounds.

However, the effectiveness of in-situ anaerobic biological treatment with HRC® for the removal of chlorinated VOCs (cis-1,2-DCE and vinyl chloride) is not as well established. There is also the possibility that anaerobic dechlorination could lead to the formation of vinyl chloride that is more toxic than the original chlorinated VOCs (i.e., cis-1,2-DCE). A treatability study would be needed in order to fully evaluate the process.

In-situ biological treatment with BNP is an innovative technology that is being tested in pilot-scale studies and is starting to be used in full-scale remedial actions. Treatment efficiencies have closely correlated with predictions from bench scale tests. BNP in-situ treatment technology has the potential to reduce the remedial costs in comparison to the conventional treatment systems. However, BNP technology appears to be most effective for anaerobic dechlorination of high concentrations of chlorinated VOCs and concerns regarding its effectiveness are similar to those discussed above for HRC®.

Implementability

In-situ biostimulation aerobic/anaerobic biological treatment processes could be implemented. The DPT application of ORC®, HRC®, and BNP would be relatively unobtrusive. The DPT application of bioventing or air diffusion would also be relatively easy, the equipment and techniques are readily available, and these treatment processes have been used in similar situations. Implementation of bioventing or air diffusion would require O&M. Several qualified contractors would be available for the implementation of this technology.

Cost

Capital and O&M costs for in-situ biostimulation aerobic/anaerobic biological treatment would be low to moderate, depending on the extent of the area treated.

Conclusion

In-situ biostimulation aerobic biological treatment is retained in combination with other processes options for the development of groundwater remedial alternatives.

3.2.4.2 In-Situ Aerobic/Anaerobic Biological Treatment - Bioaugmentation

Biological treatment involves the use of microorganisms, primarily bacteria, actinomycetes, and fungi to breakdown hazardous organic compounds into nontoxic or less toxic forms. This technology would enhance natural attenuation of organic COCs by the injection of bacteria with degradation activity into the subsurface (bioaugmentation).

This option would consist of using a microbe, inoculum, and/or bacterium to enhance the existing indigenous microorganisms and natural biodegradation processes, while monitoring groundwater quality to determine the extent to which these microorganisms and processes would break down contaminants over time. The microbe, inoculum, and/or bacterium would initially be injected into the contaminant plume using DPT, after which a maintenance dosage may be periodically fed into monitoring wells if needed. New monitoring wells would be installed as required, and samples from these new wells and existing wells would be regularly collected and analyzed.

Effectiveness

In-situ biological treatment with the injection of bacteria is an innovative technology that is being tested in pilot-scale studies and is starting to be used in full-scale remedial actions. This technology would be effective for the removal of COCs from the FFTA site, such as the benzene, cis-1,2-DCE, vinyl chloride, and SVOCs. A treatability study would be needed in order to fully evaluate the process. In-situ aerobic biological treatment may also be effective in the treatment of the dissolved arsenic and manganese contamination. The arsenic and manganese contamination is most likely associated with the reducing environment created by the degradation of other FFTA VOC and SVOC contaminants since the extent of the contamination is not widespread and is found at the wells that exhibit the highly reducing environment. The in-situ bioaugmentation treatment would degrade the VOCs and SVOCs and the site would return to an oxic environment that should cause the arsenic and manganese to transform to insoluble oxidized compounds.

Implementability

In-situ bioaugmentation aerobic/anaerobic biological treatment processes could be implemented. The DPT application of microbes, inoculum, and/or bacterium would be relatively unobtrusive. The technology would also be relatively easy, the equipment and techniques are readily available, and the treatment processes have been used in similar situations. Several suppliers of the microbes, inoculum, and/or bacterium would be available for the implementation of this technology.

Cost

Capital and O&M costs for in-situ bioaugmentation aerobic/anaerobic biological treatment would be low to moderate, depending on the extent of the area treated.

Conclusion

In-situ bioaugmentation biological treatment is retained in combination with other processes options for the development of groundwater remedial alternatives.

3.2.4.3 Air Sparging (AS) or Air Sparging/ Vapor Extraction (AS/VE)

AS consists of injecting air in the contaminant plume to induce an air current through the groundwater that promotes short-term stripping of VOCs and long-term biodegradation of VOCs and SVOCs. Air is injected through a network of vertical or horizontal wells screened at various depths within the contaminant plume. If capture and treatment of vaporized groundwater COCs or if treatment of overlying soil is required, a VE system is added. In this case, a vacuum is applied through a network of vertical or horizontal wells screened in the vadose zone above the contaminant plume and the extracted vapors are collected and treated through vapor-phase granular activated carbon (GAC) adsorption prior to venting to atmosphere. When saturated, the GAC is replaced and sent off-site for regeneration or incineration. Groundwater samples are regularly collected and analyzed to monitor the progress of the remedial action and, if a VE system is used, offgas samples are collected and analyzed to evaluate its performance and to verify compliance with regulatory emission requirements.

Effectiveness

AS or AS/VE is a very well proven technology that would be effective for the treatment of contaminated groundwater at the FFTA site. AS or AS/VE would effectively remove VOCs in the plume, primarily through volatilization and, although probably less so, for the removal of the SVOCs in the plume, principally through enhanced aerobic biodegradation. AS will also reduce the concentration of VOCs and SVOCs in the contaminated soil (smear zone) even though the FFTA soil does not present an unacceptable risk to human health. The contaminated soil will not impact the groundwater with this reduction in contaminant concentrations in the soil.

However, there are certain limitations associated with AS that should be considered. One of these is that air flow through the saturated zone may not be uniform due to non-homogenous soil conditions. Another limitation is that there may be some uncontrolled movement of potentially dangerous vapors. Although for the low concentration of contaminants at the FFTA site and the absence of occupied buildings or the presence of site workers, these potential limitations are not expected to be significant. Also, because groundwater COCs concentrations are relatively low and soil contamination is not of concern, no VE system would likely be required.

AS treatment may also be effective in the treatment of the dissolved arsenic and manganese contamination. The arsenic and manganese contamination is most likely associated with the reducing environment created by the degradation of other FFTA VOC and SVOC contaminants since the extent of the contamination is not widespread and is found at the wells that exhibit the highly reducing environment. AS treatment would change the site to an oxic environment that should cause the arsenic and manganese to transform to insoluble oxidized compounds.

Implementability

AS or AS/VE would be relatively simple to implement at the FFTA site. AS and VE wells and piping would have to be designed and located for minimum impact at the site. Several qualified contractors would be available for the implementation of this technology.

Cost

Capital and O&M costs would be low to moderate for AS and moderate for AS/VE.

Conclusion

AS is retained in combination with other process options for the development of groundwater remedial alternatives. The VE system would not be required at the FFTA site. With the low concentration of contaminants in the groundwater, the absence of occupied buildings, the absence of site workers, and the low concentrations of soil contamination, the production of dangerous vapors is not a concern.

3.2.5 Ex-Situ Treatment

Ex-situ treatment would use aboveground facilities (tanks, equipment, chemicals, etc.) to treat the extracted contaminated groundwater. Ex-situ treatment is potentially effective and applicable but it would require groundwater extraction. Since groundwater extraction has not been retained for further consideration, treatment of the groundwater using ex-situ treatment processes has been eliminated from further consideration.

3.2.6 Disposal

This technology would consist of discharging the treated (or untreated) groundwater to a surface water body or to a POTW where it would undergo either the full or incremental treatment required for discharge. Disposal/discharge is potentially effective and applicable but it would require groundwater extraction and treatment. Because groundwater extraction has not been retained for further consideration, this technology has also been eliminated from further consideration.

3.3 SELECTION OF REPRESENTATIVE GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

The following technologies and process options are retained for development of groundwater remedial alternatives:

- No Action
- Institutional Controls
- Monitoring
- Natural Attenuation
- In-situ Biostimulation Aerobic Biological Treatment
- In-situ Bioaugmentation Biological Treatment
- AS

4.0 ASSEMBLY AND DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

4.1 INTRODUCTION

This section presents an evaluation of each remedial alternative with respect to the criteria of the NCP of 40 CFR 300, as revised in 1990. The criteria as required by the NCP and the relative importance of these criteria are described in the following subsections.

4.1.1 Evaluation Criteria

In accordance to the NCP (40 CFR 300.430), the following nine criteria are used for the evaluation of remedial alternatives:

- Overall Protection of Human Health and the Environment,
- Compliance with ARARs,
- Long-term Effectiveness and Permanence,
- Reduction of Toxicity, Mobility, and Volume through Treatment,
- Short-term Effectiveness,
- Implementability,
- Cost,
- State Acceptance, and
- Community Acceptance.

Overall Protection of Human Health and the Environment

Alternatives must be assessed for adequate protection of human health and environment in both the short-and long-terms, from unacceptable risks posed by hazardous substances or contaminants present at the site by eliminating, reducing, or controlling exposure to concentrations exceeding remediation goals. Overall protection draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

Compliance with ARARs

Alternatives must be assessed to determine whether they attain ARARs under Federal environmental laws and state environmental or facility siting laws. If one or more regulations that are applicable cannot be complied with, then a waiver must be invoked. Grounds for invoking a waiver would depend on the circumstances described in Section 2.2.2.1 of this FS report.

Long-Term Effectiveness and Permanence

Alternatives must be assessed for the long-term effectiveness and permanence they offer, along with the degree of certainty that the alternative will prove successful. Factors that shall be considered as appropriate include the following:

Magnitude of Residual Risk:

Risk posed by untreated waste or treatment residuals at the conclusion of remedial activities. The characteristics of residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

Adequacy and reliability of controls:

Controls such as containment systems and institutional controls that are necessary to manage treatment residuals and untreated waste must be shown reliable. In particular, the uncertainties associated with land disposal for providing long-term protection from residuals, the assessment for the potential need to replace technical components of the alternative (such as a cap, a slurry wall, or a treatment system), and the potential exposure pathways and risks posed should the remedial action need replacement must be considered.

Reduction of Toxicity, Mobility, or Volume Through Treatment

The degree to which the alternative employs recycling or treatment that reduces the toxicity, mobility, or volume shall be assessed, including how treatment is used to address the principal threats posed by the site. Factors that shall be considered, as appropriate, include the following:

- The treatment or recycling processes the alternative employs and the materials that they will treat.
- The amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled.
- The degree of expected reduction in toxicity, mobility, or volume of waste due to treatment or recycling and the specification of which reduction(s) are occurring.

- The degree to which the treatment is irreversible.

- The type and quantity of residuals that will remain following treatment considering the persistence, toxicity, mobility, and propensity to bioaccumulate of such hazardous substances and their constituents.

- The degree to which treatment reduces the inherent hazards posed by principal threats at the site.

Short-Term Effectiveness

The short-term impacts of the alternative shall be assessed considering the following:

- Short-term risks that might be posed to the community during implementation.

- Potential impacts on workers during remedial action, and the effectiveness and reliability of protective measures.

- Potential environmental impacts of the remedial action, and the effectiveness and reliability of mitigative measures during implementation.

- Time until protection is achieved.

Implementability

The ease or difficulty of implementing the alternatives shall be assessed by considering the following types of factors, as appropriate:

- Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy.

- Administrative feasibility, including activities needed to coordinate with other offices and agencies, and the ability and time required to obtain necessary approvals and permits from other agencies (for off-site actions).

- Availability of services and materials, including the availability of adequate off-site treatment, storage capacity, and disposal capacity and services, the availability of necessary equipment and specialists, and necessary additional resources, the availability of services and materials, and availability of prospective technologies.

Cost

Capital costs shall include both direct and indirect costs. Annual O&M costs shall be provided. A net present worth (NPW) of the capital and O&M costs shall also be provided. The NPW was calculated using a discount rate of 3.5 percent based on the Office of Management and Budget Circular A-94 Appendix C that was updated in early 2004. Typically, the cost estimate accuracy range is plus 50 percent to minus 30 percent.

State Acceptance

The state's concerns that must be assessed include the following:

- The state's position and key concerns related to the preferred alternative and other alternatives
- State comments on ARARs or the proposed use of waivers

These concerns cannot be evaluated at this time in the FS until the State of Virginia has reviewed and commented on the FS. These concerns will be discussed, to the extent possible, in the Proposed Plan to be issued for public comments.

Community Acceptance

This assessment consists of responses of the community to the Proposed Plan. This assessment includes determining which components of the alternatives interested persons in the community support, have reservations about, or oppose. This assessment can be done after comments on the Proposed Plan are received from the public.

4.1.2 Relative Importance of Criteria

Among the nine criteria, the threshold criteria are considered to be:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs (excluding those that may be waived)

The threshold criteria must be satisfied in order for an alternative to be eligible for selection.

Among the remaining criteria, the following five criteria are considered to be the primary balancing criteria:

- Long-term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, or Volume Through Treatment
- Short-Term Effectiveness
- Implementability
- Cost

The balancing criteria are used to weigh the relative merits of alternatives.

The remaining two of the nine criteria, namely State Acceptance and Community Acceptance are considered to be modifying criteria that must be considered during remedy selection. These last two criteria can be evaluated after the Proposed Plan has been reviewed by the State of Virginia and has been discussed in a public meeting. Therefore, this document addresses only seven out of the nine criteria.

4.1.3 Selection of Remedy

The selection of a remedy is a two-step process. The first step consists of identification of a preferred alternative and presentation of the alternative in a Proposed Plan to the community for review and comment. The preferred alternative must meet the following criteria:

- Protection of human health and the environment.
- Compliance with ARARs unless a waiver is justified.
- Cost effectiveness in protecting human health and environment and in complying with ARARs.
- Utilization of permanent solutions and alternate treatment technologies or resource recovery technologies to the maximum extent practicable.

The second step consists of the review of the comments and determination of whether or not the preferred alternative continues to be the most appropriate remedial action for the site, in consultation with the State of Virginia.

4.2 ASSEMBLY AND DETAILED ANALYSIS OF GROUNDWATER REMEDIAL ALTERNATIVES

The following alternatives have been developed for groundwater remediation at FFTA site:

1. No Action
2. Natural Attenuation, Institutional Controls, and Monitoring
3. In-Situ Biological Treatment (Biostimulation), Institutional Controls, and Monitoring
4. In-Situ Biological Treatment (Bioaugmentation), Institutional Controls, and Monitoring
5. In-Situ AS Treatment, Institutional Controls, and Monitoring

Alternative 1 was developed and analyzed to serve as a baseline for other alternatives, as required by CERCLA and the NCP.

Alternative 2 was formulated and analyzed to evaluate the adequacy of minimal action. For FFTA site in particular, Alternative 2 was evaluated because the natural attenuation analysis as described in Section 3 indicated strong evidence of an environment favorable to biodegradation and reductive biodegradation of chlorinated VOCs in the Columbia Aquifer for both the upper and lower units. The effectiveness of natural attenuation is supported by the fact that the concentrations of the COCs in the plume have decreased since the 1990 sampling event.

Alternatives 3, 4, and 5 were formulated to evaluate active remediation of the contaminant plumes at the FFTA site. Although the FFTA VOC and SVOC plume is relatively large (approximately 1.3 acres), this approach was taken because past removal actions may have removed the primary source material and current fire training exercises do not include the use of combustible or waste materials. Alternatives 3, 4, and 5 represent relatively innovative in-situ treatment approaches.

A description and detailed analysis of these alternatives are provided in the following sections.

4.2.1 Alternative 1 - No Action

4.2.1.1 Description

This alternative is a "walk-away" alternative that is required under CERCLA to establish a basis for comparison with other alternatives. Under this alternative the property would be released for unrestricted use. This alternative cannot be chosen if waste remains on site.

4.2.1.2 Detailed Analysis

Overall Protection of Human Health and the Environment

Alternative 1 would not provide protection of human health and the environment. The current potential for human exposure to contaminated groundwater would remain. Groundwater COCs might migrate that could adversely impact additional human and ecological receptors. Because no monitoring would be performed, potential contaminant migration would not be detected.

Compliance with ARARs and TBCs

Alternative 1 would not comply with chemical-specific ARARs or TBCs because no action would be taken to reduce concentrations of COCs. Compliance with location-specific ARARs or TBCs would be purely incidental. Action-specific ARARs or TBCs are not applicable.

Long-Term Effectiveness and Permanence

Alternative 1 would have no long-term effectiveness and permanence because contaminated groundwater would remain. As there would be no institutional controls to limit groundwater use, the potential would exist for unacceptable risk to develop for human receptors. Because there would be no groundwater monitoring, potential migration of COCs would not be detected. Although concentrations of COCs might eventually decrease to the cleanup goals through natural attenuation, no monitoring would verify this.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 would not reduce toxicity, mobility, or volume of contaminants through treatment because no treatment would occur. Some reduction of contaminant toxicity or volume might occur through natural dispersion, dilution, or other attenuation process, but no monitoring would be performed to verify this.

Short-term Effectiveness

Since no action would occur, implementation of Alternative 1 would not pose a short-term risk to onsite workers or result in short-term adverse impacts to the local community and the environment. Alternative 1 would not achieve the RAOs and, although the cleanup goals might eventually be achieved through natural attenuation, it would not be known when.

Implementability

Because no action would occur, Alternative 1 would be readily implementable. The technical feasibility criteria including constructability, operability, and reliability are not applicable. Implementability of administrative measures is not applicable because no such measures would be taken.

Cost

There would be no capital or periodic costs associated with the No-Action alternative.

4.2.2 Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring

4.2.2.1 Description

Alternative 2 was formulated and analyzed to evaluate the adequacy of minimal action. For the FFTA site in particular, Alternative 2 was evaluated because the natural attenuation analysis in Section 3 indicated strong evidence of an environment favorable to biodegradation and reductive biodegradation of chlorinated VOCs in the Columbia Aquifer for both the upper and lower units. The effectiveness of natural attenuation is supported by the fact that the concentrations of the COCs in the plume have decreased since the 1990 sampling event.

Alternative 2 is illustrated on Figure 4-1 and would consist of three major components: (1) natural attenuation, (2) institutional controls, and (3) monitoring.

Component 1: Natural Attenuation

Natural attenuation would rely on naturally occurring processes within the Columbia aquifer to significantly reduce the concentrations of benzene, chlorinated VOCs, and SVOCs. These processes include a combination of biodegradation, dispersion, dilution, and adsorption in various proportions depending on the type of contaminant and aquifer conditions. Aquifer conditions would be continually monitored to make sure that they are favorable and to verify that concentrations of COCs are indeed being adequately reduced.

The arsenic and manganese contamination is most likely associated with the reduced environment created by the degradation of the FFTA VOC and SVOC contaminants. The extent of the arsenic and manganese contamination is not widespread and is found at the wells that exhibit the highly reducing environment. When the natural attenuation processes to biodegrade the VOCs and SVOCs has been completed, the conditions at the site will return to an oxic environment that should cause the arsenic and manganese to transform to insoluble oxidized compounds.

Component 2: Institutional Controls

Institutional controls would consist of prohibiting use of the groundwater from the Columbia aquifer for drinking purposes until the cleanup goals are met. Use of groundwater would be controlled through restrictions documented in the Facility Master Plan. LUC plans would be prepared and would prohibit the installation of drinking water wells that would draw water from the Columbia aquifer.

Regular site inspections would be performed to verify implementation of the institutional controls until cleanup goals are met. The frequency of these inspections is typically based upon the allowable time of exposure before an unacceptable human health risk associated with residential exposure would develop. At a minimum, the planning and construction phases for a residence is expected to be one year considering the site is located on or near a flightline. Consequently the frequency of site inspections should be annual.

Component 3: Monitoring

Monitoring would consist of regularly collecting and analyzing groundwater samples both from within the contaminant plume to assess performance of the natural attenuation processes and downgradient of the leading edge of the contaminant plumes to verify that COCs are not migrating.

Based on the results of the modeling presented in Appendix B, RAOs may be reached as soon as 5 years. However, for cost estimating purposes it was assumed that monitoring may be required for a period of up to 10 years to achieve site closure. This monitoring would consist of collecting groundwater samples from 20 existing monitoring wells at the FFTA site. Samples would be analyzed for VOCs (benzene, cis-1,2-DCE, tetrachloroethene, and vinyl chloride), SVOCs (4-methylphenol, naphthalene, and pentachlorophenol), and total and dissolved (field-filtered) metals (arsenic and manganese). In addition, it was assumed that samples would also be analyzed for natural attenuation indicator parameters such as ORP, dissolved oxygen, pH, alkalinity, temperature, conductivity, total organic carbon, ferrous and total iron, sulfur compounds (sulfates, hydrogen sulfide, sulfides), orthophosphates, chloride, and metabolic gases (methane, ethane, ethene, and CO_2). Sampling frequency was assumed to be quarterly for the first year, semi-annually for the next 2 years, and annually thereafter. Periodic review and reporting of analytical results could be used to optimize the monitoring program (reduce the number and frequency of samples and vary the analytical parameters). However, for cost estimating purposes this optimization was not predicted.

If the results of four consecutive sampling events indicate that the cleanup goals have been met, the site would be considered as remediated. Monitoring to verify that contaminant plumes are not expanding and COCs are not migrating would take place under the same frequency and periods as described above. Based on the results of the COC migration modeling provided in Appendix B, three of the 20 existing wells (monitoring wells FTA-MW-103S, FTA-MW-103I, and FTA-MW-103D) would be designated as "sentinel" wells. If analysis of the groundwater collected from this "sentinel" wells indicate that the groundwater cleanup goals have been exceeded, the following step-by-step actions would be taken:

1. The sentinel wells where the exceedance was detected would be re-sampled to verify the exceedance.

2. If the exceedance is verified, additional hydrogeological modeling would be performed to determine a revised predicted expansion of the contaminant plume based upon the new monitoring data.

3. If the revised expansion of the contaminant plume predicted by the additional modeling is such that it would be of concern, contingency remedies would be developed.

Reviews would be performed every 5 years to evaluate site status, assess the continued adequacy of remedial activities, and determine whether further action is necessary. These site reviews are required because this alternative allows contaminants to remain in groundwater at concentrations in excess of cleanup goals.

The monitoring component would include the maintenance of the existing wells that are sampled. If there is a change in the ownership of the FFTA site from the U.S. government to the private sector, provisions will need to be incorporated into the property transfer documents to make sure that monitoring and LUCs would continue.

4.2.2.2 Detailed Analysis

<u>Overall Protection of Human Health and the Environment</u>

Alternative 2 would be protective of human health and the environment.

Natural attenuation would be protective of human health and the environment as it would eventually reduce COC concentrations to the cleanup goals. Results of the cleanup time projections presented in Appendix B also indicate that this attenuation would be achieved within a reasonable timeframe.

Institutional controls would be protective of human health by prohibiting the use of the groundwater from the Columbia aquifer for drinking purposes until the cleanup goals are met, thus preventing unacceptable risks from potential future exposure to contaminated groundwater.

Monitoring would be protective of the environment by evaluating the progress of remediation and detecting potential migration of COCs so that appropriate contingency measures can be taken, if required.

Some short-term risks could be incurred by workers from exposure to contamination during implementation of this alternative. However, the potential for such exposure would be minimized by the wearing of appropriate personal protection equipment (PPE) and compliance with site-specific health and safety procedures.

No adverse short-term or cross-media effects are anticipated as a result of implementing this alternative.

Compliance with ARARs and TBCs

Alternative 2 would comply with location- and action-specific ARARs and TBCs. In the short-term, Alternative 2 would not comply with chemical-specific ARARs, but compliance would eventually be achieved as natural processes within the aquifer would reduce COC concentrations.

Long-Term Effectiveness and Permanence

Alternative 2 would provide long-term effectiveness and permanence.

Naturally-occurring processes would effectively and permanently reduce the VOC and SVOC COC concentrations to the cleanup goals. This is supported by the results of the natural attenuation monitoring and modeling conducted at FFTA site and reported upon in Section 3 of this FS Report. These results show evidence of an environment favorable to biodegradation in the Columbia Aquifer where these COCs have been detected. Long-term effectiveness of natural attenuation for the reduction of groundwater VOC and SVOC COC concentrations is also supported by U.S. EPA guidance and directives (U.S. EPA, 1999). When the natural attenuation processes to biodegrade the VOC and SVOC COCs has been completed, the conditions at the site will change to an oxic environment that should cause the arsenic and manganese to transform to insoluble oxidized compounds.

Until the cleanup goals are met, risk from exposure to contaminated groundwater would be addressed through institutional controls. Groundwater use restrictions would effectively prevent the use of the Columbia aquifer as a potable water source.

Long-term monitoring would be an effective means to evaluate the progress of natural attenuation and detect the potential migration of COCs.

Reduction of Toxicity, Mobility, or Volume through Treatment

Although no active treatment is included in this alternative, the toxicity and volume of groundwater COCs would be irreversibly reduced over time through natural processes. Alternative 2 would not provide an immediate reduction in contaminant mobility because neither groundwater containment nor extraction are proposed. This alternative would not increase the rate of natural transformation processes that reduce the toxicity, mobility, or volume of contaminants in groundwater. Small quantities of residuals would be produced if Alternative 2 were implemented from the purging of the groundwater wells prior to the monitoring.

Short-term Effectiveness

Alternative 2 would have minimal short-term effectiveness concerns. Exposure of workers to contamination during groundwater sampling would be minimized by wearing of appropriate PPE and complying with site-specific health and safety procedures. Alternative 2 would also not adversely impact the surrounding community or the environment.

The first RAO would be achieved immediately upon implementation of institutional controls and monitoring.

Cleanup time projections, as presented in Appendix B, indicate that Alternative 2 would achieve the second RAO and meet the groundwater cleanup goals through natural attenuation within approximately 5 to 10 years at the FFTA site.

The reasonableness of these remediation timeframes can be evaluated against the eight criteria provided in the Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17P (U.S. EPA, 1999) as discussed below:

Classification of the Groundwater - The Columbia aquifer is an unconfined water-table aquifer where the direct route of recharge into the aquifer is through infiltration of rainfall, and therefore surficial conditions may affect the quality of the aquifer. Groundwater is the only source for drinking, agricultural, and process water within the WFF area. This is generally true for a large portion of the Eastern Shore. Because of the reliance on groundwater and the coastal proximity of the area, the Commonwealth of Virginia has declared the Eastern Shore of Virginia a Critical Groundwater Area.

Relative Timeframe in Which the Affected Portion Might Be Used As A Future Source - The WFF and the surrounding communities rely on groundwater, primarily from the Yorktown formation, for drinking water supplies. The upper Yorktown aquifer generally occurs at a depth of about 50 to 100 feet below ground surface and is isolated from the overlying Columbia aquifer by a clay and silt aquitard that is approximately 20 to 40 feet thick. Aquifer tests at the WFF indicate that there is no significant vertical leakage across the confining unit separating the upper Yorktown aquifer from the overlying Columbia. The development of the shallow aquifer as a water supply is highly unlikely in that the lower Yorktown aquifer is more productive. In addition the FFTA is located within an area designated as a Groundwater Management Area under the Virginia Groundwater Management Act. Groundwater use in the area is managed and controlled through a permit application and review process administered by DEQ, the Virginia Department of Health, and the Accomack County Health Department. These agencies operate in consultation with the Accomack-Northampton Planning District Committee and the Eastern Shore of Virginia Groundwater Committee who administer the Groundwater Supply Protection and Management Plan adopted by the county. Under this program, NASA has abandoned the water supply wells that withdraw from the Columbia aquifer.

Subsurface Conditions and Plume Stability - The Columbia Aquifer is composed primarily of fine- to medium-sand with lesser amounts of silt and clay. A silty clay layer was encountered approximately 50 feet below the ground surface which is interpreted as the upper aquitard of the Yorktown Formation. No materials were observed that would create a significant change in the direction or velocity of the groundwater flow. Storm water and run-off controls near the runway are in place and are unlikely to be moved. Thus, the groundwater flow will not be affected by changes in the distribution of run-off and percolation.

Long-Term Impact of Contamination on Water Supplies - There are no water supplies either within or downgradient of the contaminant plume, so there is no long-term impact on water supplies. In addition, the nearest receiving water (unnamed tributary to Little Mosquito Creek and the Little Mosquito Creek) where the contaminants in the groundwater could migrate to is more than 600 feet away from the leading edges of the plumes. Based on the results of the modeling presented in Appendix B, the contaminant plumes are not predicted to reach this far.

Uncertainties Regarding Mass of Contaminants And Predictive Analyses - Physical properties of the formation were derived from the Supplemental RI field investigation and also relied on information from other sites (Old Aviation Fuel Tank Farm) at WFF. The Columbia aquifer is generally consistent throughout WFF, so information from one part of WFF can reasonably be applied at other parts of WFF. This information was used for the selection of conservative inputs to the modeling presented in Appendix B. Because of the conservativeness of these inputs, the predicted remediation time is expected to be conservative also.

Reliability of Monitoring And Institutional Controls Over Time - NASA is aware of and sensitive to the environmental issues at the site and; therefore, long-term maintenance of monitoring and institutional controls is expected.

Public Acceptance of Timeframe - Because this FS has not yet been presented to the public, its acceptance of the remediation timeframe for this alternative cannot yet be evaluated.

Provisions by Responsible Party for Adequate Monitoring and Evaluation - NASA will be making the provisions for monitoring and evaluation. This includes performing the required five-year reviews to monitor the progress of each site.

In summary:

- There are no current users or anticipated users of the Columbia aquifer.
- The subsurface and surface conditions are favorable to stable and consistent groundwater flow conditions.
- No detrimental impacts on other water supplies or environmental resources are predicted.
- NASA is committed to continuing the monitoring of the site if required (as has been done at other sites) and has the resources to maintain institutional controls and monitor environmental conditions.
- Conservative values were used in the model so uncertainties in the time frame are expected to be conservative also.

The above factors support the conclusion that the estimated remediation timeframe of 5 to 10 years for the FFTA site may be considered as reasonable.

Implementability

The technical implementation of Alternative 2 would be very simple as it would only require routine monitoring activities.

The administrative implementation of Alternative 2 would be simple. No construction permits would be required for this alternative. Appropriate provisions will be required to make sure of continued implementation of groundwater use restrictions and monitoring.

Cost

The estimated costs for Alternative 2 are:

- Capital Cost:	$11,000
- 10-Year NPW of O&M Cost:	$480,000
- 10-Year NPW:	$491,000

A detailed cost estimate for this alternative is provided in Appendix C.

4.2.3 Alternative 3: In-Situ Biological Treatment (Biostimulation), Institutional Controls, and Monitoring

4.2.3.1 Description

Alternative 3 was formulated to evaluate active remediation of the entire contaminant plume at the FFTA site. Although the FFTA VOC and SVOC plume is relatively large (approximately 1.3 acres), this approach was taken because past actions may have removed the primary source material and current fire training exercises do not include the use of combustible or waste materials.

Alternative 3 is illustrated on Figure 4-2 and would consist of three major components: (1) in-situ biological treatment (biostimulation) with ORC® injection, (2) institutional controls, and (3) monitoring.

Component 1: In-situ Biostimulation Treatment (ORC®)

In-situ biostimulation treatment would consist of using ORC® to enhance/stimulate the growth of indigenous microorganisms and augment natural biodegradation processes to breakdown the VOC and SVOC COCs into nontoxic forms in the contaminant plumes. The enhancement/stimulation of the indigenous microorganisms will increase the rate of biodegradation. A bench-scale treatability study would be required to verify the effectiveness of this alternative and to verify site-specific dosage requirements. The ORC® would be injected using DPT. The groundwater plume would be treated with an ORC® such as magnesium peroxide. Based upon the information obtained from a qualified remediation contractor specializing with this technology, the following ORC® treatment scheme is assumed.

The groundwater plume that consists mostly of benzene, cis-1,2-DCE, 4-methylphenol, and naphthalene would be treated with ORC®. The treatment would consist of two ORC® barrier walls. The application of ORC® would be performed with an injection system consisting of 10, 20-foot deep DPTs for each wall, at a spacing of 15 feet. The ORC® would be injected at the rate of 45 pounds per injection point in the 5- to 20-foot bgs interval (total of 900 pounds of ORC®). For the purposes of this FS, it is assumed that no repeat ORC® application would be required.

The arsenic and manganese contamination is most likely associated with the reduced environment created by the degradation of the FFTA VOC and SVOC contaminants. The extent of the arsenic and manganese contamination is not widespread and is found at the wells that exhibit the highly reducing environment. In-situ aerobic treatment would change the site to an oxic environment that should cause the arsenic and manganese to transform to insoluble oxidized compounds.

The ORC® injection could also be performed to introduce the treatment solution across the water table to target impacted soils in the former source area. The exact nature of the treatment scheme would be verified through treatability testing prior to implementation.

Component 2: Institutional Controls

This component would be identical to Component 2 of Alternative 2.

Component 3: Monitoring

Monitoring would consist of regularly collecting and analyzing groundwater samples both from within the contaminant plume to assess performance of the in-situ biodegradation processes and downgradient of the leading edge of the plume to evaluate potential migration of COCs.

Performance monitoring for Alternative 3 would be identical to that for Alternative 2, and results would be periodically reviewed to optimize the monitoring program. This would include the analysis of the same natural attenuation parameters as in Alternative 2.

Monitoring for potential migration of COCs and the evaluation of analytical results would be identical to that for Alternative 2. The monitoring component would include the maintenance of the existing wells that are sampled.

At the end of five years, a review would be conducted to evaluate site status, assess the continued adequacy of remedial activities, and determine whether further action is necessary.

4.2.3.2 Detailed Analysis

Overall Protection of Human Health and the Environment

Alternative 3 would be protective of human health and the environment.

In-situ biological treatment with ORC® injection would be protective of human health and the environment as it would actively reduce COCs concentrations to concentrations that would no longer constitute an unacceptable human health risk.

Institutional controls would be protective of human health by prohibiting the use of the groundwater from the Columbia aquifer for drinking purposes until the cleanup goals are met, thus preventing unacceptable risks from potential exposure to contaminated groundwater.

Monitoring would be protective of the environment by evaluating the progress of remediation and detecting potential migration of COCs so that appropriate contingency measures could be taken, if required.

Some short-term risks could be incurred by workers from exposure to contamination during implementation of this alternative. However, the potential for this exposure would be minimized by the wearing of appropriate PPE and compliance with site-specific health and safety procedures.

No adverse short-term or cross-media effects are anticipated as a result of implementing this alternative.

Compliance with ARARs and TBCs

Alternative 3 would eventually comply with chemical-specific ARARs and TBCs through active in-situ biological treatment. Alternative 3 would also comply with location- and action-specific ARARs and TBCs.

Long-Term Effectiveness and Permanence

Alternative 3 would provide long-term effectiveness and permanence.

In-situ biological treatment with ORC® injection would effectively and permanently remove groundwater COCs and could be applied to impacted soils at the site. ORC® injection is a well-established and proven technology for the treatment of organic compounds and treatability testing would be needed to verify its site-specific effectiveness.

Groundwater use restrictions would effectively prevent the use of the Columbia aquifer as a potable water source until the cleanup goals have been achieved.

Long-term groundwater monitoring would be an effective means to evaluate progress of remediation and verify that no contaminant migration is occurring.

The components proposed in this alternative are considered reliable.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 3 would reduce the toxicity and volume of groundwater COCs through biological treatment. The ORC® injection systems of this alternative are designed to irreversibly remove a total of approximately 127 pounds of contaminants (approximately 2 pounds of dissolved COCs from the contaminated groundwater plume and 125 pounds of residual petroleum contamination smeared onto the soil) over their operating life. Because this removal would be achieved through biodegradation, it would be irreversible. Small quantities of residuals would be produced from the installation of the treatment system and from the purging of the groundwater wells for the monitoring.

Short-Term Effectiveness

There would be minimal short-term concerns associated with implementation of Alternative 3. Exposure of onsite workers to contamination during installation of DPT injection points and groundwater sampling would be minimized by wearing of appropriate PPE and complying with site-specific health and safety procedures. Implementation of this alternative would also not adversely impact the surrounding community or the environment.

The first RAO would be achieved immediately upon implementation of institutional controls and monitoring.

Based on the information received from a qualified contractor, it is anticipated that ORC® treatment would achieve the second RAO and lower concentrations of groundwater COCs to cleanup goals within approximately 5 years at the FFTA site. However, for cost estimating purposes it was assumed that monitoring activities may extend for a period of up to 10 years.

Implementability

Alternative 3 would be readily implementable.

Injection of ORC® would be technically implementable but would require the installation of a number of DPT injection points (approximately 20). The location of this activity is near the runway and would need to be completed so that the activity would not interfere with the functions of the active airport facilities. Any interference would be very temporary in nature. Treatability testing would have to be performed to verify the effectiveness and the design parameters for the in-situ biological treatment injection. Groundwater monitoring and performance of five-year reviews could easily be accomplished. Although the number of contractors qualified for the application of ORC® is relatively limited, the resources, equipment, and materials required for these activities are readily available.

The administrative aspects of Alternative 3 would be relatively simple to implement. The substantive requirements of an Underground Injection Control (UIC) permit would have to be met for the injection of ORC®. A construction permit might also be needed for installation of the DPT injection points, but such a permit would be easy to secure. Appropriate provisions will be implemented at WFF to make sure continued implementation of groundwater use restrictions and monitoring.

Cost

The estimated costs for Alternative 3 are:

• Capital Cost:	$133,000
• 10-Year NPW of O&M Cost:	$585,000
• 10-Year NPW:	$718,000

Detailed cost estimates for this alternative are provided in Appendix C.

4.2.4 Alternative 4: In-Situ Biological Treatment (Bioaugmentation), Institutional Controls, and Monitoring

4.2.4.1 Description

Alternative 4 was formulated to evaluate active remediation of the entire contaminant plume at the FFTA site. Although the FFTA VOC and SVOC plume is relatively large (approximately 1.3 acres), this approach was taken because past actions may have removed the primary source material and current fire training exercises do not include the use of combustible or waste materials.

Alternative 4 is illustrated on Figure 4-3 and would consist of three major components: (1) in-situ biological treatment (bioaugmentation) with CL-Out injection, (2) institutional controls, and (3) monitoring.

Component 1: In-situ Bioaugmentation Treatment (CL-Out)

In-situ bioaugmentation treatment would consist of using CL-Out to provide microorganisms and augment natural biodegradation processes in the contaminant plumes. CL-Out would be injected using DPT at 15 foot well spacing. The groundwater plume would be treated with CL-Out. Based upon the information obtained from a qualified remediation contractor specializing with this technology (CL solutions, see Appendix A), the following CL-Out treatment scheme is assumed.

The groundwater plume that consists mostly of benzene, cis-1,2-DCE, 4-methylphenol, and naphthalene would be treated with CL-Out. The application of CL-Out would be performed with an injection system consisting of 80, 20-foot deep DPTs in which CL-Out would be injected at the rate of approximately 1 drum (unit) per well/injection point in the 5- to 20-foot bgs interval. For the purposes of this FS, it is assumed that no repeat CL-Out application would be required.

The arsenic and manganese contamination is most likely associated with the reduced environment created by the degradation of the FFTA VOC and SVOC contaminants. The extent of the arsenic and manganese contamination is not widespread and is found at the wells that exhibit the highly reducing environment. When the in-situ bioaugmentation processes to biodegrade the VOCs and SVOCs has been completed, the conditions at the site will return to an oxic environment that should cause the arsenic and manganese to transform to insoluble oxidized compounds.

The exact nature of the treatment scheme would be verified through treatability testing prior to implementation.

Component 2: Institutional Controls

This component would be identical to Component 2 of Alternative 2.

Component 3: Monitoring

Monitoring would consist of regularly collecting and analyzing groundwater samples both from within the contaminant plume to assess performance of the in-situ biodegradation processes and downgradient of the leading edge of the plume to evaluate potential migration of COCs.

Performance monitoring for Alternative 4 would be identical to that for Alternative 2, and monitoring results would be periodically reviewed to optimize the monitoring program. This would include the analysis of the same natural attenuation parameters as in Alternative 2.

Monitoring for potential migration of COCs and the evaluation of analytical results would be identical to that for Alternative 2, and monitoring would last 5 years at the FFTA site. The monitoring component would include the maintenance of the existing wells that are sampled.

At the end of five years, a review would be conducted to evaluate site status, assess the continued adequacy of remedial activities, and determine whether further action is necessary.

4.2.4.2 Detailed Analysis

Overall Protection of Human Health and the Environment

Alternative 4 would be protective of human health and the environment.

In-situ biological treatment with CL-Out injection would be protective of human health and the environment as it would actively reduce COCs concentrations to concentrations that would no longer constitute an unacceptable human health risk.

Institutional controls would be protective of human health by prohibiting the use of the groundwater from the Columbia aquifer for drinking purposes until the cleanup goals are met, thus preventing unacceptable risks from potential exposure to contaminated groundwater.

Monitoring would be protective of the environment by evaluating the progress of remediation and detecting potential migration of COCs so that appropriate contingency measures could be taken, if required.

Some short-term risks could be incurred by workers from exposure to contamination during implementation of this alternative. However, the potential for this exposure would be minimized by the wearing of appropriate PPE and compliance with site-specific health and safety procedures.

No adverse short-term or cross-media effects are anticipated as a result of implementing this alternative.

Compliance with ARARs and TBCs

Alternative 4 would eventually comply with chemical-specific ARARs and TBCs through active in-situ biological treatment. Alternative 4 would also comply with location- and action-specific ARARs and TBCs.

Long-Term Effectiveness and Permanence

Alternative 4 would provide long-term effectiveness and permanence.

In-situ biological treatment with CL-Out injection would effectively and permanently remove groundwater COCs. CL-Out injection is an established and proven technology for the treatment of organic compounds and treatability testing would be needed to verify its site-specific effectiveness.

Groundwater use restrictions would effectively prevent the use of the Columbia aquifer as a potable water source until the cleanup goals have been achieved.

Long-term groundwater monitoring would be an effective means to evaluate progress of remediation and verify that no contaminant migration is occurring.

The components proposed in this alternative are considered reliable.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 4 would reduce the toxicity and volume of groundwater COCs through biological treatment. The CL-Out injection system of this alternative is designed to irreversibly remove a total of approximately 127 pounds of contaminants (approximately 2 pounds of dissolved COCs from the contaminated groundwater plume and 125 pounds of residual petroleum contamination smeared onto the soil) over their operating life. Because this removal would be achieved through biodegradation, it would be irreversible. Small quantities of residuals would be produced from the installation of the treatment system and from the purging of the groundwater wells for the monitoring.

Short-Term Effectiveness

There would be minimal short-term concerns associated with implementation of Alternative 4. Exposure of onsite workers to contamination during installation of DPT injection points and groundwater sampling would be minimized by wearing of appropriate PPE and complying with site-specific health and safety procedures. Implementation of this alternative would also not adversely impact the surrounding community or the environment.

The first RAO would be achieved immediately upon implementation of institutional controls and monitoring.

Based on the natural attenuation modeling in Appendix B and the information received from a qualified contractor, it is anticipated that CL-Out treatment would achieve the second RAO and lower concentrations of groundwater COCs to cleanup goals within approximately 5 years at the FFTA site. However, for cost estimating purposes it was assumed that monitoring activities may extend for a period of up to 10 years.

Implementability

Alternative 4 would be readily implementable.

Injection of CL-Out would be technically implementable but would require the installation of a significant number of DPT injection points (approximately 80). The location of this activity is near the runway and would need to be completed so that the activity would not interfere with the functions of the active airport facilities. Any interference would be very temporary in nature. Treatability testing would have to be performed to verify the effectiveness and the design parameters for the in-situ biological treatment injection. Groundwater monitoring and performance of five-year reviews could easily be accomplished. Although the number of contractors qualified for the application of CL-Out is relatively limited, the resources, equipment, and materials required for these activities are readily available.

The administrative aspects of Alternative 4 would be relatively simple to implement. The substantive requirements of an UIC permit would have to be met for the injection of CL-Out. A construction permit might also be needed for installation of the DPT injection points, but such a permit would be easy to secure. Appropriate provisions will be implemented at WFF to make sure continued implementation of groundwater use restrictions and monitoring.

Cost

The estimated costs for Alternative 4 are:

Capital Cost:	$456,000
10-Year NPW of O&M Cost:	$580,000
10-Year NPW:	$1,036,000

Detailed cost estimates for this alternative are provided in Appendix C.

4.2.5 Alternative 5: In-Situ AS Treatment, Institutional Controls, and Monitoring

Alternative 5 was formulated to evaluate active remediation of the entire contaminant plume or the former source area only at the FFTA site. Remediation of the entire contaminant plume at the FFTA includes the VOC and SVOC plume of approximately 1.3 acres. Remediation in the former source area at the FFTA site encompasses an area of approximately 10,000 square feet (100 by 100 feet between monitoring wells FTA-MW-02S and FTA-MW-54S).

Alternative 5 is illustrated on Figure 4-4 and would consist of three major components: (1) AS treatment, (2) institutional controls, and (3) monitoring. The difference between the entire contaminant plume and former source area remedial efforts is the number of AS wells and the size of the AS equipment.

4.2.5.1 Detailed Description

Component 1: AS Treatment

This component would consist of installing an AS system and operating the system for a period of 2 years at the FFTA site. Figure 4-5 shows the process flow diagram for a typical AS System. The AS system would consist of one or more AS blower systems, each connected to an array of AS wells screened to a specific depth. Each AS blower system would feature a blower and the necessary instrumentation and controls. The AS blower system would be placed in a pre-engineered, pre-constructed structure in a fenced-in area.

Design AS flows would be 6 to 12 cubic feet per minute (cfm) per well. Based upon the operating results of similar AS systems at the Old Aviation Fuel Tank Farm and factoring in a conservative overlap, it is assumed that the effective treatment area and radius of influence (ROI) of each AS well would be 700 ft^2 and 15 feet, respectively.

The AS system would feature air blower systems connected to an array of AS wells. For the entire contaminant plume, the AS blower system would consist of two 450 cfm blowers. The AS well array would consist of 75 wells screened from 15 to 20 feet below the water table (35 to 40 feet bgs). For the former source area remedial action, the AS blower system would consist of a 200 cfm blower. The AS well array would consist of 16 wells screened from 15 to 20 feet below the water table (35 to 40 feet bgs). Conceptual design calculations for the AS systems are provided in Appendix A.

The arsenic and manganese contamination is most likely associated with the reduced environment created by the degradation of the FFTA VOC and SVOC contaminants. The extent of the arsenic and manganese contamination is not widespread and is found at the wells that exhibit the highly reducing environment. AS treatment would change the site to an oxic environment that should cause the arsenic and manganese to transform to insoluble oxidized compounds.

Component 2: Institutional Controls

This component would be identical to Component 2 of Alternative 2.

Component 3: Monitoring

This component would be identical to Component 3 of Alternative 2, except that performance monitoring samples would not be analyzed for natural attenuation parameters.

4.2.5.2 Detailed Analysis

Overall Protection of Human Health and the Environment

Alternative 5 would be protective of human health and the environment.

AS treatment of the entire contaminant plume would be protective of human health and the environment as it would actively reduce COC concentrations to concentrations that would no longer constitute a human health risk. AS treatment of the former source area would also be protective of human health and the environment as it would actively reduce the highest COC concentrations to concentrations that would no longer constitute a human health risk. The rest of the contaminant plume would use natural attenuation to eventually reduce COC concentrations to the cleanup goals. The cleanup time projections presented in Appendix B indicate that this attenuation would be achieved within a reasonable timeframe.

Institutional controls would be protective of human health by prohibiting the use of the groundwater from the Columbia aquifer for drinking purposes until the cleanup goals are met, thus preventing unacceptable risks from potential future exposure to contaminated groundwater.

Monitoring would be protective of the environment by evaluating the progress of remediation and detecting potential migration of contaminated groundwater so that appropriate contingency measures could be taken, if required.

Some short-term risks could be incurred by workers from exposure to contamination during implementation of this alternative. However, the potential for this exposure would be minimized by the wearing of appropriate PPE and compliance with site-specific health and safety procedures. Fugitive emissions would also result from AS treatment and it is conservatively estimated that the maximum initial level of fugitive emission would exceed the VDEQ de minimis level based on the maximum concentrations in the soil. However, the maximum initial level of fugitive emission would not exceed the VDEQ de minimis level based on the average concentrations in the soil. Therefore, the AS system would be operated so that no fugitive emissions controls would be required during the start up and first six months of operation (control the air flow of the AS system). After six months of operation, the emission levels would decrease and the AS system would be operated at full design flow.

No adverse short-term or cross-media effects are anticipated as a result of implementing this alternative.

Compliance with ARARs and TBCs

Alternative 5 would eventually comply with chemical-specific ARARs and TBCs through in-situ AS treatment. Alternative 5 would also comply with location- and action-specific ARARs and TBCs.

Long-Term Effectiveness and Permanence

Alternative 5 would provide long-term effectiveness and permanence.

AS treatment would effectively and permanently remove groundwater COCs. AS treatment is a well-established technology and its effectiveness has been proven at similar sites.

Groundwater use restrictions would effectively prevent the use of the Columbia aquifer as a potable water source until the cleanup goals have been achieved.

Long-term monitoring would be an effective means to evaluate the progress of remediation and verify that no contaminant migration is occurring.

The components proposed in this alternative are considered reliable.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 5 would reduce the toxicity and volume of groundwater COCs through AS treatment. The AS systems of Alternative 5 are designed to irreversibly remove a total of approximately 127 pounds of contaminants (approximately 2 pounds of dissolved COCs from the contaminated groundwater plume and 125 pounds of residual petroleum contamination smeared onto the soil) over its operating life. Alternative 5 would be irreversible. Small quantities of residuals would be produced from the installation of the treatment system and from the purging of the groundwater wells for the monitoring.

Short-Term Effectiveness

There would be minimal short-term concerns associated with implementation of Alternative 5. Exposure of workers to contamination during installation of AS wells and groundwater sampling would be minimized by wearing of appropriate PPE and complying with site-specific health and safety procedures. Implementation of this alternative would also not adversely impact the surrounding community or the environment.

The first RAO would be achieved immediately upon implementation of institutional controls and monitoring.

Based on the performance of similar AS systems currently operating, it is anticipated that the second RAO and the groundwater cleanup goals would be achieved within approximately 4 years at the FFTA site. However, for cost estimating purposes it was assumed that monitoring activities may extend for a period of up to 10 years to reach site closure.

Implementability

Alternative 5 would be implementable.

Although it could be implemented for the entire contaminant plume, installation of the AS system featuring 75 AS wells and several thousand feet of air distribution piping over an area approximately 1.3 acres would have somewhat of an impact. However, the site interference would be relatively temporary in nature. Qualified personnel would be required to operate and maintain this system; and such personnel are available. Installation of AS wells, maintenance of monitoring wells, sampling and analysis of groundwater, implementation of erosion and sedimentation control programs (if required), and performance of five-year reviews could easily be accomplished. The resources, equipment, and materials required for these activities are readily available.

The administrative aspects of Alternative 5 would be relatively simple to implement. This alternative would require construction permits for installation of the AS systems but such permits would be simple to obtain. Appropriate provisions will be implemented at WFF to make sure continued implementation of groundwater use restrictions and monitoring.

<u>Cost</u>

The estimated costs for Alternative 5 for the entire contaminant plume are:

- Capital Cost: $543,000
- 10-Year NPW of O&M Cost: $571,000
- 10-Year NPW: $1,114,000

The estimated costs for Alternative 5 for the former source area are:

- Capital Cost: $327,000
- 10-Year NPW of O&M Cost: $483,000
- 10-Year NPW: $810,000

A detailed cost estimate for this alternative is provided in Appendix C.

5.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section compares the analyses for each of the remedial alternatives presented in Section 4.0 of this FS. The criteria for comparison are identical to those used for the detailed analysis of individual alternatives.

5.1 COMPARISON OF GROUNDWATER REMEDIAL ALTERNATIVES BY CRITERIA

The following remedial alternatives for the FFTA groundwater are being compared in this section:

- Alternative 1: No Action
- Alternative 2: Natural Attenuation, Institutional Controls, and Monitoring
- Alternative 3: In-Situ Biological Treatment (Biostimulation), Institutional Controls, and Monitoring
- Alternative 4: In-Situ Biological Treatment (Bioaugmentation), Institutional Controls, and Monitoring
- Alternative 5: In-Situ AS Treatment, Institutional Controls, and Monitoring

5.1.1 Overall Protection of Health and Environment

Alternative 1 would not provide protection of human health and the environment because contaminants would remain in groundwater, and potential use of groundwater for drinking purpose could result in unacceptable risk to human receptors. Also under this alternative, no warning would be provided of the potential for migration of COCs because no monitoring would occur.

Alternatives 2, 3, 4, and 5 would be protective of human health and the environment.

The natural attenuation component of Alternative 2 would be protective of human health and the environment because it would eventually reduce the concentrations of COCs to the cleanup goals over a reasonable timeframe. The institutional controls component of Alternative 2 would be protective of human health and the environment as it would reduce exposure to contaminated groundwater by prohibiting use of the Columbia Aquifer for drinking purposes until the cleanup goals are met. The monitoring component of Alternative 2 would be protective of human health and the environment by evaluating the progress of remediation and detecting potential migration of COCs so that appropriate contingency measures can be taken.

Alternatives 3, 4, and 5 would be more protective than Alternative 2, because, in addition to the same institutional controls and monitoring components, these three alternatives would also include an active treatment component that would remove groundwater VOC and SVOC COCs. Although Alternative 5 could result in fugitive emissions, the operation of the AS system would be controlled so that the rate of these emissions would remain well under the VDEQ's allowable de minimis of 15 pounds of VOCs per day. Alternative 5 would be more protective than Alternative 2, 3, and 4 because it would achieve complete protection in a shorter time.

5.1.2 Compliance with ARARs and TBCs

Alternative 1 would not comply with chemical- and location-specific ARARs. Action-specific ARARs or TBCs would not apply.

Alternatives 2, 3, 4, and 5 would comply with location- and action-specific ARARs and TBCs.

Alternatives 2, 3, 4, 5 would not immediately comply with chemical-specific ARARs and TBCs, but these four alternatives would eventually achieve compliance as they attain cleanup goals either through natural attenuation alone (Alternative 2) or through active treatment (Alternatives 3, 4, and 5). First to achieve compliance would be Alternative 5, followed by Alternatives 3 and 4, and followed by Alternative 2.

5.1.3 Long-Term Effectiveness and Permanence

Alternative 1 would have very limited long-term effectiveness and permanence because no contaminant removal or reduction would occur through treatment although, over time, some contaminant reduction would occur through natural attenuation. As there would be no institutional controls to restrict residential development or use of the Columbia Aquifer groundwater for drinking water purposes, the potential would also exist for unacceptable risk to develop due to direct exposure of human or ecological receptors to contamination. Because there would be no monitoring, potential migration of COCs would remain undetected.

Alternatives 2, 3, 4, and 5 would provide long-term effectiveness and permanence.

Given that source control activities have been implemented, the natural attenuation component of Alternative 2 would effectively and permanently reduce concentrations of groundwater COCs to cleanup goals. The institutional controls component of Alternative 2 would effectively prevent the use of the Columbia Aquifer as a drinking water source until the cleanup goals have been achieved. The long-term monitoring component of Alternative 2 would provide an effective means of evaluating the progress of remediation and verifying that no COC migration is occurring.

Alternatives 3, 4, and 5 would be more effective than Alternative 2, because, in addition to the same institutional controls and monitoring components, these three alternatives would also include an active treatment component that accelerates the removal of VOC and SVOC COCs. Alternative 5 would be most effective because it would be quickest to meet the cleanup goals and would use a well-proven treatment technology. Alternatives 3 and 4 would be slightly less effective than Alternative 5 because the in-situ biological applications would use a technology that would require treatability testing. Alternatives 3 and 4 would also be slightly less effective than Alternative 5 because it would take somewhat more time to meet the cleanup goals.

5.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 1 and 2 would not achieve any reduction of toxicity, mobility, or volume of COCs through active treatment. Both alternatives would achieve irreversible reduction of contaminant toxicity and volume through natural attenuation; however, under Alternative 1, this reduction would neither be verified nor quantified.

Alternatives 3, 4, and 5 would achieve a reduction in VOC and SVOC COC toxicity and volume through treatment.

Alternatives 3, 4, and 5 would irreversibly remove an estimated 127 pounds (2 pounds of dissolved COCs from groundwater and 125 pounds of residual/smeared petroleum on the soil) of contaminants from the FFTA Site through either in-situ biological or AS treatment. Alternatives 3, 4, and 5 would generate some residues during the installation of the treatment systems and the groundwater monitoring. However, Alternatives 3, 4, and 5 would not generate treatment residues.

5.1.5 Short-Term Effectiveness

Implementation of Alternative 1 would not result in risks to site workers or adversely impact the surrounding community or environment because no remedial activities would be performed. Alternative 1 would not achieve the groundwater RAOs and although the groundwater cleanup goals might eventually be attained through natural processes, this would not be verified.

Implementation of Alternative 2 would result in a slight possibility of exposing site workers to contaminated groundwater during the maintenance and sampling of monitoring wells. However, these risks of exposure would be effectively controlled by wearing appropriate PPE and compliance with proper site-specific health and safety procedures. Implementation of Alternative 2 would not adversely impact the surrounding community or environment. Alternative 2 would achieve the first RAO immediately upon implementation of institutional controls and monitoring. Based on the results of the modeling presented in Appendix B, the second RAO and the groundwater cleanup goals would be attained within an estimated 5 to 10 years at the FFTA site.

Implementation of Alternatives 3, 4, or 5 would result in a significant possibility of exposing construction workers to contaminated groundwater during the construction and operation of the groundwater treatment systems and the sampling of existing wells. However, these risks of exposure would be effectively controlled by wearing appropriate PPE and compliance with proper site-specific health and safety procedures. Implementation of Alternatives 3, 4, and 5 would not adversely impact the surrounding community or environment. Alternatives 3, 4, and 5 would achieve the first RAO immediately upon implementation of institutional controls. It is estimated that the respective timeframes to achieve the second RAO and the groundwater cleanup goals at the FFTA site would be 5 years for Alternatives 3 and 4, and 4 years for Alternative 5.

5.1.6 Implementability

Alternative 1 would be easiest to implement because there would be no activities to implement.

Technical implementation of the various components of Alternatives 2, 3, 4, and 5 would be relatively simple.

The technical implementation of the natural attenuation, institutional controls, and monitoring components of Alternative 2 would be very simple. The resources, equipment, and material required for the activities associated with these components are readily available.

The technical implementation of Alternatives 3, 4, and 5 would be somewhat more difficult than that of Alternative 2 because each of these alternatives would require the installation and O&M of a groundwater treatment system. Of these three alternatives, Alternatives 3 and 4 would be easiest to implement because it would only require the installation of small diameter injection points and the feeding of chemicals without installation of permanent equipment. However, treatability testing would have to be performed to verify the effectiveness and design parameters for the treatment injection. Alternative 5 would be technically harder to implement than Alternatives 3 and 4 because it would require construction of an AS system with numerous sparging wells, interconnecting piping, and one or more blower systems. However, the resources, equipment, and material necessary to implement these three alternatives are readily available.

Administrative implementation of the various components of Alternatives 2, 3, 4, and 5 would be relatively simple.

Administrative implementation of the institutional controls component of Alternative 2 would be simple because LUCs or a Facility Master Plan, including land and groundwater use restrictions, would be formulated and implemented to prevent the use of the groundwater from the shallow Columbia aquifer at the FFTA site. Administrative implementation of the monitoring component of Alternative 2 would also be simple and it would not require permits.

The administrative implementation of Alternatives 3, 4, and 5 would be slightly more difficult than that of Alternative 2. In addition to the same requirements as Alternative 2, Alternatives 3, 4, and 5 might require a construction permit for installation of DPT injection points, and Alternatives 3 and 4 would need underground injection permits for the delivery of the chemicals. Also, erosion and sedimentation control plans may be required for the installation of piping to support Alternative 5. However, these permits should be relatively easy to obtain.

5.1.7 Cost

The capital and O&M costs and NPW of the groundwater alternatives are as follows.

Groundwater Alternatives	Capital	NPW of O&M (year)	NPW (year)
1	$0	$0	$0
2	$11,000	$480,000 (10 Years)	$491,000 (10 Years)
3	$ 133,000	$585,000 (10 Years)	$718,000 (10 Years)
4	$456,000	$580,000 (10 Years)	$1,036,000 (10 Years)
5 (entire plume)	$543,000	$571,000 (10 Years)	$1,114,000 (10 Years)
5 (source area)	$327,000	$483,000 (10 Years)	$810,000 (10 Years)

Detailed cost estimates are provided in Appendix C.

5.2 SUMMARY OF COMPARATIVE ANALYSIS OF GROUNDWATER REMEDIAL ALTERNATIVES

Table 5-1 summarizes the comparative analysis of the groundwater remedial alternatives.

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TABLES

TABLE 1-1
OCCURRENCE AND DISTRIBUTION OF ORGANICS AND INORGANICS IN FIRE TRAINING AREA GROUNDWATER
FFTA FS REPORT
NASA WFF - WALLOPS ISLAND, VIRGINIA

Substance	Background Data					Site-Related Data				
	Freq. of Detection	Range of Positive Detection Min.	Max.	Mean of All Data	Sampling Round and Location of Maximum	Freq. of Detection	Range of Positive Detection Min.	Max.	Mean of All Data	Sampling Round and Location of Maximum
INORGANICS (ug/L)										
Aluminum	4/5	386	1150	537	MW1-20030220	3/3	398	648	502	FTAMW-102D
Arsenic	1/6	3.8	3.8	1.88	MW1-20030303	3/20	5.1	25.4	3.49	FTAMW-55S
Barium	4/4	10.6	38.6	21.7	14-GW1	10/10	8.7	32.7	19.1	FTAMW-101S-DUP
Calcium	6/6	2970	20700	11600	MW1-20030303	21/21	1580	14800	5070	FTA-WFF14-GW3
Chromium	5/5	0.71 L	1.9	1.23	14-GW2	4/8	0.98	3.9	1.08	FTAMW-104S
Cobalt	0/5	-				2/7	7.3	7.6	2.45	FTAMW-103D
Iron	2/2	452	11500	5900	14-GW1	11/11	186	44200	6940	FTAMW-55S
Lead	0/6	-				3/21	4.1	73.2	5.64	FTAMW-55S
Magnesium	6/6	1140	5550	2940	14-GW2	21/21	2250	12300	4680	FTAMW-56D
Manganese	2/2	8.9	231	118	14-GW1	18/18	9	4990	561	FTAMW-61I
Potassium	3/3	1530	6060	3700	MW1-20030303	15/15	625	1820	1390	FTAMW-58S
Sodium	5/5	3190	8590	6660	MW1-20030303	21/21	2950	10500	6150	FTAMW-2D
Zinc	1/6	7.1	7.1	4.1	MW53S-20030219	2/9	10.7	50.8	9.56	FTAMW-55S
SEMIVOLATILE ORGANIC COMPOUNDS (ug/L)										
2,4-Dimethylphenol	0/6	-				1/15	4 J	4 J	3.1	FTAMW-55D
2-Methylnaphthalene	0/6	-				4/20	5 J	35	5.15	FTAMW-61I
2-Methylphenol	0/6	-				3/19	1 J	24	3.53	FTAMW-55S
4-Methylphenol	0/6	-				2/19	88	300	22.7	FTAMW-55S
bis(2-ethylhexyl) phthalate	1/6	7	7	3.25	MW53S-20030304	6/17	1 J	6	3.47	FTAMW-2D
Diethyl Phthalate	0/6	-				3/20	2 J	4 J	2.9	FTAMW-61I
Naphthalene	0/6	-				4/20	21	66	9.45	FTAMW-61I
Pentachlorophenol	0/6	-				1/19	2 J	2 J	11.2	FTAMW-61I
Phenol	0/6	-				2/19	7	34	4.39	FTAMW-55S
VOLATILE ORGANIC COMPOUNDS (ug/L)										
1,1,1-Trichloroethane	0/6	-				10/21	2	340	46.1	FTAMW-58S
1,1-Dichloroethane	0/6	-				9/21	1	64	9.37	FTAMW-56D
1,1-Dichloroethene	0/6	-				6/21	3	31	5.12	FTAMW-56D
1,2,4-Trimethylbenzene	0/6	-				7/21	5 L	65	10.4	FTAMW-61I
1,2-Dichloroethene (cis)	0/6	-				10/21	1	460	52.2	FTAMW-61I
1,3,5-Trimethylbenzene	0/6	-				7/21	2 L	18	2.52	FTAMW-55S
2-Butanone	0/6	-				1/20	29	29	3.83	FTAMW-55S
4-Methyl-2-pentanone	0/6	-				1/21	4 J	4 J	2.57	FTAMW-55S
Acetone	0/5	-				1/15	4 J	4 J	2.55	FTAMW-101S-DUP
Benzene	0/6	-				6/21	1	28	3.21	FTAMW-61I
Carbon Disulfide	0/6	-				1/21	1	1	0.524	FTAMW-103S
Chloroform	1/6	1	1	0.583	MW1-20030303	3/21	1	7	1.14	FTAMW-102D
Cyclohexane	0/6	-				2/21	4	7	0.976	FTAMW-61I
Ethylbenzene	0/6	-				6/21	1	22	3.67	FTAMW-61I
Isopropylbenzene	0/6	-				4/21	2	5	0.976	FTAMW-61I
m,p-xylene	0/6	-				7/21	2	58	8.95	FTAMW-61I
Methylcyclohexane	0/6	-				5/21	1 L	9	1.67	FTAMW-61I
O-xylene	0/6	-				6/21	2	28	3.55	FTAMW-58S
Tetrachloroethene	0/6	-				2/21	1	1	0.548	FTAMW-103I
Toluene	0/6	-				2/21	12	83	4.98	FTAMW-55S
Vinyl Chloride	0/6	-				2/21	2	6	0.833	FTAMW-61I
Xylene (Total)	0/6	-				7/21	2	66	12.2	FTAMW-61I

Notes:
Number of sample results excludes rejected data or blank-qualified data. Duplicates are consolidated into one result.
Mean of the data includes positive detections and non-detected results. Detection limits are divided by two.
The determination of representative concentrations is based on comparison of maximum to the 95 % UCL, which is presented in a separate table.
Frequency of detection refers to number of times compound was detected among the samples versus total number of samples.
Number of samples may vary based on the number of usable results.

TABLE 1-2
DATA SUMMARY FOR FIRE TRAINING AREA GROUNDWATER SAMPLES
FFTA FS REPORT
NASA WFF - WALLOPS ISLAND, VIRGINIA
PAGE 1 OF 6

Sample ID:	**Preliminary Remediation Goal**	**14-GW1**		**14-GW1-DUP**		**14-GW2**		**MW1-20030220**		**MW1-20030303**	
Sample Date:		**02/19/03**		**02/19/03**		**02/19/03**		**02/20/03**		**03/03/03**	
Duplicate:		**14-GW1-DUP**		**14-GW1**							
Upgradient Well (Y/N):		**Y**		**Y**		**Y**		**Y**		**Y**	
INORGANICS - FILTERED (ug/L)											
Arsenic	10	3	UL	3	UL	3	U	3	U	3	U
Manganese	124	**230**		**231**		4.9	B	5.6	B	5.6	
INORGANICS (ug/L)											
Arsenic	10	3	UL	3	UL	3	U	3	U	3.8	
Manganese	124	**231**		**225**		5.7	B	11.2	B	8.9	
SEMIVOLATILE ORGANIC COMPOUNDS (ug/L)											
4-Methylphenol	27	5	U	5	U	5	U	5	U	5	U
Naphthalene	16	5	U	5	U	5	U	5	U	5	U
Pentachlorophenol	1	**20**	U	**20**	U	**20**	U	**20**	U	**20**	U
VOLATILE ORGANIC COMPOUNDS (ug/L)											
1,2-Dichloroethene (cis)	70	1	U	1	U	1	U	1	U	1	U
Benzene	5	1	U	1	U	1	U	1	U	1	U
Tetrachloroethene	5	1	U	1	U	1	U	1	U	1	U
Vinyl Chloride	2	1	U	1	U	1	U	1	U	1	U

TABLE 1-2
DATA SUMMARY FOR FIRE TRAINING AREA GROUNDWATER SAMPLES
FFTA FS REPORT
NASA WFF - WALLOPS ISLAND, VIRGINIA
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Sample ID:	**Preliminary Remediation Goal**	**MW53S-20030219**		**MW53S-20030304**		**FTA-WFF14-GW3**		**FTA-WFF14-GW4**	
Sample Date:		**02/19/03**		**03/04/03**		**03/13/03**		**03/13/03**	
Duplicate:									
Upgradient Well (Y/N):		**Y**		**Y**		**N**		**N**	
INORGANICS - FILTERED (ug/L)									
Arsenic	10	3	U	3	U	3	U	3	U
Manganese	124	4.2	B	2	B	24.3		11.5	
INORGANICS (ug/L)									
Arsenic	10	3	U	3	U	3	U	3	U
Manganese	124	4.5	B	3.1	B	22.7		13.1	
SEMIVOLATILE ORGANIC COMPOUNDS (ug/L)									
4-Methylphenol	27	5	U	5	U	5	U	5	U
Naphthalene	16	5	U	5	U	5	U	5	U
Pentachlorophenol	1	**20**	U	**20**	U	**20**	U	**20**	U
VOLATILE ORGANIC COMPOUNDS (ug/L)									
1,2-Dichloroethene (cis)	70	1	U	1	U	1	U	1	U
Benzene	5	1	U	1	U	1	U	1	U
Tetrachloroethene	5	1	U	1	U	1	U	1	U
Vinyl Chloride	2	1	U	1	U	1	U	1	U

TABLE 1-2
DATA SUMMARY FOR FIRE TRAINING AREA GROUNDWATER SAMPLES
FFTA FS REPORT
NASA WFF - WALLOPS ISLAND, VIRGINIA

Sample ID:	Preliminary Remediation Goal	FTA-WFF14-GW5		FTAMW-101S		FTAMW-101S-DUP		FTAMW-102D	
Sample Date:		03/13/03		03/13/03		03/13/03		03/07/03	
Duplicate:				FTAMW-101S-DUP		FTAMW-101S			
Upgradient Well (Y/N):		N		N		N		N	
INORGANICS - FILTERED (ug/L)									
Arsenic	10	3	U	3	U	3	U	4.4	B
Manganese	124	48.9		116		119		**381**	
INORGANICS (ug/L)									
Arsenic	10	3	U	3	U	3	U	6.4	B
Manganese	124	50.2		116		114		**381**	
SEMIVOLATILE ORGANIC COMPOUNDS (ug/L)									
4-Methylphenol	27	5	U	5	U	5	UJ	5	U
Naphthalene	16	5	U	5	U	5	U	5	U
Pentachlorophenol	1	**20**	U	**20**	U	**20**	U	**20**	U
VOLATILE ORGANIC COMPOUNDS (ug/L)									
1,2-Dichloroethene (cis)	70	19		1	U	1	U	1	U
Benzene	5	1	U	1	U	1	U	1	U
Tetrachloroethene	5	1	U	1	U	1	U	1	U
Vinyl Chloride	2	1	U	1	U	1	U	1	U

TABLE 1-2
DATA SUMMARY FOR FIRE TRAINING AREA GROUNDWATER SAMPLES
FFTA FS REPORT
NASA WFF - WALLOPS ISLAND, VIRGINIA
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Sample ID:	**Preliminary Remediation Goal**	**FTAMW-103D**		**FTAMW-103I**		**FTAMW-103S**		**FTAMW-104S**		**FTAMW-104S-DUP**	
Sample Date:		**03/11/03**		**03/11/03**		**03/11/03**		**03/11/03**		**03/11/03**	
Duplicate:								**FTAMW-104S-DUP**		**FTAMW-104S**	
Upgradient Well (Y/N):		**N**		**N**		**N**		**N**		**N**	
INORGANICS - FILTERED (ug/L)											
Arsenic	10	3	U	3	U	3	U	3	U	3	U
Manganese	124	**240**		**388**		**191**		22.1		21	
INORGANICS (ug/L)											
Arsenic	10	3	U	3	U	3	U	3	U	3	U
Manganese	124	**286**		**361**		**183**		21.5		21	
SEMIVOLATILE ORGANIC COMPOUNDS (ug/L)											
4-Methylphenol	27	5	U	5	U	5	U	5	U	5	U
Naphthalene	16	5	U	5	U	5	U	5	U	5	U
Pentachlorophenol	1	**20**	U	**20**	U	**20**	U	**20**	U	**20**	U
VOLATILE ORGANIC COMPOUNDS (ug/L)											
1,2-Dichloroethene (cis)	70	9		55		1	U	1	U	1	U
Benzene	5	1	U	1		1	U	1	U	1	U
Tetrachloroethene	5	1	U	1		1	U	1	U	1	U
Vinyl Chloride	2	1	U	1	U	1	U	1	U	1	U

TABLE 1-2
DATA SUMMARY FOR FIRE TRAINING AREA GROUNDWATER SAMPLES
FFTA FS REPORT
NASA WFF - WALLOPS ISLAND, VIRGINIA
PAGE 5 OF 6

Sample ID:	**Preliminary Remediation Goal**	**FTAMW-105D**		**FTAMW-2D**		**FTAMW-2S**		**MW-54S**		**FTAMW-55D**		**FTAMW-55S**	
Sample Date:		**03/05/03**		**03/06/03**		**03/06/03**		**03/04/03**		**03/10/03**		**03/11/03**	
Duplicate:													
Upgradient Well (Y/N):		**N**		**N**		**N**		**N**		**N**		**N**	
INORGANICS - FILTERED (ug/L)													
Arsenic	10	3	U	3	U	3	U	3	U	5		**25.6**	
Manganese	124	**321**		3.2	B	16.6		1.3	B	**257**		**428**	
INORGANICS (ug/L)													
Arsenic	10	3	U	3	U	3	U	3	U	5.1		**25.4**	
Manganese	124	**384**		1.7	B	17.7		3.4	B	**258**		**417**	
SEMIVOLATILE ORGANIC COMPOUNDS (ug/L)													
4-Methylphenol	27	5	U	5	UR	5	U	5	U	**88**		**300**	
Naphthalene	16	5	U	5	U	5	U	5	U	5	U	**22**	
Pentachlorophenol	1	**20**	U	**20**	**UR**	**20**	U	**20**	U	**20**	U	**80**	U
VOLATILE ORGANIC COMPOUNDS (ug/L)													
1,2-Dichloroethene (cis)	70	1		1	U	1	U	1	U	1		8	
Benzene	5	1	U	1	U	1	U	1	U	1	U	2	
Tetrachloroethene	5	1	U	1	U	1	U	1	U	1	U	1	U
Vinyl Chloride	2	1	U	1	U	1	U	1	U	1	U	1	U

Data Qualifiers:
B -- Positive result is considered to be an artifact of blank contamination, and should not be considere
J -- Value is considered estimated due to exceedance of technical quality control criteria or because re
K -- Positive result is considered biased high due to exceedance of technical quality control criteria.
L -- Positive result is considered biased low due to exceedance of technical quality control criteria.
U -- Value is a non-detected result as reported by the laboratory.
UJ -- Non-detected result is considered estimated due to exceedance of technical quality control criteri
UL -- Non-detected result is considered biased low due to exceedance of technical quality control criter
UR -- Non-detected result is considered unusable due to exceedance of technical quality control criteri
NA -- No result is available/applicable for this parameter in this sample.
Highlighted cells exceed the Preliminary Remediation Goals
Database source file: S:\RITCHIEM\WALLOPS ISLAND\CTO848FTA_WOD\DATASUMDATABASES\

TABLE 1-2
DATA SUMMARY FOR FIRE TRAINING AREA GROUNDWATER SAMPLES
FFTA FS REPORT
NASA WFF - WALLOPS ISLAND, VIRGINIA
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Sample ID:	**Preliminary Remediation Goal**	**FTAMW-56D**		**FTAMW-57S**		**FTAMW-58S**		**MW-59S**		**FTAMW-60I**		**FTAMW-61I**	
Sample Date:		**03/10/03**		**03/06/03**		**03/10/03**		**03/04/03**		**03/05/03**		**03/10/03**	
Duplicate:													
Upgradient Well (Y/N):		**N**		**N**		**N**		**N**		**N**		**N**	
INORGANICS - FILTERED (ug/L)													
Arsenic	10	3	U	3	U	3	U	3	U	3	U	8.6	
Manganese	124	**2080**		36		**612**		9.1		1.2	B	**4900**	
INORGANICS (ug/L)													
Arsenic	10	3	U	3	U	3	U	3	U	3	U	**13.7**	
Manganese	124	**1990**		34.8		**563**		9		3.2	B	**4990**	
SEMIVOLATILE ORGANIC COMPOUNDS (ug/L)													
4-Methylphenol	27	5	U	5	UR	5	U	5	U	5	U	5	U
Naphthalene	16	**40**		5	UR	**21**		5	U	5	U	**66**	
Pentachlorophenol	1	**20**	U	**20**	**UR**	**20**	U	**20**	U	**20**	U	**2**	**J**
VOLATILE ORGANIC COMPOUNDS (ug/L)													
1,2-Dichloroethene (cis)	70	**360**		**110**	L	67		1	U	1	U	**460**	
Benzene	5	**14**		3	L	**12**		1	U	1	U	**28**	
Tetrachloroethene	5	1		1	UL	1	U	1	U	1	U	1	U
Vinyl Chloride	2	2		1	UL	1	U	1	U	1	U	**6**	

d present.
esult is less than the Contract Required Quantitation Limit (CRQL).

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WDFTGW.DBF data retrieved on: 07/08/03

TABLE 1-3

OCCURRENCE AND DISTRIBUTION OF RISK CONTRIBUTORS
FUTURE RESIDENTIAL GROUNDWATER USE
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA

	FFTA-RELATED		FFTA-RELATED BACKGROUND		BASE-WIDE BACKGROUND(3)	
CONTAMINANT	**Freq. of Detection(1)**	**Range of Detections(2)**	**Freq. of Detection**	**Range of Detections**	**Freq. of Detection**	**Range of Detections**
INORGANICS						
Arsenic	3/20	5.1 - 25.4	1/6	3.88	6/19	3.6 - 17.7
Iron	11/11	186 - 44,200	2/2	452 - 11,500	11/12	452 - 50,000
Manganese	18/18	9 - 4,990	2/2	8.9 - 231	15/15	4.5 - 3,110
SEMIVOLATILE ORGANIC COMPOUNDS						
bis(2-ethylhexyl) phthalate	6/17	1J - 6	1/6	7	0/11	---(4)
4-Methylphenol	2/19	88 - 300	0/6	---	0/16	---
Naphthalene	4/20	21 - 66	0/6	---	0/19	---
Pentachlorophenol	1/19	2J	0/6	---	0/19	---
VOLATILE ORGANIC COMPOUNDS						
Benzene	6/21	1 - 28	0/6	---	0/18	---
Vinyl chloride	2/21	2 - 6	0/6	---	0/15	---
1,2-DCE (cis)	10/21	1 - 460	0/6	---	1/12	1
Tetrachloroethene	2/21	1 - 1	0/6	---	0/16	---

(1) Frequency of detection indicates the number of detections and the number of total analyses for that contaminant, excluding rejected data and blank-qualified data.
(2) Units are ug/L. “J” denotes estimated value.
(3) Base-wide background results as reported in *Background Soil and Groundwater Investigation Report for the Main Base, TtNUS May 2004a.*
(4) --- denotes no positive detections for the compound.

TABLE 2-1

FEDERAL CHEMICAL-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Safe Drinking Water Act (SWDA) Regulations, MCLs	40 CFR Part 141	Relevant and Appropriate	Establishes enforceable standards for potable water for specific contaminants that have been determined to adversely affect human health.	Would be used as protective levels for groundwater or surface waters that are current or potential drinking water sources.
SDWA Regulations, National Secondary Drinking Water Standards (SMCLs)	40 CFR Part 143	To Be Considered (TBC)	Establishes welfare-based standards for public water systems for specific contaminants or water characteristics that may affect the aesthetic qualities of drinking water.	Would be used as protective levels for groundwater or surface waters that are current or potential drinking water sources.
U.S. EPA Office of Drinking Water, Health Advisories		Potential TBC	Health advisories are estimates of non-carcinogenic risk due to consumption of contaminated drinking water.	These advisories would be considered for contaminants in surface water and groundwater that is or could be used as a potable water source.
Cancer Slope Factors (CSFs)		TBC	CSFs are guidance value used to evaluate the potential carcinogenic hazard caused by exposure to contaminants.	CSFs would be considered for development of human health protection PRGs for groundwater at this site.
Reference Doses (RfDs)		TBC	RfDs are guidance values used to evaluate the potential noncarcinogenic hazard caused by exposure to contaminants.	RfDs would be considered for development of human health protection PRGs for groundwater at this site.
CWA, Federal AWQC	40 CFR Part 131	Potentially Applicable	These guidelines set concentrations of pollutants that are considered adequate to protect human health and aquatic life	The AWQC may be used as a basis for determining cleanup concentrations in the absence of State water quality standards.

TABLE 2-2

STATE CHEMICAL-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
PAGE 1 OF 2

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Virginia Surface Water Antidegradation Policy	9 VAC 25-260-30	Potentially Relevant and Appropriate	Establishes minimum standards for protecting existing water quality and uses.	Because this policy applies to all activities that potentially impact Virginia surface waters, it should be considered for remedial actions that involve a discharge to surface waters.
Virginia Numerical Criteria for Dissolved Oxygen, pH, and Maximum Temperature	9 VAC 25-260-50	Potentially Applicable	Establishes numeric criteria for specific surface water quality parameters that must be maintained to protect surface water uses.	Because these standards are specifically tailored to Virginia surface waters, they should be used in establishing discharge limits. These criteria are potentially applicable for a remedy that includes a discharge of groundwater to surface water.
Virginia Water Quality Standards	9 VAC 25-260-140	Potentially Applicable	This administrative code establishes criteria for listed pollutants to maintain surface water quality based on designated uses.	Because these standards are specifically tailored to Virginia waters, they should be used to establish cleanup concentrations rather than the Federal AWQCs. The Federal AWQCs for recreational uses, freshwater aquatic life, and non-public water supplies will be attained where a state standard does not exist.
Water Control Law -Groundwater Standards	9 VAC 25-280, Part IV	Applicable	Establishes minimum standards for groundwater quality.	Because these standards are specifically tailored to Virginia groundwater, they should be considered for developing groundwater remediation goals.
Water Control Law - Water Quality Criteria for Groundwater	9 VAC 25-280, Part V	TBC	Establishes guidance for groundwater quality.	Because these standards are specifically tailored to Virginia groundwater, they would be used for developing groundwater remediation goals.

TABLE 2-2

STATE CHEMICAL-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
PAGE 2 OF 2

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Virginia Voluntary Remediation Program	9 VAC 20-160	TBC	This administrative code establishes guidance for groundwater cleanup concentrations that can be developed on a site-by-site basis. The guidance for this administrative code also provides tables that indicated groundwater with concentrations less than the listed values are considered “free from” contamination.	These guidelines would be used in determining cleanup goals. The values provided in the tables would be considered when determining cleanup concentrations for groundwater. By definition of ARARS in the NCP, state requirements must be a state law or regulation; an environmental or facility siting law; promulgated; more stringent than the Federal requirement; identified in a timely manner; and consistently applied. These parameters must be met according to the NCP. The Virginia Voluntary Remediation Program is promulgated as law or regulation should be considered ARARs.
Department of Health Waterworks Regulations	12 VAC 5-590-10	Potentially Applicable	Establishes enforceable standards for potable water for contaminants that have been determined to adversely affect human health (MCLs/ SMCLs).	Would be used as protective concentrations for groundwater that are current or potential drinking water sources. In the absences of MCLs/SMCLs, other health-based standards or professional judgments based on risk may be employed.

TABLE 2-3

FEDERAL LOCATION-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
PAGE 1 OF 2

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Endangered Species Act Regulations	50 CFR Parts 81, 225, 402	Potentially Applicable	This act requires Federal agencies to act to avoid jeopardizing the continued existence of federally listed endangered or threatened species.	If a site investigation or remediation could potentially affect an endangered species, these regulations would apply.
Archaeological and Historic Preservation Act	36 CFR Part 62 and 65	Potentially Applicable	Establishes requirements relating to potential loss or destruction of significant scientific, historical, or archaeological data. Also requires Federal agencies to consider to existence and location of landmarks on the National Registry of Natural Landmarks to avoid undesirable impacts on such landmarks.	The existence of significant scientific, historical, archaeological data, or Natural Landmarks would be identified prior to remedial activities onsite including remedial investigations
Fish and Wildlife Coordination Act Regulations	33 CFR Subsection 320.3	Potentially Applicable	Requires that the United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service, and related state agencies be consulted prior to structural modification of any body of water, including wetlands. If modifications must be conducted, the regulation requires that adequate protection be provided for fish and wildlife	If a remedial alternative involves the alteration of a stream or wetland, these agencies would be consulted.

TABLE 2-3

FEDERAL LOCATION-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
PAGE 2 OF 2

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
National Environmental Policy Act (NEPA) Regulations, Wetlands, Floodplains, etc., Executive Order 11990	40 CFR Subsection 6.302 [a]	Potentially Applicable	These regulations contain the procedures for complying with Executive Order 11990 on wetlands protection. Appendix A states that no remedial alternative adversely affect a wetland if another practicable alternative is available. If no alternative is available, impacts from implementing the chosen alternative must be mitigated.	If remedial action affects a wetland, these regulations would apply.
NEPA Regulations, Floodplain Management, Executive Order 11988	40 CFR Part 6, Appendix A	Potentially Applicable	Appendix A describes the policy for carrying out the Executive Order regarding floodplains. If no practicable alternative exists to performing cleanup in a floodplain, potential harm must be mitigated and actions taken to preserve the beneficial value of the floodplain.	If removal actions take place in a floodplain, alternatives would be considered that would reduce the risk of flood loss and restore and preserve the floodplain.
Fish and Wildlife Conservation Act	40 CFR Section 6.302	Potentially Applicable	Requires action to be taken to protect fish and wildlife from projects affecting streams or rivers.	United States Fish and Wildlife Service (USFWS) officials would be consulted on how to minimize impacts of any remedial activities on any wildlife.

TABLE 2-4

STATE LOCATION-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Wetlands Mitigation Compensation Policy	4 VAC 20-390-10	Applicable	These regulations contain the procedures for on wetlands protection and standards for construction activities in the 100-year floodplain. These regulations also determine the extent of mitigation where wetlands are impacted.	If remedial action affects a wetland, these regulations would apply.
Chesapeake Bay Preservation Area Designation and Management Regulations	9 VAC 10-20-10	Potentially Applicable	Sites within an area designated by local government as Resource Protection Areas or Resource Management Areas must comply with these regulations. to avoid undesirable impacts.	The existence of Resource Protection Areas or Resource Management Areas would be identified prior to remedial activities onsite including remedial investigations
Virginia Natural Areas Preserve Act	Va. Code Ann. §§ 10.1-209	TBC	The provisions of this Act are applicable for project where the Department of Conservation and Recreation has accepted dedication of a natural area preserve.	If a site investigation or remediation could potentially affect a preserve area, this Act may restrict certain uses of the area and would apply.
Endangered Species Act Regulations	4 VAC 15-20-130	Potentially Applicable	These regulations from the Department of Game and Inland Fisheries prohibit the taking of endangered species. The cited regulations provide listings of endangered species and definitions of actions which constitute taking.	If a site investigation or remediation could potentially affect an endangered species, these regulations would apply.
Endangered Plant and Insect Species Act Regulations	2 VAC 5-320-10	Potentially Applicable	These regulations from the Department of Game and Inland Fisheries prohibit the taking of endangered plant and insect species.	If a site investigation or remediation could potentially affect an endangered species, these regulations would apply.
Virginia Private Well Regulations	12 VAC 5-630	Applicable	Private wells are prohibited if a source of contamination could adversely affect the well and preventative measures are not available to protect groundwater.	Wells would not be permitted at the FFTA site until groundwater has been remediated and is no longer a source of groundwater contamination.

TABLE 2-5

FEDERAL AND VIRGINIA GROUNDWATER ARARs AND TBCs FOR CONTAMINANTS OF POTENTIAL CONCERN
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA

Chemical	Safe Drinking Water Act (ug/L)		Health Advisory (mg/L) (4)		Reference Dose(1) (mg/kg/day)		Cancer Slope Factor(1) (mg/kg/day)$^{-1}$		Exposure Point Concentration	Maximum Site Concentration(1	FFTA Risk(1)
	MCL	MCLG			Oral	Inhalation	Oral	Inhalation	(ug/L)	(ug/L)	Cancer(c) Noncancer (n)
Arsenic	10	0	10-kg Child - 1 day 10-kg Child - 10 day Lifetime	- - -	$3.00 x10^{-4}$	-	$1.50x10^{0}$	$1.51x10^{1}$	9.35	25.4	$2.36x10^{-4}$ (c)
Manganese	50(2)	NA	10-kg Child - 1 day 10-kg Child - 10 day Lifetime	1 1 0.3	$2.40x10^{-2}$	$1.43x10^{-5}$	-	-	4,090	4,990	16.5 (n)
Iron	300(2)	NA	10-kg Child - 1 day 10-kg Child - 10 day Lifetime	NA NA NA	$3.00 x10^{-1}$	-	-	-	44,200	44,200	12.7 (n)
Bis(2ethylhexyl)phthalate	6(3)	0	10-kg Child - 1 day(3) 10-kg Child - 10 day(3) Lifetime(3)	- - -	$2.00x10^{-2}$	-	$1.40x10^{-2}$	$1.40x10^{-2}$	5.74	6	$2.79x10^{-6}$ (c)
4-Methylphenol	NA	NA	10-kg Child - 1 day 10-kg Child - 10 day Lifetime	NA NA NA	$5.00x10^{-3}$	-	-	-	124	300	2.28 (n)
Naphthalene	NA	NA	10-kg Child - 1 day 10-kg Child - 10 day Lifetime	0.5 0.5 0.1	$2.00x10^{-2}$	$8.60x10^{-4}$	-	-	32.8	66	1.04 (n)
Pentachlorophenol	1	0	10-kg Child - 1 day 10-kg Child - 10 day Lifetime	1 0.3 -	$3.00x10^{-2}$	-	$1.20x10^{-1}$	-	2	2	$3.8x10^{-5}$ (c)
Benzene	5	0	10-kg Child - 1 day 10-kg Child - 10 day Lifetime	0.2 0.2 -	$4.00x10^{-3}$	$8.60x10^{-3}$	$5.50x10^{-2}$	$2.70x10^{-2}$	12.6	28	$1.65x10^{-5}$ (c)
Vinyl chloride	2	0	10-kg Child - 1 day 10-kg Child - 10 day Lifetime	3 3 -	$3.00x10^{-3}$	$2.80x10^{-2}$	$7.20x10^{-1}$ (5)	$1.50x10^{-2}$	2.03	6	$2.56x10^{-5}$ (c)
1,2-DCE (cis)	70	70	10-kg Child - 1 day 10-kg Child - 10 day Lifetime	4 1 0.07	$1.00x10^{-2}$	-	-	-	321	460	2.95 (n)
Tetrachloroethene	5	0	10-kg Child - 1 day 10-kg Child - 10 day Lifetime	2 2 0.01	$1.00x10^{-2}$	$1.40x10^{-1}$	$5.40x10^{-1}$	$2.00x10^{-2}$	0.604	1	$7.39x10^{-5}$ (c)

NA Not Available.

(1) FFTA Supplemental RI (TtNUS, 2004).

(2) Non-enforceable Secondary Standard established to control taste, odor, and/or staining.

(3) Di(2-ethylhexyl) phthalate synonym listed for bis(2-ethylhexyl)phthalate.

(4) 2004 Edition of the Drinking Water Standards and Health Advisories (EPA, 2004).

(5) Cancer slope factor for oral exposure to vinyl chloride is multiplied by non-exposure duration prorated intake for the child, and summed with a prorated intake using the same slope factor (EPA, 2004). For lifetime exposure this is equivalent to using two times the slope factor listed here.

TABLE 2-6

FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
PAGE 1 OF 6

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Air/Superfund National Technical Guidance	EPA/450/1-89/001-EPA/450/1-89/004	Potential TBC	This guidance describes methodologies for predicting risks due to air release at a Superfund site.	These guidance documents would be considered when risks due to air releases from fugitive dust, air stripping, and thermal desorption are being evaluated.
Clean Air Act (CAA) Regulations, National Ambient Air Quality Standards (NAAQSs)	40 CFR Part 50	Potentially Relevant and appropriate for on-site treatment, storage, and disposal facility (TSDF) and Applicable for off-site TSDF	Establishes primary (health-based) and secondary (welfare-based) air quality standards for carbon monoxide, lead, nitrogen dioxide, particulate matter, ozone, and sulfur oxides emitted from a major source of air emissions. The NAAQSs form the basis for the regulations promulgated under the CAA. However, the NAAQSs themselves are non-enforceable and are not ARARs themselves.	Site remediation activities must comply with NAAQS. The principal application of these standards is during remedial activities resulting in exposures through dust and vapors. In general, emissions from CERCLA activities are not expected to qualify as a major source, and are therefore, not expected to be applicable requirements. However, the requirements may be determined to be relevant and appropriate for non-major sources with significantly similar emissions.
CAA Regulations, New Source Performance Standards (NSPS)	40 CFR Part 60	Potentially Relevant and Appropriate	This rule establishes NSPS for specified sources that are similar to a source that has established NSPSs (such as air stripping technologies). The NSPSs limit the emissions of a number of different pollutants, including the six criteria pollutants list (for which NAAQSs are established) as well fluorides, sulfuric acid mist, and total reduced sulfur (including hydrogen sulfide [H_2S]).	This rule may be a relevant and appropriate requirement for a new source that is similar to a source that has established NSPSs (such as air stripping technologies). If it is determined that the remedy would create potential air impacts, the response action or the equipment for the response action may qualify as a new source; therefore, these requirements would be met.
CAA National Emission Standards for Hazardous Air Pollutants (NESHAPs)	40 CFR Part 61	Potentially Applicable	NESHAPs are a set of emissions standards for specific chemicals from specific production activities.	Emissions of hazardous air pollutants would be minimized by fugitive dust control and off gas treatment from the thermal desorption facility.

TABLE 2-6

FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
CWA, National Pollution Discharge Elimination System (NPDES)	40 CFR Parts 122 through 125, and 131	Potentially Relevant and Appropriate	NPDES permits are required for any discharges to navigable waters. If remedial activities include such a discharge, the NPDES standards would be ARARs.	Any alternative which would discharge into any navigable water would require compliance with these regulations including treatment, if necessary.
CWA Regulations, National Pretreatment Standards	40 CFR Part 403	Potentially Relevant and Appropriate	Sets pretreatment standards through the National Categorical Standards of the General Pretreatment Regulations for the introduction of pollutants from non-domestic sources into publicly owned treatment works (POTWs) in order to control pollutants that pass through, cause interference, or are otherwise incompatible with treatment processes at a POTW.	If groundwater is discharged to a POTW or federally owned treatment work (FOTW), the discharge must meet local limits imposed by the POTW. A discharge from a CERCLA site must meet the POTW's pretreatment standards in the effluent of the POTW. Discharge to a POTW is considered an offsite activity and is, therefore subject to both the substantive requirements of this rule.
Federal Facilities Compliance Act of 1992	HR 2194	Potentially Relevant and Appropriate	This act amends the Solid Waste Disposal Act (SWDA) to clarify provisions concerning the application of certain requirements to federal facilities, such as providing a conditional exception to the Resource Conservation and Recovery Act's (RCRA) domestic sewage exclusion for FOTWs. In general, it allows state agencies and the U.S. EPA to enforce hazardous waste laws at government sites.	This act expands the domestic sewage exclusion policy to FOTWs. In addition, when wastewater is considered a hazardous waste under RCRA, but is mixed with domestic waste as it flows through the sewer system to the FOTW, the FOTW would not be required to meet the additional regulatory requirements for a RCRA facility.

TABLE 2-6

FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
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Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Occupational Safety and Health Act (OSHA) Regulations, General Industry Standards	29 CFR Part 1910	Applicable	Requires establishment of programs to assure worker health and safety at hazardous waste sites, including employee training requirements.	These regulations would apply to the response activities.
OSHA Regulations, Occupational Health and Safety Regulations	29 CFR Part 1910, Subpart Z	Potentially Applicable	Establishes permissible exposure limits for workplace exposure to a specific listing of chemicals.	Standards are applicable for worker exposure to OSHA hazardous chemicals during remedial activities.
OSHA Regulations, Record Keeping, Reporting, and Related Regulations	29 CFR Part 1904	Potentially Applicable	Provides record keeping and reporting requirements applicable to remedial activities.	These requirements apply to the site contractors and subcontractors and must be followed during the site work.
OSHA Regulations, Health and Safety Standards	29 CFR Part 1926	Potentially Applicable	Specifies the type of safety training, equipment, and procedures to be used during the site investigation and remediation.	The phases of the remedial response project would be executed in compliance with this regulation.
RCRA Regulations, Identification and Listing of Hazardous Wastes	40 CFR Part 261	Potentially Relevant and appropriate for on-site TSDF and Applicable for off-site TSDF	Defines the listed and characteristic hazardous wastes subject to RCRA. Appendix II contains the Toxicity Characteristic Leaching Procedure.	These regulations would apply when determining whether waste onsite is hazardous, either by being listed or by exhibiting a hazardous characteristic, as described in the regulations.

TABLE 2-6

FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
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Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
RCRA Regulations, Contingency Plan and Emergency Procedures	40 CFR 264, Subpart D	Potentially Relevant and Appropriate	Outlines requirements for emergency procedures to be followed in case of an emergency.	The administrative requirements established in this rule would be met for remedial actions involving the management of hazardous waste.
RCRA Regulations, General Facility Standards	40 CFR Subpart B, 264.10-264.18	Potentially Relevant and Appropriate	Sets the general facility requirements including general waste analysis, security measures, inspections, and training requirements. Section 264.18 establishes that a facility located in a 100-year floodplain must be designed, constructed, and maintained to prevent washout of any hazardous wastes by a 100-year flood.	If the remedial action involves construction of an onsite treatment facility, such as a groundwater treatment facility, the substantive requirements of this rule would be applicable requirements. A permitted treatment facility must be selected for offsite treatment. These regulations do not apply to the aboveground treatment or storage of hazardous waster before it is injected into underground. However, this rule may be an applicable requirement for alternatives that do not involve groundwater reinjection.
RCRA Regulations, Miscellaneous Units	40 CFR Part 264, Subpart X	Potentially Relevant and Appropriate	These standards are applicable to miscellaneous units not previously defined under existing RCRA regulations. Subpart X outlines performance requirements that miscellaneous units be designed, constructed, operated, and maintained to prevent releases to the subsurface, groundwater, and wetland that may have adverse effects on human health and the environment.	The design of proposed treatment alternatives, not specifically regulated under other subparts of RCRA, must prevent the release of hazardous constituents and future impacts on the environment. This subpart would apply to onsite construction of any treatment facility that is not previously defined under the RCRA regulation.

TABLE 2-6

FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
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Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
RCRA Regulations, Preparedness and Prevention	40 CFR Part 264, Subpart C	Potentially Relevant and Appropriate	Outlines requirements for safety equipment and spill control for hazardous waste facilities. Facilities must be designed, maintained, constructed, and operated to minimize the possibility of an unplanned release that could threaten human health or the environment.	Safety and communication equipment would be incorporated into all aspects of the remedial process and local authorities would be familiarized with site operations.
RCRA Regulations, Releases from Solid Waste Management Units (SWMUs)	40 CFR Part 264, Subpart F	Potentially Relevant and Appropriate	Establishes the requirements for SWMUs at RCRA regulated TSDFs. The scope of the regulation encompasses groundwater protection standards, point of compliance, compliance period, and requirements for groundwater monitoring.	These regulations would be followed for the treatment of hazardous waste.
RCRA Regulations, Standards for Owners and Operators of Hazardous Waste TSDF	40 CFR Part 264	Potentially Relevant and Appropriate	Establishes minimum national standards defining the acceptable management of hazardous wastes for owners and operators of facilities that treat, store, or dispose of hazardous wastes.	If remedial actions involving management of RCRA wastes at an off-site TSDF or if RCRA wastes are managed onsite, the requirements of this rule would be followed.
RCRA Regulations, Use and Management of Containers	40 CFR Part 264, Subpart I	Potentially Relevant and Appropriate	Sets standards for the storage of containers of hazardous waste.	This requirement would apply if a remedial alternative involves the storage of a hazardous waste (i.e. contaminated groundwater) in containers, prior to treatment.

TABLE 2-6

FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
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Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
RCRA Regulations, Land Disposal Restrictions (LDRs)	40 CFR Part 268	Potentially Relevant and appropriate for on-site TSDF. Applicable for off-site TSDF	This regulation prohibits the land disposal of untreated hazardous wastes and provides criteria for the treatment of hazardous waste prior to land disposal.	Remedial actions that involve treating and redepositing hazardous groundwater would comply with LDRs.
RCRA, Treatment Standards for Hazardous Debris – Thermal Desorption	40 CFR 268.45	Potentially Applicable	Sets treatment standards for utilizing thermal desorption.	Thermal desorption units would be operated in compliance with treatment standards.
SWDA Subtitle D	40 CFR 258	Potentially relevant and appropriate	Establishes design and operating criteria for solid waste (nonhazardous) landfills.	These requirements would be relevant and appropriate for landfill closure and post-closure care.
SWDA Regulations, Underground Injection Control Regulations	40 CFR Parts 144, 146, 147, and 1000	Potentially Relevant and Appropriate	Establishes minimum program and performance standards for underground injection programs. Technical criteria are included in Part 146. Also requires protection of underground sources of drinking water.	Discharge of treated groundwater, by well injection, would be in accordance with these regulations, as well as meet State Underground Injection Control Program requirements. Treated groundwater would meet SWDA standards for reinjection prior to well injection.
Department of Defense	NA	TBC	Identify Natural Resource Injury and, when practicable, redress it as part of the site assessment, investigation, and remedy selection process.	Alternatives that address natural resource injury will be developed and evaluated in the FS.
Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites	OSWER Directive 9200.4-17P	TBC	Guidelines for use of monitored natural attenuation for the remediation of contaminated soil and groundwater sites.	TBC if monitored natural attenuation is one of the selected remedial options.

TABLE 2-7

STATE ACTION-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
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Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Virginia Waste Management Act and Solid Waste Management Regulation	9 VAC 20-80	Potentially Applicable	These regulations govern the handling, storage, treatment, or disposal of solid wastes. Further, the Act provides requirements for the transportation of solid wastes.	These regulations would apply if waste onsite needed to be stored, transported, or disposed of properly.
Virginia Hazardous Waste Regulation	9 VAC 20-60	Potentially Applicable	These regulations govern the handling, storage, treatment, or disposal of hazardous waste.	These regulations would apply if waste onsite were deemed hazardous and needed to be stored, transported, or disposed of properly.
Virginia Pollutant Discharge Elimination System Permit Regulation	9 VAC 25-31-10	Potentially Applicable	This regulation governs the discharge to surface waters that must meet site-specific effluent limits.	These regulations would apply to remedial activities that involve discharges to surface water including potential sources of drinking water.
Virginia Pollutant Abatement Permit Regulation	9 VAC 25-32-10	Potentially Applicable	This regulation governs the discharge of pollutants adjacent to State waters (including groundwater) that must meet site-specific effluent discharge limits.	These regulations would apply to remedial activities that involve discharges.
Virginia Stormwater Management Act Regulation	4 VAC 3-20-10	Potentially Relevant and Appropriate	Establishes requirements for discharges of stormwater to protect the surface water of the state.	Remedial actions would consider the impact of the discharge of stormwater.
Virginia Erosion and Sediment Control Act Regulations	4 VAC 50-30-10	Potentially Relevant and Appropriate	Establishes requirements for erosion control to protect of the surface water of the state.	Remedial actions would consider the impact soil erosion and sediment control.

TABLE 2-7

STATE ACTION-SPECIFIC ARARs AND TBCs
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
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Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Virginia Water Protection Permit Regulation	9 VAC 25-210-10	Potentially Applicable	This regulation delineates the requirements applicable to activities such as dredging, filling or discharging pollutants into, or adjacent to, surface waters (the Commonwealth's definition of surface waters includes wetlands). The requirements of the regulation are in addition to those which may be found in a Corps of Engineers § 404 permit.	These regulations would apply to remedial activities that involve discharges.
Virginia Ambient Air Quality Standards	9 VAC 5-30-10	Potentially Relevant and Appropriate	This rule also establishes ambient air quality standards and air emission standards from disturbance of soil at a site, or from treatment of soil or water or from other pollutant management activities.	Although this rule is directly applicable to industrial polluters, these requirements are relevant and appropriate for a remedial action that could result in release of regulated contaminants to the atmosphere, such as may occur during air stripping or excavation.
Virginia Standards of Performance for Visible Emission and Fugitive Dust/Emissions, Standards of Performance for Toxic Pollutants, and Environmental Protection Agency National Emission Standards for Hazardous Pollutants	9 VAC 5-50-60, 9 VAC 5-50-160, and 9 VAC 5-60-60	Potentially Relevant and Appropriate	These rules establish air emission standards from disturbance of soil at a site, or from treatment of soil or water or from other pollutant management activities.	Although this rule is directly applicable to industrial polluters, these requirements are relevant and appropriate for a remedial action that could result in release of regulated contaminants to the atmosphere, such as may occur during air stripping or excavation.

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
PAGE 1 OF 6

General Response Action	Technology	Process Options	Description	Screening Comment
No Action	None	Not Applicable	No activities conducted at site to address contamination.	Required by law. Retain for baseline comparison to other technologies.
Limited Action	Monitoring	Sampling and Analysis	Periodic sampling and analysis of groundwater and other media to track the spread of contamination.	Retain to assess natural attenuation and/or migration of contaminants from site and evaluate remedial actions. Use in combination with other technologies if contaminated groundwater remains in place.
	Institutional Controls	Active Controls: Physical Barriers/ Security Guards	Fencing, markers, and warning signs to restrict site access.	Eliminate because the site is located within a limited access area and contaminated groundwater is not available for direct contact.
		Passive Controls: Deed and Land Use Restrictions, Facility Master Plan	Administrative action using property deeds to restrict future site activities and use of groundwater as source of drinking water.	Retain to limit human exposure to contaminated groundwater through the installation of wells and/or structures. Use in combination with other technologies if contaminated groundwater remains in place.
	Natural Attenuation	Naturally-Occurring Biodegradation and Dilution	Monitoring the groundwater to assess the natural processes (dilution, degradation, etc.) that affect the rate of migration and the concentrations of contaminants.	Retain. Use in combination with other technologies if contaminated groundwater remains in place.
Containment	Vertical Barriers	Slurry Wall	Low-permeability wall formed in a perimeter trench to restrict horizontal migration of groundwater.	Eliminate because the area lacks a viable confining unit to tie barrier into.
		Grout Curtain	Pressure injection of grout to form a low-permeability perimeter wall to restrict horizontal migration of groundwater.	Eliminate because the area lacks a viable confining unit to tie barrier into.

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
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General Response Action	Technology	Process Options	Description	Screening Comment
Containment (Continued)	Vertical Barriers (Continued)	Sheet Piling	Metal sheet piling driven into the ground to restrict horizontal migration of groundwater.	Eliminate because the area lacks a viable confining unit to tie barrier into.
		Hydraulic Barrier	Use of extraction wells and/or collection trenches to restrict horizontal migration of groundwater.	Eliminate the use of interceptor trenches because the contamination is too deep. Retain the use of extraction wells as a means of removal.
		Biochemical Barrier	Interception and removal of organic contaminants through injection of nutrients, oxygen release compounds (ORC$^{®}$s), and hydrogen release compounds (HRC$^{®}$s).	Eliminate because this technology is better suited to in-situ treatment and is retained for that purpose.
	Horizontal Barriers	Capping	Use of impermeable or semi-permeable materials (e.g., soil, clay, synthetic membrane) to prevent exposure to contamination and/or to reduce the vertical migration of contaminants to groundwater.	Eliminate. Capping will not address groundwater contamination. Contaminants are already present in the groundwater.
		Liner Physical Barrier	Injection of bottom sealing slurry beneath source to minimize vertical migration of groundwater.	Eliminate. Source materials are not present above groundwater and will not address groundwater contamination.
Removal	Groundwater Extraction	Extraction Wells	Series of conventional pumping wells used to remove contaminated groundwater.	Retain to remove contaminated groundwater. Use in combination with other technologies.
		Collection Trench	A permeable trench used to intercept and collect groundwater from the plume.	Eliminate because groundwater is too deep to implement an effective collection trench.

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
PAGE 3 OF 6

General Response Action	Technology	Process Options	Description	Screening Comment
In-situ Treatment	Biological – Biostimulation	Aerobic/ Anaerobic	Enhancement of biodegradation of organics in an aerobic (oxygen-rich) and/or anaerobic (oxygen-deficient) environment by injection of nutrients and ORC®/HRC®) or by injection of Bimetallic Nanoscale Particles (BNP).	Retain aerobic enhancement of the primary site organic contaminants. Anaerobic enhancement would not be effective for treatment of the primary site organic contaminants. Metals may precipitate under aerobic and more alkaline conditions.
	Biological – Bioaugmentation	Aerobic/ Anaerobic	Enhancement of biodegradation of organics in an aerobic (oxygen-rich) and/or anaerobic (oxygen-deficient) environment by injection of microbes, inoculum, and/or bacterium.	Retain aerobic bioaugmentation of the primary site organic contaminants. Anaerobic bioaugmentation would not be effective for treatment of the primary site organic contaminants. Metals may precipitate under aerobic and more alkaline conditions.
	Physical	Air Sparging (AS) or Air Sparging/ Vapor Extraction (AS/VE)	Volatilization and enhancement of biodegradation of organic compounds by supply of air with or without capture and treatment of volatilized compounds.	Retain for treatment of VOCs and SVOCs. Will also treat VOC and SVOC contaminated soil. Metals may precipitate under aerobic conditions.
		Permeable Reactive Barriers or Biological Barriers	Use of a permeable barrier which allows the passage of groundwater and reacts with the contaminants.	Eliminate because the horizontal velocity of the shallow groundwater zone is very high and the plume is not moving.
	Thermal	Dynamic Underground Stripping/Electrical Resistive Heating/ Thermal Conductive Heating	Steam injection/ electrical current/ conductive heating elements are used to create a high-temperature zone resulting in the vaporization of volatile compounds bound to soil and the movement of contaminants to a extraction wells.	Eliminate because inappropriate to the removal of relatively low concentrations of organic COCs.
In-situ Treatment (Continued)	Chemical (Continued)	Enhanced Oxidation	Chemical destruction of organic COCs through oxidation with hydrogen peroxide and ferrous iron (Fenton's Reagent) or potassium permanganate.	Eliminate because inappropriate to the removal of relatively low concentrations of organic COCs.

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
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General Response Action	Technology	Process Options	Description	Screening Comment
Ex-situ Treatment	Biological	Aerobic/ Anaerobic	Natural degradation of organic COCs via microorganisms in an aerobic (oxygen-rich) or anaerobic (oxygen-deficient) environment.	Retain aerobic for treatment of the primary site organic contaminants. Anaerobic would not be effective for treatment of the primary site organic contaminants.
	Physical	Filtration	Separation of suspended solids from water via entrapment in a bed of granular media or membrane.	Retain as a potential pretreatment step prior to certain ex-situ organic removal processes.
		Reverse Osmosis	Use of high pressure and membranes to separate dissolved materials from water.	Eliminate because primarily applicable to the removal of dissolved inorganic compounds.
		Air Stripping	Contact of water with air to remove VOCs.	Retain for removal of VOCs.
		Granular Activated Carbon (GAC) Adsorption	Separation of dissolved contaminants from water via adsorption onto activated carbon.	Retain for removal of VOCs and SVOCs.
		Solvent Extraction	Separation of contaminants from a solution by contact with an immiscible liquid with a higher affinity for the contaminants of concern.	Eliminate because not applicable to the removal of relatively low concentrations of organic contaminants. Solvent extraction is rarely used for groundwater remediation.
		Dewatering	Mechanical removal of free water from wastes using equipment such as a filter press or a vacuum filter.	Retain to be used in combination with other technologies. Dewatering of sludges resulting from precipitation processes for metals removal may be required.
Ex-situ Treatment (Continued)	Physical (Continued)	Distillation	Vaporization of a liquid following by condensation of the vapors to concentrate various constituents.	Eliminate because not applicable to the removal of relatively low concentrations of contaminants.
		Equalization	Dampening of flow and/or contaminant concentration variation in a large vessel to promote constant discharge rate and water quality.	Retain to be used in combination with other technologies. Equalization is feasible at the front end of a groundwater treatment system.
		Sedimentation	Separation of solids from water via	Retain as a potential pretreatment step prior

General Response Action	Technology	Process Options	Description	Screening Comment
			gravity settling.	to certain organics ex-situ removal processes.
Ex-situ Treatment (Continued)	Chemical	Coagulation/ Flocculation	Use of chemicals to neutralize surface charges and promote attraction of colloidal particles to facilitate settling.	Retain as a potential pretreatment step prior to certain ex-situ organic removal processes.
		Neutralization/pH Adjustment	Use of acids or bases to counteract excess pHs.	Retain as a potential pretreatment step or final step prior to discharge.
		Chemical Precipitation	Use of reagents to convert soluble compounds into insoluble compounds.	Retain. Precipitation may be warranted for dissolved metals removal.
		Ion Exchange	Removal of dissolved ions from a liquid through exchange with similarly-charged ions held by electrostatic forces to the active sites on a synthetic resin that is contacted with the liquid to be treated.	Eliminate because primarily applicable to removal of dissolved inorganic compounds.
	Chemical (Continued)	Enhanced Oxidation	Use of oxidizers such as ozone, hydrogen peroxide, or potassium permanganate to breakdown certain organic compounds through cleavage of the C-C bond.	Eliminate because not applicable to the removal of relatively low concentrations of contaminants.
		Reduction	Use of reducers such as sulfur dioxide, sulfite compounds, or ferrous iron compounds to decrease the oxidation state of organic and inorganic compounds.	Eliminate because not applicable to organic COCs.
Discharge/ Disposal	Surface Discharge	Direct or Indirect Discharge	Discharge of collected/treated water.	Retain for discharge of treated groundwater. A flowing surface water body is in the area for direct discharge with a NPDES permit or a POTW is near by for indirect discharge.

TABLE 3-1

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
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General Response Action	Technology	Process Options	Description	Screening Comment
Discharge/ Disposal (Continued)	Surface Discharge (Continued)	Off-Site Treatment Facility	Treatment and disposal of water at a permitted off-site treatment works.	Eliminate because impractical due to large volume of treated groundwater.
	Subsurface Discharge	Reinjection	Use of injection wells, spray irrigation, or infiltration to discharge collected/treated groundwater underground.	Eliminate because groundwater is too shallow for effective discharge to the surficial aquifer and because no suitable area is located close to the FFTA site for deep well injection. Spray irrigation requires relatively large areas that are not available at this facility.

TABLE 3-2
DATA SUMMARY OF FIELD RESULTS
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA

Sample ID:	**FTA-MW-1**		**FTA-MW-101S**		**FTA-MW-102D**		**FTA-MW-103D**		**FTA-MW-103I**		**FTA-MW-103S**		**FTA-MW-104S**		**FTA-MW-105D**		**FTA-MW-2D**	
Sample Date:	**03/03/03**		**03/13/03**		**03/07/03**		**03/11/03**		**03/11/03**		**03/11/03**		**03/11/03**		**03/05/03**		**03/06/03**	
MISCELLANEOUS PARAMETERS																		
Alkalinity (mg/L as $CaCO_3$)	0.87		75		40		25		45		25		15		15		30	
Conductivity (mS/cm)	0.164		0.084		0.098		0.1		0.143		0.071		0.093		0.095		0.077	
Dissolved Oxygen (mg/L)	9.77		2.28		3.02		1.6		0.93		5.9		3.23		2.95		6.29	
Ferrous Iron (mg/L)		ND	1			ND		ND		ND		ND		ND		ND	0.5	
Hydrogen Sulfide (mg/L)		ND		ND		ND		ND		ND		ND		ND		ND		ND
Oxidation Reduction Potential (mv)	152		122		157		2.39		107		169		22.5		170		234	
pH (SU)	7.23		6.28		5.69		5.6		6.01		5.88		6.12		5.51		5.64	
Salinity (%)		ND		ND		ND		ND		ND		ND		ND		ND		ND
Temperature (°C)	15.3		15.3		14.7		15.3		14.8		11.2		11.5		16.1		15.8	
Turbidity (NTU)	20		5.07		10		9.3			ND		ND	6.75		5.1		6.4	

Sample ID:	**FTA-MW-2S**		**FTA-MW-53S**		**FTA-MW-54S**		**FTA-MW-55D**		**FTA-MW-55S**		**FTA-MW-56D**		**FTA-MW-57S**		**FTA-MW-58S**		**FTA-MW-59S**	
Sample Date:	**03/06/03**		**03/04/03**		**03/04/03**		**03/10/03**		**03/11/03**		**03/10/03**		**03/06/03**		**03/10/03**		**03/04/03**	
MISCELLANEOUS PARAMETERS																		
Alkalinity (mg/L as $CaCO_3$)	20		10		20		1.17		85		75		20		2.92		20	
Conductivity (mS/cm)	0.039		0.08		0.062		0.069		0.183		0.154		0.09		0.112		0.098	
Dissolved Oxygen (mg/L)	8.07		9.75		8.41		3.06		0.46		0.67		2.83		5.59		7.17	
Ferrous Iron (mg/L)		ND		ND		ND	3		3.6			ND		ND		ND		ND
Hydrogen Sulfide (mg/L)		ND		ND		ND		ND	0.5			ND		ND		ND	NA	
Oxidation Reduction Potential (mv)	226		220		234		50		-96		44		92		167		181	
pH (SU)	5.64		5.75		5.79		6.48		7.14		6.12		5.64		7.13		5.52	
Salinity (%)		ND		ND		ND		ND		ND		ND		ND		ND		ND
Temperature (°C)	15		13.9		15.1		14.8		14		15.1		14.7		12.6		13.8	
Turbidity (NTU)	7.6		3.7		8		8.22		5.1		1		1.6		5.38		1.09	

Sample ID:	**FTA-MW-60I**		**FTA-MW-61I**		**FTA-WFF14-GW3**		**FTA-WFF14-GW4**		**FTA-WFF14-GW5**	
Sample Date:	**03/05/03**		**03/10/03**		**03/13/03**		**03/13/03**		**03/13/03**	
MISCELLANEOUS PARAMETERS										
Alkalinity (mg/L as $CaCO_3$)	15		105		100		20		40	
Conductivity (mS/cm)	0.074		0.179		0.171		0.075		0.094	
Dissolved Oxygen (mg/L)	8.72		0.56		4.9		5.78		2.4	
Ferrous Iron (mg/L)		ND	9.5		0.6			ND	2.1	
Hydrogen Sulfide (mg/L)		ND		ND		ND		ND	0.3	
Oxidation Reduction Potential (mv)	223		-45		132		245		16	
pH (SU)	5.84		6.35		6.52		5.62		5.98	
Salinity (%)		ND		ND		ND		ND		ND
Temperature (°C)	14.3		14.9		14.5		10.2		12.5	
Turbidity (NTU)	6		9		0.78		5.1		4.7	

Data Qualifiers:
ND -- Not detected.
NA -- No result is available/applicable for this parameter in this sample.

TABLE 5-1

SUMMARY OF COMPARATIVE ANALYSIS OF GROUNDWATER REMEDIAL ALTERNATIVES
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
PAGE 1 OF 2

Evaluation Criteria	Alternative 1: No Action	Alternative 2: Natural Attenuation, Institutional Controls and Monitoring	Alternative 3: In-Situ Biological Treatment (Biostimulation), Institutional Controls, and Monitoring	Alternative 4: In-Situ Biological Treatment (Bioaugmentation), Institutional Controls, and Monitoring	Alternative 5: In-Situ AS Treatment, Institutional Controls, and Monitoring
Overall Protection of Human Health and Environment	Would not be protective of human health and the environment because no action would occur. Migration of COCs would continue and remain undetected.	Would be protective of human health and the environment because natural attenuation would reduce COC concentrations down to cleanup goals over a reasonable timeframe. Institutional controls and monitoring would provide immediate protection until the cleanup goals are met by restricting use of the aquifer for drinking purposes and checking for potential migration of COCs.	Would be more protective of human health and the environment than Alternative 2 because, in addition to institutional controls and monitoring, it would feature active treatment that would accelerate the removal of COCs.	Would be more protective of human health and the environment than Alternative 2 because, in addition to institutional controls and monitoring, it would feature active treatment that would accelerate the removal of COCs. Would be as protective of human health and the environment as Alternative 3.	Would be as protective of human health and the environment as Alternatives 3 and 4 because it would provide most of the same protective components (i.e., institutional controls, and monitoring) and also accelerate the removal of COCs, but through in-situ AS treatment rather than in-situ bioremediation.
Compliance with ARARs and TBCs:					
Chemical-Specific	Would not comply.	Would eventually comply.	Would eventually comply.	Would eventually comply.	Would eventually comply.
Location-Specific	Would not comply.	Would comply.	Would comply.	Would comply.	Would comply.
Action-Specific	Not applicable.	Would comply.	Would comply.	Would comply.	Would comply.
Long-Term Effectiveness and Permanence	Would have very limited long-term effectiveness and permanence because no action would occur. Contaminant reduction or migration would remain undetected because no monitoring would occur.	Would be long-term effective and permanent. Natural attenuation would eventually reduce COC concentrations down to cleanup goals. Institutional controls would effectively prevent unacceptable human health and ecological risk from exposure to contaminated groundwater. Monitoring would effectively evaluate the progress of remediation and detect potential migration of COCs.	Would be more long-term effective and permanent than Alternative 2 by accelerating the removal of COCs through active in-situ bioremediation. However, the effectiveness of ORC® injection would have to be verified through treatability testing. The long-term effectiveness and permanence of the institutional controls, and monitoring would be the same as for Alternative 2.	Would be more long-term effective and permanent than Alternative 2 by accelerating the removal of COCs through active in-situ bioremediation. However, the effectiveness of CL-Out injection would have to be verified through treatability testing. The long-term effectiveness and permanence of the institutional controls, and monitoring would be the same as for Alternative 2.	Would be slightly more long-term effective and permanent than Alternatives 3 and 4 because it would provide the same accelerated removal of COCs, but through in-situ AS treatment that does not need to be tested. The long-term effectiveness and permanence of the institutional controls and monitoring would be the same as for Alternative 2.
Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment	Would not reduce contaminant toxicity, mobility, or volume through treatment because no treatment would occur.	Would not reduce contaminant toxicity, mobility, or volume through active treatment. The irreversible reduction of contaminant toxicity and volume by natural degradation would be monitored.	Would irreversibly and permanently reduce contaminant toxicity, mobility, and volume by removing an estimated 127 pounds of contaminants through in-situ bioremediation.	Would irreversibly and permanently reduce contaminant toxicity, mobility, and volume by removing an estimated 127 pounds of contaminants through in-situ bioremediation.	Would irreversibly and permanently reduce contaminant toxicity, mobility, and volume by removing an estimated 127 pounds of contaminants through in-situ AS treatment.
Short-Term Effectiveness	Would not result in any short-term risk to site workers or adversely impact the surrounding community or environment because no action would occur. The RAOs would never be achieved with the implementation of this alternative.	Would result in a slight possibility of exposing site workers to contaminated groundwater as a result of monitoring activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures. There would be no risk to the surrounding community and environment. The first RAO would be achieved immediately upon implementation of the institutional controls and monitoring. The second RAO and the cleanup goals would be met within 5 to 10 years.	Would result in a possibility of exposing site workers to contaminated groundwater as a result of bioremediation and monitoring activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures. There would be no risk to the surrounding community and environment. The first RAO would be achieved immediately upon implementation of the institutional controls and monitoring. The second RAO and the cleanup goals would be met within 5 years.	Would result in a possibility of exposing site workers to contaminated groundwater as a result of bioremediation and monitoring activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures. There would be no risk to the surrounding community and environment. The first RAO would be achieved immediately upon implementation of the institutional controls and monitoring. The second RAO and the cleanup goals would be met within 5 years.	Would result in a possibility of exposing site workers to contaminated groundwater as a result of the installation and O&M of the in-situ AS treatment system and of monitoring activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures. There would be no risk to the surrounding community and environment. The first RAOs would be achieved immediately upon implementation of the institutional controls and monitoring. The second RAO and the cleanup goals would be met within 4 years.

TABLE 5-1

SUMMARY OF COMPARATIVE ANALYSIS OF GROUNDWATER REMEDIAL ALTERNATIVES
FFTA FS REPORT
NASA WFF – WALLOPS ISLAND, VIRGINIA
PAGE 2 OF 2

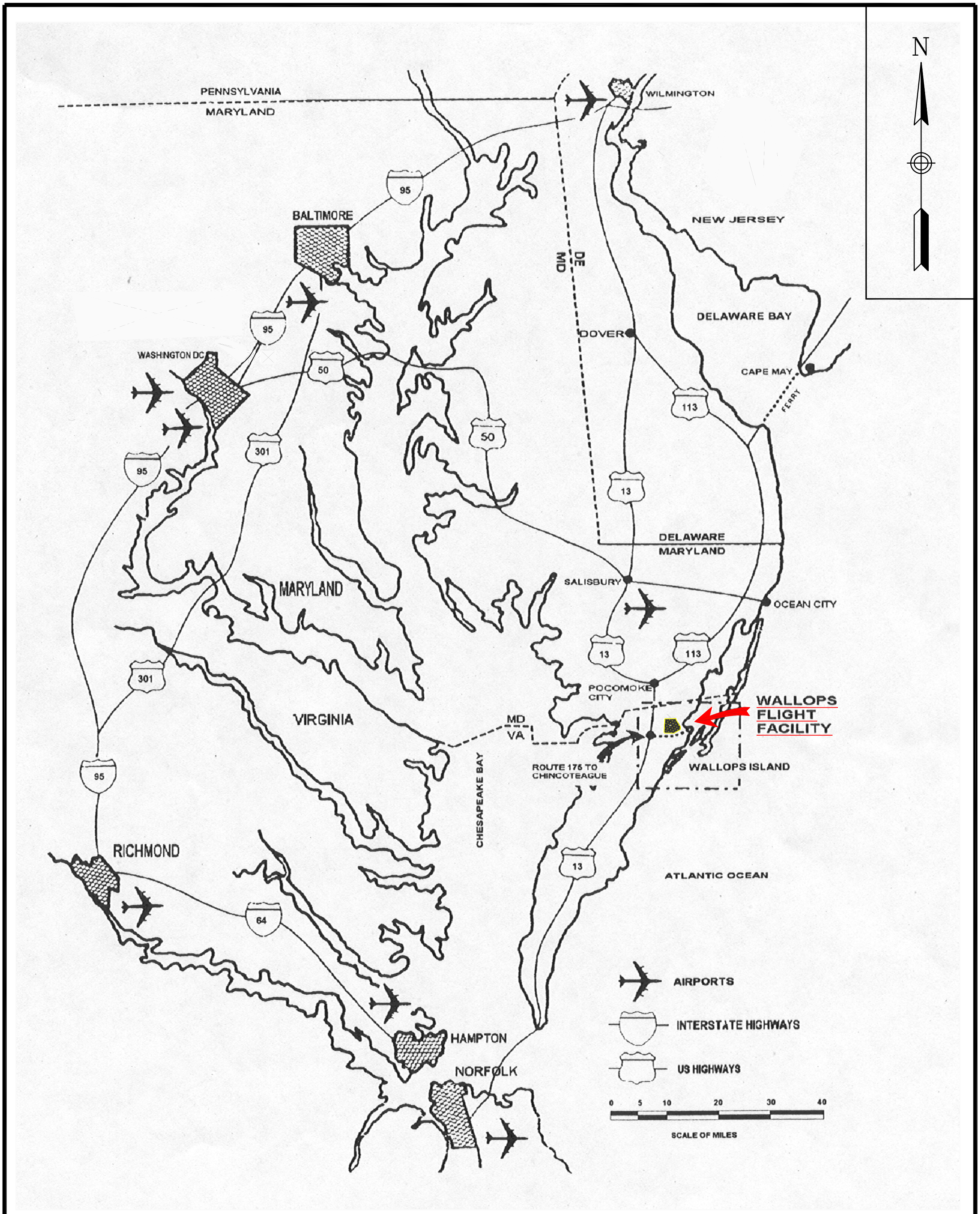
Evaluation Criteria	Alternative 1: No Action	Alternative 2: Natural Attenuation, Institutional Controls and Monitoring	Alternative 3: In-Situ Biological Treatment (Biostimulation), Institutional Controls, and Monitoring	Alternative 4: In-Situ Biological Treatment (Bioaugmentation), Institutional Controls, and Monitoring	Alternative 5: In-Situ AS Treatment, Institutional Controls, and Monitoring
Implementability	Technical and administrative implementation would be extremely simple because there would be no action to implement.	Technical implementation of the monitoring would be simple. Administrative implementation of the institutional controls would be simple.	Technical implementation of the in-situ bioremediation would be simple although it would create temporary site disruptions, and the number of qualified contractors would be limited. Technical implementation of the monitoring would be simple. Administrative implementation of the institutional controls would be simple. A construction permit might be required for installation of the ORC® injection points. A UIC permit will be required.	Technical implementation of the in-situ bioremediation would be simple although it would create temporary site disruptions, and the number of qualified contractors would be limited. Technical implementation of the monitoring would be simple. Administrative implementation of the institutional controls would be simple. A construction permit might be required for installation of the CL-Out injection points. A UIC permit will be required.	Technical implementation of the in-situ AS treatment would be significantly more complex than that of in-situ bioremediation and create much greater site disruptions. However, implementation would still be technically possible and site disruptions would be acceptable. Technical implementation of the monitoring would be simple. Administrative implementation of the institutional controls would be simple. Construction permits would be required for the installation of the in-situ AS treatment systems.
Costs:					Entire Contaminant Plume
Capital	$0	$11,000	$133,000	$456,000	$543,000
NPW of O&M	$0	$480,000 (10 Years)	$585,000 (10 Years)	$580,000 (10 Years)	$571,000 (10 Years)
NPW	$0	$491,000 (10 Years)	$718,000 (10 Years)	$1,036,000 (10 Years)	$1,114,000 (10 Years)
					Source Area
					$327,000
					$483,000 (10 Years)
					$810,000 (10 Years)

NOTES:

ARARs	Applicable or Relevant and Appropriate Requirements
AS	Air sparging
COCs	Chemicals of concern
HRC®	Hydrogen release compound
NPDES	National Pollutant Discharge Elimination System
NPW	Net present worth
O&M	Operation and maintenance
ORC®	Oxygen release compound
RAO	Remedial Action Objective
TBC	To-be-considered (criterion)

FIGURES

4740 NASA-WallopsIsland\FFTA RI\4740CP12.dwg 07/07/04 MKB PHL

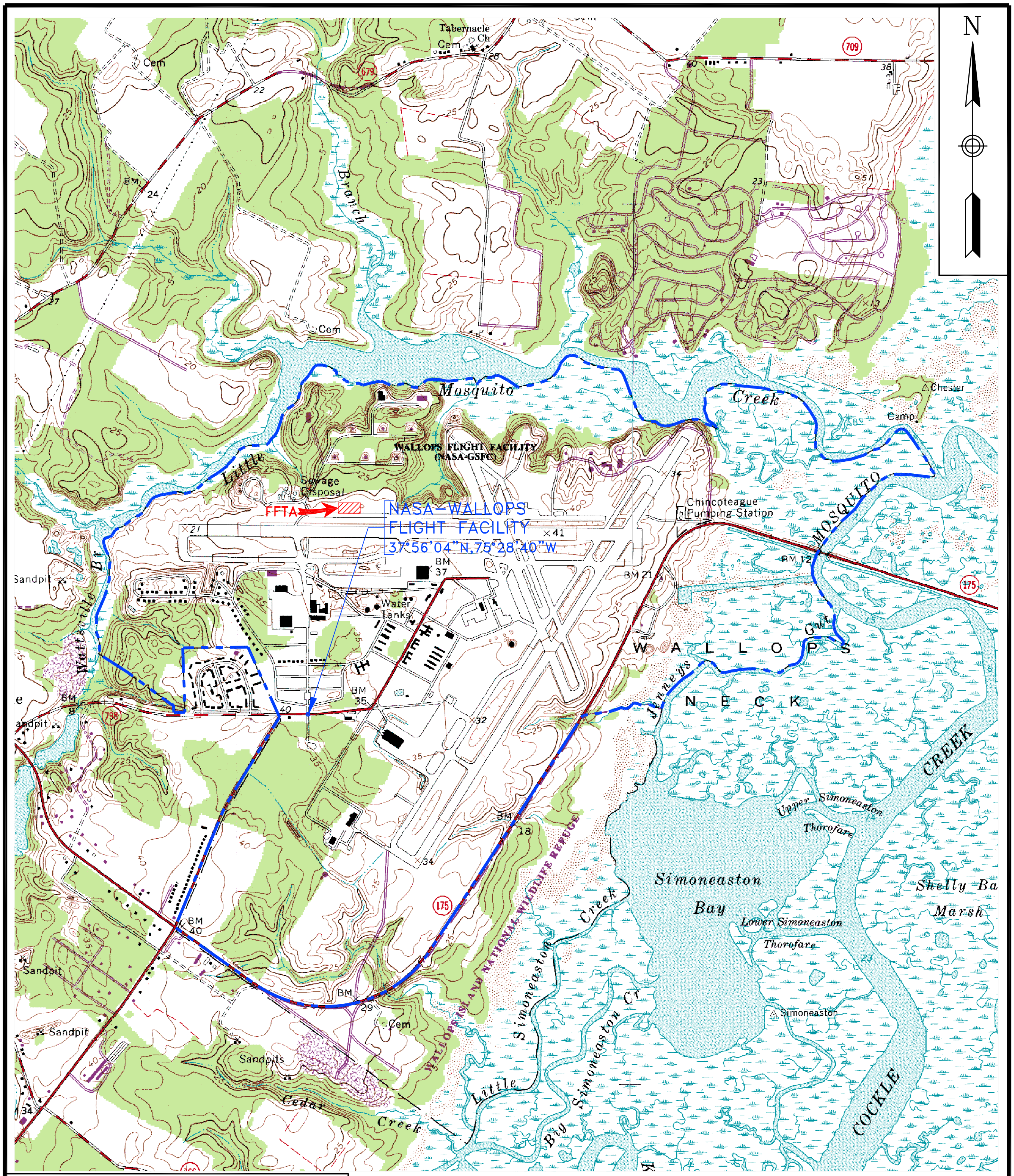


TETRA TECH NUS, INC.

SITE LOCATION MAP
OF
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

SCALE	AS NOTED
FILE:	4740CP12 MKB PHL
REV	
DATE	7/7/04
FIGURE NUMBER	FIGURE 1-1

4740 NASA-WallopsIsland\FFTA RI\4740CP11.dwg 07/07/04 MKB PHL



0 2500 5000

SCALE IN FEET

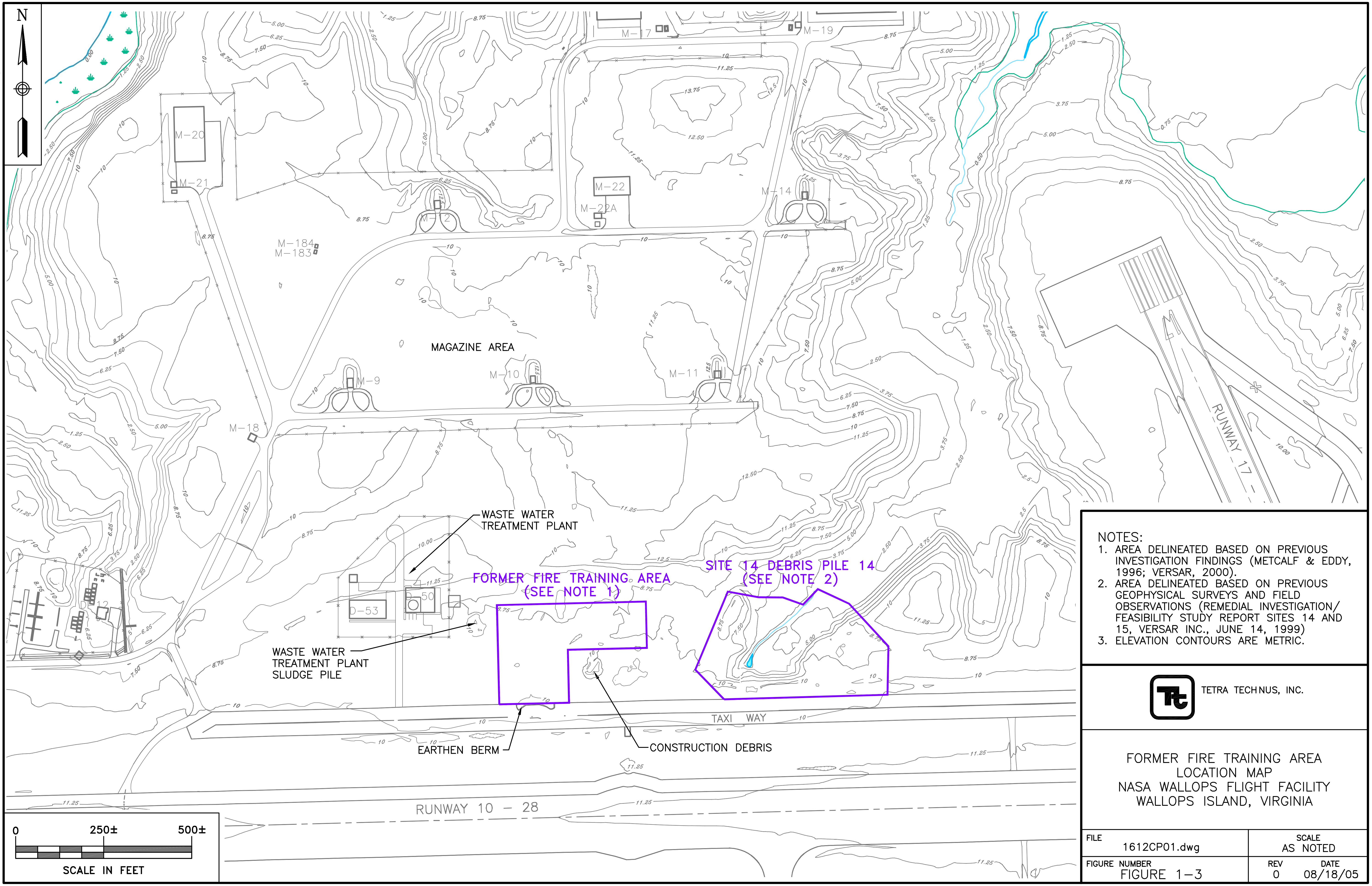
SOURCE: U.S.G.S. 7.5' QUADRANGLE MAP, CHINCOTEAGUE WEST, VA., (37075-H4-TF-024) PHOTOINSPECTED 1989.

TETRA TECH NUS, INC.

STUDY AREA LOCATION MAP
OF
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

SCALE	AS NOTED
FILE:	4740CP11 MKB PHL
REV	DATE 7/7/04
FIGURE NUMBER	FIGURE 1-2

1612\1111\1612CP01.dwg 08/17/05 MKB



NOTES:
1. AREA DELINEATED BASED ON PREVIOUS INVESTIGATION FINDINGS (METCALF & EDDY, 1996; VERSAR, 2000).
2. AREA DELINEATED BASED ON PREVIOUS GEOPHYSICAL SURVEYS AND FIELD OBSERVATIONS (REMEDIAL INVESTIGATION/FEASIBILITY STUDY REPORT SITES 14 AND 15, VERSAR INC., JUNE 14, 1999)
3. ELEVATION CONTOURS ARE METRIC.

TETRA TECH NUS, INC.

FORMER FIRE TRAINING AREA
LOCATION MAP
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	SCALE
1612CP01.dwg	AS NOTED

FIGURE NUMBER	REV	DATE
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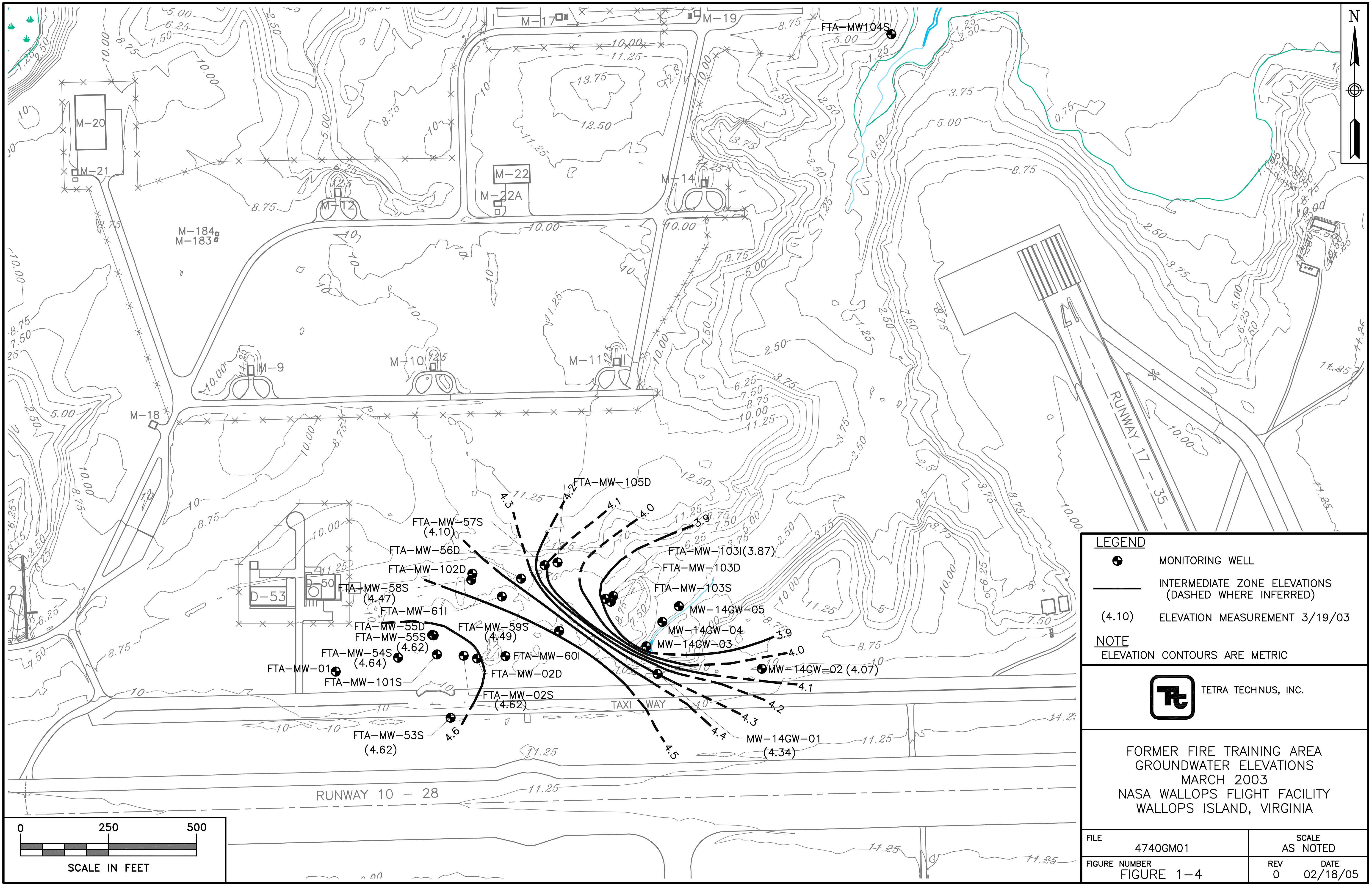
4740 NASA-Wallopsisland\4740GM01.DWG 02/18/05 MKB



LEGEND

●	MONITORING WELL
──	INTERMEDIATE ZONE ELEVATIONS (DASHED WHERE INFERRED)
(4.10)	ELEVATION MEASUREMENT 3/19/03

NOTE

ELEVATION CONTOURS ARE METRIC

TETRA TECH NUS, INC.

FORMER FIRE TRAINING AREA
GROUNDWATER ELEVATIONS
MARCH 2003
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	SCALE
4740GM01	AS NOTED

FIGURE NUMBER	REV	DATE
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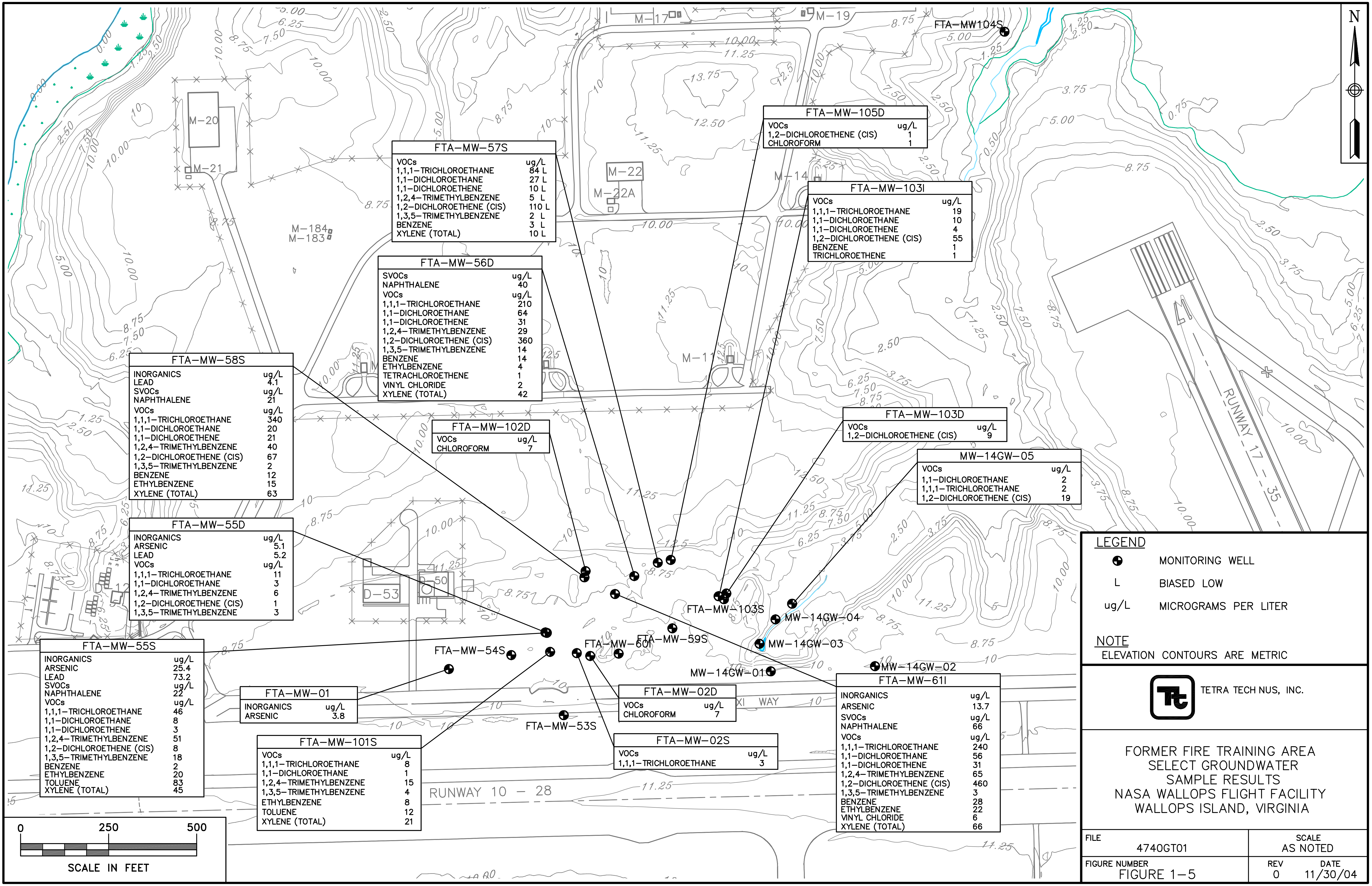


FTA-MW-57S

VOCs	ug/L
1,1,1-TRICHLOROETHANE	84 L
1,1-DICHLOROETHANE	27 L
1,1-DICHLOROETHENE	10 L
1,2,4-TRIMETHYLBENZENE	5 L
1,2-DICHLOROETHENE (CIS)	110 L
1,3,5-TRIMETHYLBENZENE	2 L
BENZENE	3 L
XYLENE (TOTAL)	10 L

FTA-MW-56D

SVOCs	ug/L
NAPHTHALENE	40
VOCs	ug/L
1,1,1-TRICHLOROETHANE	210
1,1-DICHLOROETHANE	64
1,1-DICHLOROETHENE	31
1,2,4-TRIMETHYLBENZENE	29
1,2-DICHLOROETHENE (CIS)	360
1,3,5-TRIMETHYLBENZENE	14
BENZENE	14
ETHYLBENZENE	4
TETRACHLOROETHENE	1
VINYL CHLORIDE	2
XYLENE (TOTAL)	42

FTA-MW-58S

INORGANICS	ug/L
LEAD	4.1
SVOCs	ug/L
NAPHTHALENE	21
VOCs	ug/L
1,1,1-TRICHLOROETHANE	340
1,1-DICHLOROETHANE	20
1,1-DICHLOROETHENE	21
1,2,4-TRIMETHYLBENZENE	40
1,2-DICHLOROETHENE (CIS)	67
1,3,5-TRIMETHYLBENZENE	2
BENZENE	12
ETHYLBENZENE	15
XYLENE (TOTAL)	63

FTA-MW-102D

VOCs	ug/L
CHLOROFORM	7

FTA-MW-105D

VOCs	ug/L
1,2-DICHLOROETHENE (CIS)	1
CHLOROFORM	1

FTA-MW-103I

VOCs	ug/L
1,1,1-TRICHLOROETHANE	19
1,1-DICHLOROETHANE	10
1,1-DICHLOROETHENE	4
1,2-DICHLOROETHENE (CIS)	55
BENZENE	1
TRICHLOROETHENE	1

FTA-MW-103D

VOCs	ug/L
1,2-DICHLOROETHENE (CIS)	9

MW-14GW-05

VOCs	ug/L
1,1-DICHLOROETHANE	2
1,1,1-TRICHLOROETHANE	2
1,2-DICHLOROETHENE (CIS)	19

FTA-MW-55D

INORGANICS	ug/L
ARSENIC	5.1
LEAD	5.2
VOCs	ug/L
1,1,1-TRICHLOROETHANE	11
1,1-DICHLOROETHANE	3
1,2,4-TRIMETHYLBENZENE	6
1,2-DICHLOROETHENE (CIS)	1
1,3,5-TRIMETHYLBENZENE	3

FTA-MW-55S

INORGANICS	ug/L
ARSENIC	25.4
LEAD	73.2
SVOCs	ug/L
NAPHTHALENE	22
VOCs	ug/L
1,1,1-TRICHLOROETHANE	46
1,1-DICHLOROETHANE	8
1,1-DICHLOROETHENE	3
1,2,4-TRIMETHYLBENZENE	51
1,2-DICHLOROETHENE (CIS)	8
1,3,5-TRIMETHYLBENZENE	18
BENZENE	2
ETHYLBENZENE	20
TOLUENE	83
XYLENE (TOTAL)	45

FTA-MW-01

INORGANICS	ug/L
ARSENIC	3.8

FTA-MW-101S

VOCs	ug/L
1,1,1-TRICHLOROETHANE	8
1,1-DICHLOROETHANE	1
1,2,4-TRIMETHYLBENZENE	15
1,3,5-TRIMETHYLBENZENE	4
ETHYLBENZENE	8
TOLUENE	12
XYLENE (TOTAL)	21

FTA-MW-02D

VOCs	ug/L
CHLOROFORM	7

FTA-MW-02S

VOCs	ug/L
1,1,1-TRICHLOROETHANE	3

FTA-MW-61I

INORGANICS	ug/L
ARSENIC	13.7
SVOCs	ug/L
NAPHTHALENE	66
VOCs	ug/L
1,1,1-TRICHLOROETHANE	240
1,1-DICHLOROETHANE	56
1,1-DICHLOROETHENE	31
1,2,4-TRIMETHYLBENZENE	65
1,2-DICHLOROETHENE (CIS)	460
1,3,5-TRIMETHYLBENZENE	3
BENZENE	28
ETHYLBENZENE	22
VINYL CHLORIDE	6
XYLENE (TOTAL)	66

LEGEND

●	MONITORING WELL
L	BIASED LOW
ug/L	MICROGRAMS PER LITER

NOTE

ELEVATION CONTOURS ARE METRIC

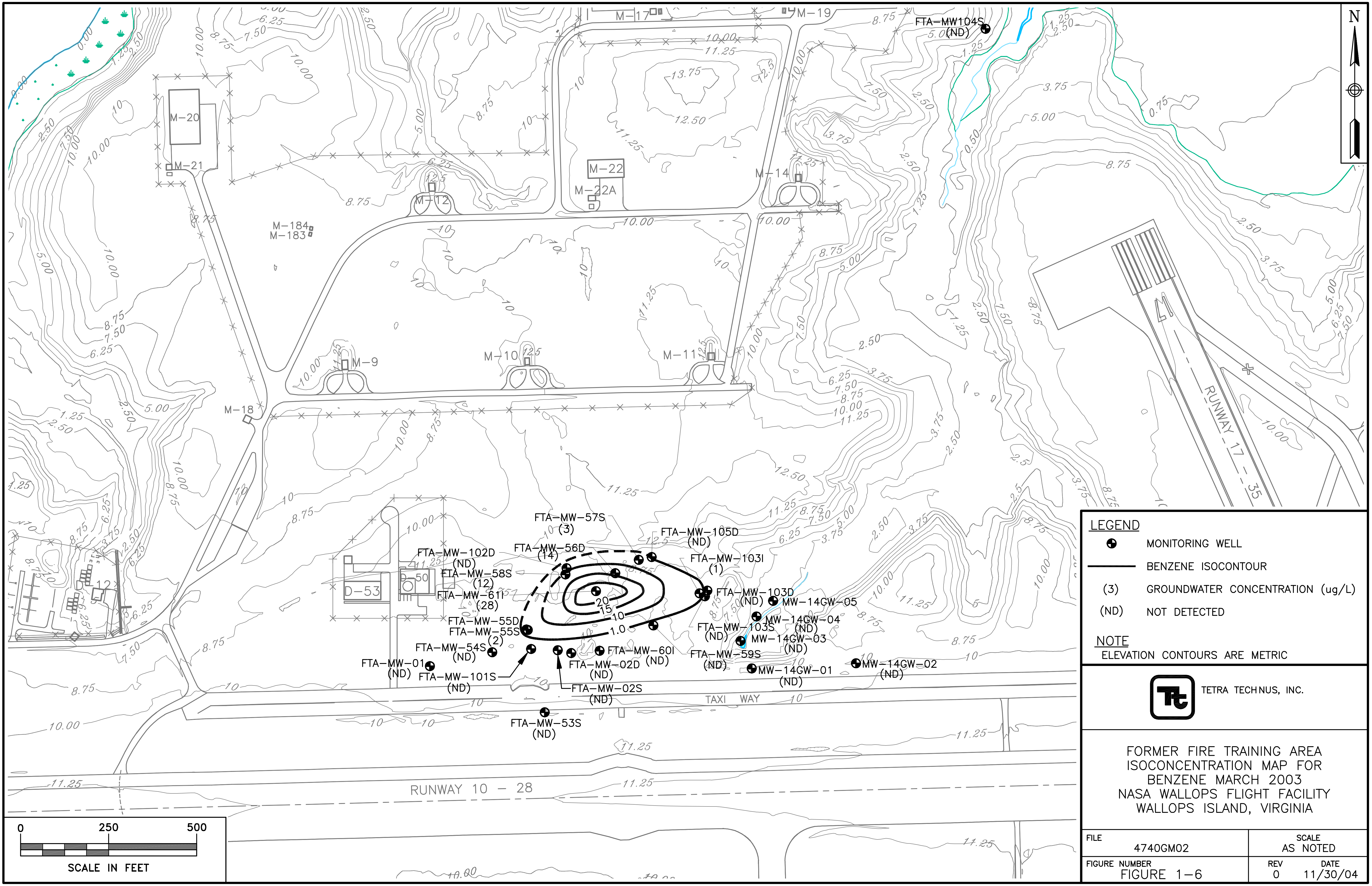
TETRA TECH NUS, INC.

FORMER FIRE TRAINING AREA
SELECT GROUNDWATER
SAMPLE RESULTS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	SCALE
4740GT01	AS NOTED

FIGURE NUMBER	REV	DATE
FIGURE 1-5	0	11/30/04

4740 NASA-Wallopsisland\4740GM02.DWG 11/30/04 MKB



LEGEND

●	MONITORING WELL
──	BENZENE ISOCONTOUR
(3)	GROUNDWATER CONCENTRATION (ug/L)
(ND)	NOT DETECTED

NOTE

ELEVATION CONTOURS ARE METRIC

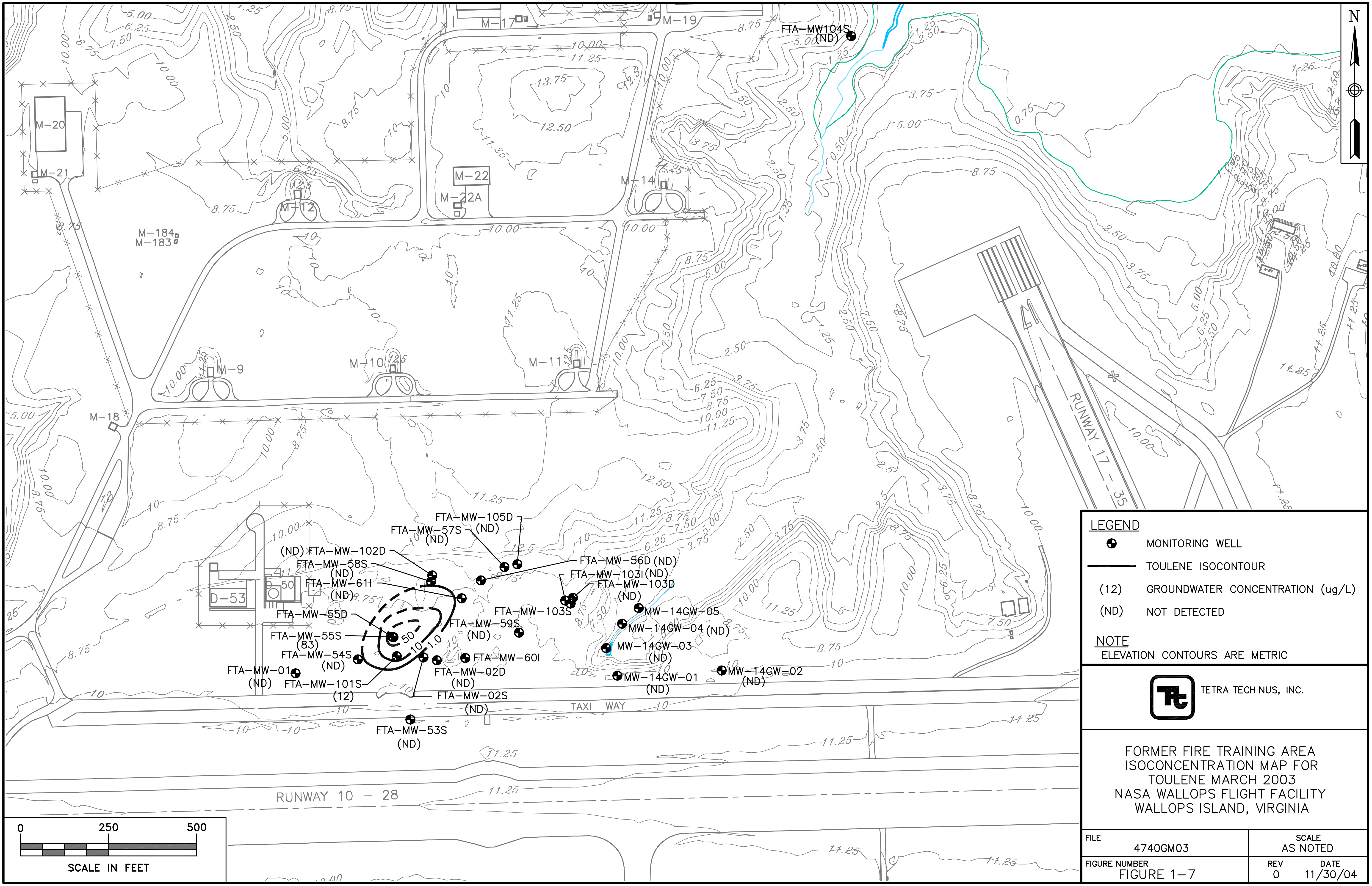
TETRA TECH NUS, INC.

FORMER FIRE TRAINING AREA
ISOCONCENTRATION MAP FOR
BENZENE MARCH 2003
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	SCALE
4740GM02	AS NOTED

FIGURE NUMBER	REV	DATE
FIGURE 1-6	0	11/30/04

4740 NASA-Wallopsisland\4740GM03.DWG 11/30/04 MKB



LEGEND

●	MONITORING WELL
―	TOULENE ISOCONTOUR
(12)	GROUNDWATER CONCENTRATION (ug/L)
(ND)	NOT DETECTED

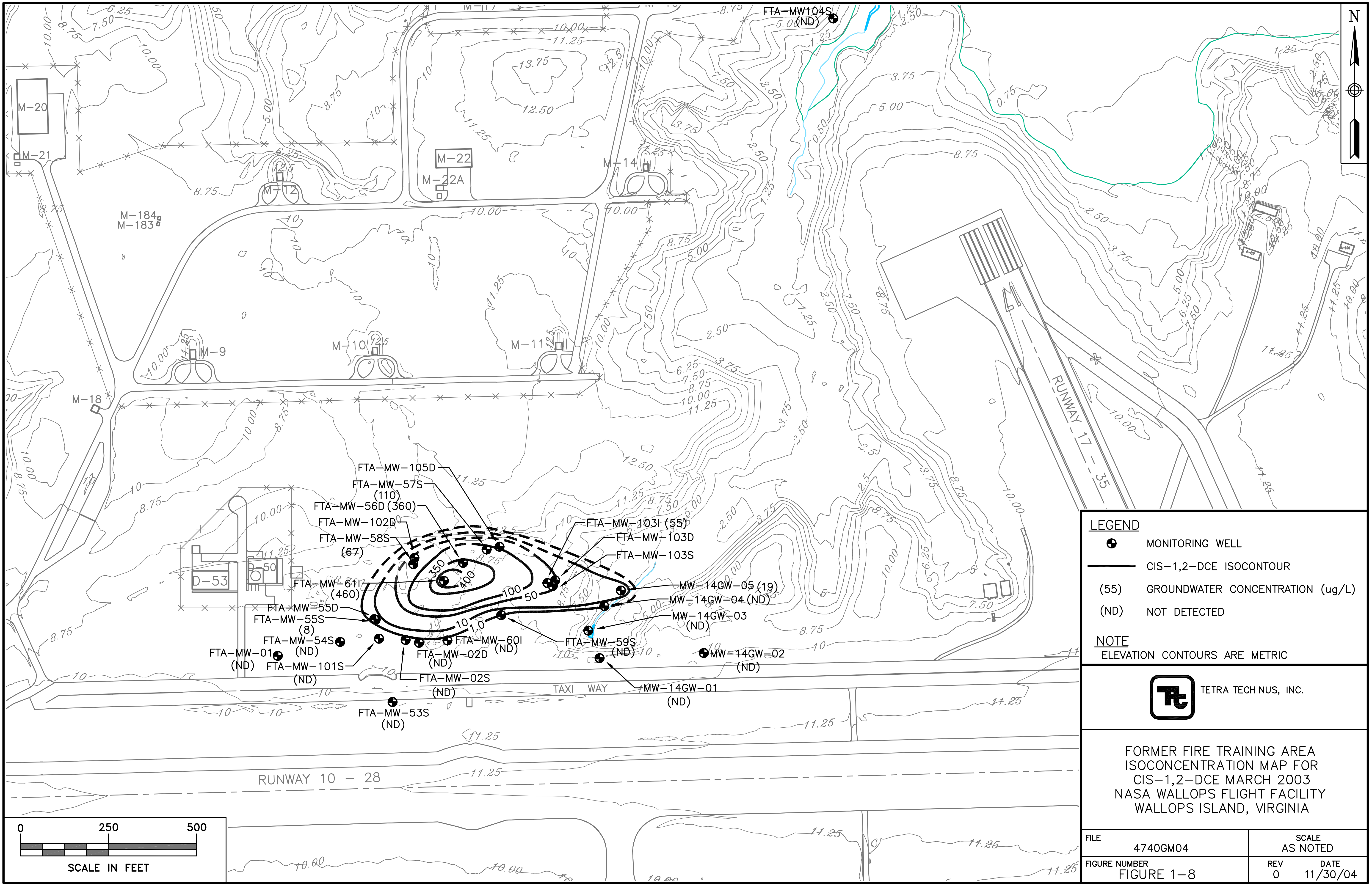
NOTE
ELEVATION CONTOURS ARE METRIC

TETRA TECH NUS, INC.

FORMER FIRE TRAINING AREA
ISOCONCENTRATION MAP FOR
TOULENE MARCH 2003
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	SCALE	
4740GM03	AS NOTED	
FIGURE NUMBER	REV	DATE
FIGURE 1-7	0	11/30/04

4740 NASA-Wallopsisland\4740GM04.DWG 11/30/04 MKB



LEGEND

●	MONITORING WELL
—	CIS-1,2-DCE ISOCONTOUR
(55)	GROUNDWATER CONCENTRATION (ug/L)
(ND)	NOT DETECTED

NOTE
ELEVATION CONTOURS ARE METRIC

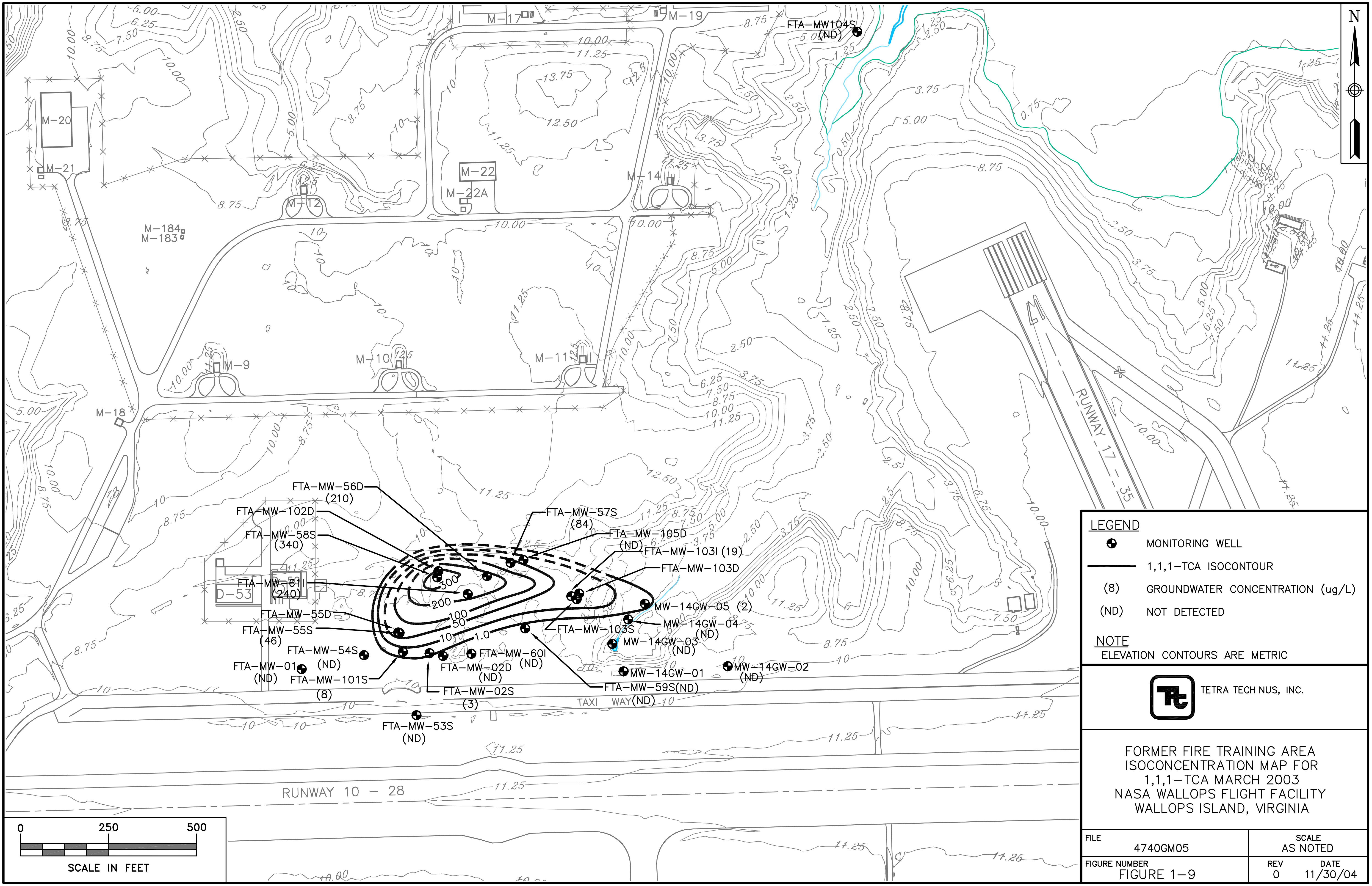
TETRA TECH NUS, INC.

FORMER FIRE TRAINING AREA
ISOCONCENTRATION MAP FOR
CIS-1,2-DCE MARCH 2003
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	SCALE
4740GM04	AS NOTED

FIGURE NUMBER	REV	DATE
FIGURE 1-8	0	11/30/04

4740 NASA-Wallopsisland\4740GM05.DWG 11/30/04 MKB



LEGEND

⊕	MONITORING WELL
―	1,1,1-TCA ISOCONTOUR
(8)	GROUNDWATER CONCENTRATION (ug/L)
(ND)	NOT DETECTED

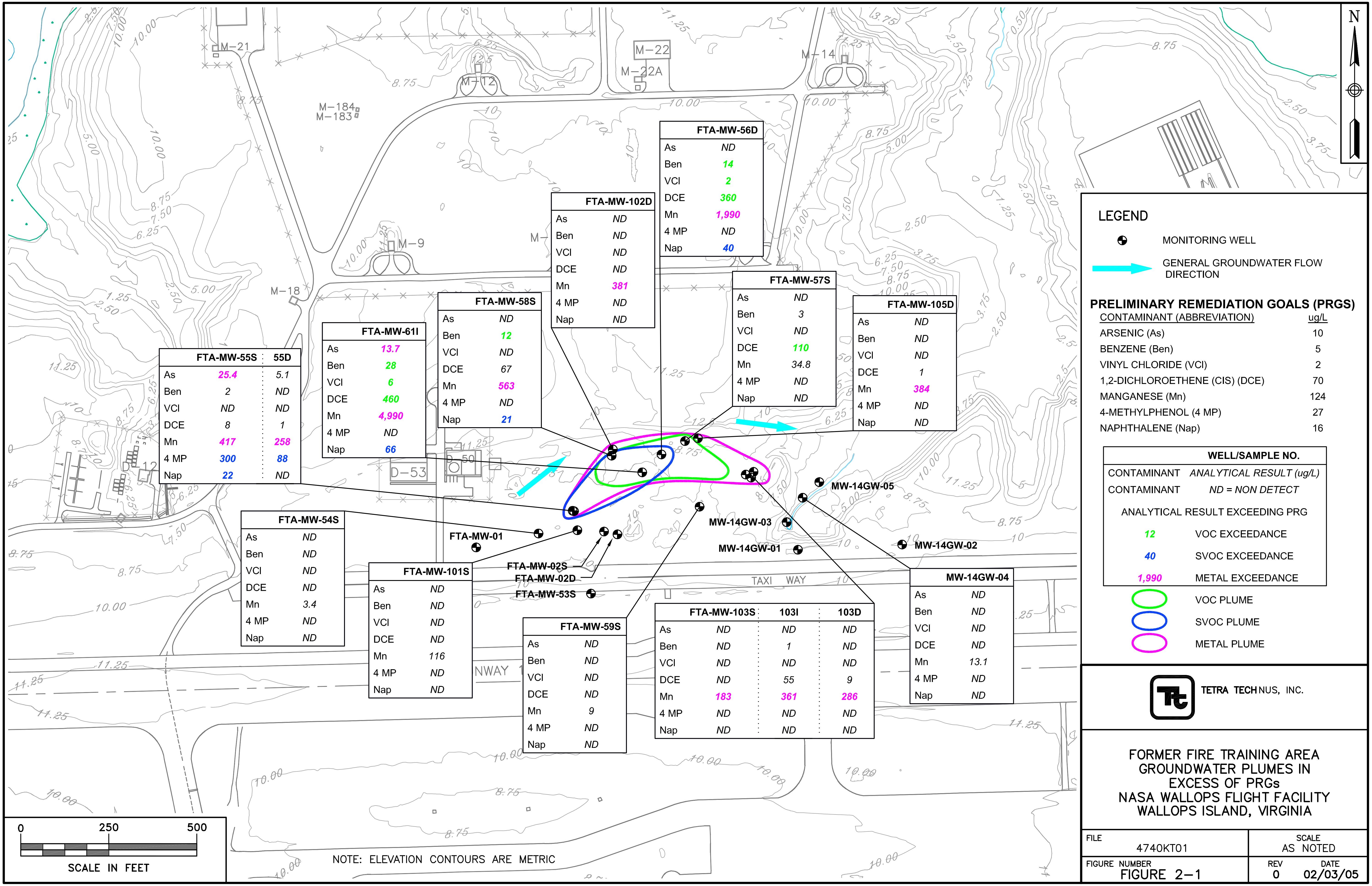
NOTE

ELEVATION CONTOURS ARE METRIC

TETRA TECH NUS, INC.

FORMER FIRE TRAINING AREA
ISOCONCENTRATION MAP FOR
1,1,1-TCA MARCH 2003
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE 4740GM05		SCALE AS NOTED	
FIGURE NUMBER FIGURE 1-9		REV 0	DATE 11/30/04



NOTE: ELEVATION CONTOURS ARE METRIC

FTA-MW-56D	
As	ND
Ben	14
VCl	2
DCE	360
Mn	1,990
4 MP	ND
Nap	40

FTA-MW-102D	
As	ND
Ben	ND
VCl	ND
DCE	ND
Mn	381
4 MP	ND
Nap	ND

FTA-MW-57S	
As	ND
Ben	3
VCl	ND
DCE	110
Mn	34.8
4 MP	ND
Nap	ND

FTA-MW-105D	
As	ND
Ben	ND
VCl	ND
DCE	1
Mn	384
4 MP	ND
Nap	ND

FTA-MW-58S	
As	ND
Ben	12
VCl	ND
DCE	67
Mn	563
4 MP	ND
Nap	21

FTA-MW-61I	
As	13.7
Ben	28
VCl	6
DCE	460
Mn	4,990
4 MP	ND
Nap	66

	FTA-MW-55S	55D
As	25.4	5.1
Ben	2	ND
VCl	ND	ND
DCE	8	1
Mn	417	258
4 MP	300	88
Nap	22	ND

FTA-MW-54S	
As	ND
Ben	ND
VCl	ND
DCE	ND
Mn	3.4
4 MP	ND
Nap	ND

FTA-MW-101S	
As	ND
Ben	ND
VCl	ND
DCE	ND
Mn	116
4 MP	ND
Nap	ND

FTA-MW-59S	
As	ND
Ben	ND
VCl	ND
DCE	ND
Mn	9
4 MP	ND
Nap	ND

	FTA-MW-103S	103I	103D
As	ND	ND	ND
Ben	ND	1	ND
VCl	ND	ND	ND
DCE	ND	55	9
Mn	183	361	286
4 MP	ND	ND	ND
Nap	ND	ND	ND

MW-14GW-04	
As	ND
Ben	ND
VCl	ND
DCE	ND
Mn	13.1
4 MP	ND
Nap	ND

LEGEND

●	MONITORING WELL
➡	GENERAL GROUNDWATER FLOW DIRECTION

PRELIMINARY REMEDIATION GOALS (PRGS)

CONTAMINANT (ABBREVIATION)	ug/L
ARSENIC (As)	10
BENZENE (Ben)	5
VINYL CHLORIDE (VCl)	2
1,2-DICHLOROETHENE (CIS) (DCE)	70
MANGANESE (Mn)	124
4-METHYLPHENOL (4 MP)	27
NAPHTHALENE (Nap)	16

WELL/SAMPLE NO.	
CONTAMINANT	*ANALYTICAL RESULT (ug/L)*
CONTAMINANT	*ND = NON DETECT*

ANALYTICAL RESULT EXCEEDING PRG

12	VOC EXCEEDANCE
40	SVOC EXCEEDANCE
1,990	METAL EXCEEDANCE

◯	VOC PLUME
◯	SVOC PLUME
◯	METAL PLUME

TETRA TECH NUS, INC.

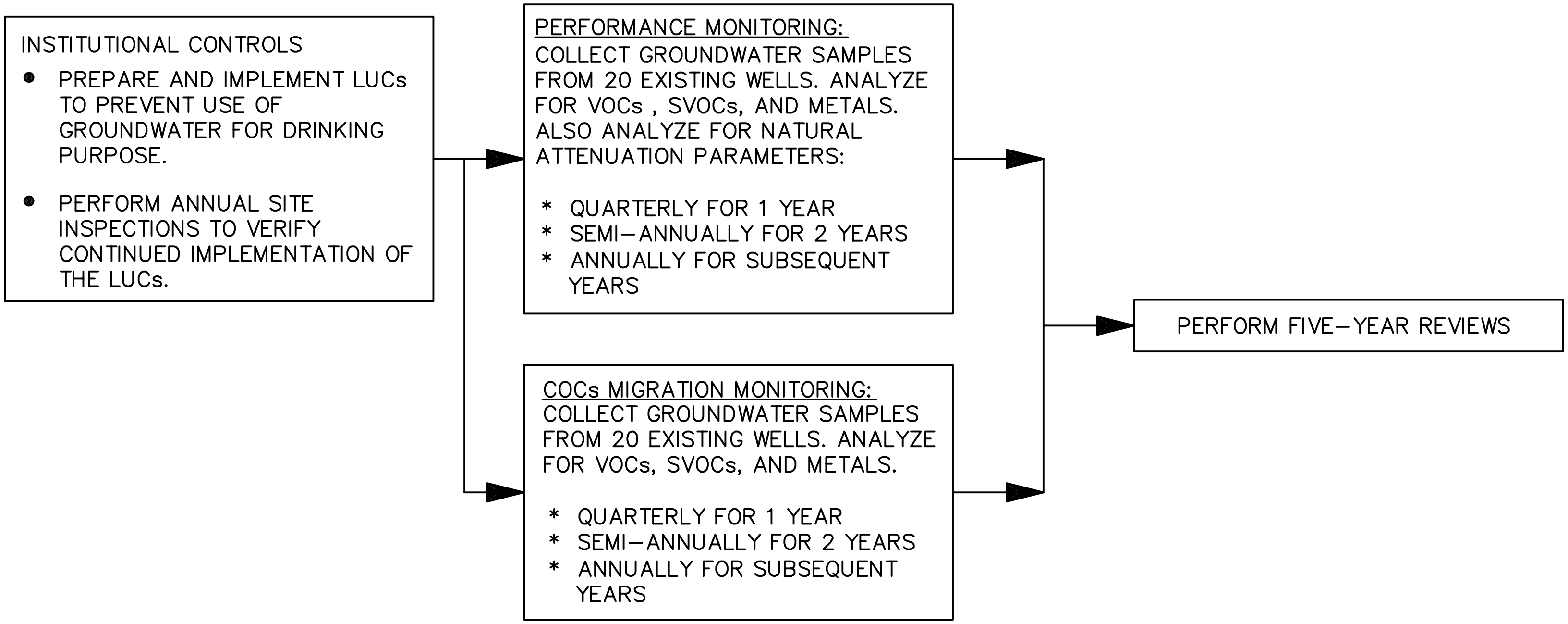
FORMER FIRE TRAINING AREA
GROUNDWATER PLUMES IN
EXCESS OF PRGs
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	SCALE
4740KT01	AS NOTED

FIGURE NUMBER	REV	DATE
FIGURE 2–1	0	02/03/05

4740/4740CF02.dwg 02/18/05 MKB

NATURAL ATTENUATION, INSTITUTIONAL CONTROLS, AND MONITORING



INSTITUTIONAL CONTROLS

- PREPARE AND IMPLEMENT LUCs TO PREVENT USE OF GROUNDWATER FOR DRINKING PURPOSE.
- PERFORM ANNUAL SITE INSPECTIONS TO VERIFY CONTINUED IMPLEMENTATION OF THE LUCs.

PERFORMANCE MONITORING:
COLLECT GROUNDWATER SAMPLES FROM 20 EXISTING WELLS. ANALYZE FOR VOCs , SVOCs, AND METALS. ALSO ANALYZE FOR NATURAL ATTENUATION PARAMETERS:

- * QUARTERLY FOR 1 YEAR
- * SEMI-ANNUALLY FOR 2 YEARS
- * ANNUALLY FOR SUBSEQUENT YEARS

COCs MIGRATION MONITORING:
COLLECT GROUNDWATER SAMPLES FROM 20 EXISTING WELLS. ANALYZE FOR VOCs, SVOCs, AND METALS.

- * QUARTERLY FOR 1 YEAR
- * SEMI-ANNUALLY FOR 2 YEARS
- * ANNUALLY FOR SUBSEQUENT YEARS

PERFORM FIVE-YEAR REVIEWS

NOTES:

COCs	CHEMICALS OF CONCERN
LUCS	LAND USE CONTROLS
VOC	VOLATILE ORGANIC COMPOUND
SVOC	SEMIVOLATILE ORGANIC COMPOUND

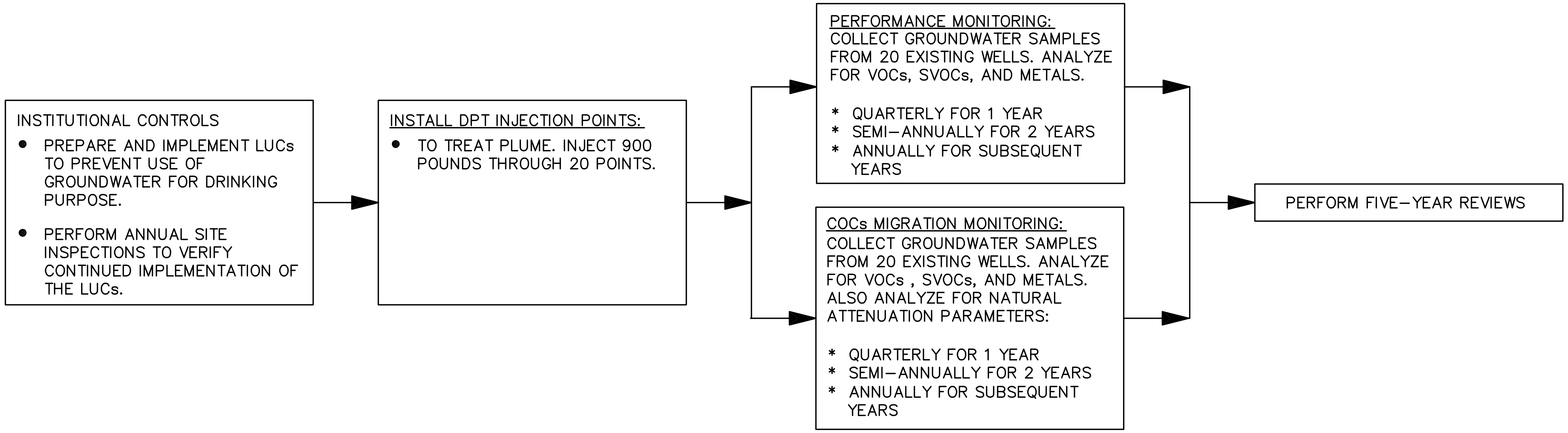
TETRA TECH NUS, INC.

BLOCK FLOW DIAGRAM
GROUNDWATER ALTERNATIVE 2
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

SCALE
NOT TO SCALE
FILE
4740CF02
REV 0
DATE 11/18/04
FIGURE NUMBER
FIGURE 4-1

4740/4740CF03.dwg 02/18/05 MKB

IN–SITU BIOLOGICAL TREATMENT (BIOSTIMULATION) INSTITUTIONAL CONTROLS, AND MONITORING



INSTITUTIONAL CONTROLS

- PREPARE AND IMPLEMENT LUCs TO PREVENT USE OF GROUNDWATER FOR DRINKING PURPOSE.
- PERFORM ANNUAL SITE INSPECTIONS TO VERIFY CONTINUED IMPLEMENTATION OF THE LUCs.

<u>INSTALL DPT INJECTION POINTS:</u>

- TO TREAT PLUME. INJECT 900 POUNDS THROUGH 20 POINTS.

<u>PERFORMANCE MONITORING:</u>
COLLECT GROUNDWATER SAMPLES FROM 20 EXISTING WELLS. ANALYZE FOR VOCs, SVOCs, AND METALS.

* QUARTERLY FOR 1 YEAR
* SEMI–ANNUALLY FOR 2 YEARS
* ANNUALLY FOR SUBSEQUENT YEARS

<u>COCs MIGRATION MONITORING:</u>
COLLECT GROUNDWATER SAMPLES FROM 20 EXISTING WELLS. ANALYZE FOR VOCs , SVOCs, AND METALS. ALSO ANALYZE FOR NATURAL ATTENUATION PARAMETERS:

* QUARTERLY FOR 1 YEAR
* SEMI–ANNUALLY FOR 2 YEARS
* ANNUALLY FOR SUBSEQUENT YEARS

PERFORM FIVE–YEAR REVIEWS

<u>NOTES:</u>

COCs	CHEMICALS OF CONCERN
LUCS	LAND USE CONTROLS
VOC	VOLATILE ORGANIC COMPOUND
SVOC	SEMIVOLATILE ORGANIC COMPOUND

TETRA TECH NUS, INC.

BLOCK FLOW DIAGRAM
GROUNDWATER ALTERNATIVE 3
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE
4740CF03

SCALE
NOT TO SCALE

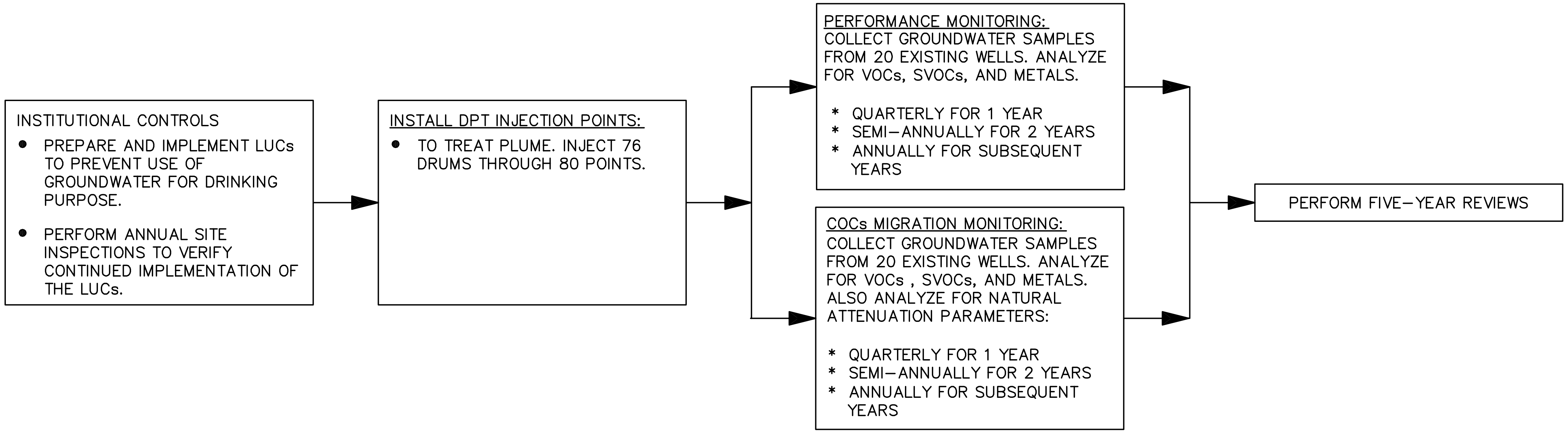
FIGURE NUMBER
FIGURE 4–2

REV
0

DATE
02/18/05

4740/4740CF04.dwg 02/18/05 MKB

IN–SITU BIOLOGICAL TREATMENT (BIOAUGMENTATION) INSTITUTIONAL CONTROLS, AND MONITORING



INSTITUTIONAL CONTROLS

- PREPARE AND IMPLEMENT LUCs TO PREVENT USE OF GROUNDWATER FOR DRINKING PURPOSE.
- PERFORM ANNUAL SITE INSPECTIONS TO VERIFY CONTINUED IMPLEMENTATION OF THE LUCs.

INSTALL DPT INJECTION POINTS:

- TO TREAT PLUME. INJECT 76 DRUMS THROUGH 80 POINTS.

PERFORMANCE MONITORING:
COLLECT GROUNDWATER SAMPLES FROM 20 EXISTING WELLS. ANALYZE FOR VOCs, SVOCs, AND METALS.

* QUARTERLY FOR 1 YEAR
* SEMI–ANNUALLY FOR 2 YEARS
* ANNUALLY FOR SUBSEQUENT YEARS

COCs MIGRATION MONITORING:
COLLECT GROUNDWATER SAMPLES FROM 20 EXISTING WELLS. ANALYZE FOR VOCs , SVOCs, AND METALS. ALSO ANALYZE FOR NATURAL ATTENUATION PARAMETERS:

* QUARTERLY FOR 1 YEAR
* SEMI–ANNUALLY FOR 2 YEARS
* ANNUALLY FOR SUBSEQUENT YEARS

PERFORM FIVE–YEAR REVIEWS

NOTES:

COCs	CHEMICALS OF CONCERN
LUCS	LAND USE CONTROLS
VOC	VOLATILE ORGANIC COMPOUND
SVOC	SEMIVOLATILE ORGANIC COMPOUND

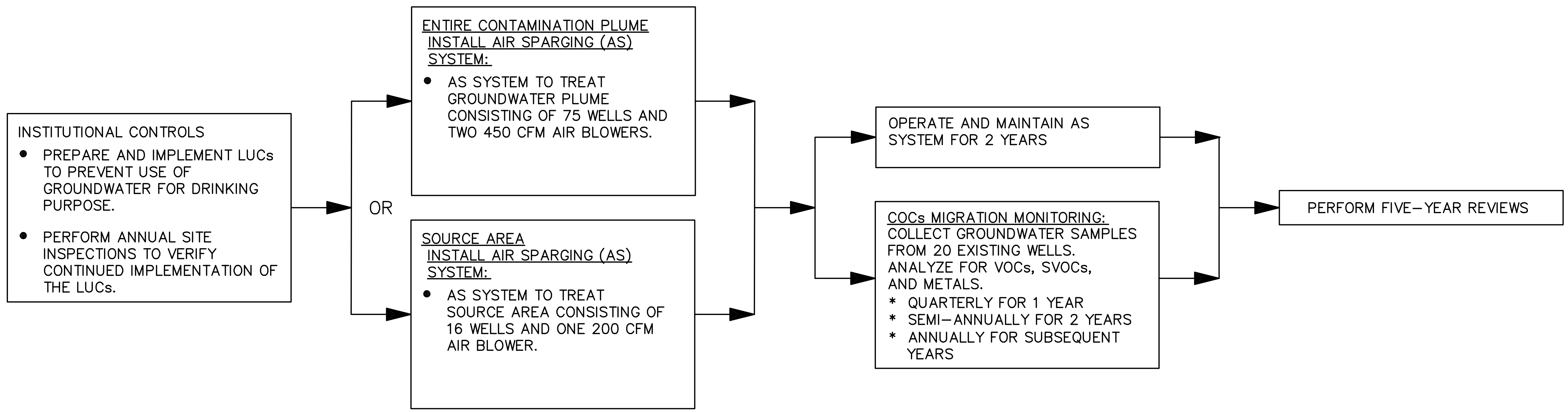
TETRA TECH NUS, INC.

BLOCK FLOW DIAGRAM
GROUNDWATER ALTERNATIVE 4
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	SCALE	
4740CF04	NOT TO SCALE	
FIGURE NUMBER	REV	DATE
FIGURE 4–3	0	02/18/05

4740/4740CF05.dwg 02/18/05 MKB

IN–SITU AIR SPARGING INSTITUTIONAL CONTROLS, AND MONITORING



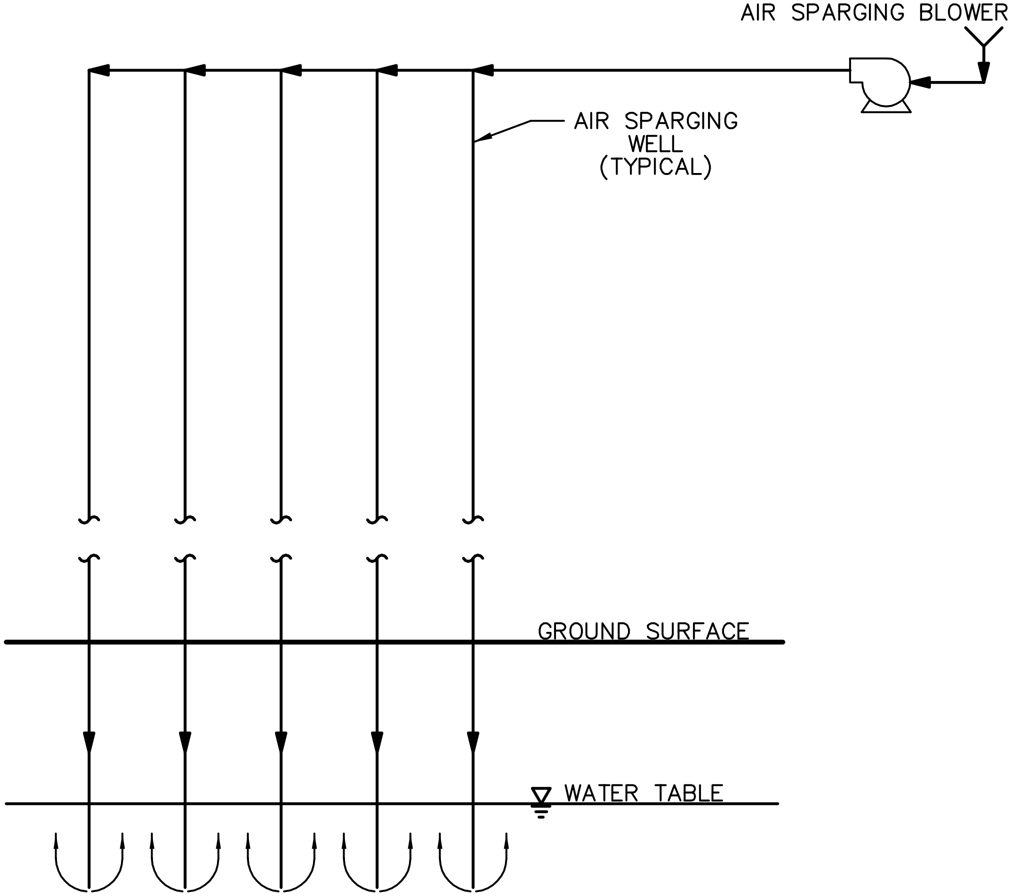
NOTES:

COCs	CHEMICALS OF CONCERN
LUCS	LAND USE CONTROLS
VOC	VOLATILE ORGANIC COMPOUND
SVOC	SEMIVOLATILE ORGANIC COMPOUND

TETRA TECH NUS, INC.

BLOCK FLOW DIAGRAM
GROUNDWATER ALTERNATIVE 5
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE: 4740CF05
SCALE: NOT TO SCALE
FIGURE NUMBER: FIGURE 4–4
REV: 0
DATE: 02/18/05



TETRA TECHNUS, INC.

PROCESS FLOW DIAGRAM
TYPICAL IN–SITU AS SYSTEM
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

SCALE
NOT TO SCALE
FILE
4740CF06
REV 0
DATE 11/18/04
FIGURE NUMBER
FIGURE 4–5

APPENDICES

APPENDIX A

CONCEPTUAL DESIGN CALCULATIONS

A.1 CONTAMINATED GROUNDWATER COMPUTATIONS

Client:	**NASA, CTO 0848, Wallops Flight Facility**	**Project Number: N1612**
Subject:	Mass/Volume Calculations	Page: 1 of 3
By:	Bob Davis	Date: 9/23/04

1.0 Mass and Volume Estimates for Former Fire Training Area

1.1 Plume Dimensions (Approximate)

Length:	660 feet
Width:	110 feet
Thickness:	15 feet
Porosity:	0.25 fraction

Measured Areas for the Plumes (see attached figure)

VOC Plume	42210 square feet
SVOC Plume	36310 square feet
VOC & SVOC Plume	55850 square feet
Metals Plume	73310 square feet

1.2 Area and Volume of Contaminated Groundwater

Approximate

Area = length x width =	72600 ft^2	(660x110)
or	1.7 acres	

Volume = length x width x thickness x porosity
Convert to gallons using a density of water of 7.48 gallons per cubic foot

Volume =	272,250 cubic feet	(72600x15x.25)
or	2,036,430 gallons	
Say	2,050,000 gallons	

Based on Measured Areas for the Plumes (see attached figure)

Volume = Area x thickness x porosity x 7.48 gallons per cf

VOC Plume	1,183,991 gallons
SVOC Plume	1,018,496 gallons
VOC & SVOC Plume	1,566,593 gallons
Metals Plume	2,056,346 gallons

1.3 Average Concentration and Soluble Mass of Contaminants

Use the average concentration of contaminants within plume area
= FTA-MW-57S, -56D, -61I, -55D, -55S, and -58S
Use 0 for none detects

	Max conc. (ug/l)	**Average Conc. (ug/l)**	**Soluble Mass (lbs)**	**PRG ug/l**	**Ave Red Required (%)**	**Max Red Required (%)**
Arsenic	25.4	7.4	0.13	10	-36	61
Benzene	28	9.8	0.10	5	49	82
Vinyl Chloride	6	1.3	0.01	2	-50	67
1,2 DCE (cis)	460	151	1.5	70	54	85
Manganese	4990	1375	24	124	91	98
4-Methylphenol	300	65	0.5	27	58	91
Naphthalene	66	23	0.20	16	30	76
Total VOC & SVOC mass =			**2.34**			

1.4 Estimate Mass of Residual Petroleum Contamination in the Water Table

The mass is not completely defined, but a preliminary estimate can be developed. This mass of contamination does not represent a threat to human health, but does act as a continuing source of groundwater contamination.

The areal extent is estimated to be defined by field observations in borings
SB101, 104, 106, 107, 108, and 109.

or an area approximately 80 feet in diameter
which equals: 5024 ft^2

The contamination likely results from the historic presence of floating free product on the water table that has smeared onto the soil as a result of a fluctuating water table. Assume that the water table has fluctuated by up to 3 feet in this area and that the residual petroleum has adsorbed onto these soils.

Volume of soil is then area (above) x 3 feet
Which equals 15072 ft^3
or 558 yd^3

At an assumed soil density of 110 lb/cf and an assumed petroleum concentration of 0.3% using the VOC and SVOC maximum concentrations (see calculations below) from the RI report

The mass of petroluem contamination present is (based on maximum concentration)
4,974 lbs
Say 5,000 lbs

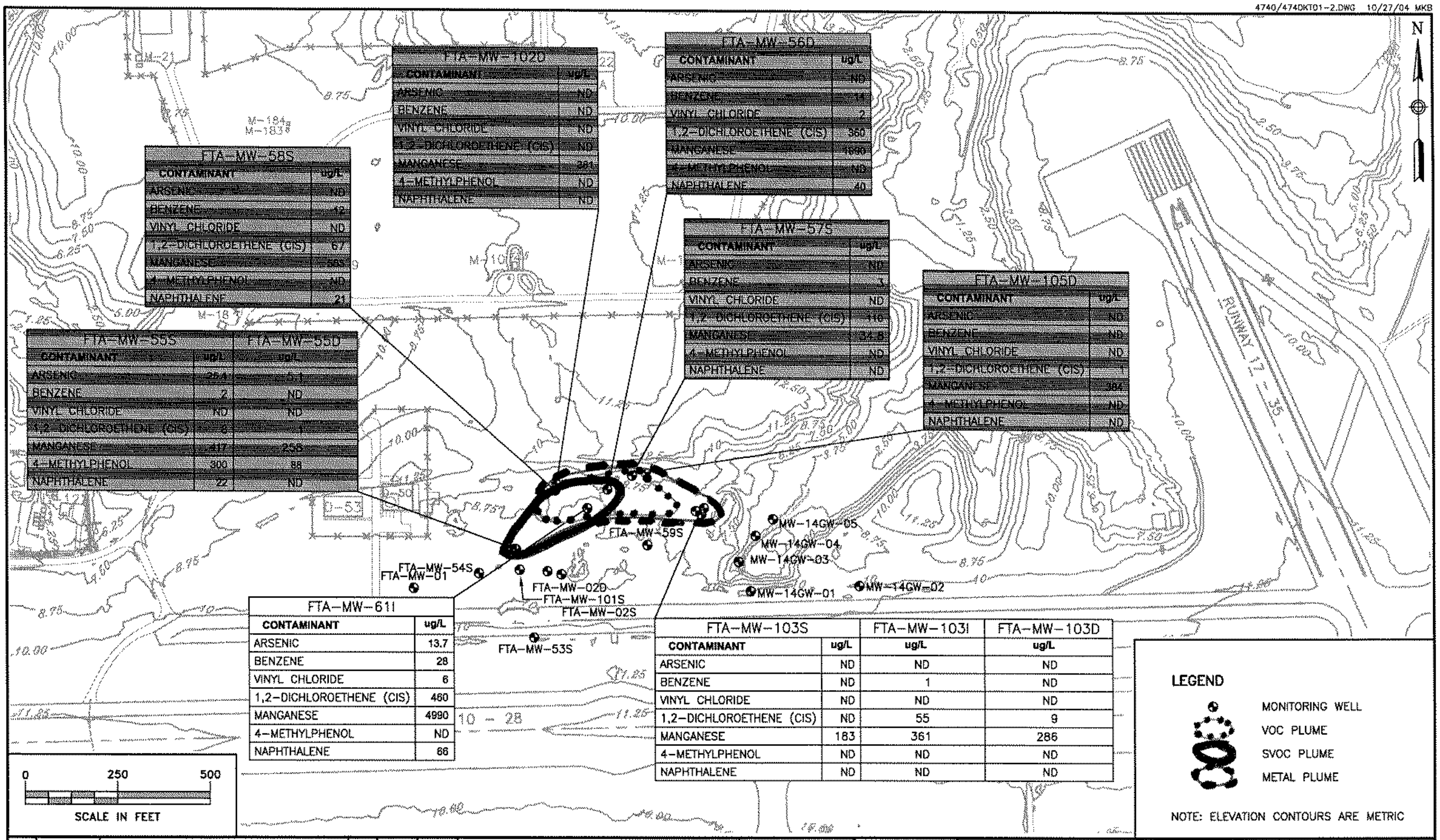
At an assumed soil density of 110 lb/cf and an assumed petroleum concentration of 0.007% using the VOC and SVOC average concentrations (see calculations below) from the RI report

The mass of petroluem contamination present is (based on average concentration)
116 lbs
Say 125 lbs

Client:	**NASA, CTO 0848, Wallops Flight Facility**	**Project Number: N1612**
Subject:	Mass/Volume Calculations	Page: 3 of 3
By:	Bob Davis	Date: 9/23/04

Chemical	Concentration	
	Average	Maximum
Chemical	ug/kg	ug/kg
2-Methylnaphthalene	2410	56000
Acenaphthene	699	25000
Anthracene	3370	160000
Benz(a)anthracene	4740	230000
Benzo(a)pyrene	2980	140000
Benzo(b)flourathene	6110	300000
Benzo(g,h,i)perylene	860	32000
Benzo(k)fluorathene	2390	110000
bis(2-ethylhexyl)phthalate	609	1300
Carbazole	1580	68000
Chrysene	4640	240000
Di-n-butyl Phthalate	741	18
Di-n-octyl Phthalate	590	100
Dibenz(a,h)anthracene	490	13000
Dibenzofuran	933	38000
Fluorathene	13600	680000
Fluorene	424	11000
Indeno(1,2,3-cd)pyrene	941	36000
Naphthalene	1200	24000
Phenanthrene	4830	230000
Pyrene	10800	540000
1,1,1-TCA	26.5	1000
1,1-DCA	5.2	3
1,1-DCE	6.9	69
1,2,4-Trimethylbenzene	562	12000
cis-1,2-DCE	5.3	10
1,3,5-Trimethylbenzene	240	5100
2-Butanone	5.8	25
Acetone	20.2	210
Benzene	5.5	7
Carbon Disulfide	5.4	3
Chloroethane	5.4	4
Cyclohexane	7.3	68
Ethylbenzene	55.8	2600
Isopropylbenzene	27.3	760
m,p xylene	14.7	180
Methyl Acetate	5.5	2
Methlycyclohexane	46.2	1500
Metheylene Chloride	6.4	18
o xylene	15.6	210
Tetrachloroethene	8.2	50
Toluene	191	9700
Xylene	170	8400
TOTAL	66373.2	2976337
Change to ppm (/1000)	66.3732	2976.337
Change to % (1%=10000 ppm)	0.007	0.298

4740/474DKT01-2.DWG 10/27/04 MKB



FTA–MW–58S

CONTAMINANT	ug/L
ARSENIC	ND
BENZENE	12
VINYL CHLORIDE	ND
1,2–DICHLOROETHENE (CIS)	67
MANGANESE	563
4–METHYLPHENOL	ND
NAPHTHALENE	21

	FTA–MW–55S	FTA–MW–55D
CONTAMINANT	ug/L	ug/L
ARSENIC	25.4	5.1
BENZENE	2	ND
VINYL CHLORIDE	ND	ND
1,2–DICHLOROETHENE (CIS)	6	1
MANGANESE	417	258
4–METHYLPHENOL	300	88
NAPHTHALENE	22	ND

FTA–MW–102D

CONTAMINANT	ug/L
ARSENIC	ND
BENZENE	ND
VINYL CHLORIDE	ND
1,2–DICHLOROETHENE (CIS)	ND
MANGANESE	281
4–METHYLPHENOL	ND
NAPHTHALENE	ND

FTA–MW–56D

CONTAMINANT	ug/L
ARSENIC	ND
BENZENE	14
VINYL CHLORIDE	2
1,2–DICHLOROETHENE (CIS)	360
MANGANESE	1640
4–METHYLPHENOL	ND
NAPHTHALENE	40

FTA–MW–57S

CONTAMINANT	ug/L
ARSENIC	ND
BENZENE	3
VINYL CHLORIDE	ND
1,2–DICHLOROETHENE (CIS)	110
MANGANESE	34.8
4–METHYLPHENOL	ND
NAPHTHALENE	ND

FTA–MW–105D

CONTAMINANT	ug/L
ARSENIC	ND
BENZENE	ND
VINYL CHLORIDE	ND
1,2–DICHLOROETHENE (CIS)	1
MANGANESE	384
4–METHYLPHENOL	ND
NAPHTHALENE	ND

FTA–MW–61I

CONTAMINANT	ug/L
ARSENIC	13.7
BENZENE	28
VINYL CHLORIDE	6
1,2–DICHLOROETHENE (CIS)	460
MANGANESE	4990
4–METHYLPHENOL	ND
NAPHTHALENE	66

	FTA–MW–103S	FTA–MW–103I	FTA–MW–103D
CONTAMINANT	ug/L	ug/L	ug/L
ARSENIC	ND	ND	ND
BENZENE	ND	1	ND
VINYL CHLORIDE	ND	ND	ND
1,2–DICHLOROETHENE (CIS)	ND	55	9
MANGANESE	183	361	286
4–METHYLPHENOL	ND	ND	ND
NAPHTHALENE	ND	ND	ND

LEGEND

⊕	MONITORING WELL
⋯	VOC PLUME
○	SVOC PLUME
▬	METAL PLUME

NOTE: ELEVATION CONTOURS ARE METRIC

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY MKB DATE 10/27/04
CHECKED BY DATE
COST/SCHED–AREA
SCALE NOT TO SCALE

FORMER FIRE TRAINING AREA GROUNDWATER PLUMES AND CONTAMINANTS OF CONCERN NASA WALLOPS FLIGHT FACILITY WALLOPS ISLAND, VIRGINIA

CONTRACT NO. 1612
APPROVED BY DATE
APPROVED BY DATE
DRAWING NO. FIGURE 1–10
REV. 0

A.2 GROUNDWATER ALTERNATIVE 3 IN-SITU BIOREMEDIATION (BIOSTIMULATION)

ORC Design Software for Barriers Using Slurry Injection

US Version 3.1

Regenesis Technical Support: USA (949) 366-8000, www.regenesis.com

Site Name: Former Fire Training Area
Location: NASA Wallops Flight Facility
Consultant:

Site Conceptual Model/Extent of Plume Requiring Remediation

Width of plume (intersecting gw flow direction)	150	ft		
Depth to contaminated zone	20	ft		
Thickness of contaminated saturated zone	15	ft		
Nominal aquifer soil (gravel, sand, silty sand, silt, clay)	sand			
Effective porosity	0.05			
Hydraulic conductivity	25	ft/day =	8.8E-03	cm/sec
Hydraulic gradient	0.005	ft/ft		
Seepage velocity	912.5	ft/yr =	2.500	ft/day

Dissolved Phase Oxygen Demand:

Individual species that represent oxygen demand:	Contaminant Conc (mg/L)	Contaminant Loading (lb/yr)	Stoich. (wt/wt) O_2/contam.	ORC (lb/yr) (10% O_2)
Benzene	0.03	0.18	3.1	6
Toluene	0.00	0.00	3.1	0
Ethylbenzene	0.00	0.00	3.2	0
Xylenes	0.00	0.00	3.2	0
MTBE	0.00	0.00	2.7	0
dichloroethene	0.46	2.95	0.7	21
vinyl chloride	0.01	0.04	1.3	0
reduced metals: Fe (+2) and Mn(+2)	1.00	6.40	0.1	6
4-methyphenol	0.09	0.56	4.0	23
naphthalene	0.07	0.45	6.0	27
Measures of total oxygen demand				
Total Petroleum Hydrocarbons	1.00	6.40	3.1	199
Biological Oxygen Demand (BOD)	10.00	64.04	1	640
Chemical Oxygen Demand (COD)	10.00	64.04	1	640

Length of time to eval. contaminant flow into barrier: 1 yr

Summary of Estimated ORC Requirement Measures		ORC for Dissolved Phase Flux (lb)	Add Dem Factor (1 to 10x)	ORC Total w/ Add Dem Factor	ORC Cost at $ 10.00	
Individual Species: Total BTEX, MTBE	☑	83	5	413	$ 4,126	<-
Total Petroleum Hydrocarbons	☐	199	2	397	$ 3,970	
Biological Oxygen Demand (BOD)	☐	640	2	1,281	$ 12,807	
Chemical Oxygen Demand (COD)	☐	640	1	640	$ 6,404	

Select above measure (button) to specify required ORC quantity (in 30 lb increments) -----------> **420** lbs ORC

Delivery Design for ORC Slurry

Spacing within rows (ft)		15.0	feet
# points per row		10	points/row
Number of rows		2.0	no.for rows
Number of points in grid		20	points
Required ORC per foot	Minimum Dose Override->	3.0	lbs/foot
Total ORC	Minimum Dose Override->	**900**	lbs of ORC

Slurry Mixing Volume for Injections

Pounds per location	45	pounds
Buckets per location	1.5	buckets
Design solids content (20-40% by wt. for injections)	30%	
Volume of water required per hole (gal)	13	gallons
Total water for mixing all holes (gal)	252	gallons
Simple ORC Backfilling: min hole diameter for 67% slurry	2.9	inches
Feasibility for slurry injection in sand: ok up to 15 lb/ft	(ok)	
Feasibility for slurry injection in silt: ok up to 10 lb/ft	(ok)	
Feasibility for slurry injection in clay: ok up to 5 lb/ft	(ok)	

Project Summary			
ORC bulk material for slurry injection (lbs)			900
Number of 30 lb ORC buckets			30.0
ORC bulk material cost		$	10.00
Cost for bulk ORC material		$	9,000
Shipping and Tax Estimates in US Dollars			
Sales Tax	rate: 0%	$	-
Total Matl. Cost		$	9,000
Shipping (call for amount)		$	-
Total Regenesis Material Cost		**$**	**9,000**

ORC Slurry Injection Cost Est. (responsibility of customer to contract work)		
Footage for each inj. point = uncontaminated + HRC inj. interval (ft)		35
Total length for direct push for project (ft)		700
Estimated daily installation rate (ft per day: 400 for push, 150 for drillin		400
Estimated points per day (15 to 30 is typical for direct push)		11.4
Required number of days		2
Mob/demob cost for injection subcontractor	$	1,000
Daily rate for inj. Sub. ($1-2K for push $3-4K for drill rig)	$	1,500
Total injection subcontrator cost for application	$	4,000
Total Install Cost (not including consultant, lab, etc.)	$	13,000

Other Project Cost Estimates		
Design	$	-
Permitting and reporting	$	-
Construction management	$	-
Groundwater monitoring and rpts	$	-
Other	$	-
Other	$	-
Other	$	-
Other	$	-
Total Project Cost	$	13,000

A.3 GROUNDWATER ALTERNATIVE 4 IN-SITU BIOREMEDIATION (BIOAUGMENTATION)

Prepared By: Bob Davis

CONCEPTUAL PROCESS DESIGN
ALTERNATIVE 4

November 12, 2004

1 Treatment

VOC/SVOC Plume Area (sq ft)	55,850 sq ft
Injection well spacing:	15 ft
Area of Injection	697
Number of Injection Points:	80

Requirements

Target Area in CI-Solutions Proposal:		31000	
Actual Target Area:		55850	
Increase Cost and quantity by:		1.8016129	
		# of Units (Drums)	Cost
1 Time injection	42*1.8	76	$113,502
		# hrs	
Injection Rate	0.5 hrs/drum	38	
		5.4	assume 7 hours injection and 3 hours set up and breakdown each day

cl solutions
Bringing bioremediation up to Speed
1157 Industrial Road
Cold Spring, Kentucky 41076
p. 877-257-6588
f. 859-781-8280
www.cl-solutions.com

November 14, 2004

Tetra Tech NUS, Inc.
661 Andersen Drive
Foster Plaza 7
Pittsburgh, PA 15220

Attention: Mr. Bob Davis

Reference: Preliminary Bioremediation Proposal
NASA Wallops Island SIte
Proposal No. 04-P0050

Dear Mr. Davis:

CL Solutions, LLC (CL Solutions) is pleased to submit this revised proposal for bioremediation of contaminated ground water at the NASA Wallops Island site. This proposal is based on the information provided in your email on November 12, 2004 and our discussion of the site. We understand that your objective is to reduce the levels of contaminats in groundwater to Maximum Contaminant Levels (MCLs). The contaminants include cis 1,2-DCE, benzene, vinyl chloride, naphthalene, and 4-methylphenol. This proposal presents a conceptual bioremediation plan and reasonable conservative estimate of the potential remediation cost.

Our proposal relies on partnership with Tetra Tech to incorporate their site knowledge for the field implementation, sampling, and monitoring. This proposal may be refined as more information becomes available and through future discussions with Tetra Tech.

CONCEPTUAL BIOREMEDIATION PLAN

The proposed bioremediation of chlorinated solvents contamination will use CL-Out, which is a consortium of naturally-occuring microbes selected for their ability to degrade chlorinated aliphatic hydrocarbons, such as cis-1,2 DCE and vinyl chloride, by cometabolism. CL-Out also includes strains of pseudomonas putida, which is widely known for its ability to directly metabolize benzene, naphthalene and phenols. The cometabolism of the aliphatic contaminants is stimulated by the presence of dextrose as a substrate. The cometabolism of cis 1,1-DCE, as found at this site, is complete and does not produce by products such as vinyl chloride. A rigorous QA/QC protocol is followed in manufacturing to assure that CL-Out is free of pathogenic microbes. Case studies and further technical information are available at www.cl-solutions.com.

CL-Out bioremediation introduces into the treatment zone a high population of effective degrading organisms. The population delivered into the treatment zone is 100 to 1000 times higher than the native bacterial population. Our preliminary proposal is based on the volume of CL-Out needed to reach a target microbial population density in the volume of contaminated ground water under the proposed treatment area.

Ground Water Plume Treatment

The area of impacted ground water above MCLs according to your Figure 1-10 is approximately 31,000 square feet, and we are assuming the impacted ground water zone is approximately 15 feet thick. We estimate that 42 units of CL-Out would be required to treat the impacted ground water and smear zone.

We anticipate repeat inoculations would only be necessary if higher concentrations are detected or resicual contamination is present in the vadose zone. However, the concentrations shown on Figure 1-10 and Table 3-2 should require only 1 treatment.

Based on results at similar sites, we estimate an effective radius of influence of 12 feet from each injection point. We recommend injecting CL-Out through 40 to 60 direct push holes on a grid to cover the plume area to maximize the CL-Out distribution. We do not anticipate biofouling of wells or the formation.

This estimate is conservative due to uncertainties related to permeability and the distribution of CL-Out in the subsurface. We recommend periodic monitoring of groundwater conditions and reassessment of the remediation plan based on the monitoring results. We recommend weekly field measurements of dissolved oxygen and pH, with monthly chemical analysis and plate count tests.

Microbial Life Enhancements

The success of CL-Out bioremediation is dependent on the availability of sufficient dissolved oxygen for complete metabolism. The dissolved oxygen levels in ground water which range from 0.56 to 5.59 in the treatment area, appear to be sufficient to support aerobic bioremediation. If groundwater monitoring reflects decreasing DO levels, we recommend an oxygen supplement should be added with the CL-Out to improve the effectiveness of the bioremediation.

Table 1: Environmental Conditions for Effective Treatment

Parameter	Effective Range	Optimum Range
pH	5.0 to 9.0	6.5 to 7.5
Temperature	55 to 95 °F	65 to 75 °F
Dissolved Oxygen	>0 to 10 ppm[1]	1 to 10 ppm

---

[1] ppm = Parts per million

BUDGET

The following conceptual budget presents both a conservative maximum based on a repeat inoculation over one half the treatment area and a minimum based on one application. The conceptual budget assumes that Tetra Tech NUS will complete all fieldwork and laboratory analysis. CL Solutions will provide bioremediation inoculants and technical support. The technical support includes assisting with treatment plans and reviewing the monitoring results to assess the remediation progress. Technical field assistance may be available at a cost ($1,000-$2,000) to assist with the initial inoculation. There is no special equipment necessary for the application of CL-Out bioremediation. The standard cost for CL-Out microbes is $1,500 per unit, plus shipping. Allow one week for schedule and delivery. This unit cost will be honored for one year after the date of this letter.

Preliminary Cost Estimate

Ground Water Plume Treatment

Maximum (2 inoculations - total of 63 units)	$94,500
Minimum (1 inoculation, total of 42 units)	$63,000

Estimated shipping costs is $300/per shipment

CLOSING

Our experience has been that CL-Out bioremediation provides a cost-effective, permanent solution for remediation of organic compounds in soil and ground water. While our estimate is conservative, it is based on information provided by others. The success of CL-Out bioremediation can be affected by many factors, including unknown subsurface conditions and field procedures, which are beyond the control of CL Solutions. For these reasons, we cannot guarantee actual field results. We recommend careful field application and monitoring. CL Solutions will also gladly review data and provide technical assistance by telephone throughout the project.

We look forward to assisting you in this matter. Please do not hesitate to contact us should you have any questions.

Sincerely,

CL Solutions, LLC
Michael T. Saul, C.P.G.
Vice President

John Morris
Managing Director

A.4 GROUNDWATER ALTERNATIVE 5 AS TREATMENT

Tetra Tech NUS

STANDARD CALCULATION SHEET

CLIENT: EFANE CLEAN	FILE No: 1612 1110	BY: RTO 11/15/04	PAGE: 1 OF 4
SUBJECT: Wallops Flight Facility – FFTA Site Groundwater Alternative 5 AS Treatment – Entire Plume		CHECKED BY:	DATE: 9/23/04

1.0 TREATMENT SCHEME

The option of Groundwater Alternative 5 would consist of an air sparging (AS) system. The AS system would feature the following elements:

- AS well array
- AS blower system

Typical remedial action duration for AS systems ranges from one to five years. For the purpose of this FS, it is assumed that remedial action duration would be 2 years.

2.0 AS WELL ARRAY

Based upon results of pilot tests at a similar Wallops Flight Facility site (Old Aviation Fuel Tank Farm), the typical radius of influence (ROI) of AS wells is approximately 15 to 17.5 ft. This ROI is used for the FFTA site.

Area of influence per AS well: $(30)^2 \times \pi/4 = 707$ ft^2, rounded down to 650 ft^2 for overlap
$(35)^2 \times \pi/4 = 961$ ft^2, rounded down to 900 ft^2 for overlap

AS wells will be installed at one depth, screened from 15 to 20 feet below the water table (total depth of the wells will be approximately 35 to 40 feet below ground surface) in the area of the VOC and SVOC plume.

Number of wells in the AS Well Array : (55,850 ft^2) $\div$ 750 ft^2 = approximately 75 wells

3.0 AS BLOWER SYSTEMS

Based upon results of pilot tests at a similar Wallops Flight Facility site (Old Aviation Fuel Tank Farm), the typical air sparging flow is approximately 6 to 12 cfm per well.

For the AS System, an individual AS Blower System would supply air to the AS Well Array installed at a given depth.

AS Blower System would feature 2 blowers. The blower would provide air to the 75 wells of the AS Well

Discharge rate of AS Blower: 75 wells x 6 cfm/well = 450, say 450 cfm
Discharge rate of AS Blower: 75 wells x 12 cfm/well = 900, say 900 cfm

Static head required for the AS Blower: 20 ft H_2O x 0.433 ft/psi = 8.7 psi

To accommodate line friction losses, design blower discharge pressure is approximately twice the required static head. The AS Blower would be designed for a discharge head of 20 psi.

$\Rightarrow$ AS Blower System would feature 2 blowers. Each AS Blower would be rated for 450 cfm @ 20 psi.

4.0 FUGITIVE EMISSIONS

As per computations presented in Appendix A.1 (Section 2.5), the total quantities of VOC and SVOC COCs for the FFTA site are estimated as follows:

Tetra Tech NUS		*STANDARD CALCULATION SHEET*	
CLIENT: EFANE CLEAN	FILE No: 1612 1110	BY: RFD 11/15/04	PAGE: 2 OF 4
SUBJECT: Wallops Flight Facility – FFTA Site Groundwater Alternative 5 AS Treatment – Entire Plume		CHECKED BY:	DATE: 9/23/04

VOCs: 1.6 pounds in groundwater
SVOCs: 0.7 pounds in groundwater
Petroleum: 5,000 pounds in soil (maximum concentrations), 125 pounds in soil (average concentrations)

Total: 5,000 + 0.7 + 1.6 = 5,002.3 pounds

Of all these, it is assumed that 100% of the VOCs, 33% of the Petroleum in soil, and 25% of the SVOCs will eventually be removed by stripping and generate fugitive emissions:

Total Fugitive Emissions (based on maximum concentrations):
1.6 + (0.25 x 0.7) + (0.33 x 5000) = 1651.8, say 1650 pounds

Total Fugitive Emissions (based on average concentrations):
1.6 + (0.25 x 0.7) + (0.33 x 125) = 43 say 45 pounds

It is assumed that 75% of these emissions will occur during the first year of operation of the AS treatment systems and that, within, that first year, half of the emissions would occur during the first 30 days:

Maximum Daily Rate of Fugitive Emissions:
1650 pounds x 0.75 x 0.5 ÷ 30 = 20.6 pounds per day (based on maximum concentrations)

Maximum Daily Rate of Fugitive Emissions:
45 pounds x 0.75 x 0.5 ÷ 30 = 0.6 pounds per day (based on average concentrations)

Based on the maximum concentrations, this is above the VDEQs deminimis level of 15 pounds per day, however based on the average concentrations, the emissions are well below the VDEQ deminimis level of 15 pounds per day. Therefore, the AS system can be operated without fugitive emissions controls. During the start up and first six months of operation the AS system will be operated to control the air flow to minimize the fugitive emissions.

Of these classes of compounds, the main concerns that need to be evaluated are the estimated air concentrations of "toxic" chemicals such as benzene, vinyl chloride, and 1,2-DCE and the potential for flammable air in the ambient. Estimated "worst-case" volatilized concentrations of benzene, vinyl chloride, and 1,2-DCE are shown below assuming very conservative conditions. These estimated concentrations show that if 100 percent of the VOCs are volatilized, and the aquifer is able to sustain the dissolved concentrations at the levels that were detected in groundwater samples, then the peak concentrations at start-up may exceed NIOSH guideline thresholds within the vapors. However, this is not expected to pose a significant human health concern because of the following reasons: (1) dilution of the vapors will occur when they reach the surface, especially during their travel to the human breathing zone, and (2) the location of the site is remote and potential human exposure to the air emissions is expected to be very unlikely.

The potential for emission of flammable air (because of volatilized petroleum compounds) is harder to predict at this time because of the unknown composition of the petroleum present in the soil. However, it does not pose a concern because of the remoteness of the site and because the potential for ignition sources to be present at the site is unlikely.

However, as a health and safety measure, it is recommended that the onsite workers monitor the breathing zone air for chlorinated VOCs and for flammable air during a pilot-scale study of the air sparging system. Based on the results of the pilot-study, the remedial design can determine the need for engineering controls. Therefore, the conceptual design in the FS does not need to include engineering controls for the fugitive emissions.

Estimation of air emissions:

Procedure: Estimate the VOC concentrations based on an assumption of 100% of mass of contaminants and compare concentrations to TLV-TWA limits for breathing-zone air.

(TLV-TWA limits are not applicable to the site because of its remote nature. However, it is being used as a threshold for evaluation of potential for the need for emission controls)

Step 1: Assume 100% volatilization of VOCs with emissions being carried by injected air

Step 2: Convert mass of VOCs being volatilized into concentration in air

Step 3: Compare air concentration to TLV-TWA

Input Assumptions:

1. Detected concentrations of VOCs in groundwater
2. Mass flow rate of groundwater through treatment zone: groundwater flow velocity of 500-1600 ft/yr through an area of influence of 20 ft x 30 ft
3. Air flow rate through treatment zone: 6 cfm
4. 100 percent volatilization of VOCs and consistent concentrations assuming no source depletion.
5. No above-ground dilution in ambient air

Calculations:

Step 1: Calculate mass of VOCs in emissions:

= [VOC] x GW velocity x 600 sq ft x 62 lb/cu ft x 100 %

Step 2: Calculate VOC concentration in emissions:

= mass of VOCs in emissions/air flow rate

Tetra Tech NUS *STANDARD CALCULATION SHEET*

CLIENT: EFANE CLEAN	FILE No: 1612 1110	BY:	PAGE: 4 OF 4
SUBJECT: Wallops Flight Facility – FFTA Site Groundwater Alternative 5 AS Treatment – Entire Plume		CHECKED BY: RFD 11/15/04	DATE: 9/23/04

Step 3: Compare VOC concentration to TLV-TWA

Results:

		STEP 1	STEP 2	STEP 3
		Mass of VOC in Emission	VOC Concentration in Air	TLV-TWA
VOC	Max conc.	(lb/min)	(ug/cu m)	(ug/cu m)
	(ug/l)			
Benzene	28	3.17E-06	8.58E+03	1600
Vinyl Chloride	6	6.79E-07	1.84E+03	2600
1,2 DCE (cis)	460	5.21E-05	1.41E+05	793000

AS System
Well Layout
~75 wells

AREA OF PLUMES

	MEASURED AREA (in²)	AVERAGE (in²)	AREA (SF)
VOCs	11.58 11.76 11.76	11.7	42,120 (0.97acres)
SVOCs	10.03 10.25 9.98	10.1	36,310 (0.83acres)
VOC+SVOC	15.33 15.62 15.59	15.5	55,850 (1.28acres)
METALS	20.51 20.09 20.49	20.4	73,310 (1.68acres)

🟨 - Arsenic
🟪 - Manganese
🟧 - SVOCs
🟦 - VOCs
▨ - VOCs + SVOCs (overlap)

Scale
1" = 60'

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: EFANE CLEAN	FILE No: 1612 1110	BY: RFO 11/15/04	PAGE: 1 OF 4
SUBJECT: Wallops Flight Facility – FFTA Site Groundwater Alternative 5 AS Treatment – Source Area		CHECKED BY:	DATE: 9/23/04

1.0 TREATMENT SCHEME

The option of Groundwater Alternative 5 would consist of an air sparging (AS) system of the source area only. The AS system would feature the following elements:

- AS well array
- AS blower system

Typical remedial action duration for AS systems ranges from one to five years. For the purpose of this FS, it is assumed that remedial action duration would be 2 years.

2.0 AS WELL ARRAY

Based upon results of pilot tests at a similar Wallops Flight Facility site (Old Aviation Fuel Tank Farm), the typical radius of influence (ROI) of AS wells is approximately 15 to 17.5 ft. This ROI is used for the FFTA site.

Area of influence per AS well: $(30)^2 \times \pi/4 = 707\ \text{ft}^2$, rounded down to 650 ft^2 for overlap
$(35)^2 \times \pi/4 = 961\ \text{ft}^2$, rounded down to 900 ft^2 for overlap

AS wells will be installed at one depth, screened from 15 to 20 feet below the water table (total depth of the wells will be approximately 35 to 40 feet below ground surface) in the area of the VOC and SVOC plume.

Number of wells in the AS Well Array: $(10{,}000\ \text{ft}^2) \div 750\ \text{ft}^2$ = approximately 13 wells. Use 16 wells for the design

3.0 AS BLOWER SYSTEMS

Based upon results of pilot tests at a similar Wallops Flight Facility site (Old Aviation Fuel Tank Farm), the typical air sparging flow is approximately 6 to 12 cfm per well.

For the AS System, an individual AS Blower System would supply air to the AS Well Array installed at a given depth.

AS Blower System would feature one (1) blower. The blower would provide air to the 16 wells of the AS Well

Discharge rate of AS Blower: 16 wells x 6 cfm/well = 96, say 100 cfm
Discharge rate of AS Blower: 16 wells x 12 cfm/well = 192, say 200 cfm

Static head required for the AS Blower: 20 ft H_2O x 0.433 ft/psi = 8.7 psi

To accommodate line friction losses, design blower discharge pressure is approximately twice the required static head. The AS Blower would be designed for a discharge head of 20 psi.

⇒ AS Blower System would feature one (1) blower. The AS Blower would be rated for 200 cfm @ 20 psi.

Tetra Tech NUS		*STANDARD CALCULATION SHEET*	
CLIENT: EFANE CLEAN	FILE No: 1612 1110	BY: RFD 11/15/04	PAGE: 2 OF 4
SUBJECT: Wallops Flight Facility – FFTA Site Groundwater Alternative 5 AS Treatment – Source Area		CHECKED BY:	DATE: 9/23/04

4.0 FUGITIVE EMISSIONS

As per computations presented in Appendix A.1 (Section 2.5), the total quantities of VOC and SVOC COCs for the FFTA site are estimated as follows:

VOCs: 1.6 pounds in groundwater
SVOCs: 0.7 pounds in groundwater
Petroleum: 5,000 pounds in soil (maximum concentrations), 125 pounds in soil (average concentrations)

Total: 5,000 + 0.7 + 1.6 = 5,002.3 pounds

Of all these, it is assumed that 100% of the VOCs, 33% of the Petroleum in soil, and 25% of the SVOCs will eventually be removed by stripping and generate fugitive emissions:

Total Fugitive Emissions (based on maximum concentrations):
1.6 + (0.25 x 0.7) + (0.33 x 5000) = 1651.8, say 1650 pounds

Total Fugitive Emissions (based on average concentrations):
1.6 + (0.25 x 0.7) + (0.33 x 125) = 43 say 45 pounds

It is assumed that 75% of these emissions will occur during the first year of operation of the AS treatment systems and that, within, that first year, half of the emissions would occur during the first 30 days:

Maximum Daily Rate of Fugitive Emissions:
1650 pounds x 0.75 x 0.5 ÷ 30 = 20.6 pounds per day (based on maximum concentrations)

Maximum Daily Rate of Fugitive Emissions:
45 pounds x 0.75 x 0.5 ÷ 30 = 0.6 pounds per day (based on average concentrations)

Based on the maximum concentrations, this is above the VDEQs deminimis level of 15 pounds per day, however based on the average concentrations, the emissions are well below the VDEQ deminimis level of 15 pounds per day. Therefore, the AS system can be operated without fugitive emissions controls. During the start up and first six months of operation the AS system will be operated to control the air flow to minimize the fugitive emissions.

Of these classes of compounds, the main concerns that need to be evaluated are the estimated air concentrations of "toxic" chemicals such as benzene, vinyl chloride, and 1,2-DCE and the potential for flammable air in the ambient. Estimated "worst-case" volatilized concentrations of benzene, vinyl chloride, and 1,2-DCE are shown below assuming very conservative conditions. These estimated concentrations show that if 100 percent of the VOCs are volatilized, and the aquifer is able to sustain the dissolved concentrations at the levels that were detected in groundwater samples, then the peak concentrations at start-up may exceed NIOSH guideline thresholds within the vapors. However, this is not expected to pose a significant human health concern because of the following reasons: (1) dilution of the vapors will occur when they reach the surface, especially during their travel to the human breathing zone, and (2) the location of the site is remote and potential human exposure to the air emissions is expected to be very unlikely.

The potential for emission of flammable air (because of volatilized petroleum compounds) is harder to predict at this time because of the unknown composition of the petroleum present in the soil. However, it does not pose a concern because of the remoteness of the site and because the potential for ignition sources to be present at the site is unlikely.

However, as a health and safety measure, it is recommended that the onsite workers monitor the breathing zone air for chlorinated VOCs and for flammable air during a pilot-scale study of the air sparging system. Based on the results of the pilot-study, the remedial design can determine the need for engineering controls. Therefore, the conceptual design in the FS does not need to include engineering controls for the fugitive emissions.

Estimation of air emissions:

Procedure: Estimate the VOC concentrations based on an assumption of 100% of mass of contaminants and compare concentrations to TLV-TWA limits for breathing-zone air.

(TLV-TWA limits are not applicable to the site because of its remote nature. However, it is being used as a threshold for evaluation of potential for the need for emission controls)

Step 1: Assume 100% volatilization of VOCs with emissions being carried by injected air

Step 2: Convert mass of VOCs being volatilized into concentration in air

Step 3: Compare air concentration to TLV-TWA

Input Assumptions:

1. Detected concentrations of VOCs in groundwater
2. Mass flow rate of groundwater through treatment zone: groundwater flow velocity of 500-1600 ft/yr through an area of influence of 20 ft x 30 ft
3. Air flow rate through treatment zone: 6 cfm
4. 100 percent volatilization of VOCs and consistent concentrations assuming no source depletion.
5. No above-ground dilution in ambient air

Calculations:

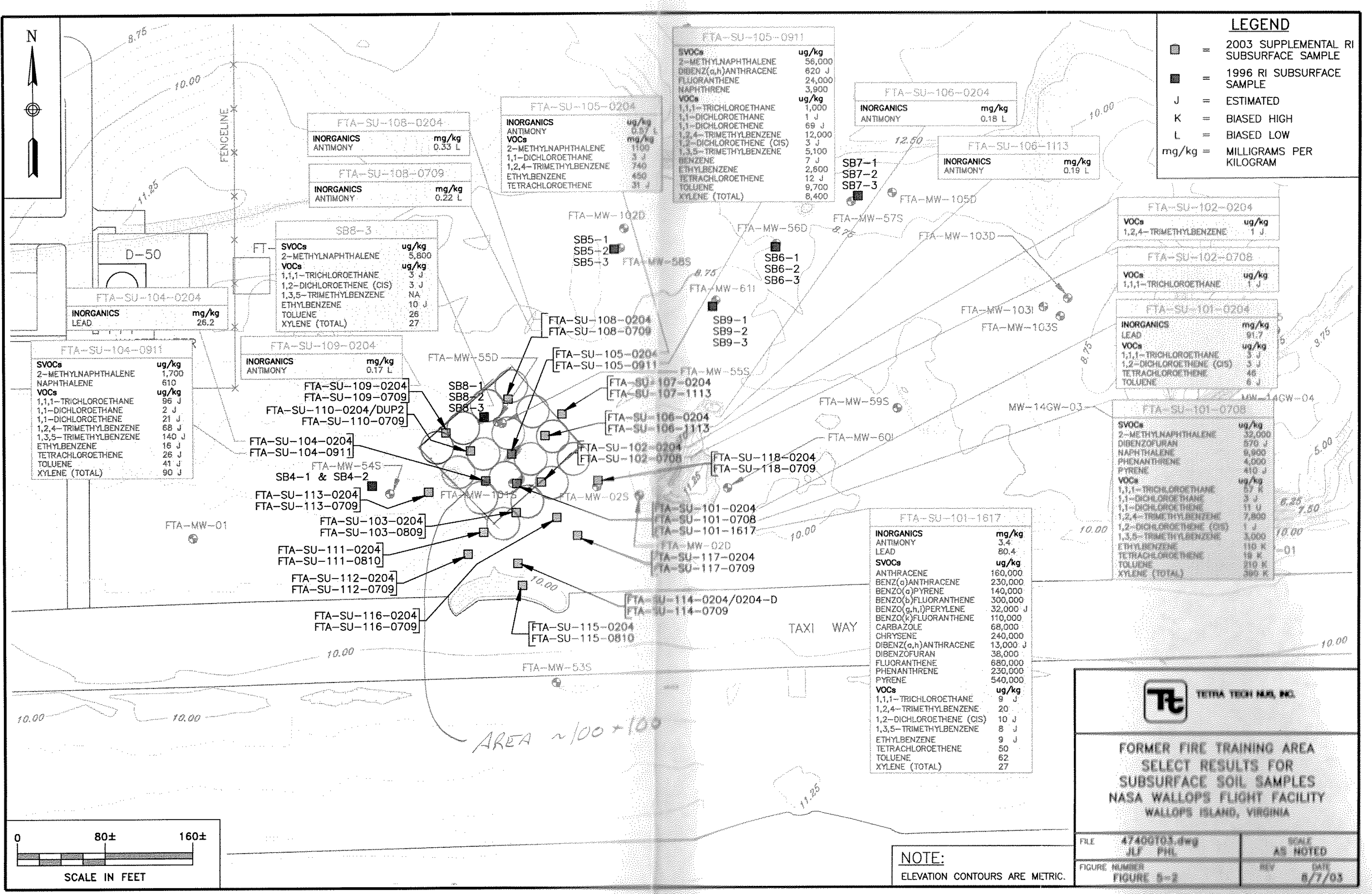
Step 1: Calculate mass of VOCs in emissions:
= [VOC] x GW velocity x 600 sq ft x 62 lb/cu ft x 100 %
Step 2: Calculate VOC concentration in emissions:
= mass of VOCs in emissions/air flow rate

Tetra Tech NUS		*STANDARD CALCULATION SHEET*	
CLIENT: EFANE CLEAN	FILE No: 1612 1110	BY:	PAGE: 4 OF 4
SUBJECT: Wallops Flight Facility – FFTA Site Groundwater Alternative 5 AS Treatment – Source Area		CHECKED BY: RFO 11/15/04	DATE: 9/23/04

Step 3: Compare VOC concentration to TLV-TWA

Results:

		STEP 1	**STEP 2**	**STEP 3**
	Max	**Mass of VOC in Emission**	**VOC Concentration in Air**	**TLV-TWA**
VOC	**conc.**	**(lb/min)**	**(ug/cu m)**	**(ug/cu m)**
	(ug/l)			
Benzene	**28**	**3.17E-06**	**8.58E+03**	**1600**
Vinyl Chloride	**6**	**6.79E-07**	**1.84E+03**	**2600**
1,2 DCE (cis)	**460**	**5.21E-05**	**1.41E+05**	**793000**



FTA-SU-108-0204

INORGANICS	mg/kg
ANTIMONY	0.33 L

FTA-SU-108-0709

INORGANICS	mg/kg
ANTIMONY	0.22 L

FTA-SU-105-0204

INORGANICS	ug/kg
ANTIMONY	0.57 L
VOCs	**mg/kg**
2-METHYLNAPHTHALENE	1100
1,1-DICHLOROETHANE	3 J
1,2,4-TRIMETHYLBENZENE	740
ETHYLBENZENE	450
TETRACHLOROETHENE	31 J

FTA-SU-105-0911

SVOCs	ug/kg
2-METHYLNAPHTHALENE	56,000
DIBENZ(a,h)ANTHRACENE	620 J
FLUORANTHENE	24,000
NAPHTHRENE	3,900
VOCs	**ug/kg**
1,1,1-TRICHLOROETHANE	1,000
1,1-DICHLOROETHANE	1 J
1,1-DICHLOROETHENE	69 J
1,2,4-TRIMETHYLBENZENE	12,000
1,2-DICHLOROETHENE (CIS)	3 J
1,3,5-TRIMETHYLBENZENE	5,100
BENZENE	7 J
ETHYLBENZENE	2,600
TETRACHLOROETHENE	12 J
TOLUENE	9,700
XYLENE (TOTAL)	8,400

FTA-SU-106-0204

INORGANICS	mg/kg
ANTIMONY	0.18 L

FTA-SU-106-1113

INORGANICS	mg/kg
ANTIMONY	0.19 L

SB8-3

SVOCs	ug/kg
2-METHYLNAPHTHALENE	5,800
VOCs	**ug/kg**
1,1,1-TRICHLOROETHANE	3 J
1,2-DICHLOROETHENE (CIS)	3 J
1,3,5-TRIMETHYLBENZENE	NA
ETHYLBENZENE	10 J
TOLUENE	26
XYLENE (TOTAL)	27

FTA-SU-104-0204

INORGANICS	mg/kg
LEAD	26.2

FTA-SU-104-0911

SVOCs	ug/kg
2-METHYLNAPHTHALENE	1,700
NAPHTHALENE	610
VOCs	**ug/kg**
1,1,1-TRICHLOROETHANE	96 J
1,1-DICHLOROETHANE	2 J
1,1-DICHLOROETHENE	21 J
1,2,4-TRIMETHYLBENZENE	68 J
1,3,5-TRIMETHYLBENZENE	140 J
ETHYLBENZENE	16 J
TETRACHLOROETHENE	26 J
TOLUENE	41 J
XYLENE (TOTAL)	90 J

FTA-SU-109-0204

INORGANICS	mg/kg
ANTIMONY	0.17 L

FTA-SU-102-0204

VOCs	ug/kg
1,2,4-TRIMETHYLBENZENE	1 J

FTA-SU-102-0708

VOCs	ug/kg
1,1,1-TRICHLOROETHANE	1 J

FTA-SU-101-0204

INORGANICS	mg/kg
LEAD	91.7
VOCs	**ug/kg**
1,1,1-TRICHLOROETHANE	3 J
1,2-DICHLOROETHENE (CIS)	3 J
TETRACHLOROETHENE	46
TOLUENE	6 J

FTA-SU-101-0708

SVOCs	ug/kg
2-METHYLNAPHTHALENE	32,000
DIBENZOFURAN	570 J
NAPHTHALENE	6,600
PHENANTHRENE	4,000
PYRENE	410 J
VOCs	**ug/kg**
1,1,1-TRICHLOROETHANE	57 K
1,1-DICHLOROETHANE	3 J
1,1-DICHLOROETHENE	11 U
1,2,4-TRIMETHYLBENZENE	7,800
1,2-DICHLOROETHENE (CIS)	1 J
1,3,5-TRIMETHYLBENZENE	3,000
ETHYLBENZENE	110 K
TETRACHLOROETHENE	19 K
TOLUENE	210 K
XYLENE (TOTAL)	390 K

FTA-SU-101-1617

INORGANICS	mg/kg
ANTIMONY	3.4
LEAD	80.4
SVOCs	**ug/kg**
ANTHRACENE	160,000
BENZ(a)ANTHRACENE	230,000
BENZO(a)PYRENE	140,000
BENZO(b)FLUORANTHENE	300,000
BENZO(g,h,i)PERYLENE	32,000 J
BENZO(k)FLUORANTHENE	110,000
CARBAZOLE	68,000
CHRYSENE	240,000
DIBENZ(a,h)ANTHRACENE	13,000 J
DIBENZOFURAN	38,000
FLUORANTHENE	680,000
PHENANTHRENE	230,000
PYRENE	540,000
VOCs	**ug/kg**
1,1,1-TRICHLOROETHANE	9 J
1,2,4-TRIMETHYLBENZENE	20
1,2-DICHLOROETHENE (CIS)	10 J
1,3,5-TRIMETHYLBENZENE	8 J
ETHYLBENZENE	9 J
TETRACHLOROETHENE	50
TOLUENE	62
XYLENE (TOTAL)	27

LEGEND

▨	=	2003 SUPPLEMENTAL RI SUBSURFACE SAMPLE
■	=	1996 RI SUBSURFACE SAMPLE
J	=	ESTIMATED
K	=	BIASED HIGH
L	=	BIASED LOW
mg/kg	=	MILLIGRAMS PER KILOGRAM

NOTE:
ELEVATION CONTOURS ARE METRIC.

TETRA TECH NUS, INC.

FORMER FIRE TRAINING AREA
SELECT RESULTS FOR
SUBSURFACE SOIL SAMPLES
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE 4740GT03.dwg JLF PHL	SCALE AS NOTED
FIGURE NUMBER FIGURE 5-2	REV DATE 8/7/03

APPENDIX B

NATURAL ATTENUATION EVALUATION

BIOCHLOR MODELING
FFTA SITE
WALLOPS ISLAND, VIRGINIA

The BIOCHLOR analytical solute transport model was used to perform modeling at the FFTA on Wallops Island, Virginia, to evaluate the long-term effectiveness of remediation by natural attenuation (RNA) of chlorinated solvents observed to occur at the site and determine when the concentrations associated with the chlorinated solvent plume(s) will reach concentrations below risk-based screening levels. BIOCHLOR, a Microsoft Excel-based spreadsheet model based on the Domenico analytical solute transport model, was developed by the Air Force Center for Environmental Excellence [AFCEE, 2002 (version 2.2)] Technology Transfer Division at Brooks Air Force Base by Groundwater Services, Inc., Houston, Texas. BIOCHLOR is a screening-level tool that has the ability to simulate 1-D advection, 3-D dispersion, linear adsorption, and biotransformation via reductive dechlorination. Reductive dechlorination is assumed to occur under anaerobic conditions and dissolved solvent degradation is assumed to follow a sequential first-order decay process. The analytical screening-level model predicts contaminant concentrations at various distances downgradient from the source area at user-selected time frames based on site-specific input parameters. Concentration trends with distance along the centerline of the plume for the selected time are developed for first order decay and instantaneous reaction models of contaminant degradation (reductive dechlorination), along with a no-degradation simulation for comparison purposes. The model also has the ability to estimate the lateral distribution of contamination and the remaining source mass and plume mass at user-selected times.

BIOCHLOR is utilized in order to investigate how far a dissolved chlorinated solvent plume will extend if no engineered controls or source area reduction measures are implemented. In other words, the model will predict the maximum extent that the dissolved-phase chlorinated solvent plume will migrate under a given groundwater regime and specified natural attenuation parameters. Concentrations of both parent and daughter products are provided from the source area to plume edge. By calibrating to site-specific data, BIOCHLOR can also be utilized to determine how long it will take for dissolved-phase chlorinated solvents to reach concentrations below risk-based or other regulatory standards.

BIOCHLOR is intended to be used as a screening-level model to determine if RNA is a feasible remedial option. Therefore, it should only be used at sites where natural attenuation is documented and known to occur. Site-specific data is necessary for accurate input and calibration in order to yield effective data evaluations of the modeling results. As with any model, there are limitations with BIOCHLOR. As an analytical model, BIOCHLOR assumes simple groundwater flow conditions. In addition, BIOCHLOR also assumes uniform hydrogeologic and environmental conditions over the entire modeling area. Not only is reductive dechlorination assumed to occur as the primary biotransformation factor, but it is assumed that sequential reductive dechlorination of ethanes and ethenes occur. Because of its simplicity and ease of use, many simulations can be performed in a short period of time.

Benzene, SVOCs, arsenic, and manganese contamination were not modeled at the FFTA site. Though a similar analytical solute transport model for benzene exists (BIOSCREEN), analysis of the time dependent benzene concentrations and their resulting spatial trends show that effective biodegradation has occurred. Concentrations of benzene have decreased several orders of magnitude since 1990, and are now just slightly above the preliminary remediation goals. Continued biodegradation, even at decreased rates, will result in benzene concentrations below the preliminary remediation goals within a few years. In addition, benzene is a carbon and energy source for the reductive dechlorination occurring for the chlorinated VOCs. SVOC contaminants are not typically modeled and generally assumed to degrade at rates similar to the VOCs. Therefore, the concentration of benzene and the SVOCs are assumed to meet the preliminary remediation goals at the same time as the chlorinated VOCs. The arsenic and manganese contamination is most likely associated with the reducing environment created by the degradation of VOC and SVOC contaminants since the extent of the contamination is not widespread and is found at the wells that exhibit the highly reducing environment. It is assumed that the site would return to an oxic environment after the VOCs and SVOCs have been biodegraded and this should cause the arsenic and manganese to transform to insoluble oxidized compounds.

Three base cases of BIOCHLOR simulations were performed for the FFTA site. Three base cases were required based on the site-specific data and model limitations. The primary reason that three base cases were required was that groundwater flow has three main flowpaths (two distinct flowpaths and gradients in the upper unit, one in the lower unit). As a result, concentrations of parents and daughter products at downgradient locations from the main source area at the FFTA also had to be carefully considered. The three base cases are summarized as: source area (near FTA-MW-101S) to turning/pivot point (near FTA-MW-57S) in the upper unit (northeasterly); from the turning/pivot point (near FTA-MW-57S) to topographic low near the unnamed tributary (near MW-14GW-04) in the upper unit (southeasterly); and, from the source area to the north (near FTA-MW-102D). For each of the series of simulations, the spreadsheet model was calibrated to existing historical conditions, then predictive simulations were run to estimate future concentration trends and time for portions of the plume to reach concentrations below risk-based screening levels based on a no further action scenario.

Verification of Natural Attenuation Processes

Inherent in the underlying base equations of BIOCHLOR, natural attenuation is assumed to occur at the site. Therefore, before BIOCHLOR is selected in order to evaluate the feasibility of RNA at a site, conditions conducive to anaerobic reductive dechlorination must be confirmed to be present at the site in the areas impacted by the chlorinated solvents. For the FFTA site, a natural attenuation analysis was performed, and is outlined in Section 3.2.2.3. Additional pertinent information is also found in Section 2 where site geology and hydrogeology is presented.

As a component of BIOCHLOR, the U.S. EPA Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water scoring table (U.S. EPA, 1998) is included for verification that effective natural attenuation processes (anaerobic reductive dechlorination) is occurring at the site where BIOCHLOR will be used. The scoring system requires the concentrations of electron acceptors, parent and daughter chlorinated solvents, methane, TOC, and chloride and ORP, temperature, and pH measurements. Additional site information can also be used as input. These field and laboratory based parameters are evaluated and scored for evidence of biotransformation.

As presented in Section 3.2.2.3, site-specific data for the FFTA was entered into this scoring table. Available site data (including historical data) was considered; however, field and laboratory data collected in March 2003 was emphasized because of its completeness of natural attenuation parameters collected and the representative nature of this data to the current groundwater conditions. Scores were determined for two main scenarios, one considering groundwater data within the contaminant plume and the second for groundwater wells near the current areas of highest concentrations. For each of the two main scenarios, slight variances in data entry were also considered, which in turn, slightly altered the score.

The first scenario analyzed considered groundwater data within the contaminant plume. Data was entered based primarily on March 2003 field and laboratory results. The first scenario scoring table with data input and resultant score is attached in this appendix. Based on the data entered for this scenario, a score of 14 was calculated. This indicates that there is limited evidence for anaerobic biodegradation of chlorinated organics. Data receiving a "Yes" that enough evidence is present where points are awarded in the scoring table are for: oxygen, nitrate, sulfate, ORP, pH, hydrogen, PCE, DCE, 1,1,1-Trichloroethane, DCA, Carbon

Tetrachloride, and Dichloromethane. Criteria necessary to be met in order to score a "Yes" can be seen in the scoring table. Because the groundwater for the whole contaminant plume was considered, certain data entry may be considered conservative. For instance, a "Yes" for oxygen was awarded for <0.5 mg/L though areas also occur where >5 mg/L occur, which would result in an additional -3 score, zeroing out the whole oxygen parameter. A similar situation occurs for nitrate since not every location shows <1 mg/L. This would reduce the score by 2. Also, Carbon Tetrachloride and Dichloromethane were only seen in historical sampling events. That would result in an additional 2 point reduction if these parameters were changed. If these reductions were to be included, the resultant score would be 10, which indicates that limited evidence for anaerobic biodegradation of chlorinated organics exists. Conversely, some parameters could also be upgraded to a "Yes" from their current "No" in the first scenario. These include the following parameters: Carbon Dioxide, Alkalinity, Chloride, BTEX, and Vinyl Chloride. If these were upgraded to "Yes", the resultant very liberal score would be 25, indicating strong evidence for anaerobic biodegradation of chlorinated organics. Therefore, the resultant score of 14 for the first main scenario is a near average of the low and high values obtained by slightly varying the input parameters to be conservative and liberal.

The second scenario analyzed considers only the groundwater from the current locations where the highest concentrations are observed. Only field and laboratory data from March 2003 was considered. This scenario most accurately reflects the current status of anaerobic biodegradation currently active at the site. Currently, contaminant concentrations are highest around FTA-MW-61I and FTA-MW-57S. The second scenario scoring table with data input and resultant score is also attached in this appendix. Based on the data entered for this scenario, a score of 21 was calculated. This indicates that there is strong evidence for anaerobic biodegradation of chlorinated organics. Data receiving a "Yes" that enough evidence is present where points are awarded in the scoring table are for: oxygen, nitrate, sulfate, ORP, pH, carbon dioxide, alkalinity, hydrogen, BTEX, DCE, vinyl chloride, 1,1,1-Trichloroethane, and DCA. Historically, Dichloromethane was also observed at these locations, which would increase the score to 23. Conversely, oxygen, ORP, and BTEX are only valid as a "Yes" for FTA-MW-61I, which if these parameters were changed to a "No", 6 points would be lost, yielding a score of 15.

As can be seen from the results of the U.S. EPA Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water scoring table for the two main scenarios, there is adequate to strong evidence that anaerobic biodegradation of chlorinated organics is occurring at the FFTA. Limited evidence is only observed when the entire groundwater contaminant plume is considered utilizing available data. Based on the results of the scoring table, it is reasonable to conclude that anaerobic biodegradation of chlorinated organics plays an important role in the reduction of contaminant concentrations over time at the FFTA.

Model Setup

Three base cases of BIOCHLOR simulations were required for the FFTA site based on the site-specific data and model limitations. The primary reason that three base cases were required was that groundwater flow has three main flowpaths (two distinct flowpaths and gradients in the upper unit, one in the lower unit). These flowpaths were determined from analysis of site conditions and the analysis of the effectiveness of natural attenuation. As a result, concentrations of parents and daughter products at downgradient locations from the main source area at the FFTA also had to be carefully considered for accurate model calibration and prediction. The three base cases are summarized as: source area (near FTA-MW-101S) to turning/pivot point (near FTA-MW-57S) in the upper unit (northeasterly); from the turning/pivot point (near FTA-MW-57S) to topographic low near the unnamed tributary (near MW-14GW-04) in the upper unit (southeasterly); and, from the source area to the north (near FTA-MW-102D). A fourth modeling case was also examined and is based on the current high area of concentrations. This additional case was necessary to more accurately predict future contaminant concentrations based on the site-specific conditions current to the site. The fourth case is a variant of the first base case, being defined as flow in the upper unit from the current area of high concentrations (near FTA-MW-61I) to the turning/pivot point (near FTA-MW-57S).

BIOCHLOR requires that the user input a number of site-specific and chemical-specific parameters for the model to operate properly. Some of the parameters are fixed input that do not vary and are specific to each base scenario (such as hydraulic conductivity, hydraulic gradient, etc.), while other parameters are initially set-up based on either site-specific data or validated reference values and are free to vary within a degree (variance for each parameter is confined by reference values for similar sites) during the calibration process. Definitions of the model input parameters, as well as representative reference values, are provided in the BIOCHLOR User's Manual.

The following are the input parameters used for each of the modeling runs and their source:

Hydrogeologic Data

- Hydraulic conductivity = 0.0494 cm/sec. Source: Mathematical average of observed range of hydraulic conductivities observed in the Columbia aquifer. Range of values observed was 80 to 200 feet/day, as seen in historical investigations.

- Hydraulic gradient varied for each of the three base cases. Hydraulic gradient was calculated based on the central flowpaths for each of the three base cases from the potentiometric surface maps for the upper and lower units based on the 2003 data from the Supplemental RI (TtNUS, 2004). For the first base case, source area (near FTA-MW-101S) to turning/pivot point (near FTA-MW-57S) in the upper unit (northeasterly groundwater flow), the hydraulic gradient was calculated 0.00258 ft/ft. For the second base case, from the turning/pivot point (near FTA-MW-57S) to topographic low near the unnamed tributary (near MW-14GW-04) in the upper unit (southeasterly groundwater flow), the hydraulic gradient was calculated to be 0.008 ft/ft. For the final base case, from the source area to the north (near FTA-MW-102D) in the lower unit, a hydraulic gradient of 0.00276 ft/ft was calculated. For the fourth, additional case, the same gradient as the first base case was used.

- Porosity = 0.25. Source: Used by TtNUS in plume mass estimation calculations and other site related work (including other work performed at adjacent Wallops Island sites also located in the Columbia aquifer). Value is consistent with literature published values (Freeze and Cherry, 1973) and with ranges based on lithology in BIOCHLOR.

For each model run, each of these hydrogeologic input parameters was fixed. No variation of these input parameters occurred during model calibration. Based on the input provided into BIOCHLOR, the seepage velocity was calculated by BIOCHLOR. Based on ranges provided by BIOCHLOR, the seepage velocity observed at the FFTA exceeded these typical values. The data and calculated seepage velocity are consistent with the lithology and gradient observed.

Dispersion Data

Selection of dispersivity values is a difficult process and research indicates that dispersivity values can range over 2-3 orders of magnitude for a given plume. A commonly accepted, simple estimation of dispersivity is to assume that alpha x is 10% of the estimated plume length. Transverse and vertical dispersivities are further assumed to be 10% of the horizontal dispersivity and nearly zero, respectively. Though this is a simple estimation approach to determine dispersion at a site, it yields the most conservative results.

- Plume Length/Alpha x varied for each of the three base cases. Alpha x was calculated as 10% of the plume length based on the observed contaminant plume for each of the three base cases. Contaminant plume lengths were estimated from the 2003 data from the Supplemental RI (TtNUS, 2004). Similar to calculation of the hydraulic gradient, the plume length was determined based on the flowpaths for each base case. For the first base case, source area (near FTA-MW-101S) to turning/pivot point (near FTA-MW-57S) in the upper unit (northeasterly groundwater flow), the plume length was estimated to be 430 feet. For the second base case, from the turning/pivot point (near FTA-MW-57S) to topographic low near the unnamed tributary (near MW-14GW-04) in the upper unit (southeasterly groundwater flow), the plume length was estimated to be 345 feet. For the final base case, from the source area to the north (near FTA-MW-58S) in the lower unit, a plume length of 250 feet was estimated. For the fourth, additional case, a plume length of 131 feet was estimated.

For each model run, each of these dispersion input parameters were fixed. No variation of these input parameters occurred during model calibration.

Adsorption Data

- Soil Bulk Density = 1.98 kg/L. Source: Assumption that is consistent with the assumed porosity and a specific gravity for the soil grains of 2.65.
- Fraction organic carbon = 0.001. Source: Average derived from TOC subsurface sample results reported in the August 1991 Supplemental Site Characterization report prepared by EBASCO at an adjacent NASA Wallops site, with the investigation also focused on contamination within the Columbia aquifer.
- Partition coefficients (Koc) were determined from literature values for each of the parameters observed to have occurred at the FFTA site.

Based on the entered data for each parameter, BIOCHLOR calculates the retardation factor. BIOCHLOR uses one retardation factor for the chemical constituents. Therefore, BIOCHLOR calculated the median retardation factor based on the parameters provided. This resulted in a common R for the site of 1.99. Typical values range from 1 to 6, where 1 indicates that no retardation occurs. A value of 1.99 is fairly conservative.

For each model run, each of these dispersion input parameters were fixed. No variation of these input parameters occurred during model calibration.

Biotransformation Data – First Order Decay Coefficient

First order decay coefficients for the dissolved constituents must be selected with great care. The optimal method to determining the first order decay coefficients at a site is to begin with literature values and calibrate to through a trial-and-error technique to match the observed field data. This is the technique employed for each of the three base modeling runs and additional run. Default literature values provided by BIOCHLOR were initially used. These values are: 2.0/year for PCE to DCE, 1.0/year for TCE to DCE, 0.7/year for DCE to VC, and 0.6/year for VC to Ethane.

General Data – General Model Parameters

- Simulation time varies throughout the modeling runs for both calibration and predictive scenarios for each of the base cases and the additional run, according to their respective goals. Generally, simulation times were 3, 4, 9, or 14 years during the calibration runs and were determined based on the available observation data for each base case. Times frames in multiples of 5 years were selected for future predictive modeling runs.
- Model area width = 110 feet. This value was estimated based on current contaminant plume maps from the Supplemental RI (TtNUS, 2004).

- Model area length was set to 500 feet for the three main base cases of modeling performed. This value was selected in order to fully encompass the plume lengths for each base case scenario. The model area length was set to 150 feet for the additional fourth case considered. The model area length was slightly larger than the actual plume lengths.

- Biotransformation zone was set to 1 zone. Site-specific data did not support the use of two zones since the environmental conditions (DO, ORP, etc.) did not change appreciably over the extent of the observed contaminant plume. BIOCHLOR automatically selects the zone length to be equal to the model area length.

For each model run, each of these general data input parameters were fixed. No variation of these input parameters occurred during model calibration.

Source Data

- Source Thickness in the Saturated Zone = 15 feet. This value was used for the base case scenarios and the additional, fourth scenario. It is based on estimated aquifer thicknesses in the upper and lower units at the FFTA. Based on water level measurements collected in March 2003 at the site, it is estimated that 30 feet of saturated thickness occurs in the Columbia aquifer. The upper and lower units divide the Columbia aquifer in nearly two equal portions, resulting in a saturated thickness of 15 feet for both subaquifers.

- Source area width = 110 feet. This was set to be equal to the model area width. Emphasis of the modeling efforts was placed on distances from the source area. Analysis of historical contaminant concentration maps (plume maps through time) indicates that the dominant contaminant migration pathway is parallel to the observed groundwater flow directions.

- Source area concentrations varied according to the base case and time frame. This data entry is discussed in detail in later sections.

- Source decay constant is a representative first order source decay constant for the chemical constituents. It is not a biotransformation rate coefficient. The source decay constant rate is determined from site-specific data. In order to estimate this decay constant, concentration versus time from a source well is plotted on a semi-log plot, and the resulting slope from the best fit straight line is the decay constant. Based on the available site data, for many wells, only two or three concentrations were available for this analysis. Therefore, values were calculated in this manner, but only considered as a starting value for calibration. Initial values ranged from 0.1 to 0.4.

For each model run, most of these source data input parameters were fixed. No variation of these input parameters occurred during model calibration. The only data input parameter that was changed during calibration was the source decay constant.

Field Data for Comparison

The field data for comparison consists of observed concentrations along the centerline of the contaminant plume for a specific model run, at the endpoint of time for that model run. For each of the base cases and the additional run, the field data varied. Distances were calculated based on distances along the primary groundwater flowpath, consistent with the potentiometric surface map for the respective upper or lower unit. Details of the field data utilized for model calibration for each of the base runs and the additional run is discussed in the model calibration section of this appendix.

Model Calibration

Model calibration is an important process by which site-specific data is varied in order to produce output that is consistent with observed concentrations and trends. A thorough understanding of the site processes and model limitations is necessary to ensure that the appropriate input parameters are varied within physical limitation ranges in order to match observed site data. For the BIOCHLOR modeling performed at the FFTA site, there were two primary input parameters that were varied in order to match the site data. These parameters were the first order decay coefficient (part of the Biotransformation data) and the source decay constant (part of the Source data). Though the partition coefficient may also vary, greater uncertainity with the first order decay coefficient and the source decay constant parameters exists and are more applicable to be varied during model calibration. It was also discovered during model calibration that these two input parameters were also more sensitive to model output.

Model calibration generally occurred in a three step process for each of the three base cases and the additional model run. First, the source decay constant was varied until the origin of the sequential first order decay line best matched the observed data at the source well. Second, the first order decay coefficient for PCE was varied until the slope of the line best fit the observed data (which was located at fixed distances from the source) at the endpoint time. Thirdly, the other first order decay coefficients were varied in order to best match the slope of the best fit line to the observed data (which was located at fixed distances from the source) at the endpoint time. To some extent, the three steps were interchangeable and adjustments had to be made to best fit the first order decay line to both the source and daughter concentrations along the centerline of the modeled plume. For each of the three base cases and additional calibration run, the BIOCHLOR input and output is provided.

Calibration of Base Case #1 - Source area (near FTA-MW-101S) to turning/pivot point (near FTA-MW-57S) in the upper unit

For the first base case, three separate BIOCHLOR modeling calibration runs were performed. The closest groundwater monitoring well to the source area (based on historical site conditions) that was installed at the earliest date is FTA-MW-02S. Located directly along the primary groundwater flowpath 202 feet from this source well is FTA-MW-61I. The final well along the primary groundwater flowpath is FTA-MW-57S, located 430 feet from the source. Available chemical data for these three wells was used in each of the three calibration runs. Simulation time varied for each of the three calibration runs, based on the available chemical data. The first calibration run had a simulation time of 4 years and represented the period 1990 to 1994. Only PCE and DCE data was available during these years. The source decay constant was determined to be 0.1/year. It was determined by trial-and-error based on the best fit sequential first order decay line through the observed data for PCE in 1994. The first order decay coefficient for PCE to TCE (PCE) was determined to be 2.0/year. PCE is over-predicted at the source in 1994. DCE could not be effectively matched with a best fit line by altering the source decay constant and first order decay coefficients. DCE is under-predicted at the locations in 1994. Decreasing the source decay constant and first order decay coefficients below these calibrated values does not improve results for DCE.

The second calibration run had a simulation time of 9 years and represented the period from 1994 to 2003. For this time period, PCE and TCE data was available in 1994, while in 2003, PCE, DCE, and VC data was available. Again, the source decay constant was determined to be 0.1/year. It was determined by trial-and-error to best fit a sequential first order decay line through the observed data for DCE in 2003. DCE is over-predicted at the source in 2003, and under-predicted at FTA-MW-61I. The first order decay coefficient for the DCE to VC pathway (DCE) was determined to be 0.2/year, based on the match to VC concentrations in 2003. VC is over-predicted in 2003 at FTA-MW-57S.

The final calibration run had a simulation time of 13 years and represented the period from 1990 to 2003. Effectively, this calibration run is a combination of the two previous calibration runs. In 1990, only PCE and TCE data was available, while in 2003, PCE, DCE, and VC data was available. The source decay constant was determined to be 0.1/year and the first order decay coefficients were consistent with the previous two calibration runs. The best fit sequential first order decay line through the observed data for PCE in 2003 is reasonably matched. PCE was over-predicted at the source in 2003. DCE could not be effectively matched with a best fit line by altering the source decay constant and first order decay coefficients. DCE is under-predicted at the locations in 2003.

Significance of the calibration results will be discussed in detail below.

Calibration of Base Case #2 - Turning/pivot point (near FTA-MW-57S) to topographic low near the unnamed tributary (near MW-14GW-04) in the upper unit

Only one calibration run was possible for the second base case since chemical data downgradient of FTA-MW-57S was only available in 2003. The source well is FTA-MW-57S. Located 191 feet directly downgradient along the primary groundwater flowpath is FTA-MW-103S, and located 369 feet directly downgradient along the primary groundwater flowpath is MW-14GW-04. This calibration run had a simulation time of 9 years and represented the period from 1994 to 2003. PCE and TCE were not detected in the source well in either 1994 or 2003. Only DCE was observed at both times at any of the groundwater monitoring wells. A very close match to the source decay constant was determined for this base case. As seen in the DCE data for 2003, this close match represented a source decay constant of 0.175 (preliminarily estimated to be 0.2 from concentration versus time plots). The first order decay coefficient for DCE to VC (DCE) was also able to be precisely determined based on the best fit line of the sequential first order decay. The first order decay for DCE to VC was determined to be 7.5/year. VC is produced during the biotransformation at measurable levels, though no VC has been detected in these monitoring wells.

Significance of the calibration results will be discussed in detail below.

Calibration of Base Case #3 - Source area to the north (near FTA-MW-102D) in the lower unit

Only one calibration run for the third base case was performed since chemical data was limited. This calibration run had a simulation time of 9 years and represented the period from 1994 to 2003. Only PCE and DCE data was available, and only two wells were used. FTA-MW-2D was located near the source area while FTA-MW-102D. Calibration centered on matching one parameter for this run, the source decay constant. A source decay constant of 0.4/year was determined for the lower unit. First order decay coefficients were not determined since no chemical concentrations were observed away from the source in 2004.

Significance of the calibration results will be discussed in detail below.

Calibration of Additional Case - Area of high concentrations (near FTA-MW-61I) to the turning/pivot point (near FTA-MW-57S) in the upper unit

This calibration run was added to assess the current biotransformation occurring at the FFTA site where observed concentrations are currently highest. This calibration run had a simulation time of 3 years and represented the period from 2000 to 2003. Available chemical concentrations for 2000 were a composite of both pre- and post-purging. Based on this fact, chemical data from this date were used sparingly during the FS.

Some input parameters were adjusted based on the monitoring wells used. The alpha x was adjusted to 13.1, ten percent of the plume length between the two wells. The model area length was also adjusted to 150 feet. No PCE was observed in 2000 or 2003 at either monitoring well. DCE was the dominant chemical observed in both 2000 and 2003, and some minor VC was observed in FTA-MW-61I in 2003. A source decay constant of 0.4/year was determined based on the concentration of DCE observed at FTA-MW-61I in 2003. As seen in the base case #2, turning/pivot point (near FTA-MW-57S) to topographic low near the unnamed tributary (near MW-14GW-04) in the upper unit, the first order decay coefficient for DCE to VC was determined to be 7.5/year. As can be observed in the DCE plot in 2003, a very tight match to the observed data for the sequential first order decay line is achieved.

Significance of the calibration results will be discussed in detail below.

Summary of Model Calibration

Overall, model calibration for the three base cases and the additional model run performed at the FFTA site was very effective. At first glance, calibration results appear poor; however, close analysis of the calibration process and results show that calibration was successful and effective predictive modeling runs can be performed. The major conclusions for each of the calibration scenarios are herein summarized.

Three main conclusions can be summarized from the calibration of base case #1, source area (near FTA-MW-101S) to turning/pivot point (near FTA-MW-57S) in the upper unit. The first main conclusion is that the source decay constant is very low, having a calibrated value of 0.1/year. The lower the source decay constant, the more persistent a chemical concentration is through time. The second main conclusion is that biotransformation is effectively occurring. Comparison of the no degradation/production results versus the sequential first order decay results (for instance in the first case from 1990 to 1994) shows that observed chemical data cannot be explained without the active presence of biotransformation. The final conclusion is that the contamination occurred in the source zone at irregular, discrete times. In other words, multiple releases (of unknown chemical types per release) occurred at discrete periods of time and were separated by unknown lengths of time. Based on the chemicals observed throughout the plume areas, it is known that PCE, DCE, and Fuels (probably jet fuel) was used as fuel to start and keep the fires burning during the fire fighting training classes. This conclusion is evident from the modeling since even when no degradation/production and low source decay constants are utilized, not enough DCE is produced at downgradient locations in the plume. This conclusion is completely consistent with the historical operations of the site where infrequent fire training activities occurred and acted as the source of the release.

In BIOCHLOR, there are two ways to represent source concentrations. One is to assume that the source concentrations remain constant through time, with degradation only occurring within the plume downgradient of the source. The second way to represent source concentrations is to assume that degradation occurs at both the source and within the downgradient plume. This is what was used for this modeling. It was known from site conditions and site history that a constant source was not present. It was also observed from concentration maps in the upper and lower units through time that more than one area of high concentrations occurs simultaneously.

An important conclusion that can be summarized from the calibration of base case #2, turning/pivot point (near FTA-MW-57S) to topographic low near the unnamed tributary (near MW-14GW-04) in the upper unit, is that the source decay constant was slightly higher, being 0.175/year versus 0.1/year. More data was also available to better match field data and determine that the first order decay coefficient for DCE to VC was 7.5/year.

Close analysis of base case #3, source area to the north (near FTA-MW-102D) in the lower unit, shows that not a lot of data is available for an effective analysis with BIOCHLOR. Only two monitoring wells were available. It should be noted, however, that based on the geologic and hydrogeologic conditions present at the site, contaminant impacts in the deep unit are more likely to be present due to the downward vertical gradients persistent across the site. Careful analysis of historical plume maps for DCE show that higher concentrations are located downgradient than upgradient locations and are associated with high concentrations observed in the upper zones at earlier times.

An important conclusion drawn from the additional modeling run, area of high concentrations (near FTA-MW-61I) to the turning/pivot point (near FTA-MW-57S) in the upper unit, is that the source decay coefficient of 0.4/year and the first order decay coefficient for DCE to VC of 7.5/year match calibrated values from the other runs. This shows that these values are representative of site conditions both in the present and in the past. Overall, this shows that the hydrogeologic conditions have not significantly changed over time, particularly the effectiveness of natural attenuation to reduce chlorinated solvents to acceptable groundwater standards.

Predictive Model Runs

Two primary predictive modeling scenarios were run for the FFTA site, both in the upper unit only. They are based on the conclusion of the calibration modeling runs and end-point goals of the remediation process. The primary goal of the predictive runs was to determine how long from present (in years) it would take for concentrations of DCE to be below the health-based screening value of 70 ppb if no active remedial action were taken at the site (source removal, in-situ injection, etc.). Since concentrations would remain highest at the source, emphasis was placed on identifying when the source zone would be below the health-based level. This would yield a conservative number since other downgradient portions would be below the health-based level before the source. Starting concentrations for the scenarios would be the March 2003 observed concentrations of DCE. The two main scenarios focused on the additional modeling run, area of high concentrations (near FTA-MW-61I) to the turning/pivot point (near FTA-MW-57S), and from the turning/pivot point (near FTA-MW-57S) to topographic low near the unnamed tributary (near MW-14GW-04), base case number 2. The predictive modeling scenarios are herein described.

Predictive Run #1 - Area of high concentrations (near FTA-MW-61I) to the turning/pivot point (near FTA-MW-57S)

The calibrated model input from the additional modeling run was utilized. It was determined that in 5 years, the concentration of DCE at the source would be 62 ppb, just below the health-based screening value of 70 ppb. Remaining portions of the plume (to the turning/pivot point) will also be below 70 ppb.

Predictive Run #2- Turning/pivot point (near FTA-MW-57S) to topographic low near the unnamed tributary (near MW-14GW-04)

The calibrated model input from base case number 2 was used. It was determined that in 5 years, the concentration of DCE at the source would be 46 ppb, below the health-based value of 70 ppb.

Additional Predictive Run – Predictive Run #2 with maximum DCE from FTA-MW-61I

As an ultra-conservative approach to yield the maximum time needed to reduce the concentrations of DCE below the health-based value, an additional predictive run was constructed. For this run, it was assumed that there would be no degradation of DCE from its current high observed at FTA-MW-61I until it reached the turning/pivot point at FTA-MW-57S. Therefore, the observed high of 460 ppb of FTA-MW-61I would be assumed to be the starting concentrations at the source for Predictive Run #2. Analysis of the output at 5 years, 10 years, and 15 years shows that DCE at the source (FTA-MW-57S) had values of 192 ppb, 80 ppb, and 33 ppb, respectively. Therefore, in slightly more than 10 years, the source zone would be reduced to near or below this health-based value of 70 ppb. It is not believed that these conditions will occur, producing this longer period of time until contaminant concentrations are below the health-based standard.

Therefore, it can be seen that based on the predictive modeling runs, the FFTA site will not have any concentrations of DCE exceeding the health-based standard in 5 years.

U.S. EPA PRELIMINARY SCREENING PARAMETERS & WEIGHTING FOR ANAEROBIC BIODEGRADTION PROCESSES TABLES

Natural Attenuation Screening Protocol

The following is taken from the USEPA protocol (USEPA, 1998). The results of this scoring process have no regulatory significance.

Interpretation	Score
Inadequate evidence for anaerobic biodegradation* of chlorinated organics	0 to 5
Limited evidence for anaerobic biodegradation* of chlorinated organics	6 to 14
Adequate evidence for anaerobic biodegradation* of chlorinated organics	15 to 20
Strong evidence for anaerobic biodegradation* of chlorinated organics	>20

* reductive dechlorination

Score: 14

Scroll to End of Table

Analysis	Concentration in Most Contam. Zone	Interpretation	Yes	No	Points Awarded
Oxygen*	<0.5 mg/L	Tolerated, suppresses the reductive pathway at higher concentrations	●	○	3
	> 5mg/L	Not tolerated; however, VC may be oxidized aerobically	○	●	0
Nitrate*	<1 mg/L	At higher concentrations may compete with reductive pathway	●	○	2
Iron II*	>1 mg/L	Reductive pathway possible; VC may be oxidized under Fe(III)-reducing conditions	○	●	0
Sulfate*	<20 mg/L	At higher concentrations may compete with reductive pathway	●	○	2
Sulfide*	>1 mg/L	Reductive pathway possible	○	●	0
Methane*	>0.5 mg/L	Ultimate reductive daughter product, VC Accumulates	○	●	0
Oxidation Reduction Potential* (ORP)	<50 millivolts (mV)	Reductive pathway possible	●	○	1
	<-100mV	Reductive pathway likely	○	●	0
pH*	5 < pH < 9	Optimal range for reductive pathway	●	○	0
TOC	>20 mg/L	Carbon and energy source; drives dechlorination; can be natural or anthropogenic	○	●	0
Temperature*	>20°C	At T >20°C biochemical process is accelerated	○	●	0
Carbon Dioxide	>2x background	Ultimate oxidative daughter product	○	●	0
Alkalinity	>2x background	Results from interaction of carbon dioxide with aquifer minerals	○	●	0
Chloride*	>2x background	Daughter product of organic chlorine	○	●	0
Hydrogen	>1 nM	Reductive pathway possible, VC may accumulate	○	●	0
Volatile Fatty Acids	>0.1 mg/L	Intermediates resulting from biodegradation of aromatic compounds; carbon and energy source	○	●	0
BTEX*	>0.1 mg/L	Carbon and energy source; drives dechlorination	○	●	0
PCE*		Material released	●	○	0
TCE*		Daughter product of PCE $^{a/}$	○	●	0
DCE*		Daughter product of TCE. If cis is greater than 80% of total DCE it is likely a daughter product of TCE$^{a/}$; 1,1-DCE can be a chem. reaction product of TCA	●	○	2
VC*		Daughter product of DCE$^{a/}$	○	●	0
1,1,1-Trichloroethane*		Material released	●	○	0
DCA		Daughter product of TCA under reducing conditions	●	○	2
Carbon Tetrachloride		Material released	●	○	0
Chloroethane*		Daughter product of DCA or VC under reducing conditions	○	●	0
Ethene/Ethane	>0.01 mg/L	Daughter product of VC/ethene	○	●	0
	>0.1 mg/L	Daughter product of VC/ethene	○	●	0
Chloroform		Daughter product of Carbon Tetrachloride	○	●	0
Dichloromethane		Daughter product of Chloroform	●	○	2

* required analysis.

a/ Points awarded only if it can be shown that the compound is a daughter product (i.e., not a constituent of the source NAPL).

SCORE Reset

End of Form

Natural Attenuation Screening Protocol

The following is taken from the USEPA protocol (USEPA, 1998). The results of this scoring process have no regulatory significance.

Interpretation	Score
Inadequate evidence for anaerobic biodegradation* of chlorinated organics	0 to 5
Limited evidence for anaerobic biodegradation* of chlorinated organics	6 to 14
Adequate evidence for anaerobic biodegradation* of chlorinated organics	15 to 20
Strong evidence for anaerobic biodegradation* of chlorinated organics	>20

* reductive dechlorination

Score: 21

Scroll to End of Table

Analysis	Concentration in Most Contam. Zone	Interpretation	Yes	No	Points Awarded
Oxygen*	<0.5 mg/L	Tolerated, suppresses the reductive pathway at higher concentrations	●	○	3
	> 5mg/L	Not tolerated; however, VC may be oxidized aerobically	○	●	0
Nitrate*	<1 mg/L	At higher concentrations may compete with reductive pathway	●	○	2
Iron II*	>1 mg/L	Reductive pathway possible; VC may be oxidized under Fe(III)-reducing conditions	○	●	0
Sulfate*	<20 mg/L	At higher concentrations may compete with reductive pathway	●	○	2
Sulfide*	>1 mg/L	Reductive pathway possible	○	●	0
Methane*	>0.5 mg/L	Ultimate reductive daughter product, VC Accumulates	○	●	0
Oxidation Reduction Potential* (ORP)	<50 millivolts (mV)	Reductive pathway possible	●	○	1
	<-100mV	Reductive pathway likely	○	●	0
pH*	5 < pH < 9	Optimal range for reductive pathway	●	○	0
TOC	>20 mg/L	Carbon and energy source; drives dechlorination; can be natural or anthropogenic	○	●	0
Temperature*	>20°C	At T >20°C biochemical process is accelerated	○	●	0
Carbon Dioxide	>2x background	Ultimate oxidative daughter product	●	○	1
Alkalinity	>2x background	Results from interaction of carbon dioxide with aquifer minerals	●	○	1
Chloride*	>2x background	Daughter product of organic chlorine	○	●	0
Hydrogen	>1 nM	Reductive pathway possible, VC may accumulate	●	○	3
Volatile Fatty Acids	>0.1 mg/L	Intermediates resulting from biodegradation of aromatic compounds; carbon and energy source	○	●	0
BTEX*	>0.1 mg/L	Carbon and energy source; drives dechlorination	●	○	2
PCE*		Material released	○	●	0
TCE*		Daughter product of PCE [a/]	○	●	0
DCE*		Daughter product of TCE. If cis is greater than 80% of total DCE it is likely a daughter product of TCE[a/]; 1,1-DCE can be a chem. reaction product of TCA	●	○	2
VC*		Daughter product of DCE[a/]	○	●	0
1,1,1-Trichloroethane*		Material released	●	○	0
DCA		Daughter product of TCA under reducing conditions	●	○	2
Carbon Tetrachloride		Material released	○	●	0
Chloroethane*		Daughter product of DCA or VC under reducing conditions	○	●	0
Ethene/Ethane	>0.01 mg/L	Daughter product of VC/ethene	○	●	0
	>0.1 mg/L	Daughter product of VC/ethene	○	●	0
Chloroform		Daughter product of Carbon Tetrachloride	○	●	0
Dichloromethane		Daughter product of Chloroform	●	○	2

* required analysis.

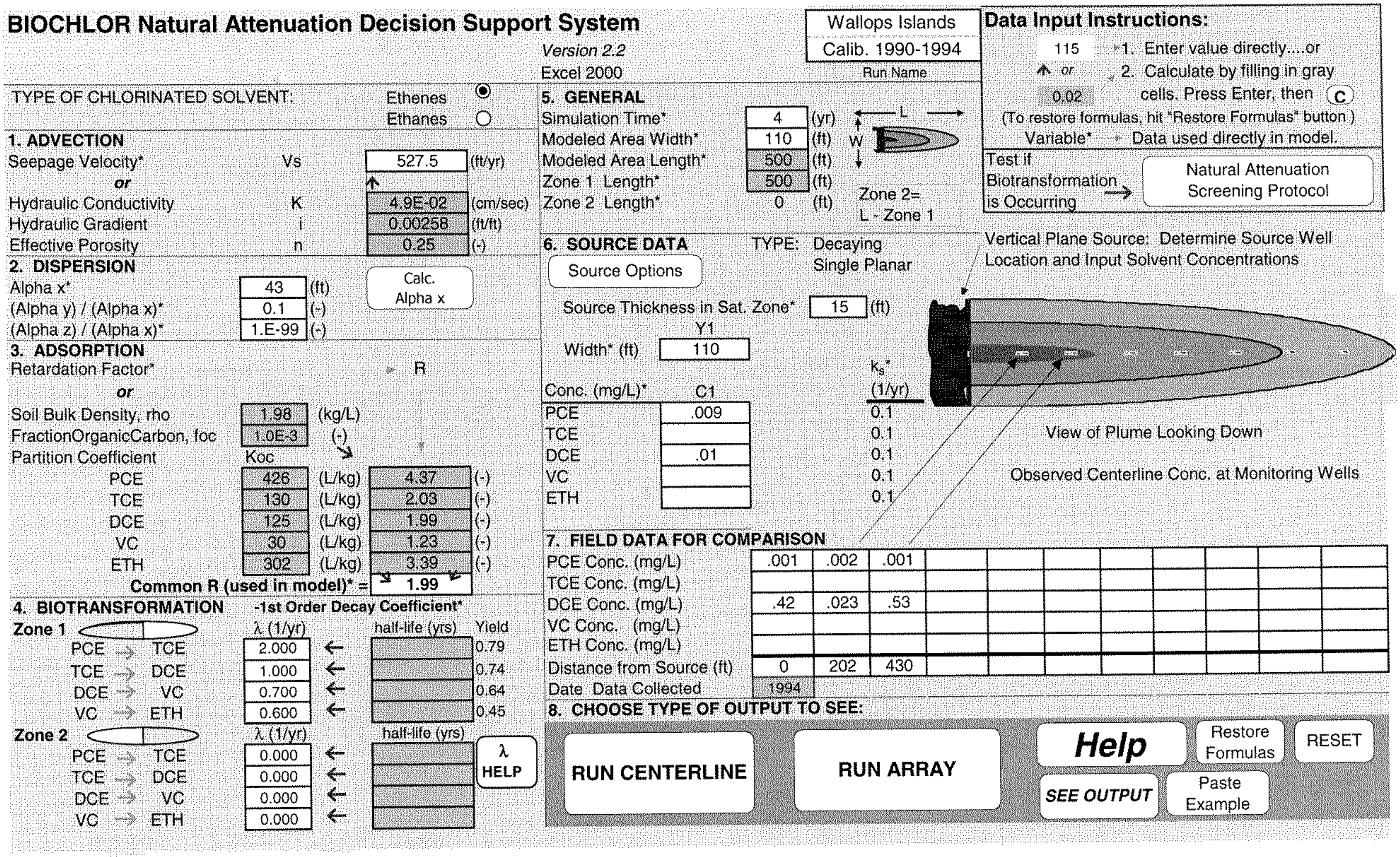
a/ Points awarded only if it can be shown that the compound is a daughter product (i.e., not a constituent of the source NAPL).

SCORE

Reset

End of Form

MODEL CALIBRATION
SOURCE AREA TO PIVOT POINT



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Wallops Islands
Calib. 1990-1994
Run Name

Data Input Instructions:
115 → 1. Enter value directly....or
↑ or → 2. Calculate by filling in gray
0.02 cells. Press Enter, then (C)
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION
Seepage Velocity* Vs 527.5 (ft/yr)
or
Hydraulic Conductivity K 4.9E-02 (cm/sec)
Hydraulic Gradient i 0.00258 (ft/ft)
Effective Porosity n 0.25 (-)

2. DISPERSION
Alpha x* 43 (ft)
(Alpha y) / (Alpha x)* 0.1 (-)
(Alpha z) / (Alpha x)* 1.E-99 (-)
Calc. Alpha x

3. ADSORPTION
Retardation Factor* → R
or
Soil Bulk Density, rho 1.98 (kg/L)
FractionOrganicCarbon, foc 1.0E-3 (-)
Partition Coefficient Koc

	Koc		R	
PCE	426	(L/kg)	4.37	(-)
TCE	130	(L/kg)	2.03	(-)
DCE	125	(L/kg)	1.99	(-)
VC	30	(L/kg)	1.23	(-)
ETH	302	(L/kg)	3.39	(-)

Common R (used in model)* = 1.99

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	2.000		0.79
TCE → DCE	1.000		0.74
DCE → VC	0.700		0.64
VC → ETH	0.600		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL
Simulation Time* 4 (yr)
Modeled Area Width* 110 (ft)
Modeled Area Length* 500 (ft)
Zone 1 Length* 500 (ft)
Zone 2 Length* 0 (ft)
Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar
Source Options
Source Thickness in Sat. Zone* 15 (ft)
Y1
Width* (ft) 110

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.009	0.1
TCE		0.1
DCE	.01	0.1
VC		0.1
ETH		0.1

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

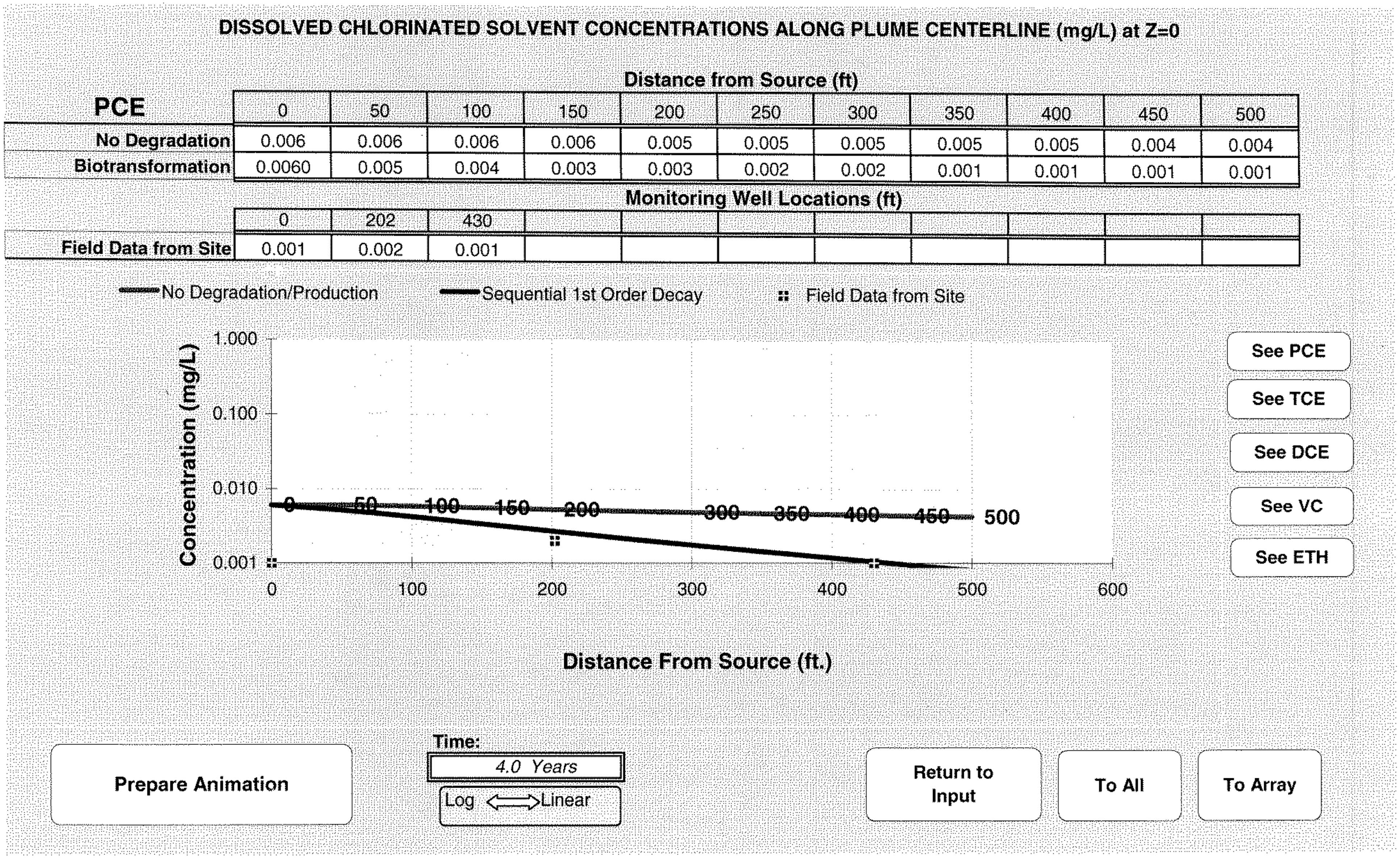
View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.001	.002	.001								
TCE Conc. (mg/L)											
DCE Conc. (mg/L)	.42	.023	.53								
VC Conc. (mg/L)											
ETH Conc. (mg/L)											
Distance from Source (ft)	0	202	430								
Date Data Collected	1994										

8. CHOOSE TYPE OF OUTPUT TO SEE:



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

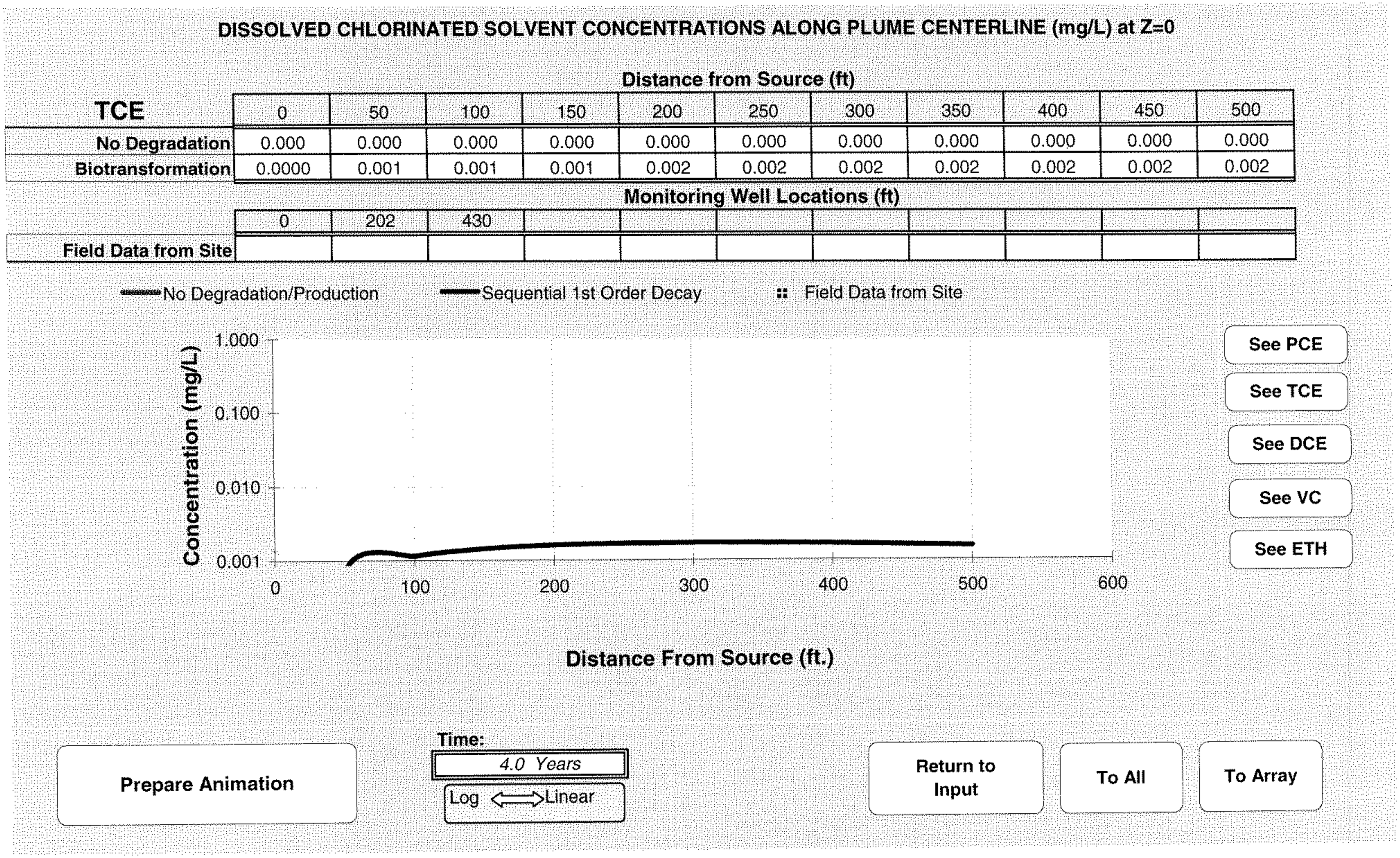
Distance from Source (ft)

PCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.006	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.004	0.004
Biotransformation	0.0060	0.005	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.001

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site	0.001	0.002	0.001								

Time: 4.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

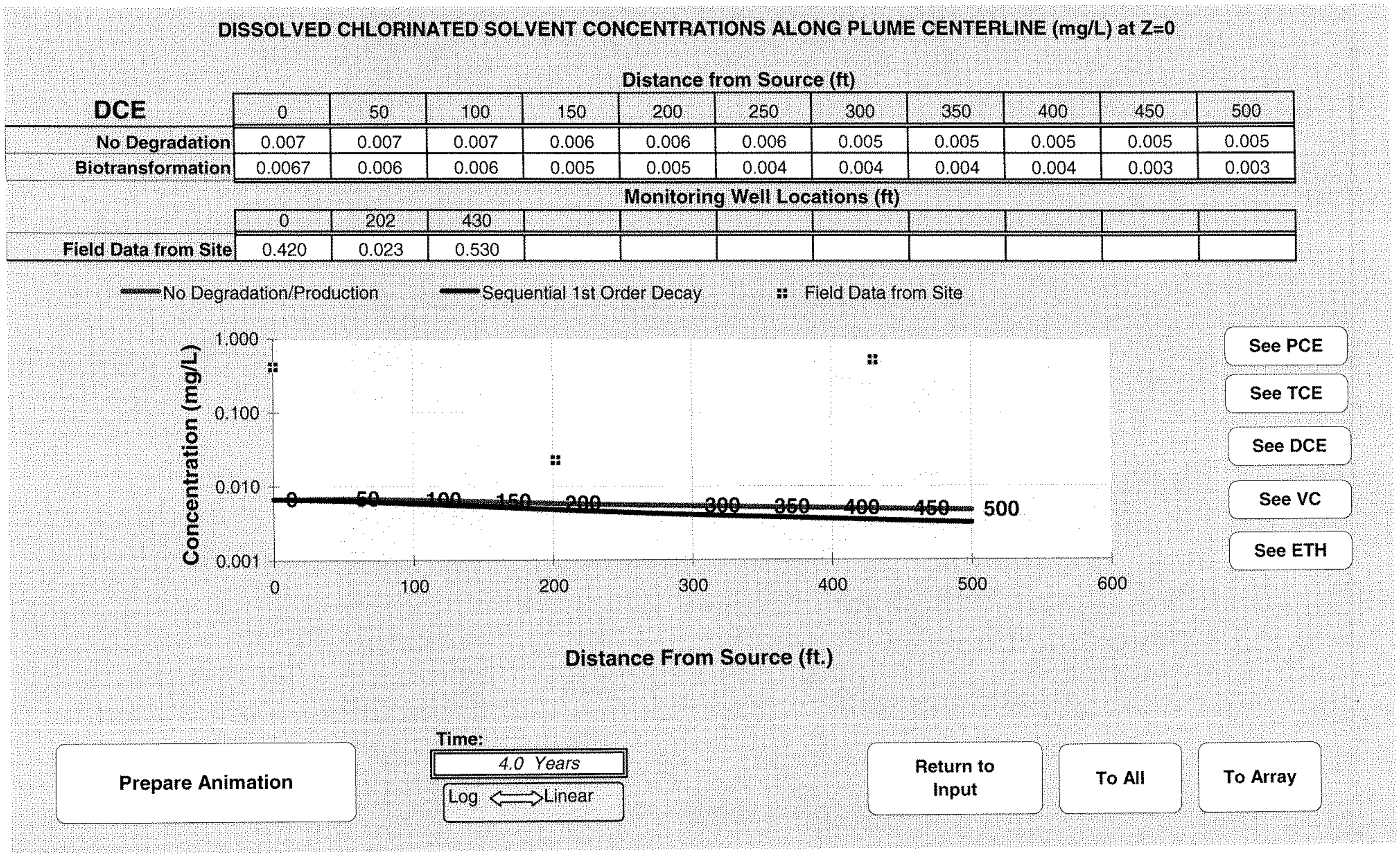
Distance from Source (ft)

TCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site											

Time: 4.0 Years



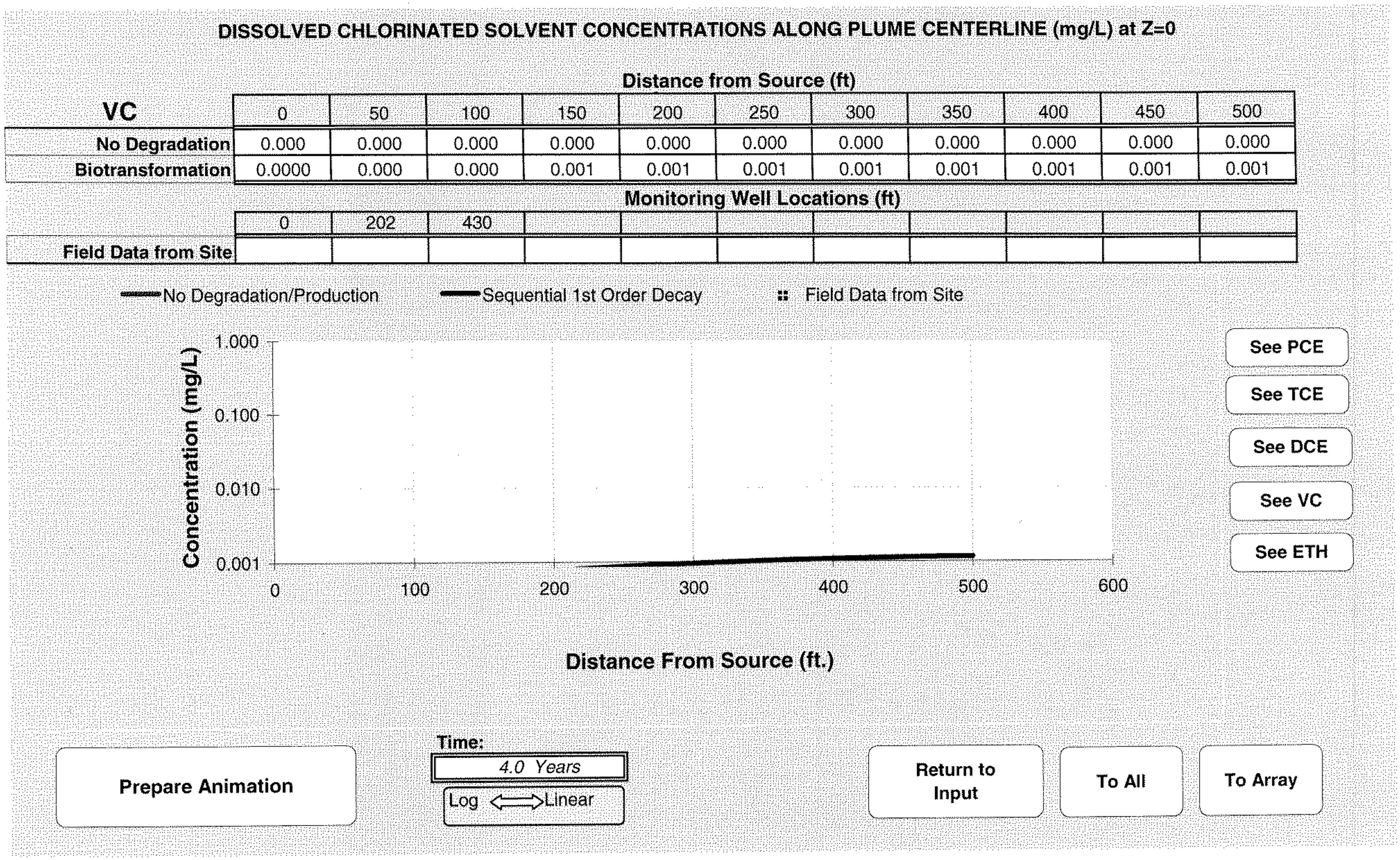
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

DCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.007	0.007	0.007	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.005
Biotransformation	0.0067	0.006	0.006	0.005	0.005	0.004	0.004	0.004	0.004	0.003	0.003

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site	0.420	0.023	0.530								

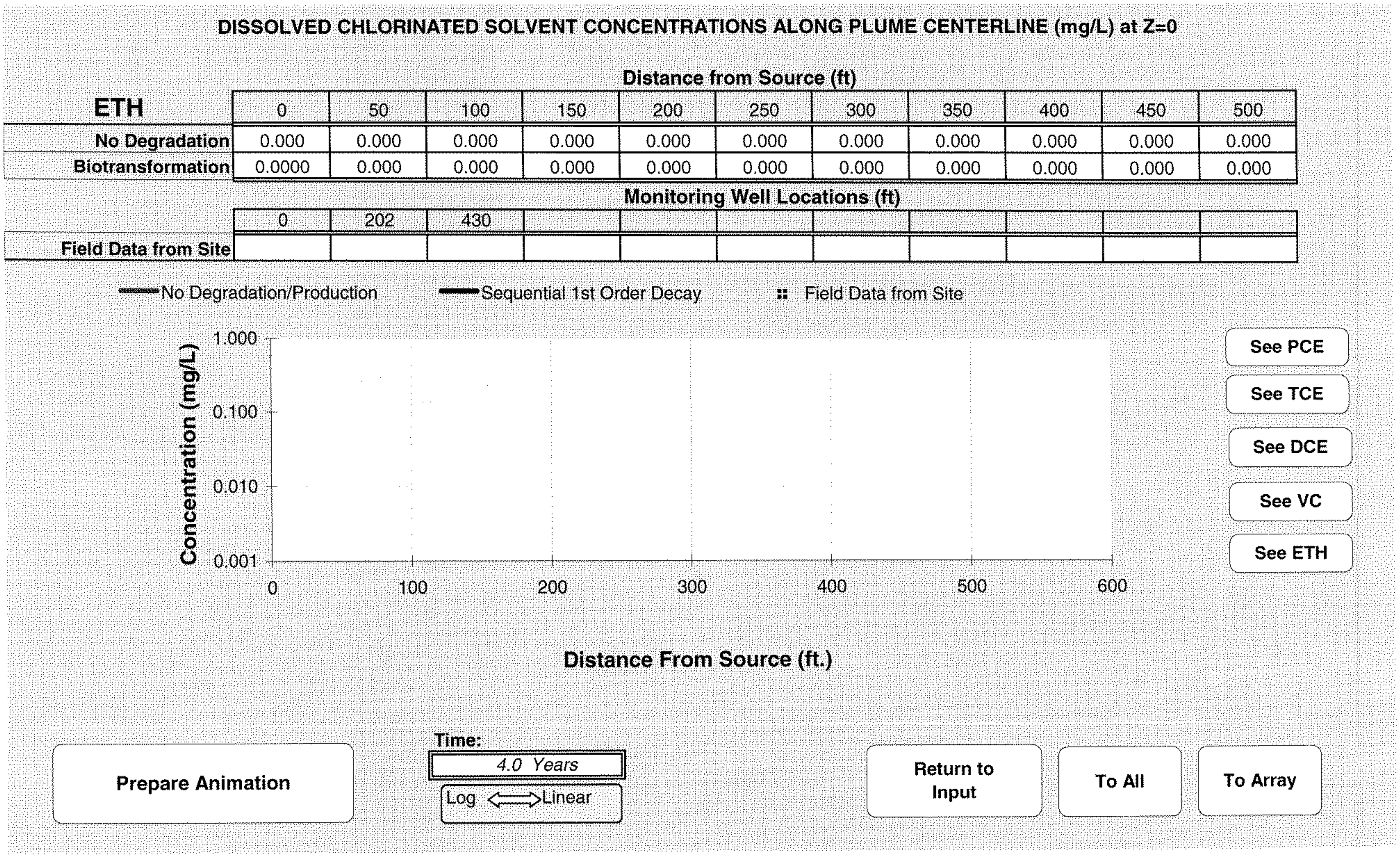


DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

VC	Distance from Source (ft)										
	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

	Monitoring Well Locations (ft)										
	0	202	430								
Field Data from Site											

Time: 4.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

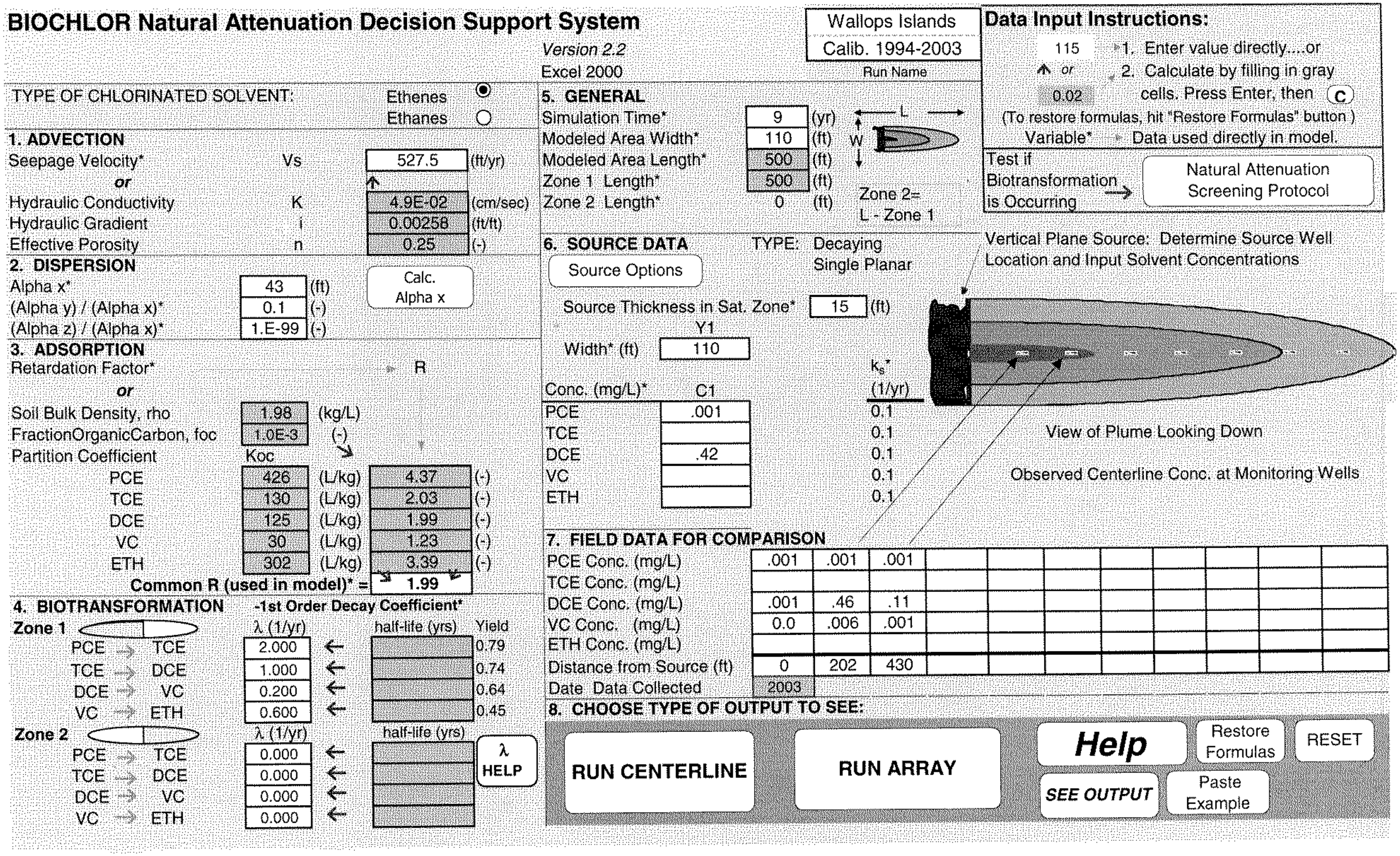
Distance from Source (ft)

ETH	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site											

Time: 4.0 Years



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Wallops Islands
Calib. 1994-2003
Run Name

Data Input Instructions:
115 → 1. Enter value directly....or
↑ or → 2. Calculate by filling in gray
0.02 cells. Press Enter, then (C)
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	527.5	(ft/yr)
or		↑	
Hydraulic Conductivity	K	4.9E-02	(cm/sec)
Hydraulic Gradient	i	0.00258	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION

Alpha x*	43	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	1.E-99	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R
or

Soil Bulk Density, rho	1.98	(kg/L)		
FractionOrganicCarbon, foc	1.0E-3	(-)		
Partition Coefficient	Koc			
PCE	426	(L/kg)	4.37	(-)
TCE	130	(L/kg)	2.03	(-)
DCE	125	(L/kg)	1.99	(-)
VC	30	(L/kg)	1.23	(-)
ETH	302	(L/kg)	3.39	(-)
Common R (used in model)* =			1.99	

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1	λ (1/yr)		half-life (yrs)	Yield
PCE → TCE	2.000	←		0.79
TCE → DCE	1.000	←		0.74
DCE → VC	0.200	←		0.64
VC → ETH	0.600	←		0.45

Zone 2	λ (1/yr)		half-life (yrs)
PCE → TCE	0.000	←	
TCE → DCE	0.000	←	
DCE → VC	0.000	←	
VC → ETH	0.000	←	

λ HELP

5. GENERAL

Simulation Time*	9	(yr)
Modeled Area Width*	110	(ft)
Modeled Area Length*	500	(ft)
Zone 1 Length*	500	(ft)
Zone 2 Length*	0	(ft)

Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 15 (ft)

	Y1
Width* (ft)	110

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.001	0.1
TCE		0.1
DCE	.42	0.1
VC		0.1
ETH		0.1

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

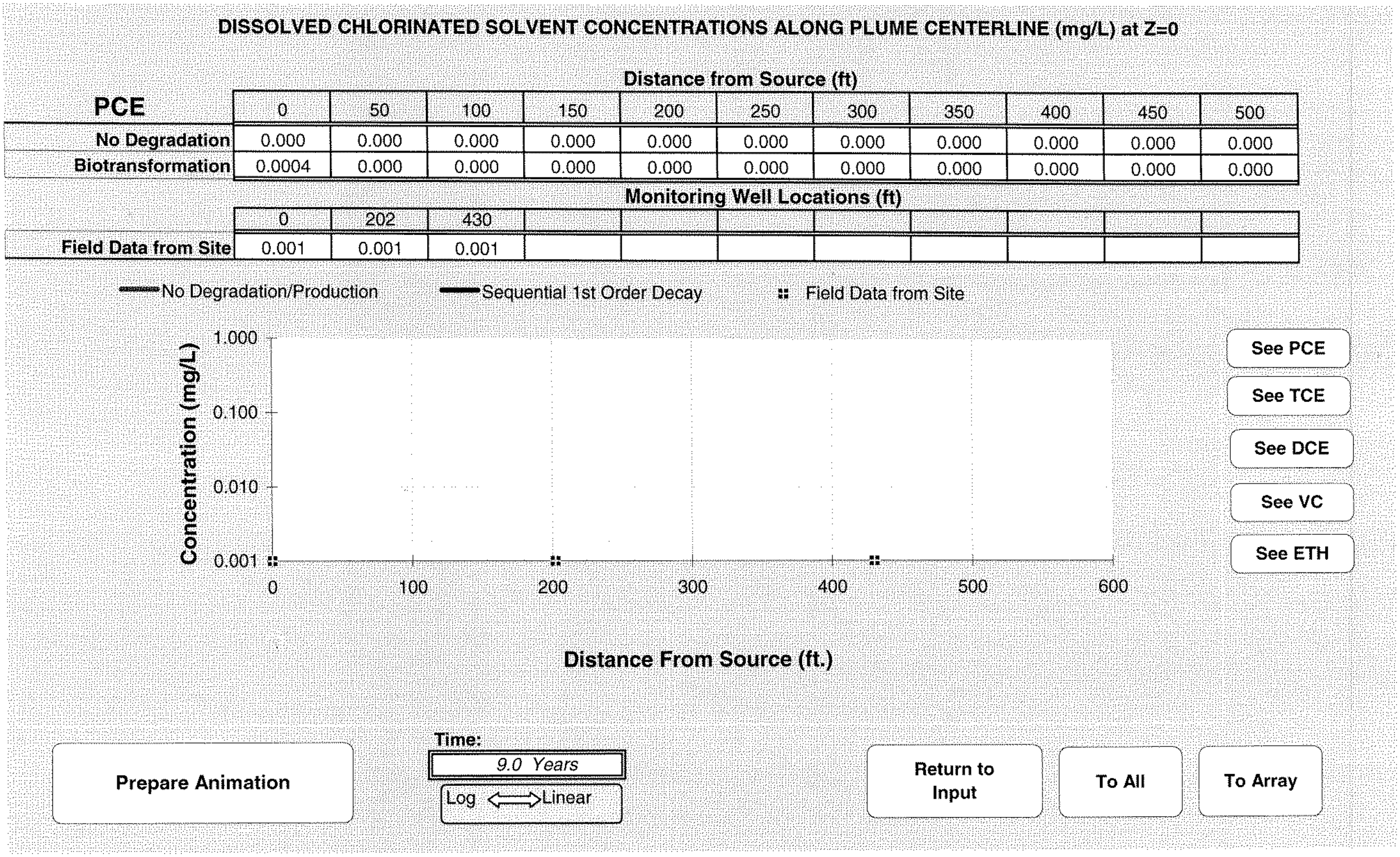
View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.001	.001	.001								
TCE Conc. (mg/L)											
DCE Conc. (mg/L)	.001	.46	.11								
VC Conc. (mg/L)	0.0	.006	.001								
ETH Conc. (mg/L)											
Distance from Source (ft)	0	202	430								
Date Data Collected	2003										

8. CHOOSE TYPE OF OUTPUT TO SEE:



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

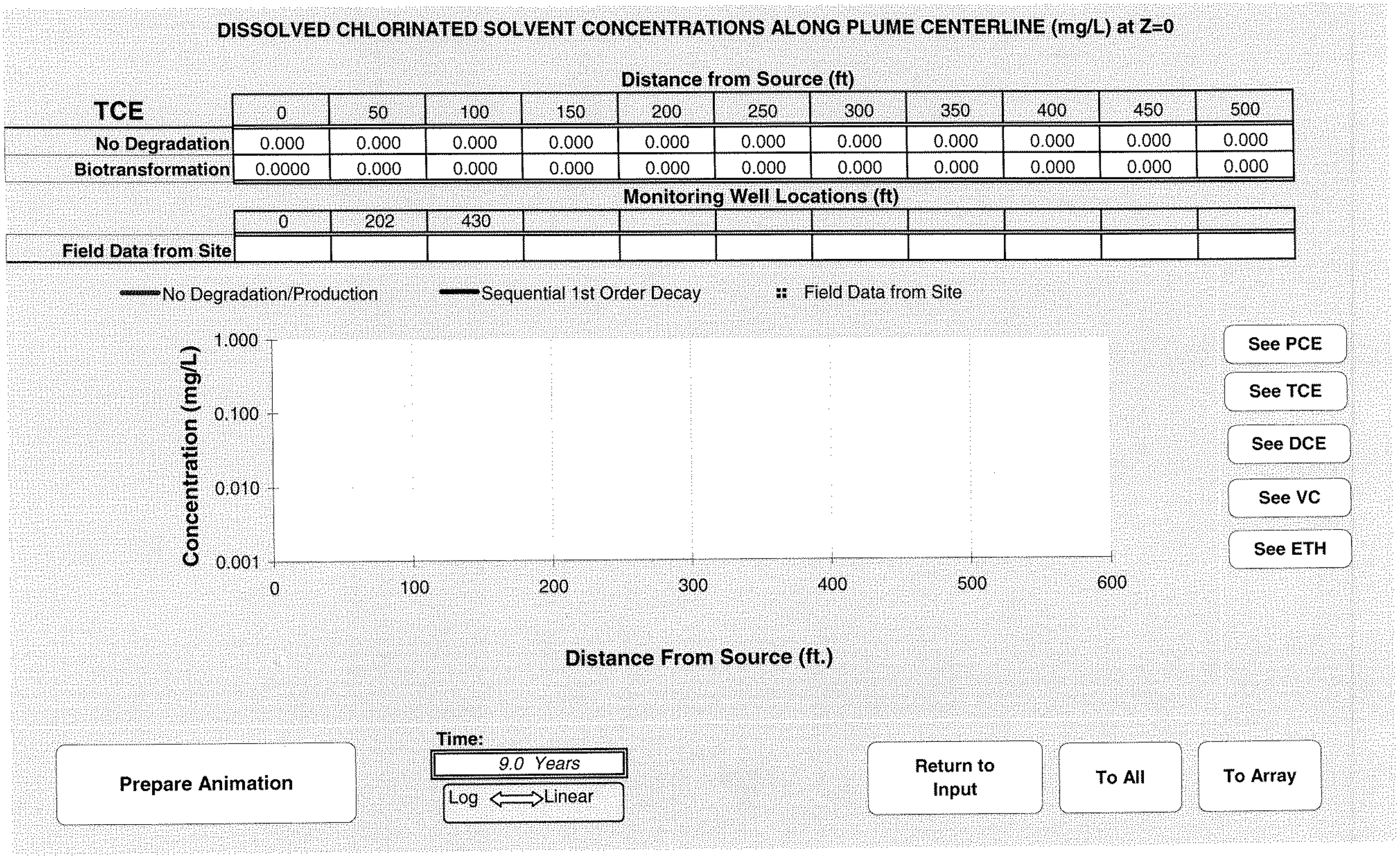
Distance from Source (ft)

PCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site	0.001	0.001	0.001								

Time: 9.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

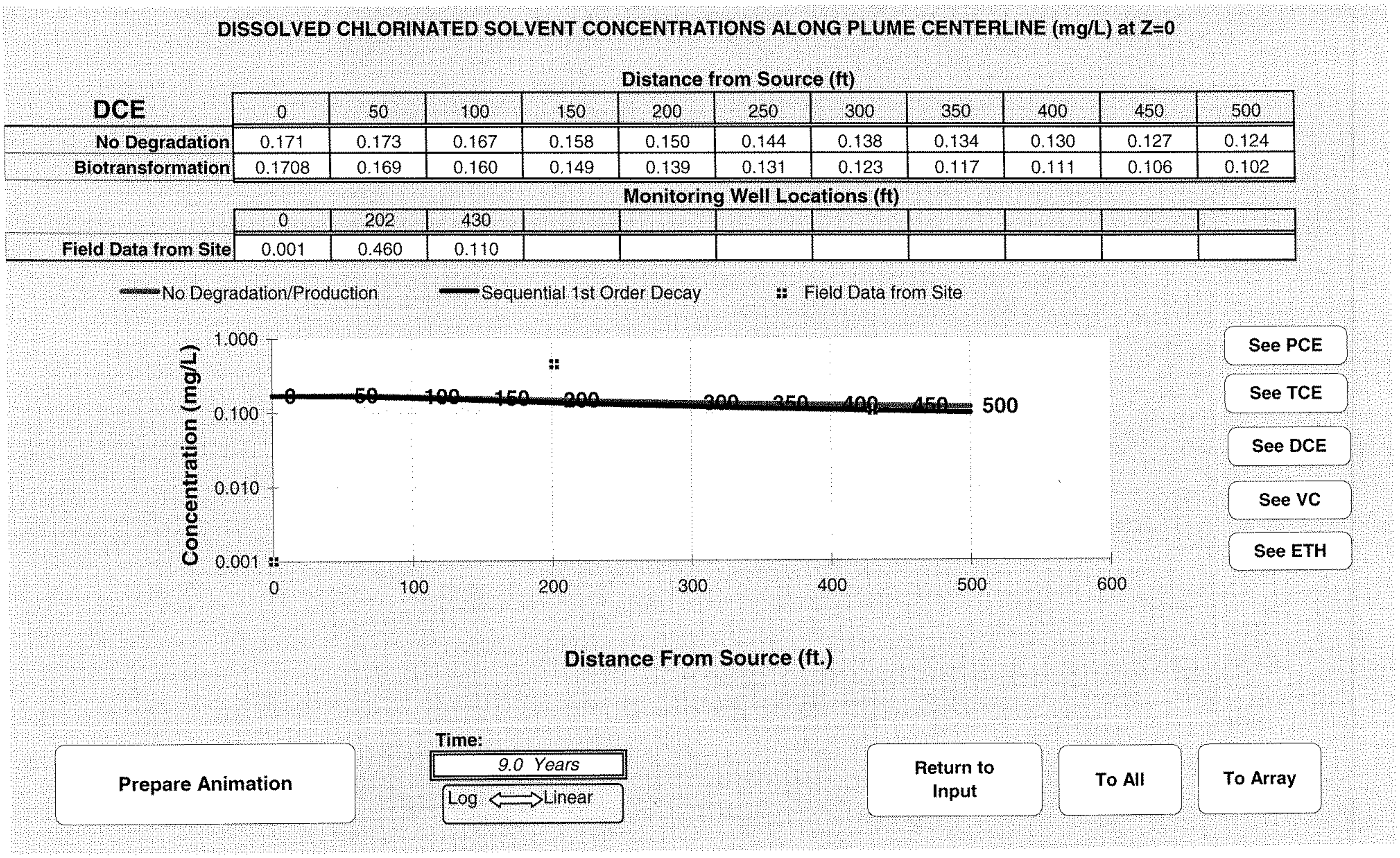
TCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site											

— No Degradation/Production — Sequential 1st Order Decay ■ Field Data from Site

Time: *9.0 Years*



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

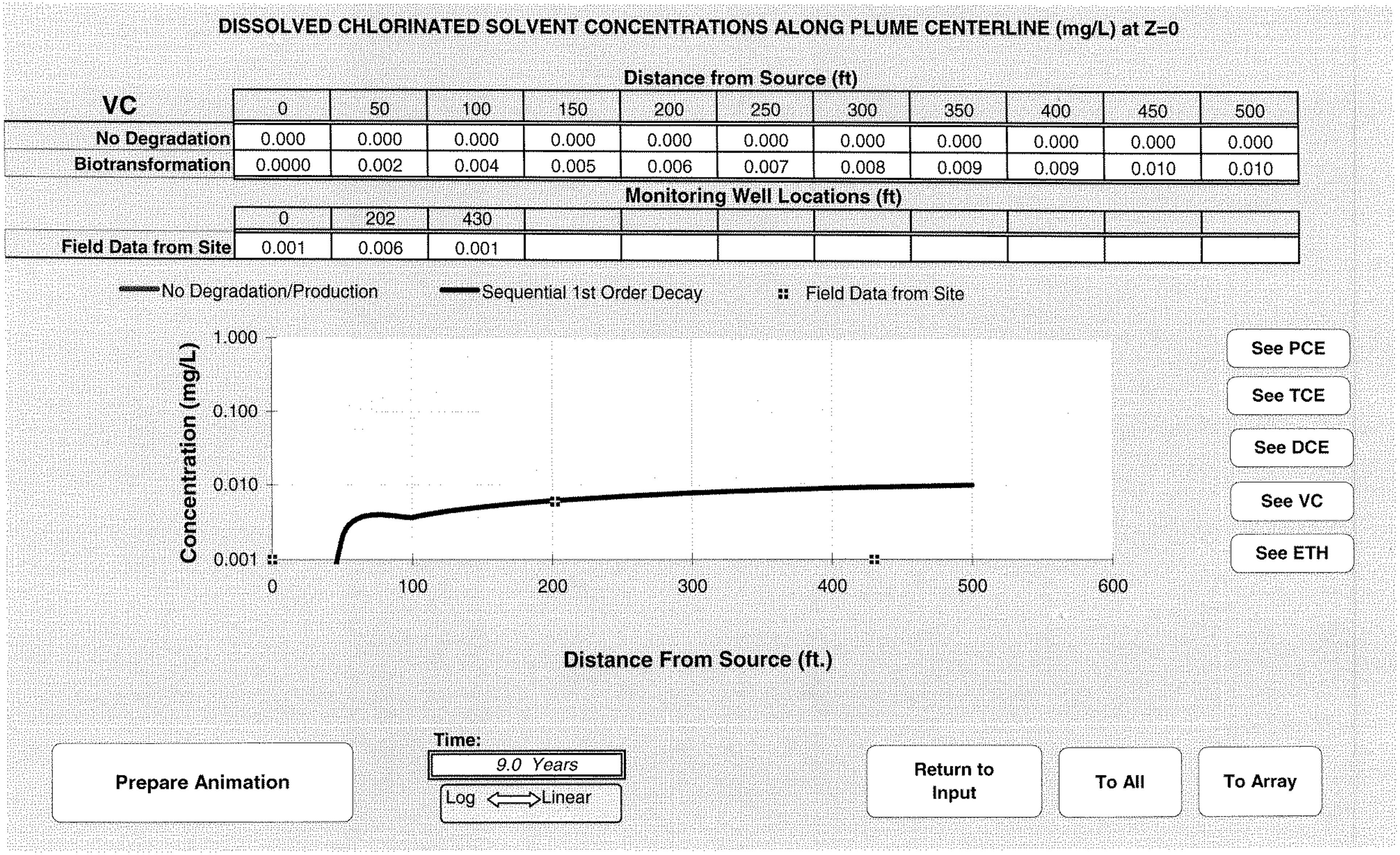
Distance from Source (ft)

DCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.171	0.173	0.167	0.158	0.150	0.144	0.138	0.134	0.130	0.127	0.124
Biotransformation	0.1708	0.169	0.160	0.149	0.139	0.131	0.123	0.117	0.111	0.106	0.102

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site	0.001	0.460	0.110								

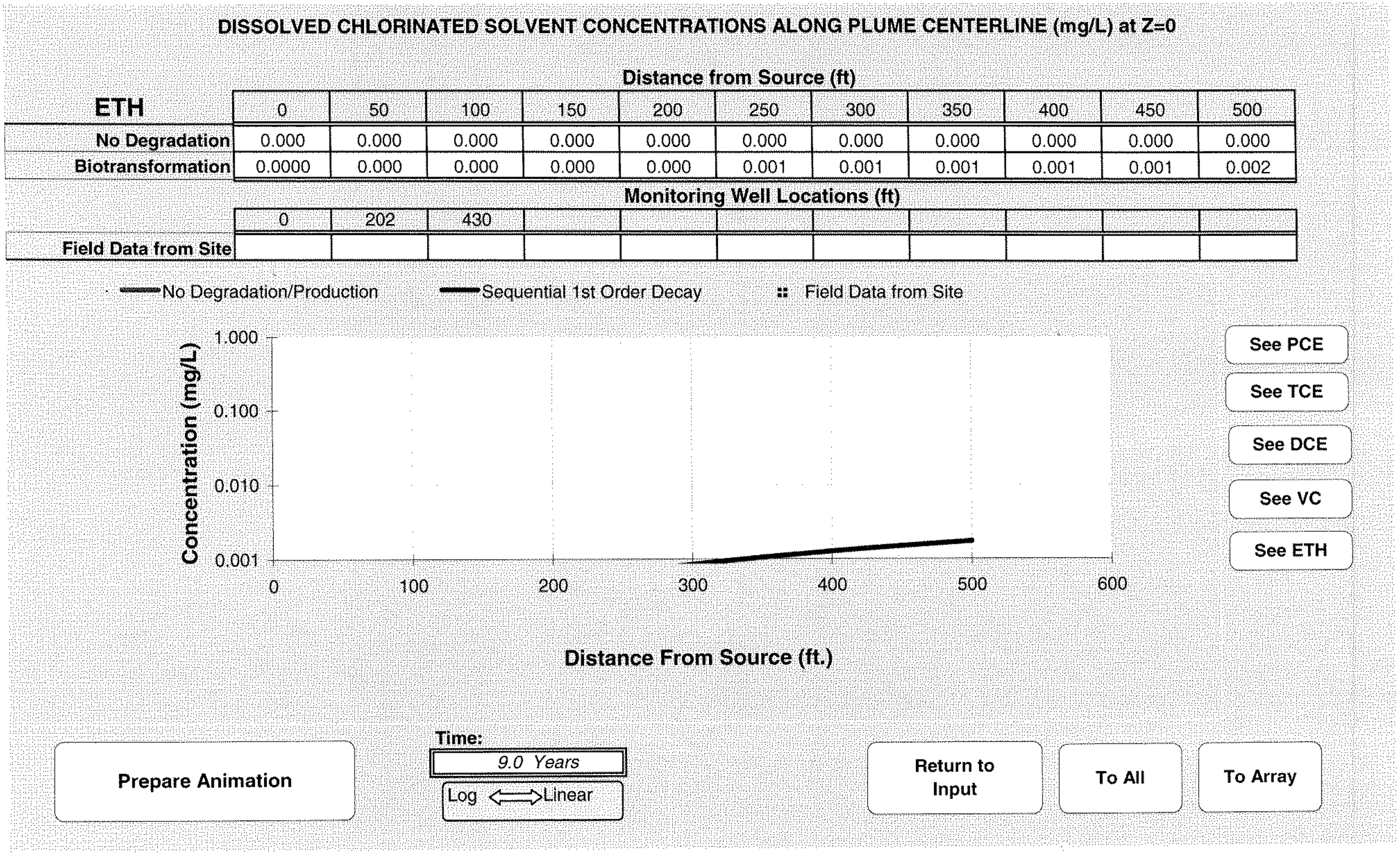
Time: 9.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

	Distance from Source (ft)										
VC	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.002	0.004	0.005	0.006	0.007	0.008	0.009	0.009	0.010	0.010

	Monitoring Well Locations (ft)										
	0	202	430								
Field Data from Site	0.001	0.006	0.001								



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

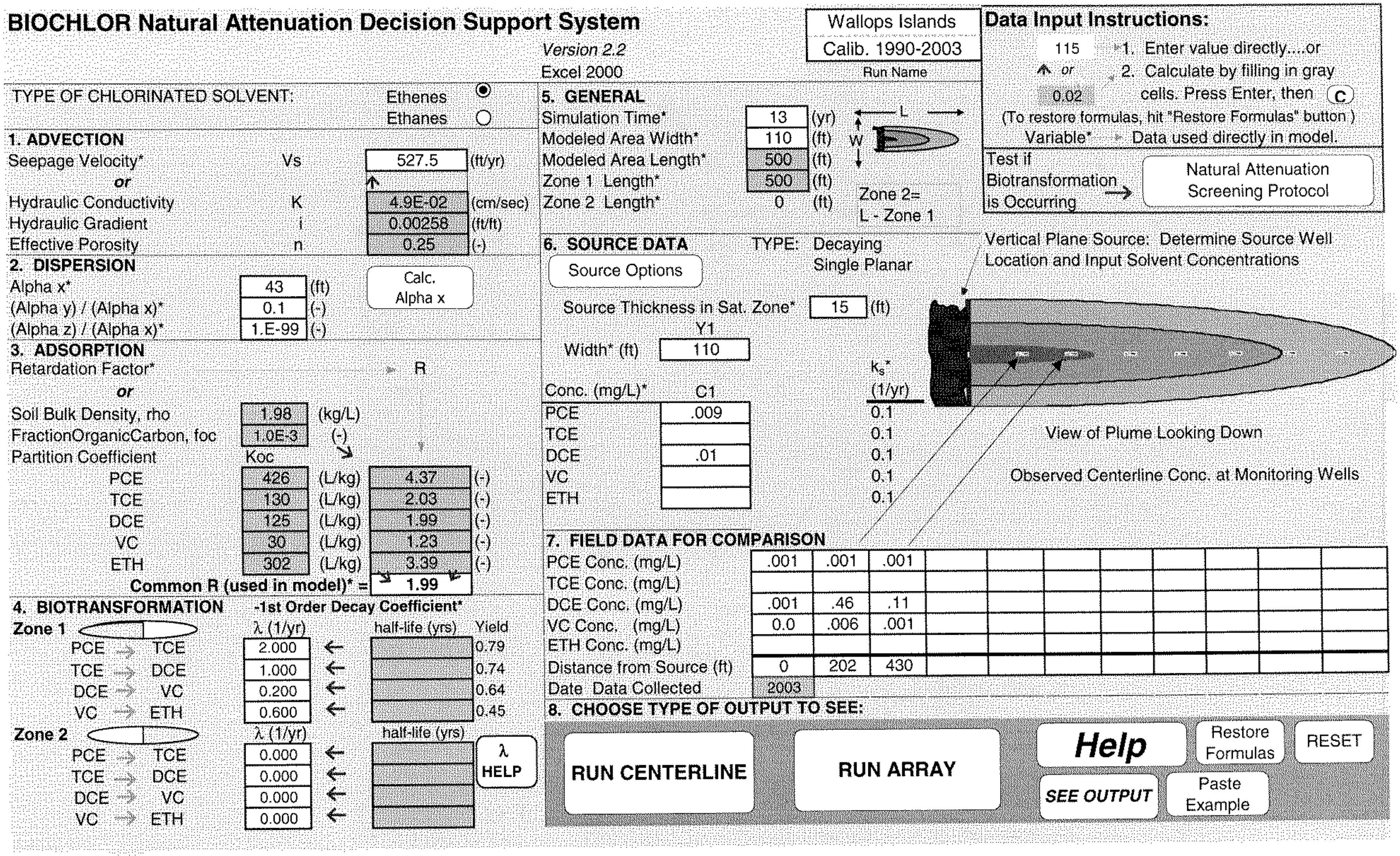
Distance from Source (ft)

ETH	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.002

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site											

Time: 9.0 Years



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Run Name: Wallops Islands Calib. 1990-2003

Data Input Instructions:
- 115 → 1. Enter value directly....or
- 0.02 → 2. Calculate by filling in gray cells. Press Enter, then C

(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity* Vs: 527.5 (ft/yr)

or

Hydraulic Conductivity K: 4.9E-02 (cm/sec)
Hydraulic Gradient i: 0.00258 (ft/ft)
Effective Porosity n: 0.25 (-)

2. DISPERSION

Alpha x*: 43 (ft)
(Alpha y) / (Alpha x)*: 0.1 (-)
(Alpha z) / (Alpha x)*: 1.E-99 (-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho: 1.98 (kg/L)
FractionOrganicCarbon, foc: 1.0E-3 (-)

Partition Coefficient	Koc		R	
PCE	426	(L/kg)	4.37	(-)
TCE	130	(L/kg)	2.03	(-)
DCE	125	(L/kg)	1.99	(-)
VC	30	(L/kg)	1.23	(-)
ETH	302	(L/kg)	3.39	(-)

Common R (used in model)* = 1.99

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1

	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	2.000		0.79
TCE → DCE	1.000		0.74
DCE → VC	0.200		0.64
VC → ETH	0.600		0.45

Zone 2

	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*: 13 (yr)
Modeled Area Width*: 110 (ft)
Modeled Area Length*: 500 (ft)
Zone 1 Length*: 500 (ft)
Zone 2 Length*: 0 (ft)

Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone*: 15 (ft)

Width* (ft) Y1: 110

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.009	0.1
TCE		0.1
DCE	.01	0.1
VC		0.1
ETH		0.1

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

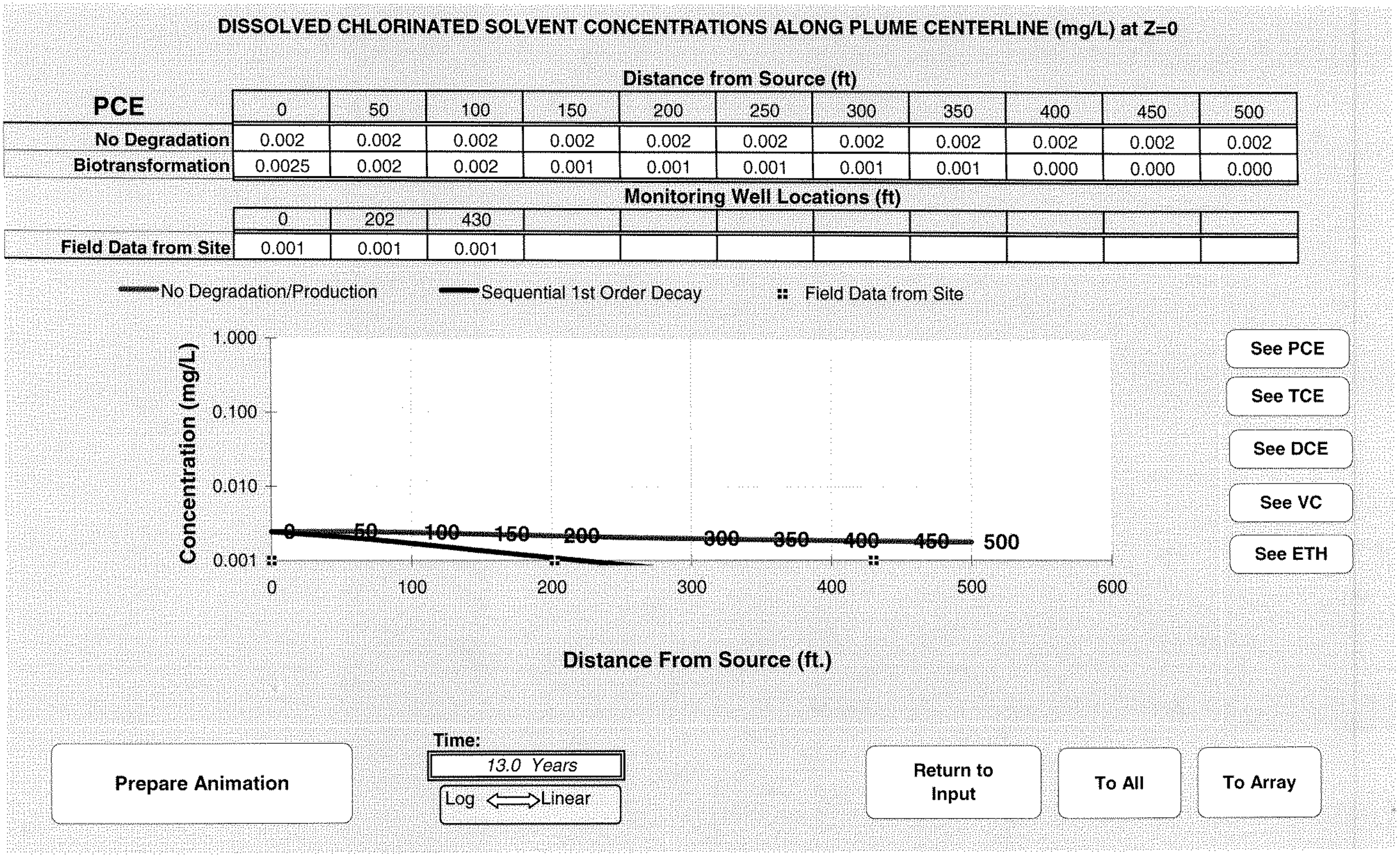
View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.001	.001	.001								
TCE Conc. (mg/L)											
DCE Conc. (mg/L)	.001	.46	.11								
VC Conc. (mg/L)	0.0	.006	.001								
ETH Conc. (mg/L)											
Distance from Source (ft)	0	202	430								
Date Data Collected	2003										

8. CHOOSE TYPE OF OUTPUT TO SEE:



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

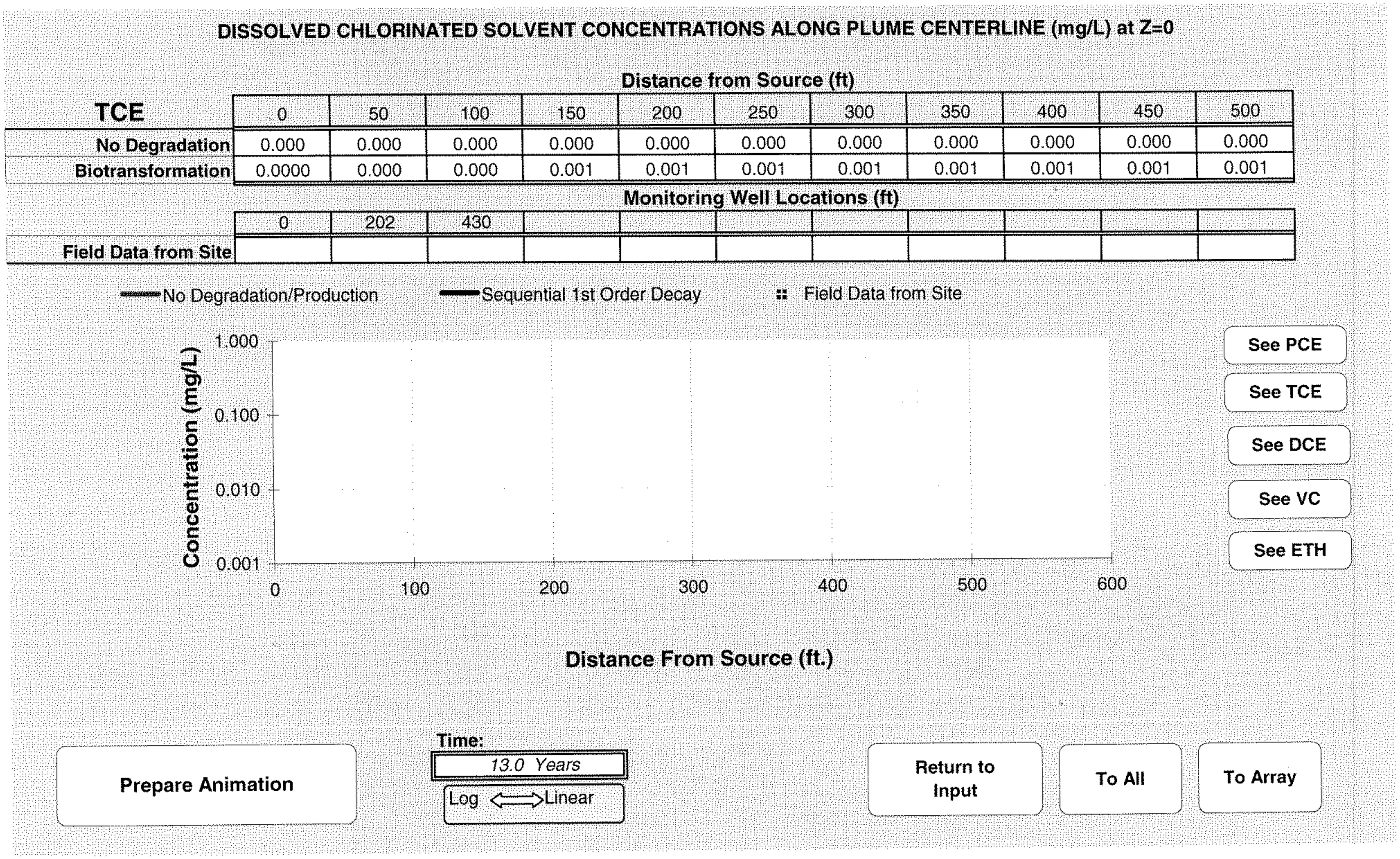
Distance from Source (ft)

PCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Biotransformation	0.0025	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site	0.001	0.001	0.001								

Time: 13.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

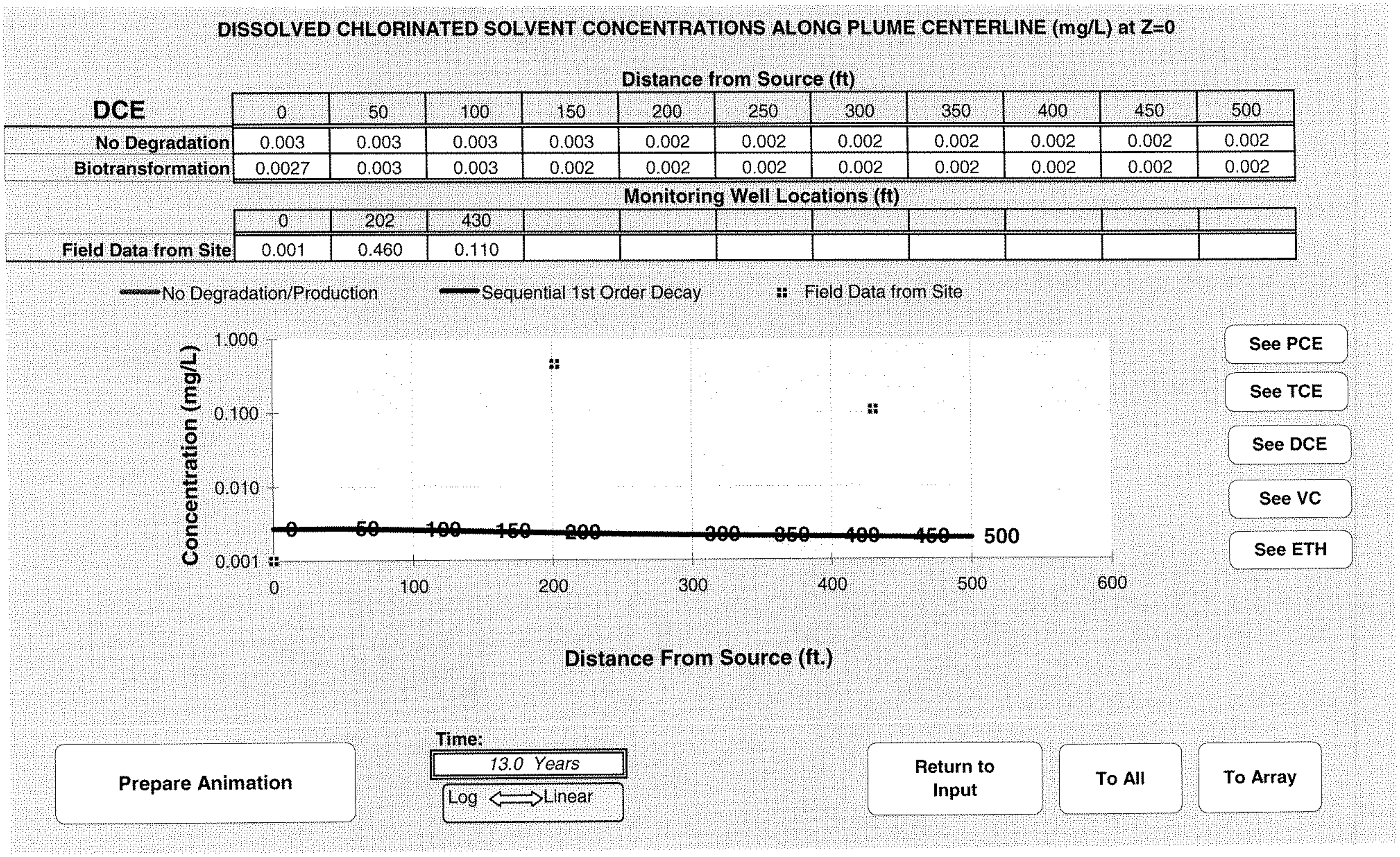
Distance from Source (ft)

TCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site											

Time: 13.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

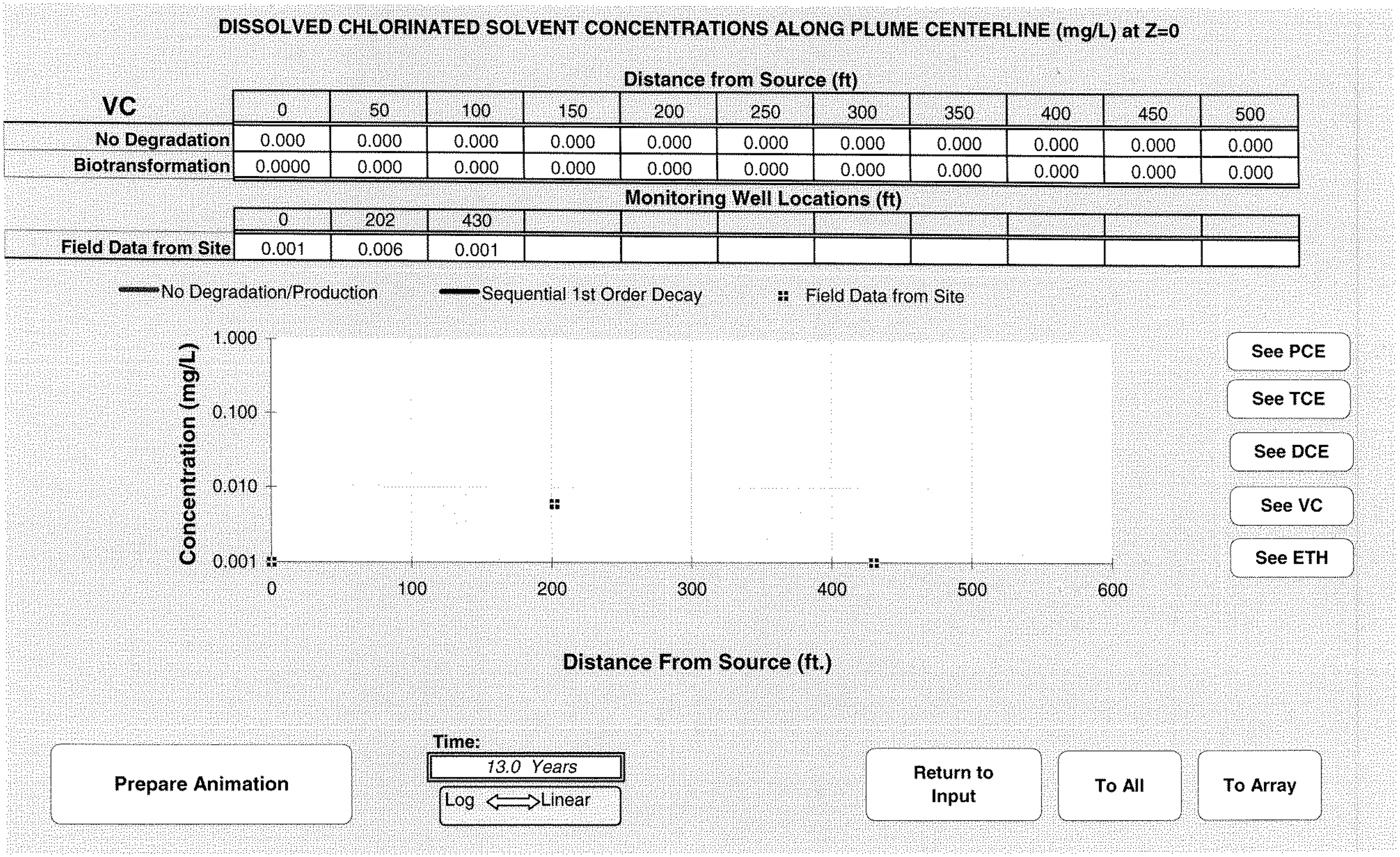
Distance from Source (ft)

DCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Biotransformation	0.0027	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site	0.001	0.460	0.110								

Time: 13.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

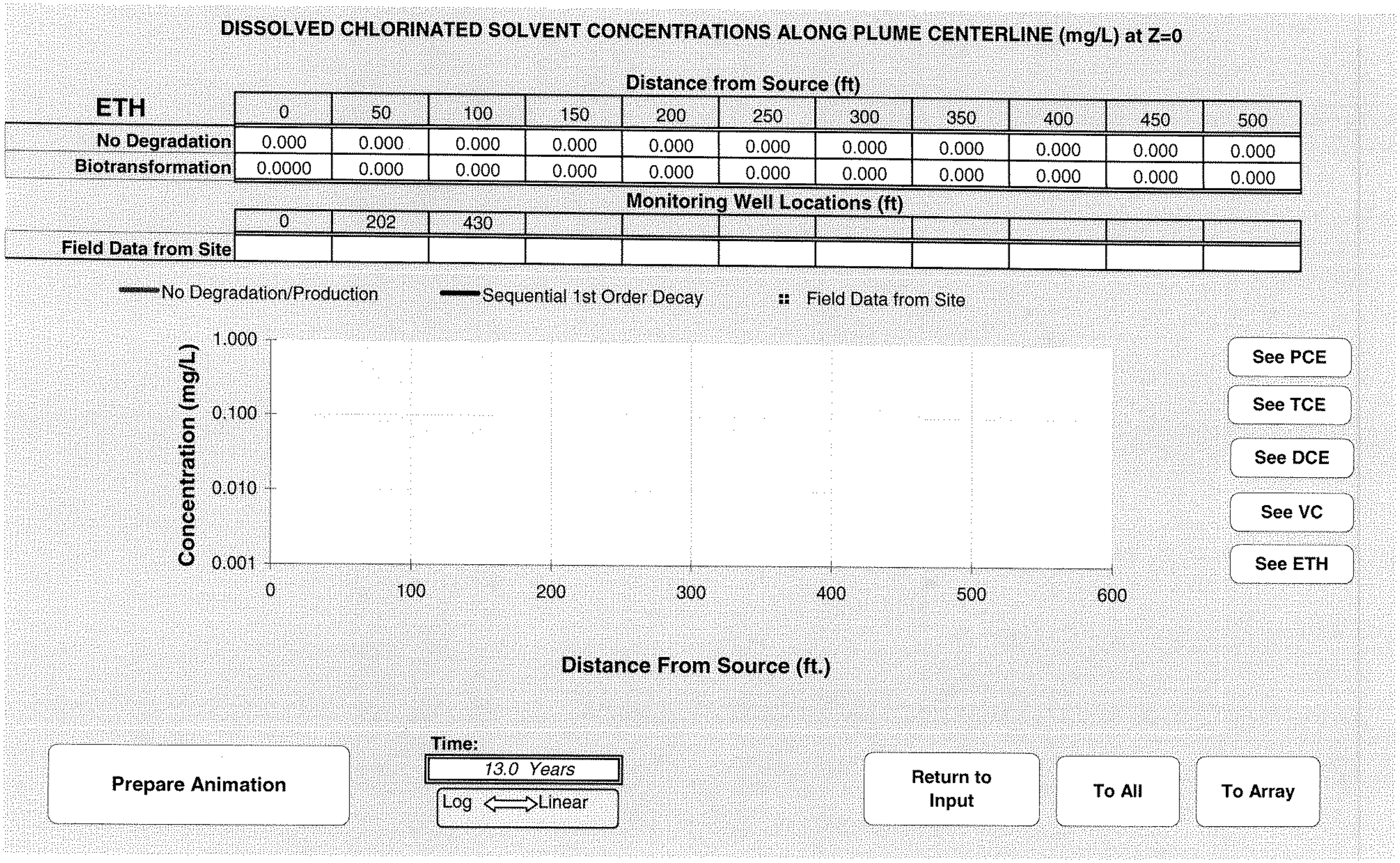
Distance from Source (ft)

VC	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site	0.001	0.006	0.001								

Time: *13.0 Years*



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

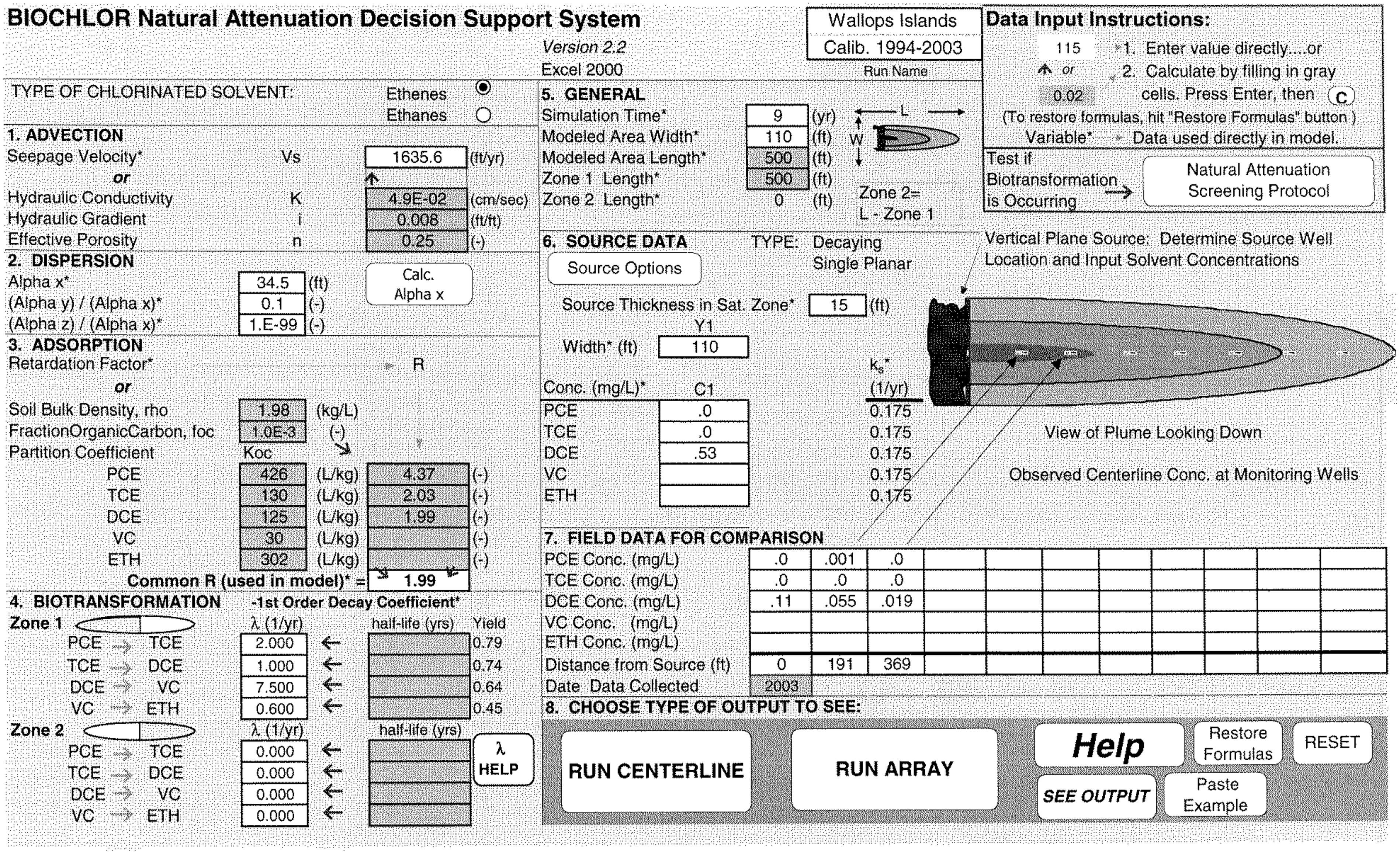
ETH	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	202	430								
Field Data from Site											

Time: 13.0 Years

MODEL CALIBRATION
PIVOT POINT TO TOPOGRAPHIC LOW



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Wallops Islands
Calib. 1994-2003
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
↑ *or* → 2. Calculate by filling in gray
0.02 cells. Press Enter, then (C)
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	1635.6	(ft/yr)
or			
Hydraulic Conductivity	K	4.9E-02	(cm/sec)
Hydraulic Gradient	i	0.008	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION

Alpha x*	34.5	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	1.E-99	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.98	(kg/L)		
FractionOrganicCarbon, foc	1.0E-3	(-)		
Partition Coefficient	Koc			
PCE	426	(L/kg)	4.37	(-)
TCE	130	(L/kg)	2.03	(-)
DCE	125	(L/kg)	1.99	(-)
VC	30	(L/kg)		(-)
ETH	302	(L/kg)		(-)

Common R (used in model)* = 1.99

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1

	λ (1/yr)		half-life (yrs)	Yield
PCE → TCE	2.000	←		0.79
TCE → DCE	1.000	←		0.74
DCE → VC	7.500	←		0.64
VC → ETH	0.600	←		0.45

Zone 2

	λ (1/yr)		half-life (yrs)
PCE → TCE	0.000	←	
TCE → DCE	0.000	←	
DCE → VC	0.000	←	
VC → ETH	0.000	←	

λ HELP

5. GENERAL

Simulation Time*	9	(yr)
Modeled Area Width*	110	(ft)
Modeled Area Length*	500	(ft)
Zone 1 Length*	500	(ft)
Zone 2 Length*	0	(ft)

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 15 (ft)

Width* (ft) Y1: 110

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.0	0.175
TCE	.0	0.175
DCE	.53	0.175
VC		0.175
ETH		0.175

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

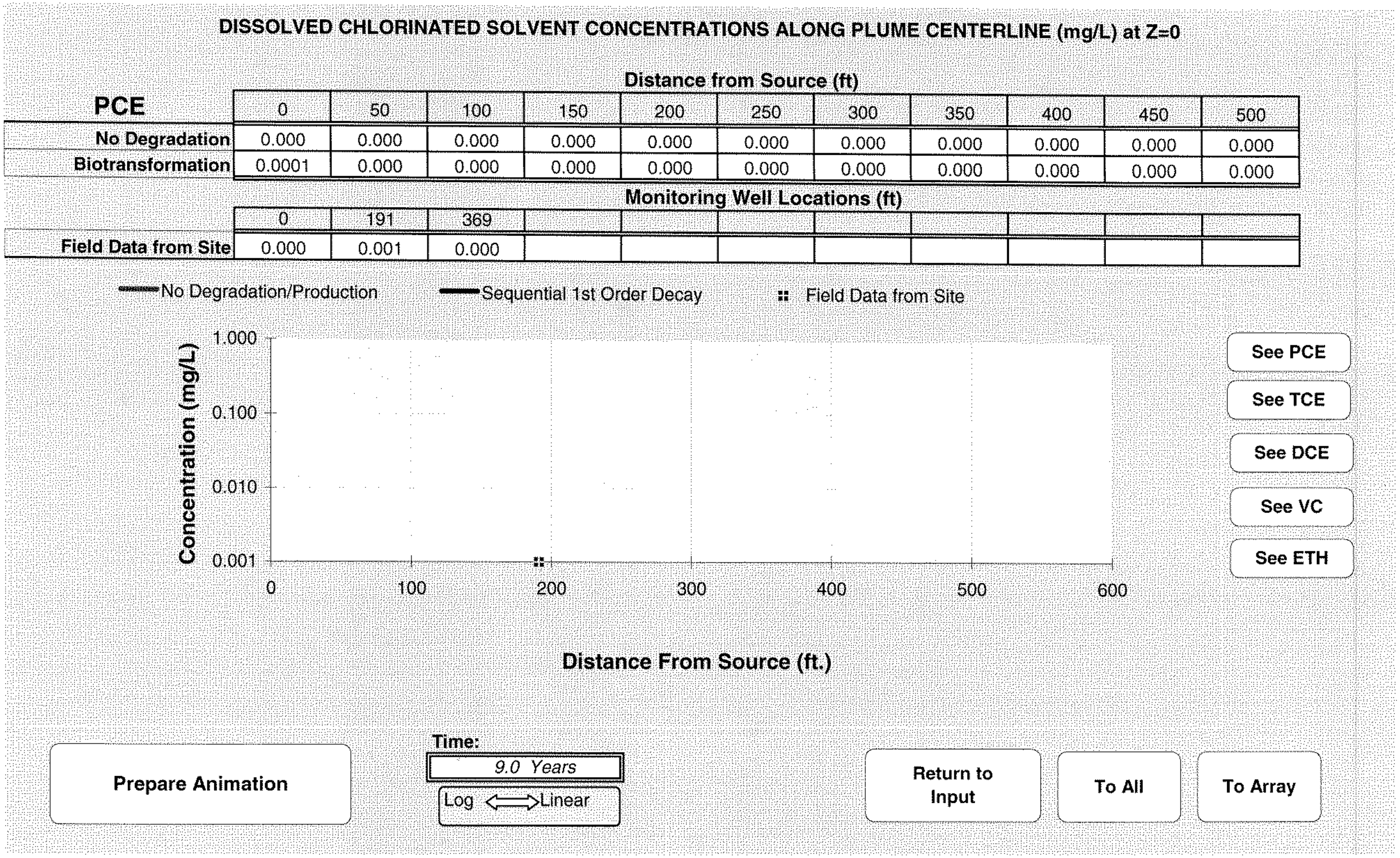
View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.0	.001	.0								
TCE Conc. (mg/L)	.0	.0	.0								
DCE Conc. (mg/L)	.11	.055	.019								
VC Conc. (mg/L)											
ETH Conc. (mg/L)											
Distance from Source (ft)	0	191	369								
Date Data Collected	2003										

8. CHOOSE TYPE OF OUTPUT TO SEE:



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

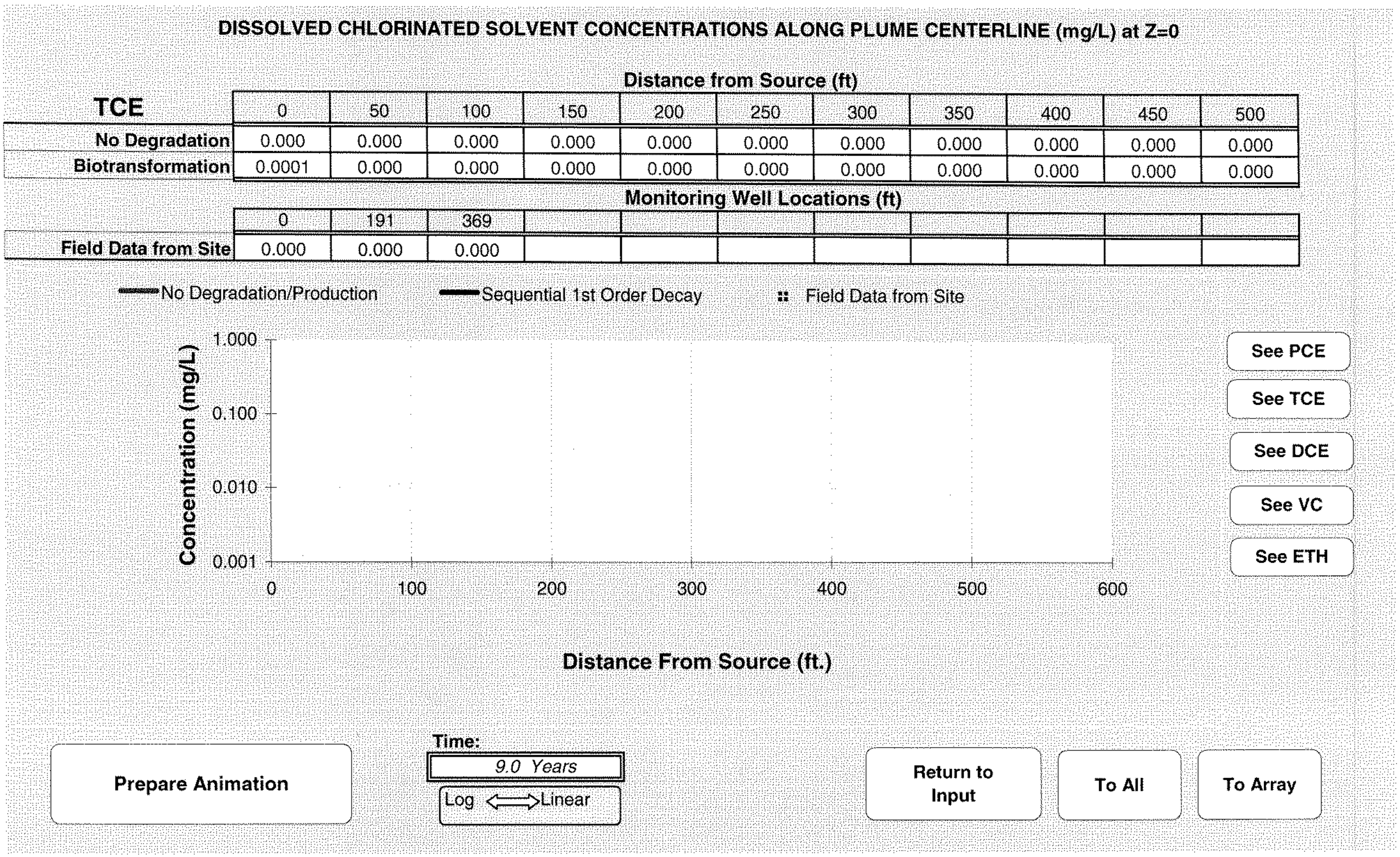
Distance from Source (ft)

PCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	191	369								
Field Data from Site	0.000	0.001	0.000								

Time:
9.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

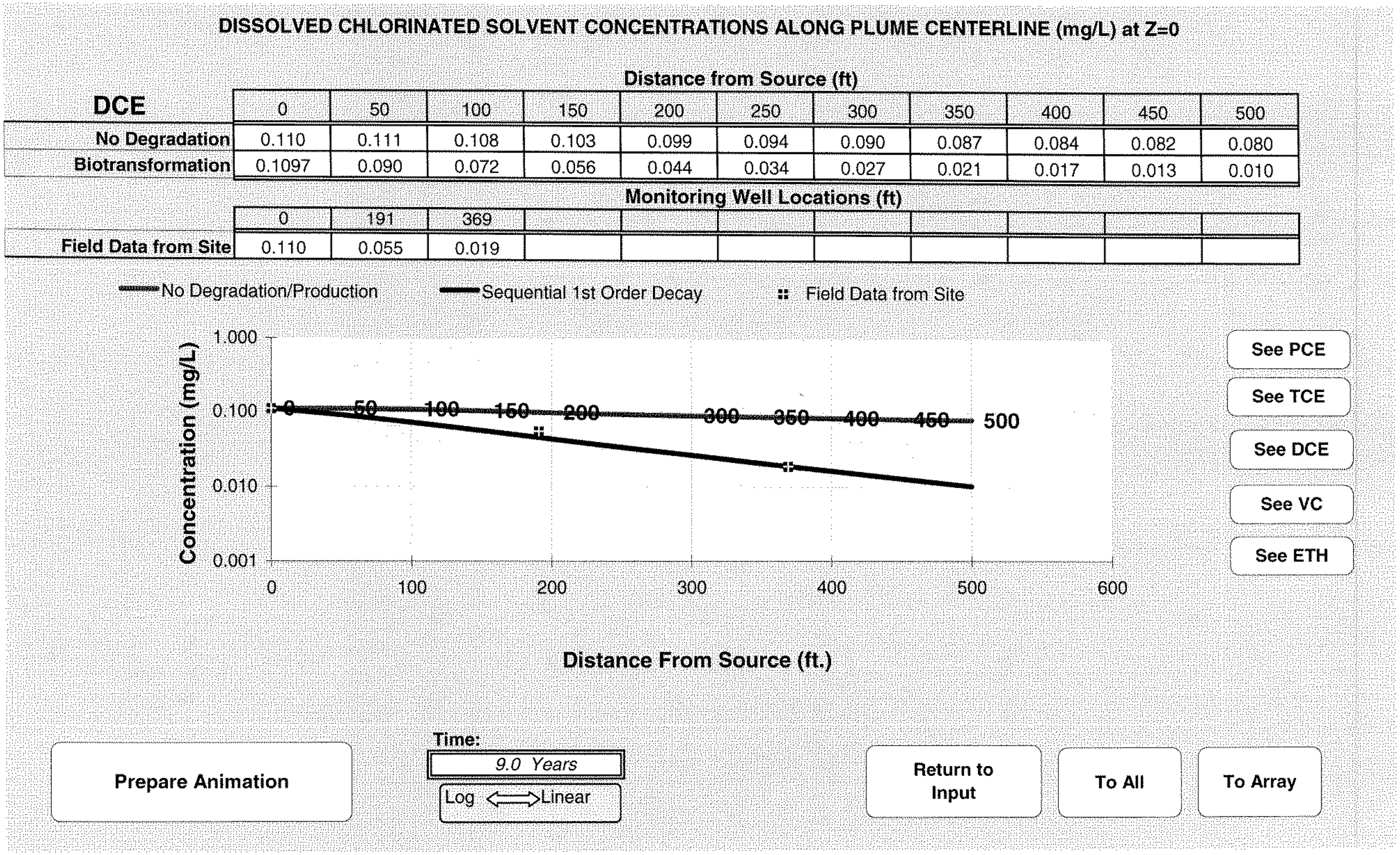
Distance from Source (ft)

TCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	191	369								
Field Data from Site	0.000	0.000	0.000								

Time: 9.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

DCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.110	0.111	0.108	0.103	0.099	0.094	0.090	0.087	0.084	0.082	0.080
Biotransformation	0.1097	0.090	0.072	0.056	0.044	0.034	0.027	0.021	0.017	0.013	0.010

Monitoring Well Locations (ft)

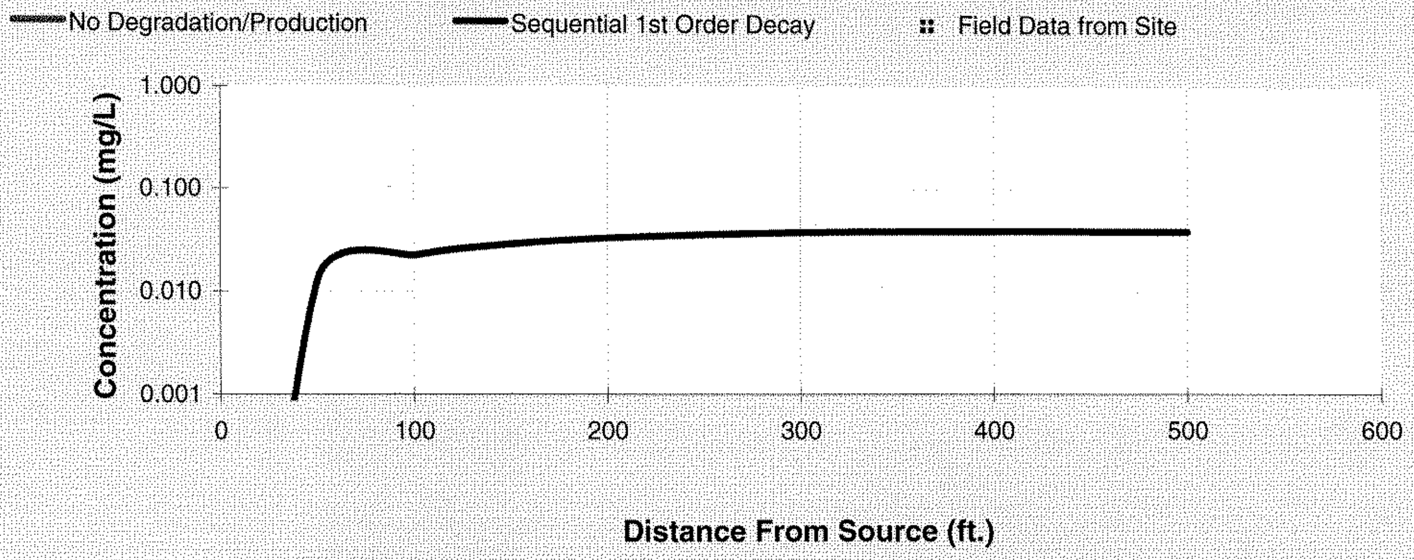
	0	191	369								
Field Data from Site	0.110	0.055	0.019								

Time: 9.0 Years

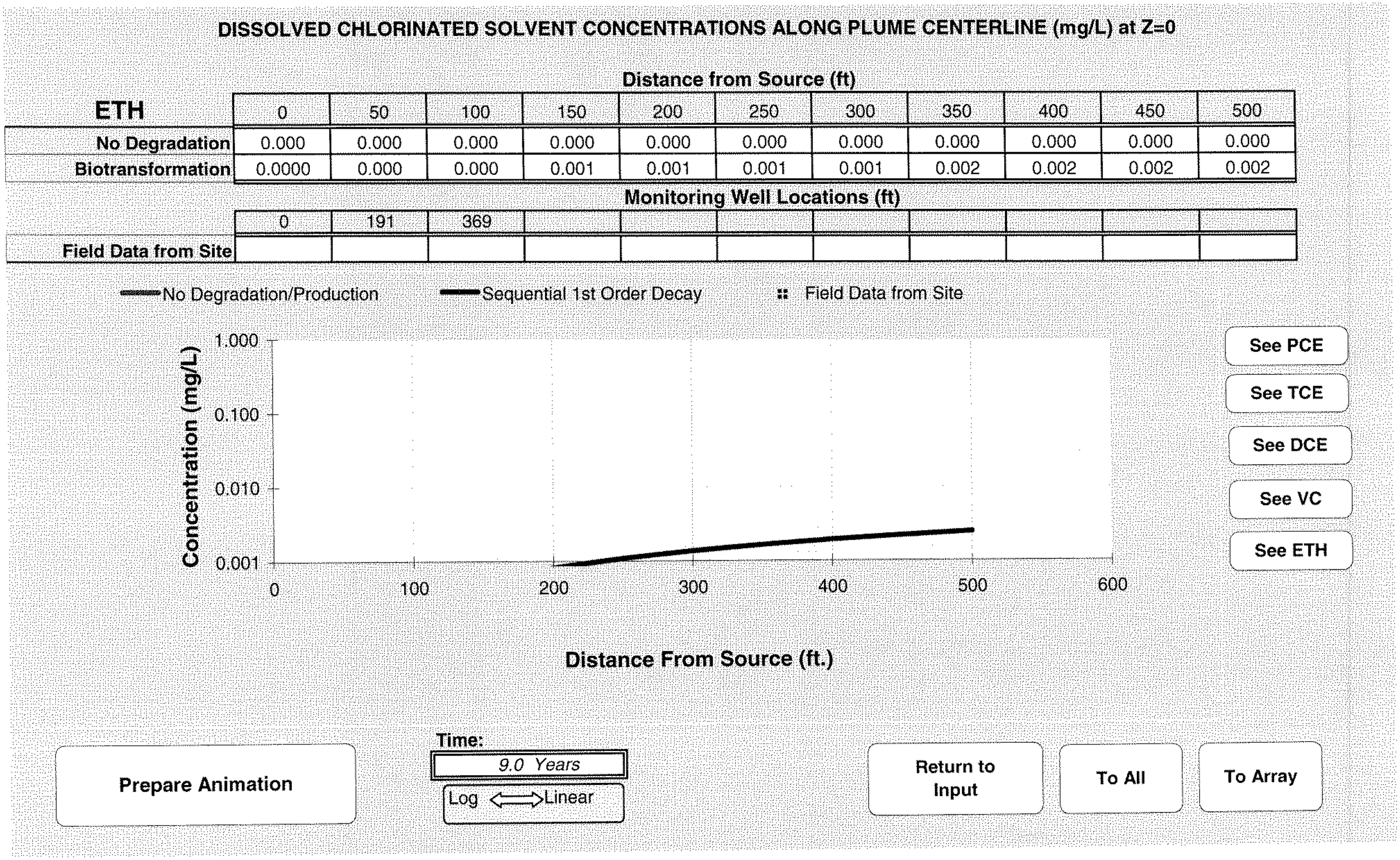
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

VC	Distance from Source (ft)										
	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.013	0.023	0.029	0.034	0.036	0.038	0.039	0.039	0.039	0.039

	Monitoring Well Locations (ft)										
	0	191	369								
Field Data from Site											



Time: 9.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

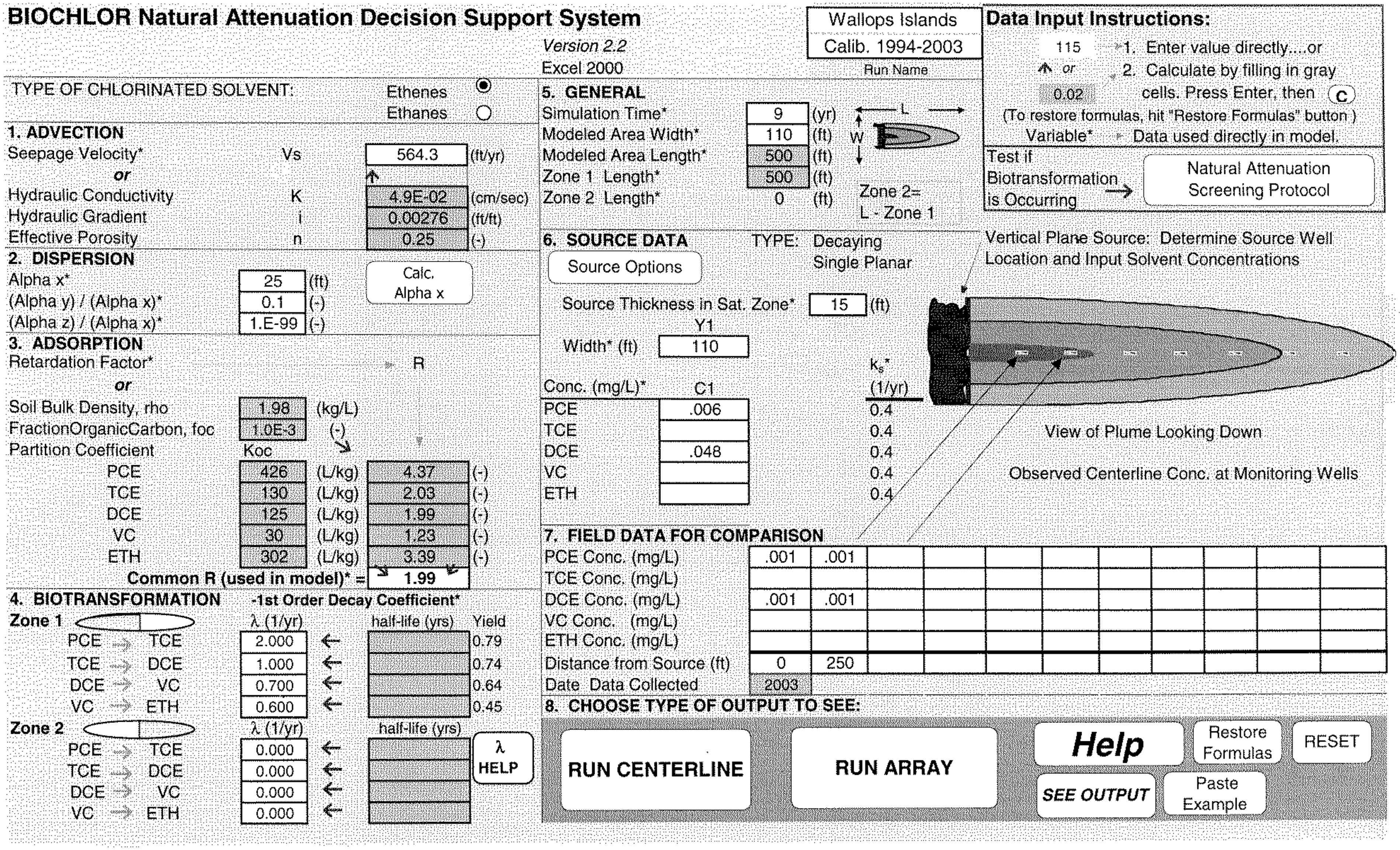
ETH	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002

Monitoring Well Locations (ft)

	0	191	369								
Field Data from Site											

Time: 9.0 Years

MODEL CALIBRATION
LOWER UNIT



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2

Excel 2000

Wallops Islands
Calib. 1994-2003
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or → 2. Calculate by filling in gray
0.02 cells. Press Enter, then (C)
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	564.3	(ft/yr)
or			
Hydraulic Conductivity	K	4.9E-02	(cm/sec)
Hydraulic Gradient	i	0.00276	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION

Alpha x*	25	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	1.E-99	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.98	(kg/L)
FractionOrganicCarbon, foc	1.0E-3	(-)

Partition Coefficient	Koc		R	
PCE	426	(L/kg)	4.37	(-)
TCE	130	(L/kg)	2.03	(-)
DCE	125	(L/kg)	1.99	(-)
VC	30	(L/kg)	1.23	(-)
ETH	302	(L/kg)	3.39	(-)

Common R (used in model)* = 1.99

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1	λ (1/yr)		half-life (yrs)	Yield
PCE → TCE	2.000	←		0.79
TCE → DCE	1.000	←		0.74
DCE → VC	0.700	←		0.64
VC → ETH	0.600	←		0.45

Zone 2	λ (1/yr)		half-life (yrs)
PCE → TCE	0.000	←	
TCE → DCE	0.000	←	
DCE → VC	0.000	←	
VC → ETH	0.000	←	

λ HELP

5. GENERAL

Simulation Time*	9	(yr)
Modeled Area Width*	110	(ft)
Modeled Area Length*	500	(ft)
Zone 1 Length*	500	(ft)
Zone 2 Length*	0	(ft)

Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 15 (ft)

Width* (ft) Y1: 110

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.006	0.4
TCE		0.4
DCE	.048	0.4
VC		0.4
ETH		0.4

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

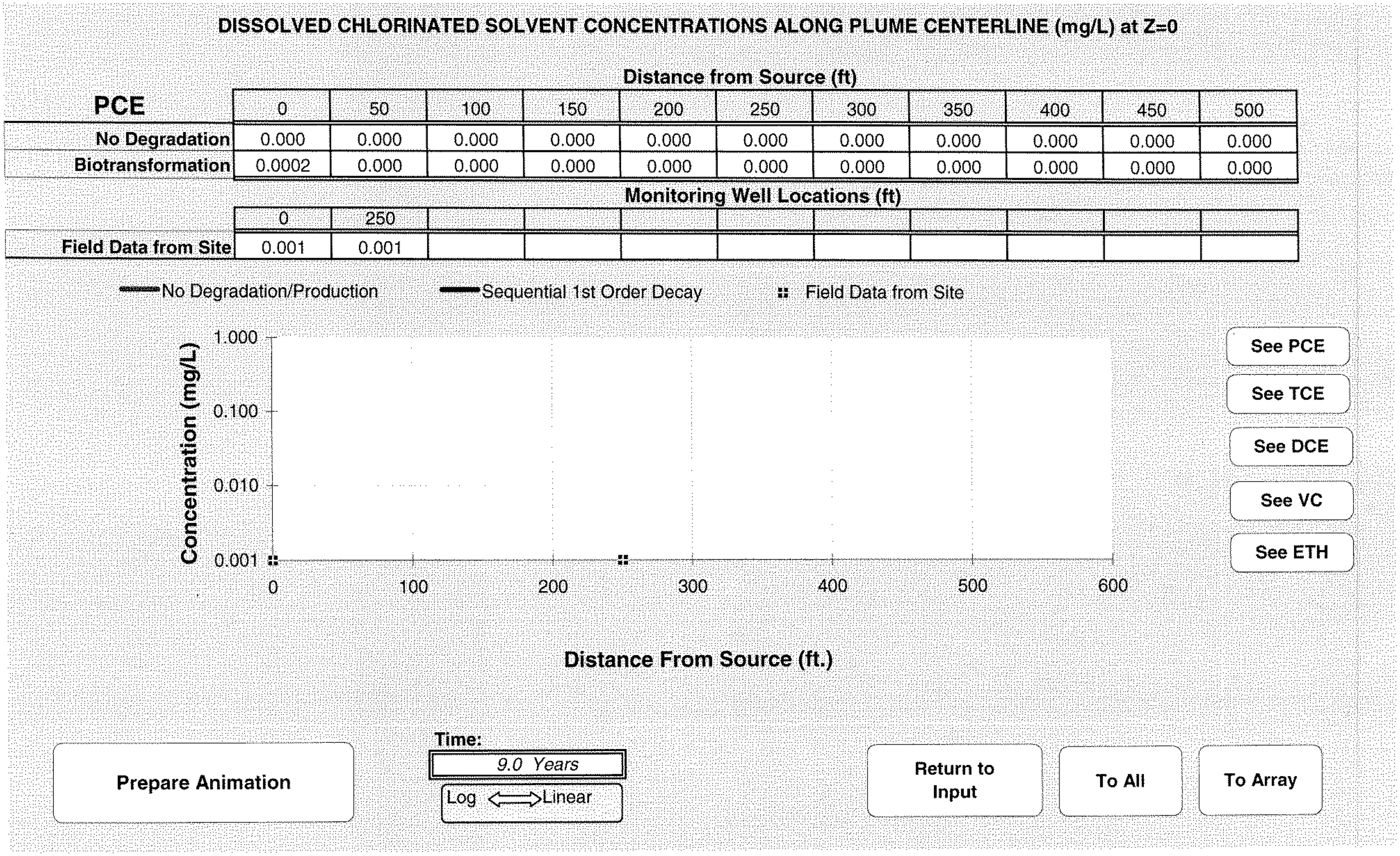
View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.001	.001									
TCE Conc. (mg/L)											
DCE Conc. (mg/L)	.001	.001									
VC Conc. (mg/L)											
ETH Conc. (mg/L)											
Distance from Source (ft)	0	250									
Date Data Collected	2003										

8. CHOOSE TYPE OF OUTPUT TO SEE:



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

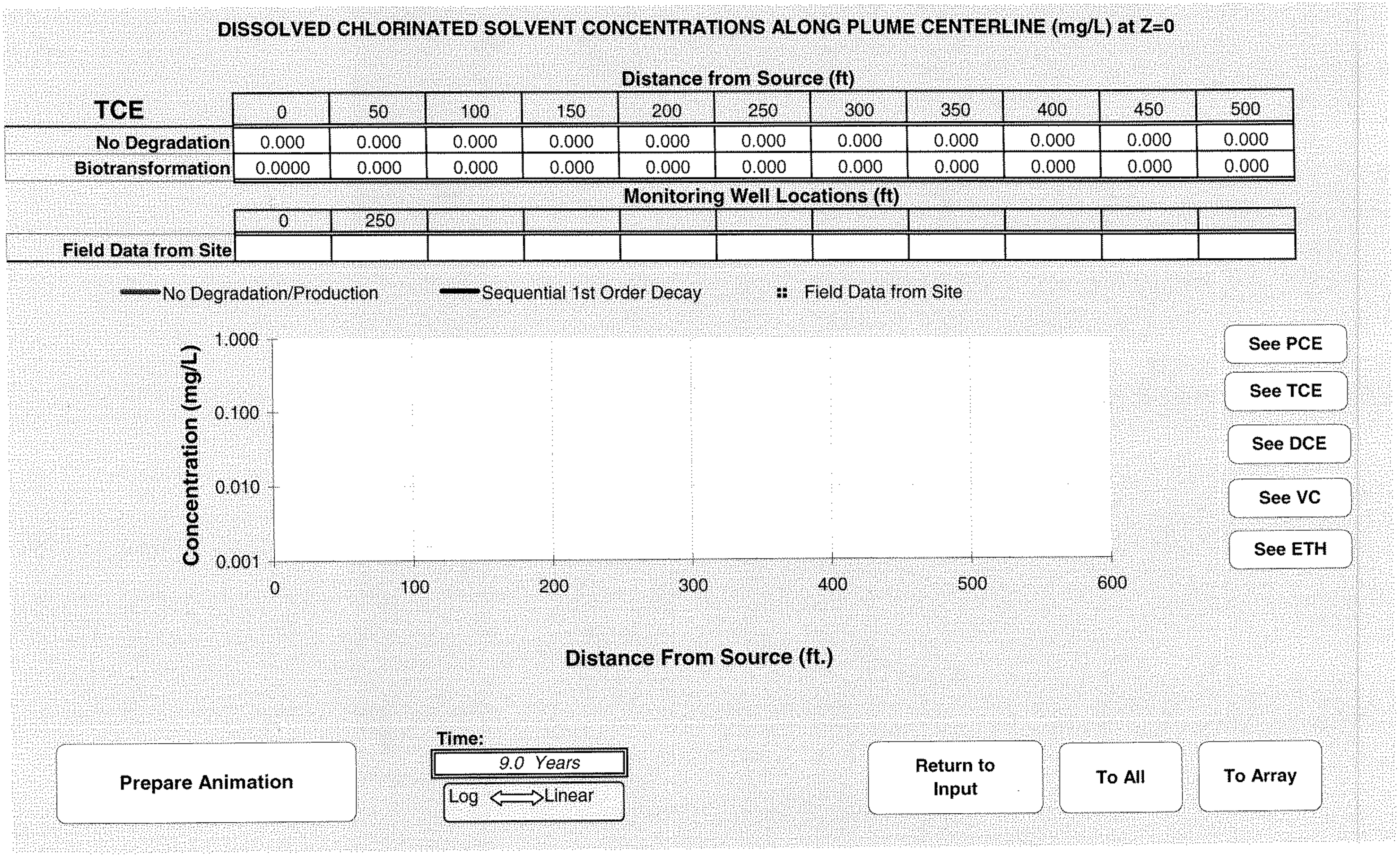
Distance from Source (ft)

PCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	250									
Field Data from Site	0.001	0.001									

Time: 9.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

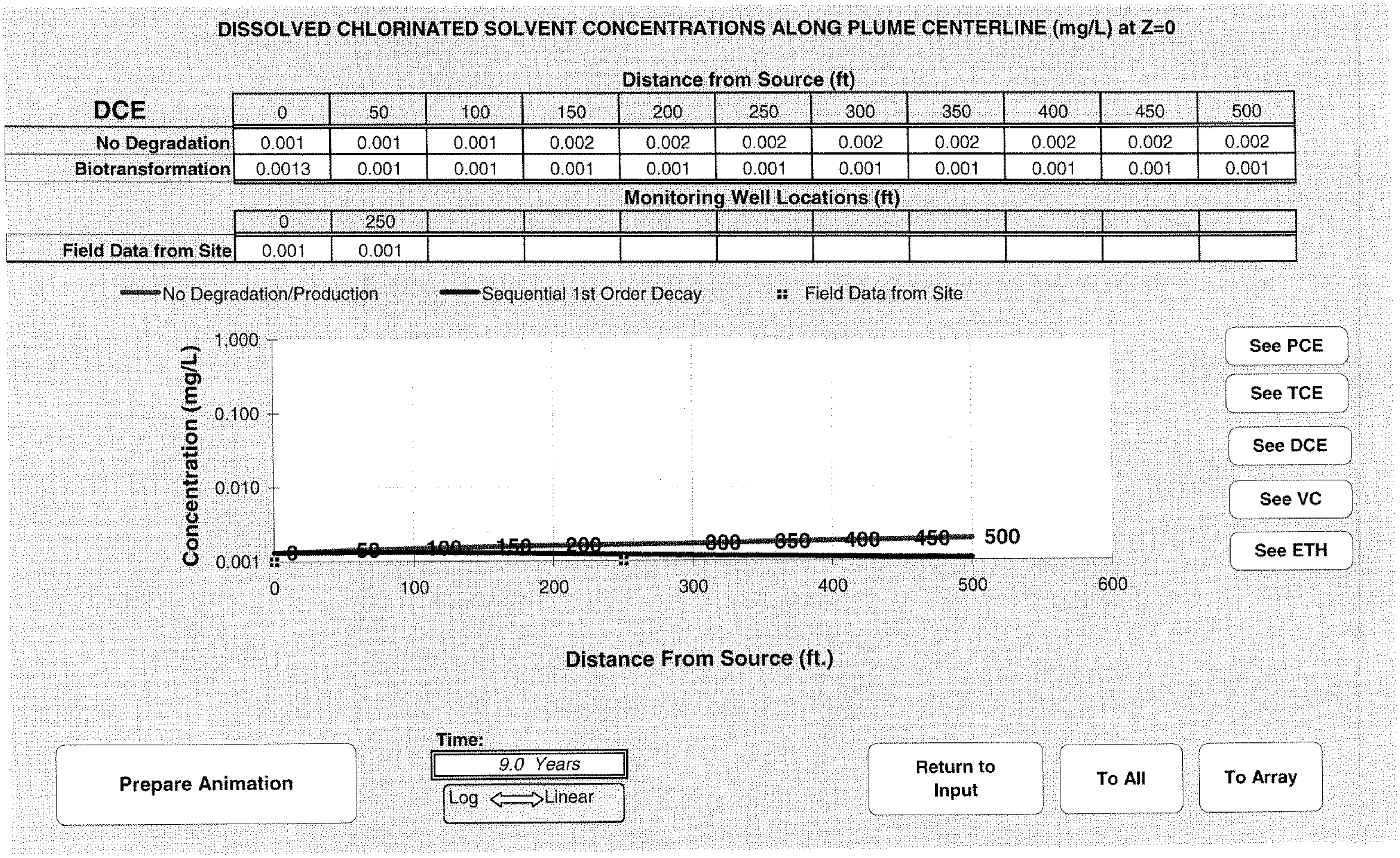
Distance from Source (ft)

TCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	250									
Field Data from Site											

Time: 9.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

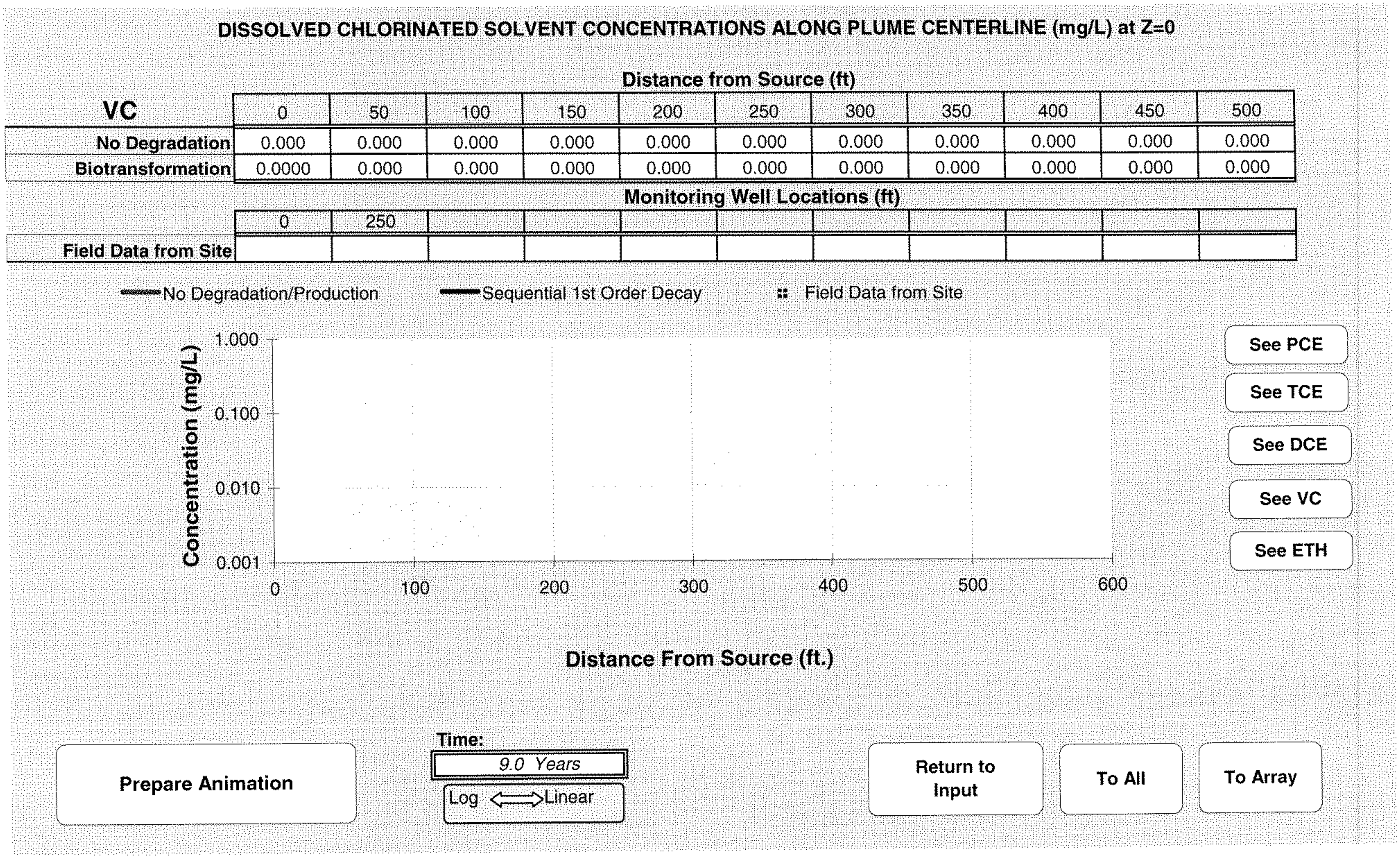
Distance from Source (ft)

DCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Biotransformation	0.0013	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Monitoring Well Locations (ft)

	0	250									
Field Data from Site	0.001	0.001									

Time: 9.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

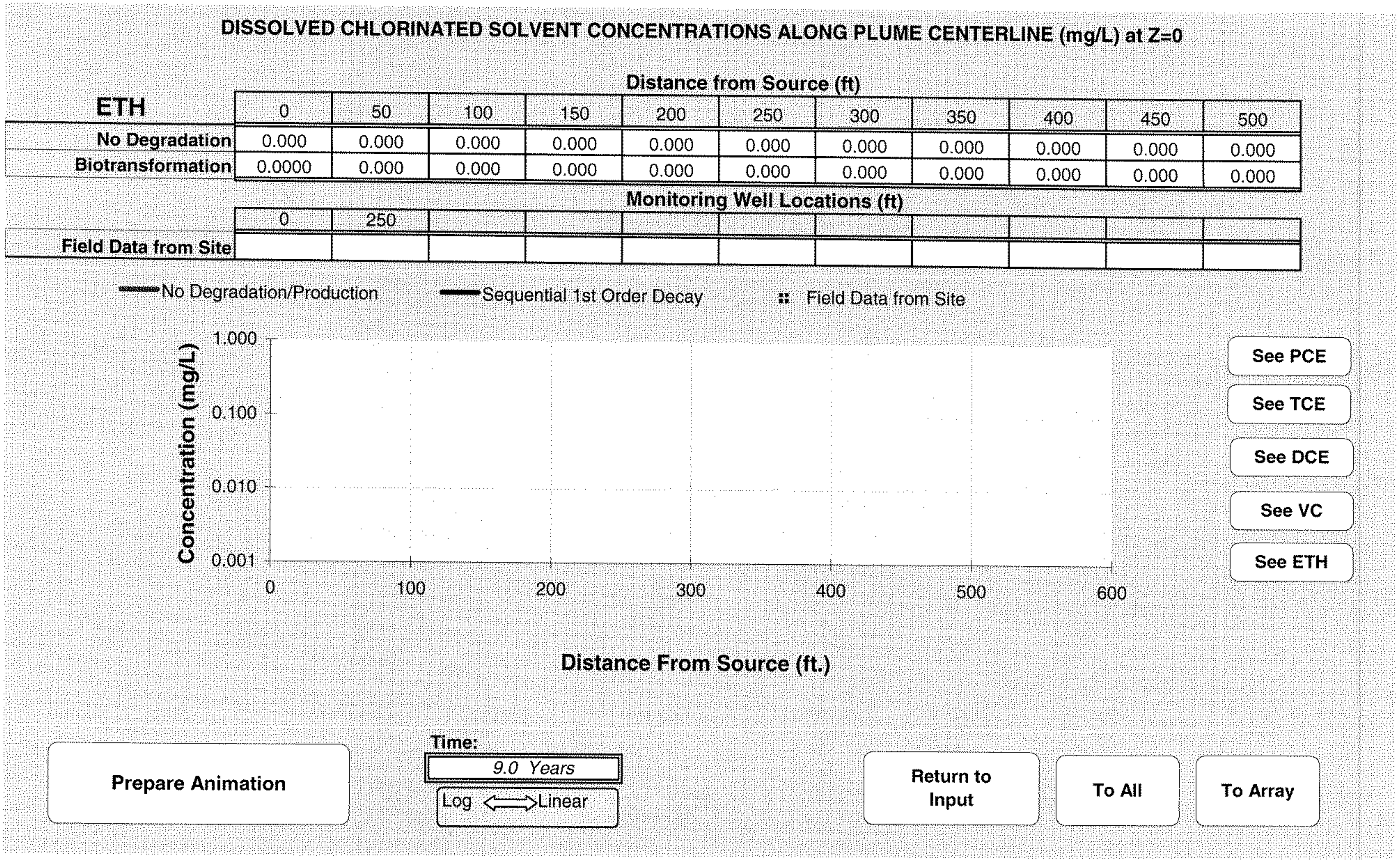
VC	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	250									
Field Data from Site											

Time:

9.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

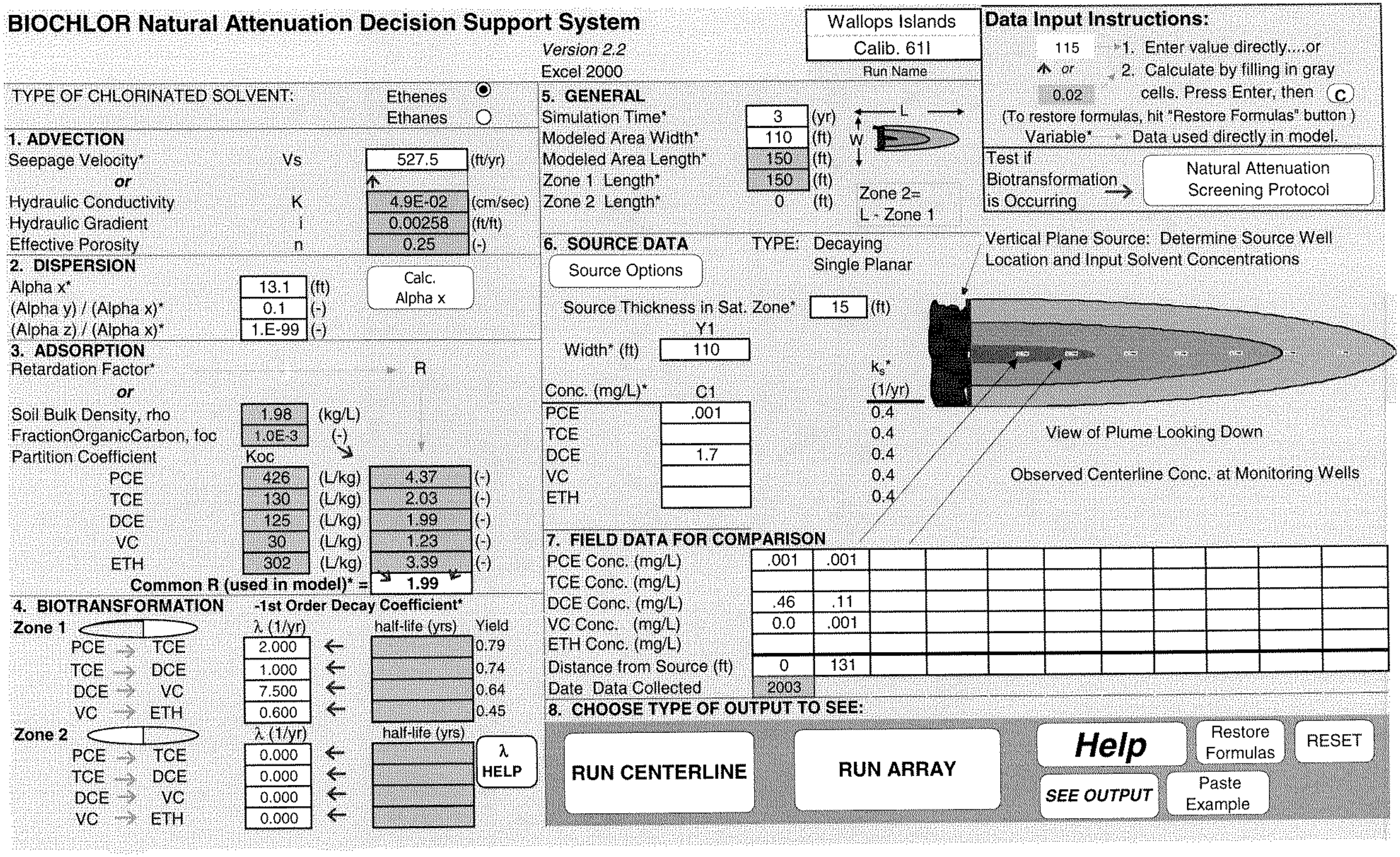
ETH	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	250									
Field Data from Site											

Time: *9.0 Years*

MODEL CALIBRATION
SOURCE AREA



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2

Excel 2000

Wallops Islands

Calib. 61I

Run Name

Data Input Instructions:

115 → 1. Enter value directly....or

↑ or → 2. Calculate by filling in gray

0.02 cells. Press Enter, then (C)

(To restore formulas, hit "Restore Formulas" button)

Variable* → Data used directly in model.

Test if Biotransformation is Occurring →

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	527.5	(ft/yr)
or		↑	
Hydraulic Conductivity	K	4.9E-02	(cm/sec)
Hydraulic Gradient	i	0.00258	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION

Alpha x*	13.1	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	1.E-99	(-)

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.98	(kg/L)		
FractionOrganicCarbon, foc	1.0E-3	(-)		
Partition Coefficient	Koc			
PCE	426	(L/kg)	4.37	(-)
TCE	130	(L/kg)	2.03	(-)
DCE	125	(L/kg)	1.99	(-)
VC	30	(L/kg)	1.23	(-)
ETH	302	(L/kg)	3.39	(-)

Common R (used in model)* = 1.99

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1

	λ (1/yr)		half-life (yrs)	Yield
PCE → TCE	2.000	←		0.79
TCE → DCE	1.000	←		0.74
DCE → VC	7.500	←		0.64
VC → ETH	0.600	←		0.45

Zone 2

	λ (1/yr)		half-life (yrs)
PCE → TCE	0.000	←	
TCE → DCE	0.000	←	
DCE → VC	0.000	←	
VC → ETH	0.000	←	

5. GENERAL

Simulation Time*	3	(yr)
Modeled Area Width*	110	(ft)
Modeled Area Length*	150	(ft)
Zone 1 Length*	150	(ft)
Zone 2 Length*	0	(ft)

6. SOURCE DATA TYPE: Decaying Single Planar

Source Thickness in Sat. Zone* 15 (ft)

Y1

Width* (ft) 110

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.001	0.4
TCE		0.4
DCE	1.7	0.4
VC		0.4
ETH		0.4

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

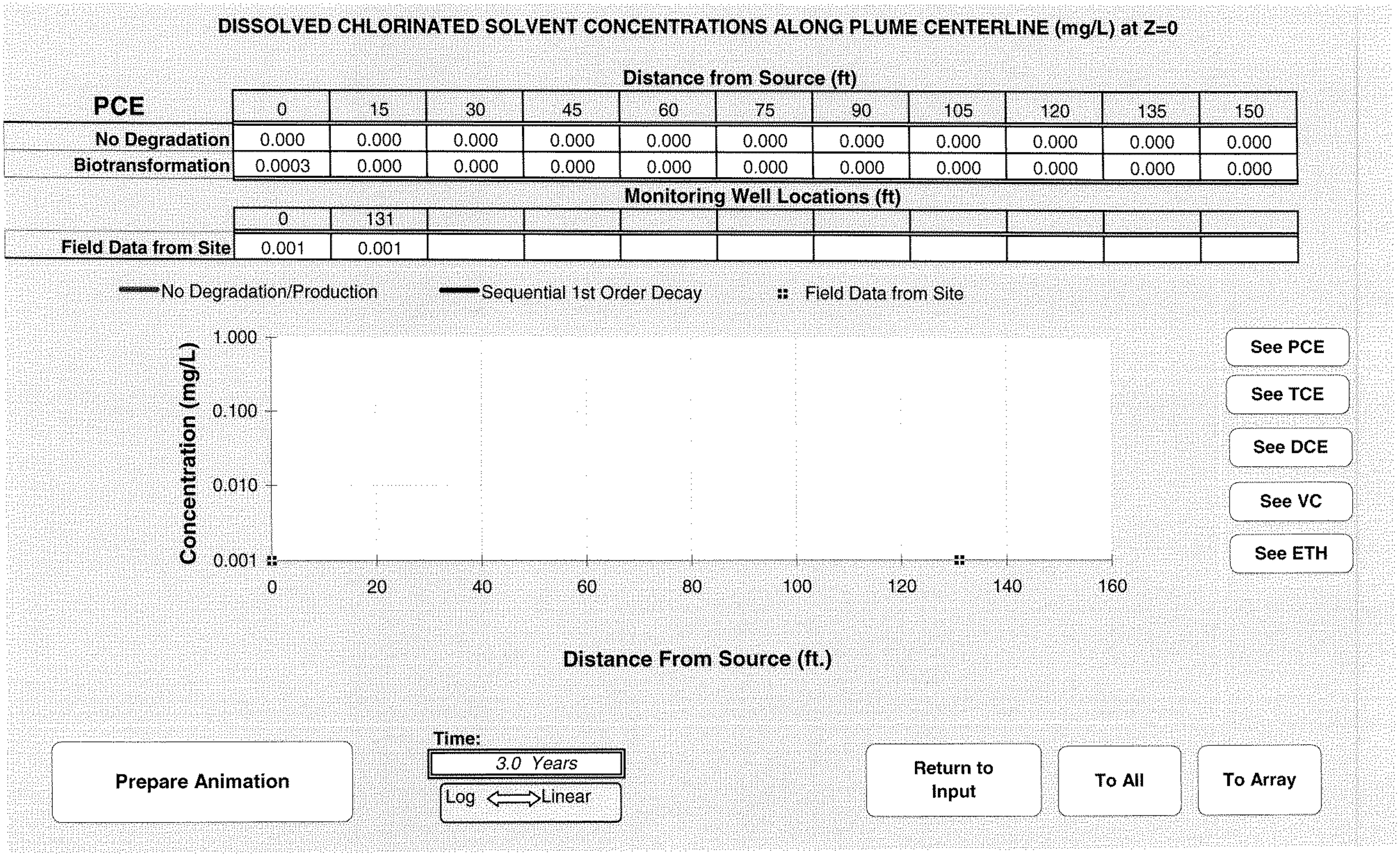
View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.001	.001									
TCE Conc. (mg/L)											
DCE Conc. (mg/L)	.46	.11									
VC Conc. (mg/L)	0.0	.001									
ETH Conc. (mg/L)											
Distance from Source (ft)	0	131									
Date Data Collected	2003										

8. CHOOSE TYPE OF OUTPUT TO SEE:



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

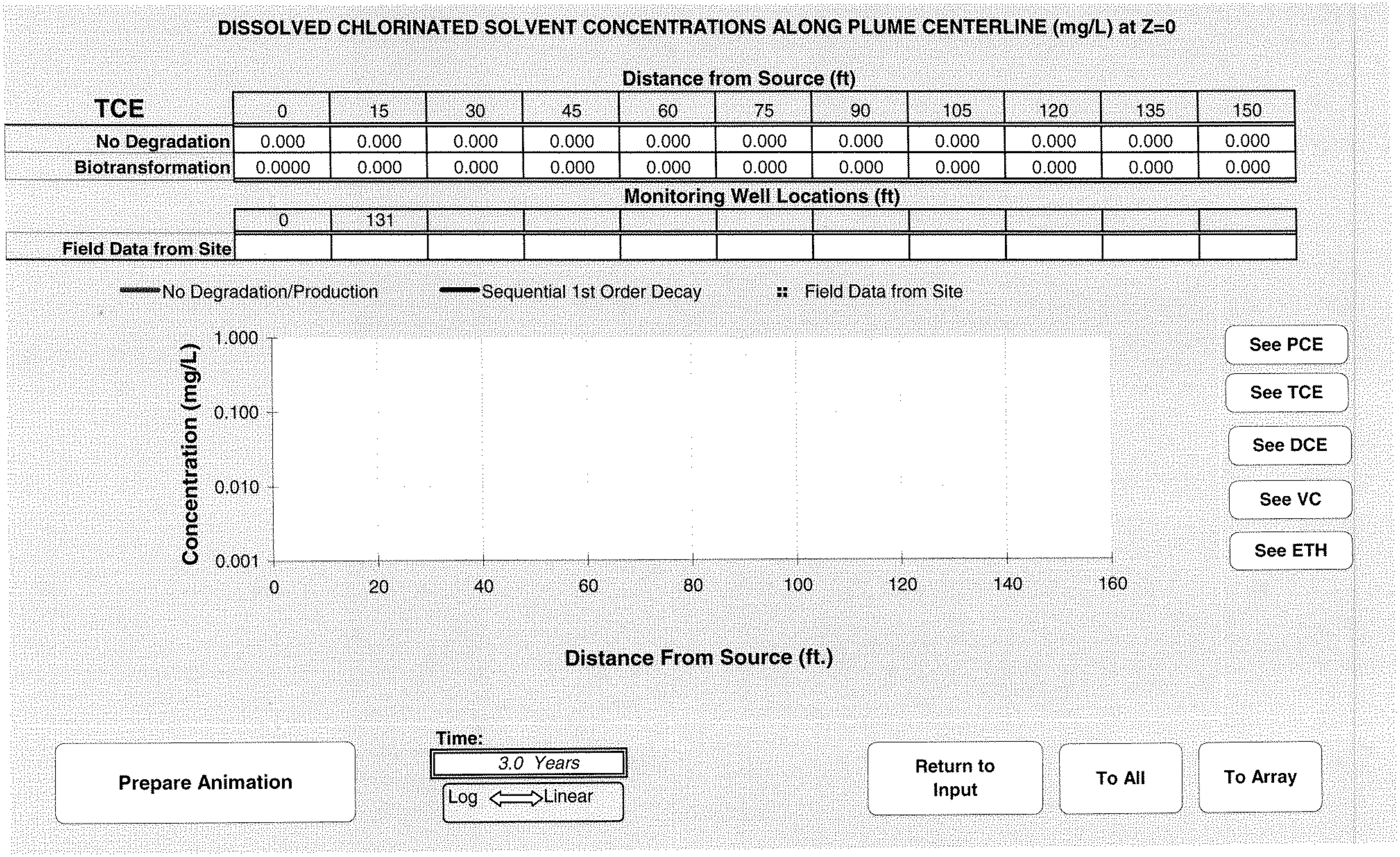
Distance from Source (ft)

PCE	0	15	30	45	60	75	90	105	120	135	150
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	0	131									
Field Data from Site	0.001	0.001									

Time: 3.0 Years

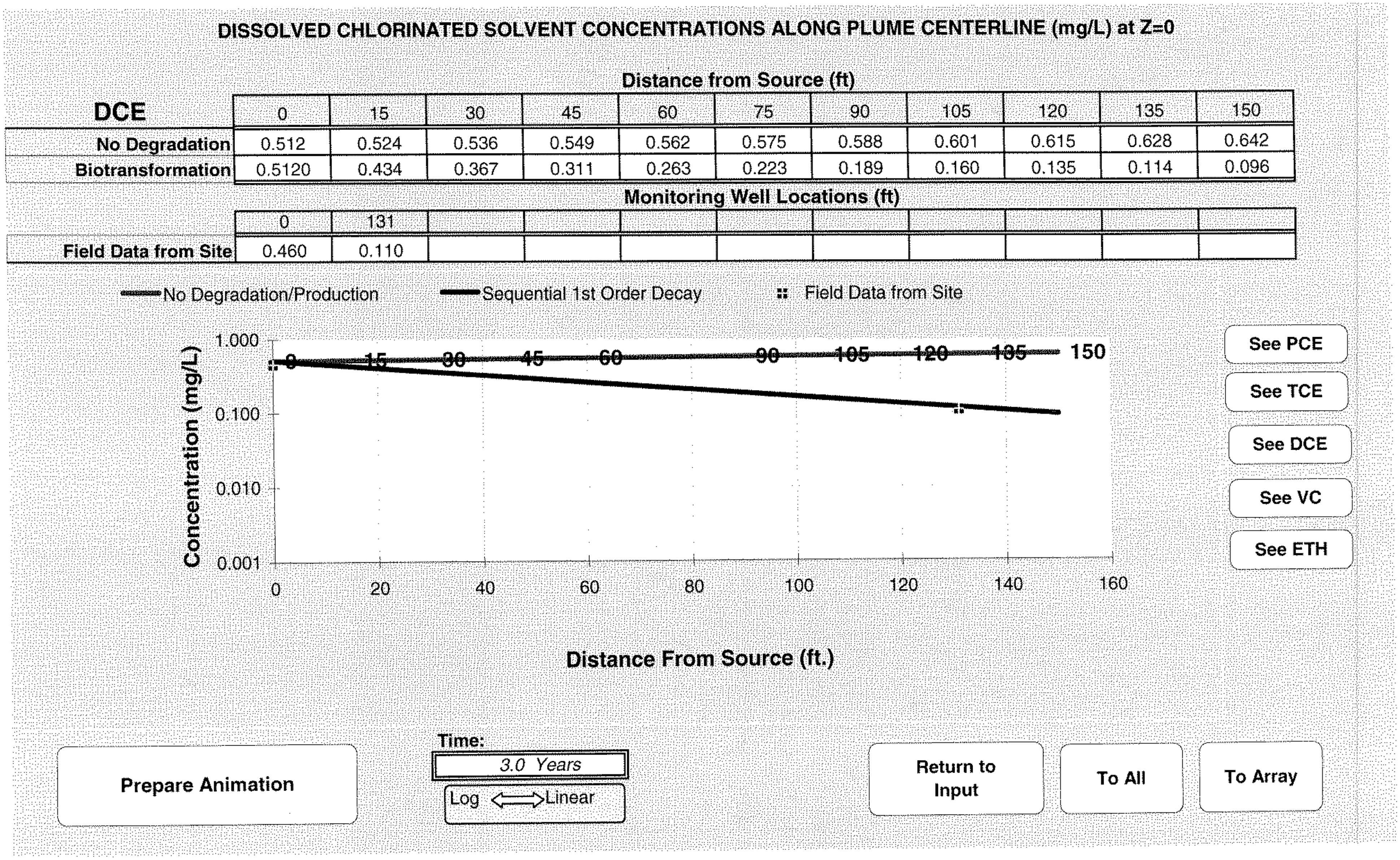


DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

	Distance from Source (ft)										
TCE	0	15	30	45	60	75	90	105	120	135	150
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	Monitoring Well Locations (ft)										
	0	131									
Field Data from Site											

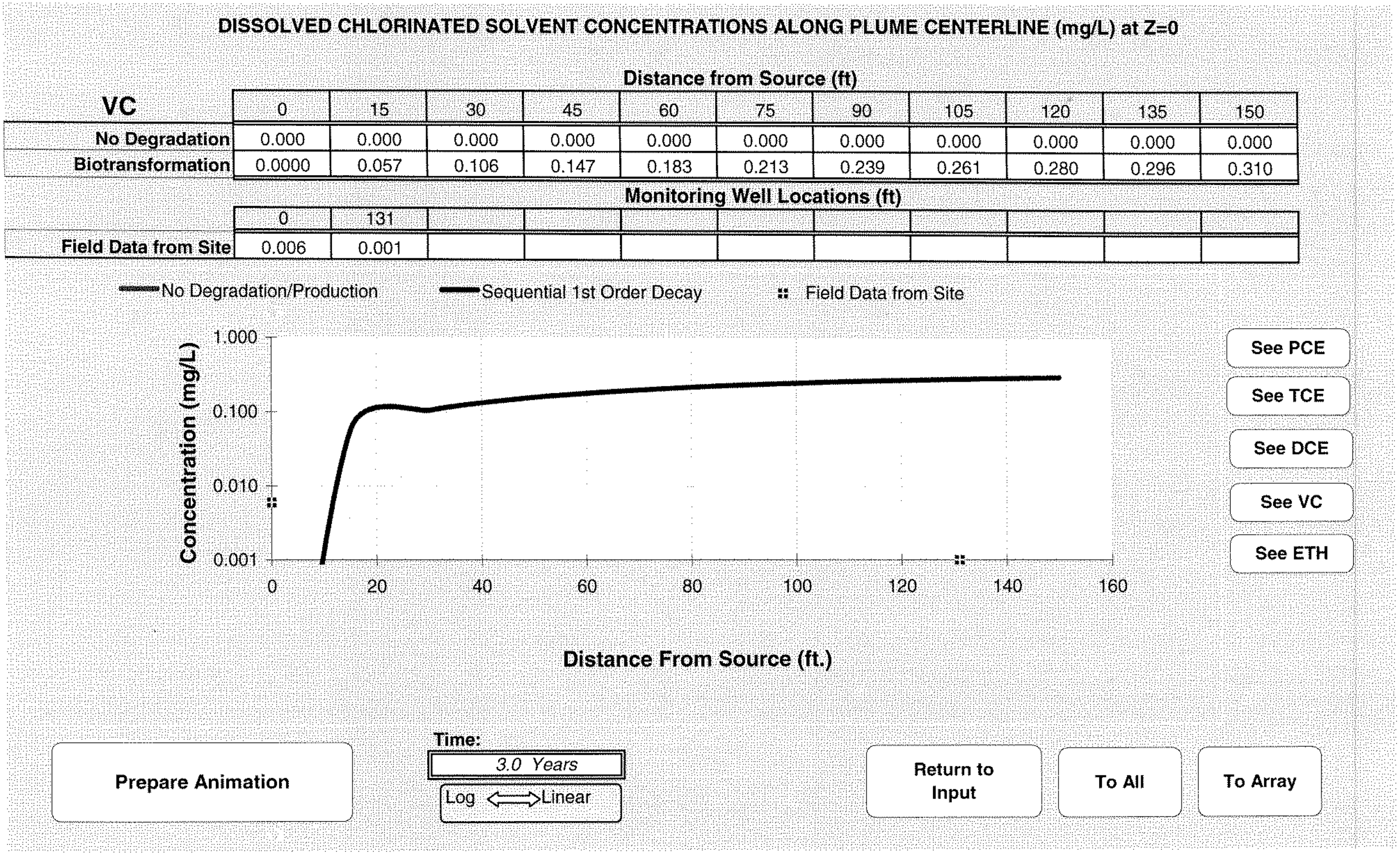
Time: 3.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

	Distance from Source (ft)										
DCE	0	15	30	45	60	75	90	105	120	135	150
No Degradation	0.512	0.524	0.536	0.549	0.562	0.575	0.588	0.601	0.615	0.628	0.642
Biotransformation	0.5120	0.434	0.367	0.311	0.263	0.223	0.189	0.160	0.135	0.114	0.096

	Monitoring Well Locations (ft)										
	0	131									
Field Data from Site	0.460	0.110									



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

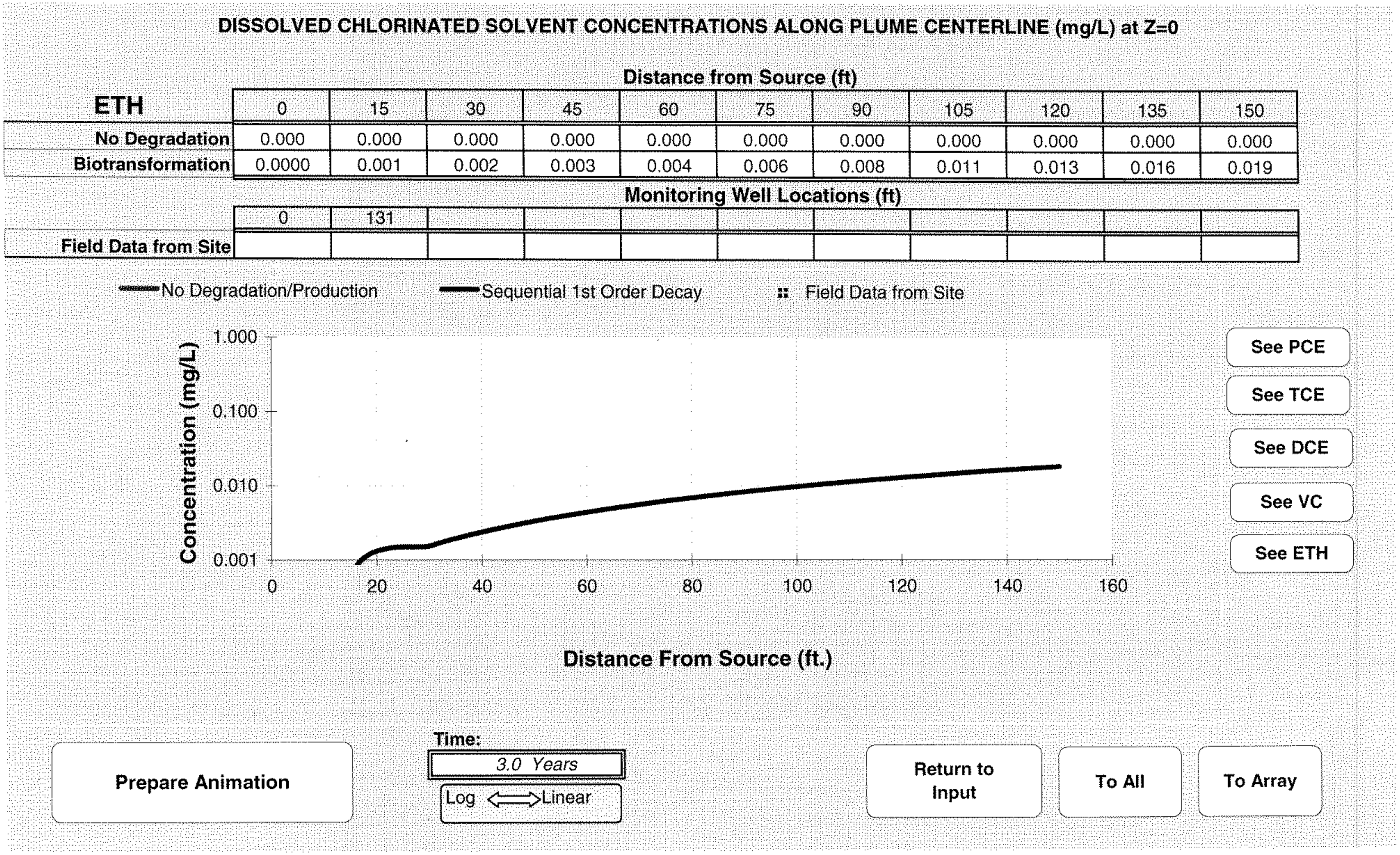
Distance from Source (ft)

VC	0	15	30	45	60	75	90	105	120	135	150
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.057	0.106	0.147	0.183	0.213	0.239	0.261	0.280	0.296	0.310

Monitoring Well Locations (ft)

	0	131									
Field Data from Site	0.006	0.001									

Time: 3.0 Years



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

ETH	0	15	30	45	60	75	90	105	120	135	150
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.001	0.002	0.003	0.004	0.006	0.008	0.011	0.013	0.016	0.019

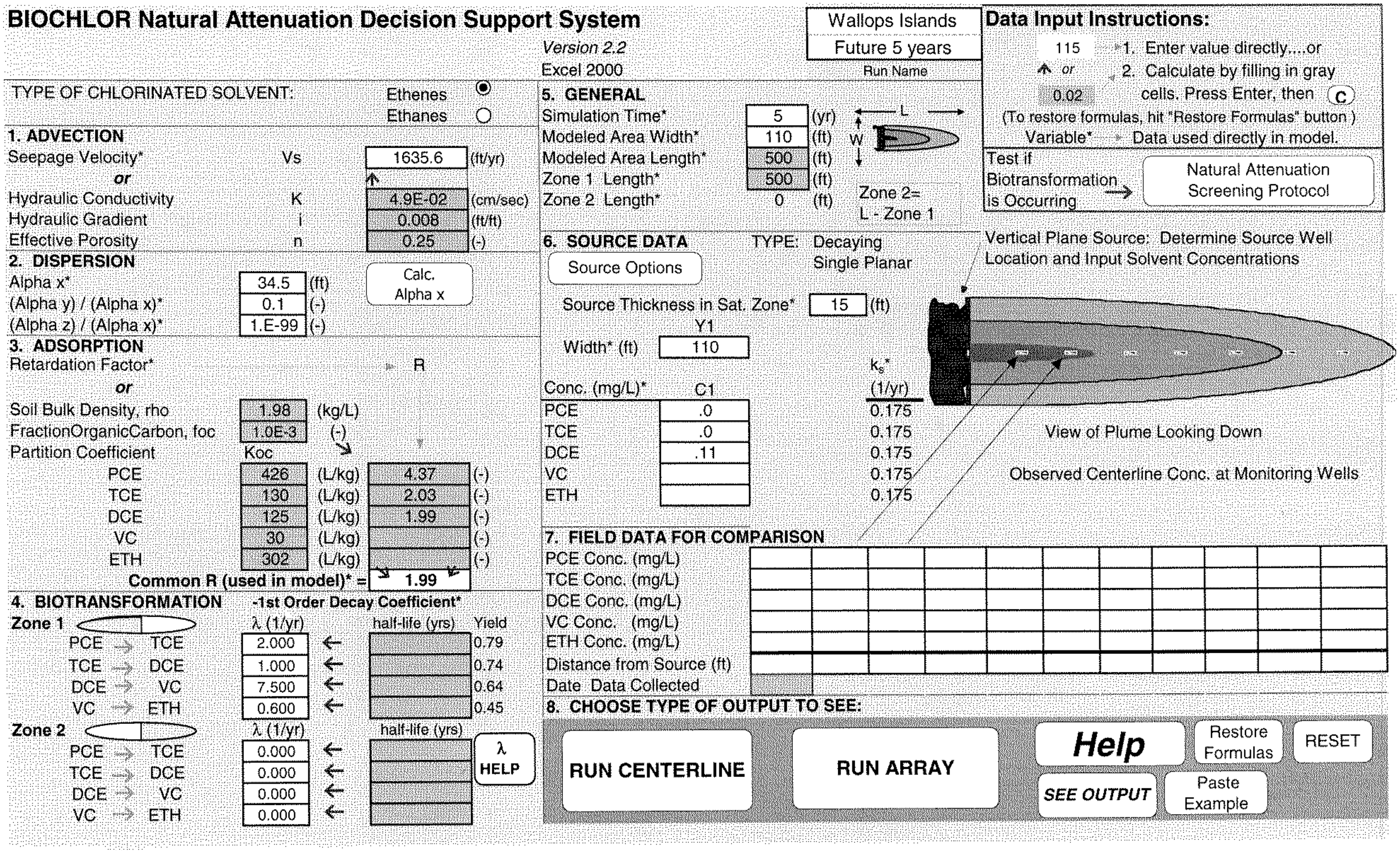
Monitoring Well Locations (ft)

	0	131									
Field Data from Site											

Time:

3.0 Years

PREDICTIVE MODEL RUNS



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Wallops Islands
Future 5 years
Run Name

Data Input Instructions:
115 → 1. Enter value directly....or
or 2. Calculate by filling in gray
0.02 cells. Press Enter, then (C)
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	1635.6	(ft/yr)
or			
Hydraulic Conductivity	K	4.9E-02	(cm/sec)
Hydraulic Gradient	i	0.008	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION

Alpha x*	34.5	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	1.E-99	(-)

Calc. Alpha x

3. ADSORPTION
Retardation Factor* → R
or

Soil Bulk Density, rho	1.98	(kg/L)		
FractionOrganicCarbon, foc	1.0E-3	(-)		
Partition Coefficient	Koc			
PCE	426	(L/kg)	4.37	(-)
TCE	130	(L/kg)	2.03	(-)
DCE	125	(L/kg)	1.99	(-)
VC	30	(L/kg)		(-)
ETH	302	(L/kg)		(-)

Common R (used in model)* = 1.99

4. BIOTRANSFORMATION **-1st Order Decay Coefficient***

Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	2.000		0.79
TCE → DCE	1.000		0.74
DCE → VC	7.500		0.64
VC → ETH	0.600		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*	5	(yr)
Modeled Area Width*	110	(ft)
Modeled Area Length*	500	(ft)
Zone 1 Length*	500	(ft)
Zone 2 Length*	0	(ft)

Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 15 (ft)

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

	Y1
Width* (ft)	110

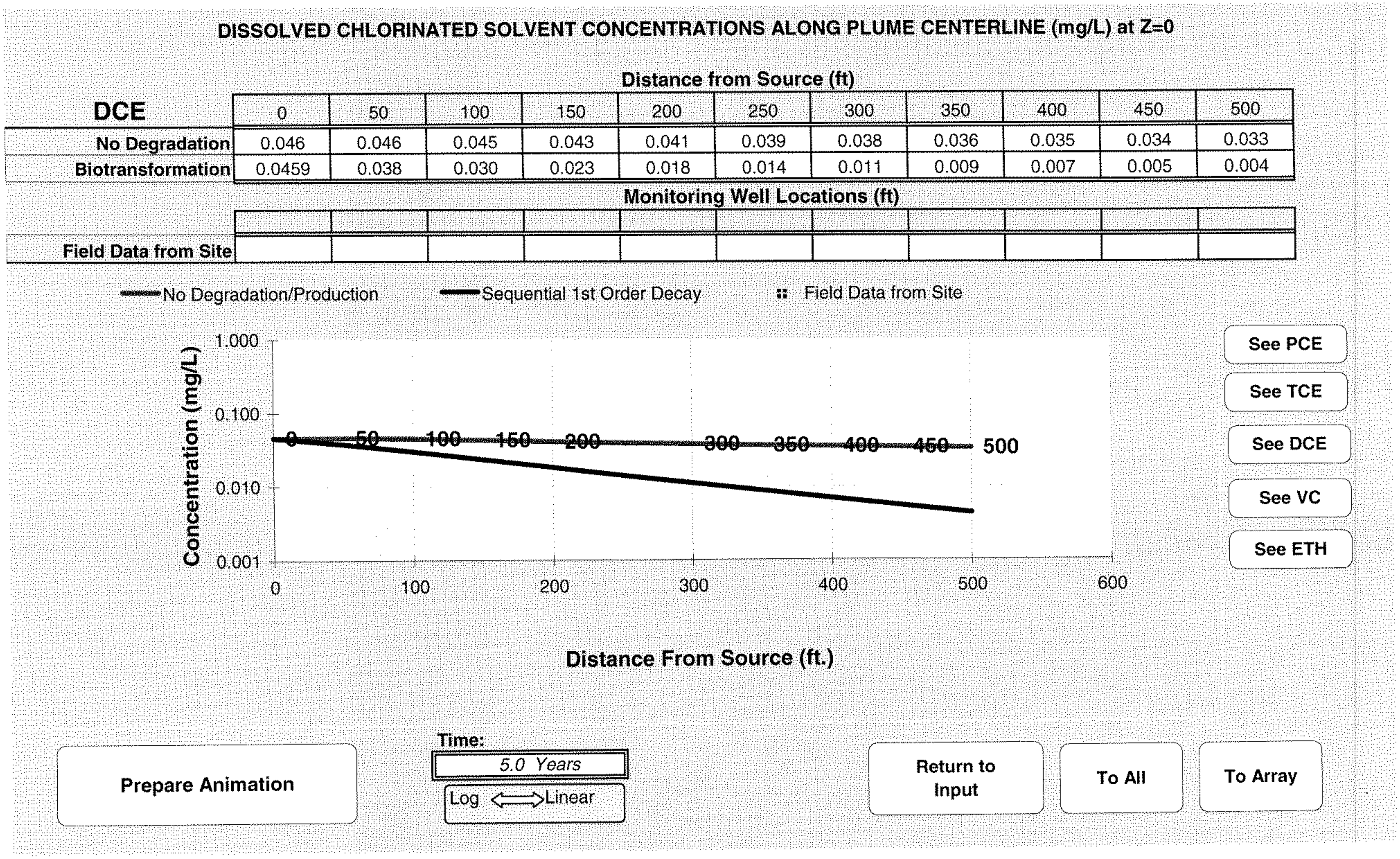
Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.0	0.175
TCE	.0	0.175
DCE	.11	0.175
VC		0.175
ETH		0.175

View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON
PCE Conc. (mg/L)
TCE Conc. (mg/L)
DCE Conc. (mg/L)
VC Conc. (mg/L)
ETH Conc. (mg/L)
Distance from Source (ft)
Date Data Collected

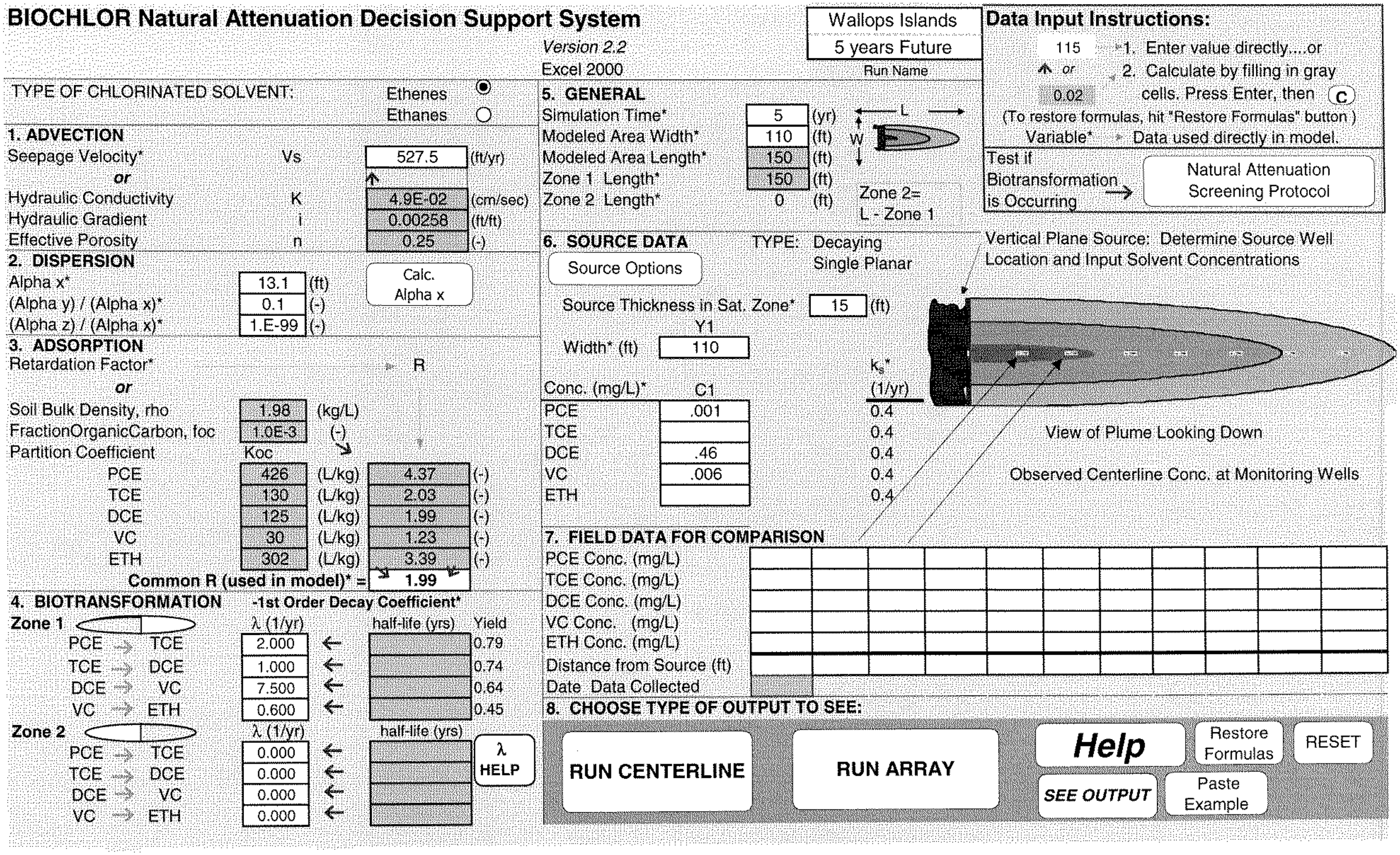
8. CHOOSE TYPE OF OUTPUT TO SEE:



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

DCE	Distance from Source (ft)										
	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.046	0.046	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033
Biotransformation	0.0459	0.038	0.030	0.023	0.018	0.014	0.011	0.009	0.007	0.005	0.004
	Monitoring Well Locations (ft)										
Field Data from Site											

Time: 5.0 Years



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2

Excel 2000

Wallops Islands

5 years Future

Run Name

Data Input Instructions:

115 → 1. Enter value directly....or

↑ *or* 2. Calculate by filling in gray

0.02 cells. Press Enter, then (C)

(To restore formulas, hit "Restore Formulas" button)

Variable* → Data used directly in model.

Test if Biotransformation is Occurring →

Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	527.5	(ft/yr)
or			
Hydraulic Conductivity	K	4.9E-02	(cm/sec)
Hydraulic Gradient	i	0.00258	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION

Alpha x*	13.1	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	1.E-99	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.98	(kg/L)
FractionOrganicCarbon, foc	1.0E-3	(-)

Partition Coefficient	Koc		R	
PCE	426	(L/kg)	4.37	(-)
TCE	130	(L/kg)	2.03	(-)
DCE	125	(L/kg)	1.99	(-)
VC	30	(L/kg)	1.23	(-)
ETH	302	(L/kg)	3.39	(-)

Common R (used in model)* = 1.99

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1	λ (1/yr)		half-life (yrs)	Yield
PCE → TCE	2.000	←		0.79
TCE → DCE	1.000	←		0.74
DCE → VC	7.500	←		0.64
VC → ETH	0.600	←		0.45

Zone 2	λ (1/yr)		half-life (yrs)
PCE → TCE	0.000	←	
TCE → DCE	0.000	←	
DCE → VC	0.000	←	
VC → ETH	0.000	←	

λ HELP

5. GENERAL

Simulation Time*	5	(yr)
Modeled Area Width*	110	(ft)
Modeled Area Length*	150	(ft)
Zone 1 Length*	150	(ft)
Zone 2 Length*	0	(ft)

Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 15 (ft)

Width* (ft) Y1 110

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.001	0.4
TCE		0.4
DCE	.46	0.4
VC	.006	0.4
ETH		0.4

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

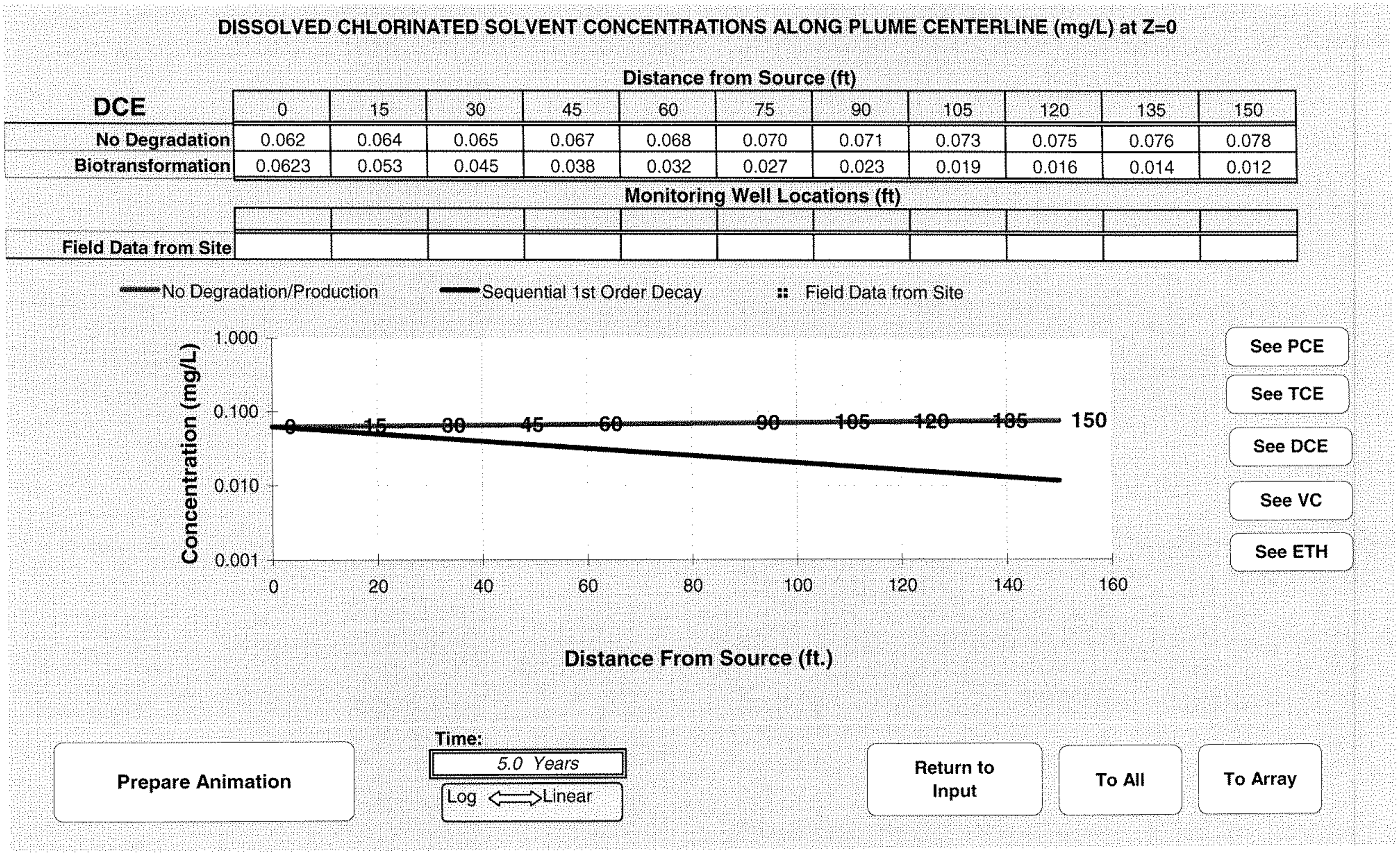
View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)											
TCE Conc. (mg/L)											
DCE Conc. (mg/L)											
VC Conc. (mg/L)											
ETH Conc. (mg/L)											
Distance from Source (ft)											
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

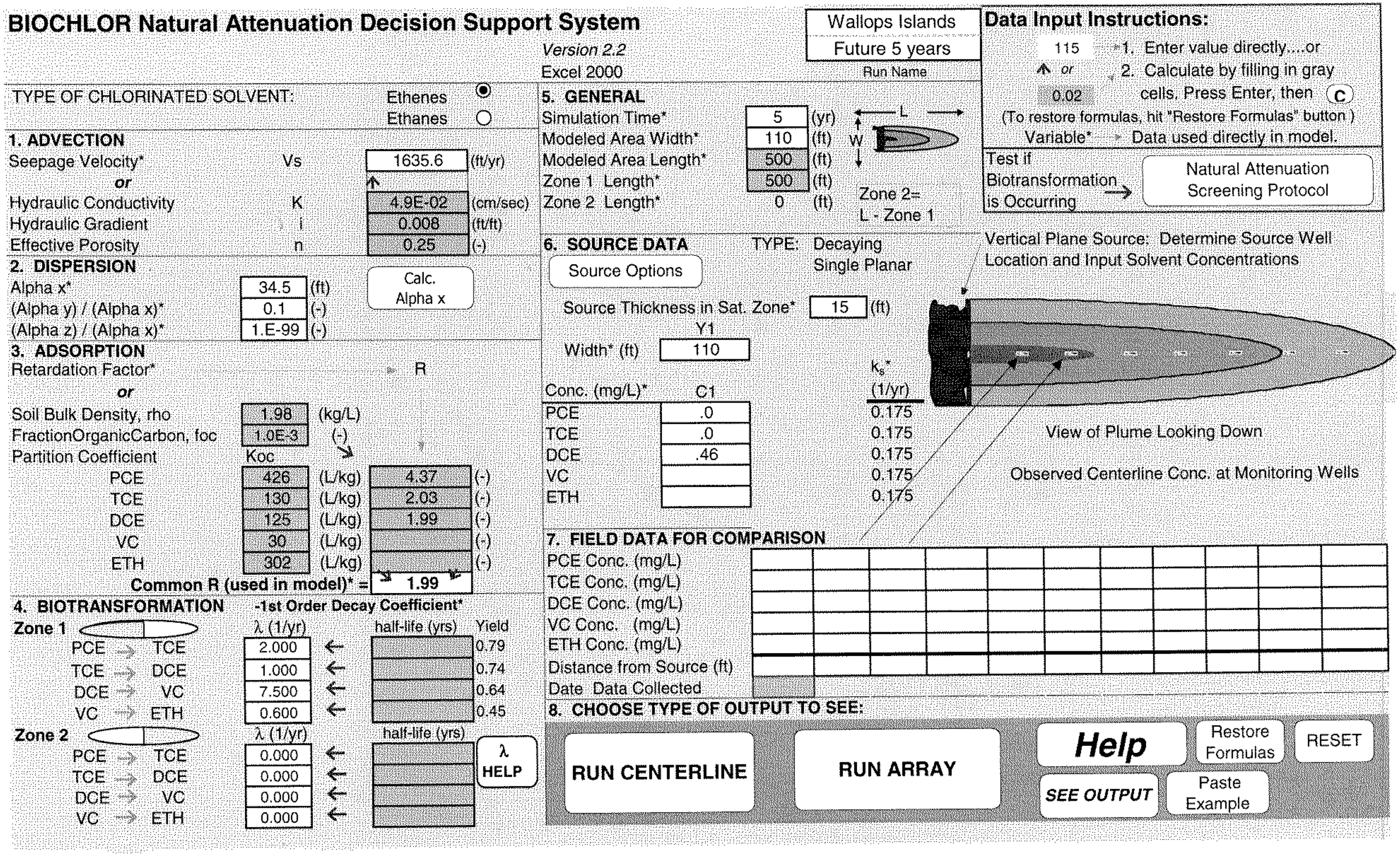
Distance from Source (ft)

DCE	0	15	30	45	60	75	90	105	120	135	150
No Degradation	0.062	0.064	0.065	0.067	0.068	0.070	0.071	0.073	0.075	0.076	0.078
Biotransformation	0.0623	0.053	0.045	0.038	0.032	0.027	0.023	0.019	0.016	0.014	0.012

Monitoring Well Locations (ft)

Field Data from Site											

Time: 5.0 Years



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Wallops Islands
Future 5 years
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
or 2. Calculate by filling in gray
0.02 cells. Press Enter, then C
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	1635.6	(ft/yr)
or			
Hydraulic Conductivity	K	4.9E-02	(cm/sec)
Hydraulic Gradient	i	0.008	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION Calc. Alpha x

Alpha x*	34.5	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	1.E-99	(-)

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.98	(kg/L)		
FractionOrganicCarbon, foc	1.0E-3	(-)		
Partition Coefficient	Koc			
PCE	426	(L/kg)	4.37	(-)
TCE	130	(L/kg)	2.03	(-)
DCE	125	(L/kg)	1.99	(-)
VC	30	(L/kg)		(-)
ETH	302	(L/kg)		(-)

Common R (used in model)* = 1.99

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	2.000		0.79
TCE → DCE	1.000		0.74
DCE → VC	7.500		0.64
VC → ETH	0.600		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*	5	(yr)
Modeled Area Width*	110	(ft)
Modeled Area Length*	500	(ft)
Zone 1 Length*	500	(ft)
Zone 2 Length*	0	(ft)

Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 15 (ft)

Width* (ft) Y1 110

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.0	0.175
TCE	.0	0.175
DCE	.46	0.175
VC		0.175
ETH		0.175

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

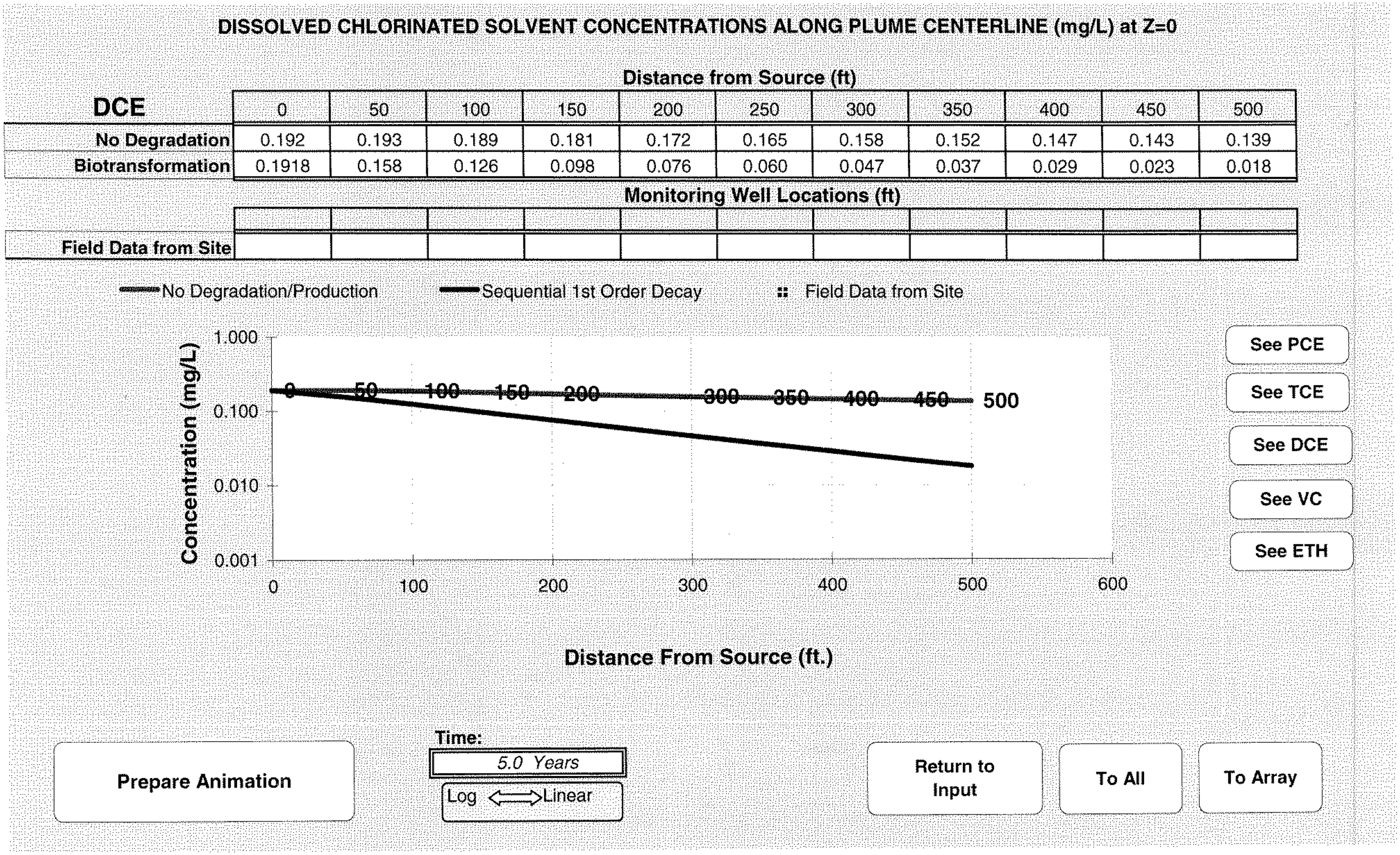
View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)											
TCE Conc. (mg/L)											
DCE Conc. (mg/L)											
VC Conc. (mg/L)											
ETH Conc. (mg/L)											
Distance from Source (ft)											
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

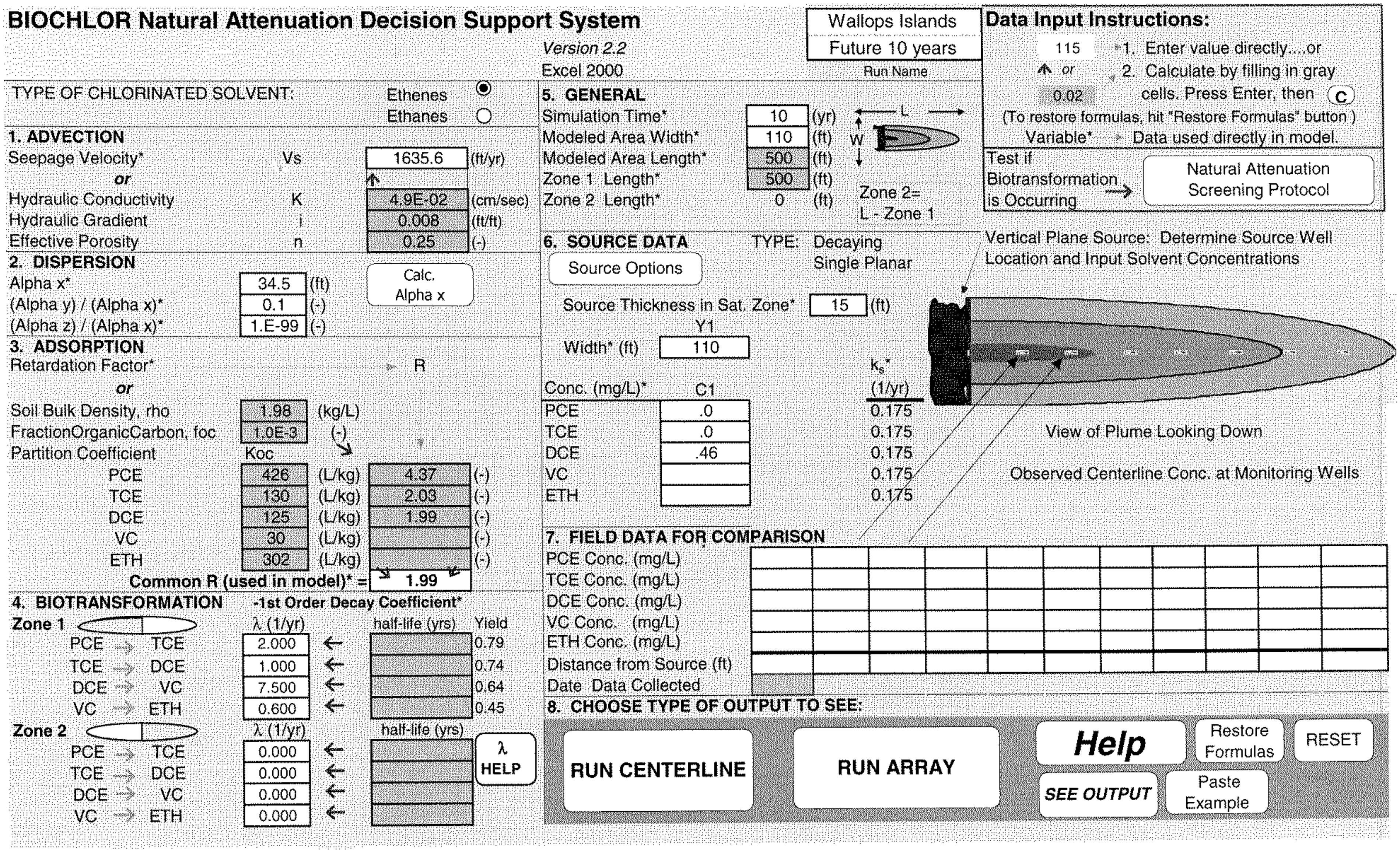
Distance from Source (ft)

DCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.192	0.193	0.189	0.181	0.172	0.165	0.158	0.152	0.147	0.143	0.139
Biotransformation	0.1918	0.158	0.126	0.098	0.076	0.060	0.047	0.037	0.029	0.023	0.018

Monitoring Well Locations (ft)

Field Data from Site											

5.0 Years



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Wallops Islands
Future 10 years
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
↑ *or* ← 2. Calculate by filling in gray
0.02 cells. Press Enter, then ⓒ
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	1635.6	(ft/yr)
or			
Hydraulic Conductivity	K	4.9E-02	(cm/sec)
Hydraulic Gradient	i	0.008	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION

Alpha x*	34.5	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	1.E-99	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.98	(kg/L)
FractionOrganicCarbon, foc	1.0E-3	(-)

Partition Coefficient	Koc			
PCE	426	(L/kg)	4.37	(-)
TCE	130	(L/kg)	2.03	(-)
DCE	125	(L/kg)	1.99	(-)
VC	30	(L/kg)		(-)
ETH	302	(L/kg)		(-)

Common R (used in model)* = 1.99

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1	λ (1/yr)		half-life (yrs)	Yield
PCE → TCE	2.000	←		0.79
TCE → DCE	1.000	←		0.74
DCE → VC	7.500	←		0.64
VC → ETH	0.600	←		0.45

Zone 2	λ (1/yr)		half-life (yrs)
PCE → TCE	0.000	←	
TCE → DCE	0.000	←	
DCE → VC	0.000	←	
VC → ETH	0.000	←	

λ HELP

5. GENERAL

Simulation Time*	10	(yr)
Modeled Area Width*	110	(ft)
Modeled Area Length*	500	(ft)
Zone 1 Length*	500	(ft)
Zone 2 Length*	0	(ft)

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 15 (ft)

	Y1
Width* (ft)	110

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.0	0.175
TCE	.0	0.175
DCE	.46	0.175
VC		0.175
ETH		0.175

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

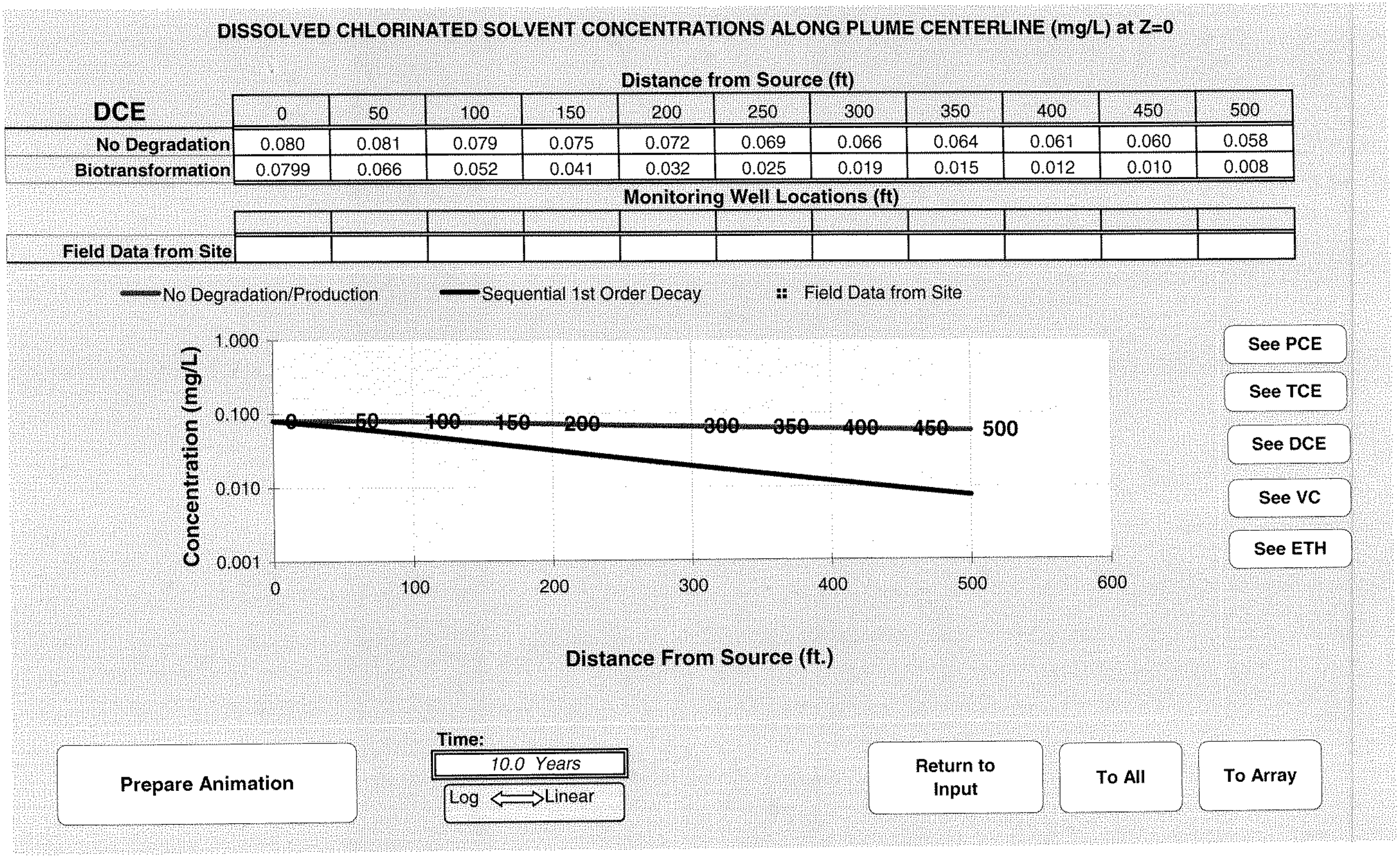
View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)											
TCE Conc. (mg/L)											
DCE Conc. (mg/L)											
VC Conc. (mg/L)											
ETH Conc. (mg/L)											
Distance from Source (ft)											
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:

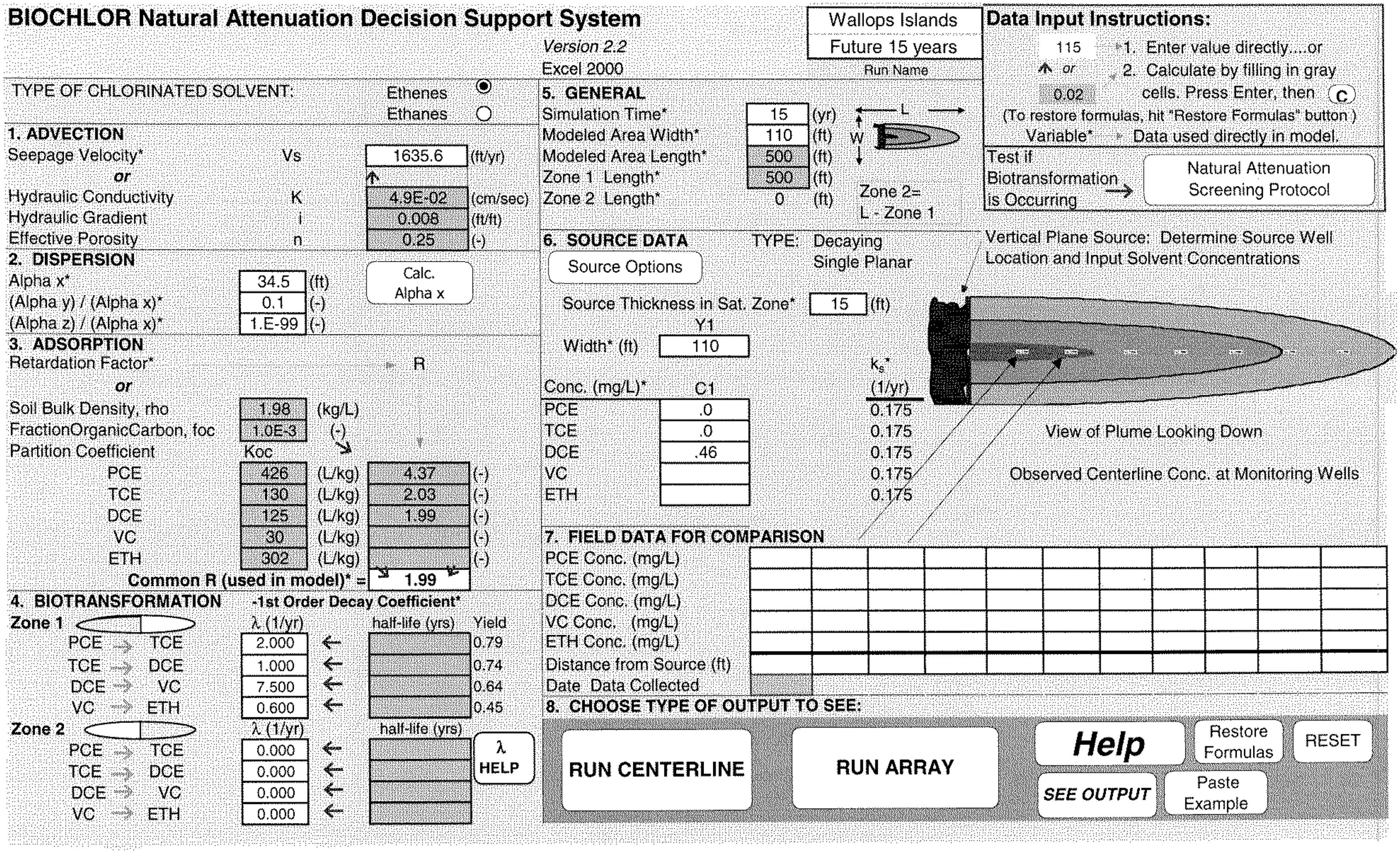


DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

	Distance from Source (ft)										
DCE	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.080	0.081	0.079	0.075	0.072	0.069	0.066	0.064	0.061	0.060	0.058
Biotransformation	0.0799	0.066	0.052	0.041	0.032	0.025	0.019	0.015	0.012	0.010	0.008

	Monitoring Well Locations (ft)										
Field Data from Site											

Time: 10.0 Years



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Wallops Islands
Future 15 years
Run Name

Data Input Instructions:
115 → 1. Enter value directly....or
↑ or → 2. Calculate by filling in gray
0.02 cells. Press Enter, then C
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring →

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	1635.6	(ft/yr)
or			
Hydraulic Conductivity	K	4.9E-02	(cm/sec)
Hydraulic Gradient	i	0.008	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION

Alpha x*	34.5	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	1.E-99	(-)

3. ADSORPTION

Retardation Factor* → R
or

Soil Bulk Density, rho	1.98	(kg/L)		
FractionOrganicCarbon, foc	1.0E-3	(-)		
Partition Coefficient	Koc			
PCE	426	(L/kg)	4.37	(-)
TCE	130	(L/kg)	2.03	(-)
DCE	125	(L/kg)	1.99	(-)
VC	30	(L/kg)		(-)
ETH	302	(L/kg)		(-)

Common R (used in model)* = 1.99

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1

	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	2.000		0.79
TCE → DCE	1.000		0.74
DCE → VC	7.500		0.64
VC → ETH	0.600		0.45

Zone 2

	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

5. GENERAL

Simulation Time*	15	(yr)
Modeled Area Width*	110	(ft)
Modeled Area Length*	500	(ft)
Zone 1 Length*	500	(ft)
Zone 2 Length*	0	(ft)

Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar

Source Thickness in Sat. Zone* 15 (ft)

Y1
Width* (ft) 110

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.0	0.175
TCE	.0	0.175
DCE	.46	0.175
VC		0.175
ETH		0.175

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

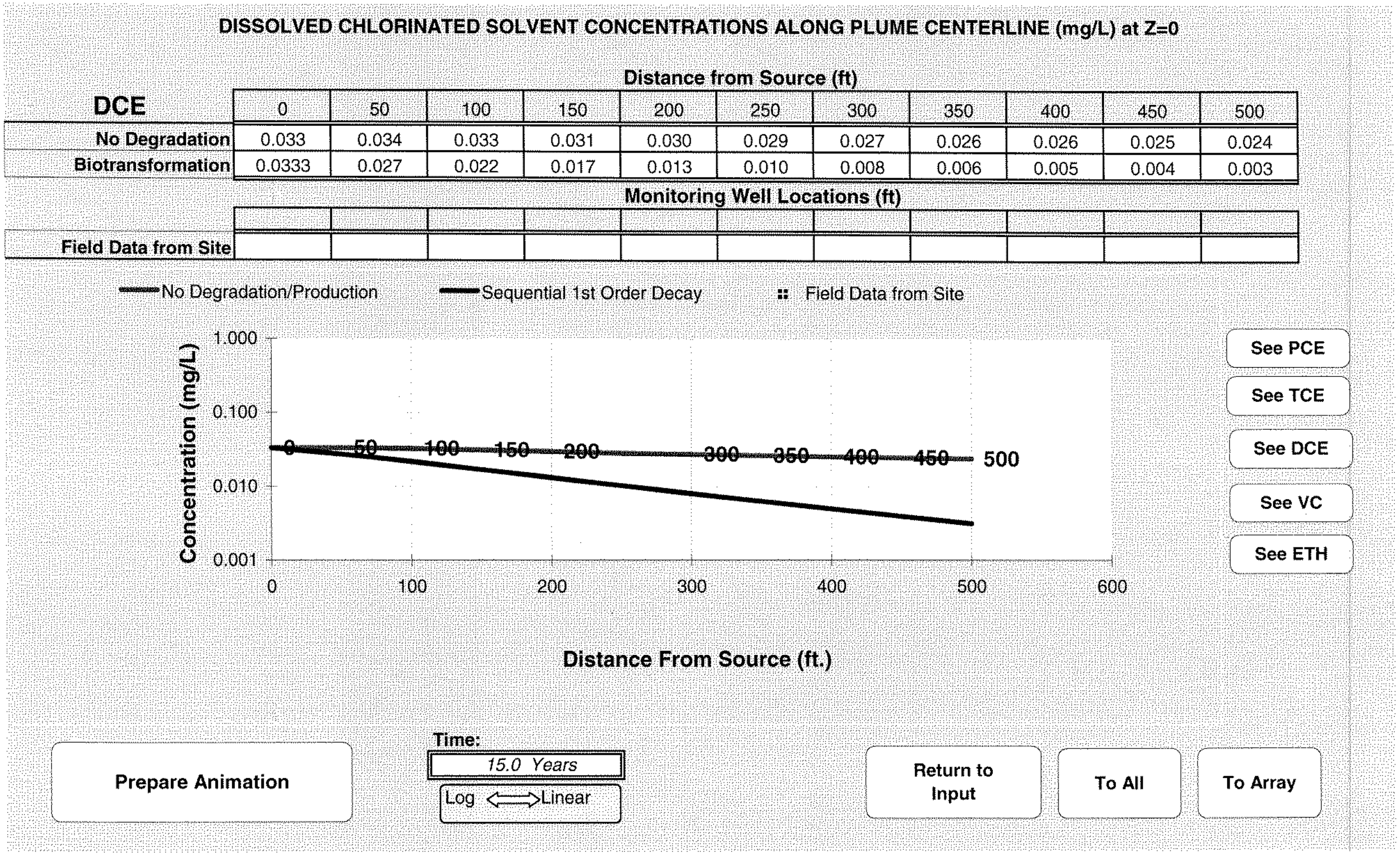
View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)											
TCE Conc. (mg/L)											
DCE Conc. (mg/L)											
VC Conc. (mg/L)											
ETH Conc. (mg/L)											
Distance from Source (ft)											
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

DCE	Distance from Source (ft)										
	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.033	0.034	0.033	0.031	0.030	0.029	0.027	0.026	0.026	0.025	0.024
Biotransformation	0.0333	0.027	0.022	0.017	0.013	0.010	0.008	0.006	0.005	0.004	0.003

	Monitoring Well Locations (ft)										
Field Data from Site											

Time: *15.0 Years*

APPENDIX C

DETAILED COST ESTIMATES

C.1 BASE COSTS

TETRA TECH NUS, INC. **CALCULATION SHEET** **PAGE 1 OF 4**

CLIENT: **NASA Wallops Flight Facility**		JOB NUMBER: **1612 1110**	
SUBJECT: **Former Fire Training Facility**			
BASED ON:		DRAWING NUMBER:	
BY: TJR Date: 11-9-2004	CHECKED BY: Date:	APPROVED BY:	DATE:

Alternative 2: Natural Attenuation, Institutional Controls and Monitoring

Annual Inspection

Assume 1 day to inspect with 2 people

2 people @ $55.00 per hour for 10 hours =	$	1,100
car for one day =	$	100
report @ $55.00 per hour for 4 hours =	$	220
Misc supplies, copying, etc. =	$	150
	$	1,570

Sampling

Labor & Materials, per round

Assume 5 days to sample with 2 people

2 people @ $55.00 per hour for 10 hours per for 5 days =	$	5,500
car for five days =	$	500
report @ $55.00 per hour for 4 hours =	$	220
Misc supplies, copying, etc. =	$	200
	$	6,420

Analytical, per round

Collect 20 water samples from wells and analyze for VOCs, SVOCs, metals

type	cost each	number	total
water VOCs	$ 100	20	$ 2,000
water SVOCs	$ 220	20	$ 4,400
water metals	$ 130	20	$ 2,600
			$ 9,000
		40% QA/QC & Data Validation	$ 3,600
			$ 12,600

Analytical, per round

Collect 20 water samples from wells and analyze for Natural Attenuation

type	cost each	number	total
Natural Attenuation parameters	$ 340	20	$ 6,800
			$ 6,800
		40% QA/QC & Data Validation	$ 2,720
			$ 9,520

5-Year Review

Assume 5-year review includes review of past data

5-year review & report	$	15,000

CLIENT: **NASA Wallops Flight Facility**	JOB NUMBER: **1612 1110**
SUBJECT: **Former Fire Training Facility**	
BASED ON:	DRAWING NUMBER:
BY: TJR Date: 11-9-2004 / CHECKED BY: Date:	APPROVED BY: DATE:

Alternative 3: In-situ Biological Treatment (Biostimulation), Institutional Controls and Monitoring

Capital Cost
Based on J.P. Kumar email of 11-16-04.
3-month Monitoring Event

1. Mob/demob one (1) DPT rig for one day.	$3,000
2. Include technical labor (consultant): $ 30/hr unburdened for 5 days including mob/demob and travel time.	$1,200
3. Include field material costs: $ 500 (tygon tubing, Chemetrics kits, monitoring instruments and peristaltic pump rental)	$500
4. Include perdiem for 2 days	$240
5. Include car rental (2 days) + gas and tolls	$150
	$5,090

Annual Inspection
same as Alternative 2
Sampling
same as Alternative 2
5-Year Review
same as Alternative 2

Alternative 4: In-situ Biological Treatment (Bioaugmentation), Institutional Controls and Monitoring

Capital Cost
Based on cl solutions proposal of 11/14/2004.
Annual Inspection
same as Alternative 2
Sampling
same as Alternative 2
5-Year Review
same as Alternative 2

Alternative 5a: In-situ Air Sparging, Institutional Controls, & Monitoring

Capital Cost
Wells: Install 75 wells to depth of 40'

Depth:	40 ft
Wells:	75
	3,000 lf

Cost to install from D. Brayack (11/04) at $28 per lf, complete.

Piping: Assume 2" & 4" PVC underground
1,350 lf of 2" & 350 lf of 4"
Include steel pipe inside building.

CLIENT: NASA Wallops Flight Facility		JOB NUMBER: 1612 1110	
SUBJECT: Former Fire Training Facility			
BASED ON:		DRAWING NUMBER:	
BY: TJR Date: 11-9-2004	CHECKED BY: Date:	APPROVED BY:	DATE:

O & M Cost

Two blowers @ 84 hp each

84	hp
2	ea
168	hp
1	kW/hp
125	kW
24	hours/day
3,008	kW/day
365	day/year
1,097,873	kW/year

Assume maintenance per year @ 5% of installation cost.

Annual Inspection

same as Alternative 2

Sampling

Labor & Materials, per round

Assume 5 days to sample with 2 people

2 people @ $55.00 per hour for 10 hours per for 5 days =	$	5,500
car for five days =	$	500
report @ $55.00 per hour for 4 hours =	$	220
Misc supplies, copying, etc. =	$	200
	$	6,420

Analytical, per round

Collect 20 water samples from wells and analyze for VOCs, SVOCs, metals

type		cost each	number		total
water VOCs	$	100	20	$	2,000
water SVOCs	$	220	20	$	4,400
water metals	$	130	20	$	2,600
				$	9,000
40% QA/QC & Data Validation				$	3,600
				$	12,600

5-Year Review

Assume 5-year review includes review of past data

5-year review & report	$	15,000

CLIENT: **NASA Wallops Flight Facility**		JOB NUMBER: **1612 1110**	
SUBJECT: **Former Fire Training Facility**			
BASED ON:		DRAWING NUMBER:	
BY: TJR Date: 11-9-2004	CHECKED BY: Date:	APPROVED BY:	DATE:

Alternative 5b: In-situ Air Sparging, Institutional Controls, & Monitoring for Source Area Only

Capital Cost

Wells: Install 16 wells to depth of 40'

Depth: 40 ft
Wells: 16
640 lf

Cost to install from D. Brayack (11/04) at $28 per lf, complete.

Piping: Assume 2" & 4" PVC underground
300 lf of 2" & 75 lf of 4"
Include steel pipe inside building.

O & M Cost

One blower @ 84 hp each

84 hp
1 ea
84 hp
1 kW/hp
63 kW
24 hours/day
1,504 kW/day
365 day/year
548,937 kW/year

Assume maintenance per year @ 5% of installation cost.

Annual Inspection
same as Alternative 5a

Sampling
same as Alternative 5a

5-Year Review
same as Alternative 5a

C.2 ALTERNATIVE 2

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 2: Natural Attenuation, Institutional Controls and Monitoring
CAPITAL COST

Item	Quantity	Unit	Unit Cost				Extended Cost				Subtotal
			Subcontract	Material	Labor	Equipment	Subcontract	Material	Labor	Equipment	
1 PROJECT DOCUMENTS											
1.1 Prepare Land Use Control (LUC)	250	hour			$30.00		$0	$0	$7,500	$0	$7,500
Subtotal							$0	$0	$7,500	$0	$7,500
Local Area Adjustments							100.0%	105.3%	85.8%	85.8%	
							$0	$0	$6,435	$0	$6,435
Overhead on Labor Cost @ 30%									$1,931		$1,931
G & A on Labor Cost @ 10%									$644		$644
G & A on Material Cost @ 10%								$0			$0
G & A on Equipment Cost @ 10%										$0	$0
G & A on Subcontract Cost @ 10%							$0				$0
Total Direct Cost							$0	$0	$9,009	$0	$9,009
Indirects on Total Direct Cost @ 0%											$0
Profit on Total Direct Cost @ 10%											$901
Subtotal											$9,910
Health & Safety Monitoring @ 0%											$0
Total Field Cost											$9,910
Contingency on Total Field Costs @ 10%											$991
Engineering on Total Field Cost @ 0%											$0
TOTAL COST											**$10,901**

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 2: Natural Attenuation, Institutional Controls and Monitoring
ANNUAL COST

Item	Item Cost Year 1	Item Cost Years 2 & 3	Item Cost Years 4 - 10	Item Cost Every 5 Years	Notes
Site Inspection & Report	$1,570	$1,570	$1,570		One-day inspection with 2 people for LUC
Sampling	$25,680	$12,840	$6,420		Labor, Field Supplies (local)
Analysis	$50,400	$25,200	$12,600		Analyze 20 water samples for VOCs, SVOCs, and metals. Quarterly year 1, semi-annually years 2 & 3, annually years 4 to 10.
Analysis	$70,560	$35,280	$17,640		Analyze 20 water samples for natural attenuation. Quarterly year 1, semi-annually years 2 & 3, annually years 4 to 10.
Sampling & Analysis Report	$20,000	$10,000	$5,000		Document sampling events and results
Site Review				$15,000	Perform 5-year review
TOTALS	$168,210	$84,890	$43,230	$15,000	

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 2: Natural Attenuation, Institutional Controls and Monitoring
PRESENT WORTH ANALYSIS

Year	Capital Cost	Annual Cost	Annual Discount Rate at 3.5%	Present Worth
0	$10,901		1.000	$10,901
1		$168,210	0.966	$162,491
2		$84,890	0.934	$79,287
3		$84,890	0.902	$76,571
4		$43,230	0.871	$37,653
5		$58,230	0.842	$49,030
6		$43,230	0.814	$35,189
7		$43,230	0.786	$33,979
8		$43,230	0.759	$32,812
9		$43,230	0.734	$31,731
10		$58,230	0.709	$41,285

TOTAL PRESENT WORTH **$590,928**

C.3 ALTERNATIVE 3

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 3: In-situ Biological Treatment (Biostimulation), Institutional Controls and Monitoring
CAPITAL COST

Item	Quantity	Unit	Unit Cost				Extended Cost				Subtotal
			Subcontract	Material	Labor	Equipment	Subcontract	Material	Labor	Equipment	
1 PROJECT DOCUMENTS/INSTITUTIONAL CONTROLS											
1.1 Prepare Documents & Plans including Permits	150	hr			$30.00		$0	$0	$4,500	$0	$4,500
1.2 Prepare Land Use Control (LUC)	250	hr			$30.00		$0	$0	$7,500	$0	$7,500
2 MOBILIZATION/DEMOBILIZATION AND FIELD SUPPORT											
2.1 Office Trailer	1	mo				$286.00	$0	$0	$0	$286	$286
2.2 Office Trailer Mob/Demo	1	ea				$225.00	$0	$0	$0	$225	$225
2.3 Field Office Support	1	mo		$139.00			$0	$139	$0	$0	$139
2.4 Utility Connection/Disconnection (phone/electric)	1	ls	$1,500.00				$1,500	$0	$0	$0	$1,500
2.5 Site Utilities (phone & electric)	1	mo		$327.00			$0	$327	$0	$0	$327
2.6 Drill Rig Mobilization/Demobilization	1	ls	$3,000.00				$3,000	$0	$0	$0	$3,000
2.7 Professional Oversight (2p * 5 days/week)	3	wk			$1,600.00		$0	$0	$4,800	$0	$4,800
3 DECONTAMINATION											
3.1 Decontamination Services	1	mo		$375.00	$1,200.00	$900.00	$0	$375	$1,200	$900	$2,475
3.2 Pressure Washer	1	mo				$1,100.00	$0	$0	$0	$1,100	$1,100
3.3 Equipment Decon Pad	1	ls		$500.00	$450.00	$155.00	$0	$500	$450	$155	$1,105
3.4 Decon Water	1	kgal		$200.00			$0	$200	$0	$0	$200
3.5 Decon Water Storage Tank, 6,000 gallon	1	mo				$635.00	$635	$0	$0	$635	$1,270
3.6 Clean Water Storage Tank, 4,000 gallon	1	mo				$570.00	$570	$0	$0	$570	$1,140
3.7 Disposal of Decon Waste (liquid & solid)	1	mo	$900.00				$900	$0	$0	$0	$900
4 BIOREMEDIATION											
4.1 Bench-Scale Treatability Study	1	ls	$5,000.00				$5,000	$0	$0	$0	$5,000
4.2 Drill 20 1-inch DPT Points to 25' bgs	500	ft	$28.00				$14,000	$0	$0	$0	$14,000
4.3 ORC Materials	1	ls		$9,500.00			$0	$9,500	$0	$0	$9,500
4.4 Supplier Technical Oversite	1	ls	$2,000.00				$2,000	$0	$0	$0	$2,000
5 SITE RESTORATION											
5.1 Vegetate Disturbed Areas	1	ls		$300.00	$500.00	$200.00	$0	$300	$500	$200	$1,000
Subtotal							$27,605	$11,341	$18,950	$4,071	$61,967
Local Area Adjustments							100.0%	105.3%	85.8%	85.8%	
							$27,605	$11,942	$16,259	$3,493	$59,299
Overhead on Labor Cost @ 30%									$4,878		$4,878
G & A on Labor Cost @ 10%									$1,626		$1,626
G & A on Material Cost @ 10%								$1,194			$1,194
G & A on Equipment Cost @ 10%										$349	$349
G & A on Subcontract Cost @ 10%							$2,761				$2,761
Total Direct Cost							$30,366	$13,136	$22,763	$3,842	$70,107
Indirects on Total Direct Cost @ 35%											$24,537
Profit on Total Direct Cost @ 10%											$7,011
Subtotal											$101,655

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 3: In-situ Biological Treatment (Biostimulation), Institutional Controls and Monitoring
CAPITAL COST

Item	Quantity	Unit	Unit Cost				Extended Cost				Subtotal
			Subcontract	Material	Labor	Equipment	Subcontract	Material	Labor	Equipment	
Health & Safety Monitoring @ 1%											$1,017
Total Field Cost											$102,671
Contingency on Total Field Costs @ 20%											$20,534
Engineering on Total Field Cost @ 10%											$10,267
TOTAL COST											**$133,473**

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 3: In-situ Biological Treatment (Biostimulation), Institutional Controls and Monitoring
ANNUAL COST

Item	Item Cost Year 1	Item Cost Years 2 & 3	Item Cost Years 4 - 10	Item Cost Every 5 Years	Notes
Site Inspection & Report	$1,570	$1,570	$1,570		One-day inspection with 2 people for LUC
3-month Monitoring	$5,090				Monitoring oxygen and carbon dioxide in treatment area 3 months following injection.
Sampling	$25,680	$12,840	$6,420		Labor, Field Supplies (local)
Analysis	$50,400	$25,200	$12,600		Analyze 20 water samples for VOCs, SVOCs, and metals. Quarterly year 1, semi-annually years 2 & 3, annually years 4 to 10.
Analysis	$70,560	$35,280	$17,640		Analyze 20 water samples for natural attenuation. Quarterly year 1, semi-annually years 2 & 3, annually years 4 to 10.
Sampling & Analysis Report	$20,000	$10,000	$5,000		Document sampling events and results
Site Review				$15,000	Perform 5-year review
TOTALS	$173,300	$84,890	$43,230	$15,000	

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 3: In-situ Biological Treatment (Biostimulation), Institutional Controls and Monitorin
PRESENT WORTH ANALYSIS

Year	Capital Cost	Annual Cost	Annual Discount Rate at 3.5%	Present Worth
0	$133,473		1.000	$133,473
1		$173,300	0.966	$167,408
2		$84,890	0.934	$79,287
3		$84,890	0.902	$76,571
4		$43,230	0.871	$37,653
5		$58,230	0.842	$49,030
6		$43,230	0.814	$35,189
7		$43,230	0.786	$33,979
8		$43,230	0.759	$32,812
9		$43,230	0.734	$31,731
10		$58,230	0.709	$41,285

TOTAL PRESENT WORTH **$718,417**

C.4 ALTERNATIVE 4

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 4: In-situ Biological Treatment (Bioaugmentation), Institutional Controls and Monitoring
CAPITAL COST

Item	Quantity	Unit	Unit Cost				Extended Cost				Subtotal
			Subcontract	Material	Labor	Equipment	Subcontract	Material	Labor	Equipment	
1 PROJECT DOCUMENTS/INSTITUTIONAL CONTROLS											
1.1 Prepare Documents & Plans including Permits	150	hr			$30.00		$0	$0	$4,500	$0	$4,500
1.2 Prepare Land Use Control (LUC)	250	hr			$30.00		$0	$0	$7,500	$0	$7,500
2 MOBILIZATION/DEMOBILIZATION AND FIELD SUPPORT											
2.1 Office Trailer	1	mo				$286.00	$0	$0	$0	$286	$286
2.2 Office Trailer Mob/Demo	1	ea				$225.00	$0	$0	$0	$225	$225
2.3 Field Office Support	1	mo		$139.00			$0	$139	$0	$0	$139
2.4 Utility Connection/Disconnection (phone/electric)	1	ls	$1,500.00				$1,500	$0	$0	$0	$1,500
2.5 Site Utilities (phone & electric)	1	mo		$327.00			$0	$327	$0	$0	$327
2.6 Drill Rig Mobilization/Demobilization	1	ls	$3,000.00				$3,000	$0	$0	$0	$3,000
2.7 Professional Oversight (2p * 5 days/week)	4	wk			$1,600.00		$0	$0	$6,400	$0	$6,400
3 DECONTAMINATION											
3.1 Decontamination Services	1	mo		$375.00	$1,200.00	$900.00	$0	$375	$1,200	$900	$2,475
3.2 Pressure Washer	1	mo				$1,100.00	$0	$0	$0	$1,100	$1,100
3.3 Equipment Decon Pad	1	ls		$500.00	$450.00	$155.00	$0	$500	$450	$155	$1,105
3.4 Decon Water	1	kgal		$200.00			$0	$200	$0	$0	$200
3.5 Decon Water Storage Tank, 6,000 gallon	1	mo				$635.00	$635	$0	$0	$635	$1,270
3.6 Clean Water Storage Tank, 4,000 gallon	1	mo				$570.00	$570	$0	$0	$570	$1,140
3.7 Disposal of Decon Waste (liquid & solid)	1	mo	$900.00				$900	$0	$0	$0	$900
4 BIOREMEDIATION											
4.1 Bench-Scale Treatability Study	1	ls	$5,000.00				$5,000	$0	$0	$0	$5,000
4.2 Drill 80 1-inch DPT Points to 25' bgs	2,000	ft	$28.00				$56,000	$0	$0	$0	$56,000
4.3 Biological Materials	76	drum		$1,505.00			$0	$114,380	$0	$0	$114,380
4.4 Supplier Technical Oversite	1	ls	$2,000.00				$2,000	$0	$0	$0	$2,000
5 SITE RESTORATION											
5.1 Vegetate Disturbed Areas	1	ls		$300.00	$500.00	$200.00	$0	$300	$500	$200	$1,000
Subtotal							$69,605	$116,221	$20,550	$4,071	$210,447
Local Area Adjustments							100.0%	105.3%	85.8%	85.8%	
							$69,605	$122,381	$17,632	$3,493	$213,111
Overhead on Labor Cost @ 30%									$5,290		$5,290
G & A on Labor Cost @ 10%									$1,763		$1,763
G & A on Material Cost @ 10%								$12,238			$12,238
G & A on Equipment Cost @ 10%										$349	$349
G & A on Subcontract Cost @ 10%							$6,961				$6,961
Total Direct Cost							$76,566	$134,619	$24,685	$3,842	$239,711
Indirects on Total Direct Cost @ 35%											$83,899
Profit on Total Direct Cost @ 10%											$23,971
Subtotal											$347,581

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 4: In-situ Biological Treatment (Bioaugmentation), Institutional Controls and Monitoring
CAPITAL COST

Item	Quantity	Unit	Unit Cost				Extended Cost				Subtotal
			Subcontract	Material	Labor	Equipment	Subcontract	Material	Labor	Equipment	
Health & Safety Monitoring @	1%										$3,476
Total Field Cost											$351,057
Contingency on Total Field Costs @	20%										$70,211
Engineering on Total Field Cost @	10%										$35,106
TOTAL COST											**$456,374**

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 4: In-situ Biological Treatment (Bioaugmentation), Institutional Controls and Monitoring
ANNUAL COST

Item	Item Cost Year 1	Item Cost Years 2 & 3	Item Cost Years 4 - 10	Item Cost Every 5 Years	Notes
Site Inspection & Report	$1,570	$1,570	$1,570		One-day inspection with 2 people for LUC
Sampling	$25,680	$12,840	$6,420		Labor, Field Supplies (local)
Analysis	$50,400	$25,200	$12,600		Analyze 20 water samples for VOCs, SVOCs, and metals. Quarterly year 1, semi-annually years 2 & 3, annually years 4 to 10.
Analysis	$70,560	$35,280	$17,640		Analyze 20 water samples for natural attenuation. Quarterly year 1, semi-annually years 2 & 3, annually years 4 to 10.
Sampling & Analysis Report	$20,000	$10,000	$5,000		Document sampling events and results
Site Review				$15,000	Perform 5-year review
TOTALS	$168,210	$84,890	$43,230	$15,000	

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 4: In-situ Biological Treatment (Bioaugmentation), Institutional Controls and Monito
PRESENT WORTH ANALYSIS

Year	Capital Cost	Annual Cost	Annual Discount Rate at 3.5%	Present Worth
0	$456,374		1.000	$456,374
1		$168,210	0.966	$162,491
2		$84,890	0.934	$79,287
3		$84,890	0.902	$76,571
4		$43,230	0.871	$37,653
5		$58,230	0.842	$49,030
6		$43,230	0.814	$35,189
7		$43,230	0.786	$33,979
8		$43,230	0.759	$32,812
9		$43,230	0.734	$31,731
10		$58,230	0.709	$41,285

TOTAL PRESENT WORTH **$1,036,401**

C.5 ALTERNATIVE 5

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 5a: In-situ Air Sparging, Institutional Controls and Monitoring
CAPITAL COST

Item	Quantity	Unit	Unit Cost				Extended Cost				Subtotal
			Subcontract	Material	Labor	Equipment	Subcontract	Material	Labor	Equipment	
1 PROJECT PLANNING AND DOCUMENTS											
1.1 Prepare Documents & Plans including Permits	150	hr			$30.00		$0	$0	$4,500	$4,500	$9,000
1.2 Prepare Land Use Control (LUC)	250	hour			$30.00		$0	$0	$7,500	$0	$7,500
2 MOBILIZATION/DEMOBILIZATION AND FIELD SUPPORT											
2.1 Office Trailer	3	mo				$286.00	$0	$0	$0	$858	$858
2.2 Office Trailer Mob/Demo	1	ea				$225.00	$0	$0	$0	$225	$225
2.3 Field Office Support	3	mo		$139.00			$0	$417	$0	$0	$417
2.4 Utility Connection/Disconnection (phone/electric)	1	ls	$1,500.00				$1,500	$0	$0	$0	$1,500
2.5 Site Utilities (phone & electric)	3	mo		$327.00			$0	$981	$0	$0	$981
2.6 Drill Rig Mobilization/Demobilization	1	ls	$3,000.00				$3,000	$0	$0	$0	$3,000
2.7 Mobilization/Demobilization Construction Equipment	2	ea			$141.00	$336.00	$0	$0	$282	$672	$954
2.8 Professional Oversight (2p * 5 days/week)	12	wk			$3,200.00		$0	$0	$38,400	$0	$38,400
3 DECONTAMINATION											
3.1 Decontamination Services	2	mo		$375.00	$1,200.00	$900.00	$0	$750	$2,400	$1,800	$4,950
3.2 Pressure Washer	2	mo				$1,100.00	$0	$0	$0	$2,200	$2,200
3.3 Equipment Decon Pad	1	ls		$500.00	$450.00	$155.00	$0	$500	$450	$155	$1,105
3.4 Decon Water	2	kgal		$200.00			$0	$400	$0	$0	$400
3.5 Decon Water Storage Tank, 6,000 gallon	2	mo				$635.00	$0	$0	$0	$1,270	$1,270
3.6 Clean Water Storage Tank, 4,000 gallon	2	mo				$570.00	$0	$0	$0	$1,140	$1,140
3.7 Disposal of Decon Waste (liquid & solid)	2	mo	$900.00				$1,800	$0	$0	$0	$1,800
4 AIR SPARGING SYSTEM											
4.1 Air Sparging Well Install, 1" PVC, 75 wells, 40' bgs	3,000	lf	$28.00				$84,000	$0	$0	$0	$84,000
4.2 Air Sparging Piping, 2" PVC, Buried	1,350	lf		$1.84	$4.12	$1.64	$0	$2,484	$5,562	$2,214	$10,260
4.3 Air Sparging Piping, 4" PVC, Buried	350	lf		$12.05	$5.86	$1.64	$0	$4,218	$2,051	$574	$6,843
4.4 Air Sparging Piping, steel	1	ls		$800.00	$400.00		$0	$800	$400	$0	$1,200
4.5 Moisture Removal Tank, 500 gal.	1	ea		$2,200.00	$300.00		$0	$2,200	$300	$0	$2,500
4.6 Blower, 84 HP, 450 cfm, 30 psi	2	ea		$11,600.00	$1,114.00		$0	$23,200	$2,228	$0	$25,428
4.7 Electric Service	1	ea		$1,375.00	$1,688.00		$0	$1,375	$1,688	$0	$3,063
4.8 Plumb & Test System	1	ls		$500.00	$8,000.00		$0	$500	$8,000	$0	$8,500
4.9 Treatment System Building	1	ls		$16,000.00	$16,000.00		$0	$16,000	$16,000	$0	$32,000
5 MISCELLANEOUS											
5.1 Post Construction Documents	100	hr			$30.00		$0	$0	$3,000	$0	$3,000
5.2 Vegetate Disturbed Areas	1	ls		$300.00	$500.00	$200.00	$0	$300	$500	$200	$1,000
Subtotal							$90,300	$54,125	$93,261	$15,808	$253,494
Local Area Adjustments							100.0%	105.3%	85.8%	85.8%	
							$90,300	$56,993	$80,018	$13,563	$240,874
Overhead on Labor Cost @ 30%									$24,005		$24,005
G & A on Labor Cost @ 10%									$8,002		$8,002
G & A on Material Cost @ 10%								$5,699			$5,699
G & A on Equipment Cost @ 10%										$1,356	$1,356
G & A on Subcontract Cost @ 10%							$9,030				$9,030
Total Direct Cost							$99,330	$62,692	$112,025	$14,920	$288,967

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 5a: In-situ Air Sparging, Institutional Controls and Monitoring
CAPITAL COST

Item	Quantity	Unit	Unit Cost				Extended Cost				Subtotal
			Subcontract	Material	Labor	Equipment	Subcontract	Material	Labor	Equipment	
Indirects on Total Direct Cost @	35%										$101,138
Profit on Total Direct Cost @	10%										$28,897
Subtotal											$419,002
Health & Safety Monitoring @	2%										$8,380
Total Field Cost											$427,382
Contingency on Total Field Costs @	20%										$85,476
Engineering on Total Field Cost @	7%										$29,917
TOTAL COST											**$542,776**

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 5a: In-situ Air Sparging, Institutional Controls and Monitoring
Operation and Maintenance Costs per Year

	Item	Qty	Unit	Unit Cost	Subtotal Cost	Notes
1	Energy - Electric	1,100,000	kWh	$0.07	$77,000	
2	Maintenance	1	ls	$6,664.68	$6,665	5% of Installation Cost
3	Labor, Per Diem, Supplies	52	day	$350.00	$18,200	1 visit per week - 1 day
4	Semi-Annual Reports	2	ea	$4,000.00	$8,000	
	Subtotal Cost for One Year Operation				$109,865	

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 5a: In-situ Air Sparging, Institutional Controls and Monitoring
ANNUAL COST

Item	Item Cost Year 1	Item Cost Years 2 & 3	Item Cost Years 4 to 10	Item Cost Every 5 Years	Notes
Site Inspection & Report	$1,570	$1,570	$1,570		One-day inspection with 2 people for LUC
Sampling	$25,680	$12,840	$6,420		Labor, Field Supplies (local)
Analysis	$50,400	$25,200	$12,600		Analyze 20 water samples for VOCs, SVOCs, and metals. Quarterly year 1, semi-annually years 2 & 3, annually years 4 to 10.
Sampling & Analysis Report	$20,000	$10,000	$5,000		Document sampling events and results
Site Review				$15,000	Perform 5-year review
TOTALS	$97,650	$49,610	$25,590	$15,000	

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 5a: In-situ Air Sparging, Institutional Controls and Monitoring
PRESENT WORTH ANALYSIS

Year	Capital Cost	Operation and Maintenance	Annual Cost	Annual Discount Rate at 3.5%	Present Worth
0	$542,776			1.000	$542,776
1		$109,865	$97,650	0.966	$204,195
2		$109,865	$49,610	0.934	$156,200
3			$49,610	0.902	$44,748
4			$25,590	0.871	$22,289
5			$40,590	0.842	$34,177
6			$25,590	0.814	$20,830
7			$25,590	0.786	$20,114
8			$25,590	0.759	$19,423
9			$25,590	0.734	$18,783
10			$40,590	0.709	$28,778

TOTAL PRESENT WORTH **$1,112,313**

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 5b: In-situ Air Sparging, Institutional Controls and Monitoring for Source Area Only
CAPITAL COST

Item	Quantity	Unit	Unit Cost				Extended Cost				Subtotal
			Subcontract	Material	Labor	Equipment	Subcontract	Material	Labor	Equipment	
1 PROJECT PLANNING AND DOCUMENTS											
1.1 Prepare Documents & Plans including Permits	150	hr			$30.00		$0	$0	$4,500	$4,500	$9,000
1.2 Prepare Land Use Control (LUC)	250	hour			$30.00		$0	$0	$7,500	$0	$7,500
2 MOBILIZATION/DEMOBILIZATION AND FIELD SUPPORT											
2.1 Office Trailer	2	mo				$286.00	$0	$0	$0	$572	$572
2.2 Office Trailer Mob/Demo	1	ea				$225.00	$0	$0	$0	$225	$225
2.3 Field Office Support	2	mo		$139.00			$0	$278	$0	$0	$278
2.4 Utility Connection/Disconnection (phone/electric)	1	ls	$1,500.00				$1,500	$0	$0	$0	$1,500
2.5 Site Utilities (phone & electric)	2	mo		$327.00			$0	$654	$0	$0	$654
2.6 Drill Rig Mobilization/Demobilization	1	ls	$3,000.00				$3,000	$0	$0	$0	$3,000
2.7 Mobilization/Demobilization Construction Equipment	2	ea			$141.00	$336.00	$0	$0	$282	$672	$954
2.8 Professional Oversight (2p * 5 days/week)	8	wk			$3,200.00		$0	$0	$25,600	$0	$25,600
3 DECONTAMINATION											
3.1 Decontamination Services	2	mo		$375.00	$1,200.00	$900.00	$0	$750	$2,400	$1,800	$4,950
3.2 Pressure Washer	2	mo				$1,100.00	$0	$0	$0	$2,200	$2,200
3.3 Equipment Decon Pad	1	ls		$500.00	$450.00	$155.00	$0	$500	$450	$155	$1,105
3.4 Decon Water	2	kgal		$200.00			$0	$400	$0	$0	$400
3.5 Decon Water Storage Tank, 6,000 gallon	2	mo				$635.00	$0	$0	$0	$1,270	$1,270
3.6 Clean Water Storage Tank, 4,000 gallon	2	mo				$570.00	$0	$0	$0	$1,140	$1,140
3.7 Disposal of Decon Waste (liquid & solid)	2	mo	$900.00				$1,800	$0	$0	$0	$1,800
4 AIR SPARGING SYSTEM											
4.1 Air Sparging Well Install, 1" PVC, 75 wells, 40' bgs	640	lf	$28.00				$17,920	$0	$0	$0	$17,920
4.2 Air Sparging Piping, 2" PVC, Buried	300	lf		$1.84	$4.12	$1.64	$0	$552	$1,236	$492	$2,280
4.3 Air Sparging Piping, 4" PVC, Buried	75	lf		$12.05	$5.86	$1.64	$0	$904	$440	$123	$1,466
4.4 Air Sparging Piping, steel	1	ls		$800.00	$400.00		$0	$800	$400	$0	$1,200
4.5 Moisture Removal Tank, 500 gal.	1	ea		$2,200.00	$300.00		$0	$2,200	$300	$0	$2,500
4.6 Blower, 84 HP, 450 cfm, 30 psi	1	ea		$11,600.00	$1,114.00		$0	$11,600	$1,114	$0	$12,714
4.7 Electric Service	1	ea		$1,375.00	$1,688.00		$0	$1,375	$1,688	$0	$3,063
4.8 Plumb & Test System	1	ls		$500.00	$8,000.00		$0	$500	$8,000	$0	$8,500
4.9 Treatment System Building	1	ls		$16,000.00	$16,000.00		$0	$16,000	$16,000	$0	$32,000
5 MISCELLANEOUS											
5.1 Post Construction Documents	100	hr			$30.00		$0	$0	$3,000	$0	$3,000
5.2 Vegetate Disturbed Areas	1	ls		$300.00	$500.00	$200.00	$0	$300	$500	$200	$1,000
Subtotal							$24,220	$36,813	$73,410	$13,349	$147,791
Local Area Adjustments							100.0%	105.3%	85.8%	85.8%	
							$24,220	$38,764	$62,985	$11,453	$137,423
Overhead on Labor Cost @ 30%									$18,896		$18,896
G & A on Labor Cost @ 10%									$6,299		$6,299
G & A on Material Cost @ 10%								$3,876			$3,876
G & A on Equipment Cost @ 10%										$1,145	$1,145
G & A on Subcontract Cost @ 10%							$2,422				$2,422
Total Direct Cost							$26,642	$42,640	$88,179	$12,599	$170,060

NASA WALLOP FLIGHT FACILITY
Wallops Island, Virginia
Former Fire Training Area
Alternative 5b: In-situ Air Sparging, Institutional Controls and Monitoring for Source Area Only
CAPITAL COST

Item	Quantity	Unit	Unit Cost				Extended Cost				Subtotal
			Subcontract	Material	Labor	Equipment	Subcontract	Material	Labor	Equipment	
Indirects on Total Direct Cost @	35%										$59,521
Profit on Total Direct Cost @	10%										$17,006
Subtotal											$246,588
Health & Safety Monitoring @	2%										$4,932
Total Field Cost											$251,519
Contingency on Total Field Costs @	20%										$50,304
Engineering on Total Field Cost @	10%										$25,152
TOTAL COST											**$326,975**

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Operation and Maintenance Costs per Year

	Item	Qty	Unit	Unit Cost	Subtotal Cost	Notes
1	Energy - Electric	550,000	kWh	$0.07	$38,500	
2	Maintenance	1	ls	$2,057.16	$2,057	5% of Installation Cost
3	Labor, Per Diem, Supplies	52	day	$350.00	$18,200	1 visit per week - 1 day
4	Semi-Annual Reports	2	ea	$4,000.00	$8,000	
	Subtotal Cost for One Year Operation				$66,757	

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ANNUAL COST

Item	Item Cost Year 1	Item Cost Years 2 & 3	Item Cost Years 4-10	Item Cost Every 5 Years	Notes
Site Inspection & Report	$1,570	$1,570	$1,570		One-day inspection with 2 people for LUC
Sampling	$25,680	$12,840	$6,420		Labor, Field Supplies (local)
Analysis	$50,400	$25,200	$12,600		Analyze 20 water samples for VOCs, SVOCs, and metals. Quarterly year 1, semi-annually years 2 & 3, annually years 4 to 10.
Sampling & Analysis Report	$20,000	$10,000	$5,000		Document sampling events and results
Site Review				$15,000	Perform 5-year review
TOTALS	$97,650	$49,610	$25,590	$15,000	

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PRESENT WORTH ANALYSIS

Year	Capital Cost	Operation and Maintenance	Annual Cost	Annual Discount Rate at 3.5%	Present Worth
0	$326,975			1.000	$326,975
1		$66,757	$97,650	0.966	$161,087
2		$66,757	$49,610	0.934	$113,093
3			$49,610	0.902	$44,748
4			$25,590	0.871	$22,289
5			$40,590	0.842	$34,177
6			$25,590	0.814	$20,830
7			$25,590	0.786	$20,114
8			$25,590	0.759	$19,423
9			$25,590	0.734	$18,783
10			$40,590	0.709	$28,778

TOTAL PRESENT WORTH **$810,297**