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CORRECTIVE MEASURES STUDY FOR SOLID WASTE MANAGEMENT UNIT 9 BOCA  
CHICA JET ENGINE TEST CELL NAS KEY WEST FL  
10/1/1999  
TETRA TECH NUS

**Corrective Measures Study**  
for  
**Solid Waste Management Unit 9**  
**(SWMU 9)**  
**Boca Chica Jet Engine Test Cell**

**Naval Air Station**  
**Key West, Florida**



**Southern Division**  
**Naval Facilities Engineering Command**

**Contract Number N62467-94-D-0888**

**Contract Task Order 0007**

October 1999

*Revision 2*

CORRECTIVE MEASURES STUDY  
FOR  
SOLID WASTE MANAGEMENT UNIT 9  
(SWMU 9)  
BOCA CHICA JET ENGINE TEST CELL

NAVAL AIR STATION  
KEY WEST, FLORIDA

COMPREHENSIVE LONG-TERM  
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

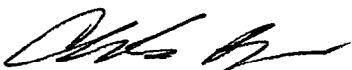
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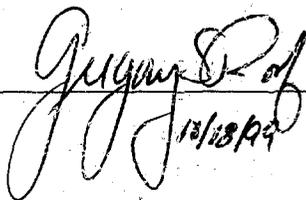
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## EXECUTIVE SUMMARY

This Corrective Measures Study (CMS) for Solid Waste Management Unit (SWMU) 9, Boca Chica Jet Engine Test Cell, at the Naval Air Station (NAS) located in Key West, Florida has been prepared for the Southern Division, Naval Facilities Engineering Command (NAVFACENGCOM). This work has been authorized under Contract Task Order No. 0007 under Contract N62467-94-D-0888.

### SITE DESCRIPTION

SWMU 9 consists of the Jet Engine Test Cell site associated with Building A-969, which was used for testing of recently repaired jet engines. Jet engine testing activities were performed under a canopy in the middle of a circular concrete pad. From 1987 through 1995, the jet engines were fueled from a bermed, 5,000-gallon aboveground storage tank (AST) containing JP-5 fuel.

In January, 1989, a filter fuel system leak resulted in the release of approximately 700 gallons of JP-5 fuel on the west side of the AST. Approximately 600 gallons of the spilled fuel were recovered from puddles by pumping free product during initial remediation activities. The observed maximum depth of soil contamination was two inches. Approximately 10 cubic yards (cy) of contaminated soil were excavated and removed from the spill site, which underwent weathering treatment for decontamination in accordance with the State of Florida guidelines for petroleum-contaminated soils. Furthermore, an overturned lubrication oil drum and stained soil in a small area adjacent to the northwest edge of the circular pad were observed during a November 1992 site investigation (ABB, 1994). Groundwater contamination has been an issue at SWMU 9 since investigations began in 1985. Chlorinated solvents are the predominant contaminants in groundwater at SWMU 9 most likely due to cleaning solvents used on the site.

### PURPOSE

The purpose of this CMS is to identify corrective action objectives (CAOs), identify and screen corrective measure technologies, develop corrective measure alternatives, evaluate corrective measure alternatives, and justify and recommend a final corrective action for groundwater contamination at SWMU 9. The classes of chemicals of concern (COCs) addressed in this CMS report consist of volatile organic compounds (VOCs) in groundwater.

### CORRECTIVE ACTION OBJECTIVES

Site-specific CAOs specify COCs, media of interest, exposure pathways, and clean-up goals or acceptable contaminant concentrations. CAOs may be developed to permit consideration of a range

of treatment and containment alternatives. This CMS addresses groundwater contamination within SWMU 9. To protect the public from potential and current future health risks, as well as to protect the environment, the following CAOs have been developed for SWMU 9 soil and groundwater to address the primary exposure pathways.

- Prevent the migration of groundwater contaminants to an adjacent lagoon (surface water and sediment) to protect ecological receptors.
- Compliance at SWMU 9 with contaminant-specific, location-specific, and action-specific Federal and State Applicable or Relevant and Appropriate Requirements (ARARs).

### **CORRECTIVE MEASURE ALTERNATIVE DEVELOPMENT**

Alternatives were developed to evaluate corrective measures for groundwater that address the COCs and exposure pathways in order to achieve the CAOs. Alternatives range from no action to those that address all contaminants that could affect ecological receptors. The alternatives that were assembled are briefly described below.

#### **SWMU 9 Alternatives**

Alternative 1 – No Action: The No Action alternative is a general response action wherein the status quo is maintained at the site. This alternative is retained to provide a baseline for comparison to other alternatives and, therefore, does not address the remaining groundwater contamination.

Alternative 2 – Natural Attenuation with Long-Term Monitoring: This alternative consists of two major components: (1) allowing natural attenuation processes to remediate the contaminated groundwater at the site and (2) monitoring the contaminant levels and natural attenuation parameters at the site by sampling groundwater (quarterly for the first year, and annually for the next nineteen years). The sampling would be performed based on state and Federal regulations. A reevaluation of the site would be performed every 5 years to determine if any changes to the controls would be required. Groundwater monitoring would include sampling and analysis for VOCs and the following natural attenuation parameters: dissolved oxygen (DO), carbon dioxide, sulfate, sulfide, and oxidation reduction potential.

Alternative 3 – Enhanced Bioremediation with Long-Term Monitoring: This alternative consists of three major components: (1) adding Oxygen Releasing Compound (ORC) downgradient from the highest contaminant levels to form an ORC barrier, (2) adding Hydrogen Releasing Compound (HRC) at the center of the plume, and (3) monitoring the contaminant levels and natural attenuation

parameters at the site by sampling groundwater (quarterly for the first year, semi-annually for the second year, and annually for the next three years). The sampling would be performed based on the state and Federal regulations. A reevaluation of the site would be performed after 5 years to determine if any additional treatment is required. Groundwater monitoring would include sampling and analysis for VOCs and the following natural attenuation parameters: DO, carbon dioxide, sulfate, methane, sulfide, oxidation reduction potential, alkalinity, and chloride.

### EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

Each alternative was evaluated using the nine criteria specified in the Guidance for RCRA Corrective Action Plan (OSWER Directive 9902.3-2A, USEPA, May, 1994). These criteria include Protection of Human Health and the Environment; Media Clean-up Standards; Source Control; Waste Management Standards; Long-Term Reliability and Effectiveness; Reduction in Toxicity, Mobility, or Volume Through Treatment; Short-Term Effectiveness; Implementability; and Cost. Section 5.0 of this report presents the results of this evaluation process.

A comparative analysis of each alternative was completed. This comparative analysis was performed with respect to specific factors for each of the nine above-mentioned criteria and differences among the alternatives were identified. The results of this analysis are presented in Section 5.0. The estimated costs for each alternative follow.

Alternative	Capital (\$)	Operating (\$/year)	Present Worth (\$)
1	0	0	0
2	0	15,000-58,500	236,403
3	51,000	15,500-60,500	183,982

The costs are itemized in the detailed cost sheets presented in Appendix D. With the exception of No Action, Alternative 3 is the most cost effective technology. Alternative 3 is also the most protective of human health and the environment and offers source control. All alternatives are readily implementable and Alternatives 2 and 3 will be effective in the short- and long-term.

It should also be noted that, to date, the Navy has spent approximately 7.9 million dollars on Interim Remedial Actions (IRAs) at nine sites/SWMUs/Areas of Concern at NAS Key West. SWMU 9 was one of the SWMUs where an IRA was performed.

The recommended alternative for SWMU 9 is Alternative 3 – Enhanced Bioremediation with Long-Term Monitoring. This alternative would treat contamination in groundwater and perform groundwater monitoring to determine the effectiveness of the alternative. If the alternative is not found to be

protective of the environment, then another alternative should be considered. However, Alternative 3 is the most aggressive alternative being considered in this CMS and is expected to effectively treat groundwater contamination.

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## LIST OF ACRONYMS

ABB	ABB Environmental Services, Inc.
ABSEFF	Absorption Efficiency
ARAR	Applicable or Relevant and Appropriate Requirement
AST	Above-ground Storage Tank
AWQC	Ambient Water Quality Criteria
B&R Environmental	Brown and Root Environmental
BDAT	Best Demonstrated Available Technology
BEI	Bechtel Environmental, Inc.
bls	below land surface
BRAC	Base Realignment and Closure
BTAG	Biological Technical Assistance Group
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
BTV	Benchmark Toxicity Value
CAMP	Corrective Action Management Plan
CAO	Corrective Action Objective
CAP	Corrective Action Program
CAR	Contamination Assessment Report
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action, Navy
CMS	Corrective Measures Study
COC	Chemical of Concern
COPC	Chemical of Potential Concern
CWA	Clean Water Act
cy	cubic yard
DCE	Dichloroethene
DDT	Dichlorodiphenyl Trichloroethane
DO	Dissolved Oxygen
DOD	Department of Defense
DOT	Department of Transportation
DPT	Direct Push Technology
ECC	Ecological Chemical of Concern
Eh	groundwater
ERA	Ecological Risk Assessment
ERNA	Environmental Restoration Navy Account
FAC	Florida Administrative Code

FDEP	Florida Department of Environmental Protection
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
HRC	Hydrogen Releasing Compound
HSWA	Hazardous and Solid Waste Amendments
ICR	Incremental Cancer Risk
IDW	investigation – derived waste
IEUBK	Integrated Exposure and Uptake Biokinetic
IRA	Interim Remedial Action
IRP	Installation Restoration Program
IT	IT Corporation
LDR	Land Disposal Restriction
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
µg	microgram
µg/dL	microgram per deciliter
µg/L	microgram per liter
mg	milligram
mg/L	milligram per liter
msl	mean sea level
mS/cm	microsiemens per centimeter
NAAQS	National Ambient Air Quality Standards
NACIP	Naval Assessment and Control of Installation Pollutants Program
NAS	Naval Air Station
NAVFACENGCOM	Naval Facilities Engineering Command
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NESHAP	Nation Emission Standards for Hazardous Air Pollutants
nM/L	nanomole per liter
NPDES	National Pollution Discharge Elimination System
NSPS	New Source Performance Standards
O&M	Operation and Maintenance
ORC	Oxygen Releasing Compound
ORP	oxidation – reduction potential
OSHA	Occupational Safety and Health Administration
OVA	Organic Vapor Analyzer

PCE	tetrachloroethene
PPE	personal protective equipment
ppm	parts per million
ppt	parts per thousand
QA	Quality Assurance
QC	Quality Control
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RGO	Remedial Goal Option
RI	Remedial Investigation
SAL	Screening Action Level
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SI	Site Inspection
SIP	State Implementation Plan
SMCL	Secondary Maximum Contaminant Level
SPT	Standard Penetration Test
SVOC	Semi-Volatile Organic Compound
SWMU	Solid Waste Management Unit
TBC	To Be Considered
TCE	trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
TEAP	Terminal Electron – Accepting Process
TOC	total organic compounds
TSDF	Treatment, Storage, and Disposal Facility
TtNUS	Tetra Tech NUS
USC	United States Code
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	Volatile Organic Compound

## 1.0 INTRODUCTION

Tetra Tech NUS (TtNUS) conducted a CMS of SWMU 9, Boca Chica Jet Engine Test Cell, Building A-969, NAS Key West under Contract Number N62467-94-D-0888, Contract Task Order 0007, for the U.S. Navy, NAVFACENGCOM-Southern Division. This CMS was based on the results of previous investigations listed below.

Investigation	Date	Regulatory Driver
Initial Assessment Study performed by Envirodyne Engineers	1985*	Naval Assessment and Control of Installation Pollutants Program (NACIP)
Verification Study performed by Geraghty and Miller	1987*	NACIP
Visual Site Inspection conducted by the United States Environmental Protection Agency (USEPA)	1988*	Resource Conservation and Recovery Act (RCRA)
Preliminary Remedial Investigation (RI) conducted by IT Corporation	1991	Comprehensive Environmental Response Compensation and Liability Act (CERCLA)
RCRA Facility Investigation/Remedial Investigation (RFI/RI) conducted by IT Corporation	1994	RCRA/CERCLA
Contamination Assessment Report Jet Engine Test Cell, Building A969 conducted by ABB Environmental Services, Inc. (ABB)	1994	RCRA/CERCLA
Groundwater Evaluation at SWMU 9 conducted by Bechtel Environmental, Inc. (BEI)	1995	RCRA/CERCLA
Supplemental RFI/RI conducted by B&R Environmental	1997	RCRA/CERCLA
Natural Attenuation Study Results for Solid Waste Management Unit 9 (TtNUS)	1999	RCRA

\* Prior to January 1989 spill of JP-5 fuel

### 1.1 PURPOSE

The purpose of this CMS is to identify CAOs, identify and screen corrective measure technologies, develop corrective measure alternatives, evaluate corrective measure alternatives, and justify and recommend a final corrective action for contamination within SWMU 9.

## **1.2 REPORT ORGANIZATION**

Section 1.0 of this report provides a brief description of the background and purpose of the CMS conducted for SWMU 9, Boca Chica Jet Engine Test Cell, Building A-969, NAS Key West. Section 2.0 presents the Description of Current Conditions, including a discussion on the nature and extent of contamination, site conditions, and IRAs. The CAOs for SWMU 9 are described in Section 3.0. Section 4.0 describes the identification, screening, and development of corrective measure alternatives. Section 5.0 presents the detailed evaluation of the corrective measure alternatives. Section 6.0 provides a comparative analysis of the corrective action alternatives and provides the recommendation for the final corrective measures.

## **1.3 BACKGROUND**

RCRA Corrective Action, as mandated by the Hazardous and Solid Waste Amendments (HSWA), is a process by which a hazardous waste treatment, storage, and disposal facility (TSDF)/SWMU is investigated and remediated, where necessary, to address routine and systematic releases of hazardous waste or hazardous waste constituents at the facility. RCRA corrective action is generally required for the TSDF/SWMU as part of the Part B permit activities conducted by authorized states or the EPA, or through enforcement actions [i.e., RCRA Section 3008(h) orders] by the USEPA. The Corrective Action Program (CAP) assists the USEPA in developing Corrective Action Orders [3008(h)] and Corrective Action requirements in permit applications and permits [3004(u)&(v)]. The objective of a CAP at a TSDF/SWMU is to evaluate the nature and extent of the release of hazardous waste or constituents; to evaluate facility characteristics; and to identify, develop, and implement the appropriate corrective measure or measures adequate to protect human health and the environment.

The CAP involves three distinct steps: RCRA Facility Investigation (RFI); CMS; and Corrective Measures Implementation. The objective of an RFI is to evaluate thoroughly the nature and extent of the release of hazardous waste and hazardous constituents and to gather necessary data to support the CMS. The objective of a CMS is to develop and evaluate a corrective measure alternative or alternatives and to recommend the final corrective measure or measures. The objective of the Corrective Measures Implementation is to design, construct, operate, maintain, and monitor the performance of the corrective measure or measures selected.

In addition to RCRA/HSWA sites at the base, there are several Installation Restoration Program (IRP) sites at NAS Key West. Clean-up activities for an IRP site are implemented in accordance with the National Contingency Plan (NCP) and CERCLA as amended by the Superfund Amendments and Reauthorization Act (SARA). CERCLA establishes the approach to address and clean up hazardous

waste sites at both private and Federal facilities. Remedial Investigations (RIs) are conducted under CERCLA to determine the nature and extent of releases or potential releases from specific sites.

A contamination assessment study was performed from October 1993 through February 1994 (ABB, 1994) and delineation sampling took place from January through September 1995 (BEI, 1995a). In 1993, sampling was performed at all SWMUs and IRP sites as part of the first full RFI/RI sampling program (IT, 1994). The RFI/RI Report recommended remedial actions to remove impacted soil at several sites. The Supplemental RFI/RI (IT, 1994) was conducted in accordance with HSWA Permit No. FL6-170-022-952 issued by the USEPA.

In January 1996, Brown and Root (B&R) Environmental implemented the Supplemental RFI/RI Sampling and Analysis Plan (SAP) in accordance with the regulatory-approved planning documents (ABB, 1995b) at SWMU 9. The RFI/RI sample results were used for chemical and toxicological analyses to determine risks to human health and ecological receptors. A limited validation effort was performed for the analytical data collected by B&R Environmental. The data provided in the RFI/RI (IT, 1994) were also used to assess risks. In July 1996, a groundwater pump and treat system was installed at SWMU 9 to provide recovery and treatment of the groundwater impacted by chlorinated solvents (BEI, 1996). The groundwater pump and treat system design included extraction wells, pumps, a header system to convey extracted groundwater from the wells to the treatment unit, a groundwater treatment unit, and an infiltration gallery (BEI, 1996). Samples of the influent and effluent were collected weekly for the first month of operation and monthly thereafter. One objective of the SWMU 9 system was to capture the free product that is present. The system maintained hydraulic control of the site during operation, but did not recover any free product (BEI, 1998). In June 1997, the Key West Tier I Partnering Team reviewed the results for the performance of the SWMU 9 treatment system and agreed that operation should cease (BEI, 1998).

In May 1998, TtNUS began natural attenuation evaluation sampling at SWMU 9. VOC samples were collected from selected monitoring wells during this sampling event. A second sampling event was conducted in November 1998 to determine the general pattern of groundwater contamination. Natural attenuation parameters were also sampled for during these sampling events to determine the type of biodegradation taking place at the site. This natural attenuation evaluation was performed to determine if natural attenuation should be considered as an alternative in the CMS. The Natural Attenuation Study Results for SWMU 9 (TtNUS, 1999b) included as Appendix B concluded that natural attenuation is a viable alternative for groundwater at SWMU 9.

## 1.4 INSTALLATION DESCRIPTION

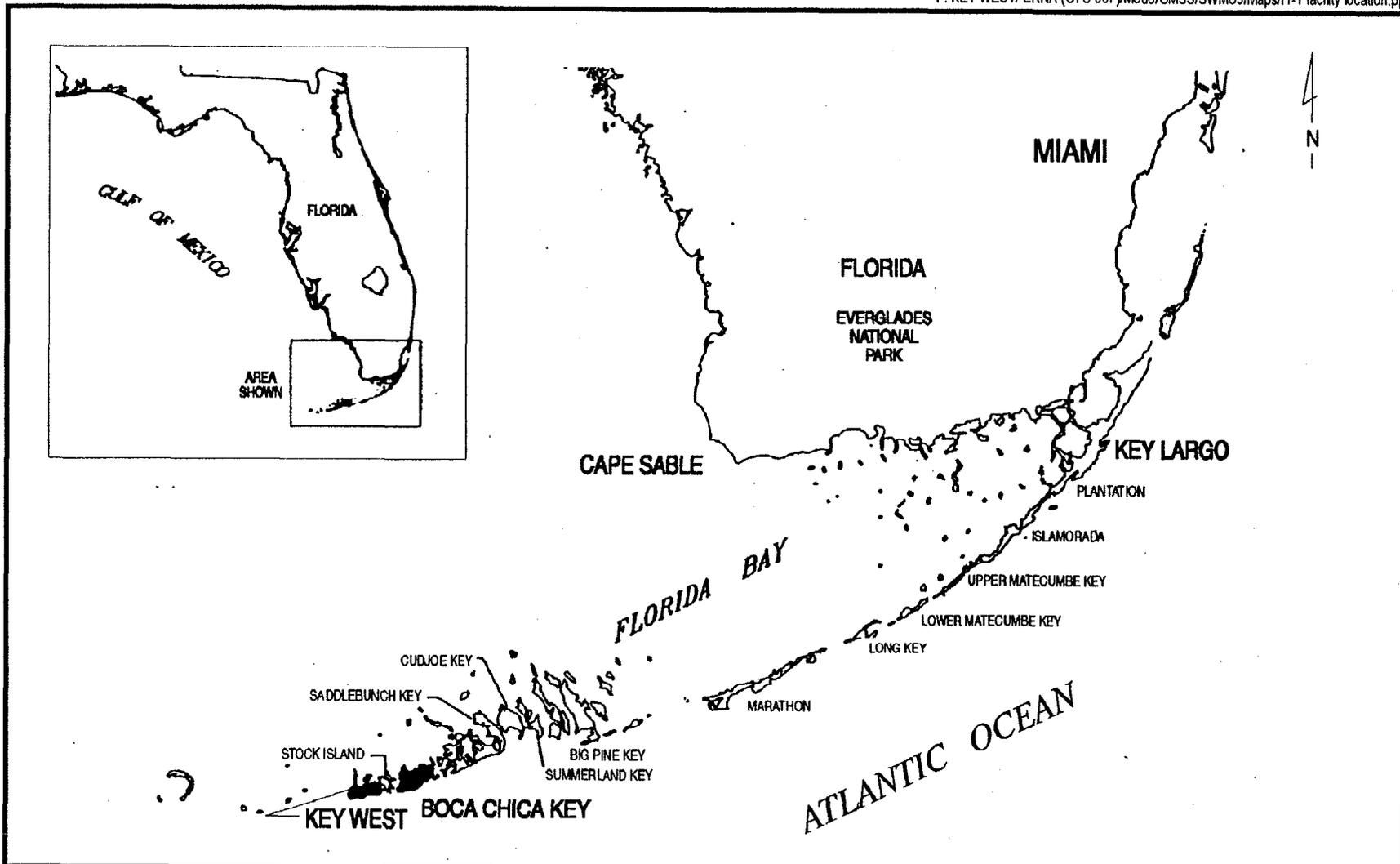
NAS Key West is in southern Monroe County, Florida, on Boca Chica Key, which is located approximately 5 miles east of Key West. Key West and Boca Chica Key, the two westernmost major islands of the Florida Keys, are approximately 150 miles southwest of Miami. The Overseas Highway (U.S. Highway No. 1) connects Key West and Boca Chica Key to the mainland. Figure 1-1 presents a regional map showing the location of Boca Chica Key and Key West within the Florida Keys. Figure 1-2 presents the location of SWMU 9. Several installations in various parts of the lower Florida Keys comprise what is known as the Naval Complex at Key West. Most of these are on Key West and Boca Chica Key. Other parts of the complex include Trumbo Point, Sigsbee Key (formerly Dredgers Key), Fleming Key, Demolition Key, Truman Annex on Key West, and Big Coppitt Key. The entire complex encompasses approximately 5,000 acres. Boca Chica Key is approximately 3 miles wide and 3 miles long; and the air station encompasses 3,250 acres. With the exception of filled areas that underlie the Overseas Highway, the elevations of Boca Chica Key are less than 5 feet above mean sea level (msl) (IT Corporation, 1994).

At present, NAS Key West maintains several aviation operations, a research laboratory, communications intelligence, counternarcotics air surveillance operations, a weather service, and several other related activities. In addition to the Naval activities and units, other Department of Defense (DOD) and Federal agencies at NAS Key West include the U.S. Air Force, the U.S. Army, and the U.S. Coast Guard.

Key West is approximately 4 miles long and 1.5 miles wide. The City of Key West, which is the county seat of Monroe County, has a residential population of 24,832 (USCBS, 1990). The principal industry is tourism, with about 1,500,000 tourists visiting annually. The major sources of employment in Key West are tourism; fishing; wholesale and retail trade; services; construction; finance; insurance; real estate; Federal, state, and local government; and transportation industries.

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1-5



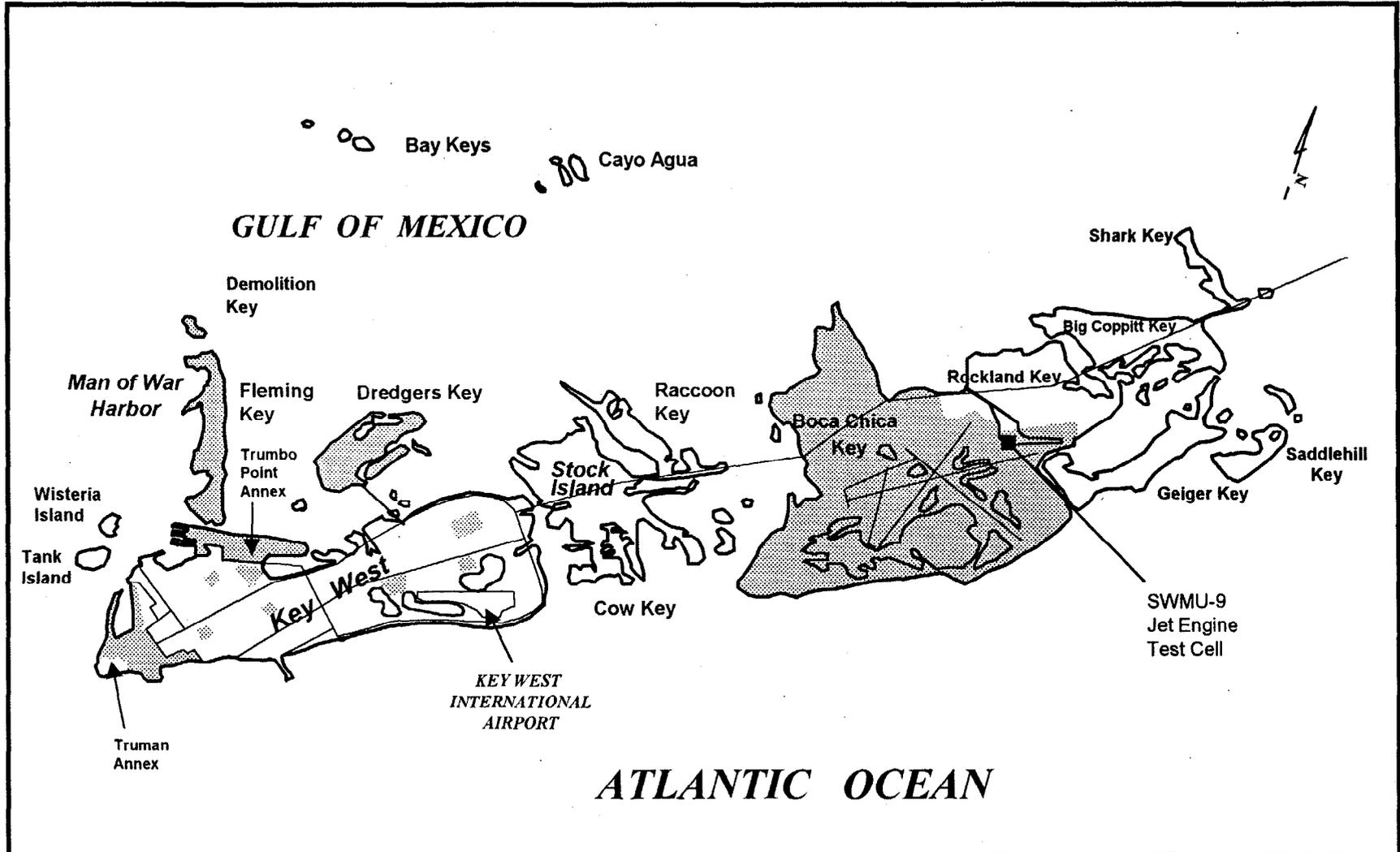
DRAWN BY MDB CHECKED BY COST/SCHED-AREA SCALE N.T.S.	DATE 11/12/98 DATE DATE DATE	 <p style="text-align: center;">                     CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9                      FIGURE 1-1. FACILITY LOCATION MAP                      NAVAL AIR STATION KEY WEST                      NAVY SOUTHERN DIVISION                      NAS KEY WEST, FLORIDA                 </p>	CONTRACT NO. 7593	
			APPROVED BY APPROVED BY	DATE DATE
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DRAWN BY RBP CHECKED BY COSTS/CHED-AREA SCALE AS NOTED	DATE ---- DATE DATE DATE DATE		CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9 FIGURE 1-2. SWMU 9 SITE LOCATION NAVY SOUTHERN DIVISION BOCA CHICA KEY, FLORIDA	CONTRACT NO. 7593	APPROVED BY _____ DATE _____
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## 2.0

## DESCRIPTION OF CURRENT CONDITIONS

### 2.1

### SITE DESCRIPTION

SWMU 9, the Jet Engine Test Cell site associated with Building A-969, is in the northernmost portion of the Boca Chica Key airfield as shown in Figure 2-1. Beginning in 1969, the site was used for the testing of recently repaired jet engines. No other activities were conducted near the site. Jet engine testing activities were performed under a canopy in the middle of a circular concrete pad approximately 60 feet in diameter in the central part of the site. Jet blast deflectors are located at the ends of two concrete pads (100 feet and 80 feet long, respectively) that connect with the north and northeast portion of the circular concrete pad. The jet engines were fueled from a bermed, 5,000-gallon AST containing JP-5 fuel that was used from 1987 through 1995. Building A-969 is 50 feet southeast of the testing area. The concrete area that extends east of the canopy was the former jet engine testing area. A small shed at the eastern end of the concrete pad was used for storage of various equipment, oils, and jet fuel. Gas path cleaners were also stored on the eastern side of the shed. An asphalt parking area extends from these structures to the asphalt road. In addition, a switch house, air tanks, voltage box, and the 5,000-gallon AST for JP-5 fuel are adjacent to the southwestern edge of the circular pad. A strip of mowed grass approximately 30 feet wide surrounds the east and west ends of the site. A narrow strip of red mangroves is located along the shoreline north of the site.

In January 1989, a filter fuel system leak resulted in the release of approximately 700 gallons of JP-5 fuel on the west side of the AST. Approximately 600 gallons of the spilled fuel were recovered from puddles by pumping free product during initial remediation activities. The observed maximum depth of soil contamination was two inches. About 10 cubic yards (cy) of contaminated soil were excavated and removed from the spill site, which underwent weathering treatment for decontamination in accordance with State of Florida guidelines for petroleum-contaminated soils. Furthermore, an overturned lubrication oil drum and stained soil in a small area adjacent to the northwest edge of the circular pad were observed by ABB in November 1992 (ABB, 1994).

The site is bordered to the south by an asphalt road that parallels a runway and to the east and west by grassy areas. The entire area is flat, open, and covered with grass where unpaved. A lagoon that opens to the Florida Bay is located north of the site, approximately 250 feet from the former location of the canopy.

## 2.2 SITE GEOLOGY AND HYDROGEOLOGY

The site-specific geology and hydrogeology of SWMU 9 were determined from soil borings and monitoring wells installed during the contamination assessment study (ABB, 1994), the groundwater evaluation study (BEI, 1995b), and the Supplemental RFI/RI (B&R Environmental, 1997). The naturally occurring oolitic limestone was encountered at the surface and was present to the termination of the borings at 13 feet below land surface (bls). The limestone was well consolidated with abundant shell fragments and fine- to medium-grain sand in the limestone matrix. The limestone was consistent in all borings, and no lateral or horizontal variations were apparent. The Standard Penetration Test (SPT) blow count indicated the limestone is of medium-to-high density.

Twenty-four monitoring wells are present at the site. No monitoring wells were installed at SWMU 9 during the Supplemental RFI/RI. The oolitic limestone was encountered to the maximum depth of 13 feet bls. The hydrogeologic unit associated with the oolitic limestone is the surficial aquifer. High conductivity values can be expected at the site due to the salt-water lagoon to the north. Recharge to the aquifer is directly through rainfall.

Groundwater elevation data collected during the contamination assessment study indicated a predominantly northerly groundwater flow direction with some tidal influence. Groundwater was reported to be approximately 1 to 3 feet bls. Groundwater elevations measured in May 1998 were consistent with those recorded during the previous investigations. The average groundwater elevations and monitoring well locations shown in Figure 2-2 and Figure 2-3 indicate the groundwater flow observed at the unit in May and November 1998, respectively.

## 2.3 SUMMARY OF THE NATURE AND EXTENT OF CONTAMINATION

Fuels, oils, and solvents stored at the Jet Engine Test Cell are potential sources of contamination. Several fuel spills have been documented, and VOC and semivolatile organic compound (SVOC) fuel constituents were detected as groundwater contaminants. Chlorinated VOCs were also frequently detected groundwater contaminants. Although no documentation exists, the chlorinated VOCs most likely came from solvents used for cleaning and degreasing at the site. Low levels of these same VOC and SVOC contaminants were found in soil, but inorganics are the primary soil contaminants. Surface-water and sediment contaminants at the shoreline on the northern edge of the site were also predominantly inorganics (B&R Environmental, 1997).

The following discussions summarize the nature and extent of contamination. All of the chemicals detected at SWMU 9 were compared to ARARs and Screening Action Levels (SALs) for each

medium. ARARs are discussed in Section 3.0 of this CMS, and SALs are discussed in Section 2.3.1 of the Supplemental RFI/RI (B&R Environmental, 1997).

### 2.3.1 Groundwater

In the Supplemental RFI/RI Report (B&R Environmental, 1997), VOCs and SVOCs were the predominant groundwater contaminants. In a given year, it was possible to determine the extent of groundwater contaminant plumes based on sampling results. In the contamination assessment (ABB, 1994), groundwater contaminant plumes of benzene and 1,2-dichloroethene (1,2-DCE) were identified in the eastern part of the site. The groundwater evaluation confirmed the presence of both plumes, but the benzene plume appeared to have changed directions from northeast to northwest. The maximum concentration in 1995 (55.2 µg/L) was found to the east of the well that exhibited the 1994 maximum. This may be indicative of eastward contaminant migration. In the groundwater evaluation (BEI, 1995b), the extent of DCE contamination appeared to have increased, spreading in a two-fingered plume to the west and northwest. The maximum detected concentration also increased and moved from well S9MW-15 to well S9MW-24, which indicates an easterly direction for contaminant migration. During the Supplemental RFI/RI (B&R Environmental, 1997), benzene was detected at a level (4 µg/L) exceeding ARAR/SAL criteria in a single well. Concentrations of 1,2-DCE decreased overall; however, the maximum concentration detected during the Supplemental RFI/RI was 3,060 µg/L (B&R Environmental). Ethylbenzene and naphthalene were found to exceed ARAR/SAL criteria in groundwater during the contamination assessment in the eastern part of SWMU 9 where documented petroleum spills occurred. 1995 sampling identified free product in two of these wells (S9MW-4 and S9MW-5). Methylene chloride was detected in a number of wells under and surrounding the concrete pad. Several other VOCs and SVOCs, usually chlorinated, were also detected in isolated instances and most likely resulted from solvents used for cleaning and degreasing at the site. In addition to benzene and 1,2-DCE, the Supplemental RFI/RI detected several pesticides in a single eastern well. Bis(2-ethylhexyl)phthalate exceeded its respective ARAR/SAL levels in a single well (B&R Environmental). Contaminants detected in excess of action levels prior to and during the Supplemental RFI/RI are shown in Figures 2-4 through 2-6.

During the Natural Attenuation evaluation (TtNUS, 1999b) in May 1998, to determine the dissolved-phase groundwater plume configuration, VOC samples were collected from 13 selected monitoring wells. The general pattern of groundwater contamination was consistent with previous sampling efforts. However, the VOC concentrations generally exceeded those reported during the previous sampling event. The greatest increase was identified in the source area at monitoring well S9MW-15 where the total VOC concentration increased from 53 µg/L to 5,650 µg/L (TtNUS, 1999b) and consisted of cis-1,2-DCE, trans-1,2-DCE, and trichloroethene (TCE). In November 1998, samples

were collected from 12 selected monitoring wells for the Natural Attenuation evaluation (TtNUS, 1999b). The general pattern of groundwater contamination, as evidenced by the current plume configuration, was inconsistent with previous sampling efforts. However, the VOC concentrations were significantly less than those reported during the May 1998 sampling event. The greatest decrease was identified in the source area at monitoring well S9MW-15, where the total VOC concentration decreased from 5,650 µg/L to 1,100 µg/L (TtNUS, 1999b). The inconsistency of the November 1998 data with previous sampling results is likely attributed to the September 25, 1998 Category 1 Hurricane (Georges) that passed directly over Key West. Although physical damage to the island was minimal, the hurricane resulted in a significant precipitation event (8 inches of rainfall). As a result, the shallow aquifer at SWMU 9 experienced significant amounts of precipitation, infiltration, and a tidal fluctuation that possibly flushed the VOCs from the surficial aquifer at least temporarily. This fluctuation in groundwater contaminant levels is not unusual following a significant precipitation event. Such natural anomalies as hurricanes have, in the past, permanently reduced soluble contaminant concentrations at other sites. However, because of the large paved apron over the source area, it is anticipated that in the future the contaminant levels will fully or partially return to levels identified prior to the hurricane (TtNUS, 1999b). Figures 2-7 and 2-8 depict analytical results in excess of the ARAR/SAL criteria for the May and November 1998 sampling events.

Although groundwater is not available to ecological receptors, it could become available by discharging to surface water or sediment. If this migration pathway existed to a significant extent at SWMU 9, the contaminants in groundwater would be present at elevated levels in surface water or sediment. The relatively low contaminant concentrations in surface water and sediment in the inlet suggest that this is presently not occurring at SWMU 9. However, potential risks resulting from future groundwater migration to surface water or sediment might be possible.

### 2.3.2 Soil

Soil sampling detected low levels of 1,2-DCE in the area of the groundwater plume. Methylene chloride was the only organic chemical to exceed an available ARAR or SAL in either surface or subsurface soil. In one subsurface sample, it was detected slightly above the 0.3-mg/kg EPA Region III Benchmark Toxicity Value (BTV). It was detected in a second subsurface sample but at a level less than the SAL. Metals were the most widespread soil contaminants. Aluminum (maximum of 4,790 mg/kg), chromium (maximum of 69.5 mg/kg) and nickel (maximum of 6.6 mg/kg) were detected in all the surface soil samples, but there did not appear to be any trend because higher concentrations were interspersed with lower ones. Chromium was also found in all subsurface samples, although concentrations were lower than those detected in the surface samples. Cyanide was significant in both surface and subsurface samples, although its maximum concentration (4.4

mg/kg) was found in a subsurface sample (B&R Environmental, 1997). Figures 2-9 and 2-10 depict surface and subsurface soil contaminants in excess of action levels.

### **2.3.3 Surface Water and Sediment**

Acetone was the only organic chemical detected in either surface water or sediment. It was detected in two sediment samples from the northeastern part of the shoreline at SWMU 9. Arsenic was also detected in two sediment samples, with the highest level (17.8 mg/kg) directly north of the testing area. Both mercury and cyanide were detected once in surface water and sediment, but the detections in the two media were not at the same locations. Thallium was found in all surface-water samples but at levels less than twice the 6.3 µg/L ARAR in each case (B&R Environmental, 1997). Figures 2-11 and 2-12 illustrate contaminants in sediment and surface water detected in excess of action levels.

## **2.4 HUMAN HEALTH RISK ASSESSMENT (HHRA) SUMMARY**

The baseline Human Health Risk Assessment (HHRA) in the Supplemental RFI/RI (B&R Environmental, 1997) is a qualitative and quantitative assessment of actual or potential risks for SWMU 9. A list of chemicals of potential concern (COPCs) was developed for each environmental medium covered by this CMS report. Only those chemicals found to be of potential concern were considered for evaluation in the quantitative risk assessment.

A list of COPCs was developed for each environmental medium, as necessary. Only those chemicals selected as COPCs were considered for evaluation in the quantitative risk assessment. The potential receptors that apply to media sampled at SWMU 9 include current adolescent and adult trespassers, current occupational workers, current site maintenance workers, future excavation workers, and future residents. However, the future resident is an unlikely receptor since there are no current plans for residential development of NAS Key West. Except for the excavation worker, all potential receptors and exposure pathways were evaluated quantitatively.

The estimated cumulative carcinogenic and noncarcinogenic risks calculated in the Supplemental RFI/RI for hypothetical future residents, trespasser adults and children, maintenance workers, excavation workers, and occupational workers at SWMU 9 are listed in Table 2-1. The total risk for each exposure route and the cumulative risk across all exposure pathways are also included. The HHRA was prepared in five parts: carcinogenic risks, noncarcinogenic risks, the result of the evaluation of lead in surface soils using the Integrated Exposure and Uptake Biokinetic (IEUBK) model, a comparison of groundwater results to screening criteria, and a special note concerning fish.

Carcinogenic Risks: The estimated carcinogenic risks for future residents ( $6 \times 10^{-5}$ ), trespasser adults ( $1 \times 10^{-5}$ ), and trespasser adolescents ( $1 \times 10^{-5}$ ) are within EPA's "target risk range" of  $1 \times 10^{-4}$  to  $1 \times 10^{-6}$  but exceed the Florida Department of Environmental Protection (FDEP) risk threshold of  $1 \times 10^{-6}$  (B&R Environmental, 1997). Dermal contact with sediment for the future resident, adult trespasser, and adolescent trespasser has incremental cancer risks (ICRs) of  $5 \times 10^{-5}$ ,  $1 \times 10^{-5}$ , and  $9 \times 10^{-6}$ , respectively (B&R Environmental, 1997). This exposure route contributes the most to the cumulative carcinogenic risk for these three receptors. However, the dermal contact route is associated with high uncertainty based on the Absorption Efficiency ( $ABSEFF_{oral}$ ) presented in Appendix G, Section 3.2.3.4 of the Supplemental RFI/RI Report. The principal COPC contributing to these cancer risks was arsenic in sediment. The estimated carcinogenic risks for the maintenance worker ( $1 \times 10^{-10}$ ) and occupational worker ( $2 \times 10^{-9}$ ) were below  $1 \times 10^{-6}$  (B&R Environmental, 1997). The carcinogenic risks for the excavation worker were not estimated because no COPCs were selected in subsurface soils (B&R Environmental, 1997).

Noncarcinogenic Risks: The cumulative hazard index (HI) for the hypothetical future resident (2.0) exceeds 1.0, a benchmark below which adverse noncarcinogenic health effects are not anticipated under conditions established in the exposure assessment (B&R Environmental, 1997). The principal COPCs contributing the noncarcinogenic risk are cadmium (hazard quotient(HQ) = 0.27), iron (HQ = 0.14), and manganese (HQ = 0.18) in surface soil; arsenic (HQ = 0.55) in sediment; and thallium (HQ = 0.45) in surface water (B&R Environmental, 1997). The target organ for arsenic and thallium is the skin. However, these COPCs add up to an HI of approximately 1.0. Therefore, no HI values based on the same target organ would exceed 1.0 for the hypothetical future resident. The cumulative HIs for adolescent trespassers, adult trespassers, maintenance workers, and occupational workers at SWMU 9 are less than 1.0 (B&R Environmental, 1997). The estimated noncarcinogenic risks for the excavation worker were not estimated because no COPCs were selected in subsurface soils (B&R Environmental).

#### 2.4.1 IEUBK Lead Results

The IEUBK Lead Model (v. 0.99) (USEPA, 1994b) was used to characterize potential efforts associated with exposure to media containing lead. The model was run two ways: using the representative concentration and using the average concentration. The purpose of this method was to give a range of risks based on a conservative exposure (using the representative concentration) and an average exposure (using the average concentration).

Using the representative concentration, the model results predict that 3.05 percent of residential children exposed under similar conditions might have blood-lead levels above 10  $\mu\text{g}/\text{dL}$  (B&R

Environmental, 1997). This is less than USEPA's protective guideline of 5 percent for the maximum proportion of individuals with blood levels above 10 µg/dL (USEPA, 1994b). The model inputs assumed were the default parameter values, 265 mg/kg lead in site-related soils, and 2.1 µg/L lead in groundwater (B&R Environmental, 1997).

Using the average concentration, the model predicts that 0.06 percent of residential children exposed under similar conditions might have blood-lead levels above 10 µg/dL (EPA, 1994b). This is less than the protective guideline of 5 percent for the maximum proportion of individuals with blood levels above 10 µg/dL (EPA, 1994b). The model inputs assumed were default parameter values, 75.6 mg/kg lead in site-related soils, and 2.1 µg/L lead in groundwater (B&R Environmental, 1997).

Quantitative and Qualitative Risk Assessment for Groundwater: Groundwater was not evaluated as part of the baseline HHRA because it is classified as G-III, nonpotable water by FDEP. As discussed in the Supplemental RFI/RI Report (B&R Environmental, 1997), groundwater obtained from the surficial aquifer at NAS Key West has a high salinity, and the public water supply obtained from the mainland is officially designated as the only potable source. No freshwater public or registered domestic wells exist, although domestic wells are reportedly used for purposes such as flushing water. Although treatment could possibly be used to improve water quality, the local water authority regulates all potable supplies in the Keys. A preliminary comparison of unfiltered groundwater concentrations at SWMU 9 versus tap water Risk Based Concentrations (RBCs) (EPA, 1995b) and Maximum Contaminant Levels (MCLs) (EPA, 1995c) is presented in Tables 2-2 and 2-3 of the Supplemental RFI/RI (B&R Environmental) to provide a benchmark of the magnitude of contamination in the groundwater.

Fish and the Quantitative Risk Assessment: Fish and shellfish at SWMU 9 were not considered a human health concern because the inlet is open to the ocean and wide-ranging fish would spend only a minor portion of time in the inlet. Mangrove oysters were sampled adjacent to the inlet and did not reveal contaminants above background. A more complete discussion of this subject is presented in Section 4.4 of the Supplemental RFI/RI Report (B&R Environmental, 1997).

#### **2.4.2                    Chemicals of Concern**

At SWMU 9, no human health COCs were selected for remedial clean-up goal option (RGO) analysis because in no instance did any receptor scenario have a total risk (combined across pathways) exceeding a level of concern ( $1 \times 10^{-04}$  cancer risk or HI of 1.0) (B&R Environmental, 1997). Other sources of risk-based criteria include RCRA Corrective Action levels, FDEP Soil Cleanup Goals (RGOs), and ARARs.

## 2.5

### ECOLOGICAL RISK ASSESSMENT SUMMARY

This section discusses the results of the ecological risk assessment (ERA) performed at SWMU 9 through a discussion of the problem formulation, effects characterization, exposure assessment, and risk characterization. The maximum detected contaminant concentrations in groundwater, surface water, sediment, and soil were used as representative exposure point concentrations for screening against benchmark values. Background values were obtained from several locations at NAS Key West. The complete Background Report is presented in Appendix J of the Supplemental RFI/RI Report (B&R Environmental, 1997).

Potential exposure routes considered in the Supplemental RFI/RI for terrestrial and aquatic receptors are incidental ingestion of soil, incidental ingestion of contaminated food items, direct aerial deposition, root translocation, and dermal contact.

Ecological chemicals of concern (ECCs) or COCs have been identified in the ERA at SWMU 9 for each media. Tables 2-2 through 2-5 identify these COCs by media and include the range of detected values, ecological threshold values, HQs, and the reason the chemical was retained as a COC in the Supplemental RFI/RI (B&R Environmental, 1997).

In the Supplemental RFI/RI ERA, several inorganic and organic compounds were detected in groundwater. Where benchmarks were available, the resulting HQs were generally indicative of low potential risk. The HQs for silver, Dichlorodiphenyl Trichloroethane (DDT), dieldrin, and endrin were quite high, but each of these contaminants was detected in only one of eight samples.

Although groundwater is not available to ecological receptors, it could become available by discharging to surface water or sediment. If this migration pathway existed to a significant extent at SWMU 9, the contaminants identified as ECCs in groundwater would be present at elevated levels in surface water or sediment. The relatively low contaminant concentrations in surface water and sediment in the inlet suggest that this is presently not occurring at SWMU 9. However, potential risks resulting from future groundwater migration to surface water or sediment is possible.

Only a few contaminants in surface water and sediment were identified as ECCs, and the resulting HQs were indicative of low risk, with the exception of cyanide. However, the frequency of detection of cyanide was low (one of six in surface water, one of five in sediment). Furthermore, the presence of cyanide is not believed to be a result of activities at SWMU 9 (B&R Environmental, 1997).

Five metals exceeded benchmark values in site soils. Of these, cyanide and chromium HQs are of potentially high risks to terrestrial receptors. Chromium was detected in all five surface soil samples, although only one sample exceeded 15.1 mg/kg. Nevertheless, all detected values exceeded the average base background concentration of 6.22 mg/kg. The source of chromium in all soil samples is unknown. Chromium was not detected in groundwater or surface water and was present in sediment at concentrations well below ecological benchmarks. Thus, it does not appear to pose potential risks to aquatic receptors (B&R Environmental, 1997). The risk of chromium and other soil ECCs to terrestrial receptors is largely mitigated by the overall lack of terrestrial habitat at this site. As mentioned earlier, the site is mostly a developed area of buildings and mowed grass.

In toxicity tests conducted with surface water and sediment taken from the inlet adjacent to the site, the survival and growth of mysid shrimp, the fertilization and development of mussel larvae, and the fertilization of sea urchin were similar to control values. The survival of silverside minnows was 95, 75, 85, 90, and 90 percent in Sample Numbers 1, 2, 3, 4, and 5, respectively (B&R Environmental, 1997). The 75 percent survival in Sample No. 2 was somewhat lower than in laboratory controls. The salinity of Sample No. 2 was 34 parts per thousand (ppt), slightly higher than the 32 ppt maximum value recommended in toxicity tests using this species. The survival of laboratory control minnows was extraordinarily high (100 percent); therefore, the slightly reduced survival in four of five SWMU samples (when compared to laboratory controls) does not appear to have been a treatment effect. Because all other toxicity tests conducted with surface water and sediment from this site indicated normal survival and growth, the reduced survival in Sample No. 2 in the silverside minnow toxicity tests is not believed to be a treatment effect (B&R Environmental, 1997). In summary, the toxicity tests indicate that potential risks to aquatic receptors in the inlet appear to be low (B&R Environmental, 1997). Section 4.4.8.4.2 in the Supplemental RFI/RI (B&R Environmental, 1997) describes the toxicity tests in more detail.

Concentrations of metals in mangrove oysters collected from the inlet were similar to concentrations in mangrove oysters collected from one background site (oysters were not available at the other two background sites) (B&R Environmental, 1997). No organic compounds were detected in oyster tissue from SWMU 9. Therefore, although the available number of samples was low, results of the tissue analyses show no indication of contaminant accumulation in these filter-feeding organisms (B&R Environmental, 1997).

Numerous organic compounds have been detected in groundwater at SWMU 9. Although migration of these contaminants to the nearby inlet does not appear to have occurred, the potential for ecological risks from future groundwater contaminant migration to surface water or sediment cannot be totally ruled out, despite the potential for some dilution on discharge to surface water. For this

reason, it is recommended that the site groundwater be treated to reduce the concentration of these organic compounds, which would reduce the possibility of future site-related risks to aquatic receptors. Although a few soil contaminants exceeded the limited areal extent of contaminated soil and the marginal habitat in the area where fuel and solvents were spilled, the results of surface-water and sediment screening assessments, toxicity tests, and tissue analyses show that, under present conditions, risks to aquatic receptors from site-related activities are negligible.

TABLE 2-1

CUMULATIVE RISKS  
 SWMU 9\*  
 NAS KEY WEST, BOCA CHICA KEY, FLORIDA  
 PAGE 1 OF 2

Exposure Route	Resident	Trespasser Adult	Trespasser Adolescent	Maintenance Worker	Excavation Worker	Occupational Worker
<b>INCREMENTAL CANCER RISK</b>						
<b>SURFACE SOIL</b>						
Incidental Ingestion	**	**	**	**	NA	**
Dermal Contact	**	**	**	**	NA	**
Inhalation of Fugitive Dust	1E-08	7E-11	9E-11	1E-10	NA	2E-09
Subtotal of Media	1E-08	7E-11	9E-11	1E-10	NA	2E-09
<b>SUBSURFACE SOIL</b>						
Incidental Ingestion	NA	NA	NA	NA	**	NA
Dermal Contact	NA	NA	NA	NA	**	NA
Inhalation of Fugitive Dust	NA	NA	NA	NA	**	NA
Subtotal of Media	NA	NA	NA	NA	**	NA
<b>SEDIMENT</b>						
Incidental Ingestion	1E-05	1E-06	1E-06	NA	NA	NA
Dermal Contact	5E-05	1E-05	9E-06	NA	NA	NA
Subtotal of Media	6E-05	1E-05	1E-05	NA	NA	NA
<b>SURFACE WATER</b>						
Incidental Ingestion	**	**	**	NA	NA	NA
Dermal Contact	**	**	**	NA	NA	NA
Subtotal of Media	**	**	**	NA	NA	NA
<b>TOTAL</b>	6E-05	1E-05	1E-05	1E-10	**	2E-09
<b>HAZARD INDEX</b>						
<b>SURFACE SOIL</b>						
Incidental Ingestion	5E-01	4E-03	8E-03	2E-03	NA	2E-02
Dermal Contact	1E-01	5E-03	7E-03	2E-03	NA	2E-02
Inhalation of Fugitive Dust	1E-03	4E-06	8E-06	4E-06	NA	8E-05
Subtotal of Media	6E-01	9E-03	2E-02	4E-03	NA	4E-02
<b>SUBSURFACE SOIL</b>						
Incidental Ingestion	NA	NA	NA	NA	**	NA
Dermal Contact	NA	NA	NA	NA	**	NA
Inhalation of Fugitive Dust	NA	NA	NA	NA	**	NA
Subtotal of Media	NA	NA	NA	NA	**	NA
<b>SEDIMENT</b>						
Incidental Ingestion	3E-01	1E-02	2E-02	NA	NA	NA
Dermal Contact	3E-01	1E-01	1E-01	NA	NA	NA
Subtotal of Media	6E-01	1E-01	1E-01	NA	NA	NA

**TABLE 2-1**  
**CUMULATIVE RISKS**  
**SWMU 9\***  
**NAS KEY WEST**  
**PAGE 2 OF 2**

Exposure Route	Resident	Trespasser Adult	Trespasser Adolescent	Maintenance Worker	Excavation Worker	Occupational Worker
<b>HAZARD INDEX (cont.)</b>						
<b>SURFACE WATER</b>						
Incidental Ingestion	3E-01	3E-02	5E-02	NA	NA	NA
Dermal Contact	2E-01	1E-02	2E-02	NA	NA	NA
Subtotal of Media	5E-01	4E-02	7E-02	NA	NA	NA
<b>Total</b>	2E+00	1E-01	2E-01	4E-03	**	4E-02

\* = Chemical-specific risks are presented in Appendix A.

\*\* = Either no COPCs were selected or the COPCs selected for this pathway did not have applicable toxicity values.

NA = Not applicable, pathway is not applicable for the respective media.

TABLE 2-2

**ECOLOGICAL CONTAMINANTS OF CONCERN IN GROUNDWATER - SWMU 9  
NAS KEY WEST, BOCA CHICA KEY, FLORIDA  
PAGE 1 OF 2**

Ecological Contaminants of Concern (ECCs)	Frequency of Detection	Average Background Concentration (µg/L)	Range of Detected Values (µg/L)	Ecological Threshold (µg/L)	Hazard Quotient	Reason for Retention as an ECC
<b>INORGANICS</b>						
Barium	8/8	13.88	5.4 - 11.7	3.9	3.0	HQ > 1
Cyanide	5/8	2.76	0.83 - 6.6	5.2	1.27	HQ > 1
Lead	1/27	1.19	2.4	1.32	1.82	HQ > 1
Selenium	2/8	ND	4.9 - 6	5.0	1.2	HQ > 1
Silver	1/8	ND	6	0.07	85.7	HQ > 1
<b>PESTICIDES/PCBs</b>						
4,4'-DDT	1/8	ND	0.26	0.00059	440	HQ > 1
Dieldrin	1/8	ND	0.19	0.0019	100	HQ > 1
Endrin	1/8	ND	0.25	0.0023	108.6	HQ > 1
<b>SEMIVOLATILE ORGANIC COMPOUNDS</b>						
1-methylnaphthalene	5/20	ND	10 - 110	NA		No suitable threshold was available
2-methylnaphthalene	3/28	ND	53 - 130	NA		No suitable threshold was available
Bis(2-ethylhexyl)phthalate	1/8	ND	9	0.3	30	HQ > 1
Chlorodibromomethane	8/47	ND	0.32 - 13.50	NA		No suitable threshold was available
Naphthalene	13/57	4.09	2 - 110	62	1.77	HQ > 1
<b>VOLATILE ORGANIC COMPOUNDS</b>						
1,1,2,2-tetrachloroethane	7/82	ND	2 - 13.50	10.8	1.25	HQ > 1
1,1-dichloroethene	8/82	ND	2 - 13.50	3.2	4.20	HQ > 1
1,2-dichloroethane	7/82	ND	2 - 13.50	NA		No suitable threshold was available
1,2-dichloroethene (total)	2/24	ND	25 - 35	NA		No suitable threshold was available
1,2-dichloropropane	7/82	ND	2 - 13.50	NA		No suitable threshold was available
2-butanone	7/47	14.66	10 - 67.50	NA		No suitable threshold was available
2-hexanone	8/51	ND	2.32 - 67.50	NA		No suitable threshold was available
4-methyl-2-pentanone	7/51	ND	10 - 67.50	NA		No suitable threshold was available
Acetone	20/51	5	5 - 100	NA		No suitable threshold was available
Bromodichloromethane	8/82	ND	0.20 - 13.50	NA		No suitable threshold was available
Bromomethane	7/82	ND	2 - 13.50	NA		No suitable threshold was available
Carbon disulfide	10/51	ND	0.11 - 67.50	NA		No suitable threshold was available
Carbon tetrachloride	7/82	ND	2 - 13.50	4.42	3.05	HQ > 1

TABLE 2-2

ECOLOGICAL CONTAMINANTS OF CONCERN IN GROUNDWATER - SWMU 9  
 NAS KEY WEST, BOCA CHICA KEY, FLORIDA  
 PAGE 2 OF 2

Ecological Contaminants of Concern (ECCs)	Frequency of Detection	Average Background Concentration (µg/L)	Range of Detected Values (µg/L)	Ecological Threshold (µg/L)	Hazard Quotient	Reason for Retention as an ECC
Chloroethane	7/82	ND	2 - 13.50	NA		No suitable threshold was available
Chloromethane	7/82	ND	2 - 13.50	NA		No suitable threshold was available
Cis-1,2-dichloroethene	26/54	ND	2 - 1,560	NA		No suitable threshold was available
Isopropyl alcohol	1/1	ND	23	NA		No suitable threshold was available
Styrene	7/51	ND	10 - 67.50	NA		No suitable threshold was available
Tetrachloroethene	8/82	ND	0.07 - 13.50	8.85	1.53	HQ > 1
Trans-1,2-dichloroethene	29/62	ND	2 - 3,060	NA		No suitable threshold was available
Trichloroethane	15/82	ND	1.50 - 44	NA		No suitable threshold was available
Trichlorofluoromethane	2/39	ND	3	NA		No suitable threshold was available
Vinyl acetate	9/51	ND	3 - 67.50	NA		No suitable threshold was available
Vinyl chloride	7/82	ND	2 - 13.50	NA		No suitable threshold was available
Xylenes (total)	10/82	ND	2 - 131.60	1.8	73.1	HQ > 1

NA = No suitable ecological threshold value was available.  
 ND = Not detected.

TABLE 2-3

ECOLOGICAL CONTAMINANTS OF CONCERN IN SURFACE WATER - SWMU 9  
 NAS KEY WEST, BOCA CHICA KEY, FLORIDA

Ecological Contaminants of Concern (ECCs)	Frequency of Detection	Average Background Concentration (µg/L)	Range of Detected Values (µg/L)	Ecological Threshold (µg/L)	Hazard Quotient	Reason for Retention as an ECC
<b>INORGANICS</b>						
Cobalt	1/6	ND	1.1	NA		No suitable threshold was available
Cyanide	1/6	1.56	45.2	1.0	45.2	HQ > 1
Thallium	6/6	4.88	5.6 - 10.1	6.3	1.6	HQ > 1

NA = No suitable ecological threshold value was available.  
 ND = Not detected.

TABLE 2-4

ECOLOGICAL CONTAMINANTS OF CONCERN IN SEDIMENT - SWMU 9  
 NAS KEY WEST, BOCA CHICA KEY, FLORIDA

Ecological Contaminants of Concern (ECCs)	Frequency of Detection	Average Background Concentration	Range of Detected Values	Ecological Threshold Value <sup>(1)</sup>	Hazard Quotient	Reason for Retention as an ECC
<b>HERBICIDES (µg/kg)</b>						
Methyl parathion	2/5	ND	14.8 - 38.8	NA		No suitable threshold was available
<b>INORGANICS (mg/kg)</b>						
Arsenic	2/5	1.71	12.6 - 17.8	7.24/70	2.46/0.25	HQ > 1
Cyanide	1/5	ND	12.1	0.10	121	HQ > 1
Mercury	1/5	ND	1.1	0.13/0.71	8.46/1.55	HQ > 1
Selenium	1/5	1.04	7.3	NA		No suitable threshold was available
Vanadium	5/5	4.84	4.7 - 13.2	NA		No suitable threshold was available
<b>PESTICIDE/PCBs (µg/kg)</b>						
4,4'-DDE	2/5	ND	6.4 - 14.3	1.22/27	11.7/0.5	HQ>1
Delta-BHC	2/5	ND	11.3 - 14.2	3	4.7	HQ > 1
<b>VOLATILE ORGANIC COMPOUNDS (µg/kg)</b>						
Acetone	2/5	34.3	275 - 1,890	64	29.53	HQ > 1

NA = No suitable ecological threshold value was available.  
 ND = Not detected.

1 When two values are presented, the left value is the most conservative available and the right value is a less conservative value, if available. In these instances, two Hazard Quotient values are presented. Contaminants were retained as final ECPCs if the most conservative ET value available was exceeded.

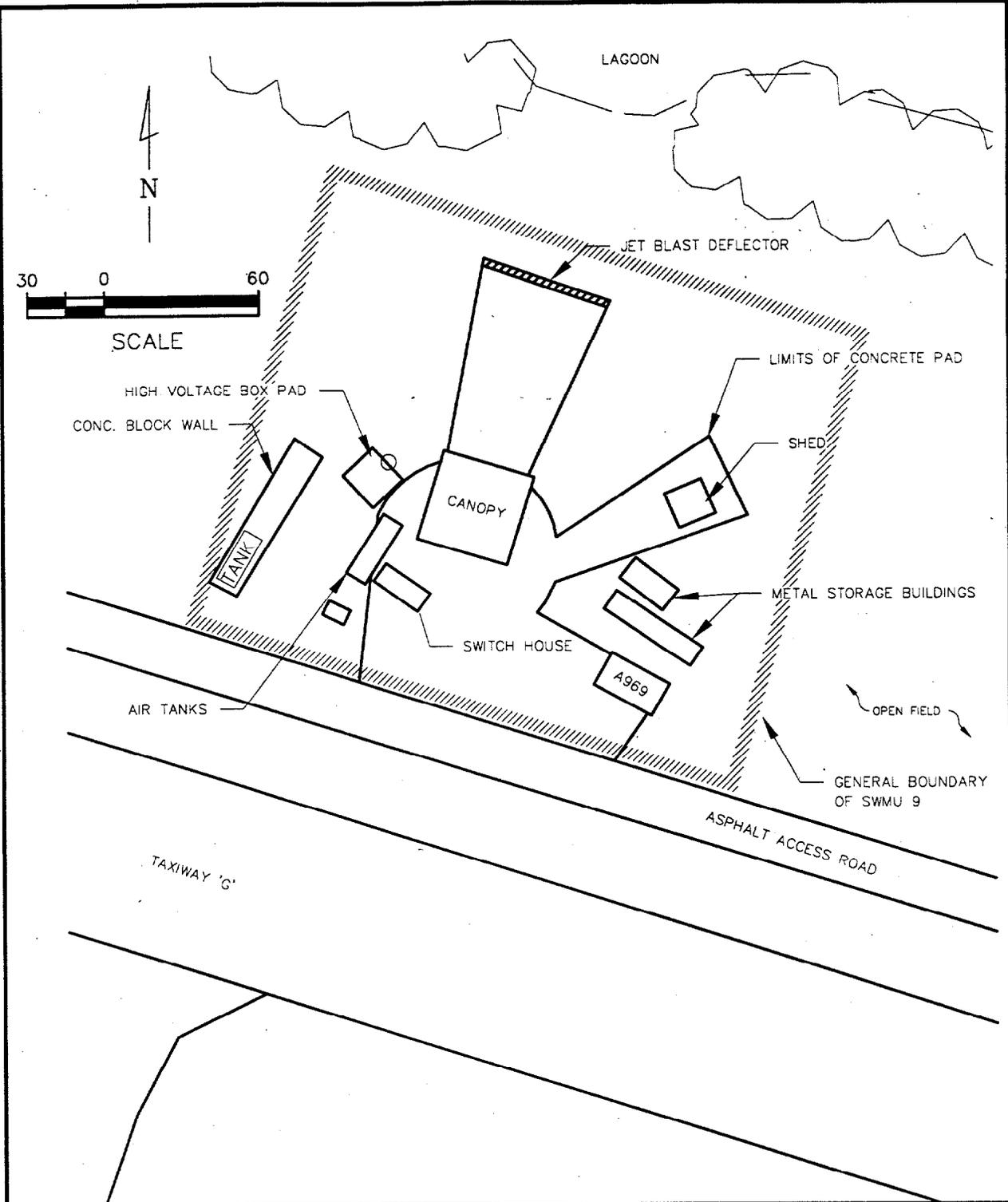
TABLE 2-5

ECOLOGICAL CONTAMINANTS OF CONCERN IN SOIL - SWMU 9  
 NAS KEY WEST, BOCA CHICA KEY, FLORIDA

Ecological Contaminants of Concern (ECCs)	Frequency of Detection	Average Background Concentration	Range of Detected Values	Ecological Threshold Value	Hazard Quotient	Reason for Retention as an ECC
<b>INORGANICS (mg/kg)</b>						
Aluminum	5/5	2,130	1,170-4,790	600	7.98	HQ > 1
Chromium	5/5	6.22	7.2-69.55	0.4	174	HQ > 1
Cyanide	2/5	ND	2.2-2.6	0.005	520	HQ > 1
Mercury	2/5	0.03	0.06-0.32	0.1	3.20	HQ > 1
Zinc	5/5	19.0	16.5-298.5	200	1.49	HQ > 1

ND = Not detected.

ACAD: P:\KEY WEST\ERNA (CTO 007)\MOD008\CMSS\SWMU9\MAPS\CMS 2-1 THRU 2-10.DWG 04/21/99 MDB



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SCALE AS NOTED	

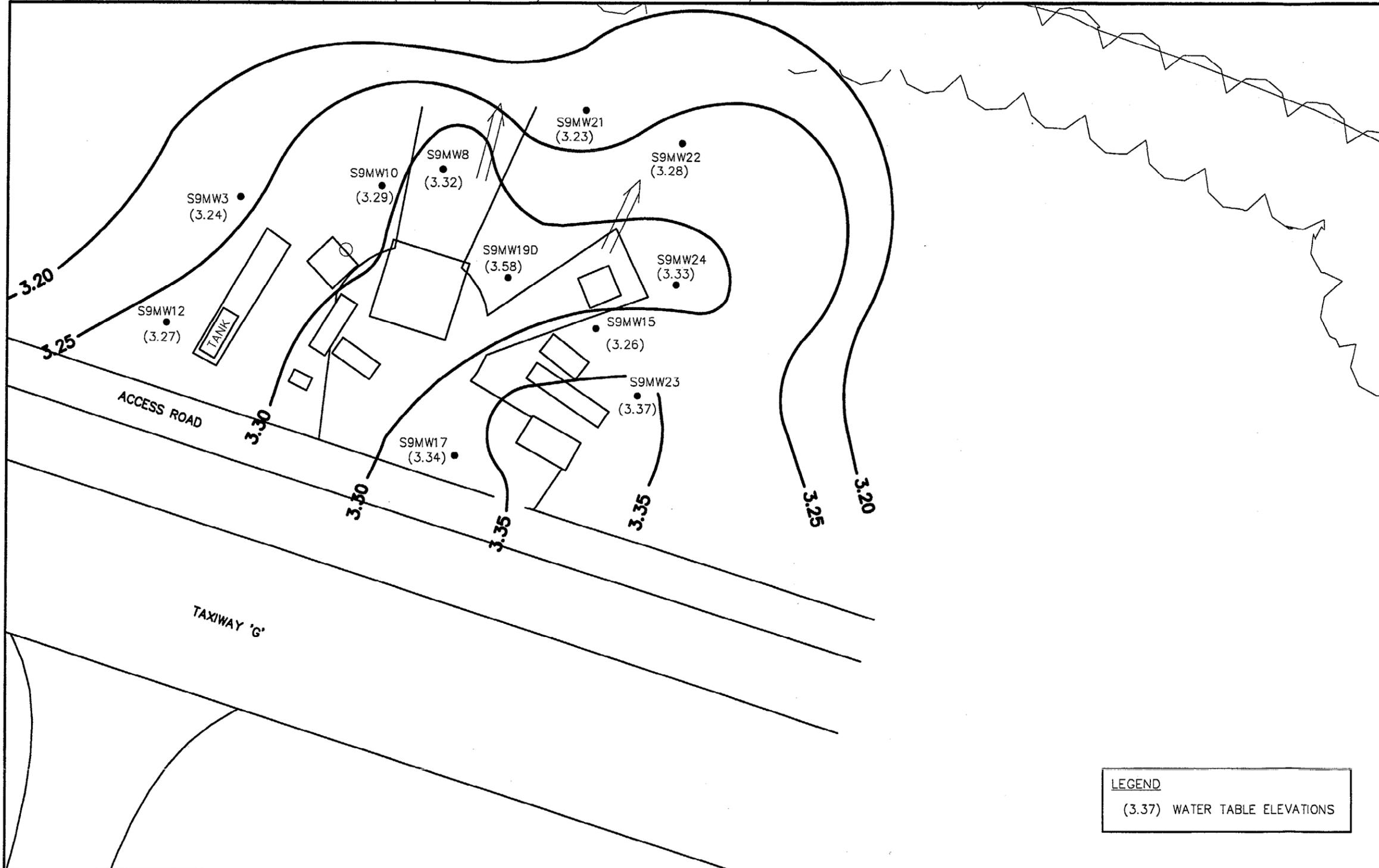


**CORRECTIVE MEASURES STUDY REPORT  
FOR SWMU 9  
FIGURE 2-1. SITE LOCATION MAP  
SWMU 9  
NAVY SOUTHERN DIVISION  
BOCA CHICA KEY, FLORIDA**

CONTRACT NO. 7046	
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FORM CADD NO. SDV\_AV12.DWG - REV 0 - 1/20/98

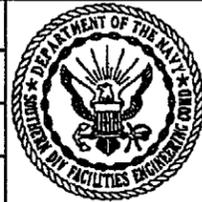
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LEGEND  
(3.37) WATER TABLE ELEVATIONS

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

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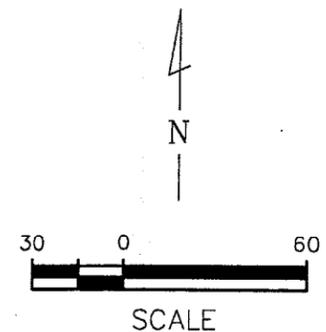
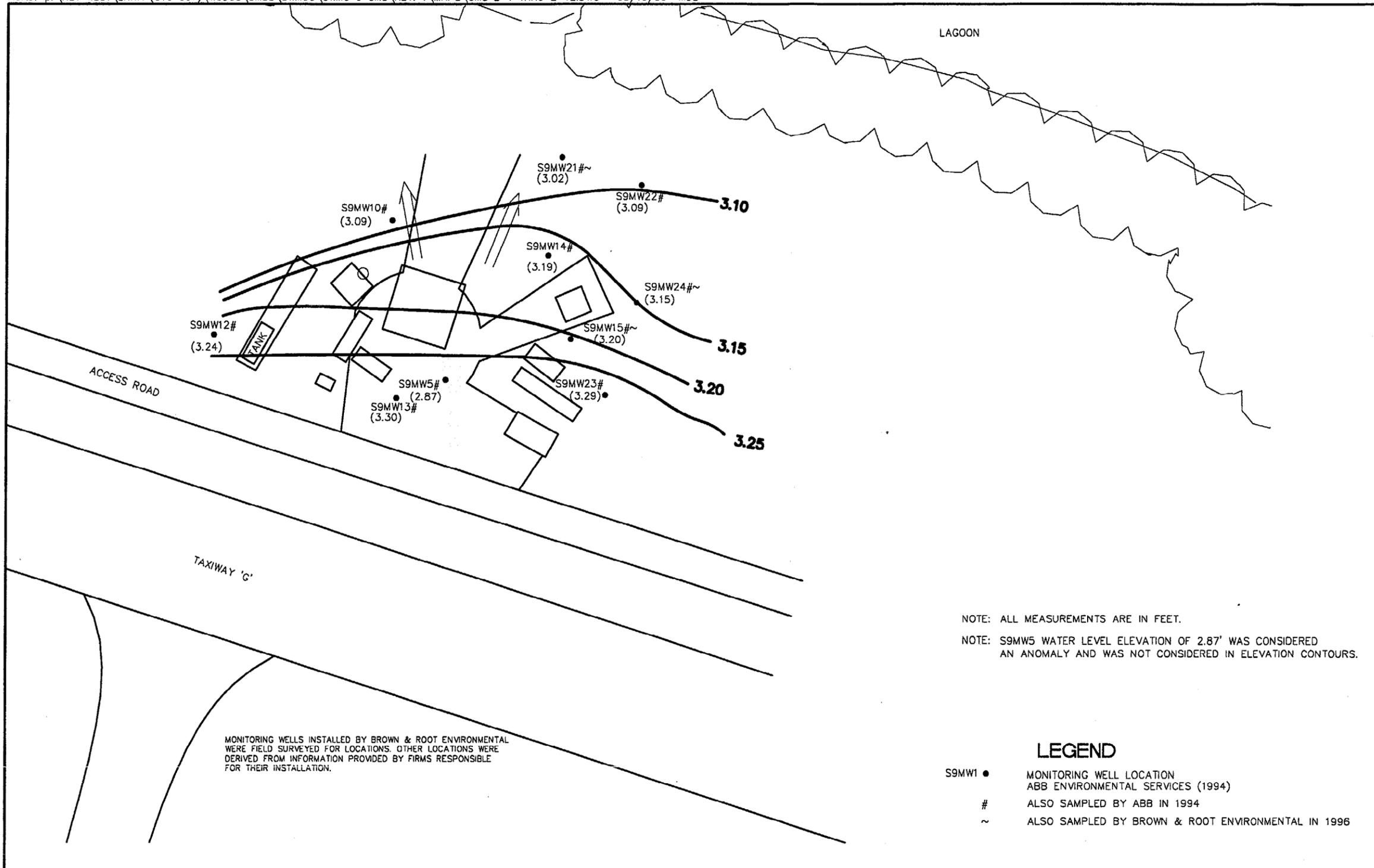


CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9  
FIGURE 2-2. MAY 1998 GROUNDWATER FLOW  
AND ELEVATIONS, SWMU 9  
NAVY SOUTHERN DIVISION  
BOCA CHICA KEY, FLORIDA

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NOTE: ALL MEASUREMENTS ARE IN FEET.  
NOTE: S9MW5 WATER LEVEL ELEVATION OF 2.87' WAS CONSIDERED AN ANOMALY AND WAS NOT CONSIDERED IN ELEVATION CONTOURS.

MONITORING WELLS INSTALLED BY BROWN & ROOT ENVIRONMENTAL WERE FIELD SURVEYED FOR LOCATIONS. OTHER LOCATIONS WERE DERIVED FROM INFORMATION PROVIDED BY FIRMS RESPONSIBLE FOR THEIR INSTALLATION.

**LEGEND**

- S9MW1 • MONITORING WELL LOCATION  
ABB ENVIRONMENTAL SERVICES (1994)
- # ALSO SAMPLED BY ABB IN 1994
- ~ ALSO SAMPLED BY BROWN & ROOT ENVIRONMENTAL IN 1996

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

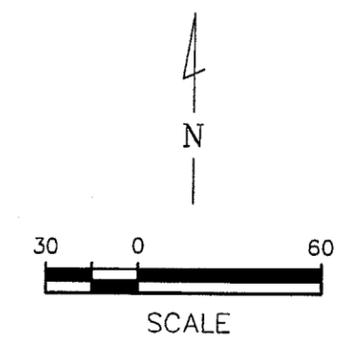
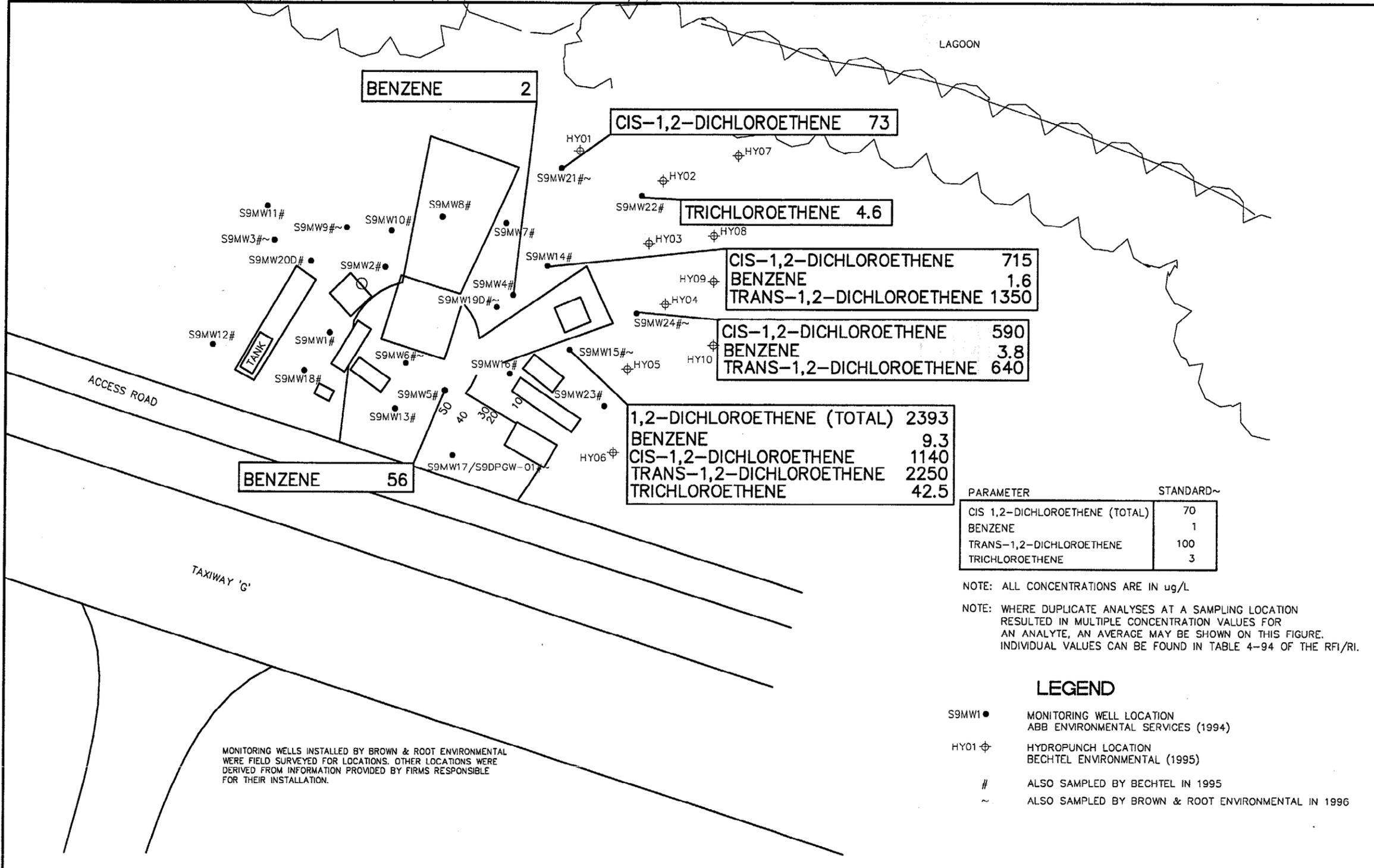
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DSF	-
COST/SCHED-AREA	
SCALE	
AS NOTED	



**CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9  
FIGURE 2-3. NOVEMBER 1998 GROUNDWATER  
FLOW AND ELEVATIONS, SWMU 9  
NAVY SOUTHERN DIVISION  
BOCA CHICA KEY, FLORIDA**

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ACAD: p:\KEY WEST\ERNA (CTO 007)\MOD08\CMSS\SWMU9\SWMU 9 CMS\Rev. 0\Maps\CMS 2-1 THRU 2-10.DWG 08/10/99 MDB



NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

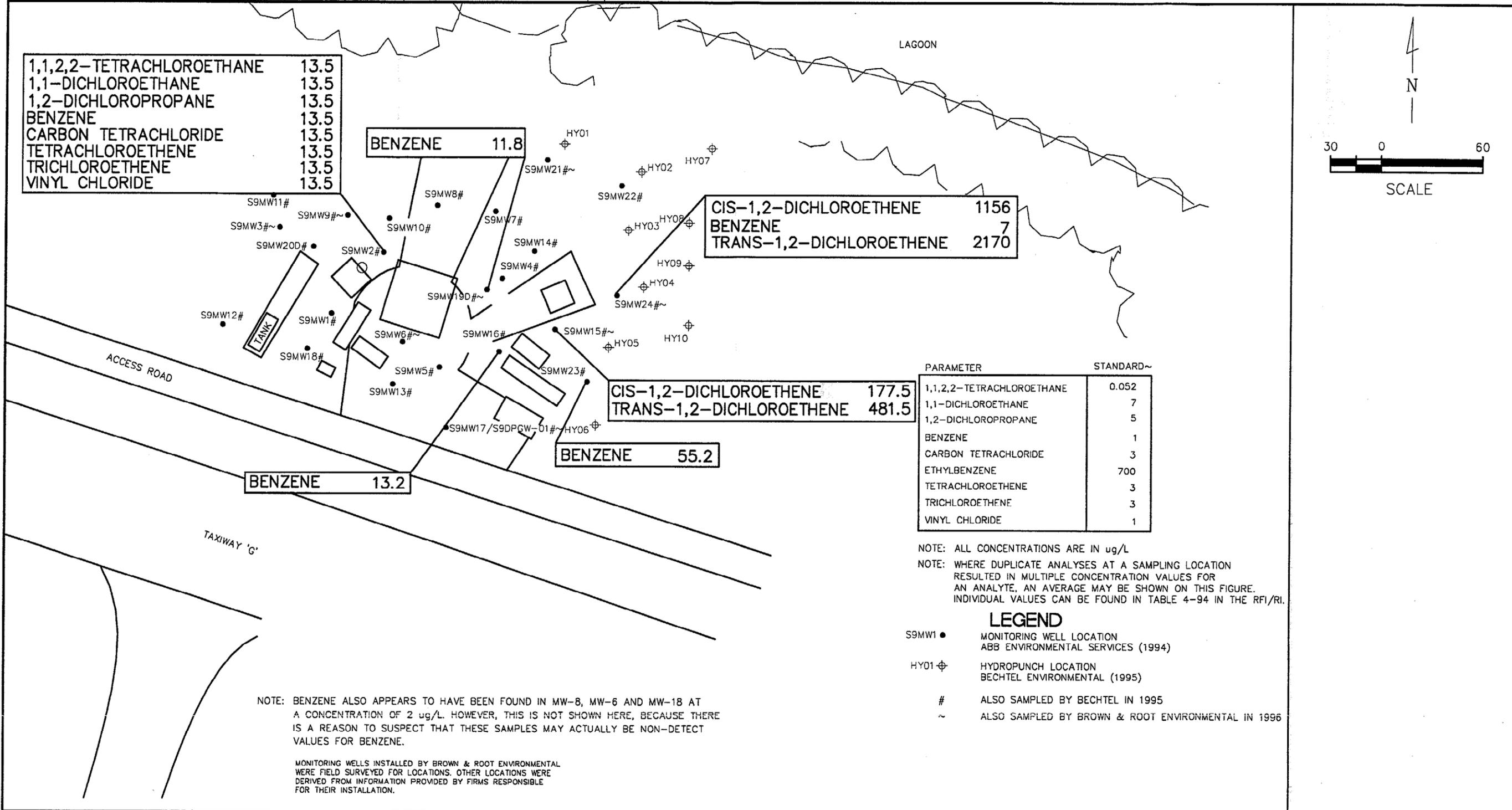
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DSF	-
COST/SCHED-AREA	
SCALE	
AS NOTED	



CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9  
FIGURE 2-4. 1993 & 1994 GROUNDWATER  
CHEMICAL CONCENTRATIONS, SWMU 9  
NAVY SOUTHERN DIVISION  
BOCA CHICA KEY, FLORIDA

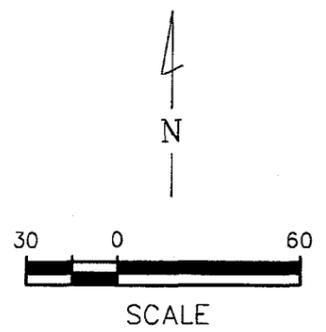
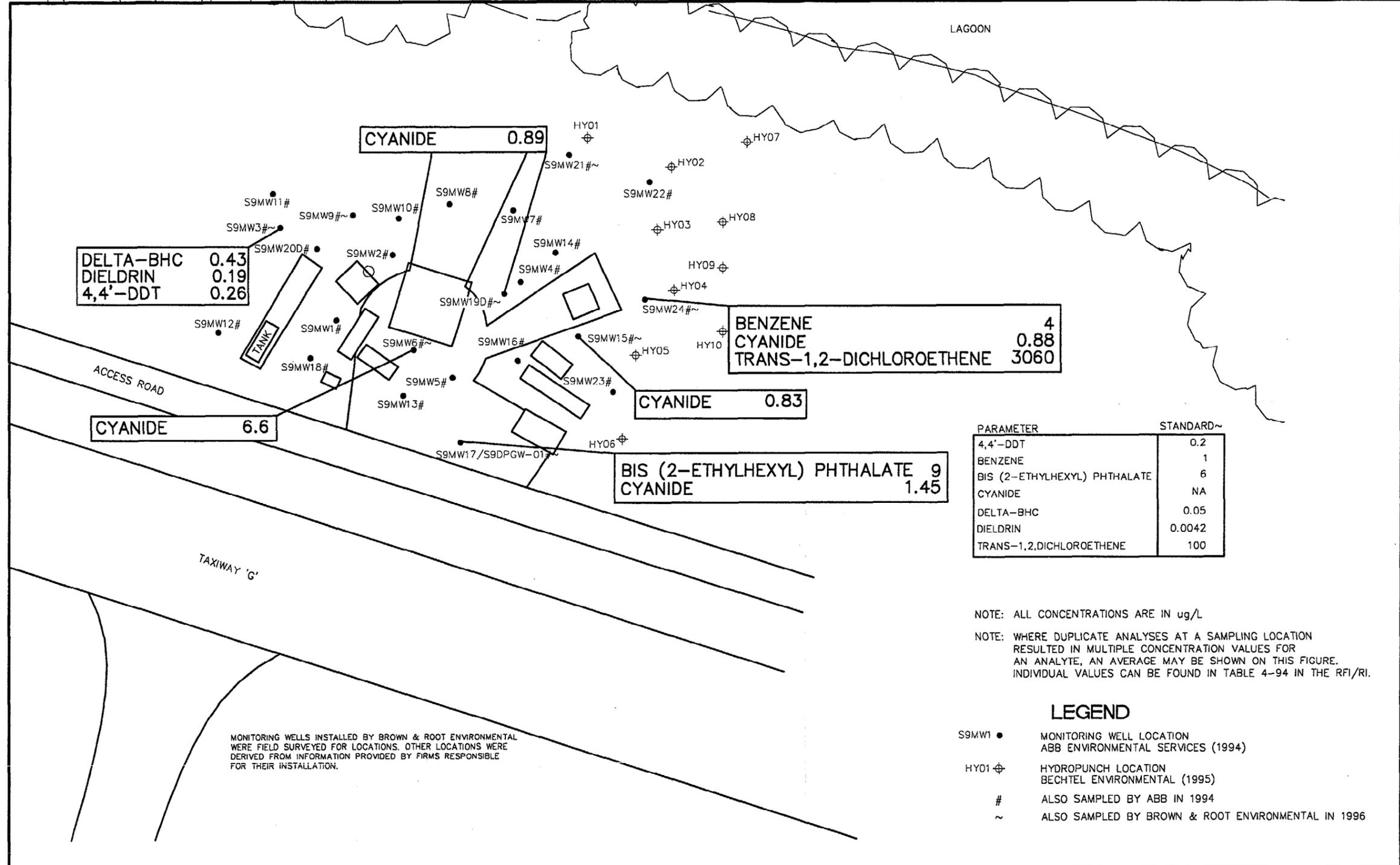
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NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	DRAWN BY	DATE		CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9 FIGURE 2-5. 1995 GROUNDWATER CHEMICAL CONCENTRATIONS, SWMU 9 NAVY SOUTHERN DIVISION BOCA CHICA KEY, FLORIDA	CONTRACT NO. 7046		
											APPROVED BY	DATE	
											APPROVED BY	DATE	
											DRAWING NO.	REV.	

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PARAMETER	STANDARD~
4,4'-DDT	0.2
BENZENE	1
BIS (2-ETHYLHEXYL) PHTHALATE	6
CYANIDE	NA
DELTA-BHC	0.05
DIELDRIN	0.0042
TRANS-1,2,DICHLOROETHENE	100

NOTE: ALL CONCENTRATIONS ARE IN ug/L  
 NOTE: WHERE DUPLICATE ANALYSES AT A SAMPLING LOCATION RESULTED IN MULTIPLE CONCENTRATION VALUES FOR AN ANALYTE, AN AVERAGE MAY BE SHOWN ON THIS FIGURE. INDIVIDUAL VALUES CAN BE FOUND IN TABLE 4-94 IN THE RFI/RI.

**LEGEND**

- S9MW1 ● MONITORING WELL LOCATION  
ABB ENVIRONMENTAL SERVICES (1994)
- HY01 ⊕ HYDROPUNCH LOCATION  
BECHTEL ENVIRONMENTAL (1995)
- # ALSO SAMPLED BY ABB IN 1994
- ~ ALSO SAMPLED BY BROWN & ROOT ENVIRONMENTAL IN 1996

MONITORING WELLS INSTALLED BY BROWN & ROOT ENVIRONMENTAL WERE FIELD SURVEYED FOR LOCATIONS. OTHER LOCATIONS WERE DERIVED FROM INFORMATION PROVIDED BY FIRMS RESPONSIBLE FOR THEIR INSTALLATION.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

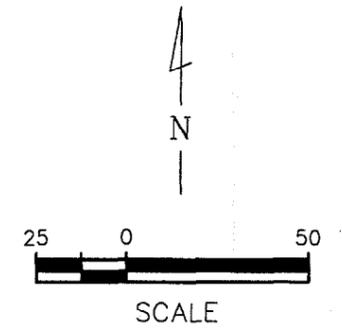
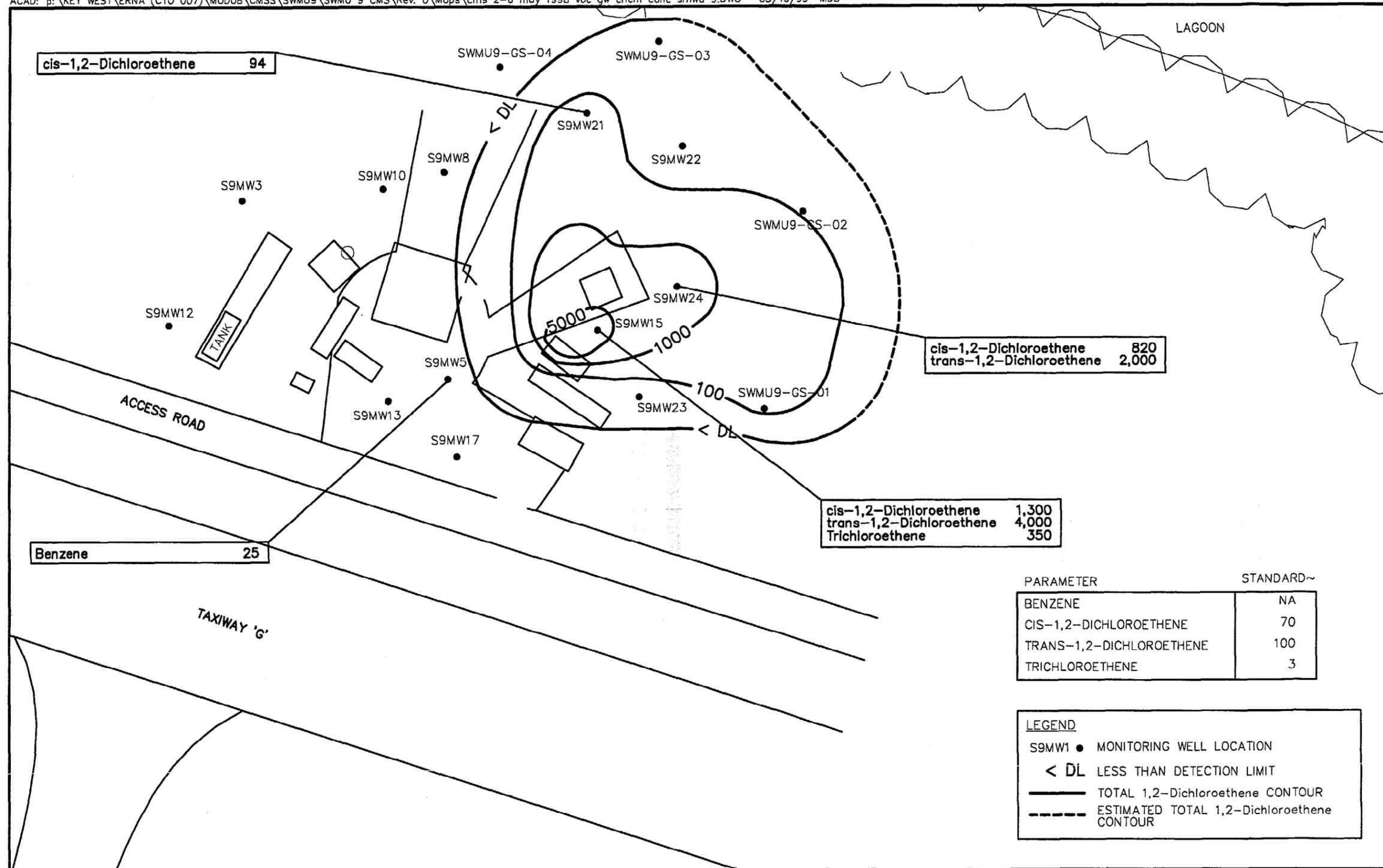
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DSF	-
COST/SCHED-AREA	
SCALE	
AS NOTED	



**CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9  
 FIGURE 2-6. 1996 GROUNDWATER CHEMICAL  
 CONCENTRATIONS, SWMU 9  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA**

CONTRACT NO. 7046	
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ACAD: p:\KEY WEST\ERNA (CTO 007)\MOD08\CMSS\SWMU9\SWMU 9 CMS\Rev. 0\Maps\cms 2-6 may 1998 voc gw chem conc smwu 9.DWG 08/10/99 MDB



PARAMETER	STANDARD~
BENZENE	NA
CIS-1,2-DICHLOROETHENE	70
TRANS-1,2-DICHLOROETHENE	100
TRICHLOROETHENE	3

**LEGEND**

- S9MW1 ● MONITORING WELL LOCATION
- < DL LESS THAN DETECTION LIMIT
- TOTAL 1,2-Dichloroethene CONTOUR
- - - - ESTIMATED TOTAL 1,2-Dichloroethene CONTOUR

~ ALL APPLICABLE RELEVANT AND APPROPRIATE REQUIREMENTS (ARAR'S) AND SCREENING ACTION LEVELS (SAL'S) are from the BRAC SI Workplan.

**NOTE:**  
All concentrations are in ug/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

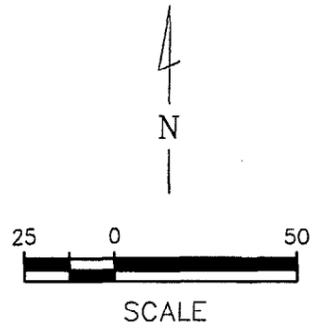
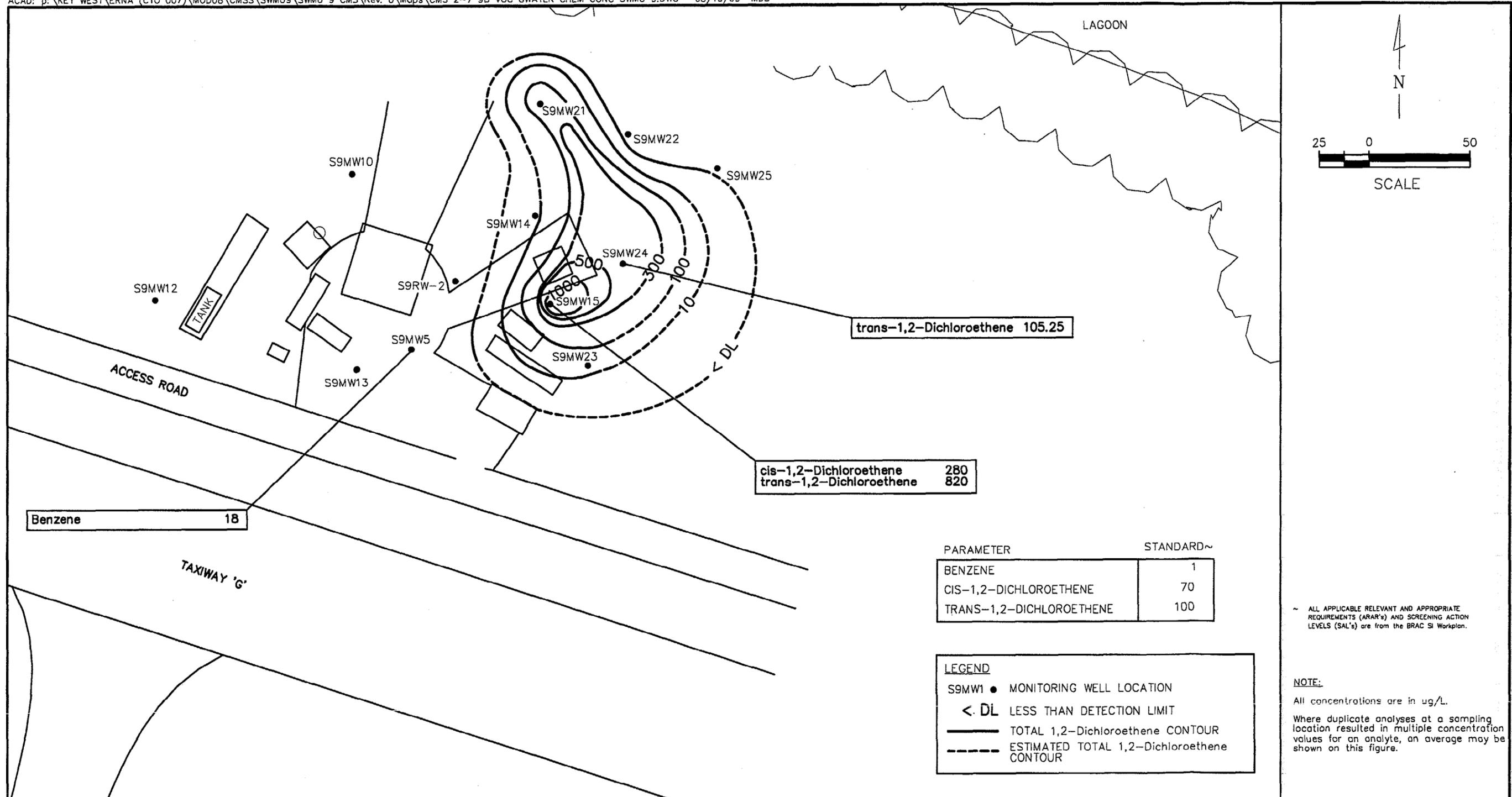
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MDB 1/22/99  
CHECKED BY DATE  
DSF 1/26/99  
COST/SCHED-AREA  
SCALE  
AS NOTED



**CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9**  
**FIGURE 2-7. MAY 1998 VOC GROUNDWATER**  
**CHEMICAL CONCENTRATIONS, SWMU 9**  
**NAVY SOUTHERN DIVISION**  
**BOCA CHICA KEY, FLORIDA**

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ACAD: p:\KEY WEST\ERNA (CTO 007)\MOD08\CMSS\SWMU9\SWMU 9 CMS\Rev. 0\Maps\CMS 2-7 9B VOC GWATER CHEM CONC SWMU 9.DWG 08/10/99 MDB



PARAMETER	STANDARD~
BENZENE	1
CIS-1,2-DICHLOROETHENE	70
TRANS-1,2-DICHLOROETHENE	100

**LEGEND**

- S9MW1 ● MONITORING WELL LOCATION
- < DL LESS THAN DETECTION LIMIT
- TOTAL 1,2-Dichloroethene CONTOUR
- - - - ESTIMATED TOTAL 1,2-Dichloroethene CONTOUR

~ ALL APPLICABLE RELEVANT AND APPROPRIATE REQUIREMENTS (ARAR's) AND SCREENING ACTION LEVELS (SAL's) are from the BRAC SI Workplan.

**NOTE:**  
All concentrations are in ug/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY  
MDB

CHECKED BY  
DSF

COST/SCHED-AREA

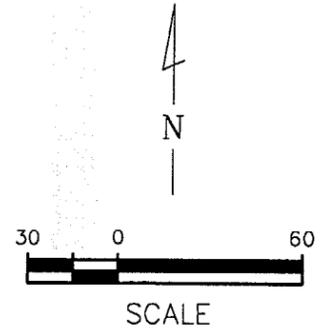
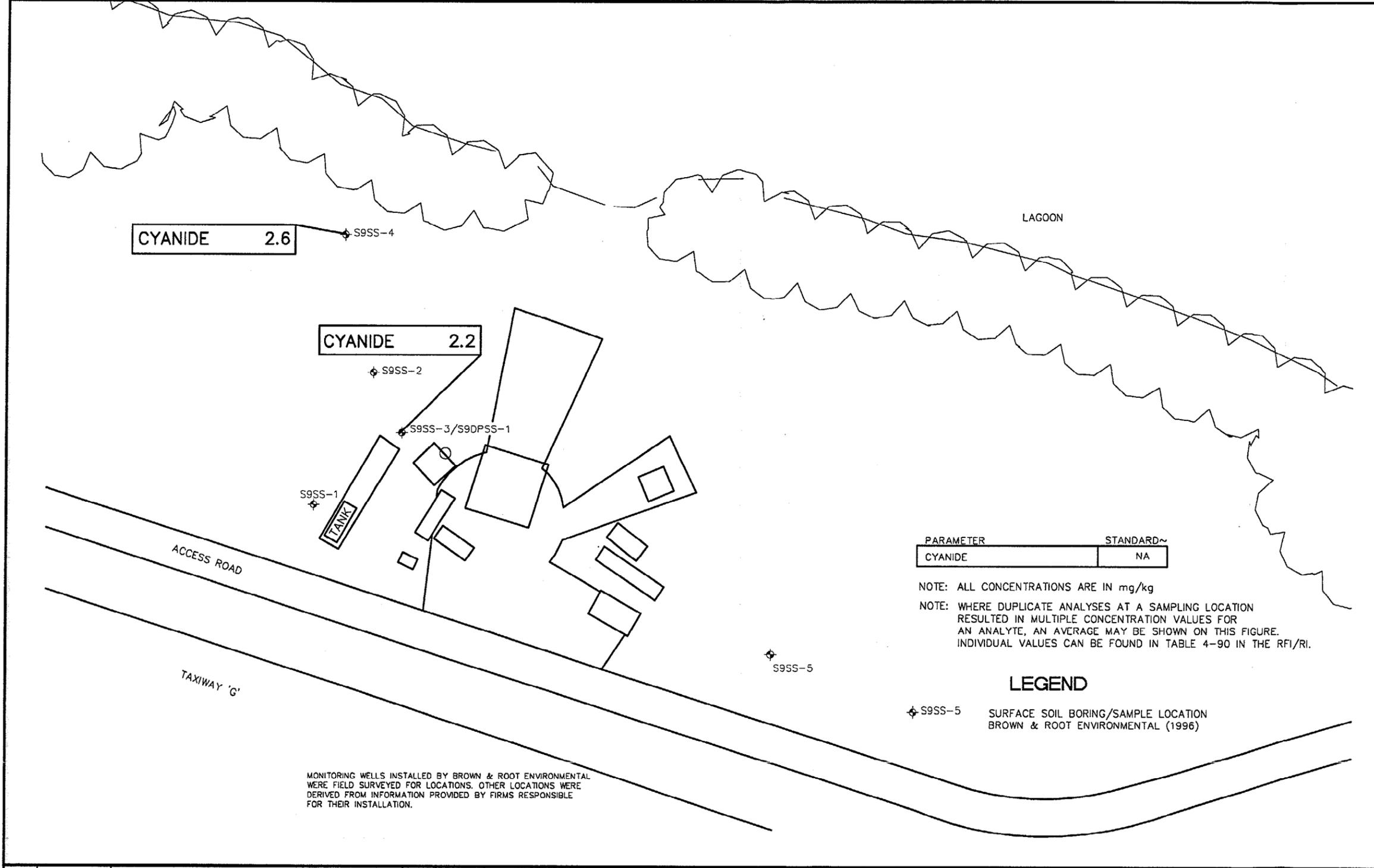
SCALE  
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**CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9**  
**FIGURE 2-8. NOVEMBER 1998 VOC GROUNDWATER**  
**CHEMICAL CONCENTRATIONS, SWMU 9**  
**NAVY SOUTHERN DIVISION**  
**BOCA CHICA KEY, FLORIDA**

CONTRACT NO. 7046	
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ACAD: p:\KEY WEST\ERNA (CTO 007)\MOD08\CMSS\SWMU9\SWMU 9 CMS\REV. 1\MAPS\CMS 2-1 THRU 2-12.DWG 08/10/99 MDB



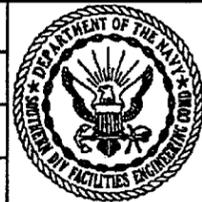
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

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DSF —

COST/SCHED-AREA

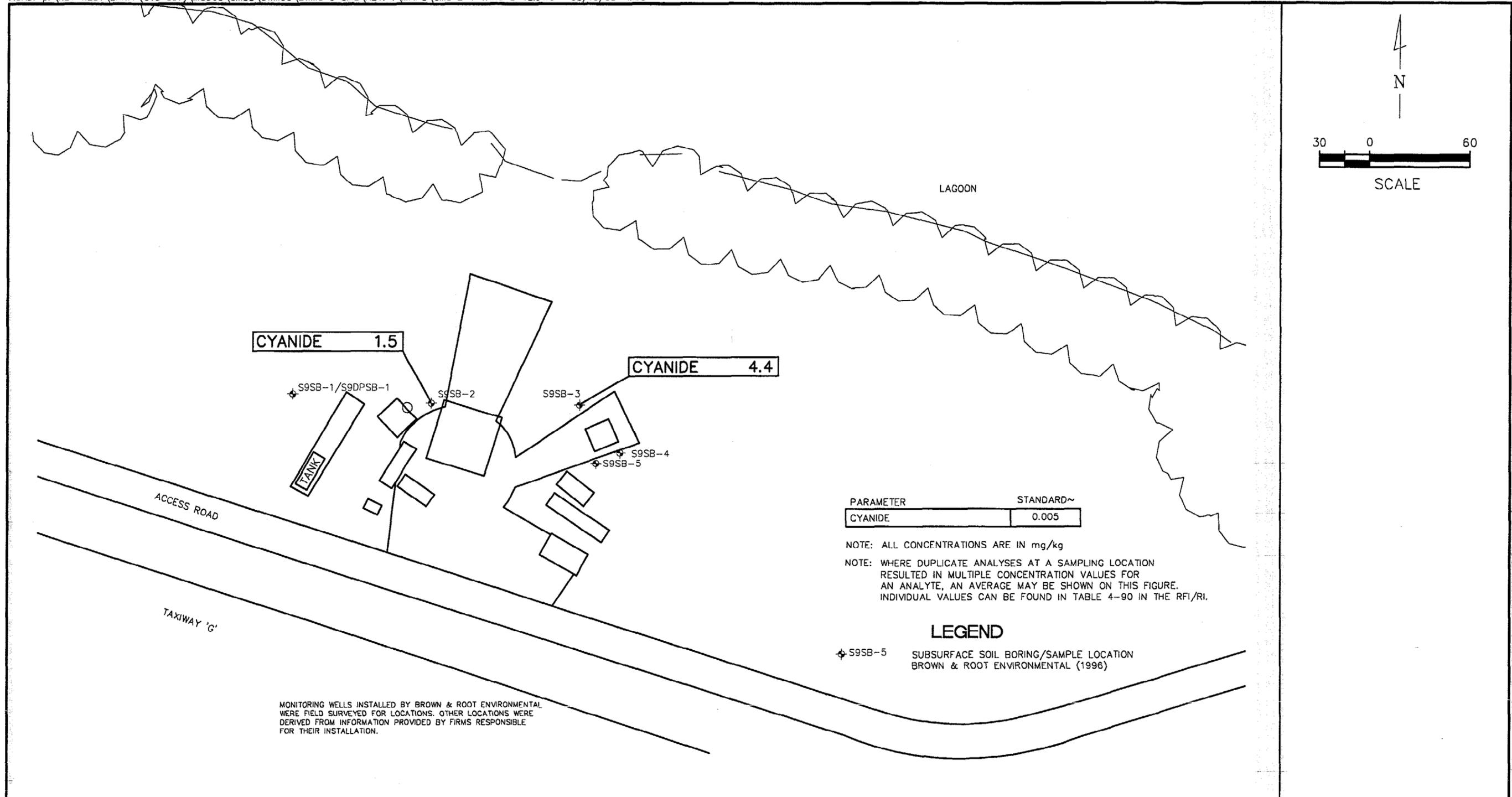
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**CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9**  
**FIGURE 2-9. SURFACE SOIL CHEMICAL**  
**CONCENTRATIONS, SWMU 9**  
**NAVY SOUTHERN DIVISION**  
**BOCA CHICA KEY, FLORIDA**

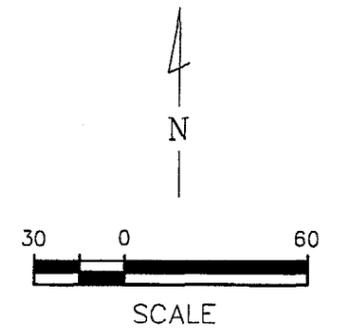
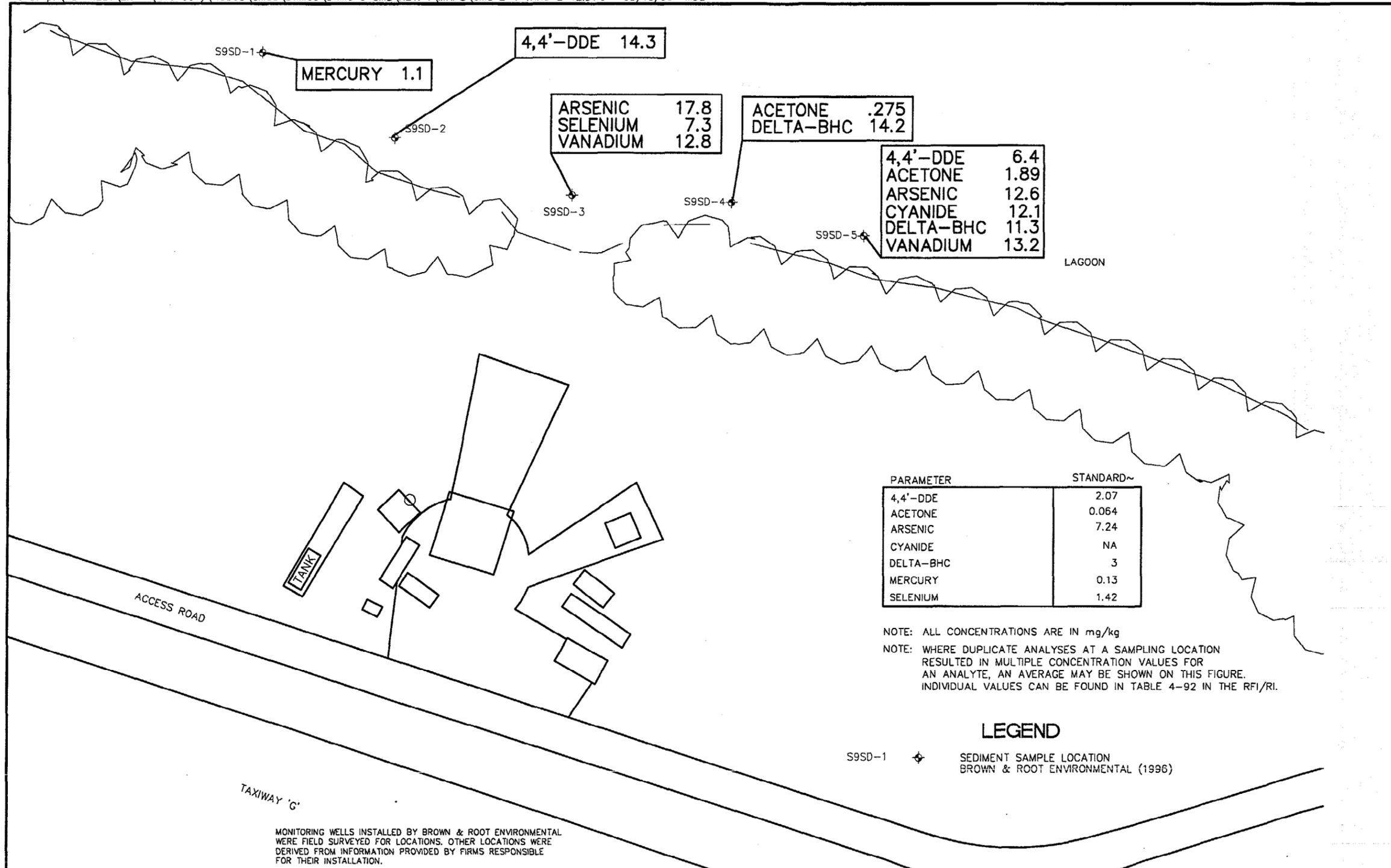
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NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	DRAWN BY	DATE		CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9		CONTRACT NO. 7046	
							MDB			FIGURE 2-10. SUBSURFACE SOIL CHEMICAL CONCENTRATIONS, SWMU 9		APPROVED BY	DATE
							DSF			NAVY SOUTHERN DIVISION		APPROVED BY	DATE
							COST/SCHED-AREA			BOCA CHICA KEY, FLORIDA		DRAWING NO.	REV. 1
							SCALE AS NOTED						

ACAD: p:\KEY WEST\ERNA (CTO 007)\MOD08\CMSS\SWMU9\SWMU 9 CMS\REV. 1\MAPS\CMS 2-1 THRU 2-12.DWG 08/10/99 MDB



PARAMETER	STANDARD~
4,4'-DDE	2.07
ACETONE	0.064
ARSENIC	7.24
CYANIDE	NA
DELTA-BHC	3
MERCURY	0.13
SELENIUM	1.42

NOTE: ALL CONCENTRATIONS ARE IN mg/kg  
NOTE: WHERE DUPLICATE ANALYSES AT A SAMPLING LOCATION RESULTED IN MULTIPLE CONCENTRATION VALUES FOR AN ANALYTE, AN AVERAGE MAY BE SHOWN ON THIS FIGURE. INDIVIDUAL VALUES CAN BE FOUND IN TABLE 4-92 IN THE RFI/RI.

**LEGEND**

S9SD-1 SEDIMENT SAMPLE LOCATION  
BROWN & ROOT ENVIRONMENTAL (1996)

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

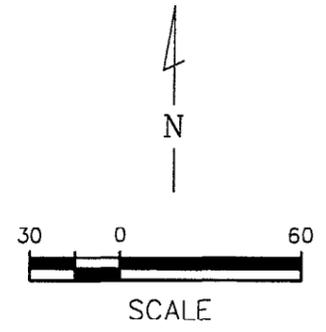
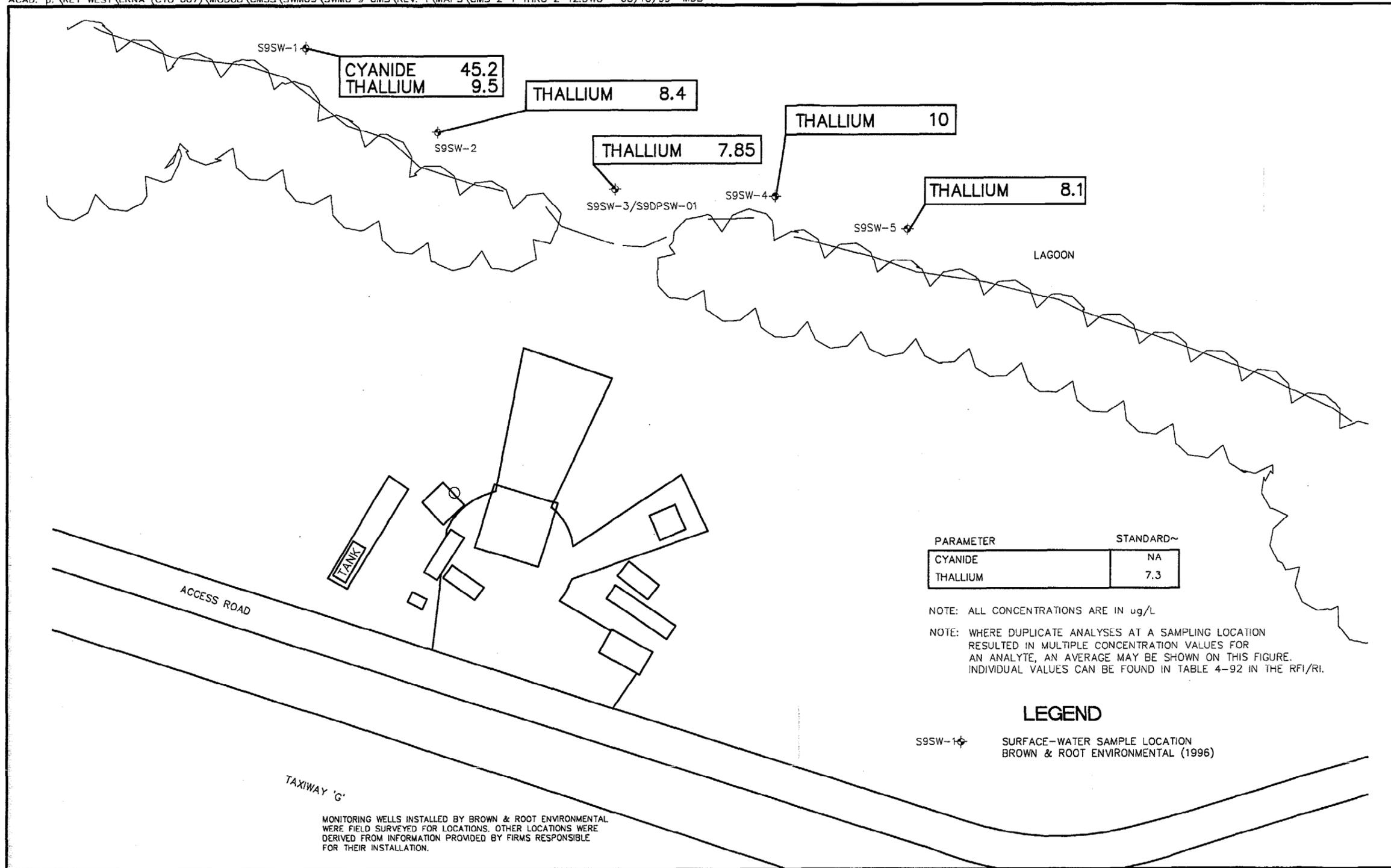
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SCALE: AS NOTED



**CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9**  
**FIGURE 2-11. SEDIMENT CHEMICAL CONCENTRATIONS, SWMU 9**  
**NAVY SOUTHERN DIVISION**  
**BOCA CHICA KEY, FLORIDA**

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NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

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 CHECKED BY: DSF      DATE: —  
 COST/SCHED-AREA: —  
 SCALE: AS NOTED



CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9  
 FIGURE 2-12. SURFACE-WATER CHEMICAL  
 CONCENTRATIONS, SWMU 9  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA

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### **3.0 CORRECTIVE ACTION OBJECTIVES**

The following section describes the development of the proposed CAOs for the NAS Key West SWMU 9, Boca Chica Jet Engine Test Cell, Building A-969. These CAOs and media clean-up standards are based on promulgated Federal and State of Florida requirements, risk-derived standards, data and information gathered during the previous investigations, the IRA (BEI, 1998), the Supplemental RFI/RI (B&R Environmental, 1997), and additional applicable guidance documents. The development of the CAOs included the consideration of cross-media concentrations, which are concentrations in one media that are protective of the migration of contaminants into another media. The cross-media evaluation utilized modeling to determine the groundwater contaminant fate and transport.

#### **3.1 INTRODUCTION**

CAOs are developed for each site as media-specific and contaminant-specific objectives that will result in the protection of human health and the environment. The development of CAOs for a SWMU or a group of SWMUs is based on human health and environmental criteria, information gathered during the Supplemental RFI/RI (B&R Environmental, 1997), USEPA guidance, and applicable Federal and state regulations. Typically, CAOs are developed based on promulgated standards, background concentrations determined from a site-specific investigation and human health and ecological risk-based concentrations developed in accordance with the USEPA risk assessment guidance. The Supplemental RFI/RI (B&R Environmental, 1997) presents a complete description of the nature and extent of contamination, contaminant fate and transport, baseline HHRA, and ERA. This section includes a discussion of the ARARs for SWMU 9, development of the RGOs, the development of the CAOs for SWMU 9, and determination of the volume of the contaminated medium.

#### **3.2 ARARS, MEDIA OF CONCERN, AND COCS**

##### **3.2.1 ARARs**

##### **3.2.1.1 Introduction**

The ARARs, which include the requirements, criteria, or limitations promulgated under the Federal and state law that address a contaminant, action, or location at a site, are presented in this section.

A definition of an ARAR is as follows:

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

One of the primary concerns during the development of corrective action alternatives for hazardous waste sites under RCRA is the degree of human health and environmental protection afforded by an alternative.

Definitions of the two types of ARARs, as well as other To Be Considered (TBC) criteria, are given below:

- Applicable Requirements means those clean-up standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that directly and fully address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.
- Relevant and Appropriate Requirements means those clean-up standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that, while not "applicable," address problems or situations sufficiently similar (relevant) to those encountered at the CERCLA site that their use is well suited (appropriate) to the particular site.
- TBC Criteria are non-promulgated, non-enforceable guidelines or criteria that may be useful for developing remedial actions or necessary for determining what are protective of human health and/or the environment. Examples of TBC criteria include USEPA Drinking Water Advisories, Carcinogenic Potency Factors, and Reference Doses.

These requirements are included in order to provide the decision-makers with a complete evaluation of potential ARARs in developing, identifying, and selecting a corrective measure alternative.

### **3.2.1.2 ARAR and TBC Categories**

ARARs fall into three categories, based on the manner in which they are applied:

- **Chemical Specific:** Health/risk-based numerical values of methodologies that establish concentration or discharge limits for particular contaminants. Examples of contaminant-specific ARARs include MCLs and Clean Water Act (CWA) water quality criteria. Contaminant-specific ARARs govern the extent of site clean up.
- **Location Specific:** Restrictions based on the concentration of hazardous substances or the conduct of activities in specific locations. These may restrict or preclude certain remedial actions or may apply only to certain portions of a site. Examples of location-specific ARARs include RCRA location requirements and floodplain management requirements. Location-specific ARARs pertain to special site features.
- **Action Specific:** Technology- or activity-based controls or restrictions on activities related to management of hazardous waste. Action-specific ARARs pertain to implementing a given remedy.

Table 3-1 presents a summary of potential Federal and state ARARs and TBCs for corrective measures undertaken for SWMU 9 at NAS Key West.

### **3.2.1.3 Chemical-Specific ARARs and TBCs**

This section presents a summary of Federal and state criteria for contaminant-specific ARARs of potential concern in the case of SWMU 9. The ARAR criteria provide medium-specific guidance on "acceptable" or "permissible" concentrations of contaminants.

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 inorganic and organic compounds in drinking water. MCLGs are set at levels 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 levels above zero shall be attained by remedial actions for groundwaters or surface waters 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  $1 \times 10^{-4}$ , 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 complete elimination of risk is not possible and because "true zero" cannot be detected.

U.S. Environmental Protection Agency Ambient Water Quality Criteria (AWQC) of the CWA are non-enforceable guidelines developed for pollutants in surface waters pursuant to Section 304(a)(1) of the CWA. However, AWQC are not legally enforceable and should be considered as potential ARARs. AWQC 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. AWQC may be considered for actions that involve groundwater treatment and/or discharge to nearby surface waters.

Proposed RCRA Action Levels (40 CFR Part 264) define the chemical concentrations in a media that could make that media a RCRA listed waste. Any media contaminated at or above these levels could be considered hazardous waste and should be managed, transported, and disposed of in accordance with Federal RCRA requirements. Because of the regulatory status of these proposed action levels, they are only "To Be Considered".

Biological Technical Assistance Group (BTAG) Screening Levels (USEPA Region III, 1995b), Oak Ridge National Laboratory Benchmark Toxicity Values (Will & Suter, 1994) and Florida RGOs (FDEP, 1995a and 1996) are published listings of ARARs and SALs for soils.

FDEP Sediment Quality Guideline (FDEP, 1994), USEPA Region IV Sediment Screening Values (EPA, 1995c), Federal Sediment Quality Screening Values (USEPA, 1996) and USEPA Sediment Quality Benchmark (USEPA, 1995d) are published listings of ARARs and SALs for sediments.

Florida Surface Water Quality Standards (Chapter 62-302 F.A.C.), USEPA Region IV Chronic Surface Water Screening Values (USEPA, 1995a), National AWQC, USEPA Region III Marine Standards (USEPA, 1995d) and USEPA Region III Fresh Water Standards (USEPA, 1995a) are published listing of ARARs and SALs for sediments.

Florida Drinking Water Standards for Monitoring and Reporting (Chapter 62-550 F.A.C.) set forth drinking water quality standards at least as stringent as the National Primary Drinking Water Regulations. MCLs that are promulgated by USEPA are automatically incorporated into the Florida SDWA. If an MCL does not exist for a contaminant, the Florida SDWA requires that no contaminant that creates or has the potential to create an imminent and substantial danger to the public shall be introduced into the public water system.

Brownfields Cleanup Criteria Rule (Chapter 62-785 F.A.C.) establishes standards for soil, sediment, surface water, and groundwater. The criteria are still in draft form, but is expected to become finalized this year.

Since the groundwater at SWMU 9 is brackish and classified as G-III (nonpotable water) by FDEP, the Florida SDWA is neither applicable nor relevant and appropriate.

#### **3.2.1.4 Location-Specific ARARs and TBCs**

This section presents a summary of Federal and state location-specific ARARs criteria in the case of SWMU 9. The ARAR criteria provide medium-specific guidance on "acceptable" or "permissible" concentrations of contaminants.

Federal Protection of Wetlands Executive Order (E.O. 11990) 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 (unless there is no practical alternative to that construction); minimizing the harm to wetlands (if the only practical alternative requires construction in the wetlands); and providing early and adequate opportunities for public review of plans involving new construction in wetlands.

Corrective measures at SWMU 9 may impact regulated wetland areas. Permits from both the State of Florida and the U.S. Army Corps of Engineers will be required if any corrective measures impact regulated wetland areas.

The Endangered Species Act of 1978 (16 USC 1531) (40 CFR Part 502) 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 ensure 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 several endangered species have been seen on base and therefore this act would apply.

The Fish and Wildlife Coordination Act (16 USC 661) provides for consideration of the impact 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.

The Fish and Wildlife Improvement Act of 1978 (16 USC 742a) and The Fish and Wildlife Conservation Act of 1980 (16 USC 2901) require consideration of the impacts on wetlands and protected habitats.

Florida Surface Waters of the State (Chapter 62-301 F.A.C.) and Florida Delineation of Landward extent of Wetlands and Surface Waters (Chapter 62-340 F.A.C.) define and provide the delineation methodology for determining the extent of surface waters and wetlands. SWMU 9 has a direct connection to the open ocean (the Gulf of Mexico).

Florida Groundwater Classes, Standards, and Exemptions (Chapter 62-520 F.A.C.) provides for the designation of the present and future most beneficial uses of all the groundwaters in the state by means of a classification system. The state classification of the groundwater at Boca Chica Key is Class G-III (nonpotable water), which is water in an unconfined aquifer that has a total dissolved solids content of 10,000 milligrams per liter or greater.

### **3.2.1.5 Action-Specific ARARs and TBCs**

This section presents a summary of Federal and state action-specific ARARs criteria of potential concern in the case of SWMU 9. The ARAR criteria provide medium-specific guidance on "acceptable" or "permissible" concentrations of contaminants.

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 (i.e., soil is found to be Toxicity Characteristic Leaching Process (TCLP) characteristic).

- 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 CERCLA site constitutes current treatment, storage, or disposal as defined by RCRA.

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 the site. RCRA Subtitle C requirements may also be relevant and appropriate when the corrective action constitutes generation of a hazardous waste. All RCRA Subtitle C requirements must be met if the cleanup is not under Federal order and/or when the hazardous waste moves off site.

An exemption from the hazardous waste rules is provided for wastewater treatment units that are tank systems discharging via regulated outfalls (40 CFR 264.1(g)(6), 40 CFR 261.10). An exclusion from permitting is provided for such facilities under 40 CFR 270.1(c)(2)(4) for owners and operators of wastewater treatment units.

The following requirements included in the RCRA Subtitle C regulations may pertain to the NAS Key West:

- 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 TSDFs (40 CFR part 264).
- Interim status standards for owners and operators of hazardous waste TSDFs (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, placarding), record keeping, and reporting requirements. The standards are applicable to actions taken at NAS Key West that constitute generation of hazardous waste (e.g., generation of water treatment residues or excavation of contaminated soils and/or sediments that may be hazardous).

Standards Applicable to Transporters of Hazardous Waste (40 CFR part 263) are applicable to off-site transportation of hazardous waste from NAS Key West. These regulations include requirements for compliance with the manifest and record keeping systems and requirements for immediate action and clean up of hazardous waste discharges (spills) during transportation.

Standards and Interim Status Standards for Owners and Operators of hazardous Waste TSDFs (40 CFR Parts 264 and 265) are applicable to remedial actions taken at NAS Key West and to off-site facilities that receive hazardous waste from the site for treatment and/or disposal and have a RCRA Part B permit. On-site facilities must also have a RCRA Part B permit if the site is not a Federally ordered CERCLA clean up. Standards for TSDFs include requirements for preparedness and prevention, releases from SWMUs (i.e., corrective action requirements), closure and post-closure care, use and management of containers, design and operating standards for tank systems, surface impoundments, waste piles, landfills, and incinerators.

RCRA LDR Requirements (40 CFR Part 268) restrict certain wastes from being placed or disposed on the land unless they meet specific BDAT treatment standards (expressed as concentrations, total or in the TCLP extract, or as specified technologies).

RCRA Criteria for Classification of Solid Waste Disposal Facilities and Practices (40 CFR Part 257) establish criteria for use in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health and thereby constitute prohibited open dumps.

Department of Transportation (DOT) Rules for Hazardous Materials Transport (49 CFR Parts 107 and 171-179) regulate the transport of hazardous materials, including packaging, shipping equipment, and placarding. These rules are considered applicable to wastes shipped off site for laboratory analysis, treatment, or disposal.

National Environmental Policy Act (NEPA) (40 CFR Part 6) requires consideration of potential environmental impacts at NAS Key West of corrective measure actions on wetlands and endangered species.

The CWA, as amended, governs point-source discharges through the National Pollutant Discharge Elimination System (NPDES), discharge, dredge, or fill material and oil and hazardous waste spills to United States waters. NPDES requirements (40 CFR Part 122) will be applicable if the direct discharge of pollutants into surface waters is part of the remedial action.

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

Florida Hazardous Waste Regulations (Chapter 62-730 F.A.C.) essentially parallel RCRA Subtitle C hazardous waste management regulations. Similar to RCRA Subtitle C regulations, Florida regulations include requirements for the following:

- Generators of hazardous waste (Chapter 262)
- Transporters of hazardous waste (Chapter 263)
- New and existing hazardous waste management facilities applying for a permit (Chapter 264)
- Interim status hazardous waste management facilities applying for a permit (Chapter 265)

The above regulations may be relevant and appropriate to on-site remedial actions and applicable to the transport of hazardous waste off site.

Florida Pretreatment Requirements for Existing and New Sources of Pollution (Chapter 62-730 F.A.C.) implements the pretreatment requirements and establishes a State NPDES permit program. These rules may be applicable for corrective measures involving a discharge to surface water.

Land Use Restrictions at Environmental Remediation Sites on board U.S. Navy Installations (CNBJAXINST 5090.2N4) establishes a systematic program to govern land use at environmental remediation sites at U.S. Navy Installations.

The Clean Air Act (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), National Emission Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR Part 61), and New Source Performance Standards (NSPS) (40 CFR Part 60). 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 NAS Key West because they were developed for a specific source.

USEPA requires the attainment and maintenance of primary and secondary NAAQS to protect public health and public welfare, respectively. These standards are not source specific but rather are national limitations on ambient air quality. States are responsible for assuring compliance with the NAAQS. Requirements in the USEPA-approved State Implementation Plan (SIP) for the implementation, maintenance, and enforcement of NAAQS are potential ARARs.

NSPS are established for new sources of air emissions to ensure 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 (BDAT).

Florida State Implementation Plan (Chapter 62-204 F.A.C.) establishes maximum allowable levels of pollutants in the ambient air necessary to protect human health and public welfare and maximum allowable increases in ambient concentrations for subject pollutants to prevent significant deterioration of air quality. It provides three general classifications for determining which set of prevention of significant deterioration increments apply.

### **3.2.2                    Media of Concern**

Based on results of the Supplemental RFI/RI (B&R Environmental, 1997) and previous investigations conducted at SWMU 9 involving the HHRAs and ERAs, the contaminated medium at SWMU 9 was determined to be groundwater. Sediment and surface water were eliminated as media of concern based on toxicity tests, which indicate that potential risks to aquatic receptors in the inlet appear to be low (B&R Environmental, 1997).

Although groundwater at SWMU 9 contains several chemicals at concentrations above background, it is not a current or potential drinking water source. As a result, it was not considered as a media of concern in the Supplemental RFI/RI HHRA. Although ecological receptors are not directly exposed to groundwater, the potential for ecological risks from future groundwater contaminant migration to surface water or sediment cannot be totally ruled out, despite the potential for some dilution on discharge to surface water. For this reason, groundwater is the medium of concern at SWMU 9.

### **3.2.3                    Chemicals of Concern**

The nature and extent of contamination for SWMU 9 were determined in the Supplemental RFI/RI (B&R Environmental, 1997) and the Natural Attenuation Evaluation (TtNUS, 1999b) by analyzing samples from surface and subsurface soil, sediment, surface water, and groundwater in the vicinity of

the Jet Engine Test Cell. At SWMU 9, no human health COCs were selected for RGO analysis because in no instance did any receptor scenarios in the HHRA have a total risk (combined across pathways) exceeding a level of concern ( $1 \times 10^{-4}$  cancer risk or HI of 1.0).

The ERA also evaluated potential concerns associated with contamination in soil. A summary of the Supplemental RFI/RI ERA was provided in Section 2.6 of the CMS. Ecological COCs are presented for each medium in this section. Tables 2-2 through 2-5 list the ecological COCs presented in the ERA. Since the RFI/RI, new action levels have been adopted by the Partnering Team. These new action levels are included in Appendix B of the Site Inspection (SI) Workplan for Ten BRAC Properties (B&R, 1998), and will be used in selecting and eliminating ecological COCs in the CMS. Industrial/commercial action levels will apply to soil contamination.

#### **3.2.3.1 Soil**

Several inorganics were retained as ecological COCs in soil in the RFI/RI because their respective HQs exceeded 1.0. These inorganics include aluminum, chromium, cyanide, mercury, and zinc. However, because action levels from the BRAC SI Workplan (B&R Environmental, 1998) are now being used, cyanide is the only contaminant in excess of its action levels. Cyanide was detected in two of the five samples taken, and had an HQ (520) indicative of potentially high risk to terrestrial receptors. However, the presence of cyanide is not believed to be a result of activities at SWMU 9. Furthermore, the risk of cyanide to terrestrial receptors is largely mitigated by the overall lack of terrestrial habitat at this site. For these reasons, cyanide will be eliminated as an ecological COC and no ecological COCs will be retained for soil at SWMU 9.

#### **3.2.3.2 Sediment**

The ERA evaluated risk associated with contamination in sediment at SWMU 9. Table 2-4 In Section 2.5 of this CMS lists the ecological COCs for sediment presented in the Supplemental RFI/RI (B&R Environmental, 1997). As discussed, new action levels that have been established for sediment in the BRAC SI Report (TtNUS, 1999a) will apply to contamination at SWMU 9. However, no COCs can be eliminated in sediment based on the new action levels. Cyanide, mercury, and selenium were detected in one of five samples. Methyl parathion, selenium, and vanadium were retained as ECCs because no suitable threshold was available. Other ECCs include arsenic, 4,4'-DDE, delta-BHC, and acetone, which were detected in two of five sediment samples. In toxicity tests conducted with surface water and sediment taken from the inlet adjacent to the site, the survival and growth of mysid shrimp, the fertilization and development of mussel larvae, and sea urchin fertilization were similar to the results in the control (B&R Environmental, 1997). The survival of laboratory control minnows was

high (100 percent); therefore, the slightly reduced survival in one sample in the silverside minnow toxicity tests is not believed to be a treatment effect. In summary, the toxicity tests indicate that the potential risks to aquatic receptors in the inlet appear to be low. Therefore, no ecological COCs will be retained for sediment at SWMU 9.

### **3.2.3.3 Surface Water**

Figure 2-10 in Section 2.3.3 shows chemicals detected in excess of action levels in surface water. The ecological assessment evaluated risk associated with contamination in surface water at SWMU 9. Table 2-3 in Section 2.5 lists the ecological COCs identified in the Supplemental RFI/RI (B&R Environmental, 1997). Cobalt, cyanide, and thallium were selected as COCs. However, cobalt was retained as a COC because no suitable threshold was available. An action level of 35,000 mg/kg was established in the BRAC SI Report (TtNUS, 1999a) and will be used in the CMS. Therefore, cobalt is eliminated as a COC because it does not exceed its action level. Cyanide was detected in one of five samples. The presence of cyanide is not believed to be a result of activities at SWMU 9. Thallium was detected in all samples, but only one detection exceeded two times the background concentration. As with sediment, surface water toxicity tests conducted at this site indicated normal survival and growth (B&R Environmental, 1997). The toxicity tests indicate that potential risks to aquatic receptors in the inlet appear to be low. Therefore, no COCs from surface water will be retained for ecological risk evaluation in the CMS for SWMU 9.

### **3.2.3.4 Groundwater**

Figures 2-3 through 2-7 in Section 2.3.1 of this CMS present groundwater chemical concentrations for contaminants in excess of action levels. Although groundwater is not a current drinking water source and is unlikely to be designated as one in the future, chemicals above the drinking water standards and ecological COCs were identified for fate and transport modeling. The development of groundwater RGOs through modeling is discussed further in Section 3.3. Following is a discussion of groundwater COCs resulting from the ERA.

Groundwater was not evaluated as part of the baseline HHRA because it is classified as Class G-III, nonpotable water by the FDEP, as summarized in Section 2.4. The surficial aquifer is the principal aquifer of concern at NAS Key West because of the potential groundwater-to-surface water contaminant migration pathway. Groundwater from the surficial aquifer at Key West has a high salinity and is unsuitable for drinking, as documented in a 1980 groundwater quality sampling study by the United States Geological Survey (USGS) (ABB, 1995b). The Monroe County Health Department recognizes the public water supply obtained from the mainland as the only potable water

source available on Key West (B&R Environmental, 1997). Even though the groundwater is not used as potable water, the groundwater concentrations at SWMU 9 were compared to Tap Water RBCs (EPA, 1996) and MCLs (EPA, 1995c) for comparison purposes. These comparisons can be found in Table 2-6 of the Supplemental RFI/RI (B&R Environmental, 1997).

The ERA evaluated risk associated with contamination in groundwater at SWMU 9. Table 2-2 in Section 2.5 lists the ecological COCs identified in the Supplemental RFI/RI. Several inorganics were retained as ecological COCs including barium, cyanide, lead, selenium, and silver. However, based on updated action levels developed during the BRAC SI, all inorganics detected in groundwater can be eliminated as ecological COCs in the CMS.

The pesticides detected in SWMU 9 groundwater include 4,4'-DDT, dieldrin, and endrin. Endrin can be eliminated as an ecological COC based on its new action level of 2 µg/L. 4,4'-DDT was detected at 0.26 µg/L in one of eight samples. The updated action level for 4,4'-DDT is 0.2 µg/L. Because 4,4'-DDT has a low frequency of detection and is barely above its action level, it will be eliminated as a COC in the CMS. Although dieldrin did exceed its action level, it was only detected in one of eight samples. This low frequency of detection is reason to eliminate dieldrin as an ecological groundwater COC in the CMS.

SVOCs selected as COCs in groundwater in the RFI/RI include 1-methylnaphthalene, 2-methylnaphthalene, bis(2-ethylhexyl)phthalate, chlorodibromomethane, and naphthalene. However, as determined during the SI Report for Nine BRAC Parcels (TtNUS, 1999a), ecological risks calculated for naphthalene compounds have been determined to be negligible. Therefore, FDEP no longer has established action levels for naphthalene, 1-methylnaphthalene, or 2-methylnaphthalene. Detections of these chemicals will not be considered exceedances at NAS Key West, and they will be eliminated as COCs for groundwater at SWMU 9. Although its HQ was originally high (30) in the RFI/RI, the new action level established for bis(2-ethylhexyl)phthalate (6 µg/L) lowers it to approximately 1.3 and since the frequency of detection was also low (1/8), bis(2-ethylhexyl)phthalate will not be retained as an ecological COC.

A large number of VOCs were retained as ecological COCs in the RFI/RI. However, based on the action levels used during the BRAC SI, several of these can be eliminated. 2-butanone, 2-hexanone, 4-methyl-2-pentanone, acetone, bromodichloromethane, carbon disulfide, chloroethane, dibromochloromethane, styrene, and xylenes (total) will be eliminated as COCs based on the current action levels in use at NAS Key West. In addition, any COCs in the RFI/RI that were not detected above action levels in the May or November 1998 sampling events will be eliminated as COCs. In May 1998, cis-1,2-dichloroethene, trans-1,2-dichloroethene, acrylonitrile, TCE, and benzene were

detected above action levels. In November 1998, only benzene, cis-1,2-dichloroethene, and trans-1,2-dichloroethene were detected above action levels. Due to these selected VOC exceedances in 1998, the following VOCs will be eliminated as COCs in the CMS: 1,1,2,2-tetrachloroethane, 1,1-chloroethene, 1,2-dichloroethane, 1,2-dichloropropane, bromomethane, chloromethane, isopropyl alcohol, tetrachloroethene, trichlorofluoromethane, vinyl acetate, and vinyl chloride. Acrylonitrile was detected in the May 1998 sampling event but was only detected in one well and will not be listed as a COC in the CMS. The following chemicals will be retained as groundwater COCs in the CMS:

- **VOCs:** cis-1,2-dichloroethene, trans-1,2-dichloroethene, trichloroethene, and benzene.

### 3.3 REMEDIAL GOAL OPTIONS (RGOS)

RGOs are developed to ensure that contaminant concentration levels remaining at the site are at levels that are protective of human health and the environment. Human health RGO development calculations were not necessary in this CMS since no human health COCs were identified in the RFI/RI. RGOs are established to:

- Protect the environment from detrimental impacts from site-related contaminants
- Comply with Federal and state ARARs

In order to evaluate and develop RGOs for groundwater which are protective of sediment and surface water, predictive contaminant transport modeling was performed based on the following criteria.

- Protection of surface water based on maximum groundwater concentrations and surface-water criteria.
- Protection of sediment based on maximum groundwater concentrations and sediment criteria.

The development of cross-media RGOs by using a groundwater flow contaminant fate and transport model is presented in Appendix C.

### 3.3.1 Groundwater RGOs Protective of Surface Water and Sediment

Groundwater RGOs were determined for the groundwater COCs identified in Section 3.2. Modeling of contaminant migration from the groundwater to the surface water was performed to determine the maximum concentration of contaminants in the groundwater that will be protective of surface water.

To be protective of the sediment from groundwater, the ER-M Sediment Value for specific contaminants was used as an endpoint concentration, if available. Since the ER-M is the median of sediment concentrations associated with the biological effects, the ER-M is the point above which adverse effects are expected to be frequent (Long et al., 1995). To be protective, concentrations above the ER-M should not be allowed. The use of the ER-M as a remediation goal means that this is the maximum allowable concentration; the average exposure concentration will necessarily be lower than the maximum. Its use creates a situation in which no concentration is in the range of frequent effects, and the average is in the range where effects are more likely not to occur.

Assumptions, equations, and additional details used in developing the groundwater RGOs protective of sediment and surface water are included in Appendix C. Table 3-2 summarizes the RGOs for groundwater protective of surface water and sediment.

The groundwater ecological risk-based RGOs indicate that the current groundwater concentrations at SWMU 9 are substantially below the groundwater RGOs. The current maximum detected groundwater concentrations from November 1998 for cis-1,2-DCE, trans-1,2-DCE, and benzene are 280, 820, and 18 µg/L, respectively (Figure 2-7). TCE was not detected in the November 1998 sampling event. As discussed in Section 2.3.1, a Category 1 Hurricane (Georges) passed directly over Key West resulting in a major precipitation event in September 1998. Contaminant levels are expected to fully or partially return to levels seen prior to the hurricane (TtNUS, 1999b). In May 1998, the maximum detections of cis-1,2-DCE, trans-1,2-DCE, benzene, and TCE were 1300, 4000, 25, and 350 µg/L, respectively (Figure 2-6). Although these levels also fall below groundwater RGOs, cis-1,2-DCE and trans-1,2-DCE concentrations may increase as TCE continues to degrade. The groundwater concentrations under the source area currently are not at levels that will adversely impact the surface water or sediment at the lagoon located to the north of SWMU 9. However, since contaminant levels at SWMU 9 are likely to fluctuate, the potential for contaminants to exceed groundwater RGOs does exist. The ecological COCs for groundwater presented in Section 3.2.3.4 are retained. The ecological RGOs for the protection of surface water and sediment are presented in Table 3-2. The mechanisms/processes affecting chemical fate and transport in groundwater that were accounted for during the modeling include sorption, dilution, advection, dispersion, and chemical/biological decay.

### 3.4 CORRECTIVE ACTION OBJECTIVES

Site-specific CAOs specify COCs, media of interest, exposure pathways, and clean-up goals or acceptable contaminant concentrations. CAOs may be developed to permit consideration of a range of treatment and containment alternatives. This CMS addresses groundwater contamination within SWMU 9. To protect the public from potential and current future health risks, as well as to protect the environment, the following CAOs have been developed for SWMU 9 groundwater to address the primary exposure pathways.

- Prevent the migration of groundwater contaminants to the lagoon (surface water and sediment) to protect ecological receptors.
- Comply at SWMU 9 with contaminant-specific, location-specific, and action-specific Federal and State ARARs.

The RGOs that would attain these objectives have been discussed in Section 3.3.

### 3.5 VOLUMES OF CONTAMINATED MEDIA

The volume of contaminated groundwater was estimated based on a comparison of the RGOs and CAOs defined in Sections 3.3 and 3.4 respectively, using a standard engineering practice. The values and assumptions used in estimating the volume of contaminated groundwater are presented in this section.

#### 3.5.1 Contaminated Groundwater

The volume of contaminated groundwater is based on plume area, plume thickness, and porosity of the soil. The plume area is assumed to be rectangular. Based on the May 1998 plume size (Figure 2-6), the estimated rectangular plume size is 250 feet by 200 feet (50,000 square feet). Plume thickness was calculated at 27 feet in groundwater modeling conducted for SWMU 9 (Appendix C). An effective porosity of 0.3 was incorporated from the Supplemental RFI/RI Report (B&R Environmental, 1997). The effective porosity of the soil is the porosity available for fluid flow (Fetter, 1994). The total volume of contaminated groundwater is calculated by multiplying the total plume volume by the effective porosity.

The total volume of contaminated groundwater is estimated to be 375,000 cubic feet or  $2.8 \times 10^6$  gallons. The table below depicts the calculations conducted for contaminated groundwater.

Length (feet)	Width (feet)	Thickness (feet)	Effective Porosity	Volume of Contaminated Groundwater (cubic feet)	Volume of Contaminated Groundwater (gallons)
250	200	25	0.3	375,000	$2.8 \times 10^6$

TABLE 3-1

**POTENTIAL ARARs AND TBCs  
CORRECTIVE MEASURE STUDY FOR SWMU 9  
NAS KEY WEST, BOCA CHICA KEY, FLORIDA  
PAGE 1 OF 3**

Chemical-Specific Requirements	Rationale
Clean Water Act (33 USC 1251-1376) Federal Ambient Water Quality Criteria (AWQCs) (40 CFR Part 50)	Surface-water and fish samples have shown contamination. Corrective measures may result in surface-water discharges that could further impact aquatic life.
Threshold Limit Values, American Conference of Government Industrial Hygienists	May be applicable to air concentrations during implementation of corrective measures.
Proposed RCRA Action Levels (40 CFR Part 264)	Corrective measures may be driven by reducing chemical concentrations in any or all of the media at SWMU 9 to meet the Action Levels.
Benchmark Toxicity Values (USEPA Region III, 1995b)	Corrective measures may be driven by reducing chemical concentrations in the soils at SWMU 9 to meet published levels.
Oak Ridge National Laboratory Benchmark Toxicity Values (Will and Suter, 1994)	
FDEP Soil Cleanup Goals (FDEP, 1995a and 1996)	
FDEP Sediment Quality Guideline (FDEP, 1994)	Corrective measures may be driven by reducing chemical concentrations in the sediments at SWMU 9 to meet published levels.
USEPA Region IV Sediment Screening Values (EPA, 1995c)	
Federal Sediment Quality Screening Criteria (EPA, 1996a)	
USEPA Sediment Quality Benchmark (EPA, 1996a)	
Florida Surface Water Quality Standards (Chapter 62-302 F.A.C.)	
USEPA Region IV Chronic Surface Water Screening Values (EPA, 1995c)	Corrective measures may be driven by reducing chemical concentrations in the surface waters at SWMU 9 to meet published levels.
National Ambient Water Quality Standards	
USEPA Region III Marine Standards (EPA, 1995b)	
USEPA Region III Fresh Water Standards (EPA, 1995b)	
Safe Drinking Water Act MCLs (EPA, 1995a)	Corrective measures may include groundwater remediation to MCLs.
Florida Drinking Water Standards, Monitoring and Reporting (MCLs) (Chapter 62-550 F.A.C.)	
Florida Department of Environmental Protection Guidance (FDEP, 1989)	Corrective measures may include clean up to FDEP Guidance.

TABLE 3-1

POTENTIAL ARARs AND TBCs  
 CORRECTIVE MEASURE STUDY FOR SWMU 9  
 NAS KEY WEST, BOCA CHICA KEY, FLORIDA  
 PAGE 2 OF 3

Location-Specific Requirements	Rationale
Federal Protection of Wetlands Executive Order (E.O. 11990)	Wetland areas at SWMU 9 may have chemical contamination and may be affected by corrective measure.
Endangered Species Act of 1978 (16 USC 1531) (40 CFR 502)	There are endangered and threatened species at NAS Key West.
Fish and Wildlife Coordination Act of 1980 (16 USC 661)	Corrective measures may affect fish and wildlife habitat.
Fish and Wildlife Conservation Act (16 USC 2901)	
Fish and Wildlife Improvement Act of 1978 (16 USC 742a)	
RCRA Standards for Owners and Operators of TSDFs.	Most of the NAS Key West facility is within the 100-year floodplain.
Florida Surface Waters of the State (Chapter 62-301 F.A.C.)	Provides designation of landward extent of surface waters in the state.
Florida Delineation of Landward extent of Wetlands and Surface Waters (Chapter 62-340 F.A.C.)	Provides the delineation methodology of the extent of wetlands.
Florida Ground Water Classes, Standards, and Exemptions (Chapter 62-520 F.A.C.)	Provides designation criteria for the groundwater classes in the state.
Clean Air Act (42 USC 7401)	
National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50)	Corrective measures may include treatment of media which could result in emissions to the atmosphere.
National Emission Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR 61.60-61.71)	
New Source Performance Standards (NSPS) (40 CFR Part 60)	
Florida State Implementation Plan (Chapter 62-204 F.A.C.)	
Hazardous Waste Generator Requirements (40 CFR Part 262)	Standards applicable to generators of hazardous wastes that may have to be met depending on corrective measures implemented.
Hazardous Waste Transportation Requirements (40 CFR Part 263)	Corrective measures may require transportation of hazardous materials off-site for treatment/disposal.

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TABLE 3-1

**POTENTIAL ARARs AND TBCs  
CORRECTIVE MEASURE STUDY FOR SWMU 9  
NAS KEY WEST, BOCA CHICA KEY, FLORIDA  
PAGE 3 OF 3**

Action-Specific Requirements	Rationale
Standards for Owners and Operators of Hazardous Waste Treatment, Storage or Disposal (TSD) Facilities (40 CFR Part 264) Interim Status Standards for Owners and Operators of Hazardous Waste or TSD Facilities (40 CFR Part 264)	Corrective measures may involve hazardous waste treatment, storage, and disposal facilities.
Land Disposal Restrictions (40 CFR Part 268)	Standards for the land disposal of hazardous waste.
Department of Transportation (DOT) Rules for Hazardous Materials Transport (49 CFR Parts 107, 171-179)	Corrective measures may include transport of waste for off-site treatment and disposal.
National Environmental Policy Act	Requires consideration of environmental effects due to Federal actions.
Clean Water Act (40 CFR Part 122) National Pollutant Discharge Elimination System (NPDES)	Corrective measures may involve discharge to surface waters.
Clean Air Act (42 USC 7401), NAAQS (40 CFR Parts 50 and 53), NESHAPs (40 CFR Part 61) and NSPS (40 CFR Part 60)	Treatment technologies for emissions to air (incineration, surface impoundments, waste piles landfills, and sources of fugitive emissions).
Occupational Safety and Health Act (29 USC 651-678)	Regulates worker health and safety.
Florida Pretreatment Requirements (NPDES) for Existing and New Sources of Pollution (Chapter 62-625 F.A.C.)	Corrective measures may include discharge to surface waters or a waste water treatment plant.
Florida Hazardous Waste (Chapter 62-730 F.A.C.)	Applicable to corrective measures that may handle and/or transport hazardous waste.
Land Use Restrictions at Environmental Remediation Sites on Board U.S. Navy Installations (CNBJAXINST 5090.2N4)	Establishes a systematic program to govern land use at environmental remediation sites at U.S. Navy Installations.

TABLE 3-2

GROUNDWATER RGOS (µg/L)  
NAVAL AIR STATION KEY WEST  
BOCA CHICA KEY, FLORIDA

COCs	Groundwater Sample Results	Remedial Goal Options	
	November 1998 Sampling Effort (µg/L)	Protection of Surface Water (µg/L)	Protection of Sediment (µg/L)
Cis-1,2-DCE	280	60,000	1,930
Trans-1,2-DCE	820	7,600	4.5 x 10 <sup>6</sup>
Benzene	18	12,600	89,500
TCE	ND	2,720	280,000

ND – Not Detected

## **4.0 IDENTIFICATION, SCREENING, AND DEVELOPMENT OF CORRECTIVE MEASURE ALTERNATIVES**

### **4.1 INTRODUCTION**

This section presents the identification, screening, and development of the corrective measure alternatives formulated to achieve the CAOs for SWMU 9. Section 3.0 presented the underlying basis for the initial identification and screening of the corrective measure technologies and included the following:

- Identification of ARARs.
- Development of CAOs and media-specific RGOs.
- Identification of volumes of contaminated media based on the RGOs.

The identification and screening of corrective measure technologies and the development of corrective measure alternatives are based upon the information presented in Section 3.0 and involve the following activities:

- Identification of corrective measure technologies and applicable process options.
- Screening of potential corrective measure technologies and applicable process options.
- Development of corrective measure alternatives by assembling the remaining technologies into alternatives that have the potential to achieve the defined CAOs.

### **4.2 IDENTIFICATION AND SCREENING OF CORRECTIVE MEASURE TECHNOLOGIES AND PROCESS OPTIONS**

This section identifies the corrective measure technologies and process options that may be used to achieve the CAOs. This process was based on the review of current literature, vendor information, and previous experience in developing alternatives for sites with similar media-specific concerns and releases.

Corrective measure technologies and process options can be grouped according to general response actions. Corrective measure alternatives are then formulated by combining general response actions to completely address the CAOs. When implemented, the corrective measure alternative should be capable of achieving the CAOs, with the exception of the No Action alternative. The categories of general response actions that could be implemented to achieve or address the CAOs for SWMU 9 include:

- No Action
- Institutional Controls
- Treatment

Each of the general response actions is discussed below (Sections 4.2.1 through 4.2.3). Corrective measure technologies and process options for each of the general response actions which are potentially applicable to SWMU 9 are identified and screened in Table 4-1 for groundwater. The criteria used for screening the technologies and process options are discussed in Section 4.2.7.

#### **4.2.1            No Action**

No Action is a general response action wherein the status quo is maintained at the site. No Action is normally retained to provide a baseline for comparison with other alternatives. No additional activities would be conducted at the site to address remaining contamination. There are no implementability concerns, because the contaminated medium is considered to be left "as is". Institutional controls or treatment are not provided to reduce the potential for exposure.

#### **4.2.2            Institutional Controls**

Access controls (e.g., physical barriers) and/or site development restrictions in the NAS Key West Master Plan are institutional control options that may be considered for implementation to reduce or eliminate pathways or exposure to hazardous substances at the site. Controls could involve the use of groundwater monitoring networks and/or groundwater use restrictions and educational programs. The application of institutional controls alone does not reduce the volume, mobility, or toxicity of the contaminants. Site development restrictions would be implemented in accordance with CNBJAXINST 5090.2N4 (U.S. Navy, 1997). This instruction has been provided as Appendix E.

#### **4.2.3            Treatment**

The treatment response action includes in situ physical, chemical, or biological processes designed to reduce the mobility, toxicity, and/or volume of the contaminants present.

#### **4.2.4            Screening Criteria for Corrective Measure Technologies and Process Options**

Corrective measure technologies and process options are screened to eliminate those that are not feasible to implement, that rely on technologies unlikely to perform satisfactorily or reliably, or that do not achieve the CAOs within a reasonable time. The corrective measure technologies and process options are also eliminated based on SWMU 9 site-specific and waste-specific conditions.

The screening process focuses on eliminating those technologies and process options that have severe limitations for a given set of waste-specific and site-specific conditions. The screening step also eliminates technologies and process options based on inherent technology limitations. Site, waste, and technology characteristics that were used as screening criteria are described below. Table 4-1 provides the identification and screening of technologies and process options for groundwater. Table 4-2 provides a summary of retained technologies for groundwater.

##### **4.2.4.1            Site Characteristics**

Site characteristics include an evaluation of RGOs for SWMU 9 or contaminant concentrations to identify site conditions that may limit or advocate the use of certain technologies. Technologies and process options are evaluated for their applicability and limitations to site conditions, including compatibility with site hydrogeology or soils.

##### **4.2.4.2            Waste Characteristics**

Waste characteristics may limit the effectiveness or feasibility of technologies. Technologies and process options are evaluated for their applicability and limitations to the waste characteristics at the site, including contaminant type and concentrations and contaminated media.

#### **4.2.4.3 Technology Limitations**

Technology limitations include the level of technology development; performance record; and inherent construction, operation, and maintenance problems. Technologies and process options are evaluated based on their reliability, performance, and ability to show proof that they work.

#### **4.3 IDENTIFICATION OF CORRECTIVE MEASURE ALTERNATIVES FOR SWMU 9**

This section describes the development of corrective measure alternatives for SWMU 9 considering the information provided in the previous sections. Additional site-specific information and assumptions are provided in this section to further explain the alternative development process. In addition, alternatives are briefly described in this section. A detailed description and an analysis of alternatives are provided in Section 5.0.

Based on the results of the risk assessment in the Supplemental RFI/RI, the following assumption was used in developing these alternatives. SWMU 9 is located within a restricted access area beside an active runway. Only military personnel have access to this location. Because of the restrictive site access, residential exposure to contaminants at SWMU 9 is highly unlikely as long as the installation is maintained as an active military base.

The corrective measures alternatives identified from the screening process described above are identified and discussed below:

- No Action
- Natural Attenuation with Long-Term Monitoring
- Enhanced Biodegradation with Long-Term Monitoring

A brief description of each alternative is provided in Sections 4.3.1 through 4.3.3.

##### **4.3.1 Alternative 1 – No Action**

The No Action alternative maintains the site at status quo. This alternative is retained to provide a baseline for comparison to other alternatives and, therefore, does not address the remaining contamination of the groundwater. There would be no reduction in toxicity, mobility, or volume of the

contaminants from treatment at SWMU 9 other than that which would result from natural dispersion, dilution, or other attenuation factors.

#### **4.3.2 Alternative 2 – Natural Attenuation with Long-Term Monitoring**

This alternative consists of two major components: (1) allowing natural attenuation processes to remediate the contaminated groundwater at the site and (2) monitoring the contaminant levels and natural attenuation parameters at the site by sampling groundwater (quarterly for the first year, and annually for the next nineteen years). The sampling would be performed based on Federal and state regulations. A reevaluation of the site would be performed every 5 years to determine if any changes to the controls would be required.

Groundwater monitoring would include sampling for VOCs and the following natural attenuation parameters: dissolved oxygen (DO), carbon dioxide, sulfate, sulfide, and oxidation reduction potential.

#### **4.3.3 Alternative 3 – Enhanced Bioremediation with Long-Term Monitoring**

This alternative consists of three major components: (1) adding Oxygen Releasing Compound (ORC) downgradient from the highest contaminant levels to form an ORC barrier, (2) adding Hydrogen Releasing Compound (HRC) at the center of the plume, and (3) monitoring the contaminant levels and natural attenuation parameters at the site by sampling groundwater (quarterly for the first year, semi-annually for the second year, and annually for the next three years). The sampling would be performed based on the Federal and state regulations. A reevaluation of the site would be performed after 5 years to determine if any changes to the controls would be required.

Groundwater monitoring would include sampling for VOCs and the following natural attenuation parameters: DO, carbon dioxide, sulfate, methane, sulfide, oxidation reduction potential, alkalinity, and chloride.

**TABLE 4-1  
PRELIMINARY SCREENING OF REMEDIATION TECHNOLOGIES FOR GROUNDWATER  
CORRECTIVE MEASURES STUDY  
SWMU 9, BOCA CHICA JET ENGINE TEST CELL  
NAVAL AIR STATION KEY WEST, BOCA CHICA KEY, FLORIDA**

TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS	OPTION RETAINED
<b>GENERAL RESPONSE ACTION: NO ACTION</b>				
No Action	No Action	No activities proposed at a site to address contamination.	Retained as a baseline for comparison.	Yes
<b>GENERAL RESPONSE ACTION: INSTITUTIONAL CONTROLS</b>				
Institutional Controls <sup>(1)</sup>	Limited Site Access	Physical barrier used to restrict access to the site.	Only effective in preventing direct contact regarding human exposure. Does not reduce contaminant exposure to ecological receptors.	No
	Site Development Restrictions	Administrative action used to restrict future site use as documented in the NAS Key West Master Plan.	Administrative action issued to prevent direct contact regarding human exposure. Does not reduce contaminant exposure to ecological receptors.	No
	Monitoring	Sampling and analysis of environmental media to assess contaminant migration and future environmental impacts.	Effective only to assess contaminant levels on-site and migration off-site. Can be used to determine if conditions are changing in order to indicate the need for further corrective measures.	Yes
	Educational Programs	Educate public concerning site hazards.	Helps to inform the public concerning possible site hazards. However, does not reduce the exposure potential for human or ecological receptors. Information for risks can be provided at Restoration Advisory Board meetings.	No
<b>GENERAL RESPONSE ACTION: TREATMENT</b>				
Treatment	Natural Attenuation <sup>(2)</sup>	Physical and chemical degradation processes already taking place are allowed to continue at the site.	It has been proven that natural attenuation processes are already occurring at the site, and may be adequate to sufficiently treat groundwater contamination.	Yes
	Adsorption <sup>(3)</sup>	Uses polymers to selectively adsorb molecules from groundwater.	The Partnering Team decided that this option would not be considered in the CMS. Similar to the pump and treat system already installed at SWMU 9.	No
	Air Sparging <sup>(3)</sup>	Involves the injection of air into the saturated zone to transport contaminants into the vadose zone for extraction.	The Partnering Team decided that this option would not be considered in the CMS.	No
	Bioremediation <sup>(3)</sup>	Enhances the subsurface environment by injecting nutrients and oxygen such that microbial degradation of organic contamination is stimulated.	Would be effective in treating contamination found in groundwater at SWMU 9.	Yes
	Soil Flushing <sup>(3)</sup>	Withdraws contaminated groundwater and returns treated effluent.	Similar to the system already installed at SWMU which was unsuccessful at treating groundwater contamination.	No

- (1) United States Environmental Protection Agency. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, October 1988.  
 (2) Tetra Tech NUS, 1999, Natural Attenuation Study Results for Solid Waste Management Unit 9, prepared for Southern Division, Naval Facilities Engineering Command.  
 (3) United States Environmental Protection Agency. Remediation and Characterization Innovative Technologies (REACH IT), posted on internet, 1999.

**TABLE 4-2**  
**SUMMARY OF RETAINED TECHNOLOGIES FOR GROUNDWATER**  
**CORRECTIVE MEASURES STUDY**  
**SWMU 9, BOCA CHICA JET ENGINE TEST CELL**  
**NAVAL AIR STATION KEY WEST, BOCA CHICA KEY, FLORIDA**

<b>GENERAL RESPONSE ACTION</b>	<b>TECHNOLOGY</b>	<b>PROCESS OPTION</b>
No Action	No Action	No Action
Institutional Controls	Institutional Controls	Monitoring
Treatment	Treatment	Natural Attenuation
		Bioremediation

## 5.0

# EVALUATION OF THE CORRECTIVE MEASURE ALTERNATIVES FOR SWMU 9

This section presents a detailed description of each corrective measure alternative developed in Section 4.0, the rationale used in evaluating each corrective measure alternative, and the results of the evaluation for each specific evaluation standard. The evaluation of corrective measure alternatives was conducted in accordance with the EPA RCRA Corrective Action Plan Guidance (Final) (USEPA, 1994a).

### 5.1 CORRECTIVE MEASURES ALTERNATIVES

This section describes in detail the corrective measure alternatives developed in Section 4.0.

#### 5.1.1 Alternative 1 – No Action

This is a "walk-away" alternative retained to provide a baseline for comparing the other alternatives. This alternative does not address the remaining groundwater contamination at SWMU 9.

#### 5.1.2 Alternative 2 – Natural Attenuation with Long-Term Monitoring

This alternative consists of two components, natural attenuation and long-term monitoring. Natural attenuation in groundwater systems results from the attenuation mechanisms that are either destructive or nondestructive. Biodegradation is the most important destructive attenuation mechanism (USEPA, 1997). Chlorinated hydrocarbon plumes, as seen at SWMU 9, have been documented to exhibit three types of behavior depending on the nature and extent of contamination, available carbon, and the type of electron acceptors available. It appears that the groundwater plume at SWMU 9 is exhibiting mixed behavior (Type 1 and Type 2) (TtNUS, 1999b). Benzene, toluene, ethylbenzene, and xylenes (BTEX) have been detected consistently in upgradient well S9MW-5, and historically in other site wells. Given the general lack of oxygen across the site and the fact that BTEX is not readily susceptible to anaerobic degradation, it would follow that BTEX would migrate downgradient (TtNUS, 1999b). Since this is not the case, it is likely that the BTEX is being used as the primary substrate, or cosubstrate, to drive reductive dechlorination of the chlorinated solvents present at SWMU 9 (Type 1 behavior) (TtNUS, 1999b). However, there appears to be an insufficient supply of BTEX to promote Type 1 behavior over a significant area of the plume. The lack of BTEX indicates that across the majority of the site, natural organic carbon is being used as the primary

substrate to drive reductive dechlorination (Type 2 behavior) (TtNUS, 1999b). Methanogenesis and sulfate reduction are the reductive pathways active at the site. Carbon dioxide and sulfate are being used as electron acceptors, resulting in the generation of methane, sulfide, chloride, and carbon dioxide (TtNUS, 1999b). The natural attenuation process is described in more detail in the *Natural Attenuation Study Results for SWMU 9* (TtNUS, 1999b). Sections 5.1.2.1 and 5.1.2.2 describe Types 1 and 2 behavior in more detail.

The second part of Alternative 2 involves long-term monitoring for 20 years. Monitoring samples would be collected quarterly for the first year and annually for the next nineteen years from seven groundwater sampling locations including well numbers S9MW5, S9MW14, S9MW15, S9MW21, S9MW22, S9MW24, and S9MW25. Groundwater modeling was performed to determine the time required (18 years) for contaminants to degrade to below action levels. The monitoring time is based on this groundwater modeling. Appendix C contains the Summary Report for groundwater modeling at SWMU 9. Samples taken would be analyzed for VOCs and natural attenuation parameters, including dissolved oxygen (DO), carbon dioxide, sulfate, sulfide, and oxidation reduction potential.

Quality Assurance/Quality Control (QA/QC) samples would also be collected. Every 5 years, a site review would be conducted to evaluate the site status and determine whether further action is necessary. The site review is required because this alternative allows contaminants to remain at levels that exceed action levels.

#### **5.1.2.1 Type 1 Behavior**

Type 1 behavior describes a chlorinated solvent plume where the primary substrate is anthropogenic carbon such as BTEX or landfill leachate. The biodegradation of the anthropogenic carbon source drives the reductive dechlorination of the solvent. This is a very efficient process for the dechlorination of the more highly chlorinated solvents such as tetrachloroethene (PCE), TCE, and DCE. Although vinyl chloride can be reduced anaerobically into ethene and further to ethane, this process occurs much more slowly than PCE, TCE, and DCE dechlorination. Therefore, under strictly Type 1 behavior, vinyl chloride will tend to accumulate in the source area or along the down gradient edge of the plume.

#### **5.1.2.2 Type 2 Behavior**

Type 2 behavior describes a chlorinated solvent plume where the primary substrate is native organic carbon. The biodegradation of the native carbon source drives the reductive dechlorination of the solvent. This is very similar to Type 1 behavior but is not as efficient for the dechlorination of the

more highly chlorinated solvents. As with Type 1 behavior, vinyl chloride will tend to accumulate in the source area or along the downgradient edge of the plume.

### 5.1.3 Alternative 3 - Enhanced Biodegradation with Long-Term Monitoring

This alternative consists of two components, enhanced biodegradation and long-term monitoring.

Enhanced biodegradation would involve adding ORC at various points throughout the site. ORC is magnesium peroxide specially formulated for slow and sustained release of molecular oxygen when hydrated. Naturally occurring micro-organisms thrive in the oxygen-enriched environment facilitated by ORC; these aerobic microbes begin to degrade toxic organic hydrocarbon compounds into harmless by-products. An ORC barrier would be set up as shown on Figure 5-1 by injecting the approximately 1,000 pounds of ORC in borings using DPT. Approximately 60 borings will be needed along the ORC barrier line. Calculations performed by an ORC/HRC vendor (Regenesis) to produce the quantity of ORC needed are shown in Table 5-1. In addition, HRC would be added at the center of the DCE plume. HRC is a polylactate ester specially formulated for slow release of lactic acid upon hydration. Bioremediation with HRC is a multi-step process. Indigenous anaerobic microbes metabolize the lactic acid released by HRC, and produce hydrogen. The resulting hydrogen can be used by reductive dehalogenators which are capable of dechlorinating chlorinated hydrocarbons. Approximately 500 pounds of HRC will be added to center of the DCE plume (around S9MW15) with the same method (DPT) used to inject the ORC. This addition of HRC was recommended by Regenesis to expedite the dehalogenation process.

The ORC/HRC treatment is expected to reduce contaminant levels to below action levels in one to two years as seen at other sites. In a similar situation (Hurlburt Field in Fort Walton Beach, FL), a 70 percent decrease in TCE was seen in the first three months after application (Ochs, 1999) indicating a decrease in TCE for this particular site of approximately 4 µg/L per day. However, the release of oxygen by the ORC may be accelerated due to carbonate interference from the oolitic limestone geologic makeup of SWMU 9. Because of this uncertainty, a treatability study will be performed to better define the ability of ORC/HRC to perform in carbonate-enriched soil and groundwater. In addition, a major precipitation event resulting in flushing would also accelerate the release of oxygen and hydrogen from the compounds. The application of ORC/HRC should be performed during the November to July period, which are the months least likely for hurricane or tropical storm flushing, to reduce these premature releases as much as possible.

Baseline conditions will be determined before the application of ORC/HRC takes place. The treatability study workplan will address the need to establish these baseline conditions and the

specifics of the sampling event. This baseline event will also be used to calculate how much ORC and HRC will actually be used during the treatability study.

The second part of Alternative 3 involves long-term monitoring for 5 years. Monitoring samples would be collected quarterly for the first year, semi-annually during the second year, and annually for the next 3 years from groundwater monitoring wells S9MW5, S9MW14, S9MW15, S9MW21, S9MW22, S9MW24, and S9MW25 as shown in Figure 5-1. A monitoring period of 5 years was chosen based on the rate of dechlorination observed at other sites. The ORC/HRC treatment is expected to reduce contaminant levels to below action levels in one to 2 years. Samples taken would be analyzed for VOCs and the following natural attenuation parameters: DO, carbon dioxide, sulfate, methane, sulfide, oxidation reduction potential, alkalinity, and chloride. QA/QC samples would also be collected. After 5 years, a site review would be conducted to evaluate the site status and determine whether further action is necessary.

## 5.2 EVALUATION STANDARDS

The corrective measures alternatives were evaluated in accordance with the Guidance for RCRA Corrective Action Plan (OSWER Directive 9902.3-2A, USEPA May, 1994a). This section describes the specific standards to be used in evaluating each of the corrective measures alternatives. The five standards are as follows:

- Protection of human health and the environment
  - Media clean-up standards
  - Source control
  - Waste management standards
  - Other factors
- Long-term reliability and effectiveness
  - Reduction in toxicity, mobility, or volume through treatment
  - Short-term effectiveness

-Implementability

-Cost

### 5.2.1 **Protection of Human Health and the Environment**

Protection of human health and the environment provides an overall evaluation of the remedies that would be appropriate for SWMU 9. This standard considers the extent to which the corrective measures alternative mitigates potential short- and long-term exposure to residual contamination and how the remedy protects human health and the environment both during and after implementation of the alternative. In addition, the levels and characterization of contaminants remaining on site, potential exposure pathways, potentially affected populations, the level of exposure to contaminants, and the associated reduction of exposure over time are considered. For management of mitigation measures, the relative reduction of environmental impact for each alternative is determined by comparing residual levels for each alternative with the existing criteria, standards, and guidelines. The ecological considerations for this evaluation standard included potential short- and long-term beneficial and adverse effects of the corrective measure, adverse effects on environmentally sensitive areas, and an analysis on how to mitigate adverse effects.

### 5.2.2 **Media Clean-Up Standards**

The media clean-up standard considers whether the corrective measure alternative would achieve the defined CAOs. In addition, this standard includes an assessment of relevant institutional needs for each corrective measure alternative. The effects of Federal, state, and local environmental and public standards, regulations, guidance, advisories, ordinances, or community relations on the design, operation, and timing of each alternative are considered.

### 5.2.3 **Source Control**

The source control standard evaluates how the corrective measure alternative addresses the source of the release in order to reduce or eliminate, to the extent practicable, further releases that may pose a threat to human health and the environment. This criterion addresses whether source control measures are necessary and what type of source control actions would be appropriate. In addition, any source control measures that are proposed should include a discussion on how well the method is expected to work given the site situation and previous experiences with the specific technology.

#### **5.2.4 Waste Management Standards**

The corrective measures alternative must comply with applicable standards for the management of wastes. This includes a description of how the specific waste management activities would be conducted in order to maintain compliance with all applicable state and Federal regulations.

#### **5.2.5 Other Factors**

In addition to the first four standards, there are five general factors that are to be addressed as part of the evaluation of corrective measure alternatives. The five general decision factors to be considered under this standard are:

- Long-term reliability and effectiveness
- Reduction in toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

##### **5.2.5.1 Long-Term Reliability and Effectiveness**

Evaluation of the long-term reliability and effectiveness of the alternatives must consider the corrective measure alternative performance. Performance considerations include the effectiveness and useful life of the corrective measures. The reliability of a corrective measure includes the Operation and Maintenance (O&M) requirements and demonstrated reliability.

##### **5.2.5.2 Reduction in Toxicity, Mobility, or Volume**

This factor includes the ability of the corrective measures to reduce the toxicity, mobility, or volume of the contaminants or media through treatment.

#### **5.2.5.3 Short-Term Effectiveness**

This factor includes evaluates the effectiveness of the measure in the short term (less than 6 months) in comparison to the long-term effectiveness; in particular, it measures potential risks to human health and the environment during implementation.

#### **5.2.5.4 Implementability**

This factor includes the relative ease of installation (constructability) and the time required to achieve a given level of response.

#### **5.2.5.5 Cost**

A cost estimate of a corrective measure includes both estimated capital and O&M costs. Capital costs include both direct and indirect costs. O&M costs are post-construction activities that may be necessary to ensure the continued effectiveness of a corrective measure.

### **5.3 EVALUATION OF ALTERNATIVES**

This section presents the final evaluation conducted for each corrective measure alternative based on the standards described in Section 5.2.

#### **5.3.1 Alternative 1 – No Action**

##### **5.3.1.1 Protection of Human Health and the Environment**

Alternative 1 is considered primarily for comparative purposes to the other measures. This alternative would not be protective of human health or the environment. COCs would remain in the groundwater and potential ecological exposure through intake routes would continue to exist. Contaminant concentrations in groundwater may decline through natural attenuation but this process would not be monitored.

Under a no action alternative, the ICR from site contaminants for occupational workers is less than  $1 \times 10^{-6}$ . The calculated risk for occupational workers is  $2 \times 10^{-9}$  (B&R Environmental, 1997). The ICR from site contaminants for both adult and adolescent trespassers is less than  $1 \times 10^{-4}$  but would still exceed  $1 \times 10^{-6}$  under the No Action alternative. The cumulative HIs for adolescent trespassers, adult

trespassers, maintenance workers, and occupational workers at SWMU 9 are less than 1.0 (B&R Environmental, 1997).

No surface water or sediment contaminants were retained as ecological COCs in the CMS. However, migration of groundwater contaminants to sediment and surface water is possible under the No Action alternative.

#### **5.3.1.2 Media-Clean-Up Standards**

Alternative 1 would not comply with media clean-up standards for groundwater under an industrial use scenario. Clean-up standards may eventually be met, but since no monitoring would be performed, compliance would not be documented.

#### **5.3.1.3 Source Control**

Alternative 1 would not involve source control because no action would be performed at SWMU 9.

#### **5.3.1.4 Waste Management Standards**

No actions would be implemented for Alternative 1; therefore, no waste would be generated.

#### **5.3.1.5 Other Factors**

##### Long-Term Reliability and Effectiveness

Given existing conditions, the current threat to human health would remain because there would be no access controls for removal or treatment of the contaminants. Except through decreases by natural processes such as advection, dispersion, biodegradation, and adsorption, contaminant concentration would remain in the groundwater at SWMU 9 at levels greater than the media clean-up standards. Any decrease in contaminant concentrations would not be monitored.

No long-term management controls would be applied to SWMU 9 under this alternative. Therefore, the adequacy and reliability of controls are not applicable. Also, there would be no long-term monitoring programs to assess the migration of contaminants from the site.

### Reduction in Toxicity, Mobility, and Volume Through Treatment

Alternative 1 would not reduce the toxicity, mobility, or volume of the contaminants through treatment. Any reductions of toxicity and volume resulting from natural dispersion, dilution, or other attenuation factors would not be quantified because of lack of monitoring.

### Short-Term Effectiveness

Alternative 1 would involve no action and, therefore, would not pose risks to on-site workers during implementation, and no environmental impacts would be expected. This alternative would not involve monitoring, and it would never be known if and when any of the CAOs have been achieved.

### Implementability

Since no actions would occur, this alternative would be readily implementable. The technical feasibility criteria, including constructability, operability, and reliability, are not applicable.

### Cost Analysis

No costs are associated with the No Action alternative.

## **5.3.2 Alternative 2 – Natural Attenuation with Long-Term Monitoring**

### **5.3.2.1 Protection of Human Health and the Environment**

Alternative 2 would eventually be protective of human health and the environment. Contaminants would remain in the groundwater until they biodegraded via natural attenuation. However, as discussed in the HHRA, groundwater was not evaluated as part of the baseline HHRA because it is classified as Class G-III, nonpotable, by FDEP. There is very little chance of human contact with site groundwater at SWMU 9. There is a possibility that groundwater contaminants will migrate to sediment or surface water, impacting the ecology of the lagoon. Monitoring will be performed to ensure that this migration is not occurring to a significant extent. Modeling shows that contaminants in groundwater will be below action levels in approximately 18 years. If natural attenuation processes are ineffective in degrading contaminants, the site will be re-evaluated.

### **5.3.2.2 Media Clean-up Standards**

Alternative 2 would eventually comply with media clean-up standards if natural attenuation continues at the present rate and long-term monitoring would determine when compliance has been achieved. If, at the end of the monitoring period, contaminant levels do not comply with media clean-up standards, additional remediation will be required.

### **5.3.2.3 Source Control**

Alternative 2 does not involve source control because natural attenuation would be the remediation choice.

### **5.3.2.4 Waste Management Standards**

Alternative 2 involves no removal of contaminated media; and therefore, this alternative would not generate any wastes (except sampling wastes).

### **5.3.2.5 Other Factors**

#### Long-Term Reliability and Effectiveness

Although no treatment would occur in Alternative 2, the current threat to human health and the environment would be reduced and the effectiveness of the alternative in reducing risk would be monitored. Environmental concerns would remain from groundwater contaminants migrating to the lagoon. The natural attenuation alternative would use long-term monitoring to determine whether unacceptable risks are posed to ecological receptors.

#### Reduction in Toxicity, Mobility, and Volume Through Treatment

Alternative 2 would not reduce toxicity, mobility, and volume of contaminants at SWMU 9 through treatment. However, contaminant toxicity and volume would be reduced.

#### Short-Term Effectiveness

Alternative 2 would involve allowing natural degradation at SWMU 9 to continue and monitoring contaminant levels and natural attenuation parameters. The short-term risks associated with these remedial activities would be minimal. Sampling personnel would wear the required personal

protective equipment (PPE) and receive appropriate health and safety training. Because SWMU 9 is located on an active military base, there would be no potential risk to the community.

### Implementability

Alternative 2 is expected to be readily implementable since SWMU 9 is located within a military facility where rules and local ordinances can be strictly enforced. Restrictions for future residential property use would involve legal assistance and regulatory approval. Provisions in the NAS Key West Master Plan would be defined and enforced relatively easily because the site is located within a Federal facility. Sampling and analysis are also readily implemented.

### Cost Analysis

The following costs are estimated for Alternative 2. It should be noted that to date, the Navy has spent approximately 7.9 million dollars on IRAs at nine sites/SWMUs/Areas of Concern. SWMU 9 was one the SWMUs where an IRA was performed.

- Capital Costs: \$0.00
- O&M Costs: \$15,000/yr - \$58,500
- Present-Worth: \$236,403 estimated over 20 years

Detailed cost estimates are included in Appendix D.

## **5.3.3 Alternative 3 – Enhanced Biodegradation with Long-Term Monitoring**

### **5.3.3.1 Protection of Human Health and the Environment**

Alternative 3 would be protective of human health and the environment. Contaminants would remain in the groundwater until they biodegraded due to the addition of ORC and HRC. However, as discussed in the HHRA, groundwater was not evaluated as part of the baseline HHRA because it is classified as Class G-III, nonpotable, by FDEP. There is very little chance of human contact with site groundwater at SWMU 9. Contamination is expected to be below action levels in less than 5 years. If enhanced biodegradation processes are ineffective in degrading contaminants, the site will be re-evaluated.

### **5.3.3.2 Media Clean-up Standards**

Alternative 3 would eventually comply with media clean-up standards. If, at the end of the monitoring period, contaminant levels do not comply with media clean-up standards, additional remediation will be required. However, Alternative 3 is expected to successfully lower contaminant levels to below action levels.

### **5.3.3.3 Source Control**

Alternative 3 does involve source control. HRC would be applied to the center of the DCE plume (highest contaminant levels), and an ORC barrier would be put in place to reduce contaminant levels to below media clean-up standards (Figure 5-1).

### **5.3.3.4 Waste Management Standards**

Alternative 3 involves no removal of contaminated media, except sampling wastes. However, small amounts of waste may be associated with the ORC and HRC injection. Any treatment residuals from implementation of this alternative would be sampled and properly disposed of.

### **5.3.3.5 Other Factors**

#### Long-term Reliability and Effectiveness

Although no media removal would occur in Alternative 3, treating groundwater would reduce the current threat to human health and the environment. Contaminant levels would be reduced to below media clean-up standards. The use of ORC is well proven and should be effective. The use of HRC as a treatment method is a fairly innovative technology, but is expected to be reliable and effective. The effectiveness of the alternative in reducing risk would be monitored. Environmental concerns would remain from groundwater contaminants migrating to the lagoon. The enhanced biodegradation alternative would use long-term monitoring to assess risks to ecological receptors.

#### Reduction in Toxicity, Mobility, and Volume Through Treatment

Alternative 3 would reduce toxicity and volume of contaminants through treatment by enhancing biodegradation processes.

### Short-term Effectiveness

Alternative 3 would involve adding ORC and HRC to groundwater at SWMU 9 and monitoring contaminant levels and natural attenuation parameters. The short-term risks associated with these remedial activities would be minimal. Sampling personnel would wear the required PPE and receive appropriate health and safety training. Because SWMU 9 is located on an active military base, there would be no potential risk to the community.

### Implementability

Alternative 3 is expected to be readily implementable since SWMU 9 is located within a military facility where rules and local ordinances can be strictly enforced. Restrictions for future residential property use would involve legal assistance and regulatory approval. Provisions in the NAS Key West Master Plan would be defined and enforced relatively easily because the site is located within a Federal facility. Sampling and analysis are also readily implemented.

### Cost Analysis

The following costs are estimated for Alternative 3. It should be noted that to date, the Navy has spent approximately 7.9 million dollars on IRAs at nine sites/SWMUs/Areas of Concern. SWMU 9 was one the SWMUs where an IRA was performed.

- Capital Costs:       \$51,000
- O&M Costs:         \$15,500/yr - \$60,500
- Present-Worth:     \$183,982 estimated over 5 years

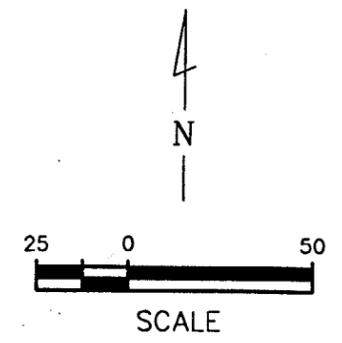
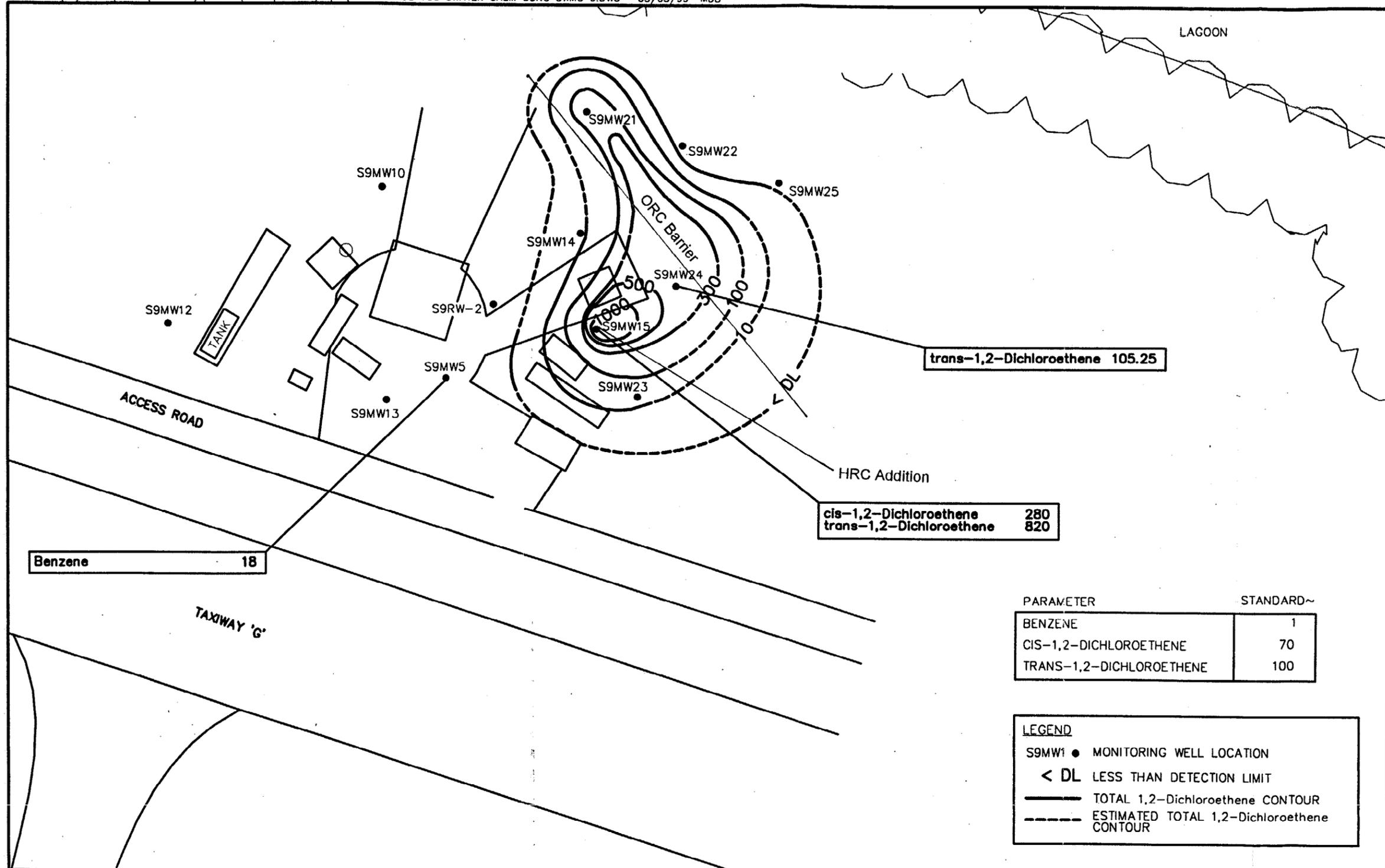
Detailed cost estimates are included in Appendix D.

**TABLE 5-1  
CALCULATIONS FOR AMOUNT OF ORC NEEDED**

Dissolved Hydrocarbon Level (ppm)	1
Plume Width (ft)	200
Plume Velocity (ft/day)	1
Thickness of contamination in Saturated Zone (ft)	5
Thickness of ORC slurry in Saturated Zone (ft)	5
Porosity	0.3
Safety factor for Injection Barriers	10
<b>Application Comments</b>	
<b>*ORC per hole is above lower limit of 1 pound per linear foot.</b>	
**Barrier Design should potential handle constant mass flux requirements.	
Hydrocarbon Load per Day (lbs)	0.187
Oxygen Demand Per Day (lbs)	0.561
Oxygen Required (lbs)	101.0
ORC Required (lbs)	1,010
ORC unit Cost	\$10.00
Total ORC Cost	\$10,100.00
Desired Number of Points	59
ORC per Hole (lbs)	17.1
ORC per foot (lbs)	3.42
Minimum Spacing (ft)	3.4
Solids Content (%)	40
Water per Hole for Slurry (gal)	3.08
<b>Solute Transport Model</b>	
Compliance Point (ft)	35
Ratio of O2 provided: O2 required (%)	75
HC Level at compliance point (ppm)	0.213

\*Calculations were obtained directly from an ORC/HRC vendor (Regenesis).

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trans-1,2-Dichloroethene 105.25

cis-1,2-Dichloroethene 280  
trans-1,2-Dichloroethene 820

Benzene 18

PARAMETER	STANDARD~
BENZENE	1
CIS-1,2-DICHLOROETHENE	70
TRANS-1,2-DICHLOROETHENE	100

**LEGEND**  
 S9MW1 ● MONITORING WELL LOCATION  
 < DL LESS THAN DETECTION LIMIT  
 ——— TOTAL 1,2-Dichloroethene CONTOUR  
 - - - ESTIMATED TOTAL 1,2-Dichloroethene CONTOUR

ALL APPLICABLE RELEVANT AND APPROPRIATE REQUIREMENTS (ARAR's) AND SCREENING ACTION LEVELS (SAL's) are from the BRAC SI Workplan.

**NOTE:**  
 All concentrations are in ug/L.  
 Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY  
MDB  
 DATE  
—  
 CHECKED BY  
DSF  
 DATE  
—  
 COST/SCHED-AREA  
 SCALE  
AS NOTED



**CORRECTIVE MEASURES STUDY REPORT FOR SWMU 9**  
**FIGURE 5-1. ALTERNATIVE 3: ENHANCED**  
**BIOREMEDIATION WITH LONG TERM MONITORING**  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA

CONTRACT NO. 7046	
APPROVED BY	DATE
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## 6.0 RECOMMENDATION OF THE FINAL CORRECTIVE MEASURE

### 6.1 INTRODUCTION

This section presents a comparison of the corrective measure alternatives in Section 5.0 for each evaluation standard. The standards for comparison are identical to those used for the detailed analysis of individual alternatives.

The following corrective measure alternatives are being compared in this section:

- Alternative 1 – No Action
- Alternative 2 – Natural Attenuation with Long-Term Monitoring
- Alternative 3 – Enhanced Biodegradation with Long-Term Monitoring

### 6.2 COMPARATIVE ANALYSIS OF ALTERNATIVES

A corrective measure alternative is selected based on a comparison between the alternatives using the standards presented in the detailed analysis in Section 5.0. This section presents a comparative discussion of the corrective measure alternatives versus the evaluation standard.

#### 6.2.1 Protection of Human Health and the Environment

Groundwater is not a human health concern at SWMU 9 since it has been classified as Class G-III, nonpotable, by FDEP. No human health COCs were selected in the HHRA. Although ecological receptors are not exposed to site groundwater, receptors could become exposed through migration of groundwater contaminants to surface water and sediment in the nearby inlet. Groundwater RGOs have been developed based on sediment and surface water contaminant concentrations protective of ecological receptors. Based on the November 1998 sampling event, there were no contaminant concentrations in excess of groundwater RGOs. The November 1998 contaminant levels are significantly lower than previously detected levels due to a major precipitation event in September 1998. Since contaminant levels at SWMU 9 are likely to fluctuate, the potential for contaminants to exceed groundwater RGOs and expose ecological receptors to unacceptable risk does exist. There would be a progressive reduction of risks to aquatic receptors as corrective measures become more

aggressive, Alternative 3 being the most aggressive alternative. Alternatives 2 and 3 would incorporate a monitoring program consisting of periodic sampling of groundwater at SWMU 9. The long-term monitoring program would verify or refute the expectation that groundwater contaminant concentrations will decrease over time, reducing the risks to ecological receptors.

- Alternative 1 may reduce the current potential risks to the environment, but the extent of this reduction, if any, would remain unknown.
- Alternative 2 would reduce the risk to the environment. Groundwater contaminant concentrations would decrease over time, reducing the risk to ecological receptors. Monitoring of the contaminants would be performed to ensure that degradation is taking place.
- Alternative 3 would reduce the risk to the environment from contaminants present in groundwater. This alternative would aggressively treat the contamination in the groundwater resulting in reduction of contaminant concentrations below action levels.

#### **6.2.2 Media Clean-Up Standards**

This standard considers whether the corrective measure alternative will achieve the Media Clean-Up Standards. In addition, this standard includes an assessment of relevant institutional needs for each corrective measure alternative. The effects of Federal, State of Florida, and local environmental regulations are also considered.

- Alternative 1 may eventually comply with Media Clean-Up Standards. However, due to the lack of monitoring, this would never be verified.
- Alternative 2 would eventually comply with Media Clean-Up Standards. Monitoring would be performed to determine the effectiveness of Alternative 2, which would rely on natural attenuation to degrade contaminants in the groundwater.
- Alternative 3 would comply with Media Clean-Up Standards for groundwater. ORC and HRC would aggressively treat groundwater contamination, reducing levels to below action levels. This alternative would monitor the potential for groundwater to migrate and adversely impact the sediment and surface water.

### 6.2.3 Source Control

This standard evaluates the corrective measure alternatives for control of the source of contamination to reduce or eliminate further releases that may pose a threat to human health and the environment, to the furthest extent possible. This standard addresses whether source control measures are necessary and what type of source control actions would be appropriate.

- Alternative 1 does not include source control measures.
- Alternative 2 does not include source control measures. Contaminants would be allowed to degrade via natural attenuation. However, natural attenuation is not targeted towards the source of contamination. Alternative 2 would monitor the effect of natural attenuation on groundwater contaminant levels.
- Alternative 3 includes source control measures for contaminated groundwater. The contaminant source would be treated, providing protection of the environment. Alternative 3 would monitor the effect of the treatment on groundwater contaminant levels.

### 6.2.4 Waste Management Standards

The corrective measure alternative must comply with applicable standards for the management of wastes. This standard includes a description of how the specific waste management activities will be conducted in order to maintain compliance with all applicable state and Federal regulations.

- Alternative 1 does not include removal of any waste materials; therefore, the management of waste material standards does not apply.
- Alternatives 2 and 3 will include removal of sampling waste materials. Alternative 3 may produce wastes through implementation of the alternative. The wastes will be sampled and properly disposed of.

### 6.2.5 Long-Term Reliability and Effectiveness

Long-term reliability and effectiveness of the corrective measure alternatives evaluation includes an assessment of useful life, operation and maintenance requirement, and demonstrated reliability.

- Alternative 1 would allow for the ecological residual risks to remain in the long term. However, risks to ecological receptors would reduce over time.
- Alternative 2 would allow contamination at SWMU 9 to degrade via natural attenuation over an extended period of time. Risks to ecological receptors would be reduced over time. This alternative would monitor long-term effects of natural attenuation on the environment.
- Alternative 3 would treat contaminated groundwater and is considered reliable and protective of the environment in the long-term.

#### **6.2.6 Reduction in Toxicity, Mobility, or Volume of Wastes through Treatment**

This standard includes the ability of the corrective measure to reduce the toxicity, mobility, or volume of the contaminated media through treatment.

- Alternative 1 does not include treatment; therefore, no reduction through treatment in the toxicity, mobility, or volume would be achieved.
- Alternative 2 is natural attenuation, which includes relying on natural processes already taking place to treat contamination in groundwater. Biodegradation of the contamination would not reduce the toxicity, mobility, and volume of groundwater contamination at SWMU 9 through treatment. However, contaminant toxicity and volume would be reduced. Monitoring would take place to ensure that natural attenuation is successfully lowering contaminant levels.
- Alternative 3 would treat contaminated groundwater using both ORC and HRC. This treatment technology provides for a reduction in the toxicity, mobility, and volume of contaminants in the groundwater.

#### **6.2.7 Short-Term Effectiveness**

This standard includes an evaluation of the potential effects to the workers and community during implementation of the corrective measure. This standard is not applicable to Alternative 1 – No Action.

- No significant risks are anticipated for Alternatives 2 and 3, other than the minimal short-term risk to workers during sampling activities, and addition of ORC and HRC to groundwater for

Alternative 3. Monitoring will continue until results adequately demonstrate to the EPA and FDEP that protection of the environment is achieved.

**6.2.8 Implementability**

This standard includes consideration of the relative ease of implementation, availability of equipment and services, the technical complexity of the process, and the ability to obtain required permits. The time needed to complete each corrective measure alternative is also provided. This criteria is not applicable to Alternative 1 – No Action.

- Alternative 2 involves monitoring natural attenuation processes and contaminant levels in groundwater. This alternative is considered readily implementable. Monitoring will continue until results adequately demonstrate to the EPA and FDEP that protection of the environment is achieved. The estimated time required for natural attenuation to reduce contaminant levels to below action levels is 18 years.
- Alternative 3 includes treatment of groundwater contamination using a mixture of ORC and HRC. Using ORC as a treatment technology is considered readily implementable. HRC is a more innovative technology, but is expected to successfully treat the source of contamination at SWMU 9. This alternative includes monitoring of groundwater until results adequately demonstrate to the USEPA and FDEP that protection of off-site residents and the environment is achieved. The estimated time required until contamination is below action levels is less than 5 years.

**6.2.9 Cost**

A cost estimate for each of the corrective measures includes both capital, operation, and maintenance costs. Capital costs include both direct and indirect cost. Operation and maintenance costs are post construction activities, which are necessary to ensure the continued effectiveness of a corrective measure. Cost calculations are included in Appendix D.

Alternative	Capital (\$)	Operating (\$/year)	Present Worth (\$)
1	0	0	0
2	0	15,000-57,000	235,000
3	51,000	15,500-60,500	183,982

### **6.3 SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES**

Table 6-1 provides a table summarizing the comparative analysis of the corrective measure alternatives for the three alternatives based on the results of the evaluation presented in Section 6.2.

### **6.4 RECOMMENDED CORRECTIVE MEASURE ALTERNATIVE**

The recommended alternative for this site is Alternative 3 – Enhanced Bioremediation with Long-Term Monitoring. This alternative would treat contamination in groundwater and perform groundwater monitoring to determine the effectiveness of the corrective measure alternative. If the alternative is not found to be protective of the environment, then another alternative should be considered. However, Alternative 3 is the most aggressive alternative being considered in this CMS and is expected to effectively treat groundwater contamination.

TABLE 6-1

**SUMMARY OF COMPARATIVE ANALYSIS OF CORRECTIVE MEASURE ALTERNATIVES  
SWMU 9  
NAS KEY WEST, BOCA CHICA KEY, FLORIDA  
Page 1 of 2**

<b>Alternative 1: No Action</b>	<b>Alternative 2: Natural Attenuation with Long-Term Monitoring</b>	<b>Alternative 3: Enhanced Bioremediation with Long-Term Monitoring</b>
<b>Protection of Human Health and the Environment</b>		
May be protective of human health and risks to the environment, but risks would be unknown since no monitoring will take place.	Would eventually be protective of human health and the environment by allowing contamination to degrade via natural attenuation. Alternative 2 would monitor the contamination and attenuation process in the environment ensuring this protection.	Would be protective of human health and the environment by treating contamination in groundwater and monitoring contaminant levels.
<b>Media Clean-up Standards</b>		
Would not comply with media clean-up standards.	Would eventually achieve groundwater clean-up standards if natural attenuation continues at the present rate. Monitoring would determine when compliance has been achieved.	Would comply with media clean-up standards. Monitoring would be performed to ensure that Alternative 3 meets these standards.
<b>Source Control</b>		
No new source control would be implemented.	Does not include source control because the groundwater contaminants would be allowed to degrade via natural attenuation.	The contaminant source would be treated.
<b>Waste Management Standards</b>		
No standards applicable as no waste will be generated.	Any waste generated from sampling activities would be sampled and properly disposed of.	Waste from sampling and implementation would be sampled and properly disposed of.
<b>Long-Term Reliability and Effectiveness</b>		
No control would be in place; residual contamination and existing risks would remain.	Long-term effectiveness of this alternative is easily measured with monitoring to assess the decrease of contamination in the environment.	This alternative would be effective in the long-term by treating the contaminated groundwater, and would monitor the effects of this treatment.
<b>Reduction in Toxicity, Mobility, or Volume through Treatment</b>		
This alternative involves no treatment to reduce toxicity, mobility, or volume of the contaminated media.	This alternative involves allowing natural biodegradation of contamination to take place, which would not reduce toxicity, mobility, and volume of the contaminated groundwater through treatment. However, contaminant toxicity and volume would be reduced through natural processes.	Alternative 3 would treat contaminated groundwater. This treatment technology provides for a reduction in toxicity and volume of contaminants in groundwater.

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TABLE 6-1

SUMMARY OF COMPARATIVE ANALYSIS OF CORRECTIVE MEASURE ALTERNATIVES  
 SWMU 9  
 NAS KEY WEST, BOCA CHICA KEY, FLORIDA  
 Page 2 of 2

Alternative 1: No Action	Alternative 2: Natural Attenuation with Long-Term Monitoring	Alternative 3: Enhanced Bioremediation with Long-Term Monitoring
<b>Short-term Effectiveness</b>		
This alternative does not reduce risk of exposure to contamination and would not pose any new risk during implementation.	No significant risks are anticipated in the short-term, other than the minimal risk to workers during sampling activities.	No significant risks are anticipated in the short-term, other than the minimal risk to workers during sampling and ORC/HRC injection activities.
<b>Implementability</b>		
Readily implementable since no action would occur.	Easily implementable, since monitoring would be the only activities performed on site.	Easily implementable. Vendors are readily available and the remediation technology is well proven.
<b>Cost (Total Present Worth)</b>		
\$0.00	\$236,403	\$183,982

Alternative 1 – No Action  
 Alternative 2 – Natural Attenuation with Long-term Monitoring  
 Alternative 3 – Enhanced Biodegradation with Long-term Monitoring

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## REFERENCES

ABB Environmental Services, Inc. (ABB), 1994. Contamination Assessment Report Jet Engine Test Cell, Building A969. Prepared for Department of the Navy, Southern Division Naval Facilities Engineering Command. Tallahassee, Florida.

ABB, 1995a, Supplemental Resource Conservation and Recovery Act Facility Investigation and Remedial Investigation Workplan, Volume I. Prepared for Department of the Navy, Southern Division Naval Facilities Engineering Command. Tallahassee Florida.

ABB, 1995b, Supplemental Resource Conservation and Recovery Act Facility Investigation and Remedial Investigation Sampling and Analysis Plan, Volume II. Prepared for Department of the Navy, Southern Division Naval Facilities Engineering Command. Tallahassee Florida.

Bechtel Environmental, Inc. (BEI), 1995a. Remediation Work Plan. Prepared for Department of the Navy, Southern Division, Naval Facilities Engineering Command. Oak Ridge, Tennessee.

BEI, 1995b. Technical Memorandum TM-321-001, Groundwater Evaluation, Jet Engine Test Cell, Prepared for Department of the Navy, Southern Division, Naval Facilities Engineering Command. Oak Ridge, Tennessee.

BEI, 1996. Project Plan Revision 321-010, SWMU-9 Jet Engine Test Cell. Prepared for Department of the Navy, Southern Division, Naval Facilities Engineering Command. Oak Ridge, Tennessee.

BEI, 1998. Project Completion Report, Prepared for Department of the Navy, Southern Division, Naval Facilities Engineering Command, Oak Ridge, Tennessee.

B&R Environmental (Brown & Root Environmental, Inc.) 1997, Supplemental RCRA Facility Investigation and Remedial Investigation Report for High-Priority Sites, Revision 2. NAS Key West, Florida prepared for SOUTHNAVFACENGCOM, Tampa, Florida.

B&R Environmental, 1998, Site Inspection Workplan for Ten BRAC Properties, Revision 2. NAS Key West, Florida prepared for SOUTHNAVFACENGCOM, North Charleston, South Carolina.

Chiou, J.D., 1996. ECTran – A Spreadsheet Based Screening-Level Multimedia Fate and Transport Model with Monte Carlo Simulation Capability. Sponsored by the U.S. Department of Energy, Augusta, Georgia.

Envirodyne Engineers, 1985. Initial Assessment Study of Naval Air Station, Key West, Florida. Prepared for Naval Energy and Environmental Support Activity. St. Louis, Missouri.

Fetter, C.W., 1994. Applied Hydrogeology, Third Edition. Prentice-Hall, Inc. Upper Saddle River, New Jersey.

FDEP (Florida Department of Environmental Protection), 1994, "Approach to the Assessment of Sediment Quality in Florida Coastal Waters: Volume 1 – Development and Evaluation of Sediment Quality Assessment Guidelines," Tallahassee, Florida.

FDEP, 1995a, "Florida Surface Water Quality Standards," Chapter 62-302.

FDEP, 1995b, memorandum to District Directors, "Soil Cleanup Goals for Florida," September.

FDEP, 1996, memorandum to District Directors, "Applicability of Soil Cleanup Goals for Florida," January.

Geraghty & Miller, Inc., 1987, Verification Study Assessment of Potential Ground-Water Pollution at the Naval Air Station, Key West, Florida, prepared for Naval Facilities Engineering Command, Southern Division, Tampa, Florida.

IT (IT Corporation), 1991, Remedial Investigation Report, Naval Air Station, Key West, Florida, Final Draft, prepared for Southern Division, Tampa Florida.

IT (IT Corporation), 1994, RCRA Facility Investigation/Remedial Investigation, Final Report, NAS Key West, Boca Raton, Florida, prepared for SOUTHNAVFACENGCOM, Tampa, Florida, June.

Long, E.R., and L.G. Morgan, 1991. Potential for Biological Effects of Sediment Sorbed Contaminants Tested in the National Status and Trends Program. NOAA/TM/NOS/OMA-52, National Ocean Service, Office of Oceanography and Marine Assessment, Rockville, Maryland.

Ochs, D. 1999, Personal communication to E. Harrison. E-mail, subject "Key West NAS," dated August 4, 1999.

Tetra Tech NUS, 1999a, Site Inspection Report for Nine BRAC Parcels, NAS Key West, Key West, Florida, prepared for SOUTHNAVFACENGCOM, North Charleston, South Carolina.

USCBS (U.S. Census Bureau Service), 1990, U.S. Census, 1990.

USEPA (U.S. Environmental Protection Agency), October 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final.

USEPA (U.S. Environmental Protection Agency), 1994a. RCRA Corrective Action Plan (Final). OSWER Directive 9902.3-2A, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 1994b. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. EPA 540/R-93/081. Office of Emergency and Remedial Response, Washington, D.C., May.

USEPA (U.S. Environmental Protection Agency), 1995a, "Supplemental Guidance to RAGs: Region 4 Bulletins, Human Health Risk Assessment," Waste Management Division, Atlanta, Georgia.

USEPA (U.S. Environmental Protection Agency), 1995b. "Risk-Based Concentration Table, July – December 1995," Region III EPA.

USEPA (U.S. Environmental Protection Agency), 1995c, "Drinking Water and Health Advisories," Office of Drinking Water, Washington, D.C., May.

USEPA (U.S. Environmental Protection Agency), 1995d, "EPA Region III BTAG Screening Levels," Philadelphia, Pennsylvania.

USEPA (U.S. Environmental Protection Agency), 1996, "Risk-Based Concentration Table, January – June 1996," Region III EPA.

USEPA (U.S. Environmental Protection Agency), 1997, Draft EPA Region 4 Suggested Practices for Evaluation of a Site for Natural Attenuation (Biological Degradation) of Chlorinated Solvents, Version 3.0.

USEPA (U.S. Environmental Protection Agency), 1999, Remediation and Characterization Innovative Technologies (REACH IT), posted on the Internet.

United States Navy, 1997. CNBJAXINST 5090.2, Land Use Restrictions at Environmental Remediation Sites on Board U.S. Navy Installations, Commander naval Base Jacksonville, Jacksonville, Florida, August.

Will, M.E. and G.W. Suter, 1994, "Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Soil Litter Invertebrates and Heterotrophic Process," Oak Ridge National Laboratory, Oak Ridge, Tennessee.

**APPENDIX A**

**RESPONSE TO COMMENTS**

## APPENDIX A. RESPONSE TO COMMENTS

### CORRECTIVE MEASURES STUDY FOR SOLID WASTE MANAGEMENT UNIT 9, BOCA CHICA JET ENGINE TEST CELL FOR NAVAL AIR STATION, KEY WEST, FLORIDA

#### RESPONSE TO COMMENTS FROM JORGE CASPARY, FDEP:

**Comment 1:** Page 5-3, Alternative No. 3: it is unclear where the 1,000 and 500 pounds of ORC and HRC that will be needed to dehalogenate the plume came from. If there are mass calculations that indicate that such quantity is adequate to treat the mass of chlorinated solvents, please attach them to the CMS; otherwise, please indicate case studies/specific references of ORC/HRC utilization that have achieved MCLs.

**Response:** *The amount of ORC and HRC recommended for use for Alternative 3 was obtained from a vendor (Regenesis). Calculations used to determine these quantities will be included in Rev. 1.*

**Comment 2:** Page 5-3, Alternative No. 3: please indicate the expected rate of dechlorination achieved by ORC/HRC. The text mentions a total of 5 years of monitoring. Is this the time frame that the proposed remedial system is expected to achieve MCLs? Or a percentage reduction coupled with monitoring/natural attenuation until year 20 is the objective?

**Response:** *Based on a similar site (Fort Walton Beach on the Gulf of Mexico) with TCE levels at 500 ppb, a 70% reduction in the TCE level was seen in the first three months. The remedial system is expected to reduce contaminant levels to below action levels in one to two years. A monitoring time of five years was assumed to be conservative.*

**Comment 3:** Has the feasibility of utilizing the HRC in highly carbonate-enriched waters been investigated? The buffering capacity of carbonate enriched waters may not produce the expected dehalogenation objectives. Also, what is the effect of severe hydraulic flushing on these compounds? Will additional quantities of the material be needed if a large storm event hits the area?

**Response:** *HRC will not be affected by carbonate interference since it is an organic. However, ORC may be affected. From work done on brackish groundwater, it has been determined that the release of oxygen is accelerated. A treatability study will be performed to better define the ability of ORC/HRC to perform in carbonate-enriched soil and groundwater.*

*Heavy storm conditions resulting in flushing would also speed the release of oxygen and hydrogen. It is recommended that the application of ORC and HRC not occur during hurricane season to reduce premature releases as much as possible since flushing could occur during a significant storm, which may have a detrimental impact on the dehalogenation process.*

**Comment 4:** While the NA study recommended four alternatives, was restarting the pump and treat system (which apparently had reduced TCE to 37 µg/L) considered? Can the ORC/HRC compound be injected utilizing the horizontal well installed as part of the pump and treat? Depending on the status of the system, and given the fact that TCE is absent, the capital cost of restarting the pump and treat system plus O & M and groundwater monitoring for a limited amount of time would probably have been an economic alternative.

**Response:** *In order to restart the pump and treat system at SWMU 9, the system would have to essentially be rebuilt to replace the system components that are not functional at this time. Capital costs for rebuilding the system would make the alternative economically infeasible.*

*The horizontal infiltration gallery could not be utilized for distributing the ORC/HRC since it is located to the east of the plume.*

**Comment 5:** Based on the May 1998 sampling event, it appears that TCE rebounded after shutting down the pump and treat system (from 37 to 350 µg/L). However, the November 1998 sampling event shows that only cis and trans-DCE are the constituents of concern. A new round of sampling and analysis of groundwater, coupled with the requested information from comments 1 and 2, would provide a more definitive set of data to justify the selected alternative.

**Response:** *The treatability study workplan will address the need to establish baseline conditions just prior to the treatment of groundwater with ORC/HRC. This baseline sampling event will also be used to calculate how much ORC/HRC will actually be used during the treatability study.*

**Comment 6:** The economic analysis presented in Appendix D is confusing. For instance, the estimated cost of item Natural Attenuation with Long Term Monitoring Analysis for Year 1 is \$4,500. The same item cost for Alternative 3 is \$8,000.

**Response:** *The estimated analysis cost for Alternative 2 for Year 1 will be changed to \$6,000 (\$1,500 per sampling event with four events the first year). For Alternative 3, Bioremediation, the analysis cost per sampling event is higher (\$2,000) because an additional parameter (methane) is*

*analyzed at the contracted laboratory making the total cost for monitoring the first year (four sampling events) \$8,000.*

**Comment 7:** For Alternative 3, only the Present Worth (PW) cost until year 5 is presented; however, the previous indicates *that \$20,000 will be spent every five years until year 20.* As in Alternative 2, this cost should also be part of the PW calculation.

**Response:** *The monitoring period for Alternative 3 is 5 years. The annual cost table for Alternative 3 should say that an Analysis Review will be performed for year 5 only, resulting in a \$20,000 cost for that year. Therefore, the Present Worth calculations are correct to calculate present worth up to year 5.*

#### RESPONSE TO COMMENTS FROM T. BALLARD, EPA REGION 4

**Comment 1:** Page 2-4, Paragraph 1 - I concur that the decreases seen in November 1998 sampling results are probably temporary. The increase in S9MW-15 from 53 parts per billion (ppb) VOC to 5,650 ppb, subsequent to shutting off the pumps, will probably be mirrored in a recovery of concentrations after the hurricane's effects pass.

**Response:** *Comment noted.*

**Comment 2:** Page 2-8, Paragraph 4 - were the HQs referenced here derived from comparison of RBCs to the one sample in which the contaminants were detected, or to the UCL 95? For soils, the latter is probably more representative of exposure to a receptor.

**Response:** *A particular exposure concentration (not the 95% UCL) was compared to the ecological threshold in order to characterize potential risk to ecological receptors of concern from contaminant exposure. For additional information, see Section 3.3 in Appendix G of the RFI/RI Report for High-Priority Sites.*

**Comment 3:** Figure 2-2 - Needs a date on the figure for which the data were collected. Also, there should be a GW elevation map for each sampling event.

**Response:** *Concur. A date will be added to Figure 2-2. A figure depicting groundwater elevation data for the November 1998 sampling event will be added.*

**Comment 4:** Figure 2-4 - For well S9MW2 - please check the data. All contaminants shown here have the same concentration.

**Response:** *The data have been rechecked. This is the correct data reported from the laboratory. These data were qualified with an 'X' qualifier by the analytical laboratory. The information packages procured from the laboratory during this phase of investigation did not include any additional information regarding these data or any data validation.*

**Comment 5:** Page 3-2, fourth bullet - Revise to reflect the correct definition of relevant and appropriate, as explained in either the NCP or in the RI/FS guidance.

**Response:** *Concur. The text will be changed.*

**Comment 6:** Page 3-11, second paragraph - just a question based on my newness to the site - were the new action levels adopted by the Team vetted in any way for appropriateness as ecological screening criteria? It seems we went from a more stringent to a less stringent set of criteria, with no explanation other than that the Team adopted them.

**Response:** *Since 1996, the ARAR/SAL criteria have been refined during the intensive DQO process undertaken by the Team as part of the BRAC activities at NAS Key West. The DQO process and BRAC action levels are addressed in the Site Inspection Workplan for Ten BRAC Properties. Sediment and surface water action levels were developed with ecological exposure in mind. In addition, the potential ecological effects caused by migration of groundwater to sediment surface water have been accounted for during the data analyses performed at SWMU 9.*

**Comment 7:** Page 3-13, paragraph 2 and 5 - same comment as #6.

**Response:** *See response for Comment number 6.*

**Comment 8:** Page 3-16, last sentence in Section 3.4 - I don't see RGOs clearly discussed in Section 3.3. The criteria they must meet are discussed. Table 3-2 has the numerical RGOs.

**Response:** *Section 3.3 explains that the development of cross-media RGOs for groundwater is presented in Appendix C. Cross-media RGOs were developed for groundwater because no direct exposure pathway exists at SWMU 9 for chemicals in groundwater. Section 3.3.1, a subsection of Section 3.3, describes in more detail how groundwater RGOs protective of sediment and surface water were developed using groundwater modeling.*

**Comment 9:** Section 3.5.1. Does the plume volume calculation take into account desorption of VOCs from potentially NAPL-saturated areas of the porous limestone? If not, this analysis may significantly underestimate the volume of contaminated ground water that will have to be remediated.

**Response:** *Surface and subsurface soil has been sampled in the plume area. The relatively low levels of chemicals of concern (CoCs) consistently detected in soil and groundwater over the past 5 years suggest a low probability that NAPL-saturated areas exist to any significant extent at SWMU 9. Therefore, the plume volume calculation is assumed to be accurate.*

**APPENDIX B**

**NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9**

# **Natural Attenuation Study Results**

for

## **Solid Waste Management Unit 9**

**Naval Air Station Key West  
Boca Chica Key, Florida**



**Southern Division  
Naval Facilities Engineering Command**

**Contract Number N62467-94-D-0888**

**Contract Task Order 0007**

August 1999

*Revision 2*

NATURAL ATTENUATION STUDY RESULTS  
FOR  
SOLID WASTE MANAGEMENT UNIT 9

NAVAL AIR STATION KEY WEST  
BOCA CHICA KEY, FLORIDA

COMPREHENSIVE LONG-TERM  
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

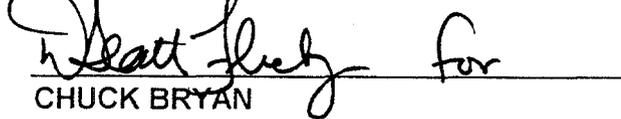
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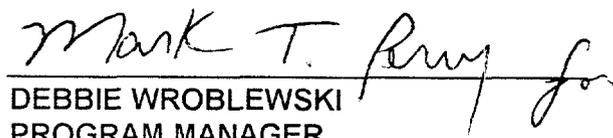
CONTRACT NUMBER N62467-94-D-0888  
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## 1.0 INTRODUCTION

### 1.1 PURPOSE AND SCOPE

Tetra Tech NUS Inc. (TtNUS, formerly Brown & Root [B&R] Environmental) has prepared Resource Conservation and Recovery Act (RCRA) documents for the 14 Environmental Navy Restoration Account (ENRA) sites at Naval Air Station (NAS) Key West including the Solid Waste Management Unit (SWMU) 9 Former Jet Engine Test Cell. TtNUS performed this SWMU 9 study on behalf of the United States Navy, Naval Facilities Engineering Command, Southern Division (SouthDiv) under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract Number N62467-94-D-0999, Contract Task Order 007. In 1996, B&R Environmental collected field data at SWMU 9 in accordance with the Supplemental RCRA Feasibility Investigation/Remedial Investigation (RFI/RI) Workplan and Sampling and Analysis Plan (SAP) prepared by ABB Environmental Services Inc., dated December 6, 1995. The RFI data was compiled with data from previous investigations performed at the site, including the 1994 Contamination Assessment Report (ABB, 1994) and the 1995 Groundwater Evaluation (BEI, 1995a), in order to prepare the RFI/RI Report.

Based upon recommendations provided in the Groundwater Evaluation, a pump and treat system design was designed, installed in 1996, and operated for 1 year. This interim remedial action paralleled the TtNUS Supplemental RFI/RI investigation at the site. Low concentrations of three chlorinated solvents (e.g., trichloroethene, cis 1,2 dichloroethene, and trans 1,2 dichloroethene [1,2-DCE]) and benzene were observed during the monthly sampling of the recovery wells.

The NAS Key West Partnering Team held several discussions concerning remedial alternatives that could be implemented to take advantage of monitored intrinsic bioremediation and natural attenuation processes at the site. Based upon the delineation of the site, the appreciable decline in contaminants levels (primarily chlorinated solvents and benzene, toluene, ethylbenzene and xylenes BTEXs) from 1993 to 1996, and the low recovery rate of chlorinated solvents by the pump and treat system, the Partnering Team thought that the groundwater cleanup standards could be achieved through monitored natural attenuation. In April 1998, a study was proposed to primarily identify the natural attenuation processes that exist at the site. The groundwater sampling event was conducted at SWMU 9 on May 13 to 15, 1998. Upon completion of the May natural attenuation study, it was determined that a more intensive groundwater sampling effort was needed to refine the natural attenuation study, and to determine if they

were sufficient to be protective of the onsite lagoon. The second sampling event was performed November 20 to 22, 1998.

## **1.2 INVESTIGATION HISTORY**

A contamination assessment report (CAR) was performed at SMWU 9 by ABB Inc. from October 1993 through February 1994 (ABB, 1994). The Groundwater Evaluation was performed by Bechtel Environmental, Inc. from January through September 1995 (BEI, 1995a). In 1996, a Supplemental RFI/RI was conducted by Brown & Root Environmental in accordance with Hazardous and Solid Waste Act (HSWA) Permit No. FL6-170-022-952, issued by the U.S. Environmental Protection Agency (EPA). A Corrective Action Management Plan (CAMP) has been prepared by ABB Inc. to describe the strategy for implementing the RCRA Corrective Action Plan at NAS Key West (ABB, 1995a).

In January 1996, TtNUS implemented the Supplemental RFI/RI SAP in accordance with the regulatory-approved planning documents (ABB, 1995b) at SWMU 9. The RFI/RI included chemical and toxicological analyses to calculate risks to human health and ecological receptors. A limited validation effort was performed on the analytical data collected by TtNUS. The data provided in the Contamination Assessment Report (ABB, 1994) and Groundwater Evaluation (BEI, 1995a) were also used to assess risk at the site. In July 1996, a groundwater pump and treat system was installed at SWMU 9. The system operated at the site from July 1996 to June 1997.

## **1.3 ORGANIZATION OF REPORT**

This Natural Attenuation Report has five sections and three appendices. Section 1 provides this brief purpose, scope, and investigative history of SWMU 9. Section 2 provides the background information on SWMU 9 including site geology and hydrogeology, and historical nature and extent of contamination. Section 3 provides the investigative activities performed during the May and November sampling events at SWMU 9. Section 4 provides the nature and extent of Volatile Organic Compound (VOC) contamination in groundwater and the natural attenuation sample results from the May and November sampling events. Section 5 provides a discussion of the summary and conclusions, and recommendations for future activities at SWMU 9.

## 2.0 SITE BACKGROUND INFORMATION

### 2.1 SITE BACKGROUND

SWMU 9, the Former Jet Engine Test Cell site, is associated with Building A-969, and is located in the northeastern portion of the Boca Chica Airfield (Figure 2-1). Beginning in 1969, the site was used for the testing of recently-repaired jet engines. No other known activities were conducted near the site. Jet engine testing activities were performed under a canopy in the middle of a circular concrete pad approximately 60 feet in diameter, in the central part of the site. The concrete area that extends east of the canopy was also used for jet engine testing activities. Jet blast deflectors are located at the ends of two concrete pads (100 feet and 80 feet long, respectively) that connect with the north and northeast portion of the circular concrete pad. The jet engines were fueled from a bermed, 5,000-gallon aboveground storage tank (AST) containing JP-5 fuel that was in use from 1987 through 1995. Building A-969 is 50 feet southeast of the testing area. A small shed at the eastern end of the concrete pad was used to store various equipment, oils, and jet fuel. Gas path cleaners also were stored on the eastern side of the shed. An asphalt parking area extends from these structures to the asphalt road. In addition, a switch house, air tanks, voltage box, and the 5,000-gallon AST are adjacent to the southwestern edge of the circular pad. A strip of mowed grass approximately 30 feet wide surrounds the east and west ends of the site. A narrow strip of red mangroves is located along the shoreline north of the site.

In January 1989, a fuel filter system leak and released approximately 700 gallons of JP-5 fuel on the west side of the AST. Approximately 600 gallons of the spilled fuel were pumped from puddles during initial remediation activities. The observed maximum depth of soil contamination was two inches. About 10 cubic yards of contaminated soil were excavated and removed from the spill site, which underwent weathering treatment for decontamination in accordance with State of Florida guidelines for petroleum-contaminated soils. An overturned lubrication oil drum and stained soil was observed by ABB in a small area adjacent to the northwest edge of the circular pad in November 1992 (ABB, 1994).

### 2.2 SITE CONDITIONS

Following is a brief description of the site history and background relevant to the natural attenuation study. Additional site background details can be found in the previously prepared Contamination Assessment Report (ABB, 1994), Groundwater Evaluation Report (BEI, 1995a), and Supplemental RFI/RI Report (B&RE 1997).

The subsections summarize the physical characteristics of the site relevant to the natural attenuation study. Although the information presented in this section duplicates much of the data presented in previous reports, a discussion of the geology, hydrogeology, and historical extent of contamination is critical to understanding the study objectives for this site. Additional details concerning the physical characteristics of the site can be found in the previously referenced Contamination Assessment Report (ABB, 1994), Groundwater Evaluation Report (BEI, 1995a), and Supplemental RFI/RI Report (B&RE, 1997).

### **2.2.1 Geology of the Lower Florida Keys**

The lower Keys, which are within the southern or distal geomorphic division of Florida, were formed during the Pleistocene era. Referred to as the "Oolite Keys," they are underlain by the Oolitic Member (Miami Oolite) of the Miami Limestone. The Oolitic Member consists of variably sandy, fossiliferous limestone composed primarily of ooids. In the lower Keys, the Oolitic Member consists of very fine to coarse sand-size, spherical carbonate grains and slightly sandy to very sandy, well- to moderately well-consolidated micritic calcite. The Miami Oolite conformably overlies the Key Largo Limestone, a geologic unit consisting of light gray to light yellow coralline limestone comprised of coral heads encased in a matrix of calcarenite. The Miami Oolite is approximately 27 feet thick. The Key Largo limestone is greater than 270-feet thick in the western portion of Key West (ABB, 1994).

### **2.2.2 Soils**

Undisturbed soil in the Keys consists of shallow marl over limestone with the substrate rock outcropping at the surface. Many areas of the Florida Keys, have been filled and graded. The soils on Boca Chica Key are primarily rockland with some filled areas and mangrove swamps. Other major soil groups on Boca Chica Key are Uthorthents, which consist of gravelly sand and marl, and Cudjoe, which consists of marl and weathered bedrock (ABB, 1995a).

### **2.2.3 Hydrogeology**

#### **2.2.3.1 Hydrogeology and Water Quality**

The surficial aquifer system that occurs in the lower Keys consists of the Oolitic Member, which is very porous and highly permeable due to the dissolution of carbonate by groundwater as it recharges the aquifer system. The aquifer is tidally controlled and fluctuates constantly. It is extremely porous, and solution holes and caverns are ubiquitous. The Tamiami Formation lies below the Key Largo Limestone unit, between 300 and 900 feet below land surface (bls). The formation contains mineralized water that

does not meet Florida drinking water standards. Underlying the Tamiami Formation are the Hawthorn and Tampa Formations, which together act as an aquiclude confining the underlying limestone units. Below the confining units of the Hawthorn and Tampa Formations is the Suwannee Limestone, a fossiliferous limestone representing the top of the water-producing zone in the Florida Keys. The water is of adequate quality for drinking after treatment. The Avon Park Limestone is 1,300 feet bls and, although it has a higher transmissivity than the Suwannee Limestone and supplies large quantities of drinking water in central Florida, the quality of water from this formation is poor in the Florida Keys (ABB, 1995a).

#### **2.2.3.2 Groundwater**

The unconfined surficial aquifer consists of the highly permeable Miami Oolite, which allows recharge from rainfall to seep quickly to the ocean and saltwater to intrude easily into the aquifer. The surficial aquifer is the principal aquifer of concern in Key West because of its use as a potable water resource to a limited extent (although not at NAS Key West) and because it is a groundwater-to-surface-water contaminant migration route. The water table ranges in depths from 0.8 to 2.4 feet below mean sea level (msl) at the center of Key West and from 0.4 to 2.2 feet below msl near the coast. The water table fluctuates diurnally because of tidal effects. Tidal influence has been measured at a maximum of 0.55 feet. According to the tidal influences study at SWMU 9 (November 1993), "Tidal fluctuations result in a temporary change in water table gradient; however these fluctuations are not expected to cause any noticeable horizontal migration of the contaminant plume." Head differentials associated with tidal variations near the shore can further accelerate groundwater movement in the area. A reconnaissance water-quality sampling study completed in 1990 by the U.S. Geological Survey in cooperation with the South Florida Water Management District indicates that the freshwater lens contains nonpotable water (ABB, 1995a).

The State of Florida classifies groundwater in unconfined aquifers that have a total dissolved solids concentration of 10,000 milligrams per liter (mg/L) or greater as Class G-III (nonpotable water). There are no freshwater public or registered domestic wells on NAS Key West (ABB, 1995a); however, surficial aquifer wells are reportedly in use by domestic residences on Boca Chica and Key West for nonpotable uses such as flushing water. The known use (laundry water) on Boca Chica is over one mile to the south of SWMU 9. The freshwater lens averages 5 feet thick below the center of the western half of Key West. The lens contains between 20 and 30 million gallons of fresh water, depending on the season. Underlying the freshwater lens is a 40-foot transition zone of brackish water (ABB, 1995a).

#### **2.2.4 Historical Nature and Extent of Contamination**

Fuels, oils, and solvents previously stored at the Former Jet Engine Test Cell were potential sources of contamination (Figure 2-2). Several fuel spills have been documented, and VOC and semi-volatile

organic compound (SVOC) fuel constituents were detected as groundwater contaminants. Chlorinated VOCs also were frequently detected groundwater contaminants; however, the three solvents reportedly used for cleaning and degreasing at the site did not contain chlorinated constituents. Low concentrations of these same VOC and SVOC contaminants were found in soil, but metals and inorganics are the primary soil contaminants. Surface-water and sediment contaminants at the shoreline on the northern edge of the site also were predominantly metals and inorganics.

In a given year, it is possible to determine the extent of groundwater contaminant plumes based on sampling results. Plume movement over time is in a northeasterly direction toward the lagoon (refer to Figure 2-3). In the contamination assessment, groundwater contaminant plumes of benzene and 1,2-DCE (total) were identified in the eastern part of the site (Figures 2-4 and 2-5). The groundwater evaluation confirmed the presence of both plumes.

The benzene contamination was of the same magnitude seen in the previous year, but the plume appeared to have changed directions between the two investigations, from northeast to northwest. The maximum concentration in 1995 was east of the well that exhibited the 1994 maximum. This may be indicative of eastward contaminant migration. In 1996, benzene was detected at 4 ( $\mu\text{g/L}$ ), exceeding applicable or relevant and appropriate/screening action level (ARAR/SAL) criteria in a single well (Figure 2-6).

The groundwater evaluation, indicated that the extent of DCE contamination may have increased, spreading in a two fingered plume to the west and northwest. The maximum detected concentration also increased from the contamination assessment study and the groundwater evaluation, and was found in a well east of the previous maximum concentration which indicates an easterly direction for contaminant migration. Concentrations of 1,2-DCE decreased overall in 1996; however, the maximum concentration detected during the Supplemental RFI/RI was 3,060  $\mu\text{g/L}$ .

Ethylbenzene and naphthalene were found to exceed ARAR/SAL criteria in groundwater in the eastern part of SWMU 9, where documented petroleum spills occurred, during the contamination assessment. 1995 sampling identified free product in two of these wells (S9MW-4 and S9MW-5). Methylene chloride was detected in a number of wells under and surrounding the concrete pad. Several other VOCs and SVOCs, usually chlorinated, were also detected in isolated instances. In addition to benzene and 1,2-DCE, the Supplemental RFI/RI detected several pesticides in a single eastern well. Bis(2-ethylhexyl)phthalate exceeded its ARAR/SAL criteria in a single well.

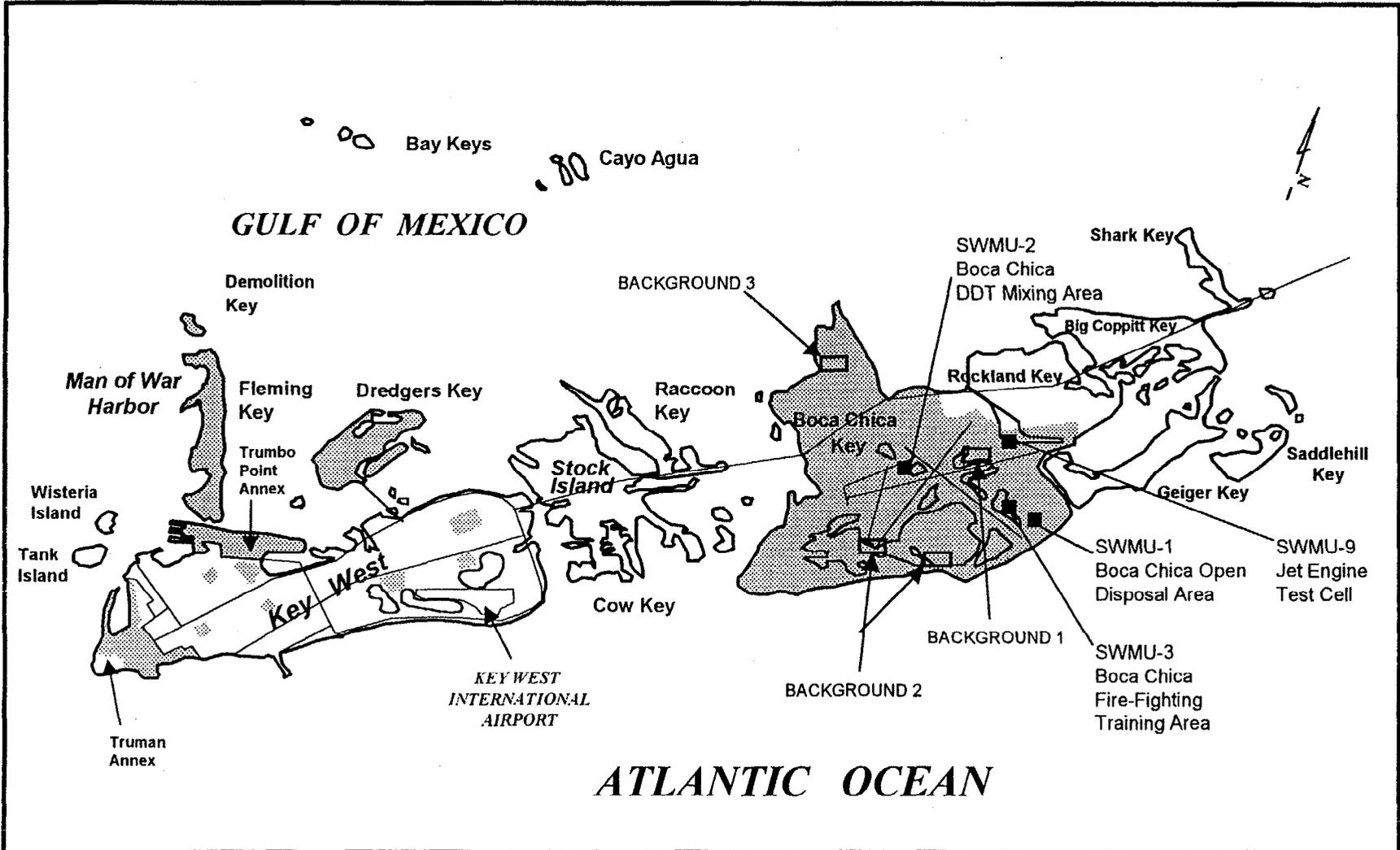
Soil sampling detected low concentrations of 1,2-DCE in the area of the groundwater plume. Methylene chloride was the only VOC or SVOC to exceed an ARAR or SAL in either surface or subsurface soil. In

one subsurface sample, it was detected slightly above the 0.366-(milligram per kilogram) mg/kg EPA Region III bench mark toxicity value (BTV). It was detected in a second subsurface sample but at a concentrated level less than the SAL. Metals were the most widespread soil contaminants. Aluminum (maximum of 4,790 mg/kg), chromium (maximum of 13.1 mg/kg) and nickel (maximum of 6.6 mg/kg) were detected in all the surface soil samples, but there did not appear to be any trend because higher concentrations were interspersed with lower ones. Chromium also was found in all subsurface samples, although concentrations were lower than those detected in the surface samples. Cyanide was found in both surface and subsurface samples, its maximum concentration (4.4 mg/kg) was in a subsurface sample.

Acetone was the only VOC or SVOC detected in either surface water or sediment. It was detected in two sediment samples from the northeastern part of the shoreline at SWMU 9. Arsenic also was detected in two sediment samples, with the highest concentration (17.8 mg/kg) directly north of the testing area. Both mercury and cyanide were detected once in surface water and sediment, but the detections in the two media were not at the same locations. Thallium was found in all surface-water samples but at concentrations less than twice the 6.3 µg/l ARAR in each case.

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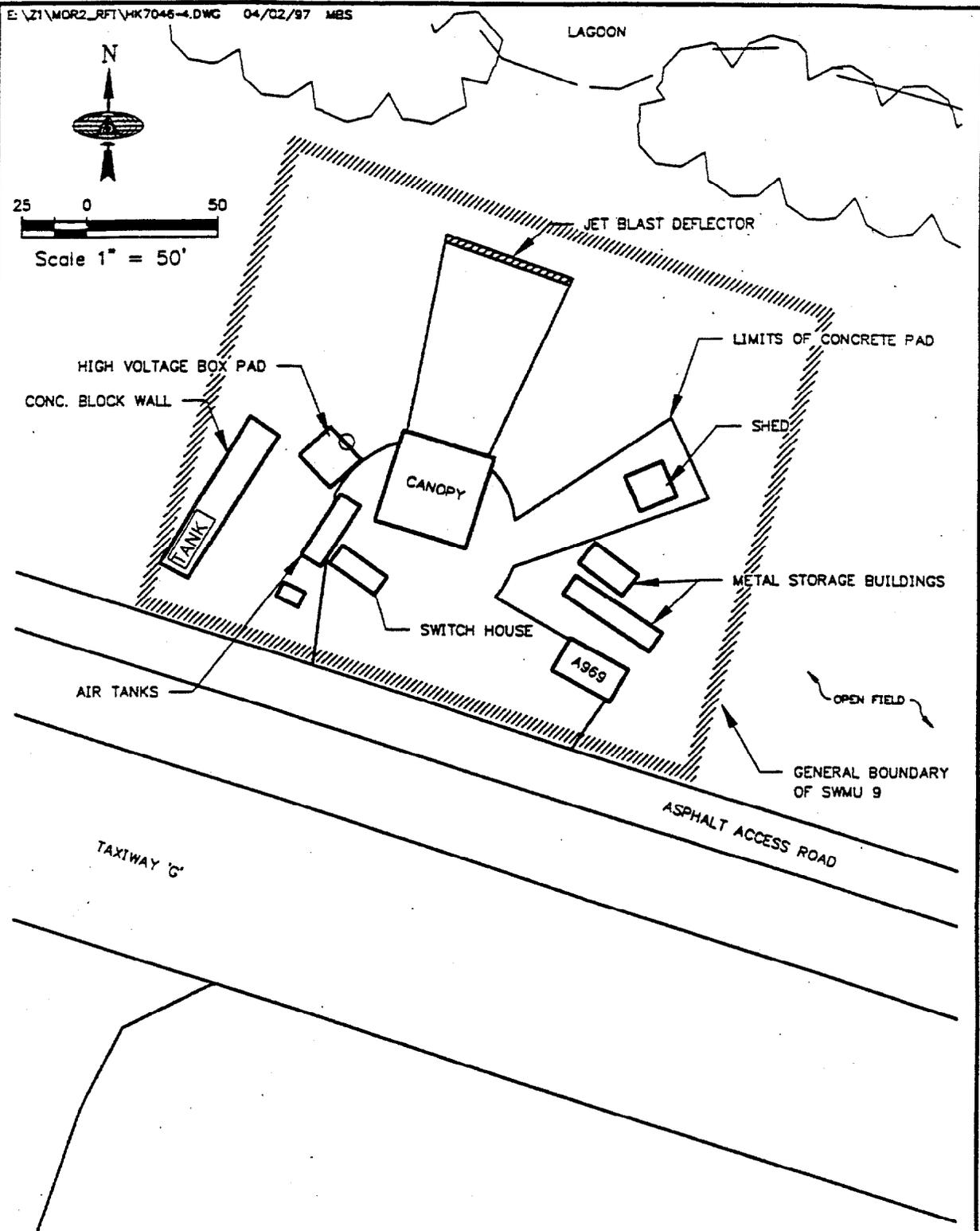
NATURAL ATTENUATION REPORT FOR SWMU 9  
 FIGURE 2-1. INSTALLATION RESTORATION SITES  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA

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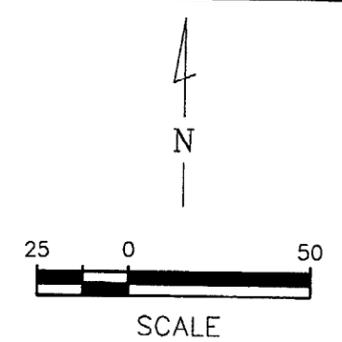
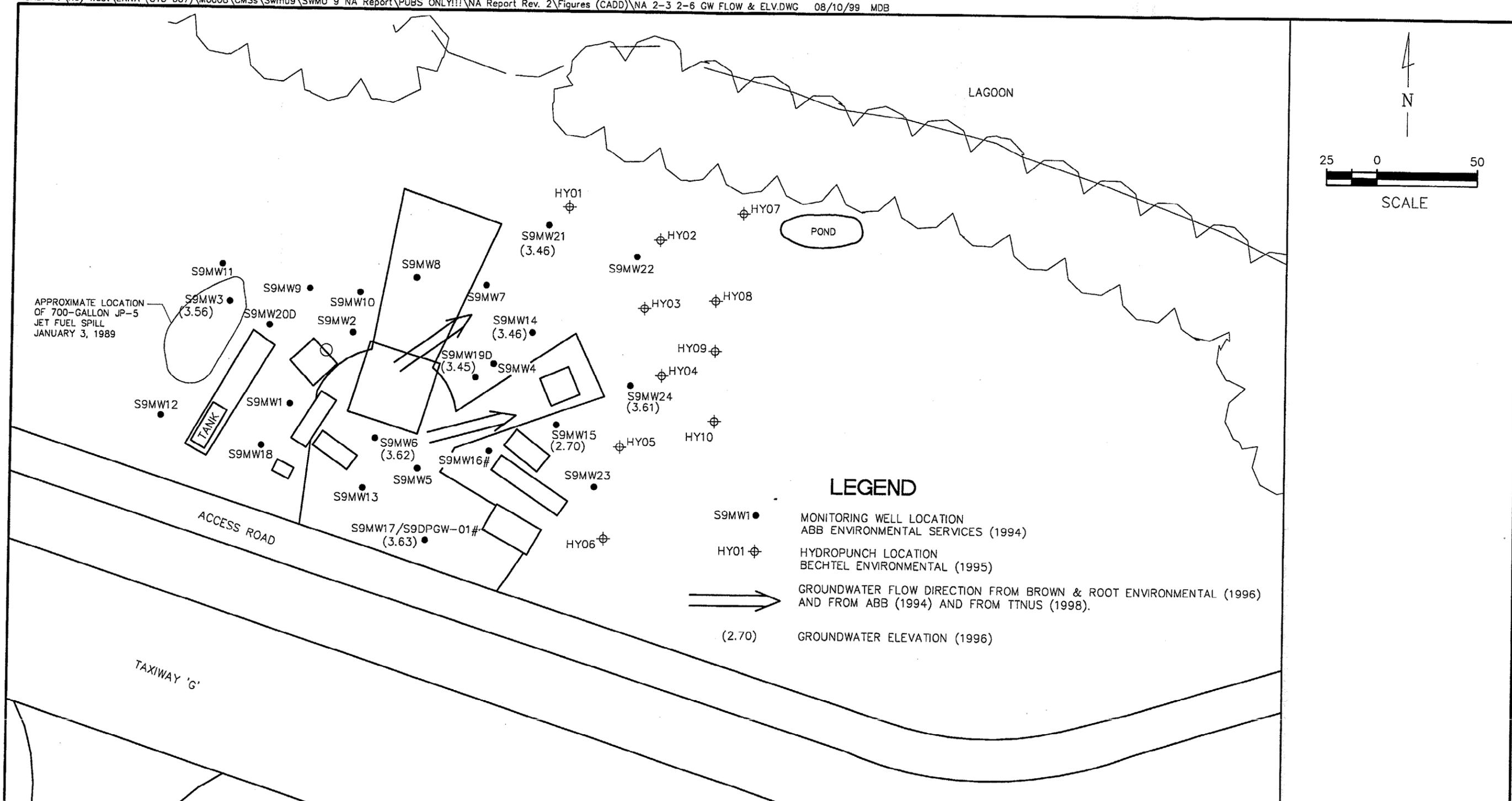


**Brown & Root Environmental**

Natural Attenuation Study Results for SWMU 9  
Figure 2-2. Site Location Map  
Navy Southern Division  
Boca Chica Key, Florida

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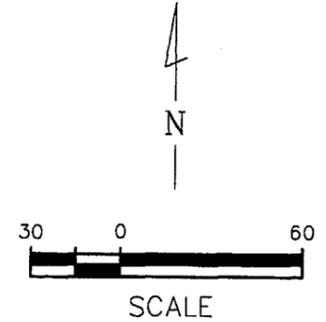
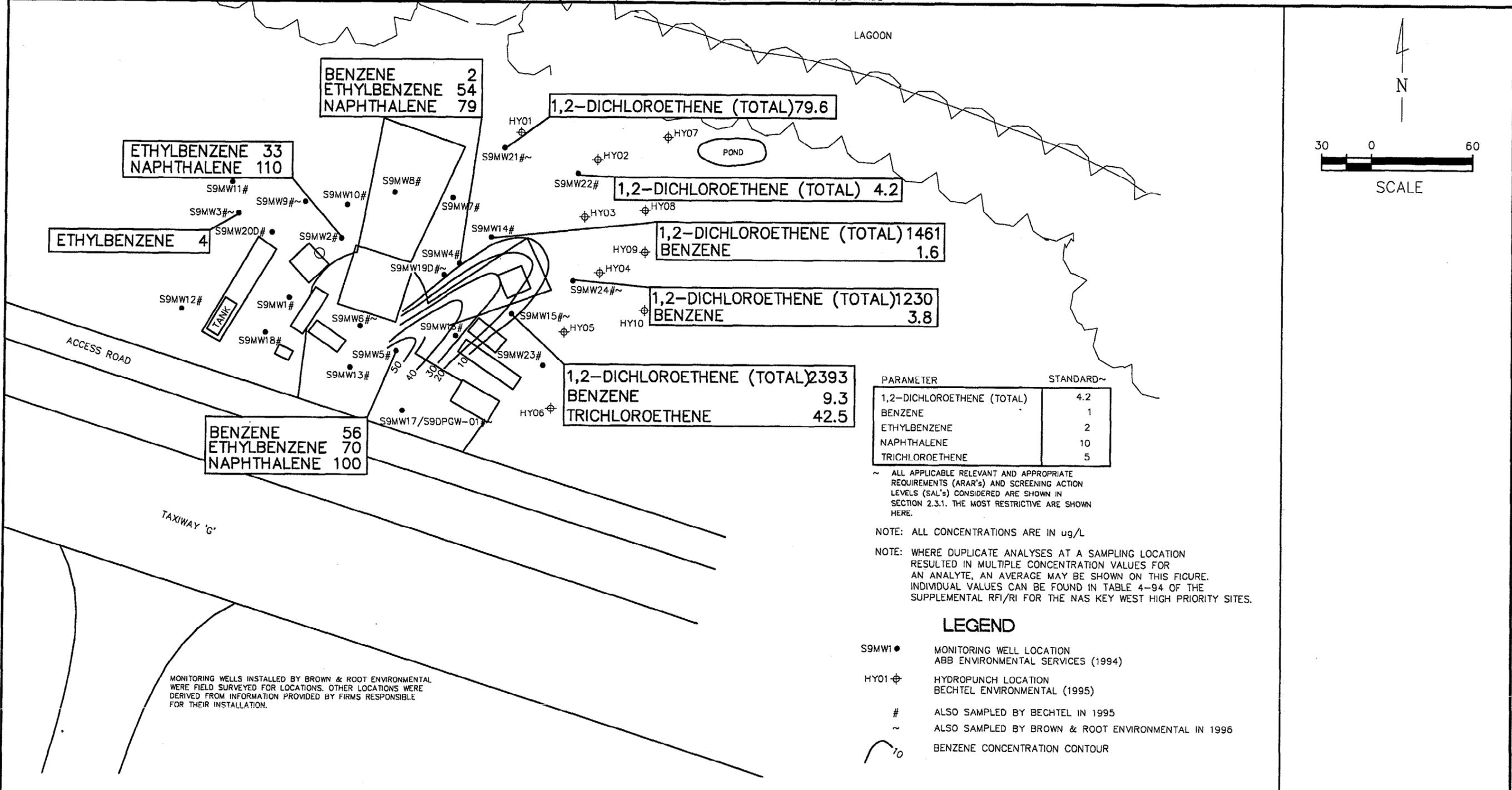
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							AS NOTED			NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9 FIGURE 2-3. GROUNDWATER FLOW AND ELEVATIONS, SWMU 9 NAVY SOUTHERN DIVISION BOCA CHICA KEY, FLORIDA		DRAWING NO.	REV. 2

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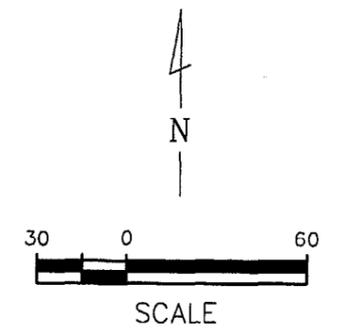
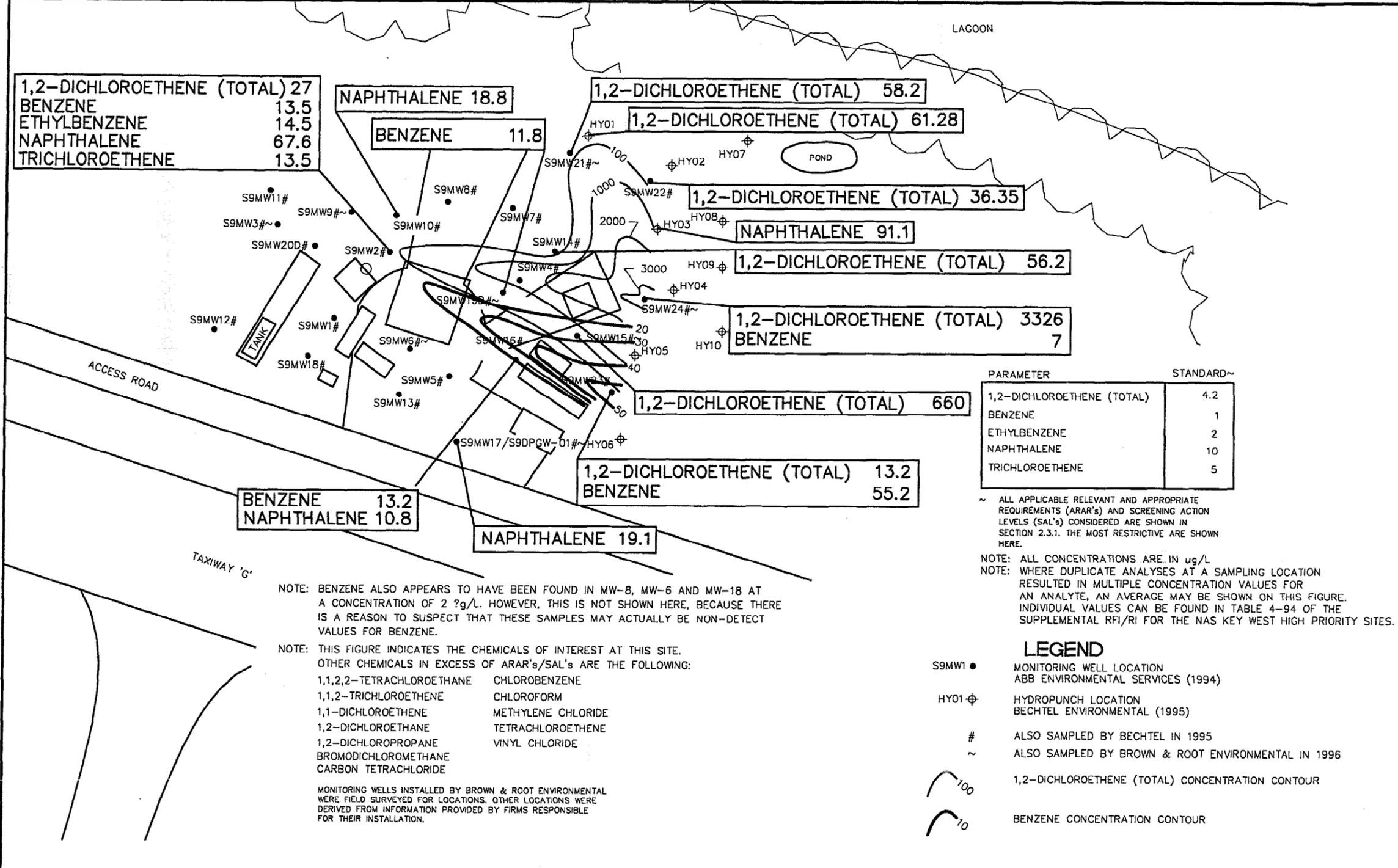
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NATURAL ATTENUATION STUDY RESULTS FOR SSMU 9  
FIGURE 2-4. 1994 GROUNDWATER CHEMICAL  
CONCENTRATIONS FOR SELECTED COIs  
NAVY SOUTHERN DIVISION  
BOCA CHICA KEY, FLORIDA

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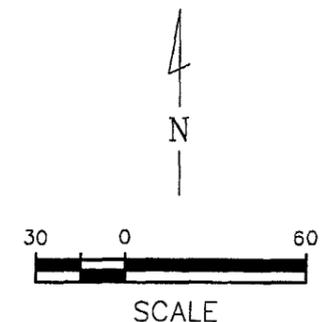
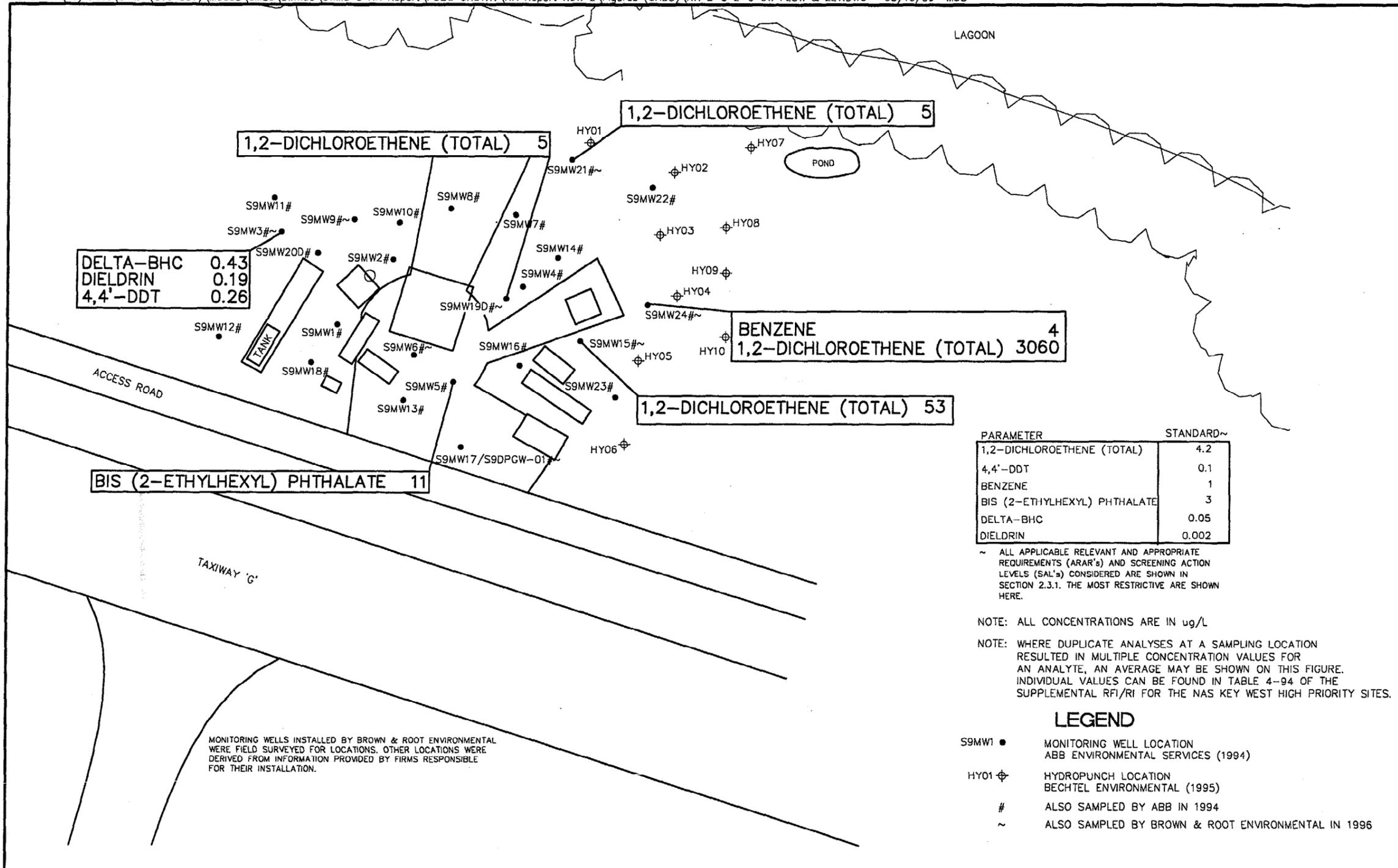
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**NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9  
 FIGURE 2-5. 1995 GROUNDWATER CHEMICAL  
 CONCENTRATIONS FOR SELECTED COIs, SWMU 9  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA**

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PARAMETER	STANDARD~
1,2-DICHLOROETHENE (TOTAL)	4.2
4,4'-DDT	0.1
BENZENE	1
BIS (2-ETHYLHEXYL) PHTHALATE	3
DELTA-BHC	0.05
DIELDRIN	0.002

~ ALL APPLICABLE RELEVANT AND APPROPRIATE REQUIREMENTS (ARAR's) AND SCREENING ACTION LEVELS (SAL's) CONSIDERED ARE SHOWN IN SECTION 2.3.1. THE MOST RESTRICTIVE ARE SHOWN HERE.

NOTE: ALL CONCENTRATIONS ARE IN ug/L

NOTE: WHERE DUPLICATE ANALYSES AT A SAMPLING LOCATION RESULTED IN MULTIPLE CONCENTRATION VALUES FOR AN ANALYTE, AN AVERAGE MAY BE SHOWN ON THIS FIGURE. INDIVIDUAL VALUES CAN BE FOUND IN TABLE 4-94 OF THE SUPPLEMENTAL RFI/RI FOR THE NAS KEY WEST HIGH PRIORITY SITES.

**LEGEND**

- S9MW1 ● MONITORING WELL LOCATION  
ABB ENVIRONMENTAL SERVICES (1994)
- HY01 ⊕ HYDROPUNCH LOCATION  
BECHTEL ENVIRONMENTAL (1995)
- # ALSO SAMPLED BY ABB IN 1994
- ~ ALSO SAMPLED BY BROWN & ROOT ENVIRONMENTAL IN 1996

MONITORING WELLS INSTALLED BY BROWN & ROOT ENVIRONMENTAL WERE FIELD SURVEYED FOR LOCATIONS. OTHER LOCATIONS WERE DERIVED FROM INFORMATION PROVIDED BY FIRMS RESPONSIBLE FOR THEIR INSTALLATION.

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NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9  
FIGURE 2-6. 1996 GROUNDWATER CHEMICAL  
CONCENTRATIONS FOR SELECTED COIs, SWMU 9  
NAVY SOUTHERN DIVISION  
BOCA CHICA KEY, FLORIDA

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## 3.0 INVESTIGATIVE ACTIVITIES

### 3.1 GENERAL FIELD OPERATIONS

This section discusses the general sampling operations, procedures, and documentation for the two 1998 field operations performed at SWMU 9 as part of the natural attenuation sampling effort investigating natural attenuation. All field procedures were performed in accordance with the Final Technical Memorandum for SMWU 9, dated May 7, 1998.

#### 3.1.1 Mobilization/Demobilization

On May 4, 1998, TtNUS began mobilization activities for the natural attenuation evaluation sampling, including purchasing of expendable equipment and preparing the field sampling equipment. Most of the equipment was shipped to the site from the Pittsburgh, Pennsylvania equipment warehouse. Prior to the May 12 mobilization to SWMU 9, the field team members reviewed the Final Technical Memorandum as well as the site-specific Health and Safety Plan (TtNUS 1998).

On September 16, 1998, three groundwater-screening samples were taken at SWMU 9 and groundwater modeling had been performed on the screening samples to site a groundwater monitoring sentry well. A discussion of the modeling is found in Section 3.2.

On November 2, 1998, TtNUS began mobilization activities for the second natural attenuation evaluation sampling event. Most of the equipment required for the field activities was shipped to the site from a third party vendor. On November 16, 1998 the initial field mobilization occurred. On November 17, 1998 the sentry well (i.e., S9MW-25) was installed downgradient of the source area east of S9MW-23. A discussion of the well installation is found in Section 3.3. On November 19, 1998, a mobile bioremediation laboratory (Target/MicroSeeps) arrived at SMWU 9, under subcontract to TtNUS. The laboratory was onsite for two days. While it performed real-time analysis of groundwater dissolved gases (dissolved oxygen, carbon dioxide, nitrogen, ethene, ethane, hydrogen, and methane) and groundwater geochemical parameters (i.e., alkalinity, ferric and ferrous iron, manganese, chloride, nitrate, nitrite, sulfate, sulfide, temperature, pH, oxidation-reduction potential, and conductivity).

### **3.1.2 Water Level Measurements**

During of both the May and November natural attenuation studies, synoptic water-level measurements were collected from existing monitoring wells at the site. All measurements were taken within a 4-hour period under consistent weather conditions to minimize tidal/precipitation effects on groundwater levels.

Measurements were taken with an electric water-level indicator using the top of the well riser pipe as the reference point for determining depths to water. A notch was used to mark the top of the riser pipe to assure that measurements were taken consistently between measuring events. Water-level measurements were recorded to the nearest 0.01-foot in the field logbook or on field data sheets.

### **3.1.3 Groundwater Sampling**

Prior to obtaining samples, water levels were measured and the wells were purged using a low-flow peristaltic pump. Approximately three to six borehole volumes were purged prior to sampling. Field measurements of water level drawdown, pH, temperature, specific conductance, dissolved oxygen, and turbidity were collected periodically during the purge period. In order to minimize the water level drawdown in the well during purging, the peristaltic pump was operated at a range of approximately 100-200 ml/min. Stabilization of the above parameters was defined as follows: temperature  $\pm 1.0^{\circ}\text{C}$ , pH  $\pm 0.1$  units, and specific conductance  $\pm 5$  percent. If these parameters did not stabilize after 3 volumes, 6 or more volumes were removed prior to sampling.

Dedicated polyethylene tubing was used for groundwater sample collection. Immediately prior to sampling, the temperature, pH, specific conductance, dissolved oxygen, and turbidity of the water sample were measured and recorded in the field logbook or on a groundwater sample form. The sample was discharged directly from the tubing into the appropriate sample analysis bottles. Samples to be analyzed for VOCs were collected first by allowing the purge water in the polyethylene tubing to gravity-drain back into the VOC vials. This eliminated the VOC samples from passing through the pump head prior to collection. The VOC vials were immediately sealed so that no headspace existed. Samples for remaining geochemical parameters then were collected and either placed in the appropriate sample bottles for shipment to the laboratory or analyzed immediately on site. The laboratory used for the natural attenuation study was Savannah Laboratories, Inc. Savannah, Georgia.

### **3.1.4 Field Measurements**

Field water-quality parameters were collected during both the May 1998 and November 1998 sampling events. Specific water-quality parameters included groundwater temperature, pH, turbidity, specific

conductance, dissolved oxygen (DO), and oxidation-reduction potential (ORP). These water-quality parameters were collected using portable water-quality meters as discussed in Section 3.1.4.1.

In addition to the water-quality parameters, a suite of geochemical indicator parameters were analyzed to evaluate the potential for natural attenuation at the site. The following table presents the field geochemical parameters collected during the two sampling events:

<b>Field Analyses: May 1998</b>			
<b>Parameter</b>	<b>Make/Model</b>	<b>Instrument</b>	<b>Analytical Method</b>
Dissolved Oxygen	HACH® OX-DT	Digital Titrator	Azide Modification to Winkler Method
Alkalinity	HACH® AL-DT	Digital Titrator	Phenolphthalein/Sulfuric Acid
Carbon Dioxide	HACH® CA-23	Drop-Count Titrator	Phenolphthalein/Sodium Hydroxide
Ferrous Iron	HACH® IR-18C	Color Wheel	1,10 Phenanthroline
Sulfide (as H <sub>2</sub> S)	HACH® HS-C	Color Chart	Effervescence of H <sub>2</sub> S

<b>Field Analyses: November 1998</b>			
<b>Parameter</b>	<b>Make/Model</b>	<b>Instrument</b>	<b>Analytical Method</b>
Dissolved Oxygen	HACH® OX-DT	Digital Titrator	Azide Modification to Winkler Method
Alkalinity/DIC	HACH® AL-DT	Digital Titrator	Phenolphthalein/Sulfuric Acid
Carbon Dioxide	HACH® CA-DT	Digital Titrator	Phenolphthalein/Sodium Hydroxide
Ferrous Iron	HACH® DR-850	Colorimeter	1,10 Phenanthroline
Manganese	HACH® DR-850	Colorimeter	Cold Periodate
Sulfide (as H <sub>2</sub> S)	HACH® HS-C	Color Chart	Effervescence of H <sub>2</sub> S
Sulfide (as S <sup>2-</sup> )	HACH® DR-850	Colorimeter	Methylene Blue
Nitrate	HACH® DR-850	Colorimeter	Cadmium Reduction
Nitrite	HACH® DR-850	Colorimeter	Cadmium Reduction, Diazotization
Sulfate	HACH® DR-850	Colorimeter	Su/FA Ver 4/Turbidimetric

### 3.1.4.1 General Water-Quality Parameters

For the May sampling event, a Horiba® Model U-10 water-quality meter was used to collect groundwater temperature, pH, turbidity, specific conductance, and DO. For the November sampling event, a YSI® water-quality meter was used to collect groundwater temperature, pH, turbidity, specific conductance, and ORP. The meters were intended to determine general groundwater quality parameters and to assist in the determination of appropriate monitoring well purge volumes. The DO measurements collected from the Horiba® were used solely for the determination of appropriate monitoring well purge volumes. All readings were recorded on the groundwater sample forms and in the field log book.

The Horiba® was auto-calibrated for pH, specific conductance, and turbidity by using a single, manufacturer-supplied standard phthalate pH solution. The dissolved oxygen sensor calibrates to the atmosphere. The YSI® is calibrated using a specific calibration standard for each of the probes. The calibration process was documented in the field log book.

### **3.1.4.2 Field Geochemical Parameters**

#### **Dissolved Oxygen**

During both sampling events, geochemical measurements of DO were made using a high-resolution, low-range, test kit (HACH® Model OX-DT). DO is one of the most important of the geochemical parameters and is also the most difficult to collect accurately. Low-flow pumping and adherence to standard operating procedures were observed during DO analyses. The test kit for DO utilizes a digital titrator and the azide modification of the Winkler methodology (HACH Method 8215). The test involves chemical extraction using manganous sulfate, alkaline iodide-azide, and sulfamic acid. Titration is then performed using 0.02N sodium thiosulfate and a starch indicator solution. The test kit can obtain a determination of DO at concentrations as low as 1.0 mg/L and as high as 10 mg/L.

#### **Alkalinity/Dissolved Inorganic Carbon (DIC)**

During both sampling events, geochemical measurements for dissolved alkalinity/DIC (as calcium carbonate [CaCO<sub>3</sub>]) were made in the field using a high-resolution, low-range, test kit (HACH® Model AL-DT). The test kit utilizes a digital titrator and sulfuric acid methodology (HACH® Method 8203). The test involves two-stage colorimetric indication using sulfuric acid, phenolphthalein, and bromcresol green-methyl red indicator solutions. This allows the determination of the three primary contributors to alkalinity; carbonate, bicarbonate, and hydroxide. The test kit can obtain reasonably accurate determination of alkalinity/DIC at concentrations as low as 10 mg/L and as high as 4000 mg/L.

#### **Carbon Dioxide**

During the May sampling, geochemical measurements for dissolved carbon dioxide (CO<sub>2</sub>) were made in the field using a high resolution low-range, test kit (HACH® Model CA-23). This test kit for CO<sub>2</sub> utilizes the drop-count titration method. The test involves colorimetric indication using sodium hydroxide and a phenolphthalein indicator solution. The test kit can obtain reasonably accurate determination of CO<sub>2</sub> at concentrations as low as 10 mg/L and as high as 1000 mg/L.

During the November sampling, geochemical measurements for dissolved carbon dioxide (CO<sub>2</sub>) were made in the field using a high-resolution, low-range, test kit (HACH® Model CA-DT). This test kit for CO<sub>2</sub> utilizes a digital titrator and the same sodium hydroxide methodology (HACH® Method 8205) as the Model CA-23. The test involves colorimetric indication using sodium hydroxide and a phenolphthalein indicator solution. The test kit can obtain a more accurate determination of CO<sub>2</sub> at concentrations as low as 10 mg/L and as high as 1000 mg/L.

### **Ferrous Iron**

During the May sampling, geochemical measurements of dissolved ferrous iron (Fe<sup>2+</sup>) were made in the field using a high resolution low-range test kit (HACH® Model IR-18C). The test kit for ferrous iron utilizes a color disc and the 1,10-phenanthroline, iron reagent method. The test kit can obtain a reasonably accurate determination of ferrous iron at concentrations down to 0.1 mg/L and as high as 10 mg/L.

During the November sampling, geochemical measurements of dissolved ferrous iron were made in the field using a high-resolution, low-range, portable colorimeter (HACH® Model DR-850). The colorimeter also utilizes the 1,10-phenanthroline, iron reagent method (HACH® Method 8146). Ferrous iron reacts with the iron reagent to form an orange color. The intensity of the orange, measured by the colorimeter, is proportional to the ferrous iron concentration. The colorimeter can obtain a quite accurate ( $\pm 0.017$  mg/L standard deviation) determination of ferrous iron with an estimated minimum detection limit of 0.03 mg/L and a maximum detection of 3.0 mg/L.

### **Manganese**

Field geochemical measurements of manganese (Mn<sup>+4</sup>) were not performed during the May sampling. During November, geochemical measurements of manganese were made using a high-resolution, low-range, portable colorimeter (HACH® Model DR-850). The colorimeter utilizes the periodate oxidation method (HACH® Method 8034). The test involves colorimetric indication using sodium periodate and a citrate buffer, whereby manganese is oxidized to the purple permanganate state. Using this method, the reduced form of manganese (Mn<sup>+2</sup>) does not react. The colorimeter can obtain a quite accurate ( $\pm 0.18$  mg/L standard deviation) determination of Mn<sup>+4</sup> with an estimated minimum detection limit of 0.12 mg/L and a maximum detection of 20.0 mg/L.

### **Sulfide**

During May, geochemical measurements for sulfide, as hydrogen sulfide (H<sub>2</sub>S), were made in the field using a high-resolution low-range, test kit (HACH® Model HS-C). The test kit for H<sub>2</sub>S utilizes a color chart

and the effervescence of  $H_2S$  in the presence of sodium/potassium bicarbonate. The test involves colorimetric indication using copper sulfate test paper. The test kit can obtain reasonably accurate determination of  $H_2S$  at concentrations as low as 0.1 mg/L and as high as 5 mg/L.

During November, geochemical measurements of sulfide, as hydrogen sulfide ( $H_2S$ ), were repeated using the high-resolution low-range, test kit (HACH® Model HS-C). In addition, measurements of sulfide, as the sulfide ion ( $S^{2-}$ ), were performed using colorimetric analysis of total sulfide using a high-resolution, low-range, portable colorimeter (HACH® Model DR-850). The colorimeter utilizes the methylene blue method (HACH Method 8131). Both hydrogen sulfide and acid-soluble metal sulfides react with N-dimethyl-p-phenylenediamine oxalate to form methylene blue. The intensity of the blue, measured by the colorimeter, is proportional to the sulfide concentration. The colorimeter can obtain a quite accurate ( $\pm 0.02$  mg/L standard deviation) determination of sulfide with an estimated minimum detection limit of 0.01 mg/L and a maximum detection limit of 0.70 mg/L.

### **Sulfate**

Field geochemical measurements of sulfate ( $SO_4$ ) were not performed during May. During November, geochemical measurements for sulfate were made using a high-resolution, low-range, portable colorimeter (HACH® Model DR-850). The colorimeter utilizes the Sulfa Ver 4 method (HACH® Method 8051). Sulfate ions present in the sample react with barium in the Sulfa Ver 4 reagent to form insoluble barium sulfate, which produces milky white turbidity. The opacity of the treated sample, measured by the colorimeter, is proportional to the sulfate concentration. The colorimeter can obtain a quite accurate ( $\pm 0.5$  mg/L standard deviation) determination of sulfate with an estimated lower detection limit of 4.9 mg/L and a maximum detection limit of 70 mg/L.

### **Nitrite**

Field geochemical measurements of nitrite ( $NO_2$ ) were not performed during May. During November, geochemical measurements for nitrite were made using a high-resolution, low-range, portable colorimeter (HACH® Model DR-850). The colorimeter utilizes the diazotization method (HACH® Method 8507). The nitrite in the sample reacts with sulfanilic acid to form diazonium salt, which in turn couples with chromotropic acid to form a pink color. The pink color of the treated sample, measured by the colorimeter, is proportional to the nitrite concentration. The colorimeter can obtain a quite accurate ( $\pm 0.001$  mg/L standard deviation) determination of nitrite with an estimated lower detection limit of 0.005 mg/L and a maximum detection limit of 0.350 mg/L.

## **Nitrate**

Field geochemical measurements of nitrate ( $\text{NO}_3$ ) were not performed during May. During November, geochemical measurements for nitrate were made using a high-resolution, low-range, portable colorimeter (HACH® Model DR-850). The colorimeter utilizes the cadmium reduction method (HACH® Method 8192). Cadmium reduces nitrate present in the sample to nitrite. The nitrite reacts with sulfanilic acid to form diazonium salt, which in turn couples with chromotropic acid to form a pink color. The pink color of the treated sample, measured by the colorimeter, is proportional to the total nitrate/nitrite concentration. In order to eliminate the nitrite, if present, pretreatment using bromine and phenol is required. The nitrite concentration is subtracted from the analysis which then represents nitrate alone. Nitrite was not detected at significant concentrations. Therefore, the pretreatment was not necessary. The colorimeter can obtain quite accurate ( $\pm 0.03$  mg/L standard deviation) determination of nitrate with an estimated lower detection limit of 0.01 mg/L and a maximum detection limit of 0.50 mg/L.

## **Oxidation Reduction Potential**

During May, the oxidation-reduction potential (ORP) of groundwater referred to as Eh, was analyzed using a portable, water-quality probe (Hanna® Model CE). During November, ORP was analyzed using the YSI water-quality meter. During both events, the probe was used in conjunction with a flow-through sample chamber to reduce sample aeration and contact with the atmosphere.

### **3.1.4.3 Fixed Laboratory Analyses**

A fixed based laboratory was subcontracted for each of the two sampling events. The intent of the laboratory is to provide VOC results. In May 1998 the fixed base laboratory also ran dissolved gasses and total petroleum hydrocarbons (TPH) by Florida Pro Method on groundwater and total organic carbon (TOC) on soils. In November 1998, VOCs in groundwater were once again analyzed. The fixed based laboratory for each sampling event was Accutest Analytical Laboratories, Orlando, Florida.

### **3.1.4.4 Mobile Laboratory Analyses**

In addition to the field geochemical parameters, a subcontracted bioremediation laboratory was mobilized to the site for the November 1998 sampling. The intent of the on-site lab was to provide geochemical data of higher quality than is afforded by the field test kits as well as providing analysis of dissolved gasses. The subcontracted laboratory was Target Environmental Services, Inc., of Jessup, Maryland. The on-site

analyses were conducted in Target's Mobile Bioremediation Laboratory for the following dissolved gasses and geochemical parameters:

<b>Mobile Lab Analyses: November 1998</b>			
<b>Parameter</b>	<b>Make/Model</b>	<b>Instrument</b>	<b>Analytical Method</b>
Dissolved Oxygen	Custom	GC/TCD	RSKSOPs 147 & 175
Nitrogen	Custom	GC/TCD	RSKSOPs 147 & 175
Carbon Dioxide	Custom	GC/TCD	RSKSOPs 147 & 175
Methane	Custom	GC/FID	RSKSOPs 147 & 175
Ethane	Custom	GC/FID	RSKSOPs 147 & 175
Ethene	Custom	GC/FID	RSKSOPs 147 & 175
Hydrogen	Custom	GC/RGD	Chappelle, et al, 1995
Ferrous Iron	Dionex 500 IC	AD 20 Absorbance	USEPA 300.0
Ferric Iron	Dionex 500 IC	AD 20 Absorbance	USEPA 300.0
Manganese	Dionex 500 IC	AD 20 Absorbance	USEPA 300.0
Chloride	Dionex 500 IC	ED 40 ECD	USEPA 300.0
Sulfide (as S <sup>2-</sup> )	CHEMetrics Chemets	Colorimetric Chemets	Methylene Blue
Nitrate	Dionex 500 IC	ED 40 ECD	USEPA 300.0
Nitrite	Dionex 500 IC	ED 40 ECD	USEPA 300.0
Alkalinity	CHEMetrics Titret	Colorimetric Titrets	Hydrochloric Acid Titrant
Sulfate	Dionex 500 IC	ED 40 ECD	USEPA 300.0

### 3.1.5 Quality Control (QC) Samples

In addition to periodic calibration of field equipment and appropriate documentation, the minimum required quality control samples were collected during the environmental sampling. Because this study was for engineering purposes, and in an effort to reduce the analytical costs, quality control samples included only field duplicates of the VOC samples. Two field duplicate samples were collected from the groundwater monitoring wells. Both duplicates were analyzed for VOCs and were identified so laboratory personnel were unable to distinguish them from normal field samples.

### 3.1.6 Decontamination

Only dedicated sampling equipment was used for the field sampling activities. Therefore, no decontamination was required. Deionized water and phosphate-free soap (e.g., Alconox®) were used for incidental cleaning of equipment.

Field analytical equipment such as water-quality meters and probes were rinsed with deionized water first and then with the sample water prior to measuring the water quality parameters.

### 3.1.7 Sample Analysis

The following analytical tasks were completed as part of the May 1998 field activities:

- To determine the current groundwater plume configuration, VOC samples were collected from 11 monitoring wells (S9MW-12, -3, -10, -8, -21, -22, -23, -24, -15, -17, and -19D). Two additional wells S9MW-5 and S9MW-13 were also sampled for VOCs.
- To perform the natural attenuation screening, fixed-base laboratory analyses were performed on 11 monitoring wells for geochemical parameters. The selected wells were S9MW12, -3, -10, -8, -21, -22, -23, -24, -15, -17, and -19D. The fixed-base laboratory parameters are discussed in Section 3.1.4.
- To further evaluate the natural attenuation processes present at the site, field analyses using field test kits (HACH®) were performed on 8 selected monitoring wells (i.e., S9MW-12, -3, -10, -21, -24, -15, -17, and -19D). These field parameters are discussed in Section 3.1.4.
- To determine the natural organic carbon present in the aquifer matrix, one upgradient soil sample (southwest side of site near S9MW12) was collected and analyzed for TOC at a depth of 6 to 12 inches bls.

The following analytical tasks were completed as part of the November 1998 field activities:

- Drilling and installation of new sentry well S9MW25.
- To determine the current groundwater plume configuration, VOC samples were collected from 12 monitoring wells (S9MW-5, -10, -12, -13, -14, -15, -21, -22, -23, -24, -25 and RW-2).
- To further evaluate the natural attenuation processes present at the site, on-site laboratory was used to perform geochemical and dissolved gas analyses on 12 selected monitoring wells. The selected wells were S9MW-5, -10, -12, -13, -14, -15, -21, -22, -23, -24, -25 and RW-2. The mobile laboratory parameters are discussed in Section 3.1.4.

- To complete the natural attenuation evaluations, field analyses using field test kits (HACH®) were performed on 12 monitoring wells (i.e., S9MW-5, -10, -12, -13, -14, -15, -21, -22, -23, -24, -25 and RW-2). These field parameters are discussed in Section 3.1.4.

### **3.1.8            Waste Handling**

All investigation-derived waste (IDW), consisting of purge liquids, was collected and stored in DOT-approved (specification 17-C/H) 55-gallon drums at the site. Based on the results of the groundwater analyses, a recommendation was made to NAS Key West that the IDW be handled as hazardous waste. This recommendation was made based on Florida Department of Environmental Protection IDW guidance that states IDW with levels of contaminants in excess of Brownsfield Cleanup Guidance Criteria be managed in accordance with RCRA. TtNUS, in coordination with the Base personnel, arranged for proper removal and disposal of the drummed wastes.

## **3.2                    GROUNDWATER MODELING**

Based on the May 1998 natural attenuation screening, modeling was performed to support the final remedial alternative of monitored site-wide natural attenuation with monitoring. The modeling consisted of two tasks:

- Task 1 - Calculate the surface water concentration at the exposure point (small surface water pond and lagoon) considering the natural attenuation processes and most recent site conditions.
- Task 2 - Select the location for a downgradient sentry well between the suspected source area and the lagoon.

The modeling was supported by data from three additional groundwater screening samples collected in September 1998 downgradient of monitoring wells (S9MW-21, -22, and -24), half the distance to the small surface water pond or lagoon. Task 1 calculated the potential maximum concentration of the contaminants (cis-1,2-dichloroethene, trans-1,2-dichloroethene, trichloroethene and benzene) in the small surface water pond and the surface water contaminant levels. The data input was based on the May 1998 groundwater contaminant levels. Task 2 used the same modeling data to select the location of a sentry well. The location of the sentry well would provide a minimum of one year advanced indication that, if present, contaminated groundwater could impact the small surface water pond. The results of the modeling are discussed in Section 5.4.3. The model used for this effort is known as ECTran, a transport model written using Crystal Ball and the Excel program environment. The inputs and outputs are presented in the full modeling report, located in Appendix B.

### 3.3 ADDITIONAL WELL INSTALLATION

The groundwater modeling discussed in Section 3.2 supported the location of a 2-inch shallow monitoring well (Figure 4-3). The flush mounted well (S9MW-25) was installed with a hollow-stem auger drill rig to a depth of 12 feet. The screened interval is 2 to 12 feet bls to allow the screen to intersect the water table at approximately 3 feet bls. Drill cutting were left onsite and the purge water was containerized and handled in accordance with Section 3.1.8 Waste Handling. The installation was performed without any unexpected delays or occurrences. The well boring log and construction diagram is found in Appendix A.

## 4.0 SAMPLE RESULTS

### 4.1 DISSOLVED-PHASE GROUNDWATER PLUME

In May 1998, to determine the dissolved-phase groundwater plume configuration, VOC samples were collected from 13 selected monitoring wells (S9MW-12, -3, -5, -8, -10, -13, -21, -22, -23, -24, -15 -17, and -19D). The most upgradient well was S9MW-12. Table 4-1 presents the analytical results for this VOC sampling. Figure 4-1 presents the isoconcentration contour map for detected VOCs during the May 1998 sampling event. Figure 4-2 presents the groundwater elevations association with the May 1998 sampling event. The entire data set, laboratory results, and chain-of-custody forms can be found in Appendix C.

The general pattern of groundwater contamination was consistent with previous sampling efforts, however, the VOC concentrations generally exceeded those reported during the previous sampling event. The greatest increase was identified in the source area at monitoring well S9MW-15 where the total VOCs increased from 53 µg/L to 5,650 µg/L.

In November 1998, to determine the current dissolved-phase groundwater plume configuration, VOC samples were collected from 12 selected monitoring wells (S9MW-5, -10, -12, -13, -14, -15, -21, -22, -23, -24, -25 and RW-2). The most upgradient well was S9MW-12. Table 4-2 presents the analytical results for the VOC samples collected during the November sampling. Figure 4-3 presents the isoconcentration contour map for detected VOCs during the November 1998 sampling event. The entire data set, laboratory results, and chain-of-custody forms can be found in Appendix C.

The general pattern of groundwater contamination as evidenced by the current plume configuration, was inconsistent with previous sampling efforts, however, the VOC concentrations were significantly less than those reported during the May 1998 sampling event. The greatest decrease was identified in the source area at monitoring well S9MW-15 where the total VOCs decreased from 5,650 to 1,100 µg/L.

### 4.2 NATURAL ATTENUATION PARAMETERS

#### 4.2.1 Dissolved Oxygen

Dissolved oxygen acts as a primary substrate or co-substrate during the initial stages of metabolism and is the single most efficient electron acceptor responsible for the biodegradation of natural or anthropogenic organic carbon. However, for highly chlorinated hydrocarbons, anaerobic pathways (e.g.,

reductive dechlorination) are more efficient than aerobic pathways. If dissolved oxygen concentrations are greater than approximately 0.5-1.0 mg/L, anaerobic bacteria cannot exist and reductive dechlorination will not occur.

During aerobic respiration, dissolved oxygen is utilized as an electron acceptor to mineralize natural organic carbon (or hydrocarbons) into CO<sub>2</sub> and water. Dissolved oxygen at concentrations less than background provides strong evidence of indigenous bacterial populations that are already established and actively degrading natural or anthropogenic carbon, utilizing aerobic pathways. However, once the available oxygen is used up, these aerobic processes will cease and the core of the plume will become anaerobic.

Dissolved oxygen concentrations were not detectable in all wells sampled with the field test kits during both the May and November sampling events. However, during the November sampling, low concentrations of dissolved oxygen were detected by the on-site laboratory. Based on the on-site laboratory data, the background oxygen concentration is 1.0 mg/L. This concentration decreases to a minimum concentration of 0.6 mg/L in the source area, near S9MW15. The small amount of dissolved oxygen that is naturally present in the aquifer is being utilized rapidly by bacteria which thrive in aerobic conditions. Typical background oxygen concentrations for such a shallow aquifer are in the range of 4-6 mg/L. These low dissolved oxygen results indicate anaerobic groundwater conditions across the site. An isoconcentration contour map (Figure 4-4) of the on-site laboratory results for dissolved oxygen is included at the end of this section.

#### **4.2.2            Nitrate/Nitrite**

After dissolved oxygen has been depleted through aerobic respiration, anaerobes will utilize nitrate (NO<sub>3</sub>) as an electron acceptor to anaerobically degrade hydrocarbons (denitrification). This process reduces nitrate to nitrite (NO<sub>2</sub>) and generates carbon dioxide. However, because chlorinated hydrocarbons are used as electron acceptors during reductive dechlorination, nitrate may actually compete as an electron acceptor if present at concentrations greater than 1.0 mg/L.

During the May sampling, nitrate and nitrite analyses were measured by Savannah Laboratory as a single combined parameter (nitrate/nitrite). All concentrations were below detection limits. During the November sampling, nitrate and nitrite concentrations were also below detection limits (less than 5 mg/L) in all the on-site laboratory analyses. Based on data from the field colorimeter, nitrate concentrations fluctuated from less than detectable (less than 0.01 mg/L) to 0.06 mg/L and nitrite fluctuated from less than detectable (less than 0.005 mg/L) to 0.03 mg/L. This lack of any significant concentration of nitrate or

nitrite indicates an insufficient supply of nitrate to act as a potential electron receptor. Therefore, there is strong evidence against anaerobic degradation of hydrocarbons via the denitrification process.

#### **4.2.3 Dissolved Manganese**

After dissolved oxygen and nitrate have been depleted, anaerobic microbes will utilize manganese ( $Mn^{+4}$ ) as an electron acceptor to anaerobically degrade hydrocarbons, generating manganese ( $Mn^{+2}$ ) and carbon dioxide.

During the May sampling, laboratory manganese concentrations were below detection limits in all wells sampled, indicating an insufficient supply of manganese to act as potential electron receptors. During the November sampling, manganese ( $Mn^{+4}$ ) concentrations were less than detection limits (less than 0.5 mg/L) in all of the on-site laboratory analyses. Based on the field colorimeter data, manganese ( $Mn^{+4}$ ) fluctuated from less than detection limits (less than 0.12 mg/L) to 1.4 mg/L. At these concentrations, there is insufficient supply of manganese to act as a potential electron receptor. Therefore, there is strong evidence against anaerobic degradation of hydrocarbons via the manganese reduction pathway.

#### **4.2.4 Dissolved Iron/Ferric Iron/Ferrous Iron**

After dissolved oxygen, nitrate, and manganese reduction, anaerobic microbes will utilize ferric iron ( $Fe^{+3}$ ) as an electron acceptor (iron reduction) to anaerobically degrade hydrocarbons, generating ferrous iron ( $Fe^{+2}$ ) and carbon dioxide. Ferric iron concentrations are either determined separately or calculated by subtracting ferrous iron ( $Fe^{+2}$ ) concentrations from total iron. The majority of ferric iron that is reduced to ferrous iron precipitates out upon contact with an oxygenated source such as surface water.

During May, total iron, ferric and ferrous iron concentrations were less than detection limits in all wells sampled, indicating an insufficient supply of iron to act as a potential electron receptor. During the November sampling, both ferric and ferrous iron were less than detection limits (less than 0.5 mg/L) in the on-site laboratory. Based on field colorimeter data, ferrous iron fluctuated from less than detection limits (less than 0.03 mg/L) to 0.12 mg/L. This was consistent with the May sampling results, and provides strong evidence against anaerobic degradation of hydrocarbons via the iron reduction pathway.

#### **4.2.5 Sulfate**

After dissolved oxygen, nitrate, manganese, and ferric iron have been utilized, anaerobic microbes will utilize sulfate ( $SO_4$ ) as an electron acceptor to anaerobically degrade hydrocarbons (sulfate reduction). The process of sulfate reduction results in the generation of sulfide and carbon dioxide. Sulfate reduction,

along with methanogenesis, is one of the most important and frequently documented reduction pathways responsible for natural attenuation of chlorinated hydrocarbon plumes. However, as previously discussed, chlorinated hydrocarbons are used as electron acceptors during reductive dechlorination. Therefore, sulfate may compete as an electron acceptor if present at concentrations greater than 20 mg/L. In order for reductive dechlorination to occur, sulfate needs to be present but at concentrations less than 20 mg/L. However, in high concentration plumes, dechlorination may still occur despite high sulfate concentrations (USEPA 1998).

During the May sampling, sulfate concentrations ranged from 34 mg/L in S9MW-17 and 47 mg/L in S9MW-12 (both generally upgradient) to 885 mg/L (average of two duplicates) in S9MW-24. A similar pattern was identified during November with laboratory concentrations ranging from 5.44 mg/L in S9MW-0.5 to 1,060 mg/L in wells S9MW-21 and S9MW-22. Although the field colorimeter had a maximum detection limit of 80 mg/L, the data trend paralleled the laboratory data.

Due to the high concentration of sulfate in the groundwater, it is likely that sulfate may compete with the chlorinated hydrocarbons as electron acceptors, thereby competitively excluding dechlorination. This is supported by the fact that the sulfate concentration actually increases in the source area and downgradient wells, an indication that the chlorinated hydrocarbon plume is competing with the natural organic carbon as electron acceptors. An isoconcentration contour map (Figure 4-5) of the on-site laboratory results for sulfate is included at the end of this Section.

#### 4.2.6 Sulfide

As mentioned previously, sulfate reduction results in the generation of sulfide and carbon dioxide. Sulfide can be present in many forms, the three primary forms being the sulfide ion ( $S^{2-}$ ), or dissolved hydrogen sulfide as  $H_2S$  or  $HS^-$ .

During May field analysis, hydrogen sulfide concentrations were detected in all wells at, or above, the maximum detection value of 5 mg/L. However, the laboratory analysis indicated that sulfide ion concentrations ranged from less than detectable in many of the upgradient and source area wells to a maximum of 7 mg/L in S9MW-10. Well S9MW-10 is a cross-gradient well with no reported VOC contamination. Based on the results during the May sampling event, monitoring well S9MW-10 is assumed to be an anomalous data point. In November S9MW-10 did not produce anomalous data.

During the November field analyses, the HACH® tests for H<sub>2</sub>S and S<sup>2-</sup> illustrated a consistent trend with the May field analyses. The CHEMetrics® test illustrated a consistent trend with the May laboratory analysis. In general, CHEMetrics® sulfide ion concentrations increased in the downgradient direction with a maximum detection of 0.8 mg/L in S9RW-2. The high hydrogen sulfide concentrations detected during the field analysis (further supported by the hydrogen sulfide odor present in many onsite wells) are evidence of natural sulfate reduction of organic carbon in the aquifer. Therefore, the fixed-base sulfide concentrations, which increase in the downgradient direction, provide evidence of the dechlorination pattern of the hydrocarbon plume.

In summary, sulfate reduction appears to be an active anaerobic pathway for dechlorination of the hydrocarbon plume, as evidenced by increased sulfide ion concentration in the downgradient direction. However, sulfate is simultaneously competing with the hydrocarbon plume as an electron acceptor, which may result in competitive exclusion of dechlorination.

#### **4.2.7            Phosphate**

Similar in mechanism to sulfate reduction (but to a lesser degree) phosphate reduction is an (minor) anaerobic biodegradation process whereby bacteria can use phosphate (PO<sub>4</sub><sup>-4</sup>) as an electron acceptor to degrade petroleum hydrocarbons.

During May, phosphate concentrations in laboratory samples were less than detection limits in all wells sampled. Phosphate was not analyzed during the November sampling. Due to the lack of phosphate as an electron acceptor in the groundwater, it is unlikely that phosphate reduction is a significant portion of the total biodegradation capacity of the aquifer. Phosphorous is an important nutrient for microbes, and its absence may limit the overall biodegradation capacity of the aquifer.

#### **4.2.8            Dissolved Carbon Dioxide**

Methanogenesis occurs after oxygen, nitrate, manganese, ferric iron, and sulfate have been utilized. As mentioned previously, methanogenesis is one of the most important and frequently documented reduction pathways responsible for natural attenuation of chlorinated hydrocarbon plumes. During methanogenesis, some strains of anaerobic bacteria utilize carbon dioxide as an electron acceptor, generating methane as a byproduct of fermentation. As previously discussed, carbon dioxide is produced during aerobic respiration (oxygen utilization), as well as anaerobic processes (denitrification, iron reduction, and sulfate reduction). Therefore, carbon dioxide is both produced and utilized by different microbes during biodegradation of a carbon source.

During the May sampling, dissolved carbon dioxide concentrations range from 43 mg/L in upgradient well S9MW-12, to 157 mg/L in S9MW-21 and 159 mg/L in S9MW-10. During the November sampling, dissolved carbon dioxide concentrations from the on-site laboratory ranged from 18.7 mg/L in upgradient well S9MW-12 to 144 mg/L in S9MW-5. Dissolved carbon dioxide concentrations from the field test kit results closely paralleled the on-site laboratory results, with concentrations ranging from 63.2 mg/L in upgradient well S9MW-12 to 430 mg/L in S9MW-10. Carbon dioxide in excess of background concentrations is a strong indicator of active biodegradation of the chlorinated solvent plume. Carbon dioxide is being generated in the plume because of microbial respiration and/or as a degradation end-product of reductive dechlorination. The carbon dioxide that is being generated is actually underestimated since some portion of the total carbon dioxide is being utilized to power methanogenesis, as discussed below. An isoconcentration contour map (Figure 4-6) of the on-site laboratory results for dissolved carbon dioxide is included at the end of this Section.

#### 4.2.9 Dissolved Methane

Methanogenesis is an anaerobic biodegradation process whereby methane-producing microorganisms utilize carbon dioxide as an electron acceptor, and generate methane as a byproduct of fermentation. Because methane is not a chemical component of fuels or solvents, its presence above background concentrations provides strong evidence of methanogenic fermentation (and carbon dioxide utilization). Background concentrations of methane are important since some natural sources of methane could exit (e.g., groundwater derived from infiltration into or through a peat bog or other natural methane source).

During the May sampling, the methane concentrations in laboratory samples range from 2 µg/L in upgradient well S9MW-12, and 17 µg/L in the deep uncontaminated well S9MW-19D, to 1,000 µg/L in S9MW-10. Many of the other source wells and downgradient wells had methane concentrations in the 30-60 µg/L range. Because of the difficulty in collecting and shipping methane samples, the Savannah Laboratory data is assumed to underestimate the true conditions. Therefore, the on-site laboratory was used to analyze the dissolved gases during the November sampling. Its analysis of methane indicated a similar pattern to that delineated in May, but at concentrations up to three times those identified in May. Concentrations ranged from 13 µg/L in upgradient well S9MW-13, to 2,840 µg/L in S9MW-10 and 3,245 µg/L in S9MW-5. These methane concentrations significantly above background provide strong evidence that methanogenesis is a significant factor in the bioremediation of the hydrocarbon plume. An isoconcentration contour map (Figure 4-7) of the on-site laboratory results for methane is included at the end of this section.

**4.2.10**      **Dissolved Hydrogen**

Hydrogen is produced in anaerobic environments by the fermentation of organic carbon. The hydrogen is then utilized by respiratory microbes such as nitrate reducers, iron reducers, sulfate reducers, and methane producers. Each microbe utilizes hydrogen more or less efficiently, leading to either a buildup or a decrease in the molecular hydrogen concentration. The efficiency of the reductive dechlorination is directly proportional to the availability of molecular hydrogen in the system. As the following table shows, methanogenic processes are the most efficient of the reductive dechlorination pathways.

Terminal Electron-Accepting Process (TEAP)	TEAP Species	Hydrogen Concentration (nM/L) <sup>a</sup>
Denitrification	$\text{NO}_3^- \Rightarrow \text{NO}_2^-$	<0.1
Ferric Iron Reduction	$\text{Fe}^{3+} \Rightarrow \text{Fe}^{2+}$	0.2 – 0.8
Sulfate Reduction	$\text{SO}_4^{2-} \Rightarrow \text{H}_2\text{S}$	1 – 4
Methanogenesis	$\text{CO}_2 \Rightarrow \text{CH}_4$	>5

<sup>a</sup> nanomole per liter

Molecular hydrogen was analyzed in the on-site laboratory during the November sampling event. The hydrogen concentrations ranged from 0.97 nM/L in S9MW-14 to 8.2 nM/L in S9MW-25. These hydrogen concentrations are characteristic of sulfate reduction and/or methanogenesis. Both sulfate reduction and methanogenesis appear to be the prevalent reductive pathways active at the site, and are the most frequently documented reduction pathways for chlorinated hydrocarbons (AFCEE, 1996). An isoconcentration contour map (Figure 4-8) of the on-site laboratory results for hydrogen is included at the end of this Section.

**4.2.11**      **Dissolved Ethene**

Under strictly anaerobic conditions, ethene and methane can be produced by the biotic dechlorination of vinyl chloride. Concentrations of ethene greater than 0.01 mg/L (10,000 nanograms per liter [ng/L]) provide strong evidence of such dechlorination. This process is less efficient than direct oxidation of vinyl chloride to carbon dioxide in an aerobic environment, and thus can lead to the accumulation of vinyl chloride.

Ethene was analyzed in the on-site laboratory during the November sampling event. The ethene concentrations ranged from <5.0 ng/L in S9MW-5 to 136 ng/L in S9MW-15. As indicated on the isoconcentration contour (Figure 4-9) map at the end of Section 4.0, there is obvious ethene production in

the source area and immediately downgradient of the source area. These concentrations, however, are significantly less than those necessary to indicate dechlorination of vinyl chloride.

#### **4.2.12 Dissolved Ethane**

Ethene is produced by the biotic dechlorination of vinyl chloride. Ethane is in turn produced by the further biotic degradation of ethene. Concentration of ethane greater than 0.1 mg/L provide strong evidence of such degradation.

Ethane was analyzed in the on-site laboratory during the November sampling event. The ethane concentrations ranged from <5.0 ng/L in several on site wells to 60.85 ng/L in S9MW-25. Like to the ethene concentrations, the isoconcentration contour map (Figure 4-10) at the end of Section 4.0 provides evidence that there is ethane production in the source area and immediately downgradient of the source area. These concentrations, however, are significantly less than those that would to indicate dechlorination of vinyl chloride.

#### **4.2.13 Dissolved Inorganic Carbon/Total Alkalinity**

Alkalinity is a measure of the buffering (neutralizing) capacity of acids in water, and is expressed as mg/L calcium carbonate ( $\text{CaCO}_3$ ). Generally, alkalinity consists of three types, carbonate ( $\text{CO}_3$ ), bicarbonate ( $\text{HCO}_3$ ), and hydroxide ( $\text{OH}$ ). Dissolved inorganic carbon (DIC) represents the sum of the carbonate and bicarbonate alkalinity. Bicarbonate is the major portion of natural groundwater alkalinity, however, carbonate and hydroxide may contribute to the total alkalinity in chemically-treated or polluted groundwater. DIC concentrations, in comparison to the total alkalinity, can give a general indication of the amount of carbon dioxide generated during aerobic or anaerobic reduction of a chlorinated hydrocarbon plume.

During the May sampling, field test kit concentrations of DIC ranged from 181 mg/L in S9MW-12 (upgradient) to 511 mg/L in S9MW-24 and 555 mg/L in S9MW-10. S9MW-24 is located in the source area and is one of the most contaminated wells at the site. As previously mentioned, well S9MW-10 is not located in the source area and its May results may be anomalous. The May alkalinity concentrations range from 210 mg/L in S9MW-12 to 420 mg/L in S9MW-24 and S9MW-21. Both S9MW-24 and S9MW-21 indicate significant levels of VOC contamination.

During the November sampling, field test kit measures of alkalinity were similar to the May results, with concentrations ranging from 183 mg/L in S9MW-12 to 530 mg/L in S9MW-22 and 535 mg/L in S9MW-10. S9MW-25 is located directly downgradient of the source area. Also during the November sampling event,

total alkalinity was analyzed by CHEMetrics® test kits. The total alkalinity concentrations ranged from 185 mg/L in S9MW-12, to 420 mg/L in S9MW-10 and 480 mg/L in S9MW-22. An isoconcentration contour map (Figure 4-11) of the on-site laboratory results for total alkalinity is included at the end of this section.

In general, both parameters (DIC and total alkalinity) increase in areas with increased contamination and in the downgradient direction. This provides confirming evidence that carbon dioxide is being generated in the hydrocarbon plume as a result of microbial respiration and/or as a degradation end-product of reductive dechlorination.

#### **4.2.14        Chloride**

Chloride concentrations are used to evaluate natural attenuation because chloride is released into groundwater during dechlorination of chlorinated solvent. Therefore, an increase in chloride ion concentration in the downgradient direction is direct evidence of dechlorination.

During the May sampling, chloride concentrations range from 40 mg/L in S9MW-12 (upgradient) to 4,000 mg/L in downgradient well S9MW-21. During November, the on-site laboratory concentrations were similar to the May data with chloride concentrations ranging from 45.2 mg/L in S9MW-13 (upgradient) to 5,920 mg/L in downgradient well S9MW-21. In general, chloride ion concentration increases in the downgradient direction. Although the majority of the chloride ion may be a result of increasing proximity to the saline lagoon located immediately north (downgradient) of the site, reductive dechlorination can also be a contributing factor. This is best illustrated in the isoconcentration contour map (Figure 4-12) at the end of this section. The spatial variability chloride ion concentrations provides strong evidence of the reductive dechlorination of the solvent plume.

#### **4.2.15        Oxidation/Reduction Potential**

The oxidation/reduction potential (ORP) of groundwater (Eh) is a measure of the relative tendency of the groundwater solution to accept or donate electrons and of as the amount of energy released during electron transfers within the solution. The Eh depends upon and influences the rates and types of biodegradation processes. Therefore, the measurement of Eh (in millivolts; mV) can provide evidence of the type of biodegradation processes that are active in a particular plume or even within different portions of the same plume. Great care must be taken during the evaluation of Eh data since most natural waters usually include mixed potentials, which cannot be related to a single electron couple. Therefore, Eh should be used only as a qualitative indicator of the overall oxidation/reduction state.

The relative Eh measurement is proportional to the efficiency of the bioremediation pathway. For example, the most efficient bioremediation pathway for a petroleum hydrocarbon plume is aerobic respiration. During aerobic respiration, oxygen is utilized as the electron acceptor to mineralize petroleum hydrocarbons into CO<sub>2</sub> and water. The Eh value for such a reaction is in the range of +800 mV.

Following is a general comparison of common metabolic pathways and related Eh measurements, quantified under laboratory conditions:

Pathway	Electron Acceptor	Eh (mV)
Aerobic Respiration	Oxygen	+820
Denitrification	Nitrate	+740
Manganese Reduction	Manganese	+520
Iron Reduction	Ferric Iron	-50
Sulfate Reduction	Sulfate	-220
Methanogenesis	Carbon dioxide	-240

Reference: AFCEE (1996)

During the May sampling, Eh values across the site ranged from -182 mV to -230 mV, with an average of -210 mV. During November, Eh values across the site ranged from -133 mV to -320 mV. There appears to be a slight trend in the Eh values collected at the site, such that the greater negative values are associated with contaminated wells and the downgradient flow direction. This indicates an energy efficiency range associated with anaerobic reduction through sulfate reduction and/or methanogenesis. As previously noted, both sulfate reduction and methanogenesis appear to be the prevalent reductive pathways active at the site, and are the most important and frequently documented reduction pathways for chlorinated hydrocarbons (AFCEE, 1996).

#### 4.2.16 Organic Carbon

Because chlorinated hydrocarbons are used as electron acceptors during reductive dechlorination, there needs to be a sufficient supply of organic carbon as the primary substrate for microbial growth. Such a supply can come from native organic carbon in the aquifer or from anthropogenic sources such as BTEXs or landfill leachate. Organic carbon concentrations greater than 20 mg/L in the aquifer indicate a sufficient supply of carbon to act as the primary substrate. TOC is a measure of the natural and anthropogenic carbon present in the aquifer.

TOC concentrations during the May sampling ranged from 2.6 mg/L in S9MW-17 (upgradient) to 24 mg/L in S9MW-24 and 28 mg/L in S9MW-10. This indicates that organic carbon is present at sufficient concentrations in the aquifer to act as the primary substrate for reductive dechlorination.

In addition to TOC, BTEXs were detected at 385 µg/L in one upgradient well (S9MW-5) during the May sampling. During the November sampling event, BTEXs again were detected in upgradient well, S9MW-5, at 96 µg/L. Under anaerobic conditions, it would be typical to see minimal BTEXs degradation over time, and a resulting BTEXs plume migrating in the downgradient direction. Even though anaerobic conditions persist in the aquifer, BTEXs which has been detected previously in this well, has never been shown to migrate in the downgradient direction. This is most likely due to the BTEXs utilization as a substrate during reductive dechlorination of the solvent plume. Therefore, in addition to the native organic carbon, BTEXs are contributing as a carbon source to drive reductive dechlorination.

#### **4.2.17        pH**

pH is a measurement of the hydrogen ion ( $H^+$ ) concentration in terms of its negative logarithm. The scale ranges from 0 to 14; values less than 7 indicate acidity and values greater than 7 indicate basic solutions. pH affects the presence and efficiency of bacterial populations in natural groundwater conditions. Neutral groundwater (i.e., pH 7) is the preferred condition for most microbes.

The pH values collected during the two sampling events ranged from 6.68 to 7.40. This indicates generally neutral groundwater, which is conducive to intrinsic bioremediation.

#### **4.2.18        Specific Conductivity**

Specific conductivity (microsiemens per centimeter [mS/cm]) is a measure of a solution's ability to carry an electrical current, and is controlled by the different quantities and types of ions in the solution. Generally, conductivity increases as ion concentration increases and can fluctuate within a plume based upon the geochemistry at that particular location. Conductivity is most frequently used as an indicator of a consistent groundwater source. For example, different water sources may have significantly different conductivity values.

Specific conductivity values during the May sampling ranged from 0.479 mS/cm in upgradient well S9MW-12 to 14.2 mS/cm in downgradient well S9MW-21. Similar results were observed during the November sampling when specific conductivity ranged from 0.680 mS/cm in upgradient well S9MW-13 to 18 mS/cm in downgradient well S9MW-21. This fluctuation indicates the increasing proximity of the downgradient wells to the highly conductive, saline lagoon immediately north of the site.

#### 4.2.19 Temperature

The temperature of groundwater affects the solubility of oxygen and other geochemical species, as well as the metabolic activity bacteria. Microbes are generally more active in warm water. The rate of hydrocarbon bioremediation doubles for every 10-degree Celsius ( $^{\circ}\text{C}$ ) increase in temperature (referred to as the "Q<sub>10</sub>" rule) in the range of 5 to 25  $^{\circ}\text{C}$  (AFCEE, 1996)

Temperatures during May ranged from 31.8  $^{\circ}\text{C}$  in upgradient well S9MW-17 to 25.9  $^{\circ}\text{C}$  in downgradient well S9MW-22. During the November sampling, temperature values ranged from 31.6  $^{\circ}\text{C}$  in upgradient well S9MW5 to 26.7  $^{\circ}\text{C}$  in downgradient well S9MW-24. This fluctuation indicates the increasing proximity of the downgradient wells to the cooler lagoon immediately north of the site. These temperatures are well within the range of values acceptable for bioremediation to take place.

TABLE 4-1

## SWMU 9 NATURAL ATTENUATION ANALYTICAL RESULT - MAY 1998

Parameter	S9MW3	S9MW5	S9MW8	S9MW10	S9MW12	S9MW13	S9MW15	S9MW17	S9MW19D	S9MW21	S9MW22	S9MW23	S9MW24
Carbon Disulfide	ND	39 <sup>1</sup>	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
cis -1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	1,300	ND	ND	94	ND	12	820
trans -1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	4,000	ND	ND	52	ND	34	2,000
<b>Total 1,2-Dichloroethene (AL - 4.2 µg/l)</b>	ND	ND	ND	ND	ND	ND	5,300	ND	ND	146	ND	56	2,820
Trichloroethene (AL - 3 µg/l)	ND	ND	ND	ND	ND	ND	350	ND	ND	ND	ND	ND	ND
Acrolein (AL - 100 µg/l)	ND	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acrylonitrile (AL - 8 µg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	20 <sup>1</sup>	ND	ND
Methylethylketone (2-butanone) (AL - 4,200 µg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16 <sup>1,2</sup>	ND	ND
Benzene (AL - 5 µg/l)	ND	25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene (AL - 700 µg/l)	ND	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Xylenes (AL-10,000 µg/l)	ND	160 <sup>1,2</sup>	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
<b>Total BTEX</b>	ND	385	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dissolved Inorganic Carbon (mg/l)	318	NA	NA	555.0	181.0	NA	324.0	258.0	318.0	420.0	375.0	NA	511.0
Dissolved Oxygen (mg/l)	0	NA	NA	0	0	NA	0	0	0	0	0	NA	0
Carbon Dioxide (mg/l)	64.2	NA	NA	159.0	42.9	NA	66.8	60.0	66.4	156.8	120.0	NA	116.4
Ferrous Iron (mg/l)	0	NA	NA	0	0	NA	0	0	0	0	0	NA	0
Hydrogen Sulfide (mg/l)	5.0	NA	NA	5.0	5.0	NA	5.0	5.0	5.0	5.0	5.0	NA	5.0
Methane (µg/l)	32	NA	NA	1,000.0	2	NA	30	40	17	61	44	NA	25
ORP (Eh)	-212	NA	-212	-228	-230	NA	-189	-190	-210	-218	-224	-210	-182
pH	7.38	6.83	7.27	6.97	7.34	7.26	7.05	7.09	7.17	6.98	7.02	7.19	7
Temperature	26.6	30.2	29.2	26.2	26.8	29.8	28.0	31.8	28.4	26.4	25.9	26.6	26.0
Alkalinity (µg/l)	320.0	NA	NA	380.0	210.0	NA	340.0	230.0	340.0	420.0	380.0	NA	420.0
Chloride (µg/l)	170.0	NA	NA	490.0	40.0	NA	2,200.0		1,900.0	4,000.0	3,600.0	NA	1,600.0
Salinity (%)	0.06	0.05	0.03		0.01	0.02		0.02	0.33	0.82	0.61	0.07	0.61
Sulfate (µg/l)	200.0	NA	NA	300.0	47	NA	300.0	34.0	420.0	820.0	650.0	NA	900.0
Sulfide (µg/l)	0	NA	NA	7.0	1.5	NA	0	0	1.7	2.0	3.4	NA	0
TOC	14.0	NA	NA	28.0	6.7	NA	10.0	2.6	3.1	9.8	17.0	NA	24.0
Nitrate-Nitrite (µg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phosphate (µg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ferric Iron (µg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

1 - Validated estimated laboratory value "J"

2 - Validated detected value less than action level (AL)

NA - Parameter not analyzed

ND - Not Detected

TABLE 4-2  
 SWMU 9 NATURAL ATTENUATION ANALYTICAL RESULTS – NOVEMBER 1998  
 PAGE 1 OF 2

Parameter	S9-MW12		S9-MW13		S9-MW05		S9-MW10		S9-MW21		S9-MW22		S9-MW25	
	Lab	Field	Lab	Field	Lab	Field	Lab	Field	Lab	Field	Lab	Field	Lab	Field
Cis-1,2-dichloroethene (µg/L)	ND	NA	ND	NA	ND	NA	ND	NA	60	NA	ND	NA	ND	NA
Trans-1,2-dichloroethene (µg/L)	ND	NA	ND	NA	ND	NA	ND	NA	51	NA	ND	NA	ND	NA
<b>Total 1,2-Dichloroethene (AL - 4.2 µg/L)</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>111</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>
Benzene (AL - 5 µg/L)	ND	NA	ND	NA	18	NA	ND	NA	ND	NA	ND	NA	ND	NA
Ethylbenzene (µg/L)	ND	NA	ND	NA	78	NA	ND	NA	ND	NA	ND	NA	ND	NA
<b>Total BTEXs</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>96</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>
Total Petroleum Hydrocarbons (µg/L)	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA
Alkalinity (mg/L) <sup>1</sup>	185	183	190	236	360	505	420	535	333	464	480	530	300	385
Carbon Dioxide (mg/L)	18.7	63.2	26.9	87.0	144	240	114	430	74.8	346.0	85.2	315.0	50.1	200.0
Chloride (mg/L)	665	NA	45.2	NA	53.2	NA	1020	NA	5920	NA	4940	NA	369 E	NA
Conductivity (mOhm/cm)	1.81	NA	0.680	NA	1.32	NA	3.10	NA	18.0	NA	6.50	NA	12.4	NA
Eh (mv)	-223	NA	-133	NA	-302	NA	-317	NA	-224	NA	-270	NA	-320	NA
Ethane (ng/L)	6.69	NA	<5.00	NA	<5.00	NA	<5.00	NA	45.70	NA	14.54	NA	60.85	NA
Ethene (ng/L)	6.56	NA	5.19	NA	<5.00	NA	<5.00	NA	60.88	NA	18.58	NA	90.66	NA
Hydrogen (nm/L)	3.49	NA	2.35	NA	6.79	NA	4.21	NA	1.88	NA	5.35	NA	8.20	NA
Hydrogen Sulfide (mg/L)	NA	2	NA	0.3	NA	>5	NA	>5	NA	>5	NA	>5	NA	>5
Ferrous Iron (mg/L)	<0.500	0	<0.500	0.02	<0.500	0.02	<0.500	0.02	<0.500	0.03	<0.500	0.03	<0.500	0.12
Ferric Iron (mg/L)	<.500	NA	<.500	NA	<.500	NA	<0.500	NA	<.500	NA	<.500	NA	<.500	NA
Manganese (mg/L)	<.500	0.2	<.500	0	<.500	0.2	<.500	0	<.500	0	<.500	1.4	<.500	0.1
Methane (ug/L)	41.80	NA	13.05	NA	3245.00	NA	2840.00	NA	116.64	NA	17.52	NA	177.68	NA
Nitrate-N (mg/L)	<.500	0.06	<.500	0.06	<.500	0.04	<.500	0.02	<.500	0	<.500	0.03	<.500	0.04
Nitrite-N (mg/L)	<.500	0.015	<.500	0.031	<.500	0.017	<.500	0.019	<.500	0.005	<.500	0.007	<.500	0.02
Oxygen (mg/L)	0.79	0.00	1.00	0.00	0.60	0.00	0.66	0.00	0.81	0.00	0.86	0.00	0.57	0.00
pH	7.1	NA	7.26	NA	6.68	NA	6.95	NA	7.05	NA	7.02	NA	7.22	NA
Sulfate (mg/L)	93.5	>80	29.3	28	5.44	0	235	>80	1060	>80	1060	>80	673	>80
Sulfide (mg/L)	0.12	0.05	0.12	0.03	0.18	>.8	0.14	>.8	0.2	>.8	0.13	0.64	0.17	>.8
Temperature (C)	28.4	NA	31	NA	31.6	NA	27.9	NA	27.8	NA	27.9	NA	28.1	NA

<sup>1</sup> Field analyses is alkalinity/DIC concentration  
 NA – Not Analyzed  
 ND – Not Detected  
 DF – Duplicate filtered  
 D – Duplicate  
 AL – Action level  
 BTEXs – Benzene, toluene, ethylbenzene and xylenes

TABLE 4-2  
SWMU 9 NATURAL ATTENUATION ANALYTICAL RESULTS – NOVEMBER 1998  
PAGE 2 OF 2

Parameter	S9-MW14		S9-MW23		S9-MW23DF		S9-MW24		S9-MW24D		S9-MW15		S9-MWRW2	
	Lab	Field	Lab	Field	Lab	Field	Lab	Field	Lab	Field	Lab	Field	Lab	Field
Cis-1,2-dichloroethene (µg/L)	3	NA	4.6	NA	ND	NA	60.25	NA	ND	NA	280	NA	ND	NA
Trans-1,2-dichloroethene (µg/L)	5.2	NA	13	NA	ND	NA	105.25	NA	ND	NA	820	NA	ND	NA
<b>Total 1,2-Dichloroethene (AL - 4.2 µg/L)</b>	<b>8.2</b>	<b>NA</b>	<b>17.6</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>165.5</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>1100</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>
Benzene (AL - 5 µg/L)	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA
Ethylbenzene (µg/L)	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA
<b>Total BTEXs</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>	<b>ND</b>	<b>NA</b>
Total Petroleum Hydrocarbons (µg/L)	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA
Alkalinity (mg/L) <sup>1</sup>	225	252	306	306	NA	305.00	330	306	335	NA	240	305	233	495
Carbon Dioxide (mg/L)	46.9	131.0	27.1	153.0	NA	159.00	71.5	300.0	70.2	NA	39.7	159.0	32.4	300
Chloride (mg/L)	683	NA	188	NA	NA	NA	3100	NA	3130	NA	701	NA	1880	NA
Conductivity (mOhm/cm)	2.87	NA	0.332	NA	NA	NA	9.00	NA	9.00	NA	2.07	NA	5.90	NA
Eh (mv)	-171	NA	-230	NA	NA	NA	-240	NA	-240	NA	-218	NA	-294	NA
Ethane (ng/L)	<5.00	NA	<5.00	NA	NA	NA	<5.00	NA	<5.00	NA	<5.00	NA	<5.00	NA
Ethene (ng/L)	21.61	NA	21.99	NA	NA	NA	82.40	NA	78.29	NA	136.07	NA	33.49	NA
Hydrogen (nm/L)	0.97	NA	2.43	NA	NA	NA	3.06	NA	1.67	NA	1.05	NA	2.94	NA
Hydrogen Sulfide (mg/L)	NA	0.2	NA	4.5	NA	3.00	NA	>5	NA	NA	NA	3	NA	>5
Iron II (mg/L)	<0.500	0.04	<0.500	0.07	NA	0.05	<0.500	0.01	<0.500	NA	<0.500	0.09	<0.500	0
Iron III (mg/L)	<.500	NA	<.500	NA	NA	NA	<.500	NA	<.500	NA	<.500	NA	<.500	NA
Manganese (mg/L)	<0.500	0.1	<0.500	0.1	NA	0.00	<0.500	0	<0.500	NA	<0.500	0	<0.500	0
Methane (ug/L)	7.00	NA	66.70	NA	NA	NA	37.61	NA	39.98	NA	14.25	NA	71.90	NA
Nitrate-N (mg/L)	<.500	NA	<.500	NA	NA	NA	<.500	NA	<.500	NA	<.500	NA	<.500	NA
Nitrite-N (mg/L)	<.500	NA	<.500	NA	NA	NA	<.500	NA	<.500	NA	<.500	NA	<.500	NA
Oxygen (mg/L)	0.65	0.00	0.63	0.00	NA	0.00	0.93	0.00	0.79	NA	0.53	0.00	0.78	0.00
pH	7.07	NA	7.26	NA	NA	NA	7.09	NA	7.09	NA	7.1	NA	7.4	NA
Sulfate (mg/L)	106	>80	107	150d	NA	>160d	953	>80	963	NA	132	153d	324	>320d
Sulfide (mg/L)	0.15	0	0.13	0.05	NA	0.00	0.14	0.37	0.17	NA	0.12	0	0.81	0.37
Temperature (C)	27.9	NA	27.5	NA	NA	NA	26.7	NA	26.7	NA	29.2	NA	29.2	NA

<sup>1</sup> Field Analyses is Alkalinity/DIC Concentration

NA – Not Analyzed

ND – Not Detected

DF – Duplicate Filtered

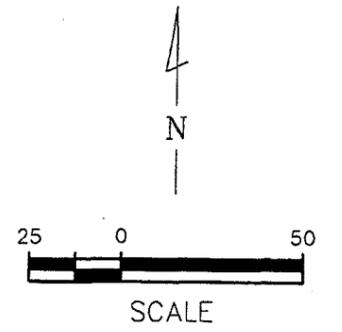
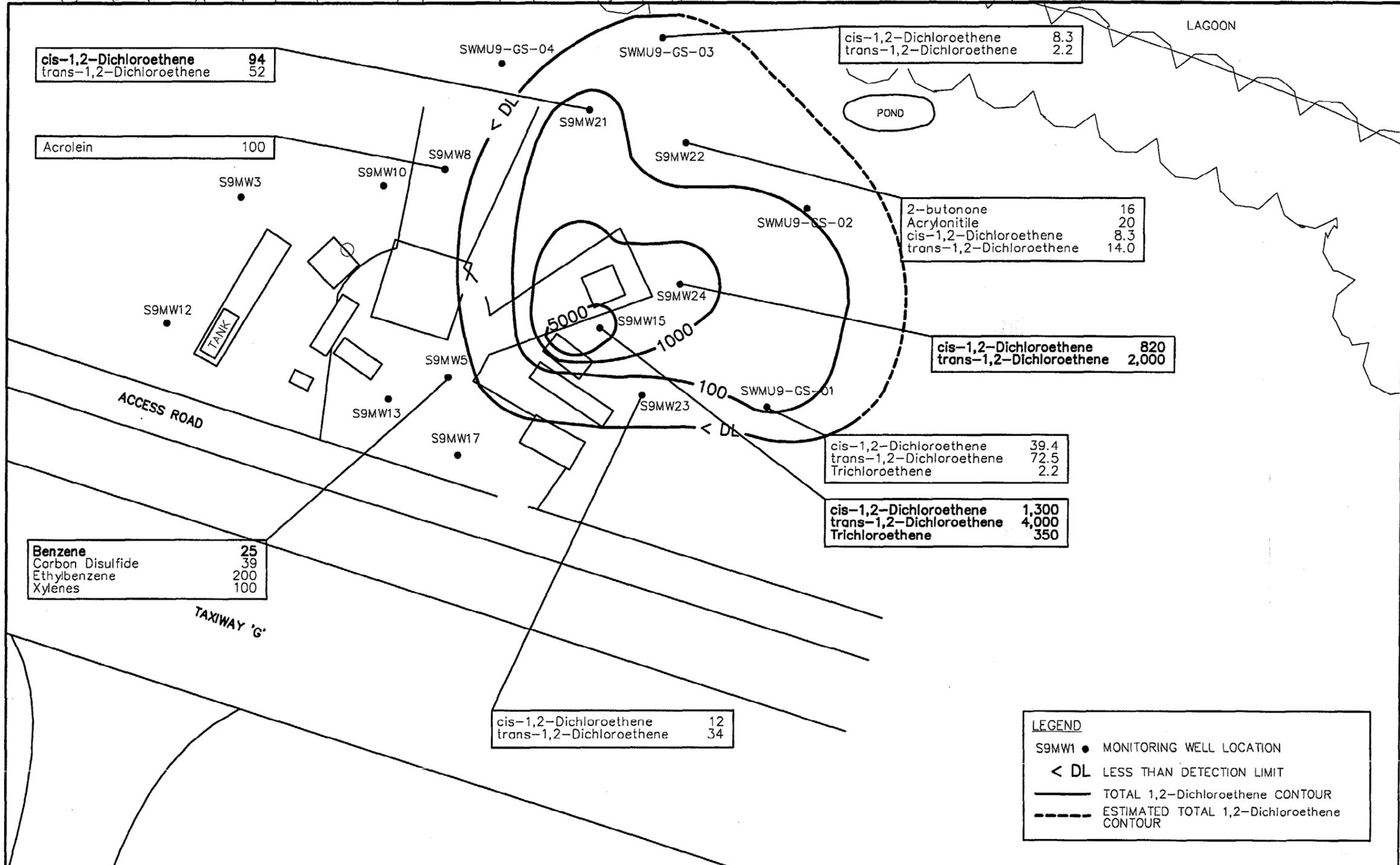
D – Duplicate

AL – Action level

BETXs – Benzene, toluene, ethylbenzene and xylenes

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**GROUNDWATER ACTION LEVELS**

PARAMETER	STANDARD
2-butanone	1,900
Acrolein	NA
Acrylonitrile	NA
<b>Benzene</b>	<b>1</b>
Carbon Disulfide	1,000
<b>cis-1,2-Dichloroethene</b>	<b>70</b>
Ethylbenzene	700
<b>trans-1,2-Dichloroethene</b>	<b>100</b>
<b>Trichloroethene</b>	<b>3</b>
Xylenes (total)	10,000

~ ALL APPLICABLE RELEVANT AND APPROPRIATE REQUIREMENTS (ARAR's) AND SCREENING ACTION LEVELS (SAL's) are from the 4-Sites RFI Report or BRAC SI Workplan.

**NOTE:**  
All concentrations are in ug/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.  
Concentrations in exceedance of action levels are noted in bold type.

**LEGEND**

- S9MW1 ● MONITORING WELL LOCATION
- < DL LESS THAN DETECTION LIMIT
- TOTAL 1,2-Dichloroethene CONTOUR
- ESTIMATED TOTAL 1,2-Dichloroethene CONTOUR

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

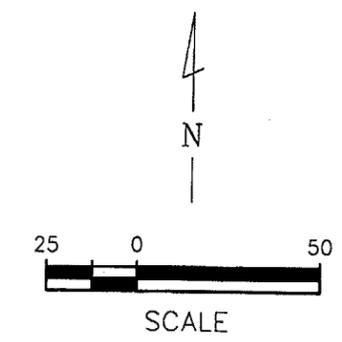
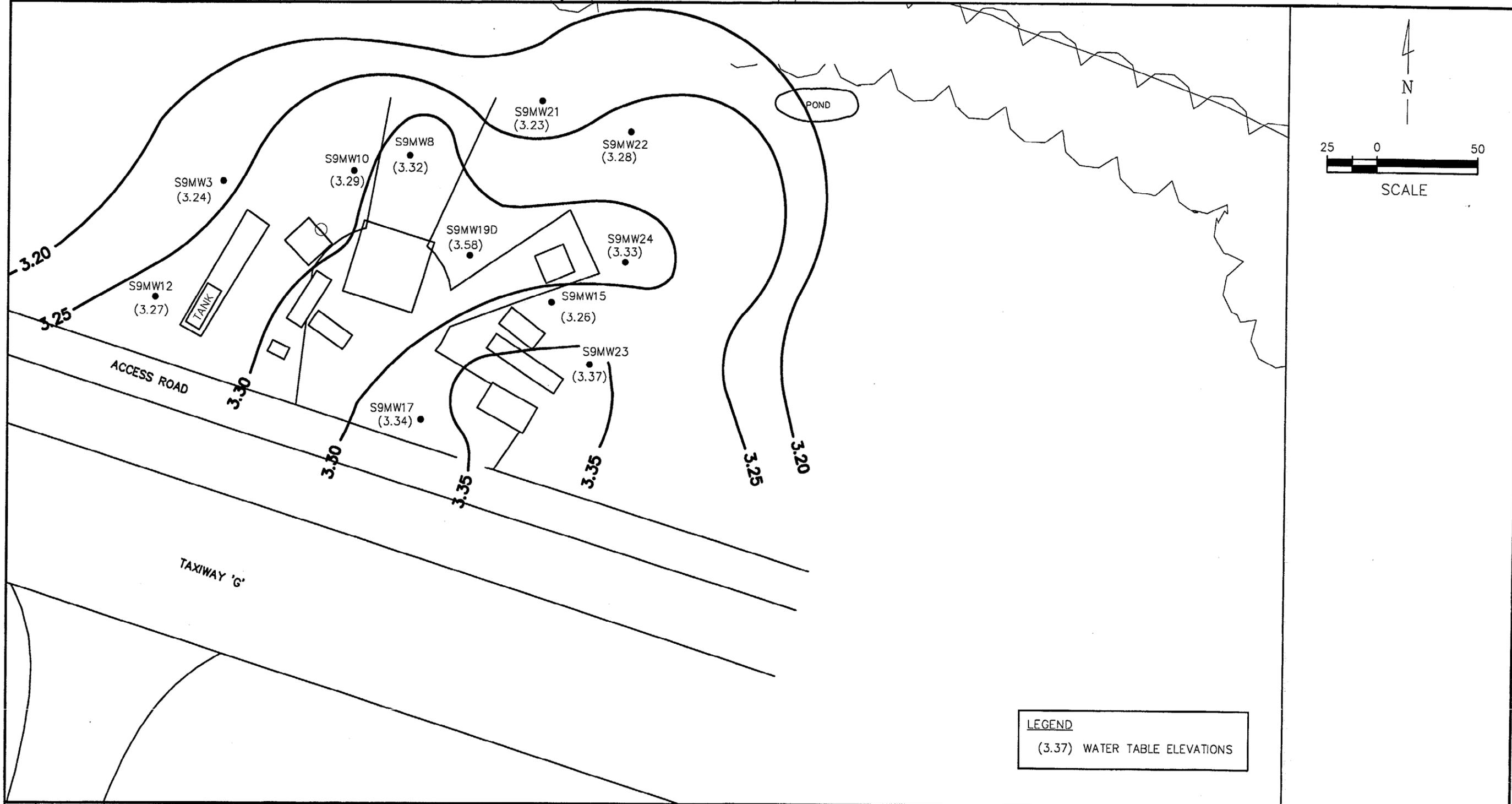
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 CHECKED BY: DSF 1/26/99  
 COST/SCHED-AREA:       
 SCALE: AS NOTED



NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9  
 FIGURE 4-1. MAY 1998 CHLORINATED VOC  
 GROUNDWATER CHEMICAL CONCENTRATIONS  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA

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**LEGEND**  
(3.37) WATER TABLE ELEVATIONS

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

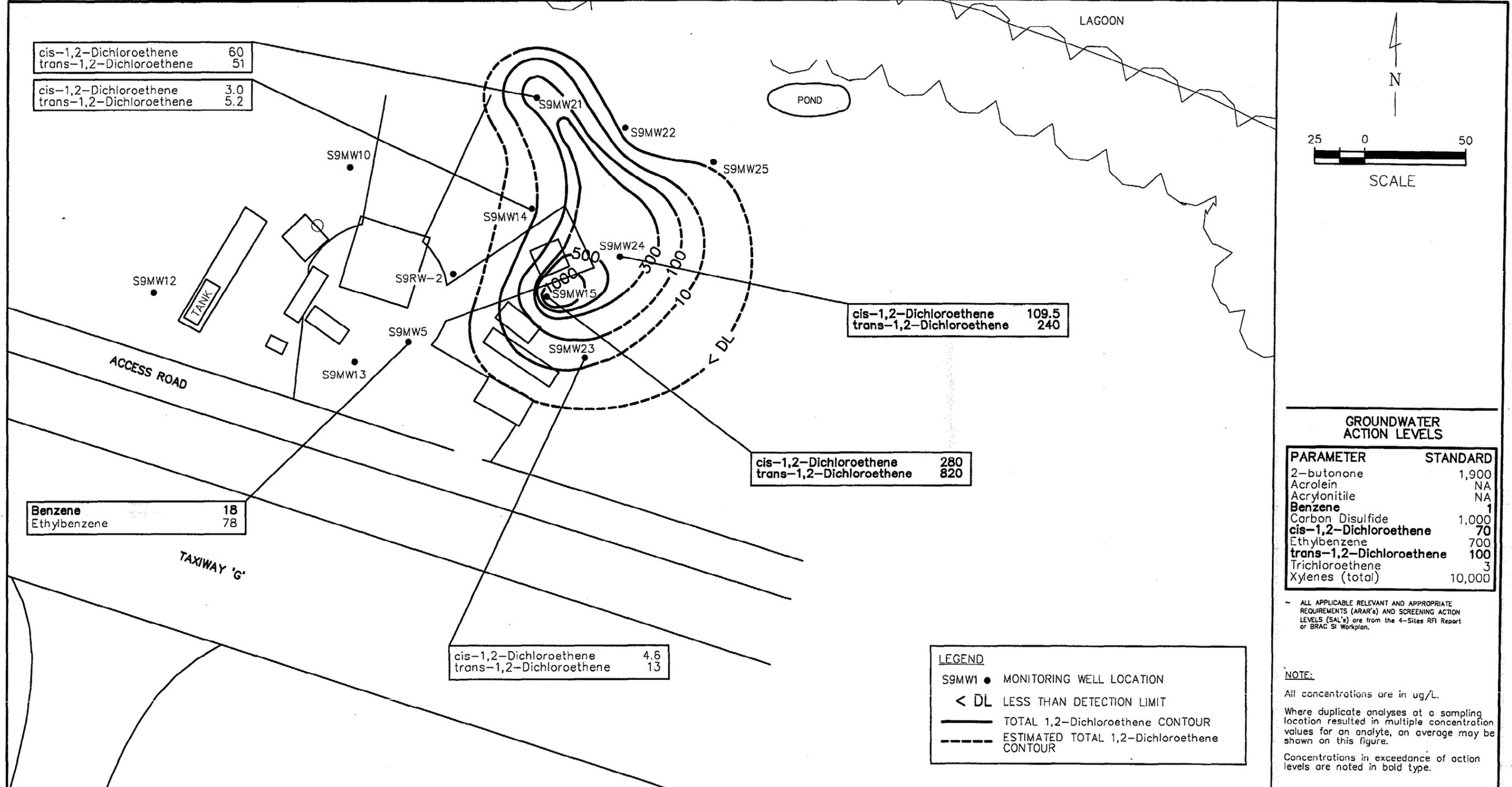
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 CHECKED BY: DSF 1/26/99  
 COST/SCHED-AREA: \_\_\_\_\_  
 SCALE: AS NOTED



**NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9**  
**FIGURE 4-2. 1998 GROUNDWATER ELEVATION**  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA

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**GROUNDWATER ACTION LEVELS**

PARAMETER	STANDARD
2-butanone	1,900
Acrolein	NA
Acrylonitrile	NA
<b>Benzene</b>	<b>1</b>
Carbon Disulfide	1,000
<b>cis-1,2-Dichloroethene</b>	<b>70</b>
Ethylbenzene	700
<b>trans-1,2-Dichloroethene</b>	<b>100</b>
Trichloroethene	3
Xylenes (total)	10,000

ALL APPLICABLE RELEVANT AND APPROPRIATE REQUIREMENTS (ARAR's) AND SCREENING ACTION LEVELS (SAL's) are from the 4-Sites RFI Report or BRAC SI Workplan.

**NOTE:**  
All concentrations are in ug/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.  
Concentrations in exceedance of action levels are noted in bold type.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

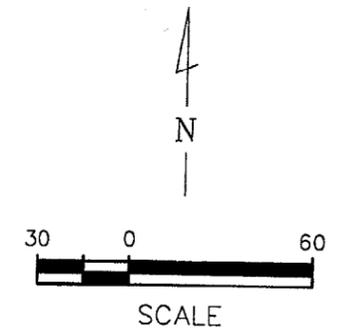
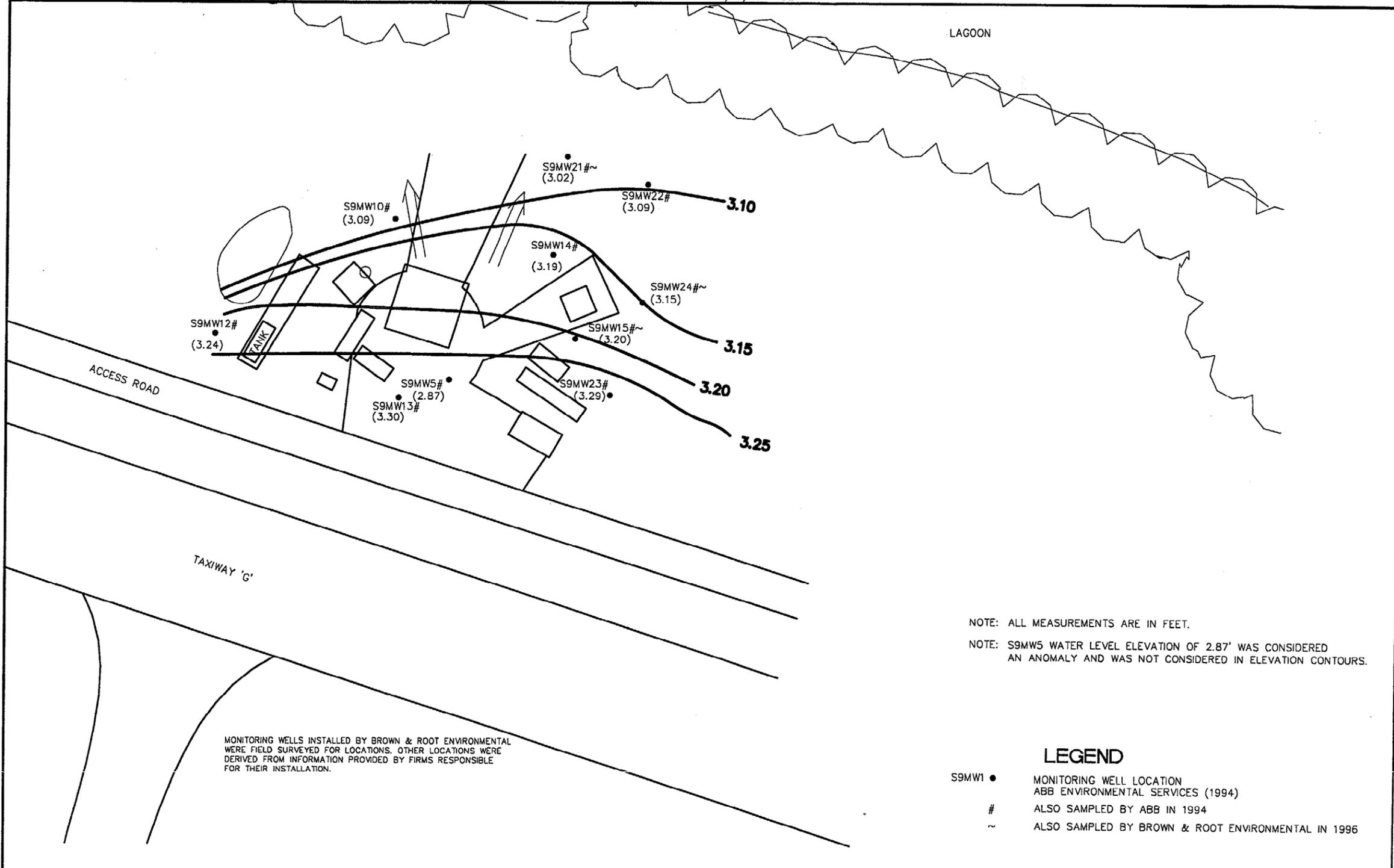
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 CHECKED BY: DSF 1/26/99  
 COST/SCHED-AREA  
 SCALE AS NOTED



NATURAL ATTENUATION STUDY RESULTS FOR S9MWU 9  
 FIGURE 4-3. NOVEMBER 1998 CHLORINATED VOC  
 GROUNDWATER CHEMICAL CONCENTRATIONS  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA

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NOTE: ALL MEASUREMENTS ARE IN FEET.  
NOTE: S9MW5 WATER LEVEL ELEVATION OF 2.87' WAS CONSIDERED AN ANOMALY AND WAS NOT CONSIDERED IN ELEVATION CONTOURS.

MONITORING WELLS INSTALLED BY BROWN & ROOT ENVIRONMENTAL WERE FIELD SURVEYED FOR LOCATIONS. OTHER LOCATIONS WERE DERIVED FROM INFORMATION PROVIDED BY FIRMS RESPONSIBLE FOR THEIR INSTALLATION.

**LEGEND**

- S9MW1 ● MONITORING WELL LOCATION  
ABB ENVIRONMENTAL SERVICES (1994)
- # ALSO SAMPLED BY ABB IN 1994
- ~ ALSO SAMPLED BY BROWN & ROOT ENVIRONMENTAL IN 1996

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

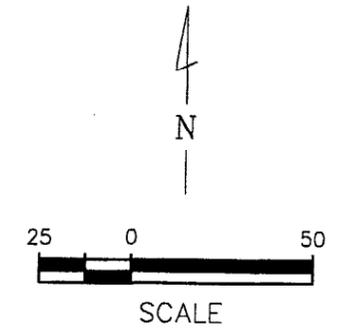
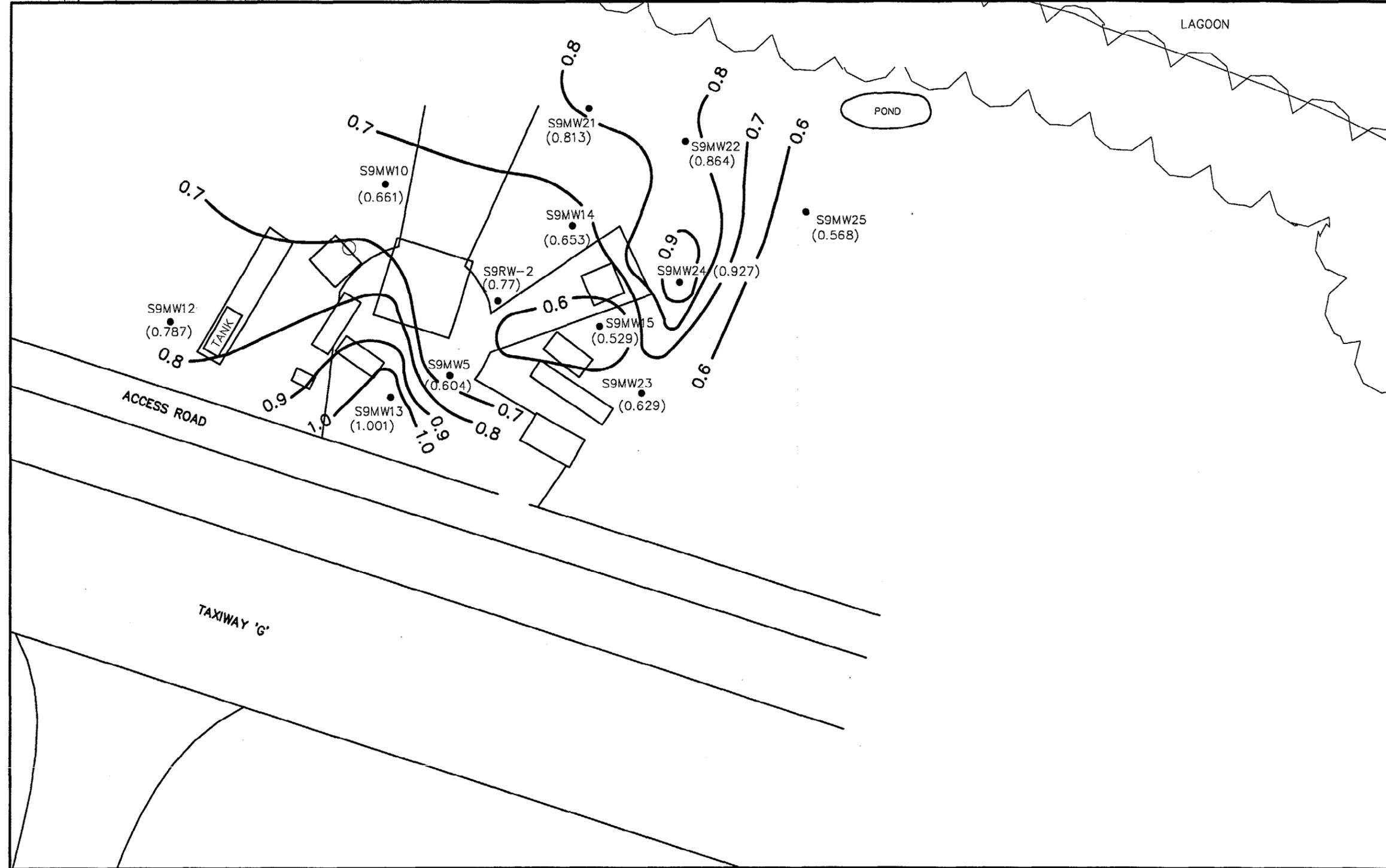
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CHECKED BY: DSF  
DATE: —  
COST/SCHED-AREA: —  
SCALE: AS NOTED



NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9  
FIGURE 4-4. NOVEMBER 1998 GROUNDWATER  
FLOW AND ELEVATIONS, SWMU 9  
NAVY SOUTHERN DIVISION  
BOCA CHICA KEY, FLORIDA

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**NOTE:**  
All concentrations are in mg/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

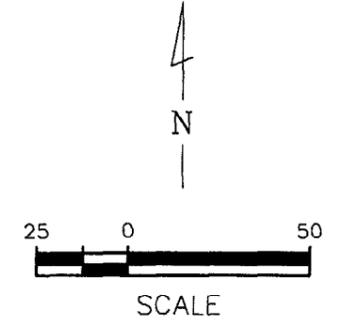
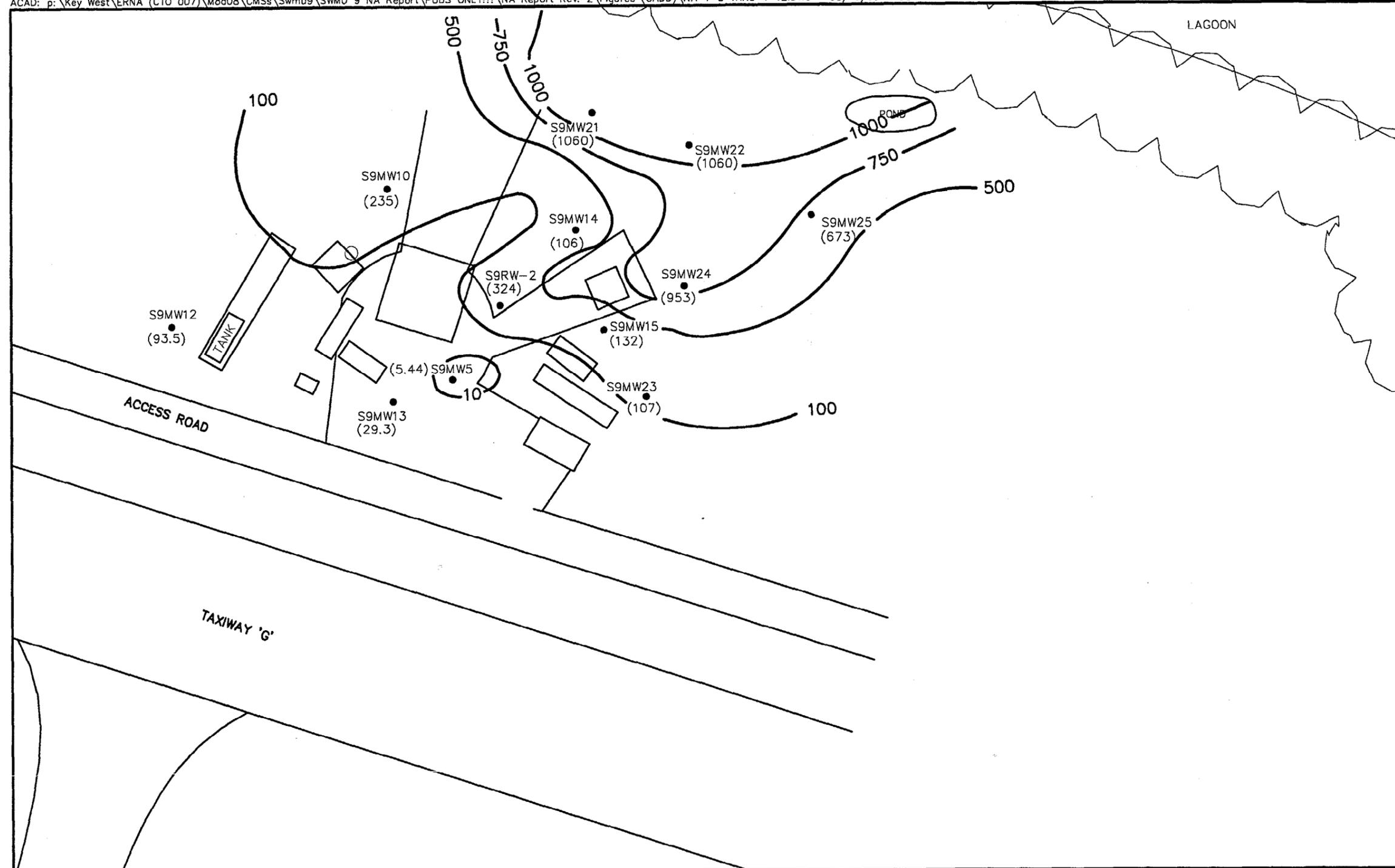
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 CHECKED BY: DSF DATE: 1/26/99  
 COST/SCHED-AREA:        
 SCALE: AS NOTED



NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9  
 FIGURE 4-5. DISSOLVED O2 (TARGET)  
 CHEMICAL CONCENTRATIONS  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA

CONTRACT NO. 7046	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO.	REV. 2

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**NOTE:**  
All concentrations are in mg/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

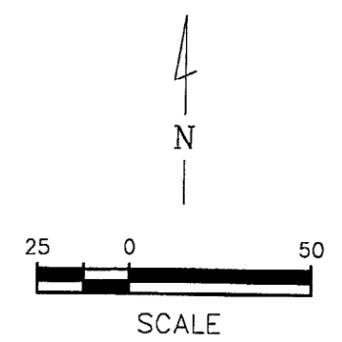
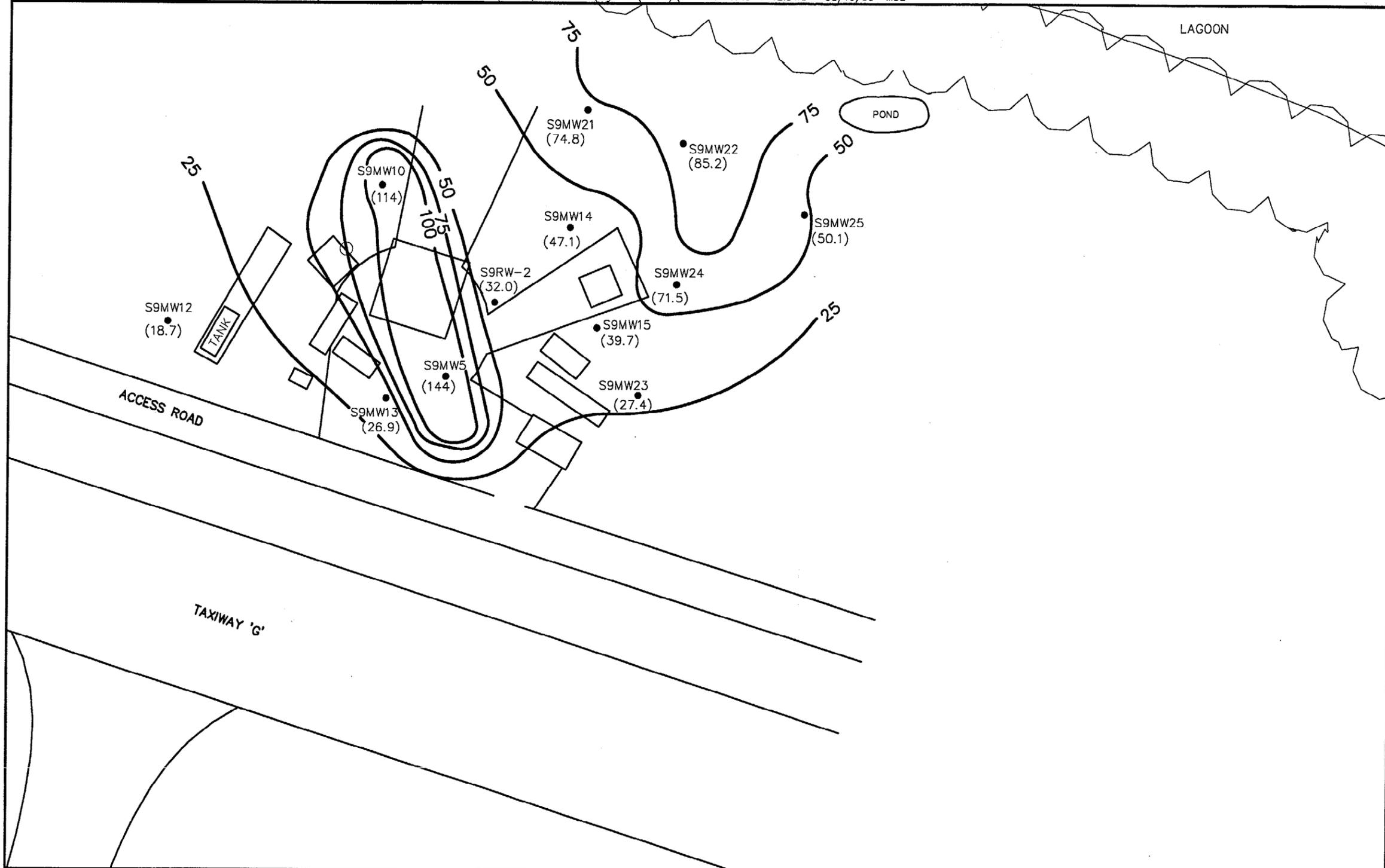
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NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9  
FIGURE 4-6. SULFATE (TARGET)  
CHEMICAL CONCENTRATIONS  
NAVY SOUTHERN DIVISION  
BOCA CHICA KEY, FLORIDA

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**NOTE:**  
All concentrations are in mg/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

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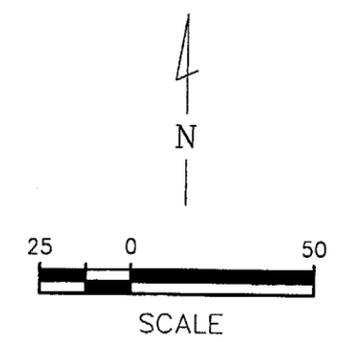
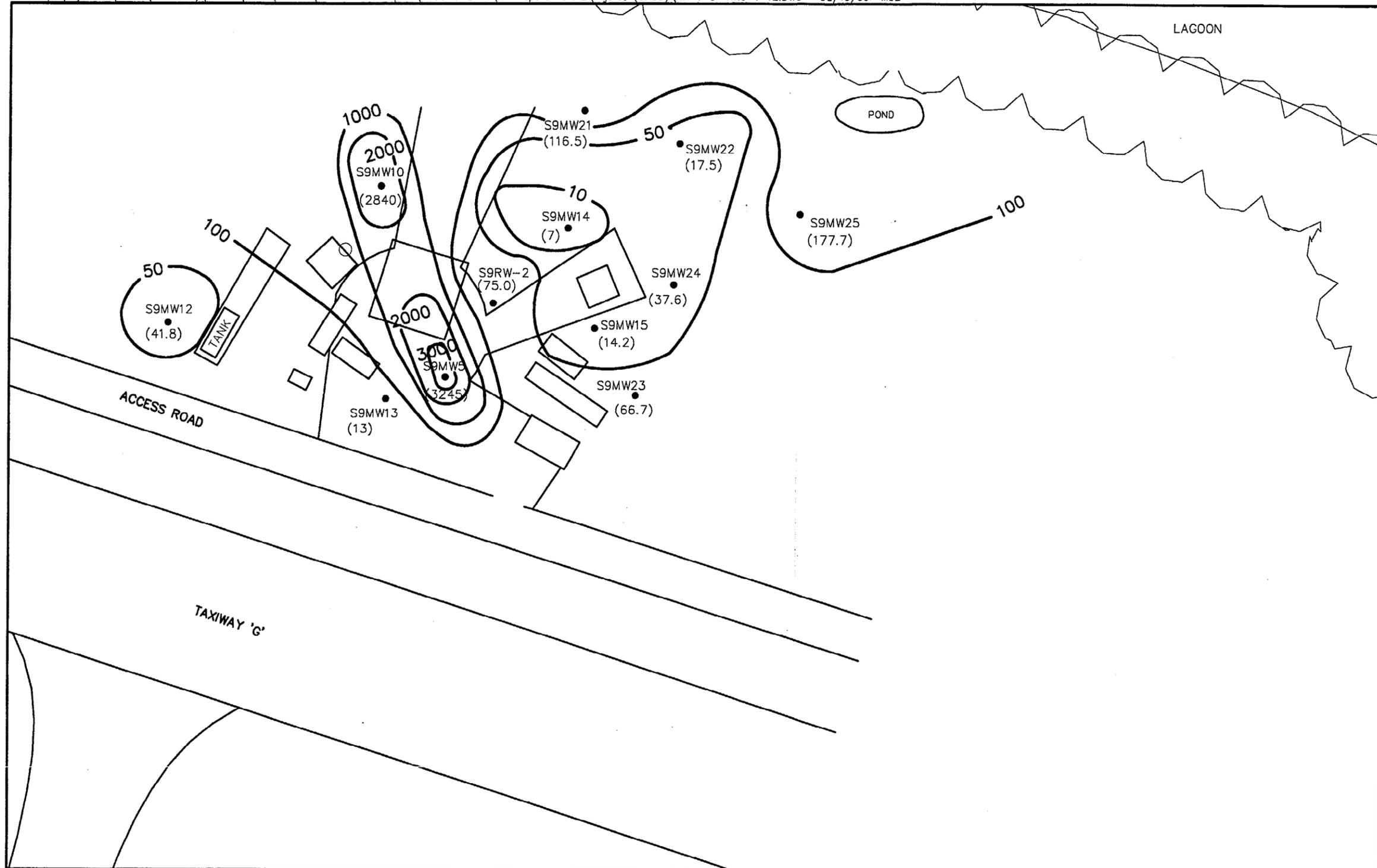
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**NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9**  
**FIGURE 4-7. CARBON DIOXIDE (TARGET)**  
 CHEMICAL CONCENTRATIONS  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA

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**NOTE:**  
All concentrations are in ug/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

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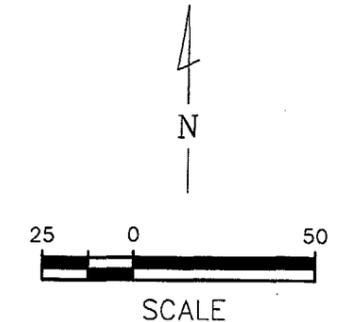
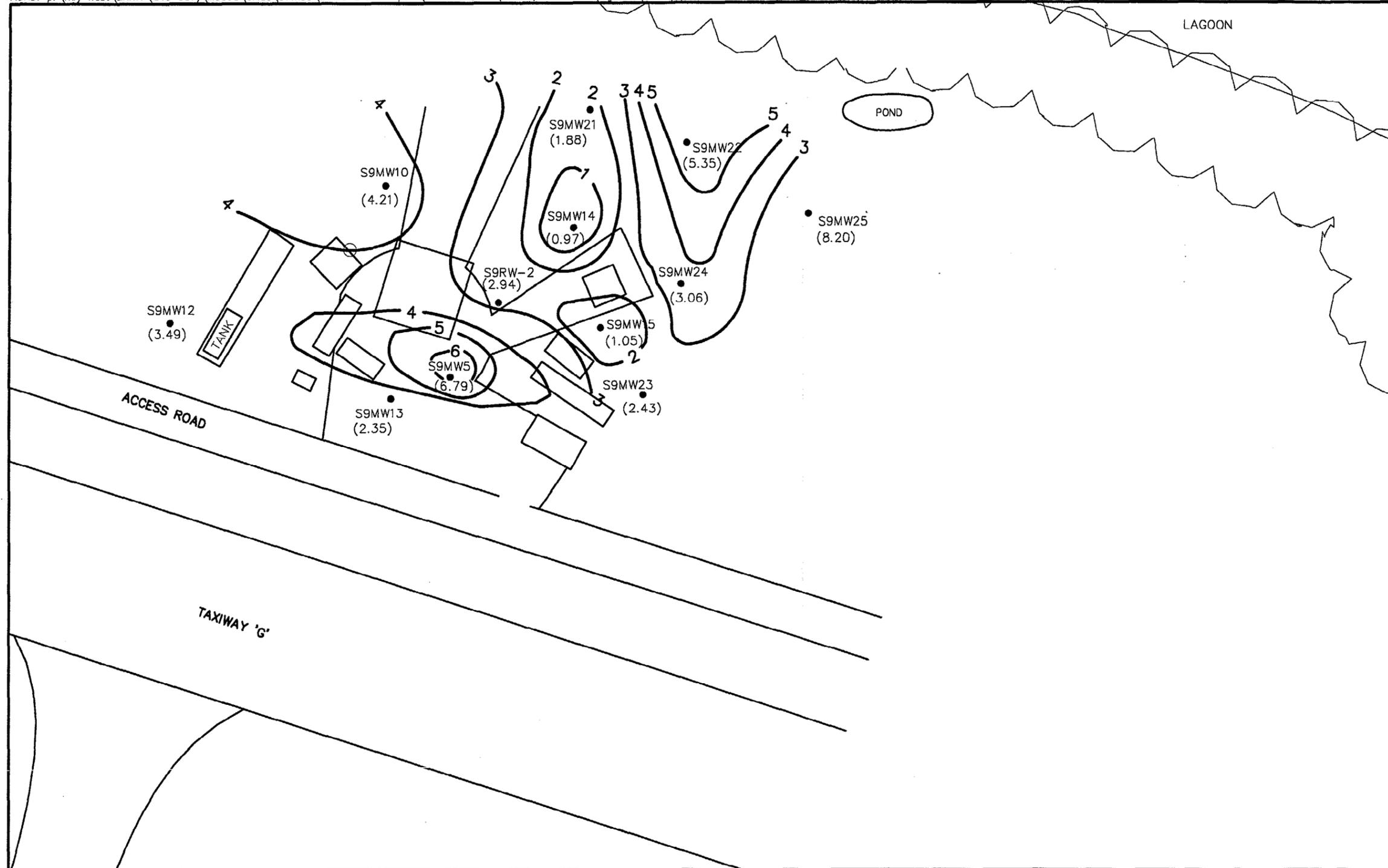
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**NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9  
 FIGURE 4-8. METHANE (TARGET)  
 CHEMICAL CONCENTRATIONS  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA**

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**NOTE:**  
All concentrations are in nm/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

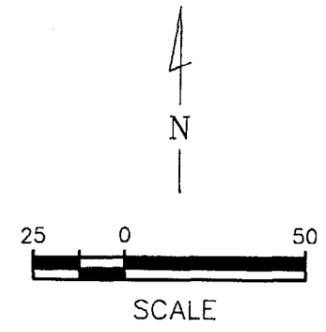
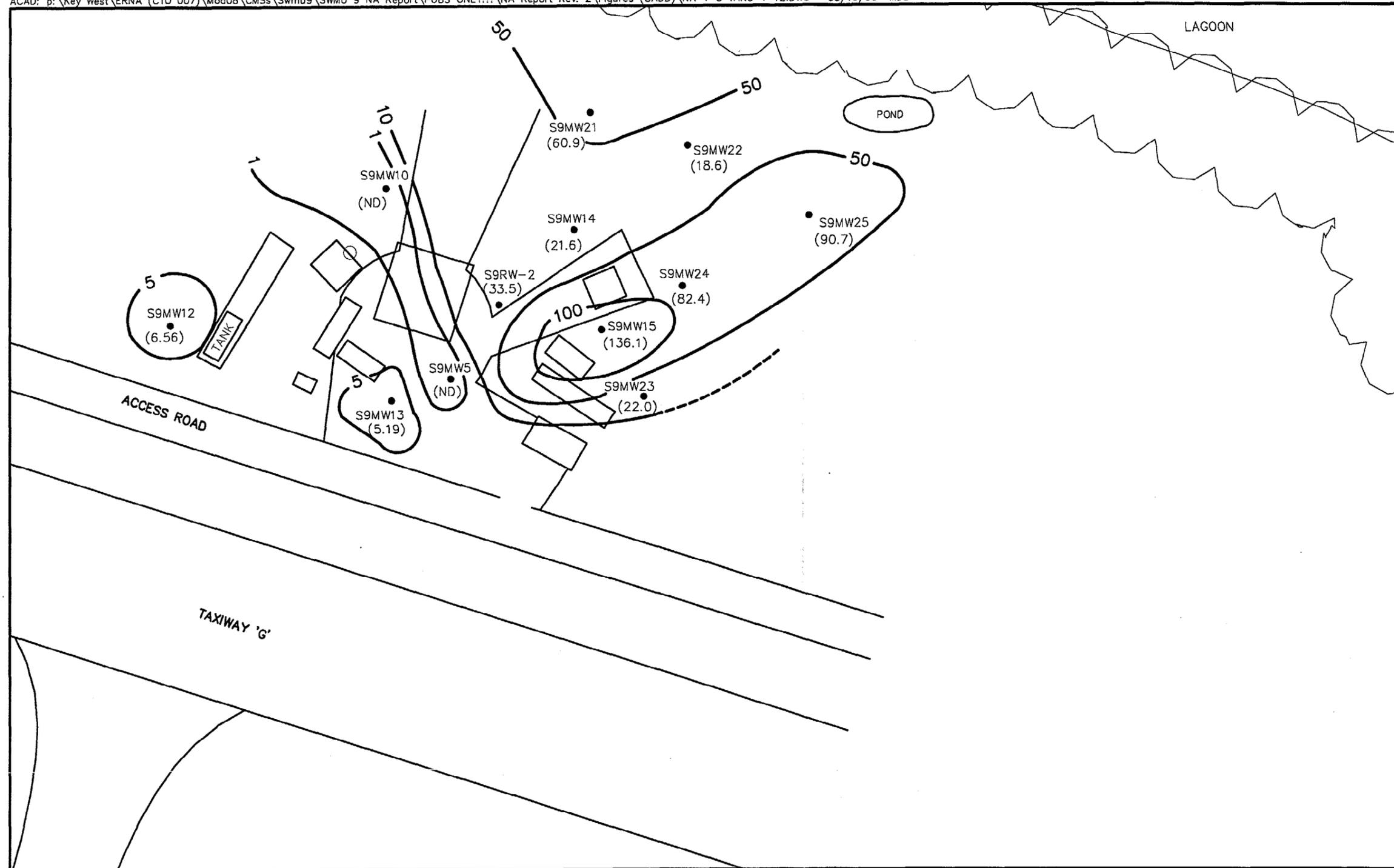
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 SCALE: AS NOTED



NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9  
 FIGURE 4-9. HYDROGEN (TARGET)  
 CHEMICAL CONCENTRATIONS  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA

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**NOTE:**  
All concentrations are in ng/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

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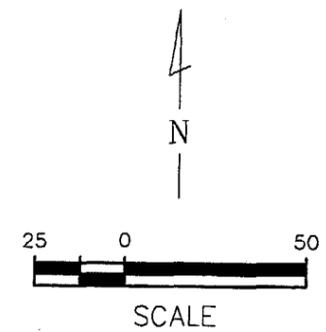
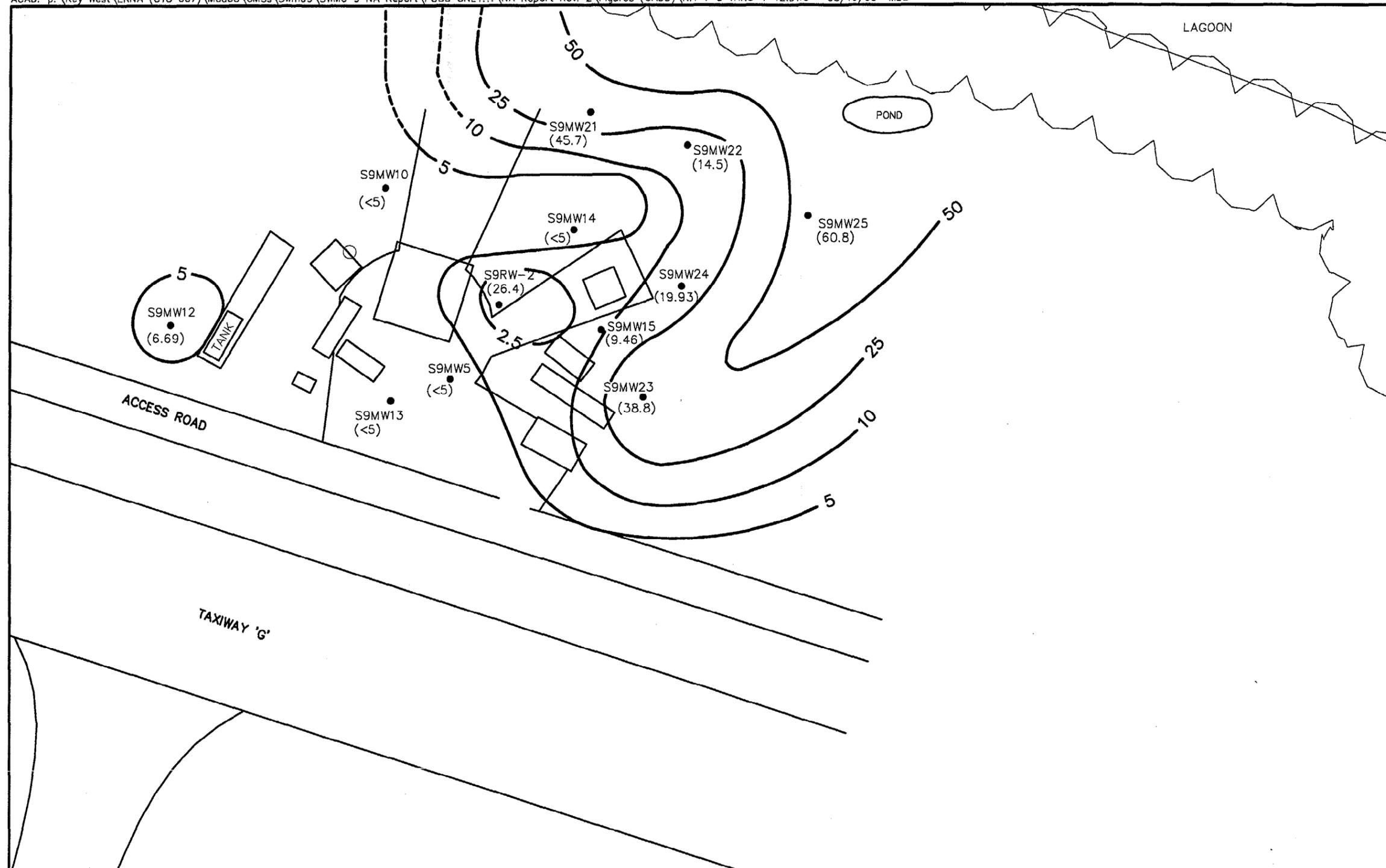
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NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9  
FIGURE 4-10. ETHENE (TARGET)  
CHEMICAL CONCENTRATIONS  
NAVY SOUTHERN DIVISION  
BOCA CHICA KEY, FLORIDA

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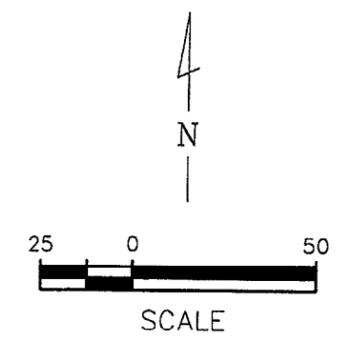
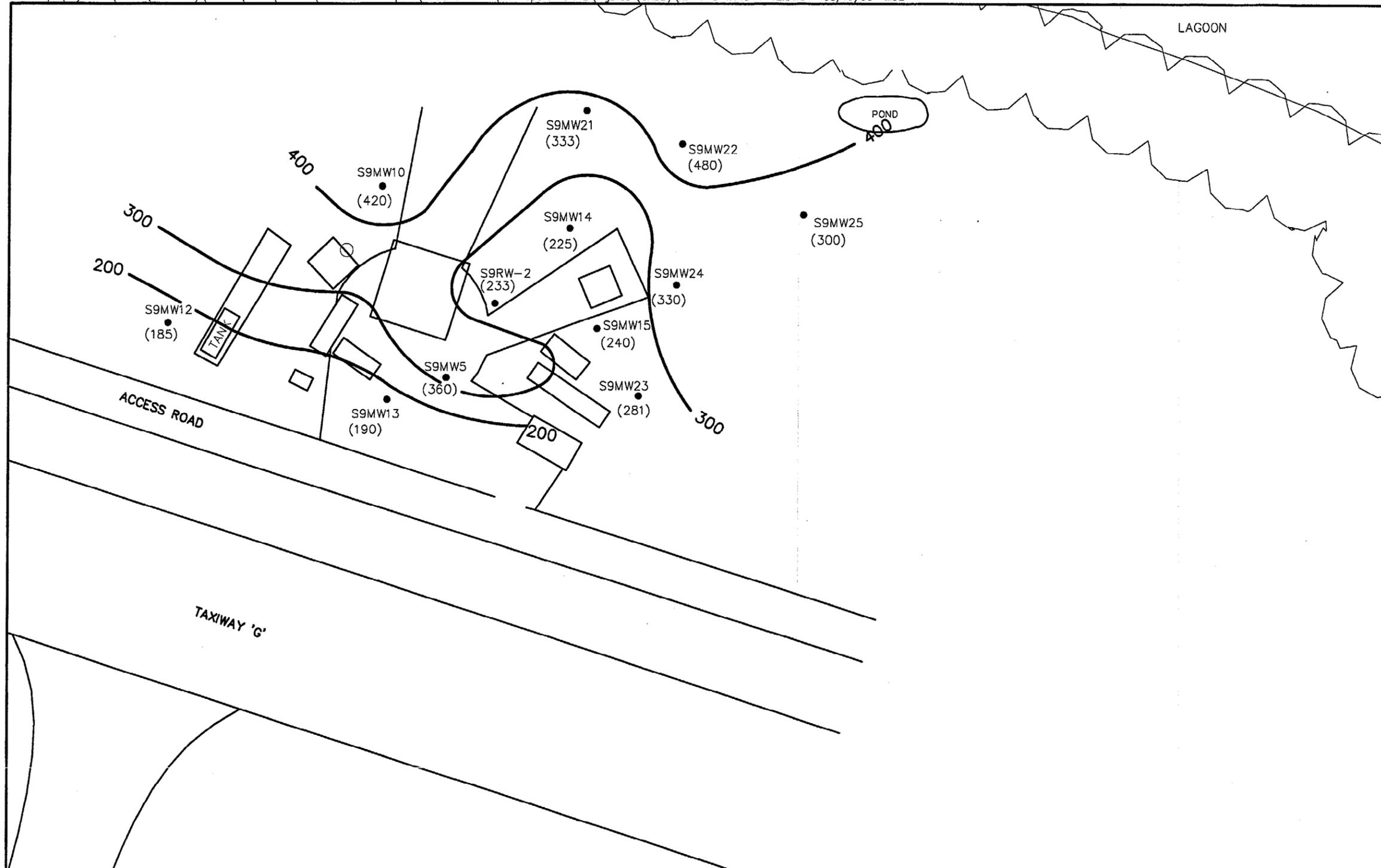
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**NOTE:**  
All concentrations are in ng/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	DRAWN BY	DATE		NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9 FIGURE 4-11. ETHANE (TARGET) CHEMICAL CONCENTRATIONS NAVY SOUTHERN DIVISION BOCA CHICA KEY, FLORIDA	CONTRACT NO.
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**NOTE:**  
All concentrations are in mg/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

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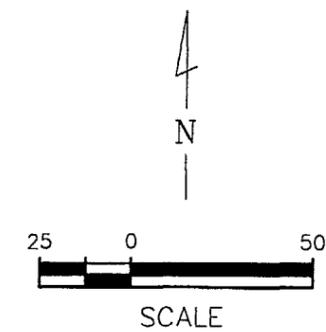
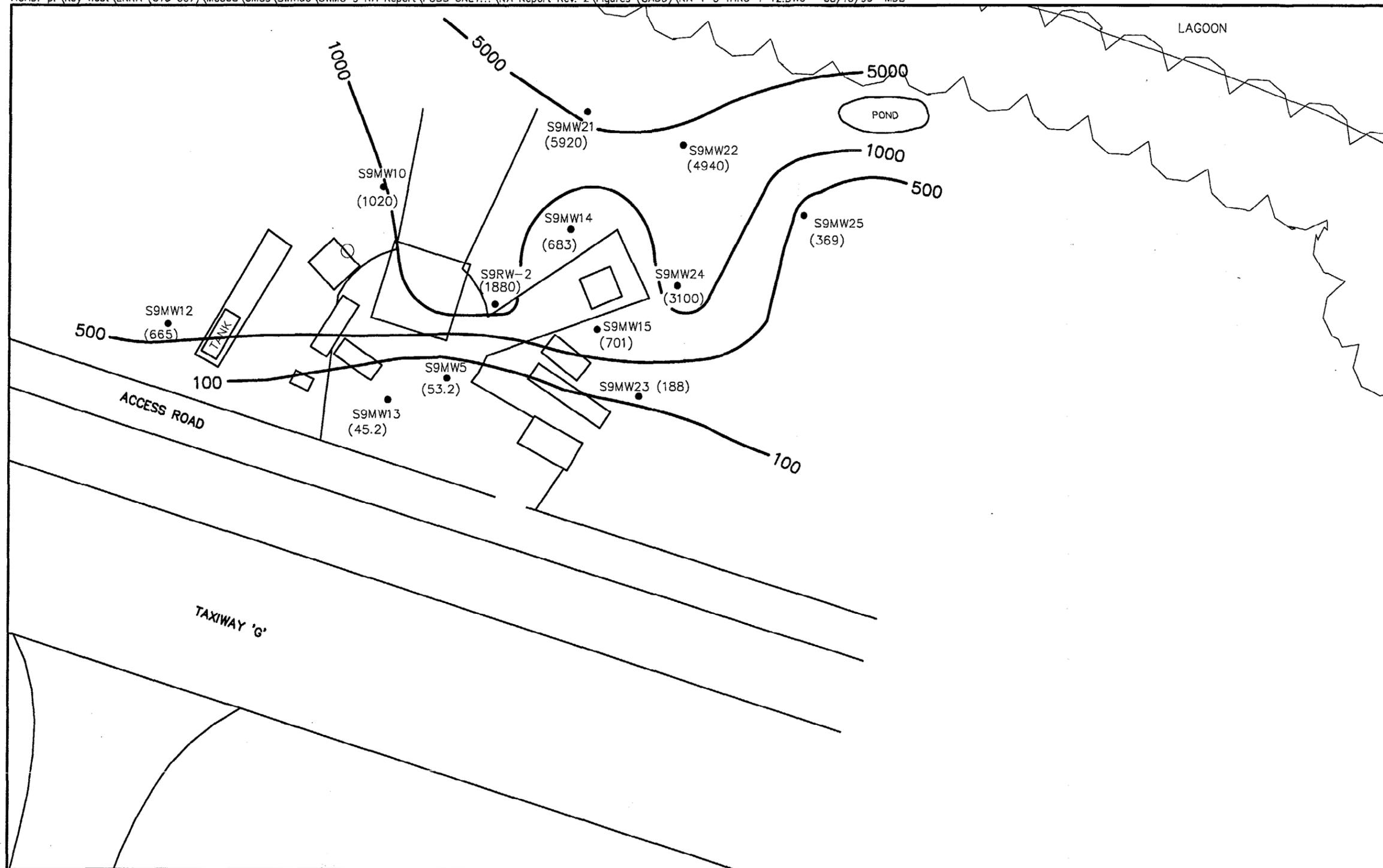
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**NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9**  
**FIGURE 4-12. ALKALINITY (TARGET)**  
**CHEMICAL CONCENTRATIONS**  
**NAVY SOUTHERN DIVISION**  
**BOCA CHICA KEY, FLORIDA**

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**NOTE:**  
All concentrations are in mg/L.  
Where duplicate analyses at a sampling location resulted in multiple concentration values for an analyte, an average may be shown on this figure.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

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**NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9**  
**FIGURE 4-13. CHLORIDE (TARGET)**  
**CHEMICAL CONCENTRATIONS**  
 NAVY SOUTHERN DIVISION  
 BOCA CHICA KEY, FLORIDA

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## 5.0 SUMMARY AND CONCLUSIONS

### 5.1 INVESTIGATION SUMMARY

As stated in the Draft EPA Region 4 Suggested Practices for Evaluation of a Site for Natural Attenuation (Biological Degradation) of Chlorinated Solvents (USEPA, 1997): "Natural attenuation in ground-water systems results from the integration of several subsurface attenuation mechanisms that are classified as either destructive or nondestructive. Biodegradation is the most important destructive attenuation mechanism." Therefore, it is important to be able to estimate the potential for natural biodegradation when selecting a remedial alternative. Depending upon the nature and extent of groundwater contamination, natural attenuation may be sufficient to be the sole remedial alternative for groundwater remediation at some sites. At other sites, natural attenuation alone would be insufficient to be protective of human health and the environment. However, natural attenuation processes could be used to facilitate more active forms of groundwater remediation.

To determine the efficiency of intrinsic biological processes to degrade a chlorinated hydrocarbon groundwater plume, the following data are required:

- Hydrogeological
- Plume geometry
- Adsorption parameters
- Biodegradation indicators
- Contaminant concentrations

Prior to May 1998 the data collected at SWMU 9 included only hydrogeological, plume geometry, and contaminant concentration information. Adsorption parameters can be reasonably estimated based on accepted literature values. The parameters that cannot be estimated are the biodegradation indicators. Therefore, biodegradation indicators and more recent contaminant concentrations were collected during the May 1998 natural attenuation screening study at SWMU 9. In November 1998, additional data on chemical parameters were collected to confirm the biological processes identified during the May sampling. In the fall, particular emphasis was given to analysis of dissolved gasses that provide evidence for the natural attenuation processes.

## 5.2 NATURAL ATTENUATION OVERVIEW

Chlorinated hydrocarbons have been shown to biodegrade along three primary pathways; as an electron acceptor; as an electron donor; or through cometabolism.

### 5.2.1 Electron Acceptor Reactions

Most commonly, highly chlorinated hydrocarbons can be used as electron acceptors. This process results in the reductive dechlorination of the solvent mass. During reductive dechlorination, a chlorine atom is removed and replaced by a hydrogen atom. Dechlorination typically occurs sequentially from most chlorinated to least chlorinated as seen in Figure 5-1. If tetrachloroethene (PCE) ( $C_2Cl_4$ ) is the source product, it will most likely be reduced to trichloroethene (TCE) ( $C_2HCl_3$ ). TCE which can be the source product or a daughter product of PCE reduction will be reduced to dichloroethene (DCE) ( $C_2H_2Cl_2$ ). DCE can be reduced to vinyl chloride, although this process is not as efficient as reduction of the more chlorinated compounds. Therefore, in a plume that originated as PCE or TCE, there frequently is an accumulation of DCE as the daughter product. Typically, the primary daughter product of PCE and/or TCE is cis-1,2-DCE. Trans-1,2-DCE also can be produced. Less frequently, 1,1-DCE can be produced. In addition, some isomers of DCE, particularly trans-1,2-DCE, can be product sources themselves. If the amount of cis-1,2-DCE is greater than that of trans-1,2-DCE, the DCE is likely a daughter product of TCE rather than a source product. Vinyl chloride (VC) can be reduced to ethene and then to ethane under these reducing conditions but this occurs at a much slower rate than the reduction of PCE, TCE, and even DCE. Therefore, VC may tend to accumulate in the source area or along the downgradient edge of the plume.

Methanogenesis and sulfate reduction are the most efficient and common reduction pathways of reductive dechlorination. Other, less common, pathways include nitrate- and iron-reducing conditions.

### 5.2.2 Electron Donor Reactions

Microbes are incapable of reducing PCE and TCE utilizing electron donor reactions (Murray and Richardson, 1993). However, it also has been documented that several of the less chlorinated hydrocarbons, such as VC, can be utilized as the primary substrate in both aerobic and anaerobic environments (McCarty and Semprini, 1994). When utilized as the primary substrate, vinyl chloride can be mineralized into carbon dioxide, water, and chloride ions.

### 5.2.3 Cometabolism

Cometabolism involves the biodegradation of a chlorinated hydrocarbon using an enzyme or cofactor that is incidentally produced by microbes for other purposes, such as the degradation of BTEXs or other carbon source. The organism does not benefit from the degradation of the chlorinated hydrocarbon, and may actually be harmed by the process. Most cases of cometabolism have been documented under aerobic conditions.

## 5.3 GEOCHEMICAL BEHAVIOR OF CHLORINATED PLUMES

Chlorinated hydrocarbon plumes have been documented to exhibit three types of "behavior" depending the nature and extent of contamination, available carbon, and the type of electron acceptors available.

Type 1 behavior describes a chlorinated solvent plume where the primary substrate is anthropogenic carbon such as BTEXs or landfill leachate. The biodegradation of the anthropogenic carbon source drives the reductive dechlorination of the solvent. This is a very efficient process for the dechlorination of the more highly chlorinated solvents such as PCE, TCE, and DCE. Although vinyl chloride can be reduced anaerobically into ethene and further to ethane, this process occurs much more slowly than PCE, TCE, and DCE dechlorination. Therefore, under strictly Type 1 behavior, vinyl chloride will tend to accumulate in the source area or along the downgradient edge of the plume.

Type 2 behavior describes a chlorinated solvent plume where the primary substrate is native organic carbon. The biodegradation of the native carbon source drives the reductive dechlorination of the solvent. This is very similar to Type 1 behavior but is not as efficient for the dechlorination of the more highly chlorinated solvents. As with Type 1 behavior, vinyl chloride will tend to accumulate in the source area or along the downgradient edge of the plume.

Type 3 behavior describes a chlorinated solvent plume where there is an inadequate source of either native or anthropogenic carbon to drive reductive dechlorination. In this case, the dissolved oxygen that is typically present in an aquifer is not utilized and the plume remains aerobic. Under Type 3 behavior, reductive dechlorination will not occur. However, under such aerobic conditions vinyl chloride can be rapidly oxidized directly to carbon dioxide, water, and chloride ions.

**5.4 STUDY RESULTS**

**5.4.1 Natural Attenuation Screening Matrix**

In accordance with the Draft USEPA Region 4 guidance (USEPA, 1997), the analytical data were evaluated quantitatively using a preliminary screening matrix to derive an interpretive score. The scores range in value from 0 to 32, assuming proof of daughter product generation is not possible. A maximum of 43 points is possible, assuming all potential daughter products are present and can be proven as degradation components. The following table presents the range of possible scores and provides an interpretation for each score.

Score	Interpretation
0 to 5	Inadequate evidence for biodegradation of chlorinated organics
6 to 14	Limited evidence for biodegradation of chlorinated organics
15 to 20	Adequate evidence for biodegradation of chlorinated organics
>20	Strong evidence for biodegradation of chlorinated organics

The Region 4 screening approach is very similar to that presented in the USEPA Technical Protocol for Evaluation Natural Attenuation of Chlorinated Solvents in Groundwater (USEPA, 1998). There are minor differences in the number of points awarded for methane, pH, ethene/ethane, and several daughter products. For SWMU 9, there is no significant difference in the outcome of the scoring between the two approaches.

In May 1998, during the initial screening evaluation, the site scored 21. In November 1998, the site scored 24. The November score of 24 was refined by the analyses of the dissolved gasses and includes the May results for BTEXs (collected prior to Hurricane Georges). The results are presented in Table 5-1. Scores greater than 20 indicate "strong" evidence for biodegradation of chlorinated organics.

**5.4.2 Degradation Pathways**

In May 1998, the well closest to the apparent source area (S9MW-15) contained TCE (350 µg/l), cis-1,2-DCE (1300 µg/L), and trans-1,2-DCE (4000 µg/L). The leading edge of the plume consisted solely of cis- and trans-1,2-DCE, with no TCE detected. At that time, TCE was assumed to be the original source of

chlorinated solvent at the site, and that it had degraded almost entirely to cis- and trans-1,2-DCE. Concentrations of cis- and trans-1,2-DCE decrease consistently in the downgradient direction to 146 µg/L and 22 µg/L total DCE in wells S9MW-21 and S9MW-22, respectively.

In November 1998, the apparent source area remained around S9MW-15 with detectable concentrations of cis-1,2-DCE (280 µg/L), and trans-1,2-DCE (820 µg/L). Again the leading edge of the plume consisted solely of cis- and trans-1,2-DCE, with no TCE detected. No TCE was detected in any of the SWMU9 wells. The decrease in contaminant levels is discussed further in Section 5.4.3.

A review of historical groundwater contaminant data indicates the possibility that two contaminant sources exist at SWMU 9. Many individual wells historically have had greater concentrations of trans-1,2-DCE than cis-1,2-DCE. This indicates that DCE was one of the source products at the site. In addition, TCE historically has been present in wells S9MW-15, S9MW-24, and S9MW-22. PCE has not been identified in any wells in the past. Therefore, it is likely that TCE also is a source product.

It appears that the groundwater plume at SWMU 9 is exhibiting mixed behavior (Type 1 and Type 2). BTEXs have been detected consistently in upgradient well S9MW-5, and historically in S9MW-2 and other site wells. Considering the general lack of dissolved oxygen across the site, and BTEXs recalcitrance to anaerobic degradation, one would have expected the BTEXs to have migrated downgradient over time. Since this is not the case, it is likely that the BTEXs is being used as the primary substrate, or co-substrate, to drive reductive dechlorination of the solvent (Type 1 behavior). However, there appears to be an insufficient supply of BTEXs to promote Type 1 behavior over a significant area of the plume. So, across the majority of the site, natural organic carbon is being used as the primary substrate to drive reductive dechlorination (Type 2 behavior). It is clear that methanogenesis and sulfate reduction are the reductive pathways active at the site. Carbon dioxide and sulfate are being used as electron acceptors, resulting in the generation of methane, sulfide, chloride, and carbon dioxide.

Both Type 1 and Type 2 behaviors are relatively efficient natural processes for the dechlorination of TCE and DCE. Although VC can be reduced anaerobically into ethene and further to ethane, this process occurs much more slowly than the dechlorination of TCE or DCE. Because of this one would expect VC to accumulate in the source area or along the downgradient edge of the plume at SWMU 9. VC can be mineralized (oxidized) into carbon dioxide, water, and chloride, under aerobic (Type 3) conditions. However, both the May and November 1998 analyses indicated the groundwater at SWMU 9 is generally anaerobic, which would prohibit VC oxidation. There is however minimal oxygen (<1.0mg/L) both upgradient and along the downgradient edge of the plume.

Several possibilities could explain the lack of VC accumulation at SWMU 9. It is most likely that natural attenuation at the site, is reducing TCE to DCE. Methanogenesis and sulfate reduction are the active anaerobic pathways of the natural attenuation, as evidenced by increased methane and sulfide ion concentrations across the site. It is generally understood that sulfate, present at such high natural concentration in the aquifer, would simultaneously compete with the hydrocarbon plume as an electron acceptor, resulting in competitive exclusion of dechlorination. This would greatly reduce the dechlorination process, resulting in the accumulation of DCE.

#### **5.4.3 Effect of Hurricane Georges**

During 1998, two independent rounds of groundwater samples were collected at SWMU 9. The initial sampling occurred May 1998. Sample analyses included VOCs and natural attenuation (NA) screening parameters. The May sampling identified VOCs in groundwater at concentrations significantly greater than had been encountered during previous sampling events. The NA screening parameters identified several potential bioremediation pathways. However, because such high VOC concentrations were not anticipated, the NA parameter suite had not been designed to provide a comprehensive evaluation of the site. Rather it had been designed to provide data to support long-term monitoring.

Because of the elevated VOC concentrations in May, a second round of groundwater samples was collected 6 months later, in November 1998. The intent of the second sampling was to confirm the May VOC results and provide additional geochemical data to support a comprehensive evaluation of NA.

The November sampling, however, contradicted the May sampling and indicated significantly reduced VOC concentrations. The November 1998 concentrations of VOCs were approximately one fifth the concentrations detected during May 1998. The marked difference in the concentrations of VOCs is most likely attributed to the September 25, 1998 Category 1 Hurricane (Georges) that passed directly over Key West. Although physical damage to the island was minimal, the hurricane resulted in a significant precipitation event. Rainfall during the hurricane was measured at 8 inches. As a result, the shallow surficial aquifer at SWMU 9 experienced significant amounts of precipitation, infiltration, and tidal fluctuation that that at least temporarily flushed the VOCs from the surficial aquifer.

This fluctuation in groundwater contaminant levels is not unusual following a significant precipitation event. Such natural anomalies as hurricanes have, in the past, permanently reduced soluble contaminant concentrations at other sites. However, because of the large paved apron over the source area, it is anticipated that in the future the contaminant levels will fully or partially return to those identified prior to the hurricane.

The conceptual model for this temporal fluctuation is as follows: during periods of low precipitation, surficial groundwater will naturally mound under the large paved portions of the site because of the lack of evaporation beneath the apron. The mounding results in seepage of contaminants out from under the apron. In addition, dispersion and dilution (flushing) of the aquifer as well as the hydraulic gradient are greatly reduced during such dry periods. Therefore, the partitioning (desorption) of VOCs from the soil/sediment matrix into the groundwater is enhanced. This causes a relatively stagnant groundwater plume which results in high apparent contaminant concentrations. Because of heavy or recent rain events, however, groundwater will frequently become depressed under a large paved apron. This is caused by the lack of natural infiltration through the apron, as well as the large infiltration line-source along the edge of the apron. In addition, dispersion and dilution of the aquifer, as well as the hydraulic gradient, are greatly enhanced during such wet periods. Therefore, the partitioning of VOCs from the soil/sediment matrix into the groundwater is reduced. This results in low apparent contaminant concentrations.

This scenario is similar to that observed during pump-and-treat remediation when contaminant concentrations rebound significantly after the pumping stops. The specific transport processes that generate this type of behavior include:

- diffusion of contaminants in low permeability sediments
- hydrodynamic isolation ('dead spots') within the plume
- desorption of contaminants from sediment surfaces
- liquid-liquid partitioning of immiscible contaminants

These hydrogeological processes are detailed in Performance Evaluations of Pump-and-Treat Remediations (EPA/540/4-89/005, October 1989).

The contaminant fluctuations identified between the two sampling events provide an excellent illustration of seasonal and temporal variations. In fact, these two sampling events more than likely reflect two extreme situations at the site, with the mean VOC concentrations of the plume falling somewhere between them.

Despite the significant flushing as a result of the hurricane, the dissolved gasses and geochemical parameters collected during the May and November samplings confirm the NA processes active at the site. The dissolved hydrogen data identified both methanogenic and sulfate reducing conditions within the groundwater plume. In addition, the decrease in DCE in the downgradient direction corresponds to increased CO<sub>2</sub> concentrations. That fact along with the presence of ethane and ethene in the area, supports natural attenuation of chlorinated hydrocarbons. The lines of evidence indicative of natural attenuation at SWMU 9 are:

- decrease in concentrations of original product
- increase in the occurrence of the daughter products
- depletion of dissolved oxygen and sulfate
- increased carbon dioxide, methane, ethane, ethene, and hydrogen

It is anticipated that the flushing because of the hurricane would equally diminish VOCs and NA parameters. Therefore, the presence of the dissolved gasses and geochemical parameters during the November sampling event provided confirming evidence of the NA processes active at the site.

#### 5.4.4 Modeling Results

The modeling results indicate that the predicted future maximum surface water concentrations for the four chemicals contaminants (cis-1,2-dichloroethene, trans-1,2-dichloroethene, trichloroethene, and benzene) are substantially below their surface water criteria: 11,600 µg/L, 1,350 µg/L, 81 µg/L, and 71 µg/L, respectively. Projected surface water concentrations in the small pond are: cis-1,2-DCE (131 µg/L), trans-1,2-DCE (373 µg/L), TCE (3 µg/L), and benzene (0.02 µg/L).

Based on the modeling results the sentry well was located 50 feet southeast of S9MW-22. An estimated 3.6 to 9 years will be required for the peak groundwater concentrations to move from the sentry well to the downgradient surface water pond. This time frame is sufficient to allow for responsive corrective action, if necessary, prior to any exceedence of surface water criteria.

#### 5.4.5 Conclusions

Based upon the past and current plume configuration, results of geochemical testing, and simple transport modeling, it is apparent that natural attenuation processes are occurring at the project site.

The recommendations in the Revision 0 Report (August 1998), resulted in the November natural attenuation sampling. That effort was designed to determine the exact natural attenuation processes at work in the SWMU 9 groundwater. To determine the processes at work, additional groundwater screening samples were collected in September 1998 to locate the downgradient edge of the chlorinated solvent plume. Further, groundwater modeling confirmed that the plume is not a threat to the downgradient lagoon and located a sentry well between the plume and the lagoon. In November 1998, a mobile laboratory performed onsite analyses of natural attenuation parameters, specifically dissolved gasses, as part of the groundwater evaluation. The evaluation also included another round of groundwater analyses for VOCs.

The chlorinated groundwater plumes at SWMU 9 are exhibiting mixed behavior (Type 1 and Type 2). In the vicinity of S9MW-5 BTEXs is being used as the primary substrate, or co-substrate, to drive reductive dechlorination of the solvent mass (Type 1 behavior). For the remainder of the site, natural organic carbon is being used as the primary substrate to drive reductive dechlorination (Type 2 behavior). Methanogenesis and sulfate reduction are the most active reductive pathways at the site. Carbon dioxide and sulfate are being used as electron acceptors, resulting in the generation of methane, sulfide, chloride, and carbon dioxide. The apparent source materials, TCE and DCE have been degraded to cis-1,2-DCE and trans-1,2-DCE. These DCE isomers are undergoing degradation although the rate of reduction is slow. Sulfate is present at high natural concentrations in the aquifer and may be competing with the DCE as an electron acceptor. Competitive exclusion of dechlorination is not occurring as previously believed. Although it may be reducing the overall efficiency of DCE dechlorination, it has not stopped the process, as evidenced by the concentration of ethane, ethene, and minimal downgradient migration over the years.

#### 5.4.6 Recommendations

The effort put forth since the issuance of the Revision 0 Report (August 1998) answered a number of open questions regarding the natural attenuation processes at SWMU 9. It is based on the conclusions of these efforts that the following recommendations are made.

In accordance with the 1995 NAS Key West RCRA Part B Permit, a Corrective Measures Study (CMS) is required for SWMU 9. Given the small size of the site and the numerous studies that has been performed, it is recommended that the CMS focus on no more than four activities for the site. Those activities include no action, long-term monitoring for VOCs, monitored natural attenuation (includes VOCs and attenuation parameters), and enhanced in-situ bioremediation technologies. Each activity, except the no action, will likely include some form of land-use controls. The information in this report will support the evaluation of each of these activities under taken by the SWMU 9 focused CMS.

TABLE 5-1

ANALYTICAL PARAMETERS AND WEIGHTING FOR  
PRELIMINARY NATURAL ATTENUATION SCREENING  
(PAGE 1 OF 2)

Analyte	Units	Contaminated Zone Concentration	SWMU 9* Concentration	Available Points	Site Points	Interpretation
Dissolved Oxygen	mg/L	<0.5	0	3	0	Tolerated; suppresses reductive dechlorination at higher concentrations
	mg/L	>1	0	-3	0	Vinyl chloride may be oxidized aerobically, but reductive dechlorination will not occur
Nitrate	mg/L	<1	0	2	2	May compete with reductive pathway at higher concentrations
Ferrous Iron (Fe2+)	mg/L	>1	0	3	0	Reductive pathway possible
Sulfate	mg/L	<20	1,060	2	0	May compete with reductive pathway at higher concentrations
Sulfide	mg/L	>1	>5	3	3	Reductive pathway possible
Methane	mg/L	>0.1	3.245	2	0	Ultimate reductive daughter product
	mg/L	>1	3.245	3	3	Vinyl chloride accumulates
	mg/L	<1	3.245	0	0	Vinyl chloride oxidizes
ORP (Eh)	mV	<50	-320	1	0	Reductive pathway possible
	mV	<-100	-320	2	2	Reductive pathway possible
pH	units	5<pH<9	7.4	-	-	Tolerated range for reductive pathway
DOC	mg/L	>20	24	2	2	Carbon and energy source; drives dechlorination; can be natural or anthropogenic
Temperature	deg-C	>20	31.6	1	1	At T> 20 C, biochemical process is accelerated
Carbon Dioxide	mg/L	>2x BG	159/18.7	1	1	Ultimate oxidative daughter product
Alkalinity	mg/L	>2x BG	535/185(AIk.)	1	1	Results from interaction of carbon dioxide with aquifer minerals
Chloride	mg/L	>2x BG	5,920/665	2	2	Daughter product of organic chlorine; compare chloride in plume to background conditions
Hydrogen	nM	>1	8.20	3	3	Reductive pathway possible; vinyl chloride may accumulate
	nM	<1	8.20	0	0	Vinyl chloride oxidized
Volatile Fatty Acids	mg/L	>0.1	Na	2	Na	Intermediates resulting from biodegradation of aromatic compounds; carbon and energy source
BTEX	mg/L	>0.1	3.25	2	2	Carbon and energy source; drives dechlorination
Perchloroethene	mg/L	-	0	-	-	Material released

TABLE 5-1

**ANALYTICAL PARAMETERS AND WEIGHTING FOR  
PRELIMINARY NATURAL ATTENUATION SCREENING  
(PAGE 2 OF 2)**

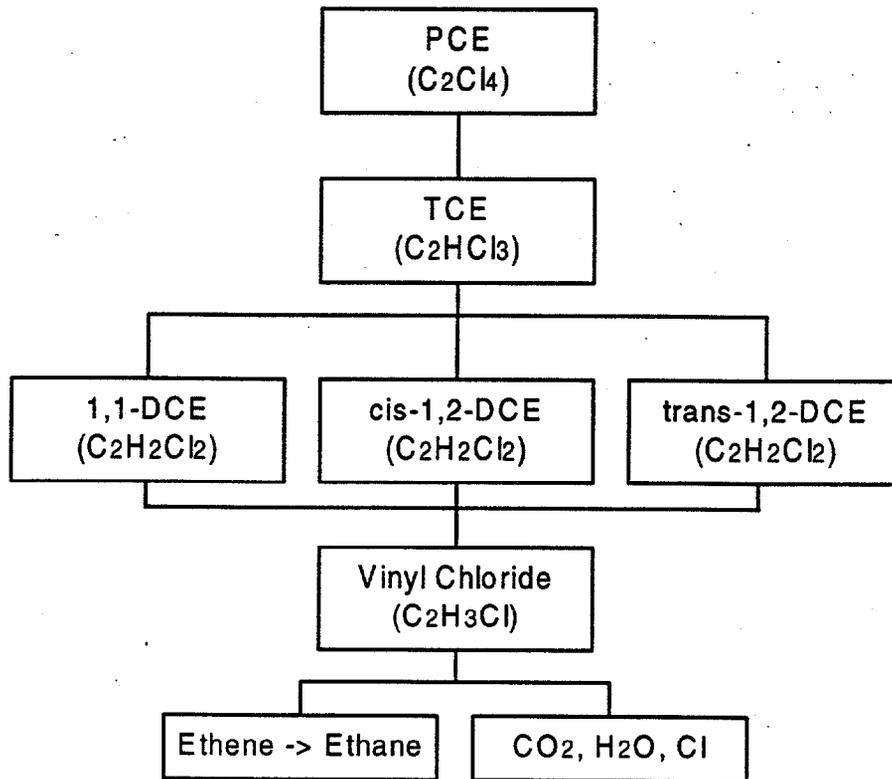
Analyte	Units	Contaminated Zone Concentration	SWMU 9* Concentration	Available Points	Site Points	Interpretation
Trichloroethene	mg/L	–	0.0	2 (b)	0	Material released or daughter product of perchloroethene
Dichloroethene	mg/L	–	1.1	2 (b)	2	Material released or daughter product of trichloroethene
Vinyl Chloride	mg/L	–	0	2 (b)	0	Material released or daughter product of dichloroethenes
Ethene/Ethane	mg/L	>0.01	6.7E-7	2	0	Daughter product of vinyl chloride/ethene
Ethene/Ethane	mg/L	>0.1	6.7E-7	3	0	Daughter product of vinyl chloride/ethene
Chloroethane	mg/L	–	0	2 (b)	0	Daughter product of vinyl chloride under reducing conditions
1,1,1-trichloroethane	mg/L	–	0	–	–	Material released
1,1-dichloroethene	mg/L	–	0	–	–	Daughter product of TCE or chemical reaction of 1,1,1-trichloroethane
Total Score				43	24	

Reference: Draft Region IV Approach to Natural Attenuation of Chlorinated Solvents

\*Value may be an average of two or more numbers or a maximum detection.

(b) – Points awarded only if it can be shown that the compound is a daughter product.

Figure 5-1. Flow Diagram



## 6.0 REFERENCES

ABB (ABB Environmental Services, Inc.), 1994, *Contamination Assessment Report Jet Engine Test Cell, Building A969*, prepared for SOUTHNAVFACENGCOM. Tallahassee, Florida.

ABB (ABB Environmental Services, Inc.), 1995a, *Facility and Remedial Investigation NAS Key West, Workplan*, Volume 1, prepared for SOUTHNAVFACENGCOM. Tampa, Florida, December.

ABB (ABB Environmental Services, Inc.), 1995b, *Facility and Remedial Investigation NAS Key West, Workplan*, Volume 1 and *Sampling and Analysis Plan*, Volume 2, prepared for SOUTHNAVFACENGCOM. Tampa, Florida, June.

AFCEE (Air Force Center for Environmental Excellence), 1996, *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater*, Draft – Revision 1. San Antonio, Texas, November.

BEI (Bechtel Environmental, Inc.), 1995a, *Technical Memorandum: Groundwater Evaluation, Jet Engine Test Cell*, NAS Key West, Florida.

BEI (Bechtel Environmental, Inc.), 1995b, *Delineation Sampling Report for SWMU 1, SWMU 2, SWMU 3, SWMU 7, AOC-A, AOC-B, IR-1, and IR-2 at the Naval Air Station Key West, Florida*, prepared for SOUTHNAVFACENGCOM. Oak Ridge, Tennessee.

B&R Environmental (Brown & Root Environmental), 1997, *Supplemental RCRA Facility Investigation and Remedial Investigation Report for NAS Key West High-Priority Sites Boca Chica Key, Florida*, prepared for SOUTHNAVFACENGCOM. Aiken, South Carolina, Revision 2, July 1997.

McCarty, P.L., and Semprini, L., 1994, "Ground-Water Treatment for Chlorinated Solvents" In: *Handbook of Bioremediation*. Lewis Publishers, Boca Raton, Florida.

Murray, W.D. and Richardson, M., 1993, "Progress toward the biological treatment of C<sub>1</sub> and C<sub>2</sub> halogenated hydrocarbons." *Critical Reviews in Environmental Science and Technology*, 23(3):195-217.

TtNUS (Tetra Tech NUS), 1998, *Technical Memorandum for Sampling and Analysis Plan Addendum Supplemental RCRA Facility Investigation/Remedial Investigation for NAS Key West Boca Chica Key, Florida*, Revision 1, Appendix A, prepared for SOUTHNAVFACENGCOM. Aiken, South Carolina, May.

United States Department of the Navy, 1998, Technical Guidelines for Evaluating Monitored Natural Attenuation of Petroleum Hydrocarbon and Chlorinated Solvents in Ground Water at Naval and Marine Corps Facilities, September 1998.

USEPA (United States Environmental Protection Agency), 1997, *Draft EPA Region 4 Suggested Practices for Evaluation of a Site For Natural Attenuation (Biological Degradation) of Chlorinated Solvents, Version 3.0*, November 1997.

USEPA, 1998, Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water, EPA/600/R-98/128, September 1998.

**APPENDIX A**

**SWMU 9 ADDITIONAL WELL (S9MW-25) BORING LOG  
AND CONSTRUCTION DIAGRAM**

**BROWN and ROOT  
ENVIRONMENTAL**

FIELD LOG OF BORING

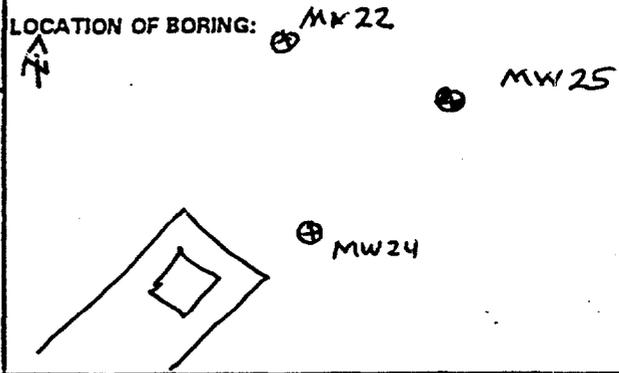
WELL NO. S9MW25

SHEET 1 OF 2

PROJECT: <u>NAS Key West SWMU 9</u>	JOB NO.: <u>N7046</u>	BORING NO.: <u>S9MW25</u>
	LOGGED BY: <u>A. Kendrick</u>	TOTAL DEPTH: <u>13.0' BES</u>

DRILLING CONTRACTOR: <u>Precision</u>	SURFACE ELEV.: _____	DATUM: _____
DRILLER'S NAME: _____	START TIME: <u>11:30</u>	DATE: <u>11/17/98</u>
DRILL RIG TYPE: <u>CME-75</u>	FINISH TIME: <u>13:00</u>	DATE: <u>11/17/98</u>
BORING METHOD: <u>4 1/4" Hollow Stem Auger</u>	WATER DEPTH: _____	
HOLE DIAMETER: <u>~ 8"</u>	DATE: _____	
SAMPLING METHOD: <u>None</u>	TIME: _____	
HAMMER WGT.: <u>NA</u>	DROP HGT: <u>NA</u>	BACKFILLED, TIME: <u>NA</u> DATE: <u>NA</u>

CONDITIONS: 86° - Pt. Cldy.  
Hand auger to 3.5' - Stop at Cap Rock



SAMPLE DEPTH	SAMPLE TYPE	BLOWS / 6-INCHES	INCHES DRIVEN	INCHES RECOVERED	OVA READING (ppm)	LAB SAMPLE	DEPTH IN FEET	LITHOLOGY
0					NA	NA		SP Loose Overburden. (Hand Auger) - Sand & gravel - Calcareous - Minor surface vegetation
1					↓	↓		
2								
3							<u>3.5</u>	Ls Cap Rock - Calcareous, oolitic Limestone. - White to tan. No samples collected. Auger from 3.5 to 13.0'.  Install 2" PVC well from 2'-12' BES. See mon. well completion form.
4								
5								
6								
7								
8								
9								
10								

NOTES: Boring Connected to Mon. Well S9MW25 EDITED BY/DATE: \_\_\_\_\_

**BROWN and ROOT  
ENVIRONMENTAL**

FIELD LOG OF BORING

WELL NO. S9 MW 25

SHEET 2 OF 2

PROJECT: <u>NAS Key West SWMU 9</u>	JOB NO.: <u>N7046</u>	BORING NO.:
	LOGGED BY: <u>A. Kendrick</u>	TOTAL DEPTH:

DRILLING CONTRACTOR: <u>Precision Drilling</u>	SURFACE ELEV.:	DATUM:
DRILLER'S NAME:	START. TIME: <u>11:30</u>	DATE: <u>11/17/98</u>
DRILL RIG TYPE: <u>CME-75</u>	FINISH. TIME: <u>13:00</u>	DATE: <u>11/17/98</u>
BORING METHOD: <u>4 1/4" HSA</u>	WATER DEPTH:	
HOLE DIAMETER: <u>2 8"</u>	DATE:	
SAMPLING METHOD: <u>None</u>	TIME:	
HAMMER WGT.: <u>NA</u>	DROP HGT: <u>NA</u>	BACKFILLED, TIME: <u>NA</u> DATE: <u>NA</u>

CONDITIONS: 86° - Pit. cldy

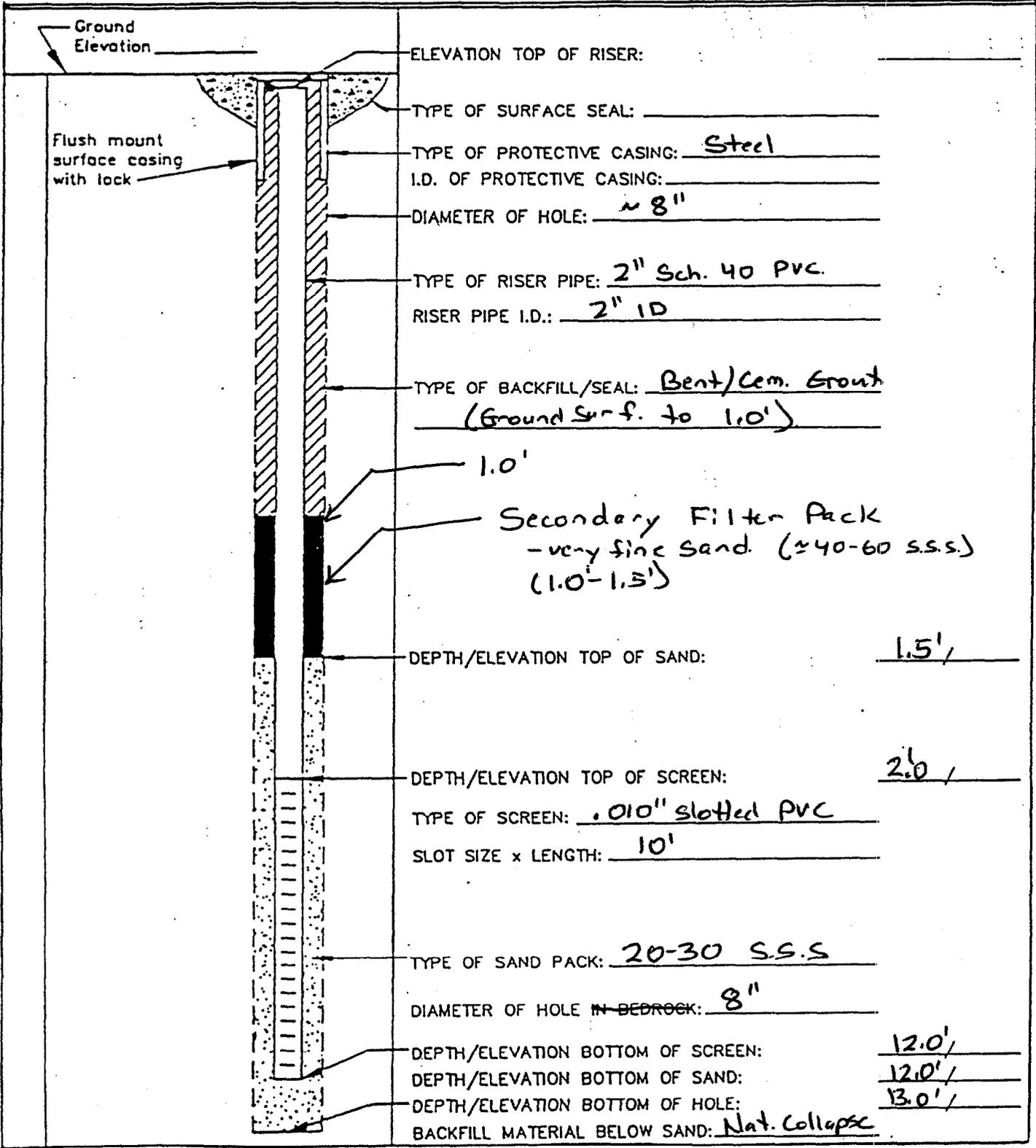
LOCATION OF BORING:  
See Pg. 1.

SAMPLE DEPTH	SAMPLE TYPE	BLOWS / 6-INCHES	INCHES DRIVEN	INCHES RECOVERED	OVA READING (ppm)	LAB SAMPLE	DEPTH IN FEET	LITHOLOGY	
10					<u>NA</u>	<u>None</u>		<u>Limestone, Oolitic. No samples collected.</u>	
11					↓	↓			
12									
13							<u>130</u>		
14									
15									
16									
17									
18									
19									
20									
									<u>End of Boring at 130'.</u>
									<u>Natural Collapse to 12.0.</u>
								<u>Install well from 2'-12'.</u>	



# MONITORING WELL SHEET

PROJECT <u>NAS Key West</u>	LOCATION <u>SWMU 9</u>	DRILLER <u>Precision Drilling</u>
PROJECT NO. <u>N7046</u>	BORING <u>59MW25</u>	DRILLING METHOD <u>Hollow Stem Auger</u>
ELEVATION _____	DATE <u>11/17/98</u>	DEVELOPMENT METHOD <u>Pump &amp; Surge</u>
FIELD GEOLOGIST <u>A. Kendrick</u>		





**APPENDIX B**

**SWMU 9 GROUNDWATER MODELING REPORT**

## B.1.0 INTRODUCTION

### B.1.1 PURPOSE AND SCOPE

The following sections present technical discussions and results of groundwater modeling at SWMU 9 for the Naval Air Station (NAS), Key West, Florida. SWMU 9, the Jet Engine Test Cell site associated with Building A-969, is located in the northeastern portion of the Boca Chica Airfield (Figure B-1).

A groundwater pump and treat system was installed in 1996 and operated for one year to remove solvent contamination. Subsequently, an additional study was conducted in May 1998 to identify the natural attenuation processes that exist at the site and to determine if they are sufficient to be protective of the onsite lagoon. As indicated in the Natural Attenuation Study report, natural attenuation processes appear to be occurring at the project site and may be used to facilitate more active forms of groundwater remediation. This modeling has been conducted to support the final remedial alternative of monitored site-wide natural attenuation.

The modeling work performed consists of the following two tasks:

- TASK 1 – Calculation of the surface water concentrations at the exposure point by natural attenuation processes under the most recent conditions.
- TASK 2 – Determination of the location of the new shallow monitoring well (sentry well).

Task 1 is to determine whether surface water quality criteria at the selected downgradient exposure point will be exceeded in the future assuming groundwater remediation solely due to the natural attenuation processes. For Task 1, the exposure point is a single point downgradient of the source along the centerline of the plume where the groundwater enters the small surface water pond located approximately 50 feet northeast of groundwater screening sample SWMU9-GS-02. Groundwater travels to and discharges to the small surface water pond prior to further discharging to the lagoons. Acceptable surface water criteria were chosen as the most restrictive ARAR/SAL criteria. Four chemicals (cis-1,2 dichloroethene, trans-1,2 dichloroethene, trichloroethene, and benzene) were selected for modeling because these chemicals exceed the groundwater action levels based on 1998 groundwater sampling data.

The computations considered natural processes affecting contaminant fate and transport in groundwater. Naturally occurring mechanisms will reduce contaminant concentrations in groundwater over time. The mechanisms/processes affecting chemical fate and transport in groundwater that were accounted for during the modeling include sorption, dilution, advection, dispersion, and chemical/biological decay.

Source area groundwater contaminant levels have been reduced substantially by the groundwater pump and treat operations, in addition, infiltration of rainfall into the aquifer will flush the aquifer with clean water.

Task 2 was to determine the optimal location of the new sentry well for inclusion in a long-term monitoring well network. The new sentry well was installed to serve two purposes: (1) provide a more detailed description of the plume configuration along with the actual location of the leading edge of the plume, and (2) provide an additional downgradient geochemical monitoring point. The new sentry well can be used as a guard so as to allow a reasonable amount of time to respond to a projected exceedence of surface water criteria at the downgradient pond, if any.

The groundwater fate and transport modeling was accomplished through the use of a combined groundwater flow/contaminant fate and transport model.

### **B.1.2 REPORT ORGANIZATION**

This appendix has been divided into four discrete sections. In addition to the introduction (Section B.1.0), Section B.2.0 presents the technical approach used for the groundwater fate and transport modeling. Section B.3.0 provides the input data used for the modeling. Section B.4.0 presents modeling results for SWMU 9.

## **B.2.0 GROUNDWATER FATE AND TRANSPORT MODELING DEVELOPMENT**

The technical approach used to develop the groundwater fate and transport modeling is described in the following subsections. The first subsection describes the analytical groundwater contaminant fate and transport model used for the task. The second subsection briefly describes the geology, hydrogeology, the pattern of contaminant releases, and the associated simplifying assumptions.

### **B.2.1. GROUNDWATER MODEL TOOL**

The groundwater modeling was performed using the ECTran model (Chiou, et al., 1993). The ECTran (Excel-Crystal Ball Transport) model is an analytical contaminant fate and transport model, and is a multi-layer one-dimensional model based on straightforward mass-balances and advection/dispersion analytical equations.

The groundwater model is implemented on the spreadsheet software Excel 4.0 and Crystal Ball 3. The ECTran model can be used to simulate a variety of complex conditions. To date, ECTran and its predecessors have been employed at hazardous waste sites in U.S. EPA Regions III, IV, V, VI, and X to evaluate soil cleanup goals, cleanup time estimations, and to support baseline risk assessments. It has been approved for use at DOD, DOE, and industrial sites for both RCRA and CERCLA applications.

The ECTran model simulates vertical contaminant transport with uniform (thickness, concentration, porosity, etc.) layers. The model predicts the contaminant concentration downgradient of the source at a single point at a specified distance from the exposure point. This predicted concentration is at the centerline of the contaminant plume.

### **B.2.2 CONCEPTUAL MODEL**

A description of the conceptualization of the natural processes that govern groundwater flow and contaminant transport at the site is provided in this subsection. Section B.2.2.1 briefly describes the geology and hydrogeology at SWMU 9. Section B.2.2.2 provides the site conceptual model. Sections B.2.2.3 and B.2.2.4 provide modeling procedures and assumptions.

The following subsections provide only a summary of the physical characteristics of the site relevant to the modeling task. Additional details concerning the physical characteristics of the site can be found in Section 3.0 of the Supplemental RFI/RI Report (B&RE 1997).

The site is bordered to the south by an asphalt road that parallels a runway and to the east and west by grassy areas. The entire area is flat open, and covered with grass where it is not paved. An inlet of Florida Bay is located north of the site, approximately 250 feet from the former location of the canopy. Beginning in 1969, the site was used for the testing of recently repaired jet engines. No other activities have been conducted near the site.

#### **B.2.2.1 Site Physical Characteristics**

##### **Geology and Soils**

The site-specific geology and hydrogeology of the unit were determined from soil borings and from monitoring wells installed during the contamination assessment study, the groundwater evaluation study, and the Supplemental RFI/RI. Based on the soil borings results, oolitic limestone was encountered at the surface and was present to the termination of the borings at 13 feet below land surface (bls). The limestone was consistent in all borings, and no lateral or horizontal variations were apparent. According to ABB, the Miami Oolite is 27 feet thick (ABB 1995).

The soils on Boca Chica Key are primarily rockland with some filled areas and mangrove swamps. Other major soil groups on Boca Chica Key are Uthorthents, which consist of gravely sand and marl, and Cudjoe, which consists of marl and weathered bedrock (ABB, 1995). The limestone was well consolidated with abundant shell fragments and medium- to fine-grain sand in the limestone matrix. The Standard Penetration Test (SPT) blow count indicated that the limestone is of medium to high density.

##### **Hydrogeology**

The hydrogeologic unit associated with the oolitic limestone is the surficial aquifer. Depth to groundwater was reported to be approximately 1 to 3 feet bls. High specific conductivity values can be expected for groundwater at the site due to the salt water inlet to the north. Recharge to the aquifer is directly through rainfall. Groundwater elevation data collected during previous studies indicated a predominantly northern groundwater flow direction, with some tidal influence. Tidal fluctuations decrease from 0.5 feet at the inlet to 0.2 feet closer to the monitoring well S9MW10. Groundwater elevations measured on May 1998, were consistent with those recorded during previous investigations. Groundwater flow is in a north-northeast direction toward the lagoon based on the 1998 groundwater contour map (see Figure B-2).

Pumping tests and slug tests were previously conducted at some existing monitoring wells at SWMU 9 to estimate hydraulic conductivity (K). The results based only on pump tests are summarized in Table B-2.

The average aquifer transmissivity value reported from pumping tests is approximately  $9.4 \times 10^{-2}$  feet<sup>2</sup>/minute (or 134.8 feet<sup>2</sup>/day) (BEI, 1995). K values are estimated by dividing the transmissivity by the thickness of the surficial aquifer, which is assumed to be 27 feet based on historical data. A more representative geometrical mean K value was used for modeling. The geometric mean K value from all the surficial wells is 4.62 feet/day (ft/day). The seepage velocity (the rate at which groundwater moves through the aquifer) is estimated at 5.26 feet per year (ft/yr). This seepage velocity was calculated using a geometric mean K value (4.62 ft/day), a hydraulic gradient of 0.0016 ft/ft, and an effective porosity of 0.3.

#### **B.2.2.2 Site Conceptual Model**

Rainwater which falls on the site transports contaminants through runoff and/or by infiltrating into the soil. Runoff can transport contaminants from the surface soils being eroded by the runoff. This pathway is not considered to be significant for the site. A portion of the rainwater that falls on the site reaches the groundwater by directly infiltrating into the soil. As the water infiltrates through the contaminated soil, contaminants leach out of the soil and are transported with the water through the unsaturated zone to the shallow groundwater below. The contaminants can then be transported laterally with the groundwater and eventually enter the surface water body.

In this study, upgradient groundwater flow is assumed to be clean (i.e., zero concentration). Upgradient flow will combine with infiltrated water and carry dissolved contaminants in the groundwater to the groundwater discharging point. Dissolved contaminants migrate through the groundwater at a slower velocity than the velocity of the groundwater. The amount of retardation is chemical-specific. Dilution and dispersion processes reduce concentrations as contaminants move through the groundwater regime. Also, the contaminant may decay in the environment by biological and/or chemical processes. Therefore, as contaminants migrate through the groundwater, they may decay and their concentrations decrease.

Figure B-3 presents the site conceptual model. Conceptually, the groundwater contaminant migration pathway consists of an unsaturated zone and an unconfined aquifer. The shallow aquifer consists of the entire thickness of the oolitic limestone, based on geology and hydrogeology of the site. The layer conceptualization is reasonable since the primary route for contaminant migration in groundwater from SWMU 9 would be through the surficial aquifer. At SWMU 9, the typical depth to groundwater is estimated to be approximately 2 feet, which is determined as the thickness of the unsaturated zone. The modeled thickness of the saturated layer includes the entire surficial aquifer system, and is selected to be 27 feet. The general groundwater flow direction in the surficial aquifer is to the north-northeast toward the

onsite lagoons (Figure B-2). Groundwater can travel both horizontally and vertically within the saturated zone.

### **B.2.2.3 Groundwater Modeling Assumptions**

#### **Modeling Assumptions**

##### **Source Area**

The source area layout was selected based on the locations at which contaminants were detected. The source area is designated as a rectangular area with length parallel to groundwater flow direction, and width perpendicular to the flow direction.

##### **Layer Simulated in the Model**

The uppermost layer simulated in the ECTran model is the unsaturated zone. The bottommost layer simulated in the ECTran model is the shallow unconfined surficial aquifer (saturated zone). Using a single layer to represent the saturated zone is reasonable since the vertical extent of the plume was only encountered within the surficial aquifer.

##### **Initial Soil Concentration**

The initial soil concentrations under the source area were assumed to be the maximum detected concentrations in the historical soil samples.

##### **Modeling Time Frame**

The contaminant simulations were continued until the concentration at the exposure point peaked, then gradually dropped off in the aquifer by natural attenuation processes.

##### **Chemical Fate and Transport**

Several mechanisms/processes affecting chemical fate and transport in groundwater were accounted for during the groundwater modeling. They include sorption, dilution, advection, dispersion, and chemical/biological decay. Sorption is the reaction that occurs between the solute and the surfaces of solids causing the solute to bond by varying degrees to the surface. Dilution occurs because of the mixing of contaminated groundwater with unaffected groundwater. Advection is the primary mechanism responsible for the movement of contaminants as a consequence of groundwater flow. Dispersion occurs

because of fluid mixing due to effects of heterogeneities in the permeability distribution. Decay involves the degradation of a chemical by natural chemical and biological processes.

#### **B.2.2.4 Groundwater to Surface Water Assumptions**

For the purpose of concentration comparison in the same medium (i.e., surface water criteria against surface water concentrations), the predicted surface water concentrations at the small pond must be derived from the predicted groundwater concentrations developed by the modeling with ECTran. The following presents the theory of converting the groundwater concentration at the surface water/groundwater interface at the edge of the pond to a surface water concentration. First, the following equation is used to calculate the chemical mass flux in the groundwater at the groundwater/surface water interface.

$$Q_c = \frac{V_{GW} A C_g}{R_d} \quad (1)$$

where:

$Q_c$  = Chemical flux (mass/time)

$V_{GW}$  = Groundwater velocity (length/time)

$C_g$  = Chemical concentration in the groundwater (mass/length<sup>3</sup>) (Predicted with the ECTran model)

$A$  = Cross sectional area of the mass flow (length<sup>2</sup>)

and  $R_d$  is chemical specific retardation factor given by:

$$R_d = 1 + \frac{\rho_b}{n} K_d \quad (2)$$

where:

$R_d$  = Chemical specific retardation factor (dimensionless)

$\rho_b$  = Dry bulk density of soil (mass/length<sup>3</sup>)

$n$  = Porosity (dimensionless)

$K_d$  = Soil / water partitioning coefficient (length<sup>3</sup>/mass)

Second, the total flow of groundwater is given by the groundwater velocity multiplied by the cross sectional area of the groundwater flow. The surface water concentration (or the seep concentration) ( $C_s$ ) is then equal to:

$$C_s = \frac{Q_c}{V_{GW} A} \quad (3)$$

After replacing  $Q_c$  in Equation (3) by Equation (1), the groundwater velocity and the area cancel out so that the surface water concentration  $C_s$  is the groundwater concentration  $C_g$  divided by the retardation factor.

$$C_s = \frac{C_g}{R_d} \quad (4)$$

Equation (4) was used to calculate the surface water concentration based on the modeled groundwater concentration at the groundwater/surface water interface.

## B.3.0 INPUT DATA FOR MODELING

### B.3.1. CHEMICAL INPUT PARAMETERS

The primary chemical input parameters include the initial contaminant concentrations, the soil/water partitioning coefficient ( $K_d$ ), the exposure criteria, and chemical and biological decay half-lives. The chemical input parameters used in the modeling were obtained from the Supplemental RFI/RI report (B&R, 1997) and the Natural Attenuation Study report (TtNUS, 1998).

#### Modeled Chemical and Initial Soil and Groundwater Concentrations

Four chemicals were modeled since they exceed the groundwater action levels. These chemicals are: cis-1,2 dichloroethene (cis-1,2 DCE), trans-1,2 dichloroethene (trans-1,2 DCE), benzene, and trichloroethene (TCE). At SWMU 9, the current maximum detected groundwater concentrations in the source area include cis-1,2 DCE (1,300 µg/L), trans-1,2 DCE (4,000 µg/L), benzene (25 µg/L), and TCE (350 µg/L). Of the four modeled chemicals, only trans-1,2-DCE has detected soil concentrations (maximum detected soil concentration of 10 ug/kg) in the source area.

#### Site-Specific Soil/Water Partitioning Coefficient

Chemical-specific soil/water partitioning coefficients ( $K_d$ s) were used to estimate each chemical's mobility. A chemical's  $K_d$  value is the ratio of its concentration in soil (or sediment) to its concentration in water when the two concentrations are in equilibrium. A high  $K_d$  value would be representative of a chemical which has a tendency to bind to the soil and is therefore less mobile in water. Depending on the chemical form of a certain contaminant (specifically for inorganics), the  $K_d$  value can vary substantially. The site-specific  $K_d$  values used in this evaluation were calculated based on the procedures proposed in the SSL Guidance Document (EPA 1996).

The  $K_d$  values for organic constituents are typically calculated by multiplying the  $K_{oc}$  value (soil organic carbon/water partition coefficient) by the  $f_{oc}$  (fraction of organic carbon) (EPA, 1988, "Superfund Exposure Assessment Manual," EPA/540/1-88/001). The source of  $K_{oc}$  values applied was the U.S. EPA document "Manual- Groundwater and Leachate Treatment Systems" (EPA/625/R-94/005). Both  $f_{oc}$  values associated with site soil and site aquifer materials were considered. The site-specific  $f_{oc}$  values used in this evaluation were obtained from the Natural Attenuation Study report (Table 4-1, TtNUS, 1998). The more natural organic carbon present in the aquifer materials, the higher the adsorption of organic

constituents within the aquifer matrix. As indicated in Table 4-1 of the Natural Attenuation Study report, Total Organic Carbon (TOC) concentrations range from 2.6 mg/L in S9MW17 (upgradient) to 24 mg/L in S9MW24 and 28 mg/L in S9MW10. The  $F_{OC}$  value for groundwater was determined based on the following two reasons: First, the TOC concentrations obtained from the Natural Attenuation Study field activity has shown that the native organic carbon is present at sufficient concentrations in the aquifer, because organic carbon concentrations greater than 20 mg/L in the aquifer indicate a sufficient supply of carbon to act as the primary substrate. Second, a  $F_{OC}$  value of 0.001 or 0.1% is the lowest acceptable value that can be used in the  $K_d = K_{oc} * F_{OC}$  model for calculating the  $K_d$  values (EPA, 1988). Note that the selected  $F_{OC}$  value of 0.001 or 0.1% is conservative since it is lower than the default  $F_{OC}$  value of 0.002 or 0.2 % suggested by EPA. The following equation was used to compute  $K_d$  values:

$$K_d = K_{oc} * f_{oc} \quad (5)$$

where:

$f_{oc}$  = fraction of organic carbon

$K_{oc}$  = soil organic carbon/water partitioning coefficient

The  $K_d$  values and the data used to derive the values are presented in Table B-3.

### **Half-life Decay Constants**

Decay of organic contaminants can occur by biological and non-biological mechanisms. This decay is quantified by chemical-specific half-life. To be conservative for the groundwater modeling, the longest reported half-life was selected from the literature source (Howard 1991). Table B-3 presents the half-life decay constants used in the modeling.

### **Exposure Criteria**

The surface water criteria were used as the exposure criteria for the groundwater fate and transport modeling. The acceptable surface water criteria chosen were the most restrictive ARAR/SAL criteria. The surface water criteria for cis-1,2 DCE, trans-1,2 DCE, benzene, and TCE are selected as 11,600, 1,350, 71, and 81 µg/L respectively.

### **B.3.2 PHYSICAL INPUT PARAMETERS AT SWMU 9**

The groundwater physical input parameters are described in the next two subsections.

### **B.3.2.1 Surface Water Infiltration Rates:**

Infiltration rates in the source area are estimated to be one-quarter of the annual precipitation (infiltration rates =10 inches per year) because the surface area of the unit is non-paved. An average of 35 to 40 inches of rainfall per year was reported in the Supplemental RFI/RI report for the area of Key West, Florida (B&R, 1997).

### **B.3.2.2 Groundwater Physical Input Parameters at SWMU 9**

Layer Thickness: As described in the Conceptual Model section, the typical thickness of the unsaturated zone was assumed to be 2 feet. The saturated zone was assumed to be 27 feet thick based on the geologic descriptions of the unit (Section B.2.2.1). Table B-4 presents a summary of physical and geologic parameters used for modeling.

Source Area Size: It is assumed that the source area for each contaminant corresponds to a rectangular area. Each contaminant source area size was determined based on the locations at which groundwater contaminants were detected. Figure B-4 and Table B-4 present the source area sizes based on the reported 1998 groundwater concentrations in the surficial aquifer.

Exposure Point: The exposure point for the groundwater modeling was at a point downgradient of the source area where groundwater discharges into a small surface water pond, located approximately 50 feet northeast of screening sample SWMU9-GS-02. Groundwater discharges into the pond and the onsite lagoons further north. The distance to this exposure point is measured along the groundwater flow path direction (Figures B-4 and Table B-4).

Hydraulic Conductivity (K): The K value was determined from the pumping tests for the wells in the surficial aquifer. The surficial aquifer has an estimated K ranging from 3.33 to 9.43 ft/day. A geometric mean K value of 4.62 ft/day was selected for modeling (Table B-2).

Gradient: The gradient was calculated to be 0.0016 (B&R, 1997). The hydraulic gradient,  $i$  was calculated based on the groundwater table elevations measured from the 1996 field event, as presented on Figure 2-3 of SMWU 9 Natural Attenuation Report (February 1996). The hydraulic gradient were formulated as follows:

$$\text{Hydraulic gradient } i = [(\text{groundwater elevation at well S9MW6} - \text{groundwater elevation at well S9MW14}) / \text{distance between these two wells}] = (3.62 \text{ feet} - 3.46 \text{ feet}) / 100 \text{ ft} = 0.0016 \text{ ft/ft}$$

Effective Porosity: An effective porosity of 0.3 was incorporated from the Supplemental RFI/RI report.

Seepage Velocity: The seepage velocity is calculated with the following equation.

$$V_{seep} = \frac{KI}{\text{effective porosity}} \quad (6)$$

Where: K = hydraulic conductivity (4.62 ft/day)  
I = gradient (0.0016)  
Effective porosity = 0.3

The seepage velocity is thus estimated to be 8.99 ft/yr.

## B.4.0 RESULTS

The results of the groundwater modeling at SWMU 9 are discussed in the following two subsections.

### B.4.1 GROUNDWATER MODELING RESULTS

Groundwater modeling results for the four chemicals (cis-1,2 DCE, trans-1,2 DCE, benzene, and TCE) under the current conditions are presented in Table B-1.

As summarized in Table B-1, the current maximum detected groundwater concentrations (May 1998) in the source area (near well S9MW15) include cis-1,2-DCE (1,300 µg/L), trans-1,2-DCE (4,000 µg/L), benzene (25 µg/L), and TCE (350 µg/L). Under the natural attenuation processes present at the site, the maximum groundwater concentrations anticipated in the future at the downgradient pond for the four modeled chemicals would be reduced to 310, 915, 0.199, and 16.9 µg/L respectively. This means that the surface water concentrations in the small pond would correspondingly contain cis-1,2-DCE (250 µg/L), trans-1,2-DCE (710 µg/L), benzene (0.141 µg/L), and TCE (10 µg/L). These conservatively projected concentrations are much lower than the surface water criteria of 11,600, 1,350, 71, and 81 µg/L.

The modeling results indicate that the predicted future maximum surface water concentrations for the four chemicals are substantially below their surface water criteria. Therefore, the groundwater concentrations currently within the source area are not at levels that will unacceptably impact the surface water at the downgradient receptor (i.e., the small water pond and lagoons) in the foreseeable future.

Natural attenuation processes that were accounted for during groundwater modeling include sorption, dilution, advection, dispersion, and chemical/biological decay. ECTran model's inputs and outputs are presented in Attachment B.1.

### B.4.2 LOCATION OF THE NEW SENTRY WELL

The time required to reach the peak concentration at both the downgradient receptor (pond) and the sentry well were computed by ECTran, and are also summarized in Table B-1. Based upon the modeling results along with the examination of the existing monitoring well network, the recommended location of the new sentry well was approximately 50 feet southeast of the existing well S9MW22 (Figure B-4). This location provides for a more detailed plume configuration and for collecting additional downgradient geochemical monitoring data.

Figures B-5 and B-6 show TCE groundwater concentration variations with time at the new sentry well and the small pond respectively. Also, as indicated in Table B-1, the required times for the peak concentrations to move from the new sentry well to the downgradient pond range from 1.8 to 5.4 years. This time frame is reasonable to allow for responsive corrective actions, if necessary, prior to any exceedence of surface water criteria. Figures depicting groundwater concentration variations with time for the other three chemicals at both the new sentry well and the small pond are also included in Attachment B.1.

## B.5.0 REFERENCES

ABB (ABB Environmental Services, Inc.), 1995, *Facility and Remedial Investigation NAS Key West, Workplan*, Volume 1, prepared for SOUTHNAVFACENGCOM. Tampa, Florida, December.

B&R Environmental (Brown & Root Environmental), 1997, *Supplemental RCRA Facility Investigation and Remedial Investigation Report for NAS Key West High-Priority Sites Boca Chica Key, Florida*, prepared for SOUTHNAVFACENGCOM. Aiken, South Carolina, Revision 2, July 1997.

Bechtel Environmental, Inc. (BEI), October 4, 1995, *Technical Memorandum Groundwater Evaluation for Pump and Treat System, Jet engine test Cell, NAS Key West*.

Aller, L., Bennett, T., Lehr, J., Petty, R., and Hackett, G., DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings, EPA-600/2-87/035, United States Environmental Protection Agency, Office of Research and Development, Robert S. Kerr Environmental Research Laboratory, Ada Oklahoma.

Chiou, J.D., C. Rich, W. Yu, 1993, "ECTran - A Spreadsheet Based Screening-Level Multimedia Fate and Transport Model with Monte Carlo Simulation Capability," in Proceedings of the ER '93 Conference, Sponsored by the U.S. Department of Energy, Augusta, Georgia, pp. 117-122.

Howard, P.H., R.S. Boething, W. F. Jarvis, W. M. Meylan, and E. M., Michalenko, 1991, Handbook of Environmental Degradation Rates, Lewis Publishers, Inc., Chelsea, Michigan.

Thibault, D. H., M. I. Sheppard and P. A. Smith, 1990, "A Critical Compilation and Review of Default Soil Solid/Liquid Partition Coefficients,  $K_d$  for use in Environmental Assessments," AECL-10125, Whiteshell Nuclear Research Center, Pinawa, Manitoba, Canada.

Tetra Tech NUS, (TtNUS) Inc, 1998 *Natural Attenuation Report for NAS Key West High-Priority Sites Boca Chica Key, Florida*, prepared for SOUTHNAVFACENGCOM. Aiken, South Carolina, August 1998.

United States Environmental Protection Agency, April, 1996, Soil Screening Guidance: Users Guide, EPA/540/R-96/018, Office of Solid Waste and Emergency Response, Washington, DC, April.

U.S. Environmental Protection Agency, 1988, "Superfund Exposure Assessment Manual," EPA/540/1-88/001, EPA, Washington, DC.



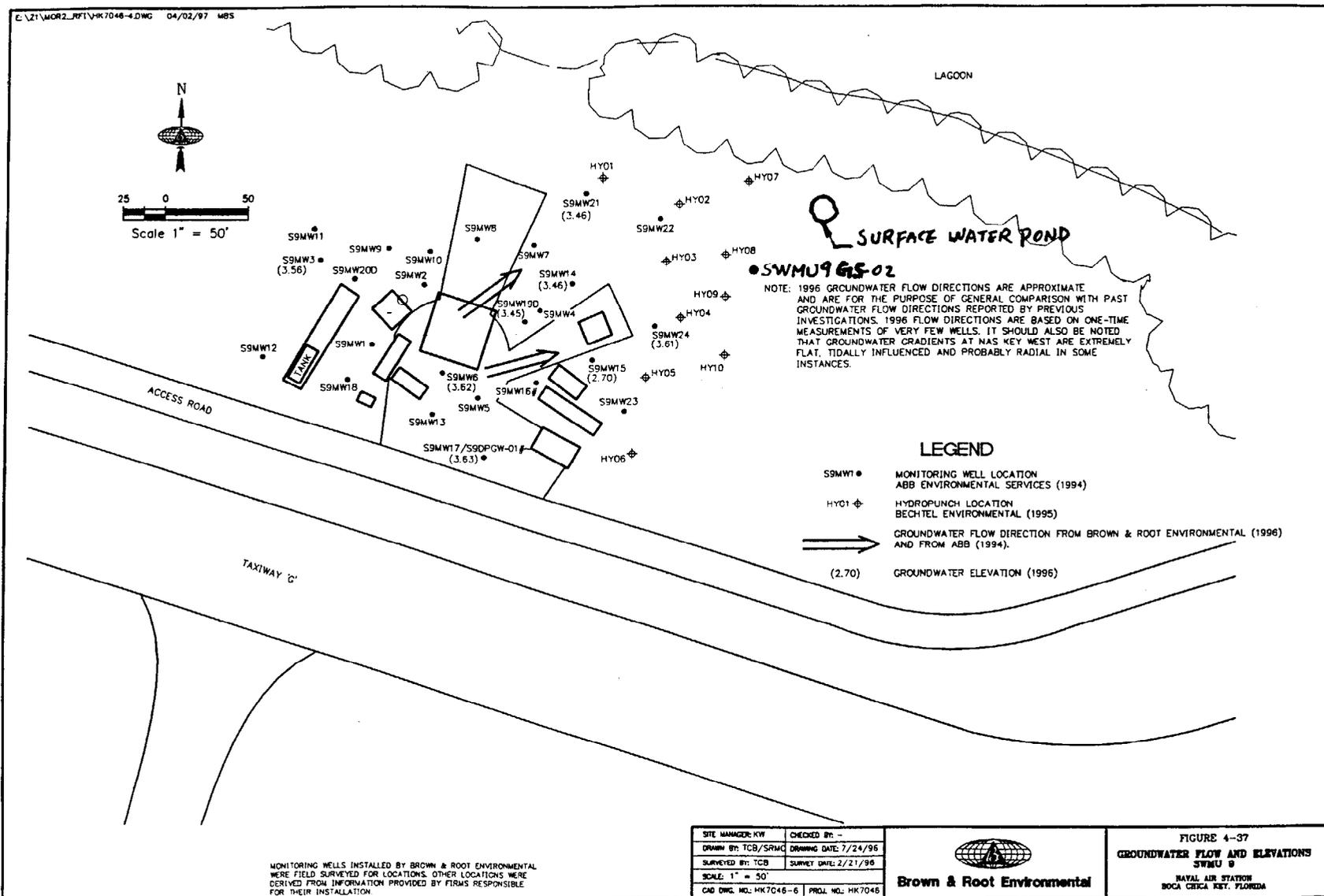
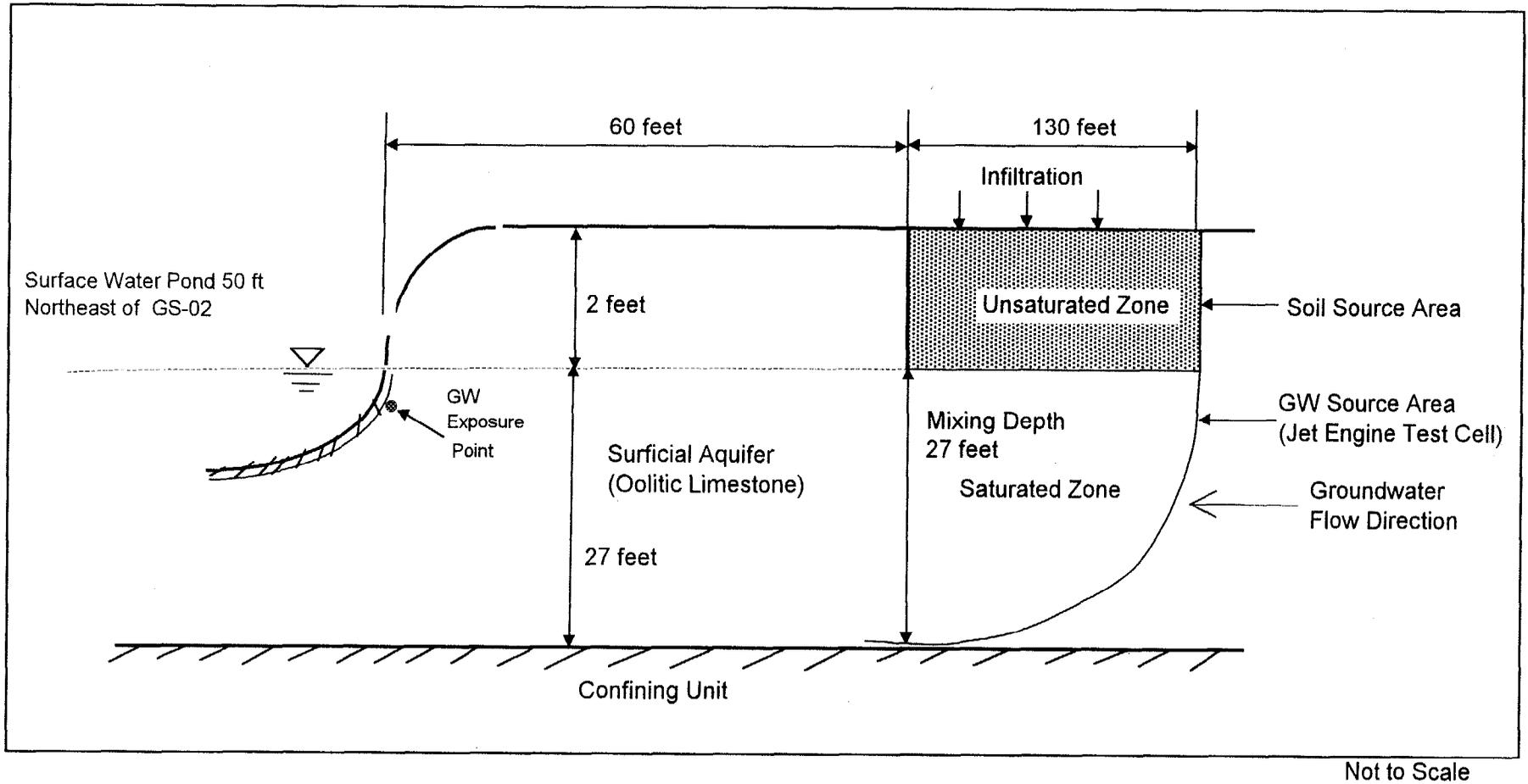


FIGURE B-2 GROUNDWATER FLOW DIRECTION (SWUM 9, AS KEY WEST)



**FIGURE B-3 CONCEPTUAL MODEL FOR GROUNDWATER FATE AND TRANSPORT (SWMU 9, NAS KEY WEST)**

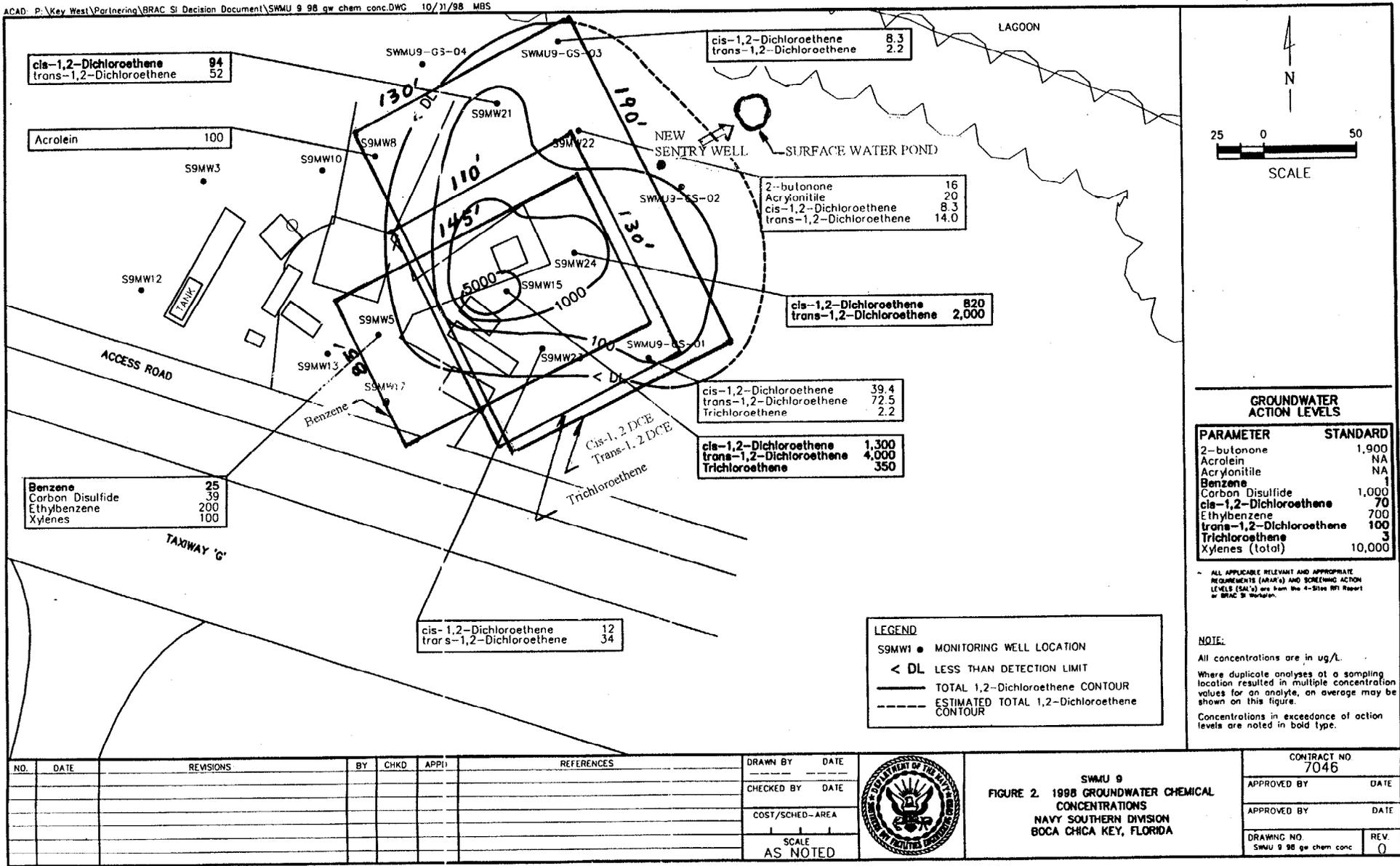


FIGURE B-4 SOURCE AREAS AND EXPOSURE POINT (SWUM 9, AS KEY WEST)

TCE; SOIL CONC. = 0 UG/KG; GW CONC. = 350 UG/L; AT THE SENTRY WELL

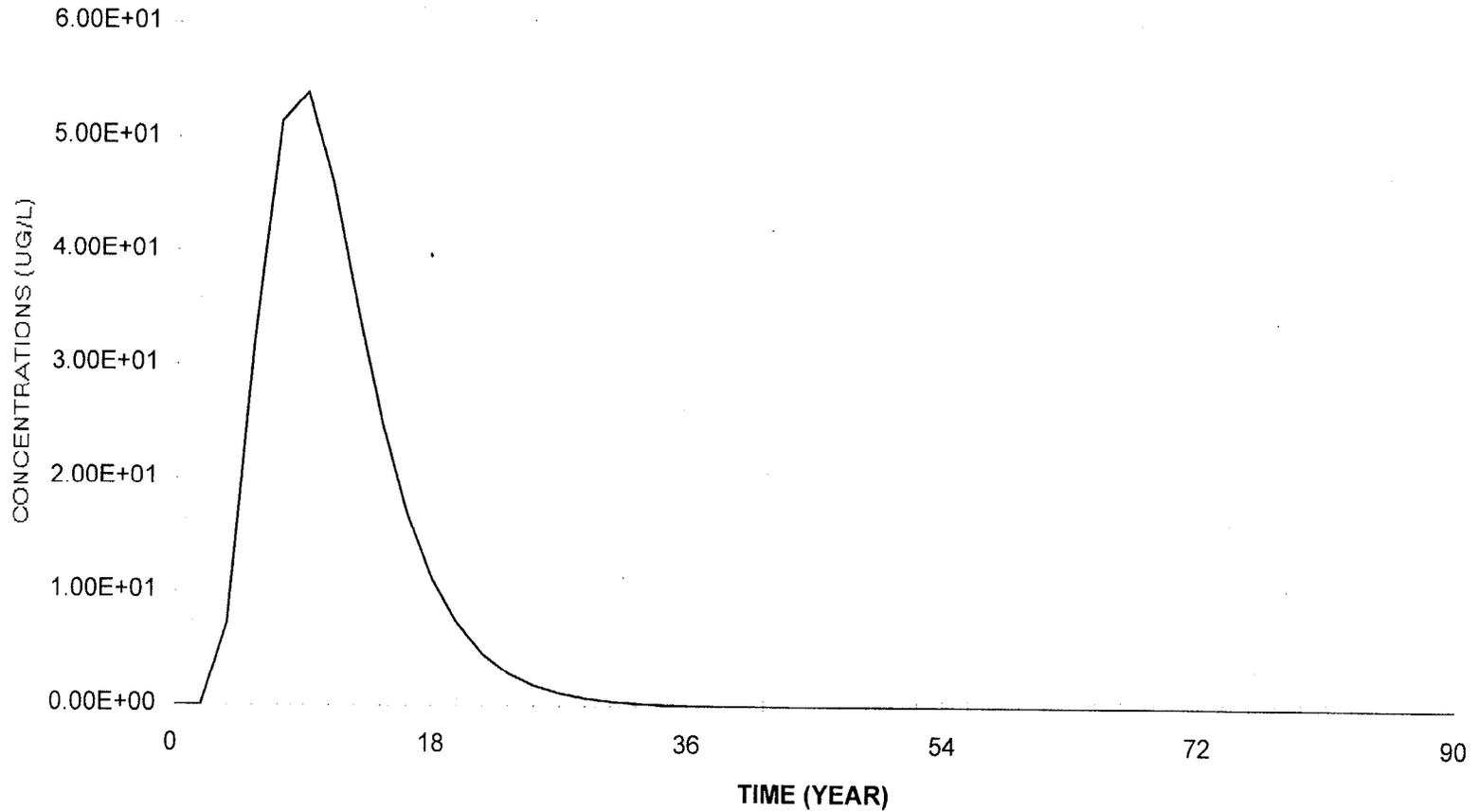


FIGURE B-5 TCE GROUNDWATER CONCENTRATIONS AT NEW SENTRY WELL  
(SWMU 9, NAS KEY WEST)

TCE; SOIL CONC. = 0 UG/KG; GW CONC. = 350 UG/L; AT THE SMALL POND

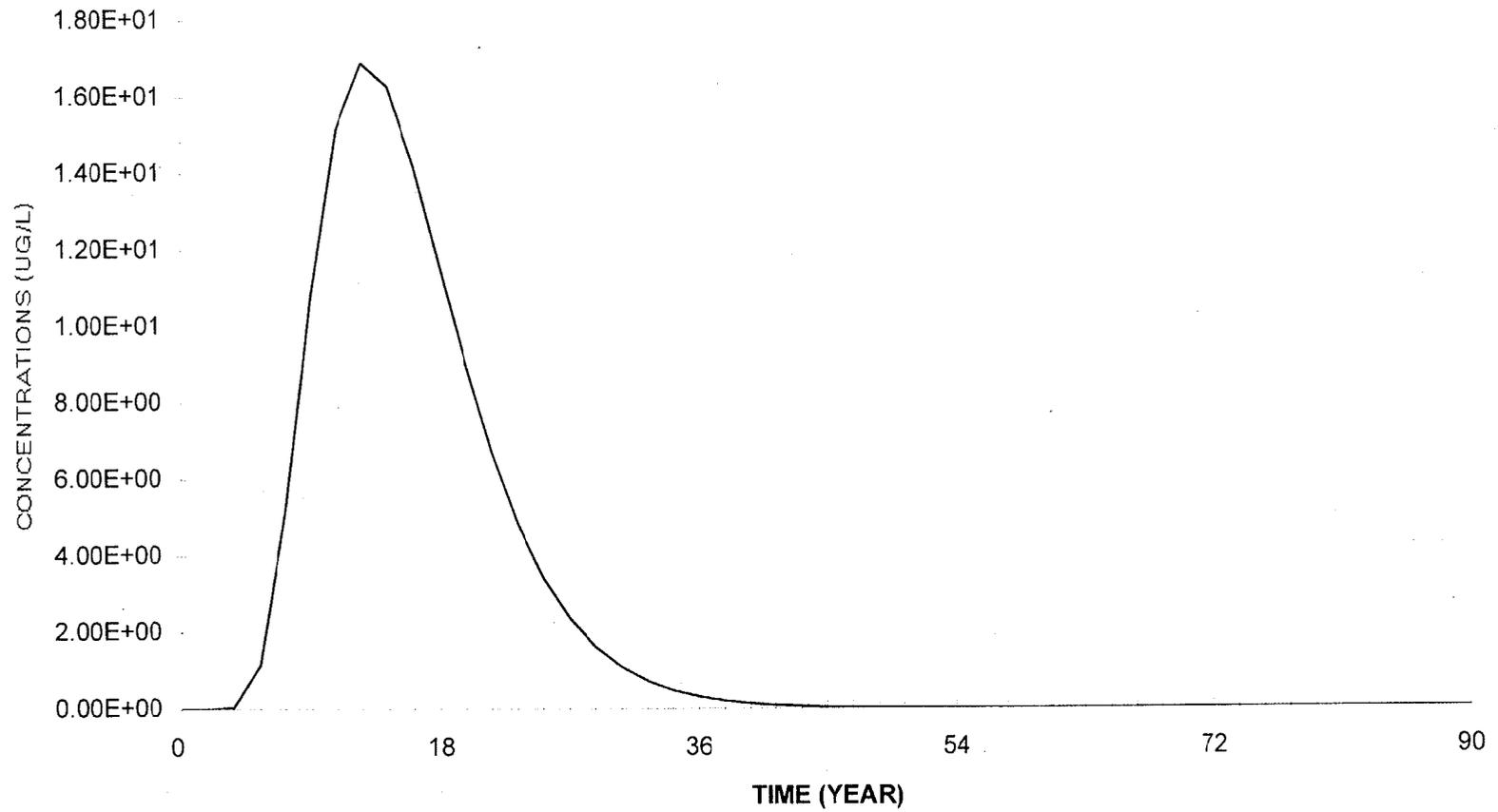


FIGURE B-6 TCE GROUNDWATER CONCENTRATIONS AT THE EDGE OF THE SURFACE WATER POND (SWMU 9, NAS KEY WEST)

**TABLE B-1**  
**SUMMARY OF GROUNDWATER FATE AND TRANSPORT MODELING UNDER CURRENT CONDITIONS**  
**SWUM 9 CORRECTIVE MEASURE STUDY**  
**NAVAL AIR STATION, KEY WEST, FLORIDA**

Chemical	Max. Detected Soil Concentrations in Source Area  (1) (ug/kg)	Max. Detected Groundwater Concentrations (1998) in Source Area  (2) (ug/L)	Model Predicted Groundwater Concentration at the New Sentry Well  (3) (ug/L)	Model Predicted Groundwater Concentration at the Water Pond  (4) (ug/L)	Model Predicted Surfacewater Concentration at the Water Pond  (4) (ug/L)	Surfacewater Criteria  (5) (ug/L)	Surfacewater Criteria Exceed?  (at the Water Pond)	Time to Peak Conc. at the New Sentry Well  (years)	Time to Peak Conc. at the Surface Water Pond  (years)
Cis-1,2-Dichloroethene	0	1,300	846	310	250	11,600	NO	3.6	9
Trans-1,2-Dichloroethene	10	4,000	2,580	915	710	1,350	NO	3.6	9
Benzene	0	25	1.26	0.199	0.141	71	NO	7.2	9
Trichloroethene (TCE)	0	350	53.9	16.9	10	81	NO	9	12.6

Notes:

- (1). The maximum detected concentrations in surface and subsurface soils were based on the Supplemental Investigation and Remedial Investigation Report (Table 4-91, B&R, July 1997).
- (2). The maximum detected groundwater concentrations were the most current data based on May 1998 groundwater sampling data (TINUS, August 1998).
- (3) The proposed new sentry well is located at approximately 50 feet southeast of the existing well S9MW22.
- (4) The surface water concentration is the groundwater concentration divided by the retardation factor.
- (5) The surface water criteria were chosen as the most restrictive ARAR/SAL criteria based on the RFI/RI (B&R, July 1997).

**TABLE B-2**  
**HYDRAULIC CONDUCTIVITIES FROM PUMPING TEST AND SLUG TEST**  
**SWMU 9 CORRECTIVE MEASURE STUDY**  
**NAVAL AIR STATION, KEY WEST, FLORIDA**

Well ID	Test Type	Transmissivity (ft <sup>2</sup> /min)	Hydraulic Conductivity (ft/day)
P-2	pump test <sup>(1)</sup>	0.06235	3.33
P-3	pump test <sup>(1)</sup>	0.08235	4.39
P-4	pump test <sup>(1)</sup>	0.17680	9.43
P-5	pump test <sup>(1)</sup>	0.07366	3.93
MW-10	pump test <sup>(1)</sup>	0.07305	3.90
Geomean (K <sub>sat</sub> ; ft/day)=			4.62

(1) The aquifer transmissivity results were based on the pumping test, and were divided by the aquifer thickness of 27 feet to obtain the hydraulic conductivities. The pumping test was started on September 6, 1995 at a pumping rate of 2.0 gpm (BEI, 1995).

TABLE B-3  
PARTITIONING COEFFICIENT AND HALF-LIVES  
SWMU 9 CORRECTIVE MEASURE STUDY  
NAVAL AIR STATION, KEY WEST, FLORIDA

Chemicals of Concern	Organic Carbon/Water Partitioning Coef. KOC (1) (L/kg)	Soil Organic Carbon Content FOC (2)	Partitioning Coefficient Kd (unsaturated zone) (3) (L/kg)	GW Organic Carbon Content FOC (4)	Partitioning Coefficient Kd (saturated zone) (3) (L/kg)	Half-Life (5) (years)
Cis-1,2-Dichloroethene	49	0.0720	3.53	0.0010	0.05	7.9
Trans-1,2-Dichloroethene	59	0.0720	4.25	0.0010	0.06	7.9
Benzene	83	0.0720	5.98	0.0010	0.08	2.0
Trichloroethene (TCE)	126	0.0720	9.07	0.0010	0.12	4.5

- (1) The KOC was imported from U.S. EPA document "Manual- Groundwater and Leachate Treatment Systems" (EPA/625/R-94/005).
- (2) The soil FOC value used in this evaluation was based on 72,000 mg/kg (or 7.2 %) TOC concentrations from one groundwater samples (S9MW-10) result collected in May1998 (TtNUS, Aug 1998).
- (3)  $K_d = FOC \times KOC$ , U.S. EPA, December 1996, Soil Screening Guidance Users Guide.
- (4) The groundwater FOC values were based on results from Natural Attenuation Study (TtNUS, Aug 1998). A geometric mean foc value was used for modeling.
- (5) Half-lives were taken from literature values (Howard 1991).

**TABLE B-4**  
**SUMMARY OF PHYSICAL AND GEOLOGIC PARAMETERS**  
**SWMU 9 CORRECTIVE MEASURE STUDY**  
**NAVAL AIR STATION, KEY WEST, FLORIDA**

Chemical	Source Area (1)		Shallow Aquifer Thickness (2) (ft)	Unsaturated Zone Thickness (3) (ft)	Hydraulic Conductivity K (4) (ft/day)	Mixing Depth (5) (ft)	Distance to Exposure Point (6) (Surfacewater Pond) (ft)	Distance to New Sentry Well (7) (ft)
	Length (ft)	Width (ft)						
Cis-1,2-Dichloroethene	130	190	27	2	4.62	27	60	15
Trans-1,2-Dichloroethene	130	190	27	2	4.62	27	60	15
Benzene	145	85	27	2	4.62	27	95	50
Trichloroethene (TCE)	110	130	27	2	4.62	27	87	45

(1) Source area size was based on the reported 1998 groundwater concentrations in the surficial aquifer (Figures B-4, and TtNUS, August 1998).

(2) Shallow surficial aquifer thickness is based on the RFI/RI (B&R, July 1997).

(3) The unsaturated zone thickness is based on the water table elevations presented in the RFI/RI (B&R, July 1997).

(4) A geometric mean K value from pumping in the surficial aquifer was selected for modeling (Table B-2).

(5) The mixing depth was calculated based on equations presented in the reference for ECTran model (Chiou et al, 1993).

(6) Measured from the edge of the source area to the surface water pond (Figure B-4).

(7) Measured from the edge of the source area to the new sentry well (Figure B-4).

**ATTACHMENT B.1**

**RESULTS OF GROUNDWATER FATE AND TRANSPORT MODELING**

**CIS-1,2 DICHLOROETHENE**

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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/28/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	cis-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL)	FL
HALF-LIFE (YRS):	7.92E+00	UNDERS: Under source, FL: Fenceline	
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	WATER CRITERIA (UG/L):	1.16E+04
		TIME FRAME (YRS):	90
		LEACHATE CONCENTRATION (YES,NO) ?	NO
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	0.000E+00
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	0.00E+00
		ACCEPTABLE!	INCREASE

SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FT/YR):	8.30E-01
KI (L/KG):	3.53E+00	LENGTH (FT):	130
DEPLETING SOURCE:		WIDTH (FT):	190
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3):	1.78
		Kd (L/KG):	1.00E-05

IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0

SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>z0</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	4.80E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	6.0	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	2.0	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	1.300E+03	DISTANCE TO Fence Line:	60

PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	1.30E+03 (UG/L)	0
FENCE LINE CONCENTRATION:	3.10E+02 (UG/L)	9

BROWN & ROOT ENVIRONMENTAL  
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTran) MODEL

SITE:	SWMU 9, NAS, Key West	CONTAMINANT:	cis-1,2-Dichloroethene	
INVESTIGATOR:	LK	HALF-LIFE (YRS):		
DATE:	5/28/99	LAYER 2:	7.92E+00	
		SATURATED LAYER	7.92E+00	
		DOWNGRADIENT	7.92E+00	INITIAL CONC. (ug/L): 1.30E+03

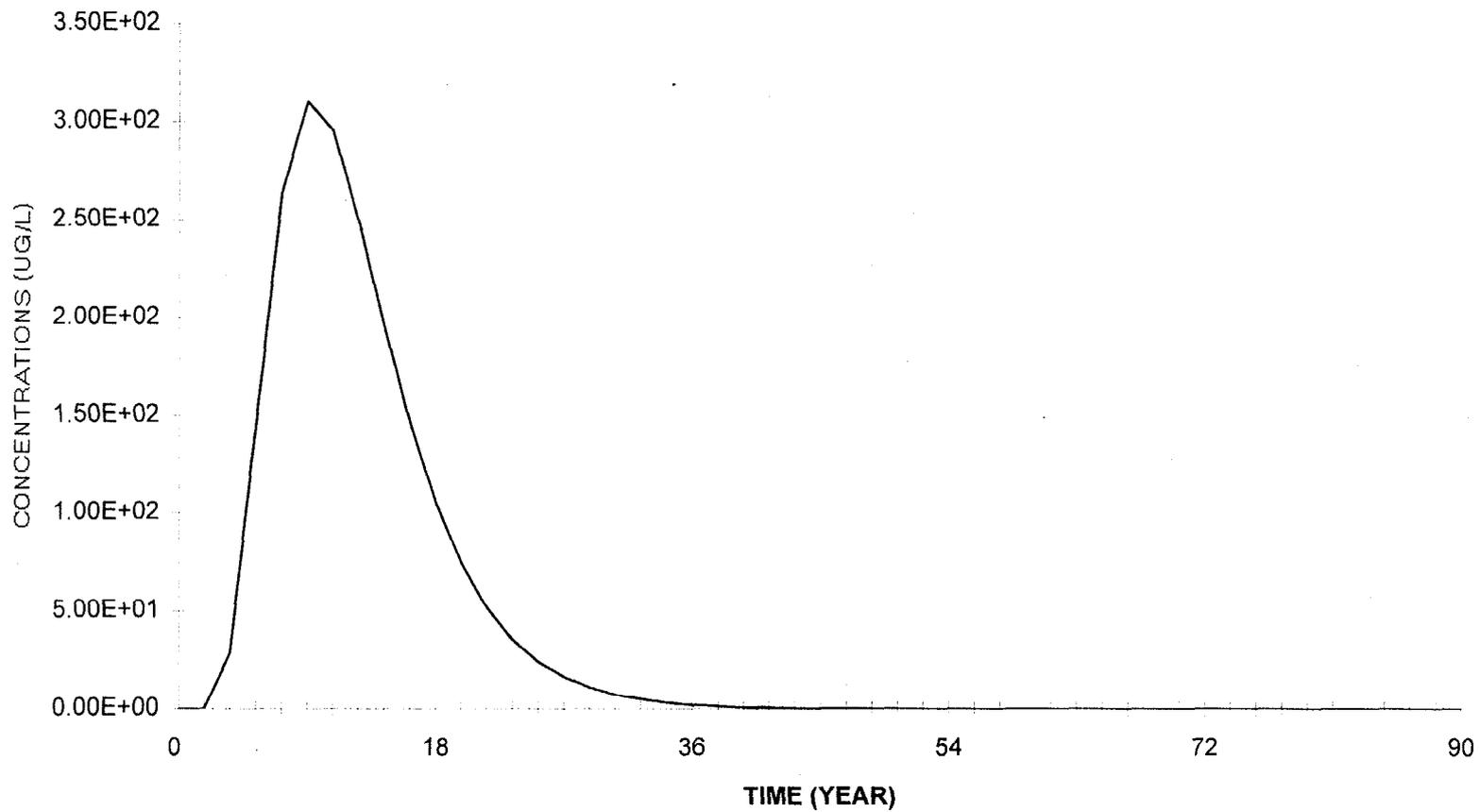
SATURATED LAYER							
INFILT (FT/YR):	0.83		B (FT):	27	Vzo (FT/YR):	4.48	
LENGTH (FT):	130		GW Q3 (L/DAY):	2.66E+03			
WIDTH (FT):	190		GW V. (FT/YR):	8.99	Kd (L/KG):	0.04802	
POROSITY 2:	0.3		H (FT):	27.0000	RETARDATION:	1.2401	
POROSITY SAT. LAYER:	0.3		THICKNESS (FT):	27.00	q (FT/YR):	0	
DENSITY 2 (G/CM3):	1.5		DECAY (1/DAY):	2.40E-04	DISPERSIVITY:	DECAY (1/YR): 8.8E-02	
DENSITY GMA (G/CM3):	1.50		CB0 (PPB):	1.30E+03	Az (FT):	0.14	
AGE (YEARS):	0	Q1 (L/DAY): 1.59E+03	CU2 (PPB):	0.00E+00	Ax (FT):	6.00	P&T (YEARS): 0
			Q2 (L/DAY):	1.07E+03	Ay (FT):	2.00	DISTANCE TO F.L. (FT): 60

TIME INTERVAL (YRS)		SOURCE AREA CONC. (GMA)		FENCE LINE CONC.	
ELAPSED TIME - YRS		(UG/L)		(UG/L)	
	LAYER 2 (PPB)				
0	0.00E+00		1.30E+03		0.00E+00
1.8	0.00E+00		8.66E+02		1.01E-01
3.6	0.00E+00		5.76E+02		2.84E+01
5.4	0.00E+00		3.84E+02		1.47E+02
7.2	0.00E+00		2.55E+02		2.64E+02
9	0.00E+00		1.70E+02		3.10E+02 ←
10.8	0.00E+00		1.13E+02		2.95E+02
12.6	0.00E+00		7.54E+01		2.49E+02
14.4	0.00E+00		5.02E+01		1.95E+02
16.2	0.00E+00		3.34E+01		1.45E+02
18	0.00E+00		2.23E+01		1.05E+02
19.8	0.00E+00		1.48E+01		7.41E+01
21.6	0.00E+00		9.86E+00		5.15E+01
23.4	0.00E+00		6.57E+00		3.54E+01
25.2	0.00E+00		4.37E+00		2.41E+01
27	0.00E+00		2.91E+00		1.63E+01
28.8	0.00E+00		1.94E+00		1.10E+01
30.6	0.00E+00		1.29E+00		7.39E+00
32.4	0.00E+00		8.59E-01		4.95E+00
34.2	0.00E+00		5.72E-01		3.31E+00
36	0.00E+00		3.81E-01		2.21E+00
37.8	0.00E+00		2.54E-01		1.48E+00
39.6	0.00E+00		1.69E-01		9.86E-01
41.4	0.00E+00		1.12E-01		6.58E-01
43.2	0.00E+00		7.49E-02		4.38E-01
45	0.00E+00		4.98E-02		2.92E-01
46.8	0.00E+00		3.32E-02		1.95E-01
48.6	0.00E+00		2.21E-02		1.30E-01
50.4	0.00E+00		1.47E-02		8.63E-02
52.2	0.00E+00		9.79E-03		5.75E-02
54	0.00E+00		6.52E-03		3.83E-02
55.8	0.00E+00		4.34E-03		2.55E-02
57.6	0.00E+00		2.89E-03		1.70E-02
59.4	0.00E+00		1.92E-03		1.13E-02
61.2	0.00E+00		1.28E-03		7.52E-03
63	0.00E+00		8.53E-04		5.01E-03
64.8	0.00E+00		5.68E-04		3.34E-03
66.6	0.00E+00		3.78E-04		2.22E-03
68.4	0.00E+00		2.52E-04		1.48E-03
70.2	0.00E+00		1.68E-04		9.84E-04
72	0.00E+00		1.12E-04		6.55E-04
73.8	0.00E+00		7.43E-05		4.36E-04
75.6	0.00E+00		4.95E-05		2.91E-04
77.4	0.00E+00		3.29E-05		1.93E-04
79.2	0.00E+00		2.19E-05		1.29E-04
81	0.00E+00		1.46E-05		8.58E-05
82.8	0.00E+00		9.72E-06		5.71E-05
84.6	0.00E+00		6.47E-06		3.80E-05
86.4	0.00E+00		4.31E-06		2.53E-05
88.2	0.00E+00		2.87E-06		1.69E-05
90	0.00E+00		1.91E-06		1.12E-05
MAXIMUM:	0.00E+00		1.30E+03		3.10E+02

9 yr →

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Cis-1,2-DCE; SOIL CONC. = 0 UG/KG; GW CONC. = 1300 UG/L; AT THE WATER POND



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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/10/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	cis-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL)	FL
HALF-LIFE (YRS):	7.92E+00	UNDERS: Under source, FL: Fenceline	
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	WATER CRITERIA (UG/L):	1.16E+04
		TIME FRAME (YRS):	90
		LEACHATE CONCENTRATION (YES,NO)?	NO
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	0.000E+00
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	0.00E+00
		ACCEPTABLE?	INCREASE
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
K <sub>d</sub> :	1.00	INFILT(FT/YR):	8.30E-01
K <sub>i</sub> (L/KG):	3.53E+00	LENGTH (FT):	130
DEPLETING SOURCE:		WIDTH (FT):	190
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM <sup>3</sup> ):	1.5	BULK DENSITY (G/CM <sup>3</sup> ):	1.78
		K <sub>d</sub> (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM <sup>3</sup> ):	1.5	BULK DENSITY (G/CM <sup>3</sup> ):	1.5
K <sub>d</sub> (L/KG):	1.00E-05	K <sub>d</sub> (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>z0</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRAIDENT AREA INFILTRATION RATE, q (FT/YR)	0
K <sub>d</sub> (L/KG):	4.80E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, A <sub>z</sub> (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, A <sub>x</sub> (FT):	1.5	AGE (YRS):	0
LATERAL DISPERSIVITY, A <sub>y</sub> (FT):	0.5	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	1.300E+03	DISTANCE TO Fence Line:	15
PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION:	1.30E+03 (UG/L)		0
FENCE LINE CONCENTRATION:	8.46E+02 (UG/L)		3.6

BROWN & ROOT ENVIRONMENTAL  
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTran) MODEL

SITE:	SWMU 9, NAS, Key West	CONTAMINANT:	cis-1,2-Dichloroethene	
INVESTIGATOR:	LK	HALF-LIFE (YRS):		
DATE:	5/10/99	LAYER 2:	7.92E+00	
		SATURATED LAYER	7.92E+00	
		DOWNGRADIENT	7.92E+00	INITIAL CONC (ug/L): 1.30E+03

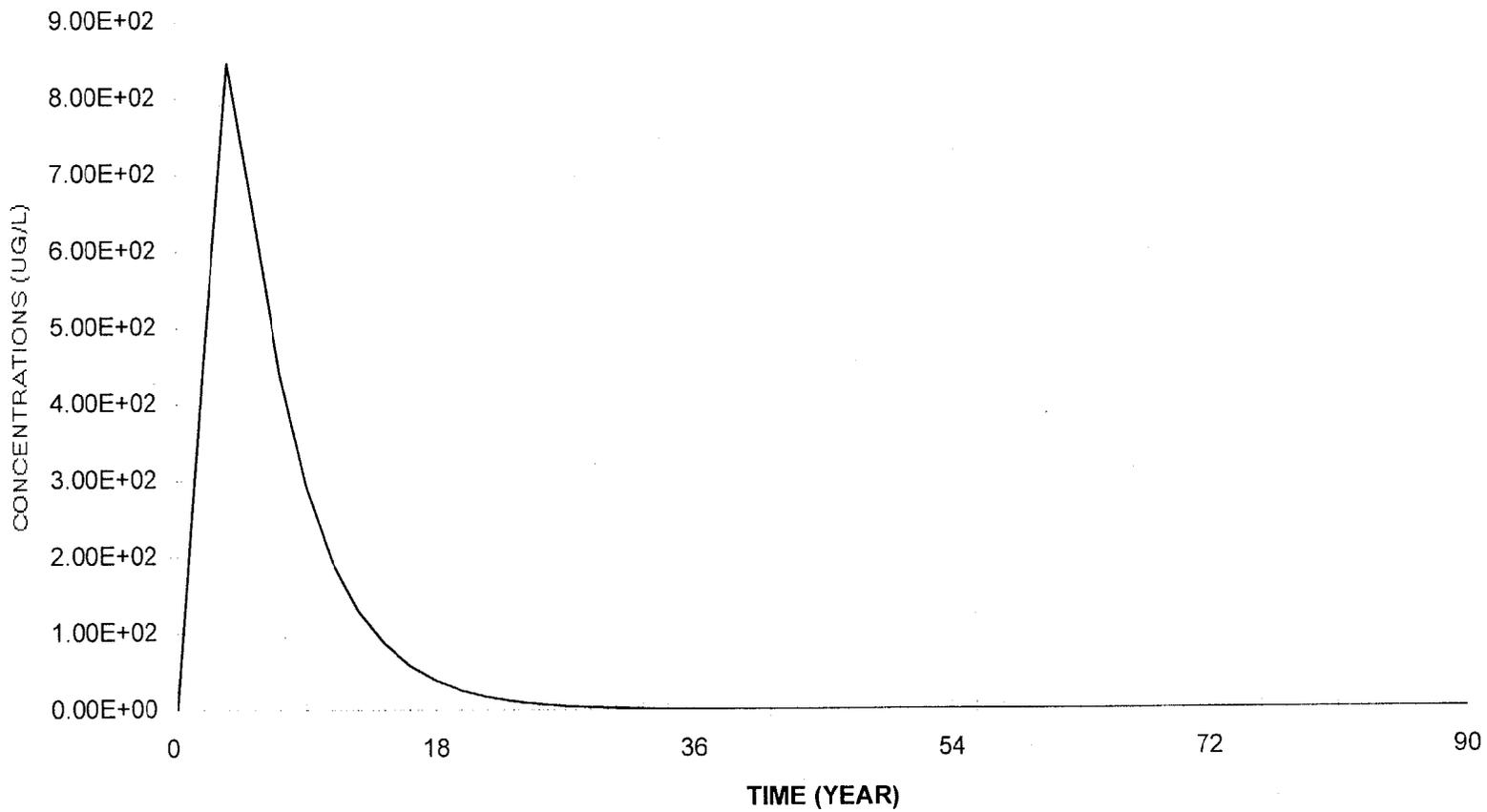
SATURATED LAYER				
INFILT (FT/YR):	0.83			B (FT): 27 Vzo (FT/YR): 4.48
LENGTH (FT):	130			GW Q3 (L/DAY): 2.66E+03
WIDTH (FT):	190	Kd (L/KG): 4.80E-02		GW V (FT/YR): 8.99 Kd (L/KG): 0.04802
POROSITY 2:	0.3	SATURATION:	1.00	H (FT): 27.0000 RETARDATION: 1.2401
POROSITY SAT. LAYER:	0.3	THICKNESS (FT):	27.00	EFF. POROSITY: 0.30 q (FT/YR): 0
DENSITY 2 (G/CM3):	1.5	DECAY (1/DAY):	2.40E-04	DISPERSIVITY: DECAY (1/YR): 8.8E-02
DENSITY GMA (G/CM3):	1.50	CBo (PPB):	1.30E+03	Az (FT): 0.14
AGE (YEARS):	0	CU2 (PPB):	0.00E+00	Ax (FT): 1.50 P&T (YEARS): 0
		Q2 (L/DAY):	1.07E+03	Ay (FT): 0.50 DISTANCE TO F.L. (FT): 15
		Q1 (L/DAY):	1.59E+03	

TIME INTERVAL (YRS)		SOURCE AREA CONC. (GMA)		FENCE LINE CONC.	
ELAPSED TIME - YRS	LAYER 2 (PPB)	(UG/L)		(UG/L)	
0	0.00E+00	1.30E+03		0.00E+00	
1.8	0.00E+00	8.66E+02		4.42E+02	
3.6	0.00E+00	5.76E+02		8.46E+02	
5.4	0.00E+00	3.84E+02		6.48E+02	
7.2	0.00E+00	2.55E+02		4.40E+02	
9	0.00E+00	1.70E+02		2.94E+02	
10.8	0.00E+00	1.13E+02		1.96E+02	
12.6	0.00E+00	7.54E+01		1.30E+02	
14.4	0.00E+00	5.02E+01		8.68E+01	
16.2	0.00E+00	3.34E+01		5.78E+01	
18	0.00E+00	2.23E+01		3.85E+01	
19.8	0.00E+00	1.48E+01		2.56E+01	
21.6	0.00E+00	9.86E+00		1.71E+01	
23.4	0.00E+00	6.57E+00		1.14E+01	
25.2	0.00E+00	4.37E+00		7.56E+00	
27	0.00E+00	2.91E+00		5.04E+00	
28.8	0.00E+00	1.94E+00		3.35E+00	
30.6	0.00E+00	1.29E+00		2.23E+00	
32.4	0.00E+00	8.59E-01		1.49E+00	
34.2	0.00E+00	5.72E-01		9.90E-01	
36	0.00E+00	3.81E-01		6.59E-01	
37.8	0.00E+00	2.54E-01		4.39E-01	
39.6	0.00E+00	1.69E-01		2.92E-01	
41.4	0.00E+00	1.12E-01		1.94E-01	
43.2	0.00E+00	7.49E-02		1.29E-01	
45	0.00E+00	4.98E-02		8.62E-02	
46.8	0.00E+00	3.32E-02		5.74E-02	
48.6	0.00E+00	2.21E-02		3.82E-02	
50.4	0.00E+00	1.47E-02		2.54E-02	
52.2	0.00E+00	9.79E-03		1.69E-02	
54	0.00E+00	6.52E-03		1.13E-02	
55.8	0.00E+00	4.34E-03		7.51E-03	
57.6	0.00E+00	2.89E-03		5.00E-03	
59.4	0.00E+00	1.92E-03		3.33E-03	
61.2	0.00E+00	1.28E-03		2.22E-03	
63	0.00E+00	8.53E-04		1.48E-03	
64.8	0.00E+00	5.68E-04		9.82E-04	
66.6	0.00E+00	3.78E-04		6.54E-04	
68.4	0.00E+00	2.52E-04		4.35E-04	
70.2	0.00E+00	1.68E-04		2.90E-04	
72	0.00E+00	1.12E-04		1.93E-04	
73.8	0.00E+00	7.43E-05		1.29E-04	
75.6	0.00E+00	4.95E-05		8.56E-05	
77.4	0.00E+00	3.29E-05		5.70E-05	
79.2	0.00E+00	2.19E-05		3.79E-05	
81	0.00E+00	1.46E-05		2.53E-05	
82.8	0.00E+00	9.72E-06		1.68E-05	
84.6	0.00E+00	6.47E-06		1.12E-05	
86.4	0.00E+00	4.31E-06		7.45E-06	
88.2	0.00E+00	2.87E-06		4.96E-06	
90	0.00E+00	1.91E-06		3.30E-06	
MAXIMUM	0.00E+00	1.30E+03		8.46E+02	

3.6 →

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CIS-1,2-DCE; SOIL CONC. = 0 UG/KG; GW CONC. =1300 UG/L; AT SENTRY WELL



**TRANS-1,2 DICHLOROETHENE**

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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/10/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT: trans-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL) FL UNDERS: Under source, FL: Fenceline WATER CRITERIA (UG/L): 1.35E+03	LEACHATE CONCENTRATION (YES,NO) ? NO INPUT SOLID-PHASE CONCENTRATION (MG/KG) 1.000E-02 CONSTANT CONCENTRATION (YES,NO)? NO TRY NEW GOAL: 1.48E-02 ACCEPTABLE! INCREASE	
HALF-LIFE (YRS): 7.92E+00	TIME FRAME (YRS): 90		
SPECIFIC ACTIVITY (Ci/g): 0.00E+00			
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke: 1.00	K1 (L/KG): 4.25E+00	INFILT(FT/YR): 8.30E-01	
DEPLETING SOURCE:		LENGTH (FT): 130	
WASTE CHARACTERISTICS:		WIDTH (FT): 190	
INITIAL SOLID-PHASE CONCENTRATION (MG/KG): 1.00E-02		IS THERE A CLAY LINER LAYER (YES,NO)? no	
INPUT FOLLOWING PARAMETERS:		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
THICKNESS (FT): 2		HOW MANY SUBLAYERS (1 - 10)? 3	
SATURATION RATE: 0.6		TOTAL THICKNESS (UP TO 30 FT) (FT): 10	
POROSITY: 0.2		SATURATION RATE: 0.95	
BULK DENSITY (G/CM <sup>3</sup> ): 1.5		POROSITY: 0.2	
		BULK DENSITY (G/CM <sup>3</sup> ): 1.78	
		Kd (L/KG): 1.00E-05	
IS THERE A TYPE 1 LAYER (YES,NO)? NO		IS THERE A TYPE 2 LAYER (YES,NO)?	
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)? 6		HOW MANY SUBLAYERS (1 - 10)? 5	
TOTAL THICKNESS (UP TO 30 FT) (FT): 2.20E+01		TOTAL THICKNESS (UP TO 30 FT) (FT): 20	
SATURATION RATE: 0.95		SATURATION RATE: 0.13	
POROSITY: 0.2		POROSITY: 0.3	
BULK DENSITY (G/CM <sup>3</sup> ): 1.5		BULK DENSITY (G/CM <sup>3</sup> ): 1.5	
Kd (L/KG): 1.00E-05		Kd (L/KG): 1.00E-05	
INITIAL SOIL CONC (MG/KG): 0		INITIAL SOIL CONC (MG/KG): 0	
SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT): 27		VERTICAL SEEPAGE VELOCITY, V <sub>z0</sub> (FT/YR): 4.48	
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR): 8.99		DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR): 0	
Kd (L/KG): 5.78E-02		SPECIFY MIXING DEPTH (Computed from formula if input NO) no	
POROSITY: 0.3		MIXING DEPTH, H (FT): 27.0	
VERTICAL DISPERSIVITY, Az (FT): 0.14		TIME OF PUMPING STOP, P&T (YEARS): 0	
LONGITUDINAL DISPERSIVITY, Ax (FT): 6.0		AGE (YRS): 0	
LATERAL DISPERSIVITY, Ay (FT): 2.0		CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L): 0	
INITIAL CONC. (ug/L): 4.000E-03		DISTANCE TO Fence Line: 60	
PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION: 4.00E+03 (UG/L)			0
FENCE LINE CONCENTRATION: 9.15E+02 (UG/L)			9

BROWN & ROOT ENVIRONMENTAL  
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTran) MODEL

SITE: SWMU 9. NAS.Key West		CONTAMINANT: trans-1,2-Dichloroethene	
INVESTIGATOR: LK		HALF-LIFE (YRS):	
DATE: 5/10/99		LAYER 2: 7.92E+00	
		SATURATED LAYER: 7.92E+00	
		DOWNGRADIENT: 7.92E+00	INITIAL CONC. (ug/L): 4.00E+03

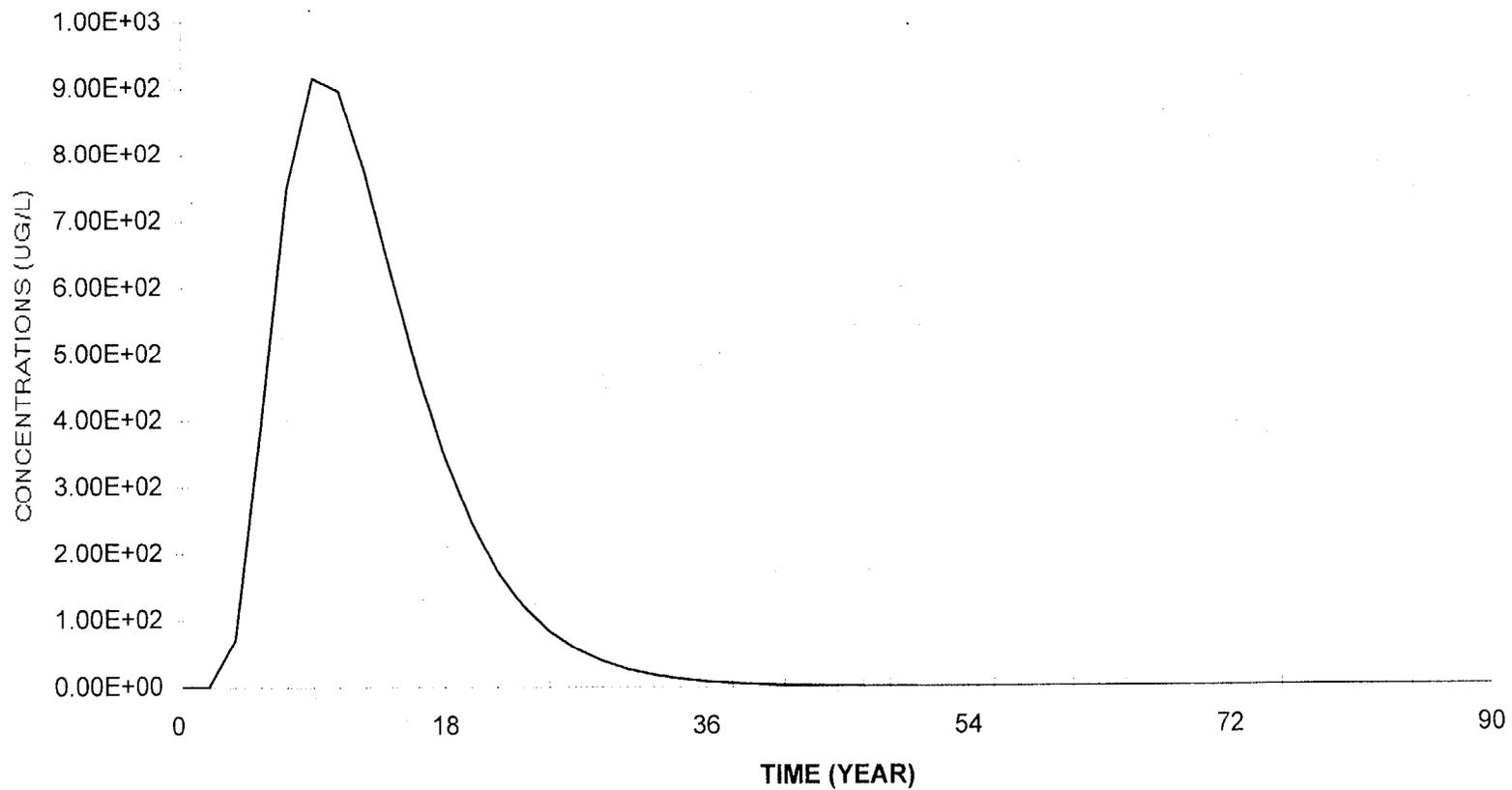
SATURATED LAYER			
INFILT (FT/YR): 0.83		B (FT): 27	V <sub>zo</sub> (FT/YR): 4.48
LENGTH (FT): 130		GW Q3 (L/DAY): 2.66E-03	
WIDTH (FT): 190		GW V. (FT/YR): 8.99	Kd (L/KG): 0.05782
POROSITY 2: 0.3		H (FT): 27.0000	RETARDATION: 1.2891
POROSITY SAT. LAYER: 0.3		EFF POROSITY: 0.30	q (FT/YR): 0
DENSITY 2 (G/CM3): 1.5		DISPERSIVITY:	DECAY (1/YR): 8.8E-02
DENSITY GMA (G/CM3): 1.50		Az (FT): 0.14	
AGE (YEARS): 0	Q1 (L/DAY): 1.59E+03	Ax (FT): 6.00	P&T (YEARS): 0
		Ay (FT): 2.00	DISTANCE TO F.L. (FT): 60
	Q2 (L/DAY): 1.07E+03		

TIME INTERVAL (YRS)	1.8	SOURCE AREA CONC. (GMA)		FENCE LINE CONC	
ELAPSED TIME - YRS	LAYER 2 (PPB)	(UG/L)		(UG/L)	
0	2.35E+00	4.00E+03	0.00E+00	0.00E+00	
1.8	1.79E+00	2.69E+03	1.96E-01	1.96E-01	
3.6	1.36E+00	1.81E+03	7.00E-01	7.00E-01	
5.4	1.04E+00	1.21E+03	3.95E-02	3.95E-02	
7.2	7.91E-01	8.17E+02	7.50E-02	7.50E-02	
9	6.02E-01	5.49E+02	9.15E-02	9.15E-02	
10.8	4.58E-01	3.69E+02	8.96E-02	8.96E-02	
12.6	3.49E-01	2.48E+02	7.74E-02	7.74E-02	
14.4	2.66E-01	1.67E+02	6.18E-02	6.18E-02	
16.2	2.02E-01	1.12E+02	4.70E-02	4.70E-02	
18	1.54E-01	7.54E+01	3.45E-02	3.45E-02	
19.8	1.17E-01	5.07E+01	2.47E-02	2.47E-02	
21.6	8.92E-02	3.41E+01	1.74E-02	1.74E-02	
23.4	6.79E-02	2.29E+01	1.21E-02	1.21E-02	
25.2	5.17E-02	1.54E+01	8.36E-01	8.36E-01	
27	3.94E-02	1.04E+01	5.73E-01	5.73E-01	
28.8	3.00E-02	6.97E+00	3.90E+01	3.90E+01	
30.6	2.28E-02	4.68E+00	2.65E+01	2.65E+01	
32.4	1.74E-02	3.15E+00	1.80E+01	1.80E+01	
34.2	1.32E-02	2.12E+00	1.22E+01	1.22E+01	
36	1.01E-02	1.43E+00	8.21E+00	8.21E+00	
37.8	7.66E-03	9.59E-01	5.54E+00	5.54E+00	
39.6	5.83E-03	6.45E-01	3.73E+00	3.73E+00	
41.4	4.44E-03	4.34E-01	2.52E+00	2.52E+00	
43.2	3.38E-03	2.92E-01	1.69E+00	1.69E+00	
45	2.57E-03	1.97E-01	1.14E+00	1.14E+00	
46.8	1.96E-03	1.32E-01	7.68E-01	7.68E-01	
48.6	1.49E-03	8.92E-02	5.17E-01	5.17E-01	
50.4	1.14E-03	6.01E-02	3.48E-01	3.48E-01	
52.2	8.65E-04	4.05E-02	2.34E-01	2.34E-01	
54	6.58E-04	2.73E-02	1.58E-01	1.58E-01	
55.8	5.01E-04	1.84E-02	1.06E-01	1.06E-01	
57.6	3.82E-04	1.24E-02	7.14E-02	7.14E-02	
59.4	2.91E-04	8.38E-03	4.81E-02	4.81E-02	
61.2	2.21E-04	5.66E-03	3.24E-02	3.24E-02	
63	1.68E-04	3.82E-03	2.18E-02	2.18E-02	
64.8	1.28E-04	2.59E-03	1.47E-02	1.47E-02	
66.6	9.76E-05	1.75E-03	9.90E-03	9.90E-03	
68.4	7.43E-05	1.18E-03	6.68E-03	6.68E-03	
70.2	5.66E-05	8.03E-04	4.50E-03	4.50E-03	
72	4.31E-05	5.45E-04	3.04E-03	3.04E-03	
73.8	3.28E-05	3.70E-04	2.05E-03	2.05E-03	
75.6	2.50E-05	2.52E-04	1.39E-03	1.39E-03	
77.4	1.90E-05	1.71E-04	9.37E-04	9.37E-04	
79.2	1.45E-05	1.17E-04	6.34E-04	6.34E-04	
81	1.10E-05	7.99E-05	4.29E-04	4.29E-04	
82.8	8.38E-06	5.47E-05	2.91E-04	2.91E-04	
84.6	6.38E-06	3.75E-05	1.97E-04	1.97E-04	
86.4	4.86E-06	2.58E-05	1.34E-04	1.34E-04	
88.2	3.70E-06	1.78E-05	9.10E-05	9.10E-05	
90	2.82E-06	1.23E-05	6.20E-05	6.20E-05	
MAXIMUM:	2.35E+00	4.00E+03	9.15E+02	9.15E+02	

9 yr →

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TRANS-1,2-DCE; SOIL CONC. = 10 UG/KG; GW CONC. =4000 UG/L; AT THE SMALL POND



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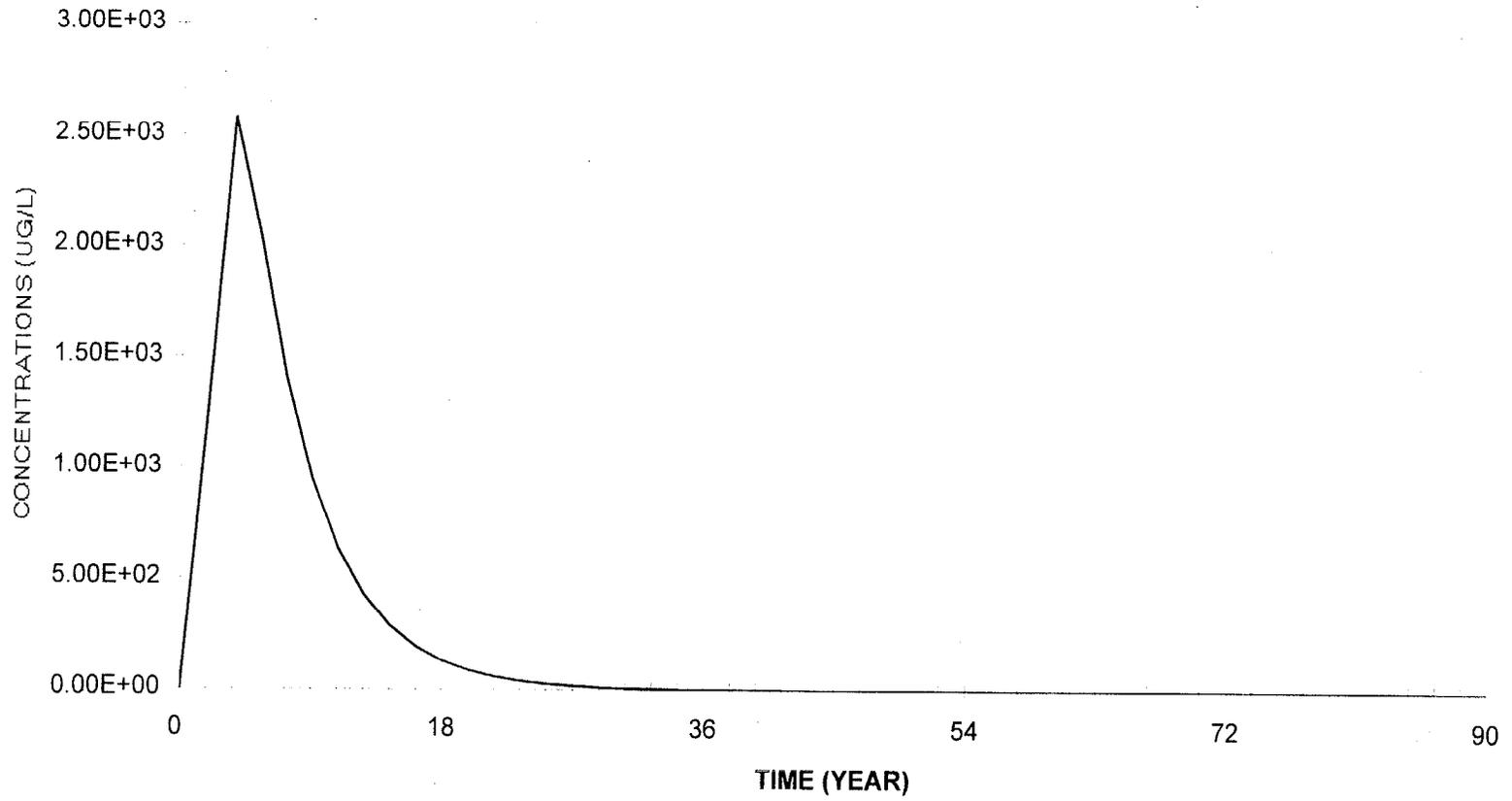


SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/10/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	trans-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL)	FL
HALF-LIFE (YRS):	7.92E+00	UNDERS: Under source, FL: Fenceline	
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	WATER CRITERIA (UG/L):	1.35E+03
		TIME FRAME (YRS):	90
		LEACHATE CONCENTRATION (YES,NO)?	NO
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	1.000E-02
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	5.23E-03
		ACCEPTABLE!	DECREASE
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FT/YR):	8.30E-01
K1 (L/KG):	4.25E+00	LENGTH (FT):	130
DEPLETING SOURCE:		WIDTH (FT):	190
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	1.00E-02	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM <sup>3</sup> ):	1.5	BULK DENSITY (G/CM <sup>3</sup> ):	1.78
		Kd (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E-01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM <sup>3</sup> ):	1.5	BULK DENSITY (G/CM <sup>3</sup> ):	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>z0</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	5.78E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, A <sub>z</sub> (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, A <sub>x</sub> (FT):	1.5	AGE (YRS):	0
LATERAL DISPERSIVITY, A <sub>y</sub> (FT):	0.5	CONC. IN UPGRADIENT GROUNDWATER, CU <sub>2</sub> (UG/L)	0
INITIAL CONC. (ug/L):	4.000E+03	DISTANCE TO Fence Line:	15
PREDICTED IMPACTS:			TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	4.00E+03 (UG/L)		0
FENCE LINE CONCENTRATION:	2.58E+03 (UG/L)		3.6



TRANS-1,2-DCE; SOIL CONC. = 10 UG/KG; GW CONC. =4000 UG/L; AT THE SENTRY WELL



**BENZENE**

Copyright 1997



SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/10/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	Benzene	EXPOSURE POINT: (UNDERS, FL) UNDERS: Under source, FL: Fenceline	LEACHATE CONCENTRATION (YES,NO) ? NO
HALF-LIFE (YRS):	2.00E+00	WATER CRITERIA (UG/L): 7.13E+01	INPUT SOLID-PHASE CONCENTRATION (MG/KG) 0.000E-00
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	TIME FRAME (YRS): 90	CONSTANT CONCENTRATION (YES,NO)? NO
			TRY NEW GOAL: 0.00E+00
			ACCEPTABLE? INCREASE

SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FT/YR):	8.30E-01
Ki (L/KG):	5.98E+00	LENGTH (FT):	145
DEPLETING SOURCE:		WIDTH (FT):	85
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3):	1.78
		Kd (L/KG):	1.00E-05

IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG)	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC (MG/KG)	0	INITIAL SOIL CONC (MG/KG)	0

SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>z0</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG)	8.13E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	9.5	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	3.2	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC (ug/L):	2.500E+01	DISTANCE TO Fence Line.:	95

PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	2.50E+01 (UG/L)	0
FENCE LINE CONCENTRATION:	1.99E-01 (UG/L)	9

BROWN & ROOT ENVIRONMENTAL  
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ETran) MODEL

SITE: SWMU 9. NAS, Key West

CONTAMINANT: Benzene

INVESTIGATOR: LK  
DATE: 5/10/99

HALF-LIFE (YRS):		
LAYER 2:	2.00E+00	
SATURATED LAYER	2.00E+00	
DOWNGRADIENT	2.00E+00	INITIAL CONC. (ug/L) 2.50E+01

SATURATED LAYER

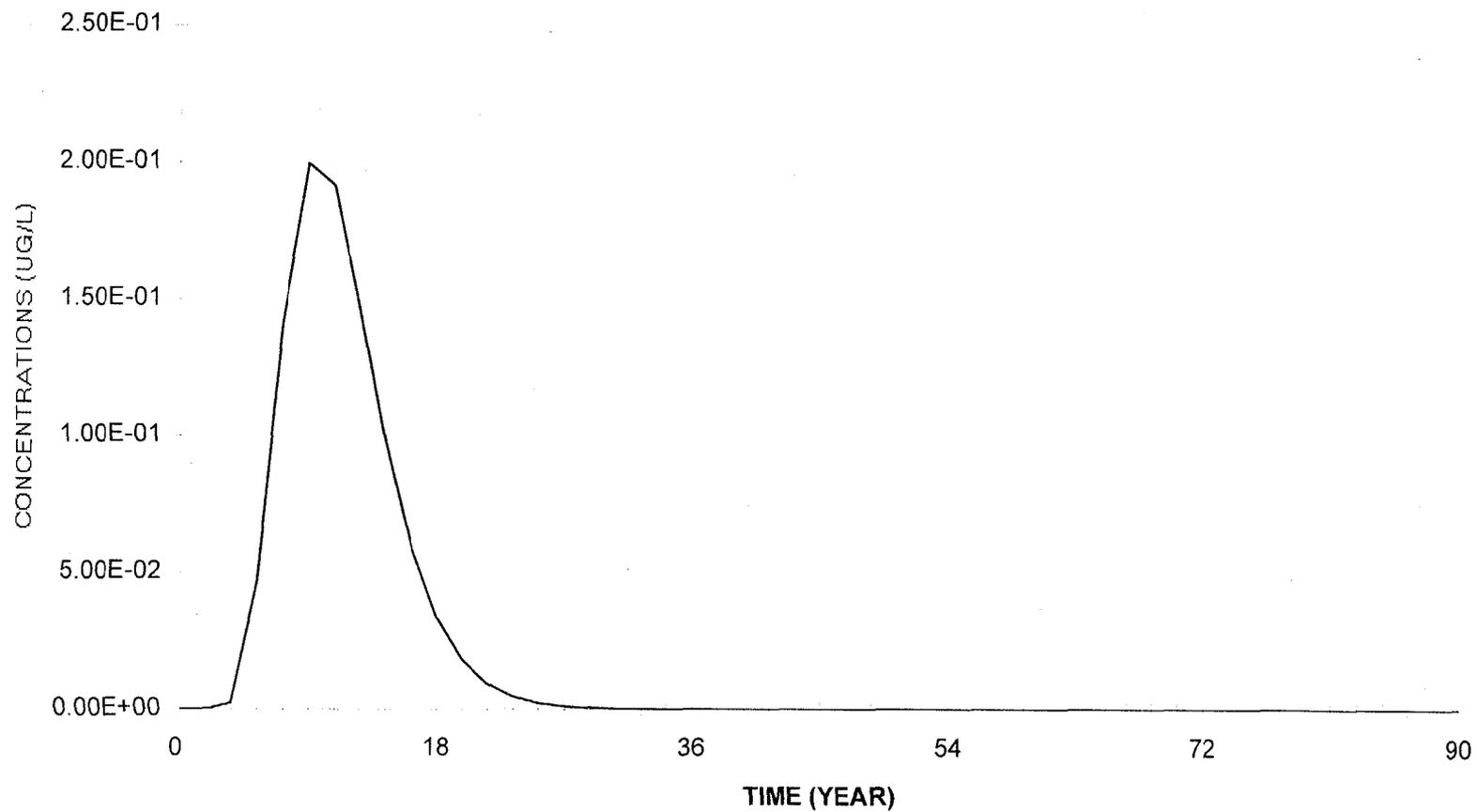
INFILT (FT/YR): 0.83		B (FT): 27	Vzo (FT/YR): 4.48
LENGTH (FT): 145		GW Q3 (L/DAY): 1.27E+03	
WIDTH (FT): 85		GW V. (FT/YR): 8.99	Kd (L/KG): 0.08134
POROSITY 2: 0.3		H (FT): 27.0000	RETARDATION: 1.4067
POROSITY SAT. LAYER: 0.3		EFF POROSITY: 0.30	q (FT/YR): 0
DENSITY 2 (G/CM3): 1.5		DISPERSIVITY:	DECAY (1/YR): 3.5E-01
DENSITY GMA (G/CM3): 1.50		Az (FT): 0.14	
		Ax (FT): 9.50	P&T (YEARS): 0
AGE (YEARS): 0	Q1 (L/DAY): 7.94E+02	Av (FT): 3.17	DISTANCE TO F.L. (FT): 95

TIME INTERVAL (YRS) 1.8		SOURCE AREA CONC (GMA)		FENCE LINE CONC	
ELAPSED TIME - YRS	LAYER 2 (PPB)	(UG/L)		(UG/L)	
0	0.00E+00	2.50E+01		0.00E+00	
1.8	0.00E+00	1.09E+01		1.11E-07	
3.6	0.00E+00	4.71E+00		2.39E-03	
5.4	0.00E+00	2.05E+00		4.63E-02	
7.2	0.00E+00	8.88E-01		1.41E-01	
9	0.00E+00	3.86E-01		1.99E-01	
10.8	0.00E+00	1.67E-01		1.91E-01	
12.6	0.00E+00	7.27E-02		1.47E-01	
14.4	0.00E+00	3.16E-02		9.79E-02	
16.2	0.00E+00	1.37E-02		5.94E-02	
18	0.00E+00	5.95E-03		3.36E-02	
19.8	0.00E+00	2.58E-03		1.81E-02	
21.6	0.00E+00	1.12E-03		9.42E-03	
23.4	0.00E+00	4.87E-04		4.75E-03	
25.2	0.00E+00	2.11E-04		2.34E-03	
27	0.00E+00	9.18E-05		1.13E-03	
28.8	0.00E+00	3.98E-05		5.41E-04	
30.6	0.00E+00	1.73E-05		2.55E-04	
32.4	0.00E+00	7.51E-06		1.19E-04	
34.2	0.00E+00	3.26E-06		5.48E-05	
36	0.00E+00	1.42E-06		2.51E-05	
37.8	0.00E+00	6.15E-07		1.14E-05	
39.6	0.00E+00	2.67E-07		5.18E-06	
41.4	0.00E+00	1.16E-07		2.34E-06	
43.2	0.00E+00	5.03E-08		1.05E-06	
45	0.00E+00	2.18E-08		4.69E-07	
46.8	0.00E+00	9.48E-09		2.09E-07	
48.6	0.00E+00	4.12E-09		9.30E-08	
50.4	0.00E+00	1.79E-09		4.12E-08	
52.2	0.00E+00	7.76E-10		1.83E-08	
54	0.00E+00	3.37E-10		8.06E-09	
55.8	0.00E+00	1.46E-10		3.55E-09	
57.6	0.00E+00	6.35E-11		1.56E-09	
59.4	0.00E+00	2.76E-11		6.88E-10	
61.2	0.00E+00	1.20E-11		3.02E-10	
63	0.00E+00	5.20E-12		1.32E-10	
64.8	0.00E+00	2.26E-12		5.84E-11	
66.6	0.00E+00	9.79E-13		2.54E-11	
68.4	0.00E+00	4.25E-13		1.10E-11	
70.2	0.00E+00	1.85E-13		4.78E-12	
72	0.00E+00	8.02E-14		2.07E-12	
73.8	0.00E+00	3.48E-14		9.01E-13	
75.6	0.00E+00	1.51E-14		3.91E-13	
77.4	0.00E+00	6.56E-15		1.70E-13	
79.2	0.00E+00	2.85E-15		7.43E-14	
81	0.00E+00	1.24E-15		3.16E-14	
82.8	0.00E+00	5.37E-16		1.38E-14	
84.6	0.00E+00	2.33E-16		6.14E-15	
86.4	0.00E+00	1.01E-16		2.61E-15	
88.2	0.00E+00	4.39E-17		1.23E-15	
90	0.00E+00	1.91E-17		3.07E-16	
MAXIMUM:	0.00E+00	2.50E+01		1.99E-01	

9 yr →

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**BENZENE; SOIL CONC. = 0 UG/KG; GW CONC. =25 UG/L; AT THE SMALL POND**



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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/10/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	Benzene	EXPOSURE POINT: (UNDERS, FL)	FL
HALF-LIFE (YRS)	2.00E+00	UNDERS: Under source, FL: Fenceline	
SPECIFIC ACTIVITY (Ci/g)	0.00E+00	WATER CRITERIA (UG/L):	7.13E+01
		TIME FRAME (YRS):	90
		LEACHATE CONCENTRATION (YES,NO) ?	NO
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	0.000E+00
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	0.00E+00
		ACCEPTABLE!	INCREASE
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke	1.00	INFILT(FT/YR):	8.30E-01
K1 (L/KG)	5.98E+00	LENGTH (FT):	145
		WIDTH (FT):	85
DEPLETING SOURCE:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
WASTE CHARACTERISTICS:		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	HOW MANY SUBLAYERS (1 - 10)?	3
INPUT FOLLOWING PARAMETERS:		TOTAL THICKNESS (UP TO 30 FT) (FT):	10
THICKNESS (FT):	2	SATURATION RATE:	0.95
SATURATION RATE:	0.6	POROSITY:	0.2
POROSITY:	0.2	BULK DENSITY (G/CM^3):	1.78
BULK DENSITY (G/CM^3)	1.5	Kd (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, Vzo (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	8.13E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	5.0	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	1.7	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	2.500E+01	DISTANCE TO Fence.Line.:	50
PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION:	2.50E+01 (UG/L)		0
FENCE LINE CONCENTRATION:	1.26E+00 (UG/L)		7.2

SITE: SWMU 9, NAS, Key West		CONTAMINANT: Benzene	
INVESTIGATOR: LK		HALF-LIFE (YRS):	
DATE: 5/10/99		LAYER 2: 2.00E+00	
		SATURATED LAYER: 2.00E+00	INITIAL CONC (ug/L): 2.50E+01
		DOWNGRADIENT: 2.00E+00	

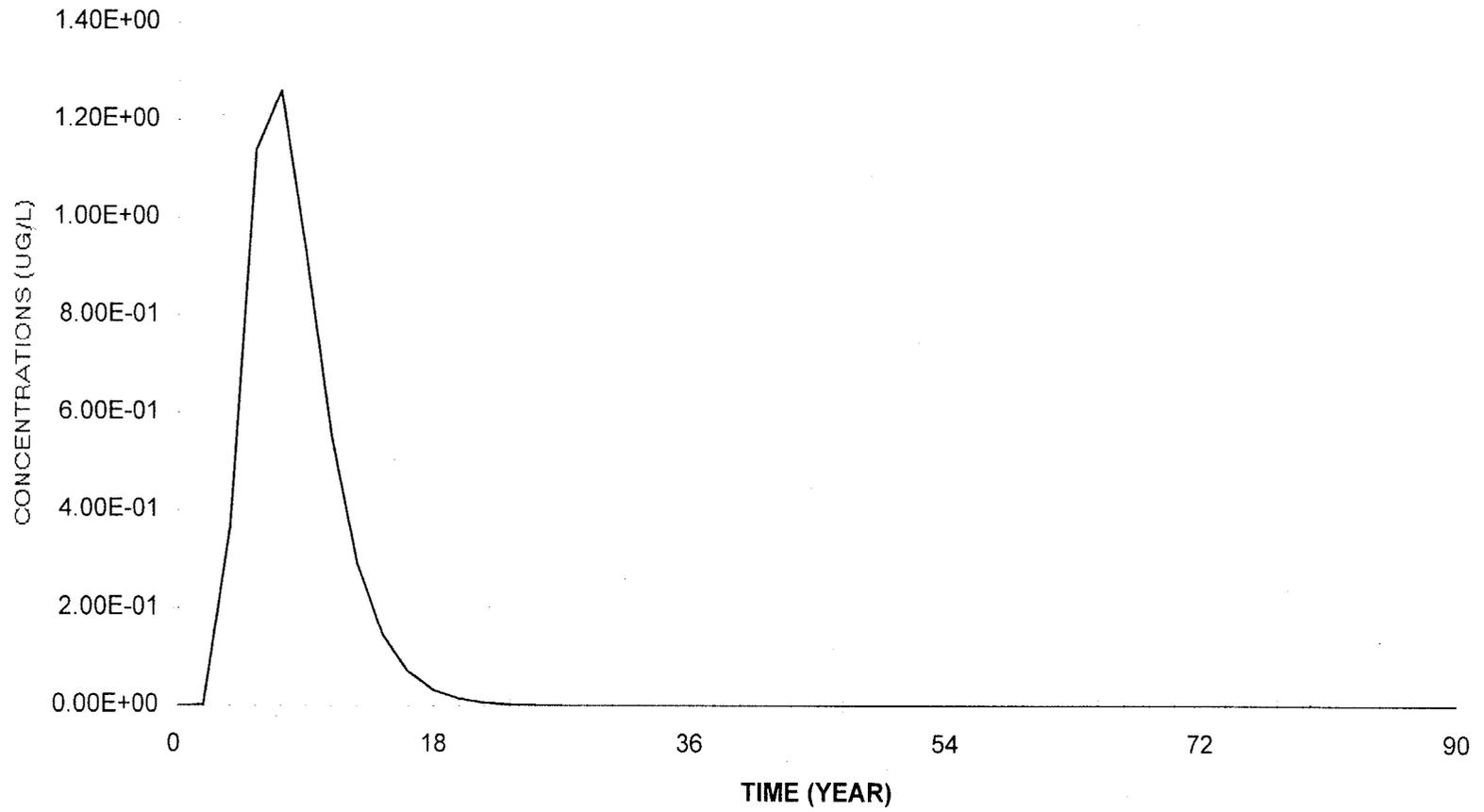
SATURATED LAYER			
INFILT (FT/YR): 0.83		B (FT): 27	Vzo (FT/YR): 4.48
LENGTH (FT): 145		GW Q3 (L/DAY): 1.27E+03	
WIDTH (FT): 85		GW V (FT/YR): 8.99	Kd (L/KG): 0.08134
POROSITY 2: 0.3		H (FT): 27.0000	RETARDATION: 1.4067
POROSITY SAT. LAYER: 0.3		EFF POROSITY: 0.30	q (FT/YR): 0
DENSITY 2 (G/CM3): 1.5		DISPERSIVITY:	DECAY (1/YR): 3.5E-01
DENSITY GMA (G/CM3): 1.50		Az (FT): 0.14	
AGE (YEARS): 0	Q1 (L/DAY): 7.94E+02	Ax (FT): 5.00	P&T (YEARS): 0
		Ay (FT): 1.67	DISTANCE TO F.L. (FT): 50
		Q2 (L/DAY): 4.80E+02	

TIME INTERVAL (YRS) 1.8		SOURCE AREA CONC (GMA) (UG/L)		FENCE LINE CONC (UG/L)	
ELAPSED TIME - YRS	LAYER 2 (PPB)				
0	0.00E+00		2.50E+01		0.00E+00
1.8	0.00E+00		1.09E+01		2.51E-03
3.6	0.00E+00		4.71E+00		3.63E-01
5.4	0.00E+00		2.05E+00		1.14E+00
7.2	0.00E+00		8.88E-01		1.26E+00 ←
9	0.00E+00		3.86E-01		9.21E-01
10.8	0.00E+00		1.67E-01		5.49E-01
12.6	0.00E+00		7.27E-02		2.91E-01
14.4	0.00E+00		3.16E-02		1.44E-01
16.2	0.00E+00		1.37E-02		6.86E-02
18	0.00E+00		5.95E-03		3.16E-02
19.8	0.00E+00		2.58E-03		1.43E-02
21.6	0.00E+00		1.12E-03		6.40E-03
23.4	0.00E+00		4.87E-04		2.83E-03
25.2	0.00E+00		2.11E-04		1.25E-03
27	0.00E+00		9.18E-05		5.46E-04
28.8	0.00E+00		3.98E-05		2.39E-04
30.6	0.00E+00		1.73E-05		1.04E-04
32.4	0.00E+00		7.51E-06		4.53E-05
34.2	0.00E+00		3.26E-06		1.97E-05
36	0.00E+00		1.42E-06		8.58E-06
37.8	0.00E+00		6.15E-07		3.73E-06
39.6	0.00E+00		2.67E-07		1.62E-06
41.4	0.00E+00		1.16E-07		7.04E-07
43.2	0.00E+00		5.03E-08		3.06E-07
45	0.00E+00		2.18E-08		1.33E-07
46.8	0.00E+00		9.48E-09		5.76E-08
48.6	0.00E+00		4.12E-09		2.50E-08
50.4	0.00E+00		1.79E-09		1.09E-08
52.2	0.00E+00		7.76E-10		4.72E-09
54	0.00E+00		3.37E-10		2.05E-09
55.8	0.00E+00		1.46E-10		8.89E-10
57.6	0.00E+00		6.35E-11		3.86E-10
59.4	0.00E+00		2.76E-11		1.68E-10
61.2	0.00E+00		1.20E-11		7.28E-11
63	0.00E+00		5.20E-12		3.16E-11
64.8	0.00E+00		2.26E-12		1.37E-11
66.6	0.00E+00		9.79E-13		5.95E-12
68.4	0.00E+00		4.25E-13		2.59E-12
70.2	0.00E+00		1.85E-13		1.12E-12
72	0.00E+00		8.02E-14		4.87E-13
73.8	0.00E+00		3.48E-14		2.12E-13
75.6	0.00E+00		1.51E-14		9.11E-14
77.4	0.00E+00		6.56E-15		3.94E-14
79.2	0.00E+00		2.85E-15		1.85E-14
81	0.00E+00		1.24E-15		5.40E-15
82.8	0.00E+00		5.37E-16		3.86E-15
84.6	0.00E+00		2.33E-16		1.54E-15
86.4	0.00E+00		1.01E-16		7.72E-16
88.2	0.00E+00		4.39E-17		0.00E+00
90	0.00E+00		1.91E-17		0.00E+00
MAXIMUM:	0.00E+00		2.50E+01		1.26E+00

7.2 →

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BENZENE; SOIL CONC. = 0 UG/KG; GW CONC. =25 UG/L; AT THE SENTRY WELL



**TRICHLOROETHENE (TCE)**

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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/10/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT: Trichloroethene (TCE)	EXPOSURE POINT: (UNDERS, FL) FL	LEACHATE CONCENTRATION (YES,NO) ?	NO
HALF-LIFE (YRS): 4.50E+00	UNDERS: Under source, FL: Fenceline	INPUT SOLID-PHASE CONCENTRATION (MG/KG)	0.000E+00
SPECIFIC ACTIVITY (Ci/g): 0.00E+00	WATER CRITERIA (UG/L): 8.07E+01	CONSTANT CONCENTRATION (YES,NO)?	NO
	TIME FRAME (YRS): 90	TRY NEW GOAL:	0.00E+00
		ACCEPTABLE?	INCREASE
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FT/YR):	5.30E-01
K1 (L/KG):	9.07E+00	LENGTH (FT):	110
DEPLETING SOURCE:		WIDTH (FT):	130
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM^3):	1.5	BULK DENSITY (G/CM^3):	1.78
		Kd (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3):	1.5	BULK DENSITY (G/CM^3):	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, Vzo (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	1.23E-01	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	8.7	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	2.9	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	3.500E+02	DISTANCE TO Fence Line:	87
PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION:	3.50E+02 (UG/L)		0
FENCE LINE CONCENTRATION:	1.69E+01 (UG/L)		12.6

BROWN & ROOT ENVIRONMENTAL  
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTran) MODEL

SITE: SWMU 9, NAS, Key West		CONTAMINANT: Trichloroethene (TCE)	
INVESTIGATOR: LK	DATE: 5/10/99	HALF-LIFE (YRS): LAYER 2: 4.50E+00	SATURATED LAYER DOWNGRADIENT: 4.50E+00
		INITIAL CONC. (ug/L): 3.50E+02	

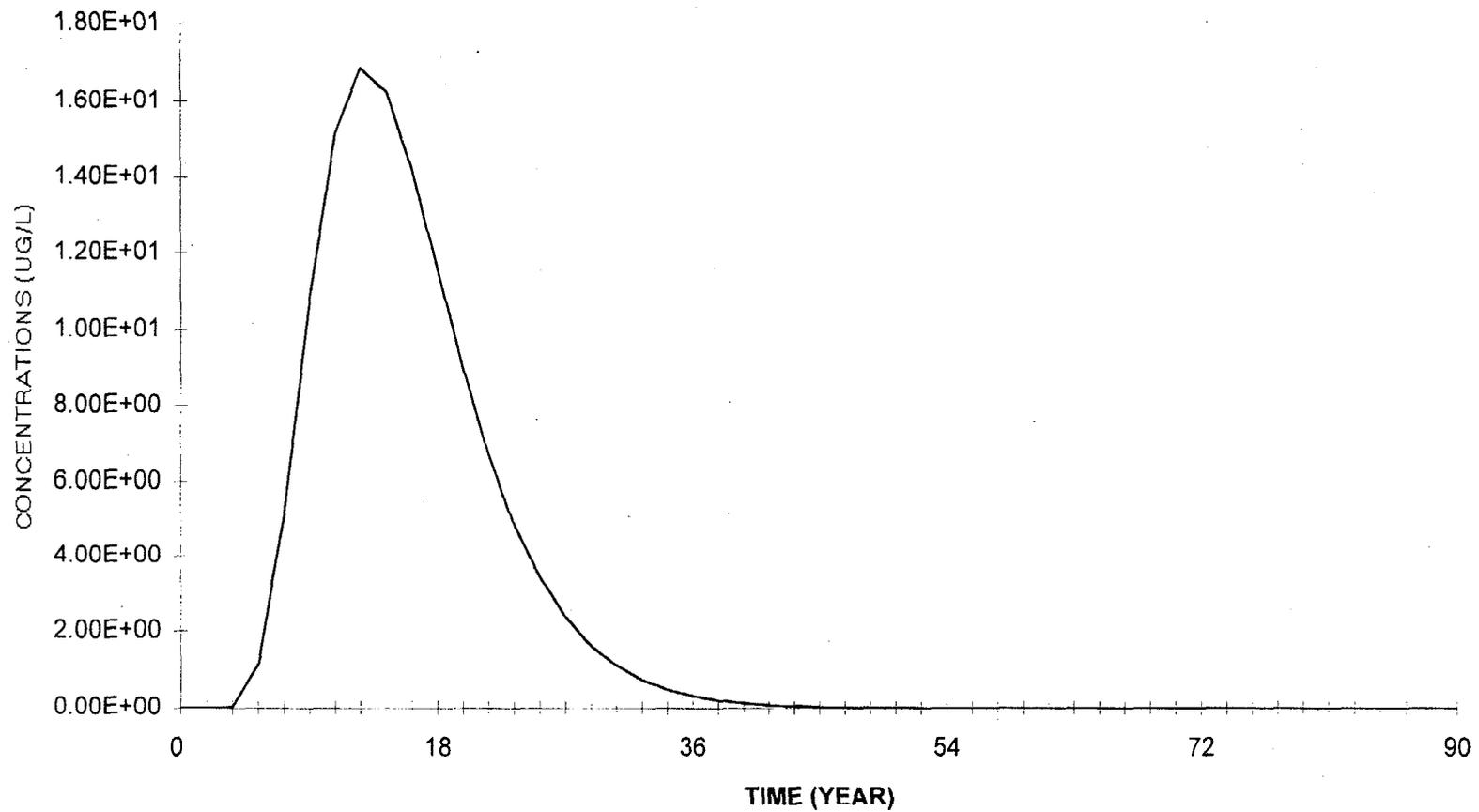
SATURATED LAYER			
INFILT (FT/YR): 0.83	LENGTH (FT): 110	WIDTH (FT): 130	POROSITY 2: 0.3
POROSITY SAT. LAYER: 0.3	DENSITY 2 (G/CM3): 1.5	DENSITY GMA (G/CM3): 1.50	AGE (YEARS): 0
Q1 (L/DAY): 9.21E+02	Kd (L/KG): 1.23E-01	SATURATION: 1.00	THICKNESS (FT): 27.00
DECAY (1/DAY): 4.22E-04	CB0 (PPB): 3.50E+02	CU2 (PPB): 0.00E+00	Q2 (L/DAY): 7.34E+02
B (FT): 27	GW Q3 (L/DAY): 1.66E+03	H (FT): 27.0000	EFF. POROSITY: 0.30
Vz0 (FT/YR): 4.48	Kd (L/KG): 0.12348	RETARDATION: 1.6174	q (FT/YR): 0
DISPERSIVITY: 0.14	Az (FT): 0.14	Ax (FT): 8.70	DECAY (1/YR): 1.5E-01
Ay (FT): 2.90	P&T (YEARS): 0	DISTANCE TO F.L. (FT): 87	

TIME INTERVAL (YRS)	LAYER 2 (PPB)	SOURCE AREA CONC. (GMA) (UG/L)	FENCE LINE CONC (UG/L)
0	0.00E+00	3.50E+02	0.00E+00
1.8	0.00E+00	2.16E+02	7.47E-07
3.6	0.00E+00	1.33E+02	3.70E-02
5.4	0.00E+00	8.24E+01	1.14E+00
7.2	0.00E+00	5.08E+01	5.20E+00
9	0.00E+00	3.14E+01	1.08E+01
10.8	0.00E+00	1.94E+01	1.52E+01
12.6	0.00E+00	1.20E+01	1.69E+01
14.4	0.00E+00	7.38E+00	1.63E+01
16.2	0.00E+00	4.56E+00	1.42E+01
18	0.00E+00	2.81E+00	1.16E+01
19.8	0.00E+00	1.74E+00	8.97E+00
21.6	0.00E+00	1.07E+00	6.68E+00
23.4	0.00E+00	6.62E-01	4.83E+00
25.2	0.00E+00	4.09E-01	3.41E+00
27	0.00E+00	2.52E-01	2.36E+00
28.8	0.00E+00	1.56E-01	1.61E+00
30.6	0.00E+00	9.62E-02	1.09E+00
32.4	0.00E+00	5.94E-02	7.24E-01
34.2	0.00E+00	3.67E-02	4.78E-01
36	0.00E+00	2.26E-02	3.13E-01
37.8	0.00E+00	1.40E-02	2.03E-01
39.6	0.00E+00	8.63E-03	1.32E-01
41.4	0.00E+00	5.33E-03	8.47E-02
43.2	0.00E+00	3.29E-03	5.43E-02
45	0.00E+00	2.03E-03	3.46E-02
46.8	0.00E+00	1.25E-03	2.20E-02
48.6	0.00E+00	7.74E-04	1.40E-02
50.4	0.00E+00	4.78E-04	8.84E-03
52.2	0.00E+00	2.95E-04	5.58E-03
54	0.00E+00	1.82E-04	3.51E-03
55.8	0.00E+00	1.12E-04	2.21E-03
57.6	0.00E+00	6.94E-05	1.39E-03
59.4	0.00E+00	4.28E-05	8.68E-04
61.2	0.00E+00	2.64E-05	5.43E-04
63	0.00E+00	1.63E-05	3.39E-04
64.8	0.00E+00	1.01E-05	2.12E-04
66.6	0.00E+00	6.22E-06	1.32E-04
68.4	0.00E+00	3.84E-06	8.23E-05
70.2	0.00E+00	2.37E-06	5.12E-05
72	0.00E+00	1.46E-06	3.19E-05
73.8	0.00E+00	9.04E-07	1.98E-05
75.6	0.00E+00	5.58E-07	1.23E-05
77.4	0.00E+00	3.44E-07	7.64E-06
79.2	0.00E+00	2.13E-07	4.74E-06
81	0.00E+00	1.31E-07	2.94E-06
82.8	0.00E+00	8.10E-08	1.83E-06
84.6	0.00E+00	5.00E-08	1.13E-06
86.4	0.00E+00	3.09E-08	7.01E-07
88.2	0.00E+00	1.91E-08	4.34E-07
90	0.00E+00	1.18E-08	2.69E-07
MAXIMUM:	0.00E+00	3.50E+02	1.69E+01

12.6 yr →

←

TCE; SOIL CONC. = 0 UG/KG; GW CONC. = 350 UG/L; AT THE SMALL POND



Copyright 1997



SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/10/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	Trichloroethene (TCE)	EXPOSURE POINT: (UNDERS, FL) UNDERS: Under source, FL: Fenceline	FL
HALF-LIFE (YRS):	4.50E+00	WATER CRITERIA (UG/L):	8.07E+01
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	TIME FRAME (YRS):	90
		LEACHATE CONCENTRATION (YES,NO)?	NO
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	0.000E+00
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	0.00E+00
		ACCEPTABLE!	INCREASE
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
K <sub>e</sub> :	1.00	INFILT (FT/YR):	8.30E-01
K <sub>i</sub> (L/KG):	9.07E+00	LENGTH (FT):	110
DEPLETING SOURCE:		WIDTH (FT):	130
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM <sup>3</sup> ):	1.5	BULK DENSITY (G/CM <sup>3</sup> ):	1.78
		K <sub>d</sub> (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM <sup>3</sup> ):	1.5	BULK DENSITY (G/CM <sup>3</sup> ):	1.5
K <sub>d</sub> (L/KG):	1.00E-05	K <sub>d</sub> (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>zo</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
K <sub>d</sub> (L/KG):	1.23E-01	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, A <sub>z</sub> (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, A <sub>x</sub> (FT):	4.5	AGE (YRS):	0
LATERAL DISPERSIVITY, A <sub>y</sub> (FT):	1.5	CONC. IN UPGRADIENT GROUNDWATER, CU <sub>2</sub> (UG/L)	0
INITIAL CONC. (ug/L):	3.500E+02	DISTANCE TO Fence Line:	45
PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION:	3.50E+02 (UG/L)		0
FENCE LINE CONCENTRATION:	5.39E+01 (UG/L)		9

SITE:	SWMU 9. NAS.Key West	CONTAMINANT:	Trichloroethene (TCE)	
INVESTIGATOR:	LK	HALF-LIFE (YRS):		
DATE:	5/10/99	LAYER 2:	4.50E+00	
		SATURATED LAYER	4.50E+00	
		DOWNGRADIENT	4.50E+00	INITIAL CONC. (ug/L): 3.50E+02

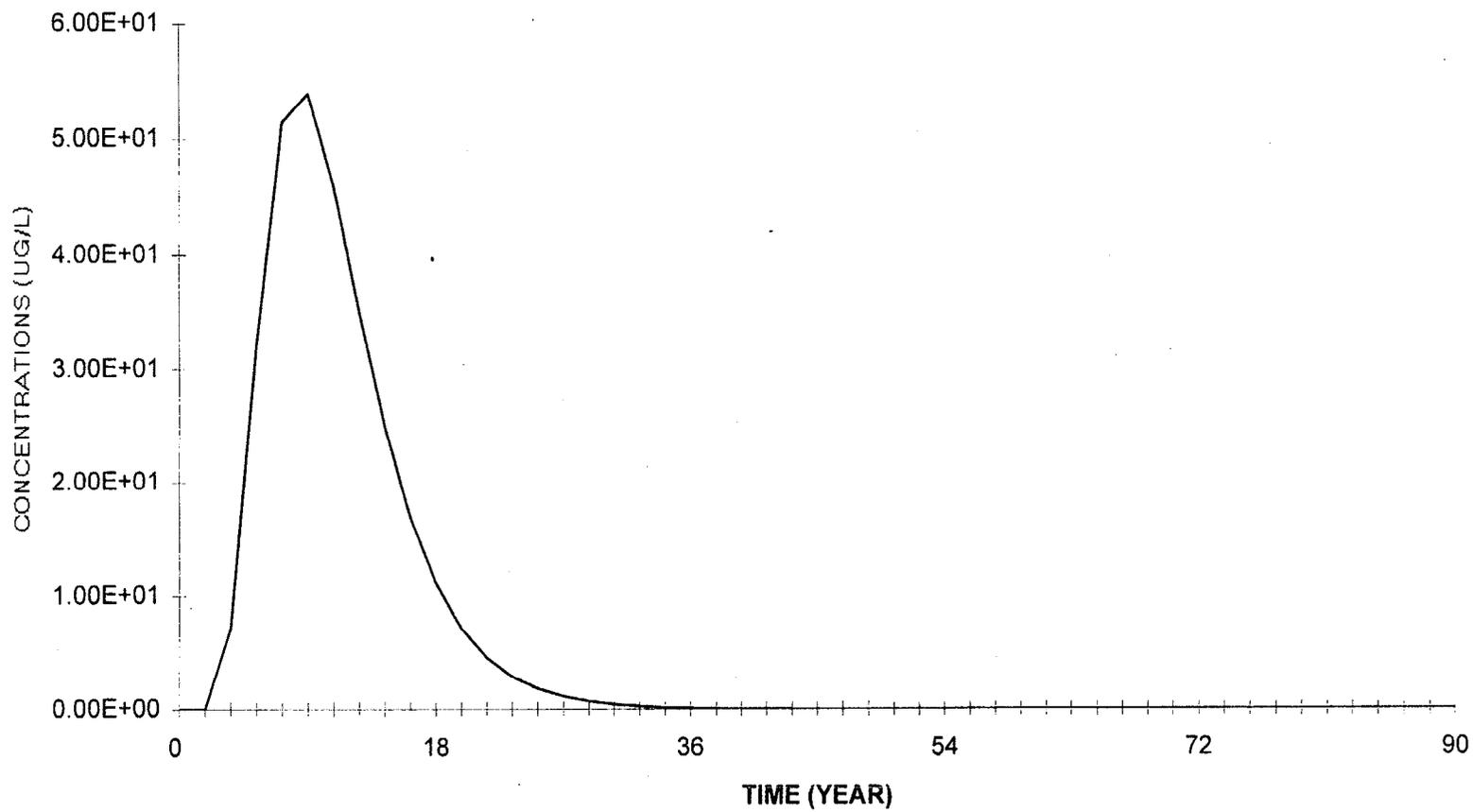
SATURATED LAYER							
INFILT (FT/YR):	0.83			B (FT):	27	Vzo (FT/YR):	4.48
LENGTH (FT):	110			GW Q3 (L/DAY):	1.66E+03		
WIDTH (FT):	130	Kd (L/KG):	1.23E-01	GW V. (FT/YR):	8.99	Kd (L/KG):	0.12348
POROSITY 2:	0.3	SATURATION:	1.00	H (FT):	27.0000	RETARDATION:	1.6174
POROSITY SAT. LAYER:	0.3	THICKNESS (FT):	27.00	EFF. POROSITY:	0.30	q (FT/YR)	0
DENSITY 2 (G/CM3):	1.5	DECAY (1/DAY):	4.22E-04	DISPERSIVITY:		DECAY (1/YR)	1.5E-01
DENSITY GMA (G/CM3):	1.50	CBo (PPB):	3.50E+02	Az (FT):	0.14		
		CU2 (PPB):	0.00E+00	As (FT):	4.50	P&T (YEARS):	0
AGE (YEARS):	0	Q2 (L/DAY):	7.34E+02	Ay (FT):	1.50	DISTANCE TO F.L. (FT):	45
		Q1 (L/DAY):	9.21E+02				

TIME INTERVAL (YRS)		SOURCE AREA CONC. (GMA)		FENCE LINE CONC.	
ELAPSED TIME - YRS		(UG/L)		(UG/L)	
TIME INTERVAL (YRS)	LAYER 2 (PPB)				
0	0.00E+00	3.50E+02		0.00E+00	
1.8	0.00E+00	2.16E+02		3.18E-02	
3.6	0.00E+00	1.33E+02		7.20E+00	
5.4	0.00E+00	8.24E+01		3.23E+01	
7.2	0.00E+00	5.08E+01		5.14E+01	
9	0.00E+00	3.14E+01		5.39E+01	
10.8	0.00E+00	1.94E+01		4.60E+01	
12.6	0.00E+00	1.20E+01		3.50E+01	
14.4	0.00E+00	7.38E+00		2.48E+01	
16.2	0.00E+00	4.56E+00		1.68E+01	
18	0.00E+00	2.81E+00		1.11E+01	
19.8	0.00E+00	1.74E+00		7.15E+00	
21.6	0.00E+00	1.07E+00		4.56E+00	
23.4	0.00E+00	6.62E-01		2.87E+00	
25.2	0.00E+00	4.09E-01		1.80E+00	
27	0.00E+00	2.52E-01		1.12E+00	
28.8	0.00E+00	1.56E-01		6.99E-01	
30.6	0.00E+00	9.62E-02		4.34E-01	
32.4	0.00E+00	5.94E-02		2.69E-01	
34.2	0.00E+00	3.67E-02		1.66E-01	
36	0.00E+00	2.26E-02		1.03E-01	
37.8	0.00E+00	1.40E-02		6.36E-02	
39.6	0.00E+00	8.63E-03		3.93E-02	
41.4	0.00E+00	5.33E-03		2.43E-02	
43.2	0.00E+00	3.29E-03		1.50E-02	
45	0.00E+00	2.03E-03		9.26E-03	
46.8	0.00E+00	1.25E-03		5.72E-03	
48.6	0.00E+00	7.74E-04		3.53E-03	
50.4	0.00E+00	4.78E-04		2.18E-03	
52.2	0.00E+00	2.95E-04		1.35E-03	
54	0.00E+00	1.82E-04		8.31E-04	
55.8	0.00E+00	1.12E-04		5.13E-04	
57.6	0.00E+00	6.94E-05		3.17E-04	
59.4	0.00E+00	4.28E-05		1.95E-04	
61.2	0.00E+00	2.64E-05		1.21E-04	
63	0.00E+00	1.63E-05		7.45E-05	
64.8	0.00E+00	1.01E-05		4.60E-05	
66.6	0.00E+00	6.22E-06		2.84E-05	
68.4	0.00E+00	3.84E-06		1.75E-05	
70.2	0.00E+00	2.37E-06		1.08E-05	
72	0.00E+00	1.46E-06		6.68E-06	
73.8	0.00E+00	9.04E-07		4.12E-06	
75.6	0.00E+00	5.58E-07		2.55E-06	
77.4	0.00E+00	3.44E-07		1.57E-06	
79.2	0.00E+00	2.13E-07		9.70E-07	
81	0.00E+00	1.31E-07		5.99E-07	
82.8	0.00E+00	8.10E-08		3.70E-07	
84.6	0.00E+00	5.00E-08		2.28E-07	
86.4	0.00E+00	3.09E-08		1.41E-07	
88.2	0.00E+00	1.91E-08		8.70E-08	
90	0.00E+00	1.18E-08		5.37E-08	
MAXIMUM:	0.00E+00	3.50E+02		5.39E+01	

9yr →

←

TCE; SOIL CONC. = 0 UG/KG; GW CONC. = 350 UG/L; AT THE SENTRY WELL



**APPENDIX C**

**SWMU 9 DATA SET AND CHAIN OF CUSTODY FORMS**

**Tetra Technus**  
Brown & Root Environmental  
REPORT TO ADDRESS: 900 Trail Ridge Road  
Aiken SC 29803  
TELEPHONE: \_\_\_\_\_ FAX: \_\_\_\_\_

SITE MANAGER: Marty Ray  
PROJECT NAME: Natural Attenuation SWMVA  
BRE PROJECT NO.: 7046 ADOS CODE: G120  
P.O. NO.: P9838

SHIPPED TO: PAGE 1 OF 1  
Savannah Laboratories  
5102 LaRoche Avenue  
Savannah GA 31404 (LABORATORY NAME, CITY)

**CHAIN OF CUSTODY RECORD**

**LABORATORY ANALYSIS**

SAMPLED BY (PRINT): Andy Kendrick / Scott Flickinger  
SAMPLER SIGNATURE: [Signature]

PREP. TYPE: 1  
PARAMETERS: Ammonia NH3  
MN-FEH63Tox 9060HCLHCLMethaneSulfide H2SZn  
NUMBER OF CONTAINERS: \_\_\_\_\_  
 STANDARD TAT  RUSH  
 24 HR.  48 HR.  72 HR.  7 DAY:  
RESULTS DUE DATE: 30 days  
COMMENTS: \_\_\_\_\_

LAB NO.	DATE	TIME	SAMPLE IDENTIFICATION	COMP.	GRAB	MATRIX
<del>S9MW-12</del>	<del>5-13-98</del>	<del>1300</del>	<del>(DF)</del>			
	5-13-98	1300	S9MW-12	X		A
	5-13-98	1545	S9MW-3	X		A
	5-6-98	-	TB01	X		A

TOTAL NUMBER OF CONTAINERS 222962

EMPTY BOTTLES RELINQUISHED BY (SIGNATURE) ① <u>Scampbell Sav. Lab</u>	SEAL INTACT? <input checked="" type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> N/A	DATE: <u>5/12/98</u> TIME: <u>520(1720)</u>	EMPTY BOTTLES RECEIVED BY (SIGNATURE) ② <u>S. Flickinger / Scott Flickinger</u>	SEAL INTACT? <input checked="" type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> N/A	DATE: <u>5/13/98</u> TIME: <u>1430</u>
RELINQUISHED BY (SIGNATURE) ③ <u>[Signature]</u>	SEAL INTACT? <input checked="" type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> N/A	DATE: <u>5/13/98</u> TIME: <u>1800</u>	RECEIVED BY (SIGNATURE) ④ <u>Fed Ex 803784079978</u>	SEAL INTACT? <input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> N/A	DATE: _____ TIME: _____
RELINQUISHED BY (SIGNATURE) ⑤ _____	SEAL INTACT? <input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> N/A	DATE: _____ TIME: _____	RECEIVED BY (SIGNATURE) ⑥ _____	SEAL INTACT? <input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> N/A	DATE: _____ TIME: _____

SPECIAL INSTRUCTIONS: \* Nitrite Nitrate analyzed separately

LABORATORY REMARKS: 58-82768

SAMPLE CONTAINERS PRECLEANED BY:  
 BRE  LABORATORY  MANUFACTURER

METHOD OF SHIPMENT: Fed Ex

BILL OF LADING NO.: 803784079978

WHITE-FULLY EXECUTED COPY  
[LOW-RECEIVING LABORATORY COPY  
INK-SAMPLERS' COPY/QA COPY  
COLD-DRAWN COPY

SAMPLING TEAM: See above

RECEIVED FOR LABORATORY BY (SIGNATURE): A. Krause

3007

200000





Tetra Tech NCS  
Brown & Root Environmental  
REPORT TO ADDRESS: 900 Trail Ridge Rd.  
Aiken SC 29803  
TELEPHONE: 803 649 7763 FAX: 803 642 8154

SITE MANAGER: Marty Ray  
PROJECT NAME: Natural Attenuation SWMU  
BRE PROJECT NO.: 7046 ADO5 CODE G120  
P.O. NO.: P98318

SHIPPED TO: Savannah  
Laboratories  
5102 La Roche Avenue  
Savannah GA 31404  
(LABORATORY NAME, CITY)  
PAGE 1 OF 1

CHAIN OF CUSTODY RECORD

LABORATORY ANALYSIS

SAMPLED BY (PRINT): Andy Kendrick / Scott Fluhjeger  
SAMPLER SIGNATURE: *Andy Kendrick / Scott Fluhjeger*

SAMPLE TYPE

PRES. TYPE

STANDARD TAT  RUSH  
 24 HR.  48 HR.  72 HR.  7 DAYS

RESULTS DUE DATE: 30 day

LAB NO.	DATE	TIME	SAMPLE IDENTIFICATION	SAMPLE TYPE		MATRIX	PARAMETERS							NUMBER OF CONTAINERS	COMMENTS	
				COMP.	GRAB		ANIONS/AN	NH FE	TOC	DBP	TRIP	TRIP	Methane			Sulfide
	5-13-98	1735	S9MW8		X	Ag									3	
	5-14-98	0950	S9MW23		X	Ag									3	
	5-14-98	1135	S9MW15 (dup)		X	Ag	1	1	1	3	3	1			10	*
	5-14-98	1330	S9MW19D		X	Ag	1	1	1	3	3	1			10	*
	5-14-98	1420	S9MW17		X	Ag	1	1	1	3	3	1			10	*
	5-6-98	-	TB02		X	Ag				3	3	0			3	

TOTAL NUMBER OF CONTAINERS 3 3 3 18 9 3 39

EMPTY BOTTLES RELINQUISHED BY (SIGNATURE)

① S. Campbell Sav. Lab

SEAL INTACT?  
 YES  NO  N/A

DATE: 5-12-98  
TIME: 1720

EMPTY BOTTLES RECEIVED BY (SIGNATURE)

② Scott Fluhjeger

SEAL INTACT?  
 YES  NO  N/A

DATE: 5/13/98  
TIME: 1430

RELINQUISHED BY (SIGNATURE)

③ Scott Fluhjeger

SEAL INTACT?  
 YES  NO  N/A

DATE: 5-14-98  
TIME: 1730

RECEIVED BY (SIGNATURE) Bill of Lading #

④ Fed EX 802414092172

SEAL INTACT?  
 YES  NO  N/A

DATE:

RELINQUISHED BY (SIGNATURE)

⑤

SEAL INTACT?  
 YES  NO  N/A

DATE:  
TIME:

RECEIVED BY (SIGNATURE)

⑥

SEAL INTACT?  
 YES  NO  N/A

DATE:

SPECIAL INSTRUCTIONS:

\* Nitrate/Nitrite Report Separately

LABORATORY REMARKS:

58-82809

SAMPLE CONTAINERS PRECLEANED BY:

BRE  LABORATORY  MANUFACTURER

METHOD OF SHIPMENT: Federal Express

BILL OF LADING NO.: 802414092172

TE-FULLY EXECUTED COPY  
LOW-RECEIVING LABORATORY COPY

SAMPLING TEAM:

See above

RECEIVED FOR LABORATORY  
BY (SIGNATURE): C. V. Adams

No. 3008

## Validated Detects

Location	Parameter	FRACTION	SORT	Results	QUAL	UNITS	IDL	MDL	CRDL_CRCL
S9MW-12	ALKALINITY (TO PH 4.5) AS CaCO3	MISC	ALK	210		MG/L	0	0.4	1
S9MW-12	CHLORIDE	MISC	CL	40		MG/L	0	0.29	1
S9MW-12	METHANE	OV	METH	2		UG/L	0	0.04	47
S9MW-12	SULFATE AS SO4	MISC	SO4	47		MG/L	0	1.4	5
S9MW-12	SULFIDE	MISC	SUL	1.5		MG/L	0	0.36	1
S9MW-12	TOTAL ORGANIC CARBON	MISC	TOC	6.7		MG/L	0	0.27	1
S9MW-3	ALKALINITY (TO PH 4.5) AS CaCO3	MISC	ALK	320		MG/L	0	0.4	1
S9MW-3	CHLORIDE	MISC	CL	170		MG/L	0	0.29	1
S9MW-3	METHANE	OV	METH	32		UG/L	0	0.04	47
S9MW-3	SULFATE AS SO4	MISC	SO4	200		MG/L	0	1.4	5
S9MW-3	TOTAL ORGANIC CARBON	MISC	TOC	14		MG/L	0	0.27	1
S9MW10	ALKALINITY (TO PH 4.5) AS CaCO3	MISC	ALK	380		MG/L	0	0.4	1
S9MW10	CHLORIDE	MISC	CL	490		MG/L	0	0.29	1
S9MW10	METHANE	OV	METH	1000	J	UG/L	0	0.04	47
S9MW10	SULFATE AS SO4	MISC	SO4	300		MG/L	0	1.4	5
S9MW10	SULFIDE	MISC	SUL	7		MG/L	0	0.36	1
S9MW10	TOTAL ORGANIC CARBON	MISC	TOC	28		MG/L	0	0.27	1
S9MW15	ALKALINITY (TO PH 4.5) AS CaCO3	MISC	ALK	340		MG/L	0	0.4	1
S9MW15	CHLORIDE	MISC	CL	2200		MG/L	0	0.29	1
S9MW15	CIS-1,2-DICHLOROETHENE	OV	OV	1300		UG/L	0	0.68	5
S9MW15	METHANE	OV	METH	30		UG/L	0	0.04	47
S9MW15	SULFATE AS SO4	MISC	SO4	300		MG/L	0	1.4	5
S9MW15	TOTAL ORGANIC CARBON	MISC	TOC	10		MG/L	0	0.27	1
S9MW15	TRANS-1,2-DICHLOROETHENE	OV	OV	4000		UG/L	0	0.68	5
S9MW15	TRICHLOROETHENE	OV	OV	350		UG/L	0	0.41	5
S9MW17	ALKALINITY (TO PH 4.5) AS CaCO3	MISC	ALK	230		MG/L	0	0.4	1
S9MW17	METHANE	OV	METH	40		UG/L	0	0.04	47
S9MW17	SULFATE AS SO4	MISC	SO4	34		MG/L	0	1.4	5
S9MW17	TOTAL ORGANIC CARBON	MISC	TOC	2.6		MG/L	0	0.27	1
S9MW19D	ALKALINITY (TO PH 4.5) AS CaCO3	MISC	ALK	340		MG/L	0	0.4	1

## Validated Detects

S9MW19D	CHLORIDE	MISC	CL	1900		MG/L	0	0.29	1
S9MW19D	METHANE	OV	METH	17		UG/L	0	0.04	47
S9MW19D	SULFATE AS SO4	MISC	SO4	420		MG/L	0	1.4	5
S9MW19D	SULFIDE	MISC	SUL	1.7		MG/L	0	0.36	1
S9MW19D	TOTAL ORGANIC CARBON	MISC	TOC	3.1		MG/L	0	0.27	1
S9MW21	ALKALINITY (TO PH 4.5) AS CaCO3	MISC	ALK	420		MG/L	0	0.4	1
S9MW21	CHLORIDE	MISC	CL	4000		MG/L	0	0.29	1
S9MW21	CIS-1,2-DICHLOROETHENE	OV	OV	94		UG/L	0	0.68	5
S9MW21	METHANE	OV	METH	61		UG/L	0	0.04	47
S9MW21	SULFATE AS SO4	MISC	SO4	820		MG/L	0	1.4	5
S9MW21	SULFIDE	MISC	SUL	2		MG/L	0	0.36	1
S9MW21	TOTAL ORGANIC CARBON	MISC	TOC	9.8		MG/L	0	0.27	1
S9MW21	TRANS-1,2-DICHLOROETHENE	OV	OV	52		UG/L	0	0.68	5
S9MW22	2-BUTANONE	OV	OV	16 J		UG/L	0	5.1	25
S9MW22	ACRYLONITRILE	OV	OV	20 J		UG/L	0	18	100
S9MW22	ALKALINITY (TO PH 4.5) AS CaCO3	MISC	ALK	380		MG/L	0	0.4	1
S9MW22	CHLORIDE	MISC	CL	3600		MG/L	0	0.29	1
S9MW22	CIS-1,2-DICHLOROETHENE	OV	OV	8.3		UG/L	0	0.68	5
S9MW22	METHANE	OV	METH	44		UG/L	0	0.04	47
S9MW22	SULFATE AS SO4	MISC	SO4	650		MG/L	0	1.4	5
S9MW22	SULFIDE	MISC	SUL	3.4		MG/L	0	0.36	1
S9MW22	TOTAL ORGANIC CARBON	MISC	TOC	17		MG/L	0	0.27	1
S9MW22	TRANS-1,2-DICHLOROETHENE	OV	OV	14		UG/L	0	0.68	5
S9MW23	CIS-1,2-DICHLOROETHENE	OV	OV	12		UG/L	0	0.68	5
S9MW23	TRANS-1,2-DICHLOROETHENE	OV	OV	34		UG/L	0	0.68	5
S9MW24	ALKALINITY (TO PH 4.5) AS CaCO3	MISC	ALK	420		MG/L	0	0.4	1
S9MW24	CHLORIDE	MISC	CL	1600		MG/L	0	0.29	1
S9MW24	CIS-1,2-DICHLOROETHENE	OV	OV	820		UG/L	0	0.68	5
S9MW24	METHANE	OV	METH	25		UG/L	0	0.04	47
S9MW24	SULFATE AS SO4	MISC	SO4	900		MG/L	0	1.4	5
S9MW24	TOTAL ORGANIC CARBON	MISC	TOC	24		MG/L	0	0.27	1

## Validated Detects

S9MW24	TRANS-1,2-DICHLOROETHENE	OV	OV	2000		UG/L	0	0.68	5
S9MW24-D	ALKALINITY (TO PH 4.5) AS CaCO3	MISC	ALK	530		MG/L	0	0.4	1
S9MW24-D	CHLORIDE	MISC	CL	1600		MG/L	0	0.29	1
S9MW24-D	CIS-1,2-DICHLOROETHENE	OV	OV	820		UG/L	0	0.68	5
S9MW24-D	METHANE	OV	METH	35		UG/L	0	0.04	47
S9MW24-D	SULFATE AS SO4	MISC	SO4	870		MG/L	0	1.4	5
S9MW24-D	SULFIDE	MISC	SUL	1.1		MG/L	0	0.38	1
S9MW24-D	TOTAL ORGANIC CARBON	MISC	TOC	23		MG/L	0	0.27	1
S9MW24-D	TRANS-1,2-DICHLOROETHENE	OV	OV	2000		UG/L	0	0.68	5
S9MW5	BENZENE	OV	OV	25		UG/L	0	0.31	5
S9MW5	CARBON DISULFIDE	OV	OV	39	J	UG/L	0	0.67	5
S9MW5	ETHYLBENZENE	OV	OV	200		UG/L	0	0.38	5
S9MW5	XYLENES, TOTAL	OV	OV	160	J	UG/L	0	1.1	5
S9MW8	ACROLEIN	OV	OV	100	J	UG/L	0	55	100
S9SB-1NA	TOTAL ORGANIC CARBON	MISC	TOC	72000	J	MG/K	0	50	100

# SL SAVANNAH LABORATORIES & ENVIRONMENTAL SERVICES, INC.

- 5102 LaRoche Avenue, Savannah, GA 31404
  - 2846 Industrial Plaza Drive, Tallahassee, FL 32301
  - 414 SW 12th Avenue, Deerfield Beach, FL 33442
  - 900 Lakeside Drive, Mobile, AL 36693
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  - 100 Alpha Drive, Suite 110, Destrehan, LA 70047
- Phone: (912) 354-7858    Fax: (912) 352-0165  
 Phone: (904) 878-3994    Fax: (904) 878-9504  
 Phone: (954) 421-7400    Fax: (954) 421-2584  
 Phone: (334) 666-6633    Fax: (334) 666-6696  
 Phone: (813) 885-7427    Fax: (813) 885-7049  
 Phone: (504) 764-1100    Fax: (504) 725-1163

## ANALYSIS REQUEST AND CHAIN OF CUSTODY RECORD

PROJECT REFERENCE <b>NAS Key West (South D)</b>		PROJECT NO. <b>7046</b>	PO NUMBER	MATRIX TYPE	REQUIRED ANALYSES	PAGE 1 OF 2
PROJECT LOC. (State) <b>FL</b>	SAMPLE(S) NAME <b>Scott Flickinger Andy Kerschick</b>	PHONE <b>803 649 7963</b>	PHONE <b>803 642 8454</b>	AQUEOUS (WATER) SOLID OR SEMISOLID AIR NONAQUEOUS LIQUID (oil, solvent, etc.) *CL	VOC BAO	STANDARD REPORT DELIVERY <input checked="" type="checkbox"/>  EXPEDITED REPORT DELIVERY (surcharge) <input type="checkbox"/>  Date Due:
CLIENT NAME <b>Tetra Tech NUS Inc.</b>		CLIENT PROJECT MANAGER <b>Chuck Bryan</b>				
CLIENT ADDRESS (CITY, STATE, ZIP) <b>900 Trail Ridge Road Aiken SC 29803</b>						

SAMPLE DATE	TIME	SL NO.	SAMPLE IDENTIFICATION	NUMBER OF CONTAINERS SUBMITTED										REMARKS						
				1	2	3	4	5	6	7	8	9	10							
11-21-98	1020		S9MW12	X																
11-21-98	1150		S9MW13	X																
11-21-98	1230		S9MW10	X																
11-21-98	1330	1130	S9MW5	X																
11-21-98	1650		S9MW21	X																
11-21-98	1735	1715	S9MW22	X																
11-21-98	1750	1735	S9MW25	X																
11-21-98	1800		S9MW14	X																
11-22-98	0930		S9MW23	X																
11-22-98	1020		S9MW24	X																
11-22-98	-		S9-DUP	X																
11-22-98	1146		S9MW15	X																
11-22-98	1200		S9RW-2	X																

RELINQUISHED BY: (SIGNATURE) <i>S. Campbell</i>	DATE 11/19/98	TIME	RELINQUISHED BY: (SIGNATURE) <i>W. Heath</i>	DATE 11/23/98	TIME 1800	RELINQUISHED BY: (SIGNATURE)	DATE	TIME
RECEIVED BY: (SIGNATURE) <i>W. Heath</i>	DATE 11/21/98	TIME 0730	RECEIVED BY: (SIGNATURE) <i>Fed Ex</i>	DATE 11/23/98	TIME 1800	RECEIVED BY: (SIGNATURE)	DATE	TIME

LABORATORY USE ONLY						
RECEIVED FOR LABORATORY BY: (SIGNATURE)	DATE	TIME	CUSTODY INTACT	CUSTODY SEAL NO.	SL LOG NO.	LABORATORY REMARKS:
			<input type="checkbox"/> YES <input type="checkbox"/> NO			

ORIGINAL







### SWMU 9 Detects

SUBZONE	LOCATION	SAMPLE	MATRIX	FRACTION	PARAMETER	RESULT	QUAL	UNITS
SWMU 9	S9SBFOC	S9SBFOC	SS	MISC	Fractional Organic Carbon	33000000		UG/KG
SWMU 9	S9-MW-05-1198	S9MW5	GW	OV	Benzene	18		UG/L
SWMU 9	S9-MW-15-1198	S9MW15	GW	OV	cis-1,2-dichloroethene	280		UG/L
SWMU 9	S9-MW-24-1198	S9MW24-AVG	GW	OV	cis-1,2-dichloroethene	60.25		UG/L
SWMU 9	S9-MW-21-1198	S9MW21	GW	OV	cis-1,2-dichloroethene	60		UG/L
SWMU 9	S9-MW-23-1198	S9MW23	GW	OV	cis-1,2-dichloroethene	4.6		UG/L
SWMU 9	S9-MW-14-1198	S9MW14	GW	OV	cis-1,2-dichloroethene	3		UG/L
SWMU 9	S9-MW-05-1198	S9MW5	GW	OV	Ethylbenzene	78		UG/L
SWMU 9	S9-MW-15-1198	S9MW15	GW	OV	trans-1,2-dichloroethene	820		UG/L
SWMU 9	S9-MW-24-1198	S9MW24-AVG	GW	OV	trans-1,2-dichloroethene	105.25		UG/L
SWMU 9	S9-MW-21-1198	S9MW21	GW	OV	trans-1,2-dichloroethene	51		UG/L
SWMU 9	S9-MW-23-1198	S9MW23	GW	OV	trans-1,2-dichloroethene	13		UG/L
SWMU 9	S9-MW-14-1198	S9MW14	GW	OV	trans-1,2-dichloroethene	5.2		UG/L
SWMU 9	S9-MW-05-1198	S9MW5	GW	TPH	Total Petroleum Hydrocarbons	5900		UG/L

**APPENDIX D**

**FIELD LOGBOOK**

1

PROJECT NAME \_\_\_\_\_

NOTEBOOK NO. \_\_\_\_\_

Lined writing area with horizontal lines and a vertical margin line on the left.

SIGNATURE \_\_\_\_\_

READ AND UNDERSTOOD \_\_\_\_\_

DATE \_\_\_\_\_

19 \_\_\_\_\_

DATE \_\_\_\_\_

19 \_\_\_\_\_

- 5/13/98 0715 NAS Key West Guard House for Badgig M. Whitten  
M. Ray, S Flickinger, A. Kendrick
- 0815 Tailgate by M. Ray FOL on days work.  
M. Ray & M. Whitten to Sigsbee Marina to perform  
IR8 and Background Site Sediment Sampling  
S. Flickinger & A. Kendrick to SWMU 9 for Groundwater  
Sampling
- 0825 Went to Public Works Office to meet P. Williams  
Got SWMU 9 keys. Informed him that I mistakenly  
left Bldg. 289 unlocked this morning at 0645.  
I told him I call A Matvers at 5169 to inform  
him of the error.
- 0845 Arrived SWMU 9 Weather warm 80°F light  
breeze from East. Sunny.
- 0900 Calibrated FID NU0853 Sensidyne Std 7012/11-1  
A. Kendrick locating and opening wells.

Synoptic Water Level Measurements

Time	Depth to H <sub>2</sub> O	T.D. FID, Well	Well	Ft. H <sub>2</sub> O	Vol.
	B.T.O.C.	B.T.O.C. Head Space			
10:04	2.24		S9 MW 17		
10:07	1.72	10.67	S9 MW 12	8.95	1.46
10:10	1.87	10.50	S9 MW 3	8.69	1.42
10:21	1.78		S9 MW 10		
10:24	1.96	10.71	S9 MW 8		
10:32	1.82	25.32	S9 MW 19 D		
10:37	1.69	9.94	S9 MW 22		
10:40	1.47	10.02	S9 MW 21		
10:43	1.43	9.95	S9 MW 24		
10:47	2.14	10.73	S9 MW 15		
10:50	1.63	9.48 (soft)	S9 MW 23		

11:10 Begin purging MW12 @ 300 mL/min.

Time	H <sub>2</sub> O	pH	S.C.	Turb.	D.O.	Temp	Sal.	Vol.
11:15	+89 <sup>AK</sup>	7.24	.547	17	8.79	26.8	0.02	
11:20	1.89	7.25	.537	16	8.92	26.7	0.02	~ 1 G.
11:40	"	7.31	.515	160	9.27	26.8	"	~ 3 G.
12:12	"	7.31	.492	57	0.13	26.8	"	~ 5 G.
12:20	"	"	.487	47	0.27	"	"	~ 6 G.
12:35		7.34	.479	38	0.28	"	0.01	~ 7.5 G. End

13:00 Collect Groundwater Sample: Fe, Mn, VOC, TOC, CH<sub>4</sub>

Anions, Sulfide.

SIGNATURE A. Kendrick  
READ AND UNDERSTOOD \_\_\_\_\_

DATE 5/13 19 98  
DATE \_\_\_\_\_ 19 \_\_\_\_\_

5/13/98

11:30 Begin purging MW 3 @ 400 ml/min

Time	H <sub>2</sub> O	pH	S.G.	Turb.	D.O.	Temp.	Sal.	Vol.
11:50	7.40	7.37	1.36	17	0.47	26.3	0.05	~2 Gal.
12:05	—	7.34	1.37	18	0.13 <sup>AK</sup> 0.07	26.4	0.06	~3 Gal.
12:30	2.23	7.38	1.37	42	0.47 <sup>AK</sup> 0.13	26.5	"	~4.5 Gal.
13:10	2.19	"	1.40	29	0.47	26.6	"	~7.5 Gal. END

13:30 Collect Natural Attenuation Parameters from MW-12.

Alkalinity (D.T.C) - Digital Titration for phenolphthalein (P) method and Total (M, Methyl) method. (Hach)

P = 0 mg/L

M =  $178 \times 1.0 = 178$  mg/L (unfiltered)Dup. M =  $184 \times 1.0 = 184$  mg/L (filtered) $362 / 2 = 181$  mg/L Total (M)

∴ Total Alkalinity = Bicarbonate Alkalinity

Carbon Dioxide (CO<sub>2</sub>) - Digital Titration method (Hach)10-50 mg/L range =  $494 \times 0.1 = 49.4$  mg/L20-100 mg/L range =  $176 \times 0.2 = 35.2$  mg/LDup. 20-100 mg/L range =  $220 \times 0.2 = 44.0$  mg/L $128.6 / 3 = 42.9$  mg/L

Cross check against drop-want titration method.

 $= 7 \times 5 = 35$  mg/LFerrous Iron (Fe<sup>2+</sup>) - Color wheel method (Hach)

= 0.0 - 0.5 mg/L - barely noticeable color change

Sulfide (H<sub>2</sub>S) - Color chart method (Hach HS-C)

= 5.0 mg/L - highest measurable concentration

Dissolved oxygen (DO) - Digital Titration method (Hach OR-DR):

- low range (1-5 mg/L) = Non Detect

Oxygen Reduction Potential (ORP/Eh) - Hanna ORP/CE Probe

= -2.30

SIGNATURE [Signature]DATE 5/13/ 19 98

READ AND UNDERSTOOD \_\_\_\_\_

DATE \_\_\_\_\_ 19 \_\_\_\_\_

4

PROJECT NAME NAS KeyWest SWMU 9

NOTEBOOK NO. \_\_\_\_\_

5/13/95

16:08 Start purge on MW-8 at 300 ml/min.

Time	H <sub>2</sub> O	pH	S.C.	Turb.	D.O.	Temp.	Sal.	Vol.
	(T.P.V.C)							

16:10 7.18 1.07 5 0.44 29.8 0.04 -

16:25 7.27 0.804 1 0.21 29.4 0.03 ~1.5 Gal.

16:55 2.35 ~~7.27~~ 7.29 0.734 1 0.20 29.4 0.03 ~4.5 Gal

17:15 2.35 7.29 0.716 1 0.36 29.2 0.03 ~5.5 Gal

17:30 2.35 7.27 0.704 1 0.67 29.2 0.03 ~6.5 Gal

17:35 Collect sample (VOCs) ORP (Eh) = -212

16:50 Start purge on MW-23 at 400 ml/min

Time	H <sub>2</sub> O	pH	S.C.	Turb.	D.O.	Temp.	Sal.	Vol.
	(T.P.V.C)							

17:00 - 7.23 1.60 28 0.76 26.6 0.07 ~0.5

17:20 1.43 7.22 1.60 11 0.40 26.5 0.07 ~2.5 Gal.

17:40 Drive to FedEx to meet Scott F

- Previous samples shipped.

- Hold VOCs from MW-8 on ice overnight.

18:30 - Arrive back on site to collect NA Parameters for MW-3. See method details on page 3.

18:50 H<sub>2</sub>S = 5.0 mg/L19:00 Fe<sup>2+</sup> = 0.0 mg/l

19:05 D.O. = 0.0 mg/l

19:20 Alk. 318 mg/L Total (Al) (1.0 multiplier)

C mg/L P

∴ Total Alk = Bicarbonate

19:40 CO<sub>2</sub> = 321 x 0.2 = 64.2 mg/L

20:00 Off site.

SIGNATURE [Signature]  
READ AND UNDERSTOOD \_\_\_\_\_DATE 5/13 19 95  
DATE \_\_\_\_\_ 19 \_\_\_\_\_

5/14/98

09:00 arrive on site (after equipment pickup at Truman Annex)

09:15 H<sub>2</sub>O (TPVC) in MW 15 = 2.17TD = 10.73 ∴ H<sub>2</sub>O column = 8.56'

× 0.163 gal/ft in 2" PVC

= 1.4 gal./vol.

× 3 vol = 4.2 Gal

× 5 vol = 6.9 Gal.

Weather

Clear 85°F

Scott F. finishes developing <sup>AK</sup> purging and sampling  
MW-23 (VOCs) and ORP (Eh) = -210.10:35 H<sub>2</sub>O (TPVC) in MW-19D = 1.76TD = 25.32 ∴ H<sub>2</sub>O column = 23.56'

× 0.163 gal/ft/2"

= 3.8 Gal/vol

× 3 vol = 11.5 Gal.

× 5 vol = 19.2 Gal.

10:55 - Start purge on

MW-19D

Time	H <sub>2</sub> O	pH	S.C.	Turb.	D.O.	Temp.	S.L.	Vol. (Gal.)
11:10		7.18	5.64	12	0.41	28.4	0.30	~1.5
11:25	1.89	7.16	5.81	2	0.18	28.4	0.30	~3.5 G.
11:50		7.18	6.05	0	0.12	28.2	0.32	~5.5 G.
12:22		7.20	6.19	1	0.27	28.4	0.33	~10 G.
12:40		7.17	6.23	2	0.11	28.4	0.33	~11.5 G.

11:15 - Set-up Pump 3 on MW-17

H<sub>2</sub>O = 2.18 TD = 10.62∴ H<sub>2</sub>O col. = 8.54'

× 0.163 gal/ft/2" = 1.4 Gal.

× 3 vol = 4.2 gal.

× 5 vol = 6.9 gal.

11:20 Start purge on MW-17

SIGNATURE

READ AND UNDERSTOOD

DATE

5/14/98

19

98

DATE

19

AIK 17

305-293-2061 - Phillip Williams

Time	Temp	pH	S.C.	Turb.	D.O.	Temp.	Sal.	Vol.
5/14/98	(C. PTC)	7.07	.562	217	0.19	31.9	0.02	(Vol) = 1.5
11:40	✓	✓	✓	✓	✓	✓	✓	✓
12:10		7.07	.560	155	0.14	31.7	0.02	~4 Gal
12:30		7.14	.556	64	0.17	31.6	0.02	~5.5 Gal
12:35		7.09	.556	55	0.15	31.3	0.02	~6 Gal

Nat. Ather. Parameters MW-15 (See Pg. 3 for method details)

12:15  $Fe^{2+}$  = 0.0-0.5 slight color change visible

$H_2S$  = 5.0 = Max detect

ORP (Eh) = -189

D.O. = N.D.

$CO_2$  =  $334 \times 0.2 = 66.8$  mg/L

AIK. P=0

Total (M) =  $324 \times 1.0 = 324$  mg/L (unfiltered)

∴ Total AIK = Bicarbonate

Total (M) =  $330 \times 1.0 = 330$  mg/L (filtered)

∴ Total AIK = Bicarbonate

12:40 - 13:15 Lunch

S. Elise leaves for meeting w/ Phillip w

13:30 Collect Env Samples from MW-19D

SEC, NH4, TOC, Fe, Mn, Arsenic, AIK, Sulfide

$Fe^{2+}$  = N.D.

$H_2S$  = 5.0 mg/L Max Det.

ORP (Eh) = -210

D.O. = N.D.

$CO_2$  =  $332 \times 0.2 = 66.4$  mg/L

AIK. P=0

M =  $318 \times 1.0 = 318$  mg/L

∴ Total AIK = Bicarbonate

SIGNATURE *Phillip Williams*  
 READ AND UNDERSTOOD \_\_\_\_\_

DATE 5/14 19\_\_\_\_  
 DATE \_\_\_\_\_ 19\_\_\_\_

5/14/98

1420 Collect G.W. Samples from MW-17  
 VOCs, Meth, TOC, Fe, Mn, Anions, Alk., Sulfide.

Based on Horiba D.O. measurements and other well titrations, D.O. is assumed to equal 0.

Based on other well titrations,  $Fe^{2+}$  is assumed to equal 0.

ORP = -190

$H_2S = 5.0$  (Max detect) mg/L

$CO_2 = 300 \times 0.2 = 60.0$  mg/L

Alk P = 0

$M = 258 \times 1.0 = 258$  mg/L

$\therefore$  Total Alk = Bicarbonate

1540 Set up on MW-21 at 300 ml/min ( $H_2O = 1.50$ )

Time	H <sub>2</sub> O	pH	SC	Turb	DO	Temp	Sal	Vol.
16:05	2.08	7.01	14.3	0	0.19	26.7	0.83	~ 2 Gal.
16:20		6.99	14.2	0	0.22	26.5	0.82	
16:35		6.98	14.2	0	0.30	26.4	0.82	~ 5 Gal

16:40 Sample MW-21

VOCs, Meth, TOC, Mn, Fe, Anions, Alk., Sulfide

Assume DO = 0 ✓

Assume  $Fe^{2+} = 0$  ✓

ORP = -218

$H_2S = 5.0$  (Max Detect) mg/L

$CO_2 = 784 \times 0.2 = ~~576.8~~ 156.8$  mg/L

Alk P = 0

$M = 420 \times 1.0 = 420$  mg/L

$\therefore$  Total Alk = Bicarbonate

Specific Capacity Testing @ 374 ml/min.

17:22 H<sub>2</sub>O = 2.31

18:04 2.33

18:36 2.41

18:50 2.44

SIGNATURE

READ AND UNDERSTOOD

DATE 5/14 19 98

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MW 21 Specific Capacity Test.

18:52 - Stop pump.

Recovery

30 sec.	2.28
1 min.	2.21
1m 30s.	2.15
2 min.	2.11
3 min.	2.05
4 min.	1.99
6 min. approx.	1.92
8 min. (18:00)	1.88
10 min. (18:05)	1.85

18:05 18:05 1.82

19:11 18:11 1.80

19:22 1.78

19:31 1.80

Tidal increase ?

MW-22 = 2.00

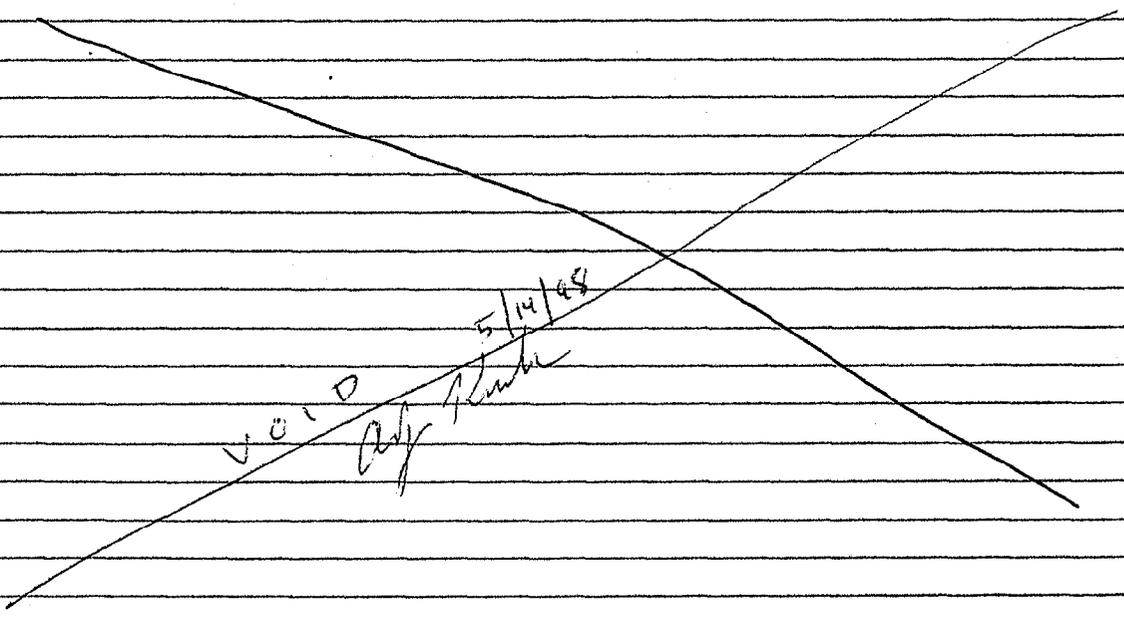
NOTE: In the morning, get a synoptic water level measurement in MW-21 and MW-22 for comparison purposes back to static.

Time: 0925 Date: 5-15-98

H2O MW-21 1.39'

H2O MW-22 1.65'

Off site at 19:40.



SIGNATURE [Signature]  
READ AND UNDERSTOOD \_\_\_\_\_

DATE 5/14 19 98  
DATE \_\_\_\_\_ 19 \_\_\_\_\_

9

PROJECT NAME NAS Key West SWMU 9

NOTEBOOK NO. \_\_\_\_\_

0100 Departed Hotel SF/MR M Whitten (MW) to look at S1 sites  
 5-15-98 0725 Arrived Bldg 289 to load equipment SF/MR  
 0830 Arrived KW Airport to pickup rental vehicle  
 0845 Arrived Boca Chica

0910 S9MW24 Purge  $\pm 400$  ml/min  
 TD 9.95' - 1.38 WL = 8.57' x .163 = ~~1.39~~ 1.40 gal/vol <sup>(DEF)</sup>  
 $1.4 \text{ gal} \times 3 = 4.2 \text{ gal}$        $1.4 \times 5 = 7 \text{ gal}$

	pH	Cond.	Turb.	DO	Temp	Sal
0915 Horiba 1	4.0	4.47	0	8.78	23.8	0.23
**Horiba 2 Error**	4.44	0	8.57	23.6	0.22	
	3.98	4.49	0	8.60	23.7	0.23

\*\* TANUS Horiba had pH probe cover

\* DO probe not in solution (suspected)

Time	pH	Cond.	Turb.	DO	Temp	Sal	GAL	Other
0925	6.99	6.83	21	1.22	25.7	0.36	1.5	2.45 WL
0945	7.00	6.87	20	0.15	25.9	0.37	3.0	
1005	7.00	6.91	20	0.11	26.0	0.37	5.0	ORP -182

1020 S9MW24 Sample All parameters  
 S9D1 Duplicate All parameters

0935 S9MW22 Purge  $\pm 300$  ml/min  
 TD 9.95 - 1.65 WL = 8.3' x .163 = 1.35 gal/vol

Time	pH	Cond.	Turb.	DO	Temp	Sal	GAL	Other
0955	7.05	10.8	6	0.12	25.5	0.61	1.5	2.88 WL
1010	7.02	10.8	5	0.12	25.6	0.61	3.0	
1020	7.02	10.8	5	0.10	25.9	0.61	4.0	ORP -182 <sup>(DEF)</sup>
1035	S9MW22 Sample	All parameters						-224

0945 S9MW21 1.39' WL

1115 Sounded S9MW5 and S9MW  
 1.94 WL S9MW5 0.16' product indicated by Keck interphase probe  
 S9MW or no product indicated

1130 SF left SWMU 9 to phone Chuck Bryan about free product. Sample other wells.

1200 S9MW5 1000 ppm TOC FID reading  
 12:09 S9MW13 20 ppm TOC FID reading

SIGNATURE [Signature]

READ AND UNDERSTOOD \_\_\_\_\_

DATE 3/15 19 98

DATE \_\_\_\_\_ 19 \_\_\_\_\_

1210 Deionized Water Rinsate Lot 6052 Jul 98 Exp  
RB01051598

1235 Purge, S9MWS  
10.81 TD - 1.94 WL = 8.87' x 0.163 = 1.44 gal/vol

	pH	Cond.	Turb	DO	Temp	Sal	GAL	OTHER
1245	6.85	1.13	21	0.16	29.9	0.05	1 gal	
1305	6.84	1.13	49	0.14	29.8	0.05	3 gal	
1325	6.83	1.14	59	0.28	20.2	0.05	4.5 gal	

1240 Field Chemistry S9MW24

DO 0 mg/L white absent oxygen  
 Fe<sup>+2</sup> 0 mg/L no color change  
 H<sub>2</sub>S > 5.0 mg/L dark brown  
 CO<sub>2</sub> 1164 mg/L 582 digits x 0.2 multiplier = 1164 mg/L  
 ALK M 511 mg/L 511 " x 1.0 " = 511 mg/L  
 P 0 mg/L Total Alkalinity = Bicarbonate

1345 Field Chemistry S9MW22

DO 0 mg/L white absent of oxygen  
 Fe<sup>+2</sup> 0 mg/L no color change  
 H<sub>2</sub>S > 50 mg/L dark brown heavy reaction 120  
 CO<sub>2</sub> 600 mg/L 600 x 1.0 x 0.2 = 600 mg/L  
 P=0 ALK M=375 mg/L 375 digits x 1.0 = 375 mg/L (Total Bicarbonate)

1355 S9MW13 Purge (See M Ray notes) S9D2 Duplicate  
 10.73 TD - 1.84 WL = 8.89 x 0.163 = 1.45 gal/vol

1430 Soil Sample S9SB-1NA white colite 0-6" <sup>REF 9/15/98</sup>

1435 S9MW13 Sample and S9D1 Duplicate VOCs Only

1515 Departed SWMU 9 2 drums 1DW

1610 Arrived Tampa Port S9D2

1700 At Bldg. 289

1740 Departed for FedEx to ship samples

SIGNATURE [Signature]  
 READ AND UNDERSTOOD \_\_\_\_\_

DATE 5/15/98 19 9  
 DATE \_\_\_\_\_ 19 \_\_\_\_\_

11/17/98 Weather: 78°-87° Ptl. Cldy.  
Book maintained by Andy Kendrick

06:45 Andy Kendrick (AK) arrives on site to locate proposed well.

07:15 AK goes to main gate to meet Precision Drilling.

07:45 AK calls Scott Flickinger (SF) and discuss project details.  
Water - Located cross Main Rd. (Midway) ~ 1/4 mile at Fuel Station  
Emergency = 305-293-2114, Office of Day = 293-2971  
Power - Driller will provide their own if needed.  
Decon - will have deconed previously  
Generators for Mobile Lab - If necessary, call 5-Star Rental  
= 30 amp. 5L-30 NEMA X 3 @ 110v (3 blade)  
- Check w/ Phillip Williams (PW) about potent. hookup  
Keys - Chuck Bryan (CB) has keys to Truman Annex.  
RAC = Bechtel = Nick Ring<sup>(NR)</sup> (305) 304-5132  
T&US office @ Truman Annex = B-112  
305-295-8382 (V) 305-295-8381 (F)  
Well details

Typical = Screen 2'-12'  
Sand 6"  
V.F. Sand 6"  
No bentonite  
Grout as required.

08:30 AK calls NR about location / schedule of drillers.  
- Drillers still busy developing Bechtel wells.  
- will be available ~ 10:00-10:30.  
- AK drives to Bechtel site along flight line.  
- Meet NR and drillers  
- AK loans NR the Horiba during their dev.  
- NR provides AK w/ Isopropanol that they did not need.

09:00 AK leaves Base to run errands:  
- Purchase supplies  
- Pickup equipment on hold at Fed Ex.

SIGNATURE Andy Kendrick

READ AND UNDERSTOOD \_\_\_\_\_

DATE 11/17/98 19

DATE \_\_\_\_\_ 19

11/17/98 (Cont.)

10:00

- AK drives back to SWMU 9 to meet drillers
- Set up equipment, decon, etc.
  - PID will not work (won't hold a charge)
    - Charged entire night before.
  - SF says a replacement is coming.
    - No historical pos. detects in breathing zone at site.
    - Well to be installed is a down-gradient, clean, sandy well.
  - Set up H<sub>2</sub>S file, folders, MSDS, etc.

10:45

- AK collects preliminary water levels from two wells near to proposed well S9MW25.
- Object is to be able to approximate H<sub>2</sub>O levels during drilling and well installation.

Well	H <sub>2</sub> O (TOC)	Total Depth (TOC)
S9MW24	1.30	9.70
S9MW22	1.70	9.70

11:00

- Precision Drilling Arrives on site
- AK provides comprehensive H<sub>2</sub>S site specific training.
  - Discuss COPCs, PPE, site conditions, site history, Completed Daily Work Permit, HASP, Addendum, Guide Manual, Objectives, and proposed activities. Collect H<sub>2</sub>S Certifications for file and have compliance letters and Personal Information forms completed. - Place in site file.

11:30

- Start drilling S9MW25; Rig = CME-75 w/hollow-stem auger (4 1/4")
- have driller post-hole dig to 3.5' (hit caprock).

13:00

- Complete drilling and well installation. (Screen 2'-12' with 0.010" slots)
- Overdrilled to 13.0 ft.; use 4 drums (1 for water - plus keep 3 for purge water).
  - No drill cutting to be collected, minor surface soil around well.
  - Drill gets stuck for 1-hr while leaving well location.
  - Begin development.

15:00

- Development complete, (2 Hr.) = 55 gal, milky white to clear, Due to pump heating, do not collect parameters.
- Complete flush mount casing and cement/grout AFTER development complete.

15:15

- Drillers mob off site back to Bechtel decon area and drive home.

16:00

AK off site. End of Record for 11/17/98 RAB Mtg. in PM

SIGNATURE *Chris Kunk* DATE 11/17/98 19\_\_

READ AND UNDERSTOOD \_\_\_\_\_ DATE \_\_\_\_\_ 19\_\_

11/18/98 - Meetings - No Field Activities (Partnering Team)

11/19/98

- Weather: 87° P+I. Cldy

BOA = 305-293-4142

09:30 AK arrives at Pub. Work w/ Chuck Bryan.

PW Home = 305-294-3936

- Teleconf. w/ AK, PW, and PW's mgr. concerning morning newspaper article about arsenic detected in G.W. at Poincienna Housing.
- CB briefs attendees about actual/true data vs article text.

10:00 AK and PW go to Electrical Shop (B-126). Call in advance. Elect. POC not at site; working near Boca Chica Marina. AK & PW find Elect. POC (Bobby) at Marina and discuss hookup schedule and needs for SWMU 9 Mobile Lab. Meet back at elect. shop at 12:30 (after-lunch).

- AK and PW discuss work at SWMU 9. AK receives a call from Target Mobile Lab (412) 999-5894. TML is driving into Miami tonight. Due down to Key West tom. PM. PW states that badging closes on Fri (tom.) at 11:00 am. Several telephone conversations later, TML agrees to be at site by 11:00 tom. PW calls security with personal info. on TML personnel.

Name

S.S

Company

Eric Magdar 084-60-6407 Target (Geochem.)

Stewart Johnson Jr. 057-72-2104 Target (Sampler)

Robert Williams 192-42-4637 Microseps (Chemist)

11:00 AK runs more errands, purchase expendables, pickup lunch, etc.

12:30 AK meets Bobby (Elect.) at B-126 shop. Bobby still not ready. Wants to try again at 07:00 AM tom. AK to meet Bobby at B-126.

13:00 AK runs errands, goes to SMWU 9 to scope elect. hookup options, goes to Truman Annex to pickup expendables and equipment from field office. Get paper work and forms from field office organized into files for field use. Goes to Fed Ex for pickup of 10 parcels. Goes to airport and leave message for SF to get a van when he arrives due to volume of supplies needed. Begin to inventory equip.

SIGNATURE

READ AND UNDERSTOOD



DATE 11/19/98 19

DATE 19

11/19/98 (cont.)

15:00 AK talk w/ SF on phone about project status, elect. hookups, equip. & supplies, mobil lab schedule, fixed based lab subcontract, status of new well, etc.

SF confirms that a NEMA 5/30A/110v power supply is required. SF calls Ned Tillman and/or Mobile Lab for further confirmation. Follows up w/ AK about requirements.

SF reminded to order groundwater filters (if needed).  
- will call Tom Patton.

SF asks AK to call Savannah Labs and confirm bottle order.

Angie Stewart @ Savannah Labs 912-354-7858  
- Need bottles delivered in AM tomorrow.  
= 16 VOCs, 12 TOC, 2 FOC, 3 trips, + extras for break

AK calls Angie Stewart and leaves voice mail

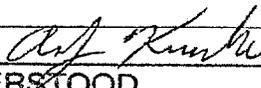
Angie calls back and confirms bottle order has been sent for hold at FedEx (Priority overnight)

Addit. shipping info: Can ship Friday for Sat. AM delivery. No receipt of samples Sat PM or Sunday. Best to hold in frig. at site and ship Monday AM rather than hope ice stays cold.  
Angie will not be in office on Mon Friday. Call Abby Paige if any problems arise (her assist.)

17:00 End of Record for 11/19/98

SIGNATURE

READ AND UNDERSTOOD



DATE 11/19/98 19

DATE \_\_\_\_\_ 19

11/20/98

Weather: 87° - Pt. Cldy - Clearing

06:45 AK and SF go to B-126 (Elect.) to meet Bobby.  
 - Pub. Works has not yet processed request forms and Max (Elect. Mgr.) is concerned about level of effort for the elect. hookup. AK clarifies needs and assumes only a min. level of effort is required. SF goes to Pub. Works to see PW and check on elect. request.  
 AK goes to SWMU 9 to meet electricians.  
 - Can't access site from 07:15 - 07:45 due to PT

08:00 Elect. begin hookup.  
 AK begins unpacking and inventory on mat. & equip.

08:50 AK calibrates Photo Vac PE (11.7 uv Lamp)

= Model 2020

- Rented from US Env. Corp.

Span Gas = Isobutylene  
 107.1 PPM in zero air.

09:30 Robert of Target/Microscopy mobile lab arrives on site.

10:30 Elect. done. Plug in lab and perform a power-up check.

All checks out OK.

11:00 Afternoon spent connecting elect., purchase supplies, package inventory, Fed Ex pickup and drop off. AK & SF to Truman Annex and go to site office.  
 - Check supplies and materials.

SFAK, PW, and Dudley Patrick have conf. call about Poinderna Hoising sampling proposed. Duplicate and filter sample.

15:30 Arrive back at site. SF goes to meet lab personnel at BOQ for check-in and goes shopping. AK stays on site and begins to calib. and run stds. on geochem equip.

SIGNATURE

READ AND UNDERSTOOD

DATE

DATE

11/20/98-19

19

11/20/98 (Cont.)

16:00 Check out Geochem. Equipment, Std's, Calib, Reagent  
 - Use Purge water from SWMU 25 as test fluid.

Check Program for - Ferrous Iron. DR-850

Concent. = 1.86 mg/L #1 } Repeat sample preparation.  
 0.86 mg/L #2 } Variation resulting from oxidation  
 0.72 mg/L #3 } of  $Fe^{2+} \rightarrow Fe^{3+}$ ,  $\approx 5$  min. per analysis

IR-18C  $\approx 0.8 - 1.0$  mg/L

0.55 mg/L #4 } Repeat colorimeter Read only.  
 0.57 mg/L #5 }  $\approx 1$  min. per Read  
 0.58 mg/L #6 }  
 0.62 mg/L #7 }

17:00

Check Program for - Manganese, High Range DR-850

- Run Reagent Blank Correction

Blank run w/ Deionized water. Blank value = 0.0 mg/L

No Reagent Blank Correction required.

- Run test analysis,

Concent. = 0.9 mg/L Mn.

2.1 mg/L  $MnO_4$

2.7 mg/L  $KMnO_4$

17:30

Check Program for - Sulfate (0-70 mg/L) DR-850

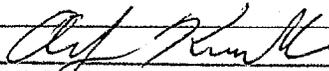
- Use Program # 91 (Default, Min. Accuracy Program)

- Concentration = 80 mg/L (Above Limits)

18:00 A/C off site. End of Record for 11/20/98

SIGNATURE

READ AND UNDERSTOOD



DATE 11/20/98 19

DATE 19

11/21/98

0530 A Kendrick on site before performing calibrations of Hach kits

0600 S. Flickinger on site began opening wells

0630 Sunrise humid partly cloudy 78°F

0710 Target E. Magder S. Johnson on site

0730 OTIS Water level readings

MW

13	2.39'
5	2.52'
15	2.20'
23	1.71'
24	1.61'

MW

14	2.12'
22	1.88'
25	1.41'
21	1.68'
10	1.98'

MW

12	1.75'
RW	2.75'

0745 Distance from MW22 to MW25 47.5'  
 MW24 to MW25 57.3'

0800 Health and Safety meeting with Target/Microseeps

0815 Began sampling purging MW12 up gradient down well.  
S. Johnson Target/Microseeps

10:12 Geochem samples on S9MW12.

CO<sub>2</sub> = 632 DT X 0.1 = 63.2 mg/LH<sub>2</sub>S = 2.0 mg/L

D.O. = 0.0 mg/L

NO<sub>2</sub>-N = 0.015 (Nitrite)Cl<sub>2</sub> = 0.0 mg/L

Alk = DIC = 183 mg/L

NO<sub>3</sub>-N = 0.04 mg/L (Nitrate) = 0.06

1030 S9MW12 VOC sample via P-Pump &gt; 100ml/min. DSF

Mn = 0.2 mg/L

MnO<sub>4</sub> = 0.2 mg/LKMnO<sub>4</sub> = 0.3 mg/LSO<sub>4</sub> = 80 mg/L (limit)S<sup>2-</sup> = 0.05 mg/L

1150 S9MW13 -VOA collected via P-pump &gt; 100ml/min DSF.

1153 S9MW13 Geochem.

DO = Assume 0.0 mg/L

CO<sub>2</sub> = 85 x 1.0 = 85 mg/L Dup = 89 x 1.0 = 89 mg/L

Alk = DIC = 236 x 1.0 = 236 mg/L

H<sub>2</sub>S = 0.3 (center only)NO<sub>2</sub>-N = 0.031 mg/LS<sup>2-</sup> = 0.03 mg/LSO<sub>4</sub> = 28 mg/LNO<sub>3</sub>-N = 0.04 mg/L = 0.06Fe<sup>2+</sup> = 0.02 "Cl<sub>2</sub> = 0.08 mg/L

Mn = 0.0 "

SIGNATURE *[Signature]*MnO<sub>4</sub> = 0.0 "

DATE 11/21/98 19

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KMnO<sub>4</sub> = 0.0 "

DATE 11/21/98 19

1230 S9MW10 VOA collected DSF > 100ml P-pump  
 weather: Warm 88°F Partly Cloudy Wind: SE 5-10mph.

1330 Collect Geochem on S9MW03

$$CO_2 = 240 \times 1.0 = \del{240} 240 \text{ mg/L}$$

$H_2S = 75.0$  - Exceeded Concent.

$$ALK = 505 \times 1.0 = 505 \text{ mg/L} = DIC$$

$$NO_3-N = 0.04 \text{ mg/L}$$

$$Fe^{2+} = 0.02 \quad S^{2-} = \del{0.02} = 0.80 \text{ mg/L (Exc. Limits)}$$

$$Mn = 0.2 \quad NO_2-N = 0.017$$

$$MnO_4 = 0.4 \quad DO = 0.0 \text{ (Assume)} \quad NaNO_2 = 0.084$$

$$KMnO_4 = 0.6 \quad Cl_2 = 0.0 \text{ mg/L} \quad NO_2^- = 0.056$$

$$SO_4 = \del{0.0/0.0} = 0.0/0.0 \quad \text{(Sulf. Reduction!!)}$$

↳ Duplicate

1400 Stewart Johnson Jr. cuts thumb on sharp edge of chipped beaker, clean w/ antiseptic wipe and bandage.

1415 Scott Flickinger transports S.J. to Hospital on Boca Chico to see if stitches are necessary

1615 SF and SJ return from hospital. 6 stitches + tetnus + Keflex (250mg)

1535 Collect Geochem on S9MW10

$$CO_2 = 430 \times 1.0 = 430 \text{ mg/L}$$

$H_2S = 75.0$  - Exceeded Concentration

$DO = 0.0$  (Assume)

$$ALK = DIC = 535 \times 1.0 = 535 \text{ mg/L}$$

$$NO_3-N = 0.02 \text{ mg/L} \quad NO_3^- = 0.10$$

$$NO_2-N = 0.019 \text{ mg/L} \quad NO_2^- = 0.064 \quad NaNO_2 = 0.095$$

$$Fe^{2+} = 0.02 \text{ mg/L}$$

$$Mn = 0.0$$

$$MnO_4 = 0.0$$

$$KMnO_4 = 0.1$$

$$SO_4 = 80 \text{ mg/L} - \text{Limit}$$

$$S^{2-} = 80 \text{ mg/L} - \text{Limit}$$

$$Cl_2 = 0.01 \text{ mg/L}$$

1745 Collect Geochem on S9MW21

$H_2S = 75.0$  (Exceed Concent.)

$$NO_3-N = 0.00 \text{ mg/L} \quad NO_3^- = 0.0 \text{ mg/L}$$

$$* CO_2 = 346 \times 1.0 = 346$$

$$DO = 0.0 \text{ (Assume)}$$

$$* ALK = DIC = 464 \times 1.0 = 464$$

$$* NO_2-N = 0.005 \quad * NO_2^- = 0.016 \quad * NaNO_2 = 0.024$$

$$* Fe^{2+} = 0.03$$

$$* Mn = 0.0 \quad * MnO_4 = 0.0 \quad * KMnO_4 = 0.0$$

$$* SO_4 = 80 \text{ (Limit)} \quad * S^{2-} = 80 \text{ (Limit)} \quad * Cl_2 = 0.01$$

\* = Run in AM of  
11/22/98

OFF Site at 18:30

SIGNATURE [Signature]

DATE 11/21/98 19

READ AND UNDERSTOOD \_\_\_\_\_

DATE \_\_\_\_\_ 19

19

PROJECT NAME NAS Key West SWMU 9 NOTEBOOK NO. \_\_\_\_\_

11/22/98 75° Ptl. Cldy.

07:00 Arrive on site.  
- Set up for sampling07:30 Target arrives  
Begin SamplingFinish Geochem Params on S9MW21  
(See pp. 18).

0815 Geochem on S9MW22

 $\text{NO}_3\text{-N} = \del{0.03} 0.03$   $\text{NO}_3 = 0.12$  $\text{NO}_2\text{-N} = 0.007$   $\text{NO}_2 = 0.024$   $\text{NaNO}_2 = 0.036$  $\text{H}_2\text{S} = > 5.0$  (Exceed.) $\text{CO}_2 = 315 \times 1.0 = 315$  $\text{DO} = 0.0$  (Assand) $\text{Alk} = \text{DIC} = 265 \times 2.0 = 530$  $\text{Fe}^{2+} = 0.03$  $\text{Mn} = \del{1.4} 1.4$   $\text{MnO}_4 = \text{X}$   $\text{KMnO}_4 = \text{X}$  $\text{SO}_4 = 80$  (Limit) $\text{S}^{2-} = .64$  $\text{Cl}_2 = 0.08$ 0930 VOC Sample Collection S9MW23 via p-pmp  $> 100 \text{ ml/min}$  DSF

0930 Geochem on S9MW25

 $\text{NO}_3\text{-N} = 0.04 \text{ mg/l}$   $\text{NO}_3 = 0.19 \text{ mg/l}$  $\text{NO}_2\text{-N} = 0.02 \text{ mg/l}$   $\text{NO}_2 = 0.06 \text{ mg/l}$   $\text{NaNO}_2 = 0.10 \text{ mg/l}$  $\text{H}_2\text{S} = > 5 \text{ mg/l}$  (Exceed) $\text{CO}_2 = 100 \times 2.0 = 200$  $\text{Alk} = \text{DIC} = 385 \times 1.0 = 385$  $\text{Fe}^{2+} = 0.12 \text{ mg/l}$  $\text{Mn} = 0.1 \text{ mg/l}$   $\text{MnO}_4 = 0.2 \text{ mg/l}$   $\text{KMnO}_4 = 0.2 \text{ mg/l}$  $\text{SO}_4 = 80 \text{ mg/l}$  (Limit)  $> 320 \text{ mg/l}$  4X dilution $\text{S}^{2-} = 0.8 \text{ mg/l}$  $\text{Cl}_2 = 0.0 \text{ mg/l}$ 1020 VOC Sample Collection S9MW24 via p-pmp  $> 100 \text{ ml/min}$  DSFSIGNATURE *Jeff T. Smith*

READ AND UNDERSTOOD \_\_\_\_\_

DATE 11/22/98 19

DATE \_\_\_\_\_ 19

11:00 Collect Geochem on S9MW14  
 $\text{NO}_3^- - \text{N} =$   $\text{NO}_3 =$   
 $\text{NO}_2^- - \text{N} =$   $\text{NO}_2 =$   $\text{NaNO}_2 =$   
 $\text{H}_2\text{S} = 0.2 \text{ mg/L}$   $\text{O}_2 = 0.2 \text{ mg/L}$   
 $\text{CO}_2 = 63 \times 2 = 126$   $\text{D}_{\text{up}} = 136 \times 1 = 136$   $(126 + 136) / 2 = 131$   
 $\text{Alk} = \text{DIC} = 252 \times 1.0 = 252$   
 $\text{Fe}^{2+} = 0.04 \text{ mg/L}$   
 $\text{Mn} = 0.1 \text{ mg/L}$   $\text{MnO}_4 = \text{X}$   $\text{KMnO}_4 = \text{X}$   
 $\text{SO}_4 = 80$  - Exceed.  
 $\text{S}^{2-} = 0.0 \text{ mg/L}$   
 $\text{Cl}_2 = 0.07 \text{ mg/L}$

11:46 S9MW15 VOC collected by A-b

12:00 S9RW-2 VOC collected by AK  
 S9-DUP VOC duplicate collected by AK (of S9RW-2)

12:45 Geochem on S9-RW-2  $\text{NO}_2$  &  $\text{NO}_3$  not run  
 $\text{CO}_2 = 150 \times 1.0 = 150$  - below NA action levels.  
 $\text{H}_2\text{S} = 5.0$   
 $\text{Alk} = \text{DIC} = 315 \times 1.0 = 315$   
 $\text{Fe}^{2+} = 0.0$   
 $\text{Mn} = 0.0$   $\text{MnO}_4 = 0.1$   $\text{KMnO}_4 = 0.1$   
 $\text{SO}_4 = 80.0$  (Limit) Duplicate = 7320 (4x Dilut.) - Exceed.  
 $\text{S}^{2-} = > 160$  (2x Dilut.) - Exceed.  
 $\text{Cl}_2 = 0.1$

Mobile Lab.

IC PAL = 0.5 for all except Alk. & Sulfide (ppm)  
 = 10.0 = 0.06

13:45 Geochem on S9MW24  
 $\text{Fe}^{2+} = 0.01$   
 $\text{Mn} = 0.0$   $\text{MnO}_4 = 0.0$   $\text{KMnO}_4 = 0.0$   
 $\text{SO}_4 = 80$  (Exceed)  
 $\text{Alk} = \text{DIC} = 495 \times 1.0 = 495$   $\text{NO}_2$  &  $\text{NO}_3$  not run  
 $\text{CO}_2 = 300 \times 1.0 = 300$  - below NA action levels.  
 $\text{H}_2\text{S} = 5^+$   $\text{S}^{2-} = 0.37$   
 $\text{Cl}_2 = 0.02$

14:00 Target off site - completed work

SIGNATURE

READ AND UNDERSTOOD

DATE

DATE

11/22/98 19

19

1405 Geochem on S9MW23

$$\text{Alk} = 306 \times 1.0 = 306$$

$$\text{H}_2\text{S} = \sim 4-5$$

$$\text{CO}_2 = 153 \times 1.0 = 153$$

$$\text{Fe}^{2+} = 0.07$$

$$\text{Mn} = 0.1 \quad \text{MnO}_4 = 0.1 \quad \text{KMnO}_4 = 0.2$$

$$\text{SO}_4 = 75 \times 2 = 150 \quad (2 \times \text{Dilution})$$

$$\text{S}^{2-} = 0.05$$

$$\text{Cl}_2 = 0.02$$

1430 Geochem on S9MW23 Dup. w/ 0.45  $\mu$  filter

$$\text{Alk} = 319 \times 1.0 = 319$$

$$\text{CO}_2 = 155 \times 1.0 = 155$$

$$\text{H}_2\text{S} = 75 \text{ Exceeds}$$

$$\text{Fe}^{2+} = 0.05$$

$$\text{Mn} = 0.0 \quad \text{MnO}_4 = 0.0 \quad \text{KMnO}_4 = 0.0$$

$$\text{SO}_4 = > 80 \times 2 = > 160 \quad (2 \times \text{Dilution})$$

$$\text{Dup. SO}_4 = 48 \times 3 = 144 \quad (3 \times \text{Dilution})$$

$$\text{S}^{2-} = 0.02$$

$$\text{Cl}_2 = 0.05$$

1530 Geochem on S9MW15

$$\text{Alk} = 305 \times 1.0 = 305$$

$$\text{CO}_2 = 159 \times 1.0 = 159$$

$$\text{H}_2\text{S} = 3$$

$$\text{Fe}^{2+} = 0.09$$

$$\text{Mn} = 0.0 \quad \text{MnO}_4 = 0.0 \quad \text{KMnO}_4 = 0.0$$

$$\text{SO}_4 = > 80 \text{ Exceeds}$$

$$\text{Dup. SO}_4 = 51 \times 3 = 153 \quad (3 \times \text{Dilution})$$

$$\text{S}^{2-} = 0.00$$

$$\text{Cl}_2 = 0.04$$

1730 Off Site after demobilizing lab, clean up, well closure,  
IOW management, data collection, etc.

End of Record for 11/22/98

SIGNATURE [Signature]

READ AND UNDERSTOOD \_\_\_\_\_

DATE 11/22/98 19

DATE \_\_\_\_\_ 19

5/15/98

MW13

Time	pH	Cond	Turb	DO	Temp	Sal
14:05	7.28	<del>6.88</del> 0.570	212	9.85	29.8	0.02
1gal	7.28	0.561	211	10.13	29.6	0.02
2gal	7.27	0.565	209	10.29	29.7	0.02
3gal	7.26	0.565	213	10.09	29.8	0.02
4gal						

Marty & Scott head to Boca Chica  
7:00 set up to sample MW22  
and MW24, see Scott's log book  
for sampling details.

Trumbo

MW-42

TOP - 4.89

TOW - 4.99

TD - 9.85

Start purge @ 16:14

	pH	Cond	Turb	DO	Temp	Sal
1gal	6.79	2.31	185	9.73	29.6	0.10
2gal	6.79	2.27	145	10.04	29.5	0.11
3gal	6.82	2.36	145	10.11	29.4	0.10

Sampled @ 16:40

**APPENDIX E**

**RESPONSE TO COMMENTS**

**DRAFT RESPONSE TO U.S. EPA COMMENTS  
NATURAL ATTENUATION STUDY RESULTS FOR SWMU 9 FEBRUARY 1999  
FOR NAVAL AIR STATION, KEY WEST, FLORIDA**

**General Response:**

*The natural attenuation report was prepared to present the results of the natural attenuation screening study performed at the site. The screening was viewed as a cost-effective measure to achieve the data quality objective as to whether or not natural attenuation was occurring at the site. This report relied heavily on previous studies and reports for the site in order to reduce the volume of the natural attenuation report. Each of these supporting documents is cited in the natural attenuation report. In addition, the site is currently undergoing a Corrective Measures Study (CMS). The natural attenuation report is designed to be an appendix to the CMS report.*

**GENERAL COMMENTS**

**Comment 1a:** While some of the geochemistry data and the presence of cis-1,2-dichloroethene suggest that natural attenuation may be occurring at the site, the occurrence of natural attenuation alone does not provide a basis for selecting natural attenuation as a remedy. The identification and location of downgradient receptors, contaminant travel time (not just select contaminants), and the time frame for aquifer remediation (by natural attenuation) are some of the other factors that need to be evaluated further.

Three lines of evidence that can be used to support natural attenuation of chlorinated aliphatic hydrocarbons include<sup>1</sup>:

1. Observed reductions in contaminant concentrations along the flow path downgradient of the source of contamination.
2. Documented loss of contaminants at the field scale using
  - a) Chemical and geochemical data including
    - decreasing parent compound concentrations
    - increasing daughter compound concentrations
    - depletion of electron acceptors and donors
    - increasing metabolic byproduct concentrations

- b) A conservative tracer and a rigorous estimate of residence time along the flow path to document contaminant mass reduction and to calculate biological decay rates at the field scale.
3. Microbiological laboratory or field data that support the occurrence of and give rates of biodegradation.

The report relies primarily on the second line of evidence, in part, to support natural attenuation as a viable remedial alternative. The first line of evidence, observed reductions in contaminant concentrations, has occurred at the site; however, this could be attributed to the former pump and treat system, tidal flushing, and Hurricane Georges. The limited data set (after the pump and treat system ceased) includes May 1998 and November 1998 sample data. Hurricane Georges occurred between these dates and had a significant impact on the analytical data. Due to these factors, the current data for the site is insufficient to demonstrate that observed reductions in contaminant concentrations is a result of natural attenuation. The third line of evidence, direct microbiological evidence, has also not been demonstrated since microbiological field or laboratory data was not collected.

**Response:** *Since natural attenuation includes not only biodegradation, but also sorption, dispersion, dilution, and volatilization, the Navy disagrees with the reviewers, conclusions that the current data for the site are insufficient to demonstrate that observed reductions in contaminant concentrations are a result of natural attenuation. While it is true that seasonal fluctuations, changes in rainfall, and changes in tidal cycle impact the plume geometry, the isoconcentration contour maps provided from 1994 through November 1998 demonstrate no significant spread in the plume geometry over the 4-year period.*

**Comment 1b:** It should also be noted that the natural attenuation screening process used in the report (Section 5.4.1) is intended to be just that - a screening process. The resultant scores provide an indication of whether it is worthwhile to spend the additional resources (time and money) to demonstrate that the degradation of site contaminants is occurring at rates sufficient to be protective of human health and the environment. Decisions regarding the applicability of natural attenuation as a remedial alternative should not be based on this screening process alone. Based on some of the geochemical data and the natural attenuation screening process for SWMU 9, it appears that natural attenuation processes are occurring; however, it has not been demonstrated that the degradation of site contaminants is occurring at rates sufficient to be protective of human health and the environment.

**Response:** *As previously mentioned, the isoconcentration contour maps provided from 1994 through November 1998 demonstrate no significant spread in the plume geometry over the 4-year period. In addition, it is anticipated that the downgradient receptor (lagoon) will not be adversely impacted by the groundwater plume.*

**Comment 1c:** The review of the report revealed several major problems (discussed in further detail below) with respect to the recommendation that Monitored Natural Attenuation (MNA) be selected as the groundwater remedy for the SWMU 9 groundwater. A greater effort is needed with respect to field data collection and the evaluation and presentation of the data before MNA can be considered as a viable groundwater remedy. Due to the number and significance of the comments raised below, it is recommended that the report be revised and resubmitted for review.

**Response:** *The Navy disagrees with the reviewers conclusions that a greater effort is needed with respect to field data collection and the evaluation before monitored natural attenuation can be considered a viable groundwater remedy. The site is currently undergoing a CMS to provide further evaluation of potential remedial alternatives for this site. The Navy does not believe that additional geochemical and microbiological characterization is warranted to support the evaluation of a long-term monitoring in the CMS.*

**Comment 2:** The report does not provide sufficient information to determine whether the stratigraphic horizon(s), where most contaminant transport is expected to occur, has been identified. For example, the depths of the screened intervals for the monitoring wells have not been provided, and it is not clear whether the depth of contamination in the surficial aquifer has been adequately defined. As such, it is not evident whether the monitoring wells that were selected for the natural attenuation study are screened in the appropriate stratigraphic horizon(s).

A table should be included to provide needed information, such as ground elevation and screen depths, for each of the SWMU 9 monitoring wells. Geological cross-sections should also be provided, both perpendicular and parallel to the critical flow path (direction of plume migration). Since the groundwater flow direction at the site is radial to some extent, there is potentially more than one critical flow path. The cross-sections should include the ground surface elevations, monitoring well locations (screened interval noted), and the location of other relevant features (access road, source area, lagoon, etc.).

**Response:** *The Supplemental RFI/RI for NAS Key West High-Priority Sites provides the well depths for the wells selected in the study. Each well is 0 to 12 feet within depth in the water table aquifer that is determined to be the appropriate stratigraphic horizon. Due to the nature of the shallow water table aquifer and the significant information included in the previously referenced reports, the Navy does not believe that the development of a cross section is necessary or cost effective.*

**Comment 3:** The site conditions, as presented in Section 2.2, are general in nature and pertain to the Lower Florida Keys or Key West. Section 2.2 is extremely lacking in the discussion of the site-specific (SWMU 9) geology and hydrogeology. An understanding of the site-specific conditions is critical to the

demonstration of natural attenuation at SWMU 9. The report should be expanded to include a detailed discussion of the site-specific geology and hydrogeology.

**Response:** *The Navy disagrees and believes that the geology and hydrogeology have been adequately described in the supporting documentation. As stated in Section 2.2, the report included "...a brief description of the site history and background relevant to the natural attenuation study. Additional site background details can be found in the previously prepared Contamination Assessment Report (ABB, 1994), Groundwater Evaluation Report (BEI, 1995a), and Supplemental RFI/RI Report (B&RE 1997)."*

**Comment 4:** Several of the comments below pertain to site-specific data such as hydraulic gradient, hydraulic conductivity, partitioning coefficients, effective porosity, etc. These data were used as input parameters for the model that estimated the contaminant concentrations for the groundwater in the sentry well and the surface water in the pond. Based on the outcome of these comments (i.e., Navy responses), it may be necessary to edit some of the input parameters and re-run the model. The revised results may have an impact on the recommendation for monitored natural attenuation as a remedial alternative.

In addition, the groundwater modeling effort only addresses four contaminants: cis-1,2-dichloroethene, trans-1,2-dichloroethene, trichloroethene, and benzene. Based on the limited information provided, it could not be determined whether there may be other contaminants of concern (CoCs) present that would not be remediated by natural attenuation processes. Historically, groundwater at SWMU 9 has also been contaminated with semi-volatile organic compounds (SVOCs). In addition, the text states that metals were the most widespread soil contaminants; however there is no discussion of metals in groundwater. The report should identify all site CoCs, and these should be included in the modeling efforts.

**Response:** *An appropriate modeling effort will be performed as indicated. The modeling effort was designed merely to assist in the location of S9MW-25. The well location effort was further aided by the use of groundwater screening samples to confirm that the well was installed beyond the downgradient edge of the contaminant plume.*

*The NAS Key West Partnering Team did not view the SVOCs at the site as contaminants of concern based on the findings of the Supplemental RFI/RI human health and ecological risk assessments. The natural attenuation study was designed specifically to evaluate the four VOCs listed above.*

**Comment 5:** The surficial aquifer at SWMU 9 is tidally controlled and fluctuates constantly; however, the report does not adequately identify the impact of tidal flushing or extent of tidal influence. The tidal effects on the site must be better understood in order to effectively interpret the contaminant and geochemical (natural attenuation parameter) data.

**Response:** *Tidal influence has been measured at a maximum of 0.55 feet. However, according to the tidal influence study performed at SWMU 9 in November 1993, "Tidal fluctuations result in a temporary change in the water table gradient; however, these fluctuations are not expected to cause any noticeable horizontal migration of the contaminant plume." Additional text will be added to Section 2.2.3 to identify the impact and extent of tidal flushing.*

**Comment 6:** Groundwater modeling was performed using the ECTran model. The applicability of this model to SWMU 9 is questionable as it is unclear whether the model accounts for, or could account for, the tidal impacts to the site. This issue requires clarification.

**Response:** *As mentioned previously, the modeling effort was performed to assist in the location of S9MW-25. Tidal influence is indirectly accounted for in the ECTran model. The only input parameter that is related to the tidal influence is the groundwater contour gradient. The groundwater contour gradient has been considered conservatively in the model. Refer to the response to Specific Comment #29 for the estimation of the gradient. In addition, tidal fluctuation has been measured at a maximum of 0.55 feet. Refer to the response to General Comment #4 for a description of tidal impacts to the site. According to the tidal influence study performed in November 1993, "these tidal fluctuations only result in a temporary change in groundwater table elevations, and therefore, were not determined to be critical." The modeling effort assisted in the location of the sentry well (S9MW-25). Although the ECTran model does not directly account for the tidal impacts to the site, using the ECTran model as a groundwater transport modeling tool is considered adequate for the determination of the location of the sentry well. This is because there is only minor tidal fluctuation at the site, and the input value for the groundwater gradient is conservative.*

## **SPECIFIC COMMENTS**

**Comment 1:** Page 2-1, Second Paragraph. It is stated that the fuel spill occurred on the west side of the AST; however, the spill location is not noted on Figure 2-2. The spill location should be outlined on this figure.

**Response:** *Concur. The spill location will be noted on Figure 2-2.*

**Comment 2:** Page 2-3, First and Second Paragraphs. The first and second paragraphs appear to conflict with each other regarding the uses of the surficial aquifer. The first paragraph states that the surficial aquifer is the key aquifer of concern in Key West because of its use as a potable water resource to a limited extent. The second paragraph states that surficial aquifer wells are reportedly in use by domestic residences on Boca Chica and Key West for nonpotable uses such as flushing water. The uses of the surficial aquifer should be clarified, and the location of the nearest surficial aquifer wells, relative to SWMU 9, should be identified in the report. In addition, the first paragraph states that the water table

elevation is below mean sea level (msl) in the center of Key West and near the coast. It should be verified whether "below" or "above" mean sea level was intended.

**Response:** *Concur. The text will be clarified with respect to use of the surficial aquifer.*

**Comment 3:** Page 2-3, Third Paragraph. Historically, groundwater at SWMU 9 has been contaminated with volatile organic compounds (VOCs) and SVOCs; however, the recent sampling events to evaluate the potential for natural attenuation did not include SVOC analysis. The rationale for not including SVOCs should be provided. In addition, the text states that metals were the most widespread soil contaminants; however there is no discussion of metals in groundwater.

Based on the limited information provided, it could not be determined whether there may be certain contaminants of concern (CoCs) present that would not be remediated by natural attenuation processes. Section 2.2.4 should be expanded to include a more comprehensive discussion of the investigation history at the site, and identify the contaminants of concern in each media. Furthermore, Section 5.0 should clearly identify any CoCs that would not be remediated by natural attenuation processes.

**Response:** *Refer to the response to General Comment #4.*

**Comment 4:** Figure 2-3, Groundwater Flow and Elevations. As noted in the report, the surficial aquifer is tidally controlled and fluctuates constantly. Depending upon the magnitude of the tidal influence, it may have a significant effect on the groundwater flow direction. During high tides, there may be a reversal in flow direction across the site. Therefore, the information provided in Figure 2-3 (which does not identify the tidal stage at the time of sampling) has limited use. To accurately present the range of groundwater elevations, hydraulic gradients, and the extent of tidal influence across the site, the groundwater elevations should be presented at both high tide and low tide.

In addition, this figure should reference the datum for the groundwater level elevations (e.g., above mean sea level).

**Response:** *Refer to the response to General Comment #5. The influence of tide on groundwater elevations was not determined to be critical when Figure 2-3 was developed for the Supplemental RFI/RI for NAS Key West High-Priority Sites or when the natural attenuation sampling was performed.*

**Comment 5:** Figure 2-4, Figure 2-5, and Figure 2-6, 1994, 1995 and 1996 Groundwater Chemical Concentrations for Selected COIs. These figures present only *selected* chemicals of interest (COIs) at this site. Figure 2-5 contains a note which identifies the additional chemicals in excess of the ARARs and

Screening Action Levels (but which are not presented on the figure); however, Figures 2-4 and 2-6 do not contain such a note. If appropriate, these figures should be edited to include this information. In addition, Section 2.3.1 and Table 4-94 are referenced in the figures; however, these references do not correspond to this report.

**Response:** *Refer to the response to General Comment #4. Figures 2-4, 2-5, and 2-6 are from the Supplemental RFI/RI Report for the NAS Key West High-Priority Sites. The Navy does not believe modification of these figures is cost effective or necessary given the additional chemicals were not widespread and are no longer detected at the site. However, the figure references will be clarified.*

**Comment 6:** Page 3-1, Third Paragraph. A groundwater monitoring sentry well was installed at SWMU 9; however, based on the complex hydrology of the site, it is not evident that one sentry well is sufficient. As noted in Section 2.2.4, "plume movement over time is uncertain due to groundwater gradients that are extremely flat, tidally influenced, and frequently radial." Since the groundwater elevation data presented in Figure 2-3 is a snapshot in time based on measurements in very few wells (as clearly stated in the note on the figure), the interpreted groundwater flow direction is an oversimplification at best. A better understanding of the site hydrology, as impacted by the tides, is necessary and may result in the need for additional sentry wells.

**Response:** *Refer to Specific Comment Response #4. The statement in Section 2.2.4 is a carryover from the Supplemental RFI/RI for NAS Key West High-Priority Sites and will be revised. Since that time, three additional sampling events have confirmed the plume direction.*

**Comment 7:** Page 3-2, First Paragraph. Groundwater elevations were measured during both the May and November natural attenuation studies; however, only one groundwater elevation figure (Figure 4-2) is presented. For each sampling event, a figure should be provided and both the figure and the text should clarify the stage of the tide when the water level measurements were collected.

**Response:** *Refer to Specific Comment Response #4. However, the text and figures will be expanded to include both rounds of groundwater level measurements.*

**Comment 8:** Page 3-2, Third Paragraph. Copies of the field logs (including groundwater sample forms), which provide field data during well purging and prior to sampling, should be included as an appendix to this report. This information is needed to conduct various checks on the field data and to evaluate the subsequent conclusions based on that data. For example, elevated turbidity in the groundwater samples can cause interferences in the Hach® chemical analyses and impact the ferrous iron and sulfate results<sup>1</sup>.

**Response:** *Concur. Copies of the field logs will be provided.*

**Comment 9:** Page 3-2, Fifth Paragraph. In addition to the field parameters specified (temperature, pH, turbidity, specific conductance, dissolved oxygen, and oxidation-reduction potential), the field parameters should have included salinity. Salinity would have provided an indication of the degree of infiltration of lagoon water. In addition, the salinity of the lagoon water should have been measured.

**Response:** *Concur. Salinity values of the groundwater are available for the May 1998 groundwater sampling event and will be included in Table 4-1. The salinity for the lagoon was not collected in May or November 1998. Previous lagoon salinity values can be found in the Supplemental RFI/RI Report for the High Priority Sites and the RFI/RI Report.*

**Comment 10:** Page 3-4, First Paragraph. The first sentence of this paragraph states that a pH standard was used to calibrate the Horiba® meter for pH, specific conductance, and turbidity. This sentence is obviously in error, because the pH standard can not be used to calibrate specific conductance and turbidity measurements. The sentence should be corrected. The field notes concerning the calibration of the Horiba® and YSI® meters should be provided in an appendix to the report.

**Response:** *The solution for the Horiba® calibration, as provided by the manufacturer, is specifically called a Standard pH Solution. This solution is an auto-calibration solution specifically designed for calibration of specific conductance, turbidity, pH, and salinity on the U-10 Water Checker. The DO probe automatically calibrates to atmospheric air during the calibration mode. Also, refer to the response to Specific Comment #9.*

**Comment 11:** Page 3-4, Second Paragraph. It is incorrectly stated that the Hach® Model OX-DT test kit can obtain accurate determination of dissolved oxygen (DO) concentrations as low as 0.02 mg/L and as high as 10 mg/L. According to Hach® literature and a confirming phone call with Hach® Customer Service, the Model OX-DT test kit is a high range DO test kit and is only accurate between 1 mg/L to 10 mg/L of DO. The text should be corrected.

**Response:** *Concur. The Hach® Model OX-DT test kit is the specific test kit recommended for use in determining dissolved oxygen concentrations in groundwater during natural attenuation studies. Since the equipment used is a field digital titrator that uses pre-measured chemical reagents sets, detection limit studies have not been performed. Therefore, the precision and accuracy of the kit, at any concentration, cannot be defined. The text will be clarified accordingly.*

**Comment 12:** Page 3-9, First Paragraph. The second bullet of this paragraph states that fixed-base laboratory analyses were performed on samples from 11 monitoring wells for geochemical parameters, and Section 3.1.4 is referenced. However, Section 3.1.4 discusses field measurements, not fixed-base laboratory analyses. In addition, Table 4-1 only presents one set of results, and does not differentiate results between the field and a laboratory (as it was done in Table 4-2). Clarify whether fixed-base analyses of geochemical parameters were conducted during the May 1998 sampling event, and if so, include this information in the report.

**Response:** *Concur. The text and tables referenced will be clarified.*

**Comment 13:** Page 3-9, First Paragraph. The fourth bullet of this paragraph indicates that an upgradient soil sample was collected and analyzed for total organic carbon (TOC). TOC samples should be collected in upgradient or background locations in the stratigraphic horizon(s) where the most contaminant transport is expected to occur<sup>1</sup>. The location and depth of the soil sample collected should be provided.

**Response:** *Concur. The TOC sample was collected in an upgradient (background) location in the stratigraphic horizon where the most contaminant transport occurs. This will be clarified in the text.*

**Comment 14:** Page 3-10, Second Paragraph. The first sentence implies that monitored natural attenuation (MNA) has already been selected as the final remedial alternative. Since the purpose of this report is to evaluate MNA, this statement is premature and should be reworded.

**Response:** *Concur. A CMS is currently being performed for this site which will evaluate monitored natural attenuation as one of the remedial alternatives.*

**Comment 15:** Page 3-10, Second Paragraph. The first bullet of this paragraph mentions a small surface water pond. The figures in Section 4.0 of the report should be revised to show the location and size of this pond.

**Response:** *Concur. The location and approximate size of this pond will be included.*

**Comment 16:** Page 3-11, First Paragraph. As noted in this paragraph, the sentry well (S9MW-25) was installed to a depth of 12 feet. The basis for the selection of the screened interval from 2 ft bgs to 12 ft bgs should be provided. Discuss the vertical profile of contamination at the site, the vertical hydraulic gradients, whether the screened interval of the sentry well is within the critical flow path, and whether it

accurately represents the depth of groundwater that would be expected to discharge to the surface water pond and lagoon.

**Response:** *Concur. Refer the responses to General Questions #2 and #3. The basis for the selection of the screened interval from 2 ft bgs to 12 ft bgs will be included in the text.*

**Comment 17:** Page 4-1, First Paragraph. According to this paragraph, S9MW-12 is the most upgradient well. However, the groundwater elevation data on Figure 4-2 indicates that S9MW-12 is not an upgradient well as the groundwater elevation in this well (3.27) [units not specified] is lower than the majority of the monitoring wells at the site. For the purposes of demonstrating natural attenuation as a viable remedial alternative, an appropriate background monitoring well is necessary.

**Response:** *Figure 4-2 is depicted in feet based on an arbitrary datum. The elevation of any particular well alone does not determine its upgradient/downgradient position in a site. Equally important is its spatial location with respect to the source area and the groundwater flow direction. For the sake of collecting a background groundwater sample for the natural attenuation study, this well was selected based on its spatial location with respect to the plume.*

**Comment 18:** Page 4-2, Second Paragraph. To demonstrate that natural attenuation, it is critical to have a valid background monitoring well. Groundwater data is compared to the background well to support the occurrence of natural attenuation. It is stated that the background oxygen concentration is 1.0 mg/L; however, a review of the data in Table 4-2 indicates that the only well with a dissolved oxygen concentration was S9MW-13 in November, 1998. Given the proximity of S9MW-13 to the site, and the hydrology of the site, it is unlikely that S9MW-13 could be considered a valid background monitoring well.

**Response:** *Table 4-2 indicates that every well sampled had detectable dissolved oxygen concentrations, ranging from 0.53 mg/L to 1.0 mg/L. The report stated that the maximum detected dissolved oxygen concentration was 1.0 mg/L, located in monitoring well S9MW-13. This is presented on Figure 4-4. From a geochemical perspective, both S9MW-13 and S9MW-12 generally reflect background conditions. Also, refer to the response to specific comment #17.*

**Comment 19:** Page 4-4, Fourth Paragraph. As stated, the sulfide result of 7 mg/L in S9MW-10 is considered an anomalous point because S9MW-10 is a cross-gradient location with respect to groundwater flow, with no reported VOC contamination. However, Figures 4-6 and 4-7 show that S9MW-10 also has among the highest carbon dioxide and methane concentrations. As shown in Figure 4-2, S9MW-10 appears down gradient of the source area. The fact that the groundwater flow directions at

SWMU 9 are not well understood may partially explain apparent anomalies. It is critical that groundwater flow patterns be clearly identified.

**Response:** Refer to Specific Comment Response #4. The report states several times that the geochemical parameters collected from S9MW-10 appear to be anomalous (and have been anomalous during both geochemical sampling rounds). The two rounds of sampling indicated that S9MW-10 is not impacted by dissolved hydrocarbons. The Navy does not believe that groundwater flow directions at SWMU 9 explain the anomaly.

**Comment 20:** Page 4-5, First Paragraph. The sulfide ion concentration discussion in this paragraph does not appear to be in agreement with the data provided on Tables 4-1 and 4-2. First, a maximum detection of 0.8 mg/L in S9RW-2 could not be verified. Second, there is discussion of a May laboratory analysis, and "fixed-base" sulfide concentrations; however, Section 3.0 does not discuss the analysis of May 1998 geochemistry samples by a fixed-base laboratory. Third, the sulfide data presented in Tables 4-1 and 4-2 do not indicate that sulfide concentrations are significantly increasing in the downgradient direction. These discrepancies should be corrected or clarified.

**Response:** Concur. A total of four separate sulfide analyses were performed during the two sampling rounds. For the first round, they included fixed-based laboratory analysis for total sulfides and field hydrogen sulfide screening. For the second round, they included mobile laboratory analysis for total sulfides, field hydrogen sulfide screening, and field colorimetric analysis for total sulfides. This, along with the respective results, will be clarified in the text.

**Comment 21:** Page 4-6, Third Paragraph. Since methanogenesis generally occurs after oxygen, nitrate, and sulfate have been depleted in the treatment zone<sup>1</sup>, a discussion is warranted regarding the occurrence of methanogenesis in the presence of elevated sulfate concentrations (particularly in S9MW-05 and S9MW-10 with methane concentrations of 3245 mg/L and 2840 mg/L, respectively, and sulfate concentrations of 5.44 mg/L and 235 mg/L, respectively).

**Response:** Theoretically, and under equilibrium conditions, redox zonation will occur at a hydrocarbon site following the predicted pattern presented by the reviewer. In reality, where equilibrium conditions do not exist, such perfect zonation rarely occurs. The fact that sulfate is elevated does not in itself preclude the presence of methanogenic bacteria. At most sites, sulfate is a relatively minor constituent that would degrade to sulfide prior to methanogenesis occurring. At this site, however, sulfate and sulfide are elevated site-wide due to biodegradation of natural organic carbon. Therefore, it not believed that the presence of sulfate implies that methanogenesis is not occurring. Additional clarifying text can be added to the report.

**Comment 22:** Page 5-5, Third Paragraph. It is stated that the groundwater plume at SWMU 9 appears to exhibit both Type 1 and Type 2 behavior. As explained in Section 5.3, vinyl chloride will tend to accumulate in the source area or along the downgradient edge of the plume in both Type 1 and Type 2 behavior. In support of this, analytical data at SWMU 9 shows elevated concentrations of 1,2-dichloroethene and the ethene/ethane concentrations indicate that vinyl chloride is not undergoing dechlorination at the site (refer to Sections 4.2.11 and 4.2.12). Therefore, it is expected that vinyl chloride concentrations would be present in the plume; however, the data presented in the report indicates that vinyl chloride has not been detected. This issue requires clarification.

**Response:** *Concur. Further clarification will be added.*

**Comment 23:** Page 5-8, Third Paragraph. The sentry well was located 50 feet southeast of S9MW-22 based on modeling results. The input parameters for the model should be re-checked based on the above comments and the model should be re-run as necessary. Also as noted in previous comments, it is likely that more than one sentry well is appropriate for SWMU 9 based on the groundwater flow patterns.

**Response:** *The modeling effort assisted in the location of S9MW-25. Suitable site sentry wells may include S9MW-21, -22, and -25. These will be evaluated in the CMS.*

**Comment 24:** Table 5-1, Analytical Parameters and Weighting for Preliminary Natural Attenuation Screening. The following comments pertain to Table 5-1:

The dissolved oxygen concentration at SWMU 9 is listed as 0 mg/L. This should be corrected based on the available data.

The sulfide concentration at SWMU 9 is listed as > 5 mg/L and 3 points were awarded. The November 1998 laboratory data showed sulfide concentrations ranging from 0.12 mg/L to 0.2 mg/L. The points awarded for sulfide concentrations should be re-evaluated.

**Response:** *Concur. The dissolved oxygen concentration will be revised accordingly. With respect to sulfide, refer to the response to Specific Comment #20.*

**Comment 25:** Page B-1, Fourth Paragraph. Acceptable surface water criteria were chosen as the most restrictive ARAR/SAL criteria and four chemicals (cis-1,2-DCE, trans-1,2-DCE, TCE, and benzene) were

selected for modeling because these chemicals exceeded the groundwater action levels based on 1998 groundwater sampling data. The text provides insufficient information to evaluate whether this approach is acceptable. First, the basis of the ARAR/SAL criteria is not provided. Therefore, it is not known whether these criteria were developed for human health or ecological exposure, or whether they are applicable to surface water. Additional information needs to be provided and evaluated further.

**Response:** *The ARAR/SAL criteria are based on the current approved ARAR/SAL criteria for NAS Key West. The criteria was used during the Supplemental RFI/RI for NAS Key West High-Priority Sites when the site under went a human health risk assessment and ecological risk assessment. Since 1996 these criteria have been updated to address the BRAC activities at NAS Key West.*

**Comment 26:** Page B-4, Fourth Paragraph. It is stated that groundwater flow is in a north-northeast direction toward the lagoon based on the 1998 groundwater contour map, and Figure B-2 is referenced. However, Figure B-2 is based on very limited 1996 data, not 1998 data as specified. The groundwater elevation and flow figures should be modified to represent the more comprehensive 1998 data sets (both May and November presented individually). In addition, since the groundwater levels are tidally impacted, the stage of the tide during sampling of the wells must be specified. To accurately present the range of groundwater elevations, hydraulic gradients, and the extent of tidal influence across the site, the groundwater elevations should be presented at both high tide and low tide.

**Response:** *Refer to Specific Comment Response #4. In addition, it is not anticipated that the 1998 data will indicate any significant difference in the groundwater flow direction for the site. The text will be changed in the model summary to indicate that Figure B-2 was prepared based on 1996 data.*

**Comment 27:** Page B-4, Fifth Paragraph. Based on the information presented in Table B-2, the average aquifer transmissivity value is  $9.4 \times 10^{-2}$  feet<sup>2</sup>/minute or 134.8 feet<sup>2</sup>/day, and not  $9.4 \times 10^{-3}$  feet<sup>2</sup>/minute or 13.5 feet<sup>2</sup>/day, as indicated in this paragraph. This error should be corrected.

**Response:** *Concur. Based on the transmissivity values presented in Table B-2, the average aquifer transmissivity value is  $9.4 \times 10^{-2}$  feet<sup>2</sup>/minute or 134.8 feet<sup>2</sup>/day. Text will be changed in this paragraph.*

**Comment 28:** Page B-5, First Sentence. It is stated that the thickness of the surficial aquifer is 27 feet. This thickness is apparently derived from the geology of the Lower Florida Keys (see Section 2.2.1) and does not necessarily reflect the site-specific thickness of the surficial aquifer. Clarify whether the investigations at SWMU 9 have confirmed the depth of the surficial aquifer at the site.

**Response:** *Based on USGS deep cores in the keys the bottom of the surficial aquifer is found at 900 feet where the Tamiami and Hawthorn and Tampa Formations act as an aquiclude. Therefore, the determination of the surficial aquifer was deemed to be costly and unnecessary during previous investigations. The surficial aquifer was sampled to a depth of 25 feet at the site in two deep wells S9MW-19D and -20D. 1,4 -dichlorobenzene was detected in these wells however it was at concentrations below the Florida MCL.*

**Comment 29:** Page B-5, Fifth Sentence. The basis of the hydraulic gradient (0.0016 ft/ft) and the effective porosity (0.3) that were used in the seepage velocity calculation should be provided.

**Response:** *The hydraulic gradient (i) was calculated based on the groundwater table elevations measured from the 1996 field event, as presented on Figure 2-3 of SMWU 9 Natural Attenuation Report (February 1996). The hydraulic gradient were formulated as follows:*

*Hydraulic gradient (i) = (groundwater elevation at well S9MW6 – groundwater elevation at well S9MW14)/ distance between these two wells) = (3.62 feet- 3.46 feet) /100 ft = 0.0016 ft/ft. Note that the calculation is conservative since another well S9MW21, approximately 1,400 feet downgradient from well S9MW6, also indicates the same groundwater elevation measurement of 3.46 feet.*

*A typical porosity value of 0.3 was used for limestone or sandy material. This is based on reference from "Civil Engineering Reference Manuals (Lindeburg, 1989, National Society of Professional Engineers, 5th edition)," and the text book of "Groundwater" by Freeze and Cherry.*

**Comment 30:** Page B-5, Third Paragraph. Assumptions that were made in the Site Conceptual Model include a surficial aquifer depth of 27 feet and a general groundwater flow direction of north-northeast. See previous Specific Comment numbers 26 and 28 concerning these assumptions.

**Response:** *The surficial aquifer assumption was a conservative estimate based on the general formation and affected aquifer depth. These assumptions are considered valid for the model.*

**Comment 31:** Page B-6, Third Paragraph. It is stated that the initial soil concentrations under the source area were assumed to be the maximum detected concentrations in the soil samples. Clarify the location and depth of these soil samples, the date of sample collection, the contaminants detected, and their concentrations.

**Response:** *The few soil contaminant concentrations are discussed in Chapter 9 of the Supplemental RFI/RI for NAS Key West High-Priority Sites.*

**Comment 32:** Page B-12, Fourth Paragraph. As noted in this paragraph, the groundwater modeling accounted for several natural attenuation processes including sorption, dilution, advection, dispersion, and chemical/biological decay. The text discussion of the model adequately addresses the source or derivation of the sorption and chemical/biological decay model input parameters. However, the model input parameters (as shown on the ECTran model's input sheets) for dilution, advection, and dispersion require an explanation regarding the source or derivation of these values.

**Response:** *A simple description of dilution, advection, and dispersion is provided on the bottom of Page B-6. Attachment B.1 presents the equations used for the calculation of these processes.*

**Comment 33:** Table B-1, Summary of Groundwater Fate and Transport Modeling Under Current Conditions. Footnote 5 states that the surface water criteria were chosen as the most restrictive ARAR/SAL criteria. As stated in a previous comment, it is not known whether these criteria were developed for human health or ecological exposure, or whether they are applicable to surface water. Additional information needs to be provided and evaluated further.

**Response:** *The ARAR/SAL criteria are discussed in the Supplemental RFI/RI for NAS Key West High-Priority Sites Appendix C and F and the NAS Key West BRAC Site Inspection WorkPlan.*

**Comment 34:** Table B-2, Hydraulic Conductivities from the Pumping Test and Slug Test. The following comments pertain to Table B-2:

1. Several of the Well IDs on this table (P-2, P-3, P-4, P-5, and MW-2) have not been previously identified in the text or figures of the report. Provide the locations and depth of screened intervals for these wells.
2. Seven hydraulic conductivity values are presented in this table. Five values range between 3.33 feet per day and 9.43 feet per day, and are derived from pump tests. The remaining two values are 0.57 feet per day and 0.86 feet per day, and are derived from slug tests. Due to the relatively significant difference in values derived from pump tests versus slug tests, and the fact that pump tests are generally more representative of the aquifer (as opposed to the immediate area surrounding a well) than slug tests, the slug test values should be considered for removal from the geometric mean calculation. Removing the two slug test values increases the geometric mean for hydraulic conductivity from 2.70 feet per day to 4.62 feet per day.

**Response:** *1. The depths of the wells are all 11 feet bls and additional data on these wells are available in the ABB 1994 Report.*

2. Generally speaking, pumping tests provide a more accurate representation of spatial hydrogeological parameters than slug tests. The data generated from the pumping test will be reviewed for accuracy and relevance. If the pumping test data appear to be more appropriate than the slug tests, those values alone will be used in the model calculations.

**Comment 35:** Table B-3, Partitioning Coefficient and Half-Lives. Footnote 4 of this table states that the groundwater  $F_{OC}$  values were obtained from the Natural Attenuation Study report dated August 1998. The reviewer assumed that the data set provided at the end of Appendix B reflects the data from this report. Based on this assumption, the geometric mean of this TOC data was calculated by the reviewer to be 10.69 mg/L or ppm, which is equivalent to 0.001%. Expressed as a fraction, the mean would be 0.00001.

While the column headings in Table B-3 suggest that the  $F_{OC}$  values are presented in % format, the  $F_{OC}$  for soil is presented as a decimal fraction (0.0720; as a percentage it is 7.2%). Therefore, it would seem that the  $F_{OC}$  for groundwater would also be presented as a decimal fraction (0.00001); however, it is presented as a percentage in the table (0.001%). Therefore, the partitioning coefficients (Kd-saturated zone) were incorrectly calculated and should be two orders of magnitude less than the values presented in the table. The input parameters for the model should be modified as necessary and the model should be re-run. This correction may significantly alter the predicted impacts to the sentry well and pond.

In addition, the  $F_{OC}$  for soil (0.0720) is based on one soil sample, which is an extremely limited representation of organic carbon. Also as noted previously, the location and depth of this soil sample are not identified in the report. Several total organic carbon concentrations should be obtained from the most transmissive zone and averaged. The most transmissive zone generally contains the lowest total organic carbon concentrations which provides a conservative prediction of contaminant sorption and retardation<sup>1</sup>.

**Response:** Based on the following explanation, the Navy does not anticipate the need for any changes to the  $F_{OC}$  values in the model.

The column headings in Table B-3 corresponding to both  $F_{OC}$  values should be presented as a decimal fraction. The % signs in column headings in Table B-3 will be deleted. Whether or not the unit of the  $F_{OC}$  value is expressed in mg/kg or mg/L, the  $F_{OC}$  values can always be converted into a dimensionless decimal fraction. Note that one liter of water weights 1,000 gram. Hence the soil  $F_{OC}$  value remains unchanged as 0.0720 in a decimal fraction.  $F_{OC}$  for groundwater will also be the same as presented in

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<sup>1</sup> AFCEE, 1996, Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater, Draft - Revision 1. San Antonio, Texas, November.

Table B-3. The  $F_{OC}$  value for groundwater was determined based on the following two reasons. First, the TOC concentrations obtained from the Natural Attenuation Study field activity has shown that the native organic carbon is present at sufficient concentrations in the aquifer because organic carbon concentrations greater than 20 mg/L in the aquifer indicate a sufficient supply of carbon to act as the primary substrate. Second, an  $F_{OC}$  value of 0.001 or 0.1% is the lowest acceptable value that can be used in the  $K_d = K_{oc} * F_{OC}$  model (EPA, 1988, "Superfund Exposure Assessment Manual," EPA/540/1-88/001) for calculating the  $K_d$  values. Also, a default  $F_{OC}$  value of 0.002 or 0.2% (higher than 0.001) was suggested by EPA.

Although the  $F_{OC}$  for soil (0.0720) is based on one soil sample, it is found that using 0.072 for the soil  $F_{OC}$  has a negligible impact on the current results. This can be explained for three reasons. First, the  $F_{OC}$  for soil was only applied for the unsaturated zone in the source area. As has been reported by the field data, the soil contaminants for the majority of chemicals are below their detection limits, with the exception that only minor soil trans-1, 2 DCE concentration (0.01 mg/kg) exists in the source area. Therefore, the  $F_{OC}$  for soil has no impact on the groundwater concentration at the sentry well or the surface water pond for the majority of chemicals. Second, the thickness of the unsaturated soil is very shallow (2 feet) at the site; hence very little leachate would be generated from the source area. Third, the minor amount of leachate from the source area soil would have little effect on the downgradient groundwater concentration since other natural processes including sorption, dilution, dispersion, and decay will further reduce the groundwater concentration at the downgradient points.

Finally, the AFCEE draft guidance document has been replaced by a USEPA document of the same name (Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater, EPA\600\R-98\128). The SWMU 9 natural attenuation report was prepared in accordance with the Draft EPA Region 4 Suggested Practices for Evaluation of a Site for Natural Attenuation of Chlorinated Solvents Version 3.0, November 1997.

**APPENDIX C**

**GROUNDWATER MODELING RESULTS FOR SWMU 9**

## SUMMARY OF GROUNDWATER MODELING FOR BENZENE, CIS-1,2 DCE, AND TRANS-1,2 DCE AT THE JET ENGINE TEST CELL SITE (SWMU 9), NAS KEY WEST

### PURPOSE

The purpose of this modeling, conducted for Solid Water Management Unit (SWMU) 9 at the Naval Air Station (NAS), Key West, Florida, is to determine the time required for downgradient groundwater concentrations to remain at or below action levels at the three modeled locations. SWMU 9, the Jet Engine Test Cell site associated with Building A-969, is located in the northeastern portion of the Boca Chica Airfield (Figure 1). Three chemicals were modeled because their current concentrations exceed the groundwater action levels. These chemicals are: benzene, cis-1,2 dichloroethene (cis-1,2 DCE), and trans-1,2 dichloroethene (trans-1,2 DCE). Three locations are evaluated: under the source area, 25 feet downgradient from the edge of the source, and at the proposed new sentry well location (approximately 50 feet southeast of well S9MW22). Conservative quantitative estimates of the time at which the groundwater concentrations will remain below the action levels at each designated location are obtained.

ECTran modeling was conducted to provide the necessary estimates to support the evaluations. The model and modeling approach used, along with the modeling results, are briefly summarized below. Additional details concerning the physical characteristics of the site can be found in Section 3.0 of the Supplemental Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) / Remedial Investigation (RI) Report (B&RE 1997). For a detailed description regarding the site conceptual model and groundwater modeling approach, refer to "Corrective Measures Study Report for Solid Waste Management Unit 9 (SWMU 9)" Appendix C, Groundwater Modeling Results, SWMU 9, NAS Key West (TiNUS, 1998).

### GROUNDWATER MODEL

The groundwater modeling was performed using the ECTran model (Chiou, et al., 1993). The ECTran model is an analytical contaminant fate and transport model, and is a multi-layer, one-dimensional model based on straightforward mass-balances and advection/dispersion analytical equations.

The groundwater model is implemented on the spreadsheet software Excel 4.0 and Crystal Ball 3.0 and is called ECTran (Excel-Crystal Ball Transport). The ECTran model can be used to simulate a variety of complex conditions. To date, ECTran and its predecessors have been employed at hazardous waste sites in United States Environmental Protection Agency (U.S. EPA) Regions III, IV, V, VI, and X to evaluate soil cleanup goals, estimate cleanup times, and to support baseline risk assessments. It has been used at Department of Defense (DOD), Department of Energy (DOE), Naval Air Station, and industrial sites for both RCRA and Comprehensive Environmental Response, Compensation, and Liability act (CERCLA) applications.

The ECTran model simulates vertical contaminant transport through the vadose zone and lateral groundwater transport with uniform (thickness, concentration, porosity, etc.) layers. The model predicts the concentration downgradient of the source at a single point at a specified distance from the exposure point.

### GENERAL APPROACH

The computations considered the natural processes affecting contaminant fate and transport in groundwater. Naturally occurring mechanisms will reduce contaminant concentrations in groundwater over time. The mechanisms/processes affecting chemical fate and transport in groundwater that were accounted for during the modeling include sorption, dilution, advection, and dispersion. A site-specific contaminant transport model was developed using the general modeling approach presented below:

- Conceptualization of the hydrogeologic conditions - Based on the soil borings results, oolitic limestone was encountered at the surface and was present to the termination of the borings at 13 feet below

ground surface (bgs). The limestone was consistent in all borings, and no lateral or horizontal variations were apparent. As stated in the RI report, the Miami Oolite is 27 feet thick (ABB-ES, 1995). The hydrogeologic unit associated with the oolitic limestone is the surficial aquifer. At SWMU 9, the typical depth to groundwater is estimated to be approximately 2 feet bgs, which is determined as the thickness of the unsaturated zone. The modeled thickness of the saturated layer includes the surficial aquifer system and is selected to be 27 feet (Figure 2). The general groundwater flow direction in the surficial aquifer is to the north-northeast (Figure 1). Groundwater can travel both horizontally and vertically within the saturated zone. The average hydraulic conductivity value was reported to be 4.62 feet/day. Site-specific physical parameters were defined based on the descriptions of site hydrogeologic data provided in Section 3.0 of the Supplemental RFI/RI Report.

- Definition of the source area and existing groundwater and soil concentrations - It is assumed that the source area for each contaminant corresponds to a rectangular area. Each contaminant source area size was determined based on the locations at which groundwater contaminants were detected. Figure 1 and Table 3 present the source area sizes based on the reported November 1998 groundwater concentrations in the surficial aquifer.

At SWMU 9, the current maximum detected groundwater concentrations in the source area include benzene (18 µg/L), cis-1,2 DCE (280 µg/L), and trans-1,2 DCE (820 µg/L). Of the three modeled chemicals, only trans-1,2-DCE has detected soil concentrations (maximum detected soil concentration of 10 ug/kg) in the source area.

- Estimation of the acceptable groundwater concentration - ECTran model simulations were conducted to determine the time at which the concentrations of the three selected chemicals will remain below the action levels at each of the three modeled locations.

## SITE-SPECIFIC ASSUMPTIONS

The site-specific assumptions used for the modeling are summarized as follows:

- |                                     |  |
|-------------------------------------|--|
| • Initial Soil Concentration        | trans-1,2 DCE - 10 ug/kg   |
| • Initial Groundwater Concentration | benzene - 18 µg/L<br>cis-1,2 DCE - 280 µg/L<br>trans-1,2 DCE - 820 µg/L  |
| • Source Area Size                  | benzene – 145 feet x 85 feet<br>cis-1,2 DCE – 110 feet x 190 feet<br>trans-1,2 DCE - 110 feet x 190 feet<br>(See Figure 1) |
| • Hydraulic Conductivity            | 4.62 feet /day   |
| • Hydraulic Gradient                | 0.0016   |
| • Effective Porosity                | 0.3  |
| • Infiltration Rate                 | 1 inches/year (based on concrete pad over source area)   |
| • Plume thickness                   | 27 feet (Calculated from mixing depth formula, Chiou, et al., 1993)  |
| • Partition Coefficient Kd          | Site-specific Kd values were estimated for both unsaturated zone and the saturated zone (See Table 2).<br>(Kd = foc * KOC) |
| • Half life                         | benzene – 2.0 years<br>cis-1,2 DCE – 7.9 years<br>trans-1,2 DCE – 7.9 years<br>(Howard, 1991)                              |

## RESULTS

Table 1 presents the groundwater modeling results for SWMU9. Tables 2 and 3 summarize the site-specific chemical and physical/hydrogeologic parameters.

Through the natural attenuation processes present at the project site, the times at which the benzene concentration will remain below the action level (1 ug/L) at the source, 25 feet downgradient from the source, and at the proposed sentry well location were computed as 7.2, 9, and 7.6 years, respectively. Natural attenuation processes that were accounted for during groundwater modeling include sorption, dilution, advection, dispersion, and chemical/biological decay. ECTran model inputs and outputs are presented in Attachment 1. Figures showing groundwater concentration variations with time at these three locations are included in Attachment 1.

The times at which cis-1,2-DCE concentration will remain below the action level (70 ug/L) at the three designated locations were estimated as 8.6, 12.1, and 12.6 years, respectively. The cis-1,2-DCE concentration variations with time at these three locations are included in Attachment 1.

The modeling results for trans-1,2 DCE indicate that the times at which trans-1,2 DCE will remain below the action level (100 ug/L) at the three designated locations are approximately 14, 16, and 18 years, respectively. As summarized in Table 1, current maximum detected soil concentration under the source area (near well S9MW15) is 10 µg/kg, and the detected maximum groundwater concentration in the source is 820 µg/L. Based on the modeling results, the low trans-1,2 DCE concentration present in soils has the effect of slightly increasing the extent of plume migration. It will also increase the time taken for this chemical to drop in concentration to below the action level at the proposed sentry well. The trans 1,2-DCE concentration variations with time at these three locations are presented in Attachment 1.

## REFERENCES

ABB-ES (ABB Environmental Services, Inc.), 1995, *Facility and Remedial Investigation NAS Key West, Workplan, Volume 1*, prepared for SOUTHNAVFACENGCOM. Tampa, Florida, December.

B&R Environmental (Brown & Root Environmental), 1997, *Supplemental RCRA Facility Investigation and Remedial Investigation Report for NAS Key West High-Priority Sites Boca Chica Key, Florida*, prepared for SOUTHNAVFACENGCOM. Aiken, South Carolina, Revision 2, July 1997.

Chiou, J.D., C. Rich, W. Yu, 1993, "ECTran - A Spreadsheet Based Screening-Level Multimedia Fate and Transport Model with Monte Carlo Simulation Capability," in Proceedings of the ER '93 Conference, Sponsored by the U.S. Department of Energy, Augusta, Georgia, pp. 117-122.

Howard, P.H., R.S. Boething, W. F. Jarvis, W. M. Meylan, and E. M., Michalenko, 1991, Handbook of Environmental Degradation Rates, Lewis Publishers, Inc., Chelsea, Michigan.

Tetra Tech NUS, (TtNUS) Inc, 1998 *Natural Attenuation Report for NAS Key West High-Priority Sites Boca Chica Key, Florida*, prepared for SOUTHNAVFACENGCOM. Aiken, South Carolina, August 1998.

Tetra Tech NUS, (TtNUS) Inc, 1998 *Corrective Measures Study Report for Solid Waste Management Unit 9 (SWMU 9) Appendix C, Groundwater Modeling Report SWMU 9, NAS Key West High-Priority Sites Boca Chica Key, Florida* prepared for SOUTHNAVFACENGCOM. Aiken, South Carolina, November 1998.

United States Environmental Protection Agency, January, 1995 "Manual- Groundwater and Leachate Treatment Systems" (EPA/625/R-94/005).

United States Environmental Protection Agency, April, 1996, Soil Screening Guidance: Users Guide, EPA/540/R-96/018, Office of Solid Waste and Emergency Response, Washington, DC, April.

U.S. Environmental Protection Agency, 1988, "Superfund Exposure Assessment Manual," EPA/540/1-88/001, EPA, Washington, DC.

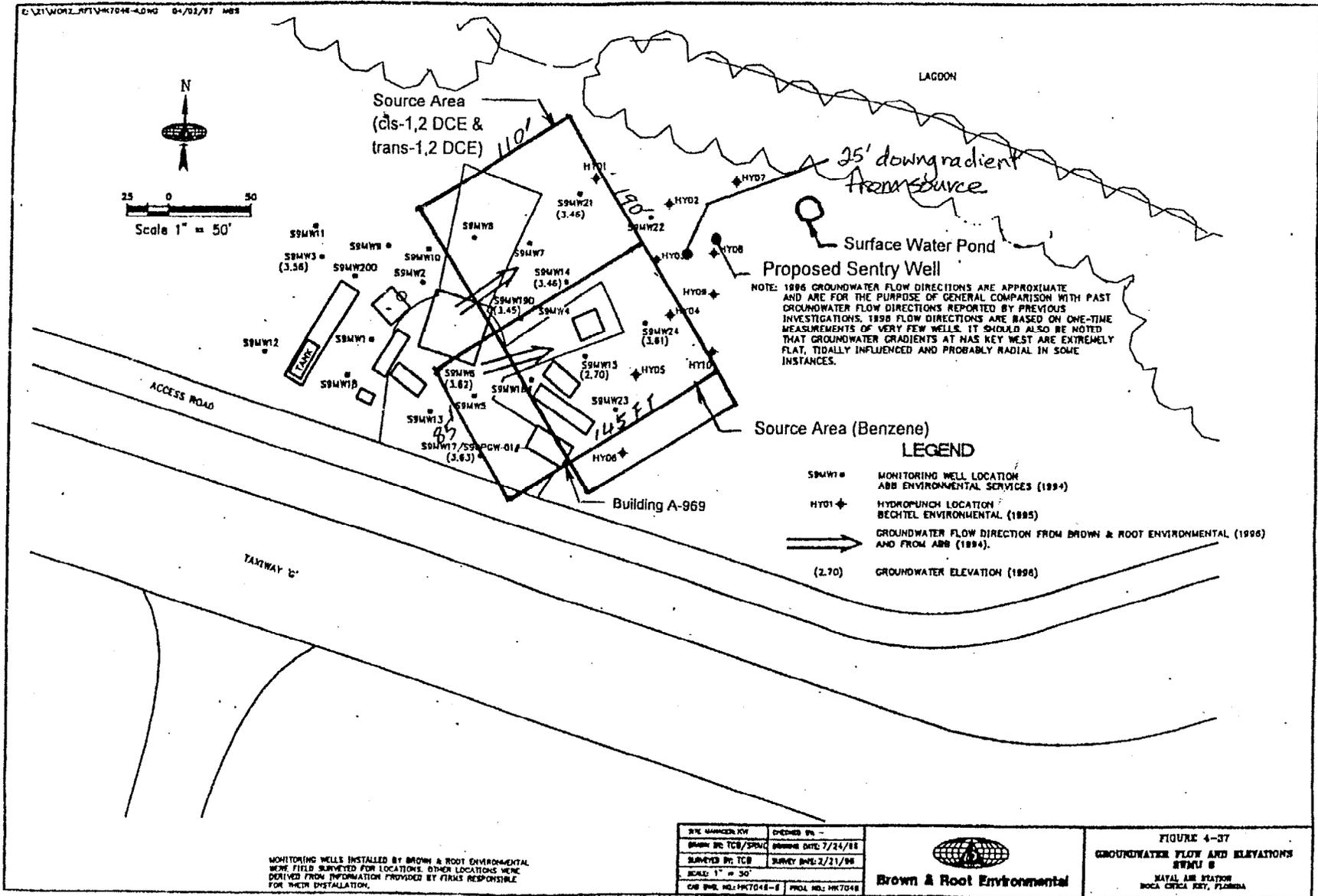
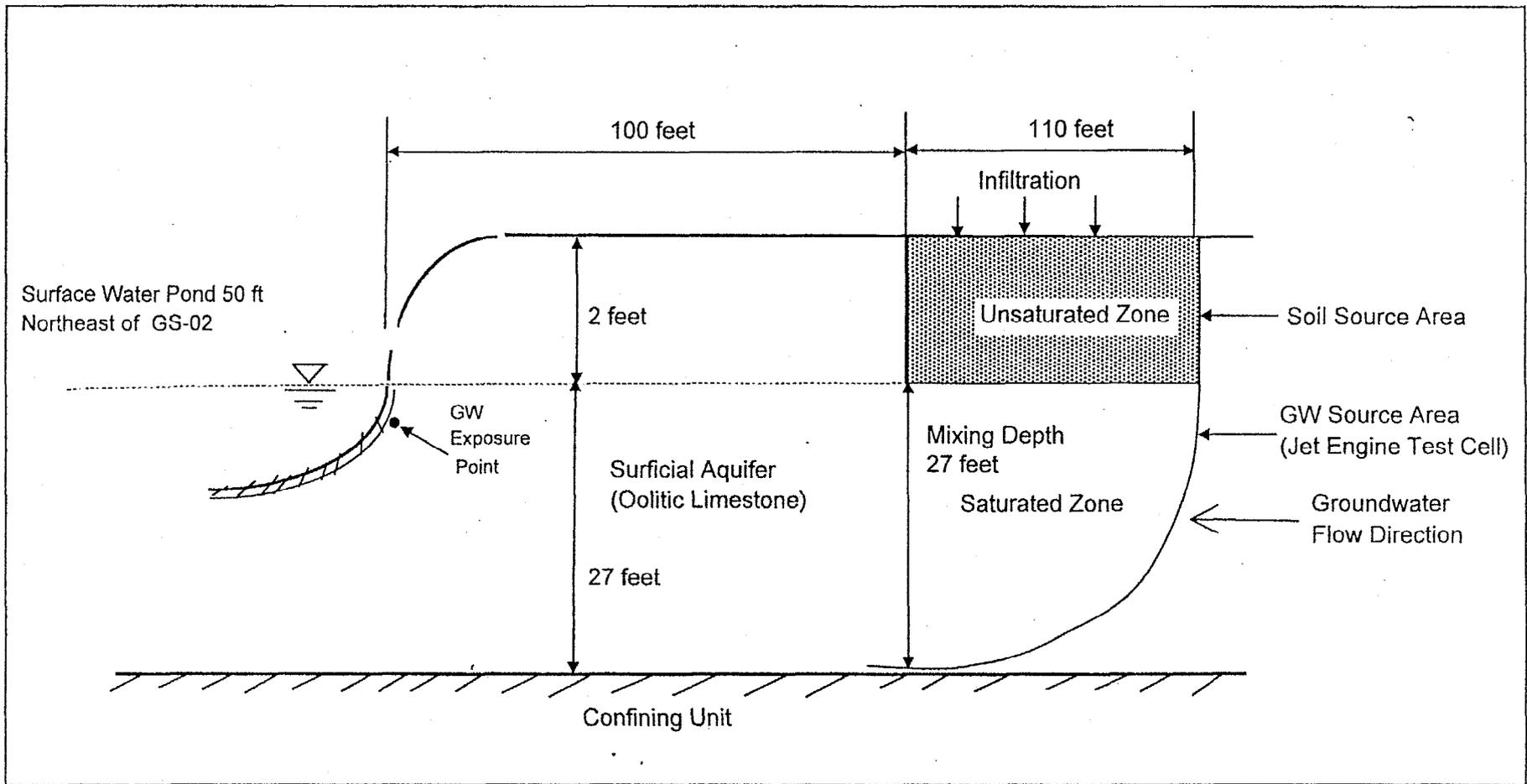


FIGURE 1 SITE MAP, GROUNDWATER FLOW DIRECTION AND SOURCE AREAS (SWUM 9, AS KEY WEST)



Not to Scale

FIGURE 2 CONCEPTUAL MODEL FOR GROUNDWATER FATE AND TRANSPORT (SWMU 9, NAS KEY WEST)

**TABLE 1**  
**SUMMARY OF GROUNDWATER FATE AND TRANSPORT MODELING UNDER CURRENT CONDITIONS**  
**SWUM 9 CORRECTIVE MEASURE STUDY**  
**NAVAL AIR STATION, KEY WEST, FLORIDA**

Chemical of Concern	Max. Detected Soil Concentration in Source Area <sup>(1)</sup>  (ug/kg)	Max. Detected Groundwater Concentration in Source Area <sup>(2)</sup>  (ug/L)	Groundwater Action Level  (ug/L)	Time to Action Level Concentration Under Source  (years)	Time to Action Level Concentration at 25 feet Downgradient from the source  (years)	Time to Action Level Concentration at New Sentry Well <sup>(5)</sup>  (years)
Benzene	0	18	1 <sup>(3)</sup>	7.2	9	7.6
Cis-1,2-Dichloroethene	0	280	70 <sup>(4)</sup>	8.6	12.1	12.6
Trans-1,2-Dichloroethene	10	820	100 <sup>(4)</sup>	14	16	18

Notes:

- (1) Maximum detected concentrations in surface and subsurface soils were based on the Supplemental Investigation and RI Report (Table 4-91, B&R, July 1997).
- (2) Maximum detected groundwater concentrations were the most current data based on November 1998 groundwater sampling data (TtNUS, Nov 1998).
- (3) Florida Maximum Contaminant Levels (FL MCL)
- (4) Safe Drinking Water Act Maximum Contaminant Levels (MCL).
- (5) The proposed new sentry well is located at approximately 50 feet southeast of the existing well S9MW22.

TABLE 2  
 PARTITIONING COEFFICIENT AND HALF-LIVES  
 SWMU 9 CORRECTIVE MEASURE STUDY  
 NAVAL AIR STATION, KEY WEST, FLORIDA

Chemicals of Concern	Organic Carbon/ Water Partitioning Coefficient <sup>(1)</sup> KOC (L/kg)	Soil Organic Carbon Content <sup>(2)</sup> FOC	Partitioning Coefficient <sup>(3)</sup> (unsaturated zone) Kd (L/kg)	Groundwater Organic Carbon Content <sup>(4)</sup> FOC	Partitioning Coefficient <sup>(3)</sup> (saturated zone) Kd (L/kg)	Half-Life <sup>(5)</sup> (years)
Cis-1,2-Dichloroethene	49	0.0720	3.53	0.0010	0.05	7.9
Trans-1,2-Dichloroethene	59	0.0720	4.25	0.0010	0.06	7.9
Benzene	83	0.0720	5.98	0.0010	0.08	2.0

(1) The KOC was imported from U.S. EPA document "Manual- Groundwater and Leachate Treatment Systems" (EPA/625/R-94/005).

(2) The soil FOC value used in this evaluation was based on 72,000 mg/kg (or 7.2 %) TOC concentrations from one groundwater samples (S9MW-10) result collected in May1998 (TtNUS, Aug 1998).

(3)  $K_d = FOC \times KOC$ , U.S. EPA, December 1996, Soil Screening Guidance Users Guide.

(4) The groundwater FOC values were based on results from Natural Attenuation Study (TtNUS, Aug 1998). A geometric mean foc value was used for modeling.

(5) Half-lives were taken from literature values (Howard 1991).

**TABLE 3**  
**SUMMARY OF PHYSICAL AND GEOLOGIC PARAMETERS**  
**SWMU 9 CORRECTIVE MEASURE STUDY**  
**NAVAL AIR STATION, KEY WEST, FLORIDA**

Chemical of Concern	Source Area <sup>(1)</sup>		Shallow Aquifer Thickness <sup>(2)</sup> (ft)	Unsaturated Zone Thickness <sup>(3)</sup> (ft)	Hydraulic Conductivity <sup>(4)</sup> K (ft/day)	Mixing Depth <sup>(5)</sup> (ft)	Distance to New Sentry Well <sup>(7)</sup> (ft)
	Length (ft)	Width (ft)					
Cis-1,2-Dichloroethene	110	190	27	2	4.62	27	45
Trans-1,2-Dichloroethene	110	190	27	2	4.62	27	45
Benzene	145	85	27	2	4.62	27	45

(1) Source area size was based on the reported 1998 groundwater concentrations in the surficial aquifer (Figures B-4, and TiNUS, August 1998).

(2) Shallow surficial aquifer thickness is based on the RFI/RI (B&R, July 1997).

(3) The unsaturated zone thickness is based on the water table elevations presented in the RFI/RI (B&R, July 1997).

(4) A geometric mean K value from pumping tests in the surficial aquifer was selected for modeling (Table B-2).

(5) The mixing depth was calculated based on equations presented in the reference for ECTran model (Chiou et al, 1993).

(6) Measured from the edge of the source area to the surface water pond (Figure 1).

(7) Measured from the edge of the source area to the new sentry well (Figure 1).

**ATTACHMENT 1**

**GROUNDWATER MODELING RESULTS - INPUTS AND OUTPUTS**

**BENZENE**

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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/6/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	benzene	EXPOSURE POINT: (UNDERS. FL)	FL
HALF-LIFE (YRS):	2.00E+00	LEACHATE CONCENTRATION (YES,NO) ?	NO
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	UNDERS: Under source. FL: Fenceline	
		WATER CRITERIA (UG/L):	1.00E+00
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	0.00E+00
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	0.00E+00
		ACCEPTABLE!	DECREASE

SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FYR):	8.30E-02
Kl (L/KG):	5.89E+00	LENGTH (FT):	145
DEPLETING SOURCE:		WIDTH (FT):	85
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3):	1.78
		Kd (L/KG):	1.00E-05

IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0

SATURATED LAYER

TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>20</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRAIDENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	8.13E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	2.5	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	0.8	CONC. IN UPGRAIDENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	1.800E+01	DISTANCE TO Fence.Line.: A + 25'	25

PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	1.80E+01 (UG/L)	0
FENCE LINE CONCENTRATION:	3.17E+00 (UG/L)	3.6

SITE: SWMU 9, NAS, Key West

CONTAMINANT: benzene

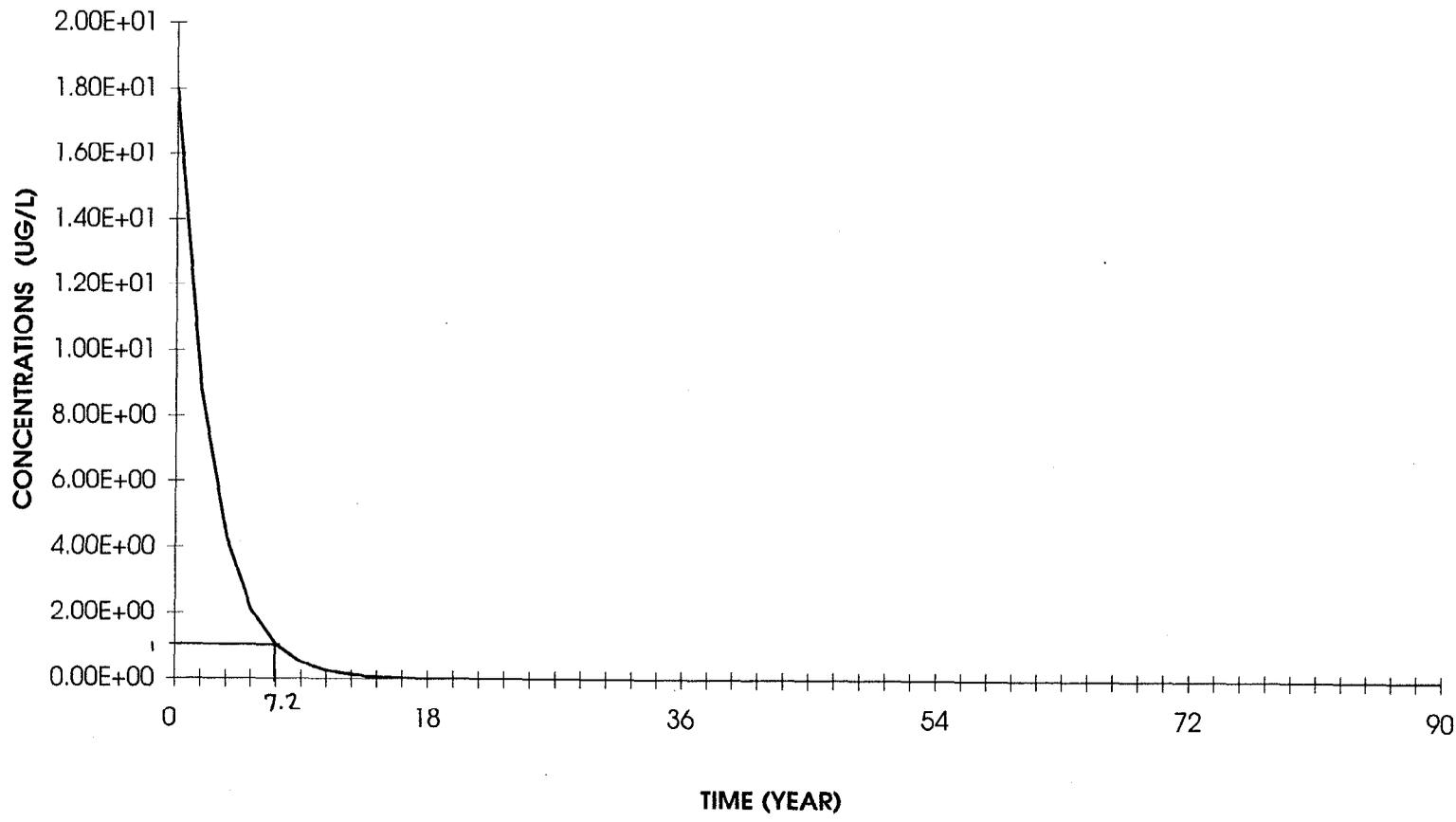
INVESTIGATOR: LK  
DATE: 5/6/99

HALF-LIFE (YRS):	
LAYER 2:	2.00E+00
SATURATED LAYER	2.00E+00
DOWNGRADIENT	2.00E+00
INITIAL CONC. (ug/L):	1.80E+01

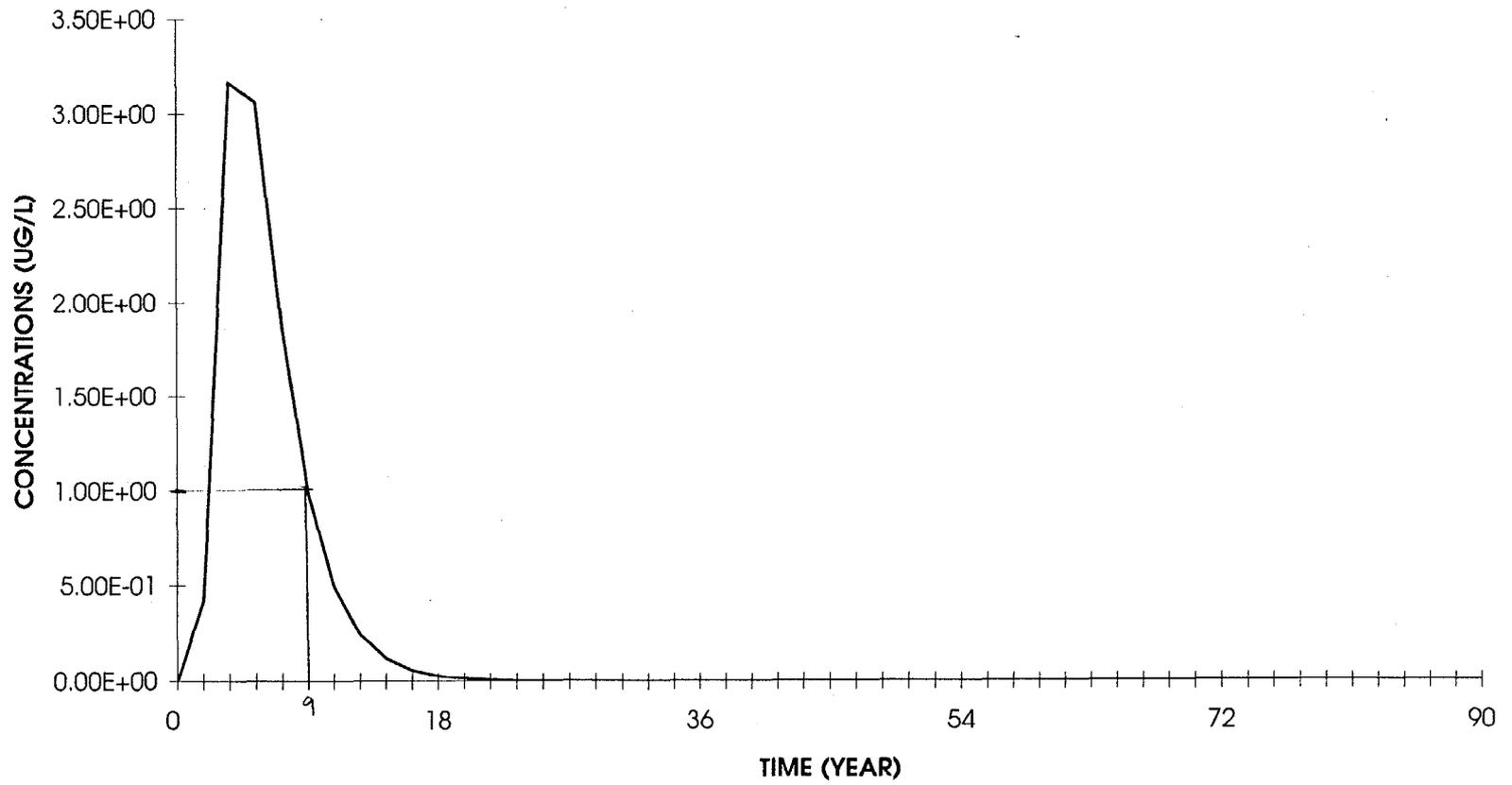
SATURATED LAYER			
INFILT (FT/YR):	0.083	B (FT):	27
LENGTH (FT):	145	Vzo (FT/YR):	4.48
WIDTH (FT):	85	GW Q3 (L/DAY):	5.60E-02
POROSITY 2:	0.3	GW V. (FT/YR):	8.99
POROSITY SAT. LAYER:	0.3	Kd (L/KG):	0.0813
DENSITY 2 (G/CM3):	1.5	H (FT):	27.0000
DENSITY GMA (G/CM3):	1.50	RETARDATION:	1.4065
AGE (YEARS):	0	EFF. POROSITY:	0.30
Q1 (L/DAY):	7.94E+01	q (FT/YR):	0
Q2 (L/DAY):	4.80E+02	DISPERSIVITY:	DECAY (1/YR):
		Az (FT):	0.14
		Ax (FT):	2.50
		P&T (YEARS):	0
		Ay (FT):	0.83
		DISTANCE TO F.L. (FT):	25

TIME INTERVAL (YRS)		SOURCE AREA CONC.(GMA)		FENCE LINE CONC.	
1.8		(UG/L)		(UG/L)	
ELAPSED TIME - YRS	LAYER 2 (PPB)				
0	0.00E+00	1.80E+01	0.00E+00		
1.8	0.00E+00	8.79E+00	4.24E-01		
3.6	0.00E+00	4.30E+00	3.17E+00		
5.4	0.00E+00	2.10E+00	3.07E+00		
7.2	0.00E+00	1.03E+00	1.87E+00		
9	0.00E+00	5.01E-01	9.90E-01		
10.8	0.00E+00	2.45E-01	4.97E-01		
12.6	0.00E+00	1.20E-01	2.45E-01		
14.4	0.00E+00	5.84E-02	1.20E-01		
16.2	0.00E+00	2.85E-02	5.88E-02		
18	0.00E+00	1.39E-02	2.88E-02		
19.8	0.00E+00	6.81E-03	1.41E-02		
21.6	0.00E+00	3.33E-03	6.87E-03		
23.4	0.00E+00	1.63E-03	3.35E-03		
25.2	0.00E+00	7.94E-04	1.64E-03		
27	0.00E+00	3.88E-04	8.01E-04		
28.8	0.00E+00	1.90E-04	3.91E-04		
30.6	0.00E+00	9.26E-05	1.91E-04		
32.4	0.00E+00	4.52E-05	9.34E-05		
34.2	0.00E+00	2.21E-05	4.56E-05		
36	0.00E+00	1.08E-05	2.23E-05		
37.8	0.00E+00	5.28E-06	1.09E-05		
39.6	0.00E+00	2.58E-06	5.32E-06		
41.4	0.00E+00	1.26E-06	2.60E-06		
43.2	0.00E+00	6.15E-07	1.27E-06		
45	0.00E+00	3.01E-07	6.20E-07		
46.8	0.00E+00	1.47E-07	3.03E-07		
48.6	0.00E+00	7.17E-08	1.48E-07		
50.4	0.00E+00	3.51E-08	7.23E-08		
52.2	0.00E+00	1.71E-08	3.53E-08		
54	0.00E+00	8.37E-09	1.73E-08		
55.8	0.00E+00	4.09E-09	8.43E-09		
57.6	0.00E+00	2.00E-09	4.12E-09		
59.4	0.00E+00	9.75E-10	2.01E-09		
61.2	0.00E+00	4.77E-10	9.83E-10		
63	0.00E+00	2.33E-10	4.80E-10		
64.8	0.00E+00	1.14E-10	2.35E-10		
66.6	0.00E+00	5.56E-11	1.15E-10		
68.4	0.00E+00	2.71E-11	5.60E-11		
70.2	0.00E+00	1.33E-11	2.74E-11		
72	0.00E+00	6.48E-12	1.34E-11		
73.8	0.00E+00	3.17E-12	6.53E-12		
75.6	0.00E+00	1.55E-12	3.19E-12		
77.4	0.00E+00	7.56E-13	1.56E-12		
79.2	0.00E+00	3.69E-13	7.61E-13		
81	0.00E+00	1.80E-13	3.75E-13		
82.8	0.00E+00	8.81E-14	1.80E-13		
84.6	0.00E+00	4.30E-14	8.91E-14		
86.4	0.00E+00	2.10E-14	4.45E-14		
88.2	0.00E+00	1.03E-14	2.12E-14		
90	0.00E+00	5.02E-15	1.06E-14		
MAXIMUM:	0.00E+00	1.80E+01	3.17E+00		

**TIME TO ACTION LEVEL CONCENTRATION  
IN AQUIFER BENEATH THE SOURCE AREA  
BENZENE**



**TIME TO ACTION LEVEL CONCENTRATION AT 25 FEET  
BENZENE**



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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/6/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	benzene	EXPOSURE POINT: (UNDERS, FL) FL UNDERS: Under source, FL: Fenceline WATER CRITERIA (UG/L): 1.00E+00	LEACHATE CONCENTRATION (YES,NO) ? NO INPUT SOLID-PHASE CONCENTRATION (MG/KG) 0.000E+00 CONSTANT CONCENTRATION (YES,NO)? NO TRY NEW GOAL: 0.00E+00 ACCEPTABLE! DECREASE
HALF-LIFE (YRS):	2.00E+00	TIME FRAME (YRS): 90	
SPECIFIC ACTIVITY (Ci/g):	0.00E+00		

SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FT/YR):	8.30E-02
Ki (L/KG):	5.89E+00	LENGTH (FT):	145
DEPLETING SOURCE:		WIDTH (FT):	85
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3):	1.78
		Kd (L/KG):	1.00E-05

IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0

SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>z0</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	8.13E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	4.5	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	1.5	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	1.800E+01	DISTANCE TO Fence.Line.: <i>At SENTRY well</i>	45

PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	1.80E+01 (UG/L)	0
FENCE LINE CONCENTRATION:	1.16E+00 (UG/L)	7.2

SITE: SWMU 9, NAS, Key West

CONTAMINANT: benzene

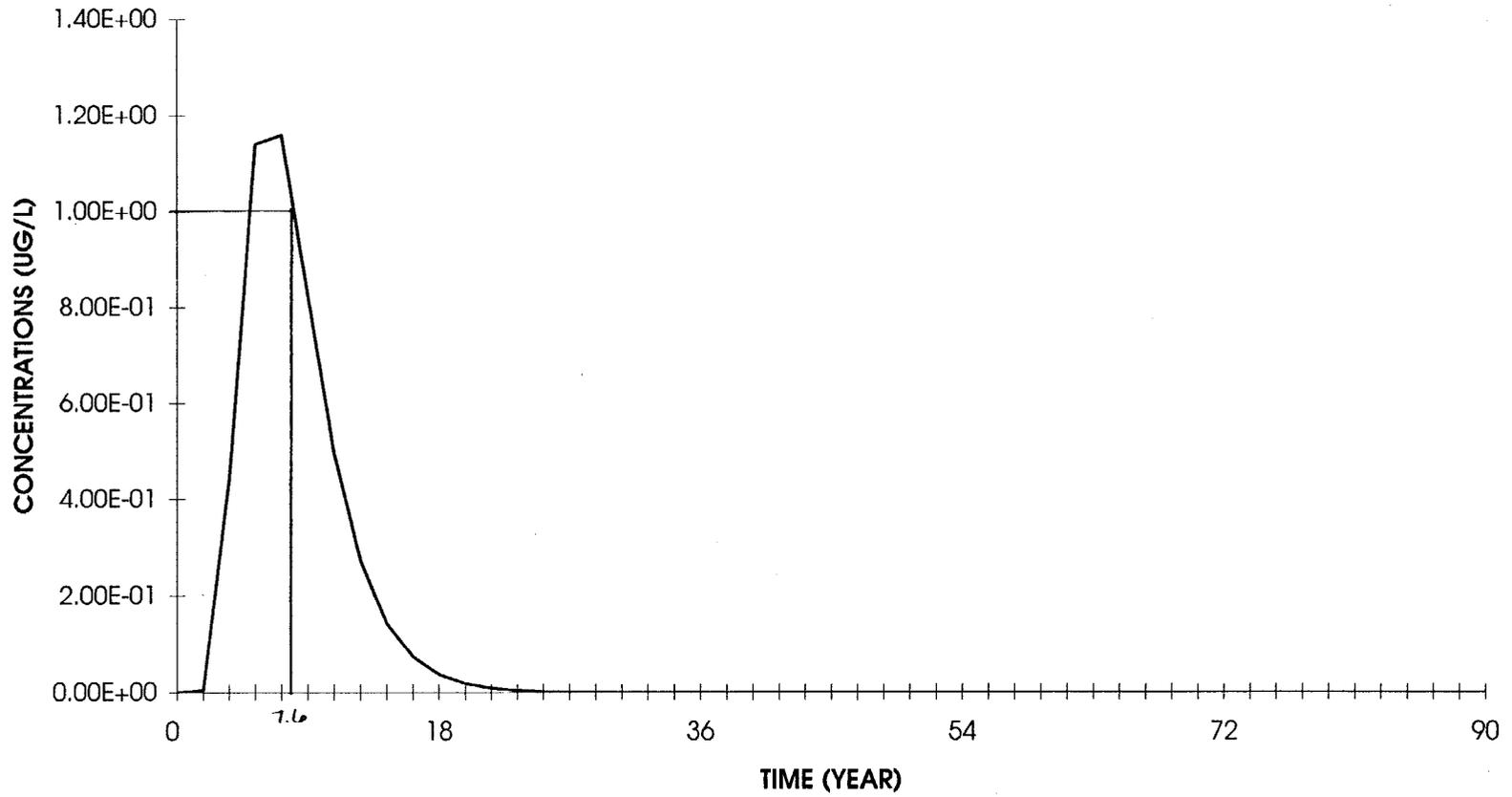
INVESTIGATOR: LK  
DATE: 5/6/99

HALF-LIFE (YRS):	
LAYER 2:	2.00E+00
SATURATED LAYER	2.00E+00
DOWNGRADIENT	2.00E+00
INITIAL CONC. (ug/L):	1.80E+01

SATURATED LAYER					
INFILT (FT/YR):	0.083			B (FT):	27
LENGTH (FT):	145			Vzo (FT/YR):	4.48
WIDTH (FT):	85			GW Q3 (L/DAY):	5.60E+02
POROSITY 2:	0.3			GW V. (FT/YR):	8.99
POROSITY SAT. LAYER:	0.3			Kd (L/KG):	0.0813
DENSITY 2 (G/CM3):	1.5			H (FT):	27.0000
DENSITY GMA (G/CM3):	1.50			RETARDATION:	1.4065
				EFF. POROSITY:	0.30
				DISPERSIVITY:	0.14
				Az (FT):	0.14
				Ax (FT):	4.50
				P&T (YEARS):	0
AGE (YEARS):	0	Q1 (L/DAY):	7.94E+01	Ay (FT):	1.50
				DECAY (1/YR):	3.5E-01
				DECAY (1/DAY):	9.50E-04
				THICKNESS (FT):	27.00
				SATURATION:	1.00
				CB0 (PPB):	1.80E+01
				CU2 (PPB):	0.00E+00
				Q2 (L/DAY):	4.80E+02
				Kd (L/KG):	8.13E-02

TIME INTERVAL (YRS)		SOURCE AREA CONC.(GMA)		FENCE LINE CONC.	
1.8		(UG/L)		(UG/L)	
ELAPSED TIME - YRS	LAYER 2(PPB)				
0	0.00E+00		1.80E+01		0.00E+00
1.8	0.00E+00		8.79E+00		5.46E-03
3.6	0.00E+00		4.30E+00		4.46E-01
5.4	0.00E+00		2.10E+00		1.14E+00
7.2	0.00E+00		1.03E+00		1.16E+00
9	0.00E+00		5.01E-01		8.24E-01
10.8	0.00E+00		2.45E-01		4.95E-01
12.6	0.00E+00		1.20E-01		2.72E-01
14.4	0.00E+00		5.84E-02		1.42E-01
16.2	0.00E+00		2.85E-02		7.24E-02
18	0.00E+00		1.39E-02		3.62E-02
19.8	0.00E+00		6.81E-03		1.79E-02
21.6	0.00E+00		3.33E-03		8.82E-03
23.4	0.00E+00		1.63E-03		4.33E-03
25.2	0.00E+00		7.94E-04		2.12E-03
27	0.00E+00		3.88E-04		1.04E-03
28.8	0.00E+00		1.90E-04		5.08E-04
30.6	0.00E+00		9.26E-05		2.48E-04
32.4	0.00E+00		4.52E-05		1.21E-04
34.2	0.00E+00		2.21E-05		5.92E-05
36	0.00E+00		1.08E-05		2.89E-05
37.8	0.00E+00		5.28E-06		1.41E-05
39.6	0.00E+00		2.58E-06		6.91E-06
41.4	0.00E+00		1.26E-06		3.38E-06
43.2	0.00E+00		6.15E-07		1.65E-06
45	0.00E+00		3.01E-07		8.06E-07
46.8	0.00E+00		1.47E-07		3.94E-07
48.6	0.00E+00		7.17E-08		1.92E-07
50.4	0.00E+00		3.51E-08		9.40E-08
52.2	0.00E+00		1.71E-08		4.59E-08
54	0.00E+00		8.37E-09		2.24E-08
55.8	0.00E+00		4.09E-09		1.10E-08
57.6	0.00E+00		2.00E-09		5.35E-09
59.4	0.00E+00		9.75E-10		2.61E-09
61.2	0.00E+00		4.77E-10		1.28E-09
63	0.00E+00		2.33E-10		6.24E-10
64.8	0.00E+00		1.14E-10		3.05E-10
66.6	0.00E+00		5.56E-11		1.49E-10
68.4	0.00E+00		2.71E-11		7.28E-11
70.2	0.00E+00		1.33E-11		3.56E-11
72	0.00E+00		6.48E-12		1.74E-11
73.8	0.00E+00		3.17E-12		8.49E-12
75.6	0.00E+00		1.55E-12		4.14E-12
77.4	0.00E+00		7.56E-13		2.03E-12
79.2	0.00E+00		3.69E-13		9.91E-13
81	0.00E+00		1.80E-13		4.82E-13
82.8	0.00E+00		8.81E-14		2.37E-13
84.6	0.00E+00		4.30E-14		1.15E-13
86.4	0.00E+00		2.10E-14		5.51E-14
88.2	0.00E+00		1.03E-14		2.80E-14
90	0.00E+00		5.02E-15		1.49E-14
MAXIMUM:	0.00E+00		1.80E+01		1.16E+00

**TIME TO ACTION LEVEL CONCENTRATION  
AT PROPOSED SENTRY WELL  
BENZENE**



**CIS-1,2 DICHLOROETHENE**

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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/7/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	cis-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL) FL	LEACHATE CONCENTRATION (YES,NO) ? NO
HALF-LIFE (YRS):	7.92E+00	UNDERS: Under source. FL: Fenceline	INPUT SOLID-PHASE CONCENTRATION (MG/KG) 0.000E+00
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	WATER CRITERIA (UG/L): 7.00E+01	CONSTANT CONCENTRATION (YES,NO)? NO
		TIME FRAME (YRS): 90	TRY NEW GOAL: 0.00E+00
			ACCEPTABLE! DECREASE

SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(Ft/YR):	8.30E-02
KI (L/KG):	3.53E+00	LENGTH (FT):	110
DEPLETING SOURCE:		WIDTH (FT):	190
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3):	1.78
		Kd (L/KG):	1.00E-05

IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0

SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>zo</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADE AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	4.80E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, A <sub>z</sub> (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, A <sub>x</sub> (FT):	2.5	AGE (YRS):	0
LATERAL DISPERSIVITY, A <sub>y</sub> (FT):	0.8	CONC. IN UPGRADIENT GROUNDWATER, CU <sub>2</sub> (UG/L)	0
INITIAL CONC. (ug/L):	2.800E+02	DISTANCE TO Fence.Line.: A + 25'	25

PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	2.80E+02 (UG/L)	0
FENCE LINE CONCENTRATION:	1.49E+02 (UG/L)	5.4

SITE: SWMU 9. NAS, Key West

CONTAMINANT: cis-1,2-Dichloroethene

INVESTIGATOR: LK  
DATE: 5/7/99

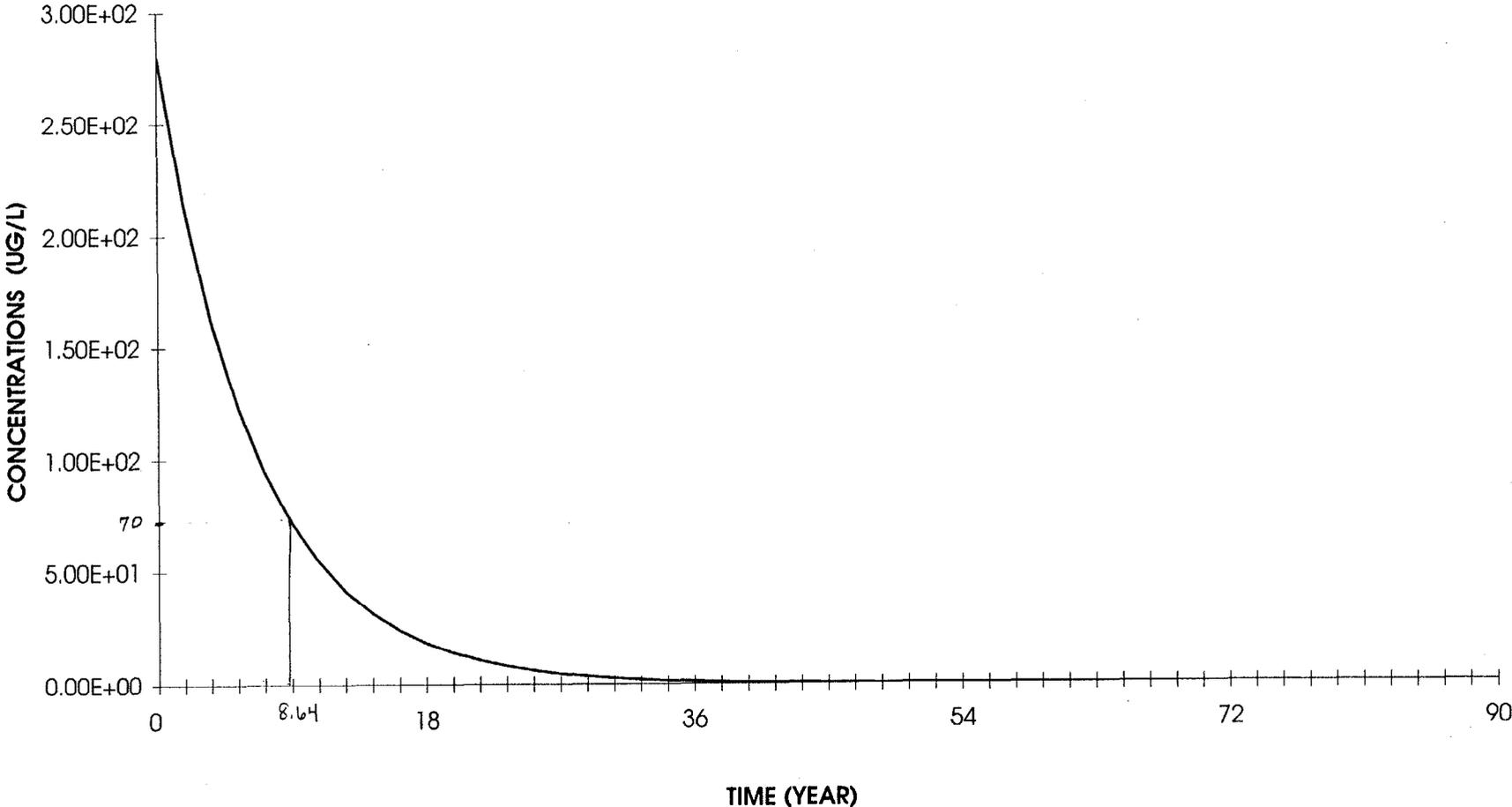
HALF-LIFE (YRS):	
LAYER 2:	7.92E+00
SATURATED LAYER	7.92E+00
DOWNGRADIENT	7.92E+00
INITIAL CONC. (ug/L):	2.80E+02

SATURATED LAYER

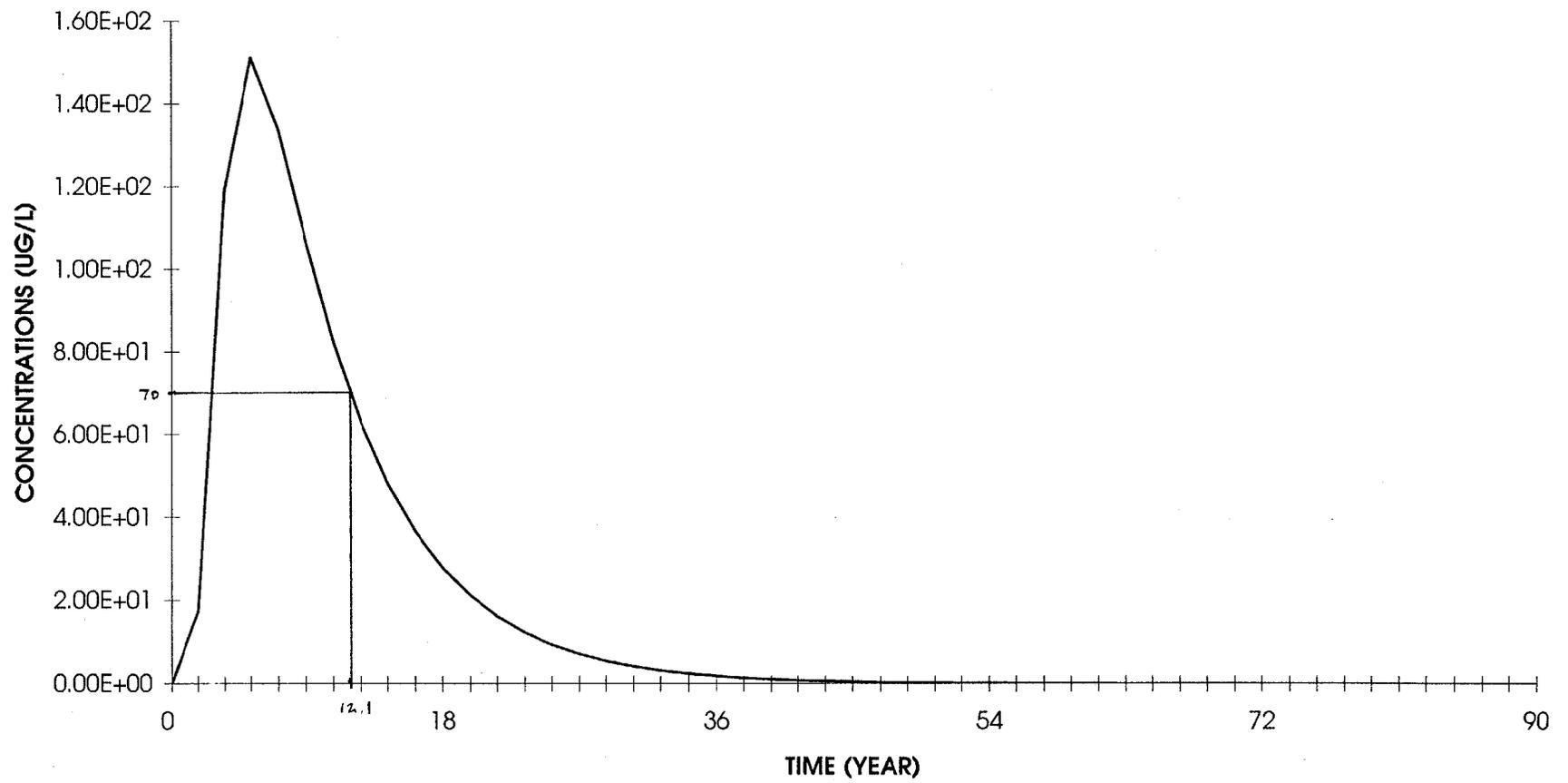
INFILT (FT/YR):	0.083		B (FT):	27	Vzo (FT/YR):	4.48	
LENGTH (FT):	110		GW Q3 (L/DAY):	1.21E+03			
WIDTH (FT):	190		Kd (L/KG):	4.80E-02	GW V. (FT/YR):	8.99	
POROSITY 2:	0.3		SATURATION:	1.00	Kd (L/KG):	0.04802	
POROSITY SAT. LAYER:	0.3		THICKNESS (FT):	27.00	H (FT):	27.0000	
DENSITY 2 (G/CM3):	1.5		DECAY (1/DAY):	2.40E-04	RETARDATION:	1.2401	
DENSITY GMA (G/CM3):	1.50		CB0 (PPB):	2.80E+02	EFF. POROSITY:	0.30	
			CU2 (PPB):	0.00E+00	DISPERSIVITY:		
AGE (YEARS):	0	Q1 (L/DAY):	1.35E+02	Q2 (L/DAY):	1.07E+03	DECAY (1/YR):	8.8E-02
						Az (FT):	0.14
						Ax (FT):	2.50
						P&T (YEARS):	0
						Ay (FT):	0.83
						DISTANCE TO F.L. (FT):	25

TIME INTERVAL (YRS)		SOURCE AREA CONC. (GMA)		FENCE LINE CONC.	
1.8		(UG/L)		(UG/L)	
ELAPSED TIME - YRS	LAYER 2 (PPB)				
0	0.00E+00		2.80E+02		0.00E+00
1.8	0.00E+00		2.09E+02		1.73E+01
3.6	0.00E+00		1.56E+02		1.19E+02
5.4	0.00E+00		1.17E+02		1.49E+02
7.2	0.00E+00		8.74E+01		1.30E+02
9	0.00E+00		6.53E+01		1.02E+02
10.8	0.00E+00		4.88E+01		7.76E+01
12.6	0.00E+00		3.65E+01		5.83E+01
14.4	0.00E+00		2.73E+01		4.36E+01
16.2	0.00E+00		2.04E+01		3.26E+01
18	0.00E+00		1.52E+01		2.44E+01
19.8	0.00E+00		1.14E+01		1.82E+01
21.6	0.00E+00		8.51E+00		1.36E+01
23.4	0.00E+00		6.36E+00		1.02E+01
25.2	0.00E+00		4.75E+00		7.61E+00
27	0.00E+00		3.55E+00		5.69E+00
28.8	0.00E+00		2.66E+00		4.25E+00
30.6	0.00E+00		1.98E+00		3.18E+00
32.4	0.00E+00		1.48E+00		2.37E+00
34.2	0.00E+00		1.11E+00		1.77E+00
36	0.00E+00		8.29E-01		1.33E+00
37.8	0.00E+00		6.19E-01		9.91E-01
39.6	0.00E+00		4.63E-01		7.41E-01
41.4	0.00E+00		3.46E-01		5.54E-01
43.2	0.00E+00		2.59E-01		4.14E-01
45	0.00E+00		1.93E-01		3.09E-01
46.8	0.00E+00		1.44E-01		2.31E-01
48.6	0.00E+00		1.08E-01		1.73E-01
50.4	0.00E+00		8.07E-02		1.29E-01
52.2	0.00E+00		6.03E-02		9.65E-02
54	0.00E+00		4.51E-02		7.21E-02
55.8	0.00E+00		3.37E-02		5.39E-02
57.6	0.00E+00		2.52E-02		4.03E-02
59.4	0.00E+00		1.88E-02		3.01E-02
61.2	0.00E+00		1.41E-02		2.25E-02
63	0.00E+00		1.05E-02		1.68E-02
64.8	0.00E+00		7.86E-03		1.26E-02
66.6	0.00E+00		5.88E-03		9.40E-03
68.4	0.00E+00		4.39E-03		7.03E-03
70.2	0.00E+00		3.28E-03		5.25E-03
72	0.00E+00		2.45E-03		3.93E-03
73.8	0.00E+00		1.83E-03		2.93E-03
75.6	0.00E+00		1.37E-03		2.19E-03
77.4	0.00E+00		1.02E-03		1.64E-03
79.2	0.00E+00		7.66E-04		1.22E-03
81	0.00E+00		5.72E-04		9.16E-04
82.8	0.00E+00		4.28E-04		6.84E-04
84.6	0.00E+00		3.20E-04		5.11E-04
86.4	0.00E+00		2.39E-04		3.82E-04
88.2	0.00E+00		1.79E-04		2.86E-04
90	0.00E+00		1.33E-04		2.14E-04
MAXIMUM:	0.00E+00		2.80E+02		1.49E+02

**TIME TO ACTION LEVEL CONCENTRATION  
IN AQUIFER BENEATH THE SOURCE AREA  
CIS-1,2-DCE**



TIME TO ACTION LEVEL CONCENTRATION AT 25 FEET  
CIS-1,2-DCE



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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/7/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	cis-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL)	FL
HALF-LIFE (YRS):	7.92E+00	UNDERS: Under source, FL: Fenceline	
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	WATER CRITERIA (UG/L):	7.00E+01
		TIME FRAME (YRS):	90
		LEACHATE CONCENTRATION (YES,NO) ?	NO
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	0.00E+00
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	0.00E+00
		ACCEPTABLE!	DECREASE
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT (FT/YR):	8.30E-02
Ki (L/KG):	3.53E+00	LENGTH (FT):	110
		WIDTH (FT):	190
DEPLETING SOURCE:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
WASTE CHARACTERISTICS:		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	HOW MANY SUBLAYERS (1 - 10)?	3
INPUT FOLLOWING PARAMETERS:		TOTAL THICKNESS (UP TO 30 FT) (FT):	10
THICKNESS (FT):	2	SATURATION RATE:	0.95
SATURATION RATE:	0.6	POROSITY:	0.2
POROSITY:	0.2	BULK DENSITY (G/CM^3):	1.78
BULK DENSITY (G/CM^3):	1.5	Kd (L/KG):	1.00E-05
		IS THERE A TYPE 1 LAYER (YES,NO)?	NO
		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
		IS THERE A TYPE 2 LAYER (YES,NO)?	NO
		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, Vzo (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	4.80E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	4.5	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	1.5	CONC. IN UPGRADIENT GROUND WATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	2.800E+02	DISTANCE TO Fence.Line.: <i>At Sentry well</i>	45
PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION:	2.80E+02 (UG/L)		0
FENCE LINE CONCENTRATION:	9.65E+01 (UG/L)		9

SITE: SWMU 9. NAS, Key West

CONTAMINANT: cis-1,2-Dichloroethene

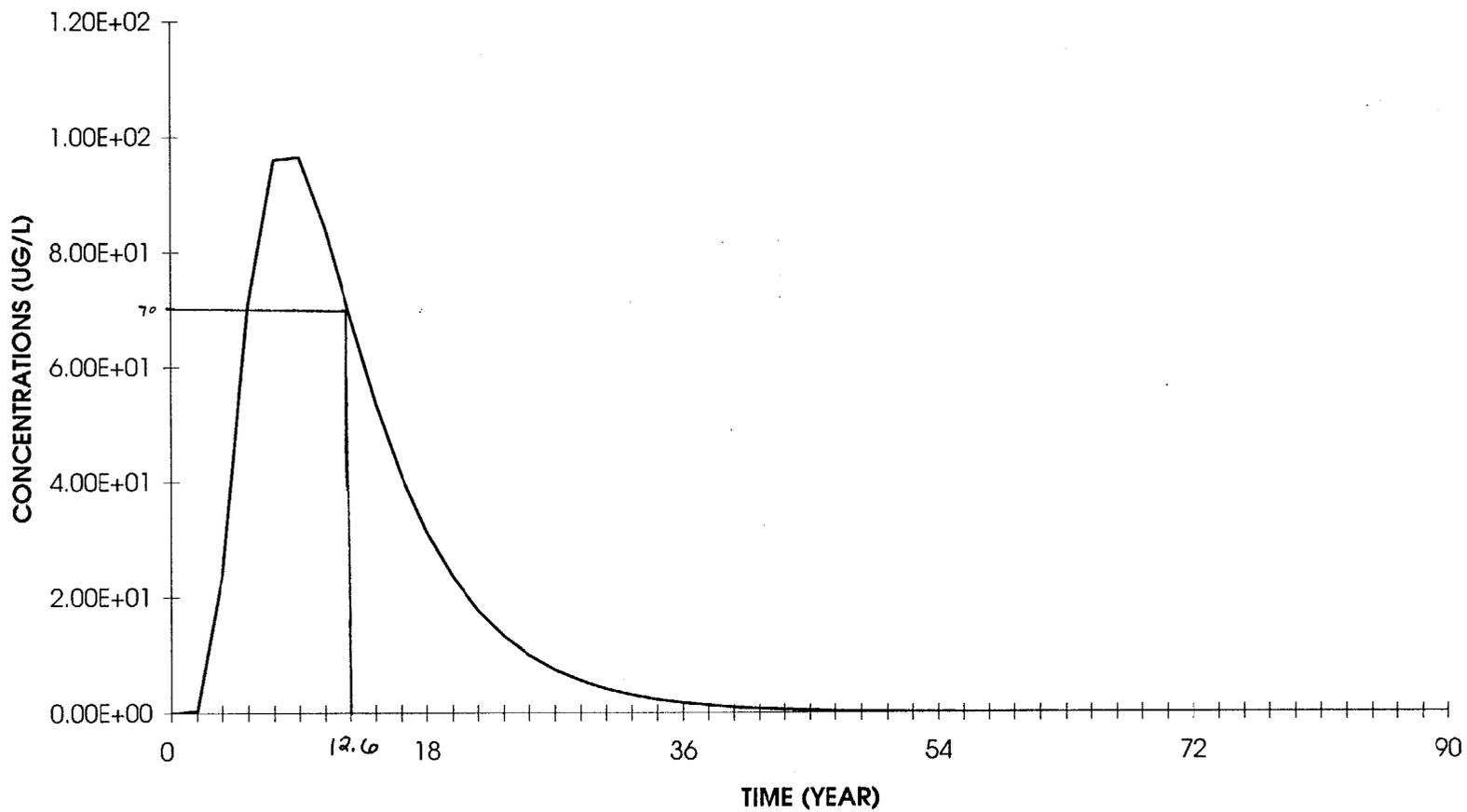
INVESTIGATOR: LK  
DATE: 5/7/99

HALF-LIFE (YRS):	
LAYER 2:	7.92E+00
SATURATED LAYER	7.92E+00
DOWNGRADEMENT	7.92E+00
INITIAL CONC. (ug/L):	2.80E+02

SATURATED LAYER	
INFILT (FT/YR):	0.083
LENGTH (FT):	110
WIDTH (FT):	190
POROSITY 2:	0.3
POROSITY SAT. LAYER:	0.3
DENSITY 2 (G/CM3):	1.5
DENSITY GMA (G/CM3):	1.50
AGE (YEARS):	0
Q1 (L/DAY):	1.35E+02
Kd (L/KG):	4.80E-02
SATURATION:	1.00
THICKNESS (FT):	27.00
DECAY (1/DAY):	2.40E-04
CBo (PPB):	2.80E+02
CU2 (PPB):	0.00E+00
Q2 (L/DAY):	1.07E+03
B (FT):	27
Vzo (FT/YR):	4.48
GW Q3 (L/DAY):	1.21E+03
GW V. (FT/YR):	8.99
H (FT):	27.0000
EFF. POROSITY:	0.30
DISPERSIVITY:	0.14
Az (FT):	4.50
Ax (FT):	1.50
Kd (L/KG):	0.04802
RETARDATION:	1.2401
q (FT/YR):	0
DECAY (1/YR):	8.8E-02
P&T (YEARS):	0
DISTANCE TO F.L. (FT):	45

TIME INTERVAL (YRS)		SOURCE AREA CONC.(GMA)		FENCE LINE CONC.	
ELAPSED TIME - YRS		(UG/L)		(UG/L)	
0	0.00E+00		2.80E+02		0.00E+00
1.8	0.00E+00		2.09E+02		3.96E-01
3.6	0.00E+00		1.56E+02		2.41E+01
5.4	0.00E+00		1.17E+02		7.09E+01
7.2	0.00E+00		8.74E+01		9.60E+01
9	0.00E+00		6.53E+01		9.65E+01
10.8	0.00E+00		4.88E+01		8.43E+01
12.6	0.00E+00		3.65E+01		6.87E+01
14.4	0.00E+00		2.73E+01		5.38E+01
16.2	0.00E+00		2.04E+01		4.13E+01
18	0.00E+00		1.52E+01		3.13E+01
19.8	0.00E+00		1.14E+01		2.36E+01
21.6	0.00E+00		8.51E+00		1.77E+01
23.4	0.00E+00		6.36E+00		1.33E+01
25.2	0.00E+00		4.75E+00		9.93E+00
27	0.00E+00		3.55E+00		7.43E+00
28.8	0.00E+00		2.66E+00		5.55E+00
30.6	0.00E+00		1.98E+00		4.15E+00
32.4	0.00E+00		1.48E+00		3.10E+00
34.2	0.00E+00		1.11E+00		2.32E+00
36	0.00E+00		8.29E-01		1.73E+00
37.8	0.00E+00		6.19E-01		1.30E+00
39.6	0.00E+00		4.63E-01		9.68E-01
41.4	0.00E+00		3.46E-01		7.24E-01
43.2	0.00E+00		2.59E-01		5.41E-01
45	0.00E+00		1.93E-01		4.04E-01
46.8	0.00E+00		1.44E-01		3.02E-01
48.6	0.00E+00		1.08E-01		2.26E-01
50.4	0.00E+00		8.07E-02		1.69E-01
52.2	0.00E+00		6.03E-02		1.26E-01
54	0.00E+00		4.51E-02		9.43E-02
55.8	0.00E+00		3.37E-02		7.05E-02
57.6	0.00E+00		2.52E-02		5.27E-02
59.4	0.00E+00		1.88E-02		3.94E-02
61.2	0.00E+00		1.41E-02		2.94E-02
63	0.00E+00		1.05E-02		2.20E-02
64.8	0.00E+00		7.86E-03		1.64E-02
66.6	0.00E+00		5.88E-03		1.23E-02
68.4	0.00E+00		4.39E-03		9.19E-03
70.2	0.00E+00		3.28E-03		6.87E-03
72	0.00E+00		2.45E-03		5.13E-03
73.8	0.00E+00		1.83E-03		3.84E-03
75.6	0.00E+00		1.37E-03		2.87E-03
77.4	0.00E+00		1.02E-03		2.14E-03
79.2	0.00E+00		7.66E-04		1.60E-03
81	0.00E+00		5.72E-04		1.20E-03
82.8	0.00E+00		4.28E-04		8.95E-04
84.6	0.00E+00		3.20E-04		6.69E-04
86.4	0.00E+00		2.39E-04		5.00E-04
88.2	0.00E+00		1.79E-04		3.74E-04
90	0.00E+00		1.33E-04		2.79E-04
MAXIMUM:	0.00E+00		2.80E+02		9.65E+01

TIME TO ACTION LEVEL CONCENTRATION AT PROPOSED SENTRY WELL  
CIS-1,2-DCE



**TRANS-1,2 DICHLOROETHENE**

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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/7/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	trans-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL)	FL
HALF-LIFE (YRS):	7.92E+00	UNDERS: Under source. FL: Fence line	
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	WATER CRITERIA (UG/L):	1.00E+02
		TIME FRAME (YRS):	90
		LEACHATE CONCENTRATION (YES,NO) ?	NO
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	1.000E-02
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	2.33E-03
		ACCEPTABLE!	DECREASE
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(Ft/YR):	8.30E-02
K1 (L/KG):	4.25E+00	LENGTH (FT):	110
DEPLETING SOURCE:		WIDTH (FT):	190
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	1.00E-02	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3):	1.78
		Kd (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>zo</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADE AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	5.78E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	2.5	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	0.8	CONC. IN UPGRADE GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	8.200E+02	DISTANCE TO Fence.Line.: A+ 25'	25
PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION:	8.20E+02 (UG/L)		0
FENCE LINE CONCENTRATION:	4.29E+02 (UG/L)		5.4

SITE: SWMU 9, NAS, Key West

CONTAMINANT: trans-1,2-Dichloroethene

HALF-LIFE (YRS):

LAYER 2: 7.92E+00

SATURATED LAYER 7.92E+00

DOWNGRADEMENT 7.92E+00

INITIAL CONC. (ug/L): 8.20E+02

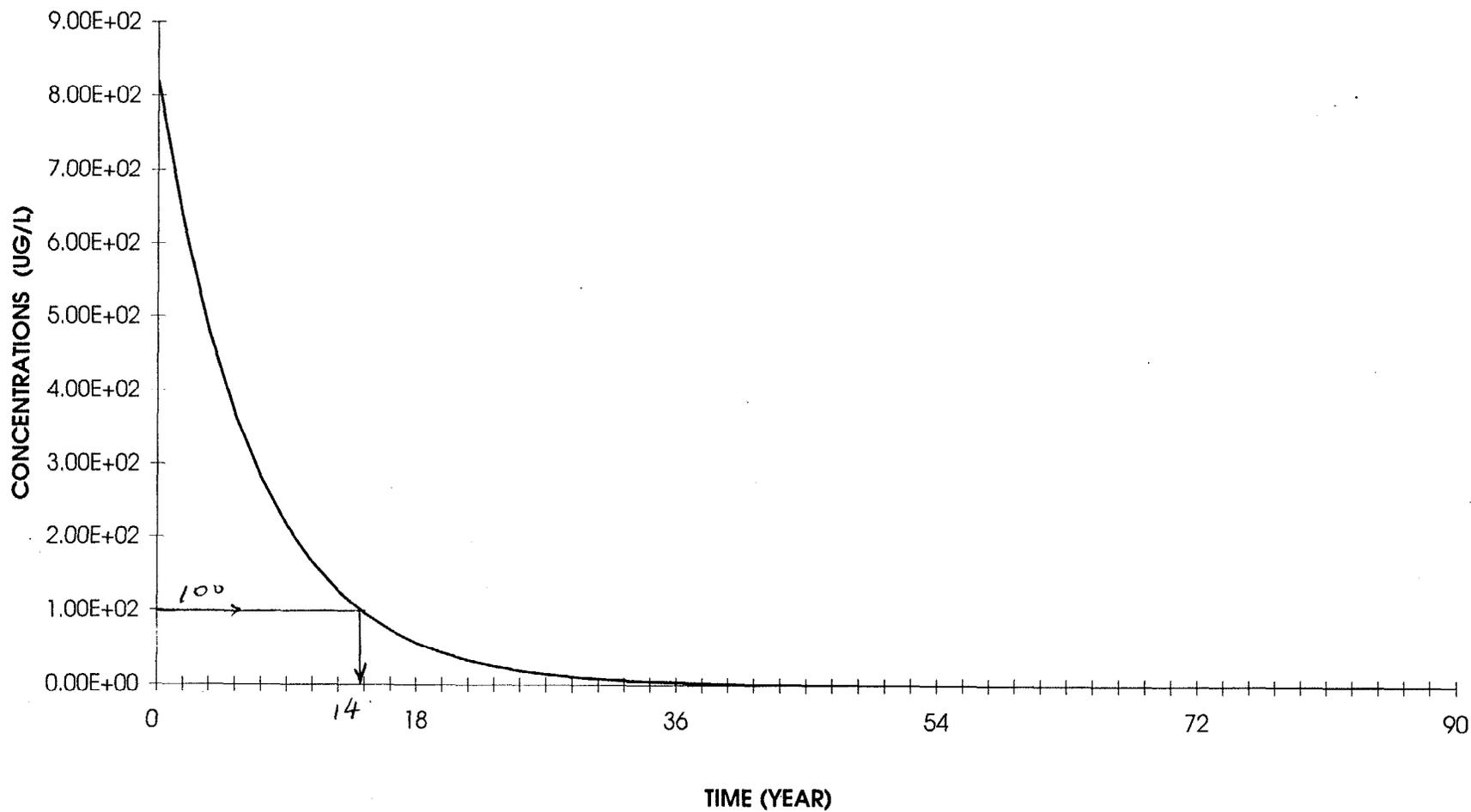
INVESTIGATOR: LK  
DATE: 5/7/99

SATURATED LAYER

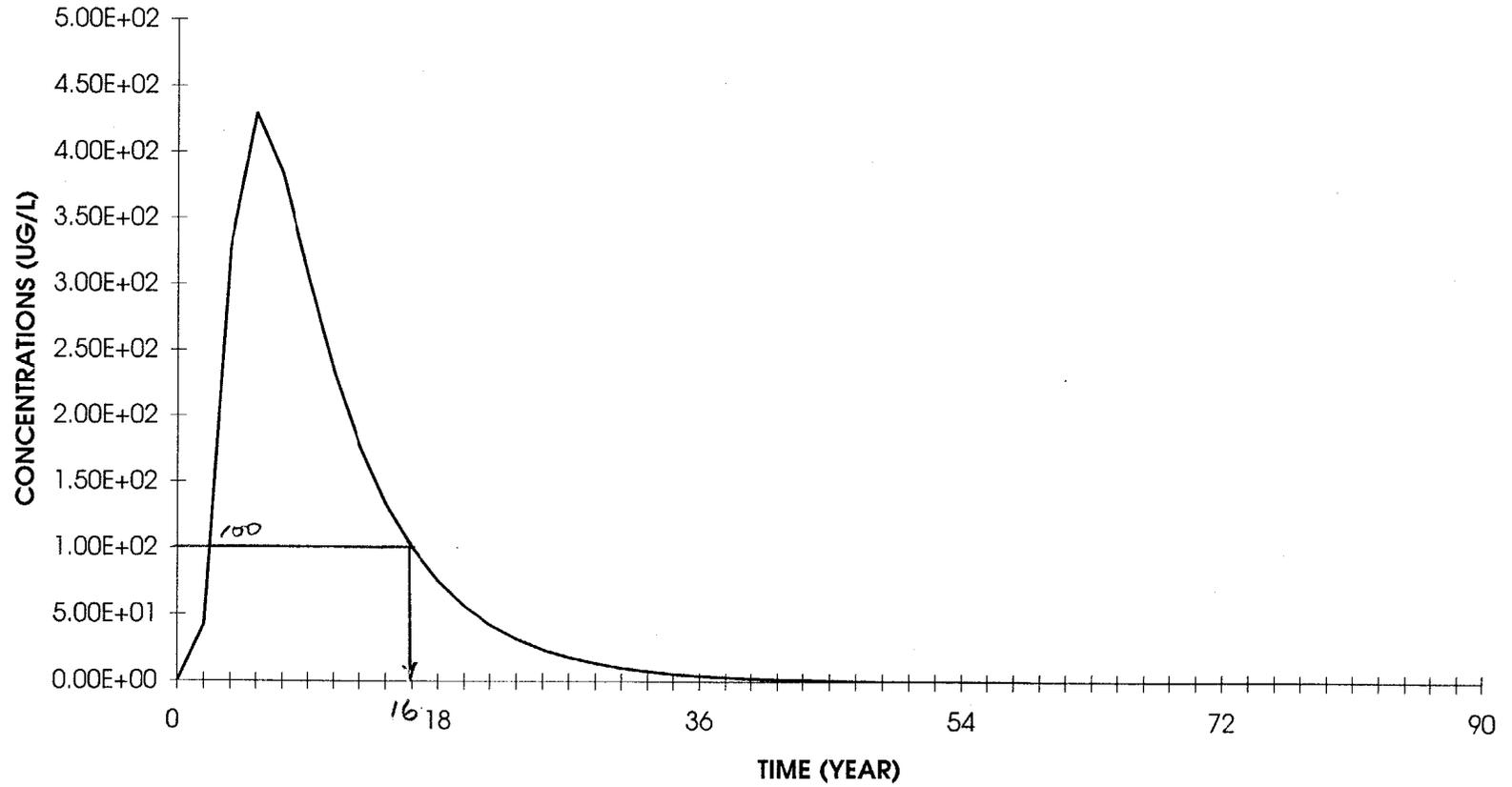
INFILT (FT/YR): 0.083		B (FT): 27	Vzo (FT/YR): 4.48
LENGTH (FT): 110		GW Q3 (L/DAY): 1.21E+03	
WIDTH (FT): 190		GW V. (FT/YR): 8.99	Kd (L/KG): 0.0578
POROSITY 2: 0.3		H (FT): 27.0000	RETARDATION: 1.289
POROSITY SAT. LAYER: 0.3		EFF. POROSITY: 0.30	q (FT/YR): 0
DENSITY 2 (G/CM3): 1.5		DISPERSIVITY: 0.14	DECAY (1/YR): 8.8E-02
DENSITY GMA (G/CM3): 1.50		Az (FT): 0.14	
		Ax (FT): 2.50	P&T (YEARS): 0
AGE (YEARS): 0	Q1 (L/DAY): 1.35E+02	Ay (FT): 0.83	DISTANCE TO F.L. (FT): 25
		Q2 (L/DAY): 1.07E+03	

TIME INTERVAL (YRS) 1.8		SOURCE AREA CONC.(GMA)		FENCE LINE CONC.	
ELAPSED TIME - YRS	LAYER 2 (PPB)	(UG/L)		(UG/L)	
0	2.35E+00	8.20E+02	0.00E+00		
1.8	1.99E+00	6.16E+02	4.24E+01		
3.6	1.68E+00	4.63E+02	3.27E+02		
5.4	1.42E+00	3.48E+02	4.29E+02		
7.2	1.20E+00	2.61E+02	3.84E+02		
9	1.01E+00	1.96E+02	3.05E+02		
10.8	8.53E-01	1.47E+02	2.33E+02		
12.6	7.20E-01	1.11E+02	1.76E+02		
14.4	6.08E-01	8.32E+01	1.33E+02		
16.2	5.14E-01	6.25E+01	9.98E+01		
18	4.34E-01	4.70E+01	7.50E+01		
19.8	3.66E-01	3.53E+01	5.63E+01		
21.6	3.09E-01	2.65E+01	4.23E+01		
23.4	2.61E-01	1.99E+01	3.18E+01		
25.2	2.21E-01	1.50E+01	2.39E+01		
27	1.86E-01	1.12E+01	1.80E+01		
28.8	1.57E-01	8.45E+00	1.35E+01		
30.6	1.33E-01	6.35E+00	1.01E+01		
32.4	1.12E-01	4.77E+00	7.62E+00		
34.2	9.47E-02	3.58E+00	5.72E+00		
36	7.99E-02	2.69E+00	4.30E+00		
37.8	6.75E-02	2.02E+00	3.23E+00		
39.6	5.70E-02	1.52E+00	2.43E+00		
41.4	4.81E-02	1.14E+00	1.82E+00		
43.2	4.06E-02	8.60E-01	1.37E+00		
45	3.43E-02	6.46E-01	1.03E+00		
46.8	2.90E-02	4.86E-01	7.75E-01		
48.6	2.45E-02	3.65E-01	5.82E-01		
50.4	2.07E-02	2.75E-01	4.38E-01		
52.2	1.74E-02	2.07E-01	3.29E-01		
54	1.47E-02	1.53E-01	2.47E-01		
55.8	1.24E-02	1.17E-01	1.86E-01		
57.6	1.05E-02	8.79E-02	1.40E-01		
59.4	8.87E-03	6.61E-02	1.05E-01		
61.2	7.49E-03	4.98E-02	7.91E-02		
63	6.33E-03	3.75E-02	5.95E-02		
64.8	5.34E-03	2.82E-02	4.48E-02		
66.6	4.51E-03	2.13E-02	3.37E-02		
68.4	3.81E-03	1.60E-02	2.54E-02		
70.2	3.22E-03	1.21E-02	1.91E-02		
72	2.72E-03	9.10E-03	1.44E-02		
73.8	2.29E-03	6.87E-03	1.09E-02		
75.6	1.94E-03	5.18E-03	8.18E-03		
77.4	1.64E-03	3.91E-03	6.17E-03		
79.2	1.38E-03	2.96E-03	4.65E-03		
81	1.17E-03	2.24E-03	3.51E-03		
82.8	9.85E-04	1.69E-03	2.65E-03		
84.6	8.31E-04	1.28E-03	2.00E-03		
86.4	7.02E-04	9.71E-04	1.52E-03		
88.2	5.93E-04	7.37E-04	1.15E-03		
90	5.01E-04	5.60E-04	8.69E-04		
MAXIMUM:	2.35E+00	8.20E+02	4.29E+02		

TIME TO ACTION LEVEL CONCENTRATION  
IN AQUIFER BENEATH THE SOURCE AREA  
TRANS-1,2-DCE



TIME TO ACTION LEVEL CONCENTRATION AT 25 FEET  
TRANS-1,2-DCE



Copyright 1997



SITE: SWMU 9, NAS, Key West

INVESTIGATOR: LK

DATE: 5/7/99

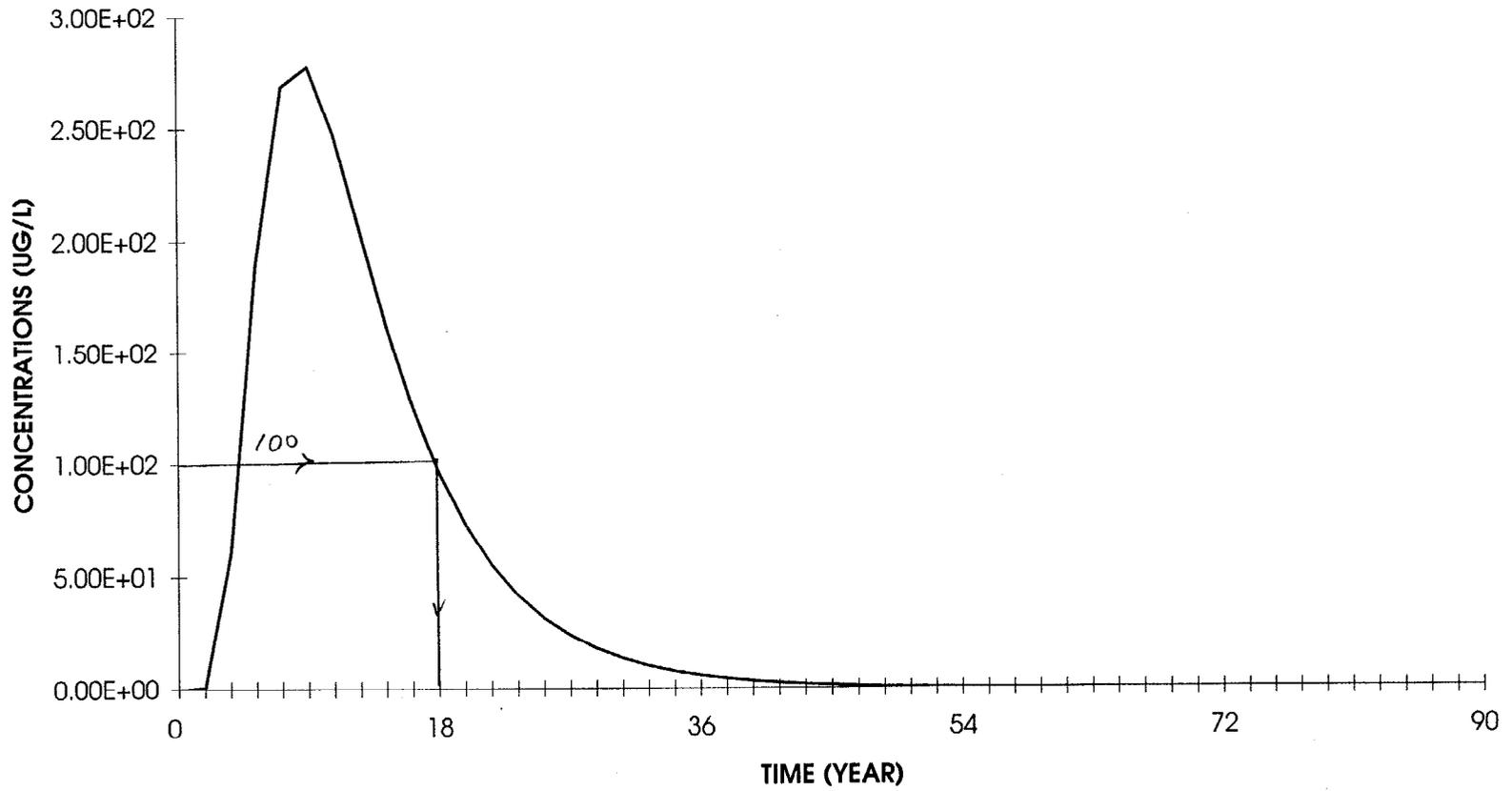
CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	trans-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL)	FL
HALF-LIFE (YRS):	7.92E+00	UNDERS: Under source, FL: Fence line	
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	WATER CRITERIA (UG/L):	1.00E+02
		TIME FRAME (YRS):	90
		LEACHATE CONCENTRATION (YES,NO) ?	NO
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	1.000E-02
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	3.60E-03
		ACCEPTABLE!	DECREASE
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FT/YR):	8.30E-02
Ki (L/KG):	4.25E+00	LENGTH (FT):	110
DEPLETING SOURCE:		WIDTH (FT):	190
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	1.00E-02	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM <sup>3</sup> ):	1.5	BULK DENSITY (G/CM <sup>3</sup> ):	1.78
		Kd (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM <sup>3</sup> ):	1.5	BULK DENSITY (G/CM <sup>3</sup> ):	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>zo</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADE AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	5.78E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, A <sub>z</sub> (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, A <sub>x</sub> (FT):	4.5	AGE (YRS):	0
LATERAL DISPERSIVITY, A <sub>y</sub> (FT):	1.5	CONC. IN UPGRADIENT GROUNDWATER, CU <sub>2</sub> (UG/L)	0
INITIAL CONC. (ug/L):	8.200E+02	DISTANCE TO Fence.Line.: <i>At Sentry well</i>	45
PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION:	8.20E+02 (UG/L)		0
FENCE LINE CONCENTRATION:	2.78E+02 (UG/L)		9

SITE:	SWMU 9, NAS, Key West	CONTAMINANT:	trans-1,2-Dichloroethene
INVESTIGATOR:	LK	HALF-LIFE (YRS):	
DATE:	5/7/99	LAYER 2:	7.92E+00
		SATURATED LAYER	7.92E+00
		DOWNGRADIENT	7.92E+00
		INITIAL CONC. (ug/L):	8.20E+02

SATURATED LAYER			
INFILT (FT/YR):	0.083	B (FT):	27
LENGTH (FT):	110	GW Q3 (L/DAY):	1.21E+03
WIDTH (FT):	190	GW V. (FT/YR):	8.99
POROSITY 2:	0.3	H (FT):	27.0000
POROSITY SAT. LAYER:	0.3	EFF. POROSITY:	0.30
DENSITY 2 (G/CM3):	1.5	DISPERSIVITY:	
DENSITY GMA (G/CM3):	1.50	Az (FT):	0.14
AGE (YEARS):	0	Ax (FT):	4.50
		Ay (FT):	1.50
Q1 (L/DAY):	1.35E+02	DECAY (1/YR):	8.8E-02
		RETARDATION:	1.289
		q (FT/YR):	0
		P&T (YEARS):	0
		DISTANCE TO F.L. (FT):	45
		Kd (L/KG):	0.0578
		THICKNESS (FT):	27.00
		DECAY (1/DAY):	2.40E-04
		CB0 (PPB):	8.20E+02
		CU2 (PPB):	0.00E+00
		Q2 (L/DAY):	1.07E+03
		SATURATION:	1.00
		Vzo (FT/YR):	4.48

TIME INTERVAL (YRS)		SOURCE AREA CONC.(GMA)		FENCE LINE CONC.	
ELAPSED TIME - YRS	LAYER 2(PPB)	(UG/L)		(UG/L)	
0	2.35E+00	8.20E+02		0.00E+00	
1.8	1.99E+00	6.16E+02		8.24E-01	
3.6	1.68E+00	4.63E+02		6.04E+01	
5.4	1.42E+00	3.48E+02		1.91E+02	
7.2	1.20E+00	2.61E+02		2.69E+02	
9	1.01E+00	1.96E+02		2.78E+02	
10.8	8.53E-01	1.47E+02		2.48E+02	
12.6	7.20E-01	1.11E+02		2.04E+02	
14.4	6.08E-01	8.32E+01		1.62E+02	
16.2	5.14E-01	6.25E+01		1.26E+02	
18	4.34E-01	4.70E+01		9.59E+01	
19.8	3.66E-01	3.53E+01		7.28E+01	
21.6	3.09E-01	2.65E+01		5.50E+01	
23.4	2.61E-01	1.99E+01		4.14E+01	
25.2	2.21E-01	1.50E+01		3.12E+01	
27	1.86E-01	1.12E+01		2.35E+01	
28.8	1.57E-01	8.45E+00		1.76E+01	
30.6	1.33E-01	6.35E+00		1.33E+01	
32.4	1.12E-01	4.77E+00		9.96E+00	
34.2	9.47E-02	3.58E+00		7.48E+00	
36	7.99E-02	2.69E+00		5.62E+00	
37.8	6.75E-02	2.02E+00		4.23E+00	
39.6	5.70E-02	1.52E+00		3.17E+00	
41.4	4.81E-02	1.14E+00		2.39E+00	
43.2	4.06E-02	8.60E-01		1.79E+00	
45	3.43E-02	6.46E-01		1.35E+00	
46.8	2.90E-02	4.86E-01		1.01E+00	
48.6	2.45E-02	3.65E-01		7.61E-01	
50.4	2.07E-02	2.75E-01		5.72E-01	
52.2	1.74E-02	2.07E-01		4.30E-01	
54	1.47E-02	1.55E-01		3.23E-01	
55.8	1.24E-02	1.17E-01		2.43E-01	
57.6	1.05E-02	8.79E-02		1.83E-01	
59.4	8.87E-03	6.61E-02		1.37E-01	
61.2	7.49E-03	4.98E-02		1.03E-01	
63	6.33E-03	3.75E-02		7.77E-02	
64.8	5.34E-03	2.82E-02		5.84E-02	
66.6	4.51E-03	2.13E-02		4.40E-02	
68.4	3.81E-03	1.60E-02		3.31E-02	
70.2	3.22E-03	1.21E-02		2.49E-02	
72	2.72E-03	9.10E-03		1.88E-02	
73.8	2.29E-03	6.87E-03		1.41E-02	
75.6	1.94E-03	5.18E-03		1.06E-02	
77.4	1.64E-03	3.91E-03		8.01E-03	
79.2	1.38E-03	2.96E-03		6.04E-03	
81	1.17E-03	2.24E-03		4.56E-03	
82.8	9.85E-04	1.69E-03		3.44E-03	
84.6	8.31E-04	1.28E-03		2.59E-03	
86.4	7.02E-04	9.71E-04		1.96E-03	
88.2	5.93E-04	7.37E-04		1.48E-03	
90	5.01E-04	5.60E-04		1.12E-03	
MAXIMUM:	2.35E+00	8.20E+02		2.78E+02	

TIME TO ACTION LEVEL CONCENTRATION  
AT PROPOSED SENTRY WELL  
TRANS-1,2-DCE



**DEVELOPMENT OF CROSS-MEDIA REMEDIAL GOAL OPTIONS  
SWMU 9**

## C.1.0 INTRODUCTION

### C.1.1 PURPOSE AND SCOPE

The following sections discuss the development of cross-media remedial goal options (RGOs) for Solid Waste Management Unit (SWMU) 9 for the Naval Air Station (NAS), Key West, Florida. SWMU 9, the Jet Engine Test Cell site associated with Building A-969, is located in the northeastern portion of the Boca Chica Airfield (Figure C-1).

A groundwater pump and treat system was installed in 1996 and operated for one year to remove solvent contamination. Subsequently, an additional study was conducted in May 1998 to identify the natural attenuation processes that exist at the site and to determine if they are sufficient to be protective of the onsite lagoon. As indicated in the Natural Attenuation Study report, natural attenuation processes are present at the project site and can be used to facilitate more active forms of groundwater remediation, based upon the past and current plume configuration and results of geochemical testing (TtNUS, 1998). This modeling has been conducted to support the final remedial alternative of monitored site-wide natural attenuation.

The following sections describe the development of groundwater to surface water and groundwater to sediment RGOs for SWMU 9. Groundwater to surface water and groundwater to sediment RGOs are groundwater concentrations that are protective of the migration of residual contaminants to surface water or sediment. The RGOs were developed through the use of a groundwater flow contaminant fate and transport model to predict maximum groundwater concentrations beneath the source area that would result in surface water and sediment concentrations less than regulatory criteria at the exposure point. The exposure point was assumed to be a single point downgradient of the source along the centerline of the plume where the groundwater enters the small surface water pond located approximately 50 feet northeast of groundwater screening sample SWMU9-GS-02. Groundwater travels to and discharges to the small surface water pond prior to further discharging to the lagoons. Acceptable surface water and sediment criteria were chosen as the most restrictive ARAR/SAL criteria. Four chemicals [cis-1,2 dichloroethene (cis-1,2-DCE), trans-1,2 dichloroethene (trans-1,2-DCE), trichloroethene (TCE), and benzene] were selected for modeling because concentrations of these chemicals (with the exception of TCE) exceeded groundwater action levels based on 1998 groundwater sampling data. RGOs developed based on ECTran modeling are presented in Table C-1.

The computations considered natural processes affecting contaminant fate and transport in groundwater that will reduce contaminant concentrations in groundwater over time. The mechanisms/processes affecting chemical fate and transport in groundwater that were accounted for during the modeling include

sorption, dilution, advection, dispersion, and chemical/biological decay. Source area groundwater contaminant levels have been reduced substantially by the groundwater pump and treat operations. In addition, infiltration of rainfall into the aquifer will flush the aquifer with clean water.

The groundwater fate and transport modeling was accomplished through the use of a combined groundwater flow/contaminant fate and transport model.

### **C.1.2 REPORT ORGANIZATION**

This appendix has been divided into four discrete sections. In addition to the introduction (Section C.1.0), Section C.2.0 presents the technical approach used for the groundwater fate and transport modeling. Section C.3.0 provides the input data used for the modeling. Section C.4.0 presents modeling results for SWMU 9.

## **C.2.0 GROUNDWATER FATE AND TRANSPORT MODELING DEVELOPMENT**

The technical approach used to develop groundwater to surface water and groundwater to sediment RGOs is described in the following subsections. Section C.2.1 describes the analytical groundwater contaminant fate and transport model used for this task. Section C.2.2.1 briefly describes the geology and hydrogeology at SWMU 9. Section C.2.2.2 provides the site conceptual model. Sections C.2.2.3 and C.2.2.4 provide modeling procedures and simplifying assumptions.

### **C.2.1. GROUNDWATER MODEL TOOL**

The groundwater modeling at SWMU 9 was performed using the ECTran model (Chiou, et al., 1993). The ECTran (Excel-Crystal Ball Transport) model is a multi-layer, one-dimensional, analytical contaminant fate and transport model based on straightforward mass-balances and advection/dispersion analytical equations.

The groundwater model is implemented on the spreadsheet software Excel 4.0 and Crystal Ball 3 and can be used to simulate a variety of complex conditions. To date, ECTran and its predecessors have been employed at hazardous waste sites in United States Environmental Protection Agency (U.S. EPA) Regions III, IV, V, VI, and X to evaluate soil cleanup goals, to estimate cleanup times, and to support baseline risk assessments. It has been used at Department of Defense (DOD), Department of Energy (DOE), Naval Air Station, and industrial sites for both Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) applications.

The ECTran model simulates vertical contaminant transport with uniform (thickness, concentration, porosity, etc.) layers. The model predicts the contaminant concentration downgradient of the source at a single point, located at the centerline of the contaminant plume, at a specified distance from the exposure point.

### **C.2.2 CONCEPTUAL MODEL**

A description of the conceptualization of the natural processes that govern groundwater flow and contaminant transport at the site is provided in this subsection. The following subsections provide only a summary of the physical characteristics of the site relevant to the modeling task. Additional details concerning the physical characteristics of the site can be found in Section 3.0 of the Supplemental RCRA Facility Investigation/Remedial Investigation (RFI/RI) Report (B&RE 1997).

The site is bordered to the south by an asphalt road that parallels a runway and to the east and west by grassy areas. The entire area is flat, open, and covered with grass where it is not paved. An inlet of Florida Bay is located north of the site, approximately 250 feet from the former location of the canopy. Beginning in 1969, the site was used for the testing of recently repaired jet engines. No other activities have been conducted near the site.

#### **C.2.2.1 Site Physical Characteristics**

##### **Geology and Soils**

The site-specific geology and hydrogeology of the unit were determined from soil borings and monitoring wells installed during the contamination assessment study, the groundwater evaluation study, and the Supplemental RFI/RI. During installation of soil borings, oolitic limestone was encountered at the surface and was present to the termination of the borings at 13 feet below land surface (bls). The limestone was consistent in all borings, and no lateral or horizontal variations were apparent. As stated in the RI workplan, the Miami Oolite is 27 feet thick (ABB 1995).

The soils on Boca Chica Key are primarily rockland with some filled areas and mangrove swamps. Other major soil groups on Boca Chica Key are Uthorthents, which consist of gravely sand and marl, and Cudjoe, which consists of marl and weathered bedrock (ABB, 1995). The limestone is well consolidated with abundant shell fragments and medium- to fine-grained sand in the limestone matrix. The Standard Penetration Test (SPT) (blow counts) indicated that the limestone is of medium to high density.

##### **Hydrogeology**

The hydrogeologic unit associated with the oolitic limestone is the surficial aquifer. Depth to groundwater was reported to be approximately 1 to 3 feet bls. High specific conductivity values can be expected for groundwater at the site due to the salt water inlet to the north. The aquifer is recharged directly through rainfall. Groundwater elevation data collected during previous studies indicated a predominantly northern groundwater flow direction, with some tidal influence. Tidal fluctuations decrease from 0.5 feet at the inlet to 0.2 feet closer to the monitoring well S9MW10. Groundwater elevations measured on May 1998, were consistent with those recorded during previous investigations. Groundwater flow is in a north-northeast direction toward the lagoon based on the 1998 groundwater contour map (see Figure C-2).

Pumping tests were conducted at some existing monitoring wells at SWMU 9 to estimate hydraulic conductivity (K). The results of pump tests are summarized in Table C-2. The average aquifer transmissivity value reported from pumping tests is approximately  $9.4 \times 10^{-2}$  feet<sup>2</sup>/minute (or 134.8

feet<sup>2</sup>/day) (BEI, 1995). K values are estimated by dividing the transmissivity by the thickness of the surficial aquifer, determined to be 27 feet. A more representative geometrical mean K value was used for modeling. The geometric mean K value from all the surficial wells is 4.62 feet/day (ft/day). The seepage velocity (the rate at which groundwater moves through the aquifer) is estimated at 8.99 feet per year (ft/yr). This seepage velocity was calculated using a geometric mean K value (4.62 ft/day), a hydraulic gradient of 0.0016 ft/ft, and an effective porosity of 0.3.

#### **C.2.2.2 Site Conceptual Model**

Rainwater that falls on the site transports contaminants through runoff and/or by infiltrating into the soil. Runoff can transport contaminants from the surface soils being eroded by the runoff. This pathway is not considered to be significant for the site. A portion of the rainwater that falls on the site reaches the groundwater by directly infiltrating into the soil. As the water infiltrates through the contaminated soil, contaminants leach out of the soil and are transported with the water through the unsaturated zone to the shallow groundwater below. The contaminants can then be transported laterally with the groundwater and eventually enter a surface water body.

In this study, upgradient groundwater flow is assumed to be clean (i.e., contaminant concentration = zero). Upgradient flow will combine with infiltrated water and carry dissolved contaminants in the groundwater to the groundwater discharge point. Dissolved contaminants migrate through groundwater at a slower velocity than the velocity of the groundwater based on chemical-specific retardation. Dilution and dispersion processes reduce concentrations as contaminants move through the groundwater regime. Also, the contaminant may decay in the environment as a result of biological and/or chemical processes. Therefore, as contaminants migrate through the groundwater, they may decay and their concentrations decrease.

Figure C-3 presents the site conceptual model. Conceptually, the groundwater contaminant migration pathway consists of an unsaturated zone and an unconfined aquifer. The shallow aquifer consists of the entire thickness of the oolitic limestone, based on the geology and hydrogeology of the site. The layer conceptualization is reasonable since the primary route for contaminant migration in groundwater from SWMU 9 would be through the surficial aquifer. At SWMU 9, the typical depth to groundwater is estimated to be approximately 2 feet, which is determined as the thickness of the unsaturated zone. The modeled thickness of the saturated layer includes the entire surficial aquifer system, and is selected to be 27 feet. The general groundwater flow direction in the surficial aquifer is to the north-northeast toward the onsite lagoons (Figure C-2). Groundwater can travel both horizontally and vertically within the saturated zone.

### **C.2.2.3 Groundwater Modeling Assumptions**

#### **Modeling Assumptions**

##### **Source Area**

The source area layout was selected based on the locations at which contaminants were detected. The source area is designated as a rectangular area with length parallel to groundwater flow direction, and width perpendicular to the flow direction.

##### **Layer Simulated in the Model**

The uppermost layer simulated in the ECTran model is the unsaturated zone. The bottommost layer simulated in the ECTran model is the shallow unconfined surficial aquifer (saturated zone). Using a single layer to represent the saturated zone is reasonable since the vertical extent of the plume was limited to the surficial aquifer.

##### **Initial Soil Concentrations**

The initial soil concentrations under the source area were assumed to be the maximum detected concentration for each contaminant in the soil samples.

##### **Modeling Time Frame**

The contaminant simulations were continued until the concentration at the exposure point peaked, then gradually dropped off in the aquifer by natural attenuation processes.

##### **Chemical Fate and Transport**

Several mechanisms/processes affecting chemical fate and transport in groundwater were accounted for during the groundwater modeling. They include sorption, dilution, advection, dispersion, and chemical/biological decay. Sorption is the reaction that occurs between the solute and the surfaces of solids causing the solute to bond to varying degrees to the surface. Dilution occurs because of the mixing of contaminated groundwater with unaffected groundwater. Advection is the primary mechanism responsible for the movement of contaminants as a consequence of groundwater flow. Dispersion occurs because of fluid mixing due to effects of heterogeneities in the permeability distribution. Decay involves the degradation of a chemical by natural chemical and biological processes.

### **C.2.2.4 Groundwater to Surface Water Assumptions**

To determine the groundwater to surface water RGO, an acceptable groundwater concentration protective of surface water at the surface water/groundwater interface must be calculated. For the purpose of concentration comparisons within the same medium (i.e., surface water criteria against surface water concentrations), the predicted surface water concentrations at the small pond must be derived from the predicted groundwater concentrations developed with ECTran modeling. This acceptable groundwater concentration was calculated based on the assumptions and equations presented in this section. The RGOs were then developed with the groundwater model and assumptions described in the previous section, based on the acceptable groundwater concentration (protective of surface water). The assumed groundwater concentration under the source area was iteratively changed until the model-predicted concentration at the edge of the surface water body was just below the acceptable groundwater concentrations. The final assumed source groundwater concentration is the groundwater to surface water RGO. These RGOs, acceptable groundwater concentrations, and associated surface water criteria are presented in Table C-1.

The theory of converting the groundwater concentration at the surface water/groundwater interface (the edge of the pond) to a surface water concentration is presented below. The following equation is used to calculate the chemical mass flux in the groundwater at the groundwater/surface water interface

$$Q_C = \frac{V_{GW} A C_g}{R_C} \quad (1)$$

where:

$Q_C$  = Chemical flux (mass/time)

$V_{GW}$  = Groundwater velocity (length/time)

$C_g$  = Chemical concentration in the groundwater (mass/length<sup>3</sup>) (Predicted with the ECTran model)

$A$  = Cross sectional area of the mass flow (length<sup>2</sup>)

and  $R_C$  is chemical specific retardation factor given by:

$$R_C = 1 + \frac{\rho_b}{n} K_d \quad (2)$$

where:

$R_C$  = Chemical specific retardation factor (dimensionless)

$\rho_b$  = Dry bulk density of soil (mass/length<sup>3</sup>)

$n$  = Porosity (dimensionless)

$K_d$  = Soil / water partitioning coefficient (length<sup>3</sup>/mass )

The total flow of groundwater is given by the groundwater velocity multiplied by the cross sectional area of groundwater flow. The surface water concentration (or the seep concentration) ( $C_s$ ) is then equal to:

$$C_s = \frac{Q_c}{V_{GW} A} \quad (3)$$

After replacing  $Q_c$  in Equation (3) by Equation (1), the groundwater velocity and the area cancel out so that the surface water concentration  $C_s$  equals the groundwater concentration  $C_g$  divided by the retardation factor.

$$C_s = \frac{C_g}{R_d} \quad (4)$$

Equation (4) was used to calculate the surface water concentration based on the modeled groundwater concentration at the groundwater/surface water interface assuming  $C_s$  is the surface water exposure criteria.

#### **C.2.2.5 Groundwater to Sediment Assumptions**

Development of the groundwater to sediment RGOs was similar to the development of the groundwater to surface water RGOs described in Section C.2.2.4. The acceptable groundwater concentrations in the sediment porewater at the exposure point were assumed to be equal to the sediment criteria divided by the  $K_d$ . These acceptable groundwater criteria are presented in Table C-1. The exposure point was assumed to be the groundwater/surface water interface.

## C.3.0 INPUT DATA FOR MODELING

### C.3.1. CHEMICAL INPUT PARAMETERS

The primary chemical input parameters include the initial contaminant concentrations, the soil/water partitioning coefficient ( $K_d$ ), the exposure criteria, and chemical and biological decay half-lives. The chemical input parameters used in the modeling were obtained from the Supplemental RFI/RI report (B&R, 1997) and the Natural Attenuation Study report (TtNUS, 1998) and are discussed below.

#### Modeled Chemical and Initial Soil and Groundwater Concentrations

Four chemicals were modeled because detected concentrations exceeded groundwater action levels. These chemicals are: cis-1,2 DCE, trans-1,2 DCE, benzene, and TCE. At SWMU 9, the current maximum detected groundwater concentrations (November 1998) in the source area include cis-1,2 DCE (280 µg/L), trans-1,2 DCE (820 µg/L), benzene (18 µg/L), and TCE (2.2 ug/L). Of the four modeled chemicals, only trans-1,2-DCE has been detected in soil within the source area (maximum detected soil concentration of 10 ug/kg).

#### Site-Specific Soil/Water Partitioning Coefficient

Chemical-specific soil/water partitioning coefficients ( $K_d$ s) were used to estimate the mobility of each chemical. A chemical's  $K_d$  value is the ratio of its concentration in soil (or sediment) to its concentration in water when the two concentrations are in equilibrium. A high  $K_d$  value would be representative of a chemical that has a tendency to bind to the soil and is therefore less mobile in water. Depending on the chemical form of a certain contaminant (specifically for inorganics), the  $K_d$  value can vary substantially. The site-specific  $K_d$  values used in this evaluation were calculated based on the procedures proposed in the Soil Screening Guidance Document (U.S. EPA 1996).

The  $K_d$  values for organic constituents are typically calculated by multiplying the  $K_{oc}$  value (soil organic carbon/water partition coefficient) by the FOC (fraction of organic carbon) (EPA, 1988). The source of  $K_{oc}$  values applied was the U.S. EPA document "Manual - Groundwater and Leachate Treatment Systems" (EPA/625/R-94/005). Both FOC values associated with site soil and site aquifer materials were considered. The site-specific FOC values used in this evaluation were obtained from the Natural Attenuation Study report (Table 4-1, TtNUS, 1998). The more natural organic carbon present in the aquifer materials, the higher the adsorption of organic constituents within the aquifer matrix. As indicated in Table 4-1 of the Natural Attenuation Study report, Total Organic Carbon (TOC)

concentrations range from 2.6 mg/L in S9MW17 (upgradient) to 24 mg/L in S9MW24 and 28 mg/L in S9MW10. A TOC concentration of 1 mg/L is equivalent to a FOC value of 0.0001 percent. A more conservative geometric mean FOC value (0.001) was used for modeling in lieu of the maximum FOC value (0.0028 %). The following equation was used to compute  $K_d$  values:

$$K_d = K_{oc} * f_{oc} \quad (5)$$

where:

$f_{oc}$  = fraction of organic carbon

$K_{oc}$  = soil organic carbon/water partitioning coefficient

The  $K_d$  values and the data used to derive the values are presented in Table C-3.

### Half-life Decay Constants

Decay of organic contaminants can occur by biological and non-biological mechanisms. This decay is quantified by chemical-specific half-life. To be conservative for the groundwater modeling, the longest reported half-life was selected from the literature source (Howard 1991). Table C-3 presents the half-life decay constants used in the modeling.

### Exposure Criteria

Surface water criteria and sediment criteria were used as the exposure criteria for groundwater fate and transport modeling. The acceptable surface water criteria chosen were the most restrictive ARAR/SAL criteria. The surface water criteria are as follows:

- cis-1,2 DCE - 11,600 µg/L
- trans-1,2 DCE - 1,350 µg/L
- benzene – 71 µg/L
- TCE - 81 µg/L

The sediment criteria are as follows:

- cis-1,2 DCE - 23 µg/kg
- trans-1,2 DCE – 62,000 µg/kg
- benzene – 57 µg/kg
- TCE – 1,600 µg/kg

### **C.3.2 PHYSICAL INPUT PARAMETERS AT SWMU 9**

The groundwater physical input parameters used in this modeling effort are described in the next two subsections.

#### **C.3.2.1 Surface Water Infiltration Rates:**

Infiltration rates in the source area are estimated to be one-quarter of the annual precipitation (infiltration rate = 10 inches per year). An average of 35 to 40 inches of rainfall per year was reported in the Supplemental RFI/RI report for the area of Key West, Florida (B&R, 1997).

#### **C.3.2.2 Groundwater Physical Input Parameters at SWMU 9**

Layer Thickness: As described in the Conceptual Model section, the typical thickness of the unsaturated zone was assumed to be 2 feet. The saturated zone was assumed to be 27 feet thick based on the geologic descriptions of the unit (Section C.2.2.1). Table C-5 presents a summary of physical and geologic parameters used for modeling.

Source Area Size: It is assumed that the source area for each contaminant corresponds to a rectangular area. Each contaminant source area size was determined based on the locations at which groundwater contaminants were detected. Figure C-4 and Table C-5 present the source area sizes based on the reported 1998 groundwater concentrations in the surficial aquifer.

Exposure Point: The exposure point for the groundwater modeling was at a point downgradient of the source area where groundwater discharges into a small surface water pond, located approximately 50 feet northeast of screening sample SWMU9-GS-02. Groundwater discharges into the pond and subsequently to the onsite lagoons further north. The distance to this exposure point is measured along the groundwater flow path direction (Figures C-4 and Table C-5).

Hydraulic Conductivity (K): The K value was determined from the pumping tests for the wells in the surficial aquifer. The surficial aquifer has an estimated K ranging from 3.33 to 9.43 ft/day. A geometric mean K value of 4.62 ft/day was selected for modeling (Table C-2).

Gradient: The gradient was calculated to be 0.0016 (B&R, 1997).

Effective Porosity: An effective porosity of 0.3 was incorporated from the Supplemental RFI/RI report.

Seepage Velocity: The seepage velocity is calculated with the following equation.

$$V_{seep} = \frac{KI}{\text{effective porosity}} \quad (6)$$

Where:      K = hydraulic conductivity (4.62 ft/day)  
              I = gradient (0.0016)  
              Effective porosity = 0.3

The seepage velocity is thus estimated to be 8.99 ft/yr.

#### C.4.0 RESULTS

Groundwater RGOs protective of surface water and sediment were developed for four chemicals (cis-1,2 DCE, trans-1,2 DCE, benzene, and TCE) and are presented in Table C-1. Acceptable groundwater concentrations, protective of surface water and sediment at the interface with the small pond, were developed to calculate the groundwater RGOs and are presented in Tables C-1 and C-4. If a chemical is detected in groundwater under the source area, the groundwater RGOs would be appropriate for comparison. If a chemical is detected in groundwater near the small pond, the acceptable groundwater concentrations would be appropriate for comparison.

The groundwater RGOs developed by ECTran modeling indicate that the current groundwater concentrations at SWMU 9 do not exceed the groundwater RGOs for surface water or sediment. The current maximum detected groundwater concentrations (November 1998) for the four chemicals are:

- cis-1,2-DCE -- 280 µg/L
- trans-1,2-DCE -- 820 µg/L
- TCE -- 2.2 µg/L
- Benzene -- 18 µg/L

Natural attenuation processes that were accounted for during groundwater modeling include sorption, dilution, advection, dispersion, and chemical/biological decay. ECTran model's inputs and outputs are presented in Attachment C.1.

## C.5.0 REFERENCES

ABB (ABB Environmental Services, Inc.), 1995, *Facility and Remedial Investigation NAS Key West, Workplan*, Volume 1, prepared for SOUTHNAVFACENGCOM. Tampa, Florida, December.

B&R Environmental (Brown & Root Environmental), 1997, *Supplemental RCRA Facility Investigation and Remedial Investigation Report for NAS Key West High-Priority Sites Boca Chica Key, Florida*, prepared for SOUTHNAVFACENGCOM. Aiken, South Carolina, Revision 2, July 1997.

Bechtel Environmental, Inc. (BEI), October 4, 1995, *Technical Memorandum Groundwater Evaluation for Pump and Treat System, Jet engine test Cell, NAS Key West*.

Aller, L., Bennett, T., Lehr, J., Petty, R., and Hackett, G., DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings, EPA-600/2-87/035, United States Environmental Protection Agency, Office of Research and Development, Robert S. Kerr Environmental Research Laboratory, Ada Oklahoma.

Chiou, J.D., C. Rich, W. Yu, 1993, "ECTran - A Spreadsheet Based Screening-Level Multimedia Fate and Transport Model with Monte Carlo Simulation Capability," in Proceedings of the ER '93 Conference, Sponsored by the U.S. Department of Energy, Augusta, Georgia, pp. 117-122.

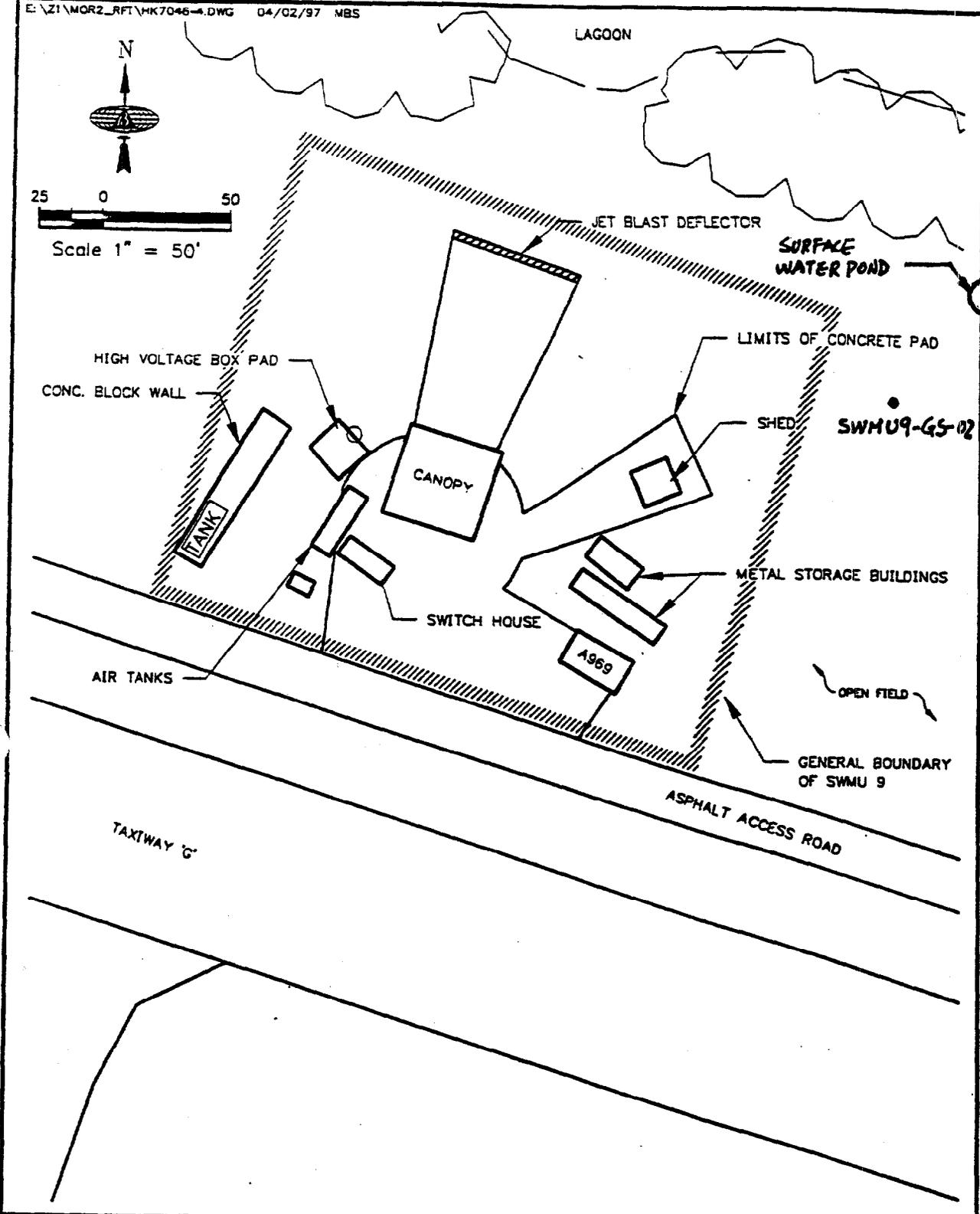
Howard, P.H., R.S. Boething, W. F. Jarvis, W. M. Meylan, and E. M., Michalenko, 1991, Handbook of Environmental Degradation Rates, Lewis Publishers, Inc., Chelsea, Michigan.

Thibault, D. H., M. I. Sheppard and P. A. Smith, 1990, "A Critical Compilation and Review of Default Soil Solid/Liquid Partition Coefficients,  $K_d$  for use in Environmental Assessments," AECL-10125, Whiteshell Nuclear Research Center, Pinawa, Manitoba, Canada.

Tetra Tech NUS, (TtNUS) Inc, 1998 *Natural Attenuation Report for NAS Key West High-Priority Sites Boca Chica Key, Florida*, prepared for SOUTHNAVFACENGCOM. Aiken, South Carolina, August 1998.

United States Environmental Protection Agency, April, 1996, Soil Screening Guidance: Users Guide, EPA/540/R-96/018, Office of Solid Waste and Emergency Response, Washington, DC, April.

U.S. Environmental Protection Agency, 1988, "Superfund Exposure Assessment Manual," EPA/540/1-88/001, EPA, Washington, DC.



SWMU9-65-02

SITE MANAGER: RD	CHECKED BY: KW
DRAWN BY: TCB	DRAWING DATE: 7/24/96
SURVEYED BY: TCB	SURVEY DATE: 2/21/96
SCALE: 1" = 50'	
CAO DWG. NO.: HK7046-6	PROJ. NO.: HK7046



**Brown & Root Environmental**

**FIGURE 4-38  
SITE LOCATION MAP  
SWMU 9**

NAVAL AIR STATION  
BOCA CHICA KEY, FLORIDA

**FIGURE C-1 SITE LOCATION MAP (SWMU 9, NAS KEY WEST)**

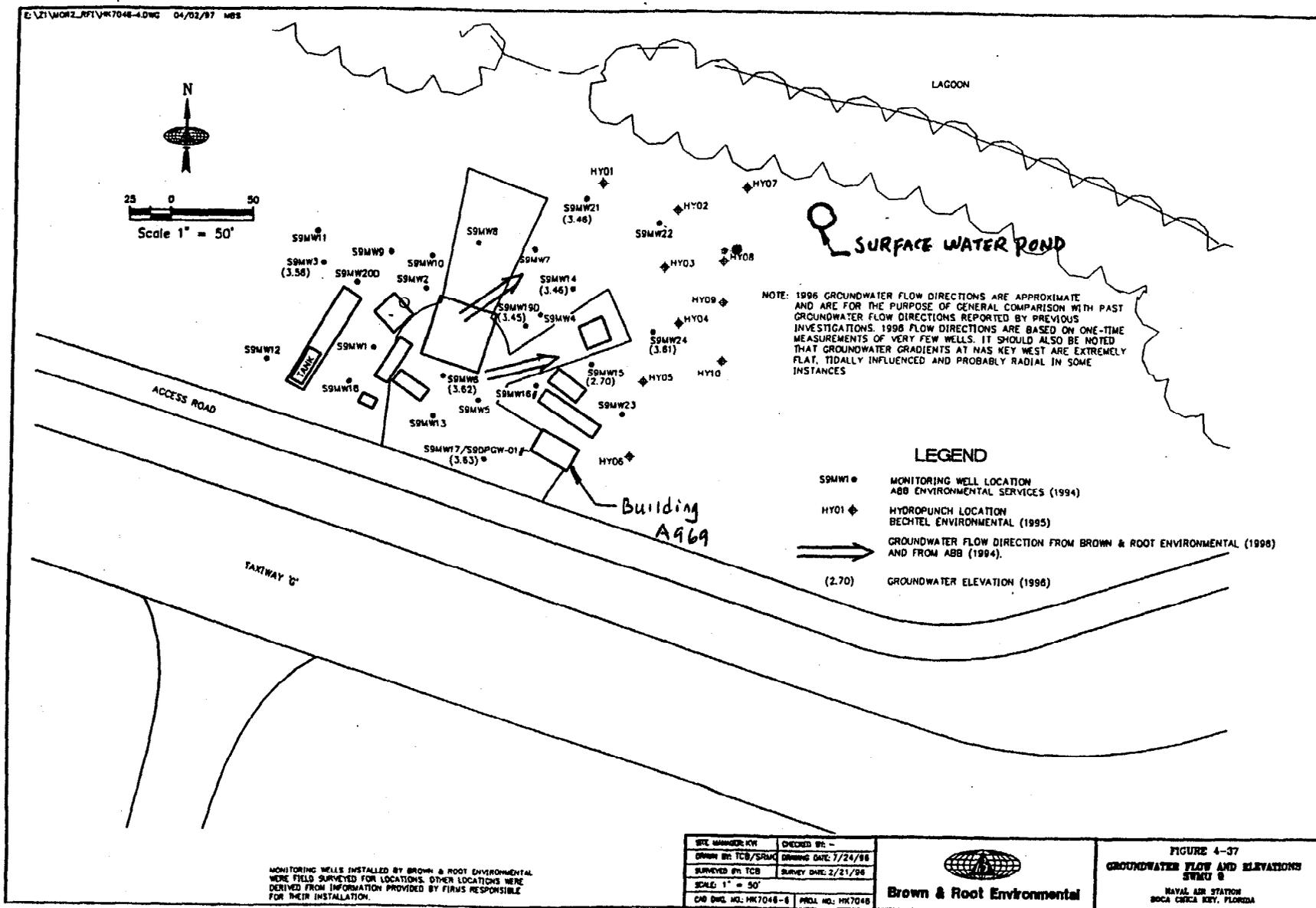
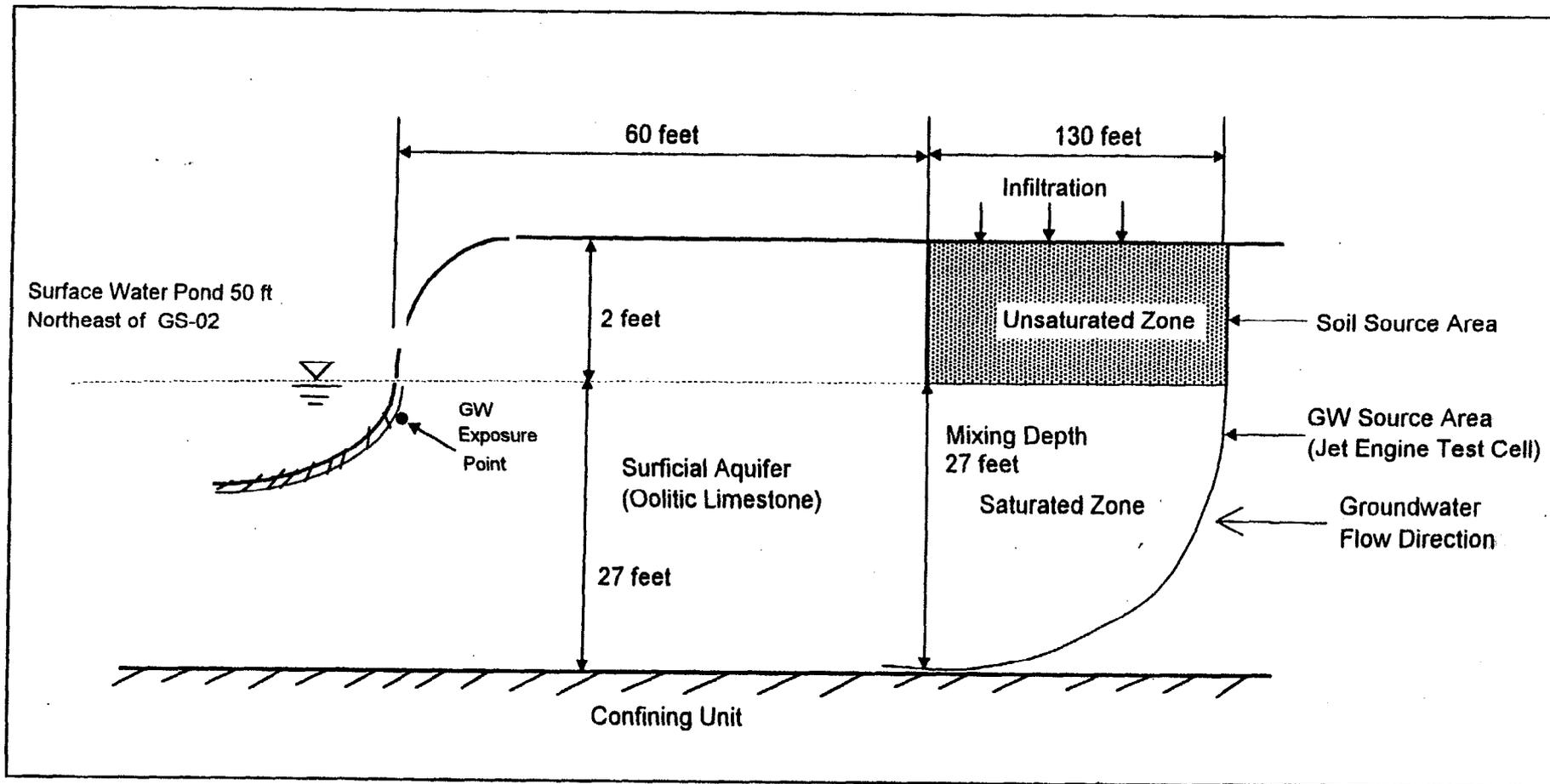


FIGURE C-2 GROUNDWATER FLOW DIRECTION (SWMU 9, NAS KEY WEST)



Not to Scale

FIGURE C-3 CONCEPTUAL MODEL FOR GROUNDWATER FATE AND TRANSPORT (SWMU 9, NAS KEY WEST)

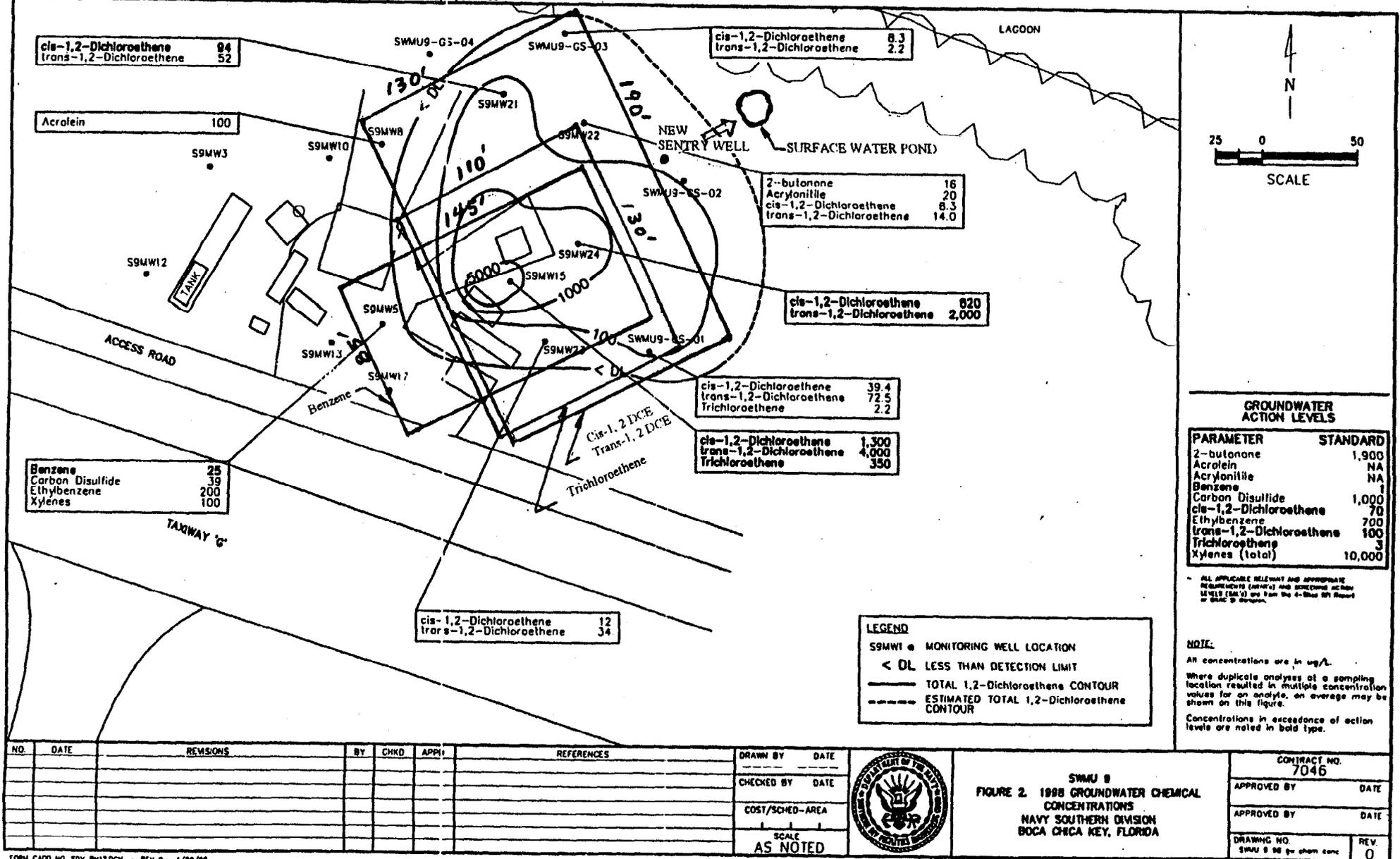


FIGURE C-4 SOURCE AREAS AND EXPOSURE POINT (SWMU 9, NAS KEY WEST)

**TABLE C-1  
GROUNDWATER RGOs PROTECTIVE OF SURFACE WATER AND SEDIMENT  
SWMU 9 CORRECTIVE MEASURE STUDY  
NAVAL AIR STATION, KEY WEST, FLORIDA**

<b>Chemical of Concern</b>	<b>Groundwater RGO Protective of Surface Water</b> ug/L	<b>Surface Water Criteria<sup>(1)</sup></b> ug/L	<b>Groundwater Criteria Protective of Surface Water<sup>(2)</sup></b> ug/L	<b>Groundwater RGO Protective of Sediment</b> ug/L	<b>Sediment Criteria<sup>(1)</sup></b> ug/kg	<b>Groundwater Criteria Protective of Sediment<sup>(3)</sup></b> ug/L	<b>Max. Detected Groundwater Concentration in Source Area</b> ug/L	<b>Groundwater in Source Area Exceedence of RGOs?</b>
cis-1,2-DCE	60,000	11,600	14,385	1,930	23	460	280	No
trans-1,2-DCE	7,600	1,350	1,740	4,500,000	62,000	1.03 x 10 <sup>6</sup>	820	No
Benzene	12,600	71	100	89,500	57	712.5	18	No
TCE	2,720	81	131	280,000	1,600	13,333	ND	No

RGO = Remedial Goal Option

DCE = Dichloroethene

TCE = Trichloroethene

- (1) Surface water and sediment criteria are the most restrictive of ARAR or SAL values (BRAC SI Workplan (B&R Environmental, 1998))
- (2) Represents groundwater concentration at groundwater/surface water interface (edge of surface water pond) that will not result in a surface water concentration in excess of surface water criteria. Calculated by multiplying surface water criteria by corresponding retardation factor.
- (3) Represents groundwater concentration in sediment porewater at groundwater/surface water interface. Calculated by dividing sediment criteria by corresponding partitioning coefficient.

**TABLE C-2**  
**HYDRAULIC CONDUCTIVITIES FROM PUMPING TEST AND SLUG TEST**  
**SWMU 9 CORRECTIVE MEASURE STUDY**  
**NAVAL AIR STATION, KEY WEST, FLORIDA**

Well ID	Test Type	Transmissivity	Hydraulic Conductivity
		(ft <sup>2</sup> /min)	(ft/day)
P-2	pump test <sup>(1)</sup>	0.06235	3.33
P-3	pump test <sup>(1)</sup>	0.08235	4.39
P-4	pump test <sup>(1)</sup>	0.17680	9.43
P-5	pump test <sup>(1)</sup>	0.07366	3.93
MW-10	pump test <sup>(1)</sup>	0.07305	3.90
Geomean ( $K_{sat}$ ; ft/day)=			4.62

(1) The aquifer transmissivity results were based on the pumping test, and were divided by the aquifer thickness of 27 feet to obtain the hydraulic conductivities. The pumping test was started on September 6, 1995 at a pumping rate of 2.0 gpm (BEI, 1995).

**TABLE C-3**  
**PARTITIONING COEFFICIENT AND HALF-LIVES**  
**SWMU 9 CORRECTIVE MEASURE STUDY**  
**NAVAL AIR STATION, KEY WEST, FLORIDA**

Chemicals of Concern	Organic Carbon/ Water Partitioning Coefficient <sup>(1)</sup>	Soil Organic Carbon Content <sup>(2)</sup>	Partitioning Coefficient <sup>(3)</sup> (unsaturated zone)	Groundwater Organic Carbon Content <sup>(4)</sup>	Partitioning Coefficient <sup>(3)</sup> (saturated zone)	Half-Life <sup>(5)</sup> (years)
	KOC (L/kg)	FOC	Kd (L/kg)	FOC	Kd (L/kg)	
Cis-1,2-Dichloroethene	49	0.0720	3.53	0.0010	0.05	7.9
Trans-1,2-Dichloroethene	59	0.0720	4.25	0.0010	0.06	7.9
Benzene	83	0.0720	5.98	0.0010	0.08	2.0
Trichloroethene	126	0.0720	9.07	0.0010	0.12	4.5

(1) The KOC was imported from U.S. EPA document "Manual- Groundwater and Leachate Treatment Systems" (EPA/625/R-94/005).

(2) The soil FOC value used in this evaluation was based on 72,000 mg/kg (or 7.2 %) TOC concentrations from one groundwater samples (S9MW-10) result collected in May1998 (TtNUS, Aug 1998).

(3)  $K_d = FOC \times KOC$ , U.S. EPA, December 1996, Soil Screening Guidance Users Guide.

(4) The groundwater FOC values were based on results from Natural Attenuation Study (TtNUS, Aug 1998). A geometric mean foc value was used for modeling.

(5) Half-lives were taken from literature values (Howard 1991).

**TABLE C-4**  
**GROUNDWATER CRITERIA PROTECTIVE OF SURFACE WATER AND SEDIMENT**  
**SWMU 9 CORRECTIVE MEASURE STUDY**  
**NAVAL AIR STATION, KEY WEST, FLORIDA**

Chemicals of Concern	Partitioning Coefficient Kd (L/kg)	Retardation Factor Rd	Surface Water Criteria <sup>(1)</sup> (ug/L)	Groundwater Criteria Protective of Surface Water <sup>(2)</sup> (ug/L)	Sediment Criteria <sup>(1)</sup> (ug/kg)	Groundwater Criteria Protective of Sediment <sup>(3)</sup> (ug/L)
Cis-1,2-Dichloroethene	0.05	1.24	11,600	14,385	23	460
Trans-1,2-Dichloroethene	0.06	1.29	1,350	1,740	62,000	1.03 x 10 <sup>6</sup>
Benzene	0.08	1.41	71	100	57	712.5
Trichloroethene	0.12	1.62	81	131	1,600	13,333

## Notes:

- (1) Surface Water and Sediment Criteria are the most restrictive ARAR or SAL values (Supplemental RFI/RI Report, 1997).  
(2) Groundwater Criteria Protective of Surface Water are calculated by multiplying the surface water criteria by their corresponding Rd (retardation factor).  
(3) Groundwater Criteria Protective of Sediment are calculated by dividing the sediment criteria by their corresponding Kd (partitioning coefficient).

**TABLE C-5**  
**SUMMARY OF PHYSICAL AND GEOLOGIC PARAMETERS**  
**SWMU 9 CORRECTIVE MEASURE STUDY**  
**NAVAL AIR STATION, KEY WEST, FLORIDA**

Chemical of Concern	Source Area <sup>(1)</sup>		Shallow Aquifer Thickness <sup>(2)</sup> (ft)	Unsaturated Zone Thickness <sup>(3)</sup> (ft)	Hydraulic Conductivity <sup>(4)</sup> K (ft/day)	Mixing Depth <sup>(5)</sup> (ft)	Distance to Exposure Point <sup>(6)</sup> (Surfacewater Pond) (ft)	Distance to New Sentry Well <sup>(7)</sup> (ft)
	Length (ft)	Width (ft)						
Cis-1,2-Dichloroethene	130	190	27	2	4.62	27	60	15
Trans-1,2-Dichloroethene	130	190	27	2	4.62	27	60	15
Benzene	145	85	27	2	4.62	27	95	50
Trichloroethene	110	130	27	2	4.62	27	87	45

(1) Source area size was based on the reported 1998 groundwater concentrations in the surficial aquifer (Figures B-4, and TINUS, August 1998).

(2) Shallow surficial aquifer thickness is based on the RFI/RI (B&R, July 1997).

(3) The unsaturated zone thickness is based on the water table elevations presented in the RFI/RI (B&R, July 1997).

(4) A geometric mean K value from pumping tests in the surficial aquifer was selected for modeling (Table B-2).

(5) The mixing depth was calculated based on equations presented in the reference for ECTran model (Chiou et al, 1993).

(6) Measured from the edge of the source area to the surface water pond (Figure B-4).

(7) Measured from the edge of the source area to the new sentry well (Figure B-4).

**ATTACHMENT C.1**

**RESULTS OF GROUNDWATER FATE AND TRANSPORT MODELING**

**GROUNDWATER RGO PROTECTIVE OF SURFACE WATER**

Copyright 1997



SITE: SWMU 9, NAS, Key West; GW RGO INVESTIGATOR: LK DATE: 5/6/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	cis-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL) UNDERS: Under source, FL: Fenceline WATER CRITERIA (UG/L): 1.16E+04	FL LEACHATE CONCENTRATION (YES,NO)? NO INPUT SOLID-PHASE CONCENTRATION (MG/KG) 0.000E+00 CONSTANT CONCENTRATION (YES,NO)? NO TRY NEW GOAL: 0.00E+00 ACCEPTABLE! DECREASE
HALF-LIFE (YRS):	7.92E+00	TIME FRAME (YRS):	90
SPECIFIC ACTIVITY (Ci/g):	0.00E+00		
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke	1.00	INFILT (FT/YR)	8.30E-01
K1 (L/KG)	3.53E+00	LENGTH (FT):	130
		WIDTH (FT):	190
DEPLETING SOURCE:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
WASTE CHARACTERISTICS:		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	HOW MANY SUBLAYERS (1 - 10)?	3
INPUT FOLLOWING PARAMETERS:		TOTAL THICKNESS (UP TO 30 FT) (FT):	10
THICKNESS (FT):	2	SATURATION RATE:	0.95
SATURATION RATE:	0.6	POROSITY:	0.2
POROSITY:	0.2	BULK DENSITY (G/CM^3):	1.78
BULK DENSITY (G/CM^3):	1.5	Kd (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3):	1.5	BULK DENSITY (G/CM^3):	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
<b>SATURATED LAYER</b>			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, Vzo (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	4.80E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT)	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	6.0	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	2.0	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	6.000E+04	DISTANCE TO Fence Line:	60
<b>PREDICTED IMPACTS:</b>			TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	6.00E+04 (UG/L)		0
FENCE LINE CONCENTRATION:	1.43E+04 (UG/L)		9

BROWN & ROOT ENVIRONMENTAL  
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTran) MODEL

SITE: SWMU 9, NAS, Key West: GW RGO

CONTAMINANT: cis-1,2-Dichloroethene

INVESTIGATOR: LK  
DATE: 5/8/99

HALF-LIFE (YRS):			
LAYER 2:	7.92E+00		
SATURATED LAYER	7.92E+00		
DOWNGRADE	7.92E+00	INITIAL CONC. (ug/L)	6.00E+04

SATURATED LAYER

INFILT (FT/YR):	0.83			B (FT):	27	V <sub>zo</sub> (FT/YR):	4.48
LENGTH (FT):	130			GW Q3 (L/DAY):	2.66E+03	Kd (L/KG):	0.04802
WIDTH (FT):	190			GW V. (FT/YR):	8.99	H (FT):	27.0000
POROSITY 2:	0.3			THICKNESS (FT):	27.00	RETARDATION:	1.2401
POROSITY SAT. LAYER:	0.3			DECAY (1/DAY):	2.40E-04	DISPERSIVITY:	
DENSITY 2 (G/CM3):	1.5			CB0 (PPB):	6.00E+04	EFF. POROSITY:	0.30
DENSITY GMA (G/CM3):	1.50			CU2 (PPB):	0.00E+00	q (FT/YR):	0
AGE (YEARS):	0	Q1 (L/DAY):	1.59E+03	Q2 (L/DAY):	1.07E+03	DECAY (1/YR):	8.8E-02
				Az (FT):	0.14	P&T (YEARS):	0
				Ax (FT):	6.00	DISTANCE TO F.L. (FT):	60
				Ay (FT):	2.00		

TIME INTERVAL (YRS)		SOURCE AREA CONC. (GMA)		FENCE LINE CONC.	
ELAPSED TIME - YRS		(UG/L)		(UG/L)	
TIME INTERVAL (YRS)	LAYER 2 (PPB)				
0	0.00E+00		6.00E+04		0.00E+00
1.8	0.00E+00		3.99E+04		4.65E+00
3.6	0.00E+00		2.66E+04		1.31E+03
5.4	0.00E+00		1.77E+04		6.76E+03
7.2	0.00E+00		1.18E+04		1.22E+04
9	0.00E+00		7.85E+03		1.43E+04
10.8	0.00E+00		5.23E+03		1.36E+04
12.6	0.00E+00		3.48E+03		1.15E+04
14.4	0.00E+00		2.32E+03		9.00E+03
16.2	0.00E+00		1.54E+03		6.71E+03
18	0.00E+00		1.03E+03		4.85E+03
19.8	0.00E+00		6.84E+02		3.42E+03
21.6	0.00E+00		4.55E+02		2.38E+03
23.4	0.00E+00		3.03E+02		1.63E+03
25.2	0.00E+00		2.02E+02		1.11E+03
27	0.00E+00		1.34E+02		7.53E+02
28.8	0.00E+00		8.95E+01		5.07E+02
30.6	0.00E+00		5.96E+01		3.41E+02
32.4	0.00E+00		3.97E+01		2.29E+02
34.2	0.00E+00		2.64E+01		1.53E+02
36	0.00E+00		1.76E+01		1.02E+02
37.8	0.00E+00		1.17E+01		6.82E+01
39.6	0.00E+00		7.79E+00		4.55E+01
41.4	0.00E+00		5.19E+00		3.03E+01
43.2	0.00E+00		3.45E+00		2.02E+01
45	0.00E+00		2.30E+00		1.35E+01
46.8	0.00E+00		1.53E+00		8.98E+00
48.6	0.00E+00		1.02E+00		5.98E+00
50.4	0.00E+00		6.79E-01		3.98E+00
52.2	0.00E+00		4.52E-01		2.65E+00
54	0.00E+00		3.01E-01		1.77E+00
55.8	0.00E+00		2.00E-01		1.18E+00
57.6	0.00E+00		1.33E-01		7.83E-01
59.4	0.00E+00		8.88E-02		5.22E-01
61.2	0.00E+00		5.91E-02		3.47E-01
63	0.00E+00		3.94E-02		2.31E-01
64.8	0.00E+00		2.62E-02		1.54E-01
66.6	0.00E+00		1.75E-02		1.02E-01
68.4	0.00E+00		1.16E-02		6.82E-02
70.2	0.00E+00		7.74E-03		4.54E-02
72	0.00E+00		5.15E-03		3.03E-02
73.8	0.00E+00		3.43E-03		2.01E-02
75.6	0.00E+00		2.28E-03		1.34E-02
77.4	0.00E+00		1.52E-03		8.93E-03
79.2	0.00E+00		1.01E-03		5.95E-03
81	0.00E+00		6.74E-04		3.96E-03
82.8	0.00E+00		4.49E-04		2.64E-03
84.6	0.00E+00		2.99E-04		1.75E-03
86.4	0.00E+00		1.99E-04		1.17E-03
88.2	0.00E+00		1.32E-04		7.78E-04
90	0.00E+00		8.82E-05		5.18E-04
MAXIMUM:	0.00E+00		6.00E+04		1.43E+04

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SITE: SWMU 9, NAS, Key West; GW RGO INVESTIGATOR: LK DATE: 5/6/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	trans-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL) UNDERS: Under source, FL: Fenceline	FL
HALF-LIFE (YRS):	7.92E+00	WATER CRITERIA (UG/L):	1.35E+03
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	TIME FRAME (YRS):	90
		LEACHATE CONCENTRATION (YES,NO)?	NO
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	1.000E-02
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	7.76E-03
		ACCEPTABLE!	DECREASE
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(Ft/YR):	8.30E-01
KI (L/KG)	4.25E+00	LENGTH (FT):	130
		WIDTH (FT):	190
DEPLETING SOURCE		IS THERE A CLAY LINER LAYER (YES,NO)?	no
WASTE CHARACTERISTICS		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	1.00E-02	HOW MANY SUBLAYERS (1 - 10)?	3
INPUT FOLLOWING PARAMETERS:		TOTAL THICKNESS (UP TO 30 FT) (FT):	10
THICKNESS (FT):	2	SATURATION RATE:	0.95
SATURATION RATE:	0.6	POROSITY:	0.2
POROSITY:	0.2	BULK DENSITY (G/CM^3):	1.78
BULK DENSITY (G/CM^3)	1.5	Kd (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG)	0	INITIAL SOIL CONC. (MG/KG):	0
SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>zo</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG)	5.78E-02	SPECIFY MIXING DEPTH (Computed from formula if input: NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, A <sub>z</sub> (FT)	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, A <sub>x</sub> (FT):	6.0	AGE (YRS)	0
LATERAL DISPERSIVITY, A <sub>y</sub> (FT):	2.0	CONC. IN UPGRADIENT GROUNDWATER, CU <sub>2</sub> (UG/L)	0
INITIAL CONC. (ug/L):	7.600E+03	DISTANCE TO Fence Line:	60
PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION:	7.60E+03 (UG/L)		0
FENCE LINE CONCENTRATION:	1.74E+03 (UG/L)		9

BROWN & ROOT ENVIRONMENTAL  
SCREENING-LEVEL EXCEL-CRYSTAL BALL TRANSPORT (ECTran) MODEL

SITE: SWMU 9, NAS, Key West, GW RGO

CONTAMINANT: trans-1,2-Dichloroethene

INVESTIGATOR: LK  
DATE: 5/8/99

HALF-LIFE (YRS):  
LAYER 2: 7.92E+00  
SATURATED LAYER  
DOWNGRADE: 7.92E+00

INITIAL CONC (ug/L): 7.60E+03

SATURATED LAYER

INFILT (FT/YR): 0.83		B (FT): 27	Vzo (FT/YR): 4.48
LENGTH (FT): 130		GW Q3 (L/DAY): 2.66E+03	
WIDTH (FT): 190		GW V (FT/YR): 8.99	Kd (L/KG): 0.05782
POROSITY 2: 0.3		H (FT): 27.0000	RETARDATION: 1.2891
POROSITY SAT. LAYER: 0.3		EFF. POROSITY: 0.30	q (FT/YR): 0
DENSITY 2 (G/CM3): 1.5		DISPERSIVITY:	DECAY (1/YR): 8.8E-02
DENSITY GMA (G/CM3): 1.50		Az (FT): 0.14	
		Ax (FT): 6.00	P&T (YEARS): 0
AGE (YEARS): 0	Q1 (L/DAY): 1.59E+03	Ay (FT): 2.00	DISTANCE TO FL (FT): 60

TIME INTERVAL (YRS): 1.8		SOURCE AREA CONC. (GMA)	FENCE LINE CONC
ELAPSED TIME - YRS	LAYER 2 (PPB)	(UG/L)	(UG/L)

0	2.35E+00	7.60E+03	0.00E+00
1.8	1.79E+00	5.11E+03	3.72E-01
3.6	1.36E+00	3.43E+03	1.33E-02
5.4	1.04E+00	2.31E+03	7.51E-02
7.2	7.91E-01	1.55E+03	1.42E-03
9	6.02E-01	1.04E+03	1.74E-03
10.8	4.58E-01	7.01E+02	1.70E-03
12.6	3.49E-01	4.71E+02	1.47E-03
14.4	2.66E-01	3.17E+02	1.17E-03
16.2	2.02E-01	2.13E+02	8.92E-02
18	1.54E-01	1.43E+02	6.55E-02
19.8	1.17E-01	9.62E+01	4.69E-02
21.6	8.92E-02	6.47E+01	3.31E-02
23.4	6.79E-02	4.35E+01	2.30E-02
25.2	5.17E-02	2.92E+01	1.59E-02
27	3.94E-02	1.97E+01	1.09E-02
28.8	3.00E-02	1.32E+01	7.41E-01
30.6	2.28E-02	8.88E+00	5.04E+01
32.4	1.74E-02	5.97E+00	3.41E+01
34.2	1.32E-02	4.02E+00	2.31E+01
36	1.01E-02	2.70E+00	1.56E+01
37.8	7.66E-03	1.82E+00	1.05E+01
39.6	5.83E-03	1.22E+00	7.08E+00
41.4	4.44E-03	8.21E-01	4.77E+00
43.2	3.38E-03	5.52E-01	3.21E+00
45	2.57E-03	3.72E-01	2.16E-00
46.8	1.96E-03	2.50E-01	1.45E+00
48.6	1.49E-03	1.68E-01	9.79E-01
50.4	1.14E-03	1.13E-01	6.58E-01
52.2	8.65E-04	7.62E-02	4.43E-01
54	6.58E-04	5.13E-02	2.98E-01
55.8	5.01E-04	3.45E-02	2.00E-01
57.6	3.82E-04	2.33E-02	1.35E-01
59.4	2.91E-04	1.57E-02	9.07E-02
61.2	2.21E-04	1.06E-02	6.11E-02
63	1.68E-04	7.11E-03	4.11E-02
64.8	1.28E-04	4.80E-03	2.77E-02
66.6	9.76E-05	3.24E-03	1.86E-02
68.4	7.43E-05	2.18E-03	1.25E-02
70.2	5.66E-05	1.47E-03	8.44E-03
72	4.31E-05	9.96E-04	5.68E-03
73.8	3.28E-05	6.73E-04	3.83E-03
75.6	2.50E-05	4.56E-04	2.58E-03
77.4	1.90E-05	3.08E-04	1.74E-03
79.2	1.45E-05	2.09E-04	1.17E-03
81	1.10E-05	1.42E-04	7.92E-04
82.8	8.38E-06	9.63E-05	5.35E-04
84.6	6.38E-06	6.55E-05	3.61E-04
86.4	4.86E-06	4.46E-05	2.44E-04
88.2	3.70E-06	3.04E-05	1.65E-04
90	2.82E-06	2.08E-05	1.12E-04

MAXIMUM 2.35E+00 7.60E+03 1.74E+03

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SITE: SWMU 9, NAS.Key West; GW RGO INVESTIGATOR: LK DATE: 5-6-99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	Benzene	EXPOSURE POINT: (UNDERS, FL) FL	LEACHATE CONCENTRATION (YES,NO)? NO
		UNDERS: Under source, FL, Fenceline	INPUT SOLID-PHASE CONCENTRATION (MG/KG) 0.000E+00
HALF-LIFE (YRS):	2.00E+00	WATER CRITERIA (UG/L): 7.13E+01	CONSTANT CONCENTRATION (YES,NO)? NO
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	TIME FRAME (YRS): 90	TRY NEW GOAL: 0.00E+00
			ACCEPTABLE! DECREASE
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FT/YR):	8.30E-01
K1 (L/KG):	5.98E+00	LENGTH (FT):	145
DEPLETING SOURCE:		WIDTH (FT):	85
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM <sup>3</sup> ):	1.5	BULK DENSITY (G/CM <sup>3</sup> ):	1.78
		Kd (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM <sup>3</sup> ):	1.5	BULK DENSITY (G/CM <sup>3</sup> ):	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, Vzo (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	8.13E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	9.5	AGE (YRS)	0
LATERAL DISPERSIVITY, Ay (FT):	3.2	CONC. IN UPGRADIENT GROUNDWATER,CU2 (UG/L)	0
INITIAL CONC. (ug/L):	1.260E+04	DISTANCE TO Fence.Line.:	95
PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION:	1.26E+04 (UG/L)		0
FENCE LINE CONCENTRATION:	1.00E+02 (UG/L)		9

SITE: SWMU 9, NAS, Key West, GW RGO

CONTAMINANT: Benzene

INVESTIGATOR: LK  
DATE: 5/8/99

HALF-LIFE (YRS):  
LAYER 2: 2.00E+00  
SATURATED LAYER: 2.00E+00  
DOWNGRADE: 2.00E+00  
INITIAL CONC. (ug/L): 1.26E+04

SATURATED LAYER

INFILT (FT/YR): 0.83		B (FT): 27	V <sub>20</sub> (FT/YR): 4.48
LENGTH (FT): 145		GW Q3 (L/DAY): 1.27E+03	
WIDTH (FT): 85		GW V (FT/YR): 8.99	Kd (L/KG): 0.08134
POROSITY 2: 0.3		H (FT): 27.0000	RETARDATION: 1.4067
POROSITY SAT. LAYER: 0.3		EFF POROSITY: 0.30	q (FT/YR): 0
DENSITY 2 (G/CM3): 1.5		DISPERSIVITY:	DECAY (1/YR): 3.5E-01
DENSITY GMA (G/CM3): 1.50		Az (FT): 0.14	
AGE (YEARS): 0	Q1 (L/DAY): 7.94E+02	Ax (FT): 9.50	P&T (YEARS): 0
		Ay (FT): 3.17	DISTANCE TO F.L. (FT): 95

TIME INTERVAL (YRS)	1.8	SOURCE AREA CONC (GMA)		FENCE LINE CONC	
ELAPSED TIME - YRS	LAYER 2 (PPB)	(UG/L)		(UG/L)	
0	0.00E+00	1.26E+04	0.00E+00		
1.8	0.00E+00	5.47E+03	5.58E-05		
3.6	0.00E+00	2.38E+03	1.20E+00		
5.4	0.00E+00	1.03E+03	2.33E+01		
7.2	0.00E+00	4.48E+02	7.11E+01		
9	0.00E+00	1.94E+02	1.00E+02		
10.8	0.00E+00	8.44E+01	9.64E+01		
12.6	0.00E+00	3.66E+01	7.40E+01		
14.4	0.00E+00	1.59E+01	4.94E+01		
16.2	0.00E+00	6.91E+00	2.99E+01		
18	0.00E+00	3.00E+00	1.70E+01		
19.8	0.00E+00	1.30E+00	9.14E+00		
21.6	0.00E+00	5.65E-01	4.75E-00		
23.4	0.00E+00	2.45E-01	2.40E+00		
25.2	0.00E+00	1.07E-01	1.18E+00		
27	0.00E+00	4.63E-02	5.72E-01		
28.8	0.00E+00	2.01E-02	2.73E-01		
30.6	0.00E+00	8.72E-03	1.28E-01		
32.4	0.00E+00	3.79E-03	5.98E-02		
34.2	0.00E+00	1.64E-03	2.76E-02		
36	0.00E+00	7.13E-04	1.27E-02		
37.8	0.00E-00	3.10E-04	5.77E-03		
39.6	0.00E+00	1.34E-04	2.61E-03		
41.4	0.00E+00	5.84E-05	1.18E-03		
43.2	0.00E+00	2.53E-05	5.29E-04		
45	0.00E+00	1.10E-05	2.36E-04		
46.8	0.00E+00	4.78E-06	1.05E-04		
48.6	0.00E+00	2.07E-06	4.69E-05		
50.4	0.00E-00	9.01E-07	2.08E-05		
52.2	0.00E+00	3.91E-07	9.20E-06		
54	0.00E+00	1.70E-07	4.06E-06		
55.8	0.00E+00	7.37E-08	1.79E-06		
57.6	0.00E+00	3.20E-08	7.89E-07		
59.4	0.00E+00	1.39E-08	3.47E-07		
61.2	0.00E+00	6.03E-09	1.52E-07		
63	0.00E-00	2.62E-09	6.68E-08		
64.8	0.00E+00	1.14E-09	2.94E-08		
66.6	0.00E+00	4.94E-10	1.28E-08		
68.4	0.00E+00	2.14E-10	5.55E-09		
70.2	0.00E+00	9.31E-11	2.41E-09		
72	0.00E+00	4.04E-11	1.05E-09		
73.8	0.00E+00	1.75E-11	4.54E-10		
75.6	0.00E+00	7.62E-12	1.97E-10		
77.4	0.00E+00	3.31E-12	8.56E-11		
79.2	0.00E+00	1.44E-12	3.70E-11		
81	0.00E+00	6.23E-13	1.63E-11		
82.8	0.00E+00	2.71E-13	6.84E-12		
84.6	0.00E+00	1.17E-13	3.15E-12		
86.4	0.00E+00	5.10E-14	1.49E-12		
88.2	0.00E+00	2.21E-14	4.72E-13		
90	0.00E+00	9.61E-15	1.57E-13		
MAXIMUM:	0.00E+00	1.26E+04	1.00E+02		

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SITE: SWMU 9, NAS, Key West; GW RGO INVESTIGATOR: LK DATE: 5/6/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	Trichloroethene (TCE)	EXPOSURE POINT: (UNDERS, FL) UNDERS: Under source, FL: Fenceline WATER CRITERIA (UG/L): 8.07E+01	LEACHATE CONCENTRATION (YES,NO)? NO INPUT SOLID-PHASE CONCENTRATION (MG/KG) 0.00E+00 CONSTANT CONCENTRATION (YES,NO)? NO TRY NEW GOAL: 0.00E+00 ACCEPTABLE! DECREASE
HALF-LIFE (YRS):	4.50E+00	TIME FRAME (YRS):	90
SPECIFIC ACTIVITY (Ci/g):	0.00E+00		
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke	1.00	INFILT (FT/YR):	8.30E-01
KI (L/KG):	9.07E+00	LENGTH (FT):	110
DEPLETING SOURCE:		WIDTH (FT):	130
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3):	1.78
		Kd (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
<b>SATURATED LAYER</b>			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, Vzo (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	1.23E-01	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	8.7	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	2.9	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L)	2.720E+03	DISTANCE TO Fence Line:	87
<b>PREDICTED IMPACTS:</b>		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION:	2.72E+03 (UG/L)		0
FENCE LINE CONCENTRATION:	1.31E+02 (UG/L)		12.6

SITE: SWMU 9, NAS, Key West, GW RGO

CONTAMINANT: Trichloroethene (TCE)

INVESTIGATOR: LK  
DATE: 5/8/99

HALF-LIFE (YRS):	
LAYER 2:	4.50E+00
SATURATED LAYER	4.50E+00
DOWNGRADE	4.50E+00
INITIAL CONC (ug/L):	2.72E+03

SATURATED LAYER

INFILT (FT/YR):	0.83			B (FT):	27	Vzo (FT/YR):	4.48
LENGTH (FT):	110			GW Q3 (L/DAY):	1.66E+03		
WIDTH (FT):	130			GW V. (FT/YR):	8.99	Kd (L/KG):	0.12348
POROSITY 2:	0.3			H (FT):	27.0000	RETARDATION:	1.6174
POROSITY SAT. LAYER:	0.3			THICKNESS (FT):	27.00	q (FT/YR):	0
DENSITY 2 (G/CM3):	1.5			DECAY (1/DAY):	4.22E-04	DISPERSIVITY:	1.5E-01
DENSITY GMA (G/CM3):	1.50			CB0 (PPB):	2.72E+03	Az (FT):	0.14
AGE (YEARS):	0	Q1 (L/DAY):	9.21E+02	CU2 (PPB):	0.00E+00	Ax (FT):	8.70
				Q2 (L/DAY):	7.34E+02	Av (FT):	2.90
						P&T (YEARS):	0
						DISTANCE TO F.L. (FT):	87

TIME INTERVAL (YRS)		SOURCE AREA CONC. (GMA)		FENCE LINE CONC.	
ELAPSED TIME - YRS	LAYER 2 (PPB)	(UG/L)		(UG/L)	
0	0.00E+00	2.72E+03	0.00E+00		
1.8	0.00E+00	1.68E+03	5.81E-06		
3.6	0.00E+00	1.04E+03	2.88E-01		
5.4	0.00E+00	6.40E+02	8.86E+00		
7.2	0.00E+00	3.95E+02	4.04E+01		
9	0.00E+00	2.44E+02	8.42E+01		
10.8	0.00E+00	1.51E+02	1.18E+02		
12.6	0.00E+00	9.30E+01	1.31E+02		
14.4	0.00E+00	5.74E+01	1.26E+02		
16.2	0.00E+00	3.54E+01	1.10E+02		
18	0.00E+00	2.19E+01	9.00E+01		
19.8	0.00E+00	1.35E+01	6.97E+01		
21.6	0.00E+00	8.34E+00	5.19E+01		
23.4	0.00E+00	5.15E+00	3.76E+01		
25.2	0.00E+00	3.18E+00	2.65E+01		
27	0.00E+00	1.96E+00	1.84E+01		
28.8	0.00E+00	1.21E+00	1.25E+01		
30.6	0.00E+00	7.48E-01	8.44E+00		
32.4	0.00E+00	4.62E-01	5.62E+00		
34.2	0.00E+00	2.85E-01	3.71E+00		
36	0.00E+00	1.76E-01	2.43E+00		
37.8	0.00E+00	1.09E-01	1.58E+00		
39.6	0.00E+00	6.70E-02	1.02E+00		
41.4	0.00E+00	4.14E-02	6.58E-01		
43.2	0.00E+00	2.56E-02	4.22E-01		
45	0.00E+00	1.58E-02	2.69E-01		
46.8	0.00E+00	9.74E-03	1.71E-01		
48.6	0.00E+00	6.01E-03	1.09E-01		
50.4	0.00E+00	3.71E-03	6.87E-02		
52.2	0.00E+00	2.29E-03	4.33E-02		
54	0.00E+00	1.41E-03	2.73E-02		
55.8	0.00E+00	8.73E-04	1.72E-02		
57.6	0.00E+00	5.39E-04	1.08E-02		
59.4	0.00E+00	3.33E-04	6.74E-03		
61.2	0.00E+00	2.05E-04	4.22E-03		
63	0.00E+00	1.27E-04	2.64E-03		
64.8	0.00E+00	7.83E-05	1.65E-03		
66.6	0.00E+00	4.83E-05	1.03E-03		
68.4	0.00E+00	2.98E-05	6.40E-04		
70.2	0.00E+00	1.84E-05	3.98E-04		
72	0.00E+00	1.14E-05	2.48E-04		
73.8	0.00E+00	7.02E-06	1.54E-04		
75.6	0.00E+00	4.34E-06	9.57E-05		
77.4	0.00E+00	2.68E-06	5.94E-05		
79.2	0.00E+00	1.65E-06	3.69E-05		
81	0.00E+00	1.02E-06	2.29E-05		
82.8	0.00E+00	6.30E-07	1.42E-05		
84.6	0.00E+00	3.89E-07	8.79E-06		
86.4	0.00E+00	2.40E-07	5.45E-06		
88.2	0.00E+00	1.48E-07	3.37E-06		
90	0.00E+00	9.15E-08	2.09E-06		
MAXIMUM:	0.00E+00	2.72E+03	1.31E+02		

**GROUNDWATER RGO PROTECTIVE OF SEDIMENT**

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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/7/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	cis-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL)	FL
HALF-LIFE (YRS):	7.92E+00	LEACHATE CONCENTRATION (YES,NO) ?	NO
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	UNDERS: Under source, FL: Fenceline	INPUT SOLID-PHASE CONCENTRATION (MG/KG)
		SEDIMENT CRITERIA (UG/KG):	2.30E+01
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	0.00E+00
		ACCEPTABLE!	DECREASE
		TIME FRAME (YRS):	90

SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FI/YR):	8.30E-01
K1 (L/KG):	3.53E+00	LENGTH (FT):	130
		WIDTH (FT):	190
DEPLETING SOURCE:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
WASTE CHARACTERISTICS:		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	HOW MANY SUBLAYERS (1 - 10)?	3
INPUT FOLLOWING PARAMETERS:		TOTAL THICKNESS (UP TO 30 FT) (FT):	10
THICKNESS (FT):	2	SATURATION RATE:	0.95
SATURATION RATE:	0.6	POROSITY:	0.2
POROSITY:	0.2	BULK DENSITY (G/CM^3):	1.78
BULK DENSITY (G/CM^3)	1.5	Kd (L/KG):	1.00E-05

IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0

SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, Vzo (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	4.80E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	6.0	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	2.0	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	1.930E+03	DISTANCE TO Fence.Line.:	60

PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	1.93E+03 (UG/L)	0
FENCE LINE CONCENTRATION:	4.61E+02 (UG/L)	9

SITE:	SWMU 9. NAS, Key West	CONTAMINANT:	cis-1,2-Dichloroethene	
INVESTIGATOR:	LK	HALF-LIFE (YRS):		
DATE:	5/7/99	LAYER 2:	7.92E+00	
		SATURATED LAYER	7.92E+00	
		DOWNGRADIENT	7.92E+00	INITIAL CONC. (ug/L): 1.93E+03

SATURATED LAYER				
INFILT (FT/YR):	0.83			B (FT): 27 V <sub>zo</sub> (FT/YR): 4.48
LENGTH (FT):	130			GW Q3 (L/DAY): 2.66E+03
WIDTH (FT):	190	Kd (L/KG): 4.80E-02		GW V <sub>z</sub> (FT/YR): 8.99 Kd (L/KG): 0.04802
POROSITY 2:	0.3	SATURATION:	1.00	H (FT): 27.0000 RETARDATION: 1.2401
POROSITY SAT. LAYER:	0.3	THICKNESS (FT):	27.00	EFF. POROSITY: 0.30 q (FT/YR): 0
DENSITY 2 (G/CM3):	1.5	DECAY (1/DAY):	2.40E-04	DISPERSIVITY: DECAY (1/YR): 8.8E-02
DENSITY GMA (G/CM3):	1.50	CB0 (PPB):	1.93E+03	Az (FT): 0.14
AGE (YEARS):	0	CU2 (PPB):	0.00E+00	Ax (FT): 6.00 P&T (YEARS): 0
		Q1 (L/DAY):	1.59E+03	Ay (FT): 2.00 DISTANCE TO F.L. (FT): 60
		Q2 (L/DAY):	1.07E+03	

TIME INTERVAL (YRS)		SOURCE AREA CONC.(GMA)		FENCE LINE CONC.	
ELAPSED TIME - YRS		(UG/L)		(UG/L)	
	LAYER 2(PPB)				
0	0.00E+00		1.93E+03		0.00E+00
1.8	0.00E+00		1.28E+03		1.50E-01
3.6	0.00E+00		8.56E+02		4.22E-01
5.4	0.00E+00		5.70E+02		2.18E+02
7.2	0.00E+00		3.79E+02		3.91E+02
9	0.00E+00		2.53E+02		4.61E+02
10.8	0.00E+00		1.68E+02		4.38E+02
12.6	0.00E+00		1.12E+02		3.70E+02
14.4	0.00E+00		7.45E+01		2.89E+02
16.2	0.00E+00		4.96E+01		2.16E+02
18	0.00E+00		3.30E+01		1.56E+02
19.8	0.00E+00		2.20E+01		1.10E+02
21.6	0.00E+00		1.46E+01		7.64E+01
23.4	0.00E+00		9.75E+00		5.25E+01
25.2	0.00E+00		6.49E+00		3.58E+01
27	0.00E+00		4.32E+00		2.42E+01
28.8	0.00E+00		2.88E+00		1.63E+01
30.6	0.00E+00		1.92E+00		1.10E+01
32.4	0.00E+00		1.28E+00		7.35E+00
34.2	0.00E+00		8.49E-01		4.92E+00
36	0.00E+00		5.66E-01		3.29E+00
37.8	0.00E+00		3.77E-01		2.19E+00
39.6	0.00E+00		2.51E-01		1.46E+00
41.4	0.00E+00		1.67E-01		9.76E-01
43.2	0.00E+00		1.11E-01		6.51E-01
45	0.00E+00		7.40E-02		4.34E-01
46.8	0.00E+00		4.93E-02		2.89E-01
48.6	0.00E+00		3.28E-02		1.92E-01
50.4	0.00E+00		2.18E-02		1.28E-01
52.2	0.00E+00		1.45E-02		8.53E-02
54	0.00E+00		9.68E-03		5.68E-02
55.8	0.00E+00		6.44E-03		3.78E-02
57.6	0.00E+00		4.29E-03		2.52E-02
59.4	0.00E+00		2.86E-03		1.68E-02
61.2	0.00E+00		1.90E-03		1.12E-02
63	0.00E+00		1.27E-03		7.44E-03
64.8	0.00E+00		8.43E-04		4.95E-03
66.6	0.00E+00		5.61E-04		3.30E-03
68.4	0.00E+00		3.74E-04		2.20E-03
70.2	0.00E+00		2.49E-04		1.46E-03
72	0.00E+00		1.66E-04		9.73E-04
73.8	0.00E+00		1.10E-04		6.48E-04
75.6	0.00E+00		7.35E-05		4.31E-04
77.4	0.00E+00		4.89E-05		2.87E-04
79.2	0.00E+00		3.26E-05		1.91E-04
81	0.00E+00		2.17E-05		1.27E-04
82.8	0.00E+00		1.44E-05		8.48E-05
84.6	0.00E+00		9.61E-06		5.64E-05
86.4	0.00E+00		6.40E-06		3.76E-05
88.2	0.00E+00		4.26E-06		2.50E-05
90	0.00E+00		2.84E-06		1.67E-05
MAXIMUM:	0.00E+00		1.93E+03		4.61E+02

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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/7/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	trans-1,2-Dichloroethene	EXPOSURE POINT: (UNDERS, FL)	FL
		LEACHATE CONCENTRATION (YES,NO)?	NO
		UNDERS: Under source, FL: Fence/line	
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	1.000E-02
		SEDIMENT CRITERIA (UG/KG):	6.20E+04
		CONSTANT CONCENTRATION (YES,NO)?	NO
HALF-LIFE (YRS):	7.92E+00	TRY NEW GOAL:	6.02E-04
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	ACCEPTABLE!	DECREASE
		TIME FRAME (YRS):	90

SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FY/YR):	8.30E-01
Ki (L/KG):	4.25E+00	LENGTH (FT):	130
		WIDTH (FT):	190
DEPLETING SOURCE:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
WASTE CHARACTERISTICS:		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	1.00E-02	HOW MANY SUBLAYERS (1 - 10)?	3
INPUT FOLLOWING PARAMETERS:		TOTAL THICKNESS (UP TO 30 FT) (FT):	10
THICKNESS (FT):	2	SATURATION RATE:	0.95
SATURATION RATE:	0.6	POROSITY:	0.2
POROSITY:	0.2	BULK DENSITY (G/CM^3):	1.78
BULK DENSITY (G/CM^3)	1.5	Kd (L/KG):	1.00E-05

IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0

SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>zo</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	5.78E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, A <sub>z</sub> (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, A <sub>x</sub> (FT):	6.0	AGE (YRS):	0
LATERAL DISPERSIVITY, A <sub>y</sub> (FT):	2.0	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	4.500E+06	DISTANCE TO Fence.Line.:	60

PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	4.50E+06 (UG/L)	0
FENCE LINE CONCENTRATION:	1.03E+06 (UG/L)	9

SITE: SWMU 9, NAS, Key West		CONTAMINANT: trans-1,2-Dichloroethene	
INVESTIGATOR: LK		HALF-LIFE (YRS):	
DATE: 5/7/99		LAYER 2: 7.92E+00	
		SATURATED LAYER: 7.92E+00	
		DOWNGRADIENT: 7.92E+00	INITIAL CONC. (ug/L): 4.50E+06

SATURATED LAYER			
INFILT (FT/YR): 0.83		B (FT): 27	Vzo (FT/YR): 4.48
LENGTH (FT): 130		GW Q3 (L/DAY): 2.66E+03	
WIDTH (FT): 190		GW V. (FT/YR): 8.99	Kd (L/KG): 0.0578
POROSITY 2: 0.3		H (FT): 27.0000	RETARDATION: 1.289
POROSITY SAT. LAYER: 0.3		EFF. POROSITY: 0.30	q (FT/YR): 0
DENSITY 2 (G/CM3): 1.5		DISPERSIVITY:	DECAY (1/YR): 8.8E-02
DENSITY GMA (G/CM3): 1.50		Az (FT): 0.14	
AGE (YEARS): 0	Q1 (L/DAY): 1.59E+03	Ax (FT): 6.00	P&T (YEARS): 0
		Ay (FT): 2.00	DISTANCE TO F.L. (FT): 60
		Q2 (L/DAY): 1.07E+03	

TIME INTERVAL (YRS) 1.8		SOURCE AREA CONC.(GMA)		FENCE LINE CONC.	
ELAPSED TIME - YRS	LAYER 2(PPB)	(UG/L)		(UG/L)	
0	2.35E+00	4.50E+06		0.00E+00	
1.8	1.79E+00	3.02E+06		2.20E+02	
3.6	1.36E+00	2.03E+06		7.88E+04	
5.4	1.04E+00	1.37E+06		4.45E+05	
7.2	7.91E-01	9.18E+05		8.43E+05	
9	6.02E-01	6.17E+05		1.03E+06	
10.8	4.58E-01	4.15E+05		1.01E+06	
12.6	3.49E-01	2.79E+05		8.70E+05	
14.4	2.66E-01	1.87E+05		6.95E+05	
16.2	2.02E-01	1.26E+05		5.28E+05	
18	1.54E-01	8.47E+04		3.88E+05	
19.8	1.17E-01	5.69E+04		2.78E+05	
21.6	8.92E-02	3.82E+04		1.96E+05	
23.4	6.79E-02	2.57E+04		1.36E+05	
25.2	5.17E-02	1.73E+04		9.39E+04	
27	3.94E-02	1.16E+04		6.43E+04	
28.8	3.00E-02	7.81E+03		4.39E+04	
30.6	2.28E-02	5.25E+03		2.98E+04	
32.4	1.74E-02	3.53E+03		2.02E+04	
34.2	1.32E-02	2.37E+03		1.36E+04	
36	1.01E-02	1.59E+03		9.21E+03	
37.8	7.67E-03	1.07E+03		6.21E+03	
39.6	5.84E-03	7.20E+02		4.19E+03	
41.4	4.45E-03	4.84E+02		2.82E+03	
43.2	3.38E-03	3.25E+02		1.90E+03	
45	2.58E-03	2.18E+02		1.28E+03	
46.8	1.96E-03	1.47E+02		8.58E+02	
48.6	1.49E-03	9.87E+01		5.77E+02	
50.4	1.14E-03	6.63E+01		3.88E+02	
52.2	8.66E-04	4.46E+01		2.61E+02	
54	6.59E-04	3.00E+01		1.75E+02	
55.8	5.02E-04	2.01E+01		1.18E+02	
57.6	3.82E-04	1.35E+01		7.93E+01	
59.4	2.91E-04	9.10E+00		5.33E+01	
61.2	2.21E-04	6.12E+00		3.58E+01	
63	1.69E-04	4.11E+00		2.41E+01	
64.8	1.28E-04	2.76E+00		1.62E+01	
66.6	9.77E-05	1.86E+00		1.09E+01	
68.4	7.44E-05	1.25E+00		7.31E+00	
70.2	5.66E-05	8.39E-01		4.91E+00	
72	4.31E-05	5.64E-01		3.30E+00	
73.8	3.28E-05	3.79E-01		2.22E+00	
75.6	2.50E-05	2.55E-01		1.49E+00	
77.4	1.90E-05	1.71E-01		1.00E+00	
79.2	1.45E-05	1.15E-01		6.74E-01	
81	1.10E-05	7.73E-02		4.53E-01	
82.8	8.40E-06	5.20E-02		3.05E-01	
84.6	6.39E-06	3.49E-02		2.05E-01	
86.4	4.87E-06	2.35E-02		1.38E-01	
88.2	3.71E-06	1.58E-02		9.25E-02	
90	2.82E-06	1.06E-02		6.22E-02	
MAXIMUM:	2.35E+00	4.50E+06		1.03E+06	

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SITE: SWMU 9, NAS, Key West INVESTIGATOR: LK DATE: 5/7/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	benzene	EXPOSURE POINT: (UNDERS, FL)	FL
HALF-LIFE (YRS):	2.00E+00	UNDERS: Under source, FL: Fenceline	
SPECIFIC ACTIVITY (Ci/g):	0.00E+00	SEDIMENT CRITERIA (UG/KG):	5.70E+01
		TIME FRAME (YRS):	90
		LEACHATE CONCENTRATION (YES,NO) ?	NO
		INPUT SOLID-PHASE CONCENTRATION (MG/KG)	0.000E+00
		CONSTANT CONCENTRATION (YES,NO)?	NO
		TRY NEW GOAL:	0.00E+00
		ACCEPTABLE!	DECREASE

SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT(FT/YR):	8.30E-01
KI (L/KG):	5.98E+00	LENGTH (FT):	145
		WIDTH (FT):	85
DEPLETING SOURCE:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
WASTE CHARACTERISTICS:		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	HOW MANY SUBLAYERS (1 - 10)?	3
INPUT FOLLOWING PARAMETERS:		TOTAL THICKNESS (UP TO 30 FT) (FT):	10
THICKNESS (FT):	2	SATURATION RATE:	0.95
SATURATION RATE:	0.6	POROSITY:	0.2
POROSITY:	0.2	BULK DENSITY (G/CM^3):	1.78
BULK DENSITY (G/CM^3)	1.5	Kd (L/KG):	1.00E-05

IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0

SATURATED LAYER			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, Vzo (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADIENT AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	8.13E-02	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	9.5	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	3.2	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	8.950E+04	DISTANCE TO Fence.Line.:	95

PREDICTED IMPACTS:		TIME OF MAXIMUM (YR)
SATURATED LAYER CONCENTRATION:	8.95E+04 (UG/L)	0
FENCE LINE CONCENTRATION:	7.14E+02 (UG/L)	9

SITE:	SWMU 9, NAS, Key West	CONTAMINANT:	benzene
INVESTIGATOR:	LK	HALF-LIFE (YRS):	
DATE:	5/7/99	LAYER 2:	2.00E+00
		SATURATED LAYER	2.00E+00
		DOWNGRADIENT	2.00E+00
		INITIAL CONC. (ug/L):	8.95E+04

SATURATED LAYER			
INFILT (FT/YR):	0.83	B (FT):	27
LENGTH (FT):	145	Vzo (FT/YR):	4.48
WIDTH (FT):	85	GW Q3 (L/DAY):	1.27E+03
POROSITY 2:	0.3	GW V. (FT/YR):	8.99
POROSITY SAT. LAYER:	0.3	Kd (L/KG):	0.0813
DENSITY 2 (G/CM3):	1.5	H (FT):	27.0000
DENSITY GMA (G/CM3):	1.50	RETARDATION:	1.4065
AGE (YEARS):	0	EFF. POROSITY:	0.30
		q (FT/YR):	0
		DISPERSIVITY:	DECAY (1/YR):
		Az (FT):	0.14
		Ax (FT):	9.50
		Ay (FT):	3.17
		P&T (YEARS):	0
		DISTANCE TO F.L. (FT):	95
Q1 (L/DAY):	7.94E+02	Q2 (L/DAY):	4.80E+02

TIME INTERVAL (YRS)	1.8	SOURCE AREA CONC. (GMA)		FENCE LINE CONC.	
ELAPSED TIME - YRS	LAYER 2 (PPB)	(UG/L)		(UG/L)	
0	0.00E+00	8.95E+04	0.00E+00		
1.8	0.00E+00	3.89E+04	3.98E-04		
3.6	0.00E+00	1.69E+04	8.55E+00		
5.4	0.00E+00	7.32E+03	1.66E+02		
7.2	0.00E+00	3.18E+03	5.05E+02		
9	0.00E+00	1.38E+03	7.14E+02		
10.8	0.00E+00	5.99E+02	6.85E+02		
12.6	0.00E+00	2.60E+02	5.26E+02		
14.4	0.00E+00	1.13E+02	3.51E+02		
16.2	0.00E+00	4.90E+01	2.13E+02		
18	0.00E+00	2.13E+01	1.20E+02		
19.8	0.00E+00	9.24E+00	6.49E+01		
21.6	0.00E+00	4.01E+00	3.37E+01		
23.4	0.00E+00	1.74E+00	1.70E+01		
25.2	0.00E+00	7.56E-01	8.39E+00		
27	0.00E+00	3.28E-01	4.06E+00		
28.8	0.00E+00	1.43E-01	1.94E+00		
30.6	0.00E+00	6.19E-02	9.12E-01		
32.4	0.00E+00	2.69E-02	4.25E-01		
34.2	0.00E+00	1.17E-02	1.96E-01		
36	0.00E+00	5.06E-03	8.99E-02		
37.8	0.00E+00	2.20E-03	4.09E-02		
39.6	0.00E+00	9.55E-04	1.85E-02		
41.4	0.00E+00	4.14E-04	8.36E-03		
43.2	0.00E+00	1.80E-04	3.75E-03		
45	0.00E+00	7.81E-05	1.68E-03		
46.8	0.00E+00	3.39E-05	7.48E-04		
48.6	0.00E+00	1.47E-05	3.33E-04		
50.4	0.00E+00	6.39E-06	1.48E-04		
52.2	0.00E+00	2.78E-06	6.53E-05		
54	0.00E+00	1.20E-06	2.88E-05		
55.8	0.00E+00	5.23E-07	1.27E-05		
57.6	0.00E+00	2.27E-07	5.60E-06		
59.4	0.00E+00	9.86E-08	2.46E-06		
61.2	0.00E+00	4.28E-08	1.08E-06		
63	0.00E+00	1.86E-08	4.74E-07		
64.8	0.00E+00	8.07E-09	2.09E-07		
66.6	0.00E+00	3.50E-09	9.07E-08		
68.4	0.00E+00	1.52E-09	3.94E-08		
70.2	0.00E+00	6.60E-10	1.71E-08		
72	0.00E+00	2.87E-10	7.42E-09		
73.8	0.00E+00	1.24E-10	3.22E-09		
75.6	0.00E+00	5.40E-11	1.40E-09		
77.4	0.00E+00	2.35E-11	6.09E-10		
79.2	0.00E+00	1.02E-11	2.64E-10		
81	0.00E+00	4.42E-12	1.13E-10		
82.8	0.00E+00	1.92E-12	5.10E-11		
84.6	0.00E+00	8.33E-13	2.08E-11		
86.4	0.00E+00	3.62E-13	9.44E-12		
88.2	0.00E+00	1.57E-13	3.15E-12		
90	0.00E+00	6.82E-14	1.26E-12		
MAXIMUM:	0.00E+00	8.95E+04	7.14E+02		

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## BROWN &amp; ROOT ENVIRONMENTAL

SITE: SWMU 9, NAS, Key West

INVESTIGATOR: LK

DATE: 5/7/99

CHEMICAL CHARACTERISTICS		ITERATIVE DECISION-MAKING BOX	
CONTAMINANT:	TCE	EXPOSURE POINT: (UNDERS, FL) UNDERS: Under source, FL: Fence line SEDIMENT CRITERIA (UG/KG):	FL 1.60E+03
HALF-LIFE (YRS):	4.50E+00		LEACHATE CONCENTRATION (YES,NO)? NO
SPECIFIC ACTIVITY (Ci/g):	0.00E+00		INPUT SOLID-PHASE CONCENTRATION (MG/KG) 0.000E+00
		TIME FRAME (YRS):	90 CONSTANT CONCENTRATION (YES,NO)? NO
			TRY NEW GOAL: 0.00E+00
			ACCEPTABLE! DECREASE
SOURCE-TERM INFORMATION		ENGINEERING CONTROL INFORMATION	
Ke:	1.00	INFILT (FT/YR):	8.30E-01
Ki (L/KG):	9.07E+00	LENGTH (FT):	110
DEPLETING SOURCE:		WIDTH (FT):	130
WASTE CHARACTERISTICS:		IS THERE A CLAY LINER LAYER (YES,NO)?	no
INITIAL SOLID-PHASE CONCENTRATION (MG/KG):	0.00E+00	THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
INPUT FOLLOWING PARAMETERS:		HOW MANY SUBLAYERS (1 - 10)?	3
THICKNESS (FT):	2	TOTAL THICKNESS (UP TO 30 FT) (FT):	10
SATURATION RATE:	0.6	SATURATION RATE:	0.95
POROSITY:	0.2	POROSITY:	0.2
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3):	1.78
		Kd (L/KG):	1.00E-05
IS THERE A TYPE 1 LAYER (YES,NO)?	NO	IS THERE A TYPE 2 LAYER (YES,NO)?	NO
THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION		THE FOLLOWING DATA ARE NOT USED IN THIS CALCULATION	
HOW MANY SUBLAYERS (1 - 10)?	6	HOW MANY SUBLAYERS (1 - 10)?	5
TOTAL THICKNESS (UP TO 30 FT) (FT):	2.20E+01	TOTAL THICKNESS (UP TO 30 FT) (FT):	20
SATURATION RATE:	0.95	SATURATION RATE:	0.13
POROSITY:	0.2	POROSITY:	0.3
BULK DENSITY (G/CM^3)	1.5	BULK DENSITY (G/CM^3)	1.5
Kd (L/KG):	1.00E-05	Kd (L/KG):	1.00E-05
INITIAL SOIL CONC. (MG/KG):	0	INITIAL SOIL CONC. (MG/KG):	0
<b>SATURATED LAYER</b>			
TOTAL SATURATED ZONE THICKNESS, B (FT):	27	VERTICAL SEEPAGE VELOCITY, V <sub>z0</sub> (FT/YR):	4.48
HORIZONTAL SEEPAGE VELOCITY, V (FT/YR):	8.99	DOWNGRADE AREA INFILTRATION RATE, q (FT/YR)	0
Kd (L/KG):	1.23E-01	SPECIFY MIXING DEPTH (Computed from formula if input NO)	no
POROSITY:	0.3	MIXING DEPTH, H (FT):	27.0
VERTICAL DISPERSIVITY, Az (FT):	0.14	TIME OF PUMPING STOP, P&T (YEARS):	0
LONGITUDINAL DISPERSIVITY, Ax (FT):	8.7	AGE (YRS):	0
LATERAL DISPERSIVITY, Ay (FT):	2.9	CONC. IN UPGRADIENT GROUNDWATER, CU2 (UG/L)	0
INITIAL CONC. (ug/L):	2.800E+05	DISTANCE TO Fence Line:	87
<b>PREDICTED IMPACTS:</b>		TIME OF MAXIMUM (YR)	
SATURATED LAYER CONCENTRATION:	2.80E+05 (UG/L)		0
FENCE LINE CONCENTRATION:	1.36E+04 (UG/L)		12.6

SITE: SWMU 9, NAS, Key West

CONTAMINANT: TCE

INVESTIGATOR: LK  
DATE: 5/7/99

HALF-LIFE (YRS):	
LAYER 2:	4.50E+00
SATURATED LAYER	4.50E+00
DOWNGRADIENT	4.50E+00
INITIAL CONC. (ug/L):	2.80E+05

SATURATED LAYER			
INFILT (FT/YR):	0.83	B (FT):	27
LENGTH (FT):	110	Vzo (FT/YR):	4.48
WIDTH (FT):	130	GW Q3 (L/DAY):	1.66E+03
POROSITY 2:	0.3	GW V. (FT/YR):	8.99
POROSITY SAT. LAYER:	0.3	Kd (L/KG):	0.123
DENSITY 2 (G/CM3):	1.5	H (FT):	27.0000
DENSITY GMA (G/CM3):	1.50	RETARDATION:	1.615
AGE (YEARS):	0	EFF. POROSITY:	0.30
Q1 (L/DAY):	9.21E+02	q (FT/YR):	0
Q2 (L/DAY):	7.34E+02	DISPERSIVITY:	0.14
		DECAY (1/YR):	1.5E-01
		Az (FT):	0.14
		Ax (FT):	8.70
		P&T (YEARS):	0
		Ay (FT):	2.90
		DISTANCE TO F.L. (FT):	87

TIME INTERVAL (YRS)	1.8	SOURCE AREA CONC.(GMA)	FENCE LINE CONC.
ELAPSED TIME - YRS	LAYER 2(PPB)	(UG/L)	(UG/L)
0	0.00E+00	2.80E+05	0.00E+00
1.8	0.00E+00	1.73E+05	6.18E-04
3.6	0.00E+00	1.07E+05	3.01E+01
5.4	0.00E+00	6.58E+04	9.21E+02
7.2	0.00E+00	4.06E+04	4.19E+03
9	0.00E+00	2.51E+04	8.72E+03
10.8	0.00E+00	1.55E+04	1.22E+04
12.6	0.00E+00	9.55E+03	1.36E+04
14.4	0.00E+00	5.89E+03	1.30E+04
16.2	0.00E+00	3.64E+03	1.14E+04
18	0.00E+00	2.24E+03	9.27E+03
19.8	0.00E+00	1.39E+03	7.17E+03
21.6	0.00E+00	8.55E+02	5.34E+03
23.4	0.00E+00	5.28E+02	3.86E+03
25.2	0.00E+00	3.26E+02	2.73E+03
27	0.00E+00	2.01E+02	1.89E+03
28.8	0.00E+00	1.24E+02	1.29E+03
30.6	0.00E+00	7.66E+01	8.66E+02
32.4	0.00E+00	4.72E+01	5.77E+02
34.2	0.00E+00	2.92E+01	3.80E+02
36	0.00E+00	1.80E+01	2.49E+02
37.8	0.00E+00	1.11E+01	1.62E+02
39.6	0.00E+00	6.85E+00	1.05E+02
41.4	0.00E+00	4.23E+00	6.74E+01
43.2	0.00E+00	2.61E+00	4.31E+01
45	0.00E+00	1.61E+00	2.75E+01
46.8	0.00E+00	9.95E-01	1.75E+01
48.6	0.00E+00	6.14E-01	1.11E+01
50.4	0.00E+00	3.79E-01	7.02E+00
52.2	0.00E+00	2.34E-01	4.43E+00
54	0.00E+00	1.44E-01	2.79E+00
55.8	0.00E+00	8.90E-02	1.75E+00
57.6	0.00E+00	5.50E-02	1.10E+00
59.4	0.00E+00	3.39E-02	6.88E-01
61.2	0.00E+00	2.09E-02	4.30E-01
63	0.00E+00	1.29E-02	2.69E-01
64.8	0.00E+00	7.97E-03	1.68E-01
66.6	0.00E+00	4.92E-03	1.05E-01
68.4	0.00E+00	3.04E-03	6.51E-02
70.2	0.00E+00	1.87E-03	4.05E-02
72	0.00E+00	1.16E-03	2.52E-02
73.8	0.00E+00	7.14E-04	1.57E-02
75.6	0.00E+00	4.41E-04	9.73E-03
77.4	0.00E+00	2.72E-04	6.04E-03
79.2	0.00E+00	1.68E-04	3.75E-03
81	0.00E+00	1.04E-04	2.32E-03
82.8	0.00E+00	6.39E-05	1.44E-03
84.6	0.00E+00	3.95E-05	8.92E-04
86.4	0.00E+00	2.43E-05	5.53E-04
88.2	0.00E+00	1.50E-05	3.42E-04
90	0.00E+00	9.27E-06	2.12E-04
MAXIMUM:	0.00E+00	2.80E+05	1.36E+04

**APPENDIX D**  
**COST ESTIMATES**

NAVAL AIR STATION KEY WEST  
 Boca Chica Key, Florida  
 SWMU 9  
 Natural Attenuation with Long-Term Monitoring  
 Alternative No. 2  
 Annual Cost

Item	Item Cost Year 1	Item Cost Years 2-20	Item Cost every 5 years	Notes*
Sampling	\$36,500	\$9,500		Collect eight groundwater samples and per sample period, run natural attenuation analyses, plus travel, living, and shipping cost
Analysis	\$6,000	\$1,500		Eight groundwater samples analyzed for VOCs, and field analyses performed to determine natural attenuation parameters
Report	\$16,000	\$4,000		Forty hours per sampling report plus other direct cost
Site Review			\$20,000	Analysis Review performed for years 5,10, 15, and 20
<b>TOTALS</b>	<b>\$58,500</b>	<b>\$15,000</b>	<b>\$20,000</b>	

\*Sample numbers include QA/QC samples

NAVAL AIR STATION  
 Boca Chica Key, Florida  
 SWMU 9  
 Natural Attenuation with Long-Term Monitoring  
 Alternative No.2  
 Annual Cost

Year	Capital Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth
0	\$0.00		\$0.00	1.000	\$0.00
1		\$58,500.00	\$58,500.00	0.935	\$54,698.00
2		\$15,000.00	\$15,000.00	0.873	\$13,095.00
3		\$15,000.00	\$15,000.00	0.816	\$12,240.00
4		\$15,000.00	\$15,000.00	0.763	\$11,445.00
5		\$35,000.00	\$35,000.00	0.713	\$24,955.00
6		\$15,000.00	\$15,000.00	0.666	\$9,990.00
7		\$15,000.00	\$15,000.00	0.623	\$9,345.00
8		\$15,000.00	\$15,000.00	0.582	\$8,730.00
9		\$15,000.00	\$15,000.00	0.544	\$8,160.00
10		\$35,000.00	\$35,000.00	0.508	\$17,780.00
11		\$15,000.00	\$15,000.00	0.475	\$7,125.00
12		\$15,000.00	\$15,000.00	0.444	\$6,660.00
13		\$15,000.00	\$15,000.00	0.415	\$6,225.00
14		\$15,000.00	\$15,000.00	0.388	\$5,820.00
15		\$35,000.00	\$35,000.00	0.362	\$12,670.00
16		\$15,000.00	\$15,000.00	0.339	\$5,085.00
17		\$15,000.00	\$15,000.00	0.317	\$4,755.00
18		\$15,000.00	\$15,000.00	0.296	\$4,440.00
19		\$15,000.00	\$15,000.00	0.277	\$4,155.00
20		\$35,000.00	\$35,000.00	0.258	\$9,030.00
<b>TOTAL PRESENT WORTH</b>					<b>\$236,403.00</b>

NAVAL AIR STATION  
 Boca Chica Key, Florida  
 SWMU 9  
 Enhanced Biodegradation with Long-Term  
 Monitoring  
 Alternative No.3

Item	Qty	Unit	Sub.	Mat.	Labor	Equip.	Total Cost				Total Direct Cost	Comments
							Sub.	Mat.	Labor	Equip.		
-----												
ORC/HRC												
1) ORC	1,010	lbs	1,200	10	50		12,000	10,100	2,400		15,500	
2) HRC	500	lbs		6	50			3,000				
-----												
							12,000	13,100	2,400	0	27,500	
Burden @ 30% of Labor Cost									720		720	
Labor @ 10% of Labor Cost									240		240	
Material @ 10% of Material Cost								1,310			1,310	
Subcontract at 10% of Sub Cost							1,200				1,200	
-----												
Total Direct Cost							13,200	14,410	3,360		30,970	
Indirects @ 75% of Total Direct Labor Cost									2,520		2,520	
Profit @ 10% of Total Direct Cost											3,097	
-----												
Health and Safety Monitoring at 15%											5,488	
-----												
Total Field Cost											42,075	
Contingency @20% of Total Field Cost											8,415	
Engineering Cost											500	
-----												
TOTAL COST THIS PAGE											50,990	

NAVAL AIR STATION  
 Boca Chica Key, Florida  
 SWMU 9  
 Enhanced Bioremediation with Long-Term Monitoring  
 Alternative No.3  
 Annual Cost

Item	Item Cost Year 1	Item Cost Year 2	Item Cost Years 3-5	Item Cost for Year 5	Notes*
Sampling	\$36,500	\$18,500	\$9,500		Collect eight groundwater samples per sample period, plus travel, living, and shipping cost
Analysis	\$8,000	\$4,000	\$2,000		Eight groundwater samples analyzed for VOCs, and field analyses performed to determine natural attenuation parameters
Report	\$16,000	\$8,000	\$4,000		Forty hours per sampling report plus other direct cost
Site Review				\$20,000	Analysis Review performed for year 5.
<b>TOTALS</b>	<b>\$60,500</b>	<b>\$30,500</b>	<b>\$15,500</b>	<b>\$20,000</b>	

\*Sample numbers include QA/QC samples

NAVAL AIR STATION  
 Boca Chica Key, Florida  
 SWMU 9  
 Enhanced Bioremediation with Long-Term Monitoring  
 Alternative No.3  
 Annual Cost

Year	Capital Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth
0	\$51,000.00		\$51,000.00	1.000	\$51,000.00
1		\$60,500.00	\$60,500.00	0.935	\$56,568.00
2		\$30,500.00	\$30,500.00	0.873	\$26,627.00
3		\$15,500.00	\$15,500.00	0.816	\$12,648.00
4		\$15,500.00	\$15,500.00	0.763	\$11,827.00
5		\$35,500.00	\$35,500.00	0.713	\$25,312.00
<b>TOTAL PRESENT WORTH</b>					<b>\$183,982.00</b>

**APPENDIX E**

**CNBJAXINST 5090.2N4**



DEPARTMENT OF THE NAVY  
COMMANDER NAVAL BASE JACKSONVILLE  
BOX 102, NAVAL AIR STATION  
JACKSONVILLE, FLORIDA 32212-0102

5-AUG-97

CNBJAXINST 5090.2  
N4

COMMANDER, NAVAL BASE, JACKSONVILLE INSTRUCTION 5090.2

Subj: LAND USE RESTRICTIONS (LURS) AT ENVIRONMENTAL REMEDIATION  
SITES ON BOARD U.S. NAVY INSTALLATIONS

- Rcf: (a) Comprehensive Environmental Response, Compensation, and Liability Act  
(CERCLA), 42 U.S.C. §§ 9601 *et seq.*  
(b) Resource Conservation and Recovery Act (RCRA), 42 U.S.C. §§ 6901 *et seq.*  
(c) OPNAVINST 5090.1B

1. Purpose. To establish a systematic program, protective of human health and the environment, governing land use at environmental remediation sites on board selected U.S. Navy installations in the Commander, Naval Base, Jacksonville (COMNAVBASE JAX) Area of Responsibility (AOR).
2. Applicability. This instruction applies to sites undergoing environmental remediation at Naval Air Station, Jacksonville, FL, Naval Air Station Key West, FL, and Naval Station, Mayport, FL.
3. Discussion. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (references (a) and (b)) are the two primary federal laws governing the remediation of sites contaminated with hazardous substances and hazardous wastes. The U.S. Navy created the environmental remediation program to oversee the clean-up of these sites on board Naval facilities. Per reference (c), the Naval Facilities Engineering Command (NAVFAC) has been assigned the responsibility for centralized management of the installation restoration program. Southern Division (SOUTHDIR) is the NAVFAC component responsible for administration of the environmental remediation program for the U.S. Navy installations in the COMNAVBASE JAX AOR. The Florida Department of Environmental Protection (FDEP) and the U.S. Environmental Protection Agency (EPA) Region IV (hereafter referred to as "the agencies") have oversight and coordinating responsibilities over NAVFAC remediation actions. Remediation standards for clean-up of contaminated sites are established to ensure protection for human health and the environment.
  - a. Environmental restoration is a very costly process. There are an estimated 3300 sites nation-wide on board U.S. Navy and U.S. Marine Corps installations. Currently, the U.S. Navy's nationwide funding level is projected at just under \$300 million per year.
  - b. Tens to hundreds of millions of dollars can be saved through the selection of clean-up remedies which appropriately reflect the current and future land use. However, to be effective,

(5) A requirement to forward an annual report to the agencies (with a copy to SOUTHDIV) certifying retention of the specified LUR category for each affected site on the installation.

(6) The installation CO must follow identification of the proper procedures in order to obtain concurrence from the agencies to change a previously identified LUR for a site. Concurrence of the agencies must be obtained in writing prior to commencing any construction or other activity inconsistent with the previous LUR. Requests for review of a LUR change proposal will consider the degree of change proposed, the effectiveness of the remediation effort to date, any natural remediation which may have occurred since the original remedial actions, etc.

(7) A requirement to notify the agencies if, despite proper precautions, an unauthorized change in land use is discovered by the installation. The change in land use will be reported immediately to the agencies for collaborative determination of an appropriate remedy.

(8) A notation that any funding associated with additional remediation caused by a LUR change (whether approved or unauthorized) will be the responsibility of the installation CO.

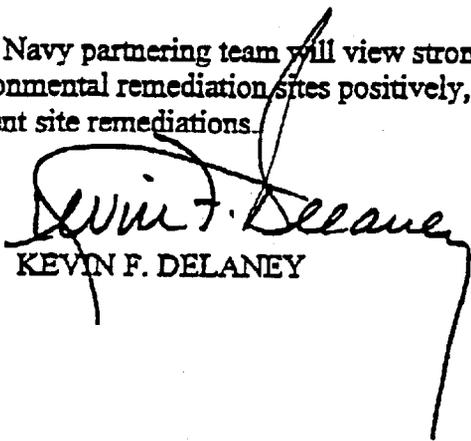
b. SOUTHDIV: As the agency responsible for the management of environmental remediation projects, SOUTHDIV shall accomplish the following:

(1) Take the lead in coordinating the drafting of a MOA to establish the specific agreement between each covered installation, the agencies and SOUTHDIV. At a minimum, the MOA will address real estate issues, LURs and remediation requirements.

(2) Support the installation CO, as required, during negotiations with the agencies.

(3) Review the installation's LUR instruction when conducting the tier two Environmental Compliance Evaluation (ECE) in support of the major claimant.

5. Special Note. The FDEP-EPA-U.S. Navy partnering team will view strong participation in this process to govern land use at environmental remediation sites positively, i.e., funding priority will be given to the most efficient site remediations.

  
KEVIN F. DELANEY

Distribution:

CNBJINST 5605.1

List IV: FA6a, FA6b, FA7a

List II: 26JJ1a, FA47a, FT48a