04.08-3/1/02-00606

# Final

# Feasibility Study for SWMUs 2B, 2C, and 2E
# Naval Air Station, Oceana
# Virginia Beach, Virginia

Prepared for

**Department of the Navy**
**Atlantic Division**
**Naval Facilities Engineering Command**
**Norfolk, Virginia**

Contract N62470-93-D-4072
CTO-153

March 2002

Prepared by

CH2MHILL

# SIGNATURE PAGE

**Final**

Feasibility Study for SWMUs 2B, 2C, and 2E

Naval Air Station Oceana
Virginia Beach, Virginia

Contract Task Order Number – 0151
Contract Number N62470-95-D-6007
Navy CLEAN II Program

*Prepared by*
CH2M HILL

**March 2002**

Approved by: _____ Date: 3/7/02
Joe Kenderdine
Task Manager

Approved by: _____ Date: 3/7/02
Tony Tomlin
Activity Manager

Approved by: _____ Date: 3/7/02
Jayanti Sachdev
Senior Reviewer

# Executive Summary

This report presents the Feasibility Study (FS) for SWMUs 2B, 2C, and 2E at the Naval Air Station (NAS), Oceana, in Virginia Beach, Virginia. SWMU 2B consists of the Line Shack 130-134 Disposal Area, SWMU 2C consists of the Line Shack 400 Disposal Area, and SWMU 2E consists of the Line Shack 109 Disposal Area. This FS report is prepared by CH2M HILL under the Naval Facilities Engineering Command, Atlantic Division (LANTDIV) Comprehensive Long-Term Environmental Action Navy II (CLEAN II) Contract N62470-93-D-4072, Contract Task Order (CTO) 153, for submittal to LANTDIV, U.S. Environmental Protection Agency (USEPA), and the Virginia Department of Environmental Quality (VDEQ).

This study uses information gathered from various previous SWMU investigations to document the analyses and evaluations used to develop remedial action objectives (RAOs) and alternatives for SWMUs 2B, 2C, and 2E. The information presented herein will be used by the Navy and regulatory agencies to select a remedial alternative for each SWMU that complies with the requirements of the National Contingency Plan (NCP).

Site-specific RAOs were developed for SWMUs 2B, 2C, and 2E, based upon the results of previous investigations and risk assessments. The site-specific RAOs for SWMUs 2B, 2C, and 2E are to prevent exposure to unacceptable risks to potential receptors of groundwater.

Several potential remedial alternatives which would be suitable to address the RAOs were selected and evaluated for each SWMU based upon the criteria set forth in the NCP to assemble and evaluate technical and policy considerations and to develop rationale for selecting a remedy for each SWMU. The three remedial alternatives considered for SWMU 2B groundwater are: (1) no action, (2) institutional controls and long-term monitoring (LTM), and (3) application of hydrogen and oxygen release compounds, institutional controls, and LTM. The three remedial alternatives considered for SWMU 2C groundwater are: (1) no action, (2) monitored natural attenuation and institutional controls, and (3) enhanced biodegradation, monitored natural attenuation, and institutional controls. The three remedial alternatives considered for SWMU 2E groundwater are: (1) no action, (2) free-phase diesel fuel removal, institutional controls, and LTM, and (3) application of oxygen release compound, free-phase diesel fuel removal, institutional controls, and LTM.

Results of the criteria evaluation indicate that the most appropriate remedial alternative for SWMU 2B groundwater is institutional controls and LTM. The most appropriate remedial alternative for SWMU 2C groundwater is enhanced biodegradation, monitored natural attenuation, and institutional controls. The most appropriate remedial alternative for SWMU 2E groundwater is free-phase diesel fuel removal, institutional controls, and LTM. These selected alternatives for SWMUs 2B, 2C, and 2E meet all NCP criteria.

# Contents

**Executive Summary** ..... iii

**Acronyms and Abbreviations** ..... v

**1 Introduction** ..... 1-1
- 1.1 Objectives ..... 1-1
- 1.2 Report Organization ..... 1-2
- 1.3 Base Location and History ..... 1-2
  - 1.3.1 Climate ..... 1-2
  - 1.3.2 Topography ..... 1-3
  - 1.3.3 Geology ..... 1-3
  - 1.3.4 Surface Water Resources ..... 1-4
  - 1.3.5 Groundwater Resources ..... 1-4
  - 1.3.6 Habitats and Biota ..... 1-4
- 1.4 SWMU Descriptions ..... 1-5
  - 1.4.1 SMWU 2B – Line Shack 130 – 134 Disposal Area ..... 1-6
  - 1.4.2 SWMU 2C – Line Shack 400 Disposal Area ..... 1-11
  - 1.4.3 SWMU 2E – Line Shack 109 Disposal Area ..... 1-14

**2 Remedial Action Objectives and ARARs** ..... 2-1
- 2.1 NCP and CERCLA Objectives ..... 2-1
- 2.2 Development of Site Specific Remedial Action Objectives (SWMUs 2B, 2C and 2E) ..... 2-2
  - 2.2.1 Site-Specific Remedial Action Objectives ..... 2-2
  - 2.2.2 Applicable or Relevant and Appropriate Requirements ..... 2-4
  - 2.2.3 Other Criteria or Guidelines to be Considered ..... 2-5
  - 2.2.4 Determination of ARARs ..... 2-5
  - 2.2.5 Chemical-Specific Requirements ..... 2-5
  - 2.2.6 Location-Specific Requirements ..... 2-5
  - 2.2.7 Action-Specific Requirements ..... 2-6
- 2.3 Development of Preliminary Remediation Goals ..... 2-6
  - 2.3.1 SWMU 2B Groundwater ..... 2-6
  - 2.3.2 SWMU 2C Groundwater ..... 2-7
  - 2.3.3 SWMU 2E Groundwater ..... 2-7
  - 2.3.4 SWMU 2E Surface Soil ..... 2-7

**3 Development of Remedial Alternatives** ..... 3-1
- 3.1 General Response Actions ..... 3-1
- 3.2 Identification and Screening of Remedial Technologies ..... 3-2
  - 3.2.1 SWMU 2B Groundwater ..... 3-2
  - 3.2.2 SWMU 2C Groundwater ..... 3-3
  - 3.2.3 SWMU 2E Groundwater ..... 3-3
- 3.3 Remedial Alternatives for SWMU 2B Groundwater ..... 3-4

3.3.1 Site-Specific Remedial Action Objectives ....3-4
3.3.2 Remedial Alternatives ....3-5
3.4 Remedial Alternatives for SWMU 2C Groundwater ....3-7
3.4.1 Site-Specific Remedial Action Objectives ....3-7
3.4.2 Remedial Alternatives ....3-7
3.5 Remedial Alternatives for SWMU 2E Groundwater ....3-14
3.5.1 Site-Specific Remedial Action Objectives ....3-14
3.5.2 Remedial Alternatives ....3-14

**4 Detailed Analysis of Remedial Alternative ....4-1**
4.1 Evaluation Criteria ....4-1
4.1.1 Overall Protection of Human Health and the Environment ....4-1
4.1.2 Compliance with ARARs ....4-1
4.1.3 Long-Term Effectiveness and Permanence ....4-1
4.1.4 Reduction of Toxicity, Mobility, and Volume ....4-2
4.1.5 Short-Term Effectiveness ....4-2
4.1.6 Implementability ....4-3
4.1.7 Cost ....4-3
4.1.8 State Acceptance ....4-3
4.1.9 Community Acceptance ....4-4
4.2 Evaluation of Remedial Alternatives for SWMUs 2B, 2C and 2E ....4-4
4.2.1 Detailed Analysis of Remedial Alternatives ....4-4

**5 Comparative Analysis and Recommended Alternative ....5-1**
5.1 SWMU 2B Groundwater ....5-1
5.1.1 Comparative Analysis ....5-1
5.1.2 Recommended Alternative ....5-2
5.2 SWMU 2C Groundwater ....5-2
5.2.1 Comparative Analysis ....5-2
5.2.2 Recommended Alternative ....5-4
5.3 SWMU 2E ....5-4
5.3.1 Comparative Analysis ....5-4
5.3.2 Recommended Alternative ....5-5

**6 References ....6-1**

## Appendices

A Excerpts from the CMS

B Draft Technical Memorandum for the SWMU 2B and 2E Groundwater Sampling

C Draft Final SWMU 2C Ground Water Investigation Report

D ARARs

E PRG Calculations

F Preliminary Cost Estimates

**Tables (located at the end of each section)**

1-1 Screening Statistics - Step 2 Table - Surface Soil

1-2 Screening Statistics - Step 3 Table - Surface Soil

2-1 Preliminary Remediation Goals - Groundwater - SWMU 2B

2-2 Preliminary Remediation Goals - Groundwater - SWMU 2C

2-3 Preliminary Remediation Goals - Groundwater - SWMU 2E

2-4 Preliminary Remediation Goals – Soil Ingestion, Dermal Contact, and Inhalation - SWMU 2E

3-1 Identification and Screening of Remedial Technologies for SWMU 2B Groundwater

3-2 Identification and Screening of Remedial Technologies for SWMU 2C Groundwater

3-3 Identification and Screening of Remedial Technologies for SWMU 2E Groundwater

4-1 Analysis of Remedial Alternatives for Groundwater at SWMU 2B

4-2 Analysis of Remedial Alternatives for Groundwater at SWMU 2C

4-3 Analysis of Remedial Alternatives for Groundwater at SWMU 2E

**Figures (located at the end of each section)**

1-1 Base Location Map

1-2 SWMU Location Map

1-3 SWMU 2B Sample Locations

1-4 Chromium Concentrations in Soil – SWMU 2B

1-5 Zinc Concentrations in Soil – SWMU 2B

2-1 Monitoring Wells and Piezometers with MCL and Human Health Risk–Based PRG Exceedances – SWMU 2B

2-2 Monitoring Wells and Piezometers with MCL and Human Health Risk–Based PRG Exceedances – SWMU 2C

2-3 Monitoring Wells and Piezometers with MCL and Human Health Risk–Based PRG Exceedances – SWMU 2E

3-1 Proposed Long-Term Monitoring Well Network - SWMU 2B

3-2 Proposed HRC/ORC Injection Barrier Locations - SWMU 2B

3-3 Proposed Monitored Natural Attenuation Well Network - SWMU 2C

3-4A Proposed HRC or Alternate Electron Donor Injection Locations - SWMU 2C (TCE Plume)

3-4B Proposed HRC or Alternate Electron Donor Injection Locations - SWMU 2C (DCE Plume)

3-5 Proposed ORC Injection Locations - SWMU 2C

3-6 Proposed Long-Term Monitoring Well Network - SWMU 2E
3-7 Proposed ORC Barrier Locations - SWMU 2E

# Acronyms and Abbreviations

| | |
|---|---|
| ARAR | Applicable or Relevant and Appropriate Requirement |
| bgs | Below Ground Surface |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) |
| CFR | Code of Federal Regulations |
| CLEAN | Comprehensive Long-term Environmental Action Navy |
| COPC | Chemical of Potential Concern |
| CTO | Contract Task Order |
| CWA | Clean Water Act |
| DD | Decision Document |
| FFA | Federal Facilities Agreement |
| FS | Feasibility Study |
| HEAST | Health Effects Assessment Summary Tables |
| HHRA | Human Health Risk Assessment |
| HQ | Hazard Quotient |
| IAS | Initial Assessment Study |
| IR | Installation Restoration |
| LANTDIV | Naval Facilities Engineering Command, Atlantic Division |
| LTM | Long-term Monitoring |
| MCL | Maximum Contaminant Level |
| msl | Mean Sea Level |
| NAVFAC | Naval Facilities Engineering Command |
| NCP | National Contingency Plan |
| NPL | National Priorities List |
| O&M | Operations and Maintenance |
| OSWER | Office of Solid Waste and Emergency Response |
| PAH | Polynuclear Aromatic Hydrocarbon |
| PRG | Preliminary Remediation Goal |
| RA | Risk Assessment |
| RAGS | Risk Assessment Guidance for Superfund |
| RAO | Remedial Action Objective |
| RCRA | Resource Conservation and Recovery Act |
| RfD | Reference Dose |
| SARA | Superfund Amendments and Reauthorization Act of 1986 |

| | |
|---|---|
| SWMU | Solid Waste Management Unit |
| TAL | Target Analyte List |
| TCL | Target Compound List |
| TPH | Total Petroleum Hydrocarbon |
| USEPA | U.S. Environmental Protection Agency |
| VC | Vinyl Chloride |
| VDEQ | Virginia Department of Environmental Quality |
| VOC | Volatile Organic Compound |

SECTION 1

# Introduction

This report presents the Feasibility Study (FS) for SWMUs 2B, 2C, and 2E at the Naval Air Station, Oceana (NAS Oceana) in Virginia Beach, Virginia. This FS report is prepared by CH2M HILL under the Naval Facilities Engineering Command, Atlantic Division (LANTDIV), Comprehensive Long-term Environmental Action Navy II (CLEAN II) Contract N62470-93-D-4072, Contract Task Order (CTO) 153, for submittal to LANTDIV, U.S. Environmental Protection Agency (US EPA), and the Virginia Department of Environmental Quality (VDEQ). SWMU 2B consists of the Line Shack 130 – 134 Disposal Area, SWMU 2C consists of the Line Shack 400 Disposal Area and hydraulically downgradient area, and SWMU 2E consists of the Line Shack 109 Disposal Area.

## 1.1 Objectives

This FS has been developed in accordance with the Navy's Installation Restoration Program (IRP). Previous SWMU investigations have been conducted under provisions of the Resource Conservation and Recovery Act (RCRA) Corrective Action program. As of July 1998, cleanup activities have been accomplished under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), within the framework of a new administrative procedure. Under the new administrative procedure, the Navy and the EPA have reached concurrence on the classification of each SWMU through a Federal Facilities Agreement (FFA) in lieu of scoring each SWMU for the National Priorities List (NPL). If the FFA process fails then the base will be subject to listing on the NPL. The FFA will supercede and rescind the RCRA 3008 (h) consent order. However, the EPA can still stipulate penalties through the FFA.

This report uses information gathered from various investigations, including the following: the Phases I, II, and III RCRA Facility Investigations, Corrective Measures Study, SWMU 2C Groundwater Investigation report, and SWMUs 2B and 2E Groundwater Sampling Technical Memorandum. These and other previous investigations were used as a basis for developing and evaluating remedial alternatives to address contamination at SWMUs 2B, 2C, and 2E. The remedial alternatives are designed to address remedial action objectives (RAOs) and risks associated with SWMUs 2B, 2C, and 2E that are consistent with the National Contingency Plan (NCP). This FS includes a site-specific explanation of how each alternative satisfies the NCP's nine site-specific remedy selection criteria.

This FS documents the analyses and evaluations used to develop remedial action alternatives for SWMUs 2B, 2C, and 2E. The information presented herein will be used by the Navy and regulatory agencies to select a remedial alternative for each SWMU that complies with the requirements of the NCP. This FS is not intended to be a design document, rather, it gives a conceptual overview of alternatives to evaluate their feasibility.

The report documents criteria used to evaluate remedial alternatives and to determine the effects of implementing them.

Section 1.0 provides a brief overview of the SWMUs, the nature and extent of contamination, and human health and ecological risk assessments (RAs) for SWMUs 2B, 2C, and 2E, as is required to introduce the remedial alternatives. A more thorough discussion of the SWMUs, remedial investigation activities and results, contaminant fate and transport, and the RAs can be found in reports under separate cover as mentioned in Section 1.4 of this FS.

## 1.2 Report Organization

This FS report is composed of the following sections:

- Section 1 - Introduction
- Section 2 - Remedial Action Objectives (RAOs) and ARARs
- Section 3 - Development of Remedial Alternatives
- Section 4 - Detailed Analysis of Remedial Alternatives
- Section 5 - Comparative Analysis and Recommended Alternative
- Section 6 – References

Figures, tables, and appendices referenced within the text are provided at the end of each section.

## 1.3 Base Location and History

NAS Oceana was established as a small auxiliary airfield in 1940. Since then, NAS Oceana has grown to more than 16 times it original size and is now a 6,000-acre master jet base supporting a community of more than 9,100 Navy personnel and 11,000 dependents. The primary mission of NAS Oceana is to provide the personnel, operations, maintenance, and training facilities to ensure that fighter and attack squadrons on aircraft carriers of the U.S. Atlantic Fleet are ready for deployment.

In 1981, NAS Oceana initiated a comprehensive hazardous waste collection and recycling program to prevent releases of hazardous wastes to the environment. The program involved constructing waste controls such as oil and water separators near aircraft cleaning and maintenance areas, and working closely with various shops to ensure that wastes were properly contained, segregated, labeled, and collected. NAS Oceana also monitors discharges within drainages on and off the station as part of its National Pollution Discharge Elimination System (NPDES) monitoring to prevent the discharge of contamination beyond the limits of the station.

### 1.3.1 Climate

NAS Oceana is near the Atlantic Ocean (Figure 1-1), which accounts for the mild year-round temperatures. The Virginia Beach area climate is characterized by hot, humid summers and mild winters. The annual average temperature is 68.2 degrees. The average annual

precipitation is 44.62 inches. Seasonal snowfall is approximately 7 inches annually. Average wind speed at the station is approximately 10 mph. Coastal storms, in the form of severe thunderstorms, northeasters, and hurricanes, frequently impact the station.

### 1.3.2 Topography

The elevation of NAS Oceana ranges from approximately 5 feet above mean sea level (MSL) in the drainage ditches to approximately 25 feet above MSL in the open fields. Elevations in the developed area of the station range from 10 to 25 feet above MSL. Topography of the station is generally flat with a gradual easterly slope to the land surface.

### 1.3.3 Geology

NAS Oceana is on the outer edge of the Atlantic Coastal Plain physiographic province. The Atlantic Coastal Plain is a broad wedge of unconsolidated sediments that dip and thicken to the east. In the vicinity of NAS Oceana, the sediments consist of several thousand feet of unconsolidated sand, clay, silt, and gravel, and are underlain by granite basement rock. The sediments range in age from early Cretaceous to Recent. From oldest to youngest, the four geologic units underlying NAS Oceana are (1) the Potomac Formation, (2) the Pamunkey Group, (3) the Chesapeake Group, and (4) the Columbia Group (Meng and Harsh 1984). The geologic units of concern in the environmental investigations at the NAS Oceana are in the Chesapeake Group (only the youngest unit, the Yorktown Formation) and the Columbia Group.

The Chesapeake Group has been differentiated into several units, which are, from oldest to youngest, the Calvert, Choptank, St. Mary's, Eastover, and Yorktown Formations. As mentioned above, only the Yorktown Formation is of potential concern at NAS Oceana. The Yorktown Formation consists of interbedded layers of shelly, very fine to coarse sands, clayey sands, and sandy clay. Siudyla *et al.* (1981) divided the Yorktown into three sand units each overlain by a confining layer of silt and clay. Regionally, the uppermost of these silt and clay beds, which is referred to as the Yorktown confining unit, separates the Yorktown Formation from the sediments of the Columbia Group that overlie it. This uppermost bed consists of massive, well-bedded yellow-gray to greenish-gray clays and silty clays, which commonly contain shells, fine sand, and mica. The clay layers within the confining bed are generally extensive but are a series of coalescing clay beds rather than a single deposited unit. This unit was deposited in a shallow open-marine environment of broad lagoons and quiet bays (Meng and Harsh 1984).

The sediments of the Columbia Group consist of interbedded gravel, sands, silts, and clays of Pleistocene and Holocene age. The Pleistocene and Holocene sediments were deposited in fluvial-marine terrace and near-shore marine environments, including lagoons, beaches, tidal flats and barrier islands (Oaks and Coch 1973; Hamilton and Larson 1988). The Columbia Group sediments are, from oldest to youngest, (1) the Great Bridge Formation, (2) the Norfolk Formation, (3) the Londonbridge Formation, and (4) the Sand Bridge Formation (Oaks and Coch 1973).

The Sand Bridge Formation consists of a pale, yellowish-brown silt to sandy silt, often characterized as being clayey. This formation extends from the surface to a depth of three to

six feet. Underlying the Sandbridge Formation is the Londonbridge Formation, a bluish-gray, fine silty sand, which is generally four to five feet thick. The third member of the Columbia Group encountered while drilling at the NAS Oceana is the Norfolk Formation. This formation, which is approximately eight to eleven feet thick, is a bluish-gray to gray, fine to medium sand with trace shell fragments. The Great Bridge Formation underlies the Norfolk. The Great Bridge has an upper and lower member. The upper member is a white to light gray, well-graded sand. The lower member exhibits similar grain sizes and colors, but contains minor amounts of pebble gravel and bluish shell fragments. The Great Bridge Formation ranges in thickness from 0 to 55 feet.

### 1.3.4 Surface Water Resources

Surface runoff from the station is facilitated by a system of drainage ditches and surface canals that flow southwest to West Neck Creek, north to London Bridge and Great Neck Creek, and east to Owls Creek and Lake Rudee. The presence of iron precipitate, organic odors, high turbidity, and thick brown algae mats are common in many ditches.

### 1.3.5 Groundwater Resources

Groundwater at NAS Oceana is generally within 4 to 10 feet of the ground surface. Aquifer conditions are unconfined in the Columbia Group and unconfined to semiconfined within the upper Yorktown Formation (Siudyla *et al.* 1981). When the clay confining unit overlying the Yorktown is absent, the upper Yorktown is generally unconfined. Natural groundwater flow directions are generally south to southeast, but flow direction is controlled locally in the Columbia Group by drainage ditches. The flow direction in the Virginia Beach area is therefore highly variable because of the complexity of the drainage patterns.

There are seven wells on the base that extract groundwater from the subsurface. Two of the seven wells (designated WS-5 and WS-7) extract groundwater from the Columbia Aquifer. The others extract water from the underlying Yorktown Aquifer. Of the two wells in the Columbia Aquifer one supplies water to a maintenance sink. The other well supplies a guard house bathroom. Both are posted as "Not for drinking water".

### 1.3.6 Habitats and Biota

This section documents the flora, fauna, and rare, threatened or endangered species observed at NAS Oceana.

#### 1.3.6.1 Flora

A wide variety of vegetation types occur at NAS Oceana. Approximately 600 acres of forest and 200 acres of open land comprise the undeveloped areas at NAS Oceana (RGH 1984). Approximately 660 acres (11 percent) of the land area at NAS Oceana are wetlands.

Most of the forested areas on the station are dominated by pine, mixed pine-hardwood, and hardwood stands. Areas with poorly drained, saturated soils are dominated by sweetgum, red maple, and, sometimes, loblolly pine. Most forested stands with unsaturated or moist soil conditions are dominated by loblolly pine or mixed pine-hardwoods. Upland forested areas usually have more oaks and cherry. Other overstory species likely to occur with these

species are water oak, southern red oak, swamp chestnut oak, willow oak, tulip poplar, and black gum. Understory vegetation in the hardwood stands is dominated by switch cane. Other species occurring in the hardwood understory include greenbriar, pawpaw, Japanese honeysuckle, and bayberry. Understory plants that commonly occur in loblolly forests include sparse stands of switch cane, greenbriar, and Japanese honeysuckle.

#### 1.3.6.2 Fauna

Mammalian species such as white-tail deer, raccoon, chipmunk, squirrel, field mouse, and red fox inhabit the forested areas around NAS Oceana or in over-grown areas in the developed section of the station. Many species of birds use the station as seasonal and year-round habitat including the yellow-rumped warbler, which occurred in large numbers on the edges of forested areas throughout the station, and starlings, crows, gulls, song sparrows, ovenbirds, blue jays, cardinals, and common flickers. Habitat exists on the station for a wide variety of reptiles and amphibians. Fishery resources are largely limited to the ponds at the inactive landfill/sand pit, and the borrow pond on the outskirts of the station.

#### 1.3.6.3 Rare, Threatened, and Endangered Species

An inventory of rare, threatened, and endangered vertebrate and plant species was conducted on NAS Oceana in 1989 by the Virginia Department of Conservation and Recreation, Department of Natural Heritage, and was published in a Natural Heritage Technical Report (DNH, 1990). These results were updates and verified by checking the DNH, VA Department of Game and Inland Fisheries, and USFWS web sites for rare and endangered species (http://www.dcr.state.va.us/dnh/rare.htm, http://www.dgif.state.va.us/wildlife/index.cfm, and http://endangered.fws.gov). The updated information, in conjunction with the earlier DNH report (DNH, 1990) suggests that no rare, threatened, or endangered wildlife species are known to occur at NAS Oceana, with the possible exception of occasional transient species (CH2M Hill, 1993) such as the peregrine falcon (*Falco peregrinus*), the bald eagle (*Haliaeetus luecocephalus*), and swainson's warbler (*Limnothlypis swainsonii*). The peregrine falcon and the bald eagle are listed as endangered, and swainson's warbler is listed as a rare species in the state of Virginia (CH2M Hill, 1993).

Other rare, threatened, or endangered wildlife species that historically were likely to occur on the station are the following:

- Red-cockaded woodpecker
- Many-lined salamander
- Greater siren

The long-leaf pine (*Pinus palustris*) and the southern twayblade (*Listera australis*), state-listed as extremely rare and very rare plants, respectively, have both been observed at the station. *Listera australis* was recommended for special concern status in 1989 (DNR 1990).

## 1.4 SWMU Descriptions

The following subsections document the location and history, previous investigations, extent of contamination, and results of RAs at SWMUs 2B, 2C, and 2E.

## 1.4.1 SMWU 2B – Line Shack 130 – 134 Disposal Area

The location and history, previous investigations, extent of contamination, and results of RAs at SWMU 2B follow.

### 1.4.1.1 Location and History

SWMU 2B is southeast of the main MATWING hangar 122 (Figure 1-2). The site includes Line Shacks 130 through 134 and the five aircraft cleaning stations northeast of Line Shack 130.

The Initial Assessment Study (IAS) states that oil, hydraulic fluid, turco, paint stripper and thinners, PD 680, and aromatic hydrocarbons (naphtha, benzene, toluene and derivatives) were used in aircraft maintenance activities at SWMU 2B. These waste oils and aircraft-maintenance chemicals were disposed of adjacent to the line shacks in unknown amounts beginning in 1963, when the line shacks were constructed, until the early 1980s. A hazardous waste collection and recycling program has been in force throughout the base since 1981. During the 1980s an oil-water separator system was installed in the aircraft cleaning area northeast of Line Shack 130 to separate oil from wash water flowing from the aircraft cleaning area (RGH, 1984).

Construction of a new corrosion control hanger and extension of the flight-line are underway in the immediate vicinity of this SWMU. Much of the ground surface in the immediate area of the Line Shacks is covered with concrete or asphalt, and the ground surface that is not covered has been heavily disturbed as a result of the on-going construction of the Aircraft Maintenance Hangar and the extension of the flight line. After construction is completed, the limited exposed ground surface between the buildings, parking areas, and tarmac will be graded. Grass will be planted and it will be maintained as mowed lawn. A fence surrounds the impervious surfaces and separates the developed portion of the area from the undeveloped portion. Most of the site is within the flight line. The flat terrain is interrupted only by a storm water drainage ditch and a few berms left from previous disturbances.

SWMU 2B contains a storm water drainage ditch that is used to convey surface runoff off the site to the southeast. Groundwater discharges to the ditch, which maintains a perennial base flow. Data show that shallow groundwater flow is to the southeast over most of the area from Line Shacks 138 to 134, but it is to the southwest northwest of Line Shacks 132, 133, and 134 (CH2M HILL, 1993). No submerged aquatic vegetation was observed in the ditch. A band of vegetation approximately 10 feet wide runs along either side of the ditch. Vegetation includes bamboo, sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*) and some shrubs. This drainage ditch originates at the end of a pipe which collects storm water runoff from parking lots, roads, and other impervious surfaces in this section the base.

Construction of the Aircraft Maintenance Hangar and extension of the flight-line are underway in the immediate vicinity of this SWMU. With the exception of a short reach (between samples OW2B-SD01 and OW2B-SD04) near the construction, in late 2000 the ditch was cleaned out to a depth of 6 to 18 inches downgradient, all the way to the golf course. The sediments that were removed were disposed of at an approved landfill.

Drains within the aircraft cleaning area of SWMU 2B direct runoff to oil-water separators before discharging to sanitary sewers. Thus, this area of the SWMU 2B does not contribute to the potential occurrence of contamination in the drainage ditches.

#### 1.4.1.2 Previous Investigations

Earlier investigations at SWMU 2B include: the Round 1 Verification Study in 1986, the Line Shack Site Inspection in 1988, and the Interim RFI in 1990. These studies indicated that the groundwater at SWMU 2B is contaminated with chlorinated organic compounds from two or more sources. In addition, contamination was detected in samples collected from the stream that flows adjacent to the site. Several soil samples also contained contamination.

In 1993, CH2M HILL conducted a Phase I RFI to (1) define the sources of groundwater contamination, (2) define the source areas through soil sampling, and (3) define the effects of groundwater discharge to surface water and sediment quality. Results are documented in the *RCRA Facility Investigation Final Report—Phase I, Naval Air Station Oceana, Virginia Beach, Virginia*, December 1993.

In 1995, CH2M HILL performed a corrective measures study (CMS). The objectives of the CMS were to further delineate the extent of groundwater, soil, and surface water/sediment contamination and to determine the need for remedial activities. Results are documented in the *Final Corrective Measures Study for SWMUs 1, 2B, and 2C, Oceana Naval Air Station, Virginia Beach, Virginia*, November 1995.

Follow-on sediment sampling was conducted by CH2M HILL as part of the Phase III RFI. Phase III RFI results are documented in the *Final RCRA Facility Investigation Report—Phase III, Naval Air Station Oceana, Virginia Beach, Virginia*, August 1999.

In 2000, CH2M HILL conducted groundwater sampling to assess site-wide groundwater quality and support a human health risk assessment (HHRA). Results are documented in the *Draft Technical Memorandum for the Groundwater Sampling at SWMUs 2B and 2E, Naval Air Station Oceana, Virginia, Beach, Virginia*, January 2001.

Results of these investigations are summarized in Section 1.4.1.4.

#### 1.4.1.3 Current Investigations

In 2001, additional soil samples were collected at SWMU 2B in order to further investigate potential inorganic contamination in the soils. Verification of elevated chromium levels at station OW2B-SS02 (collected December 1999) was undertaken because although chromium was elevated at that station, there were significantly lower in concentration at surrounding station OW2B-SS01 (as well as its duplicate sample) and station OW2B-SS03. The chromium concentration at station OW2B-SS02 was verified by collecting a confirmatory sample at the same location in May 2001 (station OW2B-SS05). In addition to this confirmatory sample, two additional samples were collected, one 100 feet east of the confirmatory sample (station OW2B-SS04), and one 100 feet west of the confirmatory sample (station OW2B-SS06).

In order to further delineate the extent of inorganic contamination at the SWMU, additional soil samples were collected in August 2001. Samples were collected 10 feet and 50 feet to the north, south, east, and west of location OW2B-SS02/OW2B-SS05, for a total of eight surface

soil samples. Samples were also collected along the galvanized chain-link fence in order to determine if the fence was the source of high zinc levels at station OW2B-SS04 (520 mg/kg). Sample OW2B-SS17-00 was collected 1.5 feet southwest of OW2B-SS04-00 and one foot from the fence. Sample OW2B-SS16-00 was collected 10 feet southwest of OW2B-SS17-00 and 1.5 feet from the fence. Sample OW2B-SS15-00 was collected 10 feet east of OW2B-SS17-00 and 11 feet from the fence.

All samples were collected from 0-6 inches below ground surface and analyzed for TAL metals.

#### 1.4.1.4 Contamination and Extent

The subsurface geology at SWMU 2B consists of three stratigraphic units. The uppermost unit is a 4- to 7-foot-thick unit of fine sediments, mainly silty clays and sandy silts. This is underlain by a 15- to 20-foot-thick layer of clean, fine to medium sand. These two units correspond to the Columbia Group sediments. The Columbia Group is underlain by the Yorktown Formation, which is silty sand interlayered with zones of cleaner sand to a depth of 55 feet below the ground surface. Shells and shell hash indicative of the top of the Yorktown Formation were typically encountered at approximately 25 feet.

Based on current survey and water-level data, the groundwater flow in the vicinity of SWMU 2B is generally southerly with localized groundwater flow toward nearby stormwater drainage channels. The average velocity of horizontal groundwater flow in the surficial aquifer is approximately 75 feet per year.

Soil samples collected at SWMU 2B during the Phase I RFI and CMS did not contain significant concentrations of chlorinated volatile organic constituents (VOCs), even when sampling was focused in areas where the highest concentrations of chlorinated VOCs were detected in groundwater. The soil sampling results indicate that the source areas are probably limited in areal extent. Shallow groundwater (Columbia Aquifer groundwater) at SWMU 2B is contaminated with trichloroethene (TCE), 1,2-dichloroethene (1,2-DCE), and vinyl chloride (VC). Much lower concentrations of VOCs were detected in the deep aquifer (Yorktown Aquifer). Low levels of chlorinated VOCs were detected in surface water and sediment during both the RFI and the CMS.

The confirmatory sample collected in May 2001, OW2B-SS05-00, had a chromium concentration of 12 mg/kg, as compared to 782 mg/kg in the sample collected in the same location in December 1999 (OW2B-SS02-00). This May 2001 confirmatory result falls within the range of detected chromium concentrations in the surrounding samples (11 to 13.7 mg/kg), which includes the samples collected 100 feet east of sample OW2B-SS05-00 and 100 feet west of sample OW2B-SS05-00.

Sample OW2B-SS04-00 had a zinc concentration of 520 mg/kg, versus zinc concentrations of 21 mg/kg to 69.1 mg/kg in the other SWMU 2B surface soil samples. This high concentration may have been due to the galvanized chain-linked fence adjacent to where the sample was collected.

The eight samples collected around station OW2B-SS02 and SS05 had chromium concentrations between 9.5 and 15.6 mg/kg as compared 782 mg/kg at station OW2B-SS02.

Three samples collected within one and a half feet of the galvanized chain-link fence show zinc concentrations ranging from 406 to 747 mg/kg. However, samples collected at distances of eleven feet and 20 feet from the fence showed considerably lower concentrations (23.2 and 23.7 mg/kg).

Sediment samples collected during the Phase I and III RFI have detected polynuclear aromatic hydrocarbons (PAHs) at levels that exceed ecological screening levels. The reach of the drainage channel in which contamination has been detected in the sediments is currently being re-engineered to accommodate the construction of additional maintenance hangers and a parking lot. Much of the old drainage channel is expected to be altered or filled in. Construction in the area began in winter of 1998 and is expected to be completed in FY02. Additionally, sediment in the drainage channel is periodically removed as part of the facility maintenance program.

During February 2000, groundwater samples were collected from shallow and deep monitoring wells at SWMU 2B. Several VOCs, specifically cis 1,2-DCE, TCE, bis(2-ethylhexyl)phthalate, and vinyl chloride, were detected in the groundwater beneath SWMU 2B at concentrations that exceed the USEPA MCLs. Antimony and arsenic were also detected at concentrations that exceed their USEPA MCLs. Surface soil, surface water, and sediment samples were also collected in 2000.

#### 1.4.1.5 Human Health Risk Assessment

The HHRA performed for SWMU 2B characterizes potential current and future risks to human health at the site using the general methodology described in the *Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual, Part A* (USEPA, 1989) and RAGS, *Volume 1, Human Health Evaluation Manual, Part D* (USEPA, 1998).

Potential risks were calculated for a current industrial worker, future adult resident, future child resident, future lifetime resident, future construction worker, future industrial worker, future adult trespasser/visitor, and future adolescent trespasser/visitor. Potential risks were calculated for exposure to surface soil and groundwater (both Columbia and Yorktown Aquifer groundwater). Although the Columbia Aquifer groundwater is not currently used as a potable water supply and will most likely never be used as a potable water supply, potential future exposure to groundwater was evaluated under a future residential and construction worker exposure scenario. Risks were not calculated for exposure to surface water and sediment because there were no COPCs retained for this media. Risks were not calculated for exposure to combined surface and subsurface soil because there were no subsurface soil samples, due to the construction of a 15-inch thick concrete cap.

The only potential scenario resulting in hazards and risks is future residential use of the shallow (Columbia Aquifer) groundwater, which would result in hazards and risks above USEPA's target levels for the residents.

#### 1.4.1.6 Ecological Risk Assessment

**Aquatic Habitat.** There is a small section of the ditch located between samples OW2B-SD01 and OW2B-SD02 and a small area near SD04 where there may be some risk to aquatic

invertebrates. If a removal action for sediments was conducted, there is a high probability of the ditch being recontaminated from the storm water draining from non-point sources (parking lots, roads, and other impervious surfaces). In addition, removing sediments may do more harm to ecological receptors and the surrounding habitat than will be gained from the removal, particularly when storm water runoff from the surrounding area will likely recontaminate the ditch following any removal action.

**Terrestrial Habitat.** A total of seventeen soil samples have been collected at SWMU 2B (Figure 1-3) and analyzed for metals. These data were screened against ecological screening values. Tables 1-1 and 1-2 present these results.

Aluminum, iron, and vanadium were detected and exceeded ecological screening values in all seventeen samples. However, the maximum concentrations were below maximum background levels.

Chromium was detected and exceeded the screening value in all seventeen samples (Figure 1-4). The maximum chromium concentration exceeded the maximum background concentration. Two samples and a duplicate of a third sample exceeded maximum background values for chromium. The first sample (SS02) was collected in 1999 and has a concentration of 782 mg/kg. Since that time, five samples were collected within ten feet of sample SS02. All five samples are below background levels and have concentrations ranging from 11 to 12 mg/kg. The second sample (duplicate of SS12) has a concentration of 24.8 mg/kg, which is above the maximum background concentration. However, the original sample (SS12) has a concentration of 12.7 mg/kg, which is below the maximum background concentration. Samples to the northeast and southwest of this sample (within about 55 feet) both have concentrations that fall below background concentrations. The third sample (SS15) has a concentration of 33.7 mg/kg which is greater than the maximum background concentration. However, this sample is adjacent to three samples (within ten feet) which all fall below the maximum background concentration. Their concentrations range from 11.0 to 13.9 mg/kg. A fourth sample which is approximately 35 feet northeast of SS15 has a concentration of 9.5 mg/kg, which is also below background.

Zinc was detected in sixteen samples and exceeded ecological screening values in six samples. However, maximum zinc concentrations were below maximum background levels. Three samples contained elevated levels of zinc ranging from 406 to 747 mg/kg. All three samples were collected within one to one and a half feet from a chain-linked fence. The two next closest samples to the fence (SS07 and SS15) were 20 feet and eleven feet from the fence, respectively. The samples had levels of 232 and 23.7 mg/kg, both of which were significantly lower and below ecological screening values (Figure 1-5). This evidence shows that zinc is not a site-related activity contaminant; rather, it is associated with the fence.

Antimony was detected in one sample (OW2B-SS02) and exceeded the ecological screening value for this one sample with an HQ of 2.0.

Cyanide and thallium were not detected in any samples, however, the maximum reporting limits exceeded the ecological screening values with HQs of 10.0 and 2.3, respectively.

Mercury was detected in six samples. It exceeded the ecological screening value in an isolated area [one sample (OW2B-SS02)] with an HQ of 6.10, and does not require further analysis.

Lead was detected in all seventeen samples. It exceeded the ecological screening value in three samples. The maximum lead sample exceeded the maximum background sample. However, samples surrounding these samples, all fell below screening criteria. For example, lead was detected in 1999 at sample SS02 at a concentration of 2760 mg/kg. In 2001, five samples were taken within ten feet of sample SS02. All five samples had lead concentrations falling below the ecological screening value. Sample SS14 has a lead concentration of 60 mg/kg. Sample SS03, which is approximately 80 feet south of SS14, has a lead concentration of 28.2 mg/kg, which is below the screening value. Sample SS12, which is approximately 55 feet northeast of SS14, has a concentration of 23.3 mg/kg, which is below the screening value. Finally, SS15 had a lead concentration of 157 mg/kg. However, the four samples (three of which are within ten feet and one is within about 35 feet) surrounding this sample all have lead concentrations below screening values. This evidence shows that although there are three samples with lead concentrations above screening values, these samples are isolated cases and there is no migration from these areas.

The lines of evidence listed above show that although there are some small areas which have exceedances, these areas are isolated and are not migrating to other areas. Therefore, no further action is recommended at SWMU 2B on the basis of ecological considerations.

## 1.4.2 SWMU 2C – Line Shack 400 Disposal Area

The location and history, previous investigations, extent of contamination, and results of RAs at SWMU 2C follow.

### 1.4.2.1 Location and History

SWMU 2C is encompassed by Line Shack 400 and Buildings 301, 401, and 404 (Figure 1-2) This general area, which is part of FITWING, has been and continues to be used for aircraft maintenance and cleaning. In earlier years, Navy personnel disposed of various maintenance and cleaning chemicals similar to those discharged at SWMU 2B. These chemicals potentially include waste oil, hydraulic fluid, PD680, paint stripper, thinner, Turco, naphtha, and B&D 3400 Engine Cleaner. Waste disposal occurred near Line Shack 400 starting in 1963, the year the line shack was constructed, until the early 1980s, when a hazardous waste recovery program was instituted. The area around the line shack originally was not paved but it was capped with 15 inches of concrete in the early 1980s . A disposal area southeast of Building 400 was reported to be visible in 1971 air photographs reviewed during the IAS. It is not known if the soil was removed and if so, where it was taken for disposal (RGH, 1984).

The small ditch conveys stormwater from the culvert at B to a larger ditch along B Avenue and 4th Street. The rest of the B Avenue ditch appears to receive flow intermittently. The ditch at 4th Street receives additional flow from the area near Buildings 500 and 402. Wet areas are limited to ditch bottoms where water accumulates. These small areas are usually mowed (CH2M HILL, 1993).

#### 1.4.2.2 Previous Investigations

Earlier investigations at SWMU 2C include: the Line Shack Inspection Study in 1988 (CH2M HILL, 1989) and the Interim RFI in 1990 (CH2M HILL, 1991). These studies showed that the groundwater is contaminated with several volatile organic compounds over a broad area.

In 1993, CH2M HILL conducted a Phase I RFI to delineate the areal and vertical extent of the groundwater contaminant plume and to identify probable contaminant source areas in soil. Results are documented in the *RCRA Facility Investigation Final Report—Phase I, Naval Air Station Oceana, Virginia Beach, Virginia*, December 1993.

Subsequently, CH2M HILL conducted a CMS in 1995 to further delineate the areal extent of the groundwater contaminant plume and further identify probable contaminant source areas in soil to support a remediation strategy. Results are documented in the *Final Corrective Measures Study for SWMUs 1, 2B, and 2C, Oceana Naval Air Station, Virginia Beach, Virginia*, November 1995.

Follow-on sediment sampling was conducted by CH2M HILL as part of the Phase III RFI. Phase III RFI Results are documented in the *Final RCRA Facility Investigation Report—Phase III, Naval Air Station Oceana, Virginia Beach, Virginia*, August 1999.

Additional sampling at SWMU 2C was performed during the SWMU 2C Groundwater Investigation (CH2M HILL, 2001). The focus of this investigation was to identify the nature and extent of the chlorinated organic compound contamination in the groundwater and to determine if natural attenuation of the chlorinated compounds was occurring.

Results are summarized in the following section.

#### 1.4.2.3 Contamination and Extent

In general, the Columbia Aquifer at SWMU 2C is composed of the fine to medium grained sand at depths from approximately 6 to 20 feet below ground surface. The aquifer is semi-confined between clay rich silt in the uppermost 6 feet and at depths below approximately 20 feet. The lower confining unit is known to extent to depths of approximately 60 feet and separates the Columbia Aquifer from the underlying Yorktown Aquifer. A south-south-westerly directed groundwater flow direction is occurring across the SWMU.

The groundwater velocity at the SWMU is consistent with velocities calculated at other SWMUs at NAS Oceana. The most recent study, at SWMU 15, indicated a groundwater velocity range of 3 to 24 feet per year in the Columbia Aquifer depending on depth and lithology. The average groundwater velocity for the sand unit comprising the Columbia Aquifer at SWMU 15 was determined to be approximately 10 feet per year. SWMU 2C is about 5,000 feet hydraulically downgradient of SWMU 15.

Investigation results indicated that VC and 1,2-DCE are the primary chlorinated VOC groundwater contaminants at SWMU 2C. The contaminant plume extends from the flight line area to the south-southeast, across London Bridge Road. During the Phase I RFI, a low concentration of 1,2-DCE was detected in a well screened in the deep aquifer. The same well was sampled during the follow-on CMS and 1,2-DCE was not detected.

A suspected contaminant source area near Building 400 was not precisely located despite the numerous soil samples collected in this area. A suspected contaminant source area near the southeastern corner of Building 301 was verified through soil sampling and the detection of chlorinated VOCs. Sediment samples collected during the Phase III RFI indicated that the sediments are contaminated with PAHs at levels that exceed ecological screening levels.

In July 1999, the Navy completed one round of groundwater sampling from 19 monitoring wells to support a human health risk assessment (HHRA) and to identify the current location of contaminant plumes at SWMU 2C. These wells were sampled again in February 2000.

This investigation identified two areas with significant concentrations of TCE, 1,2-DCE, and VC in groundwater. In addition, a third area with significant VC contamination was identified. The investigation also found that the concentration of the parent contaminant (TCE) was decreasing, while the concentrations of the daughter contaminants were increasing (1,2-DCE and VC). An increase in the ethene and chloride concentrations in groundwater further supports the occurrence of natural attenuation at this SWMU.

#### 1.4.2.4 Human Health Risk Assessment

The HHRA performed for SWMU 2C characterizes potential current and future risks to human health at the site using the general methodology described in the *Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual, Part A* (USEPA, 1989) and RAGS, *Volume 1, Human Health Evaluation Manual, Part D* (USEPA, 1998).

Potential risks were calculated for a future adult resident, future child resident, future lifetime resident, future construction worker, future industrial worker, future adult trespasser/visitor, and future adolescent trespasser/visitor. Potential risks were calculated for exposure to combined surface and subsurface soil and Columbia Aquifer groundwater. Although the Columbia Aquifer groundwater is not currently used as a potable water supply and will most likely never be used as a potable water supply, potential future exposure to this groundwater was evaluated under future residential and construction worker exposure scenarios. Risks were not calculated for exposure to surface soil because there were no COPCs retained for this medium.

The only potential scenario resulting in hazards or risks above USEPA's target levels is future residential use of the site. Future residential use of the site may result in an unacceptable HI to an adult and child resident exposed to groundwater. It should be noted that the future use of the site for residential purposes is highly unlikely.

#### 1.4.2.5 Ecological Risk Assessment

Complete exposure pathways to ecological receptors do not currently exist at SWMU 2C and are not likely to exist in the foreseeable future. Soils at SWMU 2C have either been removed or covered with asphalt or concrete. Contaminated sediments at SWMU 2C have been or are being removed.

Contaminated groundwater at SWMU 2C does not currently discharge to surface water bodies. The concentration of SWMU contaminants is expected to be attenuated through dilution, adsorption, dispersion, and biodegradation so that the risk to surface water bodies is expected to be minimal by the time that the groundwater reaches the closest surface water body, based upon travel times of 20 to 92 years.

A no further action determination for ecological concerns is appropriate if no complete pathways to ecological receptors exist. This is true even if the Navy anticipates additional investigations and potential remedial actions at sites that exceed human health regulatory limits and criteria due to its designation as a potential drinking water source.

The evidence indicated that complete exposure pathways do not likely exist at SWMU 2C. It follows that since it is unlikely that there are complete ecological exposure pathways, it is also unlikely that there is ecological risk present at the SWMU. Thus, no further action was recommended at SWMU 2C based on ecological considerations.

## 1.4.3 SWMU 2E – Line Shack 109 Disposal Area

The location and history, previous investigations, extent of contamination, and results of RAs at SWMU 2E follow.

### 1.4.3.1 Location and History

SWMU 2E includes Line Shack 109, Building 110, and the surrounding storage yard (Figure 1-2). Line Shack 109 and the adjacent areas have been used for cleaning and maintaining aircraft, and storing equipment and materials since 1963.

The IAS identified this location as an area where waste chemicals used for aircraft cleaning and maintenance were discarded on the ground (RGH, 1994). After additional review during the RFA in 1988, portions of this area were designated as SWMU 51 and SWMU 1. Due to the proximity, the SWMUs were investigated together during the Interim RFI in 1990, and eventually merged to become SWMU 2E during the RFI. During the Interim RFI, low concentrations of VOCs were detected in the groundwater at SWMU 2E, but when floating free-phase hydrocarbons were discovered in 2E-MW1 in January 1993, interim remedial measures were initiated.

The Public Works Department at NAS Oceana implemented interim remedial measures by beginning a monthly program to remove free-phase hydrocarbons from select monitoring wells. The recovery program is currently ongoing. The recovery program included digging several test pits at the site to evaluate the presence of free-phase hydrocarbons in the subsurface.

The SWMU includes a parking lot west and south of Line Shack 109 and an area of lawn between First Street and the line shacks. About half of the SWMU is in the flight line. The developed areas are either covered by asphalt or have been planted with turf grasses and maintained as lawn. The area off of the flight line is a maintained lawn. The northeastern boundary of the site is traversed by a steam line that runs generally northwest/southeast along First Street. Runoff from the paved surfaces near Building 109 flows onto the lawn and enters a drainage ditch in the southeastern part of the SWMU. The ditch apparently

connects surface flows to another small ditch adjacent to the access road. No wetlands occur in the SWMU 2E study area. Turf grasses, a few cultivated Bradford pear trees, and three sweetgum trees are the only vegetation at this site.

#### 1.4.3.2 Previous Investigations

Earlier investigations at SWMU 2E include: the Interim RFI in 1990 (CH2M HILL, 1991). The groundwater sampling results from the Interim RFI in 1990 indicated that the parameters analyzed either were detected at low levels or were not detected. However, in January 1993 during the RFI field investigation, a free-phase petroleum product that has been identified as diesel was discovered one monitoring well at this SWMU. This discovery led to additional site characterization activities.

The primary focus of subsequent SWMU 2E investigations was to characterize the extent of free-phase hydrocarbon contamination and to continue characterization of the dissolved-phase groundwater contamination.

SWMU 2E was investigated during two phases of the RFI. Phase I was completed in 1993 and Phase II was completed in 1995. The purpose of the RFIs was to delineate the source area and the extent of subsurface free-phase diesel fuel and to determine the nature and extent of the dissolved-phase groundwater contaminant plume. Results of the RFIs are documented in the *RCRA Facility Investigation Final Report—Phase I, Naval Air Station Oceana, Virginia Beach, Virginia*, December 1993 and the *RCRA Facility Investigation Report—Phase II, Naval Air Station Oceana, Virginia Beach, Virginia*, February 1995.

In 1995, CH2M HILL conducted a CMS to further delineate the areal and vertical extent of the dissolved-phase groundwater contaminant plume. Results are documented in the *Final Corrective Measures Study for SWMUs 2E, 15, and 24, Oceana Naval Air Station, Virginia Beach, Virginia*, March 1996.

In 2000, CH2M HILL conducted groundwater sampling to assess site-wide groundwater quality and support an HHRA. Results are documented in the *Draft Technical Memorandum for the Groundwater Sampling at SWMUs 2B and 2E, Naval Air Station Oceana, Virginia, Beach, Virginia*, January 2001.

Results from these investigations are presented in the next section.

#### 1.4.3.3 Contamination and Extent

The cross-section depicts the top of the Yorktown aquifer at approximately 25 to 30 feet below the ground surface. This is the depth at which shell fragments, which are characteristic of the Yorktown Formation, were encountered. Groundwater flows in an area from south-southwest to south-southeast. If porosity is assumed to be 25 percent, hydraulic conductivity is assumed to be $1.8 \times 10^{-2}$ cm/sec, and the prevailing gradient is 0.0005 ft/ft, the average velocity of groundwater flow in the surficial aquifer is approximately 40 ft/year.

Results of the investigations indicated that soil around the source area (Building 109) is contaminated with petroleum products as evidenced by elevated concentrations of total petroleum hydrocarbons (TPHs) and PAHs. Several BTEX (benzene, toluene, ethylbenzene,

and xylene) and TPH compounds were detected in surface and subsurface soil samples. Groundwater contamination at SWMU 2E consists of free-phase diesel fuel floating on the water table and dissolved-phase product in the shallow aquifer. Free-phase diesel fuel is found in wells near Building 109 at a thickness in the aquifer of less than 0.25 inch. The dissolved-phase contamination consists of volatile and semivolatile petroleum compounds and chlorinated VOCs. The petroleum contamination is primarily BTEX and diesel-related compounds and the chlorinated VOC contamination is composed primarily of VC and 1,2-DCE.

During March 2000, groundwater samples were collected from 13 shallow monitoring wells at SWMU 2E. Several VOCs, specifically benzene (bis(2-ethylhexyl)phthalate, and VC, were detected in the groundwater beneath SWMU 2B at concentrations that exceed the USEPA MCLs. Arsenic was also detected at concentrations that exceed its USEPA MCL.

#### 1.4.3.4 Human Health Risk Assessment

The HHRA performed for SWMU 2E characterizes potential current and future risks to human health at the site using the general methodology described in the *Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual, Part A* (USEPA, 1989) and RAGS, *Volume 1, Human Health Evaluation Manual, Part D* (USEPA, 1998).

Potential risks were calculated for a current industrial worker, a future adult resident, a future child resident, a future lifetime resident, a future construction worker, a future industrial worker, a future adult trespasser/visitor, and a future adolescent trespasser/visitor. Potential risks were calculated for exposure to surface soil, combined surface and subsurface soil, and groundwater. Although the Columbia Aquifer groundwater is not currently used as a potable water supply and will most likely never be used as a potable water supply, potential future exposure to groundwater was evaluated under future residential and construction worker exposure scenarios.

The only potential scenarios resulting in hazards or risks above USEPA's target levels is future residential use of the site (soil) and construction worker and residential scenarios (groundwater).

#### 1.4.3.5 Ecological Risk Assessment

Complete exposure pathways to ecological receptors do not currently exist at SWMU 2E and are not likely to exist in the foreseeable future. Soils at SWMU 2E have either been removed or covered with asphalt or concrete.

Contaminated groundwater at SWMU 2E does not currently discharge to surface water bodies. The concentration of SWMU contaminants is expected to be attenuated through dilution, adsorption, dispersion, and biodegradation so that the risk to surface water bodies is expected to be minimal by the time that the groundwater reaches the closest surface water body, based upon travel times of 20 to 92 years.

A no further action determination for ecological concerns is appropriate if no complete pathways to ecological receptors exist. This is true even if the Navy anticipates additional

investigations and potential remedial actions at sites that exceed human health regulatory limits and criteria due to its designation as a potential drinking water source.

In conclusion, the evidence indicated that complete exposure pathways do not likely exist at SWMU 2E. It follows that since it is unlikely that there are complete ecological exposure pathways, it is also unlikely that there is ecological risk present at the sites. Thus, no further action was recommended at SWMU 2E based on ecological considerations.

**Table 1-1**
**Screening Statistics - Step 2 Table - Surface Soil**
***NAS Oceana, Virginia Beach, VA***

| Chemical | Reporting Limit Range | Frequency of Detection | Maximum Concentration Detected | Sample ID of Maximum Concentration | Screening Value | Frequency of Exceedance | Maximum Hazard Quotient[1] | COPC? |
|---|---|---|---|---|---|---|---|---|
| **Inorganics (MG/KG)** | | | | | | | | |
| Aluminum | 5.60 - 45.8 | 17 / 17 | 11,300 | OW2B-SS17-00 | 50.0 | 17 / 17 | 226 | **YES** |
| Antimony | 12.0 - 13.7 | 1 / 3 | 10.0 | OW2B-SS02-00 | 5.00 | 1 / 3 | 2.00 | **YES** |
| Arsenic | 0.76 - 2.30 | 17 / 17 | 2.60 | OW2B-SS01-00 | 60.0 | 0 / 17 | 0.043 | NO |
| Barium | 0.016 - 45.8 | 17 / 17 | 49.9 | OW2B-SS16-00 | 500 | 0 / 17 | 0.100 | NO |
| Beryllium | 0.051 - 1.10 | 13 / 17 | 0.47 | OW2B-SS16-00 | 10.0 | 0 / 17 | 0.047 | NO |
| Cadmium | 0.067 - 1.10 | 16 / 17 | 1.20 | OW2B-SS02-00 | 4.00 | 0 / 17 | 0.30 | NO |
| Calcium [2] | 2.50 - 1,145 | 17 / 17 | 5,330 | OW2B-SS08-00 | NSV | -- / -- | NSV | NO |
| Chromium | 0.11 - 2.30 | 17 / 17 | 782 | OW2B-SS02-00 | 0.40 | 17 / 17 | 1,955 | **YES** |
| Cobalt | 0.16 - 11.4 | 7 / 17 | 2.50 | OW2B-SS14-00 | 100 | 0 / 17 | 0.025 | NO |
| Copper | 0.15 - 5.70 | 17 / 17 | 16.5 | OW2B-SS14-00 | 50.0 | 0 / 17 | 0.33 | NO |
| Cyanide | 0.60 - 0.60 | 0 / 3 | -- | -- | 0.060 | -- / -- | 10.0 | **YES** |
| Iron | 3.60 - 22.9 | 17 / 17 | 5,860 | OW2B-SS14-00 | 200 | 17 / 17 | 29.3 | **YES** |
| Lead | 0.35 - 6.00 | 17 / 17 | 2,760 | OW2B-SS02-00 | 50.0 | 3 / 17 | 55.2 | **YES** |
| Magnesium [2] | 1.40 - 1,145 | 17 / 17 | 1,200 | OW2B-SS08-00 | 4,400 | 0 / 17 | 0.27 | NO |
| Manganese | 0.023 - 3.40 | 17 / 17 | 115 | OW2B-SS14-00 | 330 | 0 / 17 | 0.35 | NO |
| Mercury | 0.0065 - 0.10 | 6 / 17 | 0.61 | OW2B-SS02-00 | 0.10 | 1 / 17 | 6.10 | **YES** |
| Nickel | 0.32 - 9.20 | 17 / 17 | 8.10 | OW2B-SS01-00 | 30.0 | 0 / 17 | 0.27 | NO |
| Potassium [2] | 1.20 - 1,145 | 17 / 17 | 689 | OW2B-SS16-00 | NSV | -- / -- | NSV | NO |
| Selenium | 0.67 - 1.10 | 0 / 17 | -- | -- | 1.80 | -- / -- | 0.61 | NO |
| Silver | 0.15 - 2.30 | 2 / 17 | 1.00 | OW2B-SS01-00 | 2.00 | 0 / 17 | 0.50 | NO |
| Sodium [2] | 19.0 - 1,145 | 4 / 17 | 129 | OW2B-SS14-00 | NSV | -- / -- | NSV | NO |
| Thallium | 0.68 - 2.30 | 0 / 17 | -- | -- | 1.00 | -- / -- | 2.30 | **YES** |
| Vanadium | 0.085 - 11.4 | 17 / 17 | 18.6 | OW2B-SS14-00 | 2.00 | 17 / 17 | 9.30 | **YES** |
| Zinc | 0.11 - 4.60 | 16 / 17 | 747 | OW2B-SS17-00 | 50.0 | 6 / 17 | 14.9 | **YES** |

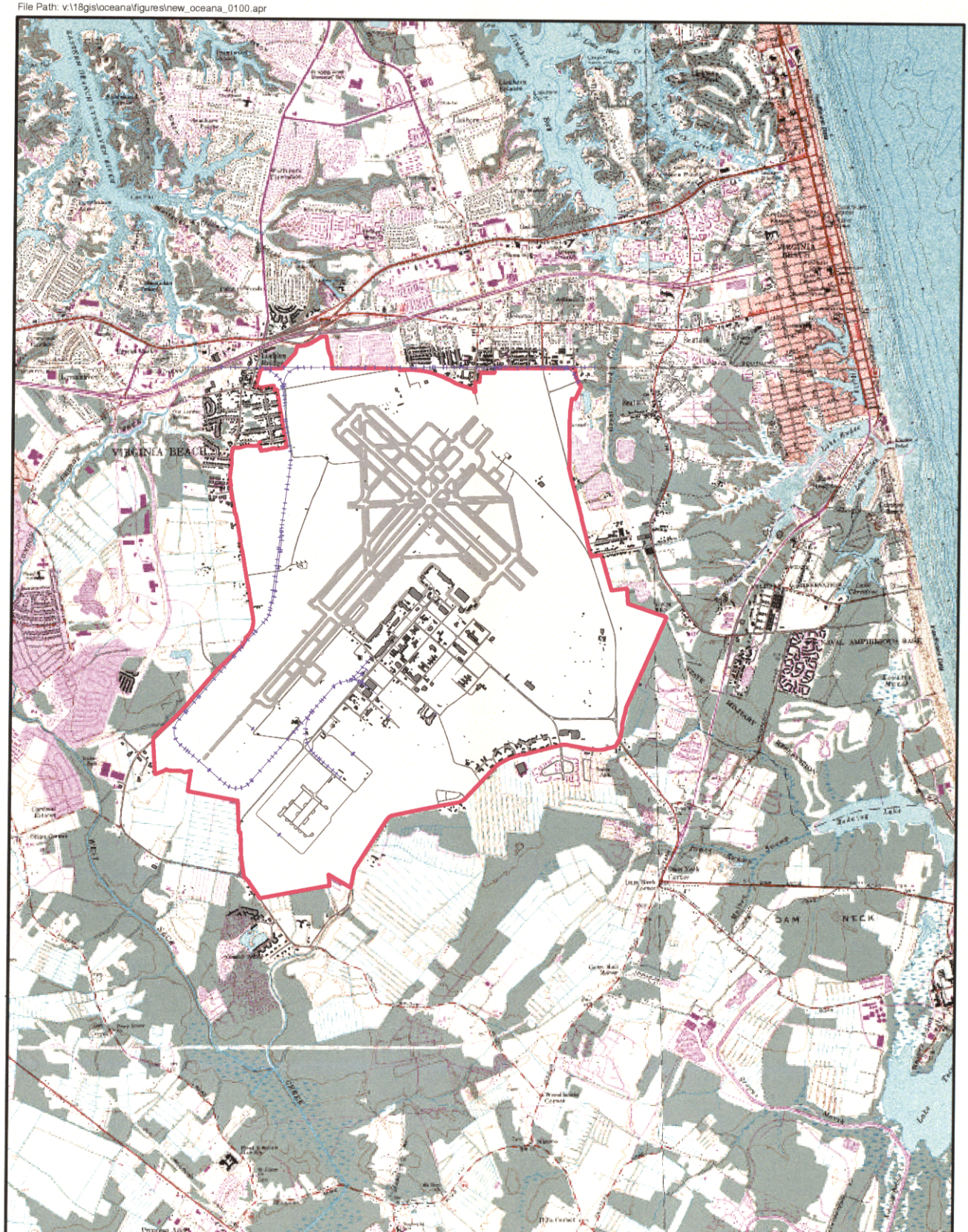
NSV - No Screening Value
1 - Shaded cells indicate hazard quotient based on reporting limits
2 - Macronutrient - Not considered to be a COPC

**Table 1-2**
**Screening Statistics - Step 3 Table - Surface Soil**
***NAS Oceana, Virginia Beach, VA***

| Chemical | Reporting Limit Range | Frequency of Detection | Maximum Concentration Detected | Sample ID of Maximum Concentration | Arithmetic Mean | Screening Value | Frequency of Exceedance | Mean Hazard Quotient[1] | COPC? |
|---|---|---|---|---|---|---|---|---|---|
| **Inorganics (MG/KG)** | | | | | | | | | |
| Aluminum | 5.60 - 45.8 | 17 / 17 | 11,300 | OW2B-SS17-00 | 9,978 | 50.0 | 17 / 17 | 200 | **YES** |
| Antimony | 12.0 - 13.7 | 1 / 3 | 10.0 | OW2B-SS02-00 | 3.49 | 5.00 | 1 / 3 | 0.70 | NO |
| Chromium | 0.11 - 2.30 | 17 / 17 | 782 | OW2B-SS02-00 | 60.0 | 0.40 | 17 / 17 | 150 | **YES** |
| Cyanide | 0.60 - 0.60 | 0 / 3 | -- | -- | 0.013 | 0.060 | -- / -- | 0.22 | NO |
| Iron | 3.60 - 22.9 | 17 / 17 | 5,860 | OW2B-SS14-00 | 4,078 | 200 | 17 / 17 | 20.4 | **YES** |
| Lead | 0.35 - 6.00 | 17 / 17 | 2,760 | OW2B-SS02-00 | 192 | 50.0 | 3 / 17 | 3.84 | **YES** |
| Mercury | 0.0065 - 0.10 | 6 / 17 | 0.61 | OW2B-SS02-00 | 0.064 | 0.10 | 1 / 17 | 0.64 | NO |
| Thallium | 0.68 - 2.30 | 0 / 17 | -- | -- | 0.39 | 1.00 | -- / -- | 0.39 | NO |
| Vanadium | 0.085 - 11.4 | 17 / 17 | 18.6 | OW2B-SS14-00 | 13.7 | 2.00 | 17 / 17 | 6.83 | **YES** |
| Zinc | 0.11 - 4.60 | 16 / 17 | 747 | OW2B-SS17-00 | 127 | 50.0 | 6 / 17 | 2.53 | **YES** |

NSV - No Screening Value
1 - Shaded cells indicate hazard quotient based on reporting limits

File Path: v:\18gis\oceana\figures\new_oceana_0100.apr




N
W E
S

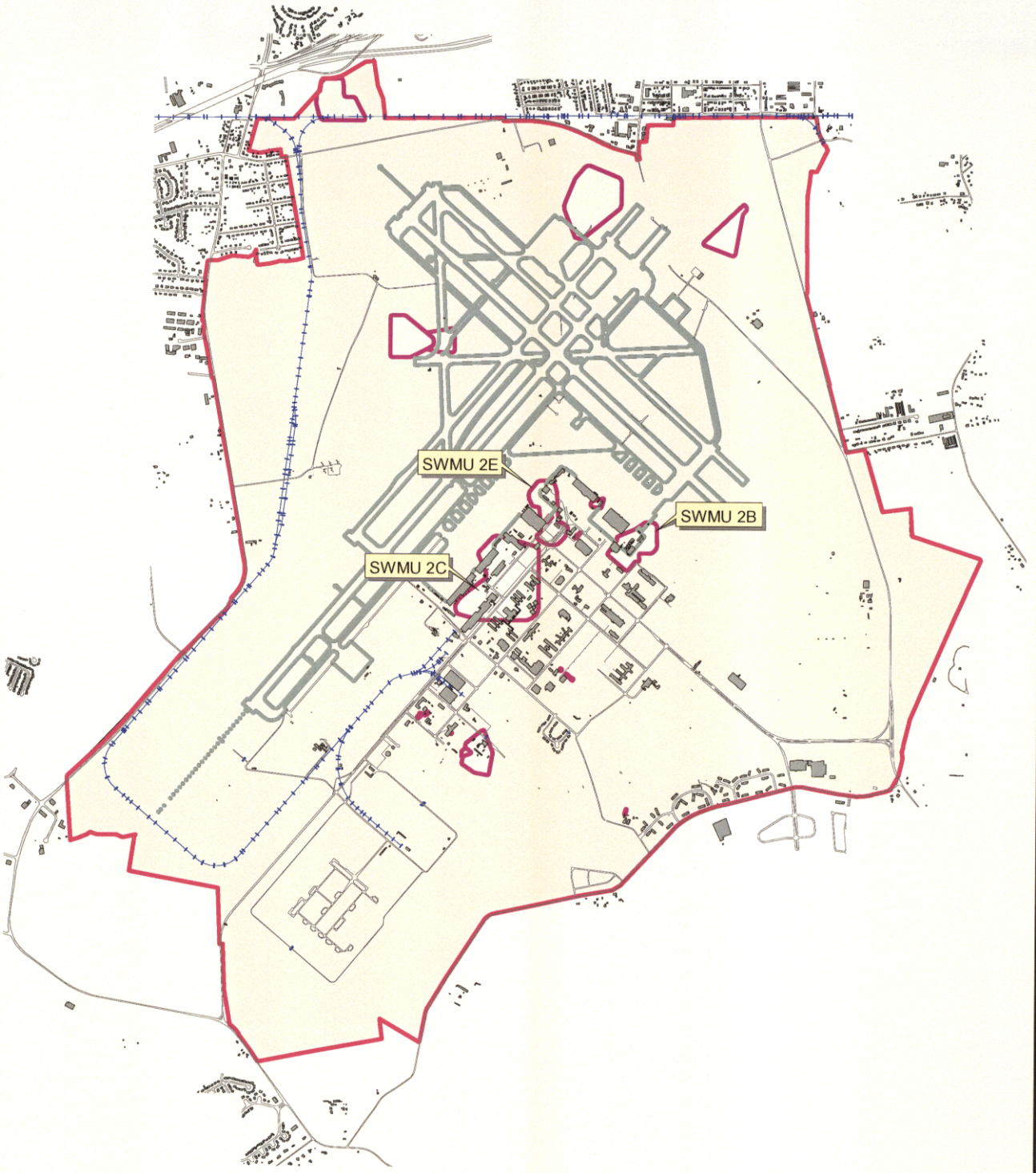
0 0.5 1 1.5 2 Miles

Figure 1-1
Base Location Map
NAS Oceana, Virginia Beach, Virginia

CH2MHILL

00606 F Biy

File Path: c:\18gis\oceana\figures\oceana_0500.apr



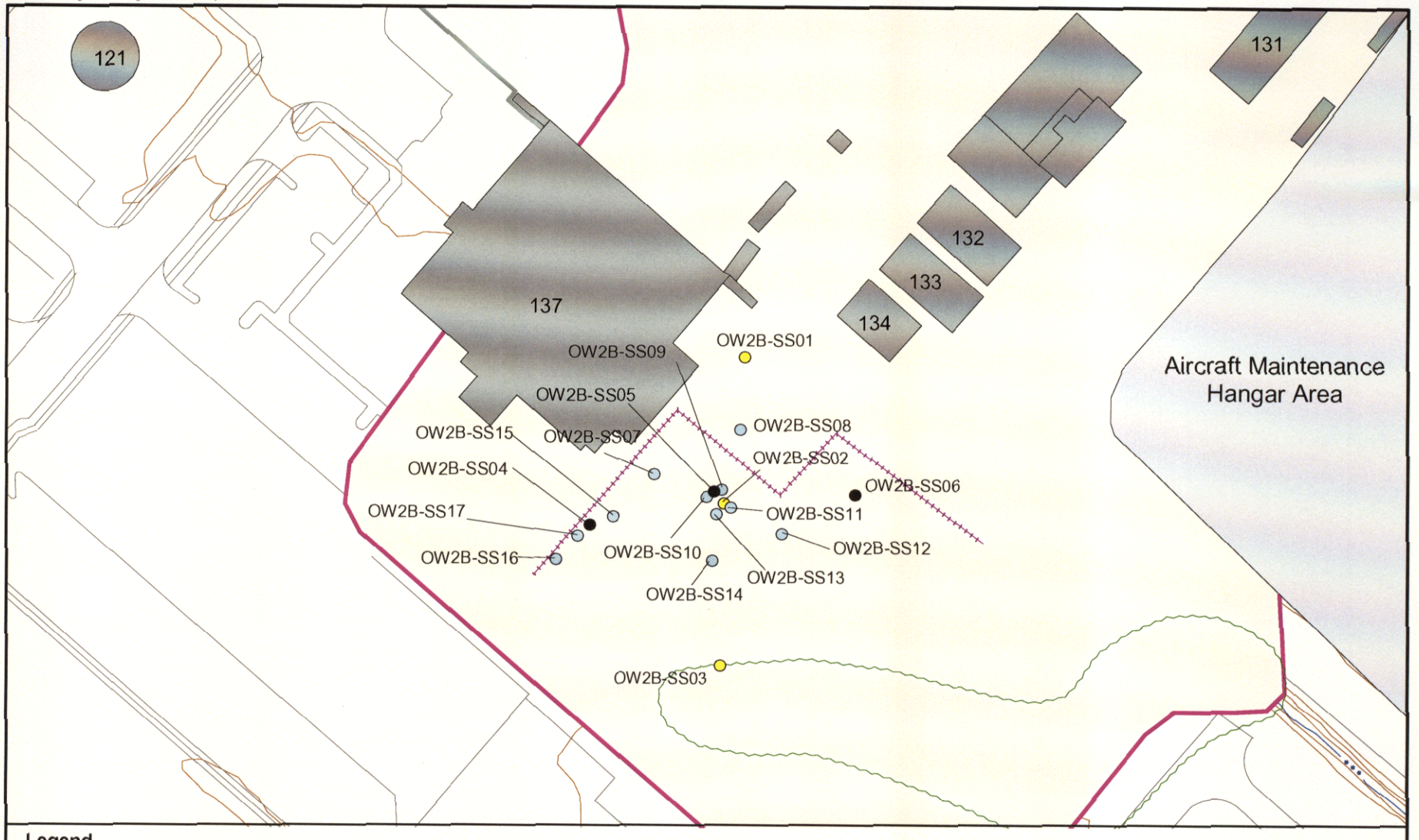

N
W E
S

0 2000 4000 6000 Feet

Figure 1-2
SWMU Location Map
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

File Path: v:\18gis\oceana\figures\swmu 2b.apr




**Legend**

- Surface Soil Sample Locations (December, 1999)
- Surface Soil Sample Locations (May, 2001)
- Surface Soil Sample Locations (August, 2001)
- SWMU Boundary
- Future Covered Area
- Fence Line
- Tree Line
- Contours
- Stormwater Drains

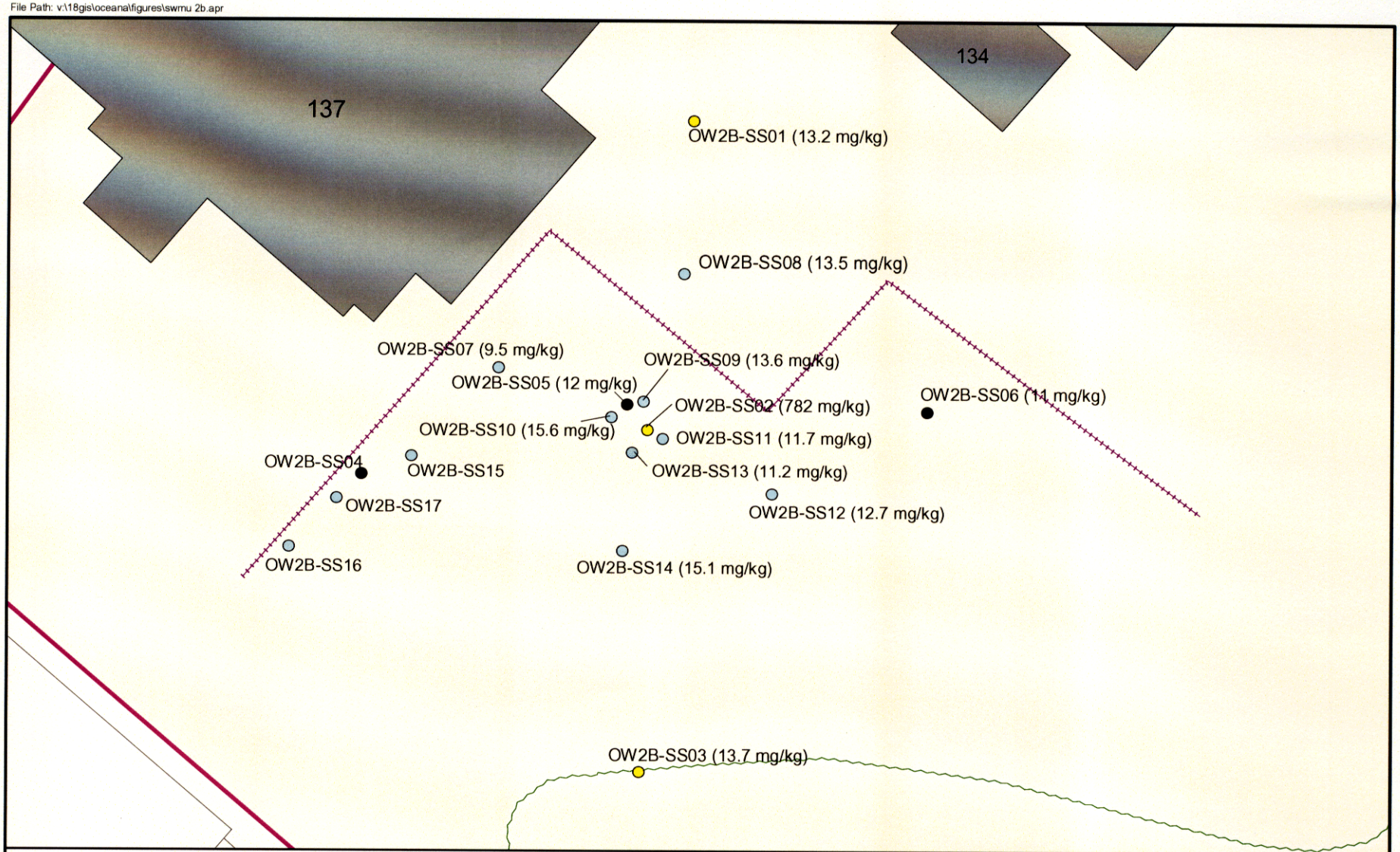
N

0 60 120 Feet

Figure 1-3
SWMU 2B Sample Locations
(December 1999, May 2001 and August 2001)
NAS Oceana
Virginia Beach, Virginia

CH2MHILL

File Path: v:\18gis\oceana\figures\swmu 2b.apr




**Legend**

- Surface Soil Sample Locations (December, 1999)
- Surface Soil Sample Locations (May, 2001)
- Surface Soil Sample Locations (August, 2001)
- SWMU Boundary
- Future Covered Area
- Fence Line
- Tree Line
- Contours
- Stormwater Drains

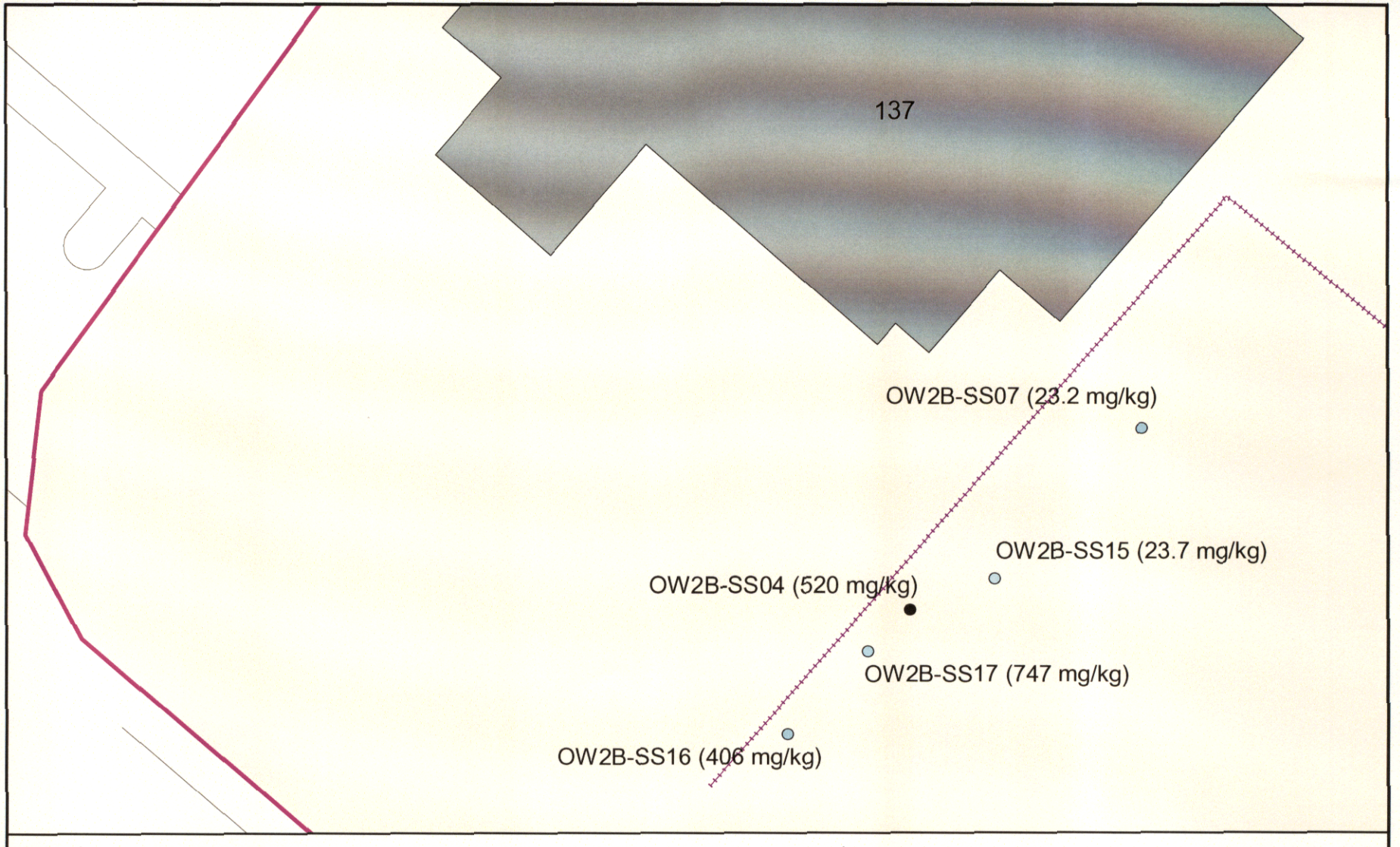
N

0 30 60 Feet

Figure 1-4
Chromium Concentrations in Soil
SWMU 2B, NAS Oceana
Virginia Beach, Virginia

CH2MHILL

File Path: v:\18gis\oceana\figures\swmu 2b.apr




**Legend**

- Surface Soil Sample Locations (May, 2001)
- Surface Soil Sample Locations (August, 2001)
- SWMU Boundary
- Future Covered Area
- Fence Line
- Tree Line
- Contours
- Stormwater Drains

N

0 20 40 Feet

Figure 1-5
Zinc Concentrations in Soil
SWMU 2B, NAS Oceana
Virginia Beach, Virginia

CH2MHILL

SECTION 2

# Remedial Action Objectives and ARARs

This section presents general and site-specific remedial action objectives (RAOs) and identifies corresponding applicable or relevant and appropriate requirements (ARARs) for SWMUs 2B, 2C and 2E. General RAOs are defined by the NCP and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (as amended by the Superfund Amendments and Reauthorization Act [SARA]), which are applicable to all Superfund sites. CERCLA defines the statutory requirements for developing remedies.

Site-specific RAOs relate to specific contaminated media and to potential exposure routes. Site-specific RAOs, which require an understanding of the contaminants and the physical properties in their respective media, are based on an evaluation of the risks to public health and to the environment and the ARARs.

## 2.1 NCP and CERCLA Objectives

The NCP requires that the selected remedy meet the following objectives:

- Each remedial action selected shall be protective of human health and the environment [40 CFR 300.430 (f)(ii)(A)].
- Onsite remedial actions that are selected must attain those applicable or relevant and appropriate requirements (ARARs) that are identified at the time of the record of decision signature [40 CFR 300.430(f)(ii)(B)].
- Each remedial action selected shall be cost effective. A remedy shall be cost effective if its costs are proportional to its overall effectiveness [40 CFR 300.430 (f)(ii)(D)].
- Each remedial action shall use permanent solutions and alternative treatment technologies or resource-recovery technologies to the maximum extent practicable [40 CFR 300.430 (f)(ii)(E)].

The statutory scope of CERCLA was amended by the Superfund Amendments and Reauthorization Act (SARA) to include the following general objectives for remedial action at all CERCLA sites:

- Remedial actions "shall attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and of control of further releases at a minimum which assures protection of human health and the environment" (Section 121(d)).
- Remedial actions "in which treatment that permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants is a principal element" (Section 121(b)) are preferred. If the treatment or recovery technologies selected are not a permanent solution, an explanation must be published.

- The least-favored remedial actions are those that include "offsite transport and disposal of hazardous substances or contaminated materials without treatment where practicable treatment technologies are available" (Section 121(b)).

The selected remedy must comply with or attain the level of any "standard, requirement, criteria, or limitation under any federal environmental law, or any promulgated standard, requirement, criteria, or limitation under a State environmental or facility siting law that is more stringent than any Federal standard, requirement, criteria, or limitation" (Section 121(d)(2)(A)).

## 2.2 Development of Site Specific Remedial Action Objectives (SWMUs 2B, 2C and 2E)

Both the level of contamination and the potential exposure routes are considered when developing site-specific RAOs for protecting public health and the environment. The future protection of environmental resources and the means of minimizing long-term disruption to existing facility operations are also considered.

### 2.2.1 Site-Specific Remedial Action Objectives

Site-specific RAOs for SWMUs 2B, 2C, and 2E are documented below.

#### 2.2.1.1 SWMU 2B Groundwater

The HHRA, summarized in Section 1.4.1.5, identified potential risks from the future residential use of groundwater at the SWMU. If the site were to be developed by construction workers, the workers would be subject to unacceptable risks from contact with shallow groundwater during construction. Groundwater from the water-table (Columbia) aquifer and the deeper Yorktown aquifer is not currently a source of drinking water. The impact of any leaching of contaminants from the SWMU would be greatest in the shallow water-table aquifer. Due to the presence of a clay confining unit between the shallow and deeper aquifers, it is not likely that any contamination that may have leached from the SWMU has reached the Yorktown aquifer.

Institutional controls will be employed to prevent any use of the water-table aquifer as a potable water source and to protect workers against contact with the shallow groundwater during construction.

The draft final ERA performed for SWMU 2B concluded that there is little potential for significant ecological risks based on future use of the site. It is anticipated that a final ERA, incorporating regulator comments, will be completed before this FS is finalized. In the event that the conclusion of the ERA is changed (to state that there is potential for significant risk) based upon regulator comments, the recommendation of a remedial alternative as presented in this draft report would need to be revised to account for ecological-risk-based remedial action objectives.

The site-specific RAO for SWMU 2B groundwater is as follows:

- Prevent exposure to unacceptable risks to potential human receptors of groundwater

#### 2.2.1.2 SWMU 2C Groundwater

The HHRA, summarized in Section 1.4.2.4, concluded that the groundwater at SWMU 2C poses unacceptable risk to potential future residents. Groundwater from the water-table (Columbia) aquifer and the deeper Yorktown aquifer is not currently a source of drinking water. The impact of any leaching of contaminants from the SWMU would be greatest in the shallow water-table aquifer. Due to the presence of a clay confining unit between the shallow and deeper aquifers, it is not likely that any contamination that may have leached from the tank farm has reached the Yorktown aquifer.

Institutional controls will be employed to prevent any future use of the water-table aquifer as a potable water source that may cause unacceptable risks, and also non-consumptive contact by construction workers with shallow groundwater.

The final ERA performed for SWMU 2C concluded that no further action is necessary based on ecological risks since it is unlikely that there are complete ecological exposure pathways and also unlikely that there is ecological risk present at the SWMU.

The site-specific RAO for SWMU 2C groundwater is as follows:

- Prevent exposure to unacceptable risks to potential human receptors of groundwater

#### 2.2.1.3 SWMU 2E Groundwater

The HHRA, summarized in Section 1.4.3.4, identified potential risks from the future residential use of groundwater at the SWMU. If the site were to be developed by construction workers, the workers would be subject to unacceptable risks from contact with shallow groundwater during excavation. Institutional controls will be employed to prevent any future use of the water-table aquifer as a potable water source.

Groundwater from the water-table (Columbia) aquifer and the deeper Yorktown aquifer is not currently a source of drinking water. The impact of any leaching of contaminants from the SWMU would be greatest in the shallow water-table aquifer. Due to the presence of a clay confining unit between the shallow and deeper aquifers, it is not likely that any contamination that may have leached from the SWMU has reached the Yorktown aquifer.

Potential risks were also identified from soil (residential scenario), however, none of the constituents detected in SWMU 2E soil exceeded the soil remediation goals (described in Section 2.3.5 of this FS).

The final ERA concluded that complete exposure pathways to ecological receptors do not currently exist at SWMU 2E and are not likely to exist in the future. Therefore no further action was recommended based on ecological risks.

The site-specific RAO for SWMU 2E groundwater is as follows:

- Prevent exposure to unacceptable risks to potential human receptors of groundwater

### 2.2.2 Applicable or Relevant and Appropriate Requirements

As required by Section 121 of CERCLA, remedial actions carried out under Section 104 or secured under Section 106 must attain the levels of standards of control for hazardous substances, pollutants, or contaminants specified by the ARARs of federal and state environmental laws and state facility-siting laws, unless waivers are obtained. According to US EPA guidance, remedial actions also must be based on nonpromulgated "to-be-considered" criteria or guidelines if the ARARs do not address a particular situation.

ARARs are distinguished by the US EPA as either being applicable to a situation or relevant and appropriate to it. These distinctions are critical to understanding the constraints imposed on remedial alternatives by environmental regulations other than CERCLA. The definitions of ARARs below are from the US EPA guidance (EPA 1988a).

"Applicable requirements" are standards and other environmental protection requirements of federal or state law dealing with a hazardous substance, pollutant, or contaminant and its remedial action. For example, the Clean Water Act (CWA) is "applicable" to a response action for discharging treated effluent.

"Relevant and appropriate requirements" are standards and environmental protection criteria of federal or state law that, although not "applicable" to a hazardous substance or remedial action, address situations sufficiently similar to those at the CERCLA site that their use is suitable. For example, although RCRA regulations are not applicable to closing a site containing hazardous waste that was disposed of before 1980, the regulations may be relevant and appropriate.

A requirement may be "relevant" to a particular situation but not "appropriate" because of differences in the duration of the regulated activity or the physical characteristics of the affected media. For example, some of the requirements for designing and operating a waste pile that are found in 40 CFR 264.251, such as using a liner of sufficient strength and thickness to prevent failure caused by pressure gradients, might be considered relevant and appropriate, although the requirement to install a liner to cover all surrounding earth in potential contact with the waste might not be appropriate if the earth already is contaminated, and the eventual remedy is to remove all the contaminated earth.

A requirement that is relevant and appropriate must be met as if it were applicable. Relevant and appropriate requirements that are more stringent than applicable requirements, take precedence. However, more discretion is allowed in determining relevant and appropriate requirements than in determining applicable requirements.

Another factor in determining which response or remedial requirements must be met is whether the requirement is substantive or administrative. Onsite CERCLA response actions must meet substantive requirements but not administrative requirements. Substantive requirements are those dealing directly with actions or with conditions in the environment. Administrative requirements implement the substantive requirements by prescribing procedures such as fees, permitting, and inspection that make substantive requirements effective. This distinction applies to onsite actions only; offsite response actions are subject to all applicable standards and regulations, including administrative requirements such as permits.

### 2.2.3 Other Criteria or Guidelines to be Considered

Many federal and state programs have criteria, advisories, guidelines, and proposed standards that provide recommended procedures if no ARARs exist or if existing ARARs are inadequate. In such situations, the "to-be-considered" criteria or guidelines should be used to set remedial action levels. Examples of criteria to be considered are reference doses (RfDs) and potency factors for ingestion of noncarcinogenic and carcinogenic compounds used in the RA.

### 2.2.4 Determination of ARARs

Federal and state ARARs for SWMUs 2B, 2C and 2E are summarized in Appendix D. The tables summarize the potential ARARs by classification and the "to-be-considered" criteria are included as appropriate for each classification. There are three classifications of ARARs: chemical-specific, location-specific, and action-specific, as further described in this section.

The remedial action alternatives developed in this FS were analyzed for compliance with the potential federal and state ARARs. This analysis involved identifying potential requirements for each of the alternatives, evaluating their applicability or relevance, and determining if the remedial alternatives can achieve the ARARs. Results of that analysis are presented in Section 4.2.

### 2.2.5 Chemical-Specific Requirements

Chemical-specific ARARs will not be utilized for surface soil in this FS because no chemical-specific ARARs have been identified for surface soil. Instead, site-specific risk-based PRGs have been developed where applicable, for evaluation of the remedial alternatives. These PRGs will serve as screening levels for any confirmatory sampling to evaluate the efficacy of the chosen remedial alternative.

Chemical specific ARARs for groundwater such as MCLs, MCLGs, SMCLs, and RBCs have been identified which are relevant and appropriate and to be considered for groundwater at SWMUs 2B, 2C and 2E. In cases where there are no established criteria for constituents of concern, risk-based preliminary remediation goals (PRGs) were established, as discussed further in Section 2.3. Potential chemical-specific requirements for the site are presented in Appendix D and Section 2.3.

### 2.2.6 Location-Specific Requirements

Location-specific requirements are design requirements or activity restrictions that are based on the geographic position of a site. An example is RCRA location requirements that set US EPA policy for carrying out provisions of Executive Order 11988 (Flood Plain Management) and Executive Order 11990 (Protection of Wetlands). Other location-specific requirements pertain to protection of critical wildlife habitats (Endangered Species Act), wilderness areas (Wilderness Act), and wildlife refuges (USC 668). Potential location-specific requirements for the site are presented in Appendix D.

### 2.2.7 Action-Specific Requirements

Action-specific requirements set performance, design, or other standards for particular activities in managing hazardous substances or pollutants. Action-specific requirements for the site are presented in Appendix D.

## 2.3 Development of Preliminary Remediation Goals

Preliminary remediation goals (PRGs) were developed from ARARs and other available information, such as concentrations associated with $10^{-6}$ cancer risk or a hazard quotient (HQ) equal to 1 for noncarcinogens calculated from EPA toxicity information. PRGs were established for each contaminant of concern in surface soil and groundwater. Risk-based PRGs were calculated when chemical-specific ARARs (MCLs) were not available. Risk-based PRGs are "to-be-considered" criteria, not ARARs. No chemical-specific ARARs have been identified for surface soil. The following discusses the methodology to calculate the risk-based PRGs.

Risk-based PRGs were calculated for scenarios (i.e. industrial worker or residential) with carcinogenic risks exceeding $10^{-4}$ or noncarcinogenic hazards exceeding 1. PRGs were calculated for individual constituents with carcinogenic risks exceeding $10^{-6}$ or noncarcinogenic hazards exceeding 0.1 for the scenarios that exceed the above criteria.

Although the three SWMUs are currently used for mainly industrial purposes, and anticipated future use of the SWMUs is for industrial purposes, risk-based PRGs were developed for potential future residential receptors, in addition to industrial/construction worker receptors, when the risks calculated for these scenarios exceeded the above criteria. The exposure parameters identified in the HHRA were used to calculate the risk-based PRGs for the residential, industrial, construction worker receptors.

Appendix E provides the equations and exposure parameters used to calculate the risk-based PRGs, and the resulting risk-based PRGs. The target noncarcinogenic HQ for the risk-based PRGs for each constituent was determined based on the number of constituents that result in an effect to the same target (i.e. nervous system). The target HQ for each constituent was chosen so that the total hazard to the receptor would be below 1. Therefore, if two constituents effect the same target, the target noncarcinogenic hazard for those constituents would be 0.5. The target carcinogenic risk level for the risk-based PRGs were selected based on the number of carcinogenic constituents, and chosen so that the total carcinogenic risk to a receptor would be below $10^{-4}$.

### 2.3.1 SWMU 2B Groundwater

Chemical-specific ARARs (MCLs) and risk-based PRGs for SWMU 2B groundwater are presented in Table 2-1 and Figure 2-1. Risk-based PRGs were calculated when MCLs were not available. Risk-based PRGs were calculated for the residential scenario for iron and manganese. Detected concentrations of benzene and 1,1-dichloroethene are less than their respective MCL. Arsenic, iron, and manganese were identified during the HHRA as risk drivers; however, based on historical use of the sites, they are not considered to be site-related contaminants.

### 2.3.2 SWMU 2C Groundwater

Chemical-specific ARARs (MCLs) and risk-based PRGs for SWMU 2C groundwater are presented in Table 2-2 and Figure 2-2. Risk-based PRGs were calculated when MCLs were not available. Risk-based PRGs were calculated for the residential scenario for benzo(b)fluoranthene, naphthalene, iron, and manganese. Detected concentrations of 1,4-dichlorobenzene, 1,1-dichloroethene, and tetrachloroethene are less than their respective MCL. Arsenic, iron, and manganese were identified during the HHRA as risk drivers; however, based on historical use of the sites, they are not considered to be site-related contaminants.

### 2.3.3 SWMU 2E Groundwater

Chemical-specific ARARs (MCLs) and risk-based PRGs for SWMU 2E groundwater are presented in Table 2-3 and Figure 2-3. Risk-based PRGs were calculated when MCLs were not available. Risk-based PRGs were calculated for the residential scenario for benzo(a)anthracene, 2-methylnaphthalene, naphthalene, pyrene, dieldrin, arsenic, iron, and manganese. Detected concentrations of naphthalene are less that its calculated risk-based PRG. Arsenic, iron, and manganese were identified during the HHRA as risk drivers; however, based on historical use of the sites, they are not considered to be site-related contaminants.

### 2.3.4 SWMU 2E Surface Soil

Risk-based PRGs were developed for SWMU 2E surface soil for the residential scenarios, since all of these scenarios exceeded the target levels listed above. Recommended risk-based PRGs for the residential scenario are based on the child or the lifetime scenarios, since these result in risk-based PRGs that are lower than the adult resident scenario. PRGs were calculated for aluminum, antimony, arsenic, cadmium, chromium, iron, and thallium (Table 2-4). None of the constituents detected in SWMU 2E soil exceed the risk-based soil PRGs.

**Table 2-1**
**Preliminary Remediation Goals**
**Groundwater**
**SWMU 2B, NAS Oceana**

| Chemicals of Concern | Maximum Detected Concentration (ug/L) | Residential Scenario Risk-Based PRG[1] (ug/L) | Maximum Contaminant Level[2] (ug/L) |
|---|---|---|---|
| ***VOCs*** | | | |
| Benzene | 2 | - | 5 |
| 1,1-Dichloroethene | 4 | - | 7 |
| cis-1,2-Dichloroethene | 120 | - | 70 |
| Trichloroethene | 14 | - | 5 |
| Vinyl Chloride | 13 | - | 2 |
| ***Inorganics*** | | | |
| Arsenic [3] | 30 | - | 10 |
| Iron | 35500 | 1544 | - |
| Manganese | 890 | 311 | - |

Notes:

1. Risk-based Preliminary Remediation Goals (PRGs) were calculated when ARARs (MCLs) were not available.
2. USEPA, Summer 2000.
3. 66 FR 6976, January 22, 2001 (for the arsenic MCL).
4. Shaded cell indicates maximum concentration detected is above risk-based PRG or MCL.

**Table 2-2**
**Preliminary Remediation Goals**
**Groundwater**
**SWMU 2C, NAS Oceana**

| Chemicals of Concern | Maximum Detected Concentration (ug/L) | Residential Scenario Risk-Based PRG[1] (ug/L) | Maximum Contaminant Level[2] (ug/L) |
|---|---|---|---|
| ***VOCs*** | | | |
| 1,4-Dichlorobenzene | 4.9 | - | 75 |
| 1,1-Dichloroethene | 1.5 | - | 7 |
| cis-1,2-Dichloroethene | 403 | - | 70 |
| Tetrachloroethene | 1.2 | - | 5 |
| Trichloroethene | 18.8 | - | 5 |
| Vinyl Chloride | 373 | - | 2 |
| ***SVOCs*** | | | |
| Benzo(b)fluoranthene | 1.2 | 0.9 | - |
| Naphthalene | 143 | 87 | - |
| ***Inorganics*** | | | |
| Arsenic [3] | 52.5 | - | 10 |
| Iron | 63600 | 772 | - |
| Manganese | 2010 | 311 | - |

Notes:

1. Risk-based Preliminary Remediation Goals (PRGs) were calculated when ARARs (MCLs) were not available.
2. USEPA, Summer 2000.
3. 66 FR 6976, January 22, 2001 (for the arsenic MCL).
4. Shaded cell indicates maximum concentration detected is above risk-based PRG or MCL.

**Table 2-3**
**Preliminary Remediation Goals**
**Groundwater**
**SWMU 2E, NAS Oceana**

| Chemicals of Concern | Maximum Detected Concentration (ug/L) | Residential Scenario Risk-Based PRG[1] (ug/L) | Maximum Contaminant Level[2] (ug/L) |
|---|---|---|---|
| ***VOCs*** | | | |
| Vinyl Chloride | 8 | - | 2 |
| ***SVOCs*** | | | |
| Benzo(a)anthracene | 4.8 | 0.9 | - |
| 2-Methylnaphthalene | 120 | 42 | - |
| Naphthalene | 130 | 131 | - |
| Pyrene | 240 | 65 | - |
| ***Pesticides*** | | | |
| Dieldrin | 0.05 | 0.02 | - |
| ***Inorganics*** | | | |
| Arsenic [3] | 55 | - | 10 |
| Iron | 67000 | 1544 | - |
| Manganese | 1920 | 311 | - |

Notes:

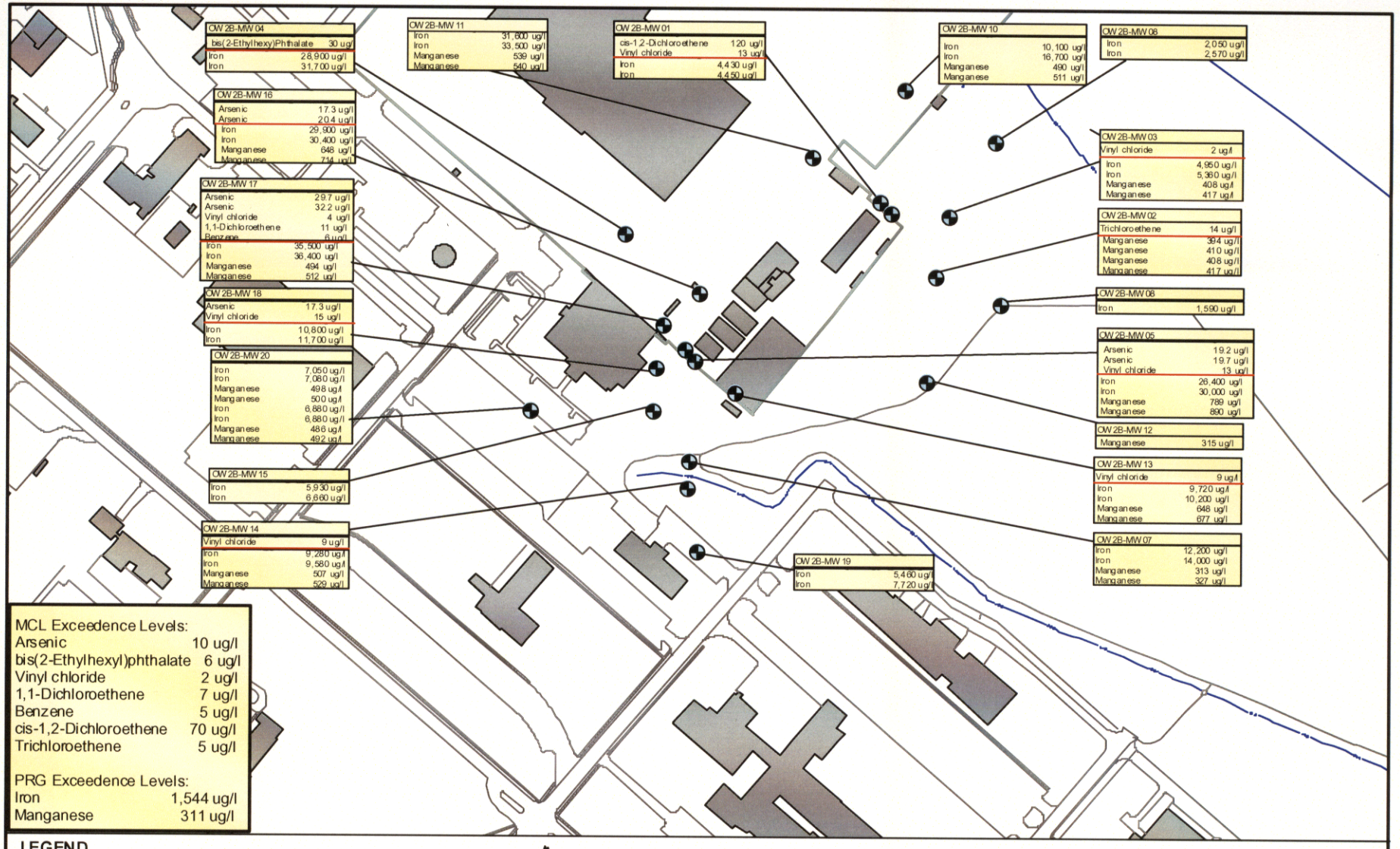
1. Risk-based Preliminary Remediation Goals (PRGs) were calculated when ARARs (MCLs) were not available.
2. USEPA, Summer 2000.
3. 66 FR 6976, January 22, 2001 (for the arsenic MCL).
4. Shaded cell indicates maximum concentration detected is above risk-based PRG or MCL.

**Table 2-4**
**Preliminary Remediation Goals**
**Soil Ingestion, Dermal Contact, and Inhalation**
**SWMU 2E, NAS Oceana**

| Chemicals of Concern | Maximum Detected Concentration (mg/kg) | Residential Scenario Risk-Based PRG (mg/kg) | Basis |
|---|---|---|---|
| ***Inorganics*** | | | |
| Aluminum | 12500 | 71500 | Child, HQ = 1 |
| Antimony | 3.6 | 14 | Child, HQ = 0.5 |
| Arsenic | 2.7 | 3.7 | Lifetime, CR = $10^{-5}$ |
| Cadmium | 6.6 | 51 | Child, HQ = 1 |
| Chromium | 22 | 101 | Child, HQ = 1 |
| Iron | 8340 | 11000 | Child, HQ = 0.5 |
| Thallium | 0.5 | 2.7 | Child, HQ = 0.5 |

Notes:
1. Child scenario selected for noncarcinogenic PRGs since child scenario more conservative (lower PRGs).
2. For constituents with basis of CR = $10^{-5}$, PRG for CR =$10^{-5}$ less than PRG for applicable HQ.
3. Used CR of $10^{-5}$ to keep overall carcinogenic risk below $10^{-4}$.
4. Applicabe HQ chosen to keep total HI for each target organ below 1.

File Path: c:\temp\oceana\proj1.apr




Note: Monitoring Wells 2B-MW2 and 2B-MW8 have been destroyed and will be replaced.

Figure 2-1
Monitoring Wells & Piezometers with MCL & Human Health Risk-Based PRG Exceedances
SWMU 2B
NAS Oceana, Virginia Beach, Virginia

CH2MHILL

00606 F 824

File Path: c:\temp\oceana\proj1.apr

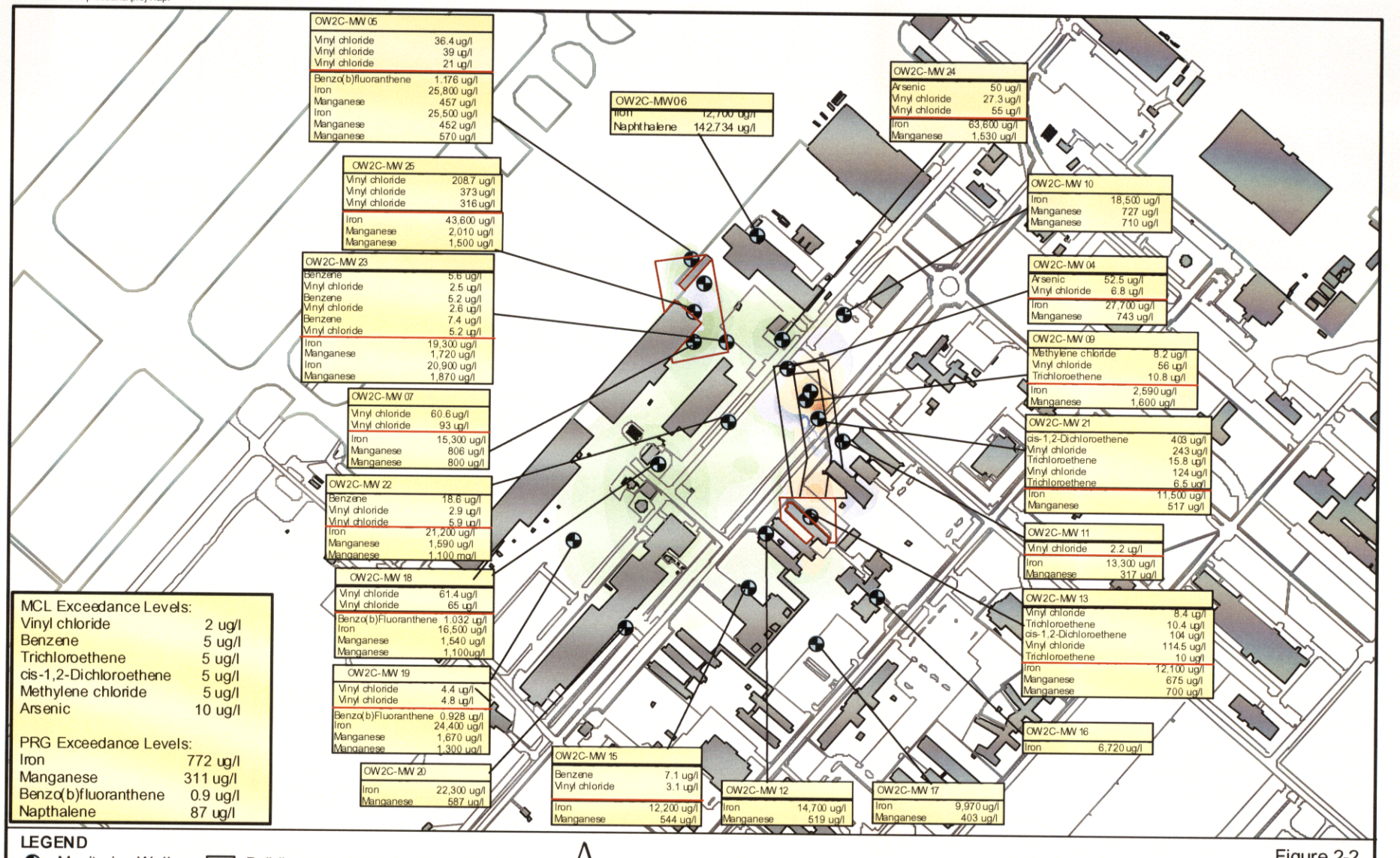



Figure 2-2
Monitoring Wells & Piezometers with MCL & Human Health Risk-Based PRG Exceedances
SWMU 2C
NAS Oceana, Virginia Beach, Virginia

**CH2MHILL**

File Path: c:\temp\oceana\proj1.apr

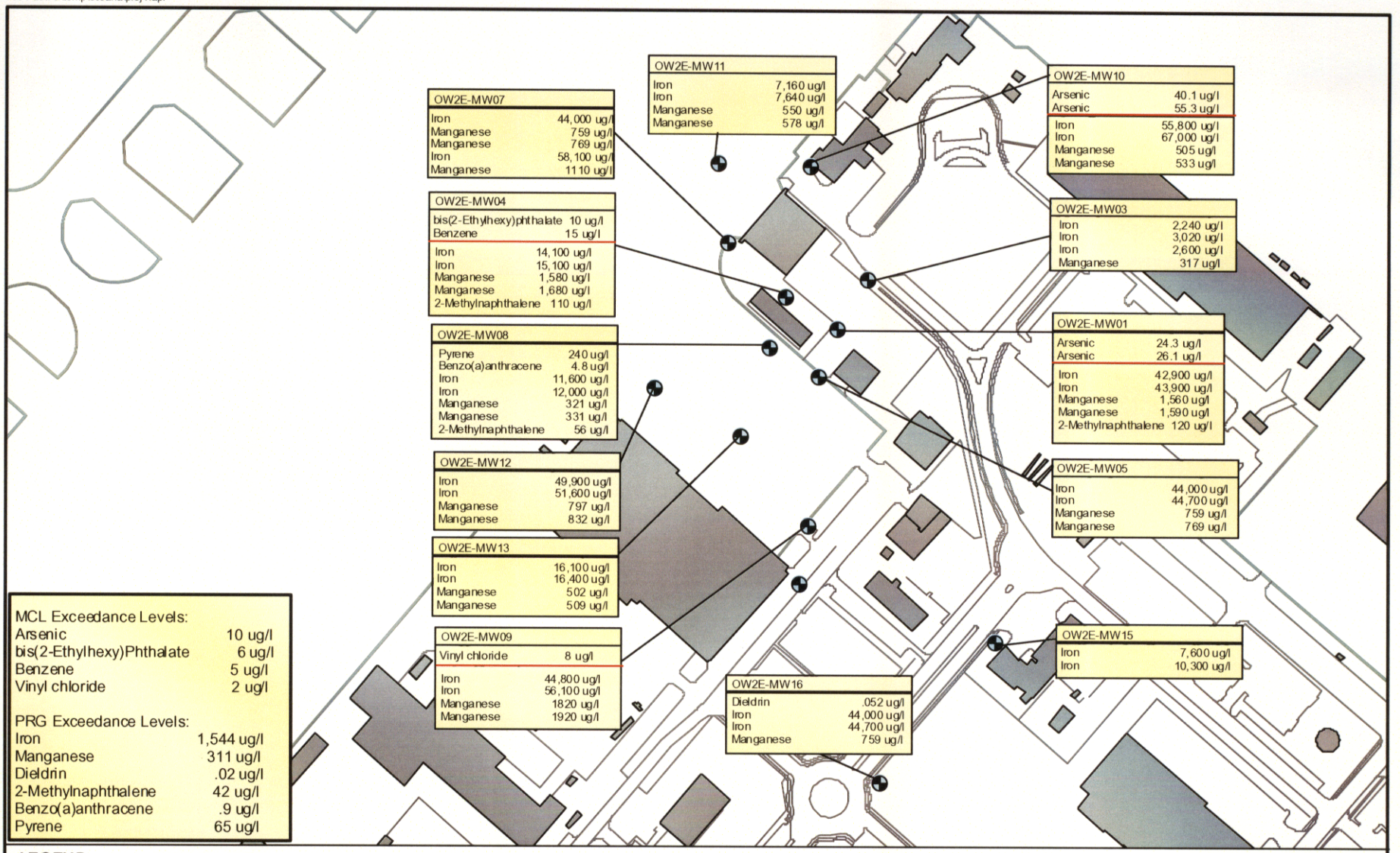



Figure 2-3
Monitoring Wells & Piezometers with MCL & Human Health Risk-Based PRG Exceedances
SWMU 2E
NAS Oceana, Virginia Beach, Virginia

CH2MHILL

SECTION 3

# Development of Remedial Alternatives

This section discusses the remedial alternatives developed to address the remedial action objectives (RAOs) for contamination present at SWMUs 2B, 2C and 2E.

## 3.1 General Response Actions

General response actions are broad classes of responses, remedies, or technologies developed to meet the site-specific RAOs. Each general response action is intended to address specific contaminants and the possible migration pathways and exposure routes in each environmental medium. Although an action may be capable of meeting the objective for a given medium, combinations of actions may later prove to be more cost effective in meeting all the objectives for the site. Therefore, to comply with the site RAOs, the general response actions are normally combined to form site-wide remedial alternatives.

The general response actions listed below have been identified for the remediation of SWMUs 2B, 2C, and 2E:

- No Action
- Institutional Control Actions
- Monitoring Actions
- Treatment Actions
- Collection Actions
- Disposal Actions

Under the *no-action response,* the current site conditions at each SWMU would remain. The NCP requires that a no-action alternative be developed as a baseline for evaluating remedial alternatives.

*Institutional control actions* consist of a number of alternatives that can be used singly or as part of a site-wide remedial alternative. Institutional controls include such activities as applying restrictions to groundwater use. Access restrictions can be effective as a means of preventing exposure to the groundwater.

*Monitoring actions* include long-term monitoring (LTM), monitoring active remediation, or monitoring natural attenuation. LTM consists of tracking groundwater quality and the potential for offsite plume migration. Remediation or attenuation of contaminants could also be monitored by collecting groundwater samples.

*Treatment actions* include technologies that prevent unacceptable risks to potential human receptors to the groundwater. One technology includes enhanced biodegradation for groundwater treatment.

*Collection actions* involve free-phase diesel fuel collection through manual bailing.

*Disposal actions* involve free-phase diesel fuel disposal at a permitted offsite facility.

The above general response actions have been used to create a range of site-wide alternatives that can be compared on the NCP criteria and compliance with the site-specific RAOs.

## 3.2 Identification and Screening of Remedial Technologies

Remedial technologies were identified which could meet the RAOs for each SWMU. These technologies were then screened using site-specific information from previous investigations to determine the feasibility of each technology, and eliminate technologies that could not be implemented effectively.

### 3.2.1 SWMU 2B Groundwater

Table 3-1 presents the identification and screening of remedial technologies for SWMU 2B groundwater. Concentrations of TCE, cis-1,2-DCE, VC, arsenic, iron, and manganese are present in SWMU 2B groundwater, which can pose risks to human health under a residential scenario. The discussion below presents the technologies that passed the initial screenings for groundwater.

#### *No Action*

The no-action response is retained to serve as a baseline for evaluating remedial alternatives.

#### *Institutional Controls*

The institutional control retained during the screening process was groundwater-use restrictions, which can be effective as a means of preventing exposure to the groundwater. The effectiveness of restrictions depends on continued use and the ability to enforce them. Institutional controls can be used as a stand-alone alternative but will also likely be a part of any other alternative.

#### *Monitoring*

Monitoring action that was retained during the screening process is LTM. Groundwater monitoring can be protective of human health by tracking changes in groundwater quality and the potential for plume migration. The groundwater contamination at SWMU 2B consists of contaminants that may become diluted to concentrations below cleanup levels before reaching downgradient monitoring wells.

#### *Treatment*

The *in-situ* treatment process retained was the use of a Hydrogen-Releasing Compound (HRC) and/or an Oxygen-Releasing Compound (ORC). The use of a HRC will encourage the reductive dehalogenation of TCE and cis-1,2-DCE. The use of an ORC will promote aerobic biodegradation of VC. Inorganics could be reduced to insoluble forms; however, this may be only on a temporary basis (while injection material persists in the aquifer) because of their ubiquitous presence in groundwater.

### 3.2.2 SWMU 2C Groundwater

Table 3-2 presents the identification and screening of remedial technologies for SWMU 2C groundwater. Concentrations of TCE, cis-1,2-DCE, VC, benzo(b)fluoranthene, naphthalene, arsenic, iron, and manganese are present in SWMU 2C groundwater that can pose risks to human health under a residential scenario. The discussion below presents the technologies that passed the initial screening.

#### *No Action*

The no-action response is retained to serve as a baseline for evaluating remedial alternatives.

#### *Institutional Controls*

The institutional control retained during the screening process was groundwater-use restrictions, which can be effective as a means of preventing exposure to the groundwater. The effectiveness of restrictions depends on continued use and the ability to enforce them.

Institutional controls can be used as a stand-alone alternative but also will likely be a part of any other alternative.

#### *Monitoring*

The monitoring action that was retained during the screening process is monitored natural attenuation (MNA). Groundwater monitoring can be protective of human health by tracking changes in the extent of contamination and groundwater quality either in conjunction with or independent of active remediation.

#### *Treatment*

The *in-situ* treatment process retained was the use of a HRC, alternative reduction agent, and an ORC. The use of a HRC and alternative reduction agent will encourage the reductive dehalogenation of TCE and cis-1,2-DCE. The use of an ORC will promote aerobic biodegradation of VC. Groundwater sampling data collected in February 2000 show that VC appears to be accumulating. Inorganics could be reduced to insoluble forms; however, this may be only on a temporary basis (while injection material persists in the aquifer) because of their ubiquitous presence in groundwater.

### 3.2.3 SWMU 2E Groundwater

Table 3-3 presents the identification and screening of remedial technologies for SWMU 2E groundwater. Concentrations of VC, benzo(a)anthracene, 2-methylnaphthalene, pyrene, dieldrin, arsenic, iron, and manganese are present in 2E groundwater, which can pose risks to human health under a residential scenario. The discussion below presents the technologies that passed the initial screening.

#### *No Action*

The no-action response is retained to serve as a baseline for evaluating remedial alternatives.

#### *Institutional Controls*

The institutional control retained during the screening process was groundwater-use restrictions, which can be effective as a means of preventing exposure to the potable use of groundwater. The effectiveness of groundwater-use restrictions depends on continued use and the ability to enforce them.

Institutional controls can be used as a stand-alone alternative but will also likely be a part of any other alternative.

#### *Monitoring*

The monitoring action that was retained during the screening process is LTM. Groundwater monitoring can be protective of human health by tracking changes in the extent of contamination and groundwater quality either in conjunction with or independent of active remediation.

#### *Free-Phase Diesel Fuel Collection*

An option retained through the screening of remedial technologies is periodic manual bailing of free-phase diesel fuel that accumulates in monitoring wells MW1, MW4, and MW8. Manual bailing of free-phase diesel fuel is currently being conducted on a monthly basis. The recovery scenarios that incorporate a constant-rate single-pump system or a constant-rate dual-pump system would not be cost-effective based upon the results of performance tests conducted at NAS Oceana that indicated that the free-product contamination is not easily recoverable by pumping systems. Free-phase diesel fuel could be recovered until the free-phase diesel fuel thickness is less than 0.01 feet (*9 VAC 25-580; UST Technical Standards and Corrective Action Requirements* and *Virginia Storage Tank Program Technical Manual* [VDEQ, 1999]) for three consecutive months.

#### *Free-Phase Diesel Fuel Disposal*

Any free-phase diesel fuel collected can be disposed of at a permitted offsite facility. The material can be managed with other NAS Oceana waste oil collection activities.

#### *Treatment*

The *in-situ* treatment process retained was the use of ORC. The use of ORC will promote aerobic biodegradation of VC. Inorganics will be reduced to insoluble forms; however, this may be only on a temporary basis (while injection material persists in the aquifer) because of their ubiquitous presence in groundwater. Inorganics will also be monitored during LTM.

## 3.3 Remedial Alternatives for SWMU 2B Groundwater

Three remedial alternatives were developed for SWMU 2B groundwater on the basis of the general response actions previously discussed in this section.

### 3.3.1 Site-Specific Remedial Action Objectives

Concentrations of TCE, cis-1,2-DCE, VC, arsenic, iron, and manganese are present in SWMU 2B groundwater and can pose risks to human health under a residential scenario. Arsenic, iron, and manganese posed unacceptable risks in the HHRA, although they are not considered to be site-related contaminants. However, monitoring of these constituents are

addressed in the alternatives described below. The site-specific RAO for SWMU 2B groundwater is as follows:

- Prevent exposure to unacceptable risks to human receptors of groundwater

## 3.3.2 Remedial Alternatives

Several remedial alternatives were developed for SWMU 2B on the basis of the general response actions and the results of the screening of remedial technologies. The alternatives identified for detailed evaluation include the following:

- Alternative 1 – No Action
- Alternative 2 – Institutional Controls and LTM
- Alternative 3 – HRC/ORC Injection, Institutional Controls, and LTM

The major components of each remedial alternative are defined in the following subsections.

### 3.3.2.1 Alternative 1 – No Action

The no-action alternative is required by the NCP and serves as the baseline alternative. All other remedial action alternatives are judged against the no-action alternative. Under this alternative, no controls or remedial technologies would be implemented. CERCLA (Section 121(c)), as amended by SARA (1986), requires that the site be reviewed every 5 years since contamination in the groundwater would remain onsite.

### 3.3.2.2 Alternative 2 - Institutional Controls and Long-Term Monitoring

Alternative 2 consists of institutional controls (groundwater-use restrictions) with LTM to track changes in groundwater quality or the potential for migration of contaminants off the site. The major components of this alternative are discussed below.

#### *Institutional Controls*

Institutional controls at SWMU 2B would include restrictions on groundwater extraction for potable use within the site boundaries, downgradient of the site, and within some distance of the site boundaries (yet to be determined).

#### *Long-Term Monitoring*

The Navy will prepare an LTM plan, using groundwater data collected at SWMU 2B, to detail the procedure for periodic LTM at the SWMU. The final LTM strategy may change from that outlined in this FS; however, it will be documented in the LTM plan. The following discussion is a preliminary plan for the LTM at SWMU 2B.

LTM at SWMU 2B would begin upon implementation of the LTM plan. Groundwater samples would be collected from the wells shown in Figure 3-1. Initially, sampling will be conducted for five consecutive quarters. The fifth quarter sampling event will begin the annual sampling. Each annual sampling event will occur in a different quarter to account for seasonal fluctuation (i.e., the fifth quarter sampling event would be conducted during the first quarter of the year, the next annual sampling event would be conducted in the second quarter of the second year, and the next event would be conducted in the third quarter of the third year). Each existing well will be sampled, and all samples will be analyzed for the full suite Target Analyte List (TAL)/Target Compound List (TCL) analyses.

After the fifth quarter of sampling, the first annual groundwater report will be produced. The report will document a trends evaluation and groundwater level/flow as well as any proposed changes to the LTM program. During the second, third, and fourth years, streamlined groundwater monitoring reports will be produced, presenting the analytical data as well as qualitative general trends in the analytical data.

After the fifth year sampling event, another report will be produced with the same level of detail as the fifth quarter report. Based on all the analytical results, the sampling and analysis scheme will be evaluated and potentially modified during the 5-year site review for the subsequent annual sampling events.

#### 3.3.2.3 Alternative 3 – HRC/ORC Injection, Institutional Controls, and Long-Term Monitoring

Alternative 3 consists of the injection of HRC and ORC to enhance biodegradation of contaminants, with the institutional controls and LTM discussed in Alternative 2. Although details of enhanced biodegradation would need to be addressed in a work plan, the major components of this alternative are discussed below.

***Hydrogen-Releasing Compound Injection***

HRC is a proprietary polylactate ester that, upon being deposited into the subsurface, slowly releases lactate. Lactate is metabolized by naturally occurring microorganisms, resulting in the creation of anaerobic aquifer conditions and the production of hydrogen. Naturally occurring microorganisms capable of reductive dechlorination then use the hydrogen to progressively remove chlorine atoms from the chlorinated hydrocarbon contaminants (i.e., TCE and cis-1,2-DCE can be reduced to VC). HRC is manufactured as a viscous gel that can be injected into the saturated zone for plume remediation. No pilot testing is necessary since the aquifer geochemistry has been measured and reactions are fairly predictable.

An HRC slurry will be injected using direct push technology in a one-time application in small scale barriers areas at SWMU 2B with TCE and cis-1,2-DCE concentrations. HRC will be injected into two barrier locations (Figure 3-2). Each barrier consists of one row of two points and one row of three points. The HRC has an estimated radius of influence of 15 feet, therefore, the final design of injection point locations will need to be closely spaced. The wells mentioned under Alternative 2 would then be sampled to ensure degradation of TCE and cis-1,2-DCE and subsequently the degradation of VC, to determine if an additional HRC application is necessary.

***Oxygen-Releasing Compound Injection***

ORC is a substance that when introduced to an aquifer, slowly releases oxygen and enhances the degradation of a contaminant. ORC has been successfully applied to VC and other contaminants (i.e., bis(2-ethylhexyl)phthalate) under a wide range of conditions. Inorganics will be reduced to insoluble forms; however, this may be done only on a temporary basis because of their ubiquitous presence in groundwater. Inorganics will also be monitored during LTM. No pilot testing is necessary since the aquifer geochemistry has been measured and reactions are fairly predictable.

An ORC slurry will be injected through direct push in a one-time application in the hot spot areas at SWMU 2B. The ORC has an estimated radius of influence of 15 feet, therefore, the final design of injection point locations will need to be closely spaced. ORC will be injected into 12 barrier locations (Figure 3-2). Each barrier consists of one row of two points and one row of three points. Existing monitoring wells will be monitored to ensure the effectiveness of the ORC injection. The LTM described under Alternative 2 would be conducted to ensure degradation of VC and other contaminants (i.e., bis(2-ethylhexyl)phthalate), to determine if an additional ORC application is necessary. The results of the sampling will determine whether another ORC injection is necessary to achieve remediation goals.

***Institutional Controls and Long-Term Monitoring***

The institutional controls to prevent groundwater exposure from the site will be the same as included in Alternative 2. The LTM program would also be implemented as in Alternative 2.

## 3.4 Remedial Alternatives for SWMU 2C Groundwater

Three remedial alternatives were developed for SWMU 2C groundwater on the basis of the general response actions previously discussed in this section.

### 3.4.1 Site-Specific Remedial Action Objectives

Concentrations of TCE, cis-1,2-DCE, VC, benzo(b)fluoranthene, naphthalene, arsenic, iron, and manganese are present in SWMU 2C groundwater and can pose risks to human health under a residential scenario. Arsenic, iron, and manganese posed unacceptable risks in the HHRA, although they are not considered to be site-related contaminants. However, monitoring of these constituents are addresses in the alternatives described below. The site-specific RAO for SWMU 2C groundwater is as follows:

- Prevent exposure to unacceptable risks to human receptors of groundwater

### 3.4.2 Remedial Alternatives

Several remedial alternatives were developed for SWMU 2C on the basis of the general response actions and the results of the screening of remedial technologies. The alternatives identified for detailed evaluation include the following:

- Alternative 1 – No Action
- Alternative 2 –Monitored Natural Attenuation and Institutional Controls
- Alternative 3 – Enhanced Biodegradation, Monitored Natural Attenuation, and Institutional Controls

The major components of each remedial alternative are defined in the following subsections.

#### 3.4.2.1 Alternative 1 – No Action

The no-action alternative is required by the NCP and serves as the baseline alternative. All other remedial action alternatives are judged against the no-action alternative. Under this alternative, no controls or remedial technologies would be implemented. CERCLA

(Section 121(c)), as amended by SARA (1986), requires that the site be reviewed every 5 years since contamination in the groundwater would remain onsite.

#### 3.4.2.2 Alternative 2 - Monitored Natural Attenuation and Institutional Controls

Alternative 2 consists of groundwater sampling to monitor the natural attenuation of contaminants, with institutional controls to restrict groundwater use. Although details of MNA would need to be addressed in a work plan, the major components of this alternative are discussed below.

***Monitored Natural Attenuation***

The natural attenuation assessment (Appendix C) indicated that biodegradation of chlorinated hydrocarbons in groundwater through reductive dechlorination and cometabolism is likely to have occurred and in some cases, is continuing to occur. It appears that VC is being further reduced to ethene. However, at this time VC appears to be accumulating. Natural attenuation is demonstrated by the following two lines of evidence.

The first line of evidence evaluated relies on observable changes in groundwater chemistry that occur during biodegradation. TCE is known to have been released at the site. Daughter products that result from TCE degradation, namely cis-1,2-DCE, VC, and ethene, are all detected in groundwater at the SWMU in locations that support their provenance from their parent product. In addition, sulfate reduction and chloride production, support the interpretation that anaerobic degradation of chlorinated hydrocarbons is occurring in groundwater.

The second line of evidence for natural attenuation show that contaminant plumes are stabilized or are shrinking in size. TCE contaminant concentrations appear to be decreasing over time. The cis-1,2-DCE plume is interpreted to have increased at one time and is now on the decline due to reduction to VC. However, a significant accumulation of VC concentrations indicate that aerobic conditions that are optimal for effective natural attenuation of VC are not currently present even though significant ethene production is observed.

MNA of the groundwater at SWMU 2C would involve annual groundwater sampling in order to effectively characterize the natural attenuation process, and assess the rate at which biodegradation of TCE and its daughter products, cis-1,2- DCE and VC is occurring. Groundwater samples will be collected annually from the existing wells in the MNA network (Figure 3-3). Due to the slow groundwater velocity, annual sampling is deemed sufficient. The groundwater will be sampled for Low-Concentration Volatiles and Semivolatiles, and TAL metals (due to PRG exceedances), and other MNA parameters such as $Fe^{2+}/Fe^{3+}$, chloride, nitrate, nitrite, sulfate, methane, ethane, and ethene. Field parameters such as dissolved oxygen, temperature, pH, conductivity, and redox potential will also be collected.

A MNA study will be performed after five years of monitoring to confirm contaminant biodegradation rates, re-evaluate the data collected, and document lines of evidence for MNA. The TTCU model will be run again using new information to modify model inputs to match site conditions more closely. With these new inputs, the TTCU model will more

accurately determine the time necessary to achieve remediation goals, and determine the length of time appropriate for the monitoring activities to continue.

#### *Institutional Controls*

Institutional controls at SWMU 2C would include restrictions on groundwater extraction for potable use within the site boundaries, downgradient of the site, and within some distance of the site boundaries (yet to be determined).

### 3.4.2.3 Alternative 3 – Enhanced Biodegradation, Monitored Natural Attenuation, and Institutional Controls

Alternative 3 consists of the addition of hydrogen and oxygen to enhance biodegradation of contaminants, with the institutional controls and LTM discussed in Alternative 2. The accumulation of VC indicates that the natural attenuation process might need to be augmented with enhanced biodegradation. Although details of the enhanced biodegradation and MNA would need to be addressed in a work plan, the major components of this alternative are discussed below.

#### *Addition of Hydrogen*

Hydrogen is necessary for reductive dehalogenation to take place. The addition of hydrogen would facilitate the dehalogenation of TCE and cis-1,2-DCE. Direct injection of hydrogen either as a gas or a liquid is infeasible. However, the injection of a carbon source which produces hydrogen during degradation is practical. Some products which have been used as a hydrogen source are molasses, lactic acid, and HRC. HRC stimulates the multi-step process of creating an environment for optimum reductive dehalogenation, and then slowly releases lactic acid which releases hydrogen during the degradation process.

A pilot study will be performed to evaluate two carbon sources, HRC and an alternate electron donor (AED). The pilot study will involve injecting each compound at separate locations (one location for HRC and one location for AED) with high TCE concentrations. The SWMU 2C groundwater sampling data will be evaluated to select the best locations. Three temporary monitoring wells (approximately 20 feet bgs) will be installed at each location to monitor TCE and cis-1,2-DCE degradation rates as well as the zone of influence, migration pathways, dosage requirements, estimated efficiency, and approximate cleanup time. The temporary monitoring wells will be removed after the pilot study is completed. Based upon the result of the pilot study, a final design of the most effective carbon source (either HRC or AED) will be developed. The following is a description of each carbon source and a discussion of a preliminary design of a full-scale system, which may need to be redeveloped based on the results of the pilot study.

#### *Hydrogen-Releasing Compound Injection*

HRC is a proprietary polylactate ester that, upon being deposited into the subsurface, slowly releases lactate. Lactate is metabolized by naturally occurring microorganisms, resulting in the creation of anaerobic aquifer conditions and the production of hydrogen. Naturally occurring microorganisms capable of reductive dechlorination then use the hydrogen to progressively remove chlorine atoms from the chlorinated hydrocarbon contaminants (i.e., TCE and cis-1,2-DCE can be reduced to VC). HRC is manufactured as a viscous gel that can be injected into the saturated zone for plume remediation.

HRC will be applied at the site using direct push hydraulic equipment. Drive rods are pushed to the bottom of the contaminated saturated zone and then HRC is injected as the rods are withdrawn. Typically, one to two HRC injection points can be completed per hour and up to 20 points can be completed per day, depending on soil type, depths of injection, and subcontractor experience. HRC will be injected using a pump capable of processing a material with a viscosity of 20,000 centipoise at flow rates of 3 to 10 gallons per minute at pressures ranging from 200 psig to 1,500 psig.

HRC will be applied to the southern TCE and cis-1,2-DCE core area at SWMU 2C (Figures 3-4A and 3-4B). The HRC has an estimated radius of influence of 10 to 15 feet, therefore, in the final design, injection locations will need to be closely spaced. Temporary monitoring wells (approximately 20 feet bgs) located downgradient of the core area will be installed and sampled to track the degradation of TCE and cis-1,2-DCE and subsequently the degradation of VC, to determine if an additional HRC application is necessary. The temporary monitoring wells will be removed after the remediation goals are achieved. For estimating purposes, a second (phase 2) application is assumed for the southern area (Figures 3-4A and 3-4B).

The estimated HRC application configurations for each phase are presented below:

| Phase 1: SWMU 2C Southern Section Core HRC Grid Treatment | |
|---|---|
| **Design Feature** | **Preliminary Specification** |
| Treatment Area | approximately 100 feet by 500 feet |
| Delivery Point Spacing and Configuration | 17 rows of 10 points; 170 total points<br>30 ft between Rows, 10 ft-on-center within rows |
| HRC dose rate in lbs/vertical foot of injection | 8 lbs/foot, (60 lbs/point) |
| Material requirement | 10,200 lbs |

| Phase 2: SWMU 2C Southern Section Non-Core HRC Grid Treatment | |
|---|---|
| **Design Feature** | **Preliminary Specification** |
| Treatment Area | approximately 165 feet by 600 feet |
| Delivery Point Spacing and Configuration | 11 rows of 14 points; 154 total points<br>45 ft between rows, 15 ft-on-center within rows |
| HRC dose rate in lbs/vertical foot of injection | 6 lbs/foot, (45 lbs/point) |
| Material requirement | 6,930 lbs |

The duration of an accelerated bioremediation cleanup is difficult to predict with any accuracy due to uncertainty about the total contaminant mass (especially sorbed and/or residual phase) and site specific biodegradation rates that can be achieved. Based on previous experience, Regenesis, manufacturer of HRC, estimated that the biodegradation

half-lives can be reduced by 10 percent and that the remediation goals may be achieved over a period of 2 to 4 years.

### *Alternate Electron Donor*

AEDs (i.e., vegetable oil, molasses) are substances that when introduced to an aquifer, slowly releases hydrogen to enhance biodegradation of contaminants through the process of reductive dehalogenation. The use of hydrogen as an electron donor encourages the removal of a chlorine atom from a chlorinated VOC and the replacement of the chlorine with a hydrogen atom. Through this process, TCE and cis-1,2-DCE can be reduced to VC.

The selected AED will be applied at the site using direct push hydraulic equipment. Drive rods are pushed to the bottom of the contaminated saturated zone and then AED is injected as the rods are withdrawn.

AED will be applied to the southern TCE and cis-1,2-DCE core area at SWMU 2C (Figures 3-4A and 3-4B). Temporary monitoring wells (approximately 20 feet bgs) located downgradient of the core area will be installed and sampled to track degradation of TCE and cis-1,2-DCE and subsequently the degradation of VC, to determine if an additional AED application is necessary. The temporary monitoring wells will be removed after the remediation goals are achieved. For estimating purposes, a second (phase 2) application is assumed for the southern area (Figures 3-4A and 3-4B).

The estimated AED application configurations for each phase are presented below:

| Phase 1: SWMU 2C Southern Section Core AED Grid Treatment | |
|---|---|
| **Design Feature** | **Preliminary Specification** |
| Treatment Area | approximately 100 feet by 500 feet |
| Delivery Point Spacing and Configuration | 17 rows of 10 points; 170 total points<br>30 ft between Rows, 10 ft-on-center within rows |
| AED dose rate in lbs/vertical foot of injection | 40 lbs/foot, (300 lbs/point) |
| Material requirement | 51,000 lbs |

| Phase 2: SWMU 2C Southern Section Non-Core AED Grid Treatment | |
|---|---|
| **Design Feature** | **Preliminary Specification** |
| Treatment Area | approximately 165 feet by 600 feet |
| Delivery Point Spacing and Configuration | 11 rows of 14 points; 154 total points<br>45 ft between rows, 15 ft-on-center within rows |
| AED dose rate in lbs/vertical foot of injection | 30 lbs/foot, (225 lbs/point) |
| Material requirement | 34,650 lbs |

The duration of an accelerated bioremediation cleanup is difficult to predict with any accuracy due to uncertainty about the total contaminant mass (especially sorbed and/or

residual phase) and site specific biodegradation rates that can be achieved. Based on previous studies, the remediation goals may be achieved over a period of 2 to 4 years.

### *Addition of Oxygen*

The addition of oxygen would be appropriate as a treatment for VC plume. The oxygen is utilized as a terminal electron acceptor, and the contaminant is the electron donor. ORC is a substance that when introduced to an aquifer, slowly releases oxygen and enhances the degradation of a contaminant. ORC has been successfully applied to VC under a wide range of conditions. A pilot study may need to be performed for the final design of an ORC injection system at SWMU 2C. The pilot study would involve injecting ORC in one location and measuring the changes in oxygen and contaminant concentrations over an 8 month period. Measurements of degradation rates, the zone of influence of the ORC, the migration pathways of the ORC, the demand factor of the ORC, and soil permeability would be determined. Based upon the result of the pilot study, a final design of an ORC injection system would be developed. The following is a discussion of a preliminary design of a full-scale system, which may need to be redeveloped based on the results of the pilot study.

An ORC slurry will be injected through direct push in a one-time application in two hot spot areas at SWMU 2C. The ORC has an estimated radius of influence of 15 feet, therefore, in the final design, the injection locations will need to be closely spaced. ORC will be injected into the northern and southern areas (Figure 3-5). Temporary monitoring wells (approximately 20 feet bgs) located downgradient of the core areas will be installed and sampled to track the degradation of VC and other hydrocarbons, to determine if an additional ORC application is necessary. The temporary monitoring wells will be removed after the remediation goals are achieved. The results of the sampling will determine whether another ORC injection is necessary to achieve remediation goals.

The estimated ORC application configurations for each area are presented below:

| SWMU 2C Northern Area ORC Grid Treatment | |
|---|---|
| **Design Feature** | **Preliminary Specification** |
| Delivery Point Spacing and Configuration | 14 rows of 14 points; 196 total points<br>30 ft between Rows, 15 ft-on-center within rows |
| ORC dose rate in lbs/vertical foot of injection | 3 lbs/foot, (21 lbs/point) |
| Material requirement | 4,410 lbs |

| SWMU 2C Southern Area ORC Grid Treatment | |
|---|---|
| **Design Feature** | **Preliminary Specification** |
| Delivery Point Spacing and Configuration | 7 rows of 17 points, 119 total points<br>30 ft between rows, 15 ft-on-center within rows |
| ORC dose rate in lbs/vertical foot of injection | 4 lbs/foot, (30 lbs/point) |
| Material requirement | 3,570 lbs |

The duration of an accelerated bioremediation cleanup is difficult to predict with any accuracy due to uncertainty about the total contaminant mass (especially sorbed and/or residual phase) and site specific biodegradation rates that can be achieved. Based on previous experience, Regenesis, manufacturer of ORC, estimated that the biodegradation half-lives can be reduced by about 10 percent and that the remediation goals may be achieved over a period of 2 to 4 years.

### *Monitoring*

Pilot study monitoring would track the degradation of the contaminants before (baseline) and after HRC or AED, and ORC injection. After injection of the material, sampling would be conducted every other month for eight months. Three temporary and seven existing monitoring wells would be monitored during the pilot study. The groundwater will be sampled for Low-Concentration Volatiles and other MNA parameters, such as $Fe^{2+}/Fe^{3+}$, chloride, nitrate, nitrite, sulfate, methane, ethane, and ethene. Field parameters such as dissolved oxygen, temperature, pH, conductivity, and redox potential will also be collected.

After the pilot test is complete, a pilot study report will be produced. The report will document groundwater level/flow, zone of influence, migration pathways, dosage requirements, estimated efficiency, and approximate cleanup time. Based upon the result of the pilot study, a final design of the most effective material will be developed.

Enhanced biodegradation and MNA monitoring would begin after the final design of the most effective material is completed. Monitoring of the groundwater would involve annual groundwater sampling in order to effectively characterize the natural attenuation process and assess the rate at which biodegradation of TCE and its daughter products, cis-1,2-DCE and VC, is occurring. Groundwater samples will be collected annually from 12 temporary and 21 existing monitoring wells (Figures 3-4A and 3-4B). Due to the slow groundwater velocity, annual sampling is deemed sufficient. The groundwater will be sampled for Low-Concentration Volatiles and Semivolatiles, TAL metals (due to PRG exceedances), and other MNA parameters.

A 5-year review report will be prepared after 4 years of monitoring to document groundwater level/flow and confirm contaminant biodegradation rates. A TTCU model will be run using new information to modify model inputs to match site considerations more closely. With these inputs, the TTCU model will more accurately determine the time necessary to achieve remediation goals and determine the length of time appropriate for the monitoring activities to continue.

LTM would begin after the 5-year review. The Navy will prepare an LTM plan, using groundwater data collected at SWMU 2C, to detail the procedure for periodic LTM of the SWMU. The final LTM strategy may change from that outlined in this FS; however, it will be documented in the LTM plan. The following discussion is a preliminary plan for the LTM of SWMU 2C.

Sampling will be conducted for five consecutive quarters. The fifth quarter sampling event (sixth year) will begin the annual sampling. Each annual sampling event will occur in a different quarter to account for seasonal fluctuation (i.e., the fifth quarter sampling event would be conducted during the first quarter of the first year, the next annual sampling event

would be conducted in the second quarter of the second year, and the next event would be conducted in the third quarter of the third year). Groundwater samples will be collected from 12 temporary and 21 existing monitoring wells (Figures 3-4A, 3-4B, and 3-5). The groundwater will be sampled for Low-Concentration Volatiles and Semivolatiles, TAL metals, and other MNA parameters.

After the fifth quarter of sampling, an annual groundwater report will be produced. The report will document groundwater level/flow and confirm contaminant biodegradation rates as well as any proposed changes to the LTM program. During the seventh and eighth years, streamlined groundwater-monitoring reports will be produced, presenting the analytical data as well as qualitative general trends in the analytical data.

After the fifth year sampling event, another report will be produced, with the same level of detail as the fifth quarter report. Based on all the analytical results, the sampling and analysis scheme will be evaluated and potentially modified during the 5-year site review for the subsequent annual sampling events.

#### *Institutional Controls*

The institutional controls to prevent groundwater exposure and residential development of the site will be the same as included in Alternative 2.

## 3.5 Remedial Alternatives for SWMU 2E Groundwater

Three remedial alternatives were developed for SWMU 2E groundwater on the basis of the general response actions previously discussed in this section.

### 3.5.1 Site-Specific Remedial Action Objectives

Concentrations of VC, benzo(a)anthracene, 2-methylnaphthalene, naphthalene, pyrene, dieldrin, arsenic, iron, and manganese are present in SWMU 2E groundwater and can pose risks to human health under a residential scenario. Arsenic, iron, and manganese posed unacceptable risks in the HHRA, although they are not considered to be site-related contaminants. However, monitoring of these constituents are addressed in the alternatives described below. The site-specific RAO for SWMU 2E groundwater is as follows:

- Prevent exposure to unacceptable risks to human receptors of groundwater

### 3.5.2 Remedial Alternatives

Several remedial alternatives were developed for SWMU 2E on the basis of the general response actions and the results of the screening of remedial technologies. The alternatives identified for detailed evaluation include the following:

- Alternative 1 – No Action
- Alternative 2 – Free-Phase Diesel Fuel Removal, Institutional Controls, and LTM
- Alternative 3 – ORC Injection, Free-Phase Diesel Fuel Removal, Institutional Controls, and LTM

The major components of each remedial alternative are defined in the following subsections.

#### 3.5.2.1 Alternative 1 – No Action

The no-action alternative is required by the NCP and serves as the baseline alternative. All other remedial action alternatives are judged against the no-action alternative. Under this alternative, no controls or remedial technologies would be implemented. CERCLA (Section 121(c)), as amended by SARA (1986), requires that the site be reviewed every 5 years since contamination in the groundwater would remain onsite.

#### 3.5.2.2 Alternative 2 - Free-Phase Diesel Fuel Removal, Institutional Controls, and Long-Term Monitoring

Alternative 2 consists of institutional controls (groundwater-use restrictions) with LTM to track changes in groundwater quality or the potential for migration of contaminants off the site, along with continued bailing to remove any free-phase diesel fuel from the water table. The major components of this alternative are discussed below.

##### *Institutional Controls*

Institutional controls at SWMU 2E would include restrictions on groundwater extraction for potable use within the site boundaries, downgradient of the site, and within some distance of the site boundaries (yet to be determined).

##### *Free-Phase Diesel Fuel Removal*

Free-phase diesel fuel has been and will continue to be recovered from monitoring wells MW1, MW4, and MW8 using manual bailing. Manual bailing should be conducted until the free-phase diesel fuel thickness is less than 0.01 feet (*9 VAC 25-580; UST Technical Standards and Corrective Action Requirements* and *Virginia Storage Tank Program Technical Manual* (VDEQ, 1999]) for three consecutive months.

##### *Long-Term Monitoring*

The Navy will prepare an LTM plan, using the 2000 groundwater data collected at SWMU 2E as a baseline, to detail the procedure for periodic LTM at the SWMU. The final LTM strategy may change from that outlined in this FS; however, it will be documented in the LTM plan. The following discussion is a preliminary plan for the LTM at SWMU 2E.

LTM at SWMU 2E would begin upon implementation of the LTM plan. Groundwater samples would be collected from the wells shown in Figure 3-6. Initially, sampling will be conducted for five consecutive quarters. The fifth quarter sampling event will begin the annual sampling. Each annual sampling event will occur in a different quarter to account for seasonal fluctuation (i.e., the first fifth quarter sampling event would be conducted during the first quarter of the first year, the next annual sampling event would be conducted in the second quarter of the second year, and the next annual sampling event would be conducted in the third quarter of the third year). Each existing well will be sampled, and all samples will be analyzed for full suite Target Analyte List (TAL)/Target Compound List (TCL) analyses.

After the fifth quarter of sampling, the first annual groundwater report will be produced. The report will document a trends evaluation and groundwater level/flow as well as any proposed changes to the LTM program. During the second, third, and fourth years,

streamlined groundwater-monitoring reports will be produced, presenting the analytical data as well as qualitative general trends in the analytical data.

After the fifth year sampling event, another report will be produced, with the same level of detail as the fifth quarter report. Based on all the analytical results, the sampling and analysis scheme will be evaluated and potentially modified during the 5-year site review for the subsequent annual sampling events.

#### 3.5.2.3 Alternative 3 – ORC Injection, Free-Phase Diesel Fuel Removal, Institutional Controls, and Long-Term Monitoring

Alternative 3 consists of the use of an ORC to enhance biodegradation of contaminants, with the institutional controls and LTM discussed in Alternative 2. Although details of the enhanced biodegradation would need to be addressed in a work plan, the major components of this alternative are discussed below.

##### *Oxygen-Releasing Compound Injection*

ORC is a substance that when introduced to an aquifer, slowly releases oxygen and enhances the degradation of a contaminant. ORC has been successfully applied to VC and other contaminants (bis(2-ethylhexyl)phthalate and benzene) under a wide range of conditions. Inorganics will be reduced to insoluble forms; however, this may be only on a temporary basis due to their ubiquitous presence in groundwater. Inorganics will also be monitored during LTM. No pilot testing is necessary since the aquifer geochemistry has been measured and reactions are fairly predictable.

An ORC slurry will be injected through direct push in a one-time application in the hot spot areas at SWMU 2E. The ORC has an estimated radius of influence of 15 feet, therefore, in the final design, the injection locations will need to be closely spaced. ORC will be injected into four barrier locations (Figure 3-7). Each barrier consists of one row of two points and one row of three points. The LTM described under Alternative 2 would be conducted to track degradation of VC and other contaminants (bis(2-ethylhexyl)phthalate and benzene), to determine if an additional ORC application is necessary. The results of the sampling will determine whether another ORC injection is necessary to achieve remediation goals.

##### *Free-Phase Diesel Fuel Removal*

Free-phase diesel fuel has been and will continue to be recovered from monitoring wells MW1, MW4, and MW8 using manual bailing. Manual bailing will occur until the free-phase diesel fuel thickness is less than 0.01 feet (9VAC 25-580; *UST Technical Standards and Corrective Action Requirements* and *Virginia Storage Tank Program Technical Manual* [VDEQ, 1999]) for three consecutive months.

##### *Institutional Controls and Long-Term Monitoring*

The institutional controls to prevent groundwater exposure from the site will be the same as described in Alternative 2. The LTM would also be implemented as in Alternative 2.

**Table 3-1**
**Identification and Screening of Remedial Technologies for SWMU 2B Groundwater**

| General Response Action | Remediation or Technology | Process Options | Description | Screening Action | | Screening Comments |
|---|---|---|---|---|---|---|
| | | | | Retain | Reject | |
| No action | None | Not applicable | No action | X | | Retain as baseline alternative |
| Institutional controls | Administrative groundwater-use restrictions | Deed restrictions | Property in the area would include groundwater-use restrictions | X | | Potentially applicable if implemented in conjunction with other process options. |
| Monitoring | Monitoring Groundwater | Long-term ground-water monitoring | Monitoring of contamination to track groundwater quality, and to monitor the potential for offsite migration. | X | | Technically feasible. |
| Containment/ collection | Physical barriers | Slurry walls | Subsurface barriers consisting of a vertically constructed trench excavated under a slurry | | X | Horizontal isolation of contaminant could induce vertical migration into Yorktown Aquifer |
| | | Sheet piling | Subsurface barriers consisting of sheet piling inserted around contaminant plume | | X | Horizontal isolation of contaminant could induce vertical migration into Yorktown Aquifer |
| | Hydraulic barriers | Extraction wells | Series of pumping wells to extract contaminated groundwater and hydraulically isolate contaminant plume | | X | Technically feasible, however would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |
| | | Subsurface drains/trenches | Perforated pipe in trenches backfilled with porous media to collect water | | X | Based on location of contamination and depth of aquifer, trenches not as cost-effective as extraction wells |
| Treatment | Ex-situ biological treatment | Aerobic | Aerobic microorganisms are used to metabolize biodegradable organics in an aeration tank | | X | Emerging technologies can remove chlorinated organics, but these high-maintenance systems are not cost-effective compared to conventional technologies for volatile compounds. |
| | Physical/chemical treatment | Air stripping | Large volumes of air are mixed with the contaminated water in a packed column to promote transfer of VOCs to air. Treatment of off-gas may be necessary. | | X | Technically feasible, however groundwater extraction would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |
| | | Carbon adsorption | Contaminants adsorbed onto activated carbon by passing water through carbon column. Typically more expensive than air stripping for large volumes of water and long-term use. | | X | Technically feasible, however groundwater extraction would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |

**Table 3-1**
**Identification and Screening of Remedial Technologies for SWMU 2B Groundwater**

| General Response Action | Remediation or Technology | Process Options | Description | Screening Action | | Screening Comments |
|---|---|---|---|---|---|---|
| | | | | Retain | Reject | |
| Treatment (cont.) | Physical/chemical treatment (cont.) | Reverse osmosis | High pressure used to force water through a membrane, leaving contaminants behind | | X | Not cost-effective for removal of organic constituents relative to other technologies |
| | | Chemical oxidation | Contaminated water mixed with an oxidant to break down the organic compounds into $H_2O$, $CO_2$, and $Cl^-$ | | X | Potentially applicable. Typically more difficult to operate than air stripping; however, would not be affected by iron in waste stream. Groundwater extraction would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |
| | | Gravity oil-water separation | Mixture of oil and water flows into a tank where fuel or oil floats to the top | | X | No free product detected at this site; oil-water mixtures or emulsions not anticipated. |
| | | Coalescing oil-water separation | Fine droplets of dissolved oil are collected on a filter medium. Enlarged droplets are then released and can be separated readily | | X | No free product detected at this site; oil-water mixtures or emulsions not anticipated. |
| | | Dissolved air flotation (DAF) | Air is bubbled through the mixture; micron-size air bubbles attach to suspended POL particles and rise to the top of the separator | | X | No free product detected at this site; oil-water mixtures or emulsions not anticipated. |
| | In-situ treatment | Aerobic biodegradation with biosparging | Air and necessary nutrients are injected into the contaminated area to enhance natural biodegradation | | X | Chlorinated VOCs are recalcitrant to aerobic biodegradation. |
| | | Volatilization with biosparging | Air injected into groundwater through a system of wells to remove volatiles and promote biodegradation. Treatment of off-gas may be necessary. | | X | Site geology would make it prohibitively costly to collect contaminated soil gas. |
| | | Reaction walls | Porous vertical wall containing a metal catalyst degrades halogenated compounds in groundwater as it passes through | | X | Difficult to implement where bottom of aquifer is greater than 15-20 feet deep. Technology is still experimental with little data available. |
| | | Biodegradation through Hydrogen Releasing Compound (HRC) injection | Hydrogen is released into the contaminated groundwater to encourage reductive dehalogenation. | X | | Technically feasible for treating chlorinated VOCs in hot spot areas to reduce 1,2 DCE and subsequently VC. |

**Table 3-1**
**Identification and Screening of Remedial Technologies for SWMU 2B Groundwater**

| General Response Action | Remediation or Technology | Process Options | Description | Screening Action | | Screening Comments |
|---|---|---|---|---|---|---|
| | | | | Retain | Reject | |
| Treatment (cont.) | In-situ treatment (cont.) | Biodegradation through Oxygen Releasing Compound (ORC) injection | An ORC is injected through direct push injections into the contaminated groundwater to enhance natural biodegradation | X | | Potentially useful. Would promote biodegradation of contamination in the sandy aquifer. May not be as effective in reducing contamination trapped in the silt and clays (lower permeability regions). |
| | | In-well air stripping (UVB or No-VOCs) | Air is injected up through water column in the well casing to circulate groundwater and strip out VOCs. Offgas is pulled from well and treated as necessary. | | X | Installation of No-VOCs could be cost-prohibitive for contaminant concentrations. |
| Discharge | Discharge of treated water | Surface water | Groundwater discharged into stormwater sewer system or ditch | | X | Not applicable. |
| | | POTW | Groundwater discharged into Hampton Roads Sanitary District system | | X | Not applicable. |
| | | Injection well | Treated groundwater discharged to groundwater injection well or field | | X | Not applicable. |
| Off-gas treatment | Physical/chemical treatment | Carbon adsorption | Contaminants adsorbed onto activated carbon by passing air through carbon column | | X | Not applicable. |
| | | Synthetic polymer membranes | Membrane allows organic contaminant to pass through, leaving clean residual air stream | | X | Not applicable. |
| | | Resin filter beds | Contaminants adsorbed onto resin by passing air through filter bed. May be less expensive over time than replacement of activated carbon. | | X | Not applicable. |
| | | Condensation | Stripping stream cooled to low temperature to condense contaminant molecules for recovery or disposal | | X | Not applicable. |
| | Thermal treatment | Direct fume incineration | Stripping stream raised to high temperature to oxidize contaminant molecules | | X | Not applicable. |
| | Biological treatment | Fixed film bioreactor | Chlorinated VOCs in gas phase are cometabolized by methanotrophic organisms | | X | Not applicable. |

**Table 3-2**
**Identification and Screening of Remedial Technologies for SWMU 2C Groundwater**

| General Response Action | Remediation or Technology | Process Options | Description | Screening Action | | Screening Comments |
|---|---|---|---|---|---|---|
| | | | | Retain | Reject | |
| No action | None | Not applicable | No action | X | | Retain as baseline alternative |
| Institutional controls | Administrative groundwater-use restrictions | Deed restrictions | Property in the area would include groundwater-use restrictions | X | | Potentially applicable if implemented in conjunction with other process options. |
| Monitoring | Monitoring groundwater | Long-term groundwater monitoring | Monitoring of contamination to track groundwater quality, and to monitor the potential for offsite migration. | X | | Technically feasible |
| Containment/ collection | Physical barriers | Slurry walls | Subsurface barriers consisting of a vertically constructed trench excavated under a slurry | | X | Horizontal isolation of contaminant could induce vertical migration into Yorktown Aquifer |
| | | Sheet piling | Subsurface barriers consisting of sheet piling inserted around contaminant plume | | X | Horizontal isolation of contaminant could induce vertical migration into Yorktown Aquifer |
| | Hydraulic barriers | Extraction wells | Series of pumping wells to extract contaminated groundwater and hydraulically isolate contaminant plume | | X | Technically feasible, however would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |
| | | Subsurface drains/trenches | Perforated pipe in trenches backfilled with porous media to collect water | | X | Based on location of contamination and depth of aquifer, trenches not as cost-effective as extraction wells |
| Treatment | Ex-situ biological treatment | Aerobic | Aerobic microorganisms are used to metabolize biodegradable organics in an aeration tank | | X | Emerging technologies can remove chlorinated organics, but these high-maintenance systems are not cost-effective compared to conventional technologies for volatile compounds. |
| | Physical/chemical treatment | Air stripping | Large volumes of air are mixed with the contaminated water in a packed column to promote transfer of VOCs to air. Treatment of off-gas may be necessary. | | X | Technically feasible, however groundwater extraction would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |
| | | Carbon adsorption | Contaminants adsorbed onto activated carbon by passing water through carbon column. Typically more expensive than air stripping for large volumes of water and long-term use. | | X | Technically feasible, however groundwater extraction would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |

**Table 3-2**
**Identification and Screening of Remedial Technologies for SWMU 2C Groundwater**

| General Response Action | Remediation or Technology | Process Options | Description | Screening Action | | Screening Comments |
|---|---|---|---|---|---|---|
| | | | | Retain | Reject | |
| Treatment (cont.) | Physical/chemical treatment (cont.) | Reverse osmosis | High pressure used to force water through a membrane, leaving contaminants behind | | X | Not cost-effective for removal of organic constituents relative to other technologies |
| | | Chemical oxidation | Contaminated water mixed with an oxidant to break down the organic compounds into $H_2O$, $CO_2$, and $Cl^-$ | | X | Potentially applicable. Typically more difficult to operate than air stripping; however, would not be affected by iron in waste stream. Groundwater extraction would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |
| | | Gravity oil-water separation | Mixture of oil and water flows into a tank where fuel or oil floats to the top | | X | No free product detected at this site; oil-water mixtures or emulsions not anticipated. |
| | | Coalescing oil-water separation | Fine droplets of dissolved oil are collected on a filter medium. Enlarged droplets are then released and can be separated readily | | X | No free product detected at this site; oil-water mixtures or emulsions not anticipated. |
| | | Dissolved air flotation (DAF) | Air is bubbled through the mixture; micron-size air bubbles attach to suspended POL particles and rise to the top of the separator | | X | No free product detected at this site; oil-water mixtures or emulsions not anticipated. |
| | In-situ treatment | Aerobic biodegradation with biosparging | Air and necessary nutrients are injected into the contaminated area to enhance natural biodegradation | | X | Chlorinated VOCs are recalcitrant to aerobic biodegradation. |
| | | Volatilization with biosparging | Air injected into groundwater through a system of wells to remove volatiles and promote biodegradation. Treatment of off-gas may be necessary. | | X | Site geology would make it prohibitively costly to collect contaminated soil gas. |
| | | Reaction walls | Porous vertical wall containing a metal catalyst degrades halogenated compounds in groundwater as it passes through | | X | Difficult to implement where bottom of aquifer is greater than 15-20 feet deep. Technology is still experimental with little data available. |
| | | Biodegradation through Hydrogen Releasing Compound (HRC) injection | Hydrogen is released into the contaminated groundwater to encourage reductive dehalogenation. | X | | Technically feasible for treating chlorinated VOCs in hot spot areas to reduce 1,2 DCE and subsequently VC. |

**Table 3-2**
**Identification and Screening of Remedial Technologies for SWMU 2C Groundwater**

| General Response Action | Remediation or Technology | Process Options | Description | Screening Action | | Screening Comments |
|---|---|---|---|---|---|---|
| | | | | Retain | Reject | |
| Treatment (cont.) | In-situ treatment (cont.) | Biodegradation through Oxygen Releasing Compound (ORC) injection | An ORC is injected through direct push injections into the contaminated groundwater to enhance natural biodegradation | X | | Potentially useful. Would promote biodegradation of contamination in the sandy aquifer. May not be as effective in reducing contamination trapped in the silt and clays (lower permeability regions). |
| | | In-well air stripping (UVB or No-VOCs) | Air is injected up through water column in the well casing to circulate groundwater and strip out VOCs. Offgas is pulled from well and treated as necessary. | | X | Installation of No-VOCs could be cost-prohibitive for contaminant concentrations. |
| Discharge | Discharge of treated water | Surface water | Groundwater discharged into stormwater sewer system or ditch | | X | Not applicable. |
| | | POTW | Groundwater discharged into Hampton Roads Sanitary District system | | X | Not applicable. |
| | | Injection well | Treated groundwater discharged to groundwater injection well or field | | X | Not applicable. |
| Off-gas treatment | Physical/chemical treatment | Carbon adsorption | Contaminants adsorbed onto activated carbon by passing air through carbon column | | X | Not applicable. |
| | | Synthetic polymer membranes | Membrane allows organic contaminant to pass through, leaving clean residual air stream | | X | Not applicable. |
| | | Resin filter beds | Contaminants adsorbed onto resin by passing air through filter bed. May be less expensive over time than replacement of activated carbon. | | X | Not applicable. |
| | | Condensation | Stripping stream cooled to low temperature to condense contaminant molecules for recovery or disposal | | X | Not applicable. |
| | Thermal treatment | Direct fume incineration | Stripping stream raised to high temperature to oxidize contaminant molecules | | X | Not applicable. |
| | Biological treatment | Fixed film bioreactor | Chlorinated VOCs in gas phase are cometabolized by methanotrophic organisms | | X | Not applicable. |

**Table 3-3**
**Identification and Screening of Remedial Technologies for SWMU 2E Groundwater**

| General Response Action | Remediation or Technology | Process Options | Description | Screening Action | | Screening Comments |
|---|---|---|---|---|---|---|
| | | | | Retain | Reject | |
| No action | None | Not applicable | No action | X | | Retain as baseline alternative |
| Institutional controls | Administrative groundwater-use restrictions | Deed restrictions | Property in the area would include groundwater-use restrictions | X | | Potentially applicable if implemented in conjunction with other process options. |
| Monitoring | Monitoring groundwater | Long-term groundwater monitoring | Monitoring of contamination to track groundwater quality, and to monitor the potential for offsite migration. | X | | Technically feasible |
| Free product collection | Extraction | Manual | Use of a bailer to remove floating hydrocarbon layer from the water table on a monthly basis until no more product is recoverable. | X | | Based upon performance testing of pump systems and distribution of free product, this scenario is technically feasible. |
| | | Pulsed positive-displacement product pump | Solar-powered unit would pump a few minutes a day until the product thickness decreases to less than 0.01 feet for 3 months. | | X | Not cost-effective based on the results of performance tests conducted at NAS Oceana that indicate that the free-product contamination is not easily recoverable by pumping systems. |
| | | Constant-rate single-pump system | Specialized pump that removes floating hydrocarbon layer from water table. | | X | Not cost-effective based on the results of performance tests conducted at NAS Oceana that indicate that the free-product contamination is not easily recoverable by pumping systems. |
| | | Constant-rate dual-pump system | Pump system that lowers water table with one pump and removes hydrocarbon layer with other. | | X | Not cost-effective based on the results of performance tests conducted at NAS Oceana that indicate that the free-product contamination is not easily recoverable by pumping systems. |
| Containment/ collection | Physical barriers | Slurry walls | Subsurface barriers consisting of a vertically constructed trench excavated under a slurry | | X | Horizontal isolation of contaminant could induce vertical migration into Yorktown Aquifer |
| | | Sheet piling | Subsurface barriers consisting of sheet piling inserted around contaminant plume | | X | Horizontal isolation of contaminant could induce vertical migration into Yorktown Aquifer |
| | Hydraulic barriers | Extraction wells | Series of pumping wells to extract contaminated groundwater and hydraulically isolate contaminant plume | | X | Technically feasible, however would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |
| | | Subsurface drains/ trenches | Perforated pipe in trenches backfilled with porous media to collect water | | X | Based on location of contamination and depth of aquifer, trenches not as cost-effective as extraction wells |

**Table 3-3**
**Identification and Screening of Remedial Technologies for SWMU 2E Groundwater**

| General Response Action | Remediation or Technology | Process Options | Description | Screening Action | | Screening Comments |
|---|---|---|---|---|---|---|
| | | | | Retain | Reject | |
| Treatment | Ex-situ biological treatment | Aerobic | Aerobic microorganisms are used to metabolize biodegradable organics in an aeration tank | | X | Emerging technologies can remove chlorinated organics, but these high-maintenance systems are not cost-effective compared to conventional technologies for volatile compounds. |
| Treatment (cont.) | Physical/chemical treatment | Air stripping | Large volumes of air are mixed with the contaminated water in a packed column to promote transfer of VOCs to air. Treatment of off-gas may be necessary. | | X | Technically feasible, however groundwater extraction would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |
| | | Carbon adsorption | Contaminants adsorbed onto activated carbon by passing water through carbon column. Typically more expensive than air stripping for large volumes of water and long-term use. | | X | Technically feasible, however groundwater extraction would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |
| | | Reverse osmosis | High pressure used to force water through a membrane, leaving contaminants behind | | X | Not cost-effective for removal of organic constituents relative to other technologies |
| | | Chemical oxidation | Contaminated water mixed with an oxidant to break down the organic compounds into $H_2O$, $CO_2$, and $Cl^-$ | | X | Potentially applicable. Typically more difficult to operate than air stripping; however, would not be affected by iron in waste stream. Groundwater extraction would be cost prohibitive, especially for the relatively low levels (and relatively small area) of contamination at the site. |
| | | Gravity oil-water separation | Mixture of oil and water flows into a tank where fuel or oil floats to the top | | X | No free product detected at this site; oil-water mixtures or emulsions not anticipated. |
| | | Coalescing oil-water separation | Fine droplets of dissolved oil are collected on a filter medium. Enlarged droplets are then released and can be separated readily | | X | No free product detected at this site; oil-water mixtures or emulsions not anticipated. |
| | | Dissolved air flotation (DAF) | Air is bubbled through the mixture; micron-size air bubbles attach to suspended POL particles and rise to the top of the separator | | X | No free product detected at this site; oil-water mixtures or emulsions not anticipated. |

**Table 3-3**
**Identification and Screening of Remedial Technologies for SWMU 2E Groundwater**

| General Response Action | Remediation or Technology | Process Options | Description | Screening Action | | Screening Comments |
|---|---|---|---|---|---|---|
| | | | | Retain | Reject | |
| | In-situ treatment | Aerobic biodegradation with biosparging | Air and necessary nutrients are injected into the contaminated area to enhance natural biodegradation | | X | Chlorinated VOCs are recalcitrant to aerobic biodegradation. |
| | | Volatilization with biosparging | Air injected into groundwater through a system of wells to remove volatiles and promote biodegradation. Treatment of off-gas may be necessary. | | X | Site geology would make it prohibitively costly to collect contaminated soil gas. |
| | | Reaction walls | Porous vertical wall containing a metal catalyst degrades halogenated compounds in groundwater as it passes through | | X | Difficult to implement where bottom of aquifer is greater than 15-20 feet deep. Technology is still experimental with little data available. |
| Treatment (cont.) | In-situ treatment (cont.) | Biodegradation using Oxygen Releasing Compound (ORC) | An ORC is injected through direct push injections into the contaminated groundwater to enhance natural biodegradation | X | | Potentially useful. Would promote biodegradation of contamination in the sandy aquifer. May not be as effective in reducing contamination trapped in the silt and clays (lower permeability regions). |
| | | In-well air stripping (UVB or No-VOCs) | Air is injected up through water column in the well casing to circulate groundwater and strip out VOCs. Offgas is pulled from well and treated as necessary. | | X | Installation of No-VOCs could be cost-prohibitive for contaminant concentrations. |
| Discharge | Discharge of treated water | Surface water | Groundwater discharged into stormwater sewer system or ditch | | X | Not applicable. |
| | | POTW | Groundwater discharged into Hampton Roads Sanitary District system | | X | Not applicable. |
| | | Injection well | Treated groundwater discharged to groundwater injection well or field | | X | Not applicable. |

**Table 3-3**
**Identification and Screening of Remedial Technologies for SWMU 2E Groundwater**

| General Response Action | Remediation or Technology | Process Options | Description | Screening Action | | Screening Comments |
|---|---|---|---|---|---|---|
| | | | | Retain | Reject | |
| Off-gas treatment | Physical/chemical treatment | Carbon adsorption | Contaminants adsorbed onto activated carbon by passing air through carbon column | | X | Not applicable. |
| | | Synthetic polymer membranes | Membrane allows organic contaminant to pass through, leaving clean residual air stream | | X | Not applicable. |
| | | Resin filter beds | Contaminants adsorbed onto resin by passing air through filter bed. May be less expensive over time than replacement of activated carbon. | | X | Not applicable. |
| | | Condensation | Stripping stream cooled to low temperature to condense contaminant molecules for recovery or disposal | | X | Not applicable. |
| | Thermal treatment | Direct fume incineration | Stripping stream raised to high temperature to oxidize contaminant molecules | | X | Not applicable. |
| | Biological treatment | Fixed film bioreactor | Chlorinated VOCs in gas phase are cometabolized by methanotrophic organisms | | X | Not applicable. |
| Free-product disposal | Disposal of collected free product | Off-site disposal facility | Free-product collected by recovery scenarios is removed and disposed of by off-site contractor at a permitted facility | X | | Technically feasible. |

File Path: v:\18gis\oceana\figures\oceana_0500.apr

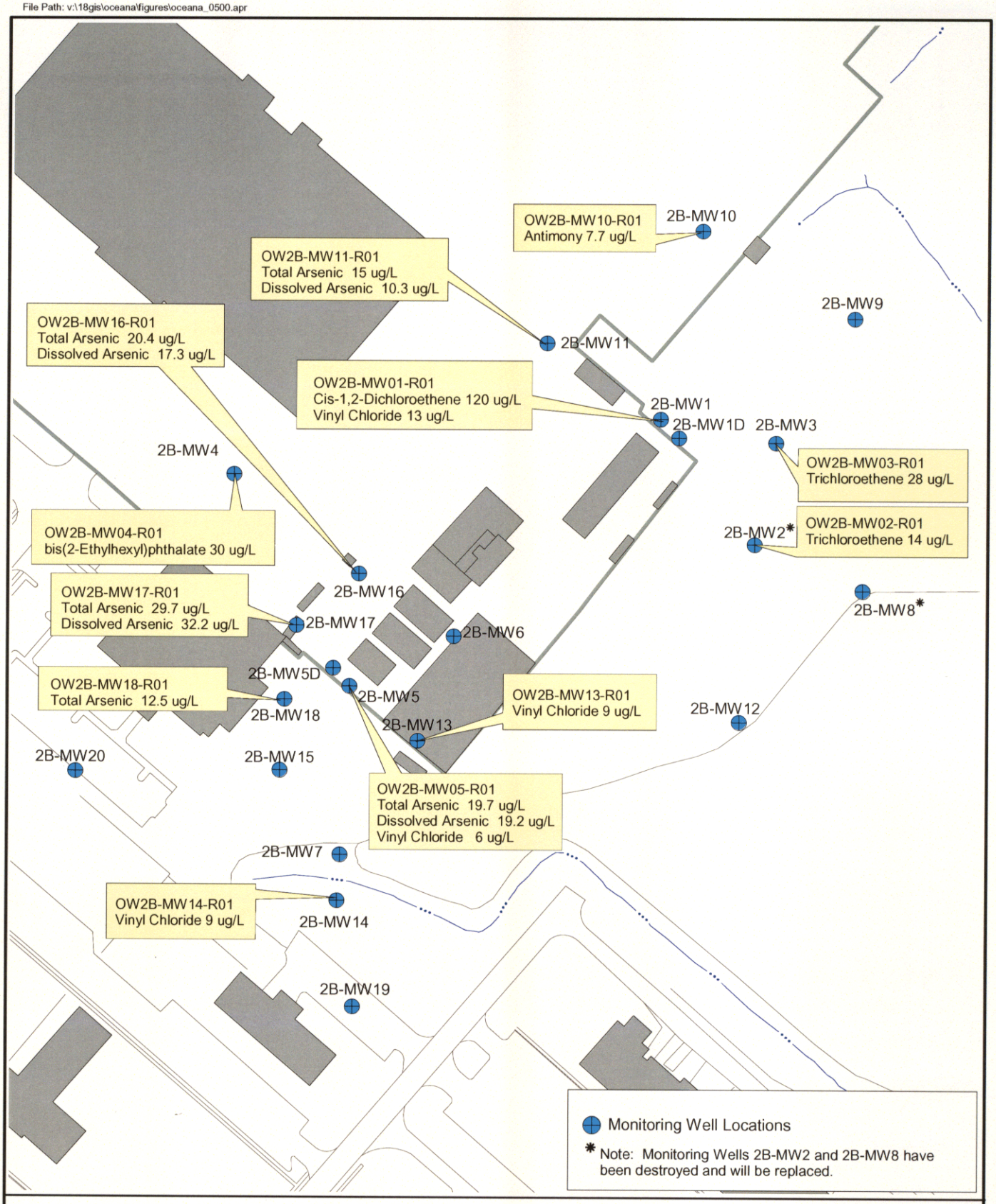



Figure 3-1
Proposed Long-Term Monitoring Well Network
SWMU 2B
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

00606 F B3y

File Path: v:\18gis\oceana\figures\oceana_0500.apr

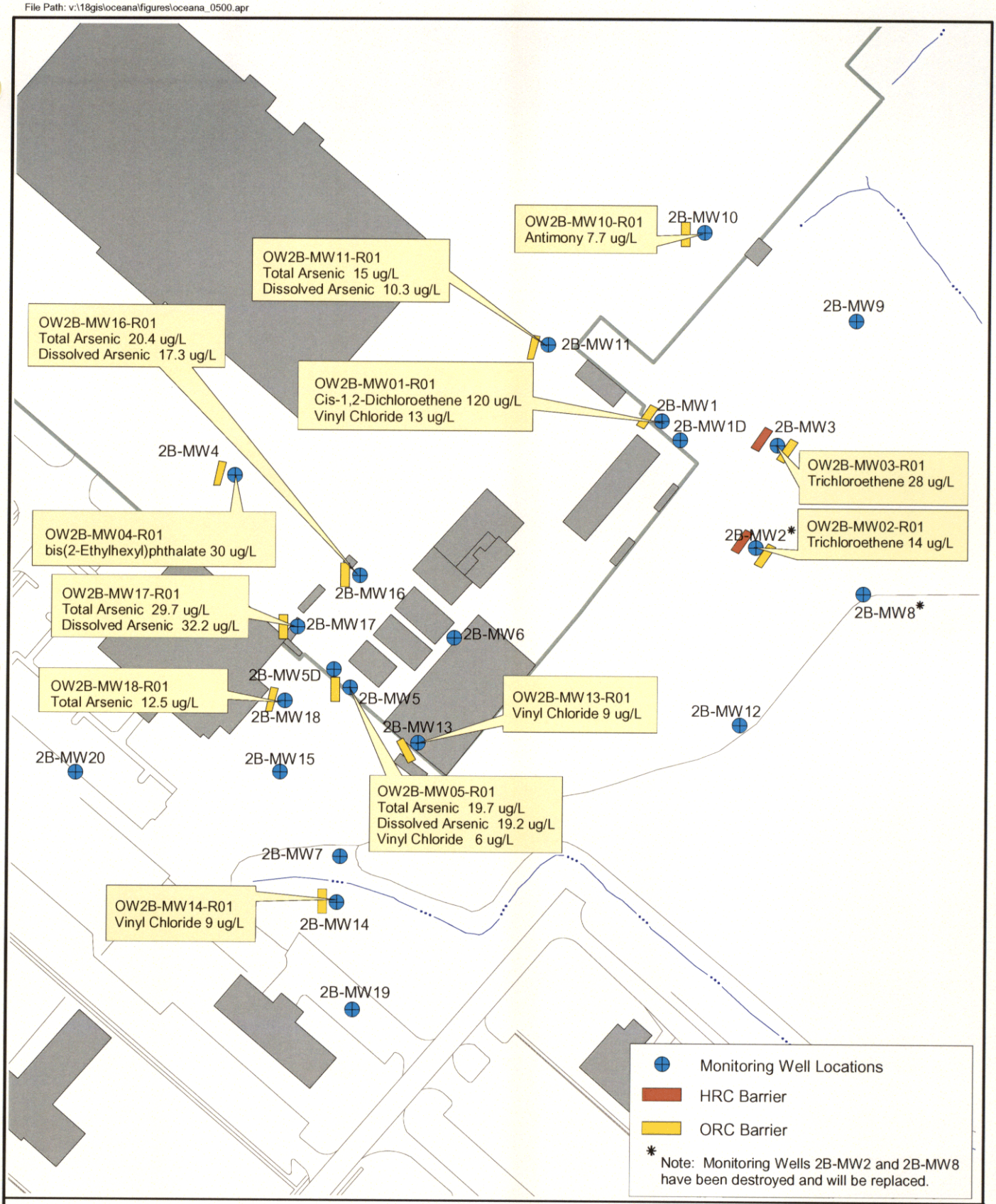
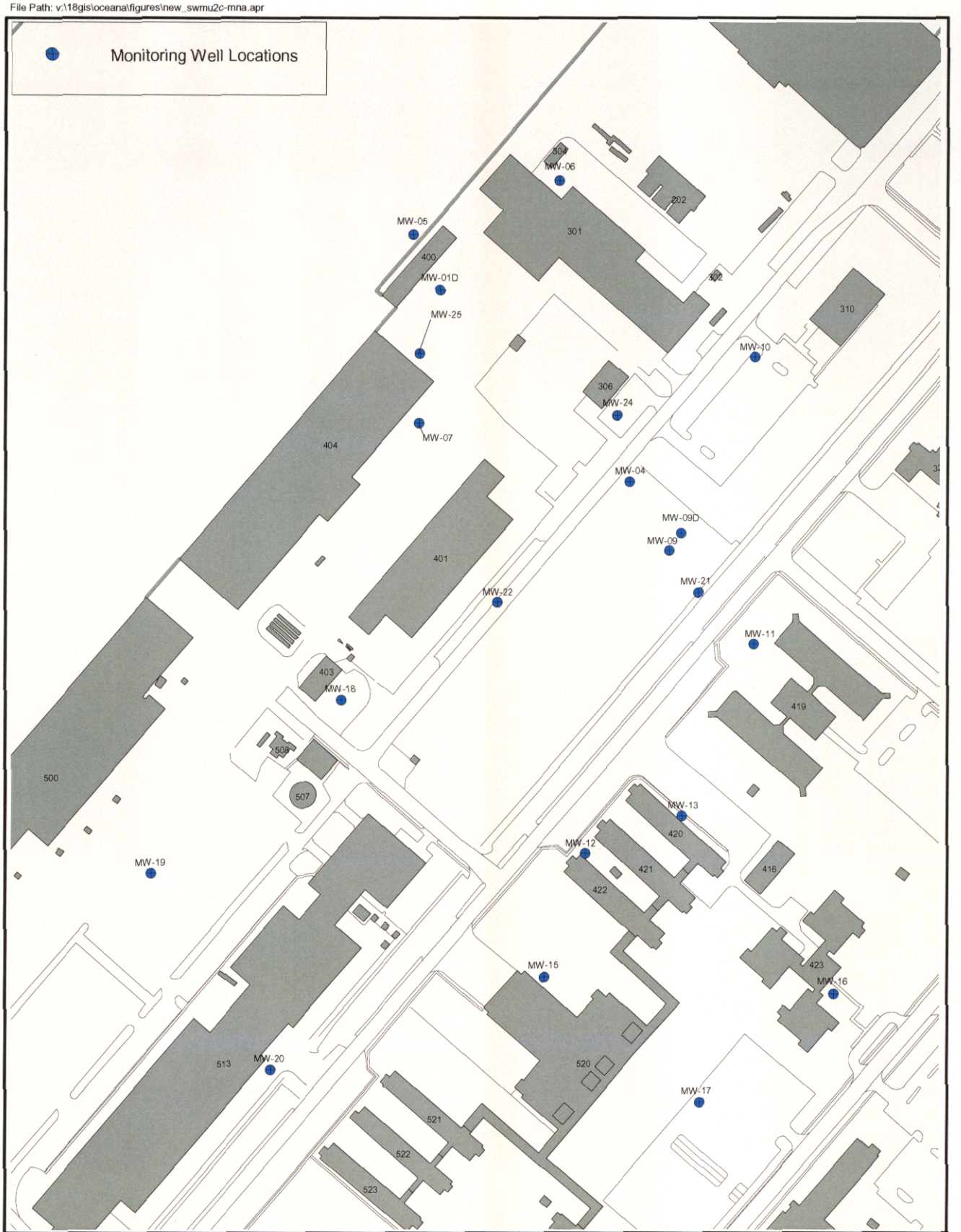



Figure 3-2
Proposed HRC/ORC Injection
Barrier Locations - SWMU 2B
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

File Path: v:\18gis\oceana\figures\new_swmu2c-mna.apr



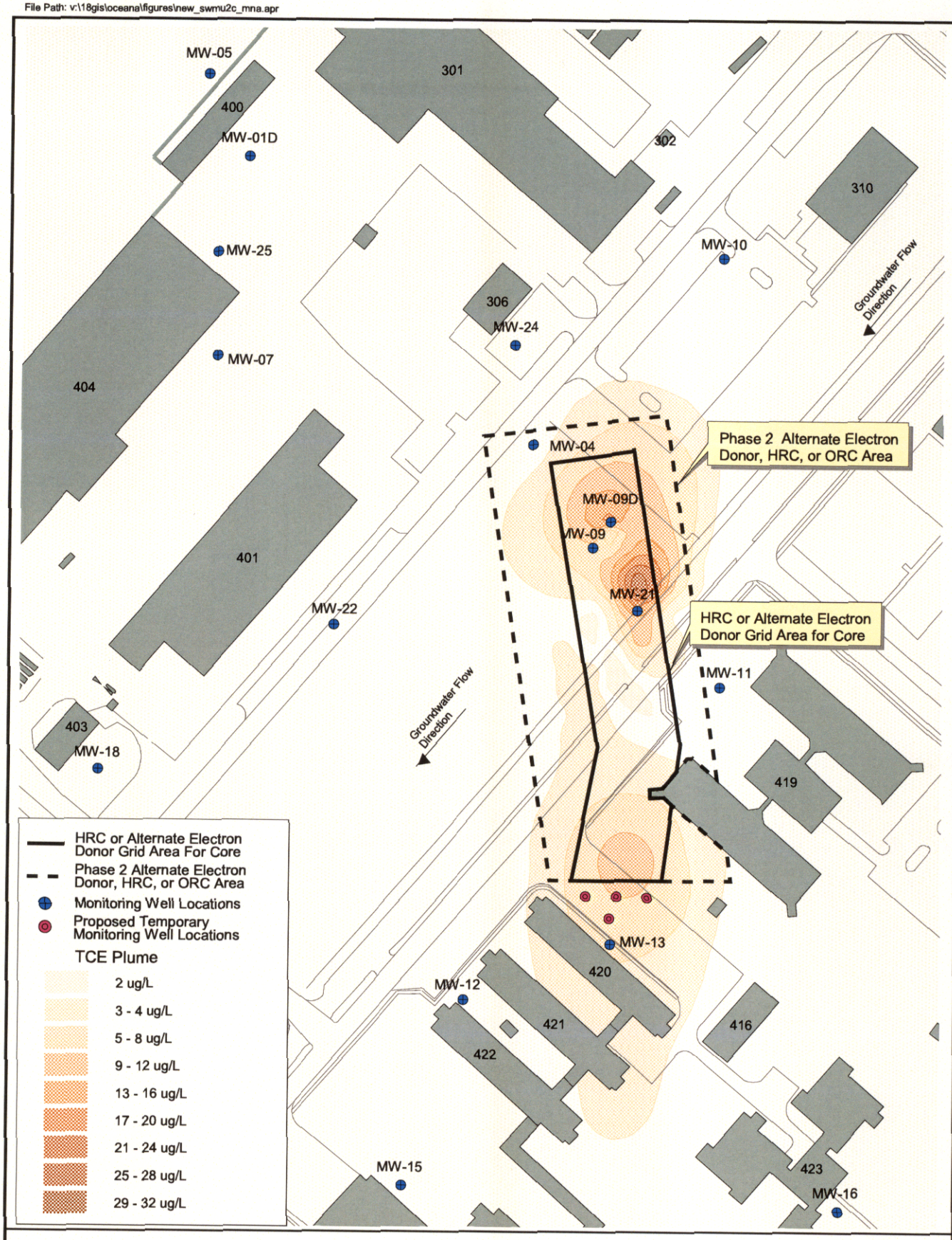

N
W E
S

0 100 200 300 Feet

Figure 3-3
Proposed Monitored Natural Attenuation
Well Network - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

File Path: v:\18gis\oceana\figures\new_swmu2c_mna.apr



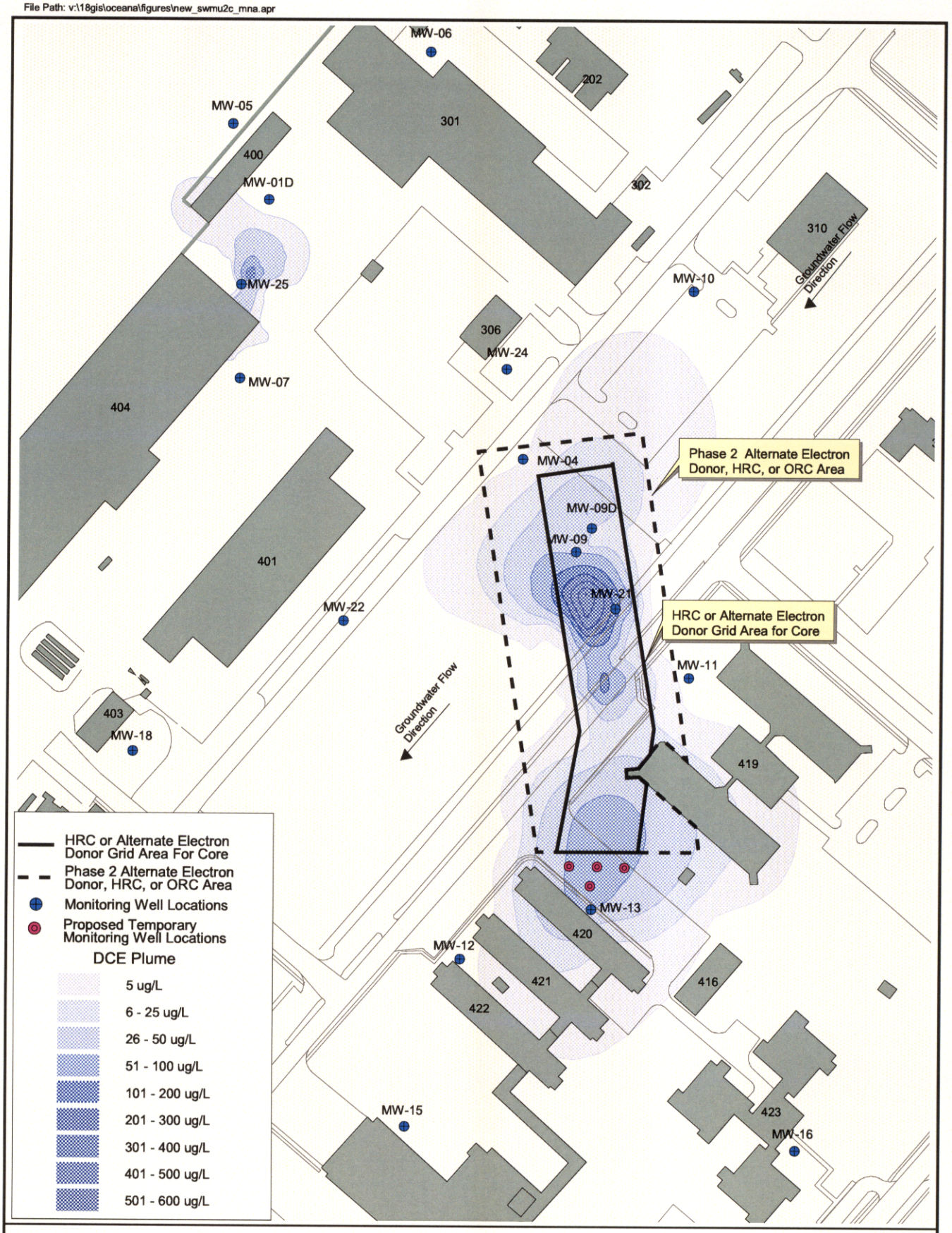

N
W E
S

0 90 180 270 Feet

Figure 3-4A
Proposed HRC or Alternate Electron Donor Injection Locations - SWMU 2C (TCE Plume)
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

File Path: v:\18gis\oceana\figures\new_swmu2c_mna.apr



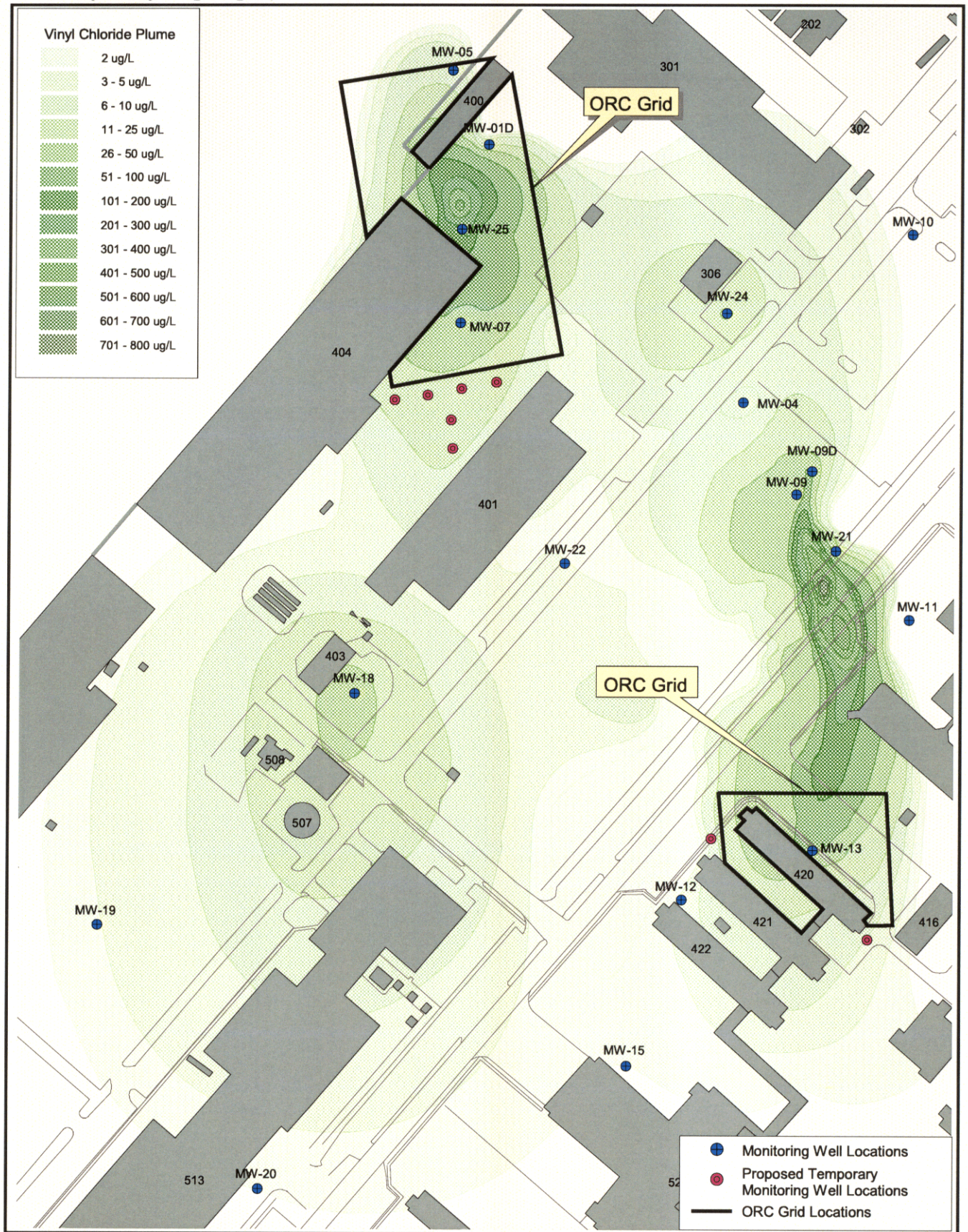

N
W E
S

0 90 180 270 Feet

Figure 3-4B
Proposed HRC or Alternative Electron
Donor Injection Locations - SWMU 2C (DCE Plume)
NAS Oceana, Virginia Beach, Virginia

CH2M HILL

File Path: v:\18gis\oceana\figures\new_swmu2c_mna.apr



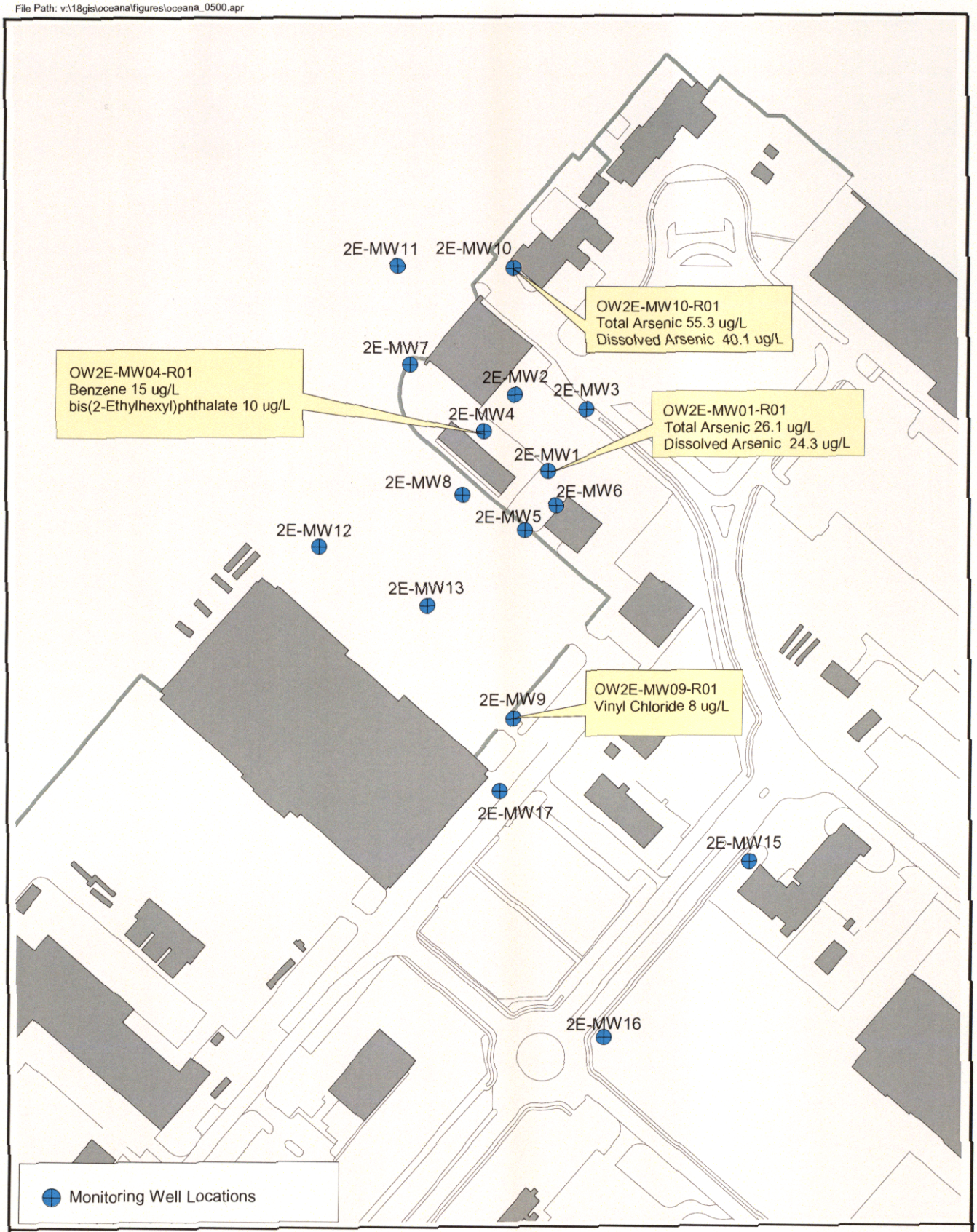

N
W E
S

0 90 180 270 Feet

Figure 3-5
Proposed ORC Injection Locations - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

CH2M HILL

File Path: v:\18gis\oceana\figures\oceana_0500.apr



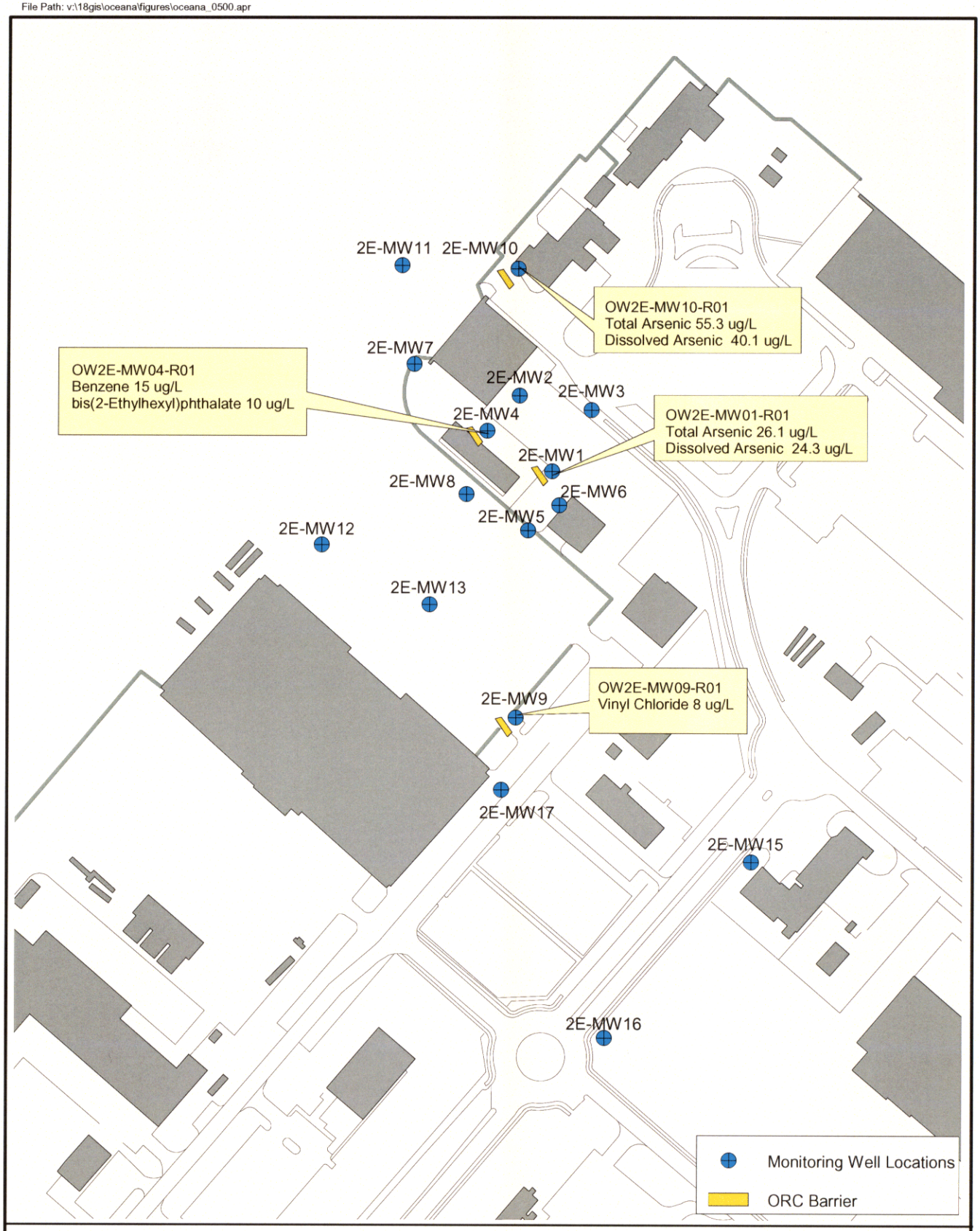

N
W E
S

0 100 200 300 Feet

Figure 3-6
Proposed Long-Term Monitoring Well Network - SWMU 2E
NAS Oceana, Virginia Beach, Virginia

CH2M HILL

File Path: v:\18gis\oceana\figures\oceana_0500.apr




N
W E
S

0 100 200 300 Feet

Figure 3-7
Proposed ORC Barrier Locations - SWMU 2E
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

SECTION 4

# Detailed Analysis of Remedial Alternative

The remedial alternatives which were developed in Section 3.0 are evaluated in detail in this section. Each alternative was developed to address threats to human health posed by contamination at SWMUs 2B, 2C and 2E. The National Contingency Plan (NCP) requires that the remedial alternatives be evaluated against the nine criteria listed below, as defined in the NCP. The first seven criteria are addressed in this Feasibility Study (FS). The last two criteria will be addressed in the Decision Document (DD). The nine criteria are:

- Protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements (ARARs)
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

## 4.1 Evaluation Criteria

The detailed alternative analysis is the means for assembling and evaluating technical and policy considerations to develop the rationale for selecting a remedy. The following paragraphs define and detail each of the nine criteria.

### 4.1.1 Overall Protection of Human Health and the Environment

This evaluation criterion is an assessment of whether each alternative achieves and maintains adequate protection of human health and the environment. The overall appraisal of protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. Another consideration is the statutory preference for onsite remedial actions.

### 4.1.2 Compliance with ARARs

This evaluation criterion is used to determine whether an alternative would meet all federal, state, and local ARARs. When an ARAR is not met, the basis for justifying one of the six waivers allowed under CERCLA would be discussed.

### 4.1.3 Long-Term Effectiveness and Permanence

Under this criterion the results of a remedial alternative are evaluated in terms of the risk remaining at the site after response objectives have been met. The primary focus of this evaluation is the extent and effectiveness of the actions or controls that may be required to

manage the risk posed by treatment residuals or untreated wastes. Factors to be considered and addressed are magnitude of residual risk, adequacy of controls, and reliability of controls. Magnitude of residual risk is the assessment of the risk remaining from untreated waste or treatment residuals after remediation. Adequacy and reliability of controls is the evaluation of the controls that can be used to manage treatment residuals or untreated wastes that remain at the facility. The evaluation may include an assessment of institutional controls to determine whether they are sufficient to ensure that any exposure to human and environmental receptors is within protective levels.

### 4.1.4 Reduction of Toxicity, Mobility, and Volume

This evaluation criterion addresses the statutory preference for selecting remedial actions that, as their principal element, use technologies that permanently remediate and significantly reduce the toxicity, mobility, or volume of the hazardous substances. This preference is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction of contaminant mobility, or reduction of total volume of contaminated media. When evaluating this criterion, an assessment is made as to whether remediation is used to reduce principal threats, including the extent to which toxicity, mobility, or volume are reduced either separately or in combination with one another. Factors that would be focused on include:

- Remediation processes employed by the remedy
- Amount of hazardous materials that would be remediated
- Degree of expected reduction in toxicity, mobility, or volume measured as a percentage of reduction
- Degree to which the remediation would be irreversible
- Type and quantity of treatment residuals that would remain following remediation
- Whether the alternative would satisfy the statutory preference for treatment as a principal element

### 4.1.5 Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation phase until remedial action objectives (RAOs) are met. Alternatives would be evaluated with respect to their effects on human health and the environment during implementation of the remedial action. The following factors remedial action objectives would be addressed for each alternative:

- Protection of the community during remedial actions
- Protection of workers during remedial actions
- Environmental impacts during remedial actions
- Time until RAOs are achieved

### 4.1.6 Implementability

The implementability criterion addresses the technical and administrative feasibility of executing an alternative and the availability of various services and materials required during its implementation. Technical feasibility includes construction, operation, reliability of technology, ease of undertaking additional remedial action, and monitoring. Administrative feasibility refers to the activities needed to coordinate with other offices and agencies (e.g., local permits). Availability of services and materials includes availability of adequate off-facility treatment, storage capacity, and disposal services; necessary equipment and specialists; services and materials; and prospective technologies.

### 4.1.7 Cost

For the cost analysis of alternatives, the expenditures required to complete each remedial action are estimated in terms of both capital and annual O&M costs. Using these values, a present-worth calculation for each alternative then can be made for comparison.

Capital costs consist of direct and indirect costs. Direct costs include the cost of construction, equipment, land and site development, treatment, transportation, and disposal. Indirect costs include engineering expenses, license or permit costs, and contingency allowances.

Annual O&M costs are the post-construction costs required to ensure the continued effectiveness of the remedial action. Components of annual O&M cost include the cost of operating labor, maintenance materials and labor, auxiliary materials and energy, residue disposal, purchased services, administration, maintenance reserve and contingency funds, rehabilitation, monitoring, and periodic site reviews.

Expenditures that occur over a time period are analyzed using present worth, which discounts all future costs to a common base year. Present-worth analysis allows the cost of remedial action alternatives to be compared on the basis of a single figure representing the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the life of the remedial project. Assumptions associated with the present-worth calculations include a discount rate of 4.2 percent (OMB Circular No. A-94, Appendix C, Revised January 2000), cost estimates in the planning years in constant dollars, and a period of performance that would vary depending on the activity, but would not exceed 30 years.

The cost estimates for this section are provided to an accuracy of +50 percent to -30 percent. The alternative cost estimates are in 2001 dollars and are based on conceptual design from information available at the time of this study. The actual cost of the project would depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables. Most of these factors are not expected to affect the relative cost differences between alternatives.

### 4.1.8 State Acceptance

This assessment evaluates the technical and administrative issues and concerns the state may have regarding each of the alternatives. This criterion is not discussed in this report, but would be addressed in the DD.

### 4.1.9 Community Acceptance

This assessment evaluates the issues and concerns the public may have regarding each of the alternatives. As with state acceptance, this criterion is not discussed in this report, but would be addressed in the DD.

## 4.2 Evaluation of Remedial Alternatives for SWMUs 2B, 2C and 2E

### 4.2.1 Detailed Analysis of Remedial Alternatives

In Section 3, remedial alternatives, including the no-action alternative, were developed for each SWMU with the goal of meeting the RAOs. This section provides a detailed evaluation of each alternative for SWMUs 2B, 2C and 2E on the basis of the seven NCP criteria previously discussed. The detailed evaluation for each alternative for SWMUs 2B, 2C and 2E is presented in Tables 4-1, 4-2, and 4-3.

**Table 4-1**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2B**

| Evaluation Criteria | Alternative 1<br>No Action | Alternative 2<br>Institutional Controls with LTM | Alternative 3<br>HRC/ORC, Institutional Controls with LTM |
|---|---|---|---|
| **Overall Protection of Human Health and Environment** | | | |
| Prevention of unacceptable risks to potential receptors to the groundwater | Potential risk to receptors from the water table aquifer is posed by current conditions at the site if the groundwater is used as a potable supply. However, potable use of the groundwater is unlikely (although no measures would be in place to prevent it). | Potential risk to receptors from the water table aquifer is posed by current conditions at the site if groundwater is used as potable water supply. However, potable use of the groundwater is unlikely and institutional controls would prevent any potential potable use. LTM will detect any change in current groundwater concentrations. | Potential risk to receptors from the water table aquifer is posed by current conditions at the site if groundwater is used as a potable water supply. However, potable use of the groundwater is unlikely and institutional controls would prevent any potential potable use. Because the use of the water table aquifer for potable water is unlikely, the benefit of potentially reducing contamination levels through HRC/ORC injection may not be warranted.LTM will detect any change in current groundwater concentrations. |

**Table 4-1**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2B**

| Evaluation Criteria | Alternative 1<br>No Action | Alternative 2<br>Institutional Controls with LTM | Alternative 3<br>HRC/ORC, Institutional Controls with LTM |
|---|---|---|---|
| **Compliance with ARARs** | | | |
| Chemical-Specific ARARs | Currently groundwater exceeds drinking water ARARs (MCLs) and tap water RBCs for several metals and chlorinated VOCs. Risk to contaminated groundwater above the MCLs and PRGs remains. | Groundwater-use restrictions would prevent groundwater use as water supply, therefore, would protect receptors against groundwater exceeding the MCLs and PRGs. LTM would track changes in groundwater quality and the potential for plume migration. | Groundwater-use restrictions would prevent groundwater use as water supply, therefore, would protect receptors against groundwater exceeding the MCLs and PRGs. HRC/ORC may reduce organic contaminant concentrations (ideally to within ARARs), however, with institutional controls in place, this may not be necessary. In addition, inorganics could be reduced to insoluble forms; however, this may be only on a temporary basis (while injection material persists in the aquifer) because of their ubiquitous presence in groundwater. Therefore, LTM would track changes in groundwater quality and the potential for plume migration of the inorganics as well as track the progress of the enhanced biodegradation. |
| Action-Specific ARARs | Not applicable. | Meets all action-specific ARARs. | Meets all action-specific ARARs. |
| Location-Specific ARARs | Not applicable. | Meets all location-specific ARARs. | Meets all location-specific ARARs. |
| **Long-Term Effectiveness and Permanence** | | | |
| Groundwater | Source not remediated. Potential risk posed by potable use of groundwater. No permanent means to prevent future use of site in a manner that would result in unacceptable risks to groundwater. | Source not remediated. Potential risk posed by potable use of groundwater. Institutional controls and monitoring would be relied upon to eliminate unacceptable risks to groundwater. | Source may be remediated through HRC/ORC injection. Potential risk posed by potable use of groundwater. Institutional controls and monitoring would be relied upon to eliminate unacceptable risks to groundwater (if ARARs are not attained). |

**Table 4-1**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2B**

| Evaluation Criteria | Alternative 1<br>No Action | Alternative 2<br>Institutional Controls with LTM | Alternative 3<br>HRC/ORC, Institutional Controls with LTM |
|---|---|---|---|
| Need for Five Year Review | Because contamination (groundwater) remains onsite, five-year reviews would be required. | See Alternative 1. | Five-year site reviews may be required if ARARs are not attained. |
| **Reduction of Toxicity, Mobility, or Volume** | | | |
| Groundwater | No toxicity or volume reduction. | Toxicity associated with contaminated media would reduce due to natural degradation of TCE and daughter products. Volume reduction is attained through natural degradation. | Toxicity associated with contaminated media may be reduced from enhanced degradation of TCE and daughter products. Volume reduction is attained through enhanced degradation. |
| Type and Quantity of Residuals Remaining After Remediation | No treatment undertaken, therefore, groundwater contamination remains onsite. | No treatment undertaken. Groundwater contamination remains onsite. | Treatment consists of HRC/ORC injection. Depending on effectiveness of HRC/ORC, residual contamination may remain after remediation. |
| **Short-Term Effectiveness** | | | |
| Groundwater | No action taken, therefore, no additional short-term risk added. | Remedy implementation does not add to risk. | A moderate amount of construction traffic will be associated with hauling material from offsite sources. |
| Time Until Action is Complete | Not applicable. | Annual LTM will occur as deemed necessary. | HRC/ORC injection is expected to take effect in approximately six months. Based on previous experience, Regenesis, the manufacturer of HRC/ORC, estimated that the biodegradation half-lives can be reduced by 10 percent and that the remediation goals may be achieved over a period of 2 to 4 years. Annual LTM will continue as deemed necessary. |

**Table 4-1**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2B**

| Evaluation Criteria | Alternative 1<br>No Action | Alternative 2<br>Institutional Controls with LTM | Alternative 3<br>HRC/ORC, Institutional Controls with LTM |
|---|---|---|---|
| **Implementability** | | | |
| Ability to Construct and Operate | Not applicable. | Operation would consist of LTM. Groundwater-use restrictions would require consent from base command. | The HRC/ORC injection would be performed using traditional direct-push methods. Operation would consist of HRC/ORC injection and LTM. Groundwater-use restrictions would require consent from base command. |
| Ease of Implementing Additional Action if Needed | Very easy to implement additional action. | Very easy to implement additional action. | Easy to implement additional action. |
| Ability to Monitor Effectiveness | Easily monitored during five-year site reviews. | Easily monitored during five-year site reviews. LTM will also be used to evaluate the groundwater quality. | HRC/ORC effectiveness will be determined through traditional sampling methods. LTM also will be used to evaluate groundwater quality. Easily monitored during five-year site reviews. |
| **Cost** | | | |
| Capital Cost | $0 | $332,200 | $493,300 |
| Annual O&M Cost | $2,000 (every 5 years) | $79,100 | $92,400 |
| Present-Worth | $6,500 | $1,645,400 | $2,026,100 |

Notes:

LTM Long-term monitoring

**Table 4-2**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2C**

| Evaluation Criteria | Alternative 1<br>No Action | Alternative 2<br>Institutional Controls with MNA | Alternative 3<br>Enhanced Biodegradation, Institutional Controls with MNA |
|---|---|---|---|
| **Overall Protection of Human Health and Environment** | | | |
| Prevention of unacceptable risks to potential receptors to the groundwater | Potential risk to receptors from the water table aquifer is posed by current conditions at the site if the groundwater is used as a potable supply. However, potable use of the groundwater is unlikely (although no measures would be in place to prevent it). | Potential risk to receptors from the water table aquifer is posed by current conditions at the site if groundwater is used as potable water supply. However, potable use of the groundwater is unlikely and institutional controls would prevent potable use. MNA will detect any change in current groundwater concentrations. | Potential risk to receptors from the water table aquifer is posed by current conditions at the site if groundwater is used as a potable water supply. However, potable use of the groundwater is unlikely and institutional controls would prevent potable use. Although pilot testing will be necessary, it is likely that enhanced biodegradation will reduce contaminant levels to below current conditions. Monitoring will track any changes in groundwater concentrations. |
| **Compliance with ARARs** | | | |
| Chemical-Specific ARARs | Currently groundwater exceeds drinking water ARARs (MCLs) and tap water RBCs for several metals and chlorinated VOCs. Risk to contaminated groundwater above the MCLs and PRGs remains. | Groundwater-use restrictions would prevent groundwater use as water supply, therefore, potential drinking water ARARs would be met. MNA would track changes in groundwater quality and the potential for plume migration. | Groundwater-use restrictions would prevent groundwater use as water supply, therefore, potential drinking water ARARs would be met. Enhanced biodegradation may reduce organic concentrations. In addition, inorganics could be reduced to insoluble forms; however, this may be only on a temporary basis (while injection material persists in the aquifer) because of their ubiquitous presence in groundwater. MNA would determine the effectiveness of enhanced biodegradation as well as track changes in groundwater quality and the potential for plume migration. |
| Action-Specific ARARs | Not applicable. | Meets all action-specific ARARs. | Meets all action-specific ARARs. |
| Location-Specific ARARs | Not applicable. | Meets all location-specific ARARs. | Meets all location-specific ARARs. |

**Table 4-2**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2C**

| Evaluation Criteria | Alternative 1<br>No Action | Alternative 2<br>Institutional Controls with MNA | Alternative 3<br>Enhanced Biodegradation, Institutional Controls with MNA |
|---|---|---|---|
| **Long-Term Effectiveness and Permanence** | | | |
| Groundwater | Source not remediated. Potential risk posed by potable use of groundwater. No permanent means to prevent future use of site in a manner that would result in unacceptable risks to groundwater. | Source not remediated. Potential risk posed by potable use of groundwater. Institutional controls and MNA would be relied upon to track changes in groundwater contaminants. | Source remediated through enhanced biodegradation. Potential risk posed by potable use of groundwater. Enhanced biodegradation will likely reduce contaminant levels to below current levels (although pilot testing will be necessary). Institutional controls and monitoring would be relied upon to ensure that degradation of residual contaminants is occurring following enhanced biodegradation, and eliminate unacceptable risks to groundwater. |
| Need for Five Year Review | Because contaminated material (groundwater) remains onsite, five-year reviews would be required. | See Alternative 1. | See Alternative 1. |
| **Reduction of Toxicity, Mobility, or Volume** | | | |
| Groundwater | No toxicity or volume reduction. | Toxicity associated with contaminated media would reduce due to natural degradation of TCE and some daughter products. Volume reduction is attained through natural degradation. | Toxicity associated with contaminated media would be reduced from enhanced degradation of TCE and daughter products. Volume reduction is attained through enhanced degradation. |
| Type and Quantity of Residuals Remaining After Remediation | No treatment undertaken. Therefore, groundwater contamination remains onsite. | No treatment undertaken. Groundwater contamination remains onsite. | Treatment consists of enhanced biodegradation. Depending on effectiveness of the enhanced biodegradation, residual contamination may remain after remediation. |

**Table 4-2**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2C**

| Evaluation Criteria | Alternative 1 No Action | Alternative 2 Institutional Controls with MNA | Alternative 3 Enhanced Biodegradation, Institutional Controls with MNA |
|---|---|---|---|
| **Short-Term Effectiveness** | | | |
| Groundwater | Remedy implementation does not add to risk. | Remedy implementation does not add to risk. | A moderate amount of construction traffic will be associated with hauling material from offsite sources. |
| Time Until Action is Complete | Not applicable. | Annual MNA monitoring will occur as deemed necessary. | Enhanced biodegradation is expected to take effect within a few years, although this cannot be predicted until a pilot study is conducted. Based on previous experience, Regenesis, the manufacturer of HRC/ORC, estimated that the biodegradation half-lives can be reduced by 10 percent and that the remediation goals may be achieved over a period of 2 to 4 years. |
| **Implementability** | | | |
| Ability to Construct and Operate | Not applicable. | Some construction required to install monitoring wells for MNA. Operation would consist of LTM for MNA parameters to track contaminant degradation. Groundwater-use restrictions would require consent from base command. | Enhanced biodegradation would be performed using traditional direct-push methods. Operation would consist of a reducing or oxidizing agent injection and MNA to track effectiveness and contaminant degradation. Groundwater-use restrictions would require consent from base command. |
| Ease of Implementing Additional Action if Needed | Very easy to implement additional action. | Very easy to implement additional action. | Easy to implement additional action. |
| Ability to Monitor Effectiveness | Easily monitored during five-year site reviews. | Easily monitored during five-year site reviews. MNA will also be used to evaluate the groundwater quality. | Enhanced biodegradation effectiveness will be determined through traditional sampling methods. MNA also will be used to evaluate groundwater quality. Easily monitored during annual sampling. |
| **Cost** | | | |
| Capital Cost | $0 | $46,800 | $726,200 |

**Table 4-2**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2C**

| Evaluation Criteria | Alternative 1<br>No Action | Alternative 2<br>Institutional Controls with MNA | Alternative 3<br>Enhanced Biodegradation, Institutional Controls with MNA |
|---|---|---|---|
| Annual O&M Cost | $2,000 (every 5 years) | $78,200 | $190,600 (average) |
| Present-Worth | $6,500 | $1,344,000 | $1,902,500 |

**Table 4-3**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2E**

| Evaluation Criteria | Alternative 1<br>No Action | Alternative 2<br>Free-Phase Diesel Fuel Removal, Institutional Controls with LTM | Alternative 3<br>ORC, Free-Phase Diesel Fuel Removal, Institutional Controls with LTM |
|---|---|---|---|
| **Overall Protection of Human Health and Environment** | | | |
| Prevention of unacceptable risks to potential receptors to the groundwater | Potential risk to receptors from the water table aquifer is posed by current conditions at the site if the groundwater is used as a potable supply. However, potable use of the groundwater is unlikely (although no measures would be in place to prevent it). | Potential risk to receptors from the water table aquifer is posed by current conditions at the site if groundwater is used as potable water supply. However, potable use of the groundwater is unlikely and institutional controls would prevent any potential potable use. Free-phase diesel fuel removal will reduce contaminant dissolution and migration. LTM will detect any change in current groundwater concentrations. | Potential risk to receptors from the water table aquifer is posed by current conditions at the site if groundwater is used as a potable water supply. However, potable use of the groundwater is unlikely and institutional controls would prevent any potential potable use. Free-phase diesel fuel removal will reduce contaminant dissolution and migration. Because the use of the water table aquifer for potable water is unlikely, the benefit of potentially reducing contamination levels through ORC injection may not be warranted. LTM will detect any change in current groundwater concentrations. |

**Table 4-3**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2E**

| Evaluation Criteria | Alternative 1<br>No Action | Alternative 2<br>Free-Phase Diesel Fuel Removal, Institutional Controls with LTM | Alternative 3<br>ORC, Free-Phase Diesel Fuel Removal, Institutional Controls with LTM |
|---|---|---|---|
| **Compliance with ARARs** | | | |
| Chemical-Specific ARARs | Currently groundwater exceeds drinking water ARARs (MCLs) and tap water RBCs for several metals and chlorinated VOCs. Risk to contaminated groundwater above the MCLs and PRGs remains. | Groundwater-use restrictions would prevent groundwater use as water supply, therefore, would protect receptors against groundwater exceeding the MCLs and PRGs. Free-phase diesel fuel removal will reduce contaminant dissolution and migration. LTM would track changes in groundwater quality and the potential for plume migration. | Groundwater-use restrictions would prevent groundwater use as water supply, therefore, would protect receptors against groundwater exceeding the MCLs and PRGs. ORC may reduce organic contaminant concentrations (ideally to within ARARs); however, with institutional controls in place, this may not be necessary. In addition, inorganics could be reduced to insoluble forms; however, this may be only on a temporary basis (while injection material persists in the aquifer) because of their ubiquitous presence in groundwater. Therefore, LTM would track changes in groundwater quality and the potential for plume migration of the inorganics as well as track the progress of the enhanced biodegradation. Free-phase diesel fuel removal will reduce contaminant dissolution and migration.. |
| Action-Specific ARARs | Not applicable. | Meets all action-specific ARARs. | Meets all action-specific ARARs. |
| Location-Specific ARARs | Not applicable. | Meets all location-specific ARARs. | Meets all location-specific ARARs. |
| **Long-Term Effectiveness and Permanence** | | | |
| Groundwater | Source not remediated. Potential risk posed by potable use of groundwater. No permanent means to prevent future use of site in a manner that would result in unacceptable risks to groundwater. | Source remediated through free-phase diesel fuel removal. Potential risk posed by potable use of groundwater. Institutional controls and monitoring would be relied upon to eliminate unacceptable risks to groundwater. | Source remediated through free-phase diesel fuel removal and injection of ORC. Potential risk posed by potable use of groundwater. Institutional controls and monitoring would be relied upon to eliminate unacceptable risks to groundwater (if ARARs are not attained). |

**Table 4-3**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2E**

| Evaluation Criteria | Alternative 1<br>No Action | Alternative 2<br>Free-Phase Diesel Fuel Removal, Institutional Controls with LTM | Alternative 3<br>ORC, Free-Phase Diesel Fuel Removal, Institutional Controls with LTM |
|---|---|---|---|
| Need for Five Year Review | Because contamination (groundwater) remains onsite, five-year reviews would be required. | See Alternative 1. | Five-year site reviews may be required if ARARs are not attained. |
| **Reduction of Toxicity, Mobility, or Volume** | | | |
| Groundwater | No toxicity or volume reduction. | Toxicity associated with contaminated media would reduce due to natural degradation of TCE and daughter products. Volume reduction is attained through free-phase diesel fuel removal and natural degradation. | Toxicity associated with contaminated media may be reduced from enhanced degradation of TCE and daughter products. Volume reduction is attained through free-phase diesel fuel removal and enhanced degradation. |
| Type and Quantity of Residuals Remaining After Remediation | No treatment undertaken, therefore, groundwater contamination remains onsite. | Treatment consists of free-phase diesel fuel removal. Groundwater contamination remains onsite. | Treatment consists of free-phase diesel fuel removal and ORC injection. Depending on effectiveness of ORC, residual contamination may remain after remediation. |
| **Short-Term Effectiveness** | | | |
| Groundwater | No action taken, therefore, no additional short-term risk added. | Remedy implementation does not add to risk. | A moderate amount of construction traffic will be associated with hauling material from offsite sources. |
| Time Until Action is Complete | Not applicable. | Annual LTM will occur as deemed necessary. | ORC insertion is expected to take effect in approximately three months. Based on previous experience, Regenesis, the manufacturer of ORC, estimated that the biodegradation half-lives can be reduced by 10 percent and that the remediation goals may be achieved over a period of 2 to 4 years. Annual LTM will continue as deemed necessary. |

**Table 4-3**
**Analysis of Remedial Alternatives for Groundwater at SWMU 2E**

| Evaluation Criteria | Alternative 1<br>No Action | Alternative 2<br>Free-Phase Diesel Fuel Removal, Institutional Controls with LTM | Alternative 3<br>ORC, Free-Phase Diesel Fuel Removal, Institutional Controls with LTM |
|---|---|---|---|
| **Implementability** | | | |
| Ability to Construct and Operate | Not applicable. | Operation would consist of LTM and operation and maintenance to collect free-phase diesel fuel. Groundwater-use restrictions would require consent from base command. | The ORC injection would be performed using traditional direct-push methods. Operation would consist of ORC injection, LTM and operation and maintenance to collect free-phase diesel fuel. Groundwater-use restrictions would require consent from base command. |
| Ease of Implementing Additional Action if Needed | Very easy to implement additional action. | Very easy to implement additional action. | Easy to implement additional action. |
| Ability to Monitor Effectiveness | Easily monitored during five-year site reviews. | Manual bailing will be easily monitored and discontinued when appropriate. LTM will also be used to evaluate the groundwater quality. Easily monitored during five-year site reviews. | ORC effectiveness will be determined through traditional sampling methods. Manual bailing will be easily monitored and discontinued when appropriate. LTM also will be used to evaluate groundwater quality. Easily monitored during five-year site reviews. |
| **Cost** | | | |
| Capital Cost | $0 | $283,200 | $352,800 |
| Annual O&M Cost | $2,000 (every 5 years) | $65,100 | $75,300 |
| Present-Worth | $6,500 | $1,363,100 | $1,601,900 |

SECTION 5

# Comparative Analysis and Recommended Alternative

A comparative analysis of remedial alternatives which leads to a recommended alternative is documented below for SWMUs 2B, 2C and 2E.

## 5.1 SWMU 2B Groundwater

The comparative analysis of proposed remedial alternatives and the recommended remedial alternative for SWMU 2B groundwater are documented below.

### 5.1.1 Comparative Analysis

The conclusions of the HHRA determined that there is unacceptable risk to potential future residential receptors at the site from potable use of groundwater from the water table aquifer at SWMU 2B. In the following analysis, the sitewide remedial alternatives are evaluated in relation to one another based on each of the seven NCP criteria discussed in Section 4.1. Keeping the potential risks in mind, the purpose of this analysis is to identify the relative advantages and disadvantages of each alternative. The comparative analysis will focus on factors that provide distinctions between the alternatives.

The site-specific RAO for the protection of human health and the environment for SWMU 2B groundwater are:

- Prevent exposure to unacceptable risks to potential human receptors of groundwater

The alternatives evaluated for SWMU 2B groundwater is:

- Alternative 1 – No Action
- Alternative 2 –Institutional Controls and LTM
- Alternative 3 –HRC/ORC Injection, Institutional Controls, and LTM

Based on the findings of the HHRA, the current site conditions present a potential risk from potable use of groundwater at SWMU 2B. However, the long-term groundwater monitoring under Alternatives 2 and 3 would track groundwater quality and the institutional controls guard against future risk of potable use of the groundwater. Alternative 3 may reduce organic contaminant levels in groundwater through the use of an HRC/ORC. Inorganics could be reduced to insoluble forms; however, this may be only on a temporary basis (while injection material persists in the aquifer) because of their ubiquitous presence in groundwater. The site-specific effectiveness of the technology is unknown until it is implemented. Furthermore, since potable use of the groundwater is unlikely (particularly

with groundwater-use restrictions in place), and because the affected area of the aquifer is small, the benefit of reducing contamination levels through remediation is small.

Alternative 1 currently exceeds chemical-specific ARARs for drinking water (MCLs) and tap water RBCs for several compounds. The groundwater-use restrictions under Alternatives 2 and 3 prevent the use of groundwater under SWMU 2B as a drinking water supply, therefore, the potential drinking water ARARs would be met. The LTM involved in Alternatives 2 and 3 would track groundwater quality.

All three alternatives comply with the location-specific ARARs. According to federal regulatory agencies, no federally listed or proposed endangered species are known to exist on SWMU 2B, except for transient individuals. Additionally, there are no federal or state regulated wetlands present within the boundaries of the site.

All alternatives comply with action-specific ARARs, including hazardous waste management requirements and state stormwater management and erosion control requirements.

On a present worth basis, Alternative 2 is more cost effective ($1,645,000) than Alternative 3. Alternative 3 has a higher present worth of $2,026,000. All costs are within the degree of accuracy associated with conceptual level cost estimate (+50% to -30% degree of accuracy). The cost estimate is provided in Appendix F.

### 5.1.2 Recommended Alternative

Alternative 2, Institutional Controls with LTM, is the recommended alternative because it achieves the remedial action objectives, meets the ARARs, guards against future risk, and is cost-effective. While Alternative 3 also meets the RAOs and ARARs, it is more costly and adds little to no benefit over Alternative 2 given the sporadic organic contamination (no plume) and given that since the Columbia Aquifer is not currently used as a potable water supply and will almost likely never be used as a potable water supply, especially with groundwater-use restrictions in place under the recommended alternative. Alternative 1 does not meet the RAOs and ARARs, and does not provide for long-term groundwater quality tracking or guard against future risk.

## 5.2 SWMU 2C Groundwater

The comparative analysis of proposed remedial alternatives and the recommended remedial alternative for SWMU 2C groundwater are documented below.

### 5.2.1 Comparative Analysis

The conclusions of the HHRA determined that there is unacceptable risk to potential future residential receptors at the site from potable use of groundwater from the water table aquifer at SWMU 2C. Furthermore, the HHRA notes the site's future development by construction workers for residential purposes is highly unlikely.

In the following analysis, the sitewide remedial alternatives are evaluated in relation to one another based on each of the seven NCP criteria discussed in Section 4.1. Keeping the

potential risks in mind, the purpose of this analysis is to identify the relative advantages and disadvantages of each alternative. The comparative analysis will focus on factors that provide distinctions between the alternatives.

The site-specific RAO for the protection of human health and the environment for SWMU 2C groundwater is:

- Prevent exposure to unacceptable risks to potential human receptors of groundwater

The alternatives evaluated for SWMU 2C are:

- Alternative 1 – No Action
- Alternative 2 –Monitored Natural Attenuation and Institutional Controls
- Alternative 3 – Enhanced Biodegradation, Monitored Natural Attenuation, and Institutional Controls

Based on the findings of the HHRA, the current site conditions present a potential risk from potable use of groundwater at SWMU 2C. The institutional controls in Alternatives 2 and 3 guard against future risk of potable use of the groundwater. Evidence suggests that natural attenuation of TCE and daughter products is occurring at SWMU 2C. The TTCU model will be used under Alternatives 2 and 3 to re-evaluate MNA and ensure remediation goals are met. Alternative 3 may reduce potential risk from groundwater faster than Alternative 2 through the use of enhanced biodegradation. Enhanced biodegradation may be able to reduce organic contamination levels in as few as 8 years in the sandy aquifer, however, will most likely be inhibited by the silts and clays. In addition, inorganics could be reduced to insoluble forms; however, this may be only on a temporary basis (while injection material persists in the aquifer) because of their ubiquitous presence in groundwater. Natural attenuation may reduce contamination levels to within ARARs in 30 years, and will be re-evaluated under Alternative 2 to confirm a reasonable cleanup time after more information is collected.

Alternative 1 is not protective of human health, as no action is taken against exposure to contaminated groundwater. The groundwater-use restrictions under Alternatives 2 and 3 prevent the use of groundwater under SWMU 2C as a drinking water supply, therefore, the potential drinking water ARARs would be met.

All three alternatives comply with the location-specific ARARs. According to federal regulatory agencies, no federally listed or proposed endangered species are known to exist on SWMU 2C, except for transient individuals. Additionally, there are no federal or state regulated wetlands present within the boundaries of the site.

All alternatives comply with action-specific ARARs, including hazardous waste management requirements and state stormwater management and erosion control requirements.

On a present worth basis, Alternative 2 is more cost effective ($1,344,000) than Alternative 3. Alternative 3 has a higher present worth of $1,903,000. All costs are within the degree of

accuracy associated with a conceptual level cost estimate (+50% to -30% degree of accuracy). The cost estimate is provided in Appendix F.

### 5.2.2 Recommended Alternative

Alternative 3, Enhanced Biodegradation, Monitored Natural Attenuation, and Institutional Controls, is the recommended alternative because it has the likelihood of meeting the RAO within a shorter time frame, meets the ARARs, and guards against future risk. The accumulation of VC indicates that the natural attenuation process needs to be augmented with enhanced biodegradation. Alternative 2 will meet the RAO in a longer time period, meets the ARARs, and guards against future risk; however, VC will continue to accumulate. Alternative 1 does not meet the RAO and ARARs, and does not provide for long-term groundwater quality tracking or guard against future risk.

## 5.3 SWMU 2E

The comparative analysis of proposed remedial alternatives and the recommended remedial alternative for SWMU 2E groundwater are documented below.

### 5.3.1 Comparative Analysis

The conclusions of the HHRA determined that there is unacceptable risk to potential future residential receptors and the construction worker from groundwater in the water table aquifer at SWMU 2E. In the following analysis, the sitewide remedial alternatives are evaluated in relation to one another based on each of the seven NCP criteria discussed in Section 4.1. Keeping the potential risks in mind, the purpose of this analysis is to identify the relative advantages and disadvantages of each alternative. The comparative analysis will focus on factors that provide distinctions between the alternatives.

The site-specific RAO for the protection of human health and the environment for SWMU 2E groundwater is:

- Prevent exposure to unacceptable risks to potential human receptors of groundwater

The alternatives evaluated for SWMU 2E groundwater are:

- Alternative 1 – No Action
- Alternative 2 – Free-Phase Diesel Fuel Removal, Institutional Controls, and LTM
- Alternative 3 – ORC Injection, Free-Phase Diesel Fuel Removal, Institutional Controls, and LTM

Based on the findings of the HHRA, the current site conditions present a potential risk from groundwater at SWMU 2E. However, the long-term groundwater monitoring under Alternatives 2 and 3 track groundwater quality, and the institutional controls guard against future risk of potable use of the groundwater. The free-phase diesel fuel removal described under Alternatives 2 and 3 will reduce the free-phase diesel fuel thickness below the VDEQ criteria. Alternative 3 may reduce potential risk from organics in groundwater more than Alternative 2 through the application of an ORC. Inorganics could be reduced to insoluble

forms; however, this may be only on a temporary basis (while injection material persists in the aquifer) because of their ubiquitous presence in groundwater. In addition,(1) potable use of the groundwater is unlikely (particularly with groundwater-use restrictions in place), (2) the contamination levels only slightly exceed MCLs, and (3) the affected area of the aquifer is small, the benefit of reducing contamination levels is small.

No chemical-specific ARARs were identified for surface soil at SWMU 2E due to the lack of risk from current receptors. The groundwater-use restrictions under Alternatives 2 and 3 prevent the use of groundwater under SWMU 2E as a drinking water supply, therefore, the potential drinking water ARARs would be met. The LTM involved in Alternatives 2 and 3 would track groundwater quality to prevent further degradation.

All three alternatives comply with the location-specific ARARs. According to federal regulatory agencies, no federally listed or proposed endangered species are known to exist on SWMU 2E, except for transient individuals. Additionally, there are no federal or state regulated wetlands present within the boundaries of the site.

All alternatives comply with action-specific ARARs, including hazardous waste management requirements and state stormwater management and erosion control requirements.

On a present worth basis, Alternative 2 is more cost effective ($1,363,000) than Alternative 3. Alternative 3 has a higher present worth of $1,602,000. All costs are within the degree of accuracy associated with conceptual level cost estimate (+50% to -30% degree of accuracy). The cost estimate is provided in Appendix F.

### 5.3.2 Recommended Alternative

Alternative 2, Free-Phase Diesel Fuel Removal and Institutional Controls with LTM, is the recommended alternative because it achieves the remedial action objectives, meets the ARARs, guards against future risk, and is cost-effective. While Alternative 3 also meets the RAO and ARARs, it is more costly and adds little to no benefit over Alternative 2 given the sporadic organic contamination (no plume) and given that the Columbia Aquifer is not currently used as a potable water supply and will almost likely never be used as a potable water supply, especially with groundwater-use restrictions in place under the recommended alternative. Alternative 1 does not meet the RAO and ARARs and does not provide for long-term groundwater quality tracking or guard against future risk.

SECTION 6

# References


American Cancer Society (ACS). *Cancer Facts and Figures - '93*. Atlanta, Georgia. 1993.

Agency for Toxic Substances and Disease Registry (ATSDR). *Toxicological Profile for Naphthalene*. August 1995.

ATSDR. *Toxicological Profile for Chloroform*. August 1995.

CH2M HILL. *Final Progress Report Round 1 Verification Step, Naval Air Station, Oceana*. October 1986.

CH2M HILL. *RCRA Facility Investigation, Final Report-Phase I, Naval Air Station Oceana, Virginia Beach, Virginia*. December 1993.

CH2M HILL. *Final Corrective Measures Study for Petroleum Contaminated SWMUs, Oceana Naval Air Station, Virginia, Beach, Virginia*. October 1994.

CH2M HILL. *Draft Final Report on the Phase II RCRA Facility Investigation of SWMUs 2D, 2E, 15, 24, and 25, Naval Air Station Oceana, Virginia, Beach, Virginia*. February 1995a.

CH2M HILL. *Final Corrective Measures Study for SWMUs 1, 2B, and 2C, Naval Air Station Oceana, Virginia, Beach, Virginia*. November 1995b.

CH2M HILL. *Draft Final Corrective Measures Study for SWMUs 2E, 15, and 24, Naval Air Station Oceana, Virginia, Beach, Virginia*. March 1996.

CH2M HILL. *Report for the Phase III RCRA Facility Investigation, Naval Air Station Oceana, Virginia, Beach, Virginia*. August 1999b.

CH2M HILL. *Final Screening Ecological Risk Assessment, SWMUs 2C, 2D, 2E, 18, 19, 20, 23, and 24, Naval Air Station Oceana, Virginia, Beach, Virginia*. April 1999c.

CH2M HILL. *Draft Work Plan, Direct Push Technology Investigation, Supplemental Activities, SWMU 2C, Naval Air Station Oceana, Virginia Beach, Virginia*. November 1999d.

CH2M HILL. *Draft Technical Memorandum for the Groundwater Sampling at SWMUs 2B and 2E, Naval Air Station Oceana, Virginia Beach, Virginia*. January 2001a.

CH2M HILL. *Final SWMUs 2C Groundwater Investigation Report, Naval Air Station Oceana, Virginia Beach, Virginia*. February 2001b.

CH2M HILL. *Final Screening and Baseline Ecological Risk Assessment, Steps 1, 2, and 3, SWMUs 2B, 11, 16, 16GC, 21, 22, and 26, Naval Air Station Oceana, Virginia, Beach, Virginia*. August 2001c.

ENSCI Env. Inc. *Excavation, Transportation, and Disposal of Petroleum Contaminated Soils*. April 26, 1995.

Foster, S. A. and P. C. Chrostowski. *Inhalation Exposures to Volatile Organic Contaminants in the Shower*. ICF-Clement Associates, Inc. Washington, D.C. 1987.

Hamilton, A.P. and Larson, J.D. *Hydrogeology and Analysis of the Groundwater Flow System in the Coastal Plain of Southeastern Virginia*. USGS WRI Report 87-4240. 1988.

HEAST. *Health Effects Assessment Summary Tables, Annual Update*. USEPA, Environmental Criterion Assessment Office, Office of Research and Development. Cincinnati, Ohio. 1997.

Howard, H. *Handbook of Environmental Fate and Exposure Data for Organic Chemicals*. Volume II. Lewis Publishers Inc. 1990.

Meng, A.A. and J.F. Harsh. *Hydrogeologic Framework of the Virginia Coastal Plain*. Open–File Report 84-728. U.S. Geological Survey. 1984.

National Library of Medicine (NLM). Searches from the Hazardous Substances Data Bank (HSDB), available online at http://sis.nlm.nih.gov/sis1/. 2000.

Oaks and Coch. *Post Miocene Stratigraphy and Morphology, Southeastern Virginia*. Virginia Division of Mineral Resources Bulletin 82, 135p. 1973.

R.E. Wright Associates, Inc. *Extent of Subsurface Fuel Contamination, Oceana Naval Air Station*. Middletown, Pennsylvania. February 1983.

Rogers, Golden & Halpern (RGH). *Initial Assessment Study, Naval Air Station Oceana, Virginia Beach, Virginia*. Prepared for Navy Assessment and Control of Installation Pollutants Department, Naval Energy and Environmental Support Activity, Port Hueneme, California. In association with BCM Eastern, Inc. NEESA 13-067. Philadelphia, Pennsylvania. December 1984.

Siudyla, E.A., May, A.E., and Hawthorne, D.W. *Ground Water Resources of the Four Cities Area, Virginia*. State Water Control Board Planning Bulletin 331. 1981.

Tumasonis, C.F., D.N. McMartin, and B. Bush. *Toxicity of Chloroform and Bromodichloromethane When Administered Over a Lifetime in Rats*. J. Environ. Pathol. Toxicol. Oncol. Vol. 7, No. 4, pp. 55-64. 1987.

USEPA. *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Groundwater*. EPA/600/6-85/002a. *September 1985*.

USEPA. *RCRA Facility Assessment, Phase II Report, Oceana Naval Air Station*. VA2170024606. August 1988.

USEPA. *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part A, Interim Final*. Office of Solid Waste and Emergency Response. EPA/540/1-89/002. December 1989.

USEPA. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors*. Office of Solid Waste and Emergency Response. OSWER Directive No. 9285.6-03, March 25, 1991a.

USEPA. *Human Health Evaluation Manual, Part B: "Development of Risk-Based Preliminary Remedial Goals."* Office of Solid Waste and Emergency Response. OSWER Directive No. 9285.7-01B. December 13, 1991b.

USEPA. *Dermal Exposure Assessment: Principles and Applications.* Interim Report. Office of Research and Development. EPA/600/8-91/011B. January 1992a.

USEPA. *Draft Guidance on the Selection of Analytical Metal Results from Monitoring Well Samples for Use in the Quantitative Assessment of Risk.* EPA Region III. August 10, 1992b.

USEPA. *Selecting Exposure Routes and Contaminants of Concern by Risk-Based Screening.* Region III, Hazardous Waste Management Division, Office of Superfund Programs. EPA/903/R-93-001. January 1993.

USEPA. *Assessing Dermal Exposure from Soil.* Region III Technical Guidance Manual, Risk Assessment. Hazardous Waste Management Division, Office of Superfund Programs. EPA/903-K-003. December 1995.

USEPA. *Soil Screening Guidance: User's Guide.* Office of Solid Waste and Emergency Response, Washington, D.C. EPA/540/R-96/018. April 1996.

USEPA. *Health Effects Assessment Summary Tables. FY 1997 Update.* EPA/540-R-97-036. 1997.

USEPA. *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments.* 1998.

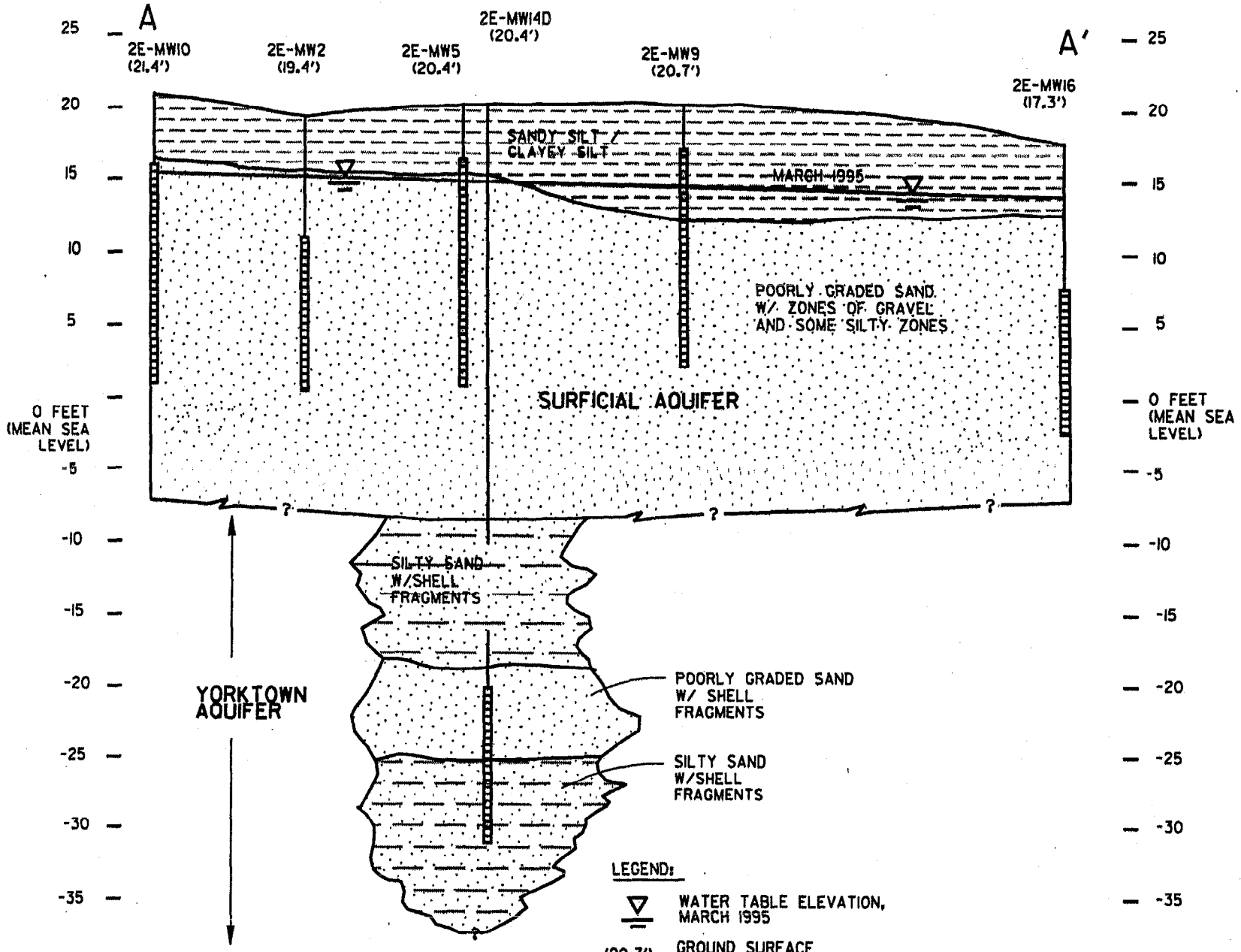
USEPA. *EPA Region III Risk-Based Concentration Table.* April 12, 1999a.

USEPA. *Oral Abs Values for Oral--to-Dermal Extrapolation per RAGS Appendix A.* Last Updated April 8, 1999b.

USEPA. *Oral Absorption Values for Oral-to-Dermal Extrapolation per RAGs Part D Appendix A,* Faxed from Dawn Ioven, USEPA Region III Toxicologist on October 13, 1999c. Last Updated April 8, 1999.

VDEQ. *Virginia Storage Tank Program Technical Manual.* Revision 2. May 1999.

# Appendix A—Excerpts from the CMS




THIS CROSS SECTION WAS INTERPOLATED BETWEEN THE BORING LOCATIONS. ACTUAL CONDITIONS BETWEEN BORINGS MAY DIFFER FROM THOSE SHOWN HERE. CROSS SECTION LOCATION IS SHOWN IN FIGURE A-3.

**Figure A-4**

GEOLOGIC CROSS SECTION OF SWMU 2E (SECTION TRENDS NORTH - SOUTH)

CH2M HILL

12-OCT-1995 368qx2el.dgn

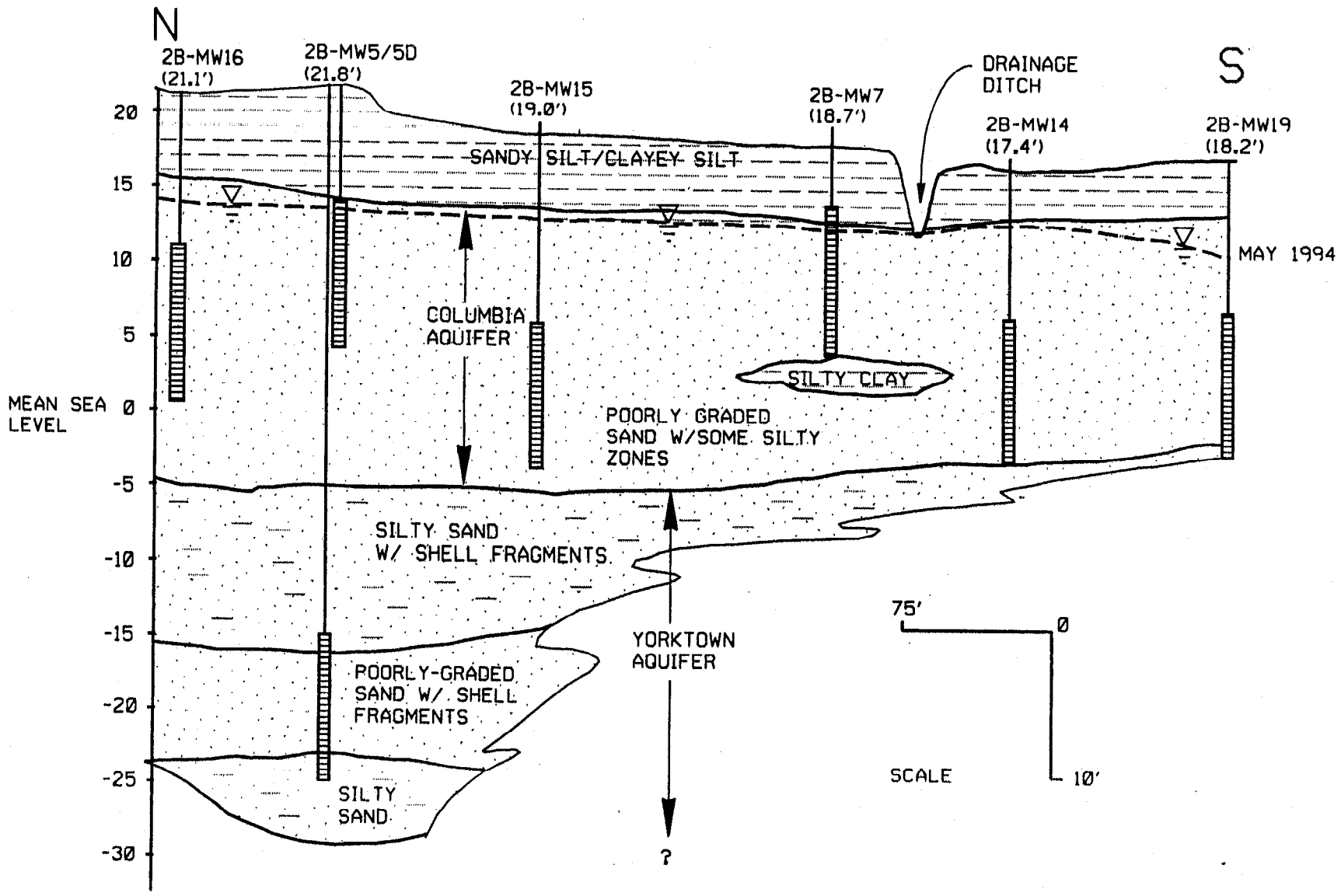



**Figure A-13**

GEOLOGIC CROSS SECTION
OF SWMU 2B
(SECTION TRENDS NORTH-SOUTH)

CH2M HILL

26-SEP-1995 03681112.dgn

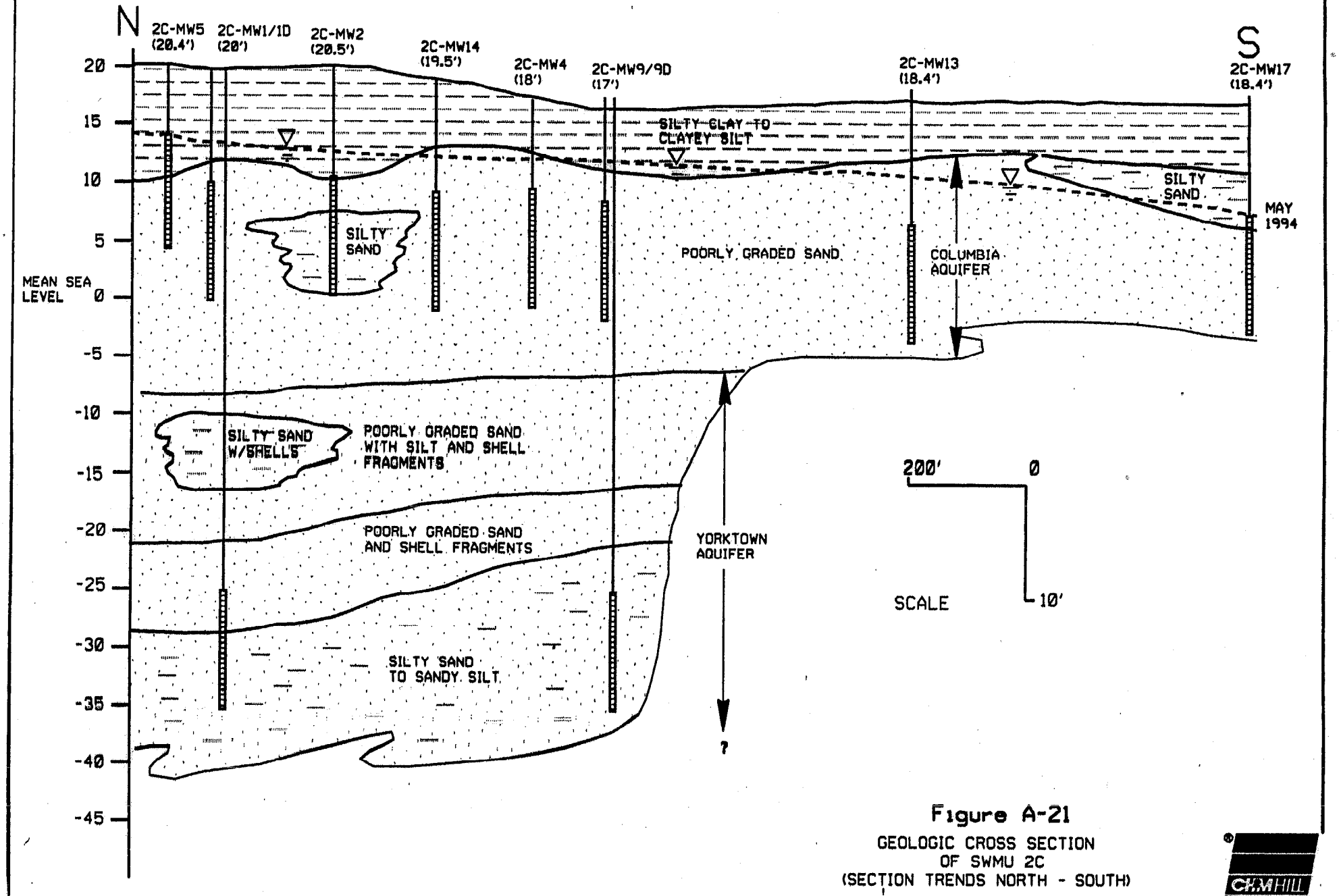



**Figure A-21**

GEOLOGIC CROSS SECTION
OF SWMU 2C
(SECTION TRENDS NORTH - SOUTH)

CH2M HILL

26-SEP-1995 03681113.dgn

# Appendix B—Draft Technical Memorandum for the SWMU 2B and 2E Groundwater Sampling

Draft

# Technical Memorandum for the SWMU 2B & 2E Groundwater Sampling

## Oceana Naval Air Station
## Virginia Beach, Virginia

CTO Task Order - 151
January 2001

Prepared for

**Department of the Navy**
**Atlantic Division**
**Naval Facilities Engineering Command**

Under the

**LANTDIV CLEAN II Program**
**Contract N62470-95-D-6007**

Prepared by

CH2MHILL

WDC010250001.ZIP/1/KTM

# Contents


Section | Page

**1.0 Introduction** ..... **1-1**

**2.0 Groundwater Sampling - SWMUs 2B and 2E** ..... **2-1**
- 2.1 SWMU 2B Groundwater Sampling Methods ..... 2-1
- 2.2 SWMU 2B Groundwater Sampling Results ..... 2-5
  - 2.2.1 SWMU 2B Water Table Elevation ..... 2-5
- 2.3 SWMU 2E Groundwater Sampling Methods ..... 2-10
- 2.4 SWMU 2E Groundwater Sampling Results ..... 2-16
  - 2.4.1 SWMU 2E Water Table Elevation ..... 2-20

**3.0 Conclusions and Future Plans** ..... **3-1**
- 3.1 Conclusions ..... 3-1
- 3.2 Current Work/Future Plans at SWMU 2B and SWMU 2E ..... 3-1
  - 3.2.1 Current Ecological Risk Assessment at SWMU 2B and SWMU 2E ..... 3-1
  - 3.2.2 Future Plans at SWMU 2B and SWMU 2E ..... 3-2

**4.0 References** ..... **4-1**


## Appendices


A-1 Groundwater Analytical Results for SWMU 2B and SWMU 2E

A-2 Summary of Detected Chemicals for Groundwater Sampling at SWMU 2B and SWMU 2E

A-3 Summary of Non-Detected Chemicals in SWMU 2B and SWMU 2E Groundwater where the Detection Limit Exceeded the Screening Level or MCL

# Contents (Continued)

**Tables** **Page**


2-1 SWMU 2B Groundwater MCL Exceedances ..... 2-5

2-2 SWMU 2B Groundwater Elevations ..... 2-6

2-3 SWMU 2E Groundwater MCL Exceedances ..... 2-11

2-4 SWMU 2E Groundwater Elevations ..... 2-12


**Figures**


1-1 NAS Oceana Base Map with Locations of SWMU 2B & SWMU 2E ..... 1-2

2-1 SWMU 2B Monitoring Well Locations ..... 2-2

2-2 SWMU 2B Groundwater MCL Exceedances ..... 2-4

2-3 SWMU 2B Water Table Elevation Map ..... 2-7

2-4 SWMU 2E Monitoring Well Locations ..... 2-8

2-5 SWMU 2E Groundwater MCL Exceedances ..... 2-10

2-6 SWMU 2E Water Table Elevation Map ..... 2-13

# 1.0 Introduction

This summary report documents the methods and analytical results of the confirmatory groundwater sampling at SWMU 2B and SWMU 2E. The fieldwork was conducted during late February and early March 2000. The analytical results from the groundwater samples collected at each SWMU were used to assess site-wide groundwater quality and will support a human health risk assessment. The location of each SWMU at Naval Air Station (NAS) Oceana is shown on Figure 1-1.

This report is divided into two sections. The first section presents a discussion of the sampling procedures and a summary of the analytical results for the groundwater samples collected at SWMUs 2B and 2E. The second section presents conclusions and future plans for each SWMU.

Figure 1-1 NAS Oceana Base Map with Locations of SWMU 2B & SWMU 2E

# 2.0 Groundwater Sampling - SWMUs 2B and 2E

Groundwater sampling methods and results for SWMUs 2B and 2E are presented below. Then, conclusions are documented and recommendations for future actions are presented.

## 2.1 SWMU 2B Groundwater Sampling Methods

During February 2000, groundwater samples were collected from nineteen shallow monitoring wells (2B-MW1 through 2B-MW20, excluding 2B-MW6) and two deep monitoring wells (2B-MW1D and 2B-MW5D) at SWMU 2B. The locations of the SWMU 2B monitoring wells are shown on Figure 2-1. Monitoring well 2B-MW6 was not sampled because the well could not be located, in the field.

All sampling activities were performed by a subcontractor in accordance with the CH2M HILL standard operating procedures (SOPs) for low-flow groundwater sampling. A CH2M HILL representative provided oversight of all field activities. The depth to groundwater in each monitoring well sampled was measured prior to the commencement of sampling activities to establish the initial depth to water. Monitoring wells were purged and sampled using a low-flow submersible pump with dedicated tubing. Field parameters (ph, specific conductivity, temperature, dissolved oxygen, Eh, turbidity, and depth to water) were measured during purging activities. These measurements were used to determine when each monitoring well had been adequately purged. The field parameter measurements collected during the SWMU 2B groundwater sampling activities are summarized in Appendix A-1.

Groundwater samples were submitted to an offsite laboratory for analysis of Target Compound List (TCL) Low-concentration (LC) Volatile Organic Compounds (VOCs), TCL Semi-Volatile Organic Compounds (SVOCs), TCL Pesticides and PCBs, Polyaromatic Hydrocarbons (PAHs) by USEPA Method 8310, Target Analyte List (TAL) Dissolved Metals, and TAL Total Metals and Cyanide. These analyses were chosen to support a human health risk assessment of this site.

In addition, the samples were analyzed for several monitored natural attenuation (MNA) parameters (alkalinity, chloride, sulfate, sulfide, methane, ethane, ethene, iron II, iron III, manganese, nitrate, nitrite, and total organic carbon). The results from these MNA analyses will be used to determine if natural attenuation, more specifically biodegradation, may be occurring at this SWMU.

The complete analytical results are provided in Appendix A-1.

Figure 2-1 SWMU 2B Monitoring Well Locations

## 2.2 SWMU 2B Groundwater Sampling Results

Twenty-four groundwater samples (including three duplicate samples) were analyzed for TCL LC-VOCs, TCL SVOCs, TCL Pesticides and PCBs, PAHs by USEPA Method 8310, TAL Dissolved Metals, and TAL Total Metals and Cyanide. The complete validated analytical results from the groundwater sampling conducted at SWMU 2B are presented in Appendix A-1 (Table A1-1). The detected chemicals from the validated analytical groundwater data are presented in Appendix A-2 (Table A2-1).

CH2M HILL compared the results from the groundwater analytical results to the USEPA MCLs for drinking water (USEPA, Summer 2000 and 66 Federal Register 6976, January 22, 2001). Compounds flagged with the "B" qualifier by the data validation subcontractor (indicating results attributed to laboratory blank contamination) were not considered during this comparison. The results of this comparison are summarized below:

- The total and dissolved arsenic concentrations exceeded the USEPA MCL for drinking water in the samples collected from 2B-MW5, 2B-MW11, 2B-MW16, and 2B-MW17. The total arsenic concentration exceeds the USEPA MCL for drinking water in the sample collected from 2B-MW18.
- The antimony concentration exceeded the USEPA MCL for drinking water in the sample collected from 2B-MW10 (filtered and unfiltered samples).
- The bis(2-Ethylhexyl)phthalate concentration exceeded the USEPA MCL for drinking water in the sample collected from 2B-MW4.
- The cis-1,2-dichloroethene concentration exceeded the USEPA MCL for drinking water in the sample collected from 2B-MW1.
- The trichloroethene concentrations exceeded the USEPA MCL for drinking water in the samples collected from 2B-MW1, 2B-MW2, and 2B-MW3.
- The vinyl chloride concentrations exceeded the USEPA MCL for drinking water in the samples collected from 2B-MW1, 2B-MW5, 2B-MW13, and 2B-MW14.

The locations where concentrations exceeded the USEPA MCLs for drinking water are shown on Figure 2-2. The analytical data for compounds exceeding the USEPA MCLs are summarized in Table 2-1.

Compounds with method detection limits that exceeded regulatory screening limits for USEPA MCLs for drinking water in the SWMU 2B analytical data are tabulated in Appendix A-3 (Table A3-1).

### 2.2.1 SWMU 2B Water Table Elevation

The depth to groundwater in each monitoring well was measured prior to the commencement of sampling activities, however, the measured water-levels did not produce an adequate water table map. The sampled wells were re-surveyed in December 2000 and a new round of water-level measurements were collected. During the December 2000 water-level measurement activities, CH2M HILL field personnel were informed that two wells

Figure 2-2 SWMU 2B Groundwater MCL Exceedances

(2B-MW2 and 2B-MW8) had been excavated by a contractor during construction activities at SWMU 2B, and that these two monitoring wells will be re-installed and re-surveyed by that contractor at a later date. In addition, the field personnel could not find well 2B-MW6, could not remove the PVC cap on well 2B-MW13, and found that well 2B-MW16 had been covered by several large roll-off containers. Therefore, it was not possible to re-survey or collect water-level measurements at these locations.

**Table 2-1**
**Exceedances of MCLs in SWMU 2B Groundwater**

| Sample ID | Analyte | Analytical Value | Unit | MCL* |
|---|---|---|---|---|
| OW2B-MW01-R01 | Cis-1,2-Dichloroethene | 120 | µg/L | 70 |
| OW2B-MW01-R01 | Vinyl chloride | 13 | µg/L | 2 |
| OW2B-MW02-R01 | Trichloroethene | 14 | µg/L | 5 |
| OW2B-MW03-R01 | Trichloroethene | 28 | µg/L | 5 |
| OW2B-MW04-R01 | Bis(2-Ethylhexyl)phthalate | 30 | µg/L | 6 |
| OW2B-MW05-R01 | Vinyl chloride | 6 | µg/L | 2 |
| OW2B-MW05-R01 | Arsenic (Total) | 19.7 | µg/L | 10 |
| OW2B-MW05-R01 | Arsenic (Dissolved) | 19.2 | µg/L | 10 |
| OW2B-MW10-R01 | Antimony | 7.7 | µg/L | 6 |
| OW2B-MW11-R01 | Arsenic (Total) | 15 | µg/L | 10 |
| OW2B-MW11-R01 | Arsenic (Dissolved) | 10.3 | µg/L | 10 |
| OW2B-MW13-R01 | Vinyl chloride | 9 | µg/L | 2 |
| OW2B-MW14-R01 | Vinyl chloride | 9 | µg/L | 2 |
| OW2B-MW16-R01 | Arsenic (Total) | 20.4 | µg/L | 10 |
| OW2B-MW16-R01 | Arsenic (Dissolved) | 17.3 | µg/L | 10 |
| OW2B-MW17-R01 | Arsenic (Total) | 29.7 | µg/L | 10 |
| OW2B-MW17-R01 | Arsenic (Dissolved) | 32.2 | µg/L | 10 |
| OW2B-MW18-R01 | Arsenic (Total) | 12.5 | µg/L | 10 |

*USEPA, Summer 2000
*66 FR 6976, January 22, 2001 (for the arsenic MCL)

An electronic water-level indicator was used to measure the depth to groundwater from the re-surveyed reference point on the PVC well casing of each monitoring well. The measured water-level was subtracted from the reference point elevation to attain the water table elevation. The measuring point elevation, depth to water, and water table elevation for each monitoring well are summarized in Table 2-2. These water table elevations were used to generate a contour map of the aquifer surface in the SWMU 2B area. The contour map is presented as Figure 2-3 and indicates that shallow groundwater flow in the vicinity of SWMU 2B is directed toward the two surface water drainage channels in south-

southeasterly directions. Deeper groundwater flow is likely to be southerly directed as indicated by adjacent line shack SWMUs without surface water influences.

**Table 2-2**
**SWMU 2B Groundwater Elevations**
**December 2000**

| Location | Measuring Point/ Top of PVC Elevation (feet) | Depth To Groundwater from Top of PVC (feet) | Elevation of Groundwater Surface (Water Table Elevation) (feet) |
|---|---|---|---|
| 2B-MW1 | 20.69 | 6.91 | 13.78 |
| 2B-MW1D | 20.48 | 8.10 | 12.38 |
| 2B-MW4 | 20.15 | 6.52 | 13.63 |
| 2B-MW5 | 20.58 | 8.11 | 12.47 |
| 2B-MW5D | 20.38 | 7.32 | 13.06 |
| 2B-MW7 | 20.20 | 7.23 | 12.97 |
| 2B-MW9 | 21.20 | 8.61 | 12.59 |
| 2B-MW10 | 21.11 | 7.40 | 13.71 |
| 2B-MW11 | 21.15 | 7.55 | 13.60 |
| 2B-MW12 | 21.40 | 8.15 | 12.25 |
| 2B-MW14 | 19.47 | 6.81 | 12.66 |
| 2B-MW15 | 20.98 | 7.76 | 13.22 |
| 2B-MW17 | 20.45 | 7.06 | 13.39 |
| 2B-MW18 | 21.76 | 8.31 | 13.45 |
| 2B-MW19 | 17.14 | 4.32 | 12.82 |
| 2B-MW20 | 18.09 | 5.44 | 12.65 |

These monitoring wells were re-surveyed and the water-levels measured in December 2000

## 2.3 SWMU 2E Groundwater Sampling Methods

CH2M HILL conducted groundwater sampling activities in early March 2000. During this period, groundwater samples were collected from thirteen shallow monitoring wells (2E-MW's 1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 15, and 16). The locations of the SWMU 2E monitoring wells are shown on Figure 2-4. Samples were not collected from monitoring wells 2E-MW2 and 2E-MW6. 2E-MW2 was covered by a temporary structure and 2E-MW6 appears to have been destroyed during construction activities.

All sampling activities were performed by a subcontractor in accordance with the CH2M HILL standard operating procedures (SOPs) for low-flow groundwater sampling. A CH2M HILL representative provided oversight during all field activities. The depth to groundwater in each monitoring well sampled was measured prior to the commencement of sampling activities to establish the initial depth to water. Monitoring wells were purged

and sampled using a low-flow submersible pump with dedicated tubing. Field parameters (ph, specific conductivity, temperature, dissolved oxygen, Eh, and turbidity) were

Figure 2-3 SWMU 2B Water Table Elevation

Figure 2-4 SWMU 2E Monitoring Well Locations

measured during purging activities. These measurements were used to determine when each monitoring well had been adequately purged. The field parameter measurements collected during the SWMU 2E groundwater sampling activities are summarized in Appendix A-1.

Groundwater samples were submitted to an offsite laboratory for analysis of Target Compound List (TCL) Low-concentration (LC) Volatile Organic Compounds (VOCs), TCL Semi-Volatile Organic Compounds (SVOCs), TCL Pesticides and PCBs, Polyaromatic Hydrocarbons (PAHs) by USEPA Method 8310, Target Analyte List (TAL) Dissolved Metals, and TAL Total Metals and Cyanide. These analyses were chosen to support a human health risk assessment of this site.

In addition, the samples were analyzed for several monitored natural attenuation (MNA) parameters (alkalinity, chloride, sulfate, sulfide, methane, ethane, ethene, iron II, iron III, manganese, nitrate, nitrite, and total organic carbon). The results from these MNA analyses will be used to determine if natural attenuation, more specifically biodegradation, may be occurring at this SWMU.

The complete list of analyses is provided in Appendix A-1.

## 2.4 SWMU 2E Groundwater Sampling Results

Sixteen groundwater samples (including three duplicate samples) were analyzed for TCL LC-VOCs, TCL SVOCs, TCL Pesticides and PCBs, PAHs by USEPA Method 8310, TAL Dissolved Metals, and TAL Total Metals and Cyanide. The complete validated analytical results from the groundwater sampling conducted at SWMU 2E are presented in Appendix A-1 (Table A1-2). The detected chemicals from the validated analytical data are presented in Appendix A-2 (Table A2-2).

CH2M HILL compared the groundwater analytical results to the USEPA MCLs for drinking water (USEPA, Summer 2000 and 66 Federal Register 6976, January 22, 2001). Compounds flagged with the "B" qualifier by the data validation subcontractor (indicating results attributed to laboratory blank contamination) were not considered during this comparison. The results of this comparison are summarized below:

- The total and dissolved arsenic concentrations exceeded the USEPA MCL for drinking water in the samples collected from 2E-MW1 and 2E-MW10.
- The benzene and bis(2-ethylhexyl)phthalate concentrations exceeded their USEPA MCLs for drinking water in the sample collected from 2E-MW4.
- The vinyl chloride concentration exceeded the USEPA MCL for drinking water in the sample collected from 2E-MW9.

The locations where concentrations exceeded the USEPA MCLs for drinking water are shown on Figure 2-5. The analytical data for compounds exceeding the USEPA MCLs are summarized in Table 2-3.

Figure 2-5 SWMU 2E Groundwater MCL Exceedances

**Table 2-3**
**Exceedances of MCLs in SWMU 2E Groundwater**

| Sample ID | Analyte | Analytical Value | Units | MCL* |
|---|---|---|---|---|
| OW2E-MW01-R01 | Arsenic (total) | 26.1 | µg/L | 10 |
| OW2E-MW01-R01 | Arsenic (dissolved) | 24.3 | µg/L | 10 |
| OW2E-MW04-R01 | Benzene | 15 | µg/L | 5 |
| OW2E-MW04-R01 | bis(2-Ethylhexyl)phthalate | 10 | µg/L | 6 |
| OW2E-MW09-R01 | Vinyl chloride | 8 | ug/L | 2 |
| OW2E-MW10-R01 | Arsenic (total) | 55.3 | ug/L | 10 |
| OW2E-MW10-R01 | Arsenic (dissolved) | 40.1 | ug/L | 10 |

*USEPA, Summer 2000
*66 FR 6976, January 22, 2001 (for the arsenic MCL)

Compounds with method detection limits that exceeded regulatory screening limits for USEPA MCLs for drinking water in the SWMU 2E analytical data are tabulated in Appendix A-3 (Table A3-2).

### 2.4.1 SWMU 2E Water Table Elevation

The depth to groundwater in each monitoring well was measured prior to the commencement of sampling activities, however, the measured water-levels did not produce an adequate water table map. The sampled wells were re-surveyed in December 2000 and a new round of water-level measurements were collected. Monitoring well 2E-MW2 was covered by a temporary structure and 2E-MW6 appeared to have been destroyed during construction activities. Therefore, it was not possible to re-survey or collect water-level measurements at these locations.

Several monitoring wells at SWMU 2E have historically contained a measurable layer of free-product (diesel fuel). An oil/water interface probe was used to measure the depth to the free-product and the depth to groundwater from a surveyed reference point on the PVC well casing of each monitoring well. For monitoring wells where measurable free-product was present, the water-level measurement was corrected to compensate for the depression of the water-table by the free-product. The free phase product in these monitoring wells was identified as diesel fuel through POL fingerprinting conducted during the Phase II RFI. The measured thickness of the free-product was multiplied by the density of diesel fuel (0.83) and the result of this calculation was subtracted from the recorded water-level measurement. Because the density of diesel fuel changes over time (primarily due to the volatilization of the lighter components in the fuel), these corrected measurements are considered estimates and were not used to develop water level elevation contours.

The measured water-level was subtracted from the reference point elevation to attain the water table elevation. The measuring point elevation, depth to water, and water table elevation for each monitoring well are summarized in Table 2-4. Water table elevations

from the monitoring wells were used to generate a contour map of the aquifer surface at SWMU 2E. The contour map is presented as Figure 2-6 and indicates that groundwater flow in the vicinity of SWMU 2E varies from southeasterly to southwesterly across the site. These groundwater flow directions are consistent with regional flow directions observed at other NAS Oceana SWMUs within and around the flight line area of the Station.

**Table 2-4**
**SWMU 2E Groundwater Elevations**
**December 2000**

| Location | Measuring Point/ Top of PVC Elevation (ft) | Depth To Groundwater from Top of PVC (feet) | Elevation of Groundwater Surface (Water table Elevation) (feet) |
|---|---|---|---|
| 2E-MW1 | 21.23 | 8.38 | 13.19* |
| 2E-MW3 | 19.61 | 6.54 | 13.07 |
| 2E-MW4 | 19.37 | 9.66 | 12.85* |
| 2E-MW5 | 19.44 | 6.54 | 12.90 |
| 2E-MW7 | 19.62 | 6.69 | 12.93 |
| 2E-MW8 | 19.32 | 9.72 | 12.78* |
| 2E-MW9 | 19.52 | 6.89 | 12.63 |
| 2E-MW10 | 20.61 | 7.53 | 13.08 |
| 2E-MW11 | 19.19 | 6.21 | 12.98 |
| 2E-MW12 | 19.32 | 6.61 | 12.71 |
| 2E-MW13 | 19.16 | 6.45 | 12.71 |
| 2E-MW15 | 17.72 | 5.02 | 12.70 |
| 2E-MW16 | 16.41 | 4.16 | 12.25 |

These monitoring wells were re-surveyed and the water-levels measured in December 2000.

* - Water-level elevation corrected to compensate for free product diesel layer present in monitoring well. These water table elevations were not used for contouring.

Figure 2-6 SWMU 2E Water Table Elevation

# 3.0 Conclusions and Future Plans

This section documents conclusions and future plans for SWMU 2B and SWMU 2E based on the monitoring well sampling results.

## 3.1 Conclusions

Several VOCs, specifically cis 1,2-DCE, TCE, bis(2-ethylhexyl)phthalate, vinyl chloride, and benzene are present in the groundwater beneath SWMU 2B and/or SWMU 2E at concentrations that exceed the USEPA MCLs. Antimony and arsenic were also detected at concentrations that exceed their USEPA MCLs.

Based on current survey and water-level data, the groundwater flow in the vicinity of SWMUs 2B and 2E is generally southerly with localized groundwater flow toward nearby stormwater drainage channels.

## 3.2 Current Work/Future Plans at SWMU 2B and SWMU 2E

The results of the groundwater sampling were presented to the NAS Oceana Tier 1 Partnering Team during the June 2000 meeting. The team reached the following conclusions about the investigation:

- The ground water data will be used for the Human Health Risk Assessments (HHRAs)of SWMUs 2B and 2E.
- For both SWMUs, the Navy will utilize institutional controls and conduct periodic groundwater monitoring per the Long Term Monitoring Plan (to be developed) to establish data trends for closing out SMWU 2B and 2E.

### 3.2.1 Current Ecological Risk Assessment at SWMU 2B and SWMU 2E

A screening and baseline Ecological Risk Assessment (ERA) is being prepared for SWMU 2B and a screening ERA has been completed for SWMU 2E. The Draft Final (CH2M HILL, December 2000) version of the ERA for SWMU 2B and the Final (CH2M HILL, December 1999) version of the ERA for SWMU 2E recommend no further evaluation of either SWMU based on the following observations:

#### SWMU 2B

- There is a potential site related risk to terrestrial organisms from the soil at SWMU 2B. However, due to the construction of the Corrosion Control Hangar, this area will eventually be maintained as a mowed lawn. The surrounding area is comprised of buildings, paved parking lots, or tarmac. Due to these alterations, the resulting habitat will be so poor that there will no longer be a reasonably complete exposure pathway from soils to ecological receptors at this SWMU.

- There does not appear to be a transfer of groundwater contaminants to the drainage channel surface water. Therefore, neither groundwater nor surface water is considered to be a risk to aquatic organisms in the SWMU 2B drainage channel sediments.

**SWMU 2E**

- Soil contaminated by waste chemicals and diesel fuel has been covered with asphalt, eliminating the exposure pathway.
- Groundwater contaminants are primarily fuel-related SVOCs, which are relatively immobile. There are no surface water resources on this site. Because the contaminated soil has been covered and there does not appear to be a transport pathway to surface water bodies via groundwater, complete exposure pathways are not present on this site.

### 3.2.2 Future Plans at SWMU 2B and SWMU 2E

Concurrently with the ERA for each SWMU, the Navy is proceeding with the preparation of an HHRA. Prior to beginning the HHRA, the Navy forwarded assumptions to facilitate the assessment of site-wide groundwater sampling results to the USEPA program toxicologist for approval.

Upon completion of the ERA for SWMU 2B and the HHRA for both SWMUs, the Navy will proceed with an FS for both SWMUs, concurrently. Based on the results of the FS, a long term monitoring strategy will be developed and documented in a LTM Work Plan for these and other SWMUs at NAS Oceana. The general LTM plan will establish the overall protocol, and individual modules of the plan will define the specific details to implement LTM at individual SWMUs recommended for LTM across NAS Oceana. The Navy anticipates that the LTM strategy for both SWMUs 2B and 2E will involve the use of institutional controls to limit access to any site related contaminants and require periodic groundwater monitoring to establish data trends to eventually close-out each SMWU, as agreed to during partnering. The Navy will also prepare a Proposed Remedial Action Plan (PRAP) and Record of Decision (ROD) documenting the acceptance of the LTM strategies by the public and the members of the NAS Oceana Tier 1 Partnering Team.

# 4.0 References

66 Federal Register 6976, January 22, 2001.

USEPA. Summer 2000. *Drinking Water Standards and Health Advisories.*

CH2M HILL. December 2000. *Draft Final Screening and Baseline Ecological Risk Assessment, Steps 1, 2, and 3, SWMUs 2B, 11, 16, 16GC, 21, 22, and 26, Naval Air Station Oceana.*

CH2M HILL. December 1999. *Final Screening Ecological Risk Assessment, SWMUs 2C, 2D, 2E, 18, 19, 20, 23, and 24, Naval Air Station Oceana.*

Appendix A-1

# Raw Data

# SWMU 2B and SWMU 2E Monitoring Well Sampling

A1-1
Raw Gr... water Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW01D-R01P 02/25/2000 | OW2B-MW01-R01 02/25/2000 | OW2B-MW02-R01 02/25/2000 | OW2B-MW02-R01P 02/25/2000 | OW2B-MW03-R01 02/25/2000 | OW2B-MW04-R01 02/29/2000 | OW2B-MW04-R01-P 02/29/2000 | OW2B-MW05D-R01 02/22/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| **Volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,1,1-Trichloroethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| 1,1,2,2-Tetrachloroethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| 1,1,2-Trichloroethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| 1,1-Dichloroethane | 1 U | 11 | 0.4 J | 0.3 J | 3 J | 0.2 J | NA | 1 U |
| 1,1-Dichloroethene | 1 U | 3 J | 0.1 J | 0.1 J | 0.8 J | 1 U | NA | 1 U |
| 1,2,4-Trichlorobenzene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| 1,2-Dibromo-3-chloropropane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| 1,2-Dibromoethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| 1,2-Dichlorobenzene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| 1,2-Dichloroethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| 1,2-Dichloropropane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| 1,3-Dichlorobenzene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 0.1 J |
| 1,4-Dichlorobenzene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| 2-Butanone | 5 R | 25 R | 5 R | 5 R | 21 R | 5 R | NA | 5 R |
| 2-Hexanone | 5 U | 25 U | 5 U | 5 U | 21 U | 5 U | NA | 5 U |
| 4-Methyl-2-pentanone | 5 U | 25 U | 5 U | 5 U | 21 U | 5 U | NA | 5 U |
| Acetone | 5 R | 25 R | 5 R | 5 R | 21 R | 7 L | NA | 5 R |
| Benzene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Bromochloromethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Bromodichloromethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Bromoform | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Bromomethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Carbon disulfide | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Carbon tetrachloride | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Chlorobenzene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Chloroethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Chloroform | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Chloromethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 0.1 B |
| cis-1,2-Dichloroethene | 0.3 J | 120 | 12 | 12 | 60 | 0.5 J | NA | 1 U |
| cis-1,3-Dichloropropene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Dibromochloromethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Ethylbenzene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Methylene chloride | 0.4 B | 10 U | 2 U | 2 U | 8 U | 0.4 B | NA | 0.6 B |
| Styrene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Tetrachloroethene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Toluene | 0.1 J | 5 U | 0.1 J | 0.1 J | 4 U | 0.6 J | NA | 0.2 J |
| trans-1,2-Dichloroethene | 1 U | 11 | 0.2 J | 0.2 J | 3 J | 1 U | NA | 1 U |
| trans-1,3-Dichloropropene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Trichloroethene | 0.2 J | 56 B | 14 | 13 | 28 B | 1 U | NA | 1 U |
| Vinyl chloride | 1 U | 13 | 0.6 J | 0.5 J | 2 J | 1 U | NA | 1 U |
| Xylene, total | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| **Semi-volatile Organic Compounds (ug/L)** | | | | | | | NA | |
| 1,2,4-Trichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 1,2-Dichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 1,3-Dichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 1,4-Dichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 2,2'-Oxybis(1-chloropropane) | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 2,4,5-Trichlorophenol | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | NA | 25 U |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-1
Raw Groundwater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW01D-R01P 02/25/2000 | OW2B-MW01-R01 02/25/2000 | OW2B-MW02-R01 02/25/2000 | OW2B-MW02-R01P 02/25/2000 | OW2B-MW03-R01 02/25/2000 | OW2B-MW04-R01 02/29/2000 | OW2B-MW04-R01-P 02/29/2000 | OW2B-MW05D-R01 02/22/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| 2,4,6-Trichlorophenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 2,4-Dichlorophenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 2,4-Dimethylphenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 2,4-Dinitrophenol | 25 U | 25 U | 25 UJ | 25 UJ | 25 UJ | 25 UJ | NA | 25 UJ |
| 2,4-Dinitrotoluene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 2,6-Dinitrotoluene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 2-Chloronaphthalene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 2-Chlorophenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 2-Methylnaphthalene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 2-Methylphenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 2-Nitroaniline | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | NA | 25 U |
| 2-Nitrophenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 3,3'-Dichlorobenzidine | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 3-Nitroaniline | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 U | NA | 25 UJ |
| 4,6-Dinitro-2-methylphenol | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | NA | 25 U |
| 4-Bromophenyl-phenylether | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 4-Chloro-3-methylphenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 4-Chloroaniline | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 4-Chlorophenyl-phenylether | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 4-Methylphenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| 4-Nitroaniline | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 U | NA | 25 UJ |
| 4-Nitrophenol | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 U | NA | 25 UJ |
| Acenaphthene | 1 UL | 1 UL | 1 U | 1 U | 1 U | 1 U | NA | 1 UL |
| Acenaphthylene | 1 UL | 1 UL | 1 U | 1 U | 1 U | 1 U | NA | 1 UL |
| Anthracene | 2 UL | 2 UL | 2 U | 2 U | 2 U | 2 UJ | NA | 2 UL |
| Benzo(a)anthracene | 0.1 UL | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U | NA | 0.1 UL |
| Benzo(a)pyrene | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | NA | 0.1 UJ |
| Benzo(b)fluoranthene | 0.1 UL | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U | NA | 0.1 UL |
| Benzo(g,h,i)perylene | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | NA | 0.1 UJ |
| Benzo(k)fluoranthene | 0.1 UL | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U | NA | 0.1 UL |
| bis(2-Chloroethoxy)methane | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| bis(2-Chloroethyl)ether | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 U | NA | 10 UJ |
| bis(2-Ethylhexyl)phthalate | 1 J | 10 U | 1 J | 2 J | 10 U | 30 | NA | 10 U |
| Butylbenzylphthalate | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 U | NA | 10 UJ |
| Carbazole | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| Chrysene | 0.1 UL | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U | NA | 0.1 UL |
| Dibenz(a,h)anthracene | 0.1 UL | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U | NA | 0.1 UL |
| Dibenzofuran | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| Diethylphthalate | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| Dimethyl phthalate | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| Di-n-butylphthalate | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| Di-n-octyl phthalate | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 U | NA | 10 UJ |
| Fluoranthene | 0.1 UL | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U | NA | 0.1 UL |
| Fluorene | 0.024 L | 1 UL | 1 U | 1 U | 1 U | 1 U | NA | 0.026 L |
| Hexachlorobenzene | 10 U | 10 U | 10 UJ | 10 UJ | 10 UJ | 10 U | NA | 10 UJ |
| Hexachlorobutadiene | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 U | NA | 10 UJ |
| Hexachlorocyclopentadiene | 10 UJ | 10 UJ | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| Hexachloroethane | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |
| Indeno(1,2,3-cd)pyrene | 0.1 UL | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U | NA | 0.1 UL |
| Isophorone | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | NA | 10 U |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

P-Presumptive
U-Not detect
E-Exceeds instrument calibration

A1-1
Raw Gr[illegible]water Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW01D-R01P 02/25/2000 | | OW2B-MW01-R01 02/25/2000 | | OW2B-MW02-R01 02/25/2000 | | OW2B-MW02-R01P 02/25/2000 | | OW2B-MW03-R01 02/25/2000 | | OW2B-MW04-R01 02/29/2000 | | OW2B-MW04-R01-P 02/29/2000 | OW2B-MW05D-R01 02/22/2000 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | | | | | | | |
| Naphthalene | 2 | UL | 2 | UL | 2 | U | 2 | U | 2 | U | 2 | U | NA | 2 | UL |
| Nitrobenzene | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | NA | 10 | U |
| n-Nitroso-di-n-propylamine | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | NA | 10 | U |
| n-Nitrosodiphenylamine | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | NA | 10 | U |
| Pentachlorophenol | 25 | U | 25 | U | 25 | U | 25 | U | 25 | U | 25 | U | NA | 25 | U |
| Phenanthrene | 0.045 | L | 1 | UL | 1 | U | 1 | U | 1 | U | 1 | U | NA | 0.033 | L |
| Phenol | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | NA | 10 | U |
| Pyrene | 0.18 | J | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | U | NA | 0.1 | UJ |
| **Pesticide/Polychlorinated Biphenyls (ug/L)** | | | | | | | | | | | | | NA | | |
| 4,4'-DDD | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | NA | 0.1 | U |
| 4,4'-DDE | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | NA | 0.1 | U |
| 4,4'-DDT | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | NA | 0.1 | U |
| Aldrin | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | NA | 0.05 | U |
| alpha-BHC | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | NA | 0.05 | U |
| alpha-Chlordane | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | NA | 0.05 | U |
| Aroclor-1016 | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | NA | 1 | U |
| Aroclor-1221 | 2 | U | 2 | U | 2 | U | 2 | U | 2 | U | 2 | U | NA | 2 | U |
| Aroclor-1232 | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | NA | 1 | U |
| Aroclor-1242 | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | NA | 1 | U |
| Aroclor-1248 | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | NA | 1 | U |
| Aroclor-1254 | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | NA | 1 | U |
| Aroclor-1260 | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U | NA | 1 | U |
| beta-BHC | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | NA | 0.05 | U |
| delta-BHC | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | NA | 0.05 | U |
| Dieldrin | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | NA | 0.1 | U |
| Endosulfan I | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | NA | 0.05 | U |
| Endosulfan II | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | NA | 0.1 | U |
| Endosulfan sulfate | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | NA | 0.1 | U |
| Endrin | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | NA | 0.1 | U |
| Endrin aldehyde | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | NA | 0.1 | U |
| Endrin ketone | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | NA | 0.1 | U |
| gamma-BHC (Lindane) | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | NA | 0.05 | U |
| gamma-Chlordane | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | NA | 0.05 | U |
| Heptachlor | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | NA | 0.05 | U |
| Heptachlor epoxide | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | NA | 0.05 | U |
| Methoxychlor | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | NA | 0.5 | U |
| Toxaphene | 5 | U | 5 | U | 5 | U | 5 | U | 5 | U | 5 | U | NA | 5 | U |
| **Total Metals (ug/L)** | | | | | | | | | | | | | NA | | |
| Aluminum | 79.3 | B | 75.4 | B | 19.5 | B | 16 | B | 150 | B | 64.7 | B | NA | 45.6 | B |
| Antimony | 2.1 | B | 1.6 | U | 1.6 | U | 1.6 | U | 1.6 | U | 1.6 | U | NA | 3.2 | B |
| Arsenic | 2.5 | U | 2.5 | U | 2.5 | U | 2.5 | U | 2.5 | U | 11 | B | NA | 2.5 | U |
| Barium | 26.3 | J | 19.2 | J | 8.4 | J | 5.8 | J | 29.2 | J | 56.5 | J | NA | 17.4 | J |
| Beryllium | 0.2 | U | 0.2 | U | 0.2 | U | 0.2 | U | 0.2 | U | 0.21 | B | NA | 0.2 | U |
| Cadmium | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U | NA | 0.7 | U |
| Calcium | 36,000 | | 10,300 | | 56,400 | | 57,300 | | 68,300 | | 17,700 | | NA | 42,400 | |
| Chromium | 2.6 | U | 2.6 | U | 2.6 | U | 2.6 | U | 2.6 | U | 2.6 | U | NA | 2.6 | U |
| Cobalt | 1.5 | U | 1.5 | U | 1.5 | U | 1.5 | U | 1.5 | U | 1.5 | U | NA | 1.5 | U |
| Copper | 2.9 | U | 2.9 | U | 2.9 | U | 2.9 | U | 2.9 | U | 2.9 | U | NA | 2.9 | U |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-1
Raw Groundwater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW01D-R01P 02/25/2000 | | OW2B-MW01-R01 02/25/2000 | | OW2B-MW02-R01 02/25/2000 | | OW2B-MW02-R01P 02/25/2000 | | OW2B-MW03-R01 02/25/2000 | | OW2B-MW04-R01 02/29/2000 | | OW2B-MW04-R01-P 02/29/2000 | | OW2B-MW05D-R01 02/22/2000 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | | | | | | | | |
| Cyanide | 10 | U | 10 | U | 10 | U | 10 | U | 1.3 | B | 1.5 | B | NA | | 10 | U |
| Iron | 546 | | 4,450 | | 1,140 | | 1,100 | | 4,950 | | 31,700 | | NA | | 735 | |
| Lead | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | NA | | 1.4 | U |
| Magnesium | 2,780 | J | 15,100 | | 6,830 | | 6,910 | | 9,540 | | 19,600 | | NA | | 4,300 | J |
| Manganese | 86.9 | | 150 | | 410 | | 417 | | 419 | | 250 | | NA | | 89.4 | |
| Mercury | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | UL | NA | | 0.031 | U |
| Nickel | 3.7 | B | 1.9 | B | 1.7 | U | 1.7 | U | 3.9 | B | 2.9 | B | NA | | 1.7 | U |
| Potassium | 8,540 | | 665 | J | 1,170 | J | 1,170 | J | 3,080 | J | 1,160 | J | NA | | 4,610 | J |
| Selenium | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | NA | | 3.1 | U |
| Silver | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | NA | | 1.9 | U |
| Sodium | 17,000 | | 32,900 | | 25,100 | | 25,400 | | 26,900 | | 30,000 | | NA | | 19,900 | |
| Thallium | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | NA | | 9.4 | U |
| Vanadium | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U | 4 | B | NA | | 2.1 | U |
| Zinc | 11.6 | B | 3.7 | B | 1.8 | B | 6.8 | B | 16.1 | B | 16.5 | B | NA | | 17.1 | B |
| **Dissolved Metals (ug/L)** | | | | | | | | | | | | | NA | | | |
| Aluminum | 20.9 | B | 19 | B | 31.9 | B | 20.8 | B | 15.5 | U | 29.2 | B | NA | | 20.2 | B |
| Antimony | 2.3 | B | 1.6 | U | 3.6 | B | 1.6 | U | 2.3 | B | 1.7 | B | NA | | 1.6 | U |
| Arsenic | 2.5 | U | 2.5 | U | 2.5 | U | 2.5 | U | 2.5 | U | 4.3 | B | NA | | 2.5 | U |
| Barium | 25.1 | J | 22 | J | 5.6 | J | 5.3 | J | 31.2 | J | 56.8 | J | NA | | 20.7 | J |
| Beryllium | 0.2 | U | 0.2 | U | 0.2 | U | 0.2 | U | 0.2 | U | 0.2 | U | NA | | 0.2 | U |
| Cadmium | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U | NA | | 0.7 | U |
| Calcium | 36,400 | | 11,400 | | 59,300 | | 61,100 | | 76,700 | | 19,000 | | NA | | 49,200 | |
| Chromium | 2.6 | U | 2.6 | U | 2.6 | U | 2.6 | U | 2.6 | U | 2.6 | U | NA | | 2.6 | U |
| Cobalt | 1.5 | U | 1.5 | U | 1.5 | U | 1.5 | U | 1.5 | U | 1.5 | U | NA | | 1.5 | U |
| Copper | 2.9 | U | 2.9 | U | 2.9 | U | 2.9 | U | 2.9 | U | 2.9 | U | NA | | 2.9 | U |
| Iron | 266 | | 4,430 | | 871 | | 911 | | 5,360 | | 28,900 | | NA | | 703 | |
| Lead | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | NA | | 1.4 | U |
| Magnesium | 2,830 | J | 16,900 | | 7,180 | | 7,390 | | 10,700 | | 20,600 | | NA | | 5,240 | |
| Manganese | 81.6 | | 172 | | 394 | | 408 | | 467 | | 269 | | NA | | 102 | |
| Mercury | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | UL | NA | | 0.031 | U |
| Nickel | 3.2 | J | 2.9 | J | 1.7 | U | 1.7 | U | 3.3 | J | 1.7 | U | NA | | 1.7 | U |
| Potassium | 8,420 | | 758 | J | 1,250 | J | 1,270 | J | 3,320 | J | 1,230 | J | NA | | 5,390 | |
| Selenium | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | NA | | 3.1 | U |
| Silver | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | NA | | 1.9 | U |
| Sodium | 16,400 | | 36,400 | | 26,600 | | 27,700 | | 30,200 | | 31,600 | | NA | | 21,200 | |
| Thallium | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | NA | | 9.4 | U |
| Vanadium | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U | NA | | 2.1 | U |
| Zinc | 3 | J | 5 | J | 9.6 | J | 6.4 | J | 12 | J | 11.6 | B | NA | | 11.2 | J |
| **Geochemistry (MG/L)** | | | | | | | | | | | | | | | | |
| Alkalinity | 85 | | 100 | | 135 | | 130 | | 190 | | 155 | | 210 | | 140 | |
| Chloride | 9.9 | | 18 | | 23 | | 22 | | 15 | | 25 | | 25 | | 15 | |
| Sulfate | 3.6 | | 30 | | 9.95 | | 10 | | 22 | | 17 | | 17 | | 2.5 | |
| Sulfide | 0.12 | | 0.13 | | 0.14 | | 0.14 | | 0.15 | | 0.1 | | 0.12 | | 0.12 | |
| Ethane (NG/L) | 5 | U | 195 | | 25 | | 5 | U | 54 | | 478 | | NA | | 5 | U |
| Ethene (NG/L) | 44 | | 821 | | 25 | | 5 | U | 163 | | 5 | U | NA | | 88 | |
| Iron II | 0.5 | U | 2.7 | | 0.5 | U | 0.5 | U | 2.1 | | 24 | E | 24 | E | 0.5 | U |
| Iron III | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.9 | | 0.8 | | 0.5 | U |
| Manganese | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |

NA-Not analyzed
B-Not c[illegible]d above associated blank
J-Estim[illegible]alue
L-Value may be biased low

R[illegible]ted
U-[illegible]tect
E-Exceeds instrument calibration

A1-1
Raw Gr[illegible]water Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW01D-R01P 02/25/2000 | | OW2B-MW01-R01 02/25/2000 | | OW2B-MW02-R01 02/25/2000 | | OW2B-MW02-R01P 02/25/2000 | | OW2B-MW03-R01 02/25/2000 | | OW2B-MW04-R01 02/29/2000 | | OW2B-MW04-R01-P 02/29/2000 | | OW2B-MW05D-R01 02/22/2000 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | | | | | | | | |
| Methane (UG/L) | 240 | | 590 | | 1.163 | | 0.363 | | 79.77 | | 22,700 | | NA | | 5,080 | |
| Nitrate | 1.6 | | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | |
| Nitrite | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Total Organic Carbon (TOC) | 4 | | 8.2 | | 6 | | 2 | U | 6.6 | | 19 | | NA | | 3.1 | |
| **Field Parameters** | | | | | | | | | | | | | | | | |
| Conductivity (MS/CM) | 215 | | 199 | | 430 | | NA | | 665 | | 329 | | NA | | 235 | |
| DO | 0.12 | | 0.06 | | 0.05 | | NA | | 0.77 | | 0.35 | | NA | | 2.57 | |
| PH (unitless) | 6.94 | | 5.46 | | 7.04 | | NA | | 6.42 | | 6.87 | | NA | | 7.47 | |
| Redox (mV) | -101.2 | | 77.2 | | -64 | | NA | | -29.5 | | -31.9 | | NA | | -90.1 | |
| Temperature (Celsius) | 15.07 | | 14.23 | | 14.92 | | NA | | 15.3 | | 16.21 | | NA | | 16.31 | |
| Turbidity (NTU) | 22.9 | | 30.6 | | 9.7 | | NA | | 85.3 | | 1,835 | | NA | | 1.5 | |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-1
Raw Groundwater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW05-R01 02/21/2000 | OW2B-MW07-R01 02/22/2000 | OW2B-MW08-R01 02/25/2000 | OW2B-MW09-R01 02/25/2000 | OW2B-MW10-R01 02/29/2000 | OW2B-MW11-R01 02/23/2000 | OW2B-MW12-R01 02/21/2000 | OW2B-MW13-R01 02/22/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| **Volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,1,1-Trichloroethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,1,2,2-Tetrachloroethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,1,2-Trichloroethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,1-Dichloroethane | 16 | 2 | 1 U | 1 U | 2 | 6 | 1 U | 8 |
| 1,1-Dichloroethene | 0.3 J | 0.3 J | 1 U | 1 U | 0.1 J | 4 | 1 U | 1 |
| 1,2,4-Trichlorobenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dibromo-3-chloropropane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dibromoethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dichlorobenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dichloroethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dichloropropane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,3-Dichlorobenzene | 0.1 J | 1 U | 1 U | 1 U | 1 U | 1 U | 0.1 J | 1 U |
| 1,4-Dichlorobenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 2-Butanone | 5 R | 5 R | 5 R | 5 R | 5 R | 5 R | 5 R | 5 R |
| 2-Hexanone | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 4-Methyl-2-pentanone | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Acetone | 5 R | 5 R | 5 R | 5 R | 3 L | 5 R | 5 R | 3 L |
| Benzene | 2 | 0.2 J | 1 U | 1 U | 1 U | 0.4 J | 1 U | 0.5 J |
| Bromochloromethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Bromodichloromethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Bromoform | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Bromomethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Carbon disulfide | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Carbon tetrachloride | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chlorobenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chloroethane | 3 | 0.3 J | 1 U | 1 U | 1 U | 1 U | 1 U | 1 |
| Chloroform | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chloromethane | 1 U | 1 U | 0.1 B | 1 U | 1 U | 1 U | 1 U | 1 U |
| cis-1,2-Dichloroethene | 3 | 3 | 0.8 J | 1 U | 4 | 0.4 J | 1 U | 4 |
| cis-1,3-Dichloropropene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Dibromochloromethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Ethylbenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Methylene chloride | 2 U | 0.6 B | 2 U | 0.4 B | 0.2 B | 2 U | 0.7 B | 0.6 B |
| Styrene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Tetrachloroethene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Toluene | 0.2 J | 0.2 J | 0.2 J | 0.1 J | 0.3 J | 0.1 J | 0.2 J | 0.2 J |
| trans-1,2-Dichloroethene | 1 U | 0.1 J | 1 U | 1 U | 0.1 J | 1 U | 1 U | 0.1 J |
| trans-1,3-Dichloropropene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Trichloroethene | 2 | 2 | 0.7 J | 0.1 J | 1 U | 1 U | 1 U | 0.4 J |
| Vinyl chloride | 6 | 2 | 1 U | 1 U | 0.3 J | 1 | 1 U | 9 |
| Xylene, total | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| **Semi-volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,2,4-Trichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 1,2-Dichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 1,3-Dichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 1,4-Dichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,2'-Oxybis(1-chloropropane) | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,4,5-Trichlorophenol | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U |

NA-Not [illegible]yzed
B-Not [illegible]d above associated blank
J-Estim[illegible] value
L-Value may be biased low

F [illegible]ted
U- [illegible]etect
E-Exceeds instrument calibration

Raw Gr[illegible]vater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW05-R01 | | OW2B-MW07-R01 | | OW2B-MW08-R01 | | OW2B-MW09-R01 | | OW2B-MW10-R01 | | OW2B-MW11-R01 | | OW2B-MW12-R01 | | OW2B-MW13-R01 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 02/21/2000 | | 02/22/2000 | | 02/25/2000 | | 02/25/2000 | | 02/29/2000 | | 02/23/2000 | | 02/21/2000 | | 02/22/2000 | |
| **Chemical Name** | | | | | | | | | | | | | | | | |
| 2,4,6-Trichlorophenol | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 2,4-Dichlorophenol | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 2,4-Dimethylphenol | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 2,4-Dinitrophenol | 25 | UJ | 25 | UJ | 25 | U | 25 | U | 25 | UJ | 25 | UJ | 25 | UJ | 25 | UJ |
| 2,4-Dinitrotoluene | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 2,6-Dinitrotoluene | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 2-Chloronaphthalene | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 2-Chlorophenol | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 2-Methylnaphthalene | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 2-Methylphenol | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 2-Nitroaniline | 25 | U | 25 | U | 25 | U | 25 | U | 25 | U | 25 | U | 25 | U | 25 | U |
| 2-Nitrophenol | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 3,3'-Dichlorobenzidine | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 3-Nitroaniline | 25 | UJ | 25 | UJ | 25 | UJ | 25 | UJ | 25 | U | 25 | UJ | 25 | UJ | 25 | UJ |
| 4,6-Dinitro-2-methylphenol | 25 | U | 25 | U | 25 | U | 25 | U | 25 | U | 25 | U | 25 | U | 25 | U |
| 4-Bromophenyl-phenylether | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 4-Chloro-3-methylphenol | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 4-Chloroaniline | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 4-Chlorophenyl-phenylether | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 4-Methylphenol | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| 4-Nitroaniline | 25 | UJ | 25 | UJ | 25 | UJ | 25 | UJ | 25 | U | 25 | UJ | 25 | UJ | 25 | UJ |
| 4-Nitrophenol | 25 | UJ | 25 | UJ | 25 | UJ | 25 | UJ | 25 | U | 25 | UJ | 25 | UJ | 25 | UJ |
| Acenaphthene | 1 | U | 1 | U | 1 | UL | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U |
| Acenaphthylene | 1.6 | J | 1 | U | 1 | UL | 1 | U | 1 | U | 1 | U | 1 | U | 1 | U |
| Anthracene | 2 | U | 2 | U | 2 | UL | 2 | U | 2 | UJ | 2 | U | 2 | U | 2 | U |
| Benzo(a)anthracene | 0.1 | U | 0.1 | U | 0.1 | UL | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U |
| Benzo(a)pyrene | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ |
| Benzo(b)fluoranthene | 0.1 | U | 0.1 | U | 0.1 | UL | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U |
| Benzo(g,h,i)perylene | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ |
| Benzo(k)fluoranthene | 0.1 | U | 0.1 | U | 0.1 | UL | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U |
| bis(2-Chloroethoxy)methane | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| bis(2-Chloroethyl)ether | 10 | UJ | 10 | UJ | 10 | UJ | 10 | UJ | 10 | U | 10 | UJ | 10 | UJ | 10 | UJ |
| bis(2-Ethylhexyl)phthalate | 10 | U | 10 | U | 1 | J | 3 | J | 10 | U | 1 | B | 10 | U | 10 | U |
| Butylbenzylphthalate | 10 | UJ | 10 | UJ | 10 | UJ | 10 | UJ | 10 | U | 10 | UJ | 10 | UJ | 10 | UJ |
| Carbazole | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| Chrysene | 0.1 | U | 0.1 | U | 0.1 | UL | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U |
| Dibenz(a,h)anthracene | 0.1 | UJ | 0.1 | UJ | 0.1 | UL | 0.1 | U | 0.1 | U | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ |
| Dibenzofuran | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| Diethylphthalate | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| Dimethyl phthalate | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| Di-n-butylphthalate | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| Di-n-octyl phthalate | 10 | UJ | 10 | UJ | 10 | UJ | 10 | UJ | 10 | U | 10 | UJ | 10 | UJ | 10 | UJ |
| Fluoranthene | 0.1 | U | 0.1 | U | 0.1 | UL | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U |
| Fluorene | 0.12 | J | 0.059 | J | 1 | UL | 1 | U | 1 | U | 1 | U | 1 | U | 0.028 | J |
| Hexachlorobenzene | 10 | UJ | 10 | UJ | 10 | U | 10 | U | 10 | U | 10 | UJ | 10 | UJ | 10 | UJ |
| Hexachlorobutadiene | 10 | UJ | 10 | UJ | 10 | UJ | 10 | UJ | 10 | U | 10 | UJ | 10 | UJ | 10 | UJ |
| Hexachlorocyclopentadiene | 10 | U | 10 | U | 10 | UJ | 10 | UJ | 10 | U | 10 | U | 10 | U | 10 | U |
| Hexachloroethane | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| Indeno(1,2,3-cd)pyrene | 0.1 | U | 0.1 | U | 0.1 | UL | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U |
| Isophorone | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-1
Raw Groundwater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW05-R01 02/21/2000 | OW2B-MW07-R01 02/22/2000 | OW2B-MW08-R01 02/25/2000 | OW2B-MW09-R01 02/25/2000 | OW2B-MW10-R01 02/29/2000 | OW2B-MW11-R01 02/23/2000 | OW2B-MW12-R01 02/21/2000 | OW2B-MW13-R01 02/22/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| Naphthalene | 0.52 J | 2 U | 2 UL | 2 U | 2 U | 2 U | 2 U | 2 U |
| Nitrobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| n-Nitroso-di-n-propylamine | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| n-Nitrosodiphenylamine | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Pentachlorophenol | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U |
| Phenanthrene | 0.045 J | 1 U | 1 UL | 1 U | 1 U | 1 U | 0.034 J | 1 U |
| Phenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Pyrene | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 U | 0.1 UJ | 0.1 UJ | 0.1 UJ |
| **Pesticide/Polychlorinated Biphenyls (ug/L)** | | | | | | | | |
| 4,4'-DDD | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| 4,4'-DDE | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| 4,4'-DDT | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Aldrin | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| alpha-BHC | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| alpha-Chlordane | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Aroclor-1016 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1221 | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| Aroclor-1232 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1242 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1248 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1254 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1260 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| beta-BHC | 0.028 J | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| delta-BHC | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Dieldrin | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endosulfan I | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Endosulfan II | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endosulfan sulfate | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endrin | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endrin aldehyde | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endrin ketone | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| gamma-BHC (Lindane) | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| gamma-Chlordane | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Heptachlor | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Heptachlor epoxide | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.062 J |
| Methoxychlor | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Toxaphene | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| ***Total Metals (ug/L)*** | | | | | | | | |
| Aluminum | 71.5 B | 15.5 U | 36.3 B | 42.9 B | 86.7 B | 39.8 B | 27.3 B | 81.4 B |
| Antimony | 1.6 U | 2.9 B | 1.6 U | 2.6 B | 3.3 B | 1.6 U | 2.1 B | 2.4 B |
| Arsenic | 19.7 | 2.5 U | 2.5 U | 2.5 U | 8.7 B | 15 | 2.8 J | 4.3 J |
| Barium | 96.3 J | 64.2 J | 4.4 J | 7 J | 19.1 J | 75.2 J | 4.3 J | 17.4 J |
| Beryllium | 0.2 U | 0.2 U | 0.2 U | 0.2 U | 0.2 U | 0.2 U | 0.2 U | 0.2 U |
| Cadmium | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.77 J | 0.7 U | 0.7 U | 0.7 U |
| Calcium | 30,100 | 7,730 | 12,400 | 43,500 | 31,600 | 29,400 | 43,600 | 61,700 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U |
| Cobalt | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U |
| Copper | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U |

NA-Not [illegible]lyzed
B-Not [illegible]d above associated blank
J-Estim[illegible]value
L-Value may be biased low

F [illegible]ted
U-[illegible]etect
E-Exceeds instrument calibration

A1-1
Raw Gr .vater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW05-R01 02/21/2000 | OW2B-MW07-R01 02/22/2000 | OW2B-MW08-R01 02/25/2000 | OW2B-MW09-R01 02/25/2000 | OW2B-MW10-R01 02/29/2000 | OW2B-MW11-R01 02/23/2000 | OW2B-MW12-R01 02/21/2000 | OW2B-MW13-R01 02/22/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| Cyanide | 1.4 B | 1.7 B | 10 U | 1.1 B | 1.7 B | 10 U | 1.2 B | 10 U |
| Iron | 30,000 | 14,000 | 1,590 | 2,570 | 16,700 | 33,500 | 1,390 | 10,200 |
| Lead | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U |
| Magnesium | 14,400 | 12,900 | 2,710 J | 5,920 | 9,190 | 38,700 | 8,150 | 11,700 |
| Manganese | 890 | 327 | 101 | 292 | 490 | 540 | 300 | 677 |
| Mercury | 0.031 U | 0.031 U | 0.031 U | 0.031 U | 0.031 UL | 0.031 U | 0.031 U | 0.031 U |
| Nickel | 1.7 U | 1.7 U | 1.7 U | 1.7 U | 2.1 B | 1.7 U | 1.7 U | 1.7 U |
| Potassium | 3,190 J | 951 J | 451 J | 1,010 J | 1,340 J | 1,250 J | 982 J | 1,460 J |
| Selenium | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.1 U |
| Silver | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U |
| Sodium | 11,600 | 14,100 | 38,400 | 20,500 | 25,800 | 28,500 | 36,300 | 21,200 |
| Thallium | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U |
| Vanadium | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U |
| Zinc | 2.5 B | 14.5 B | 3.7 B | 2.9 B | 36.4 | 12.6 B | 6.2 B | 8.8 B |
| **Dissolved Metals (ug/L)** | | | | | | | | |
| Aluminum | 20.1 B | 28.2 B | 457 J | 15.5 U | 24.8 B | 54.8 B | 51 B | 16.9 B |
| Antimony | 2.4 B | 1.6 U | 2.3 B | 2.3 B | 7.7 B | 2.7 B | 1.6 B | 1.6 U |
| Arsenic | 19.2 | 2.5 U | 2.5 U | 2.5 U | 4 B | 10.3 | 2.5 U | 3.5 J |
| Barium | 86 J | 61.7 J | 7.1 J | 3.3 J | 16.6 J | 74 J | 4.2 J | 17.2 J |
| Beryllium | 0.57 B | 0.2 U | 0.2 U | 0.2 U | 0.2 U | 0.22 B | 0.2 U | 0.21 B |
| Cadmium | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U |
| Calcium | 26,700 | 7,250 | 15,200 | 43,200 | 33,200 | 29,200 | 45,400 | 58,800 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U |
| Cobalt | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U |
| Copper | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 3 B | 2.9 U | 2.9 U | 2.9 U |
| Iron | 26,400 | 12,200 | 1,440 | 2,050 | 10,100 | 31,600 | 1,170 | 9,720 |
| Lead | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U |
| Magnesium | 12,800 | 12,400 | 2,760 J | 5,840 | 9,700 | 38,500 | 8,390 | 11,200 |
| Manganese | 789 | 313 | 105 | 290 | 511 | 539 | 315 | 648 |
| Mercury | 0.031 U | 0.031 U | 0.031 U | 0.031 U | 0.031 UL | 0.031 U | 0.031 U | 0.031 U |
| Nickel | 1.7 U | 1.7 U | 1.7 U | 1.9 J | 1.9 B | 2.4 J | 1.7 U | 1.7 U |
| Potassium | 2,840 J | 959 J | 478 J | 995 J | 1,370 J | 1,230 J | 1,020 J | 1,390 J |
| Selenium | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.1 U |
| Silver | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U |
| Sodium | 9,780 | 15,100 | 39,100 | 20,400 | 26,800 | 28,500 | 38,100 | 20,000 |
| Thallium | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U |
| Vanadium | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.2 B | 2.1 U | 2.1 U | 2.1 U |
| Zinc | 3.4 J | 18.7 J | 4.6 J | 2.5 J | 18.3 J | 13.1 J | 7.8 J | 6.2 J |
| **Geochemistry (MG/L)** | | | | | | | | |
| Alkalinity | 60 | 55 | 60 | 120 | 400 | 200 | 100 | 120 |
| Chloride | 8.9 | 19 | 11 | 18 | 24 | 32 | 21 | 15 |
| Sulfate | 1.5 | 21 | 25 | 6.9 | 8.8 | 8.7 | 9 | 11 |
| Sulfide | 0.19 | 0.12 | 0.12 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 |
| Ethane (NG/L) | 273 | 41 | 13 | 5 U | 108 | 356 | 5 U | 112 |
| Ethene (NG/L) | 869 | 158 | 23 | 5 U | 5 U | 78 | 5 U | 479 |
| Iron II | 18 | 8.4 | 0.5 U | 0.5 U | 7.6 | 22 | 0.5 U | 5.1 |
| Iron III | 1.5 | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Manganese | 1 | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.8 U | 0.5 U | 0.6 |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-1
Raw Groundwater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW05-R01 02/21/2000 | | OW2B-MW07-R01 02/22/2000 | | OW2B-MW08-R01 02/25/2000 | | OW2B-MW09-R01 02/25/2000 | | OW2B-MW10-R01 02/29/2000 | | OW2B-MW11-R01 02/23/2000 | | OW2B-MW12-R01 02/21/2000 | | OW2B-MW13-R01 02/22/2000 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | | | | | | | | |
| Methane (UG/L) | 5,070 | | 810 | | 11.73 | | 0.383 | | 250 | | 1,080 | | 2.214 | | 2,010 | |
| Nitrate | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Nitrite | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Total Organic Carbon (TOC) | 12 | | 23 | | 3.3 | | 4.8 | | 19 | | 12 | | 2.8 | | 11 | |
| **Field Parameters** | | | | | | | | | | | | | | | | |
| Conductivity (MS/CM) | 261 | | 156 | | 191 | | 215 | | 329 | | 458 | | 284 | | 320 | |
| DO | 0.2 | | 0.18 | | NA | | 0.12 | | 0.35 | | 0.05 | | 0.35 | | 0.15 | |
| PH (unitless) | 6.36 | | 5.89 | | 5.94 | | 6.94 | | 6.87 | | 5.42 | | 7 | | 6.24 | |
| Redox (mV) | -175.2 | | -80.5 | | -36 | | -101.2 | | -31.9 | | -66 | | -144.8 | | -128 | |
| Temperature (Celsius) | 14.36 | | 12.5 | | 15.08 | | 15.07 | | 16.21 | | 16.4 | | 13.73 | | 14.64 | |
| Turbidity (NTU) | 23.4 | | 29.8 | | 2.66 | | 22.9 | | 1,835 | | 48.2 | | 2.2 | | 2.3 | |

NA-Not [illegible]lyzed
B-Not [illegible]d above associated blank
J-Estim[illegible]value
L-Value may be biased low

F [illegible]ted
U-[illegible]etect
E-Exceeds instrument calibration

Raw G[illegible] water Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW14-R01 02/23/2000 | OW2B-MW15-R01 02/23/2000 | OW2B-MW16-R01 02/22/2000 | OW2B-MW17-R01 02/22/2000 | OW2B-MW18-R01 02/22/2000 | OW2B-MW19-R01 02/26/2000 | OW2B-MW20-R01 02/26/2000 | OW2B-MW20-R01P 02/26/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| **Volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,1,1-Trichloroethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,1,2,2-Tetrachloroethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,1,2-Trichloroethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,1-Dichloroethane | 12 | 0.4 J | 4 | 2 | 0.1 J | 4 | 1 U | 1 U |
| 1,1-Dichloroethene | 1 | 1 U | 0.9 J | 0.6 J | 1 U | 1 U | 1 U | 1 U |
| 1,2,4-Trichlorobenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dibromo-3-chloropropane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dibromoethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dichlorobenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dichloroethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dichloropropane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,3-Dichlorobenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,4-Dichlorobenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| 2-Butanone | 5 R | 5 R | 5 R | 5 R | 5 R | 5 R | 5 R | 5 R |
| 2-Hexanone | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| 4-Methyl-2-pentanone | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| Acetone | 5 R | 2 L | 3 L | 5 R | 5 R | 5 R | 5 R | 5 R |
| Benzene | 0.1 J | 1 U | 0.6 J | 0.5 J | 1 U | 1 U | 1 U | 1 U |
| Bromochloromethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Bromodichloromethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Bromoform | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Bromomethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Carbon disulfide | 1 U | 1 U | 1 U | 0.7 J | 1 U | 0.4 J | 0.4 J | 0.8 J |
| Carbon tetrachloride | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chlorobenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chloroethane | 2 | 1 U | 1 U | 1 | 1 U | 1 U | 1 U | 1 U |
| Chloroform | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chloromethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| cis-1,2-Dichloroethene | 1 | 0.4 J | 6 | 3 | 0.2 J | 0.1 J | 1 U | 1 U |
| cis-1,3-Dichloropropene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Dibromochloromethane | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Ethylbenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Methylene chloride | 2 U | 2 U | 0.6 B | 0.6 B | 0.6 B | 0.2 J | 0.2 J | 0.2 J |
| Styrene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Tetrachloroethene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Toluene | 0.1 J | 0.1 J | 0.2 J | 0.2 J | 0.2 J | 0.1 J | 1 U | 1 U |
| trans-1,2-Dichloroethene | 1 U | 1 U | 0.4 J | 0.3 J | 1 U | 1 U | 1 U | 1 U |
| trans-1,3-Dichloropropene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Trichloroethene | 1 U | 0.2 J | 1 U | 1 U | 0.3 J | 1 U | 1 U | 1 U |
| Vinyl chloride | 9 | 0.6 J | 0.3 J | 0.5 J | 1 U | 1 | 1 U | 1 U |
| Xylene, total | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| **Semi-volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,2,4-Trichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 1,2-Dichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 1,3-Dichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 1,4-Dichlorobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,2'-Oxybis(1-chloropropane) | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,4,5-Trichlorophenol | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-1
Raw Groundwater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW14-R01 02/23/2000 | OW2B-MW15-R01 02/23/2000 | OW2B-MW16-R01 02/22/2000 | OW2B-MW17-R01 02/22/2000 | OW2B-MW18-R01 02/22/2000 | OW2B-MW19-R01 02/26/2000 | OW2B-MW20-R01 02/26/2000 | OW2B-MW20-R01P 02/26/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| 2,4,6-Trichlorophenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,4-Dichlorophenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,4-Dimethylphenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,4-Dinitrophenol | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 UJ |
| 2,4-Dinitrotoluene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,6-Dinitrotoluene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Chloronaphthalene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Chlorophenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Methylnaphthalene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Methylphenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Nitroaniline | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U |
| 2-Nitrophenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 3,3'-Dichlorobenzidine | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 3-Nitroaniline | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 U | 25 U | 25 U |
| 4,6-Dinitro-2-methylphenol | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U |
| 4-Bromophenyl-phenylether | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Chloro-3-methylphenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Chloroaniline | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Chlorophenyl-phenylether | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Methylphenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Nitroaniline | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 U | 25 U | 25 U |
| 4-Nitrophenol | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 UJ | 25 U | 25 U | 25 U |
| Acenaphthene | 1 U | 1 U | 1 U | 1 UL | 1 U | 1 U | 1 U | 1 U |
| Acenaphthylene | 1 U | 1 U | 1 U | 1 UL | 1 U | 1 U | 1 U | 1 U |
| Anthracene | 2 U | 2 U | 2 U | 2 UL | 2 U | 2 UJ | 2 UJ | 2 UJ |
| Benzo(a)anthracene | 0.1 U | 0.1 U | 0.1 U | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Benzo(a)pyrene | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ |
| Benzo(b)fluoranthene | 0.1 U | 0.1 U | 0.1 U | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Benzo(g,h,i)perylene | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ |
| Benzo(k)fluoranthene | 0.1 U | 0.1 U | 0.1 U | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| bis(2-Chloroethoxy)methane | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| bis(2-Chloroethyl)ether | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 U | 10 U | 10 U |
| bis(2-Ethylhexyl)phthalate | 6 B | 4 B | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Butylbenzylphthalate | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 U | 10 U | 10 U |
| Carbazole | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Chrysene | 0.1 U | 0.1 U | 0.1 U | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Dibenz(a,h)anthracene | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UL | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U |
| Dibenzofuran | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Diethylphthalate | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Dimethyl phthalate | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Di-n-butylphthalate | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Di-n-octyl phthalate | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 U | 10 U | 10 U |
| Fluoranthene | 0.1 U | 0.1 U | 0.1 U | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Fluorene | 1 U | 1 U | 1 U | 1 UL | 0.098 J | 1 U | 1 U | 1 U |
| Hexachlorobenzene | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 U | 10 U | 10 U |
| Hexachlorobutadiene | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 UJ | 10 U | 10 U | 10 U |
| Hexachlorocyclopentadiene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Hexachloroethane | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Indeno(1,2,3-cd)pyrene | 0.1 U | 0.1 U | 0.1 U | 0.1 UL | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Isophorone | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |

NA-Not analyzed
B-Not d above associated blank
J-Estim alue
L-Value may be biased low

P ted
U- tect
E-Exceeds instrument calibration

Raw Gr[illegible]water Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW14-R01 | OW2B-MW15-R01 | OW2B-MW16-R01 | OW2B-MW17-R01 | OW2B-MW18-R01 | OW2B-MW19-R01 | OW2B-MW20-R01 | OW2B-MW20-R01P |
|---|---|---|---|---|---|---|---|---|
| | 02/23/2000 | 02/23/2000 | 02/22/2000 | 02/22/2000 | 02/22/2000 | 02/26/2000 | 02/26/2000 | 02/26/2000 |
| **Chemical Name** | | | | | | | | |
| Naphthalene | 2 U | 2 U | 2 U | 2 UL | 2 U | 2 U | 2 U | 2 U |
| Nitrobenzene | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| n-Nitroso-di-n-propylamine | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| n-Nitrosodiphenylamine | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Pentachlorophenol | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U |
| Phenanthrene | 1 U | 1 U | 1 U | 1 UL | 1 U | 1 U | 1 U | 1 U |
| Phenol | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Pyrene | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U |
| **Pesticide/Polychlorinated Biphenyls (ug/L)** | | | | | | | | |
| 4,4'-DDD | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| 4,4'-DDE | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| 4,4'-DDT | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Aldrin | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| alpha-BHC | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| alpha-Chlordane | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Aroclor-1016 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1221 | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| Aroclor-1232 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1242 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1248 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1254 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1260 | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| beta-BHC | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| delta-BHC | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Dieldrin | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endosulfan I | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Endosulfan II | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endosulfan sulfate | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endrin | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endrin aldehyde | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endrin ketone | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| gamma-BHC (Lindane) | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| gamma-Chlordane | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Heptachlor | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Heptachlor epoxide | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Methoxychlor | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Toxaphene | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U | 5 U |
| **Total Metals (ug/L)** | | | | | | | | |
| Aluminum | 15.5 U | 40.2 B | 66.9 B | 39.9 B | 76.1 B | 76.8 B | 35.2 B | 25.9 B |
| Antimony | 1.6 U | 1.8 B | 2 B | 1.6 U | 2.8 B | 1.6 U | 1.6 U | 1.6 U |
| Arsenic | 2.5 U | 6 J | 20.4 | 29.7 | 12.5 | 2.5 U | 2.8 B | 2.5 B |
| Barium | 11.7 J | 57.8 J | 56.9 J | 41.2 J | 54.1 J | 37.7 J | 65.6 J | 64.1 J |
| Beryllium | 0.2 U | 0.41 B | 0.2 U | 0.2 U | 0.2 U | 0.2 U | 0.2 U | 0.2 U |
| Cadmium | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U |
| Calcium | 58,800 | 6,640 | 17,500 | 17,600 | 13,900 | 12,100 | 40,800 | 40,100 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 4.8 J | 4.8 J |
| Cobalt | 1.5 U | 1.5 U | 9.3 J | 1.5 U | 1.6 J | 1.5 U | 1.5 U | 1.5 U |
| Copper | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-1
Raw Groundwater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW14-R01 | | OW2B-MW15-R01 | | OW2B-MW16-R01 | | OW2B-MW17-R01 | | OW2B-MW18-R01 | | OW2B-MW19-R01 | | OW2B-MW20-R01 | | OW2B-MW20-R01P | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 02/23/2000 | | 02/23/2000 | | 02/22/2000 | | 02/22/2000 | | 02/22/2000 | | 02/26/2000 | | 02/26/2000 | | 02/26/2000 | |
| **Chemical Name** | | | | | | | | | | | | | | | | |
| Cyanide | 10 | U | 1.7 | B | 1.5 | B | 10 | U | 10 | U | 2.5 | B | 10 | U | 10 | U |
| Iron | 9,280 | | 6,260 | | 29,900 | | 35,500 | | 11,700 | | 7,720 | | 7,080 | | 6,950 | |
| Lead | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U |
| Magnesium | 10,800 | | 10,300 | | 32,400 | | 13,500 | | 5,120 | | 8,580 | | 11,200 | | 11,000 | |
| Manganese | 507 | | 269 | | 648 | | 494 | | 230 | | 181 | | 500 | | 492 | |
| Mercury | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | UL | 0.031 | UL | 0.031 | UL |
| Nickel | 1.7 | U | 1.8 | B | 9.3 | B | 1.7 | U | 1.7 | U | 1.7 | U | 1.7 | U | 1.7 | U |
| Potassium | 1,280 | J | 897 | J | 752 | J | 1,870 | J | 1,370 | J | 1,120 | J | 2,190 | J | 2,140 | J |
| Selenium | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U |
| Silver | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U |
| Sodium | 26,800 | | 9,390 | | 36,000 | | 16,600 | | 12,200 | | 14,400 | | 28,800 | | 28,100 | |
| Thallium | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U |
| Vanadium | 2.1 | U | 2.1 | U | 2.2 | J | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U |
| Zinc | 2.9 | B | 3.8 | B | 4.4 | B | 6.5 | B | 4.9 | B | 10.3 | B | 9 | B | 12.3 | B |
| **Dissolved Metals (ug/L)** | | | | | | | | | | | | | | | | |
| Aluminum | 37 | B | 150 | B | 26 | B | 17.2 | B | 15.5 | U | 33.1 | B | 21.6 | B | 25 | B |
| Antimony | 1.6 | U | 2.2 | B | 2.4 | B | 1.8 | B | 1.6 | U | 1.6 | U | 1.6 | U | 2.4 | B |
| Arsenic | 2.5 | U | 5.2 | J | 17.3 | | 32.2 | | 9.7 | J | 3.1 | B | 2.5 | U | 2.5 | U |
| Barium | 11.6 | J | 56 | J | 61.6 | J | 42.6 | J | 51.4 | J | 36.4 | J | 64.5 | J | 63.3 | J |
| Beryllium | 0.2 | U | 0.56 | B | 0.2 | U | 0.2 | U | 0.2 | U | 0.2 | U | 0.2 | U | 0.21 | B |
| Cadmium | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U |
| Calcium | 61,800 | | 6,610 | | 19,300 | | 18,400 | | 13,900 | | 12,100 | | 40,400 | | 39,400 | |
| Chromium | 2.6 | U | 2.6 | U | 2.6 | U | 2.6 | U | 2.6 | U | 2.6 | U | 4.3 | J | 4.2 | J |
| Cobalt | 1.5 | U | 1.5 | U | 10.1 | J | 1.5 | U | 1.7 | J | 1.5 | U | 1.5 | U | 1.5 | U |
| Copper | 2.9 | U | 2.9 | U | 2.9 | U | 2.9 | U | 2.9 | U | 2.9 | U | 2.9 | U | 2.9 | U |
| Iron | 9,580 | | 5,930 | | 30,400 | | 36,400 | | 10,800 | | 5,460 | | 7,050 | | 6,880 | |
| Lead | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | 1.4 | U | 4.5 | | 1.4 | U |
| Magnesium | 11,100 | | 9,920 | | 35,700 | | 14,000 | | 5,010 | | 8,560 | | 11,200 | | 10,900 | |
| Manganese | 529 | | 259 | | 714 | | 512 | | 226 | | 180 | | 498 | | 486 | |
| Mercury | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | U | 0.031 | UL | 0.031 | UL | 0.031 | U |
| Nickel | 1.7 | U | 2.2 | J | 7.1 | J | 1.7 | U | 1.7 | U | 1.7 | U | 1.7 | U | 1.7 | U |
| Potassium | 1,360 | J | 849 | J | 866 | J | 1,960 | J | 1,350 | J | 1,040 | J | 2,120 | J | 2,060 | J |
| Selenium | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U | 3.1 | U |
| Silver | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U | 1.9 | U |
| Sodium | 28,000 | | 8,770 | | 40,000 | | 17,300 | | 11,500 | | 14,100 | | 28,200 | | 27,600 | |
| Thallium | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U | 9.4 | U |
| Vanadium | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U | 2.1 | U |
| Zinc | 4.3 | J | 9.6 | J | 5.8 | J | 4.5 | J | 12.5 | J | 9.7 | B | 10.2 | B | 8.5 | B |
| **Geochemistry (MG/L)** | | | | | | | | | | | | | | | | |
| Alkalinity | 195 | | 25 | | 85 | | 93 | | 40 | | 65 | | NA | | 110 | |
| Chloride | 19 | | 14 | | 30 | | 12 | | 14 | | 7.5 | | 22 | | 23 | |
| Sulfate | 17 | | 21 | | 20 | | 19 | | 17 | | 16 | | 1.5 | | 1.5 | |
| Sulfide | 0.12 | | 0.15 | | 0.1 | | 0.11 | | 0.08 | | 0.12 | | NA | | 0.16 | |
| Ethane (NG/L) | 363 | | 321 | | 50 | | 5 | U | 5 | U | 22 | | 109 | | 90 | |
| Ethene (NG/L) | 1,170 | | 60 | | 37 | | 64 | | 5 | U | 32 | | 5 | U | 5 | U |
| Iron II | 6.5 | | 4.3 | | 17 | | 18 | | 6.1 | | 4.2 | | 4.7 | | 4.5 | |
| Iron III | 0.8 | | 0.5 | U | 1 | | 1.1 | | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Manganese | 0.5 | | 0.5 | U | 0.5 | | 0.7 | | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |

NA-Not analyzed
B-Not d[illegible]d above associated blank
J-Estim[illegible]alue
L-Value may be biased low

R[illegible]ted
U-[illegible]tect
E-Exceeds instrument calibration

A1-1
Raw Gr. .water Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW14-R01 02/23/2000 | | OW2B-MW15-R01 02/23/2000 | | OW2B-MW16-R01 02/22/2000 | | OW2B-MW17-R01 02/22/2000 | | OW2B-MW18-R01 02/22/2000 | | OW2B-MW19-R01 02/26/2000 | | OW2B-MW20-R01 02/26/2000 | | OW2B-MW20-R01P 02/26/2000 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | | | | | | | | |
| Methane (UG/L) | 1,880 | | 1,170 | | 1,270 | | 2,150 | | 1,510 | | 73.15 | | 1,295 | | 1,160 | |
| Nitrate | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Nitrite | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Total Organic Carbon (TOC) | 6.3 | | 8.1 | | 26 | | 9.4 | | 5.9 | | 3.5 | | 4.6 | | 4.6 | |
| **Field Parameters** | | | | | | | | | | | | | | | | |
| Conductivity (MS/CM) | 372 | | 139 | | 387 | | 260 | | 140 | | 152 | | 316 | | NA | |
| DO | 0.01 | | 0.06 | | 0.13 | | 0.08 | | 0.17 | | 0.04 | | 0.08 | | NA | |
| PH (unitless) | 5.97 | | 5.56 | | 5.7 | | 6.19 | | 6.22 | | 5.89 | | 6.17 | | NA | |
| Redox (mV) | -119.1 | | -69.4 | | -57.4 | | -137.9 | | -114.7 | | 32.9 | | 18.9 | | NA | |
| Temperature (Celsius) | 16.07 | | 15.79 | | 15.81 | | 14.94 | | 15 | | 16.68 | | 17.72 | | NA | |
| Turbidity (NTU) | 13.1 | | 0.5 | | 30.8 | | 1.5 | | 9.7 | | 195 | | 0.5 | | NA | |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Raw G. water Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW01-R01 03/06/2000 | OW2E-MW03-R01 03/16/2000 | OW2E-MW03-R01-P 03/16/2000 | OW2E-MW04-R01 03/06/2000 | OW2E-MW05-R01 03/06/2000 | OW2E-MW07-R01 03/16/2000 | OW2E-MW07-R01-P 03/16/2000 | OW2E-MW08-R01 03/06/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| **Volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,1,1-Trichloroethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,1,2,2-Tetrachloroethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,1,2-Trichloroethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,1-Dichloroethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,1-Dichloroethene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,2,4-Trichlorobenzene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,2-Dibromo-3-chloropropane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,2-Dibromoethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,2-Dichlorobenzene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,2-Dichloroethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,2-Dichloropropane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,3-Dichlorobenzene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 1,4-Dichlorobenzene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 2-Butanone | 12 R | 5 R | 5 R | 25 R | 5 R | 5 R | 5 R | 25 R |
| 2-Hexanone | 12 U | 5 U | 5 U | 25 U | 5 U | 5 U | 5 U | 25 U |
| 4-Methyl-2-pentanone | 12 U | 5 U | 5 U | 25 U | 5 U | 5 U | 5 U | 25 U |
| Acetone | 12 R | 5 R | 5 R | 25 R | 9 L | 4 L | 2 L | 25 R |
| Benzene | 0.5 J | 1 U | 1 U | 15 | 0.5 J | 1 U | 1 U | 2 J |
| Bromochloromethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Bromodichloromethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Bromoform | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Bromomethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Carbon disulfide | 2 U | 1 U | 1 U | 5 U | 0.4 J | 1 U | 1 U | 5 U |
| Carbon tetrachloride | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Chlorobenzene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 0.3 J |
| Chloroethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Chloroform | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Chloromethane | 2 U | 1 U | 0.2 B | 5 U | 1 U | 1 U | 1 U | 5 U |
| cis-1,2-Dichloroethene | 2 U | 1 U | 1 U | 5 U | 0.3 J | 1 U | 1 U | 5 U |
| cis-1,3-Dichloropropene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Dibromochloromethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Ethylbenzene | 0.3 J | 1 U | 1 U | 1 J | 0.4 J | 1 U | 1 U | 11 |
| Methylene chloride | 5 U | 2 B | 2 B | 10 U | 2 U | 2 B | 2 B | 10 U |
| Styrene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Tetrachloroethene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Toluene | 2 U | 0.1 J | 0.1 J | 5 U | 0.3 J | 0.1 J | 0.1 J | 0.3 J |
| trans-1,2-Dichloroethene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| trans-1,3-Dichloropropene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Trichloroethene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 0.2 J |
| Vinyl chloride | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Xylene, total | 2 U | 1 U | 0.2 J | 2 J | 1 | 1 U | 1 U | 24 |
| **Semi-volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,2,4-Trichlorobenzene | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 1,2-Dichlorobenzene | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 1,3-Dichlorobenzene | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 1,4-Dichlorobenzene | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 2,2'-Oxybis(1-chloropropane) | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 2,4,5-Trichlorophenol | 120 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 100 U |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-2
Raw Groundwater Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW01-R01 03/06/2000 | OW2E-MW03-R01 03/16/2000 | OW2E-MW03-R01-P 03/16/2000 | OW2E-MW04-R01 03/06/2000 | OW2E-MW05-R01 03/06/2000 | OW2E-MW07-R01 03/16/2000 | OW2E-MW07-R01-P 03/16/2000 | OW2E-MW08-R01 03/06/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| 2,4,6-Trichlorophenol | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 2,4-Dichlorophenol | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 2,4-Dimethylphenol | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 2,4-Dinitrophenol | 120 UJ | 25 U | 25 U | 25 UJ | 25 UJ | 25 U | 25 U | 100 UJ |
| 2,4-Dinitrotoluene | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 2,6-Dinitrotoluene | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 2-Chloronaphthalene | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 2-Chlorophenol | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 2-Methylnaphthalene | 120 | 10 U | 10 U | 110 | 10 U | 10 U | 10 U | 56 |
| 2-Methylphenol | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 2-Nitroaniline | 120 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 100 U |
| 2-Nitrophenol | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 3,3'-Dichlorobenzidine | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 3-Nitroaniline | 120 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 100 U |
| 4,6-Dinitro-2-methylphenol | 120 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 100 U |
| 4-Bromophenyl-phenylether | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 4-Chloro-3-methylphenol | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 4-Chloroaniline | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 4-Chlorophenyl-phenylether | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 4-Methylphenol | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| 4-Nitroaniline | 120 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 100 U |
| 4-Nitrophenol | 120 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 100 U |
| Acenaphthene | 20 U | 1 U | 1 U | 2 J | 1 U | 5 U | 1 U | 50 U |
| Acenaphthylene | 20 U | 1 U | 1 U | 5 U | 1 U | 5 U | 1 U | 50 U |
| Anthracene | 40 U | 2 U | 2 U | 10 U | 2 U | 10 U | 2 U | 100 U |
| Benzo(a)anthracene | 2 U | 0.1 U | 0.1 U | 0.5 U | 0.1 U | 0.5 U | 0.1 U | 4.8 J |
| Benzo(a)pyrene | 2 UJ | 0.1 U | 0.1 U | 0.5 UJ | 0.1 UJ | 0.5 U | 0.1 U | 5 UJ |
| Benzo(b)fluoranthene | 2 U | 0.1 U | 0.1 U | 0.5 U | 0.1 U | 0.5 U | 0.1 U | 5 U |
| Benzo(g,h,i)perylene | 2 UJ | 0.1 U | 0.1 U | 0.5 UJ | 0.1 UJ | 0.5 U | 0.1 U | 5 UJ |
| Benzo(k)fluoranthene | 2 U | 0.1 U | 0.1 U | 0.5 U | 0.1 U | 0.5 U | 0.1 U | 5 U |
| bis(2-Chloroethoxy)methane | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| bis(2-Chloroethyl)ether | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| bis(2-Ethylhexyl)phthalate | 50 U | 10 U | 10 U | 10 | 10 U | 1 B | 10 U | 40 U |
| Butylbenzylphthalate | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Carbazole | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Chrysene | 2 U | 0.1 U | 0.1 U | 0.5 U | 0.1 U | 0.5 U | 0.1 U | 5 U |
| Dibenz(a,h)anthracene | 2 U | 0.1 U | 0.1 U | 0.5 U | 0.1 U | 0.5 U | 0.1 U | 5 U |
| Dibenzofuran | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Diethylphthalate | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Dimethyl phthalate | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Di-n-butylphthalate | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Di-n-octyl phthalate | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Fluoranthene | 2 U | 0.1 U | 0.1 U | 0.5 U | 0.1 U | 0.5 U | 0.1 U | 5 U |
| Fluorene | 8.2 J | 1 U | 1 U | 2.9 J | 0.28 J | 0.06 B | 0.04 B | 18 J |
| Hexachlorobenzene | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Hexachlorobutadiene | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Hexachlorocyclopentadiene | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Hexachloroethane | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Indeno(1,2,3-cd)pyrene | 2 U | 0.1 U | 0.1 U | 0.5 U | 0.1 U | 0.5 U | 0.1 U | 5 U |
| Isophorone | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |

NA-Not [illegible]lyzed
B-Not [illegible]d above associated blank
J-Estim[illegible] value
L-Value may be biased low

F [illegible]ted
U-[illegible]etect
E-Exceeds instrument calibration

Raw Gr... water Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW01-R01 03/06/2000 | OW2E-MW03-R01 03/16/2000 | OW2E-MW03-R01-P 03/16/2000 | OW2E-MW04-R01 03/06/2000 | OW2E-MW05-R01 03/06/2000 | OW2E-MW07-R01 03/16/2000 | OW2E-MW07-R01-P 03/16/2000 | OW2E-MW08-R01 03/06/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| Naphthalene | 46 | 2 U | 2 U | 130 | 3.2 | 10 U | 2 U | 95 J |
| Nitrobenzene | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| n-Nitroso-di-n-propylamine | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| n-Nitrosodiphenylamine | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Pentachlorophenol | 120 U | 25 U | 25 U | 25 U | 25 U | 25 U | 25 U | 100 U |
| Phenanthrene | 13 J | 1 U | 1 U | 6.5 J | 0.55 J | 5 U | 1 U | 59 J |
| Phenol | 50 U | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U | 40 U |
| Pyrene | 54 J | 0.1 U | 0.1 U | 10 J | 2.3 J | 0.5 U | 0.1 U | 240 J |
| **Pesticide/Polychlorinated Biphenyls (ug/L)** | | | | | | | | |
| 4,4'-DDD | 0.1 U | 0.1 U | 0.1 U | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| 4,4'-DDE | 0.1 U | 0.1 U | 0.1 U | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| 4,4'-DDT | 0.1 U | 0.1 U | 0.1 U | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Aldrin | 0.05 U | 0.05 U | 0.05 U | 0.05 UJ | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| alpha-BHC | 0.05 U | 0.05 U | 0.05 U | 0.05 UJ | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| alpha-Chlordane | 0.05 U | 0.05 U | 0.05 U | 0.05 UJ | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Aroclor-1016 | 1 U | 1 U | 1 U | 1 UJ | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1221 | 2 U | 2 U | 2 U | 2 UJ | 2 U | 2 U | 2 U | 2 U |
| Aroclor-1232 | 1 U | 1 U | 1 U | 1 UJ | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1242 | 1 U | 1 U | 1 U | 1 UJ | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1248 | 1 U | 1 U | 1 U | 1 UJ | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1254 | 1 U | 1 U | 1 U | 1 UJ | 1 U | 1 U | 1 U | 1 U |
| Aroclor-1260 | 1 U | 1 U | 1 U | 1 UJ | 1 U | 1 U | 1 U | 1 U |
| beta-BHC | 0.061 J | 0.05 U | 0.05 U | 0.05 UJ | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| delta-BHC | 0.05 U | 0.05 U | 0.05 U | 0.05 UJ | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Dieldrin | 0.1 U | 0.1 U | 0.1 U | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endosulfan I | 0.05 U | 0.05 U | 0.05 U | 0.05 UJ | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Endosulfan II | 0.1 U | 0.1 U | 0.1 U | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endosulfan sulfate | 0.1 U | 0.1 U | 0.1 U | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endrin | 0.1 U | 0.1 U | 0.1 U | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endrin aldehyde | 0.1 U | 0.1 U | 0.1 U | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| Endrin ketone | 0.1 U | 0.1 U | 0.1 U | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| gamma-BHC (Lindane) | 0.05 U | 0.05 U | 0.05 U | 0.05 UJ | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| gamma-Chlordane | 0.05 U | 0.05 U | 0.05 U | 0.05 UJ | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Heptachlor | 0.05 U | 0.05 U | 0.05 U | 0.05 UJ | 0.05 U | 0.05 U | 0.05 U | 0.05 UJ |
| Heptachlor epoxide | 0.05 U | 0.05 U | 0.05 U | 0.05 UJ | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Methoxychlor | 0.5 U | 0.5 U | 0.5 U | 0.5 UJ | 0.5 U | 0.5 U | 5 U | 0.5 U |
| Toxaphene | 5 U | 5 U | 5 U | 5 UJ | 5 U | 5 U | 5 U | 5 U |
| **Total Metals (ug/L)** | | | | | | | | |
| Aluminum | 34.9 B | 104 B | 153 B | 58.3 B | 44.6 B | 33.6 B | 95.4 B | 43.8 B |
| Antimony | 1.6 U | 1.6 U | 2.3 B | 1.6 U | 1.6 U | 1.6 U | 2.2 B | 1.6 U |
| Arsenic | 26.1 | 4.5 B | 2.9 B | 2.5 U | 8.7 B | 7.9 B | 5.7 B | 2.5 U |
| Barium | 14.7 J | 11 J | 10.3 J | 24.8 J | 28 J | 121 J | 122 J | 30.3 J |
| Beryllium | 0.2 U | 0.2 U | 0.28 B | 0.2 U | 0.2 U | 0.2 U | 0.2 U | 0.2 U |
| Cadmium | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U |
| Calcium | 14,100 | 7,090 | 7,120 | 27,100 | 28,700 | 56,300 | 56,700 | 18,400 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U |
| Cobalt | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U |
| Copper | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-2
Raw Groundwater Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW01-R01 03/06/2000 | OW2E-MW03-R01 03/16/2000 | OW2E-MW03-R01-P 03/16/2000 | OW2E-MW04-R01 03/06/2000 | OW2E-MW05-R01 03/06/2000 | OW2E-MW07-R01 03/16/2000 | OW2E-MW07-R01-P 03/16/2000 | OW2E-MW08-R01 03/06/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| Cyanide | 4.5 B | 2.3 B | 1.4 B | 3.9 B | 4.3 B | 2.5 B | 1.8 B | 3.4 B |
| Iron | 43,900 | 3,020 | 2,600 | 15,100 | 44,000 | 57,800 | 58,100 | 11,600 |
| Lead | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U |
| Magnesium | 23,000 | 8,400 | 8,580 | 51,900 | 27,800 | 12,800 | 12,900 | 16,400 |
| Manganese | 1,590 | 308 | 317 | 1,680 | 759 | 1,100 | 1,110 | 321 |
| Mercury | 0.031 UL | 0.037 U | 0.037 U | 0.031 UL | 0.031 UL | 0.037 U | 0.037 U | 0.031 UL |
| Nickel | 1.7 U | 1.7 U | 1.7 U | 2.2 B | 2.6 B | 1.7 U | 1.7 U | 1.7 U |
| Potassium | 586 J | 434 J | 415 J | 830 J | 1,940 J | 7,580 | 7,650 | 1,410 J |
| Selenium | 3.1 U | 3.1 B | 3.1 U | 3.1 U | 3.1 U | 3.1 B | 3.3 B | 3.1 U |
| Silver | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U |
| Sodium | 14,700 | 11,300 | 11,900 | 27,700 | 22,300 | 18,500 | 19,800 | 35,100 |
| Thallium | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U |
| Vanadium | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U |
| Zinc | 11.7 B | 6.3 B | 9.3 B | 9.1 B | 13.4 B | 8.1 B | 10.3 B | 12.2 B |
| **Dissolved Metals (ug/L)** | | | | | | | | |
| Aluminum | 78.5 B | 135 B | 89.2 B | 47.5 B | 44.4 B | NA | NA | 38.4 B |
| Antimony | 1.6 U | 3.4 B | 3.8 B | 1.6 U | 2.7 B | NA | NA | 1.6 U |
| Arsenic | 24.3 | 2.5 U | 2.7 B | 2.5 U | 10.4 B | NA | NA | 2.5 U |
| Barium | 14.7 J | 10.6 J | 9.9 J | 23.5 J | 28.6 J | NA | NA | 30.6 J |
| Beryllium | 0.54 B | 0.79 B | 0.2 U | 0.24 B | 0.2 U | NA | NA | 0.4 B |
| Cadmium | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | NA | NA | 0.7 U |
| Calcium | 13,900 | 7,070 | 6,960 | 25,400 | 29,300 | NA | NA | 19,000 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | NA | NA | 2.6 U |
| Cobalt | 1.5 U | 1.7 B | 1.5 U | 1.5 U | 1.5 U | NA | NA | 1.5 U |
| Copper | 2.9 U | 2.9 U | 2.9 U | 4.1 B | 5.4 B | NA | NA | 2.9 U |
| Iron | 42,900 | 2,240 | 1,420 | 14,100 | 44,700 | NA | NA | 12,000 |
| Lead | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | NA | NA | 1.4 U |
| Magnesium | 22,600 | 8,350 | 8,400 | 48,500 | 28,200 | NA | NA | 16,900 |
| Manganese | 1,560 | 305 | 311 | 1,580 | 769 | NA | NA | 331 |
| Mercury | 0.031 UL | 0.037 U | 0.037 U | 0.031 UL | 0.031 UL | NA | NA | 0.031 UL |
| Nickel | 2 B | 12.1 J | 1.7 U | 2.2 B | 3.1 B | NA | NA | 5.4 B |
| Potassium | 564 J | 432 J | 406 J | 805 J | 2,050 J | NA | NA | 1,450 J |
| Selenium | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 5.3 K | NA | NA | 3.1 U |
| Silver | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U | NA | NA | 1.9 U |
| Sodium | 14,700 | 11,400 | 11,300 | 26,500 | 23,300 | NA | NA | 35,800 |
| Thallium | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U | NA | NA | 9.4 U |
| Vanadium | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | NA | NA | 2.1 U |
| Zinc | 11 B | 20.7 B | 6.3 B | 7 B | 14 B | NA | NA | 23.1 |
| **Geochemistry (MG/L)** | | | | | | | | |
| Alkalinity | 145 | 75 | NA | 245 | 190 | 250 | 250 | 125 |
| Chloride | 11 | 7.9 | NA | 20 | 15 | 22 | 25 | 19 |
| Sulfide | 0.1 | 0.08 | NA | 0.1 | 0.1 | 0.9 | 0.9 | 0.13 |
| Sulfate | 9.5 | 13 | NA | 0.5 U | 13 | 0.5 U | 0.5 U | 1.5 |
| Ethane (NG/L) | 5 | 32 | NA | 5 | 50 | 5 | 5 | 5 |
| Ethene (NG/L) | 5 | 32 | NA | 5 | 126 | 26 | 69 | 5 |
| Iron II | 37 E | 0.8 | NA | 12 E | 36 E | 30 E | 34 E | 9 |
| Iron III | 1.3 | 0.5 U | NA | 0.7 | 2.1 | 2.3 | 2.3 | 0.5 U |
| Manganese | 1.8 | 0.5 U | NA | 1.5 | 0.5 U | 0.8 | 0.9 | 0.5 U |

NA-Not analyzed
B-Not c[illegible] above associated blank
J-Estim[illegible] alue
L-Value may be biased low

R[illegible]ted
U-[illegible]tect
E-Exceeds Instrument calibration

A1-2
Raw Gr .vater Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW01-R01 03/06/2000 | | OW2E-MW03-R01 03/16/2000 | | OW2E-MW03-R01-P 03/16/2000 | | OW2E-MW04-R01 03/06/2000 | | OW2E-MW05-R01 03/06/2000 | | OW2E-MW07-R01 03/16/2000 | | OW2E-MW07-R01-P 03/16/2000 | | OW2E-MW08-R01 03/06/2000 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | | | | | | | | |
| Methane (UG/L) | 3,233 | | 11.669 | | NA | | 8,775 | | 4,117 | | 4,623 | | 4,874 | | 7,098 | |
| Nitrate | 0.5 | U | 0.5 | U | NA | | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Nitrite | 0.5 | U | 0.5 | U | NA | | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Total Organic Carbon (TOC) | 14 | | 3.1 | | NA | | 24 | | 21 | | 12 | | 11 | | 13 | |
| **Field Parameters** | | | | | | | | | | | | | | | | |
| Conductivity (MS/CM) | 202 | | 147 | | NA | | 280 | | 276 | | 555 | | NA | | 200 | |
| DO | 0.5 | | 0.16 | | NA | | 0.31 | | 0.19 | | 0.26 | | NA | | 0.25 | |
| PH (unitless) | 6.17 | | 5.8 | | NA | | 6.16 | | 6.13 | | 6.13 | | NA | | 5.93 | |
| Redox (mV) | -35.4 | | 13.2 | | NA | | -26.9 | | -49.9 | | -48.6 | | NA | | 20.5 | |
| Temperature (Celsius) | 15.17 | | 15.69 | | NA | | 17.31 | | 17.3 | | 18.34 | | NA | | 18.58 | |
| Turbidity (NTU) | 2,016 | | 46 | | NA | | 780 | | 2,029 | | 12.7 | | NA | | 2,039 | |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-2
Raw Groundwater Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW09-R01 03/06/2000 | OW2E-MW10-R01 03/16/2000 | OW2E-MW10-R01-P 03/08/2000 | OW2E-MW11-R01 03/17/2000 | OW2E-MW12-R01 03/06/2000 | OW2E-MW13-R01 03/06/2000 | OW2E-MW15-R01 03/06/2000 | OW2E-MW16-R01 03/06/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| **Volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,1,1-Trichloroethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,1,2,2-Tetrachloroethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,1,2-Trichloroethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,1-Dichloroethane | 0.2 J | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,1-Dichloroethene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2,4-Trichlorobenzene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dibromo-3-chloropropane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dibromoethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dichlorobenzene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dichloroethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,2-Dichloropropane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,3-Dichlorobenzene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 1,4-Dichlorobenzene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 2-Butanone | 5 R | 25 R | NA | 2 L | 5 R | 5 R | 5 R | 5 R |
| 2-Hexanone | 5 U | 25 U | NA | 5 U | 5 U | 5 U | 5 U | 5 U |
| 4-Methyl-2-pentanone | 5 U | 25 U | NA | 0.8 J | 5 U | 5 U | 5 U | 5 U |
| Acetone | 5 R | 8 L | NA | 10 L | 5 R | 3 L | 5 R | 7 L |
| Benzene | 0.8 J | 3 J | NA | 1 U | 0.2 J | 1 U | 1 U | 1 U |
| Bromochloromethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Bromodichloromethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Bromoform | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Bromomethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Carbon disulfide | 0.6 J | 5 U | NA | 0.6 J | 1 U | 0.2 J | 1 U | 0.3 J |
| Carbon tetrachloride | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chlorobenzene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chloroethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chloroform | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chloromethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 0.1 J |
| cis-1,2-Dichloroethene | 13 | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| cis-1,3-Dichloropropene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Dibromochloromethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Ethylbenzene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Methylene chloride | 2 U | 1 B | NA | 2 B | 2 U | 2 U | 2 U | 2 U |
| Styrene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Tetrachloroethene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Toluene | 1 U | 5 U | NA | 0.2 J | 1 U | 1 U | 0.2 J | 1 U |
| trans-1,2-Dichloroethene | 0.9 J | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| trans-1,3-Dichloropropene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Trichloroethene | 0.8 J | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Vinyl chloride | 8 | 5 U | NA | 1 U | 1 U | 0.3 J | 1 U | 1 U |
| Xylene, total | 1 U | 5 U | NA | 0.3 J | 1 U | 1 U | 1 U | 1 U |
| **Semi-volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,2,4-Trichlorobenzene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 1,2-Dichlorobenzene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 1,3-Dichlorobenzene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 1,4-Dichlorobenzene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,2'-Oxybis(1-chloropropane) | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,4,5-Trichlorophenol | 25 U | 25 U | NA | 25 U | 25 U | 25 U | 25 U | 25 U |

NA-Not analyzed
B-Not d[illegible] above associated blank
J-Estim[illegible] alue
L-Value may be biased low

R [illegible]ted
U-[illegible]tect
E-Exceeds instrument calibration

Raw Gr[illegible] water Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW09-R01 03/06/2000 | OW2E-MW10-R01 03/16/2000 | OW2E-MW10-R01-P 03/08/2000 | OW2E-MW11-R01 03/17/2000 | OW2E-MW12-R01 03/06/2000 | OW2E-MW13-R01 03/06/2000 | OW2E-MW15-R01 03/06/2000 | OW2E-MW16-R01 03/06/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| 2,4,6-Trichlorophenol | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,4-Dichlorophenol | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,4-Dimethylphenol | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,4-Dinitrophenol | 25 UJ | 25 U | NA | 25 U | 25 UJ | 25 UJ | 25 UJ | 25 UJ |
| 2,4-Dinitrotoluene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2,6-Dinitrotoluene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Chloronaphthalene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Chlorophenol | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Methylnaphthalene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Methylphenol | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 2-Nitroaniline | 25 U | 25 U | NA | 25 U | 25 U | 25 U | 25 U | 25 U |
| 2-Nitrophenol | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 3,3'-Dichlorobenzidine | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 3-Nitroaniline | 25 U | 25 U | NA | 25 U | 25 U | 25 U | 25 U | 25 U |
| 4,6-Dinitro-2-methylphenol | 25 U | 25 U | NA | 25 U | 25 U | 25 U | 25 U | 25 U |
| 4-Bromophenyl-phenylether | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Chloro-3-methylphenol | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Chloroaniline | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Chlorophenyl-phenylether | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Methylphenol | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| 4-Nitroaniline | 25 U | 25 U | NA | 25 U | 25 U | 25 U | 25 U | 25 U |
| 4-Nitrophenol | 25 U | 25 U | NA | 25 U | 25 U | 25 U | 25 U | 25 U |
| Acenaphthene | 1 U | 1 U | 1 R | 5 U | 5 U | 1 U | 1 U | 1 U |
| Acenaphthylene | 1.8 J | 1 U | 1 R | 5 U | 5 U | 1 U | 1 U | 1 U |
| Anthracene | 2 U | 2 U | 2 R | 10 U | 10 U | 2 U | 2 U | 2 U |
| Benzo(a)anthracene | 0.1 U | 0.1 U | 0.1 R | 0.5 U | 0.5 U | 0.1 U | 0.1 U | 0.1 U |
| Benzo(a)pyrene | 0.1 UJ | 0.1 U | 0.1 R | 0.5 U | 0.5 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ |
| Benzo(b)fluoranthene | 0.1 U | 0.1 U | 0.1 R | 0.5 U | 0.5 U | 0.1 U | 0.1 U | 0.1 U |
| Benzo(g,h,i)perylene | 0.1 UJ | 0.1 U | 0.1 R | 0.5 U | 0.5 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ |
| Benzo(k)fluoranthene | 0.1 U | 0.1 U | 0.1 R | 0.5 U | 0.5 U | 0.1 U | 0.1 U | 0.1 U |
| bis(2-Chloroethoxy)methane | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| bis(2-Chloroethyl)ether | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| bis(2-Ethylhexyl)phthalate | 10 U | 10 U | NA | 2 B | 10 U | 10 U | 6 J | 10 U |
| Butylbenzylphthalate | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Carbazole | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Chrysene | 0.1 U | 0.1 U | 0.1 R | 0.5 U | 0.5 U | 0.1 U | 0.1 U | 0.1 U |
| Dibenz(a,h)anthracene | 0.1 U | 0.1 U | 0.1 R | 0.5 U | 0.5 U | 0.1 U | 0.1 U | 0.1 U |
| Dibenzofuran | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Diethylphthalate | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Dimethyl phthalate | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Di-n-butylphthalate | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Di-n-octyl phthalate | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Fluoranthene | 0.1 U | 0.1 U | 0.1 R | 0.5 U | 0.5 U | 0.1 U | 0.1 U | 0.1 U |
| Fluorene | 1 U | 1 U | 1 R | 5 U | 0.15 J | 0.029 J | 1 U | 1 U |
| Hexachlorobenzene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Hexachlorobutadiene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Hexachlorocyclopentadiene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Hexachloroethane | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Indeno(1,2,3-cd)pyrene | 0.1 U | 0.1 U | 0.1 R | 0.5 U | 0.5 U | 0.1 U | 0.1 U | 0.1 U |
| Isophorone | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-2
Raw Groundwater Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW09-R01 03/06/2000 | | OW2E-MW10-R01 03/16/2000 | | OW2E-MW10-R01-P 03/08/2000 | | OW2E-MW11-R01 03/17/2000 | | OW2E-MW12-R01 03/06/2000 | | OW2E-MW13-R01 03/06/2000 | | OW2E-MW15-R01 03/06/2000 | | OW2E-MW16-R01 03/06/2000 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | | | | | | | | |
| Naphthalene | 2 | U | 2 | U | 2 | R | 10 | U | 10 | U | 2 | U | 2 | U | 2 | U |
| Nitrobenzene | 10 | U | 10 | U | NA | | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| n-Nitroso-di-n-propylamine | 10 | U | 10 | U | NA | | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| n-Nitrosodiphenylamine | 10 | U | 10 | U | NA | | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| Pentachlorophenol | 25 | U | 25 | U | NA | | 25 | U | 25 | U | 25 | U | 25 | U | 25 | U |
| Phenanthrene | 0.037 | J | 1 | U | 1 | R | 5 | U | 5 | U | 0.031 | J | 1 | U | 1 | U |
| Phenol | 10 | U | 10 | U | NA | | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| Pyrene | 0.14 | J | 0.1 | U | 0.1 | R | 0.5 | U | 0.5 | U | 0.1 | UJ | 0.1 | UJ | 0.1 | UJ |
| **Pesticide/Polychlorinated Biphenyls (ug/L)** | | | | | | | | | | | | | | | | |
| 4,4'-DDD | 0.1 | UJ | 0.1 | U | NA | | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | UJ |
| 4,4'-DDE | 0.1 | UJ | 0.1 | U | NA | | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | UJ |
| 4,4'-DDT | 0.1 | UJ | 0.1 | U | NA | | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | UJ |
| Aldrin | 0.05 | UJ | 0.05 | U | NA | | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | UJ |
| alpha-BHC | 0.05 | UJ | 0.05 | U | NA | | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | UJ |
| alpha-Chlordane | 0.05 | UJ | 0.05 | U | NA | | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | UJ |
| Aroclor-1016 | 1 | UJ | 1 | U | NA | | 1 | U | 1 | U | 1 | U | 1 | U | 1 | UJ |
| Aroclor-1221 | 2 | UJ | 2 | U | NA | | 2 | U | 2 | U | 2 | U | 2 | U | 2 | UJ |
| Aroclor-1232 | 1 | UJ | 1 | U | NA | | 1 | U | 1 | U | 1 | U | 1 | U | 1 | UJ |
| Aroclor-1242 | 1 | UJ | 1 | U | NA | | 1 | U | 1 | U | 1 | U | 1 | U | 1 | UJ |
| Aroclor-1248 | 1 | UJ | 1 | U | NA | | 1 | U | 1 | U | 1 | U | 1 | U | 1 | UJ |
| Aroclor-1254 | 1 | UJ | 1 | U | NA | | 1 | U | 1 | U | 1 | U | 1 | U | 1 | UJ |
| Aroclor-1260 | 1 | UJ | 1 | U | NA | | 1 | U | 1 | U | 1 | U | 1 | U | 1 | UJ |
| beta-BHC | 0.05 | UJ | 0.05 | U | NA | | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | UJ |
| delta-BHC | 0.05 | UJ | 0.05 | U | NA | | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | UJ |
| Dieldrin | 0.1 | UJ | 0.1 | U | NA | | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.052 | J |
| Endosulfan I | 0.05 | UJ | 0.05 | U | NA | | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | UJ |
| Endosulfan II | 0.1 | UJ | 0.1 | U | NA | | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | UJ |
| Endosulfan sulfate | 0.1 | UJ | 0.1 | U | NA | | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | UJ |
| Endrin | 0.1 | UJ | 0.1 | U | NA | | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | UJ |
| Endrin aldehyde | 0.1 | UJ | 0.1 | U | NA | | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | UJ |
| Endrin ketone | 0.1 | UJ | 0.1 | U | NA | | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | UJ |
| gamma-BHC (Lindane) | 0.05 | UJ | 0.05 | U | NA | | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | UJ |
| gamma-Chlordane | 0.05 | UJ | 0.05 | U | NA | | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | UJ |
| Heptachlor | 0.05 | UJ | 0.05 | U | NA | | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | UJ |
| Heptachlor epoxide | 0.05 | UJ | 0.05 | U | NA | | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | UJ |
| Methoxychlor | 0.5 | UJ | 0.5 | U | NA | | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | UJ |
| Toxaphene | 5 | UJ | 5 | U | NA | | 5 | U | 5 | U | 5 | U | 5 | U | 5 | UJ |
| **Total Metals (ug/L)** | | | | | | | | | | | | | | | | |
| Aluminum | 258 | B | 44.4 | B | NA | | 4,020 | | 224 | B | 121 | B | 119 | B | 1,780 | |
| Antimony | 1.6 | U | 2.6 | B | NA | | 1.7 | B | 1.6 | U | 1.6 | U | 1.6 | U | 1.6 | U |
| Arsenic | 3.2 | B | 55.3 | | NA | | 5.4 | B | 2.9 | B | 2.5 | U | 5.5 | B | 8.2 | B |
| Barium | 27.5 | J | 70.9 | J | NA | | 46.9 | J | 69.4 | J | 24 | J | 9.8 | J | 19.4 | J |
| Beryllium | 0.2 | U | 0.2 | U | NA | | 0.2 | U | 0.2 | U | 0.2 | U | 0.35 | B | 0.38 | B |
| Cadmium | 0.7 | U | 0.7 | U | NA | | 1.1 | J | 0.7 | U | 0.7 | U | 0.7 | U | 0.7 | U |
| Calcium | 38,800 | | 11,600 | | NA | | 19,200 | | 53,500 | | 24,200 | | 22,300 | | 30,200 | |
| Chromium | 2.6 | U | 2.6 | U | NA | | 7 | J | 2.6 | U | 2.6 | U | 2.6 | U | 5.8 | J |
| Cobalt | 1.5 | U | 1.5 | U | NA | | 6 | B | 1.5 | U | 1.5 | U | 1.5 | U | 3.4 | B |
| Copper | 8.1 | B | 2.9 | U | NA | | 5.4 | J | 2.9 | U | 2.9 | U | 2.9 | U | 40.4 | |

NA-Not analyzed
B-Not de[illegible]d above associated blank
J-Estim[illegible]lue
L-Value [illegible] be biased low

R-[illegible]ted
U-[illegible]tect
E-Exceeds ins[illegible]ment calibration

Raw G. .water Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW09-R01 03/06/2000 | OW2E-MW10-R01 03/16/2000 | OW2E-MW10-R01-P 03/08/2000 | OW2E-MW11-R01 03/17/2000 | OW2E-MW12-R01 03/06/2000 | OW2E-MW13-R01 03/06/2000 | OW2E-MW15-R01 03/06/2000 | OW2E-MW16-R01 03/06/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| Cyanide | 3 B | 1.8 B | NA | 2.4 B | 5.4 B | 2.6 B | 1.7 B | 2.1 B |
| Iron | 56,100 | 67,000 | NA | 7,160 | 49,900 | 16,400 | 10,300 | 19,600 |
| Lead | 3.1 | 1.4 U | NA | 5.4 B | 1.4 U | 1.4 U | 1.4 U | 10.4 |
| Magnesium | 24,600 | 25,200 | NA | 13,900 | 12,600 | 16,300 | 7,800 | 7,030 |
| Manganese | 1,920 | 533 | NA | 578 | 797 | 502 | 306 | 327 |
| Mercury | 0.031 UL | 0.037 U | NA | 0.037 U | 0.031 UL | 0.031 UL | 0.031 UL | 0.031 UL |
| Nickel | 39 J | 1.7 U | NA | 5.8 J | 2.5 B | 3.1 B | 2.2 B | 6.6 B |
| Potassium | 1,520 J | 1,520 J | NA | 4,520 J | 4,110 J | 1,870 J | 1,370 J | 1,660 J |
| Selenium | 3.1 U | 3.1 U | NA | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.8 J |
| Silver | 1.9 U | 1.9 U | NA | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U |
| Sodium | 26,900 | 24,600 | NA | 33,100 | 30,700 | 28,400 | 26,100 | 19,200 |
| Thallium | 9.4 U | 9.4 U | NA | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U |
| Vanadium | 2.1 U | 2.1 U | NA | 10 J | 2.1 U | 2.1 U | 2.1 U | 7.4 B |
| Zinc | 62.4 | 12 B | NA | 68.2 | 8 B | 19.7 B | 8.1 B | 154 |
| **Dissolved Metals (ug/L)** | | | | | | | | |
| Aluminum | 30.6 B | 112 B | NA | 5,540 | 55.6 B | 53.7 B | 30.3 B | 28.5 B |
| Antimony | 1.6 U | 3 B | NA | 2.2 B | 2.3 B | 1.6 U | 1.6 U | 1.6 U |
| Arsenic | 2.8 B | 40.1 | NA | 6.6 B | 3.9 B | 2.5 U | 2.5 U | 2.5 U |
| Barium | 25.8 J | 58.7 J | NA | 54.3 J | 71.1 J | 24.2 J | 9.3 B | 6.1 B |
| Beryllium | 0.2 U | 0.2 U | NA | 0.2 U | 0.2 U | 0.2 U | 0.2 U | 0.2 U |
| Cadmium | 0.7 U | 0.7 U | NA | 0.92 J | 0.7 U | 0.7 U | 0.7 U | 0.7 U |
| Calcium | 39,300 | 10,900 | NA | 18,900 | 55,900 | 24,900 | 22,200 | 24,700 |
| Chromium | 2.6 U | 2.6 U | NA | 9.6 J | 2.6 U | 2.6 U | 2.6 U | 2.6 U |
| Cobalt | 1.5 U | 1.5 U | NA | 6.1 B | 1.5 U | 1.5 U | 1.5 U | 1.5 U |
| Copper | 2.9 U | 2.9 U | NA | 7.1 J | 2.9 U | 2.9 U | 2.9 U | 2.9 U |
| Iron | 44,800 | 55,800 | NA | 7,640 | 51,600 | 16,100 | 7,600 | 4,570 |
| Lead | 1.4 U | 1.4 U | NA | 2.1 B | 1.4 U | 1.4 U | 1.4 U | 1.4 U |
| Magnesium | 24,400 | 24,000 | NA | 13,500 | 13,200 | 16,500 | 7,550 | 6,330 |
| Manganese | 1,820 | 505 | NA | 550 | 832 | 509 | 303 | 299 |
| Mercury | 0.031 UL | 0.037 U | NA | 0.037 U | 0.031 UL | 0.031 UL | 0.031 UL | 0.031 UL |
| Nickel | 3.4 B | 1.7 U | NA | 7.1 J | 1.7 U | 1.7 U | 1.9 B | 1.7 U |
| Potassium | 1,570 J | 1,460 J | NA | 4,870 J | 4,410 J | 1,940 J | 1,410 J | 1,510 J |
| Selenium | 3.1 U | 3.1 U | NA | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.1 U |
| Silver | 1.9 U | 1.9 U | NA | 1.9 U | 1.9 U | 1.9 U | 1.9 U | 1.9 U |
| Sodium | 28,600 | 24,400 | NA | 32,500 | 32,600 | 28,900 | 26,400 | 19,900 |
| Thallium | 9.4 U | 9.4 U | NA | 9.4 U | 9.4 U | 9.4 U | 9.4 U | 9.4 U |
| Vanadium | 2.1 U | 2.1 U | NA | 14.4 J | 2.1 U | 2.1 U | 2.1 U | 2.1 U |
| Zinc | 14.2 B | 8.9 B | NA | 68.3 | 10.7 B | 13.5 B | 11 B | 18.1 J |
| **Geochemistry (MG/L)** | | | | | | | | |
| Alkalinity | 180 | 170 | 170 | 210 | 275 | 160 | 75 | 65 |
| Chloride | 16 | 16 | 16 | 12 | 17 | 13 | 20 | 16 |
| Sulfide | 0.05 | 1.3 | 0.13 | 1 | 0.12 | 0.13 | 0.11 | 0.12 |
| Sulfate | 2.8 | 4.1 | 2.96 | 5.3 | 0.5 U | 8.7 | 35 | 23 |
| Ethane (NG/L) | 5 | 5 | 5 | 5 | 5 | 25 | 5 | 5 |
| Ethene (NG/L) | 539 | 21 | 49 | 5 | 5 | 33 | 5 | 5 |
| Iron II | 36 E | 40 E | 43 E | 14 E | 39 E | 13 E | 6.2 | 3 |
| Iron III | 1 | 2.3 | 1.8 | 1.6 | 2.3 | 0.5 | 0.5 U | 0.5 U |
| Manganese | 1.6 | 0.5 U | 0.5 U | 0.9 | 0.5 U | 0.5 U | 0.5 U | 0.5 U |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration

Table A1-2
Raw Groundwater Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW09-R01 03/06/2000 | | OW2E-MW10-R01 03/16/2000 | | OW2E-MW10-R01-P 03/08/2000 | | OW2E-MW11-R01 03/17/2000 | | OW2E-MW12-R01 03/06/2000 | | OW2E-MW13-R01 03/06/2000 | | OW2E-MW15-R01 03/06/2000 | | OW2E-MW16-R01 03/06/2000 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | | | | | | | | |
| Methane (UG/L) | 4,209 | | 3,401 | | 36,006 | | 3,319 | | 10,359 | | 992.7 | | 6.333 | | 9.998 | |
| Nitrate | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Nitrite | 0.8 | | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Total Organic Carbon (TOC) | 20 | | 23 | | 44 | | 10 | | 33 | | 10 | | 4.5 | | 5.7 | |
| **Field Parameters** | | | | | | | | | | | | | | | | |
| Conductivity (MS/CM) | 288 | | 436 | | NA | | 457 | | 305 | | 170 | | 257 | | 231 | |
| DO | 0.21 | | 0.21 | | NA | | 0.21 | | 0.22 | | 0.18 | | 0.17 | | 0.24 | |
| PH (unitless) | 6.2 | | 6.32 | | NA | | 6.48 | | 6 | | 5.91 | | 5.61 | | 5.77 | |
| Redox (mV) | -52 | | -78.5 | | NA | | -71.4 | | -28.9 | | -3.4 | | -18.3 | | 7.6 | |
| Temperature (Celsius) | 16.5 | | 19.03 | | NA | | 18.84 | | 16.6 | | 18.54 | | 16.53 | | 15.39 | |
| Turbidity (NTU) | 101.8 | | 21.8 | | NA | | 11.7 | | 59.8 | | 65 | | 298.5 | | 65 | |

NA-Not analyzed
B-Not d[illegible]d above associated blank
J-Estim[illegible]alue
L-Value may be biased low

R[illegible]ted
U-[illegible]tect
E-Exceeds instrument calibration

Appendix A-2

# Summary of Detected Chemicals for Groundwater Sampling at SWMU 2B and SWMU 2E

Tal[illegible]
Detected Gro[illegible]ter Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW01D-R01P 02/25/2000 | OW2B-MW01-R01 02/25/2000 | OW2B-MW02-R01 02/25/2000 | OW2B-MW02D-R01P 02/25/2000 | OW2B-MW03-R01 02/25/2000 | OW2B-MW04-R01 02/29/2000 | OW2B-MW04-R01-P 02/29/2000 | OW2B-MW05D-R01 02/22/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| **Volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,1-Dichloroethane | 1 U | 11 | 0.4 J | 0.3 J | 3 J | 0.2 J | NA | 1 U |
| 1,1-Dichloroethene | 1 U | 3 J | 0.1 J | 0.1 J | 0.8 J | 1 U | NA | 1 U |
| 1,3-Dichlorobenzene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 0.1 J |
| Acetone | 5 R | 25 R | 5 R | 5 R | 21 R | 7 L | NA | 5 R |
| Benzene | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Carbon disulfide | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| Chloroethane | 1 U | 5 U | 1 U | 1 U | 4 U | 1 U | NA | 1 U |
| cis-1,2-Dichloroethene | 0.3 J | 120 | 12 | 12 | 60 | 0.5 J | NA | 1 U |
| Methylene chloride | 0.4 B | 10 U | 2 U | 2 U | 8 U | 0.4 B | NA | 0.6 B |
| Toluene | 0.1 J | 5 U | 0.1 J | 0.1 J | 4 U | 0.6 J | NA | 0.2 J |
| trans-1,2-Dichloroethene | 1 U | 11 | 0.2 J | 0.2 J | 3 J | 1 U | NA | 1 U |
| Trichloroethene | 0.2 J | 56 B | 14 | 13 | 28 B | 1 U | NA | 1 U |
| Vinyl chloride | 1 U | 13 | 0.6 J | 0.5 J | 2 J | 1 U | NA | 1 U |
| **Semi-volatile Organic Compounds (ug/L)** | | | | | | | | |
| bis(2-Ethylhexyl)phthalate | 1 J | 10 U | 1 J | 2 J | 10 U | 30 | NA | 10 U |
| Fluorene | 0.024 L | 1 UL | 1 U | 1 U | 1 U | 1 U | NA | 0.026 L |
| Naphthalene | 2 UL | 2 UL | 2 U | 2 U | 2 U | 2 U | NA | 2 UL |
| Phenanthrene | 0.045 L | 1 UL | 1 U | 1 U | 1 U | 1 U | NA | 0.033 L |
| Pyrene | 0.18 J | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 U | NA | 0.1 UJ |
| **Pesticide/Polychlorinated Biphenyls (ug/L)** | | | | | | | | |
| beta-BHC | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | NA | 0.05 U |
| Heptachlor epoxide | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | NA | 0.05 U |
| **Total Metals (ug/L)** | | | | | | | | |
| Arsenic | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 11 B | NA | 2.5 U |
| Barium | 26.3 J | 19.2 J | 8.4 J | 5.8 J | 29.2 J | 56.5 J | NA | 17.4 J |
| Cadmium | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | NA | 0.7 U |
| Calcium | 36,000 | 10,300 | 56,400 | 57,300 | 68,300 | 17,700 | NA | 42,400 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | NA | 2.6 U |
| Cobalt | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | NA | 1.5 U |
| Iron | 546 | 4,450 | 1,140 | 1,100 | 4,950 | 31,700 | NA | 735 |
| Magnesium | 2,780 J | 15,100 | 6,830 | 6,910 | 9,540 | 19,600 | NA | 4,300 J |
| Manganese | 86.9 | 150 | 410 | 417 | 419 | 250 | NA | 89.4 |
| Potassium | 8,540 | 665 J | 1,170 J | 1,170 J | 3,080 J | 1,160 J | NA | 4,610 J |
| Sodium | 17,000 | 32,900 | 25,100 | 25,400 | 26,900 | 30,000 | NA | 19,900 |
| Vanadium | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 4 B | NA | 2.1 U |
| Zinc | 11.6 B | 3.7 B | 1.8 B | 6.8 B | 16.1 B | 16.5 B | NA | 17.1 B |
| **Dissolved Metals (ug/L)** | | | | | | | | |
| Aluminum | 20.9 B | 19 B | 31.9 B | 20.8 B | 15.5 U | 29.2 B | NA | 20.2 B |
| Arsenic | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 2.5 U | 4.3 B | NA | 2.5 U |
| Barium | 25.1 J | 22 J | 5.6 J | 5.3 J | 31.2 J | 56.8 J | NA | 20.7 J |
| Calcium | 36,400 | 11,400 | 59,300 | 61,100 | 76,700 | 19,000 | NA | 49,200 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | NA | 2.6 U |
| Cobalt | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | NA | 1.5 U |
| Iron | 266 | 4,430 | 871 | 911 | 5,360 | 28,900 | NA | 703 |
| Lead | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | NA | 1.4 U |
| Magnesium | 2,830 J | 16,900 | 7,180 | 7,390 | 10,700 | 20,600 | NA | 5,240 |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration
Shaded concentrations indicate detections



00606F34y

Ta 1
Detected Gr ater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW01D-R01P 02/25/2000 | OW2B-MW01-R01 02/25/2000 | OW2B-MW02-R01 02/25/2000 | OW2B-MW02D-R01P 02/25/2000 | OW2B-MW03-R01 02/25/2000 | OW2B-MW04-R01 02/29/2000 | OW2B-MW04-R01-P 02/29/2000 | OW2B-MW05D-R01 02/22/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| Manganese | 81.6 | 172 | 394 | 408 | 467 | 269 | NA | 102 |
| Nickel | 3.2 J | 2.9 J | 1.7 U | 1.7 U | 3.3 J | 1.7 U | NA | 1.7 U |
| Potassium | 8,420 | 758 J | 1,250 J | 1,270 J | 3,320 J | 1,230 J | NA | 5,390 |
| Sodium | 16,400 | 36,400 | 26,600 | 27,700 | 30,200 | 31,600 | NA | 21,200 |
| Zinc | 3 J | 5 J | 9.6 J | 6.4 J | 12 J | 11.6 B | NA | 11.2 J |
| **Geochemistry (MG/L)** | | | | | | | | |
| Alkalinity | 85 | 100 | 135 | 130 | 190 | 155 | 210 | 140 |
| Chloride | 9.9 | 18 | 23 | 22 | 15 | 25 | 25 | 15 |
| Sulfate | 3.6 | 30 | 9.95 | 10 | 22 | 17 | 17 | 2.5 |
| Sulfide | 0.12 | 0.13 | 0.14 | 0.14 | 0.15 | 0.1 | 0.12 | 0.12 |
| Ethane (NG/L) | 5 U | 195 | 25 | 5 U | 54 | 478 | NA | 5 U |
| Ethene (NG/L) | 44 | 821 | 25 | 5 U | 163 | 5 U | NA | 88 |
| Iron II | 0.5 U | 2.7 | 0.5 U | 0.5 U | 2.1 | 24 E | 24 E | 0.5 U |
| Iron III | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.9 | 0.8 | 0.5 U |
| Manganese | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Methane (UG/L) | 240 | 590 | 1,163 | 0.363 | 79.77 | 22,700 | NA | 5,080 |
| Nitrate | 1.6 | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 |
| Total Organic Carbon (TOC) | 4 | 8.2 | 6 | 2 U | 6.6 | 19 | NA | 3.1 |
| **Field Parameters** | | | | | | | | |
| Conductivity (MS/CM) | 215 | 199 | 430 | NA | 665 | 329 | NA | 235 |
| DO | 0.12 | 0.06 | 0.05 | NA | 0.77 | 0.35 | NA | 2.57 |
| PH (unitless) | 6.94 | 5.46 | 7.04 | NA | 6.42 | 6.87 | NA | 7.47 |
| Redox (mV) | -101.2 | 77.2 | -64 | NA | -29.5 | -31.9 | NA | -90.1 |
| Temperature (Celsius) | 15.07 | 14.23 | 14.92 | NA | 15.3 | 16.21 | NA | 16.31 |
| Turbidity (NTU) | 22.9 | 30.6 | 9.7 | NA | 85.3 | 1,835 | NA | 1.5 |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration
Shaded concentrations indicate detections

T[illegible]-1
Detected Gr[illegible]water Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW05-R01 02/21/2000 | OW2B-MW07-R01 02/22/2000 | OW2B-MW08-R01 02/25/2000 | OW2B-MW09-R01 02/25/2000 | OW2B-MW10-R01 02/29/2000 | OW2B-MW11-R01 02/23/2000 | OW2B-MW12-R01 02/21/2000 | OW2B-MW13-R01 02/22/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| **Volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,1-Dichloroethane | 16 | 2 | 1 U | 1 U | 2 | 6 | 1 U | 8 |
| 1,1-Dichloroethene | 0.3 J | 0.3 J | 1 U | 1 U | 0.1 J | 4 | 1 U | 1 |
| 1,3-Dichlorobenzene | 0.1 J | 1 U | 1 U | 1 U | 1 U | 1 U | 0.1 J | 1 U |
| Acetone | 5 R | 5 R | 5 R | 5 R | 3 L | 5 R | 5 R | 3 L |
| Benzene | 2 | 0.2 J | 1 U | 1 U | 1 U | 0.4 J | 1 U | 0.5 J |
| Carbon disulfide | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chloroethane | 3 | 0.3 J | 1 U | 1 U | 1 U | 1 U | 1 U | 1 |
| cis-1,2-Dichloroethene | 3 | 3 | 0.8 J | 1 U | 4 | 0.4 J | 1 U | 4 |
| Methylene chloride | 2 U | 0.6 B | 2 U | 0.4 B | 0.2 B | 2 U | 0.7 B | 0.6 B |
| Toluene | 0.2 J | 0.2 J | 0.2 J | 0.1 J | 0.3 J | 0.1 J | 0.2 J | 0.2 J |
| trans-1,2-Dichloroethene | 1 U | 0.1 J | 1 U | 1 U | 0.1 J | 1 U | 1 U | 0.1 J |
| Trichloroethene | 2 | 2 | 0.7 J | 0.1 J | 1 U | 1 U | 1 U | 0.4 J |
| Vinyl chloride | 6 | 2 | 1 U | 1 U | 0.3 J | 1 | 1 U | 9 |
| **Semi-volatile Organic Compounds (ug/L)** | | | | | | | | |
| bis(2-Ethylhexyl)phthalate | 10 U | 10 U | 1 J | 3 J | 10 U | 1 B | 10 U | 10 U |
| Fluorene | 0.12 J | 0.059 J | 1 UL | 1 U | 1 U | 1 U | 1 U | 0.028 J |
| Naphthalene | 0.52 J | 2 U | 2 UL | 2 U | 2 U | 2 U | 2 U | 2 U |
| Phenanthrene | 0.045 J | 1 U | 1 UL | 1 U | 1 U | 1 U | 0.034 J | 1 U |
| Pyrene | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 U | 0.1 UJ | 0.1 UJ | 0.1 UJ |
| **Pesticide/Polychlorinated Biphenyls (ug/L)** | | | | | | | | |
| beta-BHC | 0.028 J | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Heptachlor epoxide | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.062 J |
| **Total Metals (ug/L)** | | | | | | | | |
| Arsenic | 19.7 | 2.5 U | 2.5 U | 2.5 U | 8.7 B | 15 | 2.8 J | 4.3 J |
| Barium | 96.3 J | 64.2 J | 4.4 J | 7 J | 19.1 J | 75.2 J | 4.3 J | 17.4 J |
| Cadmium | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.77 J | 0.7 U | 0.7 U | 0.7 U |
| Calcium | 30,100 | 7,730 | 12,400 | 43,500 | 31,600 | 29,400 | 43,600 | 61,700 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U |
| Cobalt | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U |
| Iron | 30,000 | 14,000 | 1,590 | 2,570 | 16,700 | 33,500 | 1,390 | 10,200 |
| Magnesium | 14,400 | 12,900 | 2,710 J | 5,920 | 9,190 | 38,700 | 8,150 | 11,700 |
| Manganese | 890 | 327 | 101 | 292 | 490 | 540 | 300 | 677 |
| Potassium | 3,190 J | 951 J | 451 J | 1,010 J | 1,340 J | 1,250 J | 982 J | 1,460 J |
| Sodium | 11,600 | 14,100 | 38,400 | 20,500 | 25,800 | 28,500 | 36,300 | 21,200 |
| Vanadium | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U |
| Zinc | 2.5 B | 14.5 B | 3.7 B | 2.9 B | 36.4 | 12.6 B | 6.2 B | 8.8 B |
| **Dissolved Metals (ug/L)** | | | | | | | | |
| Aluminum | 20.1 B | 28.2 B | 457 J | 15.5 U | 24.8 B | 54.8 B | 51 B | 16.9 B |
| Arsenic | 19.2 | 2.5 U | 2.5 U | 2.5 U | 4 B | 10.3 | 2.5 U | 3.5 J |
| Barium | 86 J | 61.7 J | 7.1 J | 3.3 J | 16.6 J | 74 J | 4.2 J | 17.2 J |
| Calcium | 26,700 | 7,250 | 15,200 | 43,200 | 33,200 | 29,200 | 45,400 | 58,800 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U |
| Cobalt | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U | 1.5 U |
| Iron | 26,400 | 12,200 | 1,440 | 2,050 | 10,100 | 31,600 | 1,170 | 9,720 |
| Lead | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U |
| Magnesium | 12,800 | 12,400 | 2,760 J | 5,840 | 9,700 | 38,500 | 8,390 | 11,200 |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration
Shaded concentrations indicate detections

Ta[illegible]1
Detected Gr[illegible]ater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW05-R01 02/21/2000 | OW2B-MW07-R01 02/22/2000 | OW2B-MW08-R01 02/25/2000 | OW2B-MW09-R01 02/25/2000 | OW2B-MW10-R01 02/29/2000 | OW2B-MW11-R01 02/23/2000 | OW2B-MW12-R01 02/21/2000 | OW2B-MW13-R01 02/22/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| Manganese | 789 | 313 | 105 | 290 | 511 | 539 | 315 | 648 |
| Nickel | 1.7 U | 1.7 U | 1.7 U | 1.9 J | 1.9 B | 2.4 J | 1.7 U | 1.7 U |
| Potassium | 2,840 J | 959 J | 478 J | 995 J | 1,370 J | 1,230 J | 1,020 J | 1,390 J |
| Sodium | 9,780 | 15,100 | 39,100 | 20,400 | 26,800 | 28,500 | 38,100 | 20,000 |
| Zinc | 3.4 J | 18.7 J | 4.6 J | 2.5 J | 18.3 J | 13.1 J | 7.8 J | 6.2 J |
| **Geochemistry (MG/L)** | | | | | | | | |
| Alkalinity | 60 | 55 | 60 | 120 | 400 | 200 | 100 | 120 |
| Chloride | 8.9 | 19 | 11 | 18 | 24 | 32 | 21 | 15 |
| Sulfate | 1.5 | 21 | 25 | 6.9 | 8.8 | 8.7 | 9 | 11 |
| Sulfide | 0.19 | 0.12 | 0.12 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 |
| Ethane (NG/L) | 273 | 41 | 13 | 5 U | 108 | 356 | 5 U | 112 |
| Ethene (NG/L) | 869 | 158 | 23 | 5 U | 5 U | 78 | 5 U | 479 |
| Iron II | 18 | 8.4 | 0.5 U | 0.5 U | 7.6 | 22 | 0.5 U | 5.1 |
| Iron III | 1.5 | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Manganese | 1 | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.8 U | 0.5 U | 0.6 |
| Methane (UG/L) | 5,070 | 810 | 11.73 | 0.383 | 250 | 1,080 | 2,214 | 2,010 |
| Nitrate | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Total Organic Carbon (TOC) | 12 | 23 | 3.3 | 4.8 | 19 | 12 | 2.8 | 11 |
| **Field Parameters** | | | | | | | | |
| Conductivity (MS/CM) | 261 | 156 | 191 | 215 | 329 | 458 | 284 | 320 |
| DO | 0.2 | 0.18 | NA | 0.12 | 0.35 | 0.05 | 0.35 | 0.15 |
| PH (unitless) | 6.36 | 5.89 | 5.94 | 6.94 | 6.87 | 5.42 | 7 | 6.24 |
| Redox (mV) | -175.2 | -80.5 | -36 | -101.2 | -31.9 | -66 | -144.8 | -128 |
| Temperature (Celsius) | 14.36 | 12.5 | 15.08 | 15.07 | 16.21 | 16.4 | 13.73 | 14.64 |
| Turbidity (NTU) | 23.4 | 29.8 | 2.66 | 22.9 | 1,835 | 48.2 | 2.2 | 2.3 |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration
Shaded concentrations indicate detections

Ta[illegible]1
Detected Gr[illegible]ater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW14-R01 02/23/2000 | OW2B-MW15-R01 02/23/2000 | OW2B-MW16-R01 02/22/2000 | OW2B-MW17-R01 02/22/2000 | OW2B-MW18-R01 02/22/2000 | OW2B-MW19-R01 02/26/2000 | OW2B-MW20-R01 02/26/2000 | OW2B-MW20-R01P 02/26/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| **Volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,1-Dichloroethane | 12 | 0.4 J | 4 | 2 | 0.1 J | 4 | 1 U | 1 U |
| 1,1-Dichloroethene | 1 | 1 U | 0.9 J | 0.6 J | 1 U | 1 U | 1 U | 1 U |
| 1,3-Dichlorobenzene | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U | 1 U |
| Acetone | 5 R | 2 L | 3 L | 5 R | 5 R | 5 R | 5 R | 5 R |
| Benzene | 0.1 J | 1 U | 0.6 J | 0.5 J | 1 U | 1 U | 1 U | 1 U |
| Carbon disulfide | 1 U | 1 U | 1 U | 0.7 J | 1 U | 0.4 J | 0.4 J | 0.8 J |
| Chloroethane | 2 | 1 U | 1 U | 1 | 1 U | 1 U | 1 U | 1 U |
| cis-1,2-Dichloroethene | 1 | 0.4 J | 6 | 3 | 0.2 J | 0.1 J | 1 U | 1 U |
| Methylene chloride | 2 U | 2 U | 0.6 B | 0.6 B | 0.6 B | 0.2 J | 0.2 J | 0.2 J |
| Toluene | 0.1 J | 0.1 J | 0.2 J | 0.2 J | 0.2 J | 0.1 J | 1 U | 1 U |
| trans-1,2-Dichloroethene | 1 U | 1 U | 0.4 J | 0.3 J | 1 U | 1 U | 1 U | 1 U |
| Trichloroethene | 1 U | 0.2 J | 1 U | 1 U | 0.3 J | 1 U | 1 U | 1 U |
| Vinyl chloride | 9 | 0.6 J | 0.3 J | 0.5 J | 1 U | 1 | 1 U | 1 U |
| **Semi-volatile Organic Compounds (ug/L)** | | | | | | | | |
| bis(2-Ethylhexyl)phthalate | 6 B | 4 B | 10 U | 10 U | 10 U | 10 U | 10 U | 10 U |
| Fluorene | 1 U | 1 U | 1 U | 1 UL | 0.098 J | 1 U | 1 U | 1 U |
| Naphthalene | 2 U | 2 U | 2 U | 2 UL | 2 U | 2 U | 2 U | 2 U |
| Phenanthrene | 1 U | 1 U | 1 U | 1 UL | 1 U | 1 U | 1 U | 1 U |
| Pyrene | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U |
| **Pesticide/Polychlorinated Biphenyls (ug/L)** | | | | | | | | |
| beta-BHC | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Heptachlor epoxide | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| **Total Metals (ug/L)** | | | | | | | | |
| Arsenic | 2.5 U | 6 J | 20.4 | 29.7 | 12.5 | 2.5 U | 2.8 B | 2.5 B |
| Barium | 11.7 J | 57.8 J | 56.9 J | 41.2 J | 54.1 J | 37.7 J | 65.6 J | 64.1 J |
| Cadmium | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U |
| Calcium | 58,800 | 6,640 | 17,500 | 17,600 | 13,900 | 12,100 | 40,800 | 40,100 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 4.8 J | 4.8 J |
| Cobalt | 1.5 U | 1.5 U | 9.3 J | 1.5 U | 1.6 J | 1.5 U | 1.5 U | 1.5 U |
| Iron | 9,280 | 6,260 | 29,900 | 35,500 | 11,700 | 7,720 | 7,080 | 6,950 |
| Magnesium | 10,800 | 10,300 | 32,400 | 13,500 | 5,120 | 8,580 | 11,200 | 11,000 |
| Manganese | 507 | 269 | 648 | 494 | 230 | 181 | 500 | 492 |
| Potassium | 1,280 J | 897 J | 752 J | 1,870 J | 1,370 J | 1,120 J | 2,190 J | 2,140 J |
| Sodium | 26,800 | 9,390 | 36,000 | 16,600 | 12,200 | 14,400 | 28,800 | 28,100 |
| Vanadium | 2.1 U | 2.1 U | 2.2 J | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U |
| Zinc | 2.9 B | 3.8 B | 4.4 B | 6.5 B | 4.9 B | 10.3 B | 9 B | 12.3 B |
| **Dissolved Metals (ug/L)** | | | | | | | | |
| Aluminum | 37 B | 150 B | 26 B | 17.2 B | 15.5 U | 33.1 B | 21.6 B | 25 B |
| Arsenic | 2.5 U | 5.2 J | 17.3 | 32.2 | 9.7 J | 3.1 B | 2.5 U | 2.5 U |
| Barium | 11.6 J | 56 J | 61.6 J | 42.6 J | 51.4 J | 36.4 J | 64.5 J | 63.3 J |
| Calcium | 61,800 | 6,610 | 19,300 | 18,400 | 13,900 | 12,100 | 40,400 | 39,400 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 4.3 J | 4.2 J |
| Cobalt | 1.5 U | 1.5 U | 10.1 J | 1.5 U | 1.7 J | 1.5 U | 1.5 U | 1.5 U |
| Iron | 9,580 | 5,930 | 30,400 | 36,400 | 10,800 | 5,460 | 7,050 | 6,880 |
| Lead | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 4.5 | 1.4 U |
| Magnesium | 11,100 | 9,920 | 35,700 | 14,000 | 5,010 | 8,560 | 11,200 | 10,900 |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration
Shaded concentrations indicate detections

Ta 1
Detected Gr ater Results
SWMU 2B
Oceana NAS

| Sample Date | OW2B-MW14-R01 02/23/2000 | OW2B-MW15-R01 02/23/2000 | OW2B-MW16-R01 02/22/2000 | OW2B-MW17-R01 02/22/2000 | OW2B-MW18-R01 02/22/2000 | OW2B-MW19-R01 02/26/2000 | OW2B-MW20-R01 02/26/2000 | OW2B-MW20-R01P 02/26/2000 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| Manganese | 529 | 259 | 714 | 512 | 226 | 180 | 498 | 486 |
| Nickel | 1.7 U | 2.2 J | 7.1 J | 1.7 U | 1.7 U | 1.7 U | 1.7 U | 1.7 U |
| Potassium | 1,360 J | 849 J | 866 J | 1,960 J | 1,350 J | 1,040 J | 2,120 J | 2,060 J |
| Sodium | 28,000 | 8,770 | 40,000 | 17,300 | 11,500 | 14,100 | 28,200 | 27,600 |
| Zinc | 4.3 J | 9.6 J | 5.8 J | 4.5 J | 12.5 J | 9.7 B | 10.2 B | 8.5 B |
| **Geochemistry (MG/L)** | | | | | | | | |
| Alkalinity | 195 | 25 | 85 | 93 | 40 | 65 | NA | 110 |
| Chloride | 19 | 14 | 30 | 12 | 14 | 7.5 | 22 | 23 |
| Sulfate | 17 | 21 | 20 | 19 | 17 | 16 | 1.5 | 1.5 |
| Sulfide | 0.12 | 0.15 | 0.1 | 0.11 | 0.08 | 0.12 | NA | 0.16 |
| Ethane (NG/L) | 363 | 321 | 50 | 5 U | 5 U | 22 | 109 | 90 |
| Ethene (NG/L) | 1,170 | 60 | 37 | 64 | 5 U | 32 | 5 U | 5 U |
| Iron II | 6.5 | 4.3 | 17 | 18 | 6.1 | 4.2 | 4.7 | 4.5 |
| Iron III | 0.8 | 0.5 U | 1 | 1.1 | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Manganese | 0.5 | 0.5 U | 0.5 | 0.7 | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Methane (UG/L) | 1,880 | 1,170 | 1,270 | 2,150 | 1,510 | 73.15 | 1,295 | 1,160 |
| Nitrate | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Total Organic Carbon (TOC) | 6.3 | 8.1 | 26 | 9.4 | 5.9 | 3.5 | 4.6 | 4.6 |
| **Field Parameters** | | | | | | | | |
| Conductivity (MS/CM) | 372 | 139 | 387 | 260 | 140 | 152 | 316 | NA |
| DO | 0.01 | 0.06 | 0.13 | 0.08 | 0.17 | 0.04 | 0.08 | NA |
| PH (unitless) | 5.97 | 5.56 | 5.7 | 6.19 | 6.22 | 5.89 | 6.17 | NA |
| Redox (mV) | -119.1 | -69.4 | -57.4 | -137.9 | -114.7 | 32.9 | 18.9 | NA |
| Temperature (Celsius) | 16.07 | 15.79 | 15.81 | 14.94 | 15 | 16.68 | 17.72 | NA |
| Turbidity (NTU) | 13.1 | 0.5 | 30.8 | 1.5 | 9.7 | 195 | 0.5 | NA |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration
Shaded concentrations indicate detections

Ta[illegible]2
Detected Gr[illegible]ater Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW01-R01 03/06/2000 | OW2E-MW03-R01 03/16/2000 | OW2E-MW03-R01-P 03/16/2000 | OW2E-MW04-R01 03/06/2000 | OW2E-MW05-R01 03/06/2000 | OW2E-MW07-R01 03/16/2000 | OW2E-MW07-R01-P 03/16/2000 | OW2E-MW08-R01 03/06/2000 |
|---|---|---|---|---|---|---|---|---|
| **Volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,1-Dichloroethane | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| 2-Butanone | 12 R | 5 R | 5 R | 25 R | 5 R | 5 R | 5 R | 25 R |
| 4-Methyl-2-pentanone | 12 U | 5 U | 5 U | 25 U | 5 U | 5 U | 5 U | 25 U |
| Acetone | 12 R | 5 R | 5 R | 25 R | 9 L | 4 L | 2 L | 25 R |
| Benzene | 0.5 J | 1 U | 1 U | 15 | 0.5 J | 1 U | 1 U | 2 J |
| Carbon disulfide | 2 U | 1 U | 1 U | 5 U | 0.4 J | 1 U | 1 U | 5 U |
| Chlorobenzene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 0.3 J |
| Chloromethane | 2 U | 1 U | 0.2 B | 5 U | 1 U | 1 U | 1 U | 5 U |
| cis-1,2-Dichloroethene | 2 U | 1 U | 1 U | 5 U | 0.3 J | 1 U | 1 U | 5 U |
| Ethylbenzene | 0.3 J | 1 U | 1 U | 1 J | 0.4 J | 1 U | 1 U | 11 |
| Toluene | 2 U | 0.1 J | 0.1 J | 5 U | 0.3 J | 0.1 J | 0.1 J | 0.3 J |
| trans-1,2-Dichloroethene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Trichloroethene | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 0.2 J |
| Vinyl chloride | 2 U | 1 U | 1 U | 5 U | 1 U | 1 U | 1 U | 5 U |
| Xylene, total | 2 U | 1 U | 0.2 J | 2 J | 1 | 1 U | 1 U | 24 |
| **Semi-volatile Organic Compounds (ug/L)** | | | | | | | | |
| 2-Methylnaphthalene | 120 | 10 U | 10 U | 110 | 10 U | 10 U | 10 U | 56 |
| Acenaphthene | 20 U | 1 U | 1 U | 2 J | 1 U | 5 U | 1 U | 50 U |
| Acenaphthylene | 20 U | 1 U | 1 U | 5 U | 1 U | 5 U | 1 U | 50 U |
| Benzo(a)anthracene | 2 U | 0.1 U | 0.1 U | 0.5 U | 0.1 U | 0.5 U | 0.1 U | 4.8 J |
| bis(2-Ethylhexyl)phthalate | 50 U | 10 U | 10 U | 10 | 10 U | 1 B | 10 U | 40 U |
| Fluorene | 8.2 J | 1 U | 1 U | 2.9 J | 0.28 J | 0.06 B | 0.04 B | 18 J |
| Naphthalene | 46 | 2 U | 2 U | 130 | 3.2 | 10 U | 2 U | 95 J |
| Phenanthrene | 13 J | 1 U | 1 U | 6.5 J | 0.55 J | 5 U | 1 U | 59 J |
| Pyrene | 54 J | 0.1 U | 0.1 U | 10 J | 2.3 J | 0.5 U | 0.1 U | 240 J |
| **Pesticide/Polychlorinated Biphenyls (ug/L)** | | | | | | | | |
| beta-BHC | 0.061 J | 0.05 U | 0.05 U | 0.05 UJ | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Dieldrin | 0.1 U | 0.1 U | 0.1 U | 0.1 UJ | 0.1 U | 0.1 U | 0.1 U | 0.1 U |
| **Total Metals (ug/L)** | | | | | | | | |
| Aluminum | 34.9 B | 104 B | 153 B | 58.3 B | 44.6 B | 33.6 B | 95.4 B | 43.8 B |
| Arsenic | 26.1 | 4.5 B | 2.9 B | 2.5 U | 8.7 B | 7.9 B | 5.7 B | 2.5 U |
| Barium | 14.7 J | 11 J | 10.3 J | 24.8 J | 28 J | 121 J | 122 J | 30.3 J |
| Cadmium | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U |
| Calcium | 14,100 | 7,090 | 7,120 | 27,100 | 28,700 | 56,300 | 56,700 | 18,400 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U |
| Copper | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U | 2.9 U |
| Iron | 43,900 | 3,020 | 2,600 | 15,100 | 44,000 | 57,800 | 58,100 | 11,600 |
| Lead | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U | 1.4 U |
| Magnesium | 23,000 | 8,400 | 8,580 | 51,900 | 27,800 | 12,800 | 12,900 | 16,400 |
| Manganese | 1,590 | 308 | 317 | 1,680 | 759 | 1,100 | 1,110 | 321 |
| Nickel | 1.7 U | 1.7 U | 1.7 U | 2.2 B | 2.6 B | 1.7 U | 1.7 U | 1.7 U |
| Potassium | 586 J | 434 J | 415 J | 830 J | 1,940 J | 7,580 | 7,650 | 1,410 J |
| Selenium | 3.1 U | 3.1 B | 3.1 U | 3.1 U | 3.1 U | 3.1 B | 3.3 B | 3.1 U |
| Sodium | 14,700 | 11,300 | 11,900 | 27,700 | 22,300 | 18,500 | 19,800 | 35,100 |
| Vanadium | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U |
| Zinc | 11.7 B | 6.3 B | 9.3 B | 9.1 B | 13.4 B | 8.1 B | 10.3 B | 12.2 B |
| **Dissolved Metals (ug/L)** | | | | | | | | |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration
Shaded concentrations indicate detections

T[illegible]-2
Detected G[illegible]ater Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW01-R01 03/06/2000 | OW2E-MW03-R01 03/16/2000 | OW2E-MW03-R01-P 03/16/2000 | OW2E-MW04-R01 03/06/2000 | OW2E-MW05-R01 03/06/2000 | OW2E-MW07-R01 03/16/2000 | OW2E-MW07-R01-P 03/16/2000 | OW2E-MW08-R01 03/06/2000 |
|---|---|---|---|---|---|---|---|---|
| Aluminum | 78.5 B | 135 B | 89.2 B | 47.5 B | 44.4 B | NA | NA | 38.4 B |
| Arsenic | 24.3 | 2.5 U | 2.7 B | 2.5 U | 10.4 B | NA | NA | 2.5 U |
| Barium | 14.7 J | 10.6 J | 9.9 J | 23.5 J | 28.6 J | NA | NA | 30.6 J |
| Cadmium | 0.7 U | 0.7 U | 0.7 U | 0.7 U | 0.7 U | NA | NA | 0.7 U |
| Calcium | 13,900 | 7,070 | 6,960 | 25,400 | 29,300 | NA | NA | 19,000 |
| Chromium | 2.6 U | 2.6 U | 2.6 U | 2.6 U | 2.6 U | NA | NA | 2.6 U |
| Copper | 2.9 U | 2.9 U | 2.9 U | 4.1 B | 5.4 B | NA | NA | 2.9 U |
| Iron | 42,900 | 2,240 | 1,420 | 14,100 | 44,700 | NA | NA | 12,000 |
| Magnesium | 22,600 | 8,350 | 8,400 | 48,500 | 28,200 | NA | NA | 16,900 |
| Manganese | 1,560 | 305 | 311 | 1,580 | 769 | NA | NA | 331 |
| Nickel | 2 B | 12.1 J | 1.7 U | 2.2 B | 3.1 B | NA | NA | 5.4 B |
| Potassium | 564 J | 432 J | 406 J | 805 J | 2,050 J | NA | NA | 1,450 J |
| Selenium | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 5.3 K | NA | NA | 3.1 U |
| Sodium | 14,700 | 11,400 | 11,300 | 26,500 | 23,300 | NA | NA | 35,800 |
| Vanadium | 2.1 U | 2.1 U | 2.1 U | 2.1 U | 2.1 U | NA | NA | 2.1 U |
| Zinc | 11 B | 20.7 B | 6.3 B | 7 B | 14 B | NA | NA | 23.1 |
| **Geochemistry (MG/L)** | | | | | | | | |
| Alkalinity | 145 | 75 | NA | 245 | 190 | 250 | 250 | 125 |
| Chloride | 11 | 7.9 | NA | 20 | 15 | 22 | 25 | 19 |
| Sulfate | 9.5 | 13 | NA | 0.5 U | 13 | 0.5 U | 0.5 U | 1.5 |
| Sulfide | 0.1 | 0.08 | NA | 0.1 | 0.1 | 0.9 | 0.9 | 0.13 |
| Ethane (NG/L) | 5 | 32 | NA | 5 | 50 | 5 | 5 | 5 |
| Ethene (NG/L) | 5 | 32 | NA | 5 | 126 | 26 | 69 | 5 |
| Iron II | 37 E | 0.8 | NA | 12 E | 36 E | 30 E | 34 E | 9 |
| Iron III | 1.3 | 0.5 U | NA | 0.7 | 2.1 | 2.3 | 2.3 | 0.5 U |
| Manganese | 1.8 | 0.5 U | NA | 1.5 | 0.5 U | 0.8 | 0.9 | 0.5 U |
| Methane (UG/L) | 3,233 | 11,669 | NA | 8,775 | 4,117 | 4,623 | 4,874 | 7,098 |
| Nitrite | 0.5 U | 0.5 U | NA | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Total Organic Carbon (TOC) | 14 | 3.1 | NA | 24 | 21 | 12 | 11 | 13 |
| **Field Parameters** | | | | | | | | |
| Conductivity (MS/CM) | 202 | 147 | NA | 280 | 276 | 555 | NA | 200 |
| DO | 0.5 | 0.16 | NA | 0.31 | 0.19 | 0.26 | NA | 0.25 |
| PH (unitless) | 6.17 | 5.8 | NA | 6.16 | 6.13 | 6.13 | NA | 5.93 |
| Redox (mV) | -35.4 | 13.2 | NA | -26.9 | -49.9 | -48.6 | NA | 20.5 |
| Temperature (Celsius) | 15.17 | 15.69 | NA | 17.31 | 17.3 | 18.34 | NA | 18.58 |
| Turbidity (NTU) | 2,016 | 46 | NA | 780 | 2,029 | 12.7 | NA | 2,039 |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration
Shaded concentrations indicate detections

T[illegible]2-2
Detected G[illegible]water Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW09-R01 03/06/2000 | OW2E-MW10-R01 03/16/2000 | OW2E-MW10-R01-P 03/08/2000 | OW2E-MW11-R01 03/17/2000 | OW2E-MW12-R01 03/06/2000 | OW2E-MW13-R01 03/06/2000 | OW2E-MW15-R01 03/06/2000 | OW2E-MW16-R01 03/06/2000 |
|---|---|---|---|---|---|---|---|---|
| **Volatile Organic Compounds (ug/L)** | | | | | | | | |
| 1,1-Dichloroethane | 0.2 J | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| 2-Butanone | 5 R | 25 R | NA | 2 L | 5 R | 5 R | 5 R | 5 R |
| 4-Methyl-2-pentanone | 5 U | 25 U | NA | 0.8 J | 5 U | 5 U | 5 U | 5 U |
| Acetone | 5 R | 8 L | NA | 10 L | 5 R | 3 L | 5 R | 7 L |
| Benzene | 0.8 J | 3 J | NA | 1 U | 0.2 J | 1 U | 1 U | 1 U |
| Carbon disulfide | 0.6 J | 5 U | NA | 0.6 J | 1 U | 0.2 J | 1 U | 0.3 J |
| Chlorobenzene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Chloromethane | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 0.1 J |
| cis-1,2-Dichloroethene | 13 | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Ethylbenzene | 1 U | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Toluene | 1 U | 5 U | NA | 0.2 J | 1 U | 1 U | 0.2 J | 1 U |
| trans-1,2-Dichloroethene | 0.9 J | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Trichloroethene | 0.8 J | 5 U | NA | 1 U | 1 U | 1 U | 1 U | 1 U |
| Vinyl chloride | 8 | 5 U | NA | 1 U | 1 U | 0.3 J | 1 U | 1 U |
| Xylene, total | 1 U | 5 U | NA | 0.3 J | 1 U | 1 U | 1 U | 1 U |
| **Semi-volatile Organic Compounds (ug/L)** | | | | | | | | |
| 2-Methylnaphthalene | 10 U | 10 U | NA | 10 U | 10 U | 10 U | 10 U | 10 U |
| Acenaphthene | 1 U | 1 U | 1 R | 5 U | 5 U | 1 U | 1 U | 1 U |
| Acenaphthylene | 1.8 J | 1 U | 1 R | 5 U | 5 U | 1 U | 1 U | 1 U |
| Benzo(a)anthracene | 0.1 U | 0.1 U | 0.1 R | 0.5 U | 0.5 U | 0.1 U | 0.1 U | 0.1 U |
| bis(2-Ethylhexyl)phthalate | 10 U | 10 U | NA | 2 B | 10 U | 10 U | 6 J | 10 U |
| Fluorene | 1 U | 1 U | 1 R | 5 U | 0.15 J | 0.029 J | 1 U | 1 U |
| Naphthalene | 2 U | 2 U | 2 R | 10 U | 10 U | 2 U | 2 U | 2 U |
| Phenanthrene | 0.037 J | 1 U | 1 R | 5 U | 5 U | 0.031 J | 1 U | 1 U |
| Pyrene | 0.14 J | 0.1 U | 0.1 R | 0.5 U | 0.5 U | 0.1 UJ | 0.1 UJ | 0.1 UJ |
| **Pesticide/Polychlorinated Biphenyls (ug/L)** | | | | | | | | |
| beta-BHC | 0.05 UJ | 0.05 U | NA | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 UJ |
| Dieldrin | 0.1 UJ | 0.1 U | NA | 0.1 U | 0.1 U | 0.1 U | 0.1 U | 0.052 J |
| **Total Metals (ug/L)** | | | | | | | | |
| Aluminum | 258 B | 44.4 B | NA | 4,020 | 224 B | 121 B | 119 B | 1,780 |
| Arsenic | 3.2 B | 55.3 | NA | 5.4 B | 2.9 B | 2.5 U | 5.5 B | 8.2 B |
| Barium | 27.5 J | 70.9 J | NA | 46.9 J | 69.4 J | 24 J | 9.8 J | 19.4 J |
| Cadmium | 0.7 U | 0.7 U | NA | 1.1 J | 0.7 U | 0.7 U | 0.7 U | 0.7 U |
| Calcium | 38,800 | 11,600 | NA | 19,200 | 53,500 | 24,200 | 22,300 | 30,200 |
| Chromium | 2.6 U | 2.6 U | NA | 7 J | 2.6 U | 2.6 U | 2.6 U | 5.8 J |
| Copper | 8.1 B | 2.9 U | NA | 5.4 J | 2.9 U | 2.9 U | 2.9 U | 40.4 |
| Iron | 56,100 | 67,000 | NA | 7,160 | 49,900 | 16,400 | 10,300 | 19,600 |
| Lead | 3.1 | 1.4 U | NA | 5.4 B | 1.4 U | 1.4 U | 1.4 U | 10.4 |
| Magnesium | 24,600 | 25,200 | NA | 13,900 | 12,600 | 16,300 | 7,800 | 7,030 |
| Manganese | 1,920 | 533 | NA | 578 | 797 | 502 | 306 | 327 |
| Nickel | 39 J | 1.7 U | NA | 5.8 J | 2.5 B | 3.1 B | 2.2 B | 6.6 B |
| Potassium | 1,520 J | 1,520 J | NA | 4,520 J | 4,110 J | 1,870 J | 1,370 J | 1,660 J |
| Selenium | 3.1 U | 3.1 U | NA | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.8 J |
| Sodium | 26,900 | 24,600 | NA | 33,100 | 30,700 | 28,400 | 26,100 | 19,200 |
| Vanadium | 2.1 U | 2.1 U | NA | 10 J | 2.1 U | 2.1 U | 2.1 U | 7.4 B |
| Zinc | 62.4 | 12 B | NA | 68.2 | 8 B | 19.7 B | 8.1 B | 154 |
| **Dissolved Metals (ug/L)** | | | | | | | | |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration
Shaded concentrations indicate detections

T[illegible]-2
Detected G[illegible]ater Results
SWMU 2E
Oceana NAS

| Sample Date | OW2E-MW09-R01 03/06/2000 | OW2E-MW10-R01 03/16/2000 | OW2E-MW10-R01-P 03/08/2000 | OW2E-MW11-R01 03/17/2000 | OW2E-MW12-R01 03/06/2000 | OW2E-MW13-R01 03/06/2000 | OW2E-MW15-R01 03/06/2000 | OW2E-MW16-R01 03/06/2000 |
|---|---|---|---|---|---|---|---|---|
| Aluminum | 30.6 B | 112 B | NA | 5,540 | 55.6 B | 53.7 B | 30.3 B | 28.5 B |
| Arsenic | 2.8 B | 40.1 | NA | 6.6 B | 3.9 B | 2.5 U | 2.5 U | 2.5 U |
| Barium | 25.8 J | 58.7 J | NA | 54.3 J | 71.1 J | 24.2 J | 9.3 B | 6.1 B |
| Cadmium | 0.7 U | 0.7 U | NA | 0.92 J | 0.7 U | 0.7 U | 0.7 U | 0.7 U |
| Calcium | 39,300 | 10,900 | NA | 18,900 | 55,900 | 24,900 | 22,200 | 24,700 |
| Chromium | 2.6 U | 2.6 U | NA | 9.6 J | 2.6 U | 2.6 U | 2.6 U | 2.6 U |
| Copper | 2.9 U | 2.9 U | NA | 7.1 J | 2.9 U | 2.9 U | 2.9 U | 2.9 U |
| Iron | 44,800 | 55,800 | NA | 7,640 | 51,600 | 16,100 | 7,600 | 4,570 |
| Magnesium | 24,400 | 24,000 | NA | 13,500 | 13,200 | 16,500 | 7,550 | 6,330 |
| Manganese | 1,820 | 505 | NA | 550 | 832 | 509 | 303 | 299 |
| Nickel | 3.4 B | 1.7 U | NA | 7.1 J | 1.7 U | 1.7 U | 1.9 B | 1.7 U |
| Potassium | 1,570 J | 1,460 J | NA | 4,870 J | 4,410 J | 1,940 J | 1,410 J | 1,510 J |
| Selenium | 3.1 U | 3.1 U | NA | 3.1 U | 3.1 U | 3.1 U | 3.1 U | 3.1 U |
| Sodium | 28,600 | 24,400 | NA | 32,500 | 32,600 | 28,900 | 26,400 | 19,900 |
| Vanadium | 2.1 U | 2.1 U | NA | 14.4 J | 2.1 U | 2.1 U | 2.1 U | 2.1 U |
| Zinc | 14.2 B | 8.9 B | NA | 68.3 | 10.7 B | 13.5 B | 11 B | 18.1 J |
| **Geochemistry (MG/L)** | | | | | | | | |
| Alkalinity | 180 | 170 | 170 | 210 | 275 | 160 | 75 | 65 |
| Chloride | 16 | 16 | 16 | 12 | 17 | 13 | 20 | 16 |
| Sulfate | 2.8 | 4.1 | 2.96 | 5.3 | 0.5 U | 8.7 | 35 | 23 |
| Sulfide | 0.05 | 1.3 | 0.13 | 1 | 0.12 | 0.13 | 0.11 | 0.12 |
| Ethane (NG/L) | 5 | 5 | 5 | 5 | 5 | 25 | 5 | 5 |
| Ethene (NG/L) | 539 | 21 | 49 | 5 | 5 | 33 | 5 | 5 |
| Iron II | 36 E | 40 E | 43 E | 14 E | 39 E | 13 E | 6.2 | 3 |
| Iron III | 1 | 2.3 | 1.8 | 1.6 | 2.3 | 0.5 | 0.5 U | 0.5 U |
| Manganese | 1.6 | 0.5 U | 0.5 U | 0.9 | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Methane (UG/L) | 4,209 | 3,401 | 36,006 | 3,319 | 10,359 | 992.7 | 6,333 | 9,998 |
| Nitrite | 0.8 | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| Total Organic Carbon (TOC) | 20 | 23 | 44 | 10 | 33 | 10 | 4.5 | 5.7 |
| **Field Parameters** | | | | | | | | |
| Conductivity (MS/CM) | 288 | 436 | NA | 457 | 305 | 170 | 257 | 231 |
| DO | 0.21 | 0.21 | NA | 0.21 | 0.22 | 0.18 | 0.17 | 0.24 |
| PH (unitless) | 6.2 | 6.32 | NA | 6.48 | 6 | 5.91 | 5.61 | 5.77 |
| Redox (mV) | -52 | -78.5 | NA | -71.4 | -28.9 | -3.4 | -18.3 | 7.6 |
| Temperature (Celsius) | 16.5 | 19.03 | NA | 18.84 | 16.6 | 18.54 | 16.53 | 15.39 |
| Turbidity (NTU) | 101.8 | 21.8 | NA | 11.7 | 59.8 | 65 | 298.5 | 65 |

NA-Not analyzed
B-Not detected above associated blank
J-Estimated value
L-Value may be biased low

R-Rejected
U-non-detect
E-Exceeds instrument calibration
Shaded concentrations indicate detections

Appendix A-3

# Summary of Non-Detected Chemicals in SWMU 2B and SWMU 2E Groundwater where the Detection Limit Exceeded the MCLs

**Table A3-1**
**Analytes with Laboratory Detection Limits Exceeding the MCL**
**SWMU 2B Groundwater Samples**

| Analysis | Analyte | Laboratory Detection Limit | Number of Exceedances [1] | MCL [2] | Units |
|---|---|---|---|---|---|
| FMETAL | Thallium | 9.4 | 23 | 2 | UG/L |
| METAL | Thallium | 9.4 | 23 | 2 | UG/L |
| P/PCB | Aroclor-1016 | 1 | 23 | 0.5 | UG/L |
| P/PCB | Aroclor-1221 | 2 | 23 | 0.5 | UG/L |
| P/PCB | Aroclor-1232 | 1 | 23 | 0.5 | UG/L |
| P/PCB | Aroclor-1242 | 1 | 23 | 0.5 | UG/L |
| P/PCB | Aroclor-1248 | 1 | 23 | 0.5 | UG/L |
| P/PCB | Aroclor-1254 | 1 | 23 | 0.5 | UG/L |
| P/PCB | Aroclor-1260 | 1 | 23 | 0.5 | UG/L |
| P/PCB | Toxaphene | 5 | 23 | 3 | UG/L |
| SVOA | Benzo(a)pyrene | 10 | 23 | 0.2 | UG/L |
| SVOA | bis(2-Ethylhexyl)phthalate | 10 | 22 | 6 | UG/L |
| SVOA | Hexachlorobenzene | 10 | 23 | 1 | UG/L |
| SVOA | Pentachlorophenol | 25 | 23 | 1 | UG/L |
| VOA | 1,2-Dibromo-3-chloropropane | 1 | 21 | 0.2 | UG/L |
| VOA | 1,2-Dibromoethane | 1 | 21 | 0.05 | UG/L |

1 - Number of times this laboratory detection limit exceeds the MCL in the data set.
2 - Maximum Contaminant Level - Summer 2000

**Table A3-2**
**Analytes with Laboratory Detection Limits Exceeding the MCL**
**SWMU 2E Groundwater Samples**

| Analysis | Analyte | Laboratory Detection Limit | Number of Exceedances [1] | MCL [2] | Units |
|---|---|---|---|---|---|
| FMETAL | Thallium | 9.4 | 13 | 2 | UG/L |
| METAL | Thallium | 9.4 | 15 | 2 | UG/L |
| P/PCB | Aroclor-1016 | 1 | 15 | 0.5 | UG/L |
| P/PCB | Aroclor-1221 | 2 | 15 | 0.5 | UG/L |
| P/PCB | Aroclor-1232 | 1 | 15 | 0.5 | UG/L |
| P/PCB | Aroclor-1242 | 1 | 15 | 0.5 | UG/L |
| P/PCB | Aroclor-1248 | 1 | 15 | 0.5 | UG/L |
| P/PCB | Aroclor-1254 | 1 | 15 | 0.5 | UG/L |
| P/PCB | Aroclor-1260 | 1 | 15 | 0.5 | UG/L |
| P/PCB | Toxaphene | 5 | 15 | 3 | UG/L |
| SVOA | Benzo(a)pyrene | 0.5 | 5 | 0.2 | UG/L |
| SVOA | Benzo(a)pyrene | 10 | 13 | 0.2 | UG/L |
| SVOA | bis(2-Ethylhexyl)phthalate | 10 | 13 | 6 | UG/L |
| SVOA | Hexachlorobenzene | 10 | 13 | 1 | UG/L |
| SVOA | Pentachlorophenol | 25 | 13 | 1 | UG/L |
| VOA | 1,2-Dibromo-3-chloropropane | 1 | 11 | 0.2 | UG/L |
| VOA | 1,2-Dibromo-3-chloropropane | 5 | 3 | 0.2 | UG/L |
| VOA | 1,2-Dibromoethane | 1 | 11 | 0.05 | UG/L |
| VOA | 1,2-Dibromoethane | 5 | 3 | 0.05 | UG/L |
| VOA | Methylene chloride | 10 | 3 | 5 | UG/L |
| VOA | Vinyl chloride | 5 | 3 | 2 | UG/L |

1 - Number of times this laboratory detection limit exceeds the MCL in the data set.
2 - Maximum Contaminant Level - Summer 2000

# Appendix C—Draft Final SWMU 2C Groundwater Investigation Report

Final

# SWMU 2C Ground Water Investigation Report

## Oceana Naval Air Station
## Virginia Beach, Virginia

CTO Task Order - 124
February 2001

Prepared for

**Department of the Navy**
**Atlantic Division**
**Naval Facilities Engineering Command**

Under the

**LANTDIV CLEAN II Program**
**Contract N62470-95-D-6007**

Prepared by

CH2MHILL

WDC003670349.ZIP/1/KTM

# Table of Contents


Section Page

**1.0 Introduction** ..... **1-1**

**2.0 SWMU 2C Hydrogeology** ..... **2-1**
- 2.1 Stratigraphy ..... 2-1
- 2.2 Hydrogeology ..... 2-1

**3.0 Monitoring Well Ground Water Sampling** ..... **3-1**

**4.0 SWMU 2C Plume Delineation** ..... **4-1**
- 4.1 DPT Sampling Procedures ..... 4-1
- 4.2 Results of the DPT Sampling ..... 4-3

**5.0 Vertical Profiling** ..... **5-1**
- 5.1 Equipment Description ..... 5-1
- 5.2 Test Methods, Results, and Observations ..... 5-2

**6.0 Natural Attenuation** ..... **6-1**
- 6.1 Biodegradation of Chlorinated Hydrocarbons ..... 6-1
- 6.2 Evaluation of Natural Attenuation ..... 6-4
- 6.3 Plume Stabilization, Shrinkage, or Contaminant Reduction Related to Biodegradation ..... 6-5
  - 6.3.1 Reduction in TCE Concentrations ..... 6-5
  - 6.3.2 Increase in *cis-1,2*-DCE Concentrations ..... 6-6
  - 6.3.3 Increase in Vinyl Chloride Concentrations ..... 6-10
  - 6.3.4 Increase in Ethene Concentrations ..... 6-11
  - 6.3.5 Elevated Chloride Concentrations ..... 6-11
  - 6.3.6 Summary of Natural Attenuation of Chlorinated Hydrocarbons ..... 6-11

**7.0 Enhanced Biodegradation** ..... **7-1**
- 7.1 Active Groundwater Remediation ..... 7-1
- 7.2 Attenuation Enhancement ..... 7-1
  - 7.2.1 Addition of Hydrogen ..... 7-1
  - 7.2.2 Addition of Oxygen ..... 7-1
  - 7.2.3 Addition of a Carbon Source ..... 7-2

**8.0 Conclusions** ..... **8-1**

**9.0 References** ..... **9-1**


## List of Appendices


A-1 Summary of Detected Chemicals in Monitoring Well Groundwater Samples

A-2 Summary of Detected Chemicals in DPT Groundwater Samples

# Table of Contents (Continued)

## List of Tables


| | | Page |
|---|---|---|
| 2-1 | Historic Water Level Data and Well Status – SWMU 2C | 2-5 |
| 4-1 | Statistics on DPT Groundwater Sample Results | 4-4 |


## List of Figures


| | | |
|---|---|---|
| 2-1 | SWMU 2C Location Map | 2-2 |
| 2-2 | Water Table Elevation Map | 2-4 |
| 3-1 | Ground Water Monitoring Well Locations at SWMU 2C | 3-2 |
| 4-1 | DPT Ground Water Sampling Locations | 4-2 |
| 4-2 | Distribution of TCE in Monitoring Well and DPT Groundwater Samples | 4-5 |
| 4-3 | Distribution of *cis*-1,2-DCE in Monitoring Well and DPT Groundwater Samples | 4-6 |
| 4-4 | Distribution of Vinyl Chloride in Monitoring Well and DPT Groundwater Samples | 4-7 |
| 5-1 | Vertical Profiling Locations | 5-3 |
| 5-2 | Electrical Conductivity Logs from Vertical Profiling Locations | 5-4 |
| 5-3 | ECD Detector Logs from Vertical Profiling Locations | 5-5 |
| 5-4 | FID Detector Logs from Vertical Profiling Locations | 5-6 |
| 5-5 | Full MIP Suite of Logs from Vertical Profiling Location DW30 | 5-7 |
| 6-1 | Biodegradation Diagram for TCE | 6-2 |
| 6-2 | Dissolved Oxygen Relative to TCE in Groundwater | 6-7 |
| 6-3 | Sulfate Relative to TCE in Groundwater | 6-8 |
| 6-4 | Methane Relative to TCE in Groundwater | 6-9 |
| 6-5 | Ethene Relative to Vinyl Chloride in Groundwater | 6-12 |
| 6-6 | Dissolved Oxygen Relative to Vinyl Chloride in Groundwater | 6-13 |
| 6-7 | Distribution of Chloride in Groundwater | 6-14 |

# 1.0 Introduction

This report presents the results of a ground water quality investigation for the Solid Waste Management Unit #2C (SWMU 2C) located at Naval Air Station (NAS) Oceana in Virginia Beach, Virginia. The purpose of this investigation was to delineate the horizontal and vertical extent of the chlorinated solvent contamination in groundwater at the SWMU. The contaminants of specific concern are trichloroethene (TCE) and its daughter products *cis*-1,2-dichloroethylene (*cis*-1,2-DCE) and vinyl chloride. To achieve this objective, both conventional and direct-push technology (DPT) sampling methods were utilized during this investigation. The field work was conducted during late January through early March 2000 with a follow-on vertical profiling investigation in July 2000.

The scope of work for this sampling event is documented in the *Draft Work Plan, Direct Push Technology Investigation, Supplemental Activities, SWMU 2C, Naval Air Station, Oceana, Virginia Beach, Virginia. CH2M HILL* dated November 1999. The Tier 1 Partnering Team reviewed the plan and consensus was reached to move ahead in the November 1999 meeting.

The specific objectives of the ground water investigation were to: (1) sample select monitoring wells at SWMU 2C and analyze the samples in a close-support laboratory (CSL) to guide the DPT investigation; (2) sample groundwater from the water-table aquifer using DPT and analyze groundwater sample results in the CSL to delineate the nature and extent of chlorinated VOC groundwater contamination at SWMU 2C; (3) present the interim investigation results to the NAS Oceana partnering team; (4) assess the correlation between DPT groundwater sampling results and vertical profiling results to determine the effectiveness of vertical profiling for characterizing chlorinated compound contamination, and (5) prepare a draft-final and final report presenting the results of the investigation with recommendations for application of innovative remedial technologies and the potential effectiveness of long-term monitoring.

Historical background information for SWMU 2C is documented in the following reports:

CH2M HILL, December 1993, *RCRA Facility Investigation Final Report – Phase I, Naval Air Station Oceana, Virginia Beach, Virginia,*

CH2M HILL, November 1995, *Draft Final Corrective Measures Study for SWMUs 1, 2B, and 2C, Oceana Naval Air Station, Virginia Beach, Virginia.*

This report is divided into nine sections. Section 1 provides an introduction to SWMU 2C and presents the objectives of the investigation. Section 2 summarizes the hydrogeology of the SWMU. Section 3 documents the methods for the low-flow monitoring well groundwater sampling. Section 4 summarizes the methods and results for the monitoring well and DPT groundwater sampling at SWMU 2C. Section 5 documents the results of vertical profiling. Section 6 provides a summary of natural attenuation. Section 7 provides an assessment of remedial options. Section 8 provides the conclusion for this investigation and documents recommendations for future activities at SWMU 2C. Finally, Section 9 provides references.

# 2.0 SWMU 2C Hydrogeology

## 2.1 Stratigraphy

NAS Oceana is located in the outer Atlantic Coastal Plain Physiographic Province, which is characterized by low elevations and gently sloping relief. The Station is underlain by more than 2,000 feet of gently dipping sandy sediment, ranging in age from Recent to Lower Cretaceous.

The uppermost geologic unit is the Columbia Group, composed of the Sand Bridge Formation and the underlying Norfolk Formation. The Columbia Group is approximately 60 feet thick. The upper 20 to 40 feet consist of unconsolidated fine sands and silts of low to moderate permeability. The lower 20 to 40 feet consist of relatively impermeable silt, clay, and sandy clay. The Yorktown Formation underlies the Columbia Group. The Yorktown Formation is approximately 90 to 100 feet thick in the vicinity of the Station. It consists of moderately consolidated coarse sand and gravel with abundant shell fragments.

Two significant aquifer systems in the area are the water-table aquifer in the upper 20 to 40 feet of the Columbia Group and the underlying Yorktown Aquifer. The water-table aquifer reportedly consists of discontinuous and heterogeneous sand and shell lenses. The depth to the water table is usually less than 3-7 feet. The Yorktown Aquifer is semi-confined beneath a clay layer in the upper Yorktown Formation. Water-bearing zones in the Yorktown Aquifer consist of fine to coarse sand, gravel, and shells.

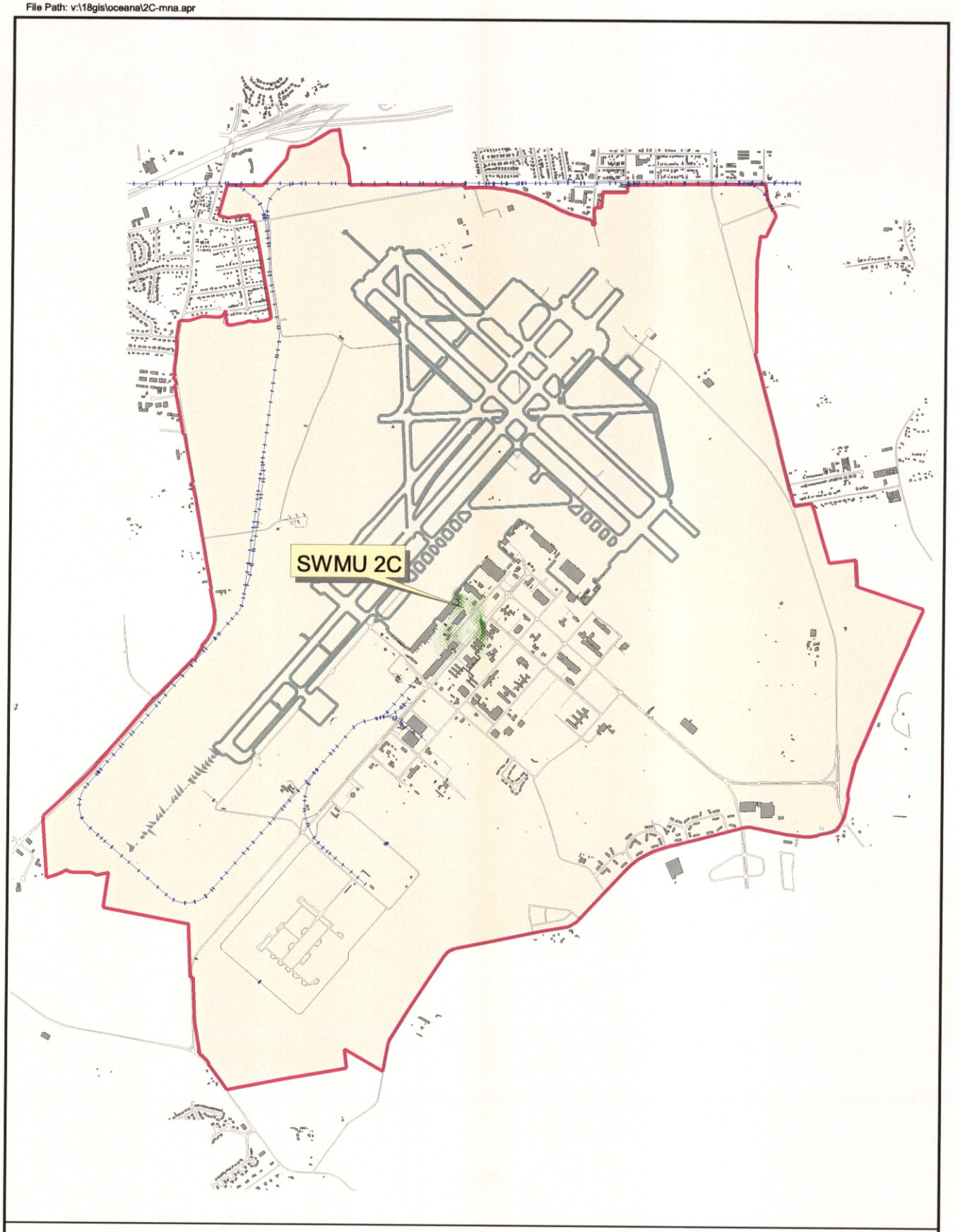
SWMU 2C is located on the flight line at the center of NAS Oceana (Figure 2-1). The lithology at SWMU 2C has been determined by soil logging during the installation of monitoring wells. According to monitoring well logs from SWMU 2C the uppermost 5 to 6 feet of the Columbia Group is composed of clay-rich silt interbedded with discontinuous lenses of fine-grained sand. At approximately 5 to 6 feet below ground surface, the silt grades into a fine to medium-grained sand. The sandy section is generally medium-grained at the top and grades into a fine-grained sand, interbedded with discontinuous thin stringers of silt.

The bottom of the sandy section, between depths of 18 and 23 feet, is generally medium grained. At a depth of approximately 23 feet the medium-grained sand grades abruptly into a silty clay with interbedded fine sand. The silty clay continues to depths greater than 30 feet.

## 2.2 Hydrogeology

In general the Columbia Aquifer at SWMU 2C is composed of the fine to medium grained sand at depths from approximately 6 to 20 feet below ground surface. The aquifer is semi confined between clay rich silt in the uppermost 6 feet and at depths below approximately 20 feet. The lower confining unit is known to extend to depths of approximately 60 feet and separates the Columbia Aquifer from the underlying Yorktown Aquifer.

File Path: v:\18gis\oceana\2C-mna.apr




N
W E
S

0 0.2 0.4 0.6 0.8 1 Miles

Figure 2-1
SWMU 2C Location Map
NAS Oceana, Virginia Beach, Virginia

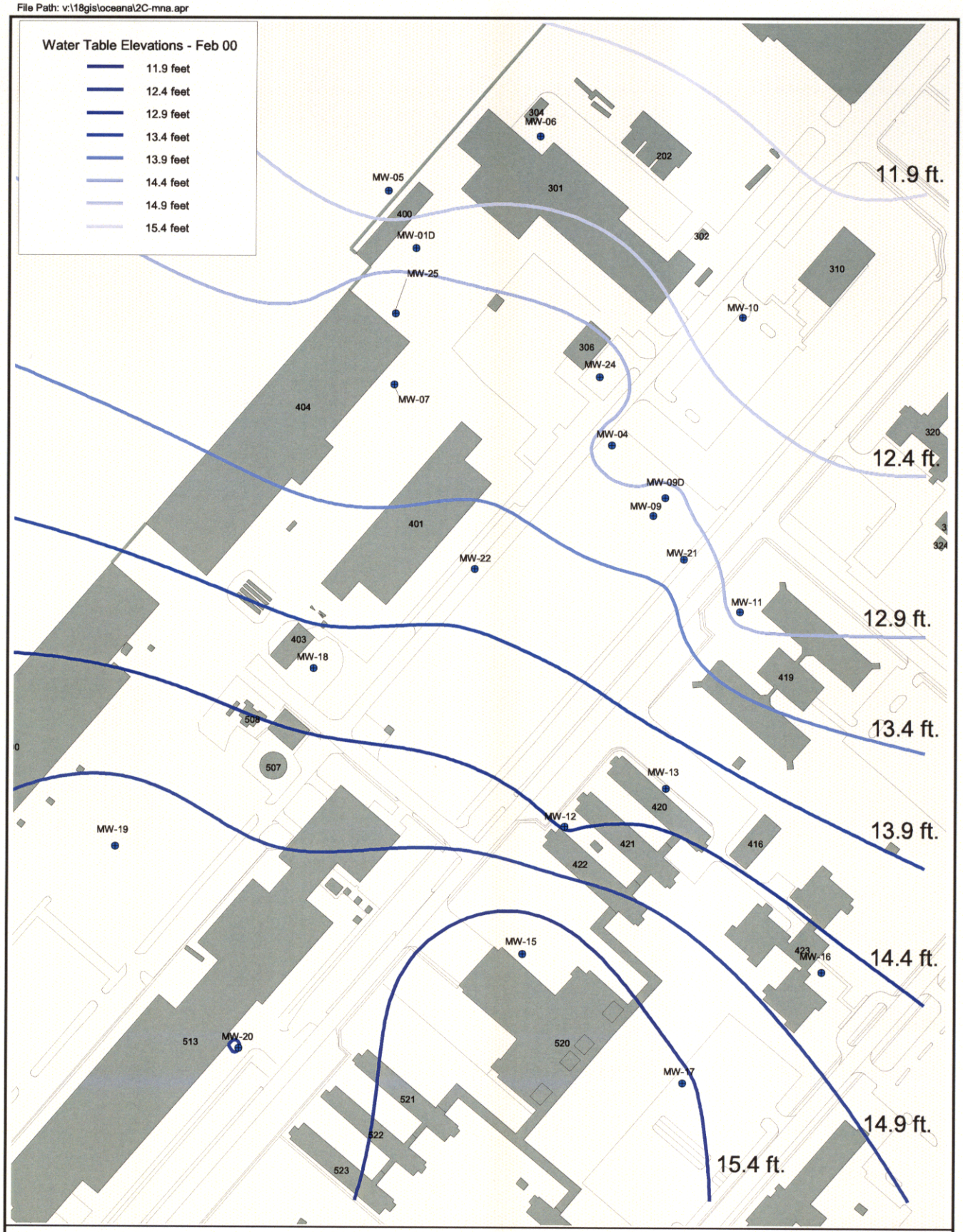
**CH2M HILL**

00606F054

Water level elevations were measured from each monitoring well prior to sampling to gather data to construct a water table elevation map. A water table map produced from these measurements illustrates a ground water flow direction which varies from south to southwesterly across the SWMU (Figure 2-2). This flow direction is consistent with historic water table elevation studies at this SWMU. The water table elevations depicted in this figure represent a period of time when abundant precipitation raised the water table to an elevation close to or above ground surface at some locations on the Station. The February water table map indicates a south-south-westerly directed groundwater flow direction across the SWMU. Historic water level data are tabulated in Table 2-1.

The groundwater velocity at the SWMU is consistent with velocities calculated at other SWMUs at NAS Oceana. The most recent study, at SWMU 15, indicated a groundwater velocity range of 3 to 24 feet per year in the Columbia Aquifer depending on depth and lithology. The average groundwater velocity for the sand unit comprising the Columbia Aquifer at SWMU 15 was determined to be approximately 10 feet per year. SWMU 2C is about 5000 feet hydraulically downgradient of SWMU 15.

File Path: v:\18gis\oceana\2C-mna.apr




N
W E
S

0 100 200 300 Feet

Figure 2-2
Water Table Elevation Map, February 2000 - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

00606 F06y

Table 2-1
Historic Water Level Data and Well Status - SWMU 2C

| Well | Date Installed | Measuring Point Elevation (ft above MSL) | Ground Surface Elevation (ft above MSL) | Total Depth (ft) | Screened Interval (ft BGS) | Water-Table Elevation (ft) | | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Sep-88 | Nov-90 | Feb-93 | Mar-94 | May-94 | Jan-00 | |
| 2C-MW1 | 9/13/88 | 20.46 | 20.5 | 20 | 10 - 20 | 12.7 | 12.37 | 13.62 | 15.04 | 13.25 | - | Removed |
| 2C-MW1D | 12/17/92 | 20.43 | 20.43 | 62 | 45 - 55 | - | - | 13.54 | 14.83 | 13.03 | 14.63 | |
| 2C-MW2 | 9/9/88 | 20.52 | 20.8 | 20 | 10 - 20 | 12.49 | 12.25 | 13.47 | 14.94 | 13.02 | - | Removed |
| 2C-MW3 | 9/9/88 | 21.29 | 20 | 18 | 8 - 18 | 12.47 | 12.04 | 13.54 | - | - | - | Abandoned |
| 2C-MW4 | 9/14/88 | 19.56 | 17 | 18 | 8 - 18 | 12.11 | 11.75 | 13.22 | 14.58 | 12.56 | 14.59 | |
| 2C-MW5 | 7/12/90 | 20.42 | 20.4 | 16 | 6 - 16 | - | 12.52 | 13.79 | 15.08 | 13.45 | 15.17 | |
| 2C-MW6 | 6/29/90 | 23.18 | 20.7 | 21 | 11 - 21 | - | 12.61 | 13.92 | 15.24 | 143.5 | 15.18 | |
| 2C-MW7 | 7/5/90 | 20.81 | 20.8 | 19 | 9 - 19 | - | 12.01 | 13.4 | 14.81 | 12.9 | 14.61 | |
| 2C-MW8 | 7/3/90 | 19.05 | 19 | 17 | 7 - 17 | - | 11.76 | 13.14 | 14.63 | - | - | Removed |
| 2C-MW9 | 7/3/90 | 19.33 | 17 | 17.5 | 7.5 - 17.5 | - | 12.61 | 12.99 | 14.27 | 12.26 | 14.38 | |
| 2C-MW9D | 12/15/92 | 19.45 | 17.1 | 57 | 42 - 52 | - | - | 12.89 | 14.11 | 12.29 | 14.3 | |
| 2C-MW10 | 12/10/92 | 18.24 | 18.24 | 20 | 10 - 20 | - | - | 13.59 | 14.88 | 12.99 | 15.24 | |
| 2C-MW11 | 12/9/92 | 18.47 | 18.47 | 23 | 13 - 23 | - | - | 12.53 | 13.69 | 11.95 | 14.52 | |
| 2C-MW12 | 12/9/92 | 17.84 | 17.84 | 23 | 13 - 23 | - | - | 11.72 | 12.98 | 11.29 | 12.94 | |
| 2C-MW13 | 12/11/92 | 18.49 | 18.49 | 21 | 11 - 21 | - | - | 11.76 | 12.86 | 11.29 | 13.09 | |
| 2C-MW14 | 3/1/94 | 19.47 | 19.5 | 24 | 10 - 20 | - | - | - | 14.79 | 12.83 | - | Removed |
| 2C-MW15 | 2/28/94 | 18.24 | 18.2 | 24 | 10 - 20 | - | - | - | 8.32 | 10.84 | 11.44 | |
| 2C-MW16 | 2/25/94 | 18.84 | 18.8 | 24 | 10 - 20 | - | - | - | 12.4 | 11.02 | 12.74 | |
| 2C-MW17 | 3/3/94 | 18.35 | 18.4 | 20 | 10 - 20 | - | - | - | 11.58 | 10.39 | 11.85 | |
| 2C-MW18 | 3/8/94 | 18.25 | 18.2 | 19 | 9 - 19 | - | - | - | 14.04 | 12.05 | 13.25 | |
| 2C-MW19 | 5/9/94 | 20.56 | 20.6 | 20 | 9 - 19 | - | - | - | - | 11.3 | 12.06 | |
| 2C-MW20 | 5/10/94 | 19.42 | 19.4 | 20 | 10 - 20 | - | - | - | - | 11.07 | 12.42 | |
| 2C-MW21 | 7/29/99 | 17.14 | 17.39 | 18 | 3 - 18 | - | - | - | - | - | 13.74 | |
| 2C-MW22 | 8/31/99 | 17.96 | 18.21 | 18 | 3 - 18 | - | - | - | - | - | 13.56 | |
| 2C-MW23 | 9/1/99 | 19.05 | 19.37 | 18 | 3 - 18 | - | - | - | - | - | 14.05 | |
| 2C-MW24 | 9/1/99 | 18.45 | 18.72 | 18 | 3 - 18 | - | - | - | - | - | 14.05 | |
| 2C-MW25 | 8/31/99 | 20.28 | 20.49 | 18 | 3 - 18 | - | - | - | - | - | 13.98 | |

# 3.0 Monitoring Well Ground Water Sampling

During February 2000, ground water samples were collected from twenty groundwater monitoring wells at SWMU 2C. The monitoring well ground water sampling locations are illustrated in Figure 3-1. The ground water sampling activities at SWMU 2C were conducted by Columbia Technologies under a subcontract to CH2M HILL. The purpose of the groundwater sampling was to provide a baseline from which to proceed with subsequent DPT groundwater sampling. The ground water analytical data were generated in an on-site close support laboratory (CSL). The monitoring well groundwater analytical results provided an estimation of the horizontal extent of the VOC contamination derived from widely spaced monitoring wells.

All ground water samples were collected using a low-flow peristaltic pump with dedicated tubing in accordance with CH2M HILL, Inc.'s standard operating procedures (SOPs) for ground water sampling.

Upon collection, all ground water samples were submitted to the CSL for analysis of Target Compound List (TCL) Low-concentration (LC) Volatile Organic Compounds (VOCs), These analyses were utilized to establish baseline data for monitoring well groundwater. Natural attenuation parameters were collected in the field and analyzed in the CSL or by field meter. These parameters included ferrous iron, nitrate, sulfate/sulfide, chloride, methane, ethane, ethene, TOC, and alkalinity. In addition, dissolved oxygen, pH, Eh, specific conductance, and temperature were measured in the field utilizing a flow through cell. These parameters were measured several times during purging activities to ensure that the sample was as representative as possible of naturally occurring conditions. The CSL monitoring well groundwater quality results were validated for use in risk assessment.

The results of groundwater sampling of monitoring wells indicated a widespread groundwater contaminant plume of vinyl chloride with two areas of significant elevation in concentrations one in the area of MW25 and the other in the area of MW21. Trichloroethene (TCE) and cis-1,2-dichloroethene (cis-1,2-DCE) were also detected in the two areas with elevated vinyl chloride concentrations. Since the monitoring wells are screened across the stratigraphic interval that was sampled during direct push sampling the monitoring well and DPT data were combined for spatial analysis. No significant disparity between the two data sets was noted.

Therefore, monitoring well groundwater sampling results are included in the summary of DPT sampling results and are documented in the next section.

File Path: v:\18gis\oceana\2C-mna.apr

N
W E
S

0 100 200 300 Feet

Figure 3-1
Monitoring Well Locations - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

CH2M HILL

00606F074

# 4.0 SWMU 2C Plume Delineation

CH2M HILL conducted a DPT ground water investigation at SWMU 2C to define the horizontal and vertical extent of the VOC contaminant plume in order to support a decision regarding the need for ground water remediation. The DPT ground water samples were analyzed on site using the CSL. Concurrently, DPT ground water samples were collected from ninety-seven DPT-installed piezometers using standard low-flow ground water sampling techniques. Procedures and results of the DPT investigation are documented below.

## 4.1 DPT Sampling Procedures

DPT groundwater sampling was used to identify the overall size of the chlorinated VOC contaminant plume in groundwater and to delineate two hotspots for potential innovative chlorinated volatile reduction. DPT sample locations are depicted in Figure 4-1.

A total of 108 DPT groundwater samples were collected from 97 piezometer locations to define the overall extent of the contaminant plume. The initial sampling locations were based on the analytical results from monitoring well sampling at SWMU 2C and the sample locations were sited on an iterative basis depending upon analytical results that were produced by the CSL on a day-to-day basis during the investigation.

Two areas of elevated chlorinated hydrocarbon contamination were identified during monitoring well sampling. These areas were identified for detailed delineation to support potential remedial designs. For elevated area delineation two grids, each measuring approximately 100-foot by 100-foot with 20-foot sampling node spacing, were completed for the vicinity of the contaminated areas around MW25 and MW21. The sampling grid was modified in the field based on the CSL analytical results and site conditions.

The initial DPT sampling locations began in the vicinity of known elevated chlorinated-VOC concentrations at MW21. To delineate the vertical extent of the contamination plume, three groundwater samples were collected at each DPT location in a transect from upgradient locations thru downgradient locations of MW21; one near the top of the surficial aquifer (3 feet deep), one near the center of the surficial aquifer (9 feet deep), and one near the bottom of the surficial aquifer (15 feet deep). The sample interval was a 5-foot screen with the depth noted being the depth at the top of the screen. Therefore, the deepest sample interval of 15 to 20 feet produced a sample collected from the base of the aquifer with the top of the silt and clay confining unit occurring at a depth of 20 feet bgs. Based on the analytical results from the CSL, the stratigraphic interval with most elevated level of chlorinated VOCs was sampled laterally to delineate the horizontal extent of the contaminant plume.

The DPT groundwater samples were analyzed by an on-site CSL. The analytical protocol for the groundwater samples included TCL VOCs including TCE, *cis*-1,2-DCE, and vinyl chloride. Natural attenuation parameters were collected in the field and analyzed in the

File Path: v:\18gis\oceana\2C-mna.apr

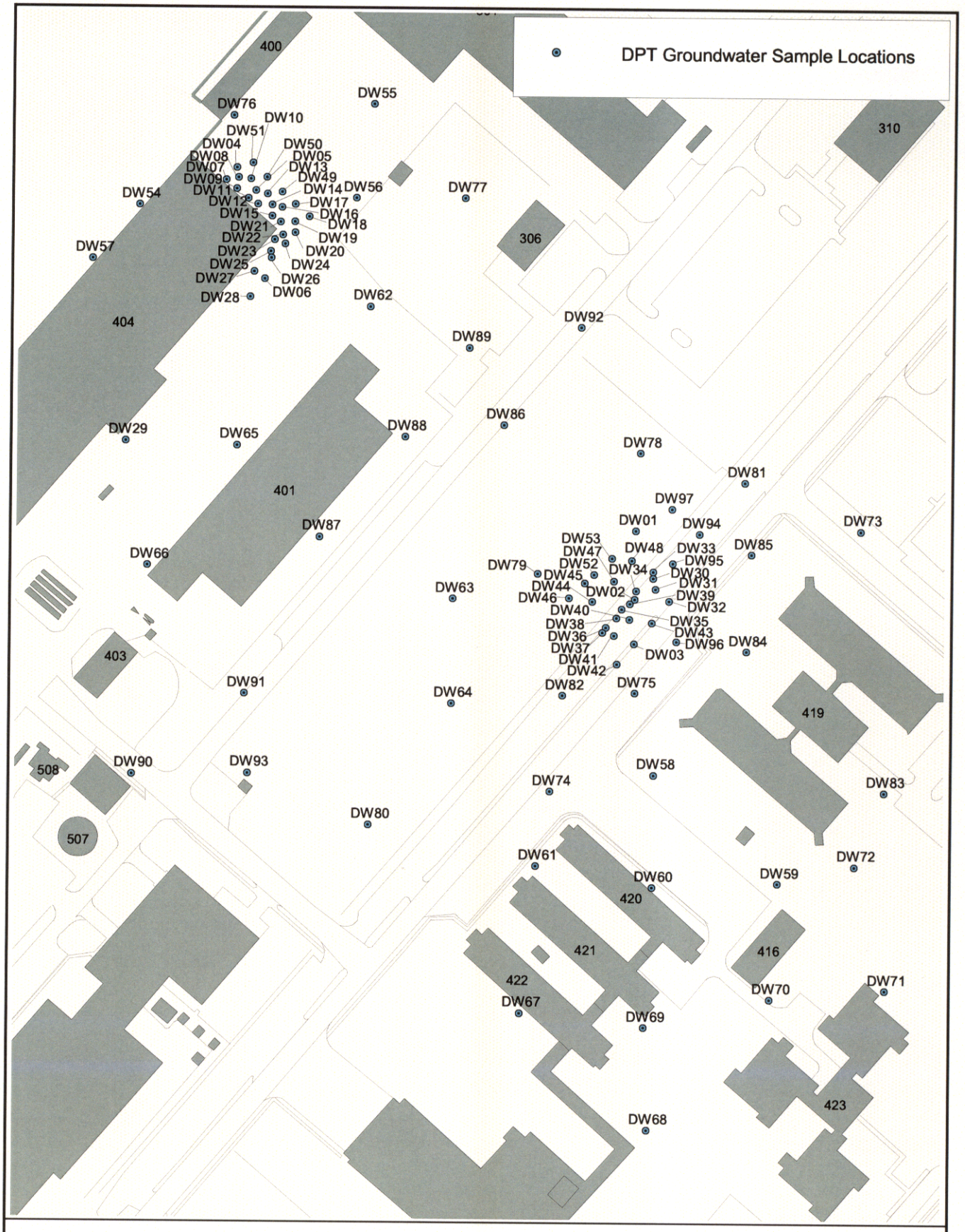



Figure 4-1
DPT Locations - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

00606F08y

CSL or by a field meter. These parameters included ferrous iron, nitrate, sulfate/sulfide, chloride, methane, ethane, ethene, TOC, and alkalinity). In addition, dissolved oxygen, pH, Eh, specific conductance, and temperature were measured in the field utilizing a flow-through cell. These parameters were measured several times during purging activities to ensure that the sample was as representative as possible of naturally occurring conditions.

## 4.2 Results of the DPT Sampling

Table 4-1 lists the chemicals detected in DPT groundwater, the frequency of detection, the maximum concentration detected, the location of the maximum concentration, the mean value, the standard deviation, and the MCL. The primary contaminants of concern are TCE and its daughter products *cis*-1,2-DCE, and vinyl chloride. All of these chemicals were detected in groundwater at levels greater than the MCL. Benzene was also detected in groundwater at levels greater than the MCL. Detected compounds in monitoring well groundwater samples are tabulated in Appendix A-1. Detected compounds in DPT groundwater samples are tabulated in Appendix A-2.

Results of DPT sampling indicate that there are two areas of elevated chlorinated hydrocarbon contamination in groundwater. The area of greatest concentrations is in the southern part of the SWMU near MW21. Multiple depth groundwater sampling at locations DW01 through DW03 indicated that the optimum depth for sampling around this area was the interval from 15 to 20 feet below ground surface (bgs) as samples from this depth interval yielded the highest detected values of chlorinated hydrocarbons. A smaller size area with lower chlorinated hydrocarbon contamination is located in the northern part of the SWMU near MW25. Multiple depth groundwater sampling at locations DW04 through DW06 indicated that the optimum depth for sampling around this area was the interval from 9 to 13 feet bgs as samples from this depth interval yielded the highest detected values of chlorinated hydrocarbons.

Figure 4-2 depicts the distribution of TCE detected in direct push and monitoring well groundwater. The highest detected TCE concentration is 37 ug/L at sample location DW97 at a depth of 15 feet. The TCE groundwater contamination is located in the southernmost elevated area around MW21 but is absent from the MW25 area. The plume seems to originate near MW9 and MW9D and it extends southerly in the direction of groundwater flow.

Figure 4-3 depicts the distribution of *cis*-1,2-DCE detected in direct push and monitoring well groundwater. The highest detected *cis*-1,2-DCE concentration is 676 ug/L at sample location DW01 at a depth of 15 feet. The groundwater contamination is located in both the northern area around MW25 and the southern area around MW21. In the northern area the plume seems to originate near the northeastern wall of building 404. In the southern area, the plume has higher concentrations and seems to originate near MW9 and MW9D and it extends southerly in the direction of groundwater flow, similarly to the TCE plume.

Figure 4-4 depicts the distribution of vinyl chloride detected in direct push and monitoring well groundwater. The highest detected vinyl chloride concentration is 897 ug/L at sample location DW30 at a depth of 15 feet. The vinyl chloride groundwater contamination is located in both the northern area around MW25 and the southern area around MW21. In

Ta. 4-1
Statistics on Groundwater Sample Results - SWMU 2C

| AnalyteName | Detection Frequency | Maximum Detected Concentration | SampleID of Maximum Detected Value | Mean Value (Norm) | Standard Deviation (Norm) | MCL (ug/L) | Exceeds MCL? |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 1 - 116 | 1.7 | OW2C-DW76-15 | 1.17 | 1.76 | 5 | |
| 1,1-DICHLOROETHANE | 76 - 116 | 76 | OW2C-DW13-09 | 4.47 | 9.20 | 999999 | |
| 1,1-DICHLOROETHENE | 9 - 116 | 3.1 | OW2C-DW81-15 | 1.21 | 1.78 | 7 | |
| 1,2,4-TRICHLOROBENZENE | 2 - 116 | 0.8 | OW2C-DW67-15 | 1.16 | 1.76 | 70 | |
| 1,2-DICHLOROBENZENE | 5 - 116 | 3 | OW2C-DW45-15 | 1.21 | 1.78 | 600 | |
| 1,4-DICHLOROBENZENE | 1 - 116 | 0.9 | OW2C-DW26-09 | 1.16 | 1.76 | 75 | |
| BENZENE | 27 - 116 | 33 | OW2C-DW87-15 | 2.05 | 4.36 | 5 | Yes |
| BROMOFORM | 5 - 116 | 1.5 | OW2C-DW67-15 | 1.18 | 1.76 | 100 | |
| CHLOROBENZENE | 8 - 116 | 1.8 | OW2C-DW24-09 | 1.19 | 1.77 | 100 | |
| CHLOROETHANE | 6 - 116 | 4.7 | OW2C-DW36-15 | 1.29 | 1.85 | 999999 | |
| CHLOROFORM | 1 - 116 | 27 | OW2C-DW49-09 | 1.39 | 2.98 | 100 | |
| CIS-1,2-DICHLOROETHENE | 86 - 116 | 676 | OW2C-DW01-15 | 42.84 | 97.20 | 70 | Yes |
| METHYLENE CHLORIDE | 4 - 116 | 2.6 | OW2C-DW70-15 | 1.19 | 1.77 | 5 | |
| O-XYLENE | 4 - 116 | 1.9 | OW2C-DW13-09 | 1.19 | 1.77 | 999999 | |
| TOLUENE | 8 - 116 | 17 | OW2C-DW13-09 | 2.00 | 3.03 | 1000 | |
| TRANS-1,2-DICHLOROETHENE | 45 - 116 | 18 | OW2C-DW51-09 | 2.97 | 3.87 | 100 | |
| TRICHLOROETHENE | 50 - 116 | 37 | OW2C-DW97-15 | 3.65 | 5.31 | 5 | Yes |
| VINYL CHLORIDE | 99 - 116 | 897 | OW2C-DW30-15 | 125.93 | 189.19 | 2 | Yes |

File Path: v:\18gis\oceana\2C-mna.apr

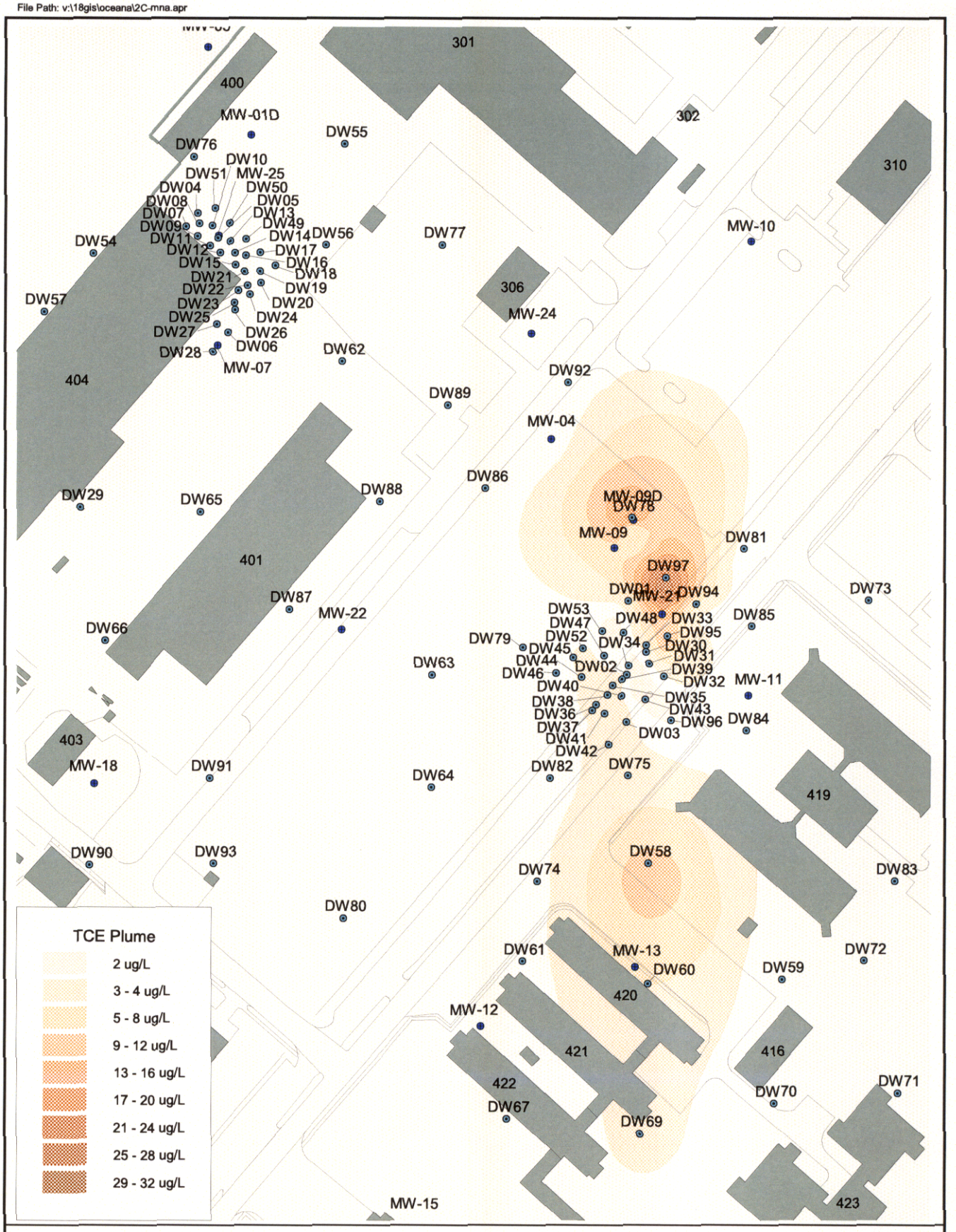



Figure 4-2
TCE in Groundwater - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

00606 F B9y

File Path: v:\18gis\oceana\2C-mna.apr

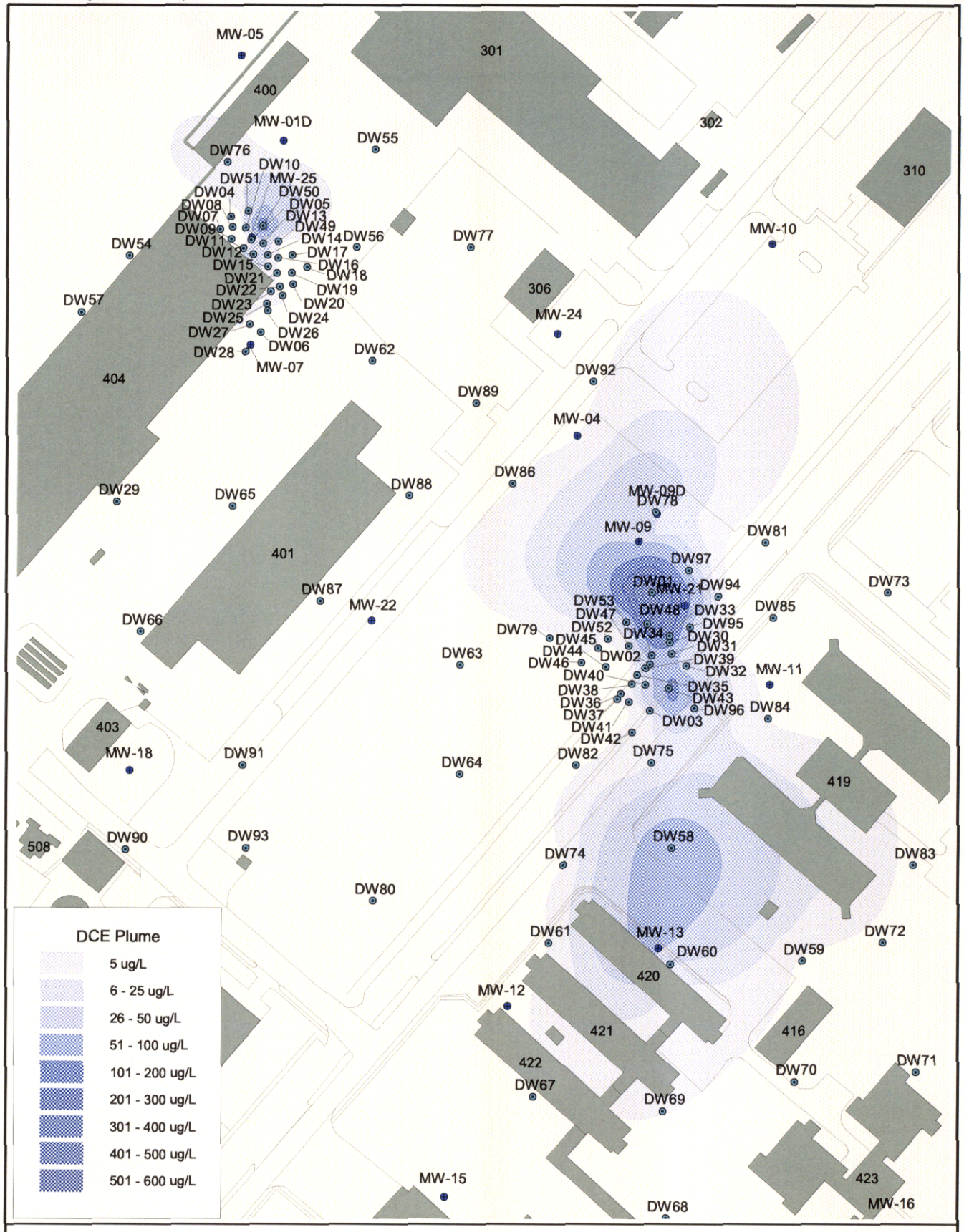



Figure 4-3
cis-1,2-DCE in Groundwater - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

File Path: v:\18gis\oceana\2C-mna.apr

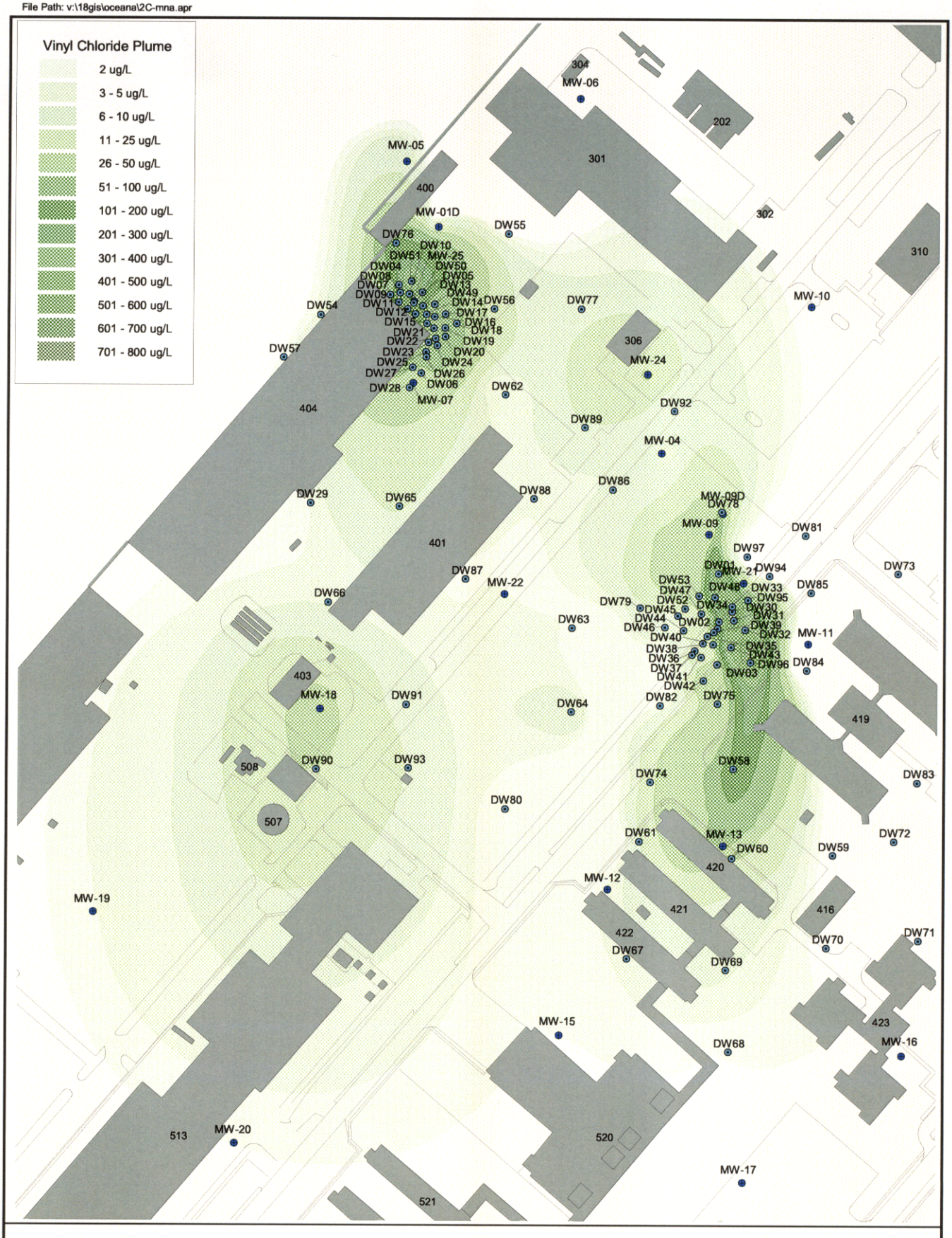



Figure 4-4
Vinyl Chloride in Groundwater - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

the northern area the plume seems to originate near the northeastern wall of building 404. In the southern area the plume seems to originate near MW9 and MW9D and it extends southerly in the direction of groundwater flow, similarly to the TCE plume. In addition, a third area of vinyl chloride contamination exists around MW18. The distribution of vinyl chloride is much greater than its parent products TCE and *cis*-1,2-DCE, indicating that significant biodegradation has taken place and vinyl chloride seems to be accumulating in the groundwater. The factors governing natural attenuation are documented in the next section.

# 5.0 Vertical Profiling

During August 1 through August 2, 2000, subsequent to the DPT sampling at SWMU 2C, COLUMBIA Technologies conducted a demonstration of Membrane Interface Probe (MIP) and Electrical Conductivity (EC) technology. The purpose of the test was to evaluate the performance of the MIP/EC technology at a site where concentrations of chlorinated solvent contamination had been previously delineated. The area of interest for this test was a hydraulic gradient-parallel transect of a dissolved chlorinated solvent plume consisting of TCE, 1,2-DCE, and vinyl chloride in the vicinity of MW25.

The objectives of the MIP/EC test were to:

1. Determine the degree of correlation between the contaminants identified by a MIP system equipped with a Flame Ionization Detector (FID), Photoionization Detector (PID) and Electron Capture Detector (ECD) with known contaminant concentrations determined by a recent (February, 2000) direct push sampling and on-site analyses event.
2. Determine relative minimum detection levels of the MIP system to various chlorinated contaminant compounds.
3. Determine the degree of vertical resolution that can be obtained for chemical contamination and electrical conductivity measurements using the MIP/EC system.
4. Verify there is no evidence of smearing of contaminants from one zone to another while using the MIP/EC system.
5. Determine to what degree contaminant compounds can be identified by using multiple detectors with the MIP/EC system.
6. Delineate the boundaries of the known contaminant plume.

## 5.1 Equipment Description

The MIP/SC probe is 1.5-inches (3.8 cm) in diameter and approximately 12-inches (30 cm) in length. The probe is driven into the ground at the rate of one foot per minute using a Geoprobe or similar direct push rig.

The soil conductivity portion of the tool utilizes a dipole measurement arrangement. An alternating electrical current is passed from the center, isolated pin of the SC probe to the probe body. The voltage response of the soil to the imposed current is measured across the same two points. The probe is reasonably accurate for measurement of soil conductivities in the range of 5 to 400 mS/m. In general, at a given location, lower conductivities will indicate sands while higher conductivities are indicative of silts and clays.

The MIP portion of the probe was developed and patented by Geoprobe Systems, Inc. The operating principle is based on heating the soil and/or water around a polymer membrane allowing volatile organic compounds (VOCs) to partition (absorb) into the polymer

membrane. Once VOCs are sorbed into the membrane, molecules will move by diffusion across the membrane to regions where their concentrations are lowest. Because the membrane is heated (80 to 125 degrees centigrade operating temperature) and the membrane is thin, this movement across the membrane is very rapid. After diffusing across the membrane, the VOCs partition into the carrier gas which sweeps the back side of the membrane. It takes about 35 seconds for the carrier gas stream to travel through about 100 feet of inert tubing and reach the installed detectors.

Columbia Technologies utilized a combination of three detectors: FID, PID, and ECD mounted on a laboratory grade gas chromatograph (Shimadzu 14A). The output signal from the detectors was then captured by a MIP data logging system installed on a laptop computer. Data is displayed continuously in real time during each push of the probe. In addition, the data logs can be printed for display and analysis following the data logging run or exported to common spreadsheet software.

## 5.2 Test Methods, Results, and Observations

Testing was conducted at five locations in a line approximately 150 feet in length along the groundwater gradient in SWMU 2C. The vertical profiling locations are co-located with previous direct push groundwater sample locations where chlorinated hydrocarbon concentrations were already determined. The locations are DW01, DW33, DW30, DW31, and DW43. DW30 was the groundwater sample location with the highest detection of vinyl chloride. Test locations are depicted on Figure 5-1. Multiple probes were conducted in each test location to evaluate the response of the different detectors. Logged results of response from the electrical conductivity detector, ECD detector, FID detector, and the suite of detectors at test location DW30 are presented as Figures 5-2 through 5-5, respectively.

The electrical conductivity logs consistently identified a region of lower permeability within 6 feet bgs, followed by a region of higher permeability down to 20 feet bgs, and then a mixture of high/low permeability between 20 and 22 feet bgs (Figure 5-2). These lithologic data are confirmed by monitoring well logs which indicate that the Columbia Aquifer, composed of fine- to medium-grained sand with minor silt is located at depths of approximately 6 to 20 feet bgs. The aquifer is semi-confined between two silt and clay units, one at the ground surface extending to approximately 6 feet bgs, and the other at a depth of approximately 20 feet bgs and extending to depths greater than 30 feet bgs.

An increasing response was noted on the ECD detector from 10 to 20 feet bgs and an abrupt signal response is evident from the uppermost zone of the silt-clay confining unit between 20 and 23 feet bgs (Figure 5-3).

A significant response was noted on the FID detector just beneath (6 to 10-feet bgs) the region of lower permeability, indicating a possible accumulation of methane at the top of the aquifer. These data are supported by the methane concentrations detected in groundwater that were observed to be lower at sample depths of 15 feet bgs when compared to concentrations detected at sample depths of 9 feet bgs.

File Path: v:\18gis\oceana\2C-mna.apr

N
W E
S

0 40 80 120 Feet

Figure 5-1
Vertical Profiling Locations - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

00606 F B10y

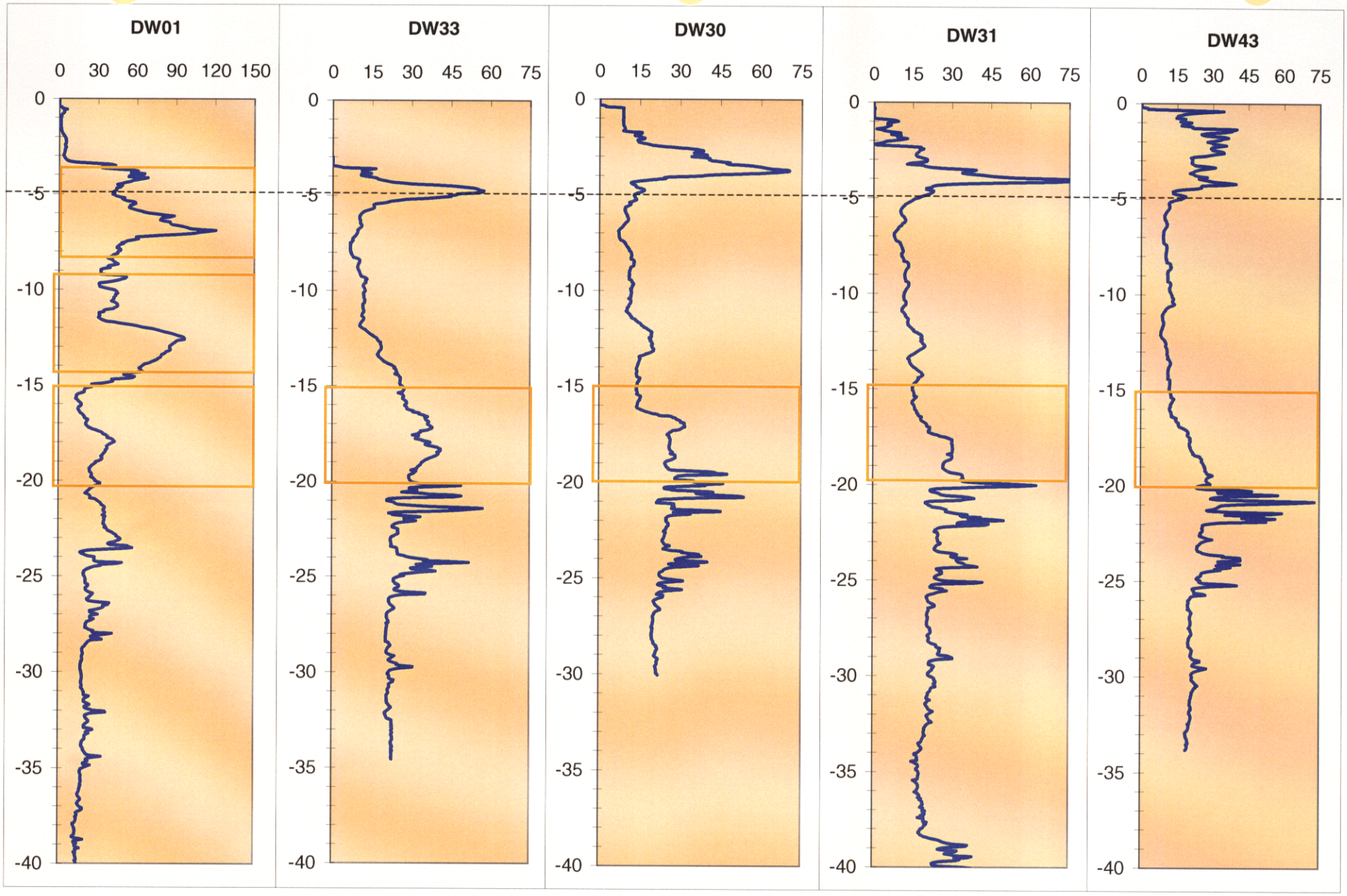



Figure 5-2: Electrical Conductivity Results from vertical profiles in August 2000.

Sampling interval in March 2000

Ground water level

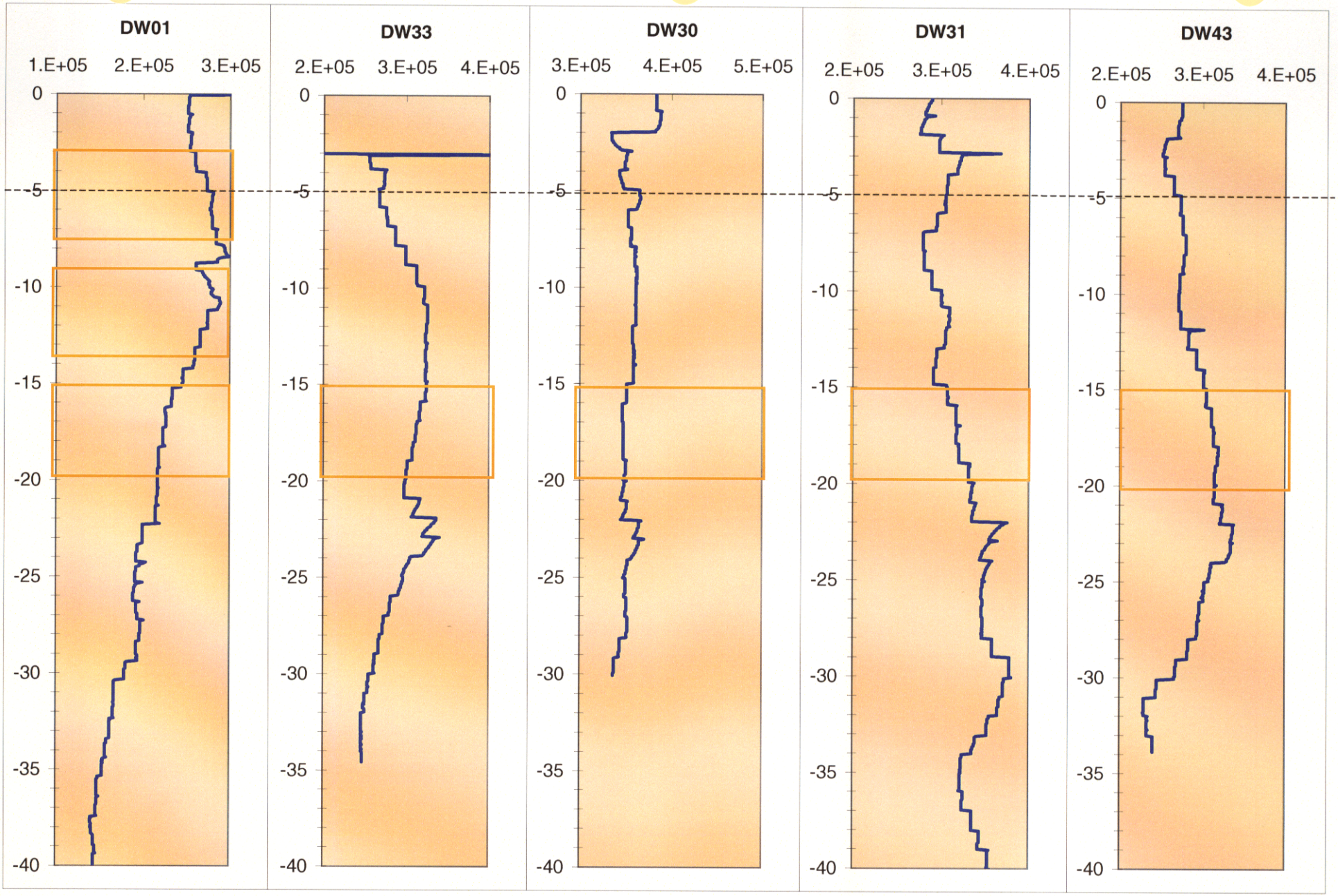



Figure 5-3: ECD Detector Results from vertical profiles in August 2000.

Sampling interval in March 2000

Ground water level

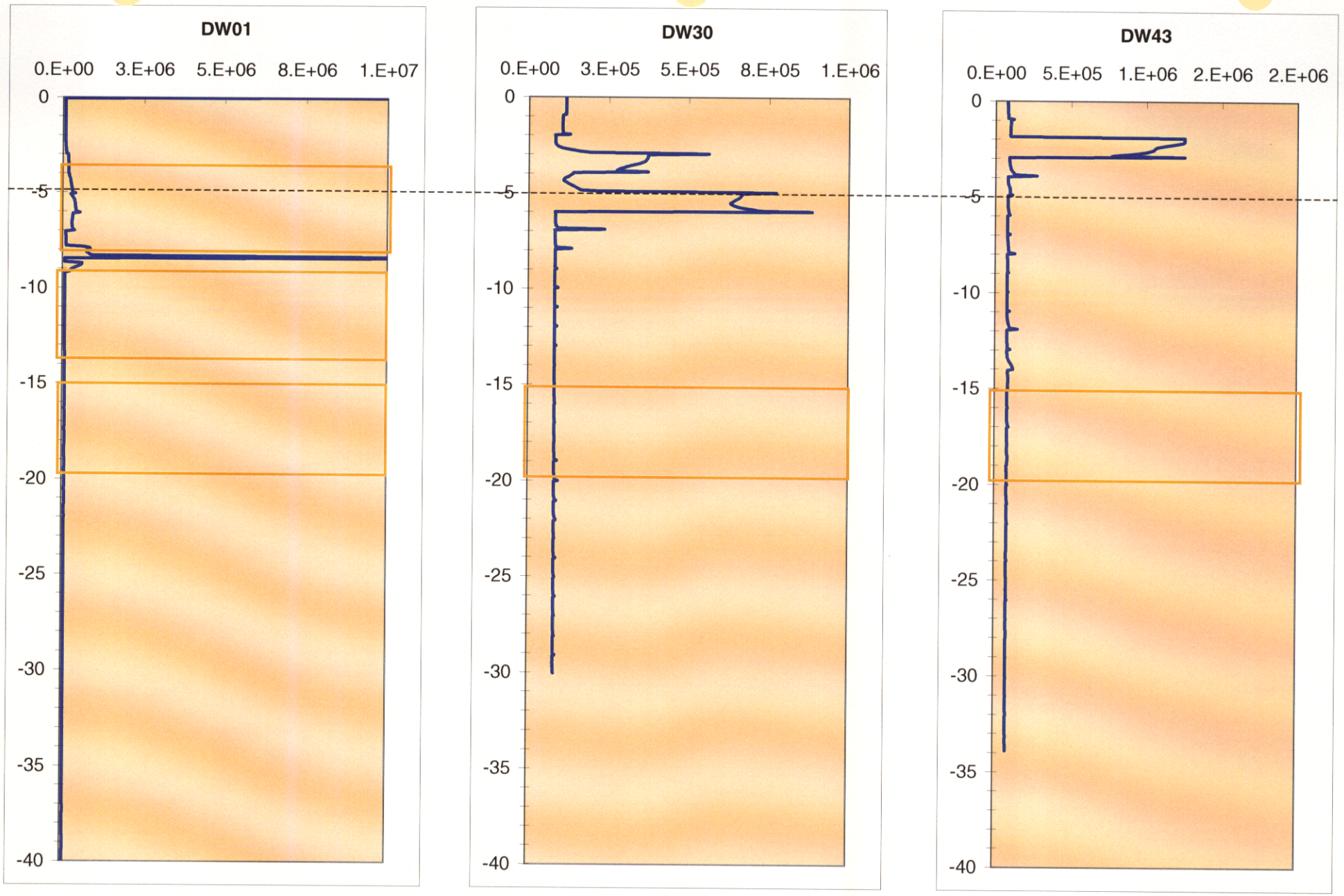



Figure 5-4: FID Detector Results from vertical profiles in August 2000.

Sampling interval in March 2000

Ground water level

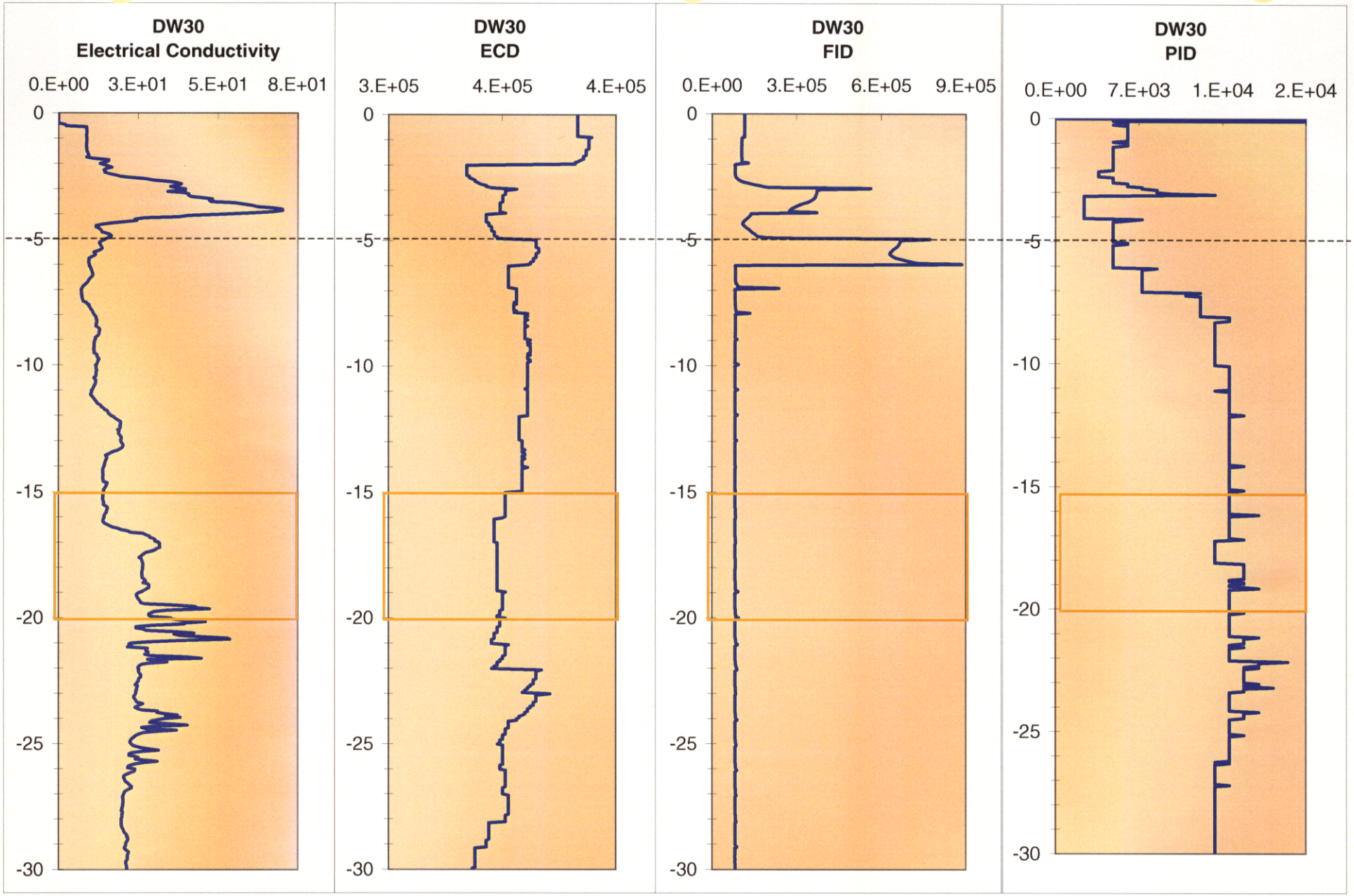



Figure 5-5: Vertical profile results from sample location DW30 in August 2000.

Sampling interval in March 2000

Ground water level

Little or no response was noted on the PID detector in many of the boring locations. However, the PID response at location DW30 shows a correlation with the ECD detector which indicates apparent elevated chlorinated concentrations between 21 and 24 feet bgs (Figure 5-4).

There was no apparent smearing of contaminant from one vertical zone to another based on the MIP/EC detector response. The MIP/EC system responded well in both unsaturated and saturated soil conditions.

The maximum detector output in response to chlorinated hydrocarbon contaminant concentrations occurred within the uppermost interval of the silt and clay confining unit at depths of 20 to 22 feet bgs. This depth interval is below where the previous direct push ground water sampling was conducted (i.e., at depths of 9 and 15 feet bgs). This depth interval is below where traditional sampling would most likely be attempted in the absence of the information provided by the MIP/EC, and this depth interval would present difficulties in obtaining a groundwater sample because of the low-permeability conditions. Because the maximum contaminant concentration as detected by the MIP/EC system was at a depth approximately 6 feet deeper than determined by direct push sampling and close support laboratory analyses in February 2000, it is possible that the maximum contaminant concentrations derived from the groundwater sampling results may be biased low.

The relatively low response of the ECD relative to test spikes indicates that the MIP technology is best suited for use in areas with elevated TCE. TCE has significantly more chlorine atoms than does vinyl chloride, the most prevalent chlorinated hydrocarbon compound found in groundwater at SWMU 2C. Higher chlorine atom compositions yield higher responses in the ECD.

# 6.0 Natural Attenuation

The potential for the natural attenuation of chlorinated hydrocarbons detected in the groundwater at SWMU 2C is documented below. The primary chlorinated hydrocarbon contaminants of concern are TCE and its daughter products, *cis*-1,2- DCE and vinyl chloride. The occurrence and degradation of these compounds are addressed in this section. TCE is known to have been used as a solvent at the facility. However, most, if not all of the TCE detected is attributed to direct release into the environment and not as a result of degradation from its parent PCE. TCE daughter products *cis*-1,2-DCE and vinyl chloride were not known to be released into the environment and their presence is considered to be due to the biodegradation of TCE. First, general principles of chlorinated hydrocarbon biodegradation are documented. Then, site-specific evidence which supports the biodegradation processes is presented.

## 6.1 Biodegradation of Chlorinated Hydrocarbons

The biodegradation process uses indigenous soil organisms to degrade contaminant to innocuous byproducts such as carbon dioxide and water. Not all contaminant are biodegradable, and chlorinated solvents are only completely degraded under special conditions. If these conditions are not met, or if one of the necessary requirements are limiting, the contaminant will not be completely degraded.

In the soil matrix organisms exist in two states, dormant and active. In order to degrade contaminants the organisms need to be in the active state. For this to occur, there are four requirements; nutrients, moisture, an electron donor, and a terminal electron acceptor. Moisture and nutrients are generally readily available in the subsurface. Therefore, the processes of electron donation or a terminal electron acceptance are generally the limiting factor in biodegradation.

Three processes govern the biodegradation of chlorinated hydrocarbons. They are reductive dechlorination/dehalogenation, oxidation, and cometabolism. In general, a chlorinated hydrocarbon contaminant must first be dechlorinated before degradation can occur. This process is called reductive dechlorination, where the contaminant acts as the terminal electron acceptor and hydrogen is the electron donor (Wiedemeier *et al,* 1999). The processes enabling the reduction and degradation of TCE, and its daughter products to carbon dioxide, the redox conditions necessary, and the relative speed of the reactions are delineated in Figure 6-1. The availability of oxygen is indicative of aerobic conditions, otherwise conditions are anaerobic.

Reductive dechlorination is the process where chlorine atoms are replaced by hydrogen atoms. This only occurs in anaerobic conditions, and as each chlorine atom is removed, it becomes increasingly difficult to remove the next one, this is because TCE is more electronegative than *cis-1,2*-DCE (because it has more $Cl^-$ atoms attached) and thus the process of reducing TCE to ethene slows down with each removal of a chlorine atom. Under anaerobic conditions, complete degradation of chlorinated compounds can only

| Process | Redox Conditions/Speed | |
|---|---|---|
| TCE | | |
| ⇓ | reductive dehalogenation | anaerobic/rapid |
| | cometabolism | aerobic |
| *Cis*-1,2-DCE | | |
| ⇓ | reductive dehalogenation | anaerobic/slower |
| | oxidation | aerobic/slow |
| | cometabolism | aerobic |
| Vinyl Chloride | | |
| ⇓ | reductive dehalogenation | anaerobic/slower |
| | oxidation | aerobic/rapid |
| | cometabolism | aerobic |
| Ethene | | |
| ⇓ | oxidation | anaerobic/slow |
| | | aerobic/rapid |
| $CO_2$ | | |

**Figure 6-1: Reaction sequences, redox conditions and rates for the reduction and degradation of TCE. Speeds for cometabolism depend on the substrate added (Adapted from Wiedemeier *et al*, 1999).**

occur after all the chlorine atoms have been removed. Frequently only the first, or the first and second chlorine atoms are removed, resulting in the accumulation of daughter products, *cis-1,2*-DCE and vinyl chloride. The accumulation of vinyl chloride is of great concern to regulators as it is a known human carcinogen, and is highly toxic at low concentrations. Under circumstances of accumulating vinyl chloride enhancement becomes necessary to drive reductive dechlorination to completion.

Reductive dehalogenation, otherwise known as halorespiration, is performed by a group of organisms known as halorespirators. These organisms utilize hydrogen as the electron donor, which is frequently the limiting factor, and the chlorinated compound as the terminal electron acceptor. Halorespirators are the only organisms which conduct reductive dehalogenation, but they are not the only organisms which utilize hydrogen. Halorespirators are most competitive for hydrogen when the redox conditions are between -150 and -320 mV, which are sulfate reducing and methanogenic conditions.

The following trends occur in environments undergoing reductive dehalogenation and biodegradation and can be monitored to determine if natural attenuation is occurring:

- Reduction in TCE concentrations
- Increase in *cis-1,2*-DCE concentrations
- Increase in vinyl chloride concentrations
- Increase in ethene and ethane concentrations
- Elevated chloride concentrations
- Methane production
- Low redox conditions
- Production of iron (II)

Oxidation is the process where the contaminant is used as a carbon source and is broken down directly into carbon dioxide and water. TCE is not degradable via this process, there is limited evidence that *cis-1,2*-DCE is degradable, but vinyl chloride is rapidly degraded in circumstances where oxygen is available as the terminal electron acceptor.

Cometabolism is an aerobic process where a carbon source other than the contaminant is degraded, and the chlorinated solvent is fortuitously degraded. This occurs because cells are 'leaky' meaning that during the growth process some cellular components and products are released into the environment. For example, during the degradation of methane an enzyme called MMO is produced. This enzyme adds an oxygen molecule to the methane. As the cell grows and divides, this enzyme is released into the environment, and will add an oxygen molecule to TCE, making it more amenable to degradation by another organisms. In the environment, cometabolism will only occur when there is oxygen and another carbon source, such as BTEX, methane, etc. available. When either the oxygen or the carbon source are depleted, cometabolism will cease (usually oxygen is depleted first). In engineered conditions, cometabolism can be achieved by the addition of oxygen and a carbon source such as methane, ethane, propane, butane, toluene, or phenol. The addition of oxygen and ammonium ($NH_4^+$) has also been documented to support this process (Wiedemeier *et al*, 1999).

In summary, there are three sets of conditions able to achieve the degradation of TCE to carbon dioxide:

- Anaerobic conditions where the requirements for reductive dehalogenation are met followed by anaerobic degradation of vinyl chloride and ethene. These conditions can sometimes be met naturally, otherwise they need to be engineered.
- Anaerobic conditions where the requirements for reductive dehalogenation are met, followed by aerobic conditions. This sequence of conditions is rarely achieved naturally and need to be engineered by enhancement.
- Aerobic degradation via cometabolism, which requires the addition of oxygen and a carbon source such as methane. These conditions will only occur naturally for a short period of time and otherwise need to be engineered.

In this section of the report, TCE and its daughter products are evaluated for reductive dehalogenation and biodegradation according to the parameters outlined above.

## 6.2 Evaluation of Natural Attenuation

To demonstrate natural attenuation it is necessary to document at least two of the following three lines of evidence (NRC, 1994; ASTM, 1998):

1. Historical data showing plume stabilization and/or loss of contaminant over time.
2. Chemical and geochemical analytical data, including:
   - Depletion of terminal electron acceptors and donors.
   - Increasing metabolic by-product concentrations.
   - Decreasing parent compound concentrations.
   - Increasing daughter product concentrations.
3. Microbiological data that support the occurrence of degradation and gives estimates of biodegradation rates.

The first line of evidence should show that the plume is stabilized or is shrinking in size. This line of evidence does not prove that the contaminants are being destroyed. Reduction in contaminant concentration could be the result of advection, dispersion, dilution from recharge, sorption, and volatilization. However, this line of evidence is critical for determining if any exposure pathways exist for current or potential future receptors. Providing historical groundwater data at appropriate monitoring or sampling points that show a trend of decreasing contaminant mass and/or concentration over time is sufficient to support this first line of evidence.

The second line of evidence relies on chemical and physical data to show that contaminant mass is being destroyed, not just being diluted or sorbed to the aquifer matrix. This is accomplished by measuring the changes in groundwater chemistry that occur during biodegradation. Each type of terminal electron acceptor causes a unique change in the groundwater's chemistry.

- During aerobic respiration, oxygen is reduced to water, and dissolved oxygen concentrations decrease.

- In anaerobic systems where nitrate is the electron acceptor, the nitrate is reduced to $NO_2^-$, $N_2O$, NO, $NH^{4+}$, or $N_2$, and nitrate concentrations decrease.
- In anaerobic systems where iron(III) is the electron acceptor, iron(III) is reduced to iron(II), and iron(II) concentrations increase.
- In anaerobic systems where sulfate is the electron acceptor, sulfate is reduced to $H_2S$, and sulfate concentrations decrease.
- In anaerobic systems where carbon dioxide is used as an electron acceptor, carbon dioxide is reduced by methanogenic bacteria, and methane is produced.

Thus an active zone of biodegradation will have depleted dissolved oxygen, nitrate, and sulfate and/or elevated iron(II) and methane concentrations. This evidence can be used to show that electron acceptor/donor concentrations in groundwater are sufficient to facilitate degradation of dissolved contaminants.

The third line of evidence is directed toward proving that the soil has the microbial capacity to degrade the contaminant. This is most commonly done by performing microcosm studies. This is the least utilized line of evidence because while it indicates that the soil has the potential to degrade the contaminant, it does not show that degradation is actually occurring. This line of evidence is not considered in this evaluation of natural attenuation.

## 6.3 Plume Stabilization, Shrinkage, or Contaminant Reduction Related to Biodegradation

In this section, site-specific biodegradation processes for detected chlorinated hydrocarbon contaminants are examined as they relate to biodegradation trends and lines of evidence for natural attenuation.

### 6.3.1 Reduction in TCE Concentrations

The first line of evidence should show that the TCE plume is stabilized or is shrinking in size due to advection, dispersion, dilution from recharge, sorption, and volatilization. In the northern study area around MW25, TCE was not detected during the RFI and CMS studies. Although MW25 did not exist until 1999, this area was monitored historically by sampling MW01 and direct push sampling of location GP13. Either TCE was not ever present or it has been completely dechlorinated. Since the daughter products *cis*-1,2-DCE and vinyl chloride are present and these chemicals are not generally utilized in solvent form and TCE was historically commonly used as a solvent on the flight line, one could assume that TCE was disposed in the area and has subsequently completely biodegraded into *cis*-1,2-DCE and vinyl chloride.

In the southern study area, there has been a reduction in the concentration of TCE in MW09. The concentration recorded in August 1990 was 63 ug/L. In January 1993 the concentration was 29 ug/L and in February 2000 the concentration was similar at 33 ug/L. Further south and hydraulically downgradient, the area near MW21 was previously monitored by direct push sampling at location GP03. In February 1994, the concentration was 3 ug/L. In February 2000, the concentration in MW21 was 6.5 ug/L.

The second line of evidence relies on chemical and physical data to show that contaminant mass is being destroyed. Additional groundwater sample data are required in order to assess future reductions and the natural attenuation process. However, the detection in groundwater of daughter products associated with the degradation of TCE is direct evidence that some contaminant mass is being destroyed, assuming that daughter products of TCE were not released.

TCE dechlorinates in an anaerobic environment but will biodegrade through cometabolism in an aerobic environment. The distribution of dissolved oxygen relative to the concentrations of TCE detected in groundwater is depicted in Figure 6-2. In the area of MW21, TCE is not detected but daughter products are present. Dissolved oxygen is now depleted compared to background conditions, indicating that aerobic conditions could have existed in this area at one time. TCE might have degraded under aerobic conditions, co-metabolically with petroleum hydrocarbons resulting in the complete degradation of TCE, the production of daughter products, and the depletion of dissolved oxygen. Some residual BTEX is present in this area.

In the area of MW25, aerobic conditions might have existed where the TCE is detected, as indicated by a decrease in dissolved oxygen in areas of elevated TCE concentration relative to background locations. There is no evidence of co-metabolic degradation. The current reducing environment is favorable for continued degradation of TCE.

In anaerobic systems where nitrate is the electron acceptor, the nitrate is reduced. The distribution of nitrate relative to the concentrations of TCE detected in groundwater is inconclusive since nitrate levels are low across the entire site. In anaerobic systems where sulfate is the electron acceptor, the sulfate is reduced. The distribution of sulfate relative to the concentrations of TCE detected in groundwater is depicted in Figure 6-3. This figure shows that anaerobic degradation of TCE through sulfate reduction might be occurring. Increases in sulfate concentrations in the area of elevated TCE concentration are observed relative to areas outside of the plume.

In anaerobic systems where carbon dioxide is used as an electron acceptor, carbon dioxide is reduced by methanogenic bacteria, and methane is produced. Concentrations of methane detected in the DPT and monitoring wells relative to the concentrations of TCE detected in groundwater are depicted in Figure 6-4. Anaerobic degradation of TCE is inconclusive. Although methane is elevated in the northern source area, it is also elevated in background locations around the known plume areas. Also, a significant decrease in concentration is evident where sample depths were increased from 9 to 15 feet bgs. This variation creates significant bias in the data. PID readings indicate possible accumulations of methane near the ground surface in comparison to depths when compared to the PID results. This trend is reflected in the groundwater analytical results.

### 6.3.2 Increase in *cis-1,2*-DCE Concentrations

The presence of *cis*-1,2-DCE in TCE-contaminated groundwater is generally indicative of TCE biodegradation. An increase in *cis*-1,2-DCE concentrations corresponding with a decrease in TCE concentrations would serve as an indicator that reductive dechlorination is occurring and TCE is biodegrading into *cis*-1,2-DCE. However, the decrease in *cis*-1,2-DCE

File Path: v:\18gis\oceana\2C-mna.apr

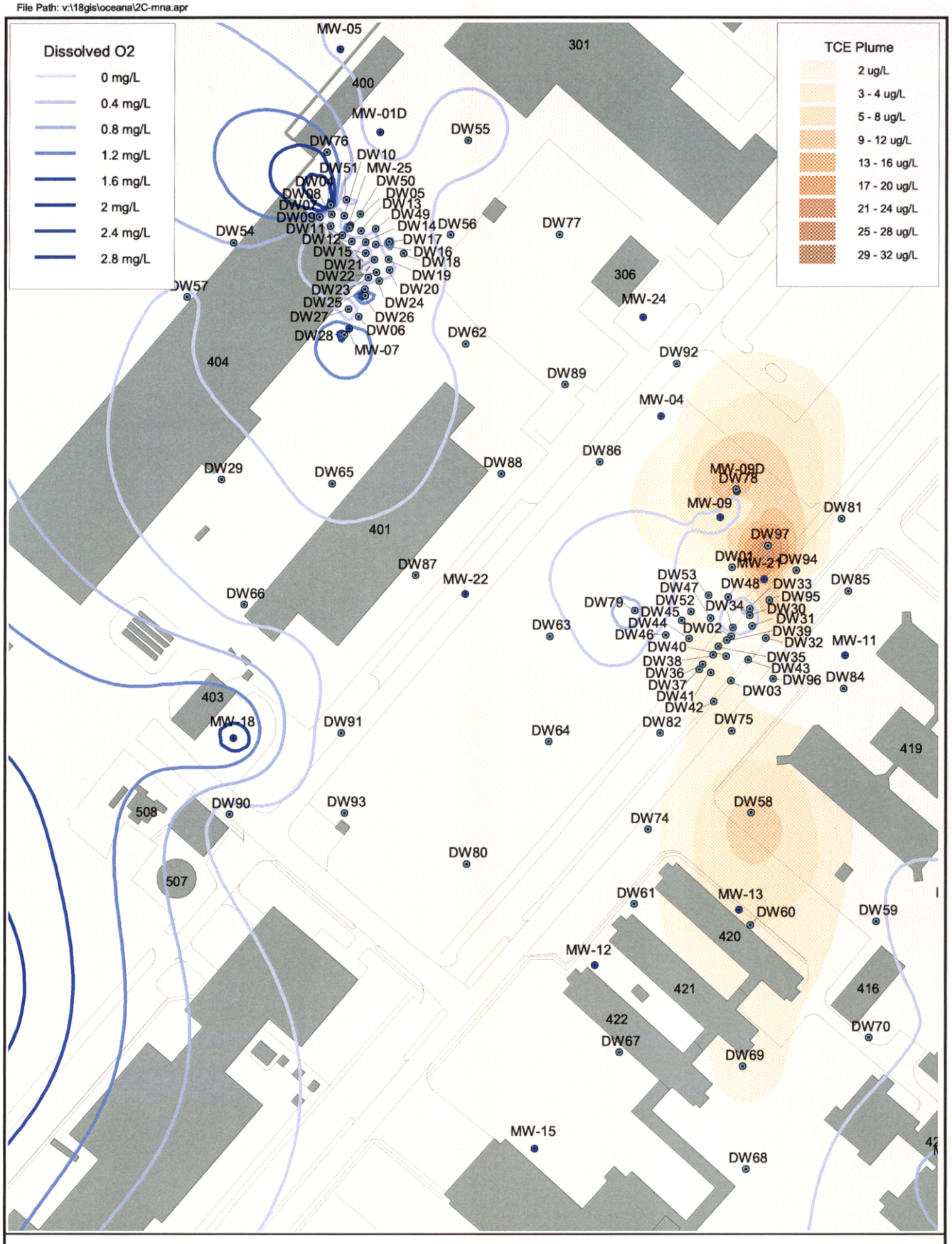



Figure 6-2
Dissolved O2 in Groundwater over TCE - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

D0606FB11y

File Path: v:\18gis\oceana\2C-mna.apr

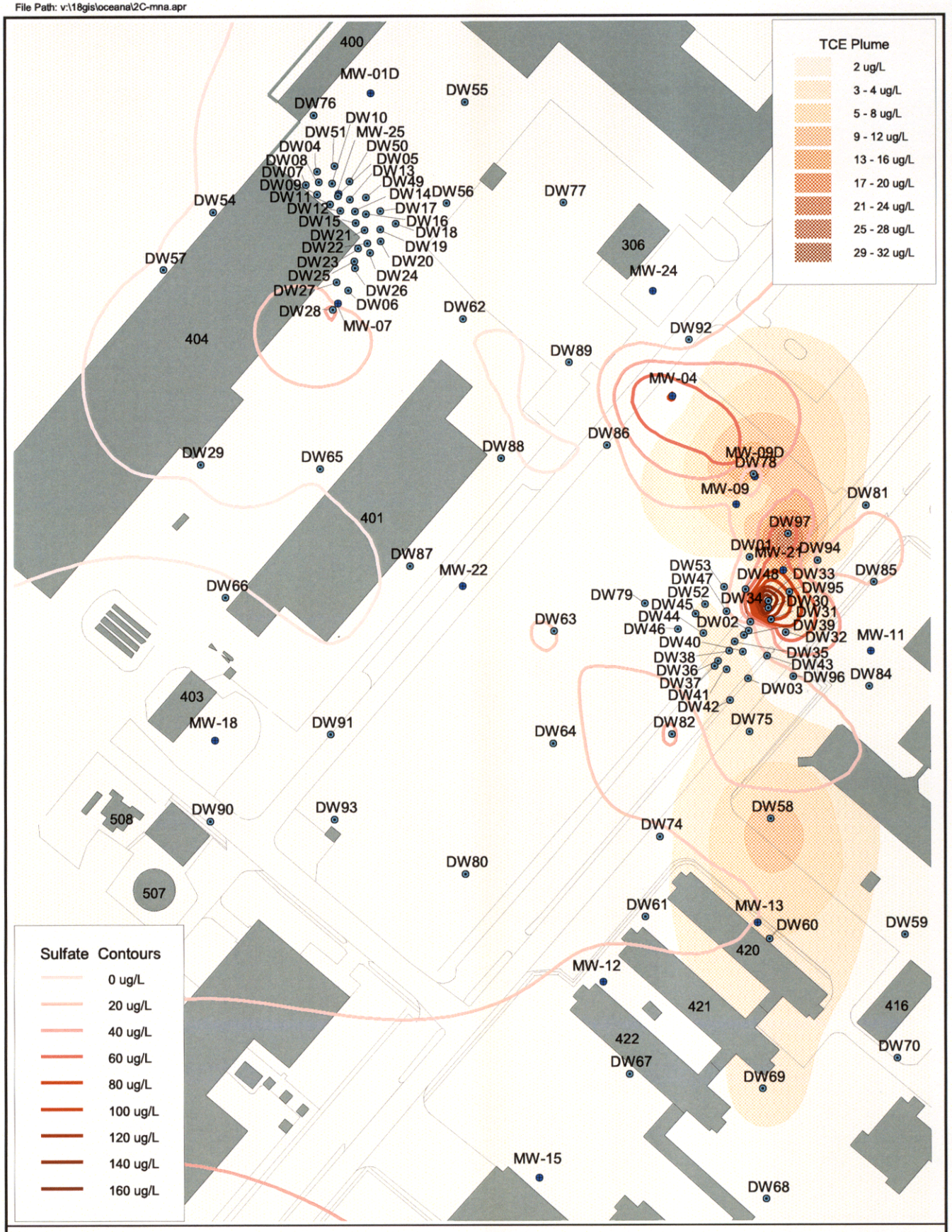



Figure 6-3
Sulfate in Groundwater Over TCE
NAS Oceana, Virginia Beach, Virginia

CH2M HILL

File Path: v:\18gis\oceana\2C-mna.apr

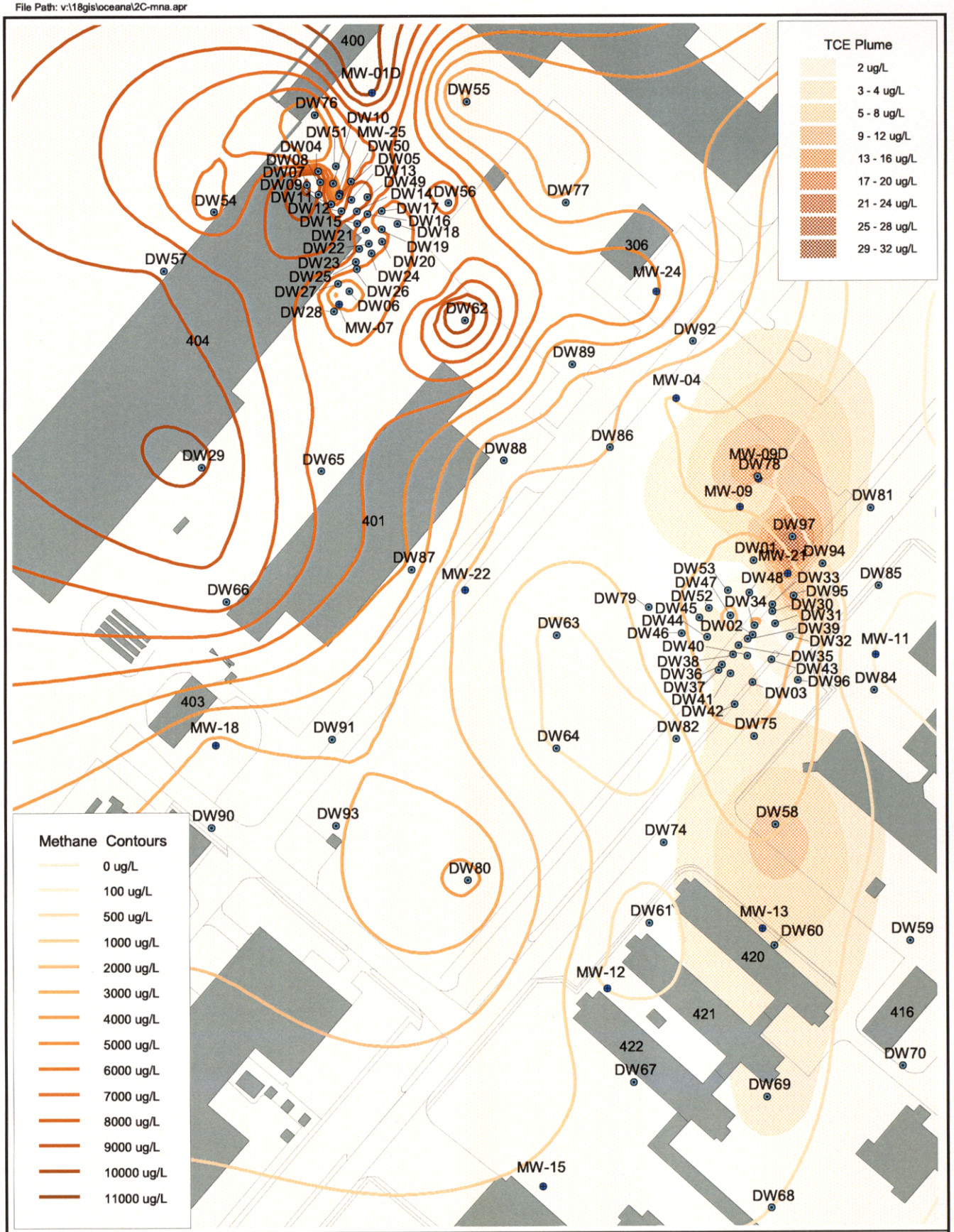



Figure 6-4
Methane in Groundwater Over TCE
NAS Oceana, Virginia Beach, Virginia

CH2M HILL

with a concurrent increase in vinyl chloride concentrations could indicate that there was ample reduction of TCE to *cis*-1,2-DCE and that the degradation process continued as *cis*-1,2-DCE decreased in concentration and vinyl chloride increased.

In the northern study area around MW25 where TCE is not detected, *cis*-1,2-DCE was detected at a concentration of 240 ug/L in November 1992. In February 2000, the highest observed concentration was 214 ug/L. The presence of *cis*-1,2-DCE and the absence of TCE supports the reduction of TCE to *cis*-1,2-DCE. A decrease in *cis*-1,2-DCE could indicate that *cis*-1,2-DCE is degrading to vinyl chloride.

In the southern study area, MW09 had a concentration of 1600 ug/L in January of 1993. In February 2000, the concentration had decreased significantly to 56 ug/L. However, 100 feet hydraulically downgradient at DPT location DW01, *cis-1,2*-DCE was detected at 676 ug/L in February 2000. Elevated *cis-1,2*-DCE detections near MW09 have apparently migrated downgradient and are being also being reduced. Historic DPT sampling location GP03 had 21 ug/L of *cis-1,2*-DCE in November 1992. In February 2000, 35 ug/L of was detected in MW21, located nearby. These data are inconclusive but can be interpreted to demonstrate an increase in *cis*-1,2-DCE due to the reduction of TCE and a decrease in *cis*-1,2-DCE corresponding to an increase in vinyl chloride.

The biodegradation of *cis*-1,2-DCE can occur either aerobically or anaerobically. The aerobic process is faster. The presence of vinyl chloride in the aquifer supports the biodegradation of *cis*-1,2-DCE. The distribution of dissolved oxygen, and sulfate support the potential for the slower, anaerobic, biodegradation of *cis*-1,2-DCE into vinyl chloride.

### 6.3.3 Increase in Vinyl Chloride Concentrations

The presence of vinyl chloride in *cis*-1,2-DCE -contaminated groundwater is generally indicative of *cis*-1,2-DCE biodegradation. An increase in vinyl chloride concentrations corresponding with a decrease in *cis*-1,2-DCE concentrations would serve as an indicator that dechlorination is occurring and *cis*-1,2-DCE is biodegrading into vinyl chloride.

In the northern study area, in November 1992, 130 ug/L of vinyl chloride was detected in DPT sample location GP13, and in January 2000, 560 ug/L was detected in MW25 located in the same vicinity. In the southern study area, the concentration of vinyl chloride detected in MW09 was 340 ug/L, in January 1993. In February 2000, the concentration of vinyl chloride detected in MW09 was 56 ug/L, a significant decrease. However, 100 feet hydraulically downgradient, 24 ug/L of vinyl chloride was detected in November 1992 and in February 2000, the concentrations detected in DW30 and DW31 are 897 ug/L and 817 ug/L, respectively. Apparently, DCE is being dechlorinated, resulting in an increase in vinyl chloride at SWMU 2C.

Vinyl chloride degrades rapidly under aerobic conditions and slowly under anaerobic conditions. The presence of ethene in the aquifer is evidence of the biodegradation of vinyl chloride. The distribution of dissolved oxygen and sulfate support the potential for the slower anaerobic biodegradation of vinyl chloride into ethene.

### 6.3.4 Increase in Ethene Concentrations

Ethene is a daughter product that results from the dechlorination of vinyl chloride. The presence of elevated ethene relative to background locations is indicative of the biodegradation of vinyl chloride.

Figure 6-5 illustrates the distribution of ethene in groundwater relative to the vinyl chloride plume. This figure clearly demonstrates that vinyl chloride is biodegrading to ethene. Figure 6-6 shows the distribution of dissolved oxygen in the aquifer relative to the vinyl chloride plume. The dissolved oxygen is depleted within the plume indicating the depletion of oxygen and the anaerobic dechlorination of TCE, cis-1,2-DCE, and vinyl chloride. Vinyl chloride degrades to ethene slowly under anaerobic conditions compared to aerobic conditions. Therefore, vinyl chloride would be expected to accumulate when the rate of production exceeds the rate of natural attenuation. This is interpreted to be occurring in groundwater at SWMU 2C based on the observed significant vinyl chloride plume detected during the sampling event.

### 6.3.5 Elevated Chloride Concentrations

The presence of elevated chloride concentrations in chlorinated hydrocarbon-contaminated groundwater, with respect to background concentrations is generally indicative of chlorinated hydrocarbon biodegradation. As reductive dechlorination occurs, chlorine atoms are stripped from the chlorinated hydrocarbon. The distribution of chloride in groundwater is depicted in Figure 6-7. The area with the most elevated chloride concentrations in groundwater corresponds with areas of elevated TCE, *cis*-1,2-DCE, and vinyl chloride concentrations.

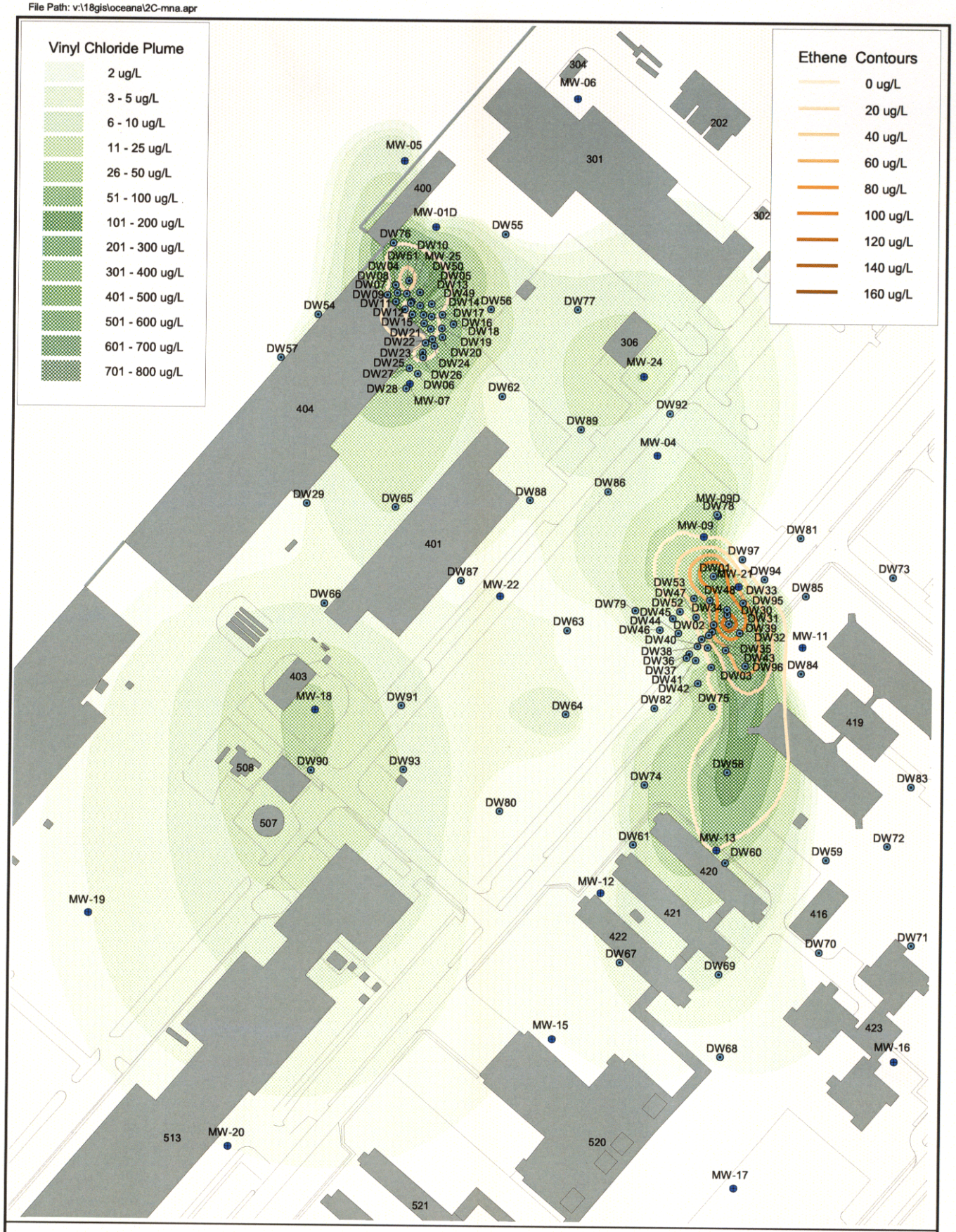
### 6.3.6 Summary of Natural Attenuation of Chlorinated Hydrocarbons

In summary, biodegradation of chlorinated hydrocarbons in groundwater through reductive dechlorination and cometabolism is likely to have occurred and in some cases, is continuing to occur. It appears that vinyl chloride is being further reduced to ethene. However, at this time vinyl chloride appears to be accumulating. Therefore, enhanced bioremediation is a viable consideration to augment the natural biodegradation process.

The first line of evidence for natural attenuation evaluated in this study should show that contaminant plumes are stabilized or are shrinking in size. TCE contaminant concentrations appear to be decreasing over time. The *cis*-1,2-DCE plume is interpreted to have increased at one time and is now on the decline due to reduction to vinyl chloride. However, a significant accumulation of vinyl chloride concentrations indicate that conditions might not be optimal for effective natural attenuation even though significant ethene production is observed.

The second line of evidence evaluated in this study relies on observable changes in groundwater chemistry that occur during biodegradation. TCE is known to have been released at the site. Daughter products that result from TCE degradation, namely *cis*-1,2-DCE, vinyl chloride, and ethene, are all detected in groundwater at the SWMU in locations that support their provenance from their parent product. In addition, sulfate reduction and chloride production, support the interpretation that anaerobic degradation of chlorinated

File Path: v:\18gis\oceana\2C-mna.apr




N
W E
S

0 100 200 300 Feet

Figure 6-5
Ethene over Vinyl Chloride - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

02606 F B124

File Path: v:\18gis\oceana\2C-mna.apr

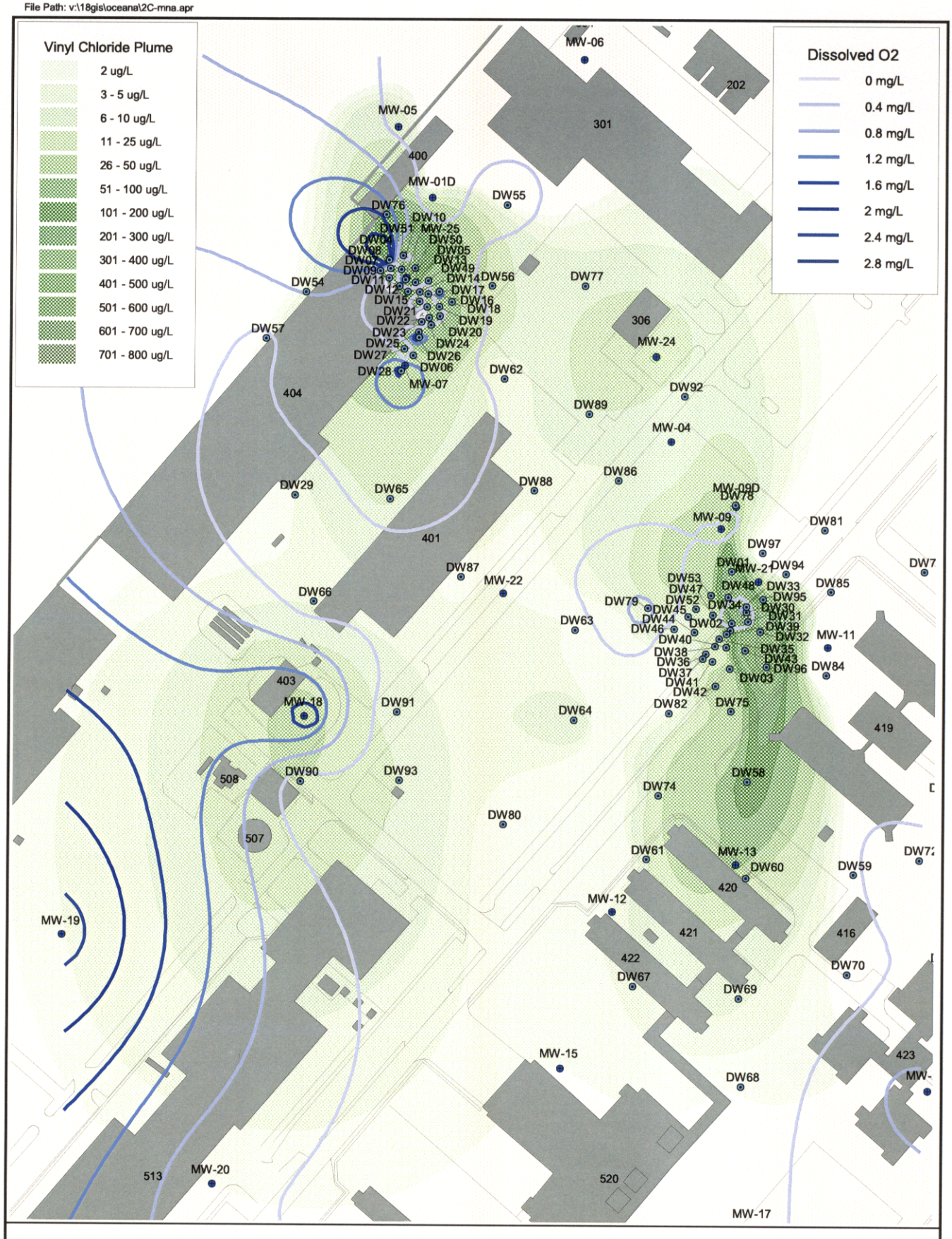



Figure 6-6
Dissolved O2 over Vinyl Chloride - SWMU 2C
NAS Oceana, Virginia Beach, Virginia

**CH2M HILL**

File Path: v:\18gis\oceana\2C-mna.apr

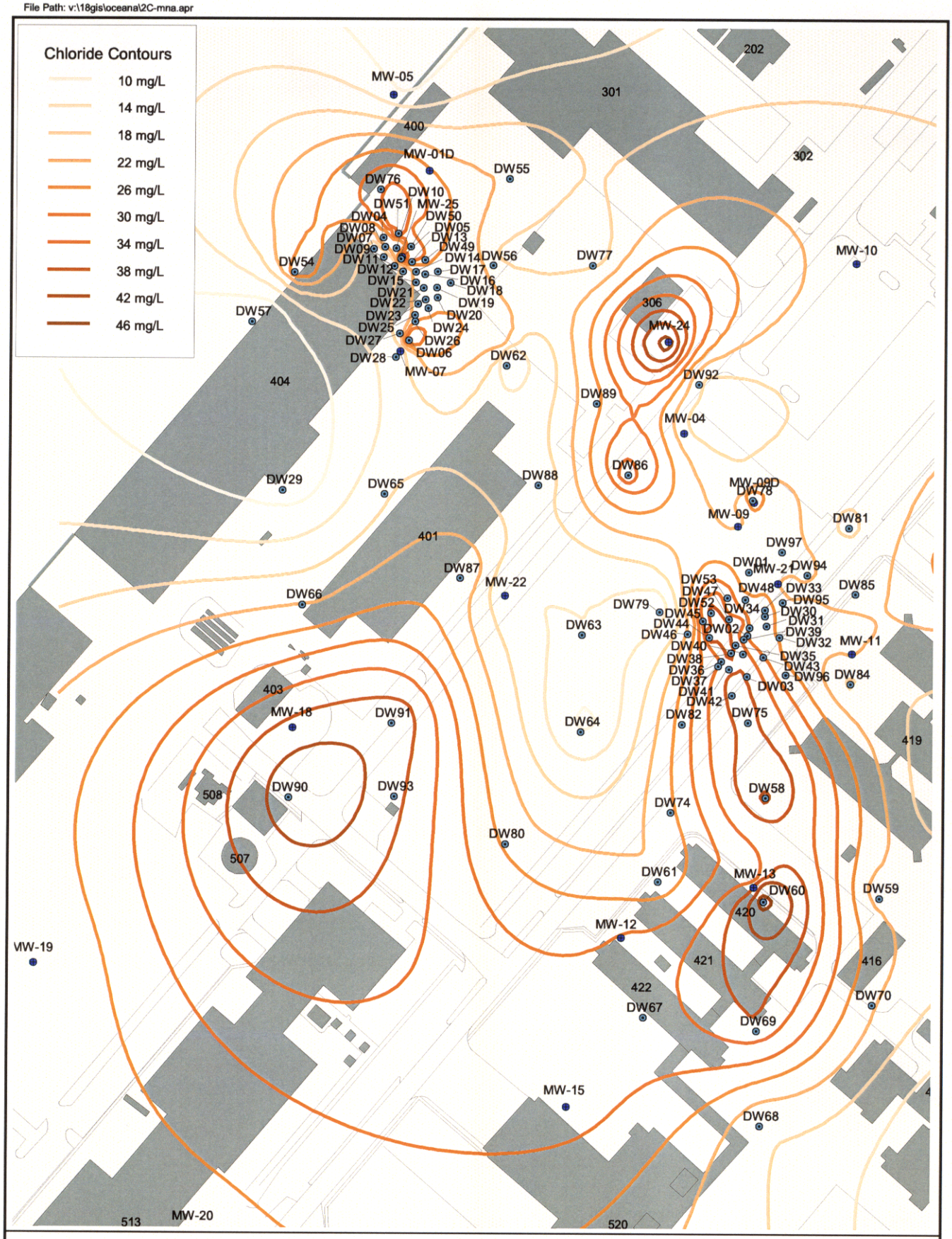



Figure 6-7
Chloride in Groundwater
NAS Oceana, Virginia Beach, Virginia

CH2M HILL

hydrocarbons is occurring in groundwater. However, the accumulation of vinyl chloride indicates that the natural attenuation process might need to be augmented with enhanced biodegradation. Recommendations will be documented in the next section.

When another assessment of natural attenuation is completed at SWMU 2C, a more detailed analysis of chemistry changes, with supporting stochiometry, calculated capacities for assimilation, and contaminant degradation modeling, should be conducted if monitored natural attenuation is to be evaluated as a remedial alternative for groundwater.

# 7.0 Enhanced Biodegradation

In order to achieve complete degradation of the chlorinated hydrocarbon contaminants at SWMU 2C, active groundwater remediation in combination with attenuation enhancement is recommended. These are summarized below. A more complete assessment of remedial alternatives will be developed in the focused feasibility study for SWMU 2C.

## 7.1 Active Groundwater Remediation

Active groundwater remediation is a viable consideration for the remediation of elevated chlorinated hydrocarbon contamination at specific locations where the contaminant concentrations are the highest ("hot spots"). Methods that could be considered are NoVOCs® or similar technologies which aerate the groundwater to strip off the volatile contaminants and re-circulate the treated groundwater. Other "hot-spot" remedial technologies could also combine groundwater aeration or re-circulation with augmentation with compounds which enhance attenuation of chlorinated compounds. A discussion of these compounds is documented below.

## 7.2 Attenuation Enhancement

Three possible attenuation enhancement strategies could be applied:

1. The addition of hydrogen to continue the reductive dehalogenation process.
2. The addition of a carbon source or ammonium with oxygen to achieve cometabolism.
3. The addition of oxygen to create aerobic conditions and enhanced oxidation.

### 7.2.1 Addition of Hydrogen

Hydrogen is necessary for reductive dehalogenation to take place. The addition of hydrogen would facilitate the dehalogenation of TCE and *cis*-1,2-DCE. Direct injection of hydrogen either as a gas or a liquid is infeasible. However, the injection of a carbon source which produces hydrogen during degradation is practical. Some products which have been used are molasses, lactic acid and Hydrogen Release Compound (HRC®). HRC stimulates the multi-step process of creating an environment for optimum reductive dehalogenation, and then slowly releases lactic acid which releases hydrogen during the degradation process.

### 7.2.2 Addition of Oxygen

The addition of oxygen would be appropriate as a treatment for the site-wide vinyl chloride plume. Treatability tests will need to be conducted to determine if the *cis-1,2*-DCE is amenable to aerobic degradation. Addition of oxygen would be the most rapid method to treat the vinyl chloride plume. The oxygen is utilized as a terminal electron acceptor, and the contaminant is the electron donor. There are several methods of oxygen introduction including the addition of air with biosparging (similar to air sparging, but at low volumes

to promote degradation not volatilization), addition of compounds which release oxygen, such as Oxygen Release Compound® (ORC ®) or magnesium peroxide, and the addition of pure oxygen.

### 7.2.3 Addition of a Carbon Source

The addition of a carbon source or ammonium in conjunction with oxygen would be a feasible remedy for the reduction of vinyl chloride in elevated areas, but might be impractical for the entire vinyl chloride plume.

# 8.0 Conclusions

Groundwater at SWMU 2C contains concentrations of TCE, cis-1,2-DCE, and vinyl chloride at concentrations that exceed MCLs. Benzene is also detected at levels that exceed MCLs. Discrete-depth groundwater sampling at SWMU 2C indicated that the highest chlorinated compound detections in the Columbia aquifer were located at depths of approximately 9 feet bgs near MW21 in the northern part of the SWMU and at depths of approximately 15 feet bgs near MW25 in the southern part of the SWMU.

MIP/EC survey work confirmed that contaminant occurrence is controlled by lithology. The greatest response to the ECD was at a depth interval of 21 to 24 feet bgs, in the upper strata of the lower confining unit. However, the low permeability of this unit would inhibit effective groundwater sampling. The MIP/EC survey showed that the EC probe response correlates with logged lithology at the SWMU. The MIP response indicated muted responses of the ECD to chlorinated hydrocarbon contamination compared to spike samples due to the prevalence of vinyl chloride over TCE. Vinyl chloride had far fewer chlorine atoms. The PID detector indicated the potential accumulation of methane at the top of the Columbia Aquifer. This finding was further supported through groundwater sampling which showed higher methane concentrations within the aquifer at 9 feet bgs than at 15 feet bgs.

The natural attenuation assessment indicated that biodegradation of chlorinated hydrocarbons in groundwater through reductive dechlorination and cometabolism is likely to have occurred and in some cases, is continuing to occur. It appears that TCE is being reduced to *cis*-1,2-DCE, which is being further reduced to vinyl chloride, which is being further reduced to ethene. However, at this time, vinyl chloride appears to be accumulating. Therefore, enhanced bioremediation is a viable consideration to augment the natural biodegradation process.

The first line of evidence for natural attenuation indicates that TCE contaminant concentrations appear to be decreasing over time. The *cis*-1,2-DCE plume is interpreted to have increased at one time and is now on the decline due to reduction to vinyl chloride. However, a significant accumulation of vinyl chloride concentrations indicate that conditions might not be optimal for effective natural attenuation even though significant ethene production is observed. The second line of evidence indicates that daughter products that result from TCE degradation, namely *cis*-1,2-DCE, vinyl chloride, and ethene, are all detected in groundwater at the SWMU in locations that support their provenance from their parent product. In addition, sulfate reduction and chloride production, support the interpretation that anaerobic degradation of chlorinated hydrocarbons is occurring in groundwater. However, the accumulation of vinyl chloride indicates that the natural attenuation process might need to be augmented with enhanced biodegradation.

Within the SWMU 2C, groundwater contaminant plume are two areas which contain significantly elevated chlorinated hydrocarbon concentrations. The area, around MW21 is contaminated with *cis-1,2*-DCE and vinyl chloride; the TCE has apparently been completely biodegraded. The area around MW25 is contaminated with TCE and its daughter products

*cis-1,2*-DCE and vinyl chloride. Vinyl chloride has apparently accumulated across the SWMU and the plume covers approximately 30 acres.

In order to achieve complete degradation of the chlorinated hydrocarbon contaminants at SWMU 2C, active groundwater remediation in combination with attenuation enhancement is recommended. "Hot-spot" remediation could be achieved using technologies which aerate and re-circulate treated groundwater. Some of these technologies include the augmentation of groundwater with compounds which promote enhanced attenuation. There are three possible enhanced attenuation treatments that could also be applied to either the elevated areas of the plume, in combination with active remediation, or the SWMU-wide vinyl chloride plume:

1. The addition of hydrogen would continue the reductive dehalogenation process of TCE, cis-1,2-DCE, and vinyl chloride and could be applied to the elevated areas or to the whole site.
2. The addition of oxygen would create aerobic conditions and enhance oxidation. An oxygen-releasing compound could be applied to the elevated areas of vinyl chloride or to the whole vinyl chloride plume.
3. The addition of a carbon source or ammonium with oxygen would enhance cometabolism. The application of a carbon source could be applied to the source areas to reduce TCE, cis-1,2-DCE, and vinyl chloride.

The practicality of these options will be addressed in the focused feasibility study for SWMU 2C.

# 9.0 References

CH2M HILL, November 1999, Draft Work Plan, Direct Push Technology Investigation, Supplemental Activities, SWMU 2C, Naval Air Station, Oceana, Virginia Beach, Virginia.

CH2M HILL, December 1993, RCRA Facility Investigation Final Report – Phase I, Naval Air Station Oceana, Virginia Beach, Virginia.

CH2M HILL, November 1995, Draft Final Corrective Measures Study for SWMUs 1, 2B, and 2C, Oceana Naval Air Station, Virginia Beach, Virginia.

Widemeier, T.H., Rifai, H.S., Newell, C.J., and Wilson, J.T., 1999. Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface. John Wiley and Sons, N.Y.

# Appendix A-1
# Summary of Detected Chemicals in Monitoring Well Groundwater Samples

Table A-1
Summary of Detected Chemicals i[illegible]oring Well Groundwater Samples
Oce[illegible]AS

| Sample Date | OW2C-MW01D-R02 1/29/00 | OW2C-MW04-R02 1/28/00 | OW2C-MW05-R02 1/31/00 | OW2C-MW06-R02 1/30/00 | OW2C-MW07-R02 1/29/00 | OW2C-MW09D-R02 1/28/00 | OW2C-MW09-R02 1/28/00 | OW2C-MW10-R02 1/30/00 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | |
| 1,1-DICHLOROETHANE | 2 U | 2 U | 5.2 | 2 U | 2 U | 2 U | 2.2 | 4.7 |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 1.1 J |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 1.6 J | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 2 U | 1.4 J | 2.1 | 2 U | 22 | 2 U | 56 E | 2.8 |
| M- AND P-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2.7 | 2 U | 0.9 J | 2 U |
| TRICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 10.8 | 2 U |
| VINYL CHLORIDE | 2 U | 1.8 J | 21 | 2 U | 93 | 2 U | 56 E | 1.2 J |
| | | | | | | | | |
| **Wet Chemistry (MG/L)** | | | | | | | | |
| ALKALINITY | 250 | 95 | 190 | 150 | 230 | 300 | 10 U | 150 |
| CHLORIDE | 23 | 17 | 8.2 | 12 | 28 | 30 | 21 | 21 |
| COND (MS/CM) | 615 | 437 | 943 | 354 | 560 | 545 | 1,998 | 446 |
| DO | 0.23 | 0.29 | 0.34 | 0.2 | 0.42 | 0.22 | 0.47 | 0.31 |
| ETHANE (NG/L) | 5 U | 3,183 | 5 U | 23 | 40 | 1,267 | 1,267 | 37 |
| ETHENE (NG/L) | 5 U | 523 | 429 | 11 | 12,294 | 9,738 | 9,738 | 123 |
| IRON II | 0.5 U | 13 | 15 | 10 | 7.2 | 0.5 U | NA | 3.7 |
| IRON III | 0.9 | 1 | 1.9 | 0.7 | 0.6 | 1.2 | 7 | 0.57 |
| MANGANESE | 0.5 U | 0.5 U | 0.57 | 0.5 U | 0.8 | 0.5 U | NA | 0.71 |
| METHANE (UG/L) | 11,400 | 990 | 11,500 | 10,600 | 3,790 | 520 | 520 | 160 |
| NITRATE | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| PH (unitless) | 6.66 | 5.58 | 6.34 | 5.94 | 5.47 | 6.84 | 3.3 | 5.93 |
| REDOX (mV) | -206.4 | -102.2 | -187 | -92.9 | -147.8 | -208.9 | 99.4 | -65.9 |
| SULFATE | 0.5 U | 89 | 2 | 1.1 | 1.6 | 0.5 U | 2,070 | 24 |
| SULFIDE | 0.11 | 0.1 | 0.31 | 0.08 | 0.16 | 0.1 | 0.08 | 0.09 |
| TEMP (Celsius) | 17.86 | 16.01 | 16.93 | 15.48 | 19.32 | 16.22 | 17.07 | 17.52 |
| TOTAL ORGANIC CARBON (TOC) | 4.3 | 12 | 26 | 11 | 14 | 4.3 | 22 | 11 |
| TURB (NTU) | -6.7 | 16 | 2,018 | 1,907 | 420 | -8.2 | 2,016 | 435.4 |

NA - Not analyzed





00606 of B134

Table A-1
Summary of Detected Chemicals in Monitoring Well Groundwater Samples
Ocean AS

| Sample Date | OW2C-MW11-R02 1/28/00 | OW2C-MW12-R02 1/30/00 | OW2C-MW13-R02 1/29/00 | OW2C-MW15-R02 1/30/00 | OW2C-MW16-R02 1/30/00 | OW2C-MW17-R02 1/30/00 | OW2C-MW17-R02-P 1/30/00 | OW2C-MW18-R02 1/29/00 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | |
| 1,1-DICHLOROETHANE | 6 U | 1.5 J | 1.4 J | 2 U | 2 U | 2 U | 2 U | 3.1 |
| 1,1-DICHLOROETHENE | 0.9 J | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 2 U | 1.1 J | 133 | 2 U | 2 U | 2 U | 2 U | 28 |
| M- AND P-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 2 U | 2 U | 4 | 2 U | 2 U | 2 U | 2 U | 2 U |
| TRICHLOROETHENE | 2 U | 0.8 J | 10 | 2 U | 2 U | 2 U | 2 U | 2 U |
| VINYL CHLORIDE | 2.2 | 3.9 | 114.5 | 2 | 2 U | 2 U | 2 U | 65 |
| | | | | | | | | |
| **Wet Chemistry (MG/L)** | | | | | | | | |
| ALKALINITY | 200 U | 60 | 225 | 105 | 33 | 90 | 90 | 255 |
| CHLORIDE | 24 | 30 | 31 | 32 | 9.1 | 18 | 19 | 39 |
| COND (MS/CM) | 483 | 462 | 750 | 644 | 331 | 461 | NA | 866 |
| DO | 0.34 | 0.13 | 0.23 | 0.19 | 0.9 | 0.27 | NA | 1.83 |
| ETHANE (NG/L) | 75 | 951 | 6,545 | 3,535 | 26 | 1,415 | 51 | 100 |
| ETHENE (NG/L) | 224 | 1,051 | 22,989 | 969 | 36 | 559 | 43 | 6,914 |
| IRON II | 7.4 U | 4.3 | 6.3 | 0.6 | 0.5 U | 1.2 | 0.7 | 6.5 |
| IRON III | 0.7 U | 0.5 U | 0.6 | 0.5 U | 0.5 U | 0.795 | 0.7 | 0.5 U |
| MANGANESE | 0.6 U | 0.5 U | 0.7 | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 1.1 |
| METHANE (UG/L) | 240 | 510 | 890 | 940 | 4,168 | 16 | 120 | 2,900 |
| NITRATE | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| PH (unitless) | 5.65 | 5.95 | 6 | 5.96 | 5.59 | 6.24 | NA | 6.19 |
| REDOX (mV) | -105.1 | -70.3 | 31.8 | -54.8 | 53.9 | -117.5 | NA | -23.4 |
| SULFATE | 30 | 24 | 16 | 33 | 43 | 13 | 13 | 6.8 |
| SULFIDE | 0.12 U | 0.1 | 0.09 | 0.12 | 0.1 | 0.11 | 0.1 | 0.11 |
| TEMP (Celsius) | 17.54 | 16.49 | 16.69 | 15.74 | 15.03 | 18.97 | NA | 16.61 |
| TOTAL ORGANIC CARBON (TOC) | 7.5 | 7.3 | 9.3 | 6.3 | 3 | 3 | 2.7 | 14 |
| TURB (NTU) | 890.1 | 69 | 717.5 | 22.8 | 1,825 | 1,836 | NA | -1.6 |

NA - Not analyzed

Table A-1
Summary of Detected Chemicals [illegible]toring Well Groundwater Samples
Oc[illegible]AS

| Sample Date | OW2C-MW19-R02 1/29/00 | OW2C-MW20-R02 1/30/00 | OW2C-MW21-R02 1/28/00 | OW2C-MW22-R02 1/30/00 | OW2C-MW23-R02 1/30/00 | OW2C-MW24-R02 1/28/00 | OW2C-MW25-R02 1/29/00 | OW2C-MW25-R02-P 1/29/00 |
|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | |
| 1,1-DICHLOROETHANE | 2 U | 2 U | 1.2 J | 6.4 | 2 U | 14 | 2 U | 2 U |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 47 E | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 4.9 | 3.1 | 2.8 U |
| BENZENE | 2 U | 2 U | 2 U | 0.7 J | 7.4 | 4.2 | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 124 E | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 22 | 2 U | 35 E | 2 U | 2 U | 2 U | 19 | 21 |
| M- AND P-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 3.6 J | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 6.8 | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 2.1 | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 9.9 | 12 |
| TRICHLOROETHENE | 2 U | 2 U | 6.5 | 2 U | 2 U | 2 U | 2 U | 2 U |
| VINYL CHLORIDE | 4.8 | 2 U | 124 E | 5.9 | 5.2 | 55 E | 373 | 316 E |
| **Wet Chemistry (MG/L)** | | | | | | | | |
| ALKALINITY | 250 | 45 | 150 U | 200 | 240 | 270 U | 280 | 270 |
| CHLORIDE | 23 | 24.5 | 39 | 14 | 24 | 50 | 34.4 | 34.4 |
| COND (MS/CM) | 758 | 565 | 397 | 447 | 570 | 654 | 751 | NA |
| DO | 2.61 | 0.48 | 0.33 | 0.36 | 0.29 | 0.4 | 0.43 | NA |
| ETHANE (NG/L) | 180 | 32 | 9,570 | 4,782 | 167 | 370,458 | 626 | 631 |
| ETHENE (NG/L) | 2,236 | 42 | 51,604 | 1,260 | 6,015 | 20,461 | 27,964 | 28,185 |
| IRON II | 7.7 | 0.5 U | 6 | 12 | 11 U | 49 | 17 | 16.7 U |
| IRON III | 1.3 | 0.5 U | 0.6 | 1.2 | 0.5 U | 2.8 | 1.7 | 2 U |
| MANGANESE | 1.3 | 0.5 U | 0.5 U | 1.1 | 0.5 U | 0.5 U | 1.5 | 1.5 U |
| METHANE (UG/L) | 2,200 | 10.2 | 1,410 | 2,220 | 6,640 | 6,550 | 4,920 | 5,340 |
| NITRATE | 0.5 U | 5 | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| PH (unitless) | 6.26 | 5.85 | 5.48 | 6.03 | 6.15 | 5.64 | 5.38 | NA |
| REDOX (mV) | -25 | 87 | -79.4 | -121.2 | -140.2 | -170 | -136.5 | NA |
| SULFATE | 6.2 | 66.5 | 17 | 0.8 | 19 | 3.7 | 6.2 | 6.2 |
| SULFIDE | 0.1 | 0.11 | 0.1 U | 0.18 | 0.11 | 0.13 U | 0.09 | 0.1 |
| TEMP (Celsius) | 18.25 | 24.12 | 15.5 | 16.36 | 18.1 | 18.6 | 17.72 | NA |
| TOTAL ORGANIC CARBON (TOC) | 12 | 7.5 | 8.6 | 16 | 14 | 19 | 21 | 29 |
| TURB (NTU) | 321.3 | 1.876 | 57.2 | 30.3 | 538.8 | 1.1 | 264.4 | NA |

NA - Not analyzed

Appendix A-2

# Summary of Detected Chemicals in DPT Groundwater Samples

Table A-2
Raw Grou[illegible]r Results
SWMU 2C[illegible]ocations
Oceana NAS

| Sample Date | OW2C-DW01-03 02/24/2000 | OW2C-DW01-09 02/24/2000 | OW2C-DW01-15 02/24/2000 | OW2C-DW02-03 02/24/2000 | OW2C-DW02-09 02/24/2000 | OW2C-DW02-15 02/24/2000 | OW2C-DW03-03 02/24/2000 | OW2C-DW03-09 02/24/2000 | OW2C-DW03-15 02/24/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 2 U | 2 U | 1.3 J | 2 U | 2 U | 0.9 J | 2 U | 2 U | 2.9 |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 5.8 | 2 JB | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BROMOFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 2 U | 36 | 676 | 2 U | 16 | 123 | 2 U | 14 | 14 |
| METHYLENE CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 1.2 J | 2 U | 2 U | 2 U |
| TRICHLOROETHENE | 2 U | 3.3 | 9.8 | 2 U | 4.2 | 4.5 | 2 U | 5.1 | 4.8 |
| VINYL CHLORIDE | 2 U | 24 | 472 | 2 U | 12 | 243 | 2 U | 7.2 | 27 |
| | | | | | | | | | |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | 10 U | 18 | 180 | 10 U | 19 | 230 | 10 U | 10 U | 190 |
| CHLORIDE | 55 | 43 | 23 | 24 | 53 | 27 | 19 | 47 | 37 |
| COND (MS/CM) | NA | 208 | 364 | 125 | 225 | 394 | NA | 359 | 739 |
| DO | NA | 0 | 0 | 0 | 0 | 0 | NA | 0.28 | 0.38 |
| ETHANE (NG/L) | 333 | 750 | 6,261 | 125 | 2,456 | 6,722 | 513 | 17,765 | 37,659 |
| ETHENE (NG/L) | 136 | 5,864 | 119,122 | 123 | 8,704 | 69,215 | 779 | 4,947 | 17,355 |
| IRON II | 7.9 | 4.6 | 10 | 3.9 | 7 | 11 | 6.4 | 5.2 | 11 |
| IRON III | 0.7 | 0.5 | 0.8 | 0.5 U | 0.5 U | 0.6 | 0.5 U | 0.5 U | 0.6 |
| MANGANESE | 0.8 | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.6 | 0.7 | 0.5 U | 0.7 |
| METHANE (UG/L) | 780 | 364.7 | 2,970 | 36.26 | 380 | 2,420 | 26.06 | 2,877 | 2,820 |
| PH (unitless) | NA | 5.33 | 5.87 | 5.32 | 5.48 | 5.87 | NA | 5.57 | 5.98 |
| REDOX (mV) | NA | 57 | -59.1 | 78 | 25.3 | -23.6 | NA | 62 | -17.8 |
| SULFATE | 323 | 51 | 5.1 | 22 | 38 | 2 | 25 | 34 | 4.3 |
| SULFIDE | 0.14 | 0.14 | 0.13 | 0.11 | 0.17 | 0.13 | 0.14 | 0.16 | 0.12 |
| TEMP (Celsius) | NA | 15.94 | 17.61 | 13.1 | 14.9 | 16.17 | NA | 16.78 | 17.93 |
| TOTAL ORGANIC CARBON (TOC) | 8.4 | 3.4 | 12 | 2.2 | 3.5 | 13 | 8.2 | 3.3 | 11 |
| TURB (NTU) | NA | 94.1 | 82 | 5.1 | 186 | 562.4 | NA | 1,836 | 71.3 |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Table A-2
Raw Grou[illegible] Results
SWMU 2C[illegible] ocations
Oceana NAS

| Sample Date | OW2C-DW04-03 02/24/2000 | OW2C-DW04-09 02/24/2000 | OW2C-DW04-15 02/24/2000 | OW2C-DW05-03 02/24/2000 | OW2C-DW05-09 02/24/2000 | OW2C-DW05-15 02/24/2000 | OW2C-DW06-09 02/24/2000 | OW2C-DW06-15 02/24/2000 | OW2C-DW07-09 02/26/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 2 U | 4.8 | 1.5 J | 2 U | 3.1 | 2 U | 2 U | 2 U | 1.1 J |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 1.7 J | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BROMOFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 2 U | 2 U | 2 U | 0.8 J | 99 | 14 | 8.5 | 21 | 3.7 |
| METHYLENE CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 1.6 J | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 4.8 | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 2 U | 5.8 | 2 U | 2 U | 18 | 2 U | 1.7 J | 2.1 | 1.2 J |
| TRICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| VINYL CHLORIDE | 2 U | 299 | 67 | 18 | 388 | 25 | 82 | 67 | 92 |
| | | | | | | | | | |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | NA | 350 | 225 | 120 | 350 | 180 | 400 | 250 | 320 |
| CHLORIDE | NA | 19 | 42 | 12 | 30 | 48 | 20 | 35 | 12 |
| COND (MS/CM) | NA | 939 | 790 | NA | 925 | 778 | 591 | 497 | 554 |
| DO | NA | 0.12 | 3 | NA | 0.14 | 2.4 | 0 | 0 | 10.01 |
| ETHANE (NG/L) | NA | 684 | 126 | 531 | 544 | 153 | 484 | 221 | 1,041 |
| ETHENE (NG/L) | NA | 33,835 | 7,267 | 2,335 | 31,083 | 2,984 | 16,044 | 11,391 | 17,321 |
| IRON II | 22 | 40 | 8.8 | 12 | 19 | 6.8 | 38 | 9.6 | 37 |
| IRON III | 15 | 1.9 | 0.5 | 1.2 | 0.8 | 0.5 | 3.6 | 0.7 | 1.5 |
| MANGANESE | 0.5 U | 0.5 U | 0.5 | 0.6 U | 2 | 0.5 U | 1.5 | 0.7 | 0.5 U |
| METHANE (UG/L) | NA | 10,660 | 2,410 | 4,950 | 8,620 | 999 | 11,030 | 4,590 | 9,530 |
| PH (unitless) | NA | 5.95 | 5.83 | NA | 5.91 | 5.88 | 6.1 | 5.98 | 6.16 |
| REDOX (mV) | NA | -70.2 | -23.9 | NA | -14.7 | 1 | -114.6 | -45.4 | -229.1 |
| SULFATE | 13 | 0.5 U | 15 | 5.3 | 0.5 U | 21 | 0.5 U | 0.5 U | 2.7 |
| SULFIDE | NA | 0.12 | 0.11 | 0.14 | 0.12 | 0.15 | 0.14 | 0.15 | 0.13 |
| TEMP (Celsius) | NA | 15.82 | 18.12 | NA | 16.04 | 18.13 | 18.11 | 20.03 | 15.74 |
| TOTAL ORGANIC CARBON (TOC) | NA | 29 | 14 | 22 | 28 | 20 | 14 | 21 | 15 |
| TURB (NTU) | NA | 61.5 | 24 | NA | 17.1 | 13.8 | 77.6 | 71.1 | 9.7 |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Table A-2
Raw Grou[illegible]r Results
SWMU 2C[illegible] Locations
Oceana NAS

| Sample Date | OW2C-DW08-09 02/26/2000 | OW2C-DW09-09 02/26/2000 | OW2C-DW10-09 02/26/2000 | OW2C-DW11-09 02/26/2000 | OW2C-DW12-09 02/26/2000 | OW2C-DW13-09 02/26/2000 | OW2C-DW14-09 02/26/2000 | OW2C-DW15-09 02/27/2000 | OW2C-DW16-09 02/26/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 4.2 | 1.8 J | 1.5 J | 1.4 J | 12 | 76 J | 30 J | 13 | 1.2 J |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 2 U | 1.3 J | 2 U | 2.2 | 2.1 | 1.5 J | 1.2 J |
| BROMOFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 1.4 J | 5.1 | 3.6 | 3 J | 142 | 80 J | 32 J | 52 | 26 |
| METHYLENE CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 1.8 J | 2 U | 2 U | 2 U | 2 U | 1.9 J | 2 U | 2 U | 2 U |
| TOLUENE | 4.8 | 3 J | 3 U | 3 U | 3 U | 17 | 3.6 | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 4.3 | 3.1 | 11 | 9.2 | 12 | 11 | 8.4 | 7.9 | 5 |
| TRICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| VINYL CHLORIDE | 220 | 123 | 350 | 292 E | 250 | 373 E | 298 | 264 | 162 |
| | | | | | | | | | |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | 333 | 350 | 350 | 400 | 340 | 410 | 400 | 360 | 350 |
| CHLORIDE | 16 | 17 | 23 | 20.2 | 25 | 29 | 26 | 27 | 25 |
| COND (MS/CM) | 636 | 709 | 617 | 663 | 625 | 636 | 660 | 938 | 636 |
| DO | 0.08 | 0.01 | 8.52 | 0 | 0.01 | 12.05 | 0 | 1.39 | 0 |
| ETHANE (NG/L) | 1,599 | 4,935 | 1,373 | 2,166 | 1,609 | 869 | 1,284 | 704 | 691 |
| ETHENE (NG/L) | 26,688 | 16,367 | 53,760 | 44,142 | 13,752 | 37,471 | 28,621 | 36,450 | 26,264 |
| IRON II | 48 | 37 | 53 | 34 | 24 | 17 | 22 | 18 E | 20 |
| IRON III | 1.7 | 1.7 | 1.3 | 1.1 | 1.2 | 0.8 | 1.1 | 0.7 | 1.1 |
| MANGANESE | 0.5 U | 0.5 U | 0.5 U | 1.8 | 1.3 | 1.5 | 1.6 | 1.4 | 2.7 |
| METHANE (UG/L) | 10,380 | 10,480 | 7,190 | 8,210 | 6,380 | 7,420 | 8,300 | 8,400 | 8,540 |
| PH (unitless) | 5.93 | 5.96 | 5.88 | 5.81 | 5.8 | 5.84 | 5.81 | 5.81 | 5.81 |
| REDOX (mV) | 59.5 | -66.3 | -180.1 | -42.3 | -20.9 | -268.6 | -28.6 | -42.3 | -27.8 |
| SULFATE | 0.5 U | 0.5 U | 0.5 U | 10 | 0.5 U | 0.84 | 1.3 | 0.5 U | 0.5 U |
| SULFIDE | 0.16 | 1.3 | 0.12 | 0.14 | 0.13 | 0.14 | 0.18 | 0.1 | 0.17 |
| TEMP (Celsius) | 14.93 | 15.54 | 15.25 | 15.96 | 16 | 15.5 | 15.63 | 17.25 | 15.85 |
| TOTAL ORGANIC CARBON (TOC) | 23 | 21 | 31 | 55 | 130 | 36 | 88 | 48 | 75 |
| TURB (NTU) | 98.1 | 49.9 | 6.1 | 32.9 | 52.3 | 20 | 77.9 | 1,841 | 58.7 |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Table A-2
Raw Grou[illegible] Results
SWMU 2C [illegible]ocations
Oceana NAS

| Sample Date | OW2C-DW17-09 02/27/2000 | OW2C-DW17-09-P 02/27/2000 | OW2C-DW18-09 02/27/2000 | OW2C-DW19-09 02/26/2000 | OW2C-DW19-09-P 02/26/2000 | OW2C-DW20-09 02/26/2000 | OW2C-DW21-09 02/27/2000 | OW2C-DW22-09 02/27/2000 | OW2C-DW23-09 02/27/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 2.9 | 3 | 2 U | 3 | 3 | 1.4 J | 1.3 J | 1.8 J | 1.6 J |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 3.1 | 1 J | 1 J | 1.4 J | 2 U | 2 U | 2 U |
| BROMOFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 1.5 J | 1.6 J | 1.6 J | 1.4 J | 1.4 J | 2 U | 2 U | 0.9 J | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 14 | 10 J | 18 | 23 | 23 | 27 | 30 | 17 | 31 |
| METHYLENE CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 2.2 | 2.3 | 7.8 | 6.3 | 6.4 | 6.4 | 5 | 3 | 3.4 |
| TRICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| VINYL CHLORIDE | 79 | 73 | 134 | 130 | 131 | 131 | 12.6 | 123 | 90 |
| | | | | | | | | | |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | 325 | 320 | 380 | 350 | 350 | 350 | 275 | 285 | 350 |
| CHLORIDE | 24 | 24 | 27 | 24 | 24 | 24 | 26 | 24 | 25 |
| COND (MS/CM) | 859 | NA | 1,117 | 573 | NA | 651 | 974 | 710 | 803 |
| DO | 1.07 | NA | 1.42 | 11.05 | NA | 0 | 0 | 12.7 * | 0 |
| ETHANE (NG/L) | 1,364 | 1,359 | 835 | 511 | 603 | 575 | 706 | 667 | 567 |
| ETHENE (NG/L) | 21,096 | 21,565 | 14,519 | 23,928 | 26,807 | 19,142 | 18,577 | 20,248 | 13,723 |
| IRON II | 17 | 14 | 33 E | 19 | 8.7 | 16 | 31 E | 27 E | 23.7 E |
| IRON III | 0.7 | 0.7 | 1.6 | 0.8 | 0.9 | 1 | 0.9 | 0.9 | 1.3 |
| MANGANESE | 2.7 | 2.7 | 3.959 | 3 | 3.2 | 2.6 | 2.3 | 2.3 | 1.7 |
| METHANE (UG/L) | 689 | 7,190 | 4,910 | 5,160 | 5,780 | 6,840 | 7,490 | 6,140 | 7,000 |
| PH (unitless) | 5.82 | NA | 5.88 | 5.93 | NA | 5.86 | 6.08 | 5.85 | 6.06 |
| REDOX (mV) | -56.1 | NA | -97.1 | -294.1 | NA | 42.1 | -44.5 | -258.9 | -54 |
| SULFATE | 2.4 | 2.4 | 0.5 U | 0.5 U | 0.5 U | 20 | 0.5 U | 0.5 U | 0.5 U |
| SULFIDE | 0.14 | 0.14 | 0.1 | 0.12 | 0.13 | 0.11 | 0.1 | 0.1 | 0.09 |
| TEMP (Celsius) | 16.74 | NA | 15.89 | 16.01 | NA | 16.41 | 17.17 | 17.65 | 18.48 |
| TOTAL ORGANIC CARBON (TOC) | 23 | 22 | 29 | 26 | 38 | 24 | 27 | 25 | 42 |
| TURB (NTU) | 1,840 | NA | 1,837 | 3 | NA | 5.1 | 93.7 | 10 | 2,039 |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Table A-2
Raw Groun[illegible] Results
SWMU 2C [illegible]ocations
Oceana NAS

| Sample Date | OW2C-DW24-09 02/27/2000 | OW2C-DW25-09 02/27/2000 | OW2C-DW26-09 02/27/2000 | OW2C-DW27-09 02/27/2000 | OW2C-DW28-09 02/27/2000 | OW2C-DW29-09 02/27/2000 | OW2C-DW30-15 02/27/2000 | OW2C-DW31-15 02/28/2000 | OW2C-DW32-15 02/28/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 1.9 J | 1.9 J | 1.8 J | 1.2 J | 2 U | 2 U | 3.4 | 3.1 | 13 |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 0.7 J | 2 U | 2 U |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 0.9 J | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 1.3 J | 2 U | 0.7 J | 0.7 J | 2 U | 2 U | 2 U | 2 U | 2 U |
| BROMOFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 1.8 J | 2 U | 1.1 J | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 31 | 29 | 23 | 30 | 13 | 2 U | 276 | 67 | 61 J |
| METHYLENE CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 9.7 | 2.9 | 4.5 | 4.3 | 1.9 J | 2 U | 4.9 | 4.1 | 2.1 |
| TRICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 12 | 8.2 | 8.2 |
| VINYL CHLORIDE | 196 | 101 | 144 | 129 | 85 | 4 | 897 | 817 | 485 |
| | | | | | | | | | |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | 300 | 375 | 400 | 350 | 480 | 218 | 210 | 210 | 170 |
| CHLORIDE | 24 | 26 | 23 | 22 | 18 | 7.3 | 28 | 27 | 26 |
| COND (MS/CM) | 865 | 781 | 828 | 793 | 1,013 | 597 | 786 | 633 | 720 |
| DO | 0 | 0 | 2.58 | 0.02 | 1.84 | -0.02 | 10.3 | 0.29 | 0.23 |
| ETHANE (NG/L) | 524 | 1,161 | 378 | 500 | 434 | 1,233 | 5,949 | 9,430 | 15,142 |
| ETHENE (NG/L) | 24,958 | 20,814 | 22,737 | 15,283 | 11,009 | 3,075 | 83,002 | 143,726 | 81,851 |
| IRON II | 24 E | 17 | 30 | 21 | 15 | 17 | 19.2 | 14 E | 19 E |
| IRON III | 1.2 | 1.5 | 1.3 | 1.5 | 1.3 | 1.2 | 0.9 | 0.8 | 0.6 |
| MANGANESE | 2.9 | 2 | 2.3 | 1.9 | 0.9 | 0.7 | 1.1 | 0.8 | 1.1 |
| METHANE (UG/L) | 6,050 | 7,540 | 7,160 | 7,040 | 5,740 | 10,280 | 1,860 | 3,320 | 2,750 |
| PH (unitless) | 6.09 | 6.03 | 5.89 | 6 | 6.04 | 6.28 | 5.68 | 6.8 | 6.75 |
| REDOX (mV) | -48.5 | -54.1 | -92.2 | -94.4 | -101.7 | -97.1 | -180.3 | -25.1 | -38.9 |
| SULFATE | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 47 | 0.5 U | 186 | 26 | 73 |
| SULFIDE | 0.11 | 0.17 | 0.17 | 0.22 | 0.16 | 0.31 | 0.1 | 0.1 | 0.11 |
| TEMP (Celsius) | 17.63 | 18.35 | 18.29 | 18.19 | 18.16 | 20.61 | 16.6 | 17.09 | 18.07 |
| TOTAL ORGANIC CARBON (TOC) | 59 | 23 | 25 | 21 | 20 | 19 | 11 | 17 | 13 |
| TURB (NTU) | 279.5 | 1,654 | 1,850 | 167 | 29.9 | 165.4 | 16 | 0.1 | 5 |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Table A-2
Raw Groun[illegible] Results
SWMU 2C [illegible]ocations
Oceana NAS

| Sample Date | OW2C-DW33-15 02/28/2000 | OW2C-DW34-15 02/29/2000 | OW2C-DW35-15 02/29/2000 | OW2C-DW36-15 02/29/2000 | OW2C-DW37-15 02/29/2000 | OW2C-DW38-15 02/28/2000 | OW2C-DW39-15 02/29/2000 | OW2C-DW40-15 02/29/2000 | OW2C-DW41-15 02/28/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 4.2 | 2 U | 3.8 | 5.3 | 3.5 | 5.2 | 2.2 | 4.4 | 4.4 |
| 1,1-DICHLOROETHENE | 0.8 J | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2.4 | 2.2 | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BROMOFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 4.7 | 3.9 | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 230 | 96 | 7.7 | 7.9 | 6.4 | 7.7 | 32 | 10 | 9.3 |
| METHYLENE CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 5.3 | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TRICHLOROETHENE | 12 | 10 | 6.5 | 5.1 | 4.1 | 6.7 | 5.4 | 5.3 | 6.1 |
| VINYL CHLORIDE | 778 | 248 | 16 | 23 | 18 | 27 | 129 | 27 | 25 |
| | | | | | | | | | |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | 170 | 155 | 230 | 210 | 225 | 255 | 230 | 160 | 250 |
| CHLORIDE | NA | 28 | 36 | 38 | 33 | 38 | 29 | 34 | 38 |
| COND (MS/CM) | 676 | 697 | 752 | 650 | 551 | 461 | 660 | 705 | 614 |
| DO | 1.03 | 0.41 | 0.37 | 0.18 | 0.19 | 0 | 0.4 | 0.38 | 0.18 |
| ETHANE (NG/L) | 9,578 | 7,512 | 21,737 | 57,029 | 42,492 | 50,899 | 16,204 | 25,702 | 75,760 |
| ETHENE (NG/L) | 108,009 | 65,211 | 12,744 | 10,019 | 4,028 | 14,563 | 71,699 | 28,368 | 15,156 |
| IRON II | NA | 12 E | 12 E | 8.3 | 8.2 | 11 | 11 | 12 E | 8.9 |
| IRON III | NA | 0.5 | 0.7 | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U |
| MANGANESE | NA | 0.7 | 0.8 | 0.7 | 0.5 | 0.7 | 0.6 | 0.6 | 0.7 |
| METHANE (UG/L) | 2,530 | 2,280 | 1,976 | 2,802 | 2,235 | 2,620 | 2,171 | 2,196 | 2,950 |
| PH (unitless) | 5.69 | 5.94 | 5.92 | 5.75 | 5.81 | 5.94 | 5.89 | 5.89 | 6.74 |
| REDOX (mV) | -25.3 | -27 | -22.9 | -302 | -325.2 | -28.3 | -17.3 | -26.2 | -6.1 |
| SULFATE | NA | 2.1 | 9 | 5.1 | 9.6 | 3.9 | 4.2 | 4.1 | 4.2 |
| SULFIDE | NA | 0.09 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.13 | 0.09 |
| TEMP (Celsius) | 15.21 | 14.8 | 15.36 | 15.66 | 15.94 | 15.48 | 15.12 | 17.03 | 16.12 |
| TOTAL ORGANIC CARBON (TOC) | 15 | 13 | 12 | 14 | 12 | 15 | 14 | 14 | 13 |
| TURB (NTU) | 783.5 | 20.1 | 130.4 | 21.8 | 20.1 | 3.4 | 50 | 6.2 | 3.5 |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Tab[illegible]2
Raw Grou[illegible] Results
SWMU 2C[illegible] Locations
Oceana NAS

| Sample Date | OW2C-DW42-15 02/28/2000 | OW2C-DW43-15 02/29/2000 | OW2C-DW43-15-P 02/29/2000 | OW2C-DW44-15 03/01/2000 | OW2C-DW45-15 03/01/2000 | OW2C-DW46-15 03/01/2000 | OW2C-DW47-15 03/01/2000 | OW2C-DW48-15 03/01/2000 | OW2C-DW49-09 02/27/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 5.3 | 0.9 J | 0.9 J | 4.1 | 4.5 | 6.6 | 5.6 | 2 U | 5.9 |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 0.7 J | 2 U | 2 U | 2 U | 2 U | 1 J | 2 U |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 1.3 J | 3 | 1.4 J | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 4.4 | 2 U | 0.7 J | 1.5 J |
| BROMOFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 3.7 | 4.6 | 1.6 J | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 27 |
| CIS-1,2-DICHLOROETHENE | 11 | 337.2 | 363.2 | 4.6 | 6.9 | 2.6 | 5.1 | 475 | 3.7 |
| METHYLENE CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 2 U | 3.1 | 3.5 | 2 U | 2 U | 2 U | 2 U | 3.6 | 2 U |
| TRICHLOROETHENE | 5.4 | 10 | 11 | 4.6 | 3.8 | 1.9 J | 3.8 | 8.6 | 2 U |
| VINYL CHLORIDE | 30 | 552 | 568 | 11 | 20 | 25 | 23 | 376 | 178 |
| | | | | | | | | | |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | 180 | 270 | 270 | 190 | 200 | 180 | 250 | 205 | 145 |
| CHLORIDE | 40 | 28 | 28 | 41 | 38 | 21 | 32 | 24 | 27 |
| COND (MS/CM) | 444 | 587 | NA | 936 | 814 | 644 | 529 | 425 | 649 |
| DO | 11.05 | 0.19 | NA | 0.27 | 0.3 | 0.19 | 0.24 | 0.22 | 0.57 |
| ETHANE (NG/L) | 86,910 | 4,855 | 4,857 | 50,423 | 62,892 | 34,811 | 36,267 | 5,699 | 1,083 |
| ETHENE (NG/L) | 17,130 | 61,579 | 70,396 | 7,757 | 10,327 | 8,627 | 39,768 | 62,385 | 39,307 |
| IRON II | 11 | 13 E | 14 E | 9.9 | 8.6 | 9.5 | 13 E | 12 E | 21 E |
| IRON III | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.5 U | 0.6 | 0.5 U | 0.6 |
| MANGANESE | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 | 0.6 | 0.7 | 0.5 | 1.9 |
| METHANE (UG/L) | 3,170 | 2,328 | 2,617 | 2,641 | 2,571 | 1,540 | 2,037 | 2,616 | 8,950 |
| PH (unitless) | 5.74 | 5.73 | NA | 6 | 5.99 | 5.96 | 5.91 | 5.8 | 5.96 |
| REDOX (mV) | -195.1 | -358 | NA | -14 | -1.8 | -9.7 | -19.4 | -11.3 | -40.5 |
| SULFATE | 6.5 | 3.9 | 4 | 2.8 | 6.3 | 6.7 | 2.8 | 4.1 | 0.5 U |
| SULFIDE | 0.1 | 0.09 | 0.1 | 0.18 | 0.18 | 0.12 | 0.09 | 0.11 | 0.11 |
| TEMP (Celsius) | 17.48 | 17.56 | NA | 16.45 | 16.25 | 14.76 | 16 | 16.63 | 16.25 |
| TOTAL ORGANIC CARBON (TOC) | 18 | 17 | 13 | 12 | 13 | 12 | 19 | 13 | 68 |
| TURB (NTU) | 7.5 | 4.6 | NA | 10.6 | 7.9 | 14.2 | 47.8 | 66.3 | 900 |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Table A-2
Raw Grou[illegible] Results
SWMU 2C[illegible] ocations
Oceana NAS

| Sample Date | OW2C-DW50-09 02/28/2000 | OW2C-DW50-09-P 02/28/2000 | OW2C-DW51-09 02/28/2000 | OW2C-DW52-15 03/01/2000 | OW2C-DW53-15 03/01/2000 | OW2C-DW54-09 02/29/2000 | OW2C-DW55-09 02/29/2000 | OW2C-DW56-09 02/29/2000 | OW2C-DW57-09 02/29/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 35 E | 33 E | 1 J | 6.1 | 2 | 2 U | 2 U | 5.8 | 2 U |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 8.4 | 1.1 J | 2 U | 2 U |
| BROMOFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 214 | 208 | 35 J | 13 | 21 | 2 U | 2 U | 1.5 J | 2 U |
| METHYLENE CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3.3 | 3.3 | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 14 | 13 | 18 | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TRICHLOROETHENE | 2 U | 2 U | 2 U | 5.2 | 5.7 | 2 U | 2 U | 1.9 J | 2 U |
| VINYL CHLORIDE | 434 | 420 | 560 | 41.44 | 83 | 3.9 | 2 U | 46 | 2 U |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | 250 | 270 | 350 | 220 | 210 | 180 | 280 | 500 | 250 |
| CHLORIDE | 28 | 30 | 31 | 39 | 31 | 28 | 22 | 17 | 6.8 |
| COND (MS/CM) | 692 | NA | 667 | 759 | 409 | NA | 847 | 792 | 753 |
| DO | 0.43 | NA | 0.42 | 0.22 | 0.23 | NA | 0.6 | 0.2 | 0.34 |
| ETHANE (NG/L) | 2,057 | 1,492 | 1,304 | 54,236 | 18,467 | 4,867 | 250 | 5 U | 180 |
| ETHENE (NG/L) | 29,240 | 25,224 | 57,673 | 22,291 | 53,002 | 540 | 156 | 8,132 | 5 U |
| IRON II | 15 E | 13 E | 23 E | 11 | 11 | 32 E | 23 E | 55 E | 44 E |
| IRON III | 0.7 | 0.5 U | 1.2 | 0.6 | 0.5 | 1.2 | 1.3 | 2.3 | 1.7 |
| MANGANESE | 1.2 | 1.1 | 2 | 0.6 | 0.5 U | 1.9 | 1.8 | 0.5 U | 0.5 U |
| METHANE (UG/L) | 4,969 | 6,262 | 6,073 | 2,562 | 1,930 | 5,484 | 1,507 | 7,688 | 8,886 |
| PH (unitless) | 5.93 | NA | 5.9 | 5.98 | 5.92 | NA | 5.92 | 6.77 | 6.15 |
| REDOX (mV) | -15.8 | NA | -21.3 | -7.3 | -14.4 | NA | -30.4 | -49.3 | -76.1 |
| SULFATE | 0.5 U | 0.5 U | 0.5 U | 9.9 | 12 | 0.5 U | 14 | 0.5 U | 0.5 U |
| SULFIDE | 0.12 | 0.13 | 0.11 | 0.16 | 0.13 | 0.09 | 0.1 | 0.12 | 0.1 |
| TEMP (Celsius) | 15.89 | NA | 15.93 | 16.27 | 16.82 | NA | 17.13 | 15.95 | 16.11 |
| TOTAL ORGANIC CARBON (TOC) | 28 | 30 | 29 | 13 | 13 | 36 | 18 | 42 | 18 |
| TURB (NTU) | 39.9 | NA | 7.1 | 7 | 40.5 | NA | 12.3 | 26.2 | 62.5 |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Table A-2
Raw Grou[illegible] Results
SWMU 2C [illegible] Locations
Oceana NAS

| Sample Date | OW2C-DW58-15 03/07/2000 | OW2C-DW59-15 03/07/2000 | OW2C-DW60-15 03/07/2000 | OW2C-DW61-15 03/07/2000 | OW2C-DW62-09 03/07/2000 | OW2C-DW63-15 03/07/2000 | OW2C-DW64-15 03/07/2000 | OW2C-DW65-09 03/07/2000 | OW2C-DW65-09-P 03/07/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 2 U | 1.7 J | 1.4 J | 2 U | 2 U | 2 U | 3.1 | 2 U | 2 U |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 0.7 J | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 2 U | 2 U | 4.2 | 2 U | 2 U | 2 U | 2 U |
| BROMOFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 149 | 1.2 J | 34 | 2 U | 2 U | 2 U | 1 J | 2 U | 2 U |
| METHYLENE CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 1.1 J | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TRICHLOROETHENE | 13 | 2 U | 6.4 | 2 U | 2 U | 2 U | 0.8 J | 2.3 | 2 U |
| VINYL CHLORIDE | 209 | 2 U | 35 | 0.9 J | 0.7 J | 4.2 | 16 | 28 | 27 |
| | | | | | | | | | |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | NA | NA | NA | NA | 160 | NA | NA | NA | NA |
| CHLORIDE | 43 | 20 | 49 | 22 | 10 | 14 | 8.7 | 18 | 20 |
| COND (MS/CM) | 361 | 336 | 336 | 181 | 404 | 169 | 162 | 669 | NA |
| DO | 0.19 | 0.13 | 0.27 | 0.11 | 0.34 | 0.18 | 0.19 | 0.6 | NA |
| ETHANE (NG/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| ETHENE (NG/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| IRON II | NA | NA | NA | NA | 17 E | NA | NA | NA | NA |
| IRON III | NA | NA | NA | NA | 1.1 | NA | NA | NA | NA |
| MANGANESE | NA | NA | NA | NA | 0.6 | NA | NA | NA | NA |
| METHANE (UG/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| PH (unitless) | 6.25 | 6.11 | 5.83 | 5.92 | 6.49 | 5.81 | 5.77 | 6.27 | NA |
| REDOX (mV) | -17.5 | -8.8 | -337.9 | 9.2 | -94.2 | 231.5 | -298.6 | -101.4 | NA |
| SULFATE | NA | NA | NA | NA | 0.5 U | NA | NA | NA | NA |
| SULFIDE | NA | NA | NA | NA | 1.1 | NA | NA | NA | NA |
| TEMP (Celsius) | 16.84 | 15.65 | 17.64 | 16.37 | 15.53 | 16.15 | 14.85 | 16.88 | NA |
| TOTAL ORGANIC CARBON (TOC) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| TURB (NTU) | 39.8 | 21.4 | 3.4 | 35.3 | 2,019 | 162.6 | 5.2 | 4 | NA |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Table A-2
Raw Groun[illegible] Results
SWMU 2C [illegible]ocations
Oceana NAS

| Sample Date | OW2C-DW66-09 03/07/2000 | OW2C-DW67-15 03/07/2000 | OW2C-DW68-15 03/07/2000 | OW2C-DW69-15 03/07/2000 | OW2C-DW70-15 03/07/2000 | OW2C-DW71-15 03/07/2000 | OW2C-DW72-15 03/07/2000 | OW2C-DW73-15 03/08/2000 | OW2C-DW74-15 03/07/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 2 U | 1.4 J | 2.2 | 2.1 | 2.2 | 2 U | 2 U | 2 U | 1.4 J |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2.4 | 2 U | 2 U | 2 U | 2.1 |
| 1,2,4-TRICHLOROBENZENE | 2 U | 0.8 J | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BROMOFORM | 1.5 J | 1.5 J | 1.3 J | 2 U | 1.4 J | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 1.7 J | 2 U | 3.4 | 6 | 2.5 | 2 U | 2 U | 2 U | 1.4 J |
| METHYLENE CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2.6 | 2 U | 2 U | 2 U | 1.9 J |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TRICHLOROETHENE | 2.6 | 0.8 J | 2 U | 4.9 | 3.2 | 2 U | 2 U | 2 U | 2.8 |
| VINYL CHLORIDE | 5.4 | 5.2 | 8.7 | 13 | 2 U | 2 U | 2 U | 2 U | 12 |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| CHLORIDE | 21 | 32 | 19 | 38 | 23 | 17 | 23 | 28 | 26 |
| COND (MS/CM) | 605 | 267 | 259 | 286 | 376 | 141 | 183 | 234 | 342 |
| DO | 0.19 | 0.13 | 0.13 | 0.16 | 0.18 | 0.44 | 0.76 | 0.17 | 0.23 |
| ETHANE (NG/L) | NA | NA | NA | NA | 18,850 | NA | NA | NA | NA |
| ETHENE (NG/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| IRON II | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| IRON III | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| MANGANESE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| METHANE (UG/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| PH (unitless) | 6.17 | 5.93 | 6.08 | 5.92 | 5.97 | 5.72 | 5.64 | 5.8 | 6.2 |
| REDOX (mV) | -268 | 3.4 | -2.9 | 9.6 | 286.5 | 33.6 | 36.7 | 36.5 | -125 |
| SULFATE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| SULFIDE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| TEMP (Celsius) | 16.63 | 16.51 | 16.04 | 16.92 | 16.83 | 14.19 | 16.47 | 16.73 | 18.33 |
| TOTAL ORGANIC CARBON (TOC) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| TURB (NTU) | 0.8 | 103.5 | 38.6 | 82.3 | 74.8 | 101.3 | 203.7 | 161.5 | 18.3 |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Table A-2
Raw Groundwater Results
SWMU 2C Locations
Oceana NAS

| Sample Date | OW2C-DW74-15-P 03/07/2000 | OW2C-DW75-15 03/08/2000 | OW2C-DW76-09 03/07/2000 | OW2C-DW76-15 03/07/2000 | OW2C-DW77-09 03/08/2000 | OW2C-DW78-15 03/08/2000 | OW2C-DW79-15 03/08/2000 | OW2C-DW80-15 03/08/2000 | OW2C-DW80-15-P 03/08/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 40 U | 1.7 J | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 1.5 J | 2.8 | 40 U | 4.8 | 2 U | 24 | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHENE | 2.1 | 2 U | 40 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 40 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 40 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 40 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 40 U | 2 U | 2 U | 2 U | 2 U | 21 | 21 |
| BROMOFORM | 2 U | 2 U | 40 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 2 U | 2 U | 40 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 1.6 J | 40 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 40 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 1.4 J | 19 | 56 | 71 E | 2 U | 129 | 0.8 J | 2 U | 2 U |
| METHYLENE CHLORIDE | 1.8 J | 2 U | 40 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 40 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 60 U | 2 J | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 2 U | 2 U | 40 U | 7.4 | 2 U | 2.2 | 2 U | 2 U | 2 U |
| TRICHLOROETHENE | 2.6 | 6.2 | 40 U | 2 U | 2 U | 24 | 1 J | 2 U | 2 U |
| VINYL CHLORIDE | 12 | 40 | 210 | 184 E | 18 | 101 | 8.8 | 1.5 J | 1.4 J |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| CHLORIDE | NA | 39 | NA | 34 | 16 | 20 | 12 | 24 | 24 |
| COND (MS/CM) | NA | 591 | 546 | NA | 612 | 415 | 236 | 523 | NA |
| DO | NA | 0.22 | 1.54 | NA | 0.19 | 0.12 | 0.99 | 0.26 | NA |
| ETHANE (NG/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| ETHENE (NG/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| IRON II | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| IRON III | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| MANGANESE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| METHANE (UG/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| PH (unitless) | NA | 6.04 | 5.95 | NA | 6.26 | 5.93 | 6.14 | 5.87 | NA |
| REDOX (mV) | NA | -10.1 | -4.1 | NA | -75.9 | -6.8 | -23.8 | -166.9 | NA |
| SULFATE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| SULFIDE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| TEMP (Celsius) | NA | 18.38 | 16.54 | NA | 15.56 | 17.23 | 15.08 | 16.62 | NA |
| TOTAL ORGANIC CARBON (TOC) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| TURB (NTU) | NA | 263.1 | 53 | NA | 55.7 | 296.8 | 682 | 0.2 | NA |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Table A-2
Raw Grou[illegible]er Results
SWMU 2[illegible] Locations
Oceana NAS

| Sample Date | OW2C-DW81-15 03/08/2000 | OW2C-DW82-15 03/08/2000 | OW2C-DW83-15 03/08/2000 | OW2C-DW84-15 03/08/2000 | OW2C-DW85-15 03/08/2000 | OW2C-DW86-15 03/08/2000 | OW2C-DW87-15 03/08/2000 | OW2C-DW88-15 03/08/2000 | OW2C-DW89-15 03/09/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 2 U | 2 U | 2 U | 1.8 J | 2.3 | 2.9 | 2 U | 0.7 J | 1.6 J |
| 1,1-DICHLOROETHENE | 3.1 | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 4.6 | 33 | 2 U | 2.6 |
| BROMOFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 1.2 J | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 3.7 |
| METHYLENE CHLORIDE | 1.2 J | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 1.2 J | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TRICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2.1 | 2 U | 2 U | 3 | 1.1 J |
| VINYL CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2 U | 9.6 | 2.5 | 5.6 | 23 |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| CHLORIDE | 17 | 77 | 9.4 | 17 | 20 | 37 | 25 | 16 | 26 |
| COND (MS/CM) | 418 | 378 | 118 | 373 | 452 | 589 | 559 | 404 | 358 |
| DO | 0.23 | 0.07 | 0.14 | 0.17 | 0.09 | 0.25 | 0.21 | 0.19 | 0.28 |
| ETHANE (NG/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| ETHENE (NG/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| IRON II | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| IRON III | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| MANGANESE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| METHANE (UG/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| PH (unitless) | 6.02 | 5.89 | 5.49 | 5.73 | 6.1 | 5.68 | 6.24 | 6.04 | 6.01 |
| REDOX (mV) | -10.5 | 18.1 | 55.9 | -12.1 | -15.2 | -224 | -46.1 | -20.6 | -272 |
| SULFATE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| SULFIDE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| TEMP (Celsius) | 17.38 | 16.6 | 21.18 | 17.47 | 18.2 | 19.09 | 18.91 | 21.16 | 20.15 |
| TOTAL ORGANIC CARBON (TOC) | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| TURB (NTU) | 16.4 | 264.7 | 187.2 | 67.5 | 365 | 13.8 | 3.5 | 93.9 | 66.4 |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

Table A-2
Raw Grou[illegible]r Results
SWMU 2[illegible] Locations
Oceana NAS

| Sample Date | OW2C-DW90-15 03/09/2000 | OW2C-DW91-15 03/09/2000 | OW2C-DW92-09 03/09/2000 | OW2C-DW93-15 03/09/2000 | OW2C-DW93-15-P 03/09/2000 | OW2C-DW94-15 03/09/2000 | OW2C-DW95-15 03/09/2000 | OW2C-DW96-15 03/09/2000 | OW2C-DW97-15 03/09/2000 |
|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | | | | | | | | | |
| **Volatile Organic Compounds (UG/L)** | | | | | | | | | |
| 1,1,2-TRICHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,1-DICHLOROETHANE | 2.3 | 2 U | 0.7 J | 2 U | 2 U | 1.1 J | 27 | 11 | 9 |
| 1,1-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 1.3 J |
| 1,2,4-TRICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,2-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| 1,4-DICHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| BENZENE | 2 U | 2 U | 2 U | 0.9 J | 1 J | 2 U | 2 U | 2 U | 2 U |
| BROMOFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROBENZENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROETHANE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CHLOROFORM | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| CIS-1,2-DICHLOROETHENE | 19 | 2.2 | 2.9 | 7.2 | 7.5 | 3.2 | 80 | 60 J | 81 |
| METHYLENE CHLORIDE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| O-XYLENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U |
| TOLUENE | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U | 3 U |
| TRANS-1,2-DICHLOROETHENE | 2 U | 2 U | 2 U | 2 U | 2 U | 2 U | 1.5 J | 1.9 J | 0.8 J |
| TRICHLOROETHENE | 2 U | 2 U | 2.3 | 2 U | 2 U | 2.9 | 16 | 20 | 37 |
| VINYL CHLORIDE | 50 | 18 | 18.1 | 26 | 27 | 2 U | 198.8 | 696 | 21 |
| **Wet Chemistry (MG/L)** | | | | | | | | | |
| ALKALINITY | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| CHLORIDE | 46 | 40 | 18 | 38 | 38 | 23 | 21 | 26 | 23 |
| COND (MS/CM) | 587 | NA | 414 | 597 | NA | 424 | 388 | 579 | 463 |
| DO | 0.19 | NA | 0.16 | 0.18 | NA | 0 | 0.18 | 0 | 0.16 |
| ETHANE (NG/L) | NA | NA | NA | NA | NA | NA | NA | NA | 787 |
| ETHENE (NG/L) | NA | NA | NA | NA | NA | NA | NA | NA | 3,135 |
| IRON II | NA | NA | NA | NA | NA | NA | NA | NA | 9.1 |
| IRON III | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| MANGANESE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| METHANE (UG/L) | NA | NA | NA | NA | NA | NA | NA | NA | 841.3 |
| PH (unitless) | 6.18 | NA | 6.17 | 6.21 | NA | 5.94 | 5.74 | 5.99 | 6 |
| REDOX (mV) | -26.9 | NA | -3.2 | -24.7 | NA | -18.2 | -264.6 | 21.7 | 2.8 |
| SULFATE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| SULFIDE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| TEMP (Celsius) | 18.51 | NA | 16.47 | 15.88 | NA | 17.61 | 16.37 | 18.76 | 16.93 |
| TOTAL ORGANIC CARBON (TOC) | NA | NA | NA | NA | NA | NA | NA | NA | 15 |
| TURB (NTU) | 93.2 | NA | 12.8 | 29.8 | NA | 46.7 | 162.4 | 27.7 | 565.8 |

NA - Not analyzed
E - Reported value is estimated because of interference
J - Reported value is estimated
U - Analyte not detected

# Appendix D—ARARs

**Table 1**
**Federal Location-Specific ARARs**
**Feasibility Study of SWMUs 2B, 2C, and 2E at NASO**

| Location | Requirement | Prerequisite | Citation | ARAR Determination | Comment |
|---|---|---|---|---|---|
| **Executive Order 11988, Protection of Floodplain*** | | | | | |
| Within floodplain | Actions taken should avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values. | Action that will occur in a floodplain, i.e., lowlands, and relatively flat areas adjoining inland and coastal waters and other flood-prone areas. | 40 CFR Part 6, Appendix A; excluding Sections 6(a)(2), 6(a)(4), 6(a)(6); 40 CFR 6.302 | Not applicable | No remedial activities are to be conducted in a floodplain. |
| **Executive Order 11990, Protection of Wetlands*** | | | | | |
| Wetland | Action to minimize the destruction, loss, or degradation of wetlands. | Wetland as defined by Executive Order 11990 Section 7. | 40 CFR 6, Appendix A; excluding Sections 6(a)(2), 6(a)(4), 6(a)(6); 40 CFR 6.302 | Relevant and appropriate | Federal and/or state regulated wetlands are present at the base, although not located within the SWMU boundaries of concern in this feasibility study. |
| **Clean Water Act, Section 404*** | | | | | |
| Wetland | Action to prohibit discharge of dredged or fill material into wetland without permit. | Wetland as defined by Executive Order 11990 Section 7. | 40 CFR 230.10; 40 CFR 231 (231.1, 231.2, 231.7, 231.8) | Not applicable | No discharge of dredged or fill material to a wetland is planned as part of the response action. |
| **Endangered Species Act of 1978*** | | | | | |
| Endangered species | Action to ensure that any action is not likely to jeopardize the continued existence of endangered or threatened species or adversely affect its critical habitat. | Applies to actions that affect endangered or threatened species or their habitat. | 16 USC 1531 50 CFR Part 402 | Relevant and appropriate | No state or federally listed threatened or endangered species were found to exist at NASO except for transient individuals. Two rare/extremely rare plant species were found at the base, however. Therefore, the requirements of the Endangered Species Act of 1973 (16 USC 1536(a)) are relevant and appropriate to remediation activities occurring at SWMUs 2B, 2C, and 2E. |
| Migratory bird area | Protects almost all species of native birds in the U.S. from unregulated taking which can include poisoning at hazardous waste sites | Presence of migratory birds | 16 USC Section 703 | Relevant and appropriate | Migratory birds are encountered at the base. These requirements are relevant and appropriate to any response actions that could result in unregulated "taking" of native birds. |

**Table 1**
**Federal Location-Specific ARARs**
**Feasibility Study of SWMUs 2B, 2C, and 2E at NASO**

| Location | Requirement | Prerequisite | Citation | ARAR Determination | Comment |
|---|---|---|---|---|---|

* Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate that DON accepts the entire statues or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading; only substantive requirements of the specific citations are considered potential ARARs.

ARARs - Applicable or relevant and appropriate requirements.
CFR - Code of Federal Regulations.
USC - United States Code.
FR – Federal Regulation

**Table 2**
**Virginia Location-Specific ARARs**
**Feasibility Study of SWMUs 2B, 2C, and 2E at NASO**

| Location | Requirement | Prerequisite | Citation | ARAR Determination | Comment |
|---|---|---|---|---|---|
| **Virginia State Water Control Laws and Virginia Wetlands Regulations*** | | | | | |
| Wetland | Action to minimize the destruction, loss, or degradation of wetlands. | Wetland as defined by Virginia statutory provision. | Virginia Code Sections 62.1-44.15:5 | Relevant and appropriate | Federal and/or state regulated wetlands are present at the base, although not located within the SWMU boundaries of concern in this feasibility study. |
| Surface waters and adjacent land | No person shall dredge, fill, or discharge any pollutant into, or adjacent to surface waters, or otherwise alter the physical, chemical, or biological properties of surface waters, except as authorized pursuant to a Virginia Water Protection Permit, a Virginia Pollution Discharge Elimination System Permit, or a Virginia Pollution Abatement Permit | Dredging, filling, or discharging of pollutants | Virginia Code Ann 62.1-44.2 to 44.4; 9 VAC 25-210-10; 9 VAC 25-31-10 to 940; 9 VAC 25-32-10 to 300 | Not applicable | No dredging or filling activities are expected to occur at SWMUs 2B, 2C, and 2E. |
| **Chesapeake Bay Preservation Act and Chesapeake Bay Preservation Area Designation and Management Regulations*** | | | | | |
| Chesapeake Bay areas | Under these requirements, certain locally designated tidal and nontidal wetlands, as well as other sensitive land areas, may be subject to limitations regarding land-disturbing activities, removal of vegetation, use of impervious cover, erosion and sediment control, stormwater management, and other aspects of land use that may have effects on water quality. | Local jurisdiction and designation as a Chesapeake Bay Preservation area. | Code of Virginia Section 10.1-2100 et seq. and 9 VAC 10-20-10 | TBC | This requirement is not an ARAR since the area affected by the response action is federally owned and the City of Virginia Beach does not have jurisdiction over the Naval Base. Compliance is voluntary based on a memorandum of agreement. |
| **Coastal Zone Management Act*; State Coastal Zone Management Programs and Consistency Determinations** | | | | | |

**Table 2**
**Virginia Location-Specific ARARs**
**Feasibility Study of SWMUs 2B, 2C, and 2E at NASO**

| Location | Requirement | Prerequisite | Citation | ARAR Determination | Comment |
|---|---|---|---|---|---|
| Within coastal zone | Conduct activities within a coastal Management Zone in a manner consistent with state requirements. | Activities affecting the coastal zone including lands thereunder and adjacent shore land. | Section 307(c) of 16 USC 1456(c); also see 15 CFR 930 and 923.45 | TBC | This requirement is not an ARAR since the Commonwealth of Virginia does not have jurisdiction over the federally owned Naval Base. Compliance is on a voluntary basis. |
| **Virginia Endangered Species Act*** | | | | | |
| Critical habitat upon which endangered species or threatened species depend. | Action to conserve endangered species or threatened species, including consultation with the Virginia Board of Game and Inland Fisheries. | Determination of effect upon endangered or threatened species or its habitat. | Code of Virginia Sections 29.1-563 through 568<br><br>4 VAC 15-20-130 | Relevant and appropriate | No state or federally listed threatened or endangered species were found to exist at NASO except for transient individuals. Two rare/extremely rare plant species were identified at the base and are protected by the Virginia endangered plant and insect species act. Therefore, the requirements of the Virginia Endangered Species Act are relevant and appropriate to remediation activities occurring at SWMUs 2B, 2C, and 2E. |
| **Virginia Natural Areas Preserves Act*** | | | | | |
| Natural preserves area | Action to conserve natural preserves areas and restrict certain activities in these areas | Applicable to sites that meet natural preserve area criteria as determined by the Virginia Department of Conservation and Recreation | Code of Virginia Sections 10.1-209 through 217 | Not Applicable | SWMUs 2B, 2C, and 2E are not natural preserves areas. |
| **Virginia Endangered Plant and Insect Species Act; Virginia Board of Game and Inland Fisheries*** | | | | | |
| Endangered plant and insect species | Action to conserve endangered or protected plant and insect species | Applies to actions that affect endangered or protected plant and insect species. | Code of Virginia Sections 29.1-100 and 29.1-565<br><br>2 VAC 5-320-10 | Relevant and Appropriate | Two rare plant species were identified on base. Therefore, the requirements of the Virginia Endangered Plant and Insect Species Act are relevant and appropriate to remediation activities occurring at SWMUs 2B, 2C, and 2E. |

**Table 2**
**Virginia Location-Specific ARARs**
**Feasibility Study of SWMUs 2B, 2C, and 2E at NASO**

| Location | Requirement | Prerequisite | Citation | ARAR Determination | Comment |
|---|---|---|---|---|---|

* Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate that Navy accepts the entire statutes or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading; only substantive requirements of the specific citations are considered potential ARARs.

ARARs- Applicable or relevant and appropriate requirements
VAC – Virginia Administrative Code
USC – United States Code
CFR – Code of Federal Regulations

**Table 3**
**Federal Chemical-Specific ARARs**
**Feasibility Study of SWMUs 2B, 2C, and 2E at NASO**

| Location | Requirement | Prerequisite | Citation | ARAR Determination | Comment |
|---|---|---|---|---|---|
| **Groundwater** | | | | | |
| **Safe Drinking Water Act (SDWA), 42 USC 300*** | | | | | |
| | National primary drinking water standards are health-based standards for public water systems (maximum contaminant levels [MCLs]). | Public water system. | 40 CFR Part 141 Subparts B & G | Relevant and appropriate | MCLs are relevant and appropriate for groundwater determined to be a current or potential source of drinking water. The Commonwealth of Virginia considers all groundwater as a potential drinking water source. |
| | Maximum contaminant level goals [MCLGs] pertain to known or anticipated adverse health effects (also known as recommended maximum contaminant levels). | Public water system. | 40 CFR Part 141, Subpart F | To be considered | MCLGs are not federally enforceable. The standards will be considered for SWMUs 2B, 2C, and 2E because the Commonwealth of Virginia considers all groundwater as a potential drinking water source. |
| | National secondary drinking water regulations are standards for the aesthetic qualities of public water systems (secondary MCLs [SMCLs]). | Public water system. | 40 CFR Part 143, excluding 143.5(b) | To be considered | SMCLs are nonenforceable federal contaminant levels intended as guidelines for the states. The SMCLs will be considered for SWMUs 2B, 2C, and 2E because the Commonwealth of Virginia considers all groundwater as a potential drinking water source. |
| | Risk Based Concentrations | Public water system. | EPA Region III Risk Based Concentration Tables, 4/2000 | To be considered | Risk Based Concentrations are used for screening of various media based on likely uses (i.e. potable water use). |

* Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate that DON accepts the entire statutes or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading; only substantive requirements of the specific citations are considered potential ARARs.

ARARs-Applicable or relevant and appropriate requirements.

CFR- Code of Federal Regulations

MCL- Maximum Contaminant Level.

MCLG – Maximum Contaminant Level Goal

TBC- To Be Considered

SMCL – Secondary Maximum Contaminant Level

SDWA – Safe Drinking Water Act

**Table 4**
**Virginia Chemical-Specific ARARs**
**Feasibility Study of SWMUs 2B, 2C, and 2E at NASO**

| Location | Requirement | Prerequisite | Citation | ARAR Determination | Comment |
|---|---|---|---|---|---|
| **Groundwater** | | | | | |
| **Virginia Drinking Water Standards*** | | | | | |
| | Primary drinking water standards are health-based standards for public water supplies (primary maximum contaminant levels [PMCLs]). | Public water system. | 12 VAC 5-590-10<br>VR 355-18-001.02 | Relevant and appropriate | Virginia PMCLs are similar to federal MCLs. PMCLs are relevant and appropriate for groundwater determined to be a current or potential source of drinking water. The Commonwealth of Virginia considers all groundwater as a potential drinking water source. |
| | Secondary drinking water regulations are chemical based standards for qualities of public water supplies (secondary MCLs [SMCLs]). | Public water system. | 12 VAC 5-590-390<br>VR 355-18-004.06 | To be considered | Virginia SMCLs are similar to federal SMCLs. In Virginia, SMCLs are enforceable only for potable water supplies. The Commonwealth of Virginia considers all groundwater as a potential drinking water source. |
| **Virginia Groundwater Standards*** | | | | | |
| | Establishes groundwater standards for State Antidegradation Policy. | Standards are used when no MCL is available. | 9 VAC 25-260-190 to 220<br>VR 680-21-04.1 | Relevant and appropriate | Relevant and appropriate when MCLs are not available, or when standards are more stringent than MCLs. Standards are relevant and appropriate because the Commonwealth of Virginia considers all groundwater as a potential drinking water source. |

*Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate that Navy accepts the entire statutes or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading; only substantive requirements of the specific citations are considered potential ARARs.

ARARs - Applicable or relevant and appropriate requirements.
VAC – Virginia Administrative Code.
VR – Virginia Regulation.
MCL – Maximum Contaminant Level.
PMCL – Primary Maximum Contaminant Level.
SMCL – Secondary Maximum Contaminant Level.

**Table 5**
**Virginia Action-Specific ARARs**
**Feasibility Study of SWMUs 2B, 2C, and 2E at NASO**

| Action | Requirement | Prerequisite | Citation | ARAR Determination | Comment |
|---|---|---|---|---|---|
| **Virginia Pollutant Discharge Elimination System (VPDES) Permit Regulations*** | | | | | |
| Discharge of Treated Water to Surface Waters, and certain storm water discharges | Regulated point-source discharges through VPDES permitting program. Permit requirements include compliance with corresponding water quality standards, establishment of a discharge monitoring system, and completion of regular discharge monitoring records. | Applicable to discharge of treated water to surface water, and to storm water dis-charges from certain facilities, including landfills. | VR 680-14-01, VR 680-15-01; 9 VAC 25-31-10 to 940 | Applicable | The base has a VPDES permit including runoff from SWMU 1. |
| **Hazardous Waste Management Regulations, Solid Waste Disposal Facility Standards (9 VAC 20-80); Virginia Waste Management Act*** | | | | | |
| Hazardous Waste Staging Transport, and Disposal | These regulations and laws define the requirements for the management of hazardous wastes. Any disposal facility must be properly permitted and in compliance with all operational and monitoring requirements of the permit and regulations. | Wastes must meet definition of hazardous waste. | VR 672-10-01, 9 VAC 20-60-580 | Applicable | Free-product recovered from the skimmers at SWMU 2E will be managed according to Virginia Hazardous Waste Regulations. |

* Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs. Specific ARARs are addressed in the table below each general heading.

**Applicable, RA- Relevant and appropriate, TBC- To Be Considered

ARAR- Applicable or relevant and appropriate requirement

VAC – Virginia Administrative Code

VPDES – Virginia Pollutant Discharge Elimination System

VR – Virginia Regulation

# Appendix E—PRG Calculations

**Table A-1**
**Preliminary Remediation Goals**
**Groundwater**
**Adult Residential Scenario**
**SWMU 2B, NAS Oceana**

| Chemical | Chronic Oral RfD (RfDo) (mg/kg-day) | Chronic Dermal RfD (RfDd) (mg/kg-day) | Chronic Inhalation RfD (RfDi) (mg/kg-day) | Target Organ | DAevent ($L/cm^2$-day) | Shower Exposure (L/day) | Noncarcinogen PRG | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | PRG (mg/kg) | Target HQ[1] (mg/kg) |
| ***VOCs*** | | | | | | | | |
| Benzene | 3.00E-03 | 3.00E-03 | 1.70E-03 | blood | 1.3E-05 | 6.5E-03 | 3.2E-02 | 0.33 |
| 1,1-Dichloroethene | 9.00E-03 | 7.20E-03 | NA | liver | 1.2E-05 | 6.2E-03 | 9.6E-02 | 0.33 |
| cis-1,2-Dichloroethene | 1.00E-02 | 1.00E-02 | NA | blood | 7.2E-06 | 6.1E-03 | 1.1E-01 | 0.33 |
| Trichloroethene | 6.00E-03 | 4.80E-03 | NA | liver, kidney | 1.5E-05 | 5.5E-03 | 6.2E-02 | 0.33 |
| Vinyl Chloride | 3.00E-03 | 3.00E-03 | 2.80E-02 | liver | 4.1E-06 | 7.2E-03 | 3.5E-02 | 0.33 |
| ***Inorganics*** | | | | | | | | |
| Arsenic | 3.00E-04 | 2.85E-04 | NA | skin, vascular | 2.0E-07 | | 1.1E-02 | 1 |
| Iron | 3.00E-01 | 6.00E-02 | NA | GI, blood | 2.0E-07 | | 3.6E+00 | 0.33 |
| Manganese | 2.00E-02 | 7.00E-03 | 1.43E-05 | CNS | 2.0E-07 | | 7.3E-01 | 1 |

**Noncarcinogenic calculations:**

$$\text{Groundwater RBC (mg/L)} = \frac{THQ \times BW \times AT_n}{EF \times ED \times (An + Bn + Cn)}$$

**An =** 1/RfDo x IR

**Bn =** 1/RfDd x SA x DAevent

**Cn =** 1/RfDi x Shower Exposure

| EXPOSURE ASSUMPTIONS | |
|---|---|
| BW - Body weight (kilograms) | 70 |
| ATnc - Averaging time for noncarcinogens (days) | 8,760 |
| ATc - Averaging time for carcinogens (days) | 25,550 |
| EF - Exposure frequency (days/year) | 350 |
| ED - Exposure duration (year) | 24 |
| IR - Ingestion rate (L/day) | 2 |
| SA - Skin surface area ($cm^2$) | 20,000 |

NA - No reference dose or slope factor available.

1 Applicable HQ calculated so that total HQ for a target organ does not exceed 1.

Table A-1a
Calculation of DAevent
Groundwater, Adult
SWMU 2B, NAS Oceana

| Chemical of Potential Concern | Permeability Constant (PC) (cm/hr) | Lag Time (t) (hr) | Duration of Event (ET) (hr) | t* (hr) | B (dimensionless) | DAevent ($L/cm^2$-day) | Eq |
|---|---|---|---|---|---|---|---|
| Benzene | 2.1E-02 | 2.6E-01 | 2.0E-01 | 6.3E-01 | 1.3E-02 | 1.3E-05 | 2 |
| 1,1-Dichloroethene | 1.6E-02 | 3.4E-01 | 2.0E-01 | 8.2E-01 | 1.3E-02 | 1.2E-05 | 2 |
| cis-1,2-Dichloroethene | 1.0E-02 | 3.4E-01 | 2.0E-01 | 8.2E-01 | 7.2E-03 | 7.2E-06 | 2 |
| Trichloroethene | 1.6E-02 | 5.5E-01 | 2.0E-01 | 1.3E+00 | 2.6E-02 | 1.5E-05 | 2 |
| Vinyl chloride | 7.3E-03 | 2.1E-01 | 2.0E-01 | 5.1E-01 | 2.3E-03 | 4.1E-06 | 2 |
| Arsenic | 1.0E-03 | N/A | 2.0E-01 | N/A | N/A | 2.0E-07 | 1 |
| Iron | 1.0E-03 | N/A | 2.0E-01 | N/A | N/A | 2.0E-07 | 1 |
| Manganese | 1.0E-03 | N/A | 2.0E-01 | N/A | N/A | 2.0E-07 | 1 |

**Inorganics: DAevent (mg/cm2-event) =**
PC x ET x CF2 (eq 1)

**Organics: DAevent (mg/cm2-event) =**

ET<t*: DAevent (mg/cm2-event) =
2 x PC x (sqrt((6 x t x ET)/3.1415))
x CF2 (eq 2)

Permeability constants from EPA 1992, Dermal Exposure Assessment: Principals and Applications.
ORD, EPA/600/8-91/001B. Default value of 0.001 cm/hour used for inorganics without published values.
N/A - not applicable.

Table A-1b

Inhalation Exposure Concentrations from Foster and Chrostowski Shower Model

SWMU 2B, NAS Oceana

| Chemical | Molecular weight (MW) (g/mole) | Henry's Law Constant (H) (atm-m$^3$/mole) | Kg (VOC) (cm/hr) | Kl(VOC) (cm/hr) | KL (cm/hr) | Kal (cm/hr) | Cwd | S (L/m$^3$-min) | Inhalation Exposure (InExp) (L/kg-shower) | Shower Exposure (InExp X BW) (L/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 78 | 5.6E-03 | 1.4E+03 | 1.5E+01 | 1.4E+01 | 1.9E+01 | 4.8E-01 | 3.2E+00 | 9.3E-05 | 6.5E-03 |
| 1,1-Dichloroethene | 97 | 3.4E-02 | 1.3E+03 | 1.3E+01 | 1.3E+01 | 1.8E+01 | 4.5E-01 | 3.0E+00 | 8.8E-05 | 6.2E-03 |
| cis-1,2-Dichloroethene | 97 | 7.6E-03 | 1.3E+03 | 1.3E+01 | 1.3E+01 | 1.8E+01 | 4.4E-01 | 3.0E+00 | 8.7E-05 | 6.1E-03 |
| Trichloroethene | 131 | 1.0E-02 | 1.1E+03 | 1.2E+01 | 1.1E+01 | 1.5E+01 | 4.0E-01 | 2.7E+00 | 7.8E-05 | 5.5E-03 |
| Vinyl chloride | 63 | 8.2E-02 | 1.6E+03 | 1.7E+01 | 1.7E+01 | 2.3E+01 | 5.3E-01 | 3.5E+00 | 1.0E-04 | 7.2E-03 |

| Variables | Units | Exposure Assumptions |
|---|---|---|
| Kg(VOC) = gas-film mass transfer coefficient | cm/hr | Solved by Eq 1 |
| Kl(VOC) = liquid-film mass transfer coefficient | cm/hr | Solved by Eq 2 |
| KL = overall mass transfer coefficient | cm/hr | Solved by Eq 3 |
| Kal = adjusted overall mass transfer coeff. | cm/hr | Solved by Eq 4 |
| Tl = Calibration temp. of water | K (20C +273) | 293 |
| Ts = Shower water temperature | k (45C) | 318 |
| Us = water viscosity at Ts | centipoise | 0.596 |
| Ul = water viscosity at Tl | cp | 1.002 |
| Cwd = conc. leaving droplets after time sdt | | Solved by Eq 5 |
| sdt = shower droplet drop time | sec | 2 |
| d = shower droplet diameter | mm | 1 |
| FR = shower water flow rate | l/min | 20 |
| SV = shower room air volume | m$^3$ | 3 |
| S = indoor VOC generation rate | L/m$^3$-min | Solved by Eq 6 |
| VR = ventilation rate | l/min | 13.8 |
| BW = body weight | kg | 70 |
| Ds = duration of shower | min | 12 |
| Dt = total duration in shower room | min | 20 |
| R = air exchange rate | min$^{-1}$ | 0.0167 |
| Ca = indoor air concentration of VOCs | L-ug/mg-m$^3$ | Solved by Eq 7 |
| Einh = inhalation exposure per shower | L/kg-shower | Solved by Eq 8 |

| | | | |
|---|---|---|---|
| Equation 1: | Kg(VOC) = | 3000 * (18 / MW)$^{0.5}$ | |
| Equation 2: | Kl(VOC) = | 20 * (44 / MW)$^{0.5}$ | |
| Equation 3: | KL = | ((1 / Kl(VOC)) + (0.024 / (Kg (VOC) * H)))$^{-1}$ | |
| Equation 4: | Kal = | (KL * (((Tl * Us) / (Ts * Ul))$^{-0.5}$)) | |
| Equation 5: | Cwd = | ((1-EXP((-1 * Kal * sdt)/(60 * d)))) | |
| Equation 6: | S = | (Cwd * FR / SV) | |
| Equation 7: | see time series example on Table I-GW-6 | | |
| Equation 8: | Einh = | If t>Ds | (((VR * S) / (BW * R * 1000000)) * ((Ds + (EXP(-R * Dt) / R)-(EXP(R * (Ds - Dt))) / R))) |

**Table A-2**
**Preliminary Remediation Goals**
**Groundwater**
**Child Residential Scenario**
**SWMU 2B, NAS Oceana**

| Chemical | Chronic Oral RfD (RfDo) (mg/kg-day) | Chronic Dermal RfD (RfDd) (mg/kg-day) | Chronic Inhalation RfD (RfDi) (mg/kg-day) | Target Organ | DAevent (L/cm$^2$-day) | Noncarcinogen PRG PRG (mg/kg) | Noncarcinogen PRG Target HQ[1] (mg/kg) |
|---|---|---|---|---|---|---|---|
| ***VOCs*** | | | | | | | |
| Benzene | 3.00E-03 | 3.00E-03 | 1.70E-03 | blood | 1.7E-05 | 1.4E-02 | 0.33 |
| 1,1-Dichloroethene | 9.00E-03 | 7.20E-03 | NA | liver | 1.5E-05 | 4.1E-02 | 0.33 |
| cis-1,2-Dichloroethene | 1.00E-02 | 1.00E-02 | NA | blood | 9.3E-06 | 4.9E-02 | 0.33 |
| Trichloroethene | 6.00E-03 | 4.80E-03 | NA | liver, kidney | 1.9E-05 | 2.6E-02 | 0.33 |
| Vinyl Chloride | 3.00E-03 | 3.00E-03 | 2.80E-02 | liver | 5.3E-06 | 1.5E-02 | 0.33 |
| ***Inorganics*** | | | | | | | |
| Arsenic | 3.00E-04 | 2.85E-04 | NA | skin, vascular | 3.3E-07 | 4.7E-03 | 1 |
| Iron | 3.00E-01 | 6.00E-02 | NA | GI, blood | 3.3E-07 | 1.5E+00 | 0.33 |
| Manganese | 2.00E-02 | 7.00E-03 | 1.43E-05 | CNS | 3.3E-07 | 3.1E-01 | 1 |

**Noncarcinogenic calculations:**

$$\text{Groundwater RBC (mg/L)} = \frac{THQ \times BW \times AT_n}{EF \times ED \times (An + Bn)}$$

$$An = 1/RfDo \times IR$$

$$Bn = 1/RfDd \times SA \times DAevent$$

| EXPOSURE ASSUMPTIONS | |
|---|---|
| BW - Body weight (kilograms) | 15 |
| ATnc - Averaging time for noncarcinogens (days) | 2,190 |
| ATc - Averaging time for carcinogens (days) | 25,550 |
| EF - Exposure frequency (days/year) | 350 |
| ED - Exposure duration (year) | 6 |
| IR - Ingestion rate (L/day) | 1 |
| SA - Skin surface area (cm$^2$) | 7,930 |

NA - No reference dose or slope factor available.

1 Applicable HQ calculated so that total HQ for a target organ does not exceed 1.

Table A-2a
Calculation of DAevent
Groundwater, Child
SWMU 2B, NAS Oceana

| Chemical of Potential Concern | Permeability Constant (PC) (cm/hr) | Lag Time (t) (hr) | Duration of Event (ET) (hr) | t* (hr) | B (dimensionless) | DAevent ($L/cm^2$-day) | Eq |
|---|---|---|---|---|---|---|---|
| Benzene | 2.1E-02 | 2.6E-01 | 3.3E-01 | 6.3E-01 | 1.3E-02 | 1.7E-05 | 2 |
| 1,1-Dichloroethene | 1.6E-02 | 3.4E-01 | 3.3E-01 | 8.2E-01 | 1.3E-02 | 1.5E-05 | 2 |
| cis-1,2-Dichloroethene | 1.0E-02 | 3.4E-01 | 3.3E-01 | 8.2E-01 | 7.2E-03 | 9.3E-06 | 2 |
| Trichloroethene | 1.6E-02 | 5.5E-01 | 3.3E-01 | 1.3E+00 | 2.6E-02 | 1.9E-05 | 2 |
| Vinyl chloride | 7.3E-03 | 2.1E-01 | 3.3E-01 | 5.1E-01 | 2.3E-03 | 5.3E-06 | 2 |
| Arsenic | 1.0E-03 | N/A | 3.3E-01 | N/A | N/A | 3.3E-07 | 1 |
| Iron | 1.0E-03 | N/A | 3.3E-01 | N/A | N/A | 3.3E-07 | 1 |
| Manganese | 1.0E-03 | N/A | 3.3E-01 | N/A | N/A | 3.3E-07 | 1 |

**Inorganics: DAevent (mg/cm2-event) =**

PC x ET x CF2 (eq 1)

**Organics: DAevent (mg/cm2-event) =**

ET<t*: DAevent (mg/cm2-event) =
2 x PC x (sqrt((6 x t x ET)/3.1415))
x CF2 (eq 2)

Permeability constants from EPA 1992, Dermal Exposure Assessment: Principals and Applications. ORD, EPA/600/8-91/001B. Default value of 0.001 cm/hour used for inorganics without published values.
N/A - not applicable.

**Table A-3**
**Preliminary Remediation Goals**
**Groundwater**
**Lifetime Residential Scenario**
**SWMU 2B, NAS Oceana**

| Chemical | Oral Slope Factor (CSFo) (kg-day/mg) | Dermal Slope Factor (CSFd) (kg-day/mg) | Inhalation Slope Factor (CSFi) (kg-day/mg) | DAevent-a ($L/cm^2$-day) | DAevent-c ($L/cm^2$-day) | Shower Exposure (L/day) | Carcinogen PRG Risk = 1E-06 (mg/L) | Carcinogen PRG Risk = 1E-05 (mg/L) | Carcinogen PRG Risk = 1E-04 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| ***VOCs*** | | | | | | | | | |
| Benzene | 5.50E-02 | 5.5E-02 | 2.90E-02 | 1.3E-05 | 1.7E-05 | 6.5E-03 | 1.1E-03 | 1.1E-02 | 1.1E-01 |
| 1,1-Dichloroethene | 6.00E-01 | 7.5E-01 | 1.75E-01 | 1.2E-05 | 1.5E-05 | 6.2E-03 | 9.7E-05 | 9.7E-04 | 9.7E-03 |
| cis-1,2-Dichloroethene | NA | NA | NA | 7.2E-06 | 9.3E-06 | 6.1E-03 | | | |
| Trichloroethene | 1.10E-02 | 1.4E-02 | 6.00E-03 | 1.5E-05 | 1.9E-05 | 5.5E-03 | 5.1E-03 | 5.1E-02 | 5.1E-01 |
| Vinyl Chloride | 1.50E+00 | 1.5E+00 | 3.00E-02 | 4.1E-06 | 5.3E-06 | 7.2E-03 | 4.3E-05 | 4.3E-04 | 4.3E-03 |
| ***Inorganics*** | | | | | | | | | |
| Arsenic | 1.50E+00 | 1.6E+00 | 1.51E+01 | 2.0E-07 | 3.3E-07 | | 4.5E-05 | 4.5E-04 | 4.5E-03 |
| Iron | NA | NA | NA | 2.0E-07 | 3.3E-07 | | | | |
| Manganese | NA | NA | NA | 2.0E-07 | 3.3E-07 | | | | |

**Carcinogen calculations:**

$$\text{Groundwater RBC (mg/L)} = \frac{TR \times AT_c}{EF \times (Ac + Bc + Cc)}$$

**Ac =** CSFo x IRadj

**Bc =** CSFd x [(SAa x DAevent-a x EDa)/BWa + (SAc x DAevent-c X EDc)/BWc]

**Cc =** CSFi x Shower Exposure x EDa x 1/BWa

| EXPOSURE ASSUMPTIONS | Lifetime | Adult (a) | Child (c) |
|---|---|---|---|
| BW - Body weight (kilograms) | | 70 | 15 |
| ATnc - Averaging time for noncarcinogens (days) | | 8,760 | 2,190 |
| ATc - Averaging time for carcinogens (days) | | 25,550 | 25,550 |
| EF - Exposure frequency (days/year) | | 350 | 350 |
| ED - Exposure duration (year) | | 24 | 6 |
| IR - Ingestion rate (L/day) | | 2 | 1 |
| IRdj - Ingestion rate (L-year/kg-day) | 1.09 | | |
| SA - Skin surface area ($cm^2$) | | 20,000 | 7,930 |
| ET - Exposure Time (hours/day) | | 0.20 | 0.33 |

NA - No reference dose or slope factor available.

Table A-3a
Calculation of DAevent
Groundwater, Child/Adult
SWMU 2B, NAS Oceana

| Chemical of Potential Concern | Permeability Constant (PC) (cm/hr) | Lag Time (t) (hr) | Duration of Event (ETa) (hr) | Duration of Event (ETc) (hr) | t* (hr) | B (dimensionless) | Daevent Adult ($L/cm^2$-day) | Daevent Child ($L/cm^2$-day) | Eq |
|---|---|---|---|---|---|---|---|---|---|
| Benzene | 2.1E-02 | 2.6E-01 | 2.0E-01 | 3.3E-01 | 6.3E-01 | 1.3E-02 | 1.3E-05 | 1.7E-05 | 2 |
| 1,1-Dichloroethene | 1.6E-02 | 3.4E-01 | 2.0E-01 | 3.3E-01 | 8.2E-01 | 1.3E-02 | 1.2E-05 | 1.5E-05 | 2 |
| cis-1,2-Dichloroethene | 1.0E-02 | 3.4E-01 | 2.0E-01 | 3.3E-01 | 8.2E-01 | 7.2E-03 | 7.2E-06 | 9.3E-06 | 2 |
| Trichloroethene | 1.6E-02 | 5.5E-01 | 2.0E-01 | 3.3E-01 | 1.3E+00 | 2.6E-02 | 1.5E-05 | 1.9E-05 | 2 |
| Vinyl chloride | 7.3E-03 | 2.1E-01 | 2.0E-01 | 3.3E-01 | 5.1E-01 | 2.3E-03 | 4.1E-06 | 5.3E-06 | 2 |
| Arsenic | 1.0E-03 | N/A | 2.0E-01 | 3.3E-01 | N/A | N/A | 2.0E-07 | 3.3E-07 | 1 |
| Iron | 1.0E-03 | N/A | 2.0E-01 | 3.3E-01 | N/A | N/A | 2.0E-07 | 3.3E-07 | 1 |
| Manganese | 1.0E-03 | N/A | 2.0E-01 | 3.3E-01 | N/A | N/A | 2.0E-07 | 3.3E-07 | 1 |

**Inorganics: DAevent (mg/cm2-event) =**
PC x ET x CF2 (eq 1)

**Organics: DAevent (mg/cm2-event) =**

ET<t*: DAevent (mg/cm2-event) =
2 x PC x (sqrt((6 x t x ET)/3.1415))
x CF2 (eq 2)

Permeability constants from EPA 1992, Dermal Exposure Assessment: Principals and Applications.
ORD, EPA/600/8-91/001B. Default value of 0.001 cm/hour used for inorganics without published values.
N/A - not applicable.

**Table A-4**
**Recommended Preliminary Remediation Goals**
**Groundwater**
**Residential Scenario**
**SWMU 2B, NAS Oceana**

| Chemical | Recommended PRG (mg/L) | Basis |
|---|---|---|
| ***VOCs*** | | |
| Benzene | 1.1E-02 | Lifetime, CR = $10^{-5}$ |
| 1,1-Dichloroethene | 9.7E-04 | Lifetime, CR = $10^{-5}$ |
| cis-1,2-Dichloroethene | 4.9E-02 | Child, HQ=0.33 |
| Trichloroethene | 2.6E-02 | Child, HQ=0.33 |
| Vinyl Chloride | 4.3E-04 | Lifetime, CR = $10^{-5}$ |
| ***Inorganics*** | | |
| Arsenic | 4.5E-04 | Lifetime, CR = $10^{-5}$ |
| Iron | 1.5E+00 | Child, HQ=0.33 |
| Manganese | 3.1E-01 | Child, HQ=1 |

Child scenario selected for noncarcinogenic PRGs since child scenario more conservative (lower PRGs).
For constituents with basis of CR = $10^{-5}$, PRG for CR =$10^{-5}$ less than PRG for applicable HQ.
Used CR of $10^{-5}$ to keep overall carcinogenic risk below $10^{-4}$.
Applicabe HQ chosen to keep total HI for each target organ below 1.

**Table A-1**
**Preliminary Remediation Goals**
**Groundwater**
**Adult Residential Scenario**
**SWMU 2C, NAS Oceana**

| Chemical | Chronic Oral RfD (RfDo) (mg/kg-day) | Chronic Dermal RfD (RfDd) (mg/kg-day) | Chronic Inhalation RfD (RfDi) (mg/kg-day) | Target Organ | DAevent ($L/cm^2$-day) | Shower Exposure (L/day) | Noncarcinogen PRG PRG (mg/kg) | Noncarcinogen PRG Target HQ[1] (mg/kg) |
|---|---|---|---|---|---|---|---|---|
| ***VOCs*** | | | | | | | | |
| 1,4-Dichlorobenzene | 3.00E-02 | 2.40E-02 | 2.29E-01 | liver | 6.4E-05 | 5.3E-03 | 1.0E-01 | 0.17 |
| 1,1-Dichloroethene | 9.00E-03 | 7.20E-03 | NA | liver | 1.2E-05 | 6.2E-03 | 4.8E-02 | 0.17 |
| cis-1,2-Dichloroethene | 1.00E-02 | 1.00E-02 | NA | blood | 7.2E-06 | 6.1E-03 | 1.7E-01 | 0.50 |
| Tetrachloroethene | 1.00E-02 | 1.00E-02 | 1.40E-01 | liver, whole body | 5.6E-05 | 5.1E-03 | 3.9E-02 | 0.17 |
| Trichloroethene | 6.00E-03 | 4.80E-03 | NA | liver, kidney | 1.5E-05 | 5.5E-03 | 3.1E-02 | 0.17 |
| Vinyl Chloride | 3.00E-03 | 3.00E-03 | 2.80E-02 | liver | 4.1E-06 | 7.2E-03 | 1.8E-02 | 0.17 |
| ***SVOCs*** | | | | | | | | |
| Benzo(b)fluoranthene | NA | NA | NA | NA | 2.6E-03 | | | |
| Naphthalene | 2.00E-02 | 1.60E-02 | 9.00E-04 | whole body | 6.2E-05 | | 2.1E-01 | 0.50 |
| ***Inorganics*** | | | | | | | | |
| Arsenic | 3.00E-04 | 2.85E-04 | NA | skin, vascular | 2.0E-07 | | 1.1E-02 | 1 |
| Iron | 3.00E-01 | 6.00E-02 | NA | GI, blood, liver | 2.0E-07 | | 1.8E+00 | 0.17 |
| Manganese | 2.00E-02 | 7.00E-03 | 1.43E-05 | CNS | 2.0E-07 | | 7.3E-01 | 1 |

**Noncarcinogenic calculations:**

$$\text{Groundwater RBC (mg/L)} = \frac{THQ \times BW \times AT_n}{EF \times ED \times (An + Bn + Cn)}$$

**An =** 1/RfDo x IR

**Bn =** 1/RfDd x SA x DAevent

**Cn =** 1/RfDi x Shower Exposure

| EXPOSURE ASSUMPTIONS | |
|---|---|
| BW - Body weight (kilograms) | 70 |
| ATnc - Averaging time for noncarcinogens (days) | 8,760 |
| ATc - Averaging time for carcinogens (days) | 25,550 |
| EF - Exposure frequency (days/year) | 350 |
| ED - Exposure duration (year) | 24 |
| IR - Ingestion rate (L/day) | 2 |
| SA - Skin surface area ($cm^2$) | 20,000 |

NA - No reference dose or slope factor available.

Table A-1a
Calculation of DAevent
Groundwater, Adult
SWMU 2C, NAS Oceana

| Chemical of Potential Concern | Permeability Constant (PC) (cm/hr) | Lag Time (t) (hr) | Duration of Event (ET) (hr) | t* (hr) | B (dimensionless) | DAevent (L/cm$^2$-day) | Eq |
|---|---|---|---|---|---|---|---|
| 1,4-Dichlorobenzene | 6.2E-02 | 6.9E-01 | 2.0E-01 | 3.3E+00 | 2.5E-01 | 6.4E-05 | 2 |
| 1,1-Dichloroethene | 1.6E-02 | 3.4E-01 | 2.0E-01 | 8.2E-01 | 1.3E-02 | 1.2E-05 | 2 |
| cis-1,2-Dichloroethene | 1.0E-02 | 3.4E-01 | 2.0E-01 | 8.2E-01 | 7.2E-03 | 7.2E-06 | 2 |
| Tetrachloroethene | 4.8E-02 | 9.0E-01 | 2.0E-01 | 4.3E+00 | 2.5E-01 | 5.6E-05 | 2 |
| Trichloroethene | 1.6E-02 | 5.5E-01 | 2.0E-01 | 1.3E+00 | 2.6E-02 | 1.5E-05 | 2 |
| Vinyl chloride | 7.3E-03 | 2.1E-01 | 2.0E-01 | 5.1E-01 | 2.3E-03 | 4.1E-06 | 2 |
| Benzo(b)fluoranthene | 1.2E+00 | 3.0E+00 | 2.0E-01 | 1.4E+01 | 1.3E+02 | 2.6E-03 | 2 |
| Naphthalene | 6.9E-02 | 5.3E-01 | 2.0E-01 | 2.2E+00 | 2.0E-01 | 6.2E-05 | 2 |
| Arsenic | 1.0E-03 | N/A | 2.0E-01 | N/A | N/A | 2.0E-07 | 1 |
| Iron | 1.0E-03 | N/A | 2.0E-01 | N/A | N/A | 2.0E-07 | 1 |
| Manganese | 1.0E-03 | N/A | 2.0E-01 | N/A | N/A | 2.0E-07 | 1 |

**Inorganics: DAevent (mg/cm2-event) =**
PC x ET x CF2 (eq 1)

**Organics: DAevent (mg/cm2-event) =**

ET<t*: DAevent (mg/cm2-event) =
2 x PC x (sqrt((6 x t x ET)/3.1415))
x CF2 (eq 2)

Permeability constants from EPA 1992, Dermal Exposure Assessment: Principals and Applications.
ORD, EPA/600/8-91/001B. Default value of 0.001 cm/hour used for inorganics without published values.
N/A - not applicable.

Table A-1b

Inhalation Exposure Concentrations from Foster and Chrostowski Shower Model

SWMU 2C, NAS Oceana

| Chemical | Molecular weight (MW) (g/mole) | Henry's Law Constant (H) (atm-m$^3$/mole) | Kg (VOC) (cm/hr) | Kl(VOC) (cm/hr) | KL (cm/hr) | Kal (cm/hr) | Cwd | S (L/m$^3$-min) | Inhalation Exposure (InExp) (L/kg-shower) | Shower Exposure (InExp X BW) (L/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1,4-Dichlorobenzene | 147 | 1.2E-01 | 1.0E+03 | 1.1E+01 | 1.1E+01 | 1.5E+01 | 3.9E-01 | 2.6E+00 | 7.6E-05 | 5.3E-03 |
| 1,1-Dichloroethene | 97 | 3.4E-02 | 1.3E+03 | 1.3E+01 | 1.3E+01 | 1.8E+01 | 4.5E-01 | 3.0E+00 | 8.8E-05 | 6.2E-03 |
| cis-1,2-Dichloroethene | 97 | 7.6E-03 | 1.3E+03 | 1.3E+01 | 1.3E+01 | 1.8E+01 | 4.4E-01 | 3.0E+00 | 8.7E-05 | 6.1E-03 |
| Tetrachloroethene | 166 | 6.1E-01 | 9.9E+02 | 1.0E+01 | 1.0E+01 | 1.4E+01 | 3.7E-01 | 2.5E+00 | 7.3E-05 | 5.1E-03 |
| Trichloroethene | 131 | 1.0E-02 | 1.1E+03 | 1.2E+01 | 1.1E+01 | 1.5E+01 | 4.0E-01 | 2.7E+00 | 7.8E-05 | 5.5E-03 |
| Vinyl chloride | 63 | 8.2E-02 | 1.6E+03 | 1.7E+01 | 1.7E+01 | 2.3E+01 | 5.3E-01 | 3.5E+00 | 1.0E-04 | 7.2E-03 |

| Variables | Units | Exposure Assumptions |
|---|---|---|
| Kg(VOC) = gas-film mass transfer coefficient | cm/hr | Solved by Eq 1 |
| Kl(VOC) = liquid-film mass transfer coefficient | cm/hr | Solved by Eq 2 |
| KL = overall mass transfer coefficient | cm/hr | Solved by Eq 3 |
| Kal = adjusted overall mass transfer coeff. | cm/hr | Solved by Eq 4 |
| Tl = Calibration temp. of water | K (20C +273) | 293 |
| Ts = Shower water temperature | k (45C) | 318 |
| Us = water viscosity at Ts | centipoise | 0.596 |
| Ul = water viscosity at Tl | cp | 1.002 |
| Cwd = conc. leaving droplets after time sdt | | Solved by Eq 5 |
| sdt = shower droplet drop time | sec | 2 |
| d = shower droplet diameter | mm | 1 |
| FR = shower water flow rate | l/min | 20 |
| SV = shower room air volume | m$^3$ | 3 |
| S = indoor VOC generation rate | L/m$^3$-min | Solved by Eq 6 |
| VR = ventilation rate | l/min | 13.8 |
| BW = body weight | kg | 70 |
| Ds = duration of shower | min | 12 |
| Dt = total duration in shower room | min | 20 |
| R = air exchange rate | min$^{-1}$ | 0.0167 |
| Ca = indoor air concentration of VOCs | L-ug/mg-m$^3$ | Solved by Eq 7 |
| Einh = inhalation exposure per shower | L/kg-shower | Solved by Eq 8 |

| | | | |
|---|---|---|---|
| Equation 1: | Kg(VOC) = | 3000 * (18 / MW)$^{0.5}$ | |
| Equation 2: | Kl(VOC) = | 20 * (44 / MW)$^{0.5}$ | |
| Equation 3: | KL = | ((1 / Kl(VOC)) + (0.024 / (Kg (VOC) * H)))$^{-1}$ | |
| Equation 4: | Kal = | (KL * (((Tl * Us) / (Ts * Ul))$^{-0.5}$)) | |
| Equation 5: | Cwd = | ((1-EXP((-1 * Kal * sdt)/(60 * d)))) | |
| Equation 6: | S = | (Cwd * FR / SV) | |
| Equation 7: | see time series example on Table I-GW-6 | | |
| Equation 8: | Einh = | If t>Ds | (((VR * S) / (BW * R * 1000000)) * ((Ds + (EXP(-R * Dt) / R)-(EXP(R * (Ds - Dt))) / R))) |

**Table A-2**
**Preliminary Remediation Goals**
**Groundwater**
**Child Residential Scenario**
**SWMU 2C, NAS Oceana**

| Chemical | Chronic Oral RfD (RfDo) (mg/kg-day) | Chronic Dermal RfD (RfDd) (mg/kg-day) | Chronic Inhalation RfD (RfDi) (mg/kg-day) | Target Organ | DAevent (L/cm$^2$-day) | Noncarcinogen PRG PRG (mg/kg) | Noncarcinogen PRG Target HQ[1] (mg/kg) |
|---|---|---|---|---|---|---|---|
| ***VOCs*** | | | | | | | |
| 1,4-Dichlorobenzene | 3.00E-02 | 2.40E-02 | 2.29E-01 | liver | 8.2E-05 | 4.3E-02 | 0.17 |
| 1,1-Dichloroethene | 9.00E-03 | 7.20E-03 | NA | liver | 1.5E-05 | 2.0E-02 | 0.17 |
| cis-1,2-Dichloroethene | 1.00E-02 | 1.00E-02 | NA | blood | 9.3E-06 | 7.3E-02 | 0.50 |
| Tetrachloroethene | 1.00E-02 | 1.00E-02 | 1.40E-01 | liver, whole body | 7.2E-05 | 1.7E-02 | 0.17 |
| Trichloroethene | 6.00E-03 | 4.80E-03 | NA | liver, kidney | 1.9E-05 | 1.3E-02 | 0.17 |
| Vinyl Chloride | 3.00E-03 | 3.00E-03 | 2.80E-02 | liver | 5.3E-06 | 7.5E-03 | 0.17 |
| ***SVOCs*** | | | | | | | |
| Benzo(b)fluoranthene | NA | NA | NA | NA | 3.3E-03 | | |
| Naphthalene | 2.00E-02 | 1.60E-02 | 9.00E-04 | whole body | 8.0E-05 | 8.7E-02 | 0.50 |
| ***Inorganics*** | | | | | | | |
| Arsenic | 3.00E-04 | 2.85E-04 | NA | skin, vascular | 3.3E-07 | 4.7E-03 | 1 |
| Iron | 3.00E-01 | 6.00E-02 | NA | GI, blood, liver | 3.3E-07 | 7.7E-01 | 0.17 |
| Manganese | 2.00E-02 | 7.00E-03 | 1.43E-05 | CNS | 3.3E-07 | 3.1E-01 | 1 |

**Noncarcinogenic calculations:**

$$\text{Groundwater RBC (mg/L)} = \frac{THQ \times BW \times AT_n}{EF \times ED \times (An + Bn)}$$

**An =** 1/RfDo x IR

**Bn =** 1/RfDd x SA x DAevent

| **EXPOSURE ASSUMPTIONS** | |
|---|---|
| BW - Body weight (kilograms) | 15 |
| ATnc - Averaging time for noncarcinogens (days) | 2,190 |
| ATc - Averaging time for carcinogens (days) | 25,550 |
| EF - Exposure frequency (days/year) | 350 |
| ED - Exposure duration (year) | 6 |
| IR - Ingestion rate (L/day) | 1 |
| SA - Skin surface area (cm$^2$) | 7,930 |

NA - No reference dose or slope factor available.

Table A-2a
Calculation of DAevent
Groundwater, Child
SWMU 2C, NAS Oceana

| Chemical of Potential Concern | Permeability Constant (PC) (cm/hr) | Lag Time (t) (hr) | Duration of Event (ET) (hr) | t* (hr) | B (dimensionless) | DAevent ($L/cm^2$-day) | Eq |
|---|---|---|---|---|---|---|---|
| 1,4-Dichlorobenzene | 6.2E-02 | 6.9E-01 | 3.3E-01 | 3.3E+00 | 2.5E-01 | 8.2E-05 | 2 |
| 1,1-Dichloroethene | 1.6E-02 | 3.4E-01 | 3.3E-01 | 8.2E-01 | 1.3E-02 | 1.5E-05 | 2 |
| cis-1,2-Dichloroethene | 1.0E-02 | 3.4E-01 | 3.3E-01 | 8.2E-01 | 7.2E-03 | 9.3E-06 | 2 |
| Tetrachloroethene | 4.8E-02 | 9.0E-01 | 3.3E-01 | 4.3E+00 | 2.5E-01 | 7.2E-05 | 3 |
| Trichloroethene | 1.6E-02 | 5.5E-01 | 3.3E-01 | 1.3E+00 | 2.6E-02 | 1.9E-05 | 2 |
| Vinyl chloride | 7.3E-03 | 2.1E-01 | 3.3E-01 | 5.1E-01 | 2.3E-03 | 5.3E-06 | 2 |
| Benzo(b)fluoranthene | 1.2E+00 | 3.0E+00 | 3.3E-01 | 1.4E+01 | 1.3E+02 | 3.3E-03 | 2 |
| Naphthalene | 6.9E-02 | 5.3E-01 | 3.3E-01 | 2.2E+00 | 2.0E-01 | 8.0E-05 | 2 |
| Arsenic | 1.0E-03 | N/A | 3.3E-01 | N/A | N/A | 3.3E-07 | 1 |
| Iron | 1.0E-03 | N/A | 3.3E-01 | N/A | N/A | 3.3E-07 | 1 |
| Manganese | 1.0E-03 | N/A | 3.3E-01 | N/A | N/A | 3.3E-07 | 1 |

**Inorganics: DAevent (mg/cm2-event) =**
PC x ET x CF2 (eq 1)

**Organics: DAevent (mg/cm2-event) =**

ET<t*: DAevent (mg/cm2-event) =
2 x PC x (sqrt((6 x t x ET)/3.1415))
x CF2 (eq 2)

Permeability constants from EPA 1992, Dermal Exposure Assessment: Principals and Applications. ORD, EPA/600/8-91/001B. Default value of 0.001 cm/hour used for inorganics without published values.
N/A - not applicable.

**Table A-3**
**Preliminary Remediation Goals**
**Groundwater**
**Lifetime Residential Scenario**
**SWMU 2C, NAS Oceana**

| Chemical | Oral Slope Factor (CSFo) (kg-day/mg) | Dermal Slope Factor (CSFd) (kg-day/mg) | Inhalation Slope Factor (CSFi) (kg-day/mg) | DAevent-a (L/cm$^2$-day) | DAevent-c (L/cm$^2$-day) | Shower Exposure (L/day) | Carcinogen PRG Risk = 1E-06 (mg/L) | Carcinogen PRG Risk = 1E-05 (mg/L) | Carcinogen PRG Risk = 1E-04 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| ***VOCs*** | | | | | | | | | |
| 1,4-Dichlorobenzene | 2.40E-02 | 3.0E-02 | 2.20E-02 | 6.4E-05 | 8.2E-05 | 5.3E-03 | 1.6E-03 | 1.6E-02 | 1.6E-01 |
| 1,1-Dichloroethene | 6.00E-01 | 7.5E-01 | 1.75E-01 | 1.2E-05 | 1.5E-05 | 6.2E-03 | 9.7E-05 | 9.7E-04 | 9.7E-03 |
| cis-1,2-Dichloroethene | NA | NA | NA | 7.2E-06 | 9.3E-06 | 6.1E-03 | | | |
| Tetrachoroethene | 5.20E-02 | 5.2E-02 | 2.00E-03 | 5.6E-05 | 7.2E-05 | 5.1E-03 | 8.2E-04 | 8.2E-03 | 8.2E-02 |
| Trichloroethene | 1.10E-02 | 1.4E-02 | 6.00E-03 | 1.5E-05 | 1.9E-05 | 5.5E-03 | 5.1E-03 | 5.1E-02 | 5.1E-01 |
| Vinyl Chloride | 1.50E+00 | 1.5E+00 | 3.00E-02 | 4.1E-06 | 5.3E-06 | 7.2E-03 | 4.3E-05 | 4.3E-04 | 4.3E-03 |
| ***SVOCs*** | | | | | | | | | |
| Benzo(b)fluoranthene | 7.30E-01 | NA | NA | 2.6E-03 | 3.3E-03 | | 9.2E-05 | 9.2E-04 | 9.2E-03 |
| Naphthalene | NA | NA | NA | 6.2E-05 | 8.0E-05 | | | | |
| ***Inorganics*** | | | | | | | | | |
| Arsenic | 1.50E+00 | 1.6E+00 | 1.51E+01 | 2.0E-07 | 3.3E-07 | | 4.5E-05 | 4.5E-04 | 4.5E-03 |
| Iron | NA | NA | NA | 2.0E-07 | 3.3E-07 | | | | |
| Manganese | NA | NA | NA | 2.0E-07 | 3.3E-07 | | | | |

**Carcinogen calculations:**

$$\text{Groundwater RBC (mg/L)} = \frac{TR \times AT_c}{EF \times (Ac + Bc + Cc)}$$

**Ac =** CSFo x IRadj

**Bc =** CSFd x [(SAa x DAevent-a x EDa)/BWa + (SAc x DAevent-c X EDc)/BWc]

**Cc =** CSFi x Shower Exposure x EDa x 1/BWa

| EXPOSURE ASSUMPTIONS | Lifetime | Adult (a) | Child (c) |
|---|---|---|---|
| BW - Body weight (kilograms) | | 70 | 15 |
| ATnc - Averaging time for noncarcinogens (days) | | 8,760 | 2,190 |
| ATc - Averaging time for carcinogens (days) | | 25,550 | 25,550 |
| EF - Exposure frequency (days/year) | | 350 | 350 |
| ED - Exposure duration (year) | | 24 | 6 |
| IR - Ingestion rate (L/day) | | 2 | 1 |
| IRdj - Ingestion rate (L-year/kg-day) | 1.09 | | |
| SA - Skin surface area (cm$^2$) | | 20,000 | 7,930 |
| ET - Exposure Time (hours/day) | | 0.20 | 0.33 |

NA - No reference dose or slope factor available.

Table A-3a
Calculation of DAevent
Groundwater, Child/Adult
SWMU 2C, NAS Oceana

| Chemical of Potential Concern | Permeability Constant (PC) (cm/hr) | Lag Time (t) (hr) | Duration of Event (ETa) (hr) | Duration of Event (ETc) (hr) | t* (hr) | B (dimensionless) | Daevent Adult ($L/cm^2$-day) | Daevent Child ($L/cm^2$-day) | Eq |
|---|---|---|---|---|---|---|---|---|---|
| 1,4-Dichlorobenzene | 6.2E-02 | 6.9E-01 | 2.0E-01 | 3.3E-01 | 3.3E+00 | 2.5E-01 | 6.4E-05 | 8.2E-05 | 2 |
| 1,1-Dichloroethene | 1.6E-02 | 3.4E-01 | 2.0E-01 | 3.3E-01 | 8.2E-01 | 1.3E-02 | 1.2E-05 | 1.5E-05 | 2 |
| cis-1,2-Dichloroethene | 1.0E-02 | 3.4E-01 | 2.0E-01 | 3.3E-01 | 8.2E-01 | 7.2E-03 | 7.2E-06 | 9.3E-06 | 2 |
| Tetrachlorothene | 4.8E-02 | 9.0E-01 | 2.0E-01 | 3.3E-01 | 4.3E+00 | 2.5E-01 | 5.6E-05 | 7.2E-05 | 2 |
| Trichloroethene | 1.6E-02 | 5.5E-01 | 2.0E-01 | 3.3E-01 | 1.3E+00 | 2.6E-02 | 1.5E-05 | 1.9E-05 | 2 |
| Vinyl chloride | 7.3E-03 | 2.1E-01 | 2.0E-01 | 3.3E-01 | 5.1E-01 | 2.3E-03 | 4.1E-06 | 5.3E-06 | 2 |
| Benzo(b)fluoranthene | 1.2E+00 | 3.0E+00 | 2.0E-01 | 3.3E-01 | 1.4E+01 | 1.3E+02 | 2.6E-03 | 3.3E-03 | 2 |
| Naphthalene | 6.9E-02 | 5.3E-01 | 2.0E-01 | 3.3E-01 | 2.2E+00 | 2.0E-01 | 6.2E-05 | 8.0E-05 | 2 |
| Arsenic | 1.0E-03 | N/A | 2.0E-01 | 3.3E-01 | N/A | N/A | 2.0E-07 | 3.3E-07 | 1 |
| Iron | 1.0E-03 | N/A | 2.0E-01 | 3.3E-01 | N/A | N/A | 2.0E-07 | 3.3E-07 | 1 |
| Manganese | 1.0E-03 | N/A | 2.0E-01 | 3.3E-01 | N/A | N/A | 2.0E-07 | 3.3E-07 | 1 |

**Inorganics: DAevent (mg/cm2-event) =**
PC x ET x CF2 (eq 1)

**Organics: DAevent (mg/cm2-event) =**

ET<t*: DAevent (mg/cm2-event) =
2 x PC x (sqrt((6 x t x ET)/3.1415))
x CF2 (eq 2)

Permeability constants from EPA 1992, Dermal Exposure Assessment: Principals and Applications.
ORD, EPA/600/8-91/001B. Default value of 0.001 cm/hour used for inorganics without published values.
N/A - not applicable.

**Table A-4**
**Recommended Preliminary Remediation Goals**
**Groundwater**
**Residential Scenario**
**SWMU 2C, NAS Oceana**

| Chemical | Recommended PRG (mg/L) | Basis |
|---|---|---|
| ***VOCs*** | | |
| 1,4-Dichlorobenzene | 1.6E-02 | Lifetime, CR = $10^{-5}$ |
| 1,1-Dichloroethene | 9.7E-04 | Lifetime, CR = $10^{-5}$ |
| cis-1,2-Dichloroethene | 7.3E-02 | Child, HQ=0.5 |
| Tetrachloroethene | 8.2E-03 | Lifetime, CR = $10^{-5}$ |
| Trichloroethene | 1.3E-02 | Child, HQ=0.17 |
| Vinyl Chloride | 4.3E-04 | Lifetime, CR = $10^{-5}$ |
| ***SVOCs*** | | |
| Benzo(b)fluoranthene | 9.2E-04 | Lifetime, CR = $10^{-5}$ |
| Naphthalene | 8.7E-02 | Child, HQ=0.5 |
| ***Inorganics*** | | |
| Arsenic | 4.5E-04 | Lifetime, CR = $10^{-5}$ |
| Iron | 7.7E-01 | Child, HQ=0.17 |
| Manganese | 3.1E-01 | Child, HQ=1 |

Child scenario selected for noncarcinogenic PRGs since child scenario more conservative (lower PRGs).
For constituents with basis of CR = $10^{-5}$, PRG for CR =$10^{-5}$ less than PRG for applicable HQ.
Used CR of $10^{-5}$ to keep overall carcinogenic risk below $10^{-4}$.
Applicabe HQ chosen to keep total HI for each target organ below 1.

**Table A-1**
**Preliminary Remediation Goals**
**Soil Ingestion, Dermal Contact, and Inhalation**
**Adult Resident Scenario**
**SWMU 2E, NAS Oceana**

| Chemical | Chronic Oral RfD (RfDo) (mg/kg-day) | Chronic Dermal RfD (RfDd) (mg/kg-day) | Chronic Inhalation RfD (RfDi) (mg/kg-day) | Target Organ | Oral Slope Factor (CSFo) (kg-day/mg) | Dermal Slope Factor (CSFd) (kg-day/mg) | Inhalation Slope Factor (CSFi) (kg-day/mg) | Absorption Factor (ABS) | Noncarcinogen PRG (mg/kg) | Noncarcinogen Target HQ[1] (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| *Inorganics* | | | | | | | | | | |
| Aluminum | 1.00E+00 | 2.70E-01 | 1.00E-03 | nervous system | NA | NA | NA | 1.00E-02 | **4.6E+05** | 1 |
| Antimony | 4.00E-04 | 4.00E-05 | NA | blood | NA | NA | NA | 1.00E-02 | **6.8E+01** | 0.5 |
| Arsenic | 3.00E-04 | 2.85E-04 | NA | skin, vascular | 1.50E+00 | 1.6E+00 | 1.51E+01 | 3.20E-02 | **1.6E+02** | 1 |
| Cadmium | 1.00E-03 | 2.50E-05 | 5.70E-05 | kidney | NA | NA | 6.30E+00 | 1.00E-02 | **1.3E+02** | 1 |
| Chromium | 3.00E-03 | 3.00E-05 | 3.00E-05 | none reported | NA | NA | 4.10E+01 | 1.00E-02 | **1.7E+02** | 1 |
| Iron | 3.00E-01 | 6.00E-02 | NA | blood, liver, GI | NA | NA | NA | 1.00E-02 | **6.9E+04** | 0.5 |
| Thallium | 7.00E-05 | 7.00E-05 | NA | liver | NA | NA | NA | 1.00E-02 | **2.3E+01** | 0.5 |

**Noncarcinogenic calculations:**

$$\text{Soil RBC (mg/kg)} = \frac{THQ \times BW \times AT_n}{EF \times ED \times (An + Bn + Cn)}$$

**An =** $1/RfDo \times IRS/10^6$ mg/kg

**Bn =** $1/RfDd \times SA \times AF \times ABS \times 1/10^6$ mg/kg

**Cn =** $1/RfDi \times IRA \times (1/PEF)$

| EXPOSURE ASSUMPTIONS | |
|---|---|
| BW - Body weight (kilograms) | 70 |
| ATnc - Averaging time for noncarcinogens (days) | 8,760 |
| ATc - Averaging time for carcinogens (days) | 25,550 |
| EF - Exposure frequency (days/year) | 350 |
| ED - Exposure duration (year) | 24 |
| IRS - Ingestion rate (mg/day) | 100 |
| SA - Skin surface area ($cm^2$) | 5,800 |
| AF - Soil to Skin Adherence Factor ($mg/cm^2$-day) | 0.20 |
| ABS - Absorption Factor (unitless) | chemical specific |
| IRA - Inhalation Rate ($m^3$/day) | 20 |
| PEF - Particulate Emission Factor ($m^3$/kg) | 1.32E+09 |

NA - No reference dose or slope factor available.

1 Applicable HQ calculated so that total HQ for a target organ does not exceed 1.

**Table A-2**
**Preliminary Remediation Goals**
**Soil Ingestion, Dermal Contact, and Inhalation**
**Child Resident Scenario**
**SWMU 2E, NAS Oceana**

| Chemical | Chronic Oral RfD (RfDo) (mg/kg-day) | Chronic Dermal RfD (RfDd) (mg/kg-day) | Chronic Inhalation RfD (RfDi) (mg/kg-day) | Target Organ | Oral Slope Factor (CSFo) (kg-day/mg) | Dermal Slope Factor (CSFd) (kg-day/mg) | Inhalation Slope Factor (CSFi) (kg-day/mg) | Absorption Factor (ABS) | Noncarcinogen PRG (mg/kg) | Noncarcinogen Target HQ[1] (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Inorganics*** | | | | | | | | | | |
| Aluminum | 1.00E+00 | 2.70E-01 | 1.00E-03 | nervous system | NA | NA | NA | 1.00E-02 | **7.1E+04** | 1 |
| Antimony | 4.00E-04 | 4.00E-05 | NA | blood | NA | NA | NA | 1.00E-02 | **1.4E+01** | 0.5 |
| Arsenic | 3.00E-04 | 2.85E-04 | NA | skin, vascular | 1.50E+00 | 1.6E+00 | 1.51E+01 | 3.20E-02 | **2.2E+01** | 1 |
| Cadmium | 1.00E-03 | 2.50E-05 | 5.70E-05 | kidney | NA | NA | 6.30E+00 | 1.00E-02 | **5.1E+01** | 1 |
| Chromium | 3.00E-03 | 3.00E-05 | 3.00E-05 | none reported | NA | NA | 4.10E+01 | 1.00E-02 | **1.0E+02** | 1 |
| Iron | 3.00E-01 | 6.00E-02 | NA | blood, liver, GI | NA | NA | NA | 1.00E-02 | **1.1E+04** | 0.5 |
| Thallium | 7.00E-05 | 7.00E-05 | NA | liver | NA | NA | NA | 1.00E-02 | **2.7E+00** | 0.5 |

**Noncarcinogenic calculations:**

$$\text{Soil RBC (mg/kg)} = \frac{THQ \times BW \times AT_n}{EF \times ED \times (An + Bn + Cn)}$$

**An =** $1/RfDo \times IRS/10^6$ mg/kg

**Bn =** $1/RfDd \times SA \times AF \times ABS \times 1/10^6$ mg/kg

**Cn =** $1/RfDi \times IRA \times (1/PEF)$

| EXPOSURE ASSUMPTIONS | |
|---|---|
| BW - Body weight (kilograms) | 15 |
| ATnc - Averaging time for noncarcinogens (days) | 2,190 |
| ATc - Averaging time for carcinogens (days) | 25,550 |
| EF - Exposure frequency (days/year) | 350 |
| ED - Exposure duration (year) | 6 |
| IRS - Ingestion rate (mg/day) | 200 |
| SA - Skin surface area ($cm^2$) | 2,379 |
| AF - Soil to Skin Adherence Factor ($mg/cm^2$-day) | 0.11 |
| ABS - Absorption Factor (unitless) | chemical specific |
| IRA - Inhalation Rate ($m^3$/day) | 12 |
| PEF - Particulate Emission Factor ($m^3$/kg) | 1.32E+09 |

NA - No reference dose or slope factor available.

1 Applicable HQ calculated so that total HQ for a target organ does not exceed 1.

**Table A-3**
**Preliminary Remediation Goals**
**Soil Ingestion, Dermal Contact, and Inhalation**
**Adult/Child Resident Scenario**
**SWMU 2E, NAS Oceana**

| Chemical | Chronic Oral RfD (RfDo) (mg/kg-day) | Chronic Dermal RfD (RfDd) (mg/kg-day) | Chronic Inhalation RfD (RfDi) (mg/kg-day) | Target Organ | Oral Slope Factor (CSFo) (kg-day/mg) | Dermal Slope Factor (CSFd) (kg-day/mg) | Inhalation Slope Factor (CSFi) (kg-day/mg) | Absorption Factor (ABS) | Carcinogen Ingestion PRG Risk = 1E-06 (mg/kg) | Carcinogen Ingestion PRG Risk = 1E-05 (mg/kg) | Carcinogen Ingestion PRG Risk = 1E-04 (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Inorganics*** | | | | | | | | | | | |
| Aluminum | 1.00E+00 | 2.70E-01 | 1.00E-03 | nervous system | NA | NA | NA | 1.00E-02 | | | |
| Antimony | 4.00E-04 | 4.00E-05 | NA | blood | NA | NA | NA | 1.00E-02 | | | |
| Arsenic | 3.00E-04 | 2.85E-04 | NA | skin, vascular | 1.50E+00 | 1.6E+00 | 1.51E+01 | 3.20E-02 | 3.7E-01 | **3.7E+00** | 3.7E+01 |
| Cadmium | 1.00E-03 | 2.50E-05 | 5.70E-05 | kidney | NA | NA | 6.30E+00 | 1.00E-02 | 1.3E+03 | **1.3E+04** | 1.3E+05 |
| Chromium | 3.00E-03 | 3.00E-05 | 3.00E-05 | none reported | NA | NA | 4.10E+01 | 1.00E-02 | 2.0E+02 | **2.0E+03** | 2.0E+04 |
| Iron | 3.00E-01 | 6.00E-02 | NA | blood, liver, GI | NA | NA | NA | 1.00E-02 | | | |
| Thallium | 7.00E-05 | 7.00E-05 | NA | liver | NA | NA | NA | 1.00E-02 | | | |

**Carcinogen calculations:**

$$\text{Soil RBC (mg/kg)} = \frac{TR \times AT_c}{EF \times (Ac + Bc + Cc)}$$

**Ac =** CSFo x IRS/$10^6$ mg/kg

**Bc =** CSFd x DA-adj x ABS x 1/$10^6$ mg/kg

**Cc =** CSFi x IRA x (1/PEF)

| **EXPOSURE ASSUMPTIONS** | |
|---|---|
| ATc - Averaging time for carcinogens (days) | 25,550 |
| EF - Exposure frequency (days/year) | 350 |
| ED - Exposure duration (year) | 30 |
| IRS - Ingestion rate (mg-year/kg-day) | 114 |
| DA-adj - Skin surface area (mg-year/kg-day) | 502 |
| ABS - Absorption Factor (unitless) | chemical specific |
| IRA - Inhalation Rate ($m^3$-year/kg-day) | 11.7 |
| PEF - Particulate Emission Factor ($m^3$/kg) | 1.32E+09 |

NA - No reference dose or slope factor available.

**Table A-4**
**Recommended Preliminary Remediation Goals**
**Soil Ingestion, Dermal Contact, and Inhalation**
**SWMU 2E, NAS Oceana**

| Chemical | Residential Scenario Recommended PRG (mg/kg) | Basis |
|---|---|---|
| ***Inorganics*** | | |
| Aluminum | 7.1E+04 | Child, HQ = 1 |
| Antimony | 1.4E+01 | Child, HQ = 0.5 |
| Arsenic | 3.7E+00 | Lifetime, CR = $10^{-5}$ |
| Cadmium | 5.1E+01 | Child, HQ = 1 |
| Chromium | 1.0E+02 | Child, HQ = 1 |
| Iron | 1.1E+04 | Child, HQ = 0.5 |
| Thallium | 2.7E+00 | Child, HQ = 0.5 |

Child scenario selected for noncarcinogenic PRGs since child scenario more conservative (lower PRGs).
For constituents with basis of CR = $10^{-5}$, PRG for CR =$10^{-5}$ less than PRG for applicable HQ.
Used CR of $10^{-5}$ to keep overall carcinogenic risk below $10^{-4}$.
Applicabe HQ chosen to keep total HI for each target organ below 1.

**Table B-1**
**Preliminary Remediation Goals**
**Groundwater**
**Adult Residential Scenario**
**SWMU 2E, NAS Oceana**

| Chemical | Chronic Oral RfD (RfDo) (mg/kg-day) | Chronic Dermal RfD (RfDd) (mg/kg-day) | Chronic Inhalation RfD (RfDi) (mg/kg-day) | Target Organ | DAevent ($L/cm^2$-day) | Shower Exposure (L/day) | Noncarcinogen PRG | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | PRG (mg/kg) | Target HQ[1] (mg/kg) |
| ***VOCs*** | | | | | | | | |
| Vinyl Chloride | 3.00E-03 | 3.00E-03 | 2.80E-02 | liver | 4.1E-06 | 7.2E-03 | 3.5E-02 | 0.33 |
| ***SVOCs*** | | | | | | | | |
| Benzo(a)anthracene | NA | NA | NA | NA | 1.5E-03 | | | |
| 2-Methylnaphthalene | 2.00E-02 | 1.60E-02 | NA | body weight | 2.1E-04 | | 1.0E-01 | 0.50 |
| Naphthalene | 2.00E-02 | 1.60E-02 | 9.00E-04 | body weight | 6.2E-05 | | 2.1E-01 | 0.50 |
| Pyrene | 3.00E-02 | 2.40E-02 | NA | kidney | 4.9E-04 | | 1.5E-01 | 1 |
| ***Pesticides*** | | | | | | | | |
| Dieldrin | 5.00E-05 | 2.50E-05 | NA | liver | 8.4E-05 | | 2.3E-04 | 0.33 |
| ***Inorganics*** | | | | | | | | |
| Arsenic | 3.00E-04 | 2.85E-04 | NA | skin, vascular | 2.0E-07 | | 1.1E-02 | 1 |
| Iron | 3.00E-01 | 6.00E-02 | NA | GI, blood, liver | 2.0E-07 | | 3.6E+00 | 0.33 |
| Manganese | 2.00E-02 | 7.00E-03 | 1.43E-05 | CNS | 2.0E-07 | | 7.3E-01 | 1 |

**Noncarcinogenic calculations:**

$$\text{Groundwater RBC (mg/L)} = \frac{THQ \times BW \times AT_n}{EF \times ED \times (An + Bn + Cn)}$$

**An =** 1/RfDo x IR

**Bn =** 1/RfDd x SA x DAevent

**Cn =** 1/RfDi x Shower Exposure

| EXPOSURE ASSUMPTIONS | |
|---|---|
| BW - Body weight (kilograms) | 70 |
| ATnc - Averaging time for noncarcinogens (days) | 8,760 |
| ATc - Averaging time for carcinogens (days) | 25,550 |
| EF - Exposure frequency (days/year) | 350 |
| ED - Exposure duration (year) | 24 |
| IR - Ingestion rate (L/day) | 2 |
| SA - Skin surface area ($cm^2$) | 20,000 |

NA - No reference dose or slope factor available.

1 Applicable HQ calculated so that total HQ for a target organ does not exceed 1.

Table B-1a
Calculation of DAevent
Groundwater, Adult
SWMU 2E, NAS Oceana

| Chemical of Potential Concern | Permeability Constant (PC) (cm/hr) | Lag Time (t) (hr) | Duration of Event (ET) (hr) | t* (hr) | B (dimensionless) | DAevent ($L/cm^2$-day) | Eq |
|---|---|---|---|---|---|---|---|
| Vinyl chloride | 7.3E-03 | 2.1E-01 | 2.0E-01 | 5.1E-01 | 2.3E-03 | 4.1E-06 | 2 |
| Benzo(a)anthracene | 8.3E-01 | 2.2E+00 | 2.0E-01 | 1.0E+01 | 4.6E+01 | 1.5E-03 | 2 |
| 2-Methylnaphthalene | 2.1E-01 | 6.4E-01 | 2.0E-01 | 4.5E+00 | 1.3E+00 | 2.1E-04 | 2 |
| Naphthalene | 6.9E-02 | 5.3E-01 | 2.0E-01 | 2.2E+00 | 2.0E-01 | 6.2E-05 | 2 |
| Pyrene | 3.2E-01 | 1.5E+00 | 2.0E-01 | 7.3E+00 | 7.6E+00 | 4.9E-04 | 2 |
| Dieldrin | 1.6E-02 | 1.8E+01 | 2.0E-01 | 9.4E+01 | 3.6E+00 | 8.4E-05 | 2 |
| Arsenic | 1.0E-03 | N/A | 2.0E-01 | N/A | N/A | 2.0E-07 | 1 |
| Iron | 1.0E-03 | N/A | 2.0E-01 | N/A | N/A | 2.0E-07 | 1 |
| Manganese | 1.0E-03 | N/A | 2.0E-01 | N/A | N/A | 2.0E-07 | 1 |

**Inorganics: DAevent (mg/cm2-event) =**
PC x ET x CF2 (eq 1)

**Organics: DAevent (mg/cm2-event) =**

ET<t*: DAevent (mg/cm2-event) =
2 x PC x (sqrt((6 x t x ET)/3.1415))
x CF2 (eq 2)

Permeability constants from EPA 1992, Dermal Exposure Assessment: Principals and Applications. ORD, EPA/600/8-91/001B. Default value of 0.001 cm/hour used for inorganics without published values.
N/A - not applicable.

Table B-1b

Inhalation Exposure Concentrations from Foster and Chrostowski Shower Model

SWMU 2E, NAS Oceana

| Chemical | Molecular weight (MW) (g/mole) | Henry's Law Constant (H) (atm-m$^3$/mole) | Kg (VOC) (cm/hr) | Kl(VOC) (cm/hr) | KL (cm/hr) | Kal (cm/hr) | Cwd | S (L/m$^3$-min) | Inhalation Exposure (InExp) (L/kg-shower) | Shower Exposure (InExp X BW) (L/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vinyl chloride | 63 | 8.2E-02 | 1.6E+03 | 1.7E+01 | 1.7E+01 | 2.3E+01 | 5.3E-01 | 3.5E+00 | 1.0E-04 | 7.2E-03 |

| Variables | Units | Exposure Assumptions |
|---|---|---|
| Kg(VOC) = gas-film mass transfer coefficient | cm/hr | Solved by Eq 1 |
| Kl(VOC) = liquid-film mass transfer coefficient | cm/hr | Solved by Eq 2 |
| KL = overall mass transfer coefficient | cm/hr | Solved by Eq 3 |
| Kal = adjusted overall mass transfer coeff. | cm/hr | Solved by Eq 4 |
| Tl = Calibration temp. of water | K (20C +273) | 293 |
| Ts = Shower water temperature | k (45C) | 318 |
| Us = water viscosity at Ts | centipoise | 0.596 |
| Ul = water viscosity at Tl | cp | 1.002 |
| Cwd = conc. leaving droplets after time sdt | | Solved by Eq 5 |
| sdt = shower droplet drop time | sec | 2 |
| d = shower droplet diameter | mm | 1 |
| FR = shower water flow rate | l/min | 20 |
| SV = shower room air volume | m$^3$ | 3 |
| S = indoor VOC generation rate | L/m$^3$-min | Solved by Eq 6 |
| VR = ventilation rate | l/min | 13.8 |
| BW = body weight | kg | 70 |
| Ds = duration of shower | min | 12 |
| Dt = total duration in shower room | min | 20 |
| R = air exchange rate | min$^{-1}$ | 0.0167 |
| Ca = indoor air concentration of VOCs | L-ug/mg-m$^3$ | Solved by Eq 7 |
| Einh = inhalation exposure per shower | L/kg-shower | Solved by Eq 8 |

| | | | |
|---|---|---|---|
| Equation 1: | Kg(VOC) = | 3000 * (18 / MW)$^{0.5}$ | |
| Equation 2: | Kl(VOC) = | 20 * (44 / MW)$^{0.5}$ | |
| Equation 3: | KL = | ((1 / Kl(VOC)) + (0.024 / (Kg (VOC) * H)))$^{-1}$ | |
| Equation 4: | Kal = | (KL * (((Tl * Us) / (Ts * Ul))$^{-0.5}$)) | |
| Equation 5: | Cwd = | ((1-EXP((-1 * Kal * sdt)/(60 * d)))) | |
| Equation 6: | S = | (Cwd * FR / SV) | |
| Equation 7: | see time series example on Table I-GW-6 | | |
| Equation 8: | Einh = | If t>Ds | (((VR * S) / (BW * R * 1000000)) * ((Ds + (EXP(-R * Dt) / R)-(EXP(R * (Ds - Dt))) / R))) |

**Table B-2**
**Preliminary Remediation Goals**
**Groundwater**
**Child Residential Scenario**
**SWMU 2E, NAS Oceana**

| Chemical | Chronic Oral RfD (RfDo) (mg/kg-day) | Chronic Dermal RfD (RfDd) (mg/kg-day) | Chronic Inhalation RfD (RfDi) (mg/kg-day) | Target Organ | DAevent (L/cm$^2$-day) | Noncarcinogen PRG PRG (mg/kg) | Noncarcinogen PRG Target HQ[1] (mg/kg) |
|---|---|---|---|---|---|---|---|
| ***VOCs*** | | | | | | | |
| Vinyl Chloride | 3.00E-03 | 3.00E-03 | 2.80E-02 | liver | 5.3E-06 | 1.5E-02 | 0.33 |
| ***SVOCs*** | | | | | | | |
| Benzo(a)anthracene | NA | NA | NA | NA | 2.0E-03 | | |
| 2-Methylnaphthalene | 2.00E-02 | 1.60E-02 | NA | body weight | 2.7E-04 | 4.2E-02 | 0.50 |
| Naphthalene | 2.00E-02 | 1.60E-02 | 9.00E-04 | body weight | 8.0E-05 | 1.3E-01 | 0.50 |
| Pyrene | 3.00E-02 | 2.40E-02 | NA | kidney | 6.3E-04 | 6.5E-02 | 1 |
| ***Pesticides*** | | | | | | | |
| Dieldrin | 5.00E-05 | 2.50E-05 | NA | liver | 1.1E-04 | 9.6E-05 | 0.33 |
| ***Inorganics*** | | | | | | | |
| Arsenic | 3.00E-04 | 2.85E-04 | NA | skin, vascular | 3.3E-07 | 4.7E-03 | 1 |
| Iron | 3.00E-01 | 6.00E-02 | NA | GI, blood, liver | 3.3E-07 | 1.5E+00 | 0.33 |
| Manganese | 2.00E-02 | 7.00E-03 | 1.43E-05 | CNS | 3.3E-07 | 3.1E-01 | 1 |

**Noncarcinogenic calculations:**

$$\textbf{Groundwater RBC (mg/L)} = \frac{THQ \times BW \times AT_n}{EF \times ED \times (An + Bn)}$$

**An =** 1/RfDo x IR

**Bn =** 1/RfDd x SA x DAevent

| EXPOSURE ASSUMPTIONS | |
|---|---|
| BW - Body weight (kilograms) | 15 |
| ATnc - Averaging time for noncarcinogens (days) | 2,190 |
| ATc - Averaging time for carcinogens (days) | 25,550 |
| EF - Exposure frequency (days/year) | 350 |
| ED - Exposure duration (year) | 6 |
| IR - Ingestion rate (L/day) | 1 |
| SA - Skin surface area (cm$^2$) | 7,930 |

NA - No reference dose or slope factor available.

1 Applicable HQ calculated so that total HQ for a target organ does not exceed 1.

Table B-2a
Calculation of DAevent
Groundwater, Child
SWMU 2E, NAS Oceana

| Chemical of Potential Concern | Permeability Constant (PC) (cm/hr) | Lag Time (t) (hr) | Duration of Event (ET) (hr) | t* (hr) | B (dimensionless) | DAevent ($L/cm^2$-day) | Eq |
|---|---|---|---|---|---|---|---|
| Vinyl chloride | 7.3E-03 | 2.1E-01 | 3.3E-01 | 5.1E-01 | 2.3E-03 | 5.3E-06 | 2 |
| Benzo(a)anthracene | 8.3E-01 | 2.2E+00 | 3.3E-01 | 1.0E+01 | 4.6E+01 | 2.0E-03 | 2 |
| 2-Methylnaphthalene | 2.1E-01 | 6.4E-01 | 3.3E-01 | 4.5E+00 | 1.3E+00 | 2.7E-04 | 2 |
| Naphthalene | 6.9E-02 | 5.3E-01 | 3.3E-01 | 2.2E+00 | 2.0E-01 | 8.0E-05 | 2 |
| Pyrene | 3.2E-01 | 1.5E+00 | 3.3E-01 | 7.3E+00 | 7.6E+00 | 6.3E-04 | 2 |
| Dieldrin | 1.6E-02 | 1.8E+01 | 3.3E-01 | 9.4E+01 | 3.6E+00 | 1.1E-04 | 2 |
| Arsenic | 1.0E-03 | N/A | 3.3E-01 | N/A | N/A | 3.3E-07 | 1 |
| Iron | 1.0E-03 | N/A | 3.3E-01 | N/A | N/A | 3.3E-07 | 1 |
| Manganese | 1.0E-03 | N/A | 3.3E-01 | N/A | N/A | 3.3E-07 | 1 |

**Inorganics: DAevent (mg/cm2-event) =**
PC x ET x CF2 (eq 1)

**Organics: DAevent (mg/cm2-event) =**

ET<t*: DAevent (mg/cm2-event) =
2 x PC x (sqrt((6 x t x ET)/3.1415))
x CF2 (eq 2)

Permeability constants from EPA 1992, Dermal Exposure Assessment: Principals and Applications.
ORD, EPA/600/8-91/001B. Default value of 0.001 cm/hour used for inorganics without published values.
N/A - not applicable.

**Table B-3**
**Preliminary Remediation Goals**
**Groundwater**
**Lifetime Residential Scenario**
**SWMU 2E, NAS Oceana**

| Chemical | Oral Slope Factor (CSFo) (kg-day/mg) | Dermal Slope Factor (CSFd) (kg-day/mg) | Inhalation Slope Factor (CSFi) (kg-day/mg) | DAevent-a ($L/cm^2$-day) | DAevent-c ($L/cm^2$-day) | Shower Exposure (L/day) | Carcinogen PRG Risk = 1E-06 (mg/L) | Carcinogen PRG Risk = 1E-05 (mg/L) | Carcinogen PRG Risk = 1E-04 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| ***VOCs*** | | | | | | | | | |
| Vinyl Chloride | 1.50E+00 | 1.5E+00 | 3.00E-02 | 4.1E-06 | 5.3E-06 | 7.2E-03 | 4.3E-05 | 4.3E-04 | 4.3E-03 |
| ***SVOCs*** | | | | | | | | | |
| Benzo(a)anthracene | 7.30E-01 | NA | 3.10E+00 | 1.5E-03 | 2.0E-03 | | 9.2E-05 | 9.2E-04 | 9.2E-03 |
| 2-Methylnaphthalene | NA | NA | NA | 2.1E-04 | 2.7E-04 | | | | |
| Naphthalene | NA | NA | NA | 6.2E-05 | 8.0E-05 | | | | |
| Pyrene | NA | NA | NA | 4.9E-04 | 6.3E-04 | | | | |
| ***Pesticides*** | | | | | | | | | |
| Dieldrin | 1.60E+01 | 3.2E+01 | 1.60E+01 | 8.4E-05 | 1.1E-04 | | 1.6E-06 | 1.6E-05 | 1.6E-04 |
| ***Inorganics*** | | | | | | | | | |
| Arsenic | 1.50E+00 | 1.6E+00 | 1.51E+01 | 2.0E-07 | 3.3E-07 | | 4.5E-05 | 4.5E-04 | 4.5E-03 |
| Iron | NA | NA | NA | 2.0E-07 | 3.3E-07 | | | | |
| Manganese | NA | NA | NA | 2.0E-07 | 3.3E-07 | | | | |

**Carcinogen calculations:**

$$\text{Groundwater RBC (mg/L)} = \frac{TR \times AT_c}{EF \times (Ac + Bc + Cc)}$$

**Ac =** CSFo x IRadj

**Bc =** CSFd x [(SAa x DAevent-a x EDa)/BWa + (SAc x DAevent-c X EDc)/BWc]

**Cc =** CSFi x Shower Exposure x EDa x 1/BWa

| EXPOSURE ASSUMPTIONS | Lifetime | Adult (a) | Child (c) |
|---|---|---|---|
| BW - Body weight (kilograms) | | 70 | 15 |
| ATnc - Averaging time for noncarcinogens (days) | | 8,760 | 2,190 |
| ATc - Averaging time for carcinogens (days) | | 25,550 | 25,550 |
| EF - Exposure frequency (days/year) | | 350 | 350 |
| ED - Exposure duration (year) | | 24 | 6 |
| IR - Ingestion rate (L/day) | | 2 | 1 |
| IRdj - Ingestion rate (L-year/kg-day) | 1.09 | | |
| SA - Skin surface area ($cm^2$) | | 20,000 | 7,930 |
| ET - Exposure Time (hours/day) | | 0.20 | 0.33 |

NA - No reference dose or slope factor available.

Table B-3a
Calculation of DAevent
Groundwater, Child/Adult
SWMU 2E, NAS Oceana

| Chemical of Potential Concern | Permeability Constant (PC) (cm/hr) | Lag Time (t) (hr) | Duration of Event (ETa) (hr) | Duration of Event (ETc) (hr) | t* (hr) | B (dimensionless) | Daevent Adult ($L/cm^2$-day) | Daevent Child ($L/cm^2$-day) | Eq |
|---|---|---|---|---|---|---|---|---|---|
| Vinyl chloride | 7.3E-03 | 2.1E-01 | 2.0E-01 | 3.3E-01 | 5.1E-01 | 2.3E-03 | 4.1E-06 | 5.3E-06 | 2 |
| Benzo(a)anthracene | 8.3E-01 | 2.2E+00 | 2.0E-01 | 3.3E-01 | 1.0E+01 | 4.6E+01 | 1.5E-03 | 2.0E-03 | 2 |
| 2-Methylnaphthalene | 2.1E-01 | 6.4E-01 | 2.0E-01 | 3.3E-01 | 4.5E+00 | 1.3E+00 | 2.1E-04 | 2.7E-04 | 2 |
| Naphthalene | 6.9E-02 | 5.3E-01 | 2.0E-01 | 3.3E-01 | 2.2E+00 | 2.0E-01 | 6.2E-05 | 8.0E-05 | 2 |
| Pyrene | 3.2E-01 | 1.5E+00 | 2.0E-01 | 3.3E-01 | 7.3E+00 | 7.6E+00 | 4.9E-04 | 6.3E-04 | 2 |
| Dieldrin | 1.6E-02 | 1.8E+01 | 2.0E-01 | 3.3E-01 | 9.4E+01 | 3.6E+00 | 8.4E-05 | 1.1E-04 | 2 |
| Arsenic | 1.0E-03 | N/A | 2.0E-01 | 3.3E-01 | N/A | N/A | 2.0E-07 | 3.3E-07 | 1 |
| Iron | 1.0E-03 | N/A | 2.0E-01 | 3.3E-01 | N/A | N/A | 2.0E-07 | 3.3E-07 | 1 |
| Manganese | 1.0E-03 | N/A | 2.0E-01 | 3.3E-01 | N/A | N/A | 2.0E-07 | 3.3E-07 | 1 |

**Inorganics: DAevent (mg/cm2-event) =**
PC x ET x CF2 (eq 1)

**Organics: DAevent (mg/cm2-event) =**

ET<t*: DAevent (mg/cm2-event) =
2 x PC x (sqrt((6 x t x ET)/3.1415))
x CF2 (eq 2)

Permeability constants from EPA 1992, Dermal Exposure Assessment: Principals and Applications.
ORD, EPA/600/8-91/001B. Default value of 0.001 cm/hour used for inorganics without published values.
N/A - not applicable.

**Table B-4**
**Preliminary Remediation Goals**
**Groundwater**
**Construction Worker Scenario**
**SWMU 2E, NAS Oceana**

| Chemical | Subchronic Oral RfD (RfDo) (mg/kg-day) | Subchronic Dermal RfD (RfDd) (mg/kg-day) | Subchronic Inhalation RfD (RfDi) (mg/kg-day) | Target Organ | Oral Slope Factor (CSFo) (kg-day/mg) | Dermal Slope Factor (CSFd) (kg-day/mg) | Inhalation Slope Factor (CSFi) (kg-day/mg) | DAevent (L/cm$^2$-day) | Noncarcinogen PRG PRG (mg/kg) | Noncarcinogen PRG Target HQ[1] (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| ***SVOCs*** | | | | | | | | | | |
| 2-Methylnaphthalene | 2.00E-02 | 1.60E-02 | NA | body weight | NA | NA | NA | 1.3E-03 | 1.0E-01 | 5.0E-01 |
| Naphthalene | 2.00E-02 | 1.60E-02 | 9.00E-04 | body weight | NA | NA | NA | 5.6E-04 | 2.4E-01 | 5.0E-01 |
| Pyrene | 3.00E-02 | 2.40E-02 | NA | kidney | NA | NA | NA | 3.0E-03 | 1.4E-01 | 1 |
| ***Inorganics*** | | | | | | | | | | |
| Iron | 3.00E-01 | 6.00E-02 | NA | GI, blood, liver | NA | NA | NA | 8.0E-06 | 1.3E+02 | 1 |

**Noncarcinogenic calculations:**

$$\text{Groundwater RBC (mg/L)} = \frac{THQ \times BW \times AT_n}{EF \times ED \times (An + Bn + Cn)}$$

**An =** Ingestion pathway not applicable for construction worker (An = 0)

**Bn =** 1/RfDd x SA x DAevent

**Cn =** 1/RfDi x VF x IN x ET

**Carcinogen calculations:**

$$\text{Groundwater RBC (mg/L)} = \frac{TR \times BW \times AT_c}{EF \times ED \times (Ac + Bc + Cc)}$$

**Ac =** Ingestion pathway not applicable for construction worker (Ac = 0)

**Bc =** CSFd x SA x DAevent

**Cc =** CSFi x VF x IN x ET

| EXPOSURE ASSUMPTIONS | |
|---|---|
| BW - Body weight (kilograms) | 70 |
| ATnc - Averaging time for noncarcinogens (days) | 365 |
| ATc - Averaging time for carcinogens (days) | 25,550 |
| EF - Exposure frequency (days/year) | 250 |
| ED - Exposure duration (year) | 1 |
| SA - Skin surface area (cm$^2$) | 6,000 |
| ET - Exposure Time (hours/day) | 8 |
| IN - Inhalation Rate (m$^3$/hour) | 2.5 |

Subchronic RfDs used if available, if not chronic RfD used.
NA - No reference dose or slope factor available.
1 Applicable HQ calculated so that total HQ for a target organ does not exceed 1.

Table B-4a
Calculation of DAevent
Groundwater, Adult Construction Worker
SWMU 2E, NAS Oceana

| Chemical of Potential Concern | Permeability Constant (PC) (cm/hr) | Lag Time (t) (hr) | Duration of Event (ET) (hr) | t* (hr) | B dimensionless | DAevent ($L/cm^2$-day) | Eq |
|---|---|---|---|---|---|---|---|
| 2-Methylnaphthalene | 2.1E-01 | 6.4E-01 | 8.0E+00 | 4.5E+00 | 1.3E+00 | 1.3E-03 | 3 |
| Naphthalene | 6.9E-02 | 5.3E-01 | 8.0E+00 | 2.2E+00 | 2.0E-01 | 5.6E-04 | 3 |
| Pyrene | 3.2E-01 | 1.5E+00 | 8.0E+00 | 7.3E+00 | 7.6E+00 | 3.0E-03 | 3 |
| Iron | 1.0E-03 | N/A | 8.0E+00 | N/A | N/A | 8.0E-06 | 1 |

**Inorganics: DAevent (mg/cm2-event) =**
PC x ET x CF2 (eq 1)

**Organics: DAevent (mg/cm2-event) =**

ET<t*: DAevent (mg/cm2-event) =
2 x PC x (sqrt((6 x t x ET)/3.1415))
x CF2 (eq 2)

ET>t*: DAevent (mg/cm2-event) =
PC x ( ET/(1+B) + 2 x t x ((1 + 3xB)/(1+B))
x CF2 (eq 3)

Permeability constants from EPA 1992, Dermal Exposure Assessment: Principals and Applications.
ORD, EPA/600/8-91/001B. Default value of 0.001 cm/hour used for inorganics without published values.
N/A - not applicable.

**Table B-5**
**Recommended Preliminary Remediation Goals**
**Groundwater**
**Residential Scenario**
**SWMU 2E, NAS Oceana**

| Chemical | Residential Scenario Recommended PRG (mg/L) | Residential Scenario Basis | Construction Worker Scenario Recommended PRG (mg/L) | Construction Worker Scenario Basis |
|---|---|---|---|---|
| ***VOCs*** | | | | |
| Vinyl Chloride | 4.3E-04 | Lifetime, CR = $10^{-5}$ | NA | |
| ***SVOCs*** | | | | |
| Benzo(a)anthracene | 9.2E-04 | Lifetime, CR = $10^{-5}$ | NA | |
| 2-Methylnaphthalene | 4.2E-02 | Child, HQ = 0.5 | 1.0E-01 | HQ = 0.5 |
| Naphthalene | 1.3E-01 | Child, HQ = 0.5 | 2.4E-01 | HQ = 0.5 |
| Pyrene | 6.5E-02 | Child, HQ = 1 | 1.4E-01 | HQ = 1 |
| ***Pesticides*** | | | | |
| Dieldrin | 1.6E-05 | Lifetime, CR = $10^{-5}$ | NA | |
| ***Inorganics*** | | | | |
| Arsenic | 4.5E-04 | Lifetime, CR = $10^{-5}$ | NA | |
| Iron | 1.5E+00 | Child, HQ = 1 | 1.3E+02 | HQ = 1 |
| Manganese | 3.1E-01 | Child, HQ = 1 | NA | |

Child scenario selected for noncarcinogenic PRGs for residential scenario since child scenario more conservative (lower PRGs).
For constituents with basis of CR = $10^{-5}$, PRG for CR =$10^{-5}$ less than PRG for applicable HQ.
Used CR of $10^{-5}$ to keep overall carcinogenic risk below $10^{-4}$.
Applicabe HQ chosen to keep total HI for each target organ below 1.

# Appendix F—Preliminary Cost Estimates

Estimate Summary

PROJECT: Feasibility Study (Groundwater)
SITE: Oceana SWMU 2B, Virginia Beach, VA
ALTERNATIVE 1
DESCRIPTION: No Action

| DESCRIPTION | QTY | UNIT | INSTALLED COSTS UNITS | INSTALLED COSTS AMOUNT | TOTAL |
|---|---|---|---|---|---|
| **5-year Site Reviews** | | | | | |
| Visual Site Inspection | 1 | LS | $1,980 | $1,980 | $1,980 |
| **GRAND TOTAL ANNUAL** | | | | | $2,000 |
| **PRESENT WORTH** | | | $6,500 | | |

Assumptions:

1. 5-year Site Inspection includes Contingency and Overhead & Profit are built into the unit cost.
2. 5-year Site Inspection will be conducted every 5 years for 30 years.
3. Discount Rate = 4.2%

Estimate Summary

| | |
|---|---|
| PROJECT: | Feasibility Study (Groundwater) |
| SITE: | Oceana SWMU 2B, Virginia Beach, VA |
| ALTERNATIVE | 2 |
| DESCRIPTION: | Institutional Controls and Long-Term Monitoring |

| DESCRIPTION | QTY | UNIT | INSTALLED COSTS UNITS | INSTALLED COSTS AMOUNT | OH&P 15.00% | CONTINGENCY 15.00% | TOTAL |
|---|---|---|---|---|---|---|---|
| **LONG-TERM MONITORING** | | | | | | | |
| Preparation of an Long-term Monitoring Plan | 1 | LS | $30,000 | $30,000 | $4,500 | $5,175 | $39,675 |
| **FIRST YEAR GROUNDWATER SAMPLING** | | | | | | | |
| Quarterly Sampling /Analysis/Reporting of existing wells | 1 | LS | $211,200 | $211,200 | $31,680 | $36,432 | $279,312 |
| First Year Groundwater Monitoring Technical Memorandum | 1 | LS | $ 10,000 | $10,000 | $1,500 | $1,725 | $13,225 |
| **TOTAL** | | | | | | | $332,200 |
| **GRAND TOTAL CAPITAL** | | | | | | | $332,200 |
| **Expenses (O&M)** | | | | | | | |
| Annual Sampling/Analysis/Reporting of existing wells | 1 | LS | $52,800 | $52,800 | $7,920 | $9,108 | $69,828 |
| Groundwater Monitoring Technical Memorandum | 1 | LS | $ 7,000 | $7,000 | $1,050 | $1,208 | $9,258 |
| **GRAND TOTAL ANNUAL** | | | | | | | $79,100 |
| **PRESENT WORTH** | | | | $1,645,400 | | | |

Assumptions:

1. There is no cost associated with the implementation of institutional controls.
2. Sampling/Analysis/Reporting will be every year for a 30-year duration.
3. Discount Rate = 4.2%

Estimate Summary

PROJECT: Feasibility Study (Groundwater)
SITE: Oceana SWMU 2B, Virginia Beach, VA
ALTERNATIVE 3
DESCRIPTION: HRC/ORC Injection, Institutional Controls, and Long-Term Monitoring

| DESCRIPTION | QTY | UNIT | INSTALLED COSTS UNITS | INSTALLED COSTS AMOUNT | OH&P 15.00% | CONTINGENCY 15.00% | TOTAL |
|---|---|---|---|---|---|---|---|
| **LONG-TERM MONITORING** | | | | | | | |
| Preparation of a HRC/ORC Injection Work Plan/ Long-term Monitoring Plan | 1 | LS | $30,000 | $30,000 | $4,500 | $5,175 | $39,675 |
| **INJECTION OF HRC/ORC** | | | | | | | |
| HRC/ORC Pilot Test | 1 | LS | $0 | $0 | $0 | $0 | $0 |
| ORC Material | 1 | LS | $48,783 | $48,783 | $7,317 | $8,415 | $64,515 |
| HRC Material | 1 | LS | $10,043 | $10,043 | $1,507 | $1,733 | $13,283 |
| Injection of HRC/ORC | 1 | LS | $22,609 | $22,609 | $3,391 | $3,900 | $29,900 |
| **FIRST YEAR GROUNDWATER SAMPLING** | | | | | | | |
| Sampling /Analysis/Reporting of existing wells (baseline then every other month for 8 months) | 1 | LS | $251,600 | $251,600 | $37,740 | $43,401 | $332,741 |
| First Year Groundwater Monitoring Technical Memorandum | 1 | LS | $ 10,000 | $10,000 | $1,500 | $1,725 | $13,225 |
| **TOTAL** | | | | | | | $493,300 |
| **GRAND TOTAL CAPITAL** | | | | | | | $493,300 |
| **Expenses (O&M)** | | | | | | | |
| MNA Annual Sampling /Analysis/Reporting of existing wells | 1 | LS | $62,900 | $62,900 | $9,435 | $10,850 | $83,185 |
| Annual Groundwater Monitoring Technical Memorandum | 1 | LS | $ 7,000 | $7,000 | $1,050 | $1,208 | $9,258 |
| **GRAND TOTAL ANNUAL** | | | | | | | $92,400 |
| **PRESENT WORTH** | | | | $2,026,100 | | | |

Assumptions:

1. There is no cost associated with the implementation of institutional controls.
2. Groundwater modeling for estimating TTCU will be conducted after one year of sampling.
3. Regenesis estimates project may require 2 to 4 years to complete.
4. Sampling/Analysis/Reporting for the first year will include baseline plus sampling every other month for 8 months (5 sampling events total).
5. Sampling/Analysis/Reporting after the first year pilot study will be every year for 30 years.
6. Discount Rate = 4.2%

## Alternative 1 - No Action

| | | E | A | B | C=A+B | C*A | C*B | C*E |
|---|---|---|---|---|---|---|---|---|
| Year | | Discount Factor at 4.2% | Capital Cost | O&M Cost | Total Cost | Total PV Capital Costs at 4.2% ($) | Total PV O&M Costs at 4.2% ($) | Total PV Costs at 4.2% ($) |
| 0 | 2001 | 1.000 | | | $ - | $ - | $ - | $ - |
| 1 | 2002 | 0.960 | | | $ - | $ - | $ - | $ - |
| 2 | 2003 | 0.921 | | | $ - | $ - | $ - | $ - |
| 3 | 2004 | 0.884 | | | $ - | $ - | $ - | $ - |
| 4 | 2005 | 0.848 | | $ 2,000 | $ 2,000 | $ - | $ 1,697 | $ 1,697 |
| 5 | 2006 | 0.814 | | | $ - | $ - | $ - | $ - |
| 6 | 2007 | 0.781 | | | $ - | $ - | $ - | $ - |
| 7 | 2008 | 0.750 | | | $ - | $ - | $ - | $ - |
| 8 | 2009 | 0.720 | | | $ - | $ - | $ - | $ - |
| 9 | 2010 | 0.691 | | $ 2,000 | $ 2,000 | $ - | $ 1,381 | $ 1,381 |
| 10 | 2011 | 0.663 | | | $ - | $ - | $ - | $ - |
| 11 | 2012 | 0.636 | | | $ - | $ - | $ - | $ - |
| 12 | 2013 | 0.610 | | | $ - | $ - | $ - | $ - |
| 13 | 2014 | 0.586 | | | $ - | $ - | $ - | $ - |
| 14 | 2015 | 0.562 | | $ 2,000 | $ 2,000 | $ - | $ 1,124 | $ 1,124 |
| 15 | 2016 | 0.539 | | | $ - | $ - | $ - | $ - |
| 16 | 2017 | 0.518 | | | $ - | $ - | $ - | $ - |
| 17 | 2018 | 0.497 | | | $ - | $ - | $ - | $ - |
| 18 | 2019 | 0.477 | | | $ - | $ - | $ - | $ - |
| 19 | 2020 | 0.458 | | $ 2,000 | $ 2,000 | $ - | $ 915 | $ 915 |
| 20 | 2021 | 0.439 | | | $ - | $ - | $ - | $ - |
| 21 | 2022 | 0.421 | | | $ - | $ - | $ - | $ - |
| 22 | 2023 | 0.404 | | | $ - | $ - | $ - | $ - |
| 23 | 2024 | 0.388 | | | $ - | $ - | $ - | $ - |
| 24 | 2025 | 0.373 | | $ 2,000 | $ 2,000 | $ - | $ 745 | $ 745 |
| 25 | 2026 | 0.358 | | | $ - | $ - | $ - | $ - |
| 26 | 2027 | 0.343 | | | $ - | $ - | $ - | $ - |
| 27 | 2028 | 0.329 | | | $ - | $ - | $ - | $ - |
| 28 | 2029 | 0.316 | | | $ - | $ - | $ - | $ - |
| 29 | 2030 | 0.303 | | $ 2,000 | $ 2,000 | $ - | $ 607 | $ 607 |
| Total Atl 1 | | | $ - | $ 12,000 | $ 12,000 | $ - | $ 6,469 | $ 6,469 |

## Alternative 2 - Institutional Controls and Long-Term Monitoring

| | | E | A | B | C=A+B | C*A | C*B | C*E |
|---|---|---|---|---|---|---|---|---|
| Year | | Discount Factor at 4.2% | Capital Cost | O&M Cost | Total Cost | Total PV Capital Costs at 4.2% ($) | Total PV O&M Costs at 4.2% ($) | Total PV Costs at 4.2% ($) |
| 0 | 2001 | 1.000 | $ 333,200 | | $ 333,200 | $ 333,200 | $ - | $ 333,200 |
| 1 | 2002 | 0.960 | | $ 79,100 | $ 79,100 | $ - | $ 75,912 | $ 75,912 |
| 2 | 2003 | 0.921 | | $ 79,100 | $ 79,100 | $ - | $ 72,852 | $ 72,852 |
| 3 | 2004 | 0.884 | | $ 79,100 | $ 79,100 | $ - | $ 69,915 | $ 69,915 |
| 4 | 2005 | 0.848 | | $ 79,100 | $ 79,100 | $ - | $ 67,097 | $ 67,097 |
| 5 | 2006 | 0.814 | | $ 79,100 | $ 79,100 | $ - | $ 64,393 | $ 64,393 |
| 6 | 2007 | 0.781 | | $ 79,100 | $ 79,100 | $ - | $ 61,797 | $ 61,797 |
| 7 | 2008 | 0.750 | | $ 79,100 | $ 79,100 | $ - | $ 59,307 | $ 59,307 |
| 8 | 2009 | 0.720 | | $ 79,100 | $ 79,100 | $ - | $ 56,916 | $ 56,916 |
| 9 | 2010 | 0.691 | | $ 79,100 | $ 79,100 | $ - | $ 54,622 | $ 54,622 |
| 10 | 2011 | 0.663 | | $ 79,100 | $ 79,100 | $ - | $ 52,420 | $ 52,420 |
| 11 | 2012 | 0.636 | | $ 79,100 | $ 79,100 | $ - | $ 50,307 | $ 50,307 |
| 12 | 2013 | 0.610 | | $ 79,100 | $ 79,100 | $ - | $ 48,280 | $ 48,280 |
| 13 | 2014 | 0.586 | | $ 79,100 | $ 79,100 | $ - | $ 46,334 | $ 46,334 |
| 14 | 2015 | 0.562 | | $ 79,100 | $ 79,100 | $ - | $ 44,466 | $ 44,466 |
| 15 | 2016 | 0.539 | | $ 79,100 | $ 79,100 | $ - | $ 42,674 | $ 42,674 |
| 16 | 2017 | 0.518 | | $ 79,100 | $ 79,100 | $ - | $ 40,954 | $ 40,954 |
| 17 | 2018 | 0.497 | | $ 79,100 | $ 79,100 | $ - | $ 39,303 | $ 39,303 |
| 18 | 2019 | 0.477 | | $ 79,100 | $ 79,100 | $ - | $ 37,719 | $ 37,719 |
| 19 | 2020 | 0.458 | | $ 79,100 | $ 79,100 | $ - | $ 36,198 | $ 36,198 |
| 20 | 2021 | 0.439 | | $ 79,100 | $ 79,100 | $ - | $ 34,739 | $ 34,739 |
| 21 | 2022 | 0.421 | | $ 79,100 | $ 79,100 | $ - | $ 33,339 | $ 33,339 |
| 22 | 2023 | 0.404 | | $ 79,100 | $ 79,100 | $ - | $ 31,995 | $ 31,995 |
| 23 | 2024 | 0.388 | | $ 79,100 | $ 79,100 | $ - | $ 30,706 | $ 30,706 |
| 24 | 2025 | 0.373 | | $ 79,100 | $ 79,100 | $ - | $ 29,468 | $ 29,468 |
| 25 | 2026 | 0.358 | | $ 79,100 | $ 79,100 | $ - | $ 28,280 | $ 28,280 |
| 26 | 2027 | 0.343 | | $ 79,100 | $ 79,100 | $ - | $ 27,140 | $ 27,140 |
| 27 | 2028 | 0.329 | | $ 79,100 | $ 79,100 | $ - | $ 26,046 | $ 26,046 |
| 28 | 2029 | 0.316 | | $ 79,100 | $ 79,100 | $ - | $ 24,997 | $ 24,997 |
| 29 | 2030 | 0.303 | | $ 79,100 | $ 79,100 | $ - | $ 23,989 | $ 23,989 |
| Total Alt 2 | | | $ 333,200 | $ 2,293,900 | $ 2,627,100 | $ 333,200 | $ 1,312,166 | $ 1,645,366 |

## Alternative 3 - HRC/ORC Injection, Institutional Controls, and Long-Term Monitoring

| | | E | A | B | C=A+B | C*A | C*B | C*E |
|---|---|---|---|---|---|---|---|---|
| Year | | Discount Factor at 4.2% | Capital Cost | O&M Cost | Total Cost | Total PV Capital Costs at 4.2% ($) | Total PV O&M Costs at 4.2% ($) | Total PV Costs at 4.2% ($) |
| 0 | 2001 | 1.000 | $ 493,300 | | $ 493,300 | $ 493,300 | $ - | $ 493,300 |
| 1 | 2002 | 0.960 | | $ 92,400 | $ 92,400 | $ - | $ 88,676 | $ 88,676 |
| 2 | 2003 | 0.921 | | $ 92,400 | $ 92,400 | $ - | $ 85,101 | $ 85,101 |
| 3 | 2004 | 0.884 | | $ 92,400 | $ 92,400 | $ - | $ 81,671 | $ 81,671 |
| 4 | 2005 | 0.848 | | $ 92,400 | $ 92,400 | $ - | $ 78,379 | $ 78,379 |
| 5 | 2006 | 0.814 | | $ 92,400 | $ 92,400 | $ - | $ 75,220 | $ 75,220 |
| 6 | 2007 | 0.781 | | $ 92,400 | $ 92,400 | $ - | $ 72,188 | $ 72,188 |
| 7 | 2008 | 0.750 | | $ 92,400 | $ 92,400 | $ - | $ 69,278 | $ 69,278 |
| 8 | 2009 | 0.720 | | $ 92,400 | $ 92,400 | $ - | $ 66,486 | $ 66,486 |
| 9 | 2010 | 0.691 | | $ 92,400 | $ 92,400 | $ - | $ 63,806 | $ 63,806 |
| 10 | 2011 | 0.663 | | $ 92,400 | $ 92,400 | $ - | $ 61,234 | $ 61,234 |
| 11 | 2012 | 0.636 | | $ 92,400 | $ 92,400 | $ - | $ 58,766 | $ 58,766 |
| 12 | 2013 | 0.610 | | $ 92,400 | $ 92,400 | $ - | $ 56,397 | $ 56,397 |
| 13 | 2014 | 0.586 | | $ 92,400 | $ 92,400 | $ - | $ 54,124 | $ 54,124 |
| 14 | 2015 | 0.562 | | $ 92,400 | $ 92,400 | $ - | $ 51,943 | $ 51,943 |
| 15 | 2016 | 0.539 | | $ 92,400 | $ 92,400 | $ - | $ 49,849 | $ 49,849 |
| 16 | 2017 | 0.518 | | $ 92,400 | $ 92,400 | $ - | $ 47,840 | $ 47,840 |
| 17 | 2018 | 0.497 | | $ 92,400 | $ 92,400 | $ - | $ 45,911 | $ 45,911 |
| 18 | 2019 | 0.477 | | $ 92,400 | $ 92,400 | $ - | $ 44,061 | $ 44,061 |
| 19 | 2020 | 0.458 | | $ 92,400 | $ 92,400 | $ - | $ 42,285 | $ 42,285 |
| 20 | 2021 | 0.439 | | $ 92,400 | $ 92,400 | $ - | $ 40,581 | $ 40,581 |
| 21 | 2022 | 0.421 | | $ 92,400 | $ 92,400 | $ - | $ 38,945 | $ 38,945 |
| 22 | 2023 | 0.404 | | $ 92,400 | $ 92,400 | $ - | $ 37,375 | $ 37,375 |
| 23 | 2024 | 0.388 | | $ 92,400 | $ 92,400 | $ - | $ 35,869 | $ 35,869 |
| 24 | 2025 | 0.373 | | $ 92,400 | $ 92,400 | $ - | $ 34,423 | $ 34,423 |
| 25 | 2026 | 0.358 | | $ 92,400 | $ 92,400 | $ - | $ 33,035 | $ 33,035 |
| 26 | 2027 | 0.343 | | $ 92,400 | $ 92,400 | $ - | $ 31,704 | $ 31,704 |
| 27 | 2028 | 0.329 | | $ 92,400 | $ 92,400 | $ - | $ 30,426 | $ 30,426 |
| 28 | 2029 | 0.316 | | $ 92,400 | $ 92,400 | $ - | $ 29,200 | $ 29,200 |
| 29 | 2030 | 0.303 | | $ 92,400 | $ 92,400 | $ - | $ 28,023 | $ 28,023 |
| Total Alt 3 | | | $ 493,300 | $ 2,679,600 | $ 3,172,900 | $ 493,300 | $ 1,532,796 | $ 2,026,096 |

Estimate Summary

| | |
|---|---|
| PROJECT: | Feasibility Study (Groundwater) |
| SITE: | Oceana SWMU 2C, Virginia Beach, VA |
| ALTERNATIVE | 1 |
| DESCRIPTION: | No Action |

| DESCRIPTION | QTY | UNIT | INSTALLED COSTS UNITS | INSTALLED COSTS AMOUNT | TOTAL |
|---|---|---|---|---|---|
| **5-year Site Reviews** | | | | | |
| Visual Site Inspection | 1 | LS | $1,980 | $1,980 | $1,980 |
| **GRAND TOTAL ANNUAL** | | | | | $2,000 |
| **PRESENT WORTH** | | | $6,500 | | |

Assumptions:

1. 5-year Site Inspection includes Contingency and Overhead & Profit are built into the unit cost.
2. 5-year Site Inspection will be conducted every 5 years for 30 years.
3. Discount Rate = 4.2%

Estimate Summary

| | |
|---|---|
| PROJECT: | Feasibility Study (Groundwater) |
| SITE: | Oceana SWMU 2C, Virginia Beach, VA |
| ALTERNATIVE | 2 |
| DESCRIPTION: | Monitored Natural Attenuation and Institutional Controls |

| DESCRIPTION | QTY | UNIT | INSTALLED COSTS UNITS | INSTALLED COSTS AMOUNT | CONTINGENCY 15.00% | OH&P 15.00% | TOTAL |
|---|---|---|---|---|---|---|---|
| **MNA STUDY/GROUNDWATER MODELING (Year 1)** | | | | | | | |
| Monitored Natural Attenuation Study | 1 | LS | $30,000 | $30,000 | $4,500 | $5,175 | $39,675 |
| Groundwater Modeling for Estimating TTCU | 1 | LS | $5,354 | $5,354 | $803 | $924 | $7,081 |
| **TOTAL** | | | | | | | $46,800 |
| **GRAND TOTAL CAPITAL** | | | | | | | $46,800 |
| **Monitored Natural Attenuation (Year 1 through Year 30)** | | | | | | | |
| Sampling /Analysis/Reporting of 21 Existing Wells | 1 | LS | $52,100 | $52,100 | $7,815 | $8,987 | $68,902 |
| Monitored Natural Attenuation Technical Memorandum | 1 | LS | $ 7,000 | $7,000 | $1,050 | $1,208 | $9,258 |
| **GRAND TOTAL ANNUAL** | | | | | | | $78,200 |
| **PRESENT WORTH** | | | | $1,344,000 | | | |

Assumptions:

1. There is no cost associated with the implementation of institutional controls.
2. Sampling/Analysis/Reporting will be every other year for a 30-year duration.
3. Discount Rate = 4.2%

Estimate Summary

| | |
|---|---|
| PROJECT: | Feasibility Study (Groundwater) |
| SITE: | Oceana SWMU 2C, Virginia Beach, VA |
| ALTERNATIVE | 3 |
| DESCRIPTION: | HRC/ORC Injection, Monitored Natural Attenuation, and Institutional Controls |

| DESCRIPTION | QTY | UNIT | INSTALLED COSTS UNITS | INSTALLED COSTS AMOUNT | CONTINGENCY 15.00% | OH&P 15.00% | TOTAL |
|---|---|---|---|---|---|---|---|
| **PILOT STUDY (Year 1)** | | | | | | | |
| ORC Material | 1 | LS | $3,788 | $3,788 | $568 | $653 | $5,009 |
| HRC Material | 1 | LS | $3,874 | $3,874 | $581 | $668 | $5,123 |
| Other Carbon Source Material | 1 | LS | $775 | $775 | $116 | $134 | $1,025 |
| Pilot Test Injection | 1 | LS | $24,348 | $24,348 | $3,652 | $4,200 | $32,200 |
| **FIRST YEAR PILOT STUDY GROUNDWATER SAMPLING (Year 1)** | | | | | | | |
| Sampling /Analysis/Reporting of temporary and existing wells (baseline then every other month for 8 months) | 1 | LS | $137,900 | $137,900 | $20,685 | $23,788 | $182,373 |
| First Year Groundwater Monitoring and Pilot Study Technical Memorandum | 1 | LS | $ 20,000 | $20,000 | $3,000 | $3,450 | $26,450 |
| **MNA STUDY/GROUNDWATER MODELING (Year 1)** | | | | | | | |
| Monitored Natural Attenuation Study | 1 | LS | $30,000 | $30,000 | $4,500 | $5,175 | $39,675 |
| Groundwater Modeling for Estimating TTCU | 1 | LS | $5,354 | $5,354 | $803 | $924 | $7,081 |
| **PHASE 1 FULL-SCALE REMEDIATION (Year 2)** | | | | | | | |
| ORC Material | 1 | LS | $64,881 | $64,881 | $9,732 | $11,192 | $85,805 |
| HRC or Other Carbon Source Material (see note 4) | 1 | LS | $53,661 | $53,661 | $8,049 | $9,257 | $70,967 |
| Material Injection | 1 | LS | $117,826 | $117,826 | $17,674 | $20,325 | $155,825 |
| Temporary Well Installation (12 wells) | 1 | LS | $10,000 | $10,000 | $1,500 | $1,725 | $13,225 |
| **PHASE 2 FULL-SCALE REMEDIATION (Year 3)** | | | | | | | |
| HRC or Other Carbon Source Material (see note 4) | 1 | LS | $38,115 | $38,115 | $5,717 | $6,575 | $50,408 |
| Material Injection | 1 | LS | $38,609 | $38,609 | $5,791 | $6,660 | $51,060 |
| **GRAND TOTAL CAPITAL** | | | | | | | $726,200 |
| Annual MNA Sampling /Analysis/Reporting of temporary and existing wells (Year 2 through Year 5) | 1 | LS | $90,600 | $90,600 | $13,590 | $15,629 | $119,819 |
| Annual LTM Sampling /Analysis/Reporting of temporary and existing wells (Year 6) | 1 | LS | $398,400 | $398,400 | $59,760 | $68,724 | $526,884 |
| Annual LTM Sampling /Analysis/Reporting of temporary and existing wells (Years 7 and 8) | 1 | LS | $99,600 | $99,600 | $14,940 | $17,181 | $131,721 |
| Annual Long-term Monitoring Technical Memorandum | 1 | LS | $7,000 | $7,000 | $1,050 | $1,208 | $9,258 |
| **GRAND TOTAL ANNUAL (average)** | | | | | | | $190,600 |

| | |
|---|---|
| **PRESENT WORTH** | $1,902,500 |

Assumptions:

1. There is no cost associated with the implementation of institutional controls.
2. Regenesis estimates project may require 2 to 4 years to complete.
3. Sampling/Analysis/Reporting for the first year will include baseline plus sampling every other month for 8 months (5 sampling events total).
4. The cost of HRC material will be used to estimate the cost of this alternative.
5. Discount Rate = 4.2%

## Alternative 1 - No Action

| | | E | A | B | C=A+B | C*A | C*B | C*E |
|---|---|---|---|---|---|---|---|---|
| Year | | Discount Factor at 4.2% | Capital Cost | O&M Cost | Total Cost | Total PV Capital Costs at 4.2% ($) | Total PV O&M Costs at 4.2% ($) | Total PV Costs at 4.2% ($) |
| 0 | 2001 | 1.000 | | | $ - | $ - | $ - | $ - |
| 1 | 2002 | 0.960 | | | $ - | $ - | $ - | $ - |
| 2 | 2003 | 0.921 | | | $ - | $ - | $ - | $ - |
| 3 | 2004 | 0.884 | | | $ - | $ - | $ - | $ - |
| 4 | 2005 | 0.848 | | $ 2,000 | $ 2,000 | $ - | $ 1,697 | $ 1,697 |
| 5 | 2006 | 0.814 | | | $ - | $ - | $ - | $ - |
| 6 | 2007 | 0.781 | | | $ - | $ - | $ - | $ - |
| 7 | 2008 | 0.750 | | | $ - | $ - | $ - | $ - |
| 8 | 2009 | 0.720 | | | $ - | $ - | $ - | $ - |
| 9 | 2010 | 0.691 | | $ 2,000 | $ 2,000 | $ - | $ 1,381 | $ 1,381 |
| 10 | 2011 | 0.663 | | | $ - | $ - | $ - | $ - |
| 11 | 2012 | 0.636 | | | $ - | $ - | $ - | $ - |
| 12 | 2013 | 0.610 | | | $ - | $ - | $ - | $ - |
| 13 | 2014 | 0.586 | | | $ - | $ - | $ - | $ - |
| 14 | 2015 | 0.562 | | $ 2,000 | $ 2,000 | $ - | $ 1,124 | $ 1,124 |
| 15 | 2016 | 0.539 | | | $ - | $ - | $ - | $ - |
| 16 | 2017 | 0.518 | | | $ - | $ - | $ - | $ - |
| 17 | 2018 | 0.497 | | | $ - | $ - | $ - | $ - |
| 18 | 2019 | 0.477 | | | $ - | $ - | $ - | $ - |
| 19 | 2020 | 0.458 | | $ 2,000 | $ 2,000 | $ - | $ 915 | $ 915 |
| 20 | 2021 | 0.439 | | | $ - | $ - | $ - | $ - |
| 21 | 2022 | 0.421 | | | $ - | $ - | $ - | $ - |
| 22 | 2023 | 0.404 | | | $ - | $ - | $ - | $ - |
| 23 | 2024 | 0.388 | | | $ - | $ - | $ - | $ - |
| 24 | 2025 | 0.373 | | $ 2,000 | $ 2,000 | $ - | $ 745 | $ 745 |
| 25 | 2026 | 0.358 | | | $ - | $ - | $ - | $ - |
| 26 | 2027 | 0.343 | | | $ - | $ - | $ - | $ - |
| 27 | 2028 | 0.329 | | | $ - | $ - | $ - | $ - |
| 28 | 2029 | 0.316 | | | $ - | $ - | $ - | $ - |
| 29 | 2030 | 0.303 | | $ 2,000 | $ 2,000 | $ - | $ 607 | $ 607 |
| Total Atl 1 | | | $ - | $ 12,000 | $ 12,000 | $ - | $ 6,469 | $ 6,469 |

## Alternative 2 - Monitored Natural Attenuation and Institutional Controls

| | | E | A | B | C=A+B | C*A | C*B | C*E |
|---|---|---|---|---|---|---|---|---|
| Year | | Discount Factor at 4.2% | Capital Cost | O&M Cost | Total Cost | Total PV Capital Costs at 4.2% ($) | Total PV O&M Costs at 4.2% ($) | Total PV Costs at 4.2% ($) |
| 0 | 2001 | 1.000 | $ 46,800 | | $ 46,800 | $ 46,800 | $ - | $ 46,800 |
| 1 | 2002 | 0.960 | | $ 78,200 | $ 78,200 | $ - | $ 75,048 | $ 75,048 |
| 2 | 2003 | 0.921 | | $ 78,200 | $ 78,200 | $ - | $ 72,023 | $ 72,023 |
| 3 | 2004 | 0.884 | | $ 78,200 | $ 78,200 | $ - | $ 69,120 | $ 69,120 |
| 4 | 2005 | 0.848 | | $ 78,200 | $ 78,200 | $ - | $ 66,334 | $ 66,334 |
| 5 | 2006 | 0.814 | | $ 78,200 | $ 78,200 | $ - | $ 63,660 | $ 63,660 |
| 6 | 2007 | 0.781 | | $ 78,200 | $ 78,200 | $ - | $ 61,094 | $ 61,094 |
| 7 | 2008 | 0.750 | | $ 78,200 | $ 78,200 | $ - | $ 58,632 | $ 58,632 |
| 8 | 2009 | 0.720 | | $ 78,200 | $ 78,200 | $ - | $ 56,268 | $ 56,268 |
| 9 | 2010 | 0.691 | | $ 78,200 | $ 78,200 | $ - | $ 54,000 | $ 54,000 |
| 10 | 2011 | 0.663 | | $ 78,200 | $ 78,200 | $ - | $ 51,824 | $ 51,824 |
| 11 | 2012 | 0.636 | | $ 78,200 | $ 78,200 | $ - | $ 49,735 | $ 49,735 |
| 12 | 2013 | 0.610 | | $ 78,200 | $ 78,200 | $ - | $ 47,730 | $ 47,730 |
| 13 | 2014 | 0.586 | | $ 78,200 | $ 78,200 | $ - | $ 45,806 | $ 45,806 |
| 14 | 2015 | 0.562 | | $ 78,200 | $ 78,200 | $ - | $ 43,960 | $ 43,960 |
| 15 | 2016 | 0.539 | | $ 78,200 | $ 78,200 | $ - | $ 42,188 | $ 42,188 |
| 16 | 2017 | 0.518 | | $ 78,200 | $ 78,200 | $ - | $ 40,488 | $ 40,488 |
| 17 | 2018 | 0.497 | | $ 78,200 | $ 78,200 | $ - | $ 38,856 | $ 38,856 |
| 18 | 2019 | 0.477 | | $ 78,200 | $ 78,200 | $ - | $ 37,290 | $ 37,290 |
| 19 | 2020 | 0.458 | | $ 78,200 | $ 78,200 | $ - | $ 35,787 | $ 35,787 |
| 20 | 2021 | 0.439 | | $ 78,200 | $ 78,200 | $ - | $ 34,344 | $ 34,344 |
| 21 | 2022 | 0.421 | | $ 78,200 | $ 78,200 | $ - | $ 32,960 | $ 32,960 |
| 22 | 2023 | 0.404 | | $ 78,200 | $ 78,200 | $ - | $ 31,631 | $ 31,631 |
| 23 | 2024 | 0.388 | | $ 78,200 | $ 78,200 | $ - | $ 30,356 | $ 30,356 |
| 24 | 2025 | 0.373 | | $ 78,200 | $ 78,200 | $ - | $ 29,133 | $ 29,133 |
| 25 | 2026 | 0.358 | | $ 78,200 | $ 78,200 | $ - | $ 27,958 | $ 27,958 |
| 26 | 2027 | 0.343 | | $ 78,200 | $ 78,200 | $ - | $ 26,832 | $ 26,832 |
| 27 | 2028 | 0.329 | | $ 78,200 | $ 78,200 | $ - | $ 25,750 | $ 25,750 |
| 28 | 2029 | 0.316 | | $ 78,200 | $ 78,200 | $ - | $ 24,712 | $ 24,712 |
| 29 | 2030 | 0.303 | | $ 78,200 | $ 78,200 | $ - | $ 23,716 | $ 23,716 |
| Total Alt 2 | | | $ 46,800 | $ 2,267,800 | $ 2,314,600 | $ 46,800 | $ 1,297,236 | $ 1,344,036 |

## Alternative 3 - HRC/ORC Injection, Monitored Natural Attenuation, and Institutional Controls

| | | E | A | B | C=A+B | C*A | C*B | C*E |
|---|---|---|---|---|---|---|---|---|
| Year | | Discount Factor at 4.2% | Capital Cost | O&M Cost | Total Cost | Total PV Capital Costs at 4.2% ($) | Total PV O&M Costs at 4.2% ($) | Total PV Costs at 4.2% ($) |
| 0 | 2001 | 1.000 | $ 298,936 | | $ 298,936 | $ 298,936 | $ - | $ 298,936 |
| 1 | 2002 | 0.960 | $ 325,822 | $ 129,077 | $ 454,899 | $ 312,689 | $ 123,874 | $ 436,563 |
| 2 | 2003 | 0.921 | $ 101,468 | $ 129,077 | $ 230,545 | $ 93,453 | $ 118,881 | $ 212,334 |
| 3 | 2004 | 0.884 | | $ 129,077 | $ 129,077 | $ - | $ 114,090 | $ 114,090 |
| 4 | 2005 | 0.848 | | $ 129,077 | $ 129,077 | $ - | $ 109,491 | $ 109,491 |
| 5 | 2006 | 0.814 | | $ 129,077 | $ 129,077 | $ - | $ 105,078 | $ 105,078 |
| 6 | 2007 | 0.781 | | $ 536,142 | $ 536,142 | $ - | $ 418,864 | $ 418,864 |
| 7 | 2008 | 0.750 | | $ 140,979 | $ 140,979 | $ - | $ 105,701 | $ 105,701 |
| 8 | 2009 | 0.720 | | $ 140,979 | $ 140,979 | $ - | $ 101,441 | $ 101,441 |
| 9 | 2010 | 0.691 | | | $ - | $ - | $ - | $ - |
| 10 | 2011 | 0.663 | | | $ - | $ - | $ - | $ - |
| 11 | 2012 | 0.636 | | | $ - | $ - | $ - | $ - |
| 12 | 2013 | 0.610 | | | $ - | $ - | $ - | $ - |
| 13 | 2014 | 0.586 | | | $ - | $ - | $ - | $ - |
| 14 | 2015 | 0.562 | | | $ - | $ - | $ - | $ - |
| 15 | 2016 | 0.539 | | | $ - | $ - | $ - | $ - |
| 16 | 2017 | 0.518 | | | $ - | $ - | $ - | $ - |
| 17 | 2018 | 0.497 | | | $ - | $ - | $ - | $ - |
| 18 | 2019 | 0.477 | | | $ - | $ - | $ - | $ - |
| 19 | 2020 | 0.458 | | | $ - | $ - | $ - | $ - |
| 20 | 2021 | 0.439 | | | $ - | $ - | $ - | $ - |
| 21 | 2022 | 0.421 | | | $ - | $ - | $ - | $ - |
| 22 | 2023 | 0.404 | | | $ - | $ - | $ - | $ - |
| 23 | 2024 | 0.388 | | | $ - | $ - | $ - | $ - |
| 24 | 2025 | 0.373 | | | $ - | $ - | $ - | $ - |
| 25 | 2026 | 0.358 | | | $ - | $ - | $ - | $ - |
| 26 | 2027 | 0.343 | | | $ - | $ - | $ - | $ - |
| 27 | 2028 | 0.329 | | | $ - | $ - | $ - | $ - |
| 28 | 2029 | 0.316 | | | $ - | $ - | $ - | $ - |
| 29 | 2030 | 0.303 | | | $ - | $ - | $ - | $ - |
| Total Alt 3 | | | $ 726,226 | $ 1,463,485 | $ 2,189,711 | $ 705,078 | $ 1,197,420 | $ 1,902,498 |

Estimate Summary

PROJECT: Feasibility Study (Groundwater)
SITE: Oceana SWMU 2E, Virginia Beach, VA
ALTERNATIVE 1
DESCRIPTION: No Action

| DESCRIPTION | QTY | UNIT | INSTALLED COSTS UNITS | INSTALLED COSTS AMOUNT | TOTAL |
|---|---|---|---|---|---|
| **5-year Site Reviews** | | | | | |
| Visual Site Inspection | 1 | LS | $1,980 | $1,980 | $1,980 |
| **GRAND TOTAL ANNUAL** | | | | | $2,000 |
| **PRESENT WORTH** | | | $6,500 | | |

Assumptions:

1. 5-year Site Inspection includes Contingency and Overhead & Profit are built into the unit cost.
2. 5-year Site Inspection will be conducted every 5 years for 30 years.
3. Discount Rate = 4.2%

Estimate Summary

PROJECT: Feasibility Study (Groundwater)
SITE: Oceana SWMU 2E, Virginia Beach, VA
ALTERNATIVE 2
DESCRIPTION: Free-Product Removal, Institutional Controls and Long-Term Monitoring

| DESCRIPTION | QTY | UNIT | INSTALLED COSTS UNIT$ | INSTALLED COSTS AMOUNT | CONTINGENCY 15.00% | OH&P 15.00% | TOTAL |
|---|---|---|---|---|---|---|---|
| **LONG-TERM MONITORING (Year 1)** | | | | | | | |
| Preparation of an Long-term Monitoring Plan | 1 | LS | $30,000 | $30,000 | $4,500 | $5,175 | $39,675 |
| **GROUNDWATER MODELING (Year 1)** | | | | | | | |
| Groundwater Modeling for Estimating TTCU | 1 | LS | $5,354 | $5,354 | $803 | $924 | $7,081 |
| **FIRST YEAR GROUNDWATER SAMPLING (Year 1)** | | | | | | | |
| Quarterly Sampling /Analysis/Reporting of existing wells | 1 | LS | $168,800 | $168,800 | $25,320 | $29,118 | $223,238 |
| First Year Groundwater Monitoring Technical Memorandum | 1 | LS | $ 10,000 | $10,000 | $1,500 | $1,725 | $13,225 |
| **TOTAL** | | | | | | | $283,200 |
| **GRAND TOTAL CAPITAL** | | | | | | | $283,200 |
| **Expenses (O&M)** | | | | | | | |
| Sampling /Analysis/Reporting of existing wells | 1 | LS | $42,200 | $42,200 | $6,330 | $7,280 | $55,810 |
| Groundwater Monitoring Technical Memorandum | 1 | LS | $ 7,000 | $7,000 | $1,050 | $1,208 | $9,258 |
| **GRAND TOTAL ANNUAL** | | | | | | | $65,100 |

| | |
|---|---|
| **PRESENT WORTH** | $1,363,100 |

Assumptions:

1. There is no cost associated with the implementation of institutional controls.
2. Sampling/Analysis/Reporting will be every year for a 30-year duration.
3. Free-product removal is presently occuring at SWMU 2E, and will continue under this alternative. Due to this, the cost for free-product removal is not included in the present worth cost for this alternative.
4. Discount Rate = 4.2%

Estimate Summary

PROJECT: Feasibility Study (Groundwater)
SITE: Oceana SWMU 2E, Virginia Beach, VA
ALTERNATIVE 3
DESCRIPTION: ORC Injection, Free-Product Removal, Institutional Controls, and Long-Term Monitoring

| DESCRIPTION | QTY | UNIT | INSTALLED COSTS UNIT$ | INSTALLED COSTS AMOUNT | CONTINGENCY 15.00% | OH&P 15.00% | TOTAL |
|---|---|---|---|---|---|---|---|
| **LONG-TERM MONITORING (Year 1)** | | | | | | | |
| Preparation of an ORC Injection Work Plan/ Long-term Monitoring Plan | 1 | LS | $30,000 | $30,000 | $4,500 | $5,175 | $39,675 |
| **INJECTION OF HRC/ORC (Year 1)** | | | | | | | |
| ORC Material | 1 | LS | $18,174 | $18,174 | $2,726 | $3,135 | $24,035 |
| Injection of ORC | 1 | LS | $8,957 | $8,957 | $1,343 | $1,545 | $11,845 |
| **FIRST YEAR GROUNDWATER SAMPLING (Year 1)** | | | | | | | |
| Sampling /Analysis/Reporting of existing wells (baseline then every other month for 8 months) | 1 | LS | $199,600 | $199,600 | $29,940 | $34,431 | $263,971 |
| First Year Groundwater Monitoring Technical Memorandum | 1 | LS | $ 10,000 | $10,000 | $1,500 | $1,725 | $13,225 |
| **TOTAL** | | | | | | | $352,800 |
| **GRAND TOTAL CAPITAL** | | | | | | | $352,800 |
| **Annual Expenses (O&M)** | | | | | | | |
| MNA Annual Sampling /Analysis/Reporting of existing wells | 1 | LS | $49,900 | $49,900 | $7,485 | $8,608 | $65,993 |
| Annual Groundwater Monitoring Technical Memorandum | 1 | LS | $ 7,000 | $7,000 | $1,050 | $1,208 | $9,258 |
| **GRAND TOTAL ANNUAL** | | | | | | | $75,300 |
| **PRESENT WORTH** | | | | $1,601,900 | | | |

Assumptions:

1. There is no cost associated with the implementation of institutional controls.
2. Regenesis estimates project may require 2 to 4 years to complete.
3. Sampling/Analysis/Reporting for the first year will include baseline plus sampling every other month for 8 months (5 sampling events total).
4. Sampling/Analysis/Reporting after the first year pilot study will be every year for 30 years.
5. Free-product removal is presently occuring at SWMU 2E, and will continue under this alternative. Due to this, the cost for free-product removal is not included in the present worth cost for this alternative.
6. Discount Rate = 4.2%

## Alternative 1 - No Action

| | | E | A | B | C=A+B | C*A | C*B | C*E |
|---|---|---|---|---|---|---|---|---|
| Year | | Discount Factor at 4.2% | Capital Cost | O&M Cost | Total Cost | Total PV Capital Costs at 4.2% ($) | Total PV O&M Costs at 4.2% ($) | Total PV Costs at 4.2% ($) |
| 0 | 2001 | 1.000 | | | $ - | $ - | $ - | $ - |
| 1 | 2002 | 0.960 | | | $ - | $ - | $ - | $ - |
| 2 | 2003 | 0.921 | | | $ - | $ - | $ - | $ - |
| 3 | 2004 | 0.884 | | | $ - | $ - | $ - | $ - |
| 4 | 2005 | 0.848 | | $ 2,000 | $ 2,000 | $ - | $ 1,697 | $ 1,697 |
| 5 | 2006 | 0.814 | | | $ - | $ - | $ - | $ - |
| 6 | 2007 | 0.781 | | | $ - | $ - | $ - | $ - |
| 7 | 2008 | 0.750 | | | $ - | $ - | $ - | $ - |
| 8 | 2009 | 0.720 | | | $ - | $ - | $ - | $ - |
| 9 | 2010 | 0.691 | | $ 2,000 | $ 2,000 | $ - | $ 1,381 | $ 1,381 |
| 10 | 2011 | 0.663 | | | $ - | $ - | $ - | $ - |
| 11 | 2012 | 0.636 | | | $ - | $ - | $ - | $ - |
| 12 | 2013 | 0.610 | | | $ - | $ - | $ - | $ - |
| 13 | 2014 | 0.586 | | | $ - | $ - | $ - | $ - |
| 14 | 2015 | 0.562 | | $ 2,000 | $ 2,000 | $ - | $ 1,124 | $ 1,124 |
| 15 | 2016 | 0.539 | | | $ - | $ - | $ - | $ - |
| 16 | 2017 | 0.518 | | | $ - | $ - | $ - | $ - |
| 17 | 2018 | 0.497 | | | $ - | $ - | $ - | $ - |
| 18 | 2019 | 0.477 | | | $ - | $ - | $ - | $ - |
| 19 | 2020 | 0.458 | | $ 2,000 | $ 2,000 | $ - | $ 915 | $ 915 |
| 20 | 2021 | 0.439 | | | $ - | $ - | $ - | $ - |
| 21 | 2022 | 0.421 | | | $ - | $ - | $ - | $ - |
| 22 | 2023 | 0.404 | | | $ - | $ - | $ - | $ - |
| 23 | 2024 | 0.388 | | | $ - | $ - | $ - | $ - |
| 24 | 2025 | 0.373 | | $ 2,000 | $ 2,000 | $ - | $ 745 | $ 745 |
| 25 | 2026 | 0.358 | | | $ - | $ - | $ - | $ - |
| 26 | 2027 | 0.343 | | | $ - | $ - | $ - | $ - |
| 27 | 2028 | 0.329 | | | $ - | $ - | $ - | $ - |
| 28 | 2029 | 0.316 | | | $ - | $ - | $ - | $ - |
| 29 | 2030 | 0.303 | | $ 2,000 | $ 2,000 | $ - | $ 607 | $ 607 |
| Total Atl 1 | | | $ - | $ 12,000 | $ 12,000 | $ - | $ 6,469 | $ 6,469 |

## Alternative 2 - Free-Product Removal, Institutional Controls and Long-Term Monitoring

| | | E | A | B | C=A+B | C*A | C*B | C*E |
|---|---|---|---|---|---|---|---|---|
| Year | | Discount Factor at 4.2% | Capital Cost | O&M Cost | Total Cost | Total PV Capital Costs at 4.2% ($) | Total PV O&M Costs at 4.2% ($) | Total PV Costs at 4.2% ($) |
| 0 | 2001 | 1.000 | $ 283,200 | | $ 283,200 | $ 283,200 | $ - | $ 283,200 |
| 1 | 2002 | 0.960 | | $ 65,100 | $ 65,100 | $ - | $ 62,476 | $ 62,476 |
| 2 | 2003 | 0.921 | | $ 65,100 | $ 65,100 | $ - | $ 59,958 | $ 59,958 |
| 3 | 2004 | 0.884 | | $ 65,100 | $ 65,100 | $ - | $ 57,541 | $ 57,541 |
| 4 | 2005 | 0.848 | | $ 65,100 | $ 65,100 | $ - | $ 55,222 | $ 55,222 |
| 5 | 2006 | 0.814 | | $ 65,100 | $ 65,100 | $ - | $ 52,996 | $ 52,996 |
| 6 | 2007 | 0.781 | | $ 65,100 | $ 65,100 | $ - | $ 50,860 | $ 50,860 |
| 7 | 2008 | 0.750 | | $ 65,100 | $ 65,100 | $ - | $ 48,810 | $ 48,810 |
| 8 | 2009 | 0.720 | | $ 65,100 | $ 65,100 | $ - | $ 46,842 | $ 46,842 |
| 9 | 2010 | 0.691 | | $ 65,100 | $ 65,100 | $ - | $ 44,954 | $ 44,954 |
| 10 | 2011 | 0.663 | | $ 65,100 | $ 65,100 | $ - | $ 43,142 | $ 43,142 |
| 11 | 2012 | 0.636 | | $ 65,100 | $ 65,100 | $ - | $ 41,403 | $ 41,403 |
| 12 | 2013 | 0.610 | | $ 65,100 | $ 65,100 | $ - | $ 39,735 | $ 39,735 |
| 13 | 2014 | 0.586 | | $ 65,100 | $ 65,100 | $ - | $ 38,133 | $ 38,133 |
| 14 | 2015 | 0.562 | | $ 65,100 | $ 65,100 | $ - | $ 36,596 | $ 36,596 |
| 15 | 2016 | 0.539 | | $ 65,100 | $ 65,100 | $ - | $ 35,121 | $ 35,121 |
| 16 | 2017 | 0.518 | | $ 65,100 | $ 65,100 | $ - | $ 33,705 | $ 33,705 |
| 17 | 2018 | 0.497 | | $ 65,100 | $ 65,100 | $ - | $ 32,347 | $ 32,347 |
| 18 | 2019 | 0.477 | | $ 65,100 | $ 65,100 | $ - | $ 31,043 | $ 31,043 |
| 19 | 2020 | 0.458 | | $ 65,100 | $ 65,100 | $ - | $ 29,792 | $ 29,792 |
| 20 | 2021 | 0.439 | | $ 65,100 | $ 65,100 | $ - | $ 28,591 | $ 28,591 |
| 21 | 2022 | 0.421 | | $ 65,100 | $ 65,100 | $ - | $ 27,438 | $ 27,438 |
| 22 | 2023 | 0.404 | | $ 65,100 | $ 65,100 | $ - | $ 26,332 | $ 26,332 |
| 23 | 2024 | 0.388 | | $ 65,100 | $ 65,100 | $ - | $ 25,271 | $ 25,271 |
| 24 | 2025 | 0.373 | | $ 65,100 | $ 65,100 | $ - | $ 24,252 | $ 24,252 |
| 25 | 2026 | 0.358 | | $ 65,100 | $ 65,100 | $ - | $ 23,275 | $ 23,275 |
| 26 | 2027 | 0.343 | | $ 65,100 | $ 65,100 | $ - | $ 22,337 | $ 22,337 |
| 27 | 2028 | 0.329 | | $ 65,100 | $ 65,100 | $ - | $ 21,436 | $ 21,436 |
| 28 | 2029 | 0.316 | | $ 65,100 | $ 65,100 | $ - | $ 20,572 | $ 20,572 |
| 29 | 2030 | 0.303 | | $ 65,100 | $ 65,100 | $ - | $ 19,743 | $ 19,743 |
| Total Alt 2 | | | $ 283,200 | $ 1,887,900 | $ 2,171,100 | $ 283,200 | $ 1,079,924 | $ 1,363,124 |

## Alternative 3 - ORC Injection, Free-Product Removal, Institutional Controls, and Long-Term Monitoring

| | | E | A | B | C=A+B | C*A | C*B | C*E |
|---|---|---|---|---|---|---|---|---|
| Year | | Discount Factor at 4.2% | Capital Cost | O&M Cost | Total Cost | Total PV Capital Costs at 4.2% ($) | Total PV O&M Costs at 4.2% ($) | Total PV Costs at 4.2% ($) |
| 0 | 2001 | 1.000 | $ 352,800 | | $ 352,800 | $ 352,800 | $ - | $ 352,800 |
| 1 | 2002 | 0.960 | | $ 75,300 | $ 75,300 | $ - | $ 72,265 | $ 72,265 |
| 2 | 2003 | 0.921 | | $ 75,300 | $ 75,300 | $ - | $ 69,352 | $ 69,352 |
| 3 | 2004 | 0.884 | | $ 75,300 | $ 75,300 | $ - | $ 66,557 | $ 66,557 |
| 4 | 2005 | 0.848 | | $ 75,300 | $ 75,300 | $ - | $ 63,874 | $ 63,874 |
| 5 | 2006 | 0.814 | | $ 75,300 | $ 75,300 | $ - | $ 61,299 | $ 61,299 |
| 6 | 2007 | 0.781 | | $ 75,300 | $ 75,300 | $ - | $ 58,829 | $ 58,829 |
| 7 | 2008 | 0.750 | | $ 75,300 | $ 75,300 | $ - | $ 56,457 | $ 56,457 |
| 8 | 2009 | 0.720 | | $ 75,300 | $ 75,300 | $ - | $ 54,182 | $ 54,182 |
| 9 | 2010 | 0.691 | | $ 75,300 | $ 75,300 | $ - | $ 51,998 | $ 51,998 |
| 10 | 2011 | 0.663 | | $ 75,300 | $ 75,300 | $ - | $ 49,902 | $ 49,902 |
| 11 | 2012 | 0.636 | | $ 75,300 | $ 75,300 | $ - | $ 47,891 | $ 47,891 |
| 12 | 2013 | 0.610 | | $ 75,300 | $ 75,300 | $ - | $ 45,960 | $ 45,960 |
| 13 | 2014 | 0.586 | | $ 75,300 | $ 75,300 | $ - | $ 44,108 | $ 44,108 |
| 14 | 2015 | 0.562 | | $ 75,300 | $ 75,300 | $ - | $ 42,330 | $ 42,330 |
| 15 | 2016 | 0.539 | | $ 75,300 | $ 75,300 | $ - | $ 40,624 | $ 40,624 |
| 16 | 2017 | 0.518 | | $ 75,300 | $ 75,300 | $ - | $ 38,986 | $ 38,986 |
| 17 | 2018 | 0.497 | | $ 75,300 | $ 75,300 | $ - | $ 37,415 | $ 37,415 |
| 18 | 2019 | 0.477 | | $ 75,300 | $ 75,300 | $ - | $ 35,907 | $ 35,907 |
| 19 | 2020 | 0.458 | | $ 75,300 | $ 75,300 | $ - | $ 34,459 | $ 34,459 |
| 20 | 2021 | 0.439 | | $ 75,300 | $ 75,300 | $ - | $ 33,070 | $ 33,070 |
| 21 | 2022 | 0.421 | | $ 75,300 | $ 75,300 | $ - | $ 31,738 | $ 31,738 |
| 22 | 2023 | 0.404 | | $ 75,300 | $ 75,300 | $ - | $ 30,458 | $ 30,458 |
| 23 | 2024 | 0.388 | | $ 75,300 | $ 75,300 | $ - | $ 29,231 | $ 29,231 |
| 24 | 2025 | 0.373 | | $ 75,300 | $ 75,300 | $ - | $ 28,052 | $ 28,052 |
| 25 | 2026 | 0.358 | | $ 75,300 | $ 75,300 | $ - | $ 26,922 | $ 26,922 |
| 26 | 2027 | 0.343 | | $ 75,300 | $ 75,300 | $ - | $ 25,837 | $ 25,837 |
| 27 | 2028 | 0.329 | | $ 75,300 | $ 75,300 | $ - | $ 24,795 | $ 24,795 |
| 28 | 2029 | 0.316 | | $ 75,300 | $ 75,300 | $ - | $ 23,796 | $ 23,796 |
| 29 | 2030 | 0.303 | | $ 75,300 | $ 75,300 | $ - | $ 22,837 | $ 22,837 |
| Total Alt 3 | | | $ 352,800 | $ 2,183,700 | $ 2,536,500 | $ 352,800 | $ 1,249,129 | $ 1,601,929 |