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Red Hill Bulk Fuel Storage Facility Work Plan

Pearl Harbor, Hawaii

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June 2005

Prepared for:

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NAVFAC PACIFIC

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LIST OF ACRONYMS

AMEC	AMEC Earth and Environmental, Inc.
AOC	Area of Concern
ARAR	Applicable or Relevant and Appropriate Requirements
AST	Aboveground Storage Tank
AVGAS	Aviation Gasoline
bgs	Below existing ground surface
BOWS	Honolulu Board of Water Supply
CAD	Computer-Aided Design
COPC	Chemical of Potential Concern
CSEM	Conceptual Site Exposure Model
CSM	Conceptual Site Model
CTO	Contract Task Order
DFM	Diesel Fuel Marine
DO	Diesel Oil
DPP	Department of Planning and Permitting
DQO	Data Quality Objective
EarthTech	EarthTech, Inc.
EAL	Environmental Action Level
ECD	Electron Capture Devise
ESRI	Environmental Systems Research Institute
F	Fahrenheit
FID	Flame Ionization Detection
FISC	Fleet Industrial Supply Center
FME	Feature Manipulation Engine
FS	Feasibility Study
FSP	Field Sampling Plan
GIS	Geographic Information System
GC	Gas Chromatography
HDOH	State of Hawaii Department of Health
JP-5	Jet Propulsion Fuel
LNAPL	Light Non-aqueous Phase Liquid
MGD	Million Gallons per Day
MOGAS	Motor Gasoline
msl	Mean Sea Level
MTBE	Methyl Tertiary Butyl Ether
MVS	Mining Visualization System
MW	Monitoring Well
NAPL	Non-aqueous Phase Liquid
NAVFAC	Naval Facilities Engineering Command
NDS	Navy Distillate
NSFO	Navy Special Fuel Oil

Ogden	Ogden Environmental and Energy Services Company, Inc.
OWDF	Oil Waste Disposal Facility
PACDIV	Pacific Division
PAH	Polynuclear Aromatic Hydrocarbons
PID	Photoionization Detector
PWC	Public Works Center
QAPP	Quality Assurance Project Plan
RA	Risk Assessment
RBCA	Risk Based Corrective Action
RHSF	Red Hill Bulk Fuel Storage Facility
RI	Remedial Investigation
SCS	Site Characterization Study
SI	Site Investigation
SOP	Standard Operating Procedure
SOW	Statement of Work
SSHSP	Site-Specific Health and Safety Plan
SVMW	Soil Vapor Monitoring Well
SVOC	Semi-volatile Organic Compounds
TBC	To Be Considered
TCLP	Toxicity Characteristic Leaching Program
TEC	The Environmental Company, Inc.
TFH	Total Fuel Hydrocarbons
TPH	Total Petroleum Hydrocarbons
TRC	Technical Review Committee
UDA	Unauthorized Discharge Area
UIC	Underground Injection Control Line
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VOC	Volatile Organic Compound
VRML	Virtual Reality Modeling Language
WP	Work Plan
3-D	Three Dimensional
4DIM	Four Dimensional Interactive Model

SECTION 1
INTRODUCTION

This document serves as a Work Plan (WP) for a Site Investigation (SI) and Risk Assessment (RA) at the Red Hill Bulk Fuel Storage Facility (herein referred to as RHSF) operated by the Fleet Industrial Supply Center (FISC), Pearl Harbor, Hawaii. The study area is defined as Red Hill, Oahu, Hawaii (**Figure 1-1** and **Figure 1-2**). This Work Plan has been prepared by The Environmental Company, Inc. (TEC) and AMEC, Earth and Environmental (AMEC) for Naval Facilities Engineering Command (NAVFAC) Pacific as part of Contract Task Order (CTO) 007. The plan has been prepared on the basis of the Statement of Work (SOW), dated September 1, 2004, and the Technical Proposal and Cost Estimate negotiated on September 15, 2004. All work for these planning documents have been authorized under the U.S. Navy Environmental Contract No. N62742-02-1802.

This WP, along with the companion Field Sampling Plan (FSP) and Quality Assurance Project Plan (QAPP), will be the basis for conducting a SI and RA for the Site. The SI will supplement previous environmental investigations conducted at the site and acquire data to support the RA. This WP provides a summary of the site background, proposed fieldwork, analytical testing program, construction of a geographic information system (GIS) three-dimensional (3-D) model, fate and transport modeling, and conduct of a Tier 3 Comprehensive RA.

The WP is divided into the following sections:

- Section 1 provides a site description, location, and general project approach.
- Section 2 provides a summary of previous environmental investigations and describes the physical setting of the RHSF.
- Section 3 presents the results of a preliminary risk evaluation, a preliminary conceptual model for the RHSF, and identifies site-specific applicable or relevant and appropriate requirements (ARARs) and to be considered (TBC) benchmarks.

- Section 4 identifies focus components for the field investigation activities and Data Quality Objectives (DQOs) to support the activities.

- Section 5 discusses the general protocol for field investigations, data management and validation, preparation of the site characterization report, GIS modeling, fate and transport modeling, conduct of a comprehensive RA, and contingency plan preparation.

- Section 6 presents a proposed project schedule.

- Section 7 provides document references.

Three companion documents supplement this WP. A FSP (provided in **Appendix A**) presents the study design and includes detailed information on sample locations, sampling methods, and environmental matrices for sampling. A QAPP (provided in **Appendix B**) summarizes the analytical chemistry program including sampling methods, desired analytical chemistry quantitation limits, and the general quality assurance program. A Site Specific Health and Safety Plan (SSHSP) provided under separate cover outlines the procedures to protect all personnel present during field activities.

Various supporting documents are provided in the remaining appendices including a summary of construction activities at the facility (**Appendix C**), a previously conducted Preliminary Risk Evaluation (**Appendix D**), regulatory correspondence (**Appendix E**), auxiliary maps, and logs and report excerpts (**Appendix F**), FISC specifications for GIS data presented in Phase SOW (**Appendix G**), and Pacific Division (PACDIV) standard operating procedures (SOPs) (**Appendix H**).

1.1 LOCATION AND SETTING

The RHSF is located on the island of Oahu, Hawaii, approximately 2.5 miles northeast of Pearl Harbor. The facility lies along the western edge of the Koolau Range and is situated on a topographic ridge that divides the Halawa Valley and the Moanalua Valley. The site is bordered to the south by the Salt Lake volcanic crater. The Site occupies approximately 144 acres of land. The majority of the surface topography of the Site lies at an elevation of approximately 200 to 500 feet above mean sea level (msl), however, much of the work conducted onsite will be in underground tunnels, which are located between 100 to 120 feet msl. The approximate location of the Site is depicted on the Site Vicinity Map, **Figure 1-1**.

1.2 Site History

The facility was constructed by the U.S. Government in the early 1940s and incorporates 20 underground storage tanks (USTs), each with a capacity of approximately 12.5 million gallons (see Site Plan, Figure 1-2). The tanks are constructed of steel and currently contain JP-5 and Diesel Fuel Marine. Previously, several of the tanks have also been used to store Navy Special Fuel Oil, Navy Distillate, aviation gasoline (AVGAS) and motor gasoline (MOGAS). The fueling system is a self-contained underground unit that was installed into native rock comprised primarily of basalt with some inter-bedded tuffs and breccias. Each tank measures approximately 245 feet in height and 100 feet in diameter. The upper domes of the tanks lie at depths varying between approximately 100 feet and 200 feet below the existing ground surface. It is unknown if the tanks are presently leaking; however, on the basis of the previous site investigation and associated analytical data, one or more unauthorized releases have occurred at the site. Additional site history is provided in Section 2.3 and a summary of the facility construction history is provided in **Appendix C**.

1.3 Project Objectives

The results of a previous SI (AMEC, 2002) indicated that petroleum hydrocarbons were reported in rock samples obtained beneath the USTs and that lead was detected in groundwater samples obtained from a monitoring well situated hydraulically down-gradient from the facility. The SI recommended the completion of a comprehensive RA to quantify the risks associated with the observed compounds. In an effort to evaluate current and potential future risks from unauthorized releases to the subsurface the State of Hawaii Department of Health (HDOH), Solid Waste Branch concurred in a letter dated October 10, 2003 (**Appendix E**) that the U.S. Navy would:

- Conduct a comprehensive Tier 3 RA,

- Develop a comprehensive Conceptual Site Model (CSM) incorporating Fate and Transport Models to facilitate preparation of the RA,
- Prepare a Contingency Plan to protect the Navy's groundwater supply at Red Hill, and
- Monitor groundwater in the underlying basal aquifer and at the Public Works Center (PWC) potable water source at Red Hill.

To accomplish these goals, the Navy has adopted the following project objectives:

1. **GIS Model.** Compile existing electronic and hardcopy data regarding past activities at the Site, including lithologic descriptions obtained from excavation and boring logs; facility construction details, and published environmental information. The compiled data will be used to create a 3-D GIS model to facilitate data storage and 3-D visualization.

2. **Conceptual Site Model (CSM).** Develop a comprehensive CSM to illustrate potential sources, exposure pathways, and receptors. The CSM will be used to refine the site characterization activities, facilitate fate and transport calculations, and to communicate site conditions to regulators and stakeholders.

3. **Site Characterization Study (SCS).** Conduct a SCS to obtain data necessary to further characterize the documented release and to complete a Comprehensive Risk Assessment. The SCS will include the installation and sampling of groundwater monitoring wells and soil vapor monitoring points and the evaluation of Fate and Transport mechanisms using analytical and numerical modeling techniques.

4. **Applicable or Relevant and Appropriate Requirements (ARARs).** Prepare a list of ARARs and risk-based action levels for potentially impacted media.

5. **Risk Assessment (RA).** Conduct a Tier 3 Comprehensive RA to determine COPCs, potentially complete exposure pathways, potential receptors, and exposure point action levels for each receptor and media.

6. **Monitoring System.** Develop a groundwater and soil vapor monitoring system that will allow the U.S. Navy to characterize the Site both laterally and temporally for past, present and future releases.

7. **Contingency Plan.** Develop a contingency plan that ensures unacceptable risks to human health and/or the environment from any past, present, and/or future releases are mitigated.

1.4 PROJECT APPROACH

The approach for the RHSF investigation is to obtain and evaluate information necessary to conduct a Tier 3 Comprehensive RA, and prepare a Site Contingency Plan. This will be accomplished through the excavation of exploratory borings, installation of groundwater monitoring wells and soil vapor monitoring points, collection and analyses of soil, groundwater, and soil vapor samples from the monitoring network, construction of a GIS-based 3-D Site Model, and contaminant fate and transport modeling. The resulting information will be used to conduct the Risk Assessment and prepare the Contingency Plan. Specific COPCs to be evaluated in soil, groundwater, and soil vapor samples have been selected on the basis of chemical data collected during the previous SI (Ogden 1999) and the evaluation of fuels currently stored onsite. All COPCs are associated with petroleum fuels stored onsite. The proposed site investigation activities are further discussed in Sections 5.1 through 5.5 of this WP and the proposed field activities are further detailed in the FSP (**Appendix A**).

1.5 INVESTIGATIVE TEAM

The prime contractor and investigative team leader for the project is TEC. Primary support contractors include AMEC, Valley Well Drilling, and Accutest, Inc. **Table 1-1** presents a contact listing with a brief description of project responsibilities.

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Table 1-1

Contact Listing

Red Hill Bulk Fuel Storage SI and RA

Pearl Harbor, Hawaii

NAVFAC Pacific		
Project Contract Specialist	Ms. Jean Kuboyama	(808) 471-4666
Remedial Project Manager/Navy Technical Representative	Mr. Glenn Yoshinaga	(808) 472-1416
Fleet Industrial Supply Center		
Fuels Terminal Director	Lt.Com. Tom Gorman	(808) 473-7801
FISC Project Manager	Mr. Victor Peters	(808) 473-7890
RHSF Site Supervisor	Mr. Herb Kikuchi	(808) 437-7805 or 479-1063
Public Works Center		
Navy Hydrogeologist	Mr. Paul Eyre	(808) 473-0938
Halawa Firing Range		
Staff NCOIC	GySgt. Robert Flores robert.flores@navy.mil	(808) 471-4798, 471-2916, or 358-2407
Senior Instructor	Sgt. Steven Christopher steven.e.christopher@navy.mil	(808) 471-4798, 471-2916, or 358-2407
TEC Inc.		
Deputy Program Manager	Mr. Ryan Pingree	(808) 554-2433
Project Manager/ Hydrogeologist	Mr. Jeff Hart, R.G.	(808) 554-2433
Senior Risk Assessor	Mr. Glenn Metzler	(808) 554-2433
Regional Manager, Health and Safety Coordinator	Mr. Karl Bromwell	(808) 554-2433
Project Chemist	Mr. Peter Chapman	(808) 554-2433
Onsite Health and Safety Coordinator	Ms. April Chan	(808) 554-2433
Senior Geologist	Ms. Nicole Griffin	(808) 554-2433

Table 1-1 (continued)

Contact Listing

Red Hill Bulk Fuel Storage SI and RA

Pearl Harbor, Hawaii

TEC Inc.		
Site Technician	Mr. Shawn Macmillan	(808) 554-2433
Project Engineer	Mr. Kevin McNiel, PE	(808) 554-2433
Subcontractors		
AMEC Project Manager	Mr. Jon McMillen	(256) 716-0083
AMEC Site Supervisor	Mr. Jamie Anderson	(808) 306-4415
Valley Well Drilling, Supervisor	Mr. Mike Sober	(808) 682-1767
Accutest Analytical Services, Orlando Florida	Ms. Susan Bell	(407) 425-6700
Pacific Commercial Disposal Services	Mr. Jingbo Chang	(808) 545-4599

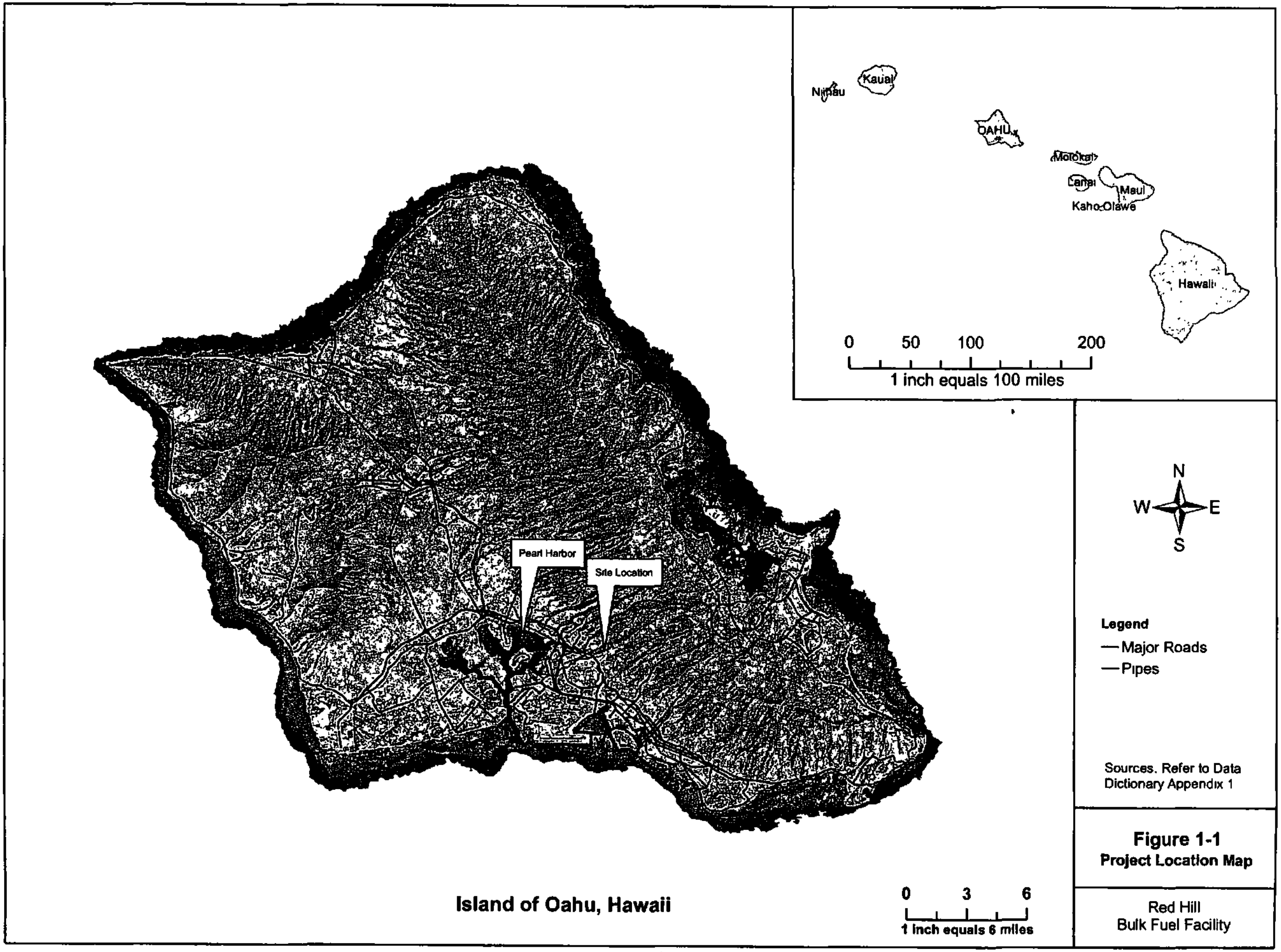

Figure 1-1
Project Location Map

Red Hill
Bulk Fuel Facility

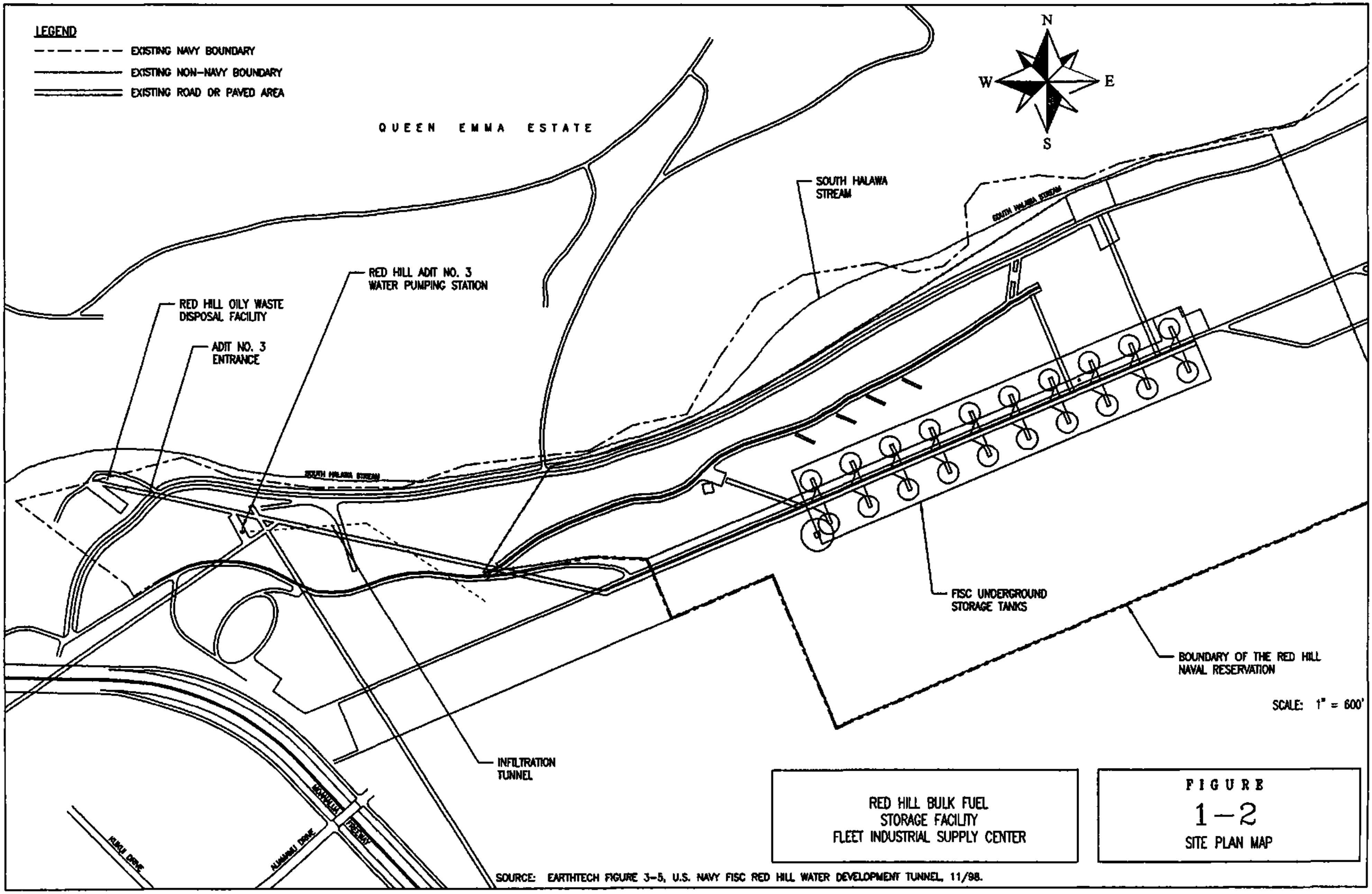

FIGURE 1-2
SITE PLAN MAP

SECTION 2
SITE BACKGROUND

2.1 REGIONAL ENVIRONMENTAL DATA

2.1.1 PHYSICAL SETTING

The island of Oahu, part of the Hawaiian Island chain, lies at the northern margin of the tropics region (**Figure 1-1**). Oahu is located at latitude 21.433 North and longitude 157.966 West. Oahu is the third largest island in the chain and consists of extensive areas of mountainous land as well as coastal plains. The mountainous areas are comprised of two mountain ridges, the Koolau Range along the eastern side of the island, and the Waianae Range along the western side of the island.

2.1.2 LAND USE

Oahu is the center of economic activity for the Hawaiian Islands. Honolulu, located in the south-central portion of the island, is heavily urbanized and densely populated (**Figure 2-1).** The RHSF lies at the northern edge of an urbanized area (**Figure 2-2**) that is zoned Government (**Figure 2-3**). Urbanized areas stretch from the southern coast of Oahu northward, occupying the majority of the coastal plain.

2.1.3 DEMOGRAPHY

Oahu (Honolulu County) has a population of approximately 876,156 people. Populated areas closest to the Red Hill facility are Pearl City and Aiea to the west and Honolulu to south and east. On the basis of 2000 census data, the populations of Pearl City and Aiea are 30,976 and 9,019, respectively, and the population of Honolulu is 371,657 (2000 US Census data). There is a Coast Guard and US Navy housing complex in Aliamanu Crater to the southwest of the RHSF. Pearl Harbor lies to the southwest of the Red Hill facility. The population of the Pearl Harbor military base is unlisted (Ogden, 1999). The nearest residential area is located southeast of the site in Moanalua Valley, directly adjacent to the facility perimeter.

2.1.4 CLIMATE

The prevailing northeast trade winds and the ocean currents cause the air and water of the region to be cooler than other areas of similar latitude. Ocean temperatures range from 75 to 85 degrees Fahrenheit (F) at Honolulu. Northeasterly winds persist most of the year and the northeastern, or windward, side of the island is commonly the wettest. Southerly winds blow for only a few days at a time during the winter months. Most of the severe storms on the island come from the south, as southerly winds pick up moisture from the open ocean before they arrive at the islands. Precipitation is at a maximum at elevations above 2,000 feet msl. October to April is the wet season, and May to September is the dry season. Small areas of northeast Oahu receive annual precipitation greater than 300 inches per year, however, most of the island receives 20 to 75 inches of precipitation annually. Precipitation on the island is most commonly in the form of rain.

2.1.5 REGIONAL TOPOGRAPHY

Topographically, the island of Oahu is divided into four geomorphic regions: the Waianae Mountain Range, the Koolau Mountain Range, the Schofield Plateau, and the Coastal Plains, which form the northwest and south island margins (**Figure 2-1**). The site is located on a ridge between Halawa and Moanalua Valleys and on the lower portion of the southwestern wall of Halawa Valley, the easternmost Koolau stream valley emptying into Pearl Harbor. The valley was formed by the coalescence of two valley heads, drained by the North and South Halawa Streams that merge on the Coastal Plain before emptying into Pearl Harbor. Regional topography in the vicinity of the Site is depicted on **Figure 2-4**.

2.1.6 REGIONAL GEOLOGY

The island of Oahu is comprised of the erosional remnants of two distinct volcanic ranges, the Waianae and the Koolau volcanoes. The Waianae Range covers the western side of the island, and the Koolau Range covers the central and eastern portions of the island. Red Hill is located on the southern edge of the Koolau Range, approximately 2.5 miles northeast of Pearl Harbor. The Koolau formation consists almost entirely of basaltic lava flows that erupted from a fissure line approaching 30 miles in length (Wentworth, 1951) and trending in a northwest rift zone.

During a volcanic quiet period approximately 2 million years, valleys approaching 600 meters in depth were cut into the Koolau volcanic range and sediment accumulated in the valley floors. The erosion of the Koolau volcano resulted in the formation of a delta of sediment consisting of silt and sand. The delta increased in thickness as it approached the sea. The RHSF is located along the topographic ridge that separates the Moanalua and Halawa Valleys. The ridge drops steeply on either side with the aforementioned sediments deposited in the valley bottoms.

Both pahoehoe and a'a lava flows are present in the Koolau formation. Pahoehoe is smooth, fine-grained lava with a rope-like appearance and is characterized by thin-walled vesicles. A'a lava is a jagged, blocky lava flow that contains clinker beds. These clinker beds are the more permeable feature of the a'a lava. According to Mink (1999), the a'a lava may act as a very localized confining layer to the basal system with unconfined conditions present just a few feet away. The a'a lava is more abundant in the lower flanks (Wentworth, 1951).

2.1.7 Regional Hydrogeology

Five primary groundwater flow systems have been described on Oahu: Northern, Eastern, Western, Southern, and Southeastern **(Figure 2-5)**. The Site is located in the Southern Oahu Groundwater Flow System. The regional groundwater flow in the vicinity of the Site is directed to the southwest **(Figure 2-6)**. The geology of the island has been classified into six main aquifer systems, with many sub-systems **(Figure 2-5)**. The RHSF lies on a border of two such sub-systems, the Moanalua Aquifer and Waimalu Aquifer **(Figure 2-7)**.

The HDOH has adopted the State of Hawaii regional aquifer classification by Mink and Lau (1990, hereafter referred to as "Mink and Lau") to determine the permissible uses for groundwater in the different areas of Hawaii. This classification is used to determine the set of HDOH criteria used for evaluation of soil and groundwater contaminants detected at the site (HDOH 1995). The aquifer classification criteria and groundwater designations are patterned after the United States Environmental Protection Agency (USEPA) Groundwater Protection Guidelines (USEPA 1984) and are used in conjunction with the HDOH Soil and Groundwater Action Levels. (EarthTech Phase II RI Report 1999)

2.1.8 Regional Water Quality

Groundwater provides most municipal and domestic water for a large and expanding population on Oahu. Most of the water is derived from extensive volcanic aquifers in thin-bedded basalts in central and southern Oahu. Although depth to groundwater can be as great as 600 to 1,000 feet in the interior of the island, most aquifers are considered unconfined and are vulnerable to contamination. There has been widespread detection of pesticides and herbicides in aquifers situated beneath agricultural lands and reports of volatile organic compounds (VOCs) in aquifers situated beneath known use or spillage (USGS Fact Sheet 006-98, 1998). A study completed in 1999-2001 reported organic compounds in most public water supply wells, but seldom at concentrations exceeding drinking-water standards. **Figure 2-8** depicts the approximate locations and contaminant status of groundwater supply wells in the Pearl Harbor and Honolulu area.

2.2 SITE-SPECIFIC ENVIRONMENTAL DATA

This section outlines the geographic features, land use, soils, geology, and hydrogeology of the site and surrounding areas.

2.2.1 Physical Setting

The RHSF is located on the island of Oahu approximately 2.5 miles northeast of Pearl Harbor. The facility lies along the western edge of the Koolau Range and is situated on a topographic ridge that divides the Halawa Valley and the Moanalua Valley (see **Figure 2-4**). The site is bordered to the south by the Salt Lake volcanic crater. The Site occupies approximately 144 acres of land. The majority of the Site lies at an elevation of approximately 200 to 500 feet above msl. The facility access adits generally exit the lower slopes of the South Halawa Valley. A general facility layout is provided in **Figure 2-9**.

2.2.2 LAND USE

Current zoning information obtained from the City and County of Honolulu's Department of Planning and Permitting (DPP) (**Figure 2-3**) indicates that the site is located on federal government land (zoned F1 - Military and Federal) with public land adjacent to the north and northeast (zoned P1 - Restricted Parkland). A high cliff (approximately 100 to 200 feet elevation difference) in the public land area separates the Red Hill Naval Reservation from a mixed industrial area (zoned I2) and a residential area (zoned R5) containing the Halawa Correctional Facility further to the north and northwest. A quarry is located further to the northwest in an agricultural zone (zoned Ag2). The H3 Freeway is located northwest of the quarry.

A residential development, Moanalua Village, is located adjacent to the Red Hill Naval Reservation to the south and east (zoned R5- Residential). Further south is the Moanalua Golf Course (zoned P2- General Parkland and R5- Residential), a section of public land (zoned P1- Restricted Parkland), and the Tripler Army Medical Center (zoned F1- Military and Federal). A high cliff (approximately 100 to 200 feet elevation difference) separates the Red Hill Naval Reservation from Moanalua Village and the Moanalua Golf Course. The area to the northeast of the site is public land, which is mostly forested (zoned P1- Restricted Parkland). Moanalua Valley Park (zoned P2- General Parkland) and more public land (zoned P1- Restricted Parkland) are located to the east of the Moanalua Village residential development.

A gated residential community (zoned A2- Apartments), comprised primarily of townhouses and apartment buildings, is located to the southwest of the site and a public school (Red Hill Elementary School) is also present in this area. The Red Hill Naval Reservation continues to the west and is adjacent to the Coast Guard Reservation, which borders Highway 78. Land use relationships are depicted on **Figure 2-2** (land use map), **Figure 2-3** (zoning map), and **Figure 2-10** (urban development map).

The closest residential property is within the area zoned for apartment buildings located approximately 305 feet southwest of Tank 2 and approximately 2,113 feet southwest of Tank 20 (the tank farthest to the east). Red Hill Elementary School is located approximately 1,080 feet southwest of Tank 2 and approximately 2,850 feet from Tank 20. The Moanalua Village residential development is located approximately 880 feet south of Tank 2 and approximately 875 feet south of Tank 20.

2.2.3 Precipitation

The closest weather station is located at Aiea Heights 764.6, Honolulu at approximately 21.40°N latitude and 157.91°W longitude. The elevation at the weather station is approximately 777 feet above msl. The following summary presents mean annual precipitation proximal to the site over a 13-year period from 1982 to 1995.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
mm	105.2	128.9	144.3	130.5	83.4	93.1	114.8	79.5	95.4	130.3	138.1	195.7	1440.1
inches	4.1	5.1	5.7	5.1	3.3	3.7	4.5	3.1	3.8	5.1	5.4	7.7	56.7

2.2.4 Vegetation Communities

As shown in **Figure 2-1**, approximately 15% of the island is urbanized, approximately 65% of the island is non-forested (i.e., grassland, agriculture, scrub-shrub, wetland), and approximately 20% of the island remains forested. For the most part, only the mountainous regions of Oahu remain forested.

The aboveground portion of the Site is inhabited by: (1) Haole koa scrub *(Leucaena leucocephala)*, (2) disturbed habitat, and (3) landscaped areas. Haole koa grows throughout Oahu, primarily in areas that have been disturbed by grazing or human activities (Wagner et al., 1990). The scrub community on Red Hill is dominated by Haole koa, Guinea grass *(Panicum maximum)*, and Chinese violet *(Asystasia gangetica)*. The disturbed habitat is comprised of weedy plant species that can withstand frequent disturbance by human activities or natural events. Although this vegetation does support some wildlife species, the habitat is considered to be of very low quality and is primarily used by introduced, common urban species (Ogden, 1996).

2.2.5 Sensitive Species and Habitats

Hawaii is home to numerous federally listed threatened and endangered species, including 44 federally listed animals and 273 federally listed plants. Much of the non-developed portions of Oahu are currently proposed as critical habitat for numerous species. Due to the highly developed nature of the site, it is not anticipated that any Federal or state-listed threatened or endangered species occur onsite. Habitats onsite are not considered sensitive and are dominated by introduced species that do not usually support native species. However, no threatened or endangered species surveys have been conducted at the facility.

2.2.6 Topography

The ground elevations at the aboveground facilities of the site range from approximately 200 to 500 feet above msl (see **Figure 2-4**). The tops of the bulk fuel storage tanks are approximately 100 to 200 feet below the existing ground surface (bgs), located directly below the aboveground facilities.

2.2.7 Soils

Soils in the vicinity of the RHSF are mapped as Helemano-Wahiawa association consisting of well-drained, moderately fine textured and fine textured soils. These soils typically range from nearly level to moderately sloping and occur in broad areas dissected by very steep gulches. They formed in material weathered from basalt (United States Department of Agriculture [USDA], 1972).

On the basis of a review of previous investigations performed in the vicinity of the Red Hill facility, soils consisting of clays and clayey gravels are common to a depth of 10 feet bgs. Along the slopes and over much of the open area south of the Schofield Saddle, the basaltic bedrock is covered with 10 to 30 feet of Koolau residuum (Wentworth, 1945). These soils were derived from weathering of the underlying basalt bedrock or were deposited as alluvium/colluvium. The younger alluvium/colluvium deposits were derived from fractured basalts and tuff. Beneath the surficial soils, alternating layers of clay and fractured basalts were encountered at depth. The western slope of the Halawa Valley is generally barren of soil and consists of outcropping basalt lava flows to the valley floor.

2.2.8 GEOLOGY

As discussed in **Section 2.1.6**, the RHSF lies along a topographic ridge between the Halawa and Moanalua Valleys. The ridge is a remnant of the original Koolau shield volcano flank and it is composed of basaltic lava flows. The valleys on either side of the ridge are a result of fluvial erosion and are filled with alluvium/colluvium. A review of soil boring logs of boring V1D at the Site indicates that the Site is predominantly underlain by pahoehoe lava with small to medium sized vesicles. Pahoehoe lava is characterized by relatively thin-bedded basaltic flows with abundant thin-walled vesicles.

At a nearby drilling site, approximately 2000 feet southwest of V1D, the EarthTech, Inc. (EarthTech) reported (EarthTech 1999) the basalt bedrock appeared completely dry and massive at approximately 20 feet above msl, which was distinct from the highly fractured basalt overlying this unit and significantly different from the log of V1D. At the southwest location, basal groundwater was encountered directly beneath this massive unit at an elevation of approximately one to two feet below msl. After the monitoring wells were installed, the potentiometric groundwater surface stabilized at an elevation of approximately 16 feet above msl, suggesting that the massive lower basalt acts as a localized low-permeability layer, resulting in the confined groundwater conditions exhibited by the basal aquifer. However, Mink (1999) states that although the a'a lava can act as a local confining unit, it tends to be very limited in extent and, therefore, unconfined conditions may be encountered in close proximity.

Information in the Wilbros Engineers report (1998) supports Mink's findings and states that the RHSF is bounded on each side by deep alluvial fills and sedimentary caprock (marine and terrestrial sediments) in the down-gradient direction. In the area of the lower tunnel and the Red Hill portion of the Harbor Tunnel, the basal aquifer is located in permeable basalt on which the tunnel and tanks are located (Wilbros Engineers, 1998). This further supports Mink's theory that confined conditions are generally limited in extent.

2.2.9 Hydrogeology

The fuel storage tanks appear to be located above the Moanalua Aquifer system, which is part of the Honolulu Aquifer sector. However, Red Hill effectively serves as a geomorphic boundary between the Honolulu and the Pearl Harbor Aquifers. Therefore, the western part of the site overlies the Waimalu Aquifer system, which is part of the Pearl Harbor Aquifer sector. Both the Moanalua Aquifer and Waimalu Aquifer systems are classified by Mink and Lau as unconfined, basal, and flank. Their status is listed as a currently used, fresh (chloride content below 250 milligrams per liter [mg/l]) drinking water source that is irreplaceable and has a high vulnerability to contamination (Mink and Lau 1990).

The Site is located up-gradient of the Hawaii State Underground Injection Control Line (UIC), which typically segregates potable from non-potable groundwater. The nearest public drinking water well (Halawa Shaft, well number 2354-01) is located hydraulically cross-gradient of the Site. This drinking water well is approximately 5,000 feet to the northwest of the Site and pumps water from the basal aquifer. On average, 11 million gallons per day (MGD) are withdrawn from this location and account for approximately 7% of Honolulu County's water supply (Honolulu Board of Water Supply, 2005). In addition, one U.S. Navy drinking water well (2254-01) is located near the site. This well is approximately 3,000 feet to the west of the site and is possibly hydraulically down-gradient from the site. Approximately 4.2 MGD are withdrawn from this location.

On the basis of water table measurements conducted in wells near the site, the basal groundwater potentiometric surface is approximately 16 feet above msl. The groundwater flow in the Red Hill area is expected to be to the southwest toward Aliamanu Crater (see **Figure 2-5** and **Figure 2-6**). Hydraulic conductivity varies from 500 to 1500 feet per day in this area; however, welded tuffs associated with the Aliamanu Crater may have significantly lower permeabilities and may affect the groundwater flow direction from the Site.

2.2.10 LOCAL WATER QUALITY

The basal aquifer is tapped as a source of drinking water by the Navy PWC and supplies the drinking water for the Pearl Harbor Naval Complex. The pumping station is located within the lower tunnel system and is situated approximately 0.5 mile to the west of the bulk fuel storage tanks. Regular testing of the basal aquifer is conducted through the PWC pump station by the PWC and HDOH to ensure that the water is maintained within drinking water standards. The analytical program at the PWC pump station addresses VOCs and other petroleum constituents of concern. No indication of petroleum contamination has been reported in basal aquifer water samples collected during periodic monitoring at the PWC pump station. A profile of the tanks and infiltration tunnel is provided in **Figure 2-11**.

2.3 Facility Description and History

Section 2.3 provides an overview of the general site layout and a summary of previous environmental investigations at the RHSF. Additional information regarding construction details and history is provided in **Appendix C**.

2.3.1 Facility Layout

The RHSF is located on the topographic ridgeline between south Halawa Valley and Moanalua Valley, west of Honolulu. Construction of the RHSF began late in 1940 and was completed in 1943. The facility incorporates 20 USTs, each with a capacity ranging from 285,000 barrels to 300,000 barrels, or approximately 12.5 million gallons **(Figure 2-9)**.

The tanks are constructed of steel and currently contain Jet Propulsion Fuel (JP-5) and Diesel Fuel Marine (DFM). The bulk tanks were constructed in two parallel rows sloping south by southwest towards Pearl Harbor **(Figure 2-9)**. The fueling system is a self-contained underground unit that was installed into native rock comprised primarily of basalt with some inter-bedded tuffs and breccias. Each tank measures approximately 245 feet in height and 100 feet in diameter. The upper domes of the tanks lie at depths varying between approximately 100 feet and 200 feet bgs. The tanks are connected by main upper and lower subsurface service tunnels, which contain light rail systems, water, electric utilities, and fuel pipelines. In the lower tunnel, each parallel tank is connected by a short access tunnel, which branches off the main service tunnel and terminates into a face-wall under each tank. Individual tank ancillary piping emerging from each face-wall connects the fuel transmission lines. The fuel pipelines traverse approximately 2.5 miles from the bulk tanks to a pump station at Pearl Harbor. The pump station is used to pump fuel from fuel tankers in Pearl Harbor to the bulk fuel storage facility. **Figure 2-9** depicts the approximate locations of the underground storage tanks and associated appurtenances in relation to nearby improvements and features.

The Navy PWC operates a water pumping station within the lower tunnel system proximal to Adit 3 and situated hydraulically down-gradient from the tank facility. The water pumping station is referred to as the Red Hill Adit No. 3 Water Pumping Station, referred to previously as 2254-01, and its location is depicted on **Figure 2-9** and **Figure 2-11**. The water pumping station pumps water from the basal aquifer beneath Red Hill to the Pearl Harbor water distribution system. **Figure 2-11** depicts a generalized vertical cross section of the tank farm and the PWC public water pumping shaft. **Figure 2-12** through **Figure 2-14** provide additional plan views of the facility.

2.3.2 Storage Tank Usage

The tanks have historically contained diesel oil (DO), Navy special fuel oil (NSFO), Navy distillate (NDS), DFM, AVGAS, MOGAS, and JP-5. Originally, Tanks 3 through 20 contained NSFO and Tanks 1 and 2 stored DO. However, over time, each tank has been utilized to store a variety of different fuel types. Currently, the tanks contain JP-5 or DFM. **Table 2-1** presents a historical record of petroleum storage in the tanks.

2.3.3 Unauthorized Releases

Historically, due to the sensitive classification of the fuel farm as the primary fuel storage facility for Pearl Harbor, public access has been limited and independent investigations to confirm suspected unauthorized releases were not conducted. The Red Hill facility was declassified in 1995. Facility records indicate that suspected or potential leaks may have occurred and have been repaired in several of the tanks. No record of a catastrophic release (such as most or all of a tank's contents being released) has been identified.

2.3.4 Ongoing Site Activities

The RHSF is currently functioning as a storage and distribution center for JP-5 and DFM. Ongoing site activities may potentially impact Site access or field investigation schedules. All site access should be coordinated through the RHSF manager. Currently, Tanks 15 and 16 are empty and undergoing maintenance. Tank 16 is expected to be the focus of soil vapor monitoring and just up-gradient from the middle Tank Farm monitoring well proposed to be installed during the current site investigation.

2.5 Previous Investigations

This section provides a summary of environmental investigations conducted at RHSF since the facility has been declassified.

2.5.1 Wilbros Engineering Report

FISC retained Wilbros Engineers to evaluate the conditions of the RHSF and to estimate the impact to the basal aquifer if a major release were to occur. During the environmental impact evaluation, Wilbros Engineers used two hypothetical scenarios of petroleum releases from the large capacity USTs in conjunction with geologic/hydrogeologic data to estimate the potential environmental impact to the potable drinking water source of the basal aquifer. The first scenario comprised a massive petroleum release with no improvements to the facility, and the second scenario included improvements to the facility designed to prevent large-scale impacts to the environment. (Wilbros Engineers, 1998).

Wilbros Engineers determined that, under both scenarios, a massive release of petroleum from storage tank 15 would detrimentally impact the basal aquifer beneath the Red Hill area, but the degree of impact in scenario two was significantly reduced in comparison to scenario one. Wilbros suggested that the lateral spreading of the contaminant would be impeded by the presence of natural groundwater barriers. Red Hill is bounded on each side of the ridge by alluvial fills derived from the Halawa and Moanalua streams (hydraulically cross-gradient) and the sedimentary caprock located near the harbor (hydraulically down-gradient). Wilbros proposed that the valley fill and caprock would act as groundwater barriers, and should help minimize the potential for lateral spreading of fuel in the event of a release (Wentworth, 1951). Because fuel is usually less dense than water, the fuel would primarily impact the upper portions of the aquifer.

Wilbros Engineers (1998) suggested that due to the potential for irreparable damage to the aquifer in the event of a massive release, preventive measures be taken to avoid a catastrophic disruption of potable water service to the Pearl Harbor community.

2.5.2 Ogden Oily Waste Facility RI/FS

Ogden Environmental and Energy Services (Ogden) completed several investigations at the Red Hill Oily Waste Disposal Facility (OWDF), which is located approximately 3,200 feet west of the RHSF tanks. The primary fieldwork for a Remedial Investigation/Feasibility Study (RI/FS) was conducted from August 1991 through June 1992. The results of this investigation were presented in the document entitled, *Technical Review Committee (TRC) Findings Summary, Red Hill Oily Waste Disposal Pit, Naval Supply Center, Pearl Harbor, O'ahu, Hawai'i* (1992). Ogden performed additional field investigation activities in January 1993. The results of the second investigation are presented in the document entitled, *Red Hill Oily Waste Disposal Pit Site Stilling Basin Closure Plan, CTO 0109*, (1993). Additional risk assessment and removal action activities were performed in 1994 and 1995.

The Ogden investigations of the Red Hill OWDF found that the stilling basin contained liquids and solid debris containing VOCs, total petroleum hydrocarbons (TPH) and total fuel hydrocarbons (TFH), semi-volatile organic compounds (SVOCs), and priority pollutant metals. Soil and the perched water system beneath the stilling basin were found to contain VOCs, TPH, TFH, and polynuclear aromatic hydrocarbons (PAHs). Ogden developed plans for closure of the stilling basin by removal of the waste liquids and solid debris and removal of soil containing TPH and PAHs near the base of the stilling basin. Further investigation activities were summarized in the report entitled, *Red Hill Oily Waste Disposal Facility Phase I RI Report, June 1996.*

2.5.3 Earth Tech Oily Waste Facility Investigations

EarthTech performed a Phase II RI at the OWDF in 1998 (EarthTech, 1999). The objective of the RI was to determine the nature and extent of impact to the soil and groundwater beneath the site resulting from site activities. Four Areas of Concern (AOCs) were identified and investigated during the Phase II RI.

During the investigation, limited areas of soil impacted by TPH were identified near the 8,000-gallon aboveground storage tank (AST) and in the unauthorized discharge area (UDA). PAHs were detected in the soils of the UDA and AST, but with the exception of benzo(a)pyrene, the reported concentrations were less than the Phase II RI OWDF-specific evaluation criteria.

TPH and one PAH compound (pyrene) were detected in a groundwater sample collected from a monitoring well installed within locally perched groundwater at the site. During a second sampling event in this well, PAH compounds were not reported at concentrations greater than the laboratory method detection limit. Neither TPH nor PAH was detected in groundwater samples obtained from within the basal aquifer during the RI sampling. Two VOCs were detected in the basal groundwater samples beneath the OWDF; however, both were characterized as common laboratory contaminants and neither was identified in the liquid or sludge samples obtained from the former stilling basin. Therefore, these two contaminants were eliminated from consideration in the subsequent risk evaluations.

The EarthTech report concluded that transport of contaminants to the basal aquifer from the OWDF would be insignificant. OWDF-related contaminants had not been detected in groundwater samples obtained from within the basal aquifer or from water samples obtained from the Navy's PWC pumping station located in Adit #3. Therefore, EarthTech recommended no further action regarding the perched groundwater or the basal aquifer beneath the OWDF. A map depicting the approximate locations of the three site monitoring wells completed in the basal aquifer and the respective boring logs and monitoring well completion logs are presented in **Appendix F**.

2.5.4 Ogden/AMEC Red Hill Investigations

In March 1998, the Navy authorized Ogden (subsequently known as AMEC) to proceed with engineering services to identify potential petroleum product releases from the RHSF. The resulting site characterization was conducted in two phases: Phase I - Research Activities and Phase II - Investigation Activities.

2.5.4.1 Phase I Research Activities

Phase I activities were conducted in April 1998 and consisted of site reconnaissance and data gathering. The Phase I operations included interviews and meetings with remedial-project-manager, facility and FISC representatives to determine an efficient method to accomplish the fieldwork required to complete the site investigation. Much of the research focused on resolving the unique technical requirements of drilling in the environmentally sensitive and potentially explosive location within the lower tunnel and tank area.

2.5.4.2 Phase II Investigation Activities

The Navy authorized Ogden to proceed with an initial Phase II site investigation in August 1998. The Phase II investigation activities were conducted in two tasks.

- Task 1: The initial Phase II task comprised a limited investigation of two of the 20 USTs and preparation of an Initial Phase II Investigation Report.
- Task 2: The second task comprised an investigation of the remaining 18 USTs and the basal aquifer, conduct of a screening-level human-health risk evaluation, and preparation of a Phase II SI Report.

The Phase II field activities were conducted from October 19 through November 1, 1998. The Phase II activities are fully described in the report entitled "Initial Phase II Site Characterization Report, Fleet Industrial Supply Center, Bulk Fuel Storage Facility at Red Hill" (Ogden, 1999) and are summarized below.

2.5.4.2.1 Task 1 Field Activities

The primary objective of Task 1 was to conduct exploratory borings beneath Tank 9 and Tank 16 to evaluate potential petroleum releases. The condition of the lower tunnel interior walls and fluctuating fuel levels in Tank 16 suggested that leaks had occurred at this location.

Portable drilling equipment was used to advance six exploratory borings through the lower tunnel floor. Three directional borings were advanced (from one drilling location) beneath Tank 9 and three directional borings were advanced (from a second drilling location) beneath Tank 16. To avoid penetration of the concrete and grout backfill surrounding the tanks, the centerline borings beneath each tank were advanced through the tunnel floor at a slight downward angle (approximately 11° to 15° from horizontal). The other two borings at each tank location were advanced with an approximate deflection of 22° right or 35° left from the centerline, with the downward deflection angle similar to the centerline boring (approximately 11° to 15° from horizontal). These type borings are often referred to as "angled" or "slant" borings. The geometric relationships of the angled borings are depicted on **Figure 2-15 and Figure 2-16.**

Bedrock core and/or encountered soils, groundwater, and petroleum product were sampled and analyzed for petroleum constituents. A total of 14 samples (12 core samples, one duplicate core sample, and one fluid sample) were collected for offsite laboratory analyses. The samples were analyzed for TPH by Method-D-Triregional, VOCs by Method 8260, and PAHs by Method 8270. Laboratory results confirmed the presence of petroleum compounds in the bedrock beneath Tank 16. The samples obtained beneath Tank 9 did not contain the analytes at concentrations greater than the laboratory method detection limits.

2.5.4.2.2 Task 2 Field Activities

The Task 2 field investigation activities were conducted during the period from October 29, 2000 through March 9, 2001. The primary objectives of Task 2 were to evaluate potential petroleum releases beneath the remaining 18 tanks and to install two monitoring wells to obtain and analyze groundwater samples from within the basal aquifer and a shallower zone of perched groundwater.

The centerline borings conducted beneath Tank 9 and Tank 16 in Task 1 were over-drilled and converted to vadose zone groundwater/fuel monitoring wells. The other two existing borings beneath each of these tanks were abandoned by filling with grout. One angled boring was also advanced beneath each of the remaining 18 storage tanks (Tanks 1-8, 10-15, and 17-20). Each of the 18 new exploratory borings was subsequently converted to a vadose zone monitoring well. **Figure 2-16** depicts a typical cross section across one of the ten pairs of tanks. All slant boring wells were constructed approximately 80 to 100 feet above the basal aquifer to capture leachate or fuel released beneath the associated USTs.

Two vertical borings were also advanced from within the lower access tunnel to investigate potential impacts to the basal aquifer. One boring (V1D) was advanced into the basal aquifer and one shallower boring (V2S) was advanced to investigate and monitor a zone above the basal aquifer. The borings were converted into monitoring wells and sampled during the March and August 2001 monitoring events. The two vertical monitoring wells are situated hydraulically down-gradient from the tank locations.

The approximate boring locations are depicted on **Figure 2-17.** Note that each boring converted to a monitoring well is numbered in accordance with the corresponding monitoring well and tank number (e.g., boring B-5 was drilled to install monitoring well MW-5 and corresponds to Tank 5). A summary of the boring and monitoring well specifications is presented in **Table 2-2**. Copies of the boring logs and well construction diagrams are provided in **Appendix F**.

One hundred seven (107) samples (87 primary core samples, 10 duplicate core sample, eight fluid samples, and two groundwater samples) were collected during the completion of field activities and subjected to offsite laboratory analyses. Samples were analyzed for TPH by Method 8015 (modified), VOCs by Method 8260, SVOCs by Method OLM03.2, PAHs by Method 8270, and Toxicity Characteristic Leaching Program (TCLP) metals by Method ILM0.40. In addition, four samples (two fluid and two core samples) were collected for fingerprinting analysis using gas chromatography with flame ionization detection (GC/FID) and an electron capture detector (ECD).

Hydrocarbon impacts were noted beneath the tunnel floor and at depth within some of the angle borings advanced beneath the USTs. Six borings (B-1, B-2, B-3, B-6, B-13, and B-20) exhibited evidence of hydrocarbon impacts (i.e., sheen on drill water, hydrocarbon odor, and/or elevated Photoionization Detector (PID) measurements) directly beneath the concrete floor. Hydrocarbon odor and elevated PID readings were observed in core samples obtained at depth in the angle borings located beneath 15 of the 20 tanks (Tanks 1, 3-7, 11-14, and 16-20). **Table 2-3** presents a summary of core sample depths, PID measurements, and physical observations. **Table 2-4** presents a summary of fluids observed. The fingerprinting analyses confirmed that the samples contained petroleum hydrocarbons consistent with those stored in the tanks (**Table 2-5**). **Figure 2-18** and **Figure 2-19** present a plan and cross section view depicting the location of core samples that contained compounds in concentrations greater than HDOH Tier 1 Action Levels. **Table 2-6** provides a summary of results for samples that contained analytes at concentrations greater than the respective laboratory method detection limit.

2.5.4.2.3 Task 2 Preliminary Risk Evaluation

A preliminary screening-level risk evaluation (**Appendix D**) was conducted on the basis of the Task 1 and Task 2 field activity findings. The results of the evaluation indicate that seven constituents were detected in core samples at concentrations of potential concern: ethylbenzene, methylene chloride, 2-methylnaphthalene, naphthalene, phenanthrene, TPH (hydrocarbon range C10-C28), and an unknown hydrocarbon compound. Three constituents were detected in groundwater at concentrations of potential concern: bis(2-ethylhexyl)phthalate, lead, and TPH (hydrocarbon range C10-C28). The field investigation also identified the presence of light non-aqueous phase liquid (LNAPL) within several monitoring wells at the site.

On the basis of the preliminary risk screening, it was recommended that a comprehensive RA be completed to accurately assess current and potential future risk associated with the RHSF. The comprehensive RA should include a site-specific exposure assessment, including the use of fate and transport modeling, to identify potential migration pathways, potential receptor populations, and relevant exposure routes.

2.6 Regulatory Correspondence

In an effort to evaluate current and potential future risks to the basal aquifer underlying the facility and to nearby drinking water wells (including the Navy Pumping Station located directly down-gradient from the USTs), the HDOH Solid Waste Branch concurred in a letter dated October 10, 2003 **(Appendix E)** that the US Navy would:

- Conduct a comprehensive Tier 3 Comprehensive RA,
- Develop a comprehensive CSM incorporating Fate and Transport Models to facilitate preparation of the RA,
- Prepare a Contingency Plan to protect the Navy's groundwater supply at Red Hill, and
- Monitor groundwater in the underlying basal aquifer and at the PWC potable water source at Red Hill.

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Table 2-1
Historical Summary of Products Stored at the Red Hill Bulk Fuel Storage Facility

Tank ID	Contents	Date
1	Diesel Oil (DO)	10/26/1942
	JP-5	02/04/1970
2	DO	09/28/1942
	JP-5	1962
3	Navy Special Fuel Oil (NSFO)	01/26/1943
	Navy Distillate (ND)	08/27/1970
	Diesel Fuel, Marine (DFM)	04/03/1973
	JP-5	12/26/1973
4	NSFO	11/15/1942
	ND	02/17/1971
	DFM	06/06/1973
	JP-5	01/26/1974
5	NSFO	12/19/1942
	Empty	04/06/1970
	ND	12/29/1971
	JP-5	Oct-74
6	NSFO	12/30/1942
	Empty	03/29/1970
	ND	02/29/1972
	JP-5	Oct-74
	DFM	01/15/1982
	Empty	07/22/1994
	JP-5	05/19/1995
	Empty	04/15/1998
7	NSFO	03/16/1943
	ND	05/04/1971
	DFM	09/11/1973
	Empty	04/25/1995
8	NSFO	03/02/1943
	ND	05/21/1971
	DFM	09/12/1973
	Empty	04/13/1995
9	NSFO	02/14/1943
	ND	06/23/1972
	DFM	09/13/1973
	Empty	09/14/1995
	JP-5	05/30/1996
10	NSFO	01/26/1943
	ND	06/29/1972
	DFM	09/01/1973
	Empty	10/03/1995
11	NSFO	02/11/1943
	ND	06/29/1972
	DFM	Oct-73
12	NSFO	03/19/1943
	Empty	04/28/1970
	ND	05/26/1972
	DFM	01/29/1981
	Empty	08/24/1994
	DFM	07/25/1995
13	NSFO	03/23/1943
	DFM	04/21/1976
	Empty	12/01/1994
	JP-5	10/04/1995
14	NSFO	03/21/1943
	ND	03/13/1973
	NSFO	10/25/1973
	ND	08/26/1975
	DFM	04/12/1981
	Empty	01/19/1995
	JP-5	04/29/1996
15	NSFO	04/29/1943
	ND	10/27/1972
	DFM	09/14/1973
	Empty	10/02/1998
16	NSFO	05/08/1943
	ND	11/10/1971
	DFM	06/15/1975
	Empty	05/25/1994
	JP-5	10/01/1998
	Empty	11/04/1998
17	NSFO	05/23/1943
	Empty	03/30/1960
	AVGAS	12/11/1964
	MOGAS	08/29/1968
	JP-5	01/15/1969
18	NSFO	06/13/1942
	Empty	03/30/1960
	JP-5 (for leak tests)	May-63
	AVGAS	08/18/1964
	Empty	10/30/1968
	JP-5	01/10/1969
19	NSFO	06/13/1943
	Empty	03/30/1960
	JP-5	01/17/1964
	Empty	Oct-85
20	NSFO	07/20/1943
	Empty	03/30/1960
	JP-5	06/14/1964
	Empty	12/28/1971
	JP-5	04/04/1972
355[a]	Slop Oil	1966

[a] – The slop oil tank (Tank 355) was not included in this investigation.
DO = Diesel Oil
NSFO = Navy Special Fuel Oil
ND = Navy Distillate
DFM = Diesel Fuel, Marine

Table 2-2
Summary of Monitoring Well Installation
Red Hill Bulk Fuel Facilty

Progression	Tank ID	Monitoring Well ID	Date Well Installed	Angle from Horizontal (degree)	Elevation at Ground Surface (Ft AMSL)	Riser Stick-Up (ft, POE)[a]	Total Depth (ft, POE)[a]	Corrected Elevation of Well Total Depth (Ft AMSL)	Vertical Drop (ft) to Bottom of Well from POE Elevation	Number of Isolation Casings	Well Diameter (Inches)	Screen Interval Upper Depth (ft, POE)[a]	Screen Interval Lower Depth (ft, POE)[a]	Screen Length ft long	Depth of Fluid Detected (ft, POE)[a b c]	Corrected Elevation of Fluid Level (ft, POE)[a b c]
1	Tank 01	RH-MW-1	02/09/2001	15	102 66	0 42	129 7	69.09	33 57	2	1.5	109.4	124 4	15	129 4	69 17
2	Tank 02	RH-MW-2	02/07/2001	15	102 31	0 44	124 0	70 22	32 09	1	2.0	104 7	119.7	15	ND	ND
3	Tank 03	RH-MW-3	02/02/2001	15	102 72	0 36	130 2	69 02	33 70	2	1 5	109 9	124 9	15	ND	ND
4	Tank 04	RH-MW-4	01/31/2001	15	102 62	0 36	129 1	69 21	33.41	2	1 5	108 8	123.8	15	ND	ND
5	Tank 05	RH-MW-5	01/29/2001	15	105 98	0 43	124 3	73 81	32 17	1	2 0	104 0	119 0	15	ND	ND
6	Tank 06	RH-MW-6	01/24/2001	15	105 68	0 3	126 6	72 92	32 76	2	1.5	106 3	121 3	15	ND	ND
7	Tank 07	RH-MW-7	01/19/2001	15	113 96	0 33	128 9	80 60	33 36	2	1 5	108 6	123 6	15	ND	ND
8	Tank 08	RH-MW-8	01/17/2001	15	113 67	0 42	127 2	80 75	32 92	2	1 5	107 0	122 0	15	ND	ND
9	Tank 09	RH-MW-9	01/12/2001	11	113 94	0 36	100 0	94 89	19 05	2	1 5	80 0	95 0	15	ND	ND
10	Tank 10	RH-MW-10	01/10/2001	15	113 71	0 39	130 7	79 88	33 83	2	1 5	110 7	125 7	15	ND	ND
11	Tank 11	RH-MW-11	12/19/2000	15	117 98	0 42	131 0	84 08	33 90	2	1 5	95 7	125 7	30	ND	ND
12	Tank 12	RH-MW-12	12/14/2000	15	117 71	0 37	133 6	83 13	34 58	1	2 0	108 3	128 3	20	ND	ND
13	Tank 13	RH-MW-13	12/12/2000	15	121 95	0 39	133 1	87 50	34 45	1	2 0	107 8	127 8	20	132 50	87 66
14	Tank 14	RH-MW-14	12/07/2000	15	121 75	0 33	136 0	86 55	35 20	1	2 0	110 7	130 7	20	135 30	86 73
15	Tank 15	RH-MW-15	12/05/2000	13	125 88	0 36	126 4	97 45	28 43	2	1 5	106 4	121 4	15	ND	ND
16	Tank 16	RH-MW-16A	01/08/2001	11	125 70	0 37	104 8	105 70	20 00	1	2 0	84 5	99 5	15	ND	ND
17	Tank 17	RH-MW-17	11/07/2000	13	129 75	0 27	124 2	101 81	27 94	2	1 5	104 2	119 2	15	114 80	103 92
18	Tank 18	RH-MW-18	11/21/2000	13	129 58	0 33	126 0	101 24	28 34	2	1 5	106 0	121 0	15	ND	ND
19	Tank 19	RH-MW-19	03/02/2001	13	133 68	0 27	121 1	106 44	27 24	2	1 5	101 1	116 1	15	110 52	108 81
20	Tank 20	RH-MW-20	03/05/2001	15	133 54	0 39	127 7	100.49	33 05	2	1 5	107 5	122 5	15	ND	ND
21	Tank 1/2	RH-MW-V1D	02/20/2001	90	102 56	-0 11	100 0	2 56	100.00	4	1 0	89 8	99 8	10	86 28	16 28
22	Tank 1/2	RH-MW-V2S	02/23/2001	90	102 56	-0 14	52 0	50 56	52 00	2	1 5	32 0	47 0	15	ND	ND

[a] Measurements for the riser stick-up, total depth, screened interval, and depth to fluid are **not** angle corrected depth from ground surface measurements

[b] The depth to fluid provided is an approximation, accurate measurements are not available in angle wells

[c] Fluid measurements were obtained on 08/24/01

bgs - below ground surface

ft, POE - feet from boring point of entry

ND - Not detected

Ft AMSL - Feet Above Mean Sea Level

Table 2-3
Summary of Boring Locations with Physical Indications of Petroleum Hydrocarbons Present

Boring Location ID	Depth in Boring of Evidence of PH Observed (ft, POE)	Elevated PID Measurement (ppm)	Sample Obtained for Analysis	Product Observed Beneath Concrete Floor (Yes/No)
B-01	2.00	330.0	X (S01)	Yes (Sheen)
	8.00	573.0	X (S02)	
	59.60	266.0	X (S03)	
	60.70	453.0	X (S04)	
	71.10	478.0	No	
B-02	89.45	74.7	X (S02)	No
B-03	2.00	214.0	X (S01)	No
	7.40	244.6	No	
	42.90	189.2	X (S02)	
B-04	7.00	294.0	No	No
	8.20	180.0	X (S02)	
	15.60	225.0	No	
B-05	7.60	72.0	X (S01)	No
	14.70	63.1	X (S02)	
	55.25	262.0	X (S03)	
	113.30	308.0	X (S04)	
B-06	0.50	78.0	X (S01 L)[a]	Yes
	0.50	78.0	X (S01 S)	
	1.50	74.0	X (S02)[a]	
	11.30	163.0	No	
	19.80	191.0	X (S03)	
	26.10	40.0	No	
B-07	0.50	NM	X (S01)	No
	25.90	110.0	X (S02)	
	40.50	26.5	No	
	93.10	6.6	No	
	105.95	9.6	X (S04)	
	111.20	41.0	X (S05)	
B-08	NA	NM	X (S01)	No
B09A	3.20	NM	X (B09A-1)	No
B-10	NA	NM	No	No
B-11	4.50	14.1	X (S01)	No
	7.40	12.0	No	
	11.30	19.8	X (S02)	
	20.30	3.1	No	
	38.20	9.8	No	
	67.10	24.3	X (S03)	
	85.00	21.4	X (S04)	
	89.50	55.8	No	
	95.00	80.3	X (S05)	

Boring Location ID	Depth in Boring of Evidence of PH Observed	Elevated PID Measurement (ppm)	Sample Obtained for Analysis	Product Observed Beneath Concrete Floor (Yes/No)
B-12	8.00	0.3	X (S01)	No
	33.50	26.0	X (S02)	
	36.70	2.8	No	
	61.00	1.9	X (S03)	
	62.20	17.3	No	
	107.90	0.7	No	
	121.90	26.4	X (S05)	
B-13	2.00	NM	No	Yes (Sheen)
	10.70	10.7	X (S04)	
B-14	95.50	19.7	X (S04)[a]	No
	101.40	9.1	No	
	116.00	2.0	X (S05)	
B-15	NA	NM	No	No
B16A	NA	NM	No	No
	83.75	NM	X (B16A-4)	
B-17	81.80	83.2	No	No
	90.30	95.1	No	
B-18	121.50	125.8	No	No
B-19	43.00	94.7	X (S01)	No
	51.40	131.0	No	
	60.30	154.0	No	
	62.70	175.0	X (S02)	
	67.80	167.0	No	
	79.90	334.0	No	
	93.20	630.0	X (S03)	
	109.30	350.0	No	
	118.00	406.0	X (S04)	
B-20	2.25	75.1	X (S01)	No
	8.80	375.0	X (S02)	
	116.20	467.0	No	
	125.80	420.0	No	
B-V1D	NA	NM	No	No
B-V2S	NA	NM	No	No

[a] - Sample also obtained for fingerprinting analysis
ft, POE - feet from boring point of entry
NA - Not applicable
NM - Not measured
PH - Petroleum hydrocarbons
ppm - parts per million
X - Sample was obtained for analysis

Table 2-4
Summary of Fluid Levels Detected in Monitoring Wells

Monitoring Well ID	Fluid Media	Elevation at Ground Surface	Date	Depth to Fluid Level (ft, POE)	Corrected Elevation of Fluid Level
RH-MW-1	LNAPL	102.66	03/07/2001	124.2	70.52
			08/24/2001	129.4	69.17
RH-MW-13	LNAPL	121.95	03/07/2001	NFD	NA
			08/24/2001	132.5	87.66
RH-MW-14	LNAPL	121.75	03/07/2001	NFD	NA
			08/24/2001	135.3	86.73
RH-MW-17	LNAPL	129.75	03/07/2001	NFD	NA
			08/24/2001	114.8	103.92
RH-MW-19	Infiltration Fluid	133.68	03/07/2001	113.1	104.41
			08/24/2001	110.52	108.81
RH-MW-V1D	GW	102.56	03/07/2001	86.1	16.46
			08/24/2001	86.28	16.28

LNAPL - Light phase non aqueous phase liquid (which may be mixed with drill fluid)
ft, POE - feet from boring point of entry
NA - Not applicable
NFD - No fluid detected

Table 2-5
Summary and Comparison of Samples Obtained for Fingerprinting Analysis

Tank Location	Sample ID	Sample Date	Matrix	Sample Depth (ft, POE)	F&B GC Petroleum Hydrocarbon Identification	F&B GC Petroleum Hydrocarbon Characterization	Historical Contents and Start Use Year
6	RH-BR-6-S01 (L)	01/18/2001	Fluid	0.5	Indicative of a mixture of a degraded middle distillates such as kerosene or Jet A.	• Fuel has undergone substantial biological degradation • Lower level of degraded middle distillates (diesel fuel #2) may be present	NSFO - 1942 ND - 1972 JP-5 - 1974 DFM - 1982 JP-5 - 1995
	RH-BR-6-S02	01/19/2001	Core	1.5	Indicative of a mixture of middle distillates, which may include kerosene, JP-5, diesel fuel #2 and similar fuels.	• Mixture of degraded and relatively undegraded fuels	
11	RH-MW-11	12/18/2000	Fluid	20.3	Indicative of a mixture of middle distillates such as diesel fuel #2 or similar fuels.	• Fuel has undergone substantial biological degradation	NSFO - 1943 ND - 1972 DFM - 1973
14	RH-BR-14-S04	12/06/2000	Core	95.5	Indicative of a mixture of middle distillates, which may include kerosene, JP-5, diesel fuel #2 and similar fuels.	• Mixture of degraded and relatively undegraded fuels	NSFO - 1943 ND - 1973 NSFO - 1973 ND - 1975 DFM - 1981 JP-5 - 1996

DFM - Diesel Fuel, Marine
F&B - Friedman & Bruya
GC - Gas chromatograph
JP-5 - Jet Fuel
ND - Navy Distillate
NSFO - Navy Special Fuel Oil

Table 2-6
All Sample Detects Summary (ppm)
Red Hill Bulk Fuel Storage Facility, Oahu, Hawaii

LOCATION	SAMPLE NO	TYPE	SAMPLE DEPTH (ft, pos)	SAMPLE DATE	MEDIA	1,1-Dichloroethylene	2-Methylnaphthalene	4-Methyl-2-pentanone	Acetone	bis(2-Ethylhexyl)phthalate	Chrysene	Dibenzofuran	Ethylbenzene	Fluorene	Lead	m,p xylene	Methyl ethyl ketone	Methylene chloride	Naphthalene	o-xylene	Phenanthrene	Pyrene	Toluene	TPH (C10-C28)	Unknown Hydrocarbon	Xylene (total)
TANK- 1	RH-BR-1-D09	DUP	59 6	02/08/2001	CORE	--	5 02	--	--	--	--	--	--	--	--	--	--	--	1.23	--	--	--	--	890	--	--
TANK- 1	RH-BR-1-S01	REG	2	02/07/2001	CORE	--	--	--	--	--	--	--	--	--	293	--	--	--	--	--	--	--	--	$\boxed{25300}$	--	--
TANK- 1	RH-BR-1-S02	REG	8	02/08/2001	CORE	--	0 25	--	--	0.162	--	--	--	--	--	--	--	--	--	--	--	--	--	1500	--	--
TANK- 1	RH-BR-1-S03	REG	59 6	02/08/2001	CORE	--	10 2	--	--	--	--	--	--	--	--	--	--	--	3 72	--	--	--	--	2330	--	0 436
TANK- 1	RH-BR-1-S04	REG	61 35	02/08/2001	CORE	--	39 6	--	--	--	--	--	0 49	--	--	--	--	--	16 3	--	--	--	--	3300	--	4 81
TANK- 1	RH-BR-1-S05	REG	129 2	02/09/2001	CORE	--	--	--	--	0.132	--	--	--	--	--	--	--	--	--	--	--	--	--	27 7	--	--
TANK- 1	RH-MW-1-S01	REG	124 2	03/07/2001	DFLNAPL	0 00065	--	--	--	--	--	--	--	--	$\boxed{0.0756}$	--	--	--	--	--	--	--	--	1 88	--	--
TANK- 1	RH-MW-1-S01	REG	129 4	08/27/2001	DFLNAPL	0 0013	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1 3	--	--
TANK- 2	RH-BR-2-S01	REG	2 5	02/05/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	910	--	--
TANK- 2	RH-BR-2-S02	REG	89 45	02/06/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	$\boxed{0.011}$	--	--	--	--	--	22 2	--	--
TANK- 2	RH-BR-2-S03	REG	119 9	02/06/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	$\boxed{0.0127}$	--	--	--	--	--	--	--	--
TANK- 3	RH-BR-3-S01	REG	2	01/31/2001	CORE	--	--	--	0 0412	0.159	--	--	--	--	14 5	--	--	--	--	--	--	--	--	386	--	--
TANK- 3	RH-BR-3-S02	REG	46 35	02/01/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	774	--	--
TANK- 3	RH-BR-3-S03	REG	125 2	02/02/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	28 9	--	--
TANK- 4	RH-BR-4-D08	DUP	123 9	01/31/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14 5	--	--
TANK- 4	RH-BR-4-S01	REG	2 5	01/29/2001	CORE	--	0 392	--	0 045	--	--	--	--	--	84 5	--	--	--	--	--	--	--	--	238	--	--
TANK- 4	RH-BR-4-S02	REG	8 2	01/29/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1330	--	--
TANK- 4	RH-BR-4-S03	REG	123 9	01/31/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	49 8	--	--
TANK- 5	RH-BR-5-S01	REG	9 15	01/25/2001	CORE	--	1 85	--	--	--	--	--	--	--	--	--	0 29	--	0 266	--	0 226	--	--	503	--	--
TANK- 5	RH-BR-5-S02	REG	14 7	01/25/2001	CORE	--	--	--	0 0234	0.251	--	--	--	--	24	--	--	--	--	--	--	--	--	11 8	--	--
TANK- 5	RH-BR-5-S03	REG	55 25	01/26/2001	CORE	--	--	--	--	0 178	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK- 5	RH-BR-5-S04	REG	113 3	01/26/2001	CORE	--	--	--	--	0 435	--	--	--	--	2.1	--	--	--	--	--	--	--	--	12 4	--	--
TANK- 5	RH-BR-5-S05	REG	115 3	01/26/2001	CORE	--	--	--	--	*0.214*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK- 6	RH-BR-6-D07	DUP	19 8	01/22/2001	CORE	--	--	--	--	0.456	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK- 6	RH-BR-6-S01	REG	0 5	01/19/2001	CORE	--	18 9	--	--	--	--	--	--	--	11.3	--	--	--	--	--	10 9	--	--	$\boxed{10200}$	--	--
TANK- 6	RH-BR-6-S02	REG	6	01/19/2001	CORE	--	--	--	--	--	--	--	--	--	11.2	--	--	--	--	--	--	8.45	--	$\boxed{43100}$	--	--
TANK- 6	RH-BR-6-S03	REG	19 8	01/22/2001	CORE	--	--	--	--	0 265	--	--	--	--	--	--	--	--	--	--	--	--	--	8 83	--	--
TANK- 6	RH-BR-6-S04	REG	125 1	01/24/2001	CORE	--	--	--	--	0 375	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK- 6	RH-MW-6-S01	REG	0 5	01/19/2001	DFLNAPL	--	36 8	--	--	--	--	--	--	--	$\boxed{27.5}$	--	--	--	--	--	--	--	--	29500	--	--
TANK- 7	RH-BR-7-S01	REG	0 5	01/17/2001	CORE	--	--	--	0 0295	--	--	--	--	--	17.6	--	--	--	--	--	--	--	--	631	--	--
TANK- 7	RH-BR-7-S02	REG	25 9	01/18/2001	CORE	--	19 1	--	--	--	--	--	0 122	--	--	--	0 431	--	7 09	--	--	--	--	2420	--	1 23
TANK- 7	RH-BR-7-S03	REG	92 4	01/18/2001	CORE	--	--	--	0 04	--	--	--	--	--	--	--	--	--	--	--	--	--	--	24 4	--	--
TANK- 7	RH-BR-7-S04	REG	105 95	01/19/2001	CORE	--	--	--	--	0 291	--	--	--	--	--	--	--	--	--	--	--	--	--	22 3	--	--
TANK- 7	RH-BR-7-S05	REG	111 2	01/19/2001	CORE	--	--	--	--	0 18	--	--	--	--	--	--	--	--	--	--	--	--	--	208	--	--

Table 2-6
All Sample Detects Summary (ppm)
Red Hill Bulk Fuel Storage Facility, Oahu, Hawaii

LOCATION	SAMPLE NO	TYPE	SAMPLE DEPTH (ft, bgs)	SAMPLE DATE	MEDIA	1,1-Dichloroethylene	2-Methylnaphthalene	4-Methyl-2-pentanone	Acetone	bis(2-Ethylhexyl)phthalate	Chrysene	Dibenzofuran	Ethylbenzene	Fluorene	Lead	m,p xylene	Methyl ethyl ketone	Methylene chloride	Naphthalene	o-xylene	Phenanthrene	Pyrene	Toluene	TPH (C10-C28)	Unknown Hydrocarbon	Xylene (total)
TANK- 8	RH-BR-8-S01	REG	0.5	01/15/2001	CORE	–	–	–	–	0 189	–	–	–	–	47.1	–	–	–	–	–	–	–	–	1030	–	–
TANK- 8	RH-BR-8-S03	REG	114.5	01/16/2001	CORE	–	–	–	–	0.123	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK- 9	B09A-1	REG	3 2	10/26/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	600	–
TANK- 9	B09A-2	REG	97.1	10/27/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3 5	–
TANK- 9	B09B-1	REG	55	10/29/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	48	–
TANK- 9	B09B-2	REG	74 6	10/29/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2 3	–
TANK- 9	B09C-1	REG	50	10/28/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6 9	–
TANK- 9	B09C-2	REG	66	10/28/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3 1	–
TANK-11	RH-BR-11-S01	REG	4 5	12/15/2000	CORE	–	1 56	–	0 0632	0 286	–	–	–	–	4.7	–	0 0165	–	–	–	0 534	–	–	1690	–	0 0084
TANK-11	RH-BR-11-S02	REG	11 3	12/15/2000	CORE	–	6 11	–	0 0243	–	–	0 992	0 002	1.14	–	–	–	–	0 776	–	2 09	–	–	3130	–	–
TANK-11	RH-BR-11-S03	REG	67 1	12/18/2000	CORE	–	–	0 0067	0 0215	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1440	–	–
TANK-11	RH-BR-11-S04	REG	85	12/18/2000	CORE	–	1 78	–	–	–	–	–	–	–	–	–	–	–	–	–	0 926	–	–	2320	–	0 0073
TANK-11	RH-BR-11-S05	REG	95	12/18/2000	CORE	–	6 81	–	–	–	–	–	0 0194	0 72	–	–	–	–	1 09	–	1 5	–	0 0086	2910	–	0 298
TANK-12	RH-BR-12-D06	DUP	104 3	12/14/2000	CORE	–	–	–	–	0.12	–	–	–	–	–	–	–	–	–	–	–	–	–	19 6	–	–
TANK-12	RH-BR-12-S01	REG	8	12/12/2000	CORE	–	–	–	–	0 169	–	–	–	–	–	–	–	–	–	–	–	–	–	31.7	–	–
TANK-12	RH-BR-12-S02	REG	33 5	12/13/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	232	–	–
TANK-12	RH-BR-12-S03	REG	61	12/13/2000	CORE	–	–	–	–	0 199	–	–	–	–	–	–	–	–	–	–	–	–	–	780	–	–
TANK-12	RH-BR-12-S04	REG	104 3	12/14/2000	CORE	–	–	–	–	0 125	–	–	–	–	–	–	–	–	–	–	–	–	–	77 1	–	–
TANK-12	RH-BR-12-S05	REG	121 9	12/14/2000	CORE	–	3 38	–	–	–	–	–	0 002	–	–	–	–	–	–	–	0 798	–	–	1710	–	0 018
TANK-13	RH-BR-13-D05	DUP	72	12/11/2000	CORE	–	–	–	–	0 566	–	–	–	–	–	–	–	–	–	–	–	–	–	26 1	–	–
TANK-13	RH-BR-13-S01	REG	72	12/11/2000	CORE	–	–	–	–	0 176	–	–	–	–	–	–	–	–	–	–	–	–	–	20 3	–	–
TANK-13	RH-BR-13-S02	REG	100	12/11/2000	CORE	–	–	–	–	0 342	–	–	–	–	–	–	–	–	–	–	–	–	–	31 9	–	–
TANK-13	RH-BR-13-S03	REG	125	12/11/2000	CORE	–	–	–	–	0.416	–	–	–	–	–	–	–	–	–	–	–	–	–	32 6	–	–
TANK-13	RH-BR-13-S04	REG	8	12/12/2000	CORE	–	–	–	0 0216	0 942	–	–	–	–	6 8	–	–	–	–	–	–	–	–	2160	–	–
TANK-13	RH-MW-13-S01	REG	132 5	08/27/2001	DFLNAPL	0 0021	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2 39	–	–
TANK-14	RH-BR-14-D04	DUP	60 5	12/06/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2090	–	–
TANK-14	RH-BR-14-S01	REG	35	12/06/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	581	–	–
TANK-14	RH-BR-14-S02	REG	60 5	12/06/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2810	–	–
TANK-14	RH-BR-14-S03	REG	75	12/06/2000	CORE	–	–	–	–	0.146	–	–	–	–	–	–	–	–	–	–	–	–	–	292	–	–
TANK-14	RH-BR-14-S04	REG	95 5	12/06/2000	CORE	–	57 8	–	–	–	–	–	*1.55*	–	–	–	–	–	11.4	–	12 8	–	0 17	*26200*	–	6.4
TANK-14	RH-BR-14-S05	REG	118	12/06/2000	CORE	–	3 06	–	–	–	–	–	–	–	–	–	–	–	–	–	0 974	–	–	651	–	–
TANK-15	RH-BR-15-D03	DUP	62 5	12/04/2000	CORE	–	–	–	–	0.291	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK-15	RH-BR-15-S01	REG	62 5	12/04/2000	CORE	–	–	–	–	0 206	–	–	–	–	–	–	–	–	–	–	–	–	–	8.05	–	–
TANK-15	RH-BR-15-S02	REG	86	12/04/2000	CORE	–	–	–	–	0.176	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK-15	RH-BR-15-S03	REG	115	12/04/2000	CORE	–	–	–	0 0257	0 191	–	–	–	–	–	–	–	–	–	–	–	–	–	10 7	–	–

Table 2-6
All Sample Detects Summary (ppm)
Red Hill Bulk Fuel Storage Facility, Oahu, Hawaii

LOCATION	SAMPLE NO	TYPE	SAMPLE DEPTH (ft, poe)	SAMPLE DATE	MEDIA	1,1-Dichloroethylene	2-Methylnaphthalene	4-Methyl-2-pentanone	Acetone	bis(2-Ethylhexyl)phthalate	Chrysene	Dibenzofuran	Ethylbenzene	Fluorene	Lead	m,p xylene	Methyl ethyl ketone	Methylene chloride	Naphthalene	o-xylene	Phenanthrene	Pyrene	Toluene	TPH (C10-C28)	Unknown Hydrocarbon	Xylene (total)
TANK-16	B16-DUP	DUP	83 75	10/23/1998	CORE	–	–	–	–	–	–	–	–	6 4	–	0 085	–	–	14	0 071	14	13	–	–	*6600*	0 156
TANK-16	B16A-4	REG	83 75	10/22/1998	CORE	–	–	–	–	–	–	–	0 24	10	–	0 31	–	–	*43*	0 22	23	22	–	–	*11000*	0.53
TANK-16	B16A-5	REG	101 83	10/22/1998	CORE	–	–	–	–	–	–	–	–	4.7	–	–	–	–	–	–	4 4	20	–	–	2800	–
TANK-16	B16B-4	REG	66 15	10/23/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6 4	–
TANK-16	B16B-5	REG	75 58	10/23/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	29	–
TANK-16	B16C	REG	103 6	10/26/1998	DFLNAPL	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*0.011*		–	–	8 1	*0 031*
TANK-16	B16C-4	REG	60	10/26/1998	CORE	–	–	–	–	–	6 3	–	0 16	12	–	0 059	–	–	*47*	0.082	26	11	–	–	*9400*	0 141
TANK-16	B16C-5	REG	67	10/26/1998	CORE	–	–	–	–	–	–	–	0 054	–	–	0.19	–	–	8 2	0 13	6 5	–	0 048	–	4500	0 32
TANK-17	RH-BR-17-D02	DUP	34	11/10/2000	CORE	–	–	–	–	0.133	–	–	–	–	–	–	–	–	–	–	–	–	0 0029	–	–	–
TANK-17	RH-BR-17-S01	REG	10	11/10/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	861	–	–
TANK-17	RH-BR-17-S02	REG	34	11/10/2000	CORE	–	–	–	–	0 294	–	–	–	–	–	–	–	**0.0152**	–	–	–	–	–	–	–	–
TANK-17	RH-BR-17-S03	REG	66 2	11/10/2000	CORE	–	–	–	–	0 224	–	–	–	–	–	–	–	**0.0108**	–	–	–	–	–	–	–	–
TANK-17	RH-MW-17-S01	REG	114 6	08/27/2001	DFLNAPL	–	–	–	–	–	–	–	–	–	*0.072*	–	–	–	–	–	–	–	–	–	–	–
TANK-18	RH-BR-18-D01	DUP	116	11/06/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0 0177	–	–	–
TANK-18	RH-BR-18-S02	REG	104 4	11/06/2000	CORE	–	–	–	–	0 93	–	–	–	–	0 55	–	–	–	–	–	–	–	–	–	–	–
TANK-18	RH-BR-18-S03	REG	116	11/06/2000	CORE	–	–	–	–	0 419	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK-19	RH-BR-19-S01	REG	43	11/22/2000	CORE	–	4 31	–	–	0 174	–	–	0 174	–	–	–	–	–	0 682	–	–	–	–	1620	–	0 267
TANK-19	RH-MW-19-S01	REG	110 52	08/27/2001	INFILTWAT	0.0015	–	–	–	0.0078	–	–	–	–	*0.0666*	–	–	–	–	–	–	–	–	–	–	–
TANK-19	RH-MW-19-S01	REG	113 1	03/07/2001	INFILTWAT	0 0014	–	–	–	0 0073	–	–	–	–	*0.0568*	–	–	–	–	–	–	–	–	0 312	–	–
TANK-20	RH-BR-20-S01	REG	0 5	03/02/2001	CORE	–	–	–	–	–	–	–	–	–	9 8	–	–	–	–	–	–	–	–	975	–	–
TANK-20	RH-BR-20-S02	REG	8 8	03/03/2001	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	794	–	–
VERTICAL WELL-D	RH-MW-V1D-S01	REG	86 1	03/07/2001	GW	–	–	–	–	0 0058	–	–	–	–	*0.015*	–	–	–	–	–	–	–	–	0 883	–	–
VERTICAL WELL-D	RH-MW-V1D-S01	REG	86 28	08/27/2001	GW	–	–	–	–	0 0109	–	–	–	–	*0.0104*	–	–	–	–	–	–	–	–	1 07	–	–
VERTICAL WELL-S	RH-BR-V2S-S03	REG	43	02/23/2001	CORE	–	–	–	–	–	–	–	–	–	4 1	–	–	–	–	–	–	–	–	–	–	–

Abbreviations:
– Parameter not detected
REG - Regular sample
DUP - Duplicate sample
GW - Groundwater
PPM - parts per million

DFLNAPL - Drill fluid/LNAPL (light non-aquious phase liquid) mixture
INFILTWAT - Infiltration Water
25300 - Analytical result exceeds the Hawaii DOH Tier I Action Level
TPH - Total petroleum hydrocarbon
ft, poe - feet from point of entry

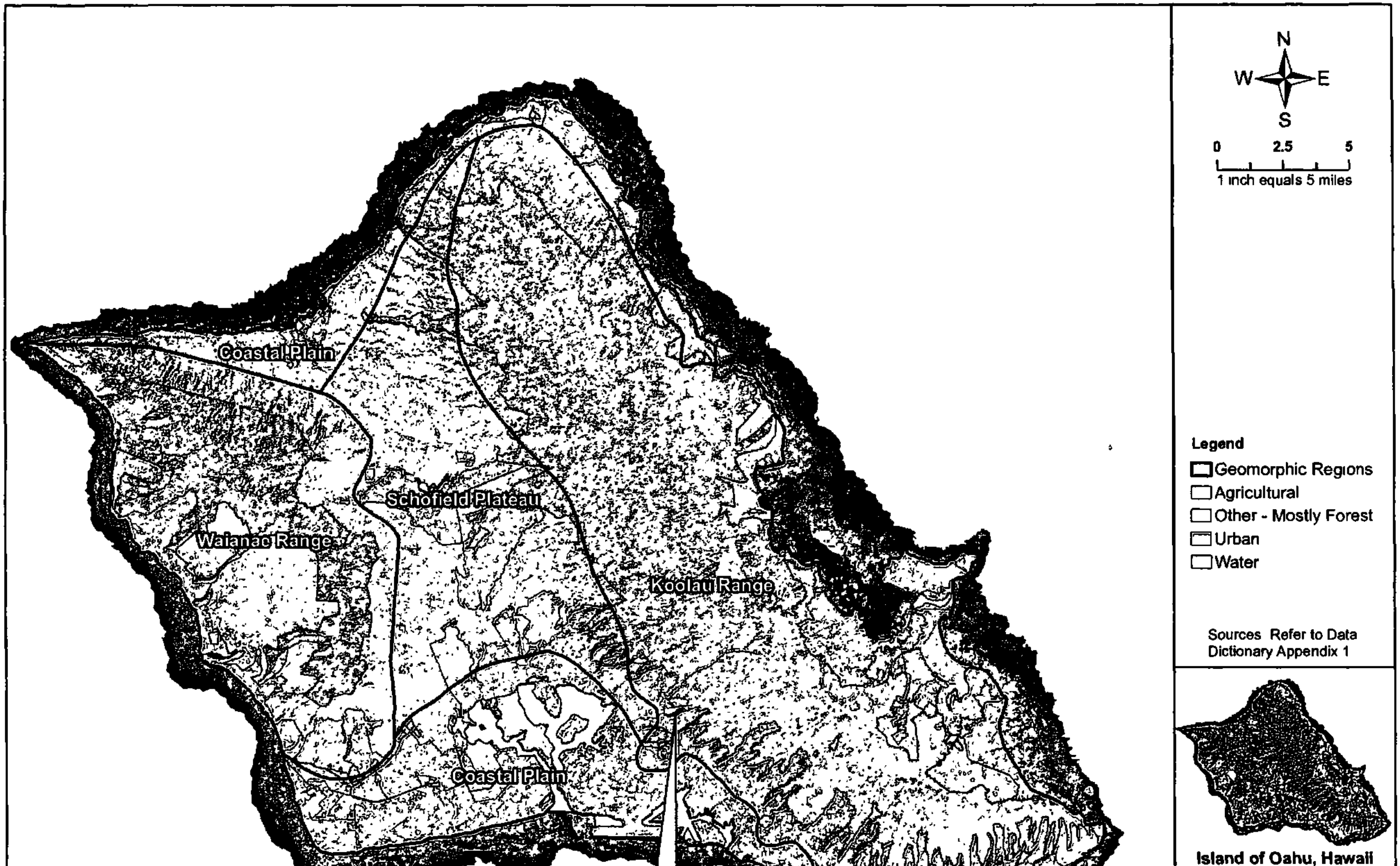


Figure 2-1
Geomorphic Regions

Red Hill
Bulk Fuel Facility

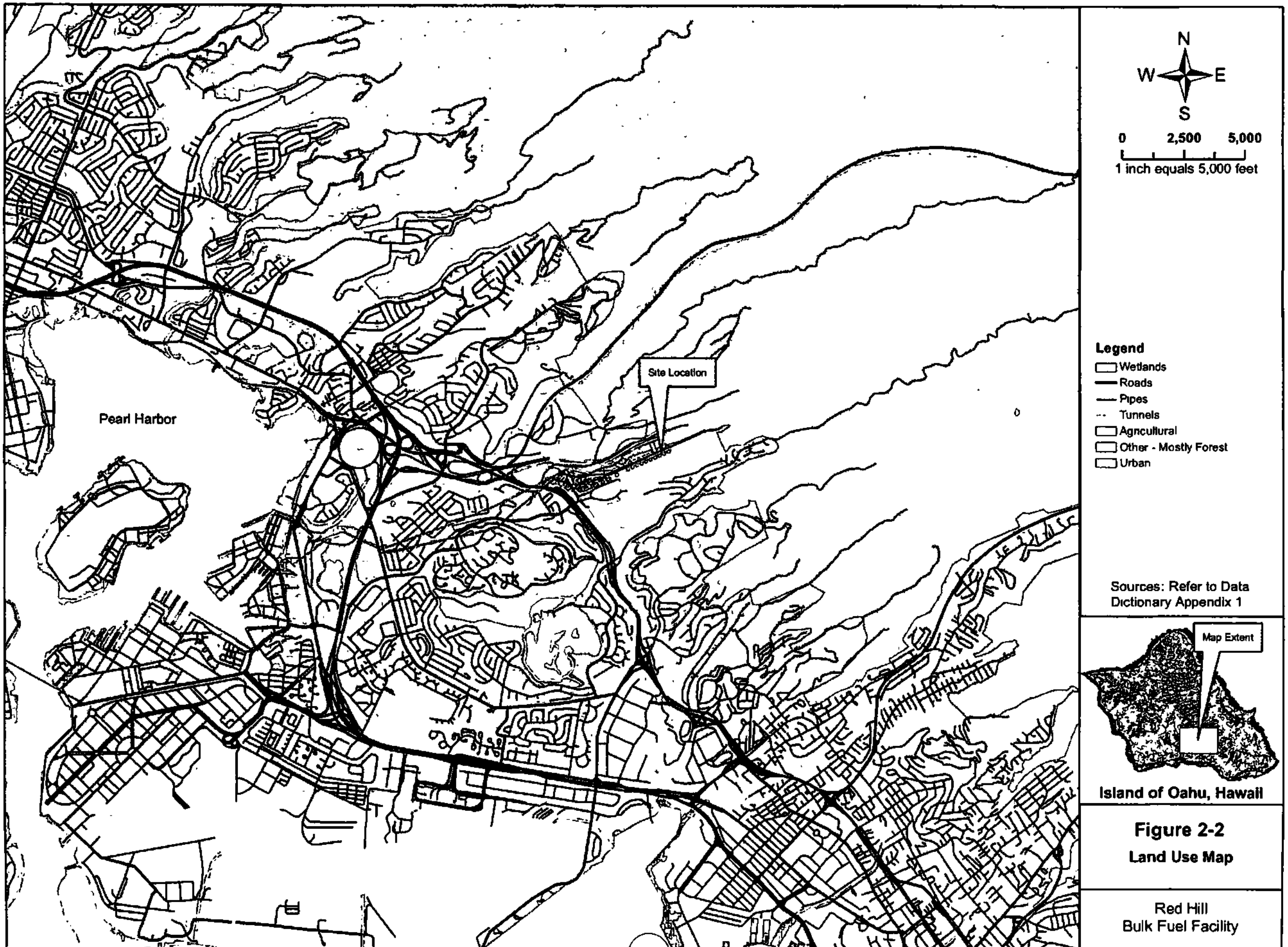


Figure 2-2
Land Use Map

Red Hill
Bulk Fuel Facility

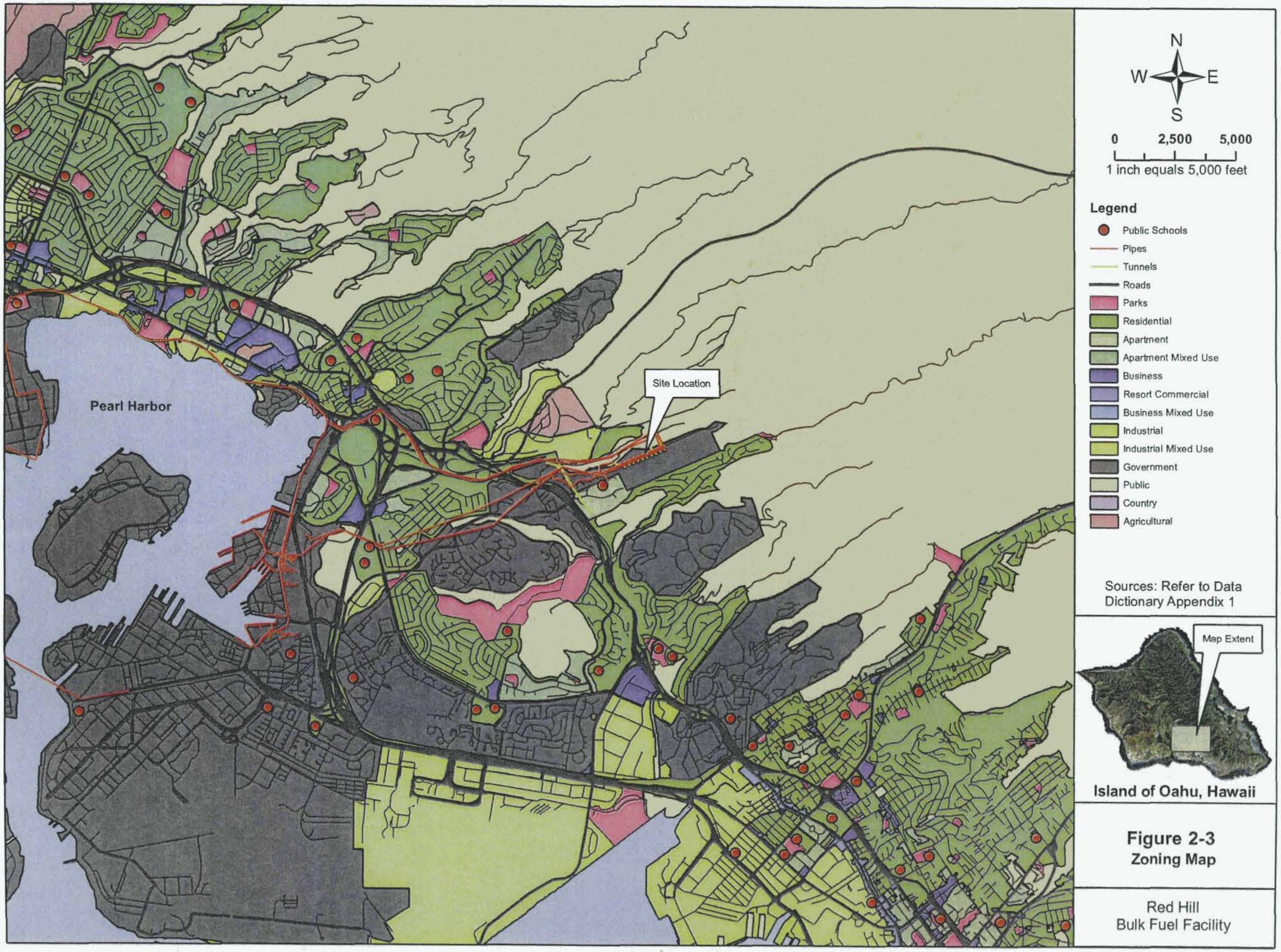
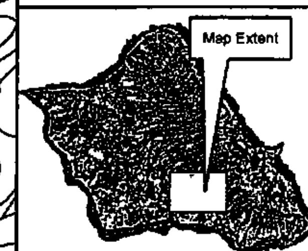


Figure 2-3
Zoning Map

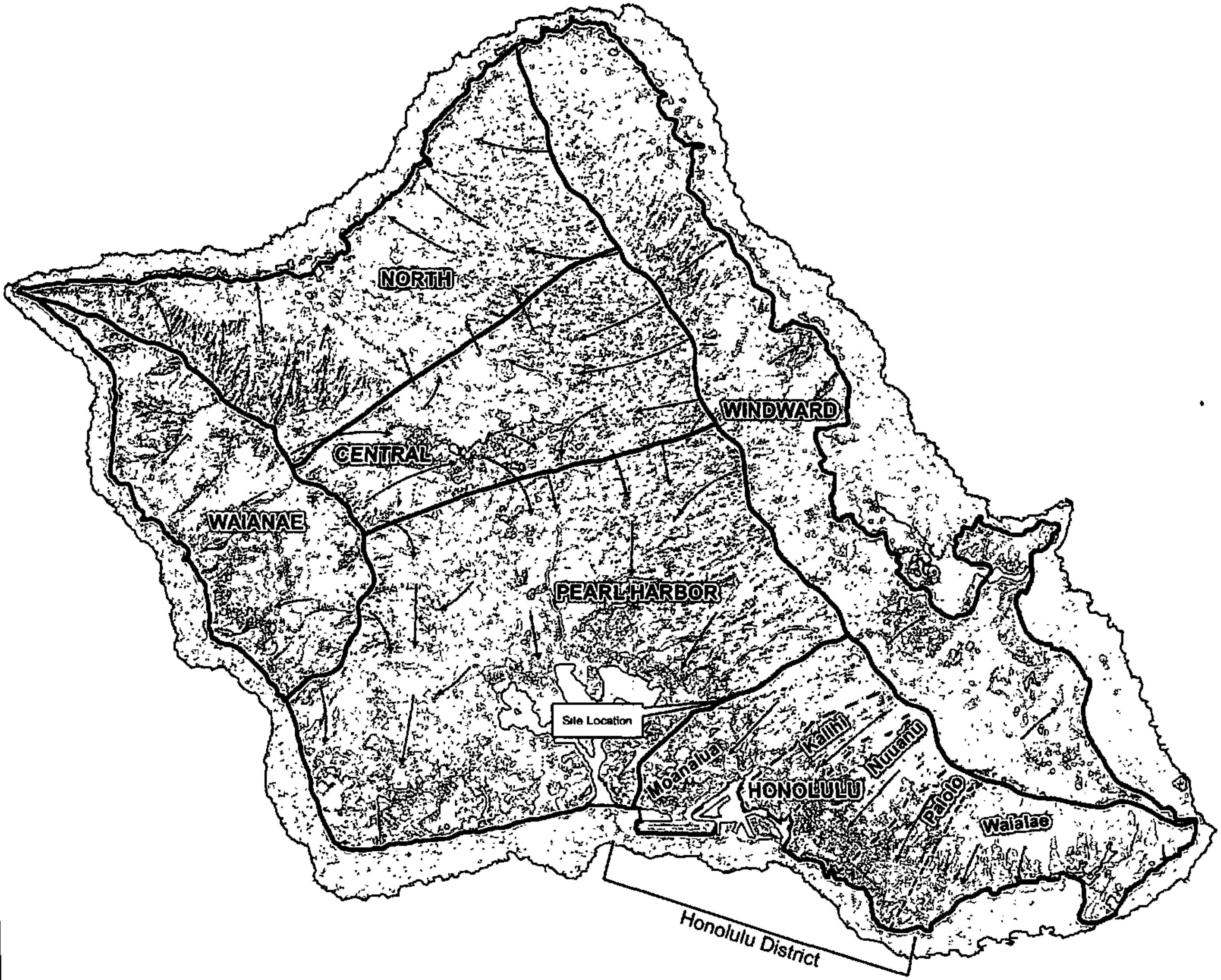
Sources: Refer to Data Dictionary Appendix 1



Island of Oahu, Hawaii

Figure 2-4
Elevation Contours

Red Hill
Bulk Fuel Facility



Legend
- Major Geohydrologic Boundaries
- Sub Geohydrologic Boundaries
- Groundwater Flow Direction
- Water

Sources. Refer to Data Dictionary Appendix 1

Island of Oahu, Hawaii

Figure 2-5
Generalized Groundwater Flow & Geohydrologic Boundaries

Red Hill Bulk Fuel Facility

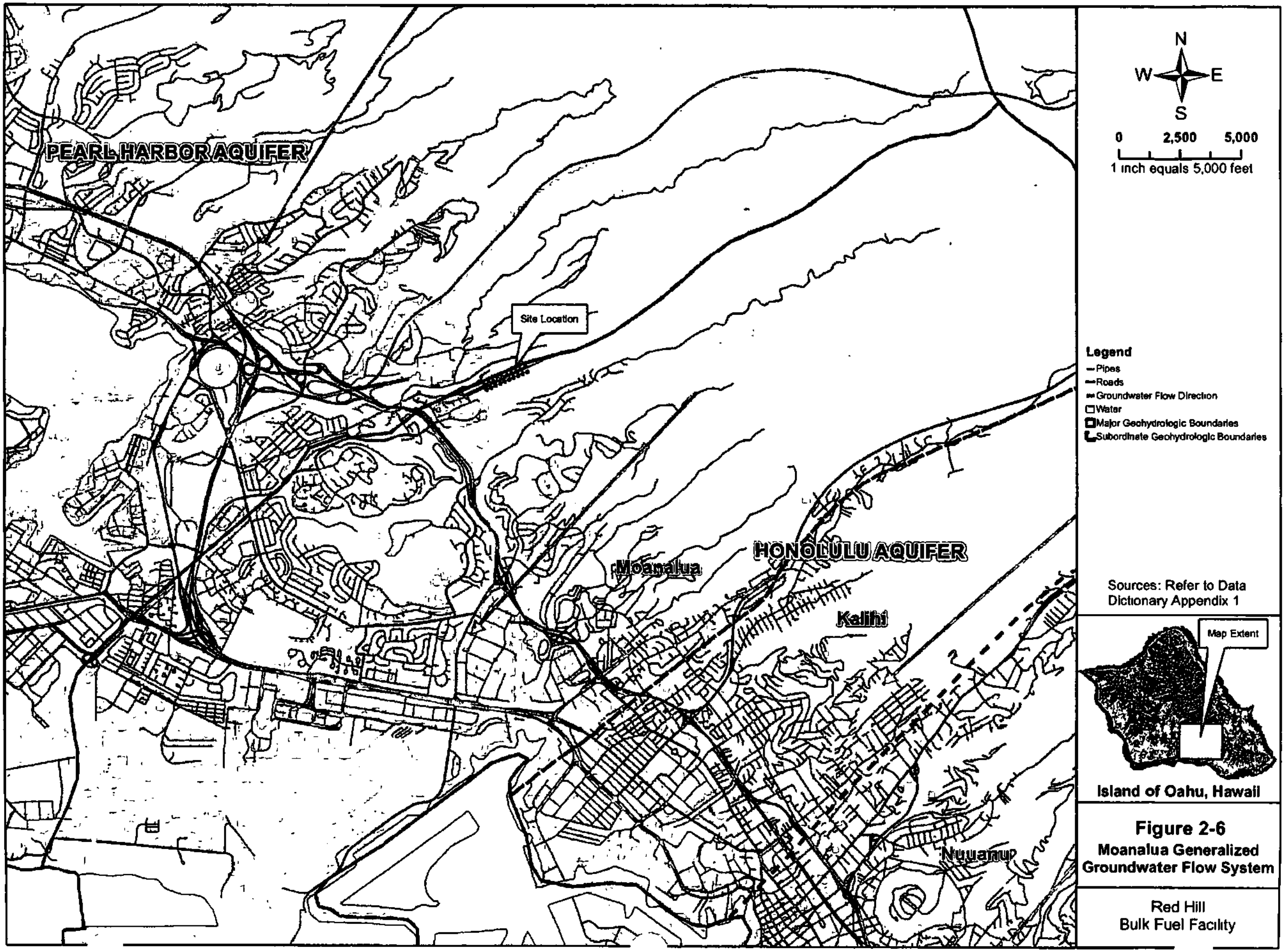
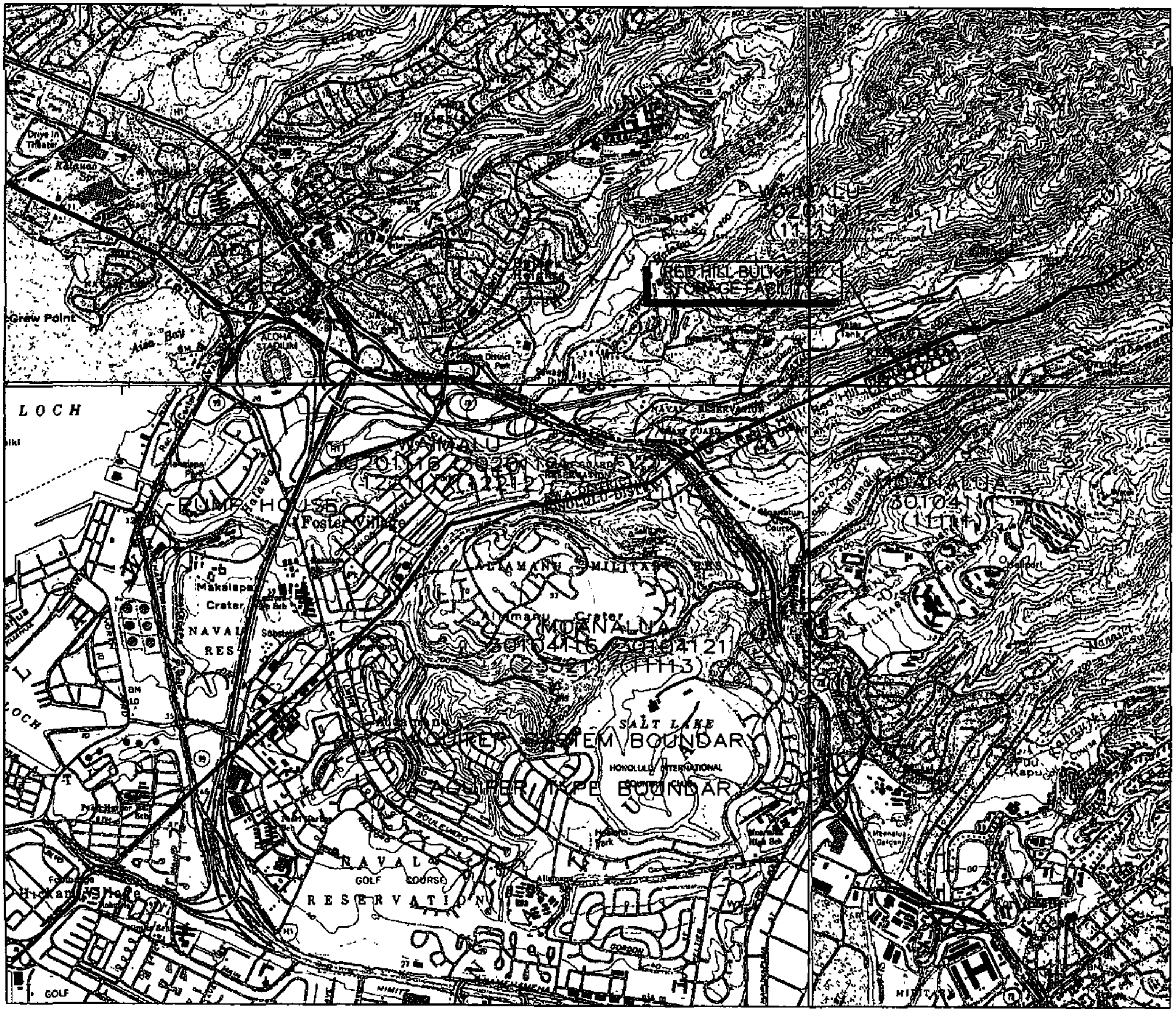


Figure 2-6
Moanalua Generalized Groundwater Flow System



N

LEGEND

———	AQUIFER SYSTEM BOUNDARY
— — —	AQUIFER TYPE BOUNDARY
30201111	AQUIFER CODE
(11111)	STATUS CODE

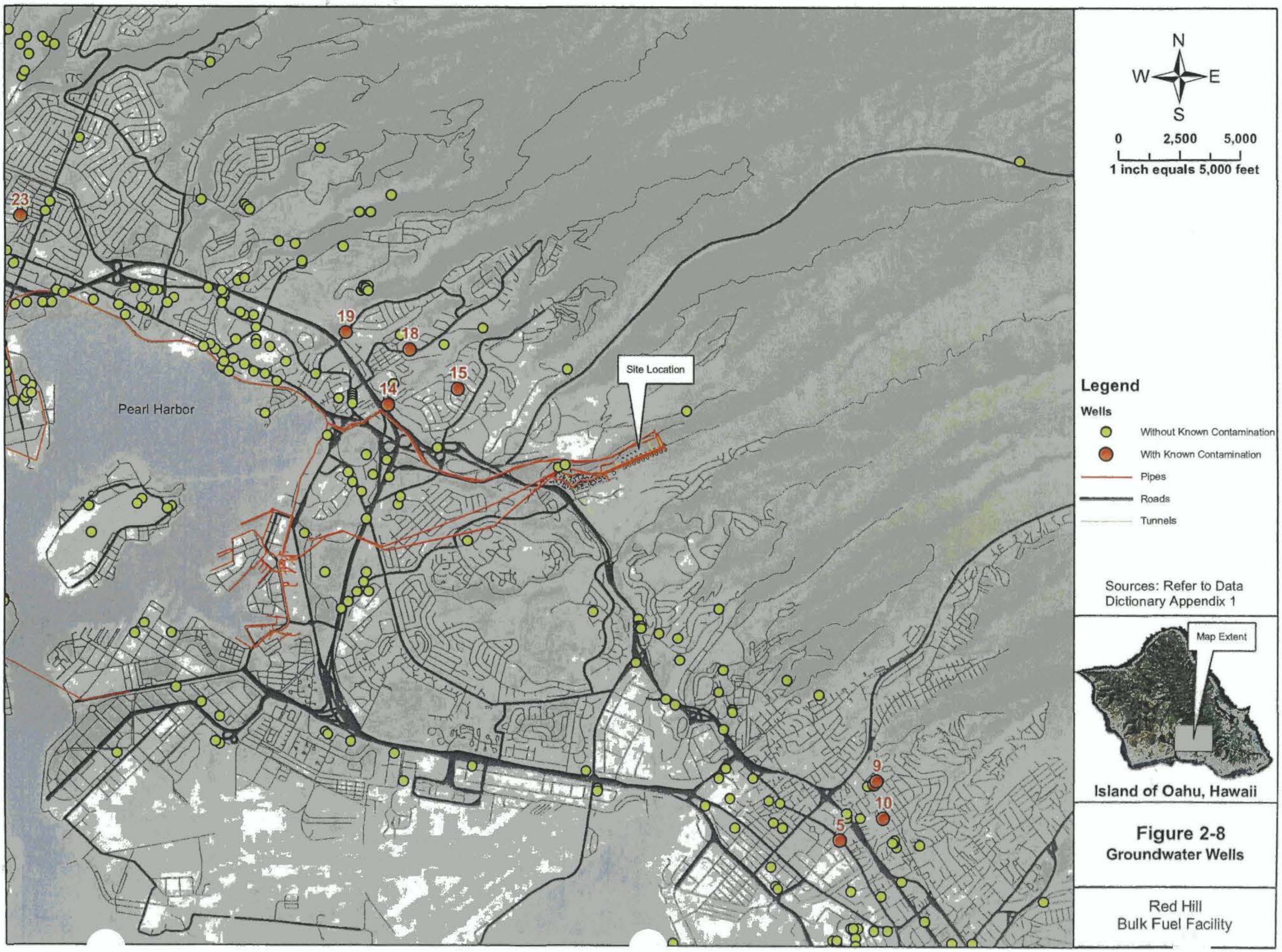
NOTE

SOURCES: MINK & LAU (1990); DLNR (1990); USGS (1983)

250 500 1000 Feet

Figure 2-7
Aquifer System and
Type Boundaries

Red Hill
Bulk Fuel Facility



Sources: Refer to Data Dictionary Appendix 1

Figure 2-8
Groundwater Wells

Red Hill
Bulk Fuel Facility

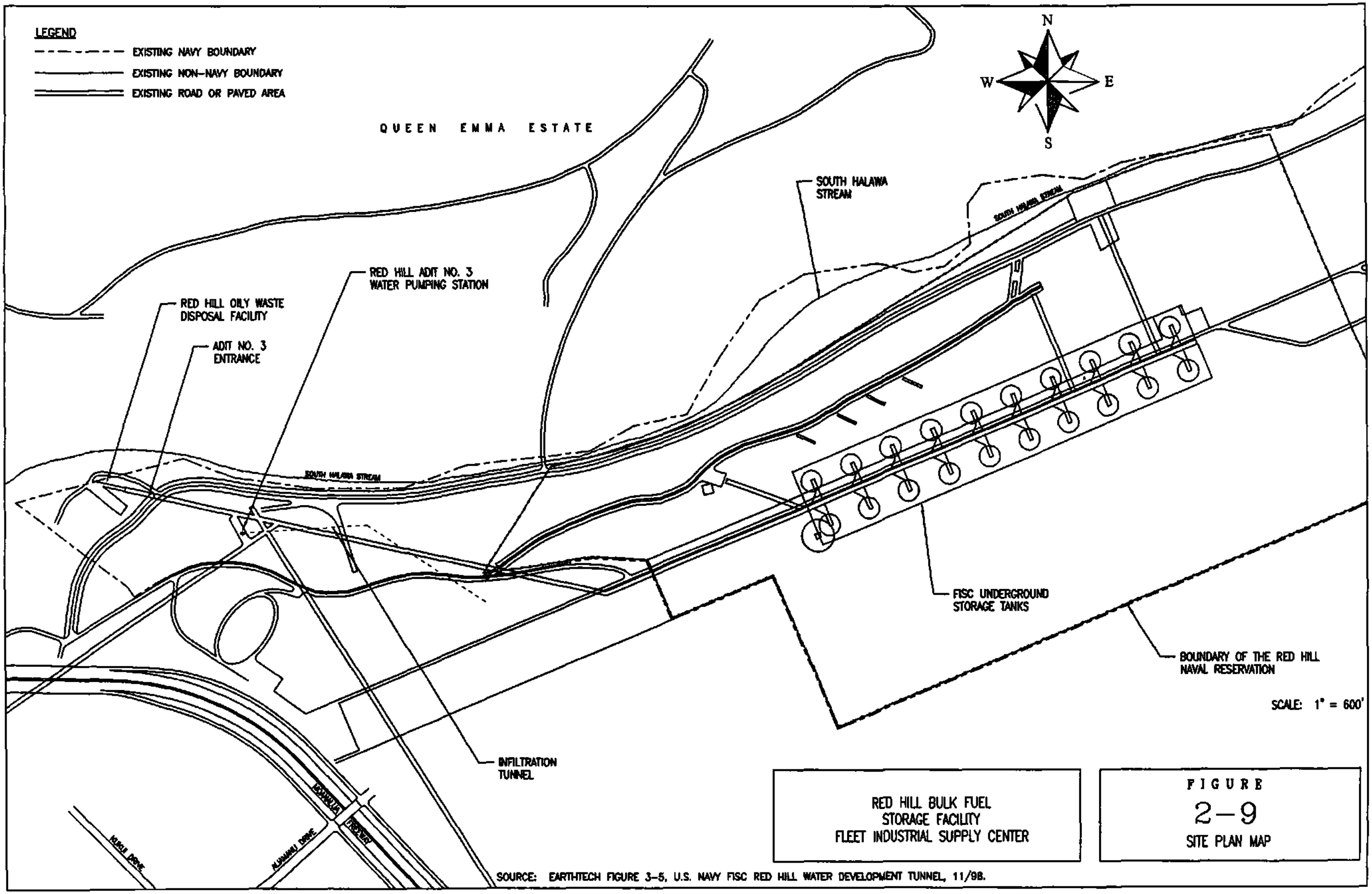
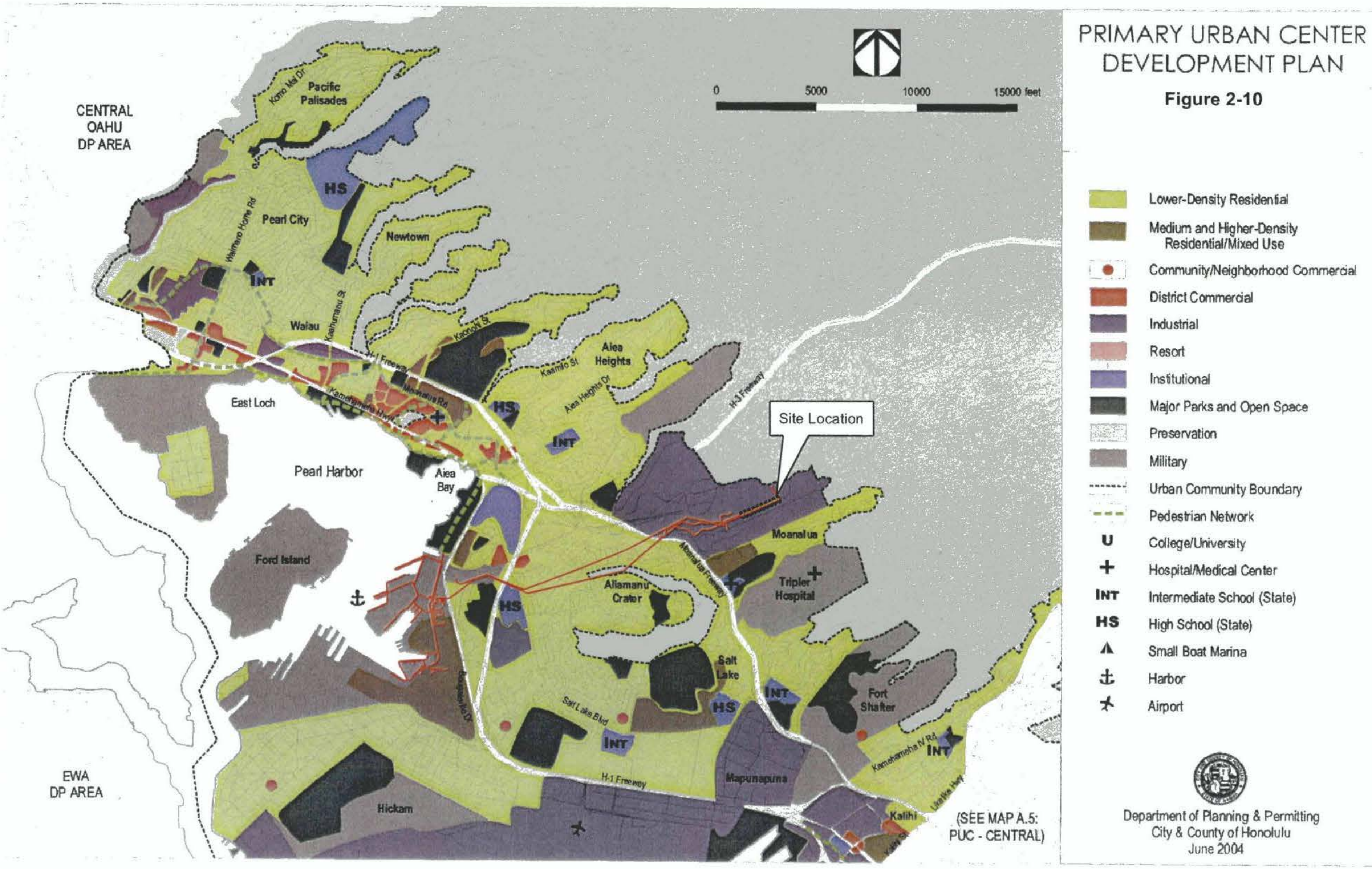
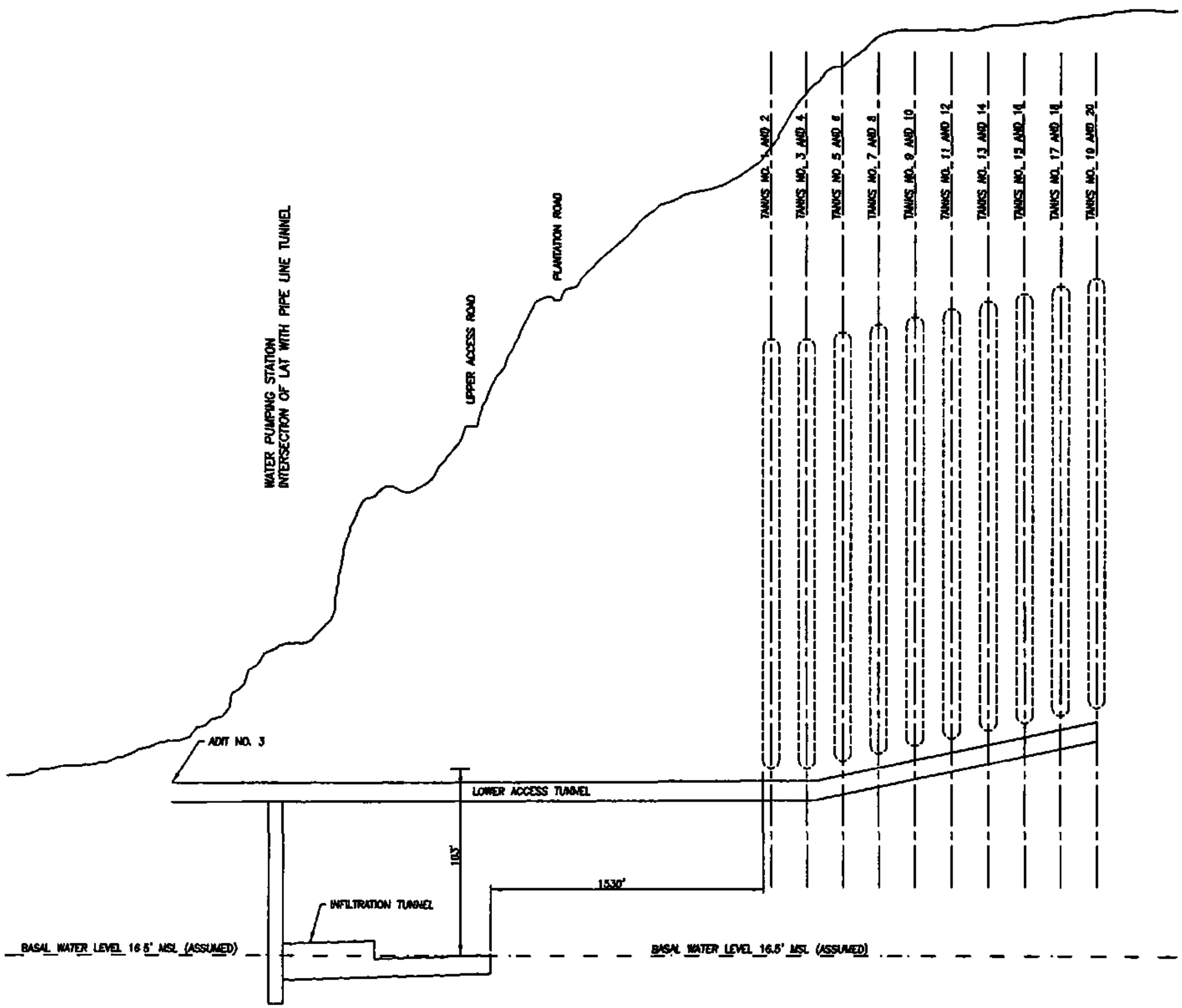


FIGURE 2-9
SITE PLAN MAP


PRIMARY URBAN CENTER DEVELOPMENT PLAN
Figure 2-10
0
5000
10000
15000 feet
CENTRAL OAHU DP AREA
EWA DP AREA
(SEE MAP A.5: PUC - CENTRAL)
Site Location
Pacific Palisades
Pearl City
Newtown
Waiau
Aiea Heights
East Loch
Pearl Harbor
Aiea Bay
Ford Island
Moanalua
Aliamanu Crater
Tripler Hospital
Salt Lake
Fort Shafter
Mapunapuna
Hickam
Kalihi
H-1 Freeway
H-3 Freeway
Kamehameha Hwy
Salt Lake Blvd
Lower-Density Residential
Medium and Higher-Density Residential/Mixed Use
Community/Neighborhood Commercial
District Commercial
Industrial
Resort
Institutional
Major Parks and Open Space
Preservation
Military
Urban Community Boundary
Pedestrian Network
U College/University
Hospital/Medical Center
INT Intermediate School (State)
HS High School (State)
Small Boat Marina
Harbor
Airport
Department of Planning & Permitting
City & County of Honolulu
June 2004

RED HILL BULK FUEL
STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER



SCALE: HORIZ. 1" = 500'
VERT. 1" = 60'

FIGURE
2-11
BULK FUEL TANK AND
WATER TUNNEL PROFILE

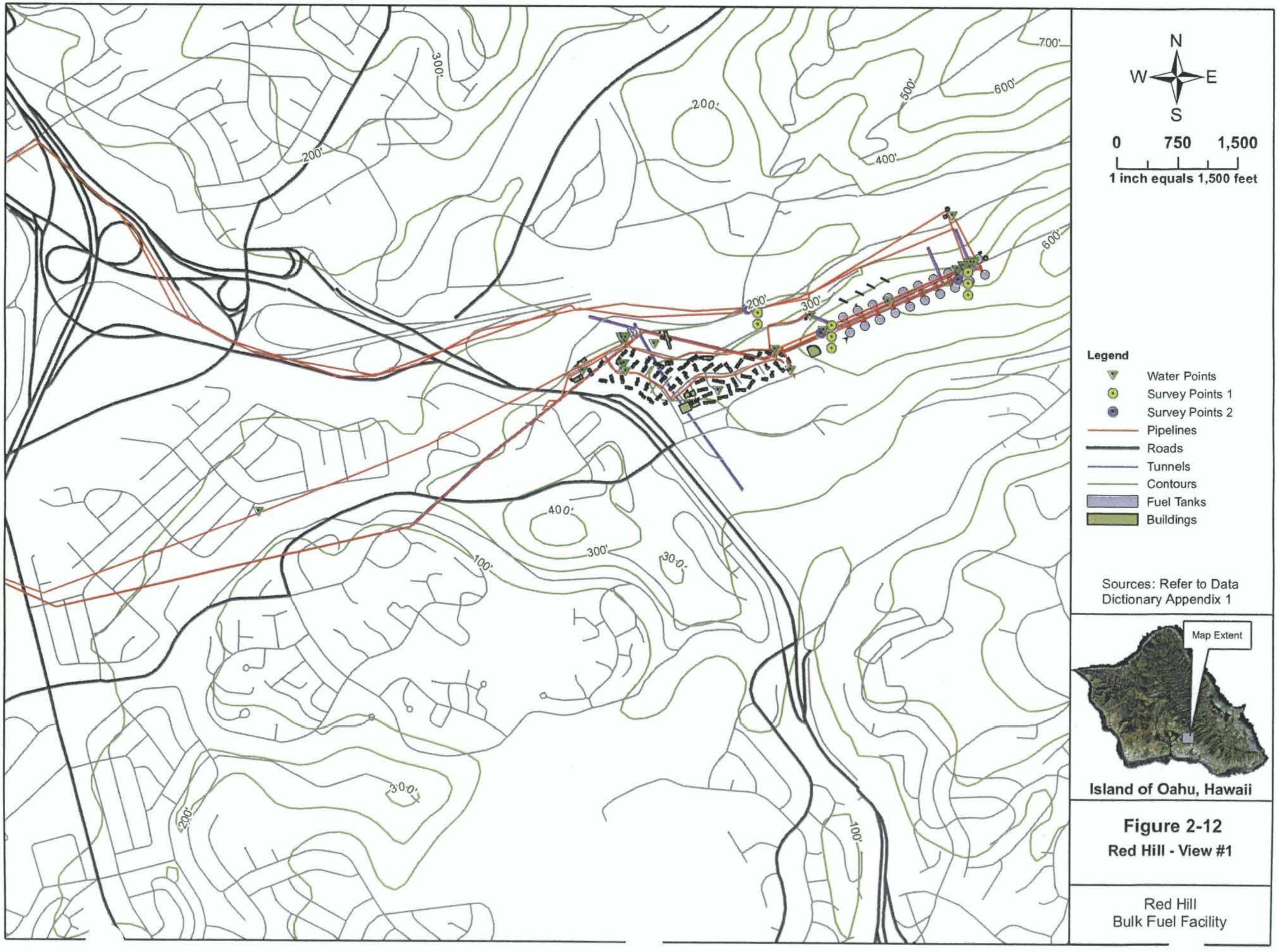


Figure 2-12

Red Hill - View #1

Red Hill
Bulk Fuel Facility

Figure 2-13
Red Hill - View #2

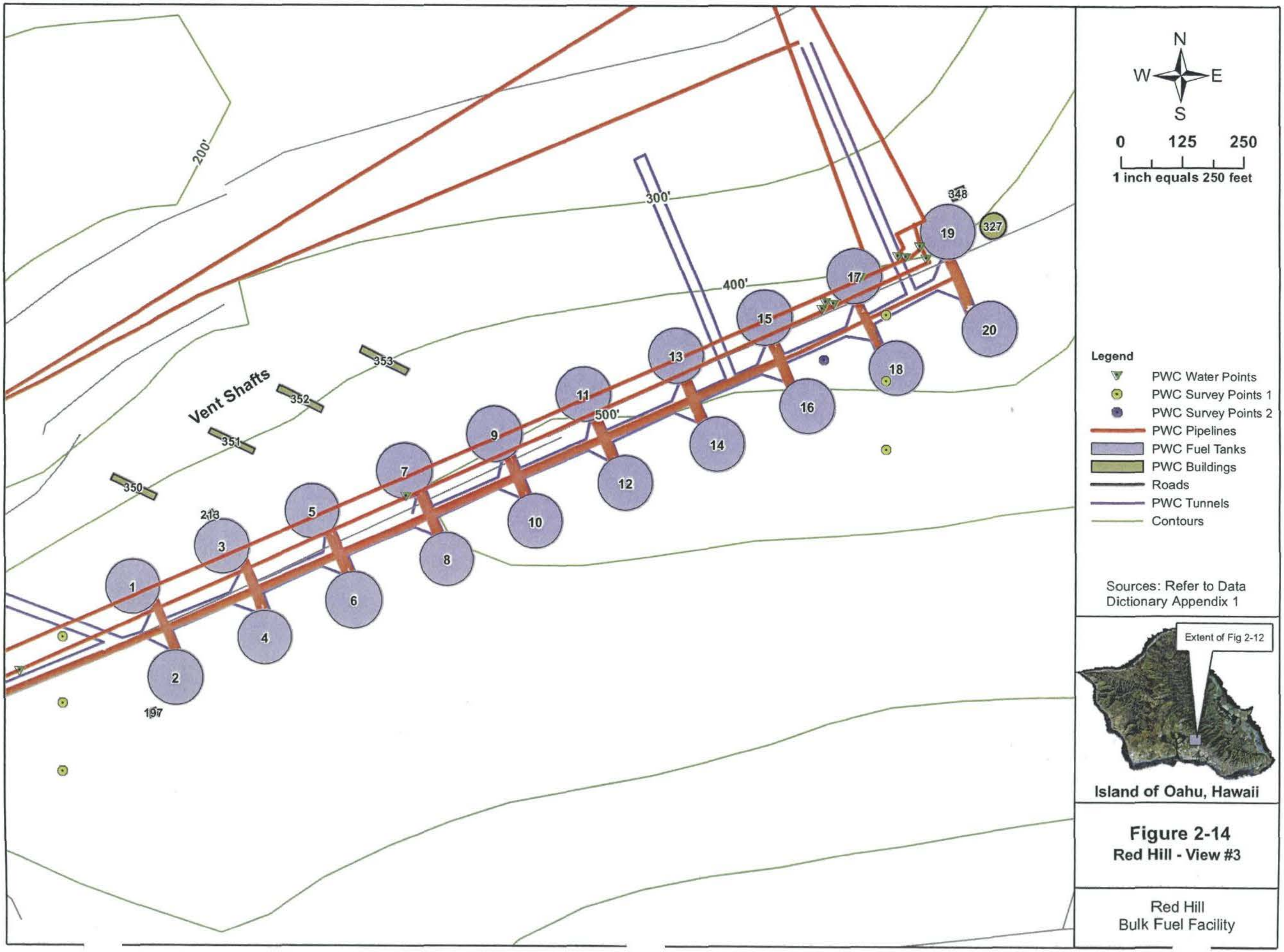
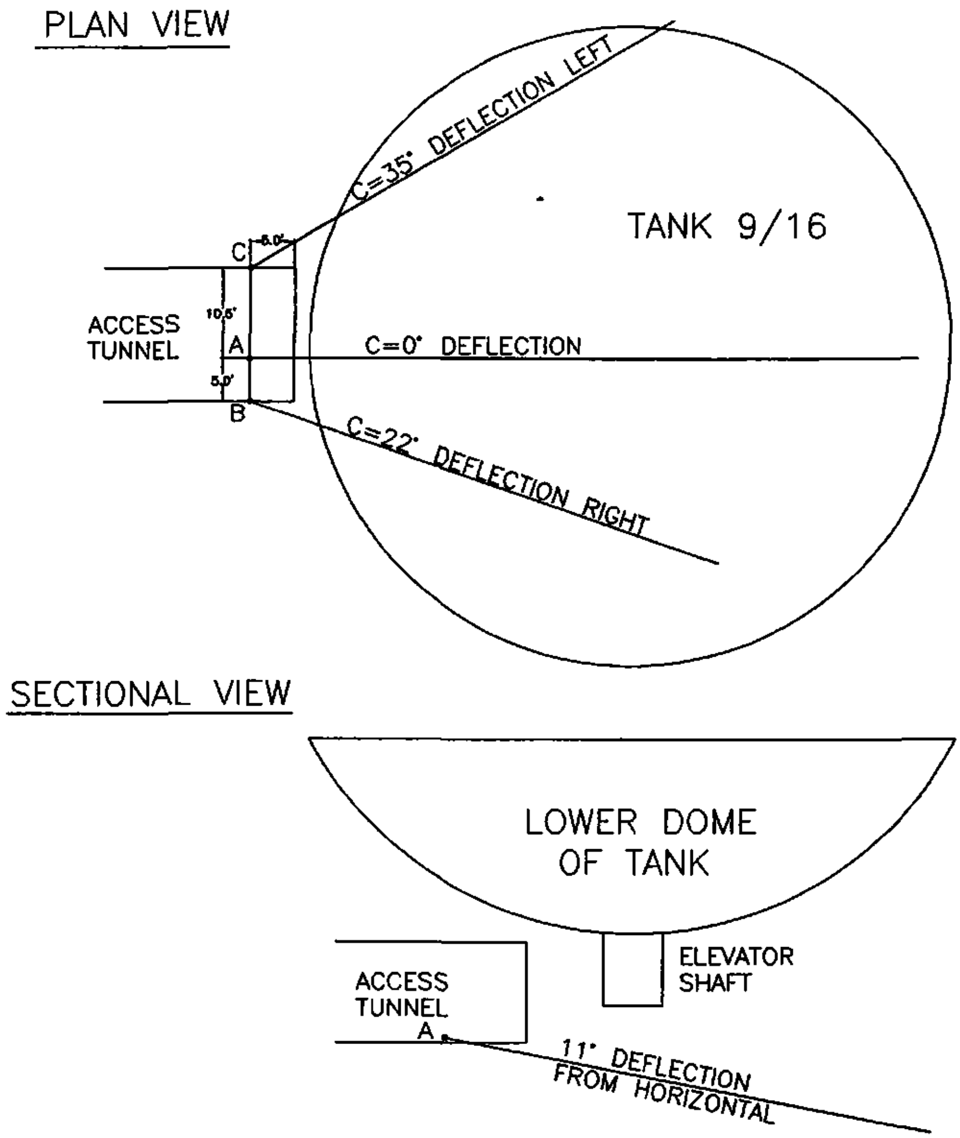


Figure 2-14
Red Hill - View #3

Red Hill
Bulk Fuel Facility



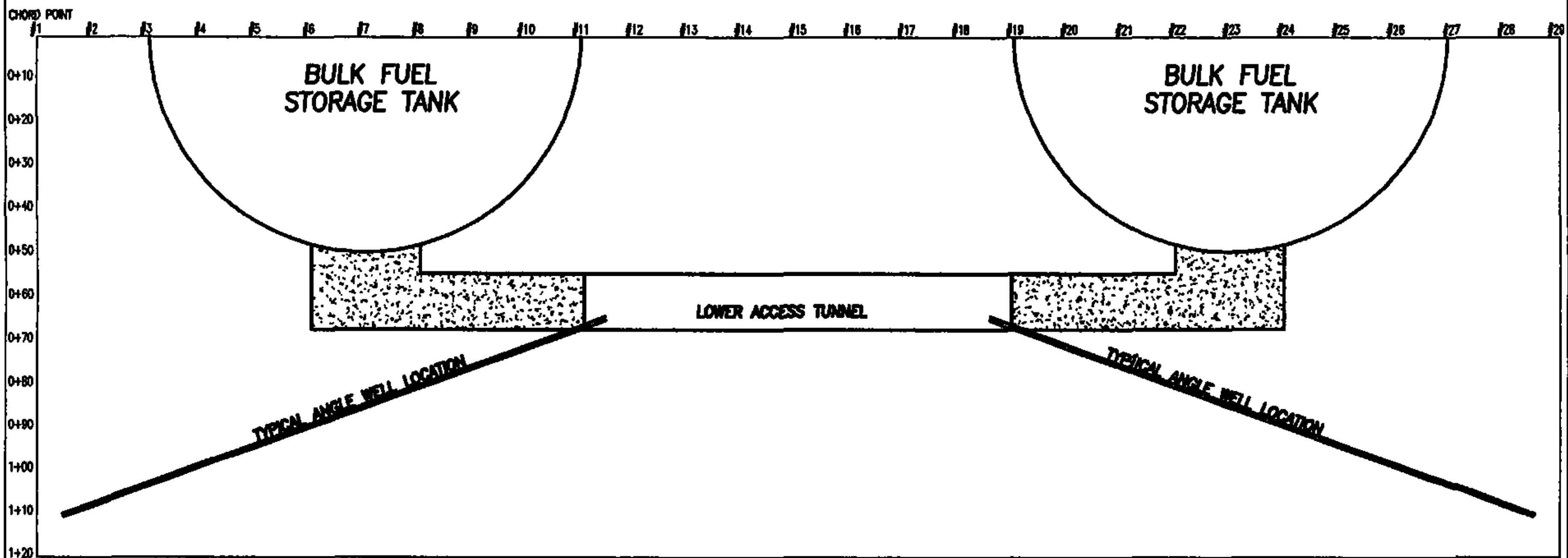
FILE NAME: NAVY\0229\BORING DIAGRAM-T16

BORING	DISTANCE
B09-A	93.80'
B09-B	75.00'
B09-C	72.50'
B16-A	102.70'
B16-B	76.40'
B16-C	74.50'

NOT TO SCALE

FIGURE 2-15

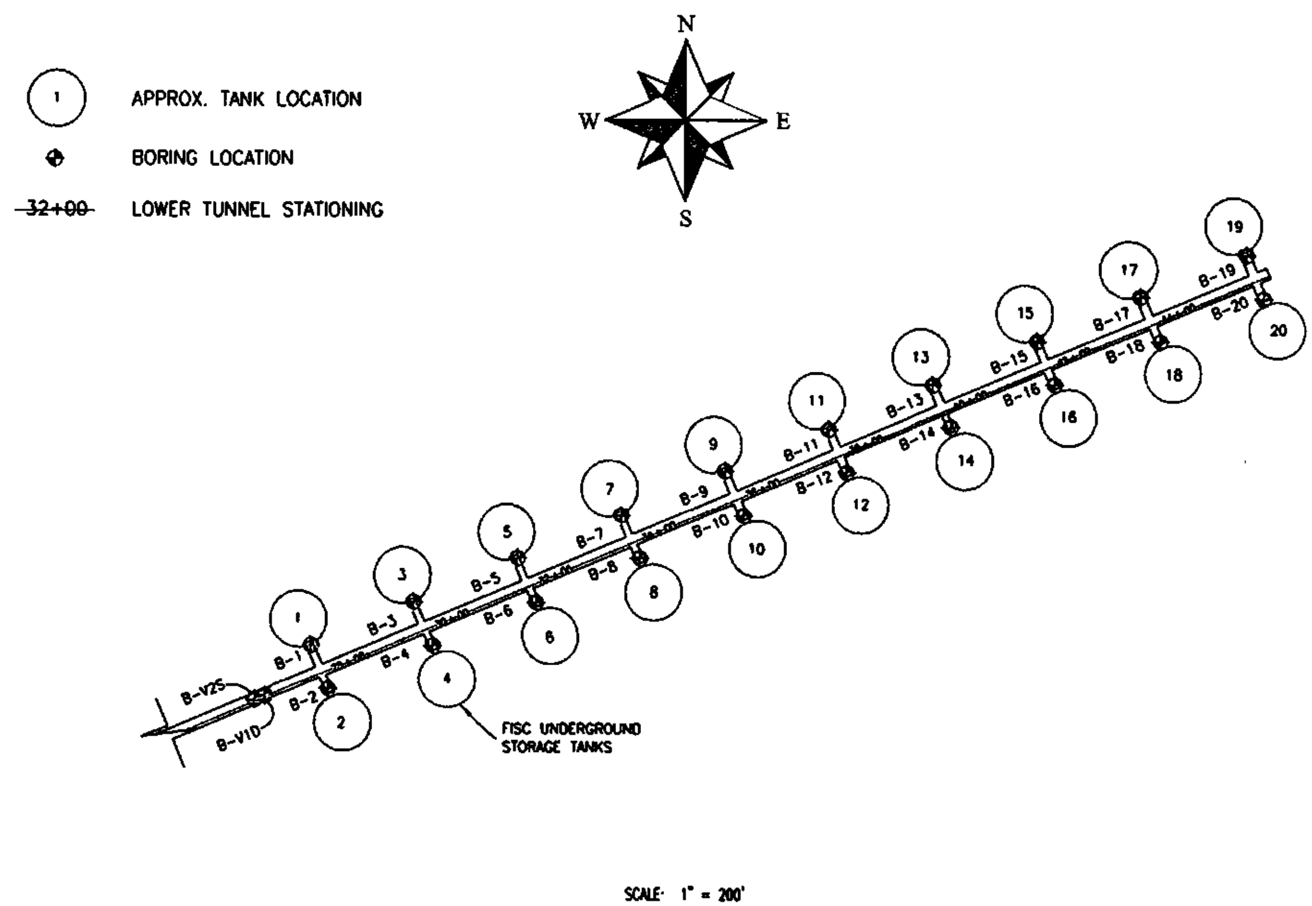
LOCATION, ANGLE, AND DISTANCE OF BORINGS
TANK 9 & 16
RED HILL BULK FUEL STORAGE



PLOT: 1" = 20'

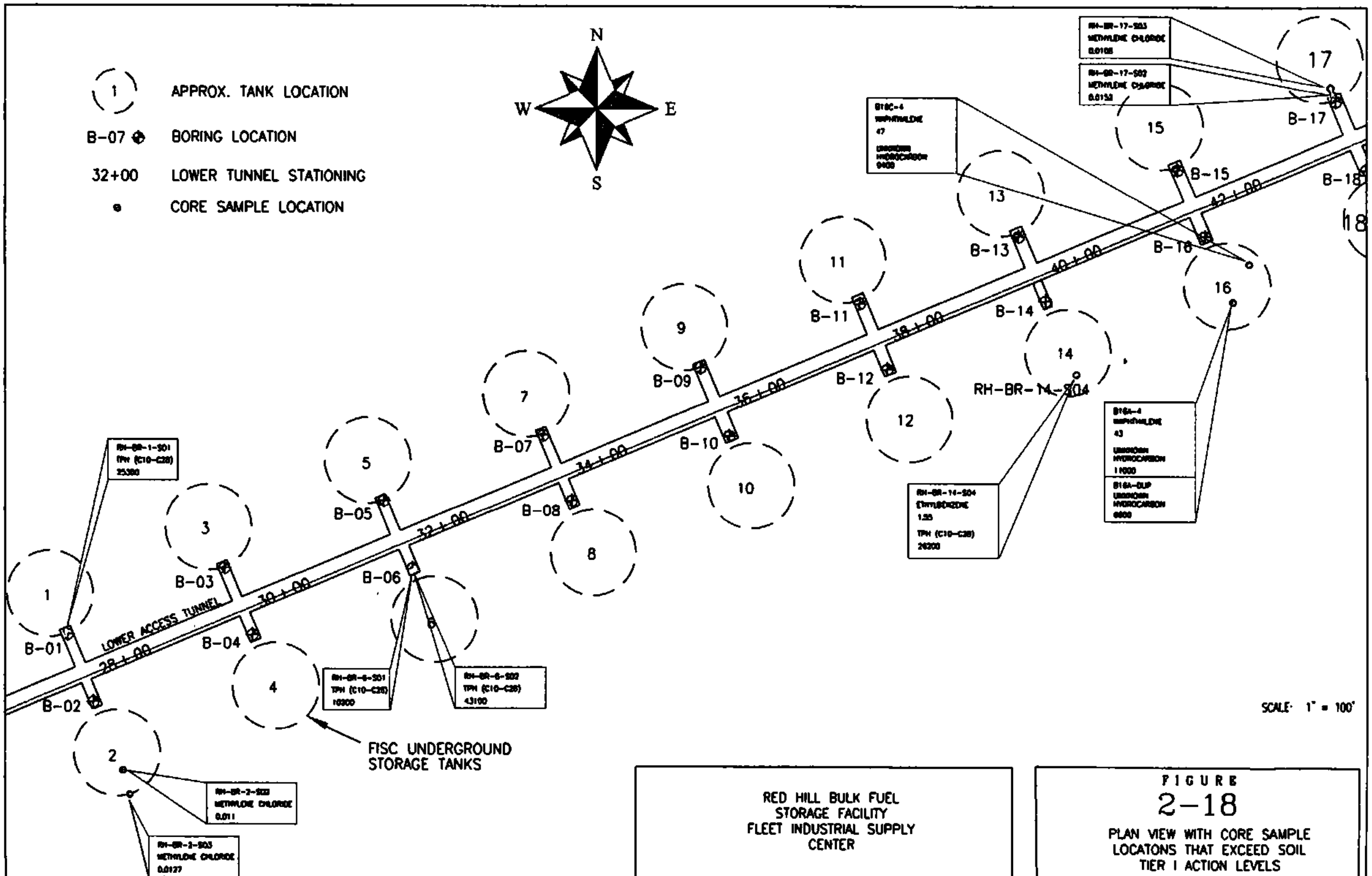
RED HILL BULK FUEL STORAGE
FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

FIGURE
2-16
PROPOSED DRILLING ALIGNMENT



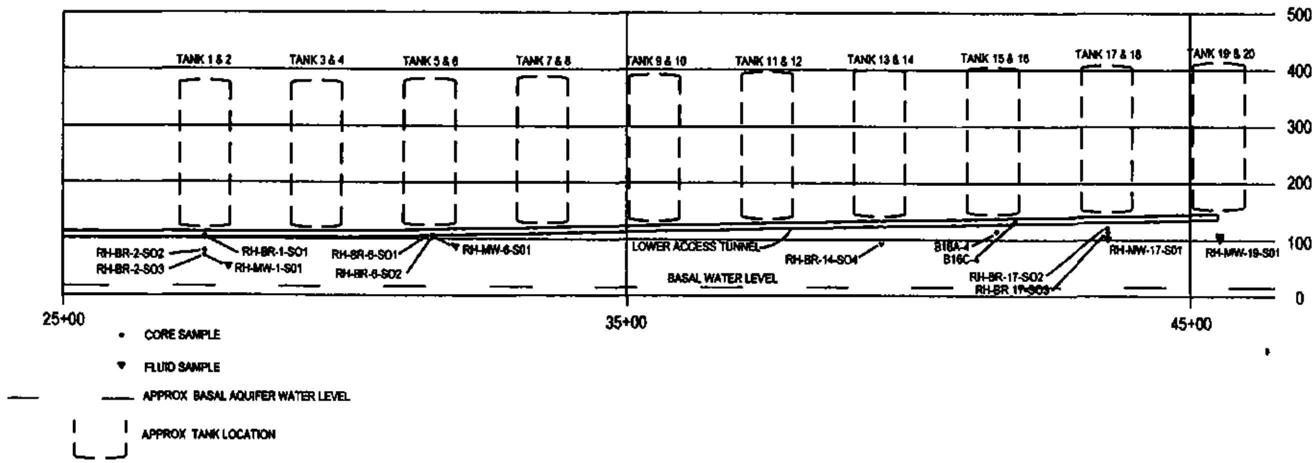
RED HILL BULK FUEL
STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

FIGURE
2-17
PLAN VIEW OF BORINGS



RED HILL BULK FUEL
STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY
CENTER

FIGURE
2-18
PLAN VIEW WITH CORE SAMPLE
LOCATONS THAT EXCEED SOIL
TIER I ACTION LEVELS



CORE SAMPLE RESULTS

SAMPLE ID	CONSTITUENTS WHICH EXCEED TIER I ACTION LEVELS	ANALYTICAL RESULTS (PPM)
RH-BR-1-S01	TPH (C10-C28)	25300
RH-BR-2-S02	METHYLENE CHLORIDE	0.011
RH-BR-2-S03	METHYLENE CHLORIDE	0 0127
RH-BR-6-S01	TPH (C10-C28)	10200
RH-BR-6-S02	TPH (C10-C28)	43100
RH-BR-14-S04	ETHYLBENZENE	1.55
	TPH (C10-C28)	26200
B16A-4	NAPHTHALENE	43
	UNKNOWN HYDROCARBON	11000
B16A-DUP	UNKNOWN HYDROCARBON	6600
B16C-4	NAPHTHALENE	47
	UNKNOWN HYDROCARBON	9400
RH-BR-17-S02	METHYLENE CHLORIDE	0.0152
RH-BR-17-S03	METHYLENE CHLORIDE	0.0108

FLUID SAMPLE RESULTS

SAMPLE ID	DATE SAMPLED	CONSTITUENTS ANALYZED	ANALYTICAL RESULTS (PPM)
RH-MW-1-S01	03/07/01	LEAD	0.0756
RH-MW-6-S01	01/19/01	LEAD	27 5
RH-MW-17-S01	08/27/01	LEAD	0 0720
RH-MW-19-S01	03/07/01	LEAD	0.0568
	08/27/01	LEAD	0 0666

RED HILL BULK FUEL STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

FIGURE
2-19

CROSS SECTIONAL VIEW WITH SOIL AND FLUID SAMPLE LOCATIONS WHICH EXCEED THEIR RESPECTIVE TIER I ACTION LEVELS

SECTION 3
INITIAL EVALUATION

This section presents the results of a preliminary risk evaluation previously conducted for the RHSF, a preliminary conceptual model of the Site, and identifies Site-specific ARARs and to be considered (TBC) benchmarks.

3.1 Preliminary Risk Summary

An initial risk screening level assessment was performed for the RHSF as part of the Phase II SI Report (AMEC, 2002). The results of the screening level assessment indicated that seven constituents were detected in core samples at concentrations of potential concern: ethylbenzene, methylene chloride, 2-methylnaphthalene, naphthalene, phenanthrene, TPH (carbon range C10-C28), and an unknown hydrocarbon. Three constituents were detected in groundwater samples at concentrations of potential concern: bis(2-ethylhexyl)phthalate, lead, and TPH (C10-C28). The investigations also reported the presence of petroleum LNAPL in several monitoring wells at the site. The preliminary risk evaluation conducted for the RHSF is included as **Appendix D**.

On the basis of the preliminary risk screening, it was recommended that a comprehensive RA be completed to assess current and potential future risk associated with the RHSF.

3.2 Preliminary Conceptual Site Model

Based on the results of the previous investigation and an initial pathway evaluation, a set of preliminary CSM graphical interpretations have been prepared to illustrate general geologic, hydrologic and fate and transport principals that are the current paradigm for the project area. These include a topographic relief model (**Figure 3-1**), which illustrates the area of potential impact, including land use, and defines the cross sections A-A' and B-B'.

Figure 3-2 is a CSM describing the hydrogeology and pathways of concern along transect A-A', which runs longitudinally through the Red Hill facility ridge line and illustrates the sources of contamination (primary USTs, secondary vadose zone, and tertiary basal groundwater) with respect to potential receptor endpoints (surface receptors, tunnel receptors, and groundwater supply wells).

Figure 3-3 is CSM describing the hydrogeology and pathways of concern along transect B-B', which runs transverse to the Red Hill facility ridge line and illustrates the sources of contamination (primary USTs, secondary vadose zone, and tertiary basal groundwater) with respect to potential receptor endpoints (valley fill, Halawa and Moanalua streams and groundwater supply wells).

The key information that is provided by these figures is the site geometry and the impacts of site features on potential contaminant migration pathways. Most importantly:

- Releases from the USTs are expected to be focused below the bottom of the tanks due to the concrete liner. The bottom of the tanks are located between 100 (Tank 1) and 150 feet (Tank 20) above msl, and consistently below the level of the surrounding valley fill, which will act as a barrier to horizontal migration. In addition, the USTs are between 500 and 750 feet horizontally from the valley walls. Lateral movement over this distance is not expected in the fractured basalt. For these reasons, the pathway for LNAPL or leachate to migrate to the valley surface and surface water/sediments is incomplete.

- Releases from the USTs are approximately 300 to 350 feet bgs in a fractured basalt environment. Due to the highly oxygenated subsurface and large distance to the ground surface, and the types of fuel that have been most recently stored in the USTs (NSFO, DFM, and JP-5, which are relatively low in volatility), volatile compounds are not expected to migrate to the ground surface. For these reasons, the pathway for organic compounds volatilized in soil vapor to migrate to the ground surface is insignificant.

- Releases from the USTs are in close proximity to the lower access tunnels and vapors may volatilize through cracks in the tunnel floor and impact current and future workers. Although the tunnels are ventilated to ensure that breathing conditions are appropriate for onsite workers, this pathway may potentially be complete and therefore should be evaluated in the project RA.

- Releases from the USTs may impact the groundwater beneath the USTs, either in the form of contaminated infiltrating rainwater (leachate) where rainwater passes through secondary sources of petroleum adsorbed to the fractured basalt substrate, or as LNAPL in the case of relatively large releases. Soil vapor monitoring points may provide long-term monitoring points for the unsaturated zone beneath each tank, and will be installed and sampled as part of a pilot study during this site characterization study. Two additional monitoring wells will be installed in the lower access tunnel, which will provide three basal water sampling points inside the facility adjacent to the USTs (including the existing V1D well). These will monitor the upper, middle and lower portions of the farm respectively, for groundwater impact within the UST facility.

- Past, current, or future releases may reach the basal groundwater and migrate as dissolved compounds in the basal aquifer to down-gradient supply wells. Currently, three nearby wells are within the study area as the closest and most vulnerable to being impacted by releases to groundwater (Board of Water Supply (BOWS) Halawa Pumping Shaft Well No. 2354-01, PWC Red Hill Navy Pumping Shaft Well No. 2254-01, and BOWS Moanalua Supply Well No. 2153-10). These will be evaluated for potential vulnerability using 3-D groundwater modeling techniques and analytical evaluation of the basal aquifer assimilative capacity based on the assessment of natural attenuation parameters.

In addition to the comprehensive graphics, a preliminary Conceptual Site Exposure Model (CSEM) schematic is provided to define the current understanding of the exposure pathways as a facet of the Preliminary Risk Evaluation. The CSEM identifies the relationships among potential sources, release and transport mechanisms, exposure media and routes, and potential receptors at the Site. The preliminary CSEM is presented as **Figure 3-4**. The CSEM defines an exposure pathway as Incomplete, Potentially Complete and Minor, or Potentially Complete and Major.

- o Pathways that are considered Incomplete are defined as pathways in which no contaminants can migrate from the source to the exposure point.

- o Pathways that are considered Potentially Complete and Minor are defined as pathways in which, if complete, contaminants concentrations that would reach the exposure points are very small compared to the screening action levels and therefore deemed insignificant in impacting human health and the environment.

- Pathways that are considered Potentially Complete and Major are defined as pathways in which, if complete, contaminants concentrations that would reach the exposure points have the potential to present an unacceptable risk to human health and the environment.

The CSEM identifies several pathways classified as major and potentially complete. These pathways include exposure to potable groundwater through ingestion, dermal contact, and inhalation for residential and occupational receptors. The other potentially complete pathway of concern is soil vapor intrusion to tunnel work areas.

3.3 Applicable or Relevant and Appropriate Requirements And To Be Considered Benchmarks

It is U.S. Navy policy that environmental investigations and removal actions be conducted in accordance with all applicable federal and state ARARs. TBCs may also be used as guidance for evaluating chemicals without ARARs or in situations where ARARs are not sufficiently protective of human health and the environment. ARARs/TBCs are used to determine the scope and extent of cleanup for a site. They help to formulate remedial action alternatives as well as govern the implementation and operation of a selected action.

The following bulleted list provides the ARARs/TBCs that have been considered during this phase of the investigation. Only State of Hawaii requirements are applicable to the Red Hill Site. The State of Hawaii, Department of Health Underground Storage Section is the lead agency responsible for the investigation.

- State of Hawaii Administrative Rules (HAR), Title 11, Chapter 451, *State Contingency Plan* (August 1995)
- Technical Guidance Manual for Underground Storage Tank Closure and Release Response (March 2000)

- Technical Guidance Manual for the Implementation of the Hawaii State Contingency Plan, Risk-Based Corrective Action and Decision Making at Sites with Contaminated Soil and Groundwater, Volume 1 (June 1996).

- Screening for Environmental Concerns at Sites with Contaminated Soils and Groundwater, Volume 1: Summary Tier 1 Lookup Tables (December 2003, Interim Draft.

Potential regulatory requirements for the RHSF include State of Hawaii environmental laws as promulgated by the Hawaii State Contingency Plan and administered by the State of Hawaii Solid and Hazardous Waste Branch, Underground Storage Tank Section and the Hazard Evaluation and Emergency Response Section. ARARs are regulatory requirements that are directly applicable or relevant and appropriate to a contaminant or situation. TBCs are nonpromulgated guidelines or benchmarks that may be considered in determining cleanup levels but are not enforceable guidelines or benchmarks.

3.3.1 ARARs – Defined

Applicable requirements refer to standards and other substantive environmental protection requirements promulgated under U.S. federal or Hawaii state laws that specifically address a circumstance at a hazardous waste site such as the presence of a hazardous substance, pollutant, contaminant, remedial action, or location. "Applicability" implies that the circumstances at the site satisfy all of the jurisdictional prerequisites of a requirement and are legally applicable for the site.

Relevant and appropriate requirements refer to standards and other substantive environmental protection requirements promulgated under U.S. federal or state law that are not legally applicable to a site but address situations sufficiently similar to be of use in evaluating the site. "Relevance" implies that the requirement regulates or addresses situations sufficiently similar to those found at the hazardous waste site. "Appropriateness" implies that the circumstances of a release or threatened release of chemicals are such that use of the standard is suitable. A requirement may be relevant but not appropriate for a site and therefore would not be an ARAR.

3.3.1.1 ARARs for the RHSF

There are no identified ARARs associated with potential soil contamination at the RHSF. There are also no substantive environmental protection requirements for potentially contaminated groundwater wells at the Site. All standards applicable to the RHSF are nonpromulgated advisories put forth by the HDOH. These benchmarks are described below.

3.3.2 TBCs – Defined

TBCs are nonpromulgated advisories, guidances or benchmarks that are not generally enforceable. Where no specific ARARs exist for a chemical or situation, or where such ARARs are not sufficient to be protective, guidance documents or advisories may be considered in determining the necessary cleanup level for the protection of human health or the environment. Levels of concern developed during a risk assessment are considered TBCs.

3.3.2.1 TBCs For the RHSF

Nonpromulgated criteria have been identified as potential chemical-specific TBCs for this investigation. They are described below.

3.3.2.1.1 HDOH Tier 1 Environmental Action Levels

As initial guidance, the HDOH recommends that contaminated soil and groundwater discovered at leaking underground storage tank sites be screened to Tier 1, TPH and constituent-specific Environmental Action Levels (EALs). The HDOH stipulates separate action levels for TPH and its indicator chemicals. TPH EALs should be used in conjunction with EALs for these chemicals. Indicator chemicals typically recommended to be included at sites where petroleum mixtures are assumed present include:

Monocyclic Aromatic Hydrocarbons

- Benzene
- Ethylbenzene

- Toluene
- Xylene

Fuel Additives

- Methyl Tertiary Butyl Ether (MTBE)
- Other oxygenates as necessary

Polycyclic Aromatic Hydrocarbons (primarily middle distillates and residual fuels)

- Acenaphthene
- Acenaphthylene
- Anthracene
- Benzo(a)anthracene
- Benzo(b)fluoranthene
- Benzo(g,h,i)perylene
- Benzo(a)pyrene
- Benzo(k)fluoranthene
- Chrysene
- Dibenzo(a,h)anthracene
- Fluoranthene
- Fluorene
- Indeno(1,2,3)pyrene
- Methylnaphthalene (1-and 2-)
- Naphthalene
- Phenanthrene
- Pyrene

Site Category

Under the HDOH 1996 Risk Based Corrective Action (RBCA) program, release sites are categorized into groundwater utility scenarios – "Drinking Water Source Threatened" and "Drinking Water Source NOT Threatened". Groundwater utility is determined based on the location of the site with respect to the UIC line and the State of Hawaii Aquifer Identification and Classification technical reports prepared by the University of Hawaii.

The Tier 1 action levels are further delineated/categorized based on annual rainfall (<200 cm/year and >200 cm/year). The HDOH draft screening guidance further categorizes sites and corresponding EALs by "Release Site ≤ 150 m From a Surface Water Body" and "Release Site > 150 m From a Surface Water Body" (HDOH 2003). This is intended to enhance screening and monitoring of contaminated groundwater in close proximity to surface water bodies. The categories and EALs applicable for the RHSF are:

- Drinking Water Source Threatened
- Rainfall <200 cm/year
- Release Site > 150 m From a Surface Water Body

The RHSF is located hydraulically up-gradient of the UIC line. The nearest BOWS drinking water well (Halawa Shaft, well number 2354-01) is located hydraulically cross-gradient of the Site. This drinking water well is approximately 5,000 feet northwest of the Site and pumps water from the basal aquifer. In addition, a U.S. Navy drinking water well (2254-01) is located approximately 3,000 feet southwest of the site and is possibly hydraulically down-gradient from the site. Because the RHSF is situated above a drinking water aquifer, the Tier 1 standards protective of a drinking water source apply. The nearest surface water body is not located within 150 meters of the RHSF and rainfall is less than 200 cm/year.

Tier 1 EALs are not required, regulatory "cleanup standards" and have currently only been presented in Draft form (December 2003). Use of Tier 1 EALs as actual cleanup levels should be evaluated in view of the overall site investigation results. For the RHSF, a comprehensive site-specific Tier 3 RA will be conducted based on the results of earlier investigations. The applicable screening criteria are summarized in **Table 3-1**.

3.3.2.1.2 Tier 2 and Tier 3 Environmental Risk Assessments

The RHSF is an active petroleum storage facility with a maximum capacity of approximately 240 million gallons. As such, the US Navy will estimate action levels at monitoring points on site that will have the potential to result in unacceptable chemical concentrations at the exposure points (groundwater in nearby supply wells and ambient air in breathing space within the lower access tunnel of the RHSF). The US Navy will estimate these concentrations using accepted analytical and numerical modeling techniques. These site-specific Tier 2 and Tier 3 EALs will be considered site-specific TBCs. The HDOH RBCA approach is a three-tiered system. The RBCA Tier 1 EALS have previously been described. The Tier 1 EALS feature highly conservative recommended soil and groundwater action levels intended for direct comparison to organic compounds or compound classes and heavy metals in both soil and groundwater samples collected at a site. RBCA Tiers 2 and 3 provide guidelines for calculating site-specific criteria based upon encountered geologic conditions and detected COPCs at a site. The RBCA Tier criteria applicable to a site are also determined by the classification of the groundwater beneath a site location, with separate criteria for sites not overlying drinking water sources and more conservative criteria for sites overlying potential drinking water sources. If Tier 1 EALs are exceeded, site-specific information will be utilized to calculate Tier 2 or 3 action level criteria at the RHSF.

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Ta[illegible]-1
Screening Criteria
HDOH Tier 1 Environmental Action Levels

Constituent	Soil Action Level, Drinking Water Resource (Soil Leaching)	Soil Action Level, Indoor Air Impacts	Groundwater Action Level, Drinking Water Toxicity	Groundwater Action Level, Indoor Air Impacts	Shallow Soil Gas Action Level, Indoor Air Impacts (residential exposure)
	mg/kg	mg/kg	ug/L	ug/L	ug/m^3
VOCs					
Benzene	0 22	0 67	5	2000	310
Toluene	2 9	650	1000	530000	420000
Ethylbenzene	3 3	4 7	700	14000	2200
Xylenes	2 3	220	10000	160000	100000
MTBE	0 023	5.2	13	62000	24000
SVOCs					
Acenaphthene	16	130	370	4200	220000
Acenaphthylene	100	(soil gas)	240	(soil gas)	150000
Anthracene	2 8	6 1	1800	43	1100000
Benzo(a)anthracene	12	NA	0.092	NA	NA
Benzo(b)fluoranthene	46	NA	0 092	NA	NA
Benzo(g,h,i)perylene	27	NA	1500	NA	NA
Benzo(a)pyrene	130	NA	0.2	NA	NA
Benzo(k)fluoranthene	37	NA	0.92	NA	NA
Chrysene	23	NA	9.2	(soil gas)	NA
Dibenzo(a,h)anthracene	9.9	NA	0.0092	NA	NA
Fluoranthene	250	NA	1500	NA	NA
Fluorene	560	160	240	1900	150000
Indeno(1,2,3)pyrene	24	NA	0.092	NA	NA
Methylnaphthalene (total 1-and 2-)	1.2	110	240	26000	150000
Naphthalene	1.2	23	6 2	31000	3100
Phenanthrene	18	(soil gas)	240	(soil gas)	150000
Pyrene	85	85	180	140	110000
Metals					
Lead	NA	NA	15	NA	NA
Lead, Tetraethyl	NA	NA	15	NA	NA
Lead, Dissolved	NA	NA	15	NA	NA
Total Petroleum Hydrocarbons					
GRO	2,000	(soil gas)	100	(soil gas)	52000
DRO	5,000	(soil gas)	100	(soil gas)	52000

Notes:
(soil gas) = Chemical constants not available for modeling. Use soil gas data to evaluate potential indoor-air concerns
NA = Not applicable
Reference:
HDOH, 2004
Assumptions:
(1) Rainfall <200 cm/year
(2) Drinking water source threatened
(3) Surface water body is not located within 150 meters of release site

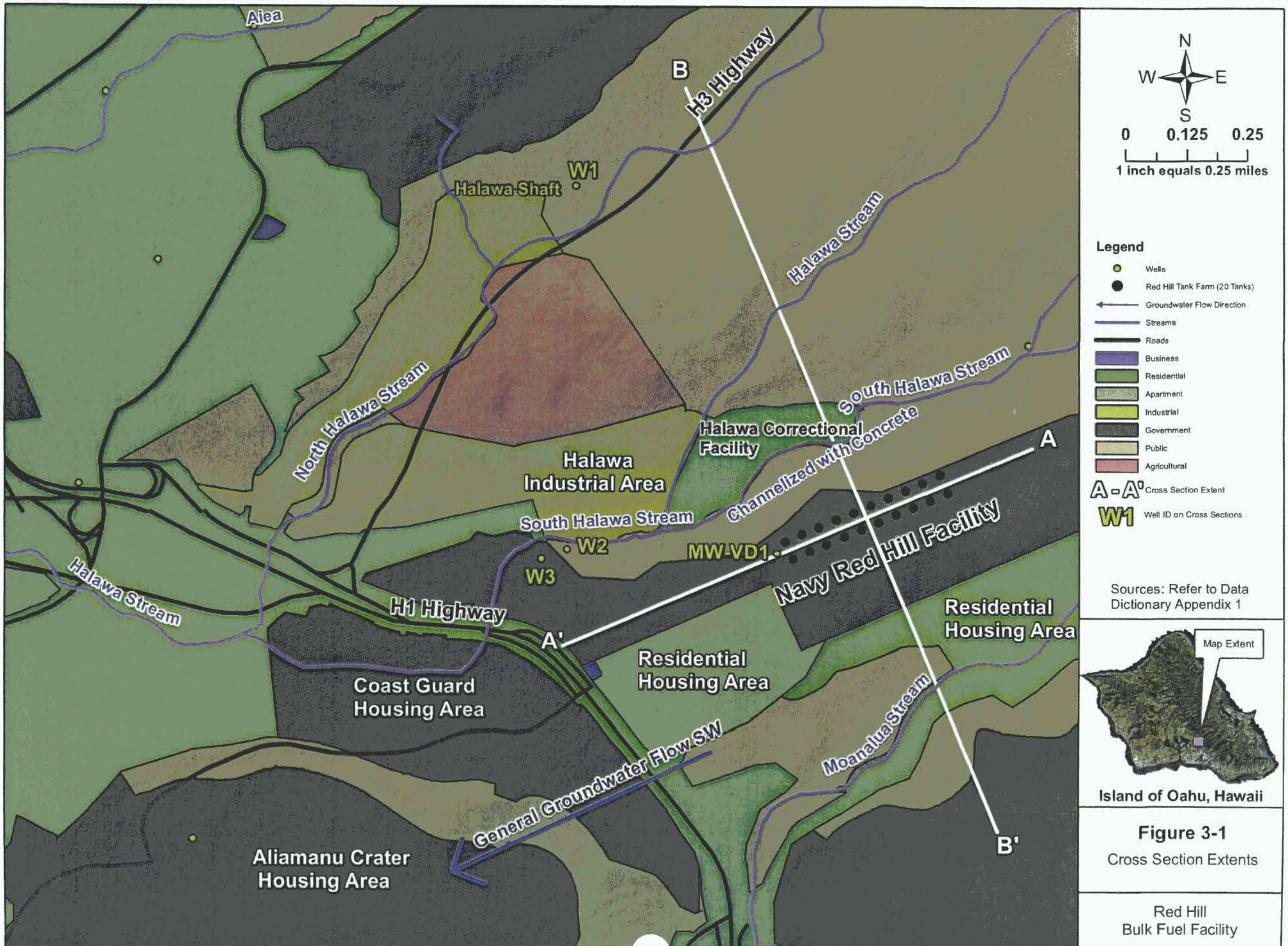
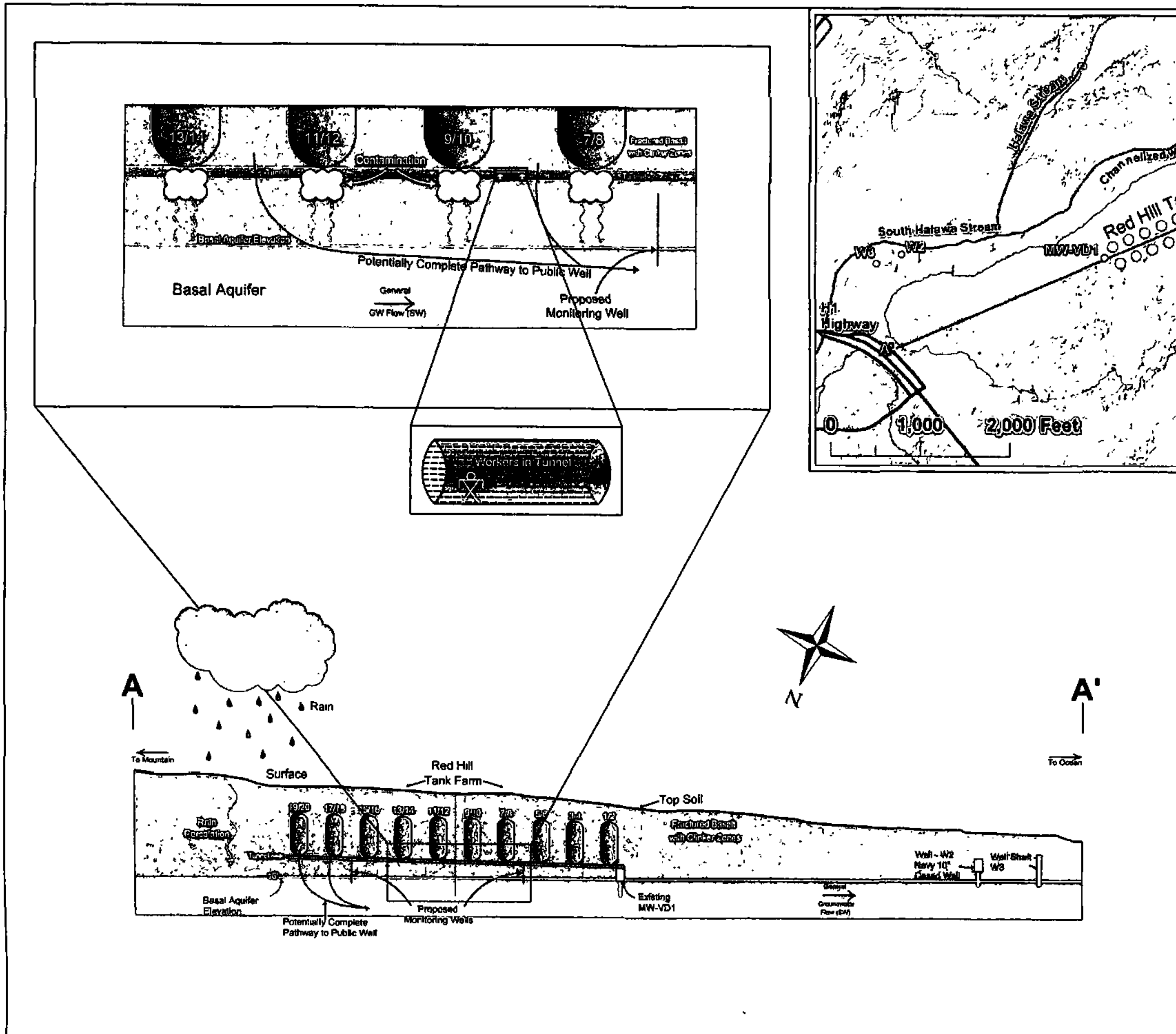


Figure 3-1
Cross Section Extents

Red Hill
Bulk Fuel Facility

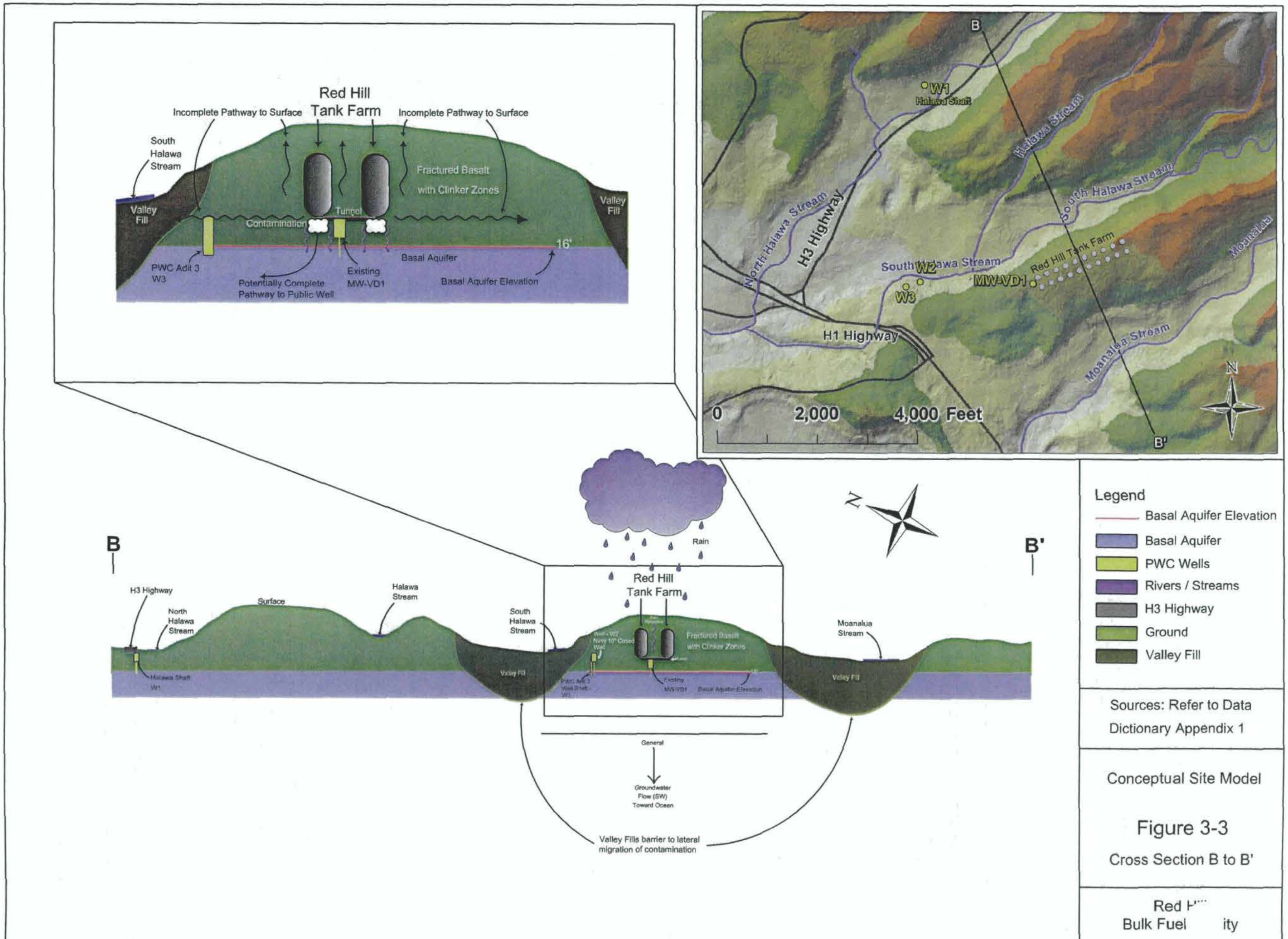


Conceptual Site Model

Figure 3-2

Cross Section A to A'

Red Hill Bulk Fuel Facility



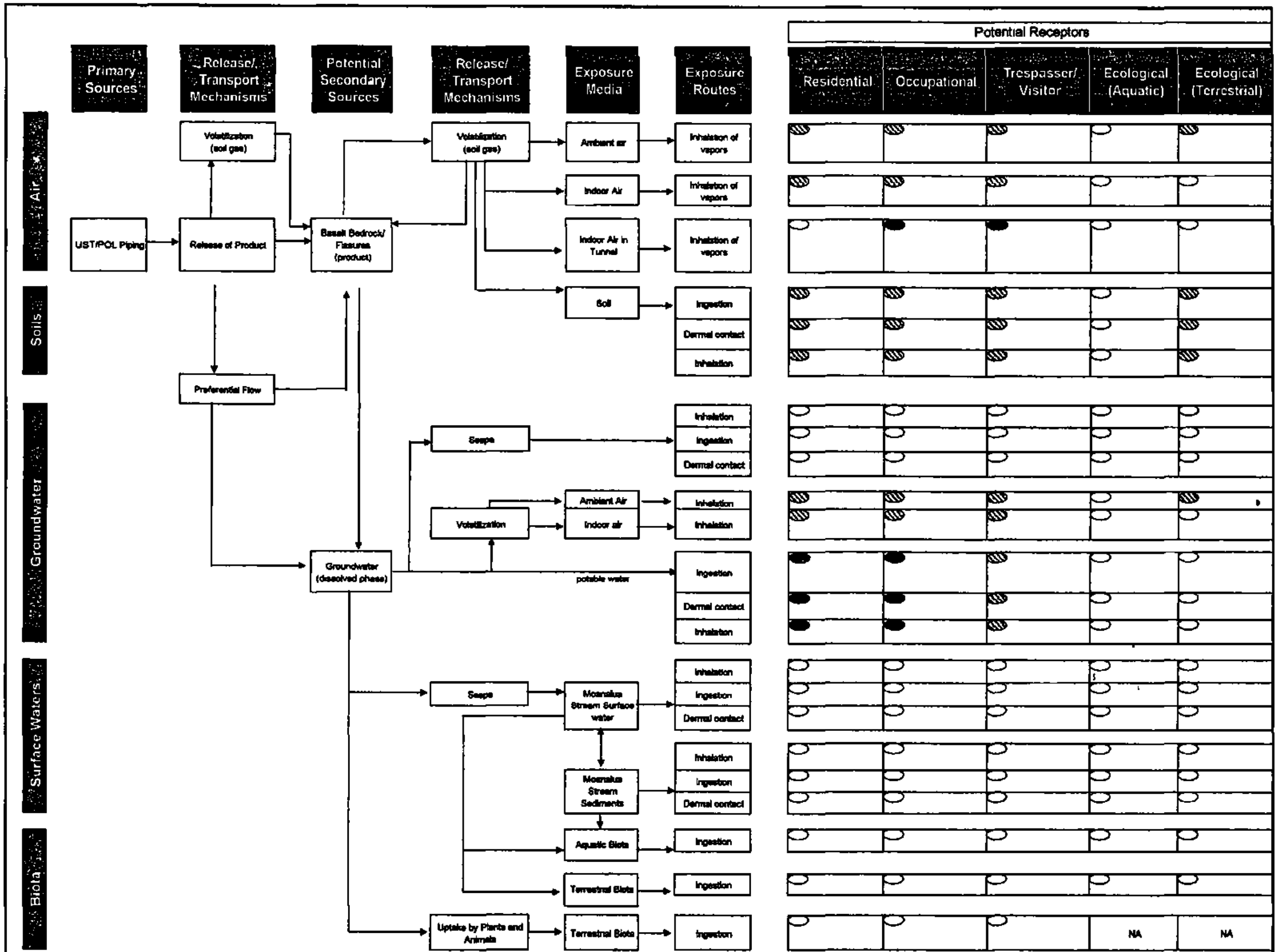
Sources: Refer to Data Dictionary Appendix 1

Conceptual Site Model

Figure 3-3

Cross Section B to B'

Red H[illegible]
Bulk Fuel [illegible]ity



LEGEND
Exposure Pathway Evaluated and Incomplete
Exposure Pathway Evaluated and Potentially Complete - Minor
Exposure Pathway Evaluated and Potentially Complete - Major
Minor Exposure Pathway = contaminants concentrations that would reach the exposure points are very small compared to the screening action levels and therefore deemed insignificant in impacting human health and the environment.
Major Exposure Pathway = contaminants concentrations that would reach the exposure points have the potential to present an unacceptable risk to human health and the environment.
NA = Not Applicable

Figure 3-4

Preliminary Conceptual Site Exposure Model

SECTION 4
PROJECT INVESTIGATION RATIONALE

This section identifies the primary focus areas of the RHSF field investigation and DQOs associated with the focus areas.

4.1 FOCUS AREAS

The overall project objectives for the RHSF field investigation can be categorized into two main areas of focus:

- **Characterize and monitor the vadose zone and basal groundwater aquifer beneath the RHSF Site** – A groundwater monitoring network will be established to monitor potential releases from the RHSF, evaluate the nature and extent of COPCs, and evaluate the fate and transport of COPCs in the groundwater. Groundwater monitoring wells will be screened across the water table, approximately 10 feet above and 10 feet below the water table (see Section 3 of the FSP [**Appendix A**]). Groundwater sampling will be conducted to measure and characterize COPC concentrations beneath and in the vicinity of the RHSF. Groundwater level measurements will be recorded to evaluate the fluctuation in the local groundwater gradient resulting from seasonal precipitation, and will be used to calibrate the numerical groundwater flow model to be developed in Phase II of the project. A pilot soil vapor monitoring network will be established in a maximum of three existing angle borings to evaluate the feasibility of converting the existing 20 angled-bore monitoring wells to soil vapor monitoring wells. Data collected will be incorporated with existing data from prior investigations and site activities to provide a more complete assessment of COPCs at the Site.

- **Evaluate and mitigate risk factors resulting from potential petroleum product releases at RHSF** - Information obtained during the field investigation activities will be used to support fate and transport modeling and preparation of a comprehensive risk assessment. A 3-D GIS database integrating existing and newly acquired site-specific data will be prepared and used as the basis for a CSM for the RHSF. Hydrologic testing will be conducted in the vicinity of the Navy Red Hill groundwater supply well (No. 2254-01) to develop site-specific hydraulic parameters to aid in the development of the CSM. In turn, the CSM will be used to design and conduct groundwater flow and COPC Fate and Transport modeling in environmental media beneath the Site (e.g., vadose zone transport of soil vapor and liquids, and groundwater transport of non-aqueous phase liquids (NAPL) and aqueous phase constituents). The modeling efforts will be supported by physical parameter data obtained by the collection and geotechnical analysis of soil core samples and the conduct of a continuous rate aquifer pumping test using observation wells. The results of the site characterization and modeling efforts will be used to conduct a Comprehensive RA for the Site. Finally, the accumulated knowledge of the Site will be used to prepare a Contingency Plan that will be to monitor site characterization data over time and provide long-term actions to mitigate future threats to human health and the environment from unauthorized releases from the Site.

The above focus areas for the RHSF field investigation effort have particular data objectives requiring data input from the investigation activities. Decisions relevant to subsequent activities (e.g., additional sampling) will be made on the basis of results from the RHSF field activities.

4.2 Data Quality Objectives

Particular data objectives, necessary data input, and decisions for the above focus areas for the RHSF field investigation activities are supported through considerations of a formal DQO Process (USEPA 2000a and 2000b). The DQO Process is a seven-step planning approach to develop sampling designs for data collection activities that will support decision making. The seven steps in the DQO process are as follows:

Step 1: State the problem.
Step 2: Identify the decision.
Step 3: Identify the inputs to the decision.
Step 4: Define the boundaries of the study.
Step 5: Develop a decision rule.

Step 6: Specify tolerable limits for decision errors.

Step 7: Optimize the design for obtaining data.

DQOs are qualitative and quantitative statements, developed using the DQO process, that are intended to clarify study objectives, define an appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. DQOs for each of the above focus areas for the RHSF field investigation effort are presented in the following sections.

4.2.1 DQOs for Characterization of the Nature of COPCs at RHSF

Data to support characterization of the nature and extent of COPCs in the soil, soil vapor, and basal aquifer for the field investigation activities include measurement of COPC concentrations in samples collected from three types of media beneath the RHSF Site: soil/rock cores, soil vapor, and groundwater. The proposed sampling program approach will meet the DQOs defined for characterization of the COPCs at RHSF. The monitoring well (V1D) installed within the basal aquifer during the previous RI work has been effective in monitoring COPCs. The proposed boring/monitoring well locations are located to monitor different sections of the facility. As such, the facility will be partitioned into Upper Tank Farm (Tanks 20 through 15), Middle Tank Farm (Tanks 14 through 7), and Lower Tank Farm (Tanks 6 through 1). The proposed pilot soil vapor monitoring wells will be installed within existing angled borings located beneath the USTs. Descriptions of the groundwater monitoring well network, pilot soil vapor monitoring network, and media sampling programs are provided in Section 3.0 of the FSP (**Appendix A**).

DQOs and their associated seven-step procedures for the media types to characterize the nature of COPCs for the RHSF field investigation activities are presented in **Table 4-1**.

4.2.2 DQOs for Evaluation of Physical Parameters at RHSF

Supplemental data to support the evaluation of the groundwater and fate and transport modeling efforts will be generated by two approaches:

- collection and evaluation of continuous rate aquifer pumping test data; and
- collection and geotechnical analyses of soil core samples.

The modeling efforts will utilize the analytical chemical COPC data generated during the site characterization field activities. These data will be supplemented by physical parameter estimates derived from the analysis of soil cores and the interpretation of long-term continuous rate pumping test data. The physical parameter data will be site-specific and will provide data to facilitate evaluation of the nature of groundwater and COPC movement in the subsurface. Descriptions of the aquifer test procedures and geotechnical analyses are provided in Section 3.8 of the FSP (**Appendix A**).

DQOs and their associated seven-step procedures for the media types to evaluate the vadose and basal aquifer physical parameters for the field investigation activities are presented in **Table 4-2**.

Table 4-1
Characterization of COPCs at RHSF
DATA QUALITY OBJECTIVE #1[a]

1. <u>State the problem</u> The nature and extent of potential impacts of COPCs in the soil, soil vapor, and groundwater beneath the RHSF Site are not adequately defined. Additional COPC data is needed to perform Fate and Transport and Risk Assessment calculations.
2. <u>Identify the Decision</u> Are detectable levels of COPCs present in the soil, soil gas, or groundwater beneath the RHSF at levels of concern? Levels of concern are based on soil and water quality screening thresholds discussed in Section 3 of this Work Plan.
3. <u>Identify the inputs to the decision</u> • COPCs are measured in the soil core samples. • COPC measurements from collected soil core samples are compared to soil screening thresholds. Screening thresholds are identified in Section 3 of this WP. • COPCs are measured in the groundwater samples. • COPC measurements from collected groundwater samples are compared to water quality screening thresholds. Screening thresholds are identified in Section 3 of this WP. • COPCs are measured in the soil vapor samples. • COPC measurements from soil vapor samples are used to evaluate the feasibility of converting existing angle borings to soil vapor monitoring points.
4. <u>Define the Boundaries of the Study</u> • Soil core samples are collected from within the three (3) new borings excavated to install groundwater monitoring wells at the Site. • Groundwater samples are collected from the existing vertical monitoring well (V1D) and three (3) newly installed monitoring wells that penetrate the basal aquifer underlying the Site. • New borings and wells are located by their association with potential petroleum releases from USTs or are situated up-gradient of the USTs (for use as a background well) as determined during previous site investigations. • Soil vapor samples are collected from within three (3) of the 20 existing shallow angled borings underlying the USTs at the Site.
5. <u>Develop a Decision Rule</u> • COPCs are defined as present in a soil, soil vapor, or groundwater sample if they are measured above the respective laboratory method detection limit applied for COPC measurements. • If measured COPCs exceed screening thresholds, then the COPCs are identified as problematic. Screening thresholds are identified and discussed in Section 3 of this Work Plan.
6. <u>Minimizing Decision Errors</u> • Use of trained collection personnel will minimize decision errors in soil, soil vapor, and groundwater samples collected for the effort. • Use of standard operating procedures in field collections will minimize decision errors in soil, soil vapor, and groundwater samples collected for the effort. • Use of standard laboratory analytical methods will minimize decision errors in resulting COPC measurements in soil, soil vapor, and groundwater samples collected for the effort. Analytical methods and their adequacy for achieving measurement levels to address Levels of concern (e.g., water quality thresholds) are discussed in the companion RHSF QAPP (**Appendix B**). • Collection of samples will be coordinated with information for system variables that may influence measurement results (e.g., rainfall events) to minimize decision errors.

Table 4-1
Characterization of COPCs at RHSF
DATA QUALITY OBJECTIVE #1[a]

7. Optimize the Design for Obtaining Data • Selection of proposed locations for borings, monitoring wells, and soil vapor monitoring points is based on information and COPC measurements obtained during previous Site investigation activities. • Use appropriate analytical chemistry methods for COPC measurements to maximize the likelihood of detecting COPCs in various media samples for levels of concern represented by screening thresholds. Screening thresholds are discussed in Section 3 of this Work Plan and chemistry methods are discussed in the companion RHSF QAPP (**Appendix B**).

[a] The 7-Step DQO progress is defined in Guidance for Data Quality Objectives Process (USEPA 2000a and b).

Table 4-2
Characterization of Vadose and Aquifer Physical Properties at RHSF
DATA QUALITY OBJECTIVE #2[a]

1. State the problem The nature of the physical properties of the vadose zone and the basal aquifer underlying the Site are not adequately defined to conduct groundwater modeling and COPC fate and transport modeling.
2. Identify the Decision • What site-specific physical parameters are required as input variables for groundwater modeling and COPC fate and transport modeling? • What is the best method to obtain the necessary parameters?
3. Identify the inputs to the decision • Aquifer testing will be conducted to obtain the necessary aquifer parameters. • Soil core samples obtained from exploratory borings will be subjected to geophysical testing to obtain supplementary aquifer and vadose zone parameters.
4. Define the Boundaries of the Study • A continuous rate pumping test is conducted within a groundwater well penetrating the basal aquifer. Groundwater monitoring wells at the Site are used as observation wells during the aquifer test. • Soil core samples are collected from within the three (3) new borings excavated to install groundwater monitoring wells at the Site.
5. Develop a Decision Rule • Representative aquifer parameters are calculated using standard hydrodynamic relationships to estimate necessary physical parameters such as hydraulic conductivity, transmissivity, and storage coefficient from the aquifer test data. • Selected physical parameters such as porosity and soil moisture content are measured or calculated from geotechnical analyses of soil core samples.
6. Minimizing Decision Errors • Use of trained collection personnel will minimize decision errors in soil core samples collected for the effort. • Use of standard operating procedures in field collections will minimize decision errors in soil core samples collected for the effort. • Use of standard laboratory analytical methods will minimize decision errors in resulting physical parameter measurements in soil core samples collected for the effort. • Use of standard hydrodynamic relationships to estimate necessary physical parameters from aquifer test data will minimize decision errors in aquifer characteristics.
7. Optimize the Design for Obtaining Data • Selection of proposed locations for borings, monitoring wells, and soil vapor monitoring points is based on information obtained during previous Site investigation activities. • Use appropriate analytical methods to maximize the likelihood of accurately estimating physical parameters in soil core samples. • Selection of long-term continuous rate pumping test with observation wells to maximize accuracy of aquifer parameter estimation in the basal groundwater aquifer beneath the Site.

[a] The 7-Step DQO progress is defined in Guidance for Data Quality Objectives Process (USEPA 2000a and b).

SECTION 5
PROJECT INVESTIGATION TASKS

This section provides a brief summary of Red Hill data compilation, field investigation, and modeling tasks that will occur during the implementation of these project plans. The field investigation tasks are only briefly discussed, a detailed discussion can be found in the attached FSP companion document (**Appendix A**). The project investigation tasks are presented in the following subsections:

- Section 5.1 GIS Database and Model Construction;
- Section 5.2 Site Characterization Activities;
- Section 5.3 Fate and Transport Modeling;
- Section 5.4 Risk Assessment;
- Section 5.5 Data Interpretation and Technical Report Development; and
- Section 5.6 Contingency Plan Preparation.

5.1 GIS DATABASE AND MODEL CONSTRUCTION

The primary objectives of the GIS model-building task are to collect and integrate site-specific geospatial project data and metadata to facilitate conduct of the site characterization, fate and transport modeling, risk assessment and contingency plan preparation, as well as provide a permanent database for future use by the client. To accomplish these objectives, the collected data will be assembled into a 3-D GIS database. An integrated visualization tool will be developed using C Tech's Mining Visualization System (MVS) 3-D visualization and animation software. Deliverables will include interactive georeferenced files that will provide the facility infrastructure, topographic features, water table surface, site lithology, and the results of environmental studies in a format that can be viewed using free software. The Intergraph Feature Manipulation Engine (FME) Environmental Systems Research Institute (ESRI) Suite has been selected to generate a database in the Geomedia warehouse format, selected to be compatible with the GIS systems currently in use by FISC (i.e., GeoMedia Professional 5.2, GeoMedia WebMap Professional 5.2, GeoMedia Transportation 5.2, and Oracle 8i) and PWC (i.e., ESRI ArcInfo, Arc IMS, ArcView (versions 8 and 3.2) and Oracle). The data will be formatted in accordance with the specifications defined in *FISC Specifications for GIS data presented in Phase SOW* (**Appendix G**). A proposed GIS activity schedule is presented in **Section 6**.

5.1.1 Initial Data Gathering and Integration

The initial GIS database will be constructed on the basis of existing site-specific data. Site data currently available for GIS database construction includes;

- Existing geologic logs for vertical and angled borings;
- Existing barrel logs from facility construction;
- As-built construction drawings and electronic files of the Red Hill storage and fuel distribution system;
- Electronic topographic information;
- Aerial photographs;
- Building locations;
- Laboratory analytical results;
- Geologic cross sections, and
- Land-use maps and electronic files.

Existing data will be converted from current formats (e.g., paper copy, computer-aided design [CAD] file) to the appropriate digital format for inclusion in the GIS database.

5.1.2 GIS Database Refinement

The GIS database will be used to generate and manage maps, figures, models, and data throughout the site characterization process. The GIS database will be modified and refined as new data becomes available from the results of the proposed site characterization activities. Site-specific data generated and integrated during the field investigation and modeling activities are anticipated to include:

- New borings logs and rock core information;
- Laboratory analytical results;
- Land survey data;

- Groundwater elevation data;
- Fate and Transport Modeling data;
- RA data; and
- Contingency Plan data.

5.1.3 GIS Visualization Tool

A digital 3-D CSM will be constructed using the GIS database. The CSM will facilitate decisions regarding field investigation activities and will be used to visualize and illustrate conditions and processes occurring at the Site. The CSM will be used for the following purposes:

- Create maps and vertical cross-sections of the Site;
- Depict spatial relationships of petroleum sources and other contaminates in the subsurface;
- Visualize potential contaminant migration pathways in the vadose and saturated zones;
- Visualize groundwater flow conditions;
- Facilitate Groundwater Modeling and Fate and Transport Modeling;
- Facilitate a Tier 3 RA; and
- Facilitate preparation of a Contingency Plan.

5.1.4 GIS Deliverables

The following products will be delivered to the client:

- GIS database;
- Electronic visualization package data files and output files;
- Interactive model and viewing software;
- Paper hardcopies of selected maps and figures;

A node locked-licensed copy of FME ESRI Suite shall be transferred to FISC following completion of the contract. Data will be delivered to the client in Geomedia Warehouse Database format and in Personal Geodatabase or Shapefile format. A digital 3-D model generated using MVS will be provided. The 3-D model may be viewed by the client using a four-dimensional interactive model (4DIM) viewer, which is free software designed to view MVS models. Open Flight and virtual reality modeling language (VRML) versions of the finished 3-D model will also be created.

5.2 SITE CHARACTERIZATION ACTIVITIES

Section 5.2 subsections provide a brief synopsis of proposed field activities. A detailed discussion of field activities is provided in the attached FSP companion document (**Appendix A**).

5.2.1 HEALTH AND SAFETY PROTOCOL

Health and Safety protocols are detailed in the SSHSP companion document provided under separate cover (USN 2005).

5.2.2 EXPLORATORY BORINGS AND CORE SAMPLING

Three exploratory borings will be advanced to collect soil and rock samples for laboratory analyses and to install groundwater monitoring wells that penetrate the basal aquifer underlying and adjacent to the Site. Drilling and sampling protocols are detailed in the attached FSP, Sections 3.2 and 3.3 (**Appendix A**). The following activities will be conducted:

- **Excavate and Sample One Up-gradient Background Soil Boring** to evaluate background soil conditions in the vicinity of the RHSF and install a vertical groundwater monitoring well from the existing ground surface at the RHSF. Samples will be evaluated for lithology, and soil overburden will be evaluated for potential surface contamination that may affect groundwater results at this location. The boring/monitoring well will be located adjacent to the Navy rifle range, hydraulically up-gradient from the USTs. An air rotary drill rig will be used to excavate the boring to penetrate the basal aquifer. No coring will be conducted at this location. Rock lithology will be evaluated via cuttings.

- **Excavate and Sample Two Soil Borings** to evaluate bedrock conditions directly beneath the Middle and Upper RHSF and install vertical groundwater monitoring wells within the lower access shaft at the RHSF. A portable drill rig will be used to excavate the borings to penetrate the basal aquifer. Soil borings will be advanced by continuous coring techniques that will be reviewed by a experienced geologist and environmental professional for fate and transport assessment, as well to determine whether isolation casing will be required to advance the boring without jeopardizing the quality of the basal aquifer at the location. Soil borings will be located as far away from the surrounding USTs as possible (approximately 150 feet) to minimize the potential for encountering highly-petroleum impacted rock that will require isolation casing during excavation.

- **Install Isolation Casing** within the excavated borings as warranted to prevent contaminates migrating into the basal aquifer through the boreholes.

- **Collect Soil and Rock Core Samples** from within the borings for laboratory analysis. Soil and core samples will be selected for analysis on the basis of visual observations and field screening results.

- **Analyze Selected Core Samples** for Site COPCs. Sampling locations are not expected to be impacted in the vadose zone, but are located to optimize groundwater sampling locations.

5.2.3 GROUNDWATER STUDY

The three exploratory borings excavated will be converted to groundwater monitoring wells that penetrate the basal aquifer. These newly installed monitoring wells will be used in conjunction with one existing onsite monitoring well (V1D), at least two existing offsite groundwater monitoring wells (Red Hill OWDF MW-08 and Moanalua Valley BOWS Well No. 2253-02), and accessible groundwater production wells (e.g., PWC production well) to characterize and monitor the conditions of the basal aquifer underlying the Site. Well installation, sampling, and aquifer testing protocols are detailed in the attached FSP, Sections 3.2 and 3.3 (**Appendix A**). The following activities will be conducted:

- **Install and Develop Three Monitoring Wells** that penetrate the basal aquifer to establish a groundwater monitoring network at the RHSF (in conjunction with existing monitoring well V1D).

- **Collect Groundwater Chemical Samples** to provide data to characterize the existing groundwater conditions, support fate and transport calculations, facilitate conduct of a Tier 3 comprehensive RA, and monitor natural attenuation processes at the Site using V1D (Lower Monitoring Well [MW]), the Middle MW (MMW) and Upper MW (UMW), as well as the up-gradient background well (BKGMW01). Additional sampling of the Red Hill Pumping Well No. 2254-01 will be accomplished with the assistance of The Dawson Group, who is the Navy contractor that is conducting groundwater sampling there.

- **Conduct Groundwater Level Measurements** to assess the nature of potential long-term changes of the local groundwater gradient. Measurements will be collected at all wells described above, including offsite wells.

- **Perform Aquifer Testing** to characterize hydraulic properties of the basal aquifer underlying the Site. Pumping tests will be conducted using the Navy Red Hill Pumping Station and nearby monitoring wells.

- **Conduct a Land Survey** to document the locations and elevations of the monitoring wells.

- **Analyze Groundwater Samples** for Site COPCs.

5.2.4 Soil Vapor Pilot Study

A pilot study will be conducted to evaluate the feasibility of using existing angle borings beneath the USTs to install soil vapor monitoring probes for site characterization and long-term monitoring. Three of the twenty existing angle borings will be converted to permanent soil vapor monitoring wells (SVMWs), with each SVMW containing three soil vapor monitoring probes at varying depths. SVMW installation and soil vapor sampling protocols are detailed in the attached FSP, Sections 3.2 and 3.3 (**Appendix A**). The following activities will be conducted:

- **Install Three SVMWs** in existing angle borings to evaluate the feasibility of using the 20 existing borings to establish a soil vapor monitoring network.

- **Collect Soil Vapor Samples** to provide data to supplement rock core analyses regarding the nature of volatile compounds within the vadose zone, provide qualitative information regarding the general location of releases beneath the USTs, and to facilitate evaluation of the SVMWs for long-term monitoring of the vadose zone as part of a Site Contingency Plan.

- **Analyze Soil Vapor Samples** for Site COPCs.

5.2.5 DATA MANAGEMENT AND VALIDATION

- Data management and validation will be performed in accordance with the procedures and protocols specified in Section 6.0 – Data Management and Section 8.0 – Data Validation of the attached QAPP (**Appendix B**).

5.3 CONTAMINANT FATE AND TRANSPORT MODELING

The results of the field investigation and GIS 3-D model construction will be used to conduct fate and transport modeling of COPCs. The fate and transport calculations will be comprised of the following aspects:

- **Soil Vapor** modeling will be conducted to evaluate the potential migration of volatile compounds through the subsurface and to identify potential receptors.
- **Vadose Zone** modeling will be conducted to evaluate the potential migration of LNAPLs or aqueous phase COPCs through the unsaturated zone.

- **Groundwater** modeling will be conducted to estimate groundwater flow conditions and evaluate the potential movement of LNAPL and aqueous phase contaminants in the saturated zone.
- **Potential release** scenarios will be evaluated using the results of the soil vapor, vadose zone, and groundwater models. Scenarios investigated will include the potential role of pipelines as migrations pathways for LNAPLs and dissolved COPCs, potential impact of vadose zone contamination to surface water bodies, and potential impact of soil vapors to human receptors (e.g., workers in access tunnels).

5.4 TIER 3 COMPREHENSIVE RA

The results of the field investigation, GIS 3-D model construction, and Fate and Transport modeling will be used to conduct a Tier 3 Comprehensive RA.

5.5 DATA INTERPRETATION AND TECHNICAL REPORT DEVELOPMENT

A comprehensive report will be prepared following the completion of the RA. The report will include:

- A summary of previous studies;
- A summary of the existing characterization activities;
- A comprehensive assessment of the nature and extent of contamination;
- A summary of ARARs and TBCs;
- A comprehensive assessment of fate and transport results;
- A comprehensive presentation of the Tier 3 RA results;
- A comprehensive set of recommendations and conclusions, including the outline of a Contingency Plan to ensure that current and future risks are properly evaluated and mitigated.

5.6 CONTINGENCY PLAN PREPARATION

The results of the field investigation, GIS 3-D model construction, Fate and Transport modeling, and Tier 3 RA will be integrated and used as the basis to prepare a

Contingency Plan for the RHSF. The Contingency Plan will consider methods to avoid and mitigate catastrophic releases from the USTs, to minimize impacts to human health and the environment, and to protect the drinking water source of the basal aquifer.

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SECTION 6
PROJECT SCHEDULE

A proposed project schedule in Gant Chart format is presented as **Figure 6-1**. A supplementary schedule detailing GIS activities is presented as **Figure 6-2**.

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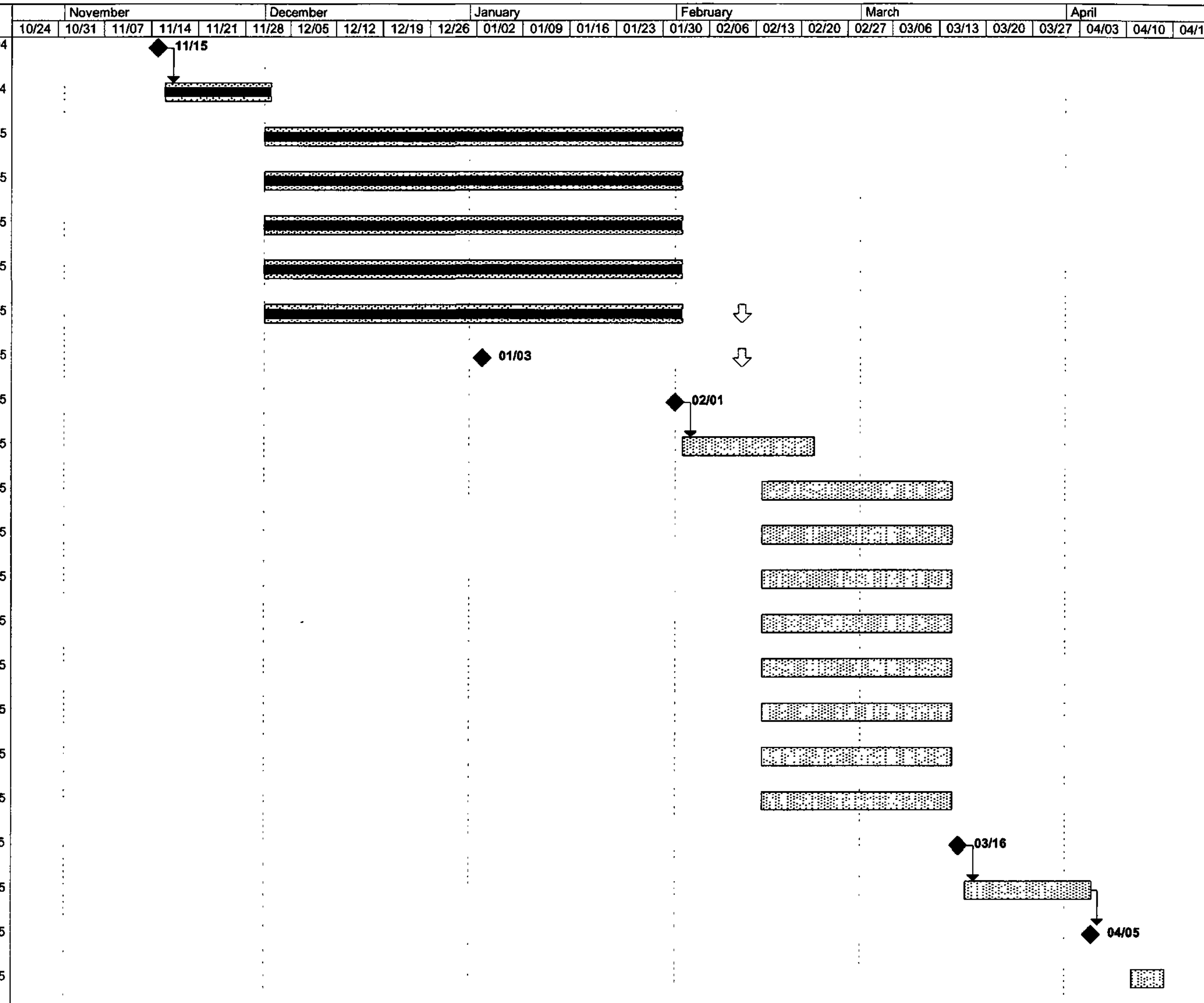
Figure 6-2
Schedule of GIS Activities

ID	Task Name	Duration	Start	Finish
1	Project Start Date	1 day?	Mon 11/15/04	Mon 11/15/04
2	Data Familiarization / Content Filter	12 days	Tue 11/16/04	Wed 12/01/04
3	Surface Topology - DEM	45 days?	Wed 12/01/04	Tue 02/01/05
4	Surface Plainemetrics - Buildings	45 days?	Wed 12/01/04	Tue 02/01/05
5	Tank Barrel Logs	45 days?	Wed 12/01/04	Tue 02/01/05
6	Tank Features	45 days?	Wed 12/01/04	Tue 02/01/05
7	Fuel Pipeline	45 days?	Wed 12/01/04	Tue 02/01/05
8	FME Software Purchase	1 day	Mon 01/03/05	Mon 01/03/05
9	50% Deliverable	1 day?	Tue 02/01/05	Tue 02/01/05
10	50% Deliverable Modifications	14 days?	Wed 02/02/05	Mon 02/21/05
11	Water Supply	21 days?	Mon 02/14/05	Mon 03/14/05
12	Access Tunnels (Upper and Lower)	21 days?	Mon 02/14/05	Mon 03/14/05
13	Angled Borings	21 days?	Mon 02/14/05	Mon 03/14/05
14	1 Existing Vertical Well	21 days?	Mon 02/14/05	Mon 03/14/05
15	2 Additional Vertical Wells	21 days?	Mon 02/14/05	Mon 03/14/05
16	Aerial Photography / USGS Topo	21 days?	Mon 02/14/05	Mon 03/14/05
17	Basal Aquifer	21 days?	Mon 02/14/05	Mon 03/14/05
18	Data Format Conversion	21 days?	Mon 02/14/05	Mon 03/14/05
19	90% Deliverable	1 day?	Wed 03/16/05	Wed 03/16/05
20	90% Deliverable Modifications	13 days?	Thu 03/17/05	Mon 04/04/05
21	100% Deliverable	1 day	Tue 04/05/05	Tue 04/05/05
22	3D Model Demonstration and Training	5 days?	Mon 04/11/05	Fri 04/15/05

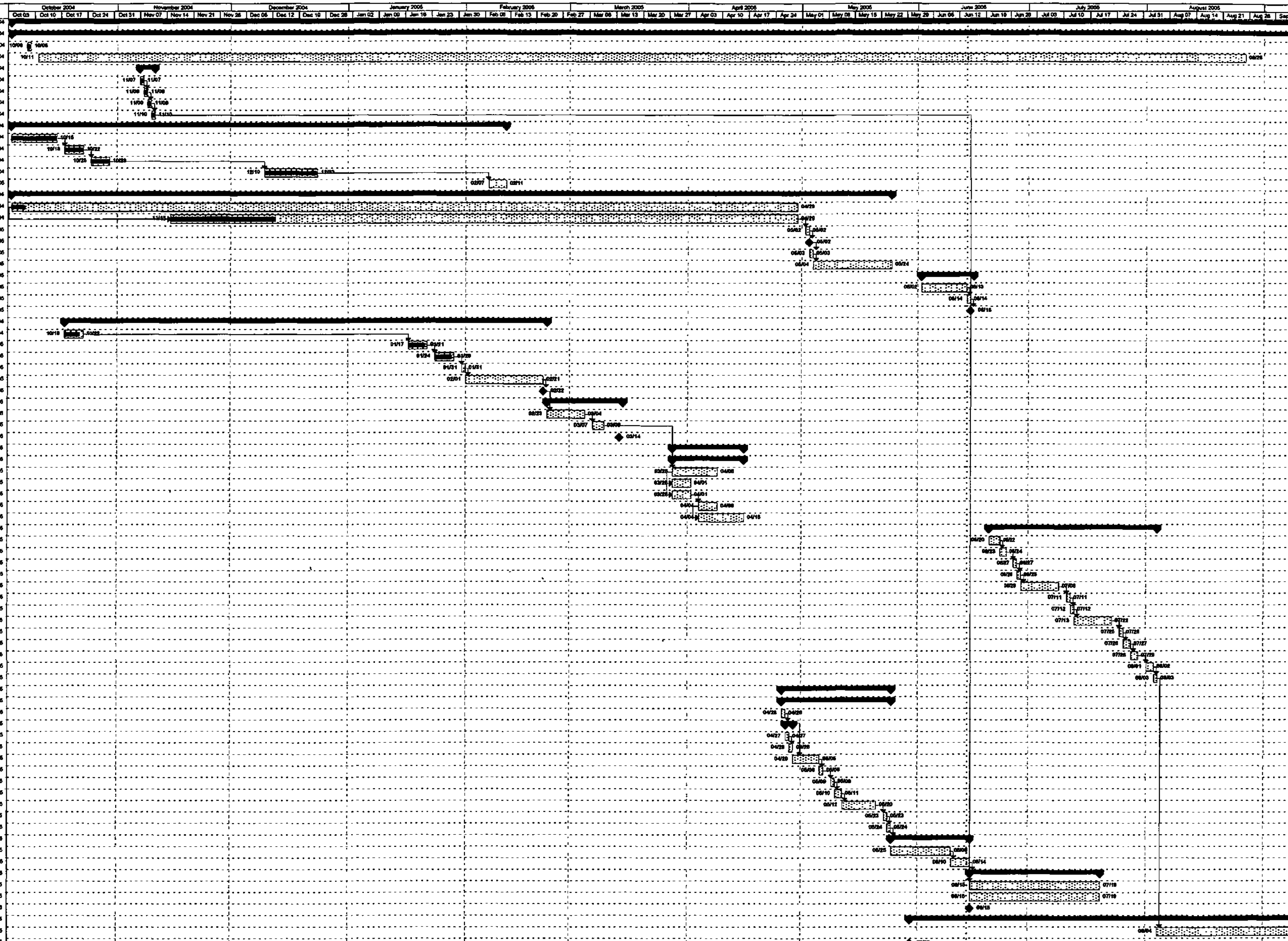


Project: RedHill3DModel

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

Red Hill Phase 1 Proposed Schedule of Activities

ID	ID	Task Name	Start
1	1	Red Hill Phase 1 Activities	Mon 10/04/04
2	2	Task 1 - Project Management - Phase 1	Mon 10/04/04
3	3	Notice to Proceed	Fri 10/08/04
4	4	Project Management Activities	Mon 10/11/04
5	5	Task 2 - Kick off Meeting	Sun 11/07/04
6	6	Mobe to Hawaii	Sun 11/07/04
7	7	Meetings with POCs	Mon 11/08/04
8	8	Site Reconnaissance & Equipment Assessment	Tue 11/09/04
9	9	Demobe from Hawaii	Wed 11/10/04
10	10	Task 3 - Preliminary Risk Assessment Activities	Mon 10/04/04
11	11	Files Investigation	Mon 10/04/04
12	12	Site and Area Walk-Over	Mon 10/18/04
13	13	Prepare Maps/Figures	Mon 10/25/04
14	14	Perform Preliminary Exposure Assessment Calculations	Fri 12/10/04
15	15	Attend HDOH Meeting	Mon 02/07/05
16	16	Task 4 - Draft Work Plan	Mon 10/04/04
17	17	Prepare Quality Assurance Project Plan	Mon 10/04/04
18	18	Prepare Text, Tables & Figures	Mon 11/15/04
19	19	Submit Draft Work Plan to TEC	Mon 05/02/05
20	20	Submit Draft Work Plan to Navy	Mon 05/02/05
21	21	Submit Work Plan to HDOH During Meeting	Tue 05/03/05
22	22	Navy Review Cycle	Wed 05/04/05
23	23	Task 5 - Final Work Plan	Thu 06/02/05
24	24	Address Comments & Submit Report Final	Thu 06/02/05
25	25	Submit Final Work Plan to TEC	Tue 06/14/05
26	26	Submit Final Work Plan to Navy	Wed 06/15/05
27	27	Task 6 - Draft Health and Safety Plan	Mon 10/18/04
28	28	Update Previous HSP	Mon 10/18/04
29	29	Prepare Health & Safety Plan	Mon 01/17/05
30	30	Internal Peer Review	Mon 01/24/05
31	31	Submit Draft HSP to TEC	Mon 01/31/05
32	32	Navy Review Cycle	Tue 02/01/05
33	33	Submit Draft Health and Safety Plan to Navy	Tue 02/22/05
34	34	Task 7 - Final Health and Safety Plan	Wed 02/23/05
35	35	Address Comments & Submit HSP Final	Wed 02/23/05
36	36	Submit Final HSP to TEC	Mon 03/07/05
37	37	Submit Final Health and Safety Plan to Navy	Mon 03/14/05
38	38	Task 8 - Project Planning for Field Work	Mon 03/28/05
39	39	Subcontracting Subcontractors	Mon 03/28/05
40	40	Coordinate with all Subcontractors	Mon 03/28/05
41	41	Coordinate with FISC/PWC	Mon 03/28/05
42	42	Security Arrangements	Mon 03/28/05
43	43	Premobe Staff Prep	Mon 04/04/05
44	44	Ship Drilling Equipment to Hawaii	Mon 04/04/05
45	45	Task 9 - Field Work	Mon 06/20/05
46	46	Mobilize to Hawaii	Mon 06/20/05
47	47	Set up Activities	Thu 06/23/05
48	48	Meet with POCs	Mon 06/27/05
49	49	Mobilize Equipment to 1st Drilling Location	Tue 06/28/05
50	50	Drill First Vertical Well	Wed 06/29/05
51	51	Perform Geophysical Electrode Insertion	Mon 07/11/05
52	52	Mobilize to 2nd Drilling location	Tue 07/12/05
53	53	Drill Second Vertical Well	Wed 07/13/05
54	54	Perform Geophysical Electrode Insertion	Mon 07/25/05
55	55	Mobilize Equipment out of Tunnels	Tue 07/26/05
56	56	Develop New Wells	Thu 07/28/05
57	57	Sample All Designated Sample Locations	Mon 08/01/05
58	58	Demobe from Hawaii	Wed 08/03/05
59	59	Task 10 - Geophysical Data Acquisition (Pilot Study)	Tue 04/26/05
60	60	Geophysical Field Activities	Tue 04/26/05
61	61	Mobe Geophysical Crew to Hawaii	Tue 04/26/05
62	62	Set up Activities	Wed 04/27/05
63	63	Meet With POCs/Make Access Arrangements	Wed 04/27/05
64	64	Mobilize Equipment To Tunnels	Thu 04/28/05
65	65	EM Activities (4 slant MWs & 2 new MWs)	Fri 04/29/05
66	66	Geophysical Probe Insertion First MW	Fri 05/06/05
67	67	Geophysical Probe Insertion Second MW	Mon 05/09/05
68	68	Begin Angle Well Modifications (4 slant MWs)	Tue 05/10/05
69	69	Geophysical Testing	Thu 05/12/05
70	70	Demobe Equipment from Tunnels	Mon 05/23/05
71	71	Demobe from Hawaii	Tue 05/24/05
72	72	Geophysical Data Evaluation	Wed 05/25/05
73	73	Geophysical Draft Pilot Study Report & Electronic Data Submittals	Wed 05/25/05
74	74	Geophysical Final Pilot Study Report & Electronic Data Submittals	Fri 06/10/05
75	75	Task 11 - 3D GIS Data Base	Wed 06/15/05
76	76	Phase 1 - Data Conversion to Digital Format	Wed 06/15/05
77	77	Phase 2 - Data Interpolation	Wed 06/15/05
78	78	Phase 1 3D GIS Data Base Deliverable	Wed 06/15/05
79	79	Task 12 - IDW Disposal	Mon 05/30/05
80	80	Core Review & Disposal	Thu 08/04/05
81	81	IDW Disposal Letter	Mon 05/30/05



Project: Red Hill Phase 1 Tier III Proposed Schedule 7-20-04
Date: Tue 06/14/05

Task | Critical Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Critical Task | Rolled Up Milestone | Rolled Up Progress | Split | External Tasks | Project Summary | Group By Summary

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Appendix A

Field Sampling Plan

Red Hill Bulk Fuel Storage Facility Field Sampling Plan

Pearl Harbor, Hawaii

June 2005

Department of the Navy
Commander
Naval Facilities Engineering Command, Pacific
Pearl Harbor, HI 96860-3134

Naval Facilities Engineering Command

NAVFAC PACIFIC

Indefinite Delivery/Indefinite Quantity Contract
Contract Number N62742-02-D-1802, CTO 007

Red Hill Bulk Fuel Storage Facility Field Sampling Plan

Pearl Harbor, Hawaii

June 2005

Prepared for:

Department of the Navy
Commander
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite #100
Pearl Harbor, HI 96860-3134

Prepared by:

The Environmental Company, Inc.
1001 Bishop Street, Suite 1400
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and

AMEC Earth & Environmental, Inc.
3375 Koapaka Street, Suite F251
Honolulu, Hawaii 96819

Prepared under:

Indefinite Delivery/Indefinite Quantity Contract
Contract Number N62742-02-D-1802, CTO 007

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ATTACHMENTS

A	Phase II Boring Logs

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LIST OF ACRONYMS

ATL	Air Toxics Ltd.
AMEC	AMEC Earth and Environmental, Inc.
ARAR	Applicable or Relevant and Appropriate Requirements
bgs	Below existing ground surface
COC	Chain of Custody
COPC	Chemical of Potential Concern
CSM	Conceptual Site Model
CTO	Contract Task Order
DOT	Department of Transportation
DQO	Data Quality Objective
DRO	Diesel Range Organics
EAL	Environmental Action Level
EPH	Extractable Petroleum Hydrocarbons
FISC	Fleet Industrial Supply Center
FSP	Field Sampling Plan
GIS	Geographic Information System
GRO	Gasoline Range Organics
HDOH	State of Hawaii Department of Health
ID	Inner Diameter
IDW	Investigation-Derived Waste
IRP	Installation Restoration Program
LNAPL	Light Non-aqueous Phase Liquid
MP	Monitoring Point
msl	Mean Sea Level
MADEP	Massachusetts Department of Environmental Protection
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MW	Monitoring Well
NAPL	Non-aqueous Phase Liquid
NAVFAC	Naval Facilities Engineering Command
NOAA	National Oceanic and Atmospheric Administration
OSWER	Office of Solid Waste and Emergency Response
OVM	Organic Vapor Meter
PACDIV	Pacific Division
PID	Photoionization Detector
POE	Point of Entry
PPE	Personal Protective Equipment
PVC	Polyvinyl Chloride
PWC	Public Works Center
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
QC	Quality Control

RA	Risk Assessment
RCRA	Resource Conservation and Recovery Act
RHSF	Red Hill Bulk Fuel Storage Facility
SCS	Site Characterization Study
SI	Site Investigation
SOP	Standard Operating Procedure
SSHSP	Site-Specific Health and Safety Plan
SVOC	Semi-Volatile Organic Compound
TEC	The Environmental Company, Inc.
TPH	Total Petroleum Hydrocarbons
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
UST TGM	State of Hawaii Technical Guidance Manual for Underground Storage Tanks Closure and Release Response
VOC	Volatile Organic Compound
VPH	Volatile Petroleum Hydrocarbons
WP	Work Plan
XRF	portable x-ray fluorescence spectroscopy
3-D	Three Dimensional

SECTION 1
INTRODUCTION

This document serves as a Field Sampling Plan (FSP) for a Site Investigation (SI) and Risk Assessment (RA) at the Red Hill Bulk Fuel Storage Facility (herein referred to as RHSF) operated by the Fleet Industrial Supply Center (FISC), Pearl Harbor, Hawaii. The general Site vicinity is depicted on **Figure 1-1.**

Overall objectives of this investigation are:

1. **GIS Model.** Compile existing electronic and hardcopy data regarding past activities at the Site, including lithologic descriptions obtained from excavation and boring logs; facility construction details, and published environmental information. The compiled data will be used to create a three-dimensional (3-D) geographic information system (GIS) model to facilitate data storage and 3-D visualization.

2. **Conceptual Site Model (CSM).** Develop a comprehensive CSM to illustrate potential sources, exposure pathways, and receptors. The CSM will be used to refine the site characterization activities, facilitate fate and transport calculations, and to communicate site conditions to regulators and stakeholders.

3. **Site Characterization Study (SCS).** Conduct a SCS to obtain data necessary to further characterize the documented release and to complete a Comprehensive RA. The SCS will include the installation and sampling of groundwater monitoring wells and soil vapor monitoring points and the evaluation of Fate and Transport mechanisms using analytical and numerical modeling techniques.

4. **Applicable or Relevant and Appropriate Requirements (ARARs).** Prepare a list of ARARs and risk-based action levels for potentially impacted media.

5. **Risk Assessment.** Conduct a Tier 3 Comprehensive RA to determine chemicals of potential concern (COPCs), potentially complete exposure pathways, potential receptors, and exposure point action levels for each receptor and media.

6. **Monitoring System.** Develop a groundwater and soil vapor monitoring system that will allow the U.S. Navy to characterize the Site both laterally and temporally for past, present and future releases.

7. **Contingency Plan.** Develop a contingency plan that ensures unacceptable risks to human health and/or the environment from any past present and/or future releases are mitigated.

This FSP has been prepared by The Environmental Company, Inc. (TEC) and AMEC, Earth and Environmental (AMEC) for Naval Facilities Engineering Command (NAVFAC) Pacific as part of Contract Task Order (CTO) 007. All work for these planning documents have been authorized under the U.S. Navy Environmental Contract No. N62742-02-1802. Companion documents to this FSP include the Work Plan (WP), Quality Assurance Project Plan (QAPP), and a Site-Specific Health and Safety Plan (SSHSP). A detailed discussion of site background, sampling data objectives, and strategy are presented in Section 2 of the WP.

The following sections of this FSP describe proposed activities and procedures to be implemented for the SCS portion of this project (Objective 3, above). This FSP provides a detailed description of the proposed field activities, including (1) monitoring well installation; (2) monitoring well development; (3) groundwater sampling locations and methods; (4) soil vapor well installation; (5) soil vapor sampling; and, (6) analytical chemistry program. Fieldwork is anticipated to commence during the summer of 2005.

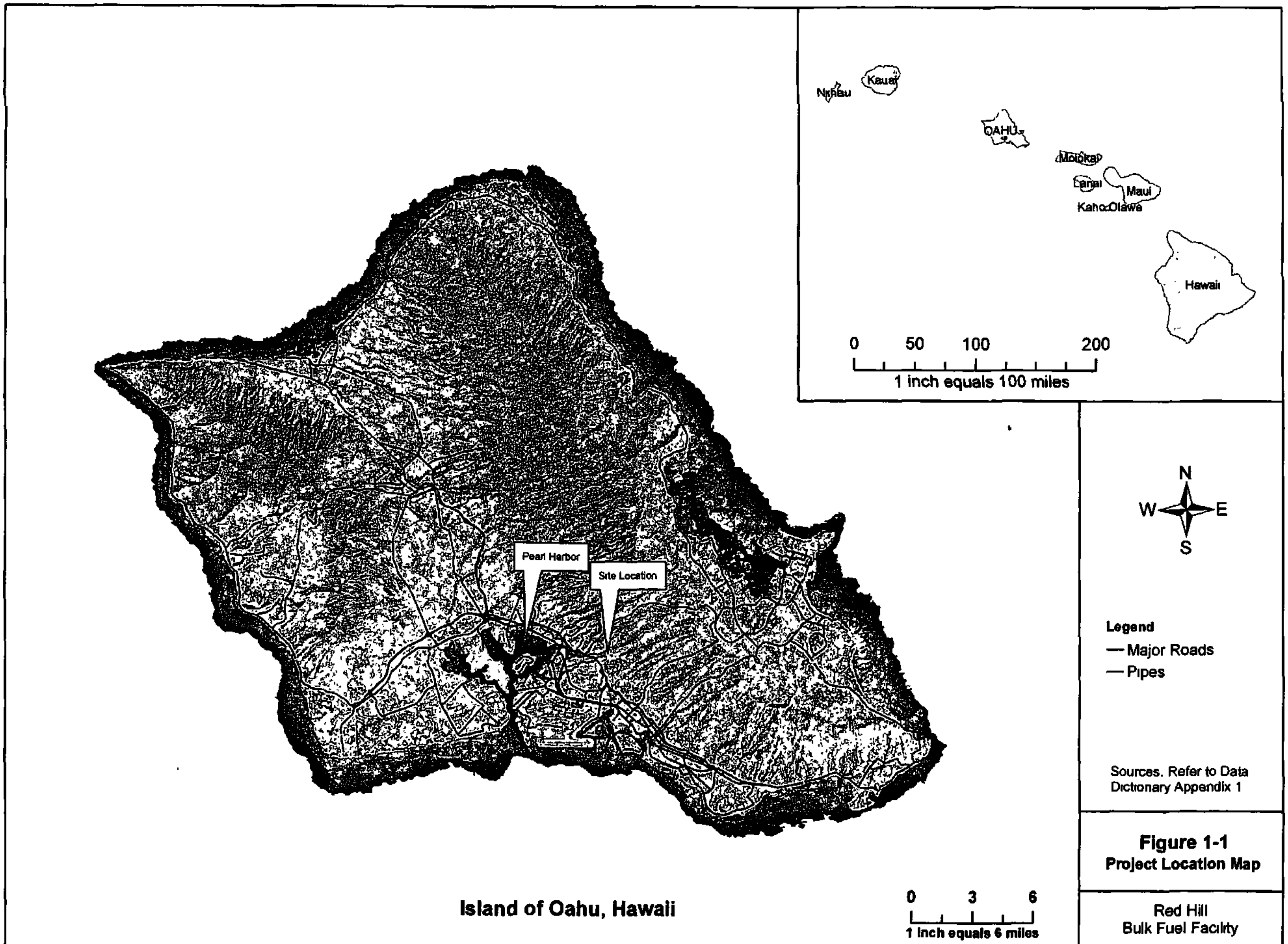


Figure 1-1
Project Location Map

Red Hill
Bulk Fuel Facility

SECTION 2
FIELD SAMPLING DESIGN

The RHSF was constructed in the early 1940s and incorporates 20 underground storage tanks (USTs), each with a capacity of approximately 12.5 million gallons (**Figure 2-1**). The results of a previous Phase II SI (AMEC, 2002) indicated that petroleum hydrocarbons were reported in rock samples obtained beneath the USTs and that lead was detected in groundwater samples obtained from a monitoring well situated hydraulically down-gradient from the facility. An initial risk screening level assessment was performed as part of the Phase II SI Report. The results of the screening level assessment indicated that seven constituents were detected in core samples at concentrations of potential concern: ethylbenzene, methylene chloride, 2-methylnaphthalene, naphthalene, phenanthrene, total petroleum hydrocarbon (TPH) (carbon range C10-C28), and an unknown hydrocarbon. Three constituents were detected in groundwater samples at concentrations of potential concern: bis(2-ethylhexyl)phthalate, lead, and TPH (C10-C28). The investigations also reported the presence of petroleum light non-aqueous phase liquid (LNAPL) in several monitoring wells at the site. Additional monitoring wells are required to characterize the subsurface conditions at the Site. To obtain the necessary information regarding COPC fate and transport, three (3) additional monitoring wells and a pilot study will be conducted in which soil vapor monitoring points will be installed in three (3) existing slant borings in the first phase of the project. Based on the results of the first phase of the investigation, additional monitoring points (MPs) and monitoring wells (MWs) may be required. If so, an Addendum WP and FSP will be generated to conduct that work as required. **Table 2-1** summarizes the field investigation objectives and proposed field investigation actions for each activity.

2.1 Monitoring Well Locations and Rationale

Three borings will be excavated at the site for installation of groundwater monitoring wells. One (1) boring will be advanced from the ground surface to total depths of approximately 15 feet below the top of the basal aquifer underlying the Site. The remaining two (2) borings will be advanced from within the lower access tunnel to total depths of approximately 20 feet below the top of the basal aquifer. The locations of the proposed monitoring wells are depicted on **Figure 2-2**. Individual monitoring well rationale are described in detail in the following subsections.

2.1.1 MW-1 and MW-2

Two new groundwater monitoring wells will be installed within the lower access tunnel among the USTs. The proposed location of MW-1 is situated midway between the Tank pairs 5/6 and 7/8. The proposed location of MW-2 is situated midway between the Tank pairs 13/14 and 15/16. Both of these proposed monitoring well locations were chosen to monitor potential petroleum product releases from the middle and upper sections of the Tank Farm, respectively, while the existing V1D will monitor the lower (down-gradient) section of the Tank Farm, between Tank 1 and Tank 6. Each groundwater monitoring well will evaluate the conditions of the basal groundwater aquifer underlying the Site. These include contaminant concentrations, groundwater quality and geochemistry, and water table elevation for groundwater flow assessment. The proposed monitoring well locations are depicted on **Figure 2-2**.

2.1.2 MW-3

One new groundwater monitoring well will be installed at the ground surface. The proposed location of MW-3 is in the northern portion of RHSF adjacent to a U.S. Navy Halawa firing range. This location was chosen to monitor background conditions in the basal aquifer hydraulically up-gradient of the USTs. The background well will be used to monitor natural attenuation parameters (e.g., dissolved oxygen, nitrate, sulfate, iron II, methane, carbon dioxide, oxidation/reduction potential and alkalinity) as well as the background concentration of COPCs in the basal aquifer. This location is located hydraulically down-gradient from the firing range and may be used to evaluate whether lead originating within the firing range may impact the groundwater prior to reaching the RHSF. The proposed monitoring well location is depicted on **Figure 2-2**.

2.1.3 Groundwater Samples

A groundwater monitoring well screened within the basal aquifer will be installed within each of the three boring locations. Groundwater samples will be collected from within one existing (MW-V1D) and three new monitoring wells and subjected to field and laboratory analyses for COPCs and groundwater chemistry. The groundwater sample results will facilitate characterization of COPCs in the basal aquifer underlying RHSF and provide data necessary to conduct Fate and Transport Modeling, assess assimilative capacity via natural attenuation and conduct a Comprehensive RA.

2.2 Soil Vapor Monitoring Well Locations and Rationale

A soil vapor pilot study will be conducted to evaluate usage of the existing slant borings beneath the Facility USTs as locations for multiple soil vapor probes for long term site characterization. Currently these slant borings contain casing and screen installed during the previous investigation (AMEC, 2002). It is anticipated that soil vapor samples obtained from within these borings will provide data that will more effectively meet the site characterization requirements of the regulatory agencies. These are:

- Provide qualitative information on the volatile contaminants of concern in the vadose zone directly beneath the study area USTs to supplement the rock core analyses, which are biased low due to the analytical requirements for pulverizing the material in the lab;
- Provide qualitative information on the general location of releases beneath the study area USTs;
- Provide temporal information on the conditions of the vadose zone directly under the study area USTs for potential long-term monitoring as part of a contingency plan for long-term site assessment.

2.2.1 Potential Angled Borings To Be Evaluated

On the basis of data collected during the previous investigation, soil vapor MPs will be installed in existing angled borings where the greatest measured concentrations of TPH and/or where volatile organic compounds (VOCs) were detected. MPs will be positioned within the angled borings at depths where these samples were collected. The soil vapor sample analytical results will facilitate the determination of whether VOC concentrations are greater than previously indicated, and will be used to provide input to the fate and transport models, and to assess risk. Soil vapor MPs may also be installed in other slant borings to assess how conditions change over time. These may provide information on future releases. The pilot study is scoped to evaluate three slant borings with a maximum of three nested MPs in each boring. Currently, it is proposed that MPs be installed in borings BR1, BR14, and BR16. **Table 2-2** summarizes the results from previous investigations. Boring logs for these and other potential candidates for soil vapor MP construction are provided as **Attachment A.**

- Results from core samples collected from bore holes BR14 and BR16 indicate that these cores intercepted the most impacted areas of all borings onsite; therefore, they are primary choices for this pilot study.

- Although results from previous sampling at BR1 indicate the subsurface is impacted, it has been chosen as a primary candidate for the pilot study because it is located under the UST that is nearest to the Receptor Point (Navy Pumping Well 2254-01).

Boreholes BR4, BR6, BR7, BR11, BR13, and BR20 are also potential candidates for the installation of MPs. These will be considered in lieu of one or more of the previously described locations as alternatives, in the event that the original choice is not feasible.

2.2.2 Soil Vapor Samples

Three MPs will be installed within each of three angled boring locations. One soil vapor sample will be collected from each MP, for a total of nine samples. The soil vapor samples will facilitate evaluation of using the existing angled borings as soil vapor MPs and will provide additional information regarding volatile COPCs in the vadose zone underlying the RHSF. The soil vapor sample results will also provide data necessary to conduct Fate and Transport Modeling and a Comprehensive RA.

2.3 Proposed Sampling Schedule

A proposed schedule for the fieldwork portion of this project is presented in **Table 2-3**.

Table 2-1
Sampling and Analytical Program Rationale
Red Hill Bulk Fuel Storage Facility
Pearl Harbor, Hawaii

ACTIVITY	OBJECTIVES	ACTION
Monitoring Well Installation	Establish a monitoring well and network to characterize and monitor the basal aquifer hydrogeology.	Install two (2) new monitoring wells within the lower access tunnel to monitor potential releases. Install one (1) new monitoring well in background location to monitoring ambient water quality, assimilative capacity.
Groundwater Sampling and Analyses (during the wet and dry seasons)	Evaluate the nature and extent of COPC impacts within the basal aquifer. Evaluate if the RHSF is the source of COPCs being introduced to the basal aquifer. Obtain data to facilitate the conduct of Fate and Transport Modeling and a Comprehensive Risk Assessment.	Collect groundwater samples from two existing and three proposed monitoring wells. A laboratory will analyze groundwater samples to quantitatively determine concentrations of chemicals of potential concern. Field measurements will be conducted for water quality criteria and natural attenuation parameters. Evaluate variability of water quality with seasonal variations
Soil Vapor Monitoring Point Installation Pilot Study	Evaluate the feasibility of using existing angled borings for soil vapor monitoring point locations. Obtain data to facilitate the conduct of Fate and Transport Modeling and a Comprehensive Risk Assessment.	Install three (3) soil vapor monitoring points within each of three existing angled borings beneath USTs at the RHSF. Samples will be analyzed at a certified laboratory for VOCs and will provide nature of VOCs and a qualitative assessment of temporal changes in the unsaturated zone. SVMPs may provide monitoring network in vadose zone for potential future releases.
Land Survey	Identify the locations and elevations of groundwater monitoring wells and piezometers. This information will facilitate calculating the groundwater elevations, gradients, and flow rate at the Site.	A registered land surveyor will survey the horizontal coordinates and the elevations of the monitoring wells and piezometers with reference to the National Geodetic Datum and mean sea level (MSL) level.
Groundwater Level Measurements (during the wet and dry seasons)	Estimate the groundwater piezometric surface elevations and hydraulic gradient to facilitate evaluations of the flow rate and potential fate and transport of identified constituents.	Conduct groundwater level measurements of all monitoring wells prior to collection of groundwater samples. Evaluate variability of water flow patterns with seasonal variations.

Table 2-1 (continued)

Sampling and Analytical Program Rationale

Red Hill Bulk Fuel Storage Facility

Pearl Harbor, Hawaii

ACTIVITY	OBJECTIVES	ACTION
Groundwater Level Measurement (long term measurement)	Analyze fluctuations in groundwater elevation due to seasonal precipitation and storm events.	Install data loggers into four (4) monitoring wells to collect groundwater elevations every 15 minutes for a prolonged period.
Hydrogeologic Pump Tests	Assess hydraulic properties of the basal aquifer in the vicinity of Navy Red Hill Pumping Shaft (No. 2254-01)	Conduct synchronized measurements with data loggers in at least two monitoring wells located in proximity to the Navy pumping well. Tests include equilibrium drawdown and transient drawdown, as feasible.
Sample Management	Maintain sample integrity and document field activities and sampling operations.	Maintain a bound field logbook. Samples will be labeled. Sample custody procedures will be observed from collection through transfer, analyses, and disposal.

Table 2-2
Phase II Analytical Results
Red Hill Bulk Fuel Storage Facility, Pearl Harbor, Hawaii

LOCATION	SAMPLE NO	TYPE	SAMPLE DEPTH (ft, pos)	SAMPLE DATE	MEDIA	1,1-Dichloroethylene	2-Methylnaphthalene	4-Methyl-2-pentanone	Acetone	bis(2-Ethylhexyl)phthalate	Chrysene	Dibenzofuran	Ethylbenzene	Fluorene	Lead	m,p xylene	Methyl ethyl ketone	Methylene chloride	Naphthalene	o-xylene	Phenanthrene	Pyrene	Toluene	TPH (C10-C28)	Unknown Hydrocarbon	Xylene (total)
TANK- 1	RH-BR-1-D09	DUP	59 6	02/08/2001	CORE	–	5 02	–	–	–	–	–	–	–	–	–	–	–	1 23	–	–	–	–	890	–	–
TANK- 1	RH-BR-1-S01	REG	2	02/07/2001	CORE	–	–	–	–	–	–	–	–	–	293	–	–	–	–	–	–	–	–	***25300***	–	–
TANK- 1	RH-BR-1-S02	REG	8	02/08/2001	CORE	–	0 25	–	–	0 162	–	–	–	–	–	–	–	–	–	–	–	–	–	1500	–	–
TANK- 1	RH-BR-1-S03	REG	59 6	02/08/2001	CORE	–	10 2	–	–	–	–	–	–	–	–	–	–	–	3 72	–	–	–	–	2330	–	0 436
TANK- 1	RH-BR-1-S04	REG	61 35	02/08/2001	CORE	–	39 8	–	–	–	–	–	0 49	–	–	–	–	–	16 3	–	–	–	–	3300	–	4 81
TANK- 1	RH-BR-1-S05	REG	129 2	02/09/2001	CORE	–	–	–	–	0 132	–	–	–	–	–	–	–	–	–	–	–	–	–	27 7	–	–
TANK- 1	RH-MW-1-S01	REG	124 2	03/07/2001	DFLNAPL	0 00065	–	–	–	–	–	–	–	–	***0.0756***	–	–	–	–	–	–	–	–	1 88	–	–
TANK- 1	RH-MW-1-S01	REG	129 4	08/27/2001	DFLNAPL	0 0013	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 3	–	–
TANK- 2	RH-BR-2-S01	REG	2 5	02/05/2001	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	910	–	–
TANK- 2	RH-BR-2-S02	REG	89 45	02/06/2001	CORE	–	–	–	–	–	–	–	–	–	–	–	–	***0.011***	–	–	–	–	–	22 2	–	–
TANK- 2	RH-BR-2-S03	REG	119 9	02/06/2001	CORE	–	–	–	–	–	–	–	–	–	–	–	–	***0.0127***	–	–	–	–	–	–	–	–
TANK- 3	RH-BR-3-S01	REG	2	01/31/2001	CORE	–	–	–	0 0412	0.159	–	–	–	–	14 5	–	–	–	–	–	–	–	–	386	–	–
TANK- 3	RH-BR-3-S02	REG	46 35	02/01/2001	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	774	–	–
TANK- 3	RH-BR-3-S03	REG	125 2	02/02/2001	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	28 9	–	–
TANK- 4	RH-BR-4-D08	DUP	123 9	01/31/2001	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14 5	–	–
TANK- 4	RH-BR-4-S01	REG	2 5	01/29/2001	CORE	–	0 392	–	0 045	–	–	–	–	–	84.5	–	–	–	–	–	–	–	–	238	–	–
TANK- 4	RH-BR-4-S02	REG	8.2	01/29/2001	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1330	–	–
TANK- 4	RH-BR-4-S03	REG	123 9	01/31/2001	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	49 8	–	–
TANK- 5	RH-BR-5-S01	REG	9 15	01/25/2001	CORE	–	1 85	–	–	–	–	–	–	–	–	–	0 29	–	0 266	–	0 226	–	–	503	–	–
TANK- 5	RH-BR-5-S02	REG	14 7	01/25/2001	CORE	–	–	–	0 0234	0 251	–	–	–	–	24	–	–	–	–	–	–	–	–	11 8	–	–
TANK- 5	RH-BR-5-S03	REG	55 25	01/26/2001	CORE	–	–	–	–	0 178	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK- 5	RH-BR-5-S04	REG	113 3	01/26/2001	CORE	–	–	–	–	0 435	–	–	–	–	2 1	–	–	–	–	–	–	–	–	12 4	–	–
TANK- 5	RH-BR-5-S05	REG	115 3	01/26/2001	CORE	–	–	–	–	0.214	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK- 6	RH-BR-6-D07	DUP	19 8	01/22/2001	CORE	–	–	–	–	0 456	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK- 6	RH-BR-6-S01	REG	0 5	01/19/2001	CORE	–	18 9	–	–	–	–	–	–	–	11 3	–	–	–	–	–	10 9	–	–	***10200***	–	–
TANK- 6	RH-BR-6-S02	REG	6	01/19/2001	CORE	–	–	–	–	–	–	–	–	–	11 2	–	–	–	–	–	–	8 45	–	***43100***	–	–
TANK- 6	RH-BR-6-S03	REG	19 8	01/22/2001	CORE	–	–	–	–	0 265	–	–	–	–	–	–	–	–	–	–	–	–	–	8 83	–	–
TANK- 6	RH-BR-6-S04	REG	125 1	01/24/2001	CORE	–	–	–	–	0.375	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK- 6	RH-MW-6-S01	REG	0 5	01/19/2001	DFLNAPL	–	36 8	–	–	–	–	–	–	–	***27.5***	–	–	–	–	–	–	–	–	29500	–	–
TANK- 7	RH-BR-7-S01	REG	0 5	01/17/2001	CORE	–	–	–	0 0295	–	–	–	–	–	17 6	–	–	–	–	–	–	–	–	631	–	–
TANK- 7	RH-BR-7-S02	REG	25 9	01/18/2001	CORE	–	19.1	–	–	–	–	–	0 122	–	–	–	0 431	–	7 09	–	–	–	–	2420	–	1 23
TANK- 7	RH-BR-7-S03	REG	92 4	01/18/2001	CORE	–	–	–	0 04	–	–	–	–	–	–	–	–	–	–	–	–	–	–	24 4	–	–
TANK- 7	RH-BR-7-S04	REG	105 95	01/19/2001	CORE	–	–	–	–	0 291	–	–	–	–	–	–	–	–	–	–	–	–	–	22 3	–	–
TANK- 7	RH-BR-7-S05	REG	111 2	01/19/2001	CORE	–	–	–	–	0 18	–	–	–	–	–	–	–	–	–	–	–	–	–	208	–	–

Table 2-2
Phase II Analytical Results
Red Hill Bulk Fuel Storage Facility, Pearl Harbor, Hawaii

LOCATION	SAMPLE NO	TYPE	SAMPLE DEPTH (ft, poe)	SAMPLE DATE	MEDIA	1,1-Dichloroethylene	2-Methylnaphthalene	4-Methyl-2-pentanone	Acetone	bis(2-Ethylhexyl)phthalate	Chrysene	Dibenzofuran	Ethylbenzene	Fluorene	Lead	m,p xylene	Methyl ethyl ketone	Methylene chloride	Naphthalene	o-xylene	Phenanthrene	Pyrene	Toluene	TPH (C10-C28)	Unknown Hydrocarbon	Xylene (total)
TANK- 8	RH-BR-8-S01	REG	0 5	01/15/2001	CORE	–	–	–	–	0.189	–	–	–	–	47 1	–	–	–	–	–	–	–	–	1030	–	–
TANK- 8	RH-BR-8-S03	REG	114 5	01/16/2001	CORE	–	–	–	–	0 123	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK- 9	B09A-1	REG	3 2	10/26/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	600	–
TANK- 9	B09A-2	REG	97 1	10/27/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3 5	–
TANK- 9	B09B-1	REG	55	10/29/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	48	–
TANK- 9	B09B-2	REG	74 6	10/29/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2 3	–
TANK- 9	B09C-1	REG	50	10/28/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6 9	–
TANK- 9	B09C-2	REG	66	10/28/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3 1	–
TANK-11	RH-BR-11-S01	REG	4 5	12/15/2000	CORE	–	1 56	–	0 0632	0 286	–	–	–	–	4 7	–	0 0165	–	–	–	0 534	–	–	1690	–	0 0084
TANK-11	RH-BR-11-S02	REG	11 3	12/15/2000	CORE	–	6 11	–	0.0243	–	–	0 992	0 002	1 14	–	–	–	–	0 776	–	2 09	–	–	3130	–	–
TANK-11	RH-BR-11-S03	REG	67 1	12/18/2000	CORE	–	–	0 0067	0.0215	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1440	–	–
TANK-11	RH-BR-11-S04	REG	85	12/18/2000	CORE	–	1 78	–	–	–	–	–	–	–	–	–	–	–	–	–	0 926	–	–	2320	–	0 0073
TANK-11	RH-BR-11-S05	REG	95	12/18/2000	CORE	–	6 81	–	–	–	–	–	0 0194	0 72	–	–	–	–	1 09	–	1 5	–	0 0086	2910	–	0 298
TANK-12	RH-BR-12-D06	DUP	104 3	12/14/2000	CORE	–	–	–	–	0.12	–	–	–	–	–	–	–	–	–	–	–	–	–	19 6	–	–
TANK-12	RH-BR-12-S01	REG	8	12/12/2000	CORE	–	–	–	–	0 169	–	–	–	–	–	–	–	–	–	–	–	–	–	31 7	–	–
TANK-12	RH-BR-12-S02	REG	33 5	12/13/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	232	–	–
TANK-12	RH-BR-12-S03	REG	61	12/13/2000	CORE	–	–	–	–	0 199	–	–	–	–	–	–	–	–	–	–	–	–	–	780	–	–
TANK-12	RH-BR-12-S04	REG	104 3	12/14/2000	CORE	–	–	–	–	0 125	–	–	–	–	–	–	–	–	–	–	–	–	–	77 1	–	–
TANK-12	RH-BR-12-S05	REG	121 9	12/14/2000	CORE	–	3 38	–	–	–	–	–	0.002	–	–	–	–	–	–	–	0 798	–	–	1710	–	0 018
TANK-13	RH-BR-13-D05	DUP	72	12/11/2000	CORE	–	–	–	–	0 566	–	–	–	–	–	–	–	–	–	–	–	–	–	26.1	–	–
TANK-13	RH-BR-13-S01	REG	72	12/11/2000	CORE	–	–	–	–	0 178	–	–	–	–	–	–	–	–	–	–	–	–	–	20 3	–	–
TANK-13	RH-BR-13-S02	REG	100	12/11/2000	CORE	–	–	–	–	0 342	–	–	–	–	–	–	–	–	–	–	–	–	–	31 9	–	–
TANK-13	RH-BR-13-S03	REG	125	12/11/2000	CORE	–	–	–	–	0 416	–	–	–	–	–	–	–	–	–	–	–	–	–	32 6	–	–
TANK-13	RH-BR-13-S04	REG	8	12/12/2000	CORE	–	–	–	0 0216	0 942	–	–	–	–	6 8	–	–	–	–	–	–	–	–	2160	–	–
TANK-13	RH-MW-13-S01	REG	132 5	08/27/2001	DFLNAPL	0 0021	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2 39	–	–
TANK-14	RH-BR-14-D04	DUP	60 5	12/06/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2090	–	–
TANK-14	RH-BR-14-S01	REG	35	12/06/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	581	–	–
TANK-14	RH-BR-14-S02	REG	60 5	12/06/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2810	–	–
TANK-14	RH-BR-14-S03	REG	75	12/06/2000	CORE	–	–	–	–	0 146	–	–	–	–	–	–	–	–	–	–	–	–	–	292	–	–
TANK-14	RH-BR-14-S04	REG	95 5	12/06/2000	CORE	–	57 8	–	–	–	–	–	$\boxed{1.55}$	–	–	–	–	–	11 4	–	12 8	–	0 17	$\boxed{26200}$	–	6 4
TANK-14	RH-BR-14-S05	REG	116	12/06/2000	CORE	–	3 06	–	–	–	–	–	–	–	–	–	–	–	–	–	0 974	–	–	851	–	–
TANK-15	RH-BR-15-D03	DUP	62 5	12/04/2000	CORE	–	–	–	–	0 291	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK-15	RH-BR-15-S01	REG	62 5	12/04/2000	CORE	–	–	–	–	0 206	–	–	–	–	–	–	–	–	–	–	–	–	–	8 05	–	–
TANK-15	RH-BR-15-S02	REG	86	12/04/2000	CORE	–	–	–	–	0 176	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK-15	RH-BR-15-S03	REG	115	12/04/2000	CORE	–	–	–	0 0257	0 191	–	–	–	–	–	–	–	–	–	–	–	–	–	10 7	–	–

Table 2-2
Phase II Analytical Results
Red Hill Bulk Fuel Storage Facility, Pearl Harbor, Hawaii

LOCATION	SAMPLE NO	TYPE	SAMPLE DEPTH (ft, poe)	SAMPLE DATE	MEDIA	1,1-Dichloroethylene	2-Methylnaphthalene	4-Methyl-2-pentanone	Acetone	bis(2-Ethylhexyl)phthalate	Chrysene	Dibenzofuran	Ethylbenzene	Fluorene	Lead	m,p xylene	Methyl ethyl ketone	Methylene chloride	Naphthalene	o-xylene	Phenanthrene	Pyrene	Toluene	TPH (C10-C28)	Unknown Hydrocarbon	Xylene (total)
TANK-16	B16-DUP	DUP	83 75	10/23/1998	CORE	–	–	–	–	–	–	–	–	6 4	–	0 085	–	–	14	0 071	14	13	–	–	6600	0 156
TANK-16	B16A-4	REG	83 75	10/22/1998	CORE	–	–	–	–	–	–	–	0.24	10	–	0 31	–	–	43	0 22	23	22	–	–	11000	0 53
TANK-16	B16A-5	REG	101 83	10/22/1998	CORE	–	–	–	–	–	–	–	–	4 7	–	–	–	–	–	–	4 4	20	–	–	2800	–
TANK-16	B16B-4	REG	66 15	10/23/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6 4	–
TANK-16	B16B-5	REG	75 58	10/23/1998	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	29	–
TANK-16	B16C	REG	103.6	10/28/1998	DFLNAPL	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0 011		–	–	8 1	0 031
TANK-16	B16C-4	REG	60	10/26/1998	CORE	–	–	–	–	–	6 3	–	0.16	12	–	0 059	–	–	47	0 082	26	11	–	–	9400	0 141
TANK-16	B16C-5	REG	67	10/26/1998	CORE	–	–	–	–	–	–	–	0 054	–	–	0 19	–	–	8 2	0 13	6 5	–	0 048	–	4500	0 32
TANK-17	RH-BR-17-D02	DUP	34	11/10/2000	CORE	–	–	–	–	0 133	–	–	–	–	–	–	–	–	–	–	–	–	0 0029	–	–	–
TANK-17	RH-BR-17-S01	REG	10	11/10/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	861	–	–
TANK-17	RH-BR-17-S02	REG	34	11/10/2000	CORE	–	–	–	–	0 294	–	–	–	–	–	–	–	0.0152	–	–	–	–	–	–	–	–
TANK-17	RH-BR-17-S03	REG	66 2	11/10/2000	CORE	–	–	–	–	0 224	–	–	–	–	–	–	–	0.0108	–	–	–	–	–	–	–	–
TANK-17	RH-MW-17-S01	REG	114 8	08/27/2001	DFLNAPL	–	–	–	–	–	–	–	–	–	0.072	–	–	–	–	–	–	–	–	–	–	–
TANK-18	RH-BR-18-D01	DUP	116	11/06/2000	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0 0177	–	–	–
TANK-18	RH-BR-18-S02	REG	104 4	11/06/2000	CORE	–	–	–	–	0 93	–	–	–	–	0 55	–	–	–	–	–	–	–	–	–	–	–
TANK-18	RH-BR-18-S03	REG	116	11/06/2000	CORE	–	–	–	–	0 419	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TANK-19	RH-BR-19-S01	REG	43	11/22/2000	CORE	–	4 31	–	–	0 174	–	–	0 174	–	–	–	–	–	0 682	–	–	–	–	1620	–	0 267
TANK-19	RH-MW-19-S01	REG	110 52	08/27/2001	INFILTWAT	0 0015	–	–	–	0 0078	–	–	–	–	0.0666	–	–	–	–	–	–	–	–	–	–	–
TANK-19	RH-MW-19-S01	REG	113 1	03/07/2001	INFILTWAT	0 0014	–	–	–	0 0073	–	–	–	–	0.0568	–	–	–	–	–	–	–	–	0 312	–	–
TANK-20	RH-BR-20-S01	REG	0 5	03/02/2001	CORE	–	–	–	–	–	–	–	–	–	9 8	–	–	–	–	–	–	–	–	975	–	–
TANK-20	RH-BR-20-S02	REG	8 8	03/03/2001	CORE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	794	–	–
VERTICAL WELL-D	RH-MW-V1D-S01	REG	86 1	03/07/2001	GW	–	–	–	–	0 0058	–	–	–	–	0.015	–	–	–	–	–	–	–	–	0 883	–	–
VERTICAL WELL-D	RH-MW-V1D-S01	REG	86 28	08/27/2001	GW	–	–	–	–	0 0109	–	–	–	–	0.0104	–	–	–	–	–	–	–	–	1 07	–	–
VERTICAL WELL-S	RH-BR-V2S-S03	REG	43	02/23/2001	CORE	–	–	–	–	–	–	–	–	–	4.1	–	–	–	–	–	–	–	–	–	–	–

Abbreviations:

– Parameter not detected
REG - Regular sample
DUP - Duplicate sample
GW - Groundwater
PPM - parts per million

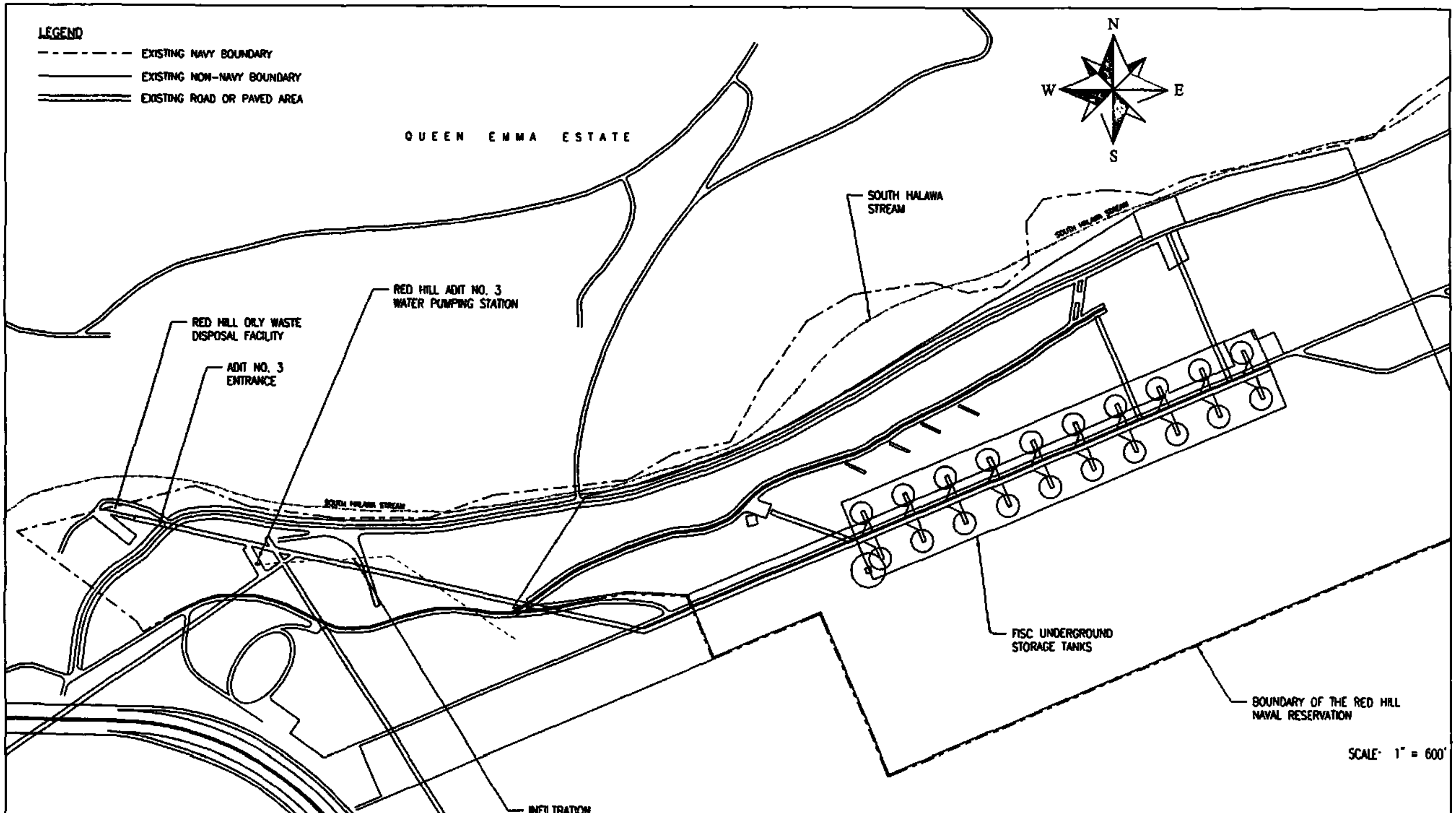
DFLNAPL - Drill fluid/LNAPL (light non-aqueous phase liquid) mixture
INFILTWAT - Infiltration Water
25300 - Analytical result exceeds the Hawaii DOH Tier I Action Level
TPH - Total petroleum hydrocarbon
ft, poe - feet from point of entry

Notes:
Analytical results are presented in ppm

Table 2-3

Proposed Schedule of Fieldwork
Red Hill Bulk Fuel Storage Facility
Pearl Harbor, Hawaii

Event	Estimated Work Days
Site Reconnaissance and Boring Placement Marking	1
Rock Borings and Installation of Monitoring Wells	20
Monitoring Well Development	3
Groundwater Level Measurements	1
Groundwater Sampling	2
Installation of Soil Vapor Monitoring Points	3
Soil Vapor Sampling	2
Land Survey	1



RED HILL BULK FUEL
STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

FIGURE
2-1
SITE PLAN MAP

SOURCE EARTHTECH FIGURE 3-5, U.S. NAVY FISC RED HILL WATER DEVELOPMENT TUNNEL, 11/98.

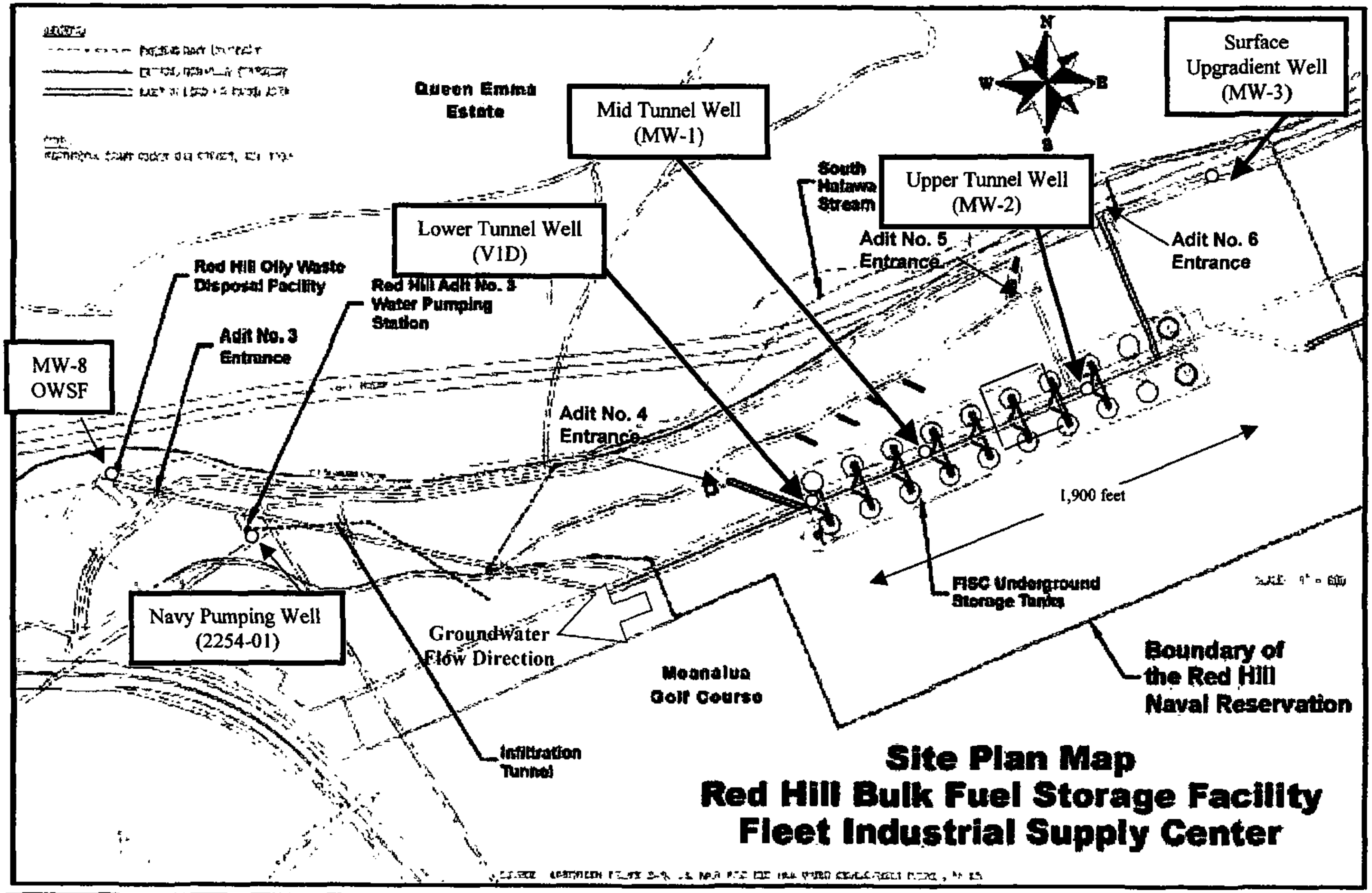


Figure 2-2
Groundwater Monitoring Well Locations

SECTION 3
FIELD TASKS

The field activities will employ sampling procedures and methodologies in accordance with those described in the standard operating procedures (SOPs) in the *Project Procedures Manual, U.S. Navy Pacific Division (PACDIV) Installation Restoration Program (IRP)* (PACDIV 1998). Although this contract is not part of the IRP, the specified SOPs provide excellent guidelines for completing these tasks. However, when appropriate, other procedures are described below that may deviate from the IRP SOPs, but are in accordance with the State Contingency Plan and the State of Hawaii *Technical Guidance Manual for Underground Storage Tank Closure and Release Response* (UST TGM) (Hawaii Department of Health [HDOH], 1992 and subsequent policy updates). The technical tasks described below are cross-referenced to applicable procedures and methodologies in the SOPs and the UST TGM.

3.1 Red Hill Contractors Access

Short-term contractors (=5 days) will receive a daily magnetic access key that can be obtained from the Fuel Operation Department receptionist in building 1757, first floor. Daily issued magnetic key cards must be returned at the end of every workday. Long-term contractors will be issued a magnetic key card and/or access code. In order to obtain a magnetic key card and/or access code, the following information is needed for each contractor employee that is to be issued a magnetic key card and/or access code.

- Name (First, M.I., Last)
- Social Security Number or Naturalization Number if not a US citizen.
- Digital Passport Type Photo (jpg. or tiff.)
- Home Address (Including Town, State, Zip Code)
- Start and End date and daily hours of work

- Gates/Adits for which access is requested (Adit 3, Adit 5, Adit 6, Halawa Prison Gate, Navy Red Hill Firing Range Gate)
- Company Name, Address (Including Town, State, and Zip Code), and Phone Number
- Point of Contact and Phone Number for Contractor Security Coordinator or FISC Engineer Project Manager
- Contractor's Email Address.
- Work, Home, Cell, and/or Fax Phone Numbers if applicable.

Not all personnel working at Red Hill need a magnetic key card and/or access code. Designated personnel form each contractor will appoint a work group foreman that will provide access for his/her crew with his/her magnetic key card and/or access code. Access will be granted only for the planned period of work. Should the work schedule be extended, notify FISC Lee Uyeda of the revised schedule, and extension of access privileges will be considered. Access magnetic key card and/or access codes will be limited to specific adits and gates needed to access the respective work sites. If access to additional restricted areas is required, contact FISC Lee Uyeda for a change to the key/code. Applications for magnetic key cards and/or access codes should be made as early as possible by contacting Lee Uyeda at 473-7830, building 1757 2nd deck to make an appointment. Information and jpg files may be emailed to Lee at lee.uyeda@navy.mil. Do not send Zip files via email or jpg pictures in a Word Document. Please notify and return your magnetic key cards and/or access codes in person to Lee Uyeda upon completion of scheduled work.

Access to the tunnels below Tanks 17 to 20 will be gained through Adit 6 and access to the tunnels below Tanks 1 to 16 will be gained through Adit 5. Adit 3 will be used for transporting material, which is where the train system in the tunnels is accessed. Train support needs to be arranged ahead of time with Herb Kikuchi at 473-7805 or 479-1063. Access to the background soil boring location near the Halawa firing range should be open. The lock has been removed from the firing range gate and the gate will remain unsecured until after completion of fieldwork. Contractors have unrestricted access to the background soil boring location, between the firing range gate and the stop sign at the boundary of the range. The point of contact at the Halawa firing range is Sgt. Stephen Cristopher who can be reached at 471-4798, 471-2916, or 358-2407 or via email at steven.e.christopher@navy.mil.

3.2 Health and Safety

All Site personnel performing field activities (i.e. drilling, groundwater sampling, etc.) shall adhere to applicable PACDIV safety procedures, which are summarized in the SSHSP, and sign the SSHSP Acceptance Sheet. Additionally, Site visitors will "check-in" with the Field Manager or Site Health and Safety Coordinator and will sign the Site Visitor Health and Safety Orientation Form. Field tasks and associated potential hazards, summarized in the SSHSP, will be discussed in daily tailgate meetings attended by all Site personnel.

3.3 Preliminary Monitoring Activities

Prior to conduct of the proposed intrusive activities, groundwater samples will be obtained from the existing vertical monitoring wells (MW-V1D, 2254-01, and MW-V2S) and subjected to analysis for COPCs. Prior to the construction of soil vapor MPs, chosen slant wells will be monitored for the presence of LNAPL using an electronic product indicator. The locations of the newly proposed groundwater monitoring wells and soil vapor monitoring wells may be modified on the basis of the preliminary monitoring results.

3.4 Groundwater Monitoring Well Installation

Three (3) soil borings will be advanced for the installation of the groundwater monitoring wells at the Site (see **Figure 2-2**). One of the borings will be advanced from the ground surface to a depth sufficient to penetrate the basal groundwater aquifer underlying the Site. The remaining two soil borings will be advanced from within the lower access tunnel to depths sufficient to penetrate the basal groundwater aquifer. It is anticipated that the basal aquifer will be encountered at an elevation of approximately 16.5 feet above mean sea level (msl). A description of the monitoring wells is provided in the following subsections.

3.4.1 Background Surface Boring Excavation

One (1) boring will be located along the northern access road, up-gradient from the facility USTs at an elevation of approximately 250 feet msl and will be advanced from the ground surface to a depth of approximately 20 feet below the confining caprock of the basal aquifer underlying the Site. It is anticipated that an air rotary - air percussion drill rig will be used to advance the boring. Samples will be collected in the soil over burden using wire-line split spoon techniques. Samples in the bedrock will be collected from cuttings. All samples will be screened for VOCs using an organic vapor meter (OVM) equipped with a photo-ionization detector (PID). A portable x-ray fluorescence spectroscopy (XRF) device will be used to screen shallow soil samples for lead content. The lithology of the samples will be recorded on boring logs. Select samples will be retained for laboratory analyses. This surface boring will be used to install a hydraulically up-gradient monitoring well at the Site, to be used to evaluate background conditions. It is not anticipated that this boring will encounter petroleum constituents from the site, or other offsite activities in the subsurface as it is located away from potential sources. There is a small chance that lead from the up-gradient firing range may have impacted the groundwater at this location and groundwater samples will be evaluated for dissolved lead, as well as other petroleum and geochemical constituents to compare to onsite well groundwater.

3.4.2 Tunnel Boring Excavation

Two (2) borings will be advanced from within the lower access tunnel to depths of approximately 15 feet below the water table of the basal aquifer underlying the Site. It is anticipated that the total boring depths will extend approximately 100 feet and 150 feet below the concrete tunnel floor, respectively. A portable rotary drill rig will be used to advance the borings. It is anticipated that initial borehole diameter will be approximately 6-inches to advance surface conductor casing to between 5 and 10 feet below ground surface (bgs). The initial core size will be PQ and the respective corehole will be approximately 4.8-inch diameter.

Although the borehole will be located in the middle of the access tunnel, as far away as possible from the surrounding USTs (approximately 90 feet laterally from the edge of the surrounding tank pairs), there is a small chance that extensive petroleum impacted material will be encountered in the vadose zone during drilling. Due to the minimal size of the initial borehole, only one isolation casing will be feasible to be located within the 4.8-inch borehole. Isolation casing will not be installed without expressed agreement from the US Navy and the Prime Contractor Project Manager. The minimum core size acceptable to install a 2-inch monitoring well will be HQ (3.77-inch diameter). Rock cores will be obtained continuously within the boreholes. The cores will be screened for VOCs using an OVM equipped with a PID. A portable XRF device will be used to screen shallow core samples for lead content. A physical description of the cores (e.g., lithology, fractures, color, etc.) will be recorded on boring logs. Select core samples will be retained for laboratory analyses. These tunnel borings will be used to install groundwater monitoring wells at the Site, to be used to monitor for the presence COPCs in the basal aquifer. In the event that non-aqueous phase liquid (NAPL) is encountered within these borings, isolation casing may be installed following concurrence from project principals (**Section 3.3.3**).

3.4.3 Isolation Casing Requirements and Procedures

On the basis of previous investigations in the Red Hill area, the greatest likelihood of intercepting NAPL is within more permeable clinker zones of the a'a lava. The clinker beds are typically less than 10 feet thick and are generally separated by less than 30 feet of competent rock.

In the event that NAPL is encountered in the subsurface, isolation casing will be installed within the borehole to preclude the downward migration of NAPL along the borehole conduit. Isolation casing will be installed as described in procedure I-C-1, *Monitoring Well Installation* (PACDIV 1998). Polyvinyl chloride (PVC) or steel casing will be installed from below the NAPL-containing zone to the ground surface (tunnel floor). Quick-setting grout will be placed using a tremie pipe that extends to the base of the casing, with an inflatable packer set above the tremie opening or other suitable method for pressure grouting the annulus. Grout will be pumped into the boring until it rises to the ground surface (tunnel floor) around the outside annulus. After the isolator casing grout has hardened (no less than 24-hours), the borehole will be advanced through the casing to the total depth of the boring using HQ coring equipment. In the event that a second NAPL bearing zone is encountered, the boring will be abandoned and grouted to the surface, or will be reamed to a larger size to facilitate the placement of additional isolator casings. Anticipated total depths for each monitoring well are identified on **Table 3-1**.

3.4.4 Soil Core Samples

It is anticipated that a maximum of eight soil or rock samples and one duplicate soil/rock sample will be subjected to laboratory analyses for COPCs. A maximum of three samples will be selected from within any one boring. Samples will be selected for analysis on the basis of visual observations during drilling and the results of PID and XRF screening.

3.4.5 Monitoring Well Installation

Three (3) borings will be completed as a groundwater monitoring wells (see **Figure 2-2**). The monitoring wells will be installed in accordance with procedure I-C-1, *Monitoring Well Installation* (PACDIV 1998). The precise depths of screen casing, approximately twenty feet in length, will be determined in the field and based on the encountered subsurface geologic conditions. Each of the monitoring wells will be screened over a 20-foot interval at the top of the basal aquifer and will include a minimum of 5 feet of screen above the water table.

Each monitoring well will be constructed using minimum 2-inch inner diameter (ID) Schedule 40, PVC casing. Other well construction materials, such as filter pack and grouting materials, will be selected and installed in accordance with procedure I-C-1, *Monitoring Well Installation* (PACDIV 1998). Each monitoring well will be surged for approximately 10 minutes after filter pack placement and prior to placement of the bentonite seal to ensure that the filter pack has properly settled.

For locations where petroleum-based NAPL is encountered within the subsurface, permanent surface casing will be installed to isolate the geologic material and prevent downward migration of NAPL. The surface casing will be installed as described in Section 5.5.7 of procedure I-C-1, *Monitoring Well Installation* (PACDIV 1998).

The new monitoring wells located in the lower access tunnel will be completed with an inner PVC pressure locking cap, and an outer steel cap threaded to the conductor casing. Both inner and outer caps will be contained within a waterproof flush-mounted steel traffic-rated well box completed flush with the tunnel floor with high-impact resistant cement and a brass monument tag labeling the well.

Following the installation of each monitoring well, each well casing will be notched at the surface on the northern edge to serve as a reference point when taking water level measurements. The elevation of the notched edge and a specified mark on the brass monument tag will be surveyed by a licensed land surveyor.

3.5 MONITORING WELL DEVELOPMENT

Monitoring well development procedures prepare a well for sampling by enhancing the flow of groundwater from the formation into the well and by removing clay, silt, and other fine particles from the filter pack. This increases the probability that groundwater samples from the well will not be turbid or contain suspended matter, which may interfere with chemical analyses. Monitoring well development will be performed in accordance with procedure I-C-2, *Monitoring Well Development* (PACDIV 1998).

Each monitoring well will be developed by mechanical surging for 10 to 15 minutes prior to the removal of groundwater with a stainless steel bailer. At least three cycles of surging will be performed. Alternatively, each monitoring well may be developed using a bladder pump. The pump will be manipulated to create a bidirectional groundwater flow to aid in the removal of the fine particulate matter from the well screen and filter pack. The well will be pumped until dry or until a minimum of ten volumes of water is purged from the well. Qualitative observations such as the presence of hydrocarbon sheen or product, color, and odor will be noted. The purge water from above-ground monitoring wells will be containerized in 55-gallon drums or temporary storage tanks for later sampling and characterization prior to disposal. The purge water from the lower tunnel wells will be discharged into the facility drain and sump treatment system.

In addition, a flow cell will be used to measure and record temperature, pH, reduction-oxidation potential, turbidity, dissolved oxygen, and specific conductivity. Field data will be documented on well development logs. Development will continue until the measured parameters have stabilized and turbidity is low. Parameters are considered stabilized if three successive readings are within 10% of each other. If extremely slow recovery rates are observed, development will cease after two or more complete drawdowns are completed.

The primary purpose of collecting water parameter data is to determine the well purging endpoint and not for a quantitative assessment of hydraulic effects at the site. Field measurements will be qualitatively assessed in accordance to PACDIV level E guidelines (see Section 4.0 – Data Validation of the QAPP [**Work Plan, Appendix B**]).

3.6 LAND SURVEY

Following the installation of the monitoring wells, the horizontal coordinates and elevations of selected surface structures, each groundwater monitoring well, and each soil vapor monitoring well will be surveyed by a land surveyor registered in Hawaii. The survey will be conducted in accordance with procedure I-I, *Land Surveying* (PACDIV 1998), and the National Oceanic and Atmospheric Administration (NOAA) standards, using horizontal accuracies of (+/-) 0.1 feet and vertical and benchmark elevation accuracy of (+/-) 0.01 feet if possible. If the surveyor cannot produce the accuracy required due to the technical reasons, they must specify the accuracy that they can obtain. Top of monitoring well casing elevations will be used as the elevation reference to facilitate the calculation of groundwater elevations and gradients. The coordinates shall be reported in the Universal Transverse Mercator, State Plane, Zone 3, NAD83 (meters) coordinate system. The surveys shall be third order (cf. Urquhart, L.C., *1962 Civil Engineering Handbook*, 4th Edition, pp. 96 and 97). An XYZ-coordinate system using northings, eastings, and elevations shall be used to identify locations. Each well will be tied to a single benchmark reference point via a closed loop survey and that benchmark will be specified in all reports. A permanent brass survey marker will be installed at each monitoring well head, and stamped with the monitoring well designation and elevation.

3.7 Groundwater Sampling

After the installation and development of the proposed monitoring wells, two rounds of groundwater samples will be collected from the one existing and three newly installed wells. A single round will be collected in Phase 1 of the project during the dry season, and a second round will be collected in Phase 2 of the project in accordance with the State Contingency Plan that a minimum of two groundwater samples be collected for evaluation and RA from new monitoring wells. The objectives of the monitoring program are to collect data necessary to assess the groundwater quality within the basal aquifer underlying the RHSF Site and determine if the RHSF is the source of COPCs being released to the subsurface. The groundwater samples will be analyzed for COPCs identified in **Section 4.**

Groundwater samples will be labeled and documented in accordance with Procedure III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody Procedures* (PACDIV 1998) and Section 2.4 and 4.0 of the QAPP (see **Work Plan, Appendix B**). Sample handling, storage, and transport will be performed according to the requirements outlined in Procedure III-F, *Sample Handling, Storage, and Shipment Procedures* (PACDIV 1998) and **Section 3.12.**

A representative groundwater sample will be collected from each monitoring well in accordance with procedure I-C-3, *Monitoring Well Sampling* (PACDIV 1998). Thus, a period of at least 24 hours will be allowed to pass between well development and groundwater sampling.

Prior to collecting a groundwater sample, the *in situ* groundwater in each monitoring well will be removed, or purged via a dedicated PVC bailer or a clean submersible bladder pump fitted with dedicated PVC tubing. The purge water will be containerized in 55-gallon drums or temporary storage tanks for later sampling and characterization prior to disposal. Field parameters such as: pH, temperature, specific conductivity, dissolved oxygen, reduction-oxidation potential, and turbidity will be measured using a flow through cell and recorded at approximate five minute intervals on a *Groundwater Sampling Log* data sheet. Purging shall be considered complete when field parameter measurements (i.e.: pH, conductivity, etc.) stabilize within approximately 10% of the last three consecutive recorded measurements for each well.

Field equipment that may be used during groundwater field activities for monitoring purposes include:

- pH, temperature, conductivity, dissolved oxygen, reduction-oxidation potential, and turbidity meters (flow through cell); and,
- electronic water level indicator.

The field monitoring equipment will be calibrated daily (if applicable) according to manufacturer's guidelines and procedures for each item of equipment stated.

3.8 Groundwater Level Measurements

Groundwater surface elevations will be used to make an initial assessment of the groundwater potentiometric surface, hydraulic gradient, and direction of groundwater flow. Two sets of water table elevations will be collected following the groundwater sampling events in the dry and rainy season, respectively. Sets of groundwater surface elevation measurements for site monitoring wells will be conducted manually prior to each sampling event. To assess the fluctuations in the water table resulting from synoptic fluctuations and precipitation, a water level survey using automatic data loggers will be conducted in the site wells. Water level measurements will also be conducted in other available groundwater wells penetrating the basal aquifer (such as the Public Works Center [PWC] groundwater supply well) if accessible.

3.8.1 Manual Measurements

During groundwater monitoring events, groundwater levels will be recorded in each well prior to sample collection. These measurements will be obtained using an electronic water level indicator, as described in procedure I-C-3, *Monitoring Well Sampling* (PACDIV 1998). The groundwater level measurements will provide data on the current groundwater elevations at the Site prior to sampling. Data will be recorded on sampling logs for each monitoring well.

3.8.2 Automatic Data Logger Units

Following the installation and development of the wells, continuous monitoring of groundwater levels will be conducted in all of the wells at the RHSF Site using down-hole, data loggers. The data will provide information regarding temporal fluctuations in water surface elevation and changes in groundwater flow direction due to seasonal precipitation or storm events. Data loggers will also be used to assess hydrogeologic pumping tests. Data loggers will be installed in Phase 2 of the project.

3.9 Hydrogeologic Tests

Hydrogeologic tests are proposed for Phase 2 of the project to be conducted using the Navy Red Hill Pumping Station (2254-01) as the pumping well and the Red Hill Oily Waste Basin MW-8 and potentially 2254-02, if usable, as observation wells. Additional wells at the Adit 3 location may be used to provide additional data for distance drawdown tests. The pumping tests will be conducted in strict concert with US Navy PWC, who will be managing the pumping station. The Contractor proposes conducting equilibrium or constant head tests, as well as transient tests, which may include time-drawdown and/or distance-drawdown methods. Additional scoping will be required to detail the specifics of these tests

3.10 Soil Vapor MP Installation

Each of three (3) angled soil borings will be completed as Soil Vapor Monitoring Wells (see **Figure 2-2**). Three soil vapor MPs will be installed inside each of the chosen angled borings to assess vapors in the outer third, middle third, and inner third of the vadose zone below the bottom of the study USTs. Typical construction details for installation are depicted on **Figure 3-1**.

Construction of the soil vapor MPs will require close attention to the sizes of the required tremie pipe and MP diameters and lengths in comparison to the existing slant boring casing inside diameters. It will be necessary to install all instrumentation through the existing casing, which ranges from 1.5 to 2 inches inner diameter. In addition, it will be necessary for the casing to be evaluated for contamination that may have entered through the screened section and pooled in the sumps at the end of the screened sections. In general, the screens are 15 feet long and locate at the outer third of the borings. In order to isolate each third of the boring, grout will be injected through tremie pipes at 100 feet, 66 feet, 33 feet, and at the surface. MPs will be installed in sections of open hole approximately 30-feet long, separated by grout plugs.

The following steps should be taken when installing the MPs.

1. Ensure that instrumentation, material, and tools are onsite to complete each installation;

   a. approximately 200 feet of 1/4–inch PVC tubing (100-foot, 60-foot, and 40-foot sections [make sure each section is marked with depth using metal tag labels]), three MP screens (3/4-inch by 2 feet), and three check valves;

   b. 120 feet of swabbing and casing assessment pipe (3/4-inch diameter), flush-threaded;

   c. casing swabs, 1.5- and 2-inch swabs to fit on the end of the tremie pipe for initial cleaning of casing;

   d. 120 feet of tremie pipe (3/4-inch diameter) flush-threaded;

   e. cement, bentonite, and grout pump;

   f. 6-inch surface traffic box;

   g. casing puller for 1.5- and 2-inch casing;

   h. down-hole casing cutter to cut 1.5- to 2-inch casing at approximately 110 feet from the point of entry (POE);

   i. two 55-gallon drums to mix grout and to clean tremie.

2. Insert swab and assessment pipe to end of casing and draw vacuum to determine if product is at bottom of casing. Collect product in 1-liter amber sampling jar. Remove pipe and save swab for evaluation.

3. Insert downhole pipe cutter to endpoint of UST and cut internal casing at approximately 110 feet from POE. Remove Pipe cutter from casing.

4. Break casing from surface seal and pull 5 feet into tunnel.

5. Insert grout tremie pipe to 110 feet from POE and plug end with approximately 4 gallons of grout (at 3.5 inch diameter borehole, 0.5 gallons per foot). Remove tremie pipe and rinse.

6. Pull casing to 80 feet from POE, cut off stick-up and discard.

7. Insert 100-foot MP and 2-foot screen to 80 feet from POE.

8. Pull casing to 65 feet from POE, cut off stick-up and discard.

9. Insert grout tremie pipe to 65 feet from POE and plug end with approximately 4 gallons of thick grout (at 3.5 inch diameter borehole, 0.5 gallons per foot). Remove tremie pipe and rinse.

10. Pull casing to 45 feet from POE, cut off stick-up and discard.

11. Insert 60-foot MP and 2-foot screen to 45 feet from POE.

12. Pull casing to 33 feet from POE, cut off stick-up and discard.

13. Insert grout tremie pipe to 33 feet from POE and plug end with approximately 4 gallons of thick grout (at 3.5 inch diameter borehole, 0.5 gallons per foot). Remove tremie pipe and rinse.

14. Pull casing to 20 feet from POE, cut off stick-up and discard.

15. Insert 40-foot MP and 2-foot screen to 25 feet from POE.

16. Pull remaining casing out of hole and discard.

17. Install surface mount traffic box.

18. Grout traffic box in-place to 5 feet from POE.

19. Install check valves on each MP and metal labels on each point with depth indicated.

20. Allow at least 24 hours for grout to cure before sampling.

3.11 SOIL VAPOR SAMPLING

Soil vapor MPs will be purged and sampled for VOCs using Method TO-15, which is described in the QAPP accompanying this document. Purging will be accomplished using a 1-gallon per minute electric air pump or comparable equipment. It is estimated that three MP volumes should be removed from each MP prior to sampling. A typical MP will consist of approximately 25 feet of 3.5-inch open hole to purge at 0.5 gallon per foot. Therefore, approximately 36 gallons are to be removed per MP prior to sampling.

Sampling will consist of field readings, and samples collected for laboratory analysis. Field readings will include oxygen, carbon dioxide, and TPH by volume, which shall be collected using a calibrated multi-gas meter and data will be entered on field forms and in the dedicated logbook for the project.

Laboratory samples will be analyzed at Air Toxics Ltd. (ATL), Folsom California. ATL will provide 6-liter summa canisters for 10 samples, including nine MP sampling locations and a duplicate. Following purging, the summa canister dedicated to the MP will be labeled and logged with appropriate quality control (QC) information. The summa canister inlet will then be connected directly to the MP outlet barb via tygon tubing and the outlet barb will be opened. The summa canister valve will then be opened slowly, and the soil vapor will be drawn into the canister, replacing the vacuum. When the canister vacuum has returned to ambient pressure, the canister valve will be closed, the check valve on the MP will be closed, and the dedicated tygon tubing will be removed from the summa canister inlet. QC information, such as final pressure will be recorded on the sample label and the logbook and field forms and the summa canister will be capped. Canisters will be shipped to ATL under chain of custody procedures via direct air courier.

3.12 FIELD LOGBOOK

The field logbook serves as the primary record of field activities. Entries shall be made chronologically and in sufficient detail to allow the writer or a knowledgeable reviewer to reconstruct the applicable events. The field logbook shall be bound with consecutively numbered and water repellent pages. The logbook shall be stored in a clean location and used only when outer gloves used for personal protective equipment have been removed. The logbook procedures will conform to SOP III-D *Logbook* (PACDIV 1998).

Individual data forms may be generated to provide systematic data collection documentation. Entries on these forms shall meet the same requirements as entries in the logbook. At a minimum, names of all samples collected shall be included in the logbook even if recorded elsewhere.

At a minimum, the following information will be recorded in either the field logbook or a separate sample log sheet during the collection of each sample:

- Sample location and description;
- Sampler's name(s);
- Date and time of sample collection;
- Type of sample (groundwater, soil, or soil vapor);
- Type of sampling equipment used;
- Field instrument readings and calibration; and
- Field observations and details related to analysis or integrity of samples (e.g., weather conditions, noticeable odors, colors, etc.).

In addition to the sampling information, the following specific information will also be recorded in the field logbook for each day of sampling:

- Time of arrival/entry on site and time of site departure;
- Other personnel on site;
- Summary of any meetings or discussions with regulators, contractor, or federal agency personnel;
- Deviations from sampling plans, site safety plans, and QC procedures; and
- Changes in personnel and responsibilities with reasons for the changes.

3.13 Sample Management

The integrity of data obtained for samples collected in the field depends on adherence to proper procedures for sample management involving both proper labeling and handling of samples. To ensure proper labeling and handling, sampling activities will be carried out according to PACDIV SOP III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody* (PACDIV 1998) and PACDIV SOP III-F, *Sample Handling, Storage, and Shipment* (PACDIV 1998). These procedures are briefly outlined below.

3.13.1 Sample Logs, Labeling, and Chain-of-Custody

Detailed entries for logging and identifying samples and chain-of-custody (COC) procedures will be used to document acceptability of data generated. To minimize possibility of error, the number of personnel assuming custody for a sample will be minimized. Sample documentation and custody procedures will include completion of sample labels and COC forms for all samples. COC forms will typically serve as analytical request forms to a receiving laboratory.

The label for each field sample will contain the following information:

- unique Sample Number
- project name
- location, time, and date of collection
- name of sampler(s)

A preprinted COC form will accompany samples from their time of collection and processing in the field through submittal to a particular testing laboratory. The COC form will trace and document the path of each individual sample by means of a unique COC identification number. The following information will be included on a COC form:

- project name (Red Hill Phase 1 RA)
- sampling location, date, and time

- sample identification
- number of unique sample containers for a sample
- type of sample containers
- sample preservative (if any)
- number of samples addressed on the COC form
- type of analysis required for each sample
- special instructions (if any)
- signatures indicating sample relinquishment and receipt

COC forms to accompany the samples during shipment to a designated testing laboratory will be placed in a sealed plastic bag and taped to the inside of the shipping container. To document the transfer of samples from the field to a receiving laboratory, a representative of the receiving laboratory will sign the accompanying COC form upon arrival of the shipping container at the laboratory. All samples will be shipped from the field to a receiving laboratory by Federal Express or equivalent carrier. Facsimiles of COC forms will be submitted to a laboratory and the project manager within 24 hours of each sample shipment.

3.13.2 Project-Specific Sample Identifier

A unique Project-Specific Sample Identifier will be assigned to each sample. This identifier will use the following format of "aabbccdee."

aa = two-letter acronym designating a specific CTO site (RH = Red Hill)

bb = location acronym (e.g., MW for monitoring well, SV for Soil Vapor Well)

cc = location number (e.g., 01 for monitoring well MW-01 or Soil Vapor SV-01)

d = type of field QC (e.g., S for primary field sample and Q for QC sample)]

ee = chronological sample number from a particular sampling location/event (e.g., 01, 02, 03)

An example of the Project-Specific Sample Identifier for this project might be RHMW01S01.

The nine-character Project-Specific Sample Identifier establishes a unique sample identifier that can be used in reports, tables, figures, etc. A great deal of information is contained in the name that makes it meaningful. The Project-Specific Sample Identifier will be entered into the COC logbooks (see PACDIV SOP III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody* [PACDIV 1998]) so that the database can be used to track samples by Project-Specific Sample Identifier.

3.13.3 Sample Handling, Storage, and Transport

Sample handling during all phases of sample collection, transport, and receipt by laboratories will be performed according to the requirements of PACDIV SOP III-F, *Sample Handling, Storage, and Shipping* (PACDIV 1998). All Department of Transportation (DOT) regulations will be followed for packaging and shipment of samples, as described in PACDIV SOP III-F. Formal training in shipping hazardous materials is required prior to shipping samples that could potentially contain hazardous materials.

Glass containers for shipping of chemistry samples will be wrapped in bubble wrap or other appropriate protection to prevent breakage during shipment. As appropriate, Styrofoam will be placed on the bottom and top of the inside of shipment coolers. Styrofoam peanuts also may be used to fill spaces between containers in coolers. An appropriate absorbent material will be added to coolers on the bottom and top to absorb any water, act as cushioning material, and absorb any sample material that may leak or otherwise spill due to breakage.

All samples will be kept in insulated coolers with ice, or taken to a secured location and transferred from the insulated cooler with blue-ice to a refrigerator or freezer (as appropriate) until shipment. If a nearby refrigerator or freezer for storage is not available, dry ice may be used to keep blue-ice blocks frozen onsite. Fresh, frozen blue-ice blocks will be repacked with samples prior to shipment. COC forms will be placed inside sealable storage plastic bags and placed inside sample coolers. Coolers will then be closed and sealed with waterproof tape, and lids will be sealed with two custody seals to enable detection of tampering during shipment. Coolers will be delivered to the appropriate shipping courier or office (i.e., Federal Express or equivalent carrier).

3.13.4 AGRICULTURAL REQUIREMENTS FOR SAMPLE SHIPMENT

All appropriate DOT regulations (e.g., 49 Code of Federal Regulations, Parts 171-179) will be followed in shipment of air, soil, water, and other samples. Shipment of sample coolers to the U.S. from locations outside the continental U.S. is controlled by the United States Department of Agriculture (USDA) and is subject to their inspection and regulation. USDA regulations pertaining to the shipment of soil samples require that a valid USDA permit be maintained by the receiving laboratory.

3.14 EQUIPMENT DECONTAMINATION

Decontamination of sampling equipment will be performed to ensure data quality, to prevent cross-contamination, and to prevent the potential introduction of contaminants into previously unimpacted areas. Non-disposable sampling equipment will be decontaminated between samples in accordance with procedure I-F, *Equipment Decontamination* (PACDIV 1998).

Decontamination liquids and rinsate will be containerized and stored as Investigation Derived Waste (IDW). Onsite sampling personnel will perform decontamination procedures prior to leaving the site.

3.15 INVESTIGATION-DERIVED WASTE (IDW) MANAGEMENT

IDW generated during the course of the field investigation will be handled in accordance with current U.S. Environmental Protection Agency (USEPA) guidelines described in the EPA document *Management of Investigation-Derived Wastes During Site Inspections*

(EPA 1991) and procedure I-A-7, *IDW Management* (PACDIV 1998). The various waste streams will include (but may not be limited to) the following:

- Personal protective equipment (PPE) including: tyvek coveralls, respirator cartridges, nitrile gloves, etc.;
- Disposable sampling equipment and supplies, including: bailers, plastic sheeting, etc.;
- Potentially contaminated solids, principally soil/rock cuttings;
- Purged groundwater from monitoring well development and sampling; and
- Decontamination fluids.

Classification of the generated IDW will be performed in accordance with the procedures and parameters specified in PACDIV SOP I-A-7, *IDW Management* (PACDIV 1998). All IDW will be segregated by matrix. Liquid IDW, such as equipment rinse water and well development effluent, will be stored in 55-gallon drums or equivalent container until drilling activities are completed. Equipment decontamination water that may contain soap or solvents will be segregated from the well construction, development, and purge water. Water containing soap or solvents must be disposed offsite by a certified disposal subcontractor. Water from the wells that does not contain soap, solvents or other unacceptable material can be disposed of in the RHSF oil-water separator system. Used PPE will be stored onsite in a secured storage container. IDW will be sampled and characterized for disposal following field activities.

Soils from the excavated borings will be placed in drums for storage while samples are analyzed to determine whether the soils are considered hazardous waste. Screening procedures will follow applicable regulatory standards (i.e., Resource Conservation and Recovery Act (RCRA) established hazardous waste characterization criteria) and EPA analytical methods recommended for adequately characterizing IDW contained in each drum. Hazardous waste threshold concentrations may vary depending on the selected disposal option (i.e. incineration verses land disposal and may dependent on class of landfill.

Drums containing IDW will be labeled, sealed, and placed on pallets. The palletized drums will be inventoried and stored in an approved area onsite. Drum labels will include following information: CTO Number, responsible Navy activity, contact phone number, boring/well identification number, generation date, drum number, and contents.

Following receipt of all analytical data, the available options to dispose of the IDW will be evaluated and recommendations will be presented to the NAVFAC representative who is responsible for the disposal of all IDW generated from the RHSF field activities. Soil and groundwater samples analyzed in the analytical laboratory will be disposed of by the laboratory. Non-contaminated sample jars and bottles will be disposed as municipal trash. All IDW will be secured, labeled, and stored onsite until available options to dispose of the IDW are evaluated.

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Table 3-1

Anticipated Elevations and Total Depths of Proposed Monitoring Wells and Piezometers Red Hill Bulk Fuel Storage Facility Pearl Harbor, Hawaii

	Surface Elevation of Monitoring Well / Piezometer (feet above sea level)[1]	Groundwater Elevation (feet above sea level)[2]	Total Depth of Well / Piezometer (feet below ground surface)[1]
MW-1	104	16	120
MW-2	164	16	180
MW-3	384	16	400

[1] Surface elevation and total well depth measured from lower access tunnel floor for MW-1 and MW-2.
[2] Groundwater elevation based upon the water level recorded in existing monitoring well MW-V1D.

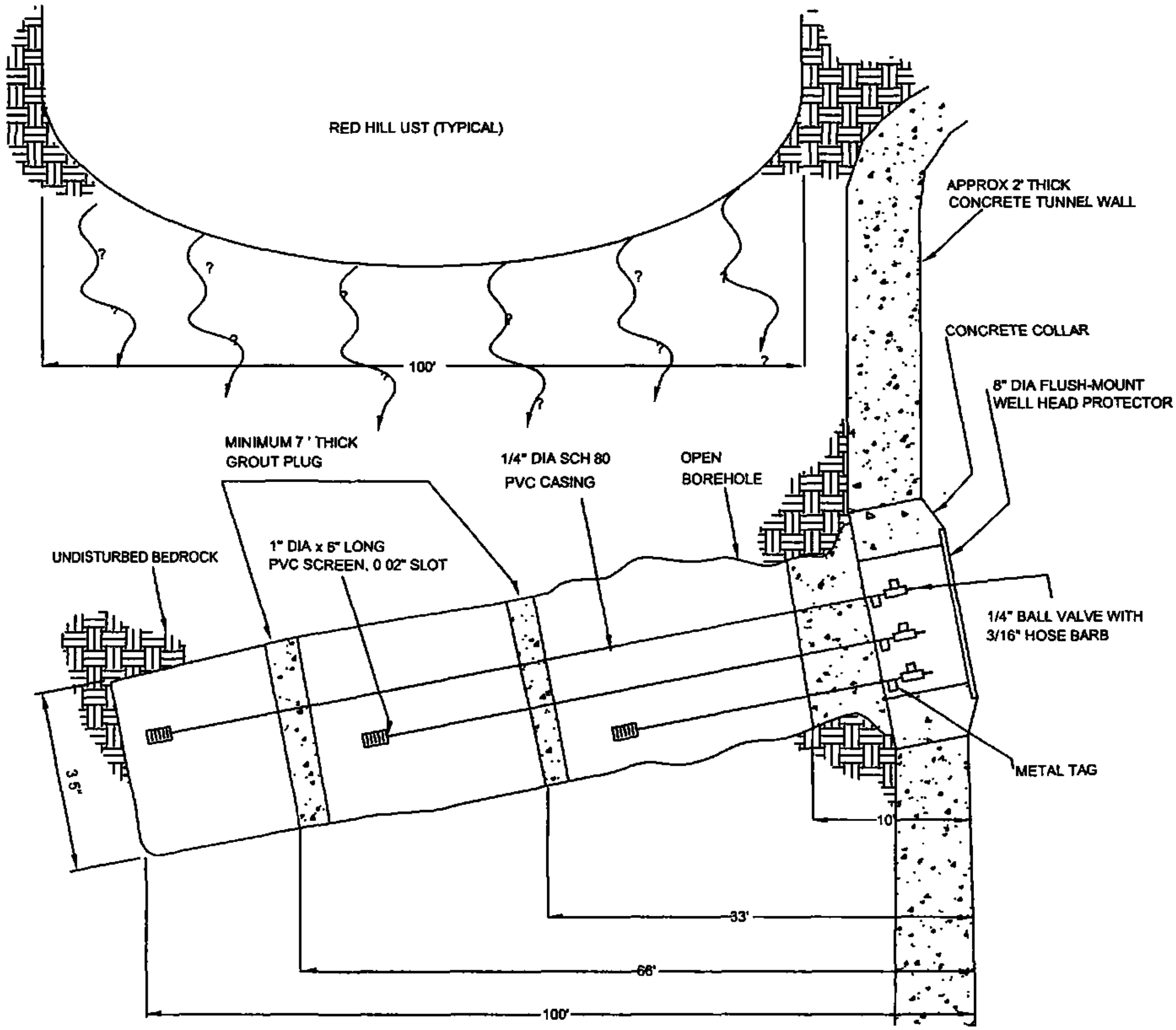

Figure 3-1
Soil Vapor Monitoring Point Construction Details
Red Hill Bulk Fuel Storage Facility

SECTION 4
ANALYTICAL PROGRAM

This section presents the analytical program for this FSP. Chemical analytical requirements for the field investigation have been developed to support the data quality objectives (DQOs) described in Section 3 of the WP. The parameters and analyses identified in the QAPP program have been selected based on the COPCs identified for the RHSF. The following sections identify the analytical parameters selected for each sample type and location.

4.1 Subsurface Soil/Rock Analyses

Soil borings will be located in specific areas of the Tank Farm to avoid contact with petroleum-impacted material in the vadose zone. However, if large petroleum releases have occurred in the past at tanks near these locations, LNAPL may have migrated the 80 to 90 feet laterally to be intercepted by the boreholes. All cores from the tunnel borings, and periodic rock cuttings (every 5 feet) from the background boring, will be screened by an experienced environmental geologist using field organic vapor analyzers and field observations to determine when samples should be collected. Soil/rock samples will be obtained within the three (3) newly excavated borings proposed at the Site. Solid and fragmented rock cores will be pulverized by the laboratory to facilitate analysis. It is anticipated that a maximum of six (6) primary and three (3) QC samples (one field duplicate, one matrix spike/matrix spike duplicate [MS/MSD], and one equipment blank) samples will be submitted to the laboratory to be analyzed for Volatile TPH - gasoline range organics (GRO) using method SW846 8015B, Semi-Volatile TPH - diesel range organics (DRO) using method SW846 8015B, Volatile Petroleum Hydrocarbons (VPH) using method Massachusetts Department of Environmental Protection (MADEP) VPH, Extractable Petroleum Hydrocarbons (EPH) using method MADEP EPH, VOCs using method SW846 8260B, SemiVolatile Organic Compounds (SVOCs) using method SW846 8270C SIM, Lead using method SW846 6010B, and Tetraethyl Lead using method ASTM D3341 87M. The analytical program for subsurface soil and rock samples is summarized in **Table 4-1**.

Detected COPC concentrations will be screened against HDOH Tier 1 Environmental Action Level (EAL) soil criteria based on potential impact to potable groundwater toxicity and potential impact to soil vapor intrusion to buildings as defined in *Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater, Review Draft,* (HDOH 2004). These soil/rock threshold levels are presented on Table 3-1 in the companion WP. The decision rule for determining the need for further investigation is based on the detected COPC concentrations and the results of a comprehensive RA.

4.2 Groundwater Analyses

Two rounds of groundwater monitoring will be conducted during this field investigation. One (1) existing monitoring well and one (1) existing groundwater production well will be sampled during the first round of groundwater monitoring. For the first round, it is anticipated that two (2) primary and one (1) field duplicate groundwater samples will be submitted to the laboratory to be analyzed for alkalinity using method E310.1, methane using method RSK-175, and nitrate, sulfate, phosphate, chloride, and fluoride using method E300. Ferrous iron, dissolved oxygen, and carbon dioxide will be measured in the field using colorimetric methods and a field meter. The analytical program for groundwater samples is summarized in **Table 4-2.**

During the second round of groundwater monitoring, groundwater samples will be collected from one (1) existing monitoring well, one (1) existing groundwater production well, and the three (3) newly installed monitoring wells. During the second round of groundwater monitoring, it is anticipated that five (5) primary and one (1) field duplicate groundwater samples will be submitted to the laboratory to be analyzed for TPH-GRO using method SW846 8015B, TPH-DRO using method SW846 8015B, EPH using method MADEP EPH, VPH using method MADEP VPH, VOCs using method SW846 8260B, SVOCs using method SW846 8270C SIM, Lead using method SW846 6010B, Tetraethyl Lead using method ASTM D3341 87M, and Dissolved Lead using method SW846 6010B. In addition, these groundwater samples will be subjected to the following general chemistry analyses: alkalinity using method E310.1; methane using method RSK-175; dissolved silica using EPA Method 370.1/SM19 4500SID; nitrate, sulfate, phosphate, chloride, and fluoride using method E300; and sodium, magnesium, calcium, potassium, and strontium using method SW846 6010B. Ferrous iron, dissolved oxygen, and carbon dioxide will be measured in the field using colorimetric methods and a field meter. In addition, one (1) trip blank will be packed with the VOC samples being submitted to the laboratory and analyzed for VOCs using method SW846 8260B. The analytical program for groundwater samples is summarized in **Table 4-2.**

Detected COPC concentrations will be screened against HDOH Tier 1 EAL water quality criteria specifically for potable water toxicity to humans and potential impact of volatile intrusion to buildings. These water quality threshold levels are presented on Table 3-1 in the companion WP. The decision rule for determining the need for further investigation is based on the detected COPC concentrations and the results of a comprehensive RA.

4.3 Soil Vapor Analyses

Soil vapor samples will be obtained from monitoring points installed within three (3) existing angled borings at the Site. Three monitoring points will be installed at varying depths within each boring. It is anticipated that nine (9) primary and one (1) duplicate soil vapor samples will be submitted to the laboratory to be analyzed for VOCs using method TO-15. The analytical program for soil vapor samples is summarized in **Table 4-3.**

4.4 Field QA/QC Requirements and Procedures

Quality assurance/quality control (QA/QC) field procedures will be followed to ensure viability and integrity of sample analytical data. Field duplicates, equipment rinsates, and trip blanks will be collected. Guidelines for minimum QC samples are presented in the QAPP **(Work Plan, Appendix B)**. In summary, field duplicate samples will be collected at a minimum of 10% of primary samples; one equipment rinsate will be collected from non-disposable equipment for soil/rock and one will be collected for groundwater per sampling event; trip blanks will accompany each cooler containing the VOC samples that are not frozen (water) and will be analyzed for the same VOC analytes as the primary water samples; and temperature blanks will accompany each cooler shipped to the laboratory.

4.5 Laboratory QA/QC Requirements and Procedures

Laboratory QC samples are analyzed by the laboratory as part of the standard laboratory QC protocols are presented in the QAPP **(Work Plan, Appendix B)**. The laboratory monitors the precision and accuracy of the results of its analytical procedures through analysis of QC samples. Laboratory QC samples consist of MS/MSD samples for organic analysis and a laboratory duplicate and MS samples for inorganic analyses. Laboratory QC samples will be collected and analyzed in accordance with SOP III-A and III-G in the *Project Procedures Manual* (PACDIV 1998). Laboratory QC MS/MSD samples are an aliquot (subset) of the field sample. They are not separate samples, but a special designation of an existing sample. Laboratory QC MS/MSD samples will be analyzed for the same analyses as the standard samples. At a minimum, one MS/MSD sample is required per 20 samples (including blanks and duplicates). The QC level selected for the Red Hill investigation will be the NAVFAC Level D.

4.6 Data Validation

Full data validation will be performed on 10% of all analyses. Data from all other analyses will undergo a data quality review. Validation and data quality review will be performed according to the current EPA functional guidelines for organic and inorganic data review, the EPA Office of Solid Waste and Emergency Response (OSWER) SOPs for inorganic and organic data review, SW-846 Method requirements, and project-specific requirements specified in the QAPP **(Work Plan, Appendix B)**. Results of the data validation and data quality review will be presented in the Data Validation Report.

Table 4-1
Summary of Analytical Program for Subsurface Soil/Rock Samples
Red Hill Bulk Fuel Storage Facility
Pearl Harbor, Hawaii

Sample Description	Sample Type	Matrix	TPH-DRO 8015B	TPH-GRO 8015B	MADEP EPH	MADEP VPH	VOCs 8260B	SVOCs 8270C SIM	Pb 6010B	Tetraethyl Pb ASTM D3341 87M	Comments
Basal Aquifer											
RHMW02*	N	SO	2	2	2	2	2	2	2	2	
RHMW03*	N	SO	2	2	2	2	2	2	2	2	
RHMW04*	N	SO	2	2	2	2	2	2	2	2	
Totals - Environmental samples			6	6	6	6	6	6	6	6	
QC Samples (estimated numbers)											
Duplicates (RHMW06)	FD	SQ	1	1	1	1	1	1	1	1	FD (RHMW02)
Trip Blanks	TB	WQ	-	-	-	-	-	-	-	-	
MS/MSD	MS/SD	SQ	1	1	1	1	1	1	1	1	
Equipment Blanks	EB	WQ	1	1	1	1	1	1	1	1	RHBHEB-1, -2
Totals (QC samples)			3	3	3	3	3	3	3	3	
Grand Total			9	9	9	9	9	9	9	9	

Notes:

* Borings converted into Monitering wells

N	Normal Sample	MS/MSD	Matrix Spike/ Spike Duplicate
SO	Soil	EB	Equipment Blank
FD	Field Duplicate	SQ	Soil Quality Sample
TB	Trip blank	WQ	Water Quality Sample
VPH	Volatile Petroleum Hydrocarbons	MADEP	Massachusetts Department of Environmental Protection
EPH	Extractable Petroleum Hydrocarbons	Pb	Lead
VOC	Volatile Organic Compounds	GRO	Gasoline Range Organics
SVOC	Semi-Volitile Organic Compounds	DRO	Diesel Range Organics
TPH	Total Petroleum Hydrocarbons		

Table 4-2
Summary of Analytical Program for Groundwater Samples
Red Hill Bulk Fuel Storage Facility
Pearl Harbor, Hawaii

																	Field Measurements			
Sample Description	Sample Type	Matrix	TPH-DRO 8015B	TPH-GRO 8015B	VOCs 8260B	SVOC's 8270C SIM	Total Lead 6010B	Tetraethyl Pb ASTM D3341 87M	Dissolved Pb 6010B	MADEP EPH	MADEP VPH	Alkalinity E310.1	Methane RSK-175	Silica, Dissolved EPA370.1/ SM19 4500SID	Anions[1] E300	Cations[2] 6010B	Ferrous Iron	Dissolved Oxygen	Carbon Dioxide	Comments
Round 1																				
RHMW01	N	WG	-	-	-	-	-	-	-	-	-	1	1	-	1	-	1	1	-	
RHMW2254	N	WG	-	-	-	-	-	-	-	-	-	1	1	-	1	-	1	1	1	
Totals - Environmental samples			0	0	0	0	0	0	0	0	0	2	2	0	2	0	2	2	1	
QC Samples*																				
Duplicates (RHMW05)	FD	WQ	-	-	-	-	-	-	-	-	-	1	1	-	1	-	-	-	-	FD (RHMW01)
Trip Blanks	TB	WQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
MS/MSD	MS/SD	WQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Equipment Blanks	EB	WQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total QC samples for Round 1			0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	
Round 2																				
RHMW01	N	WG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
RHMW02	N	WG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
RHMW03	N	WG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
RHMW04	N	WG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
RHMW2254	N	WG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Totals - Environmental samples			5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
QC Samples*																				
Duplicates (RHMW05)	FD	WQ	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-	FD (RHMW01)
Trip Blanks	TB	WQ	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
MS/MSD	MS/SD	WQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Equipment Blanks	EB	WQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total QC samples for Round 2			1	1	2	1	1	1	1	1	1	1	1	1	1	1	0	0	0	
Grand Total (Rounds 1 and 2)			6	6	7	6	6	6	6	6	6	9	9	6	9	6	7	7	6	

Notes:

N	Normal Sample	EB	Equipment Blank
FD	Field Duplicate	WG	Groundwater
TB	Trip blank	WQ	Water Quality Sample
Pb	Lead		

1 = Anions by Method E300 include: Phosphate, Nitrate, Sulfate, Chloride, and Fluoride.
2 = Cations by Method SW846 6010B include: Sodium, Magnesium, Calcium, Potassium, and Strontium.
* Number of QC samples are estimated.

Table 4-3
Summary of Analytical Program for Soil Vapor Samples
Red Hill Bulk Fuel Storage Facility
Pearl Harbor, Hawaii

Sample Description	Sample Type	Matrix	VOCs TO-15	Comments
RHSV01-25	N	GS	1	
RHSV01-45	N	GS	1	
RHSV01-80	N	GS	1	
RHSV14-25	N	GS	1	
RHSV14-45	N	GS	1	
RHSV14-80	N	GS	1	
RHSV16-25	N	GS	1	
RHSV16-45	N	GS	1	
RHSV16-80	N	GS	1	
Totals - Environmental samples			9	
QC Samples (estimated numbers)				
Duplicates	FD	AQ	1	RHSV01-0
Trip Blanks	TB	WQ	-	
MS/MSD	MS/SD	AQ	-	
Equipment Blanks	EB	WQ	-	
Totals - QC samples			1	
Grand Total			10	

N	Normal Sample	MS/MSD
GS	Soil Gas	EB
FD	Field Duplicate	AQ
TB	Trip blank	WQ

SECTION 5
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Attachment A

Phase II Boring Logs

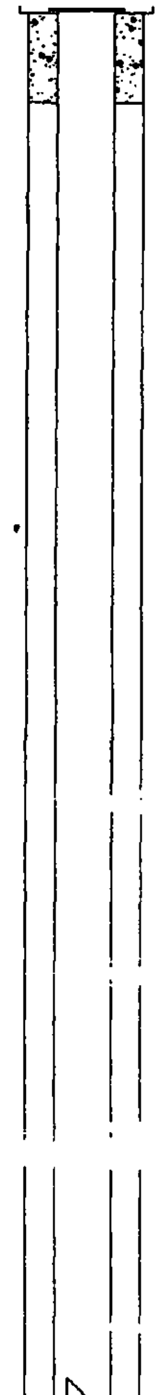
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-01
Project No. CTO 0229

LOCATION: Tank 1	ELEVATION: 102.66		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 02/08/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: 124.20
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/	Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
102.66	0	1	300		80	Concrete 0-2' over fine coarse sand, slightly fine gravel and silt; odor
102.01						
101.70		2	103.7	RH-BR-1-S01	29	Concrete fragments with metal and core 2.5-3.7'; odor Small vesicles; 10YR 2/2
100.77						
100.38		3	573	RH-BR-1-S02	80	Concrete 7.3-7.35'; small to medium vesicles 7.36-8.8'; strong odor; 10YR 2/2
	10	4	185		100	Small to medium vesicles; odor; 10YR 2/2 to 3/1
99.61		5	235.5		103	Small to medium vesicles; no odor; 10YR 3/1
98.62		6	204.8		100	Small vesicles; no odor; 10YR 2/2 to 2/1
97.90	20	7	38.9		100	Small vesicles; grout seams 20-22.9'; no odor; 10YR 2/1 to 5YR 3/2
96.60		8	301		100	Small vesicles; grout seams 24.05-26'; no odor; 10YR 2/2 to 5YR 3/3
95.93		9	NM		90	Small to medium vesicles; no odor; 10YR 2/2
94.58	30	10	147.1		113	Small to medium vesicles; grout seams throughout; no odor; 10 YR 3/1 to 5YR 3/2
93.39		11	164.3		102	Small to medium vesicles; grout seams throughout; no odor; 5YR 3/2 to 10YR 3/1
92.23	40	12	76.2		106	Small to large vesicles; grout seams 40-40.4 and 42.25-43.95'; no odor; 10YR 3/1 to 2/1
90.94		13	48.7		94	Small to large vesicles; grout seams 45.3-46.1, 47.3-48.95, and 49.05 -49.8'; no odor; 10YR 3/1 to 5YR 3/2
89.56	50	14	116		102	Small to medium vesicles; no odor; 5YR 3/2 to 10YR 3/1
88.27		15	266		100	Small to large vesicles; odor; 10YR 3/1
86.95	60	16	453	RH-BR-1-S03 RH-BR-1-D09 RH-BR-1-S04	100	Small to large vesicles; strong odor; 10YR 3/1
85.63		17	192		98	Small to large vesicles; grout seams 67.3-67.45'; strong odor; 10YR 3/1
84.26	70	18	478		102	Small to large vesicles; strong odor; 10YR 3/1
82.96		19	NM		87	Small to large vesicles; odor; 10YR 3/1

WELL CONSTRUCTION



This information pertains only to this boring and sh... ot be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

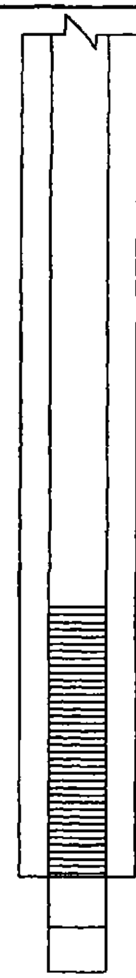
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-01
Project No. CTO 0229

LOCATION: Tank 1	ELEVATION: 102.66		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 02/08/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: 124.20
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
81.62 (80)	20	48.5		102	Small to medium vesicles; no odor; 10YR 3/1
80.45	21	NM		94	Small to large vesicles; grout seams 87.35-87.95'; no odor; 5YR 3/2 to 10YR 3/1
79.13 (90)	22	59.2		111	Small to medium vesicles; grout seams 90.9-92.45 and 93.1-93.35'; no odor; 10YR 3/1 to 5YR 3/2
77.92	23	43		86	Small to medium vesicles; no odor; 10YR 3/1
76.55 (100)	24	43.7		95	Small to large vesicles; silty clay in fractures 104.2-104.8'; no odor; 10YR 3/1
75.35	25	115.3		111	Small to large vesicles; no odor; 10YR 3/1
74.14 (110)	26	222.7		79	Small to medium vesicles; silty clay in vesicles; no odor; 10YR 3/1
72.84	27	151.7		119	Small to large vesicles; silty clay in some vesicles; no odor; 10YR 3/1
71.73 (120)	28	118.5		100	Small to large vesicles; silty clay noted in few vesicles and most fractures; no odor; 10YR 3/1
70.44	29	542		98	Small to medium vesicles; silty clay in fractures and vesicles; no odor; 10YR 3/1
69.09 (130)			RH-BR-1-S05		B-01 terminated at 129.7'
(140)					
(150)					

WELL CONSTRUCTION



This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

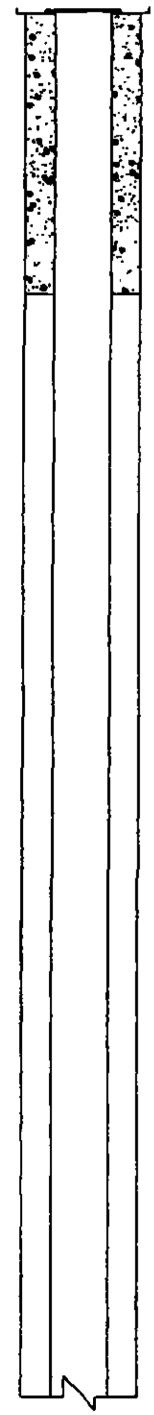
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-04
Project No. CTO 0229

LOCATION: Tank 4	ELEVATION: 102.62
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/29/01 — LOGGED BY: Gary Gleason
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER> FIRST: NA — COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
102.62 (0)	1	5.6		100		Concrete over fine to coarse sand with slight fine gravel and silt; no odor
101.97	2	95	RH-BR-4-S01	44		Concrete 2.5-3.8'; small to medium vesicles 3.8-7'; odor; 10YR 2/2
100.81	3	294		83		Fine to coarse sand with slight fine gravel, rock fragments, and silt; odor; 10YR 3/1
100.50	4	180	RH-BR-4-S02	100		Small to medium vesicles; odor; 10YR 3/1
99.72 (10)	5	103		89		Small to medium vesicles; slight odor; 10YR 3/1 to 5YR 3/2
98.58	6	225		100		Small to medium vesicles; odor; 10YR 3/1 to 5YR 3/2
98.43	7	48		100		Small to large vesicles; grout seams 19.9-20.15, 18.5, and 17.95'; no odor; 5YR 3/2 to 10YR 3/1
97.11 (20)	8	308		95		Small to large vesicles; grout seams 24.95-25.5'; no odor; 10YR 3/1
95.97	9	308		106		Small to primarily large vesicles; grout seams 25.4-27.8'; no odor; 10YR 3/1
94.73 (30)	10	NM		100		Small to primarily large vesicles; grout seams 30.05-30.15, 30.55, and 33.25-33.35'; no odor; 10YR 3/1
93.38	11	191		100		Small to primarily large vesicles; grout seams 36.55, 38.05-38.15, 39.85-40, and 40.5'; no odor; 10YR 3/1
92.14 (40)	12	465		100		Small to medium vesicles; grout seams 40.5-40.8'; no odor; 10YR 3/1
90.82	13	465		98		Small to large vesicles; grout seams 47.05, 48.05-48.7, and 50.4'; no odor; 10YR 3/1 to 5YR 3/2
89.45 (50)	14	120.1		100		Small to medium vesicles; grout seams 51.9-52.1 and 54.7'; no odor; 10YR 2/2
88.13	15	47.1		100		Small to medium vesicles; grout seams 59.35-59.5 and 59.95'; no odor; 10YR 2/2
86.81 (60)	16	465		81		Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/2
85.43	17	37.5		121		Small to medium vesicles; grout seams 68.85, 69.75-69.9, 69.97, and 70.7'; no odor; 10YR 2/2 to 5YR 3/2
84.32 (70)	18	46.5		100		Small to medium vesicles; grout seams 71.15, 72.65-71.55, and 75.9-73.75'; no odor; 5YR 3/2 to 10YR 2/2
82.98	19	51.7		100		Small to medium vesicles; grout seams 75.9-78.3 and

WELL CONSTRUCTION



Corrected elevations are provided for angle borings.

This information pertains only to this boring and sh... ...ot be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility	Boring/Monitoring Well No. B-04
CLIENT: PACNAVFACENGCOM	Project No. CTO 0229

LOCATION: Tank 4	ELEVATION: 102.62		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/29/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

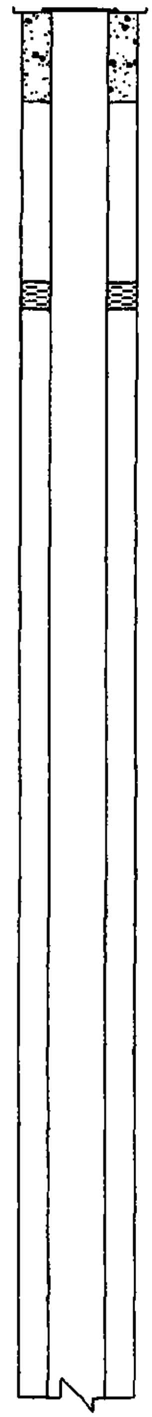
Corrected Elevation/	Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
							79.45-80'; no odor; 10YR 2/2	
81.66	80	20	66.1		98		Small to medium vesicles; grout seams 83.9-83.95 and 84. 45'; no odor; 10YR 3/2 to 5YR 3/2	
80.28		21	14.2		140		Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/2	
79.92	90	22	112.2		100		Small to medium vesicles; grout seams 87.7-89.8, 90.95- 91.45, 91.9, and 92.7'; no odor; 10YR 2/2 to 3/1	
78.60		23	NM		27		Small to medium vesicles; no odor; 10YR 3/1	
78.34		24	41.7		98		Small to large vesicles with primarily medium vesicles; 93.85-93.95, 94.3-94.5, and 96.1'; no odor; 10YR 3/1 to 2/2	
77.18	100	25	50.7		104		Small to medium vesicles; grout seam 99.8'; no odor; 10YR 3/1 to 5YR 3/2	
75.88		26	53.2		98		Small to medium vesicles; no odor; 10YR 2/2 to 3/1	
74.51	110	27	74.3		70		Small to large vesicles; no odor; 10YR 3/1 to 2/2	
73.22		28	96.4		100		Small to large vesicles; grout seams 113.6-114.15'; no odor; 10YR 3/1	
71.87	120	29	45.4		100		Primarily small to medium vesicles; grout seam 122.35'; no odor; 10YR 3/1	
70.55		30	91.6	RH-BR-4-S03 RH-BR-4-D08	100		Small vesicles; no odor; 10YR 3/1	
69.21	130						B-04 terminated at 129.1'	
	140							
	150							

This information pertains only to this boring and sh... ...ot be interpreted as being indicitive of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility	**Boring/Monitoring Well No.** B-06
CLIENT: PACNAVFACENGCOM	**Project No.** CTO 0229

LOCATION: Tank 6	ELEVATION: 105.68		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/19/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
105.68 — 0	1	78	RH-BR-6-S01(L)	100		Concrete 0-0.5'; strong odor	
105.16	2	132	RH-BR-6-S01(S) RH-BR-6-S02	20		Concrete over fine to coarse sand with fine gravel; strong odor; product present	
103.87							
103.45	3	0.6		81		Concrete 7-7.5'; primarily small to medium vesicles 7.5- 8.6'; odor; 10 YR 2/1 to 5YR 3/2	
	4	0		89			
102.76 — 10	5	163		100		Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/1	
						Small to medium vesicles; slight odor; 5YR 3/2 to 10YR 2/2	
101.41							
101.38	6	47		400		Small to medium vesicles; no odor; 10YR 2/2	
100.63	7	191		93		Small to medium vesicles; odor; 5YR 3/2 to 10YR 2/1	
100.06 — 20	8	121	RH-BR-6-S03 RH-BR-6-D07	100		Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/1	
	9	21		98		Small to primarily medium vesicles; grout seams 24.95-24.45'; no odor; 10YR 2/1 to 2/2	
98.92	10	40		98		Small to medium vesicles; grout seams 26.15-27.6, 29, and 30.05'; strong odor; 10YR 2/2 to 2/1	
97.68 — 30	11	65		70		Small to primarily large vesicles; odor; 10YR 2/1	
96.03	12	42		98		Small to large vesicles; grout seams 37.3-38.05 and 40.9-41.45'; slight odor; 10YR 2/2	
— 40							
94.65	13	66.7		105		Primarily small to medium vesicles; grout seams 42.95-46.9'; odor; 10YR 2/2	
93.54	14	40		96		Small to medium vesicles; grout seams 46.9-47.25'; odor; 10YR 2/2 to 5YR 3/2	
— 50							
92.14	15	65		100		Small to medium vesicles; grout seams 52.7-53, 53.55-53.85, and 56.9-57.1'; odor; 10YR 2/2 to 2/1	
90.80	16	26		98		Small to medium vesicles; grout seams 57.9-59.5, 59.9, and 60.65'; no odor; 5YR 3/2 to 10YR 2/2	
— 60							
89.40	17	16		98		Small to large vesicles; grout seams 63.35, 65.4-65.9, 66.1-66.35, and 68.1'; no odor; 10YR 2/2	
88.03	18	25		102		Small to large vesicles; grout seams 68.7 and 71.1-71.3'; no odor; 10YR 2/2	
— 70							
86.79	19	25		83		Medium to primarily large vesicles; no odor; 10YR 2/2	
85.57							

This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

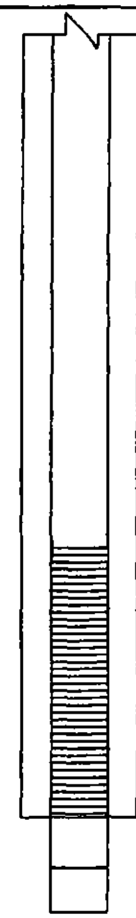
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-06
Project No. CTO 0229

LOCATION: Tank 6	ELEVATION: 105.68
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/19/01 — LOGGED BY: Gary Gleason
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER> FIRST: NA — COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
80	20	0.3		120		Small to large vesicles; no odor; 10YR 2/2 to 2/1
84.43	21	16.8		102		Small to medium vesicles; grout seams 82-82.3'; no odor; 10YR 2/1 to 5YR 3/2
83.14 / 90	22	30.1		92		Small to medium vesicles; grout seams 88.2-90.4, 91.05- 91.55, and 91.8'; no odor; 5YR 3/2 to 10YR 2/1
81.82	23	10.1		111		Small to medium vesicles; grout seam 91.75'; no odor; 10YR 2/1 to 5YR 3/2
80.60	24	3		98		Small to large vesicles; no odor; 5YR 3/2 to 10YR 3/1
100 / 79.23	25	0.9		106		Small to large vesicles; no odor; no odor; 10YR 3/1
77.96	26	17.8		100		Small to large vesicles; no odor; 10YR 3/1 to 5YR 3/2
110 / 76.61	27	12.2		95		Primarily small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/1
75.19	28	3.3		21		Small vesicles; no odor; 5YR 3/2
120 / 73.82	29	0		68		Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/2
73.17 / 72.91	30	15	RH-BR-6-S04	250		Small to medium vesicles; no odor; 10YR 2/2
	31	10		100		B-06 terminated at 126.6'
130						
140						
150						

WELL CONSTRUCTION



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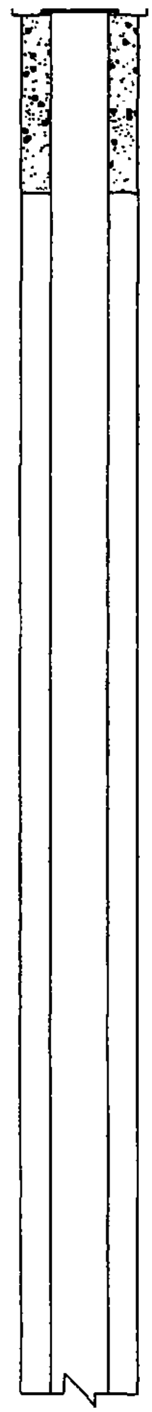
Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility	**Boring/Monitoring Well No.** B-11
CLIENT: PACNAVFACENGCOM	**Project No.** CTO 0229

LOCATION: Tank 11	ELEVATION: 117.98		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/15/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)		Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
117.98	0	1	NM		53	Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5'; basalt 2.5'; slight odor
116.95		2	14.1	RH-BR-11-S01	100	Basalt; strong odor
116.56		3	NM		60	Concrete and wood recovered; strong odor
116.43		4	NM		114	Concrete and wood recovered; strong odor
116.07		5	12.0		14	Wood recovered; slight odor
115.70	10	6	17.0		100	Medium vesicles; strong odor; 10YR 2/2
115.52		7	19.4	RH-BR-11-S02	100	Medium vesicles; sheen on rock; strong odor; 10YR 2/2
115.31		8	19.8		104	Medium vesicles; strong odor; 10YR 2/2
114.07		9	2.7		100	Medium vesicles; no odor; 10YR 2/2
112.73	20	10	3.1	RH-MW-11 (FP)	95	Large vesicles; slight odor; 10YR 2/2
111.67		11	4.0		100	Medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
110.32	30	12	2.3		45	Large vesicles; no odor; 5YR 3/2
108.09	40	13	9.8		102	Medium vesicles; slight odor; 10YR 2/2
106.77		14	0.0		98	Medium vesicles; slight odor; 10YR 2/2
105.43	50	15	0.5		100	Small vesicles; no odor; 10YR 2/2
104.11		16	0.2		102	Medium vesicles; no odor; 10YR 2/2
102.79	60	17	0.2		72	Medium vesicles; no odor; 10YR 2/2
101.75		18	24.3		96	Large vesicles; strong odor; 5YR 3/2
				RH-BR-11-S03		
	70					
99.01		20	3.9		90	Medium vesicles; no odor; 5YR 3/2
98.23		21	2.8		100	Large vesicles; no odor; 10YR 2/2

WELL CONSTRUCTION



Corrected elevations are provided for angle borings.

This information pertains only to this boring and should not be interpreted as being indicative of the site.

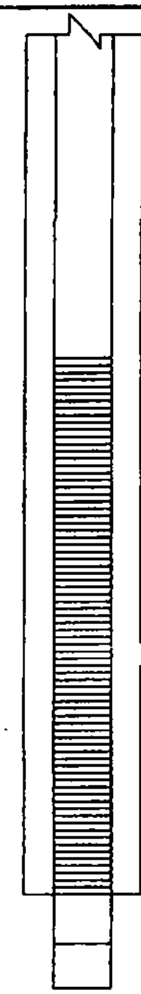
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-11
Project No. CTO 0229

LOCATION: Tank 11	ELEVATION: 117.98		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/15/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)		Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
96.91	80	22	21.4		39		Medium vesicles; grout seam 86.5'; strong odor; 10YR 2/2
95.46		23		RH-BR-11-S04	20		Medium vesicles; no odor; 10YR 2/2
94.82	90	24	55.8		96		Large vesicles; grout seams 90.2, 91.4, and 94.8'; strong odor; 10YR 2/2
93.42		25	80.3	RH-BR-11-S05	93		Large vesicles; strong odor; 10YR 2/2
92.59		19	7.9		100		Large vesicles; strong odor; 5YR 3/2
92.28	100	26	3.5		106		Large vesicles; grout seam 101.1'; no odor; 10YR 2/2
91.06		27	1.6		93		Medium vesicles; no odor; 10YR 2/2
89.67	110	28			104		Large vesicles; no odor; 10YR 2/2
88.35		29	0.5		43		Small vesicles; no odor; 10YR 2/2
86.53	120	30					Medium vesicles; no odor; 10YR 2/2
84.85		31			17		Small vesicles; no odor; 10YR 2/2
84.07	130						B-11 terminated at 131.0'
	140						
	150						

WELL CONSTRUCTION



This information pertains only to this boring and sh... not be interpreted as being indicative of the site.

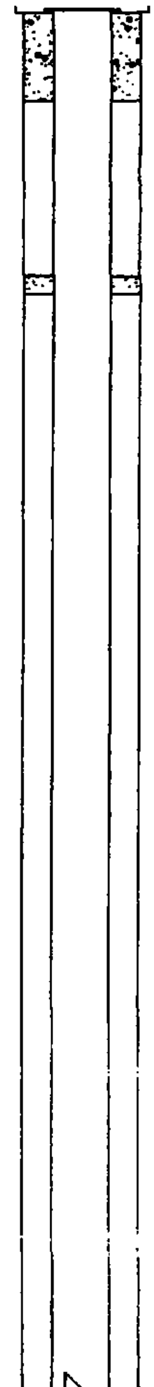
Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-13
Project No. CTO 0229

LOCATION: Tank 13	ELEVATION: 121.95		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/8/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)		Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
121.95	0	1	NM		100		Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5; basalt 2.5'; odor; sheen on drill water	
120.92								
120.50		2	179.2		4		Small vesicles; strong odor; 10YR 5/3	
119.98		3	83.2		73		Small vesicles; strong odor; 10YR 3/1	
119.88		4	92.9	RH-BR-13-S04	100		Large vesicles; strong odor; 10YR 2/2	
119.72	10	5	10.7		100		Sample was obtained from adjacent boring	
			4.4				Large vesicles; no odor; 10YR 2/2	
118.46								
		6	6.4		100		Medium vesicles; no odor; 10YR 2/2	
117.84								
		7	6.7		68		Large vesicles; no odor; 10YR 2/2	
116.77	20						Lava tube 20-22.8'	
115.84								
		8	5.7		91		Large vesicles; no odor; 10YR 2/2	
114.50								
	30	9	7.0		100		Medium vesicles; no odor; 10YR 2/2	
113.20		10	7.4		100		Large vesicles; no odor; 10YR 2/2	
111.91	40	11	6.8		104		Large vesicles; no odor; 10YR 2/2	
110.72		12	3.3		64		Large vesicles; no odor; 10YR 2/2	
109.81		13	4.4		113		Medium vesicles; no odor; 10YR 2/2	
108.67	50	14	2.3		102		Medium vesicles; no odor; 10YR 2/2	
107.35		15	5.9		93		Small vesicles; no odor; 5YR 2.5/2	
105.96	60	16	7.1		100		Small vesicles; no odor; 5YR 2.5/2	
104.97		17	5.5		102		Medium vesicles; no odor; 10YR 2/2	
103.65	70	18	5.3	RH-BR-13-S01 RH-BR-13-D05	94		Medium vesicles; no odor; 10YR 2/2	
102.25		19	6.8		100		Medium vesicles; no odor; 10YR 2/2	



Corrected elevations are provided for angle borings.

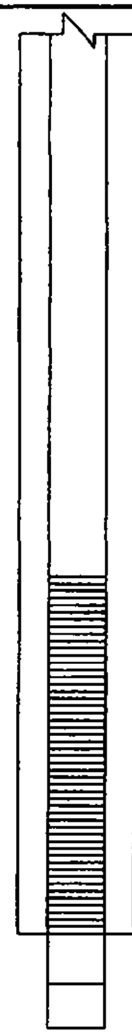
This information pertains only to this boring and sho ot be interpreted as being indicitive of the site.

PROJECT: Red Hill Bulk Storage Facility	**Boring/Monitoring Well No.** B-13
CLIENT: PACNAVFACENGCOM	**Project No.** CTO 0229

LOCATION: Tank 13	ELEVATION: 121.95		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/8/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
100.93 / 80	20	7.0		84		Small vesicles; no odor; 10YR 2/2 to 5YR 2.5/2
99.33	21	5.8		98		Small vesicles; no odor; 10YR 2/2
97.96 / 90	22	7.8		102		Medium vesicles; no odor; 10YR 2/2
96.66	23	5.5		96		Small vesicles; no odor; 10YR 2/2
100			RH-BR-13-S02			
95.29	24	6.8		100		Medium vesicles; no odor; 5YR 2.5/2
93.95	25	6.7		104		Large vesicles; no odor; 10YR 2/2
110						
92.65	26	5.7		94		Medium vesicles; no odor; 10YR 2/2
91.41	27	5.0		100		Small vesicles; no odor; 10YR 2/2
120						
90.09	28	5.1		104		Small vesicles; no odor; 10YR 2/2
			RH-BR-13-S03			
88.80	29	1.9		100		Small vesicles; no odor; 10YR 2/2
130						
87.50						B-13 terminated at 133.1'
140						
150						

WELL CONSTRUCTION



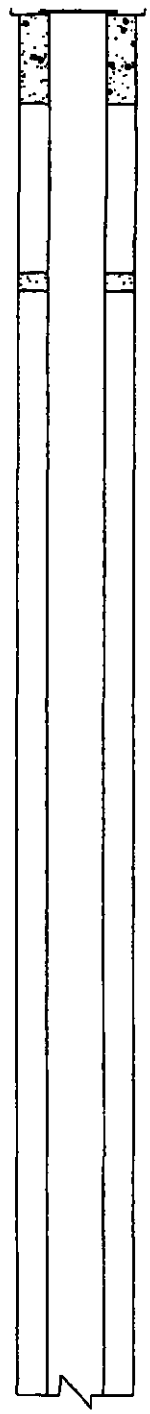
This information pertains only to this boring and sh... t be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-14
Project No. CTO 0229

LOCATION: Tank 14	ELEVATION: 121.75		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/05/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
121.75 — 0	1			13		Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5'; basalt 2.5'	
	2			75			
119.60	3	0.0		95		Medium vesicles; 10YR 3/1	
119.11 — 10	4	0.0		100		Medium vesicles; grout seam 13.2'; 10YR 3/1 to 2/2	
117.76	5	0.0		100		Medium vesicles; 10YR 3/1	
116.50 — 20	6	0.0		102		Medium vesicles; grout seams 23.4-25'; 10YR 2/2	
115.18	7	2.0		98		Small vesicles; grout seams 26.7-28.3 and 30.4'; 10YR 2/2	
113.80 — 30	8	6.2		98		Medium vesicles; grout seams 31.5-33.5 and 34.9'; 10YR 3/2	
112.43	9	9.8	RH-BR-14-S01	102		Large vesicles; grout seams throughout; 10YR 3/2	
111.11 — 40	10	10.8		102		Medium vesicles; 10YR 3/1	
109.82	11	4.7		100		Medium vesicles; 10YR 3/1	
108.52 — 50	12	2.0		100		Grout seam 55.7'; 10YR 2/2	
107.20	13	2.0		100		Small vesicles; grout seam 57.1'; 10YR 3/2	
105.86 — 60	14	1.6	RH-BR-14-S02 RH-BR-14-D04	92		Small vesicles; 10YR 2/2	
104.51	15	0.6		113		Medium vesicles; grout seam 67.2, 68, 68.7, and 69.7-70.8'; 10YR 2/1	
103.35 — 70	16	NM		100		Medium vesicles; grout seam 72'; 10YR 3/2	
102.03	17	1.6	RH-BR-14-S03	98		Large vesicles; 10YR 2/2	

Corrected elevations are provided for angle borings.

This information pertains only to this boring and sh... ...ot be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility	Boring/Monitoring Well No. B-14
CLIENT: PACNAVFACENGCOM	Project No. CTO 0229

LOCATION: Tank 14	ELEVATION: 121.75		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/05/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
100.66 (80)	18	2.0		102		Medium vesicles; 10YR 2/2	
99.49	19	19.8		100		Medium vesicles; grout seam 90.2-91.2'; 10YR 2/2	
98.15 (90)	20	19.7		100		Small vesicles; grout seams throughout; 10YR 2/2; heavy staining on core	
96.83	21	44.4	RH-BR-14-S04	100		Large vesicles; grout seam 100.4'; 10YR 2/2	
95.51 (100)	22	9.1		100		Small vesicles; hydrocarbon odor and stain; 10YR 2/2	
94.16	23	3.9		100		Medium vesicles; grout seam 109.3-110.7'; hydrocarbon odor and stain; 10YR 2/2	
92.81 (110)	24	2.0		100		Small vesicles; hydrocarbon odor and stain; 10YR 2/2	
91.47	25	NA	RH-BR-14-S05	102		Medium vesicles; hydrocarbon odor and sheen; 10YR 2/2	
90.20 (120)	26	2.0		96		Large vesicles; hydrocarbon odor and sheen; 10YR 2/ 2	
88.83 / 88.60	27	2.0		85		Large vesicles; hydrocarbon odor and sheen; 10YR 2/ 2	
(130)						Lava tube 128.1-129.2'	
87.22 / 86.55	28	68.4		100		Medium vesicles; 10YR 2/2	
(140)						B-14 terminated at 136.0'	
(150)							

This information pertains only to this boring and sh ot be interpreted as being indicitive of the site.

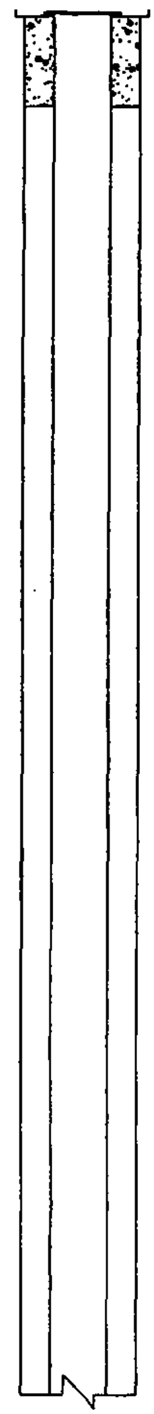
Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility	**Boring/Monitoring Well No.** B16A
CLIENT: PACNAVFACENGCOM	**Project No.** CTO 0229

LOCATION: Tank 16A	ELEVATION: 125.70		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 10/21/98	LOGGED BY: Fermin Esquibell	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 11	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
125.70 (0)	1			69		Concrete 0-2' over grout 2-3.8'; basalt 3.8'; medium gray
125.32	2			86		Grout
124.98						Basalt; medium gray
124.25	3			103		Basalt; very dark gray
123.30 (10)	4			108		Basalt; gray
121.45 (20)	5			104		Basalt; grayish black
119.56 (30)	6			90		Basalt; medium gray
117.65 (40)	7			104		Basalt; dark, greenish gray
115.70 (50)	8			93		Basalt; dark, reddish brown
113.76 (60)	9			88		Basalt; medium dark gray
(70)	10			103		
110.91						

WELL CONSTRUCTION



This information pertains only to this boring and sh... ot be interpreted as being indicative of the site.

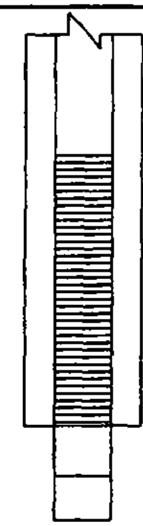
Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility	**Boring/Monitoring Well No.** B16A
CLIENT: PACNAVFACENGCOM	**Project No.** CTO 0229

LOCATION: Tank 16A	ELEVATION: 125.70		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 10/21/98	LOGGED BY: Fermin Esquibell	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 11	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
	11			102		Grout seam 81-81.8'
80						
109.72			BR16A-4 B16A-DUP			Basalt; brownish black; grout seam 84-85.6'
109.05	12			69		Basalt; medium dark gray
90						
107.62	13			100		Basalt; medium gray
106.81	14			91		Basalt; dusky, yellowish brown
100			BR16A-5			
105.70						B16A terminated at 104.8'
110						
120						
130						
140						
150						

WELL CONSTRUCTION



Corrected elevations are provided for angle borings.

This information pertains only to this boring and sh ot be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-20
Project No. CTO 0229

LOCATION: Tank 20	ELEVATION: 133.54	
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 3/2/01	LOGGED BY: Lance Williams
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER> FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2	

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
133.54 — 0	1	75.1		84		Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5'; basalt 2.5'; strong odor	
132.89	2		RH-BR-20-S01	24		Medium vesicles; no odor; 10YR 2/2	
131.60	3	375		40		Small vesicles; strong odor; 10YR 2/2	
	4		RH-BR-20-S02	85			
— 10; 130.56	5			100		Small vesicles; no odor; 10YR 2/2	
129.43	6			109		Medium vesicles; no odor; 10YR 2/2	
128.26 — 20	7			177		Small vesicles; no odor; 5YR 3/2	
127.92	8			84		Small vesicles; grout seam 22.7-25.2'; no odor; 5YR 3/2 to 10YR 2/2	
126.32	9			98		Small vesicles; no odor; 10YR 2/2 to 5YR 3/2	
— 30; 124.95	10			111		Small vesicles; no odor; 10YR 2/2	
124.25	11			90		Medium vesicles; no odor; 10YR 2/2	
122.90 — 40	12			113		Medium vesicles; no odor; 10YR 2/2	
121.71	13			100		Small vesicles; no odor; 5YR 3/2	
121.35	14			100		Small vesicles; no odor; 10YR 2/2	
120.50 — 50	15			96		Large vesicles; grout seam 52.3'; no odor; 10YR 2/2	
119.10	16			98		Medium vesicles; grout seam 58'; no odor; 10YR 2/2	
117.75 — 60	17			90		Large vesicles; grout seams 61.3-64.3 and 65.5'; no odor; 10YR 2/2	
116.46	18			111		Medium vesicles; no odor; 10YR 2/2	
115.24 — 70	19			52		Small vesicles; no odor; 5YR 2/2	
115.01						Clinker zone 71.6-73.6'	
'14.15	20			98		Small vesicles; grout seam 75.0-79.1'; no odor; 10YR 2/2	

This information pertains only to this boring and sh... ot be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-20
Project No. CTO 0229

LOCATION: Tank 20		ELEVATION: 133.54	
DRILLER: Salisbury & Associates, Inc.		DATE DRILLED: 3/2/01	LOGGED BY: Lance Williams
DRILL RIG: SAITECH EH5, Portable Core Drill		DEPTH TO WATER>	FIRST: NA / COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
113.04 — 80	21			62	Small vesicles; grout seam 79.4'; no odor; 10YR 2/2
112.42	22			66	Small vesicles; grout seam 81.7-81.9'; no odor; 10YR 2/2
111.44	23			100	Small vesicles; no odor; 5YR 3/2
110.40 — 90	24			103	Small vesicles; no odor; 5YR 3/2
109.65	25			96	Small vesicles; no odor; 10YR 2/2
108.95	26			69	Small vesicles; no odor; 10YR 2/2
108.54	27			31	Small vesicles; no odor; 10YR 2/2
107.87 — 100	28			73	Small vesicles; no odor; 10YR 2/2
107.48	29			100	Small vesicles; no odor; 10YR 2/2
107.30	30			32	Small vesicles; no odor; 5YR 3/2
106.65	31	NM	RH-BR-20-S03	50	Small vesicles; no odor; 5YR 3/2
106.03	32	NM		97	Large vesicles; no odor; 10YR 2/2
105.25 — 110	33			53	Small vesicles; no odor; 10YR 2/2
04.76	34			29	Small vesicles; no odor; 10YR 2/2
103.88	35			125	Small vesicles; no odor; 10YR 2/2
103.67	36	467		112	Small vesicles; no odor; 10YR 2/2
103.47	37			80	Medium vesicles; no odor; 10YR 2/2
102.30 — 120	38	629		75	Large vesicles; no odor; 10YR 2/2
100.98	39	420		147	Large vesicles; no odor; 10YR 2/2
100.49					BR-20 terminated at 127.7'
— 130					
— 140					
— 150					

WELL CONSTRUCTION

Corrected elevations are provided for angle borings.

This information pertains only to this boring and sh ot be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-V1D
Project No. CTO 0229

LOCATION: V1D - Basal Aquifer	ELEVATION: 102.56		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 2/13/01	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: 86.0	COMPL.: 86.1
BORING ANGLE: 90	WELL DIAMETER (inch): 1"		

Corrected Elevation/ Boring Length (ft)		Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
102.56	0	1	NM		100		Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5; basalt 2.5'; no odor
102.06		2	172		83		
98.56			NM				Small to large vesicles; no odor; 10YR 3/1
		3	NM		71		Small to medium vesicles; no odor; 10YR 3/1 to 2/1
95.36			99.2				
94.16		4	NM		0		Small vesicles; no odor; 5YR 3/2 to 10YR 2/2
93.66		5	NM		33		Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/2
91.76	10	6			100		
		7	124		105		Small to large vesicles; no odor; 10YR 2/2
		8			93		Small to large vesicles; no odor; 10YR 2/2 to 3/2
86.06		9	NM		96		Primarily small to medium vesicles; no odor; 10YR 2/2
81.66	20	10	NM		100		Small to primarily large vesicles; no odor; 10YR 2/2 to 5YR 3/2 to 10YR 3/1
76.26		11	3.2		100		Small to large vesicles; no odor; 10YR 3/1 to 5YR 3/2
71.26	30	12	10.8		100		Small to medium vesicles; no odor; 5YR 3/2 to 10YR 3/1
66.16		13	NM		102		Small to large vesicles; no odor; 5YR 3/2 to 10YR 3/1
60.96	40	14	NM		100		Small to large vesicles; no odor; 10YR 2/2 to 5YR 3/2
57.26							
56.91		15	NM		98		Small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
							Void
53.06	50	16	NM		98		Small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
48.06		17	1.0		89		Small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
43.36	60	18	6.9		100		Small to large vesicles; no odor; 10YR 3/1 to 2/2 to 5YR 3/2
38.36		19	1.8		83		Small to large vesicles; no odor; 10YR 2/5 to 5YR 3/2
34.26	70	20	0.0		92		Small to medium vesicles; no odor; 10YR 2/1 to 2/2 tp 5YR 3/2
29.16		21	0.0	RH-BR-V1D-S01	102		Small vesicles; no odor; 10YR 2/1

WELL CONSTRUCTION

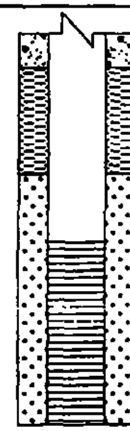
This information pertains only to this boring and sh... not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-V1D
Project No. CTO 0229

LOCATION: V1D - Basal Aquifer	ELEVATION: 102.56		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 2/13/01	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: 86.0	COMPL.: 86.1
BORING ANGLE: 90	WELL DIAMETER (inch): 1"		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
24.06	22	0		100		Medium vesicles; no odor; 10YR 2/2	
18.86	23	0.0	RH-BR-V1D-S02	106		Medium vesicles; no odor; 10YR 2/2	
15.66	24	0.0		96		Large vesicles; no odor; 10YR 2/1	
10.16							
9.56	25	0.0		86		Small vesicles; no odor; 10YR 2/2	
						Clinker zone 93-100'	
6.56							
4.96	26	0.0		56		Medium vesicles; clinker zone; no odor; 10YR 2/1	
4.96	27	0.0	RH-BR-V1D-S03	50		Medium vesicles; clinker zone; no odor; 10YR 2/2	
2.56						Clinker zone	
						B-V1D terminated at 100.0'	

Boring length scale: 80, 90, 100, 110, 120, 130, 140, 150

This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

Appendix B

Quality Assurance Project Plan

Red Hill Bulk Fuel Storage Facility Quality Assurance Project Plan (QAPP)

Pearl Harbor, Hawaii

June 2005

Department of the Navy
Commander
Naval Facilities Engineering Command, Pacific
Pearl Harbor, HI 96860-3134

NAVFAC
Naval Facilities Engineering Command
NAVFAC PACIFIC

Indefinite Delivery/Indefinite Quantity Contract
Contract Number N62742-02-D-1802, CTO 007

Red Hill Bulk Fuel Storage Facility Quality Assurance Protection Plan (QAPP)

Pearl Harbor, Hawaii

June 2005

Prepared for:

Department of the Navy
Commander
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite #100
Pearl Harbor, HI 96860-3134

Prepared by:

The Environmental Company, Inc.
1001 Bishop Street, Suite 1400
Honolulu, Hawaii 96813

and

AMEC Earth & Environmental, Inc.
3375 Koapaka Street, Suite F251
Honolulu, Hawaii 96819

Prepared under:

Indefinite Delivery/Indefinite Quantity Contract
Contract Number N62742-02-D-1802, CTO 007

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List of Acronyms

AMEC	AMEC Earth and Environmental, Inc.
ARAR	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
BS	Blank Spike
CAR	Certified Analytical Report
CCAL	Continuing Calibration
CCV	Continuing Calibration Verification
CLP	Contract Laboratory Program
COC	Chain-of-Custody
COPC	Chemical of Potential Concern
CTO	Contract Task Order
DQI	Data Quality Indicator
DQO	Data Quality Objective
EDD	Electronic Data Deliverable
EPH	Extractable Petroleum Hydrocarbons
FSP	Field Sampling Plan
GC/MS	Gas Chromatography/Mass Spectrometry
HDOH	Hawaii State Department of Health
ICAL	Initial Calibration
ICV	Initial Calibration Verification
LCS	Laboratory Control Sample
LIMS	Laboratory Information Management System
MADEP	Massachusetts Department of Environmental Protection
MDL	Method Detection Limit
MRL	Method Reporting Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NAPL	Non-aqueous Phase Liquid
NAVFAC	Naval Facilities Engineering Command
NIST	National Institute of Standards and Technology
OSWER	Office of Solid Waste and Emergency Response
PARCCS	Precision, Accuracy, Representativeness, Comparability, Completeness, and Sensitivity
QA	Quality Assurance
QC	Quality Control
QAM	Quality Assurance Manual
QAP	Quality Assurance Plan
QAPP	Quality Assurance Project Plan
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
SDG	Sample Delivery Group

SOP	Standard Operating Procedure
SQL	Sample Quatitation Limit
SVOC	Semi-Volatile Organic Compound
TEC	The Environmental Company, Inc.
TPH	Total Petroleum Hydrocarbons
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VOA	Volatile Organic Analysis
VOC	Volatile Organic Compound
VPH	Volatile Petroleum Hydrocarbons
WP	Work Plan
%R	Percent Recovery

SECTION 1

INTRODUCTION

This Quality Assurance Project Plan (QAPP) has been prepared as a companion document to the Work Plan (WP) to support generation of groundwater and soil data under activities specified in the WP for the Red Hill Bulk Fuel Storage Facility (Site). This QAPP describes the policy, organization and functional activities necessary to collect data of known quality that will stand up to legal and scientific scrutiny. This includes defining data quality needs of the project, the quality assurance/quality control (QA/QC), and data management activities needed to achieve these data quality needs. A field sampling plan (FSP), including number type and location of samples, is provided as Appendix A of the WP.

This QAPP has been prepared by The Environmental Company, Inc. (TEC) and AMEC, Earth and Environmental (AMEC) for Naval Facilities Engineering Command (NAVFAC), Pacific as part of Contract Task Order (CTO) 007. All work for these planning documents have been authorized under the U.S. Navy Environmental Contract No. N62742-02-1802.

This QAPP has been prepared using guidance elements from the Hawaii State Department of Health (HDOH) document Technical Guidance Manual for Underground Storage Tank (UST) Closure and Release Response, Appendix 7B, Suggested Outline of a Quality Assurance Project Plan (HDOH, 2000). It is intended for use only in conjunction with the Site WP and FSP. The WP describes project data quality objectives (DQOs) and intended use of data generated during this project. The field sampling program is addressed in Section 5 of the WP and Sections 2 through 4 of the FSP, and describes the proposed field procedures and analytical parameters. NAVFAC approved Standard Operating Procedures (SOPs) for specific field tasks (e.g., monitoring well sampling) are included in the WP as Appendix H.

A summary of analytical methods and sample matrices that will be used for the analysis of these samples is presented in **Table 1-1** through **Table 1-3**.

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SECTION 2

DATA QUALITY OBJECTIVES AND INDICATORS

2.1 PROJECT DATA QUALITY OBJECTIVES

Project-level DQOs and Applicable or Relevant and Appropriate Requirements (ARARs) to be considered for data collected during this project are outlined in the WP. The ARARs are based on "TIER 1 ACTION LEVELS FOR GROUND WATER RAINFALL ≤ 200 CM/YEAR, DRINKING WATER SOURCE THREATENED" for Site contaminants of potential concern (COPCs) as detailed in Section 3 of the WP. The primary DQO supported by this QAPP is production of chemical analysis data of known and sufficient quality to support the project-level DQOs defined in Section 4 of the WP.

Definitive data are required to achieve the project-level DQOs, and strict adherences to requirements of this document are required so that the data are of known and sufficient quality. The data quality indicators (DQIs) discussed in the following section of this document will be used to control data quality; laboratory compliance with DQI goals, analytical methodology requirements, and good laboratory practice will be assessed during the data verification and validation procedure.

Field measurement of chemical and physical parameters and the subsequent results will be used to assess Site conditions for worker's health and safety, to evaluate groundwater conditions for sample collection, and to screen for possible presence of any potential non-aqueous phase liquid (NAPL). Field measurement methodology is discussed in the SOPs. The tolerable limits on uncertainty and resulting decision errors are less stringent for field measurements than the limits for definitive data.

Precision, accuracy, representativeness, comparability, completeness, sensitivity (PARCCS) criteria and DQIs are described in detail in Section 2.2 of this document. **Table 2-1** provides a comprehensive summary of the desired detection limits, reporting limits and corresponding analytical objectives for precision and accuracy on a compound specific basis.

2.2 DATA QUALITY INDICATORS (DQIS)

The DQIs presented in this section are: precision, accuracy, representativeness, comparability, completeness, sensitivity (PARCCS), and the additional indicator of selectivity. PARCCS can be applied to both field and laboratory analytical measurements to ensure that data of known and appropriate quality are obtained to support specific decisions or regulatory actions. Selectivity is a data quality indicator that applies specifically to laboratory data to ensure that reported data are representative of the reported compound, and not of a positive or negative artifact. Discussion of the project DQIs in this QAPP will be limited to their application and goals for purposes of this project. Except where specified, the DQI goals discussed below are not intended to be used as criteria for acceptance or rejection of data, but rather as guidance to indicate when further evaluation of data quality is needed.

2.2.1 PRECISION

Precision is defined as the degree of agreement between or among independent, similar, or repeated measures. Precision will be measured as the relative percent difference (RPD) between duplicate analyses when analyte concentration is greater than five times the method reporting limit (MRL) or sample quantitation limit (SQL), and as an absolute concentration based on the MRL or SQL when analyte concentration is less than five times the MRL or SQL.

When analyte concentrations are more than five times the MRL or SQL, precision will be calculated as the RPD as follows:

$$\%RPD_i = \left(\frac{2 \times |O_i - D_i|}{(O_i + D_i)} \right) \times 100$$

Where:

$\%RPD_i$= Relative percent difference for compound i

O_i = Concentration of compound i in original sample or matrix spike (MS)

D_i = Concentration of compound i in duplicate sample or matrix spike duplicate (MSD)

For laboratory precision, performance goals will be:

- RPD between duplicate blank spikes less than or equal to 20%.
- RPD between duplicate samples less than or equal to 30% for analyte concentrations greater than or equal to five times the MRL or SQL, and the absolute concentration difference less than or equal to the MRL or SQL for analyte concentrations less than five times the MRL or SQL.
- RPD between duplicate MSs less than or equal to 30%.

If these goals are not met, the laboratory will investigate the cause of the DQI exceedance and include a discussion of the exceedance and any impact on data usability in the case narrative. If the cause of the DQI exceedance is determined to be laboratory error, the laboratory will reprepare and/or reanalyze the sample as appropriate.

Precision related to sample collection in the field will be monitored as the difference between field duplicates. The RPD between field duplicates for samples with analyte concentrations greater than the MRL or SQL will be less than or equal to 30% for aqueous and air samples and less than or equal to 40% for soil samples. The absolute concentration difference between duplicate samples with concentrations less than five times the MRL or SQL will be less than or equal to the corresponding MRL or SQL. If this DQI goal is exceeded, AMEC will investigate possible causes and will discuss the results of the investigation and any effect on data usability in the data quality evaluation report.

2.2.2 ACCURACY

Accuracy is the amount of agreement between a measured value and the true value. It will be monitored as the percent recovery (%R) of the MS and/or the MSD, laboratory control samples (also known as blank spikes), and surrogate spike compounds. It will also be measured using the analytical results of instrument calibration and other laboratory internal standards.

Accuracy will be calculated as the %R of analytes as follows:

$$\%R_i = \left(\frac{Y_i}{X_i}\right) \times 100$$

Where:

$\%R_i$ = percent recovery for compound i

Y_i = measured analyte concentration in sample i (measured - original sample concentration)

X_i = known analyte concentration in sample i

Project-specific DQI goals for each type of accuracy control sample are discussed below and will be applied unless an analytical method contains defined performance criteria for the DQI.

The DQI goal for organic analyte and surrogate spike recovery in laboratory control samples is 70% to 130% of the known value for all compounds. Recovery in this range should be routinely achievable as the spike is added to an interference-free matrix.

The DQI goal for inorganic analyte recovery in laboratory control samples is 80% to 120% of the known value for all compounds. Recovery in this range should be routinely achievable as the spike is added to an interference-free matrix.

The DQI goal for recovery of analytes and surrogate compounds spiked into the sample matrix is that recoveries outside the 60% to 140% recovery limits must be reflective of the sample matrix rather than laboratory procedural bias, and that all matrix-related recovery problems are adequately documented in the laboratory report and raw data. Compliance with this DQI goal will be assessed by comparison of analyte and surrogate recovery in the sample matrix to laboratory performance on method blanks and blank spikes, and by results of the data validation and data quality review process.

The DQI goal for recovery of inorganic analytes spiked into the sample matrix is that recoveries outside the 75% to 125% recovery limits must be reflective of the sample matrix rather than laboratory procedural bias, and that all matrix-related recovery problems are adequately documented in the laboratory report and raw data. Compliance with this DQI goal will be assessed by comparison of analyte recovery in the sample matrix to laboratory performance on method blanks and blank spikes, and by results of the data validation and data quality review process.

2.2.3 Representativeness

Representativeness requires a more subjective evaluation, which includes evaluating the adequacy of the number of samples collected given specific Site conditions and approved sampling procedures.

2.2.4 Comparability

Comparability also requires the use of subjective evaluation which includes review of such elements as normalizing data to standard conditions, such as reporting concentrations in soil based on dry weight, and appropriate units, such as those required for comparison against regulatory standards. Data for each analytical method will be reported in consistent units for each sample matrix to maximize data comparability.

2.2.5 Completeness

For the field sampling effort, completeness will be determined by calculating the percentage of the actual samples taken versus the number of samples scoped for the project. The field sampling effort will be at least 90% complete.

For each analytical method, completeness will be determined by calculating the ratio of non-rejected data points to the number of data points requested for analyses. Data will be at least 90 percent complete. Completeness will be assessed through data validation of 10 percent (by matrix) of the analytical results and data quality review of the remaining analytical results.

2.2.6 Sensitivity

Sensitivity refers to the need for MRLs and method detection limits (MDLs) that are sufficiently low to meet project data needs. For water and solid data generated as part of activities specified in the work plan, the methods must be sensitive enough to produce data that are usable to support human health and ecological risk assessment activities, to allow evaluation of contamination fate and transport, and to compare chemical concentrations to potentially applicable regulatory criteria.

The sensitivity goal is that MRL for each analyte be less than the Hawaii Tier 1 Action Level for Soil and Groundwater: Rainfall = 200 cm/year, Drinking Water Source Threatened. If the MRL cannot meet this goal, a secondary objective is that the MDL meet this goal.

A list of regulated compounds along with the applicable sensitivity goals is provided in **Table 2-2.**

SECTION 3

SAMPLING DESIGN, FIELD PROCEDURES, AND CHAIN OF CUSTODY

Sampling design and field procedures for this project are discussed in detail in the WP. Observations of field activities related to data collection are integral to comprehensive data evaluation. Field forms and notes should be up to date with respect to: samples to be collected, sample IDs, QA/QC sample collection requirements, and where the samples are to be turned in for analysis.

Samples shall be maintained under customary chain-of-custody (COC) protocols while in the field, until receipt by the lab. Samples will be transported directly to the contract laboratory or back to a secure facility at the end of the sampling day, soil and water samples will be stored in refrigerators, and air samples will be stored at room temperature until shipped. COC forms will be retained with the respective samples at all times and signed and dated appropriately.

Samples shall be submitted to the Project laboratories in sample delivery groups (SDGs) of approximately 20 field samples or fewer, if there are not 20 samples to include. Grouping the samples in sets of 20 allows efficient reporting of results, and facilitates the data verification and validation process because laboratory batches and associated quality control are based on groups of 20 samples.

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SECTION 4

SAMPLE COLLECTION AND PRESERVATION

Sample locations, sample collection procedures, and sample preservation are specified in the FSP. A summary of the sampling requirements for each laboratory method including laboratory containers, sample volumes, preservation, and holding times is provided as **Table 4-1**.

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SECTION 5

QUALITY CONTROL PROCEDURES AND CORRECTIVE ACTIONS

In order to attain data of sufficient quality to support project DQOs, specific procedures are required to allow evaluation of data quality. These procedures and requirements for their evaluation are described in this section.

5.1 FIELD QUALITY CONTROL

Evaluation of field sampling procedures requires the collection and evaluation of field QC samples. Trip blanks and field replicates will be collected and submitted to the laboratory to provide a means of assessing the quality of data resulting from the field sampling program.

5.1.1 TRIP BLANKS

Trip blanks will be used to evaluate whether the shipping and handling procedures are introducing contaminants into the samples, and if cross-contamination in the form of volatile organic compound (VOC) migration has occurred between the collected samples. One trip blank will be submitted to the laboratory for analysis each day that samples are collected for VOCs. Trip blanks will not be submitted for soil/rock samples because these samples will be submitted frozen, which will result in broken volatile organic analysis (VOA) vials due to thermal expansion. Trip blanks for water samples are VOA vials filled with purged deionized water that are transported to the field and then returned to the laboratory without being opened.

Trip blanks should not contain detectable concentrations of target analytes greater than the MRL for the compound. Any detection of target analytes in a trip blank will result in an investigation to determine effect on overall data usability, and affected results will be qualified as estimates or as non-detects at an elevated MRL as appropriate.

5.1.2 FIELD REPLICATE SAMPLES

Field replicates are collocated samples that are collected simultaneously in separate containers. The purpose of field replicates is to allow evaluation of the contribution of random error from sampling to the total error associated with the data. A minimum of one set of field replicates will be collected and submitted for every ten field samples collected. Field replicate precision will be evaluated as described in Section 2.2.1 above.

5.1.3 CALIBRATION REQUIREMENTS

Field-based analytical instruments, such as turbidometers and pH electrodes, must be calibrated following manufacturers' instructions and frequency recommendations (or following appropriate SOPs) before they may be used for data collection.

5.2 LABORATORY QUALITY CONTROL

Laboratory quality control samples are used to monitor the laboratory's precision and accuracy of the analytical procedure results. Laboratory QC samples are analyzed as part of the standard laboratory QC protocols and are accomplished through analyzing method blanks, laboratory control samples (blank spikes), surrogate spikes, and internal standards. Not all analyses require the above QC sample types. Typically, these QC samples are not required for non-SW-846 methods. Method specific laboratory QC samples are summarized in **Table 5-1**.

5.2.1 METHOD BLANKS

Method blanks will be used to check the level of laboratory background contamination. Laboratory method blanks will be analyzed with each sample batch. Results will be compared to all samples in the analytical batch.

Quality control criteria require that no contaminants be detected in the blank(s) above the MRL. If an analyte is detected, the action taken will follow the laboratory SOPs and QAMs. Blank samples will be analyzed for the same parameters as the associated field samples.

5.2.2 LABORATORY CONTROL SAMPLES

Laboratory control samples (LCS), also known as blank spikes (BS), are used to monitor the laboratory's day-to-day performance of routine analytical methods, independent of matrix effects. LCSs are prepared by spiking reagent water (aqueous samples) or silica sand (soil or sediment samples) with standard solutions prepared independently from those used in establishing instrument calibration. LCSs must undergo the same preparation, cleanup (if used), and analyses as the associated field samples. Results are compared on a per-batch basis to pre-established control limits and are used to evaluate laboratory performance for precision and accuracy.

5.2.3 Matrix Spike/Matrix Spike Duplicate

MS and MSDs are used to evaluate analytical (preparation and analysis) precision and accuracy (Section 2.2.1 and Section 2.2.2). The MS/MSDs will be collected and analyzed at a rate of 5% of the primary samples for each analytical method and matrix or at least one for each analytical batch, whichever is greater.

Because MS/MSD samples measure the effect of a specific sample matrix on analyte recovery, only MS/MSD samples from this investigation will be analyzed, and not samples from other projects. The MS/MSD samples will be analyzed for the same parameters as the primary samples in the same QC analytical batch. Results will be expressed as a percent recovery of the known spiked amount and as a RPD for the MS/MSD pairs.

The goal for recovery of analytes spiked into the sample matrix is that recoveries less than 60% or greater than 140% for organic analytes; or less than 75% or greater than 125% for inorganic analytes must be reflective of the sample matrix rather than procedural bias, and that all matrix-related recovery problems are adequately documented in the laboratory report and in the raw data. Compliance with this goal will be assessed by comparison of analyte and surrogate recovery in the sample matrix with laboratory performance on method blanks and blank spikes.

5.2.4 Laboratory Duplicates

Precision of the analytical system is evaluated by using laboratory duplicates. Laboratory duplicates are two portions of a single homogeneous sample analyzed for the same parameters. Laboratory duplicates will be prepared and analyzed for all analytical batches requiring duplicates as specified per method in the laboratory QAMs.

Not all methods require laboratory duplicates and matrix spike duplicates are preferred for many organic methods. LCS duplicates will be prepared and analyzed for all batched when insufficient sample is collected for matrix spike duplicates. The RPD calculation (precision) is described in Section 2.2.1.

5.2.5 SURROGATE SPIKES

Surrogate spikes are used to evaluate accuracy, method performance, and extraction efficiency. Surrogate compounds are compounds not normally found in environmental samples; however, they are similar to the target analytes in chemical composition and behavior in the analytical process. Samples for organic analysis will be spiked with surrogate compounds consistent with the requirements described in the laboratory SOPs and QAMs.

Since sample characteristics will affect the %R, %R is a measurement of accuracy of the overall analytical method on each individual sample. The %R of surrogates is calculated concurrently with the analytes of interest, using the equation in Section 2.2.2.

5.2.6 INTERNAL STANDARDS

Internal standards are used in gas chromatograph/mass spectrometry (GC/MS) analyses. A constant amount of internal standard is added to all standards, samples, and extracts. The ratio of the peak area, height, or intensity of the target analyte to the peak area, height, or intensity of the internal standard in the sample or extract is compared to a similar ratio derived for each calibration standard. The target analyte response is calculated relative to that of the internal standard.

For GC/MS analyses of soil and water samples, internal standard areas or heights for all blanks, samples, and spikes must be 50 percent to 200 percent of the internal standard areas or heights from the last passing continuing calibration (CCAL). The laboratory must re-prepare and/or reanalyze any blank, sample, or spike that does not meet this DQI goal. If the internal standard area or height does not meet the DQI goal upon reanalysis, the laboratory must include a discussion of the possible cause and effect on data usability in the case narrative.

5.3 INSTRUMENT CALIBRATION AND FREQUENCY

Analytical instrument calibration and maintenance will be conducted in accordance with the QC requirements identified in each laboratory SOPs and QAMs, U.S. Environmental Protection Agency (USEPA) guidance, and the instrument manufacturers' instructions. General requirements are discussed below.

5.3.1 STANDARD SOLUTIONS

A critical element in the generation of quality data is the purity/quality and traceability of the standard solutions and reagents used in the analytical operations. To ensure the highest purity possible, the primary reference standards and standard solutions will be obtained from the National Institute of Standards and Technology (NIST), the USEPA repository, or a reliable commercial source, and will be traceable to NIST Primary Reference Standards. The laboratories will maintain written records of the supplier, lot number, concentration, receipt date, preparation date, preparer's name, method of preparation, expiration date, and all other pertinent information for all standards, standard solutions, and individual standard preparation logs.

Standard solutions will be validated prior to use. Validation procedures can range from a check for chromatographic purity to verification of the concentration of the standard solution using another standard solution prepared at a different time or obtained from a different source. Stock and working standard solutions will be checked regularly for signs of deterioration, such as discoloration, formation of precipitates, or change of concentration. Care will be exercised in the proper storage and handling of standard solutions. All containers will be labeled as to compound, concentration, solvent, expiration date, and preparation data (initials of preparer/date of preparation). Reagents will be examined for purity by subjecting an aliquot or subsample to the corresponding analytical method.

5.3.2 BALANCES

Analytical balances will be calibrated annually according to manufacturer's instructions and have a daily calibration check against NIST Class I weights before use by laboratory personnel. Balance calibration shall be documented in appropriate bound logbooks with pre-numbered pages.

5.3.3 REFRIGERATORS

The refrigerators will be monitored for proper temperature by measuring and recording internal temperatures on a daily basis. At a minimum, thermometers used for these measurements will be calibrated annually, against a thermometer traceable to NIST.

5.3.4 WATER SUPPLY SYSTEM

The laboratories will maintain an appropriate water supply system that is capable of furnishing American Society for Testing and Materials (ASTM) Type II polished water to the various analytical areas. This laboratory pure water shall not contain detectable concentrations of target analytes or interfering substances.

5.3.5 LABORATORY AND FIELD INSTRUMENTS

Calibration of analytical instrumentation is required to ensure that the analytical system is operating correctly and functioning at the sensitivity required to meet project-specific DQOs. Each instrument will be calibrated with standard solutions appropriate to the instrument and analytical method, in accordance with the methodology specified and at the QC frequency specified in the laboratory SOPs.

The calibration and maintenance history of the laboratory instrumentation is an important aspect of the project's overall QA/QC program. As such, the initial calibration (ICAL), initial calibration verification (ICV) and continuing calibration verification (CCV) procedures will be implemented by trained personnel following the manufacturer's instructions and in accordance with applicable USEPA protocols to ensure the equipment is functioning within the tolerances established by the manufacturer and the method-specific analytical requirements.

5.3.5.1 Initial Calibration

ICAL of instruments used for the analysis of organic analytes in soil and water samples must be performed using a minimum of five standards for all single-component target analytes and surrogates.

- The relative standard deviation (RSD) shall be less than or equal to 15% for each compound included in the calibration standard, unless the criteria is superceded by method-specific acceptance limits, before an average response factor calibration may be considered valid. AMEC will not accept grand mean calibration models as valid for analytes that exceed RSD criteria.

- If RSD criteria cannot be met, linear or non-linear calibration models will be considered acceptable as long as the correlation coefficients are greater than or equal to 0.99.

- If a first order (linear) regression model is used for organic analytes, the line should not be forced through the origin, but have the intercept calculated from the five calibration points and the origin (0,0) must not be used as a fictitious calibration point. Additionally, the lowest calibration point must be at a concentration less than or equal to the method quantitation limit.

- If a second order (quadratic) model is used, six calibration standards instead of five must be analyzed. The curve must be continuous, continuously differentiable, and monotonic over the calibration range. The line must not be forced through the origin, but have the intercept calculated from the six calibration points. In addition, the origin (0,0) must not be included as a seventh calibration point.

Analytes with calibration models which cannot meet any of the above criteria may still be considered valid if AMEC has been notified in writing of the calibration difficulties before the start of analysis, and the laboratory qualified all affected data as estimated values.

ICAL of instruments used for the analysis of inorganic analytes will be conducted in accordance with the manufacturer's instructions and QC requirements identified in each laboratory SOP and QAM.

5.3.5.2 Initial Calibration Verification

Immediately after calibration, the analysis of an ICV standard containing the same analytes as the calibration standards, at a concentration close to the middle of the calibration range, and made from a different source, manufacturer, or lot number than the calibration standards will be required. ICV standards serve to verify the preparation and concentration of the instrument calibration standards. A single ICV is required each time the instrument is calibrated.

5.3.5.3 Continuing Calibration Verification

Continuing calibration verification (CCV – inorganic analyses) or continuing calibration (CCAL – organic analyses) standards will be analyzed (as per method requirements) to verify the calibration of the analytical system over time. If the response or calculated concentration for an analyte is within the method-specific acceptance limits of the response obtained during the initial calibration or the expected concentration, the curve is considered valid and analysis may proceed. Samples may not be analyzed unless the calibration curve is proven valid. Once verified, an organic ICAL is valid until a CCAL fails or significant instrument maintenance is performed. Calibration procedure frequency is summarized in **Table 5-1**.

5.3.6 PREVENTATIVE MAINTENANCE

Preventative maintenance on laboratory systems will be performed as needed. No project samples will be analyzed on a system that is not in good working order and properly calibrated.

SECTION 6

DATA MANAGEMENT PROCEDURES

AMEC and the project laboratories are responsible for generating, controlling, and archiving laboratory and field reports. This information should be maintained with a system that is effective for retrieval of any documentation that affected the reported results. This includes record generation and control, security, and maintenance for the project related documents.

6.1 DATA REDUCTION AND REPORTING

The QA Officer, Project Chemist, and Database Manager will work together to perform the final review and approval of the data prior to its entry into the database system. This will include examining the results for field duplicates, MS/MSDs, laboratory blanks, and laboratory duplicates to ensure they are acceptable. This will also include comparing the sample descriptions with the field sheets for consistency and ensuring that any anomalies in the data are appropriately documented.

6.1.1 FIELD DATA REDUCTION, REVIEW, AND DELIVERABLES

Field data will be reviewed to a lesser degree than laboratory data. The Field Manager will debrief field personnel during sampling events and identify anomalous data or observations. The Field Manager will evaluate if any action needs to be taken and make recommendations to the Project Manager.

6.1.2 LABORATORY DATA REDUCTION, REVIEW, AND DELIVERABLES

The project laboratories shall deliver final tabulated results and electronic data deliverables (EDDs) by email or fax in no more than 14 days after receipt of the final sample in each SDG. Hardcopy data packages shall be received by TEC no later than 30 days after receipt of the samples by the project laboratory.

It is possible that expedited turnaround time may be required on some project samples. If this is the case, it is expected that project laboratories will make every reasonable effort to accommodate the expedited schedule, or assist TEC to identify a qualified laboratory that can meet the schedule.

Data generated by the project laboratories will undergo data reduction and review procedures described in the laboratory QAMs and SOPs. Data generated, reduced, and reviewed by the laboratories will undergo a comprehensive data review by a QA reviewer or designee.

For all analyses, USEPA CLP equivalent Level IV deliverable requirements will be employed for documentation and reporting of all data. CLP report forms will not be required.

6.1.2.1 Laboratory Data Reduction

Each project laboratory will perform in-house analytical reduction under the direction of the laboratory QA manager. Laboratory reduction procedures will be those adopted, where appropriate, from SW-846 (EPA, 1997 and updates) and those described in the QAM. The data reduction steps will be documented, signed, and dated by the analyst or designee. Data reduction will be conducted as follows:

- Raw data produced by the analyst will be processed and reviewed for attainment of QC criteria as outlined in this document and/or established USEPA method for overall reasonableness and for calculation or transcription errors.
- Data will then be entered into the laboratory information management system (LIMS) and a computerized report will be generated and sent to the laboratory QA manager or designee for review.

Laboratory data reduction procedures will be those adopted, where appropriate, from Test Methods for Evaluation of Solid Waste, Physical/Chemical Methods, SW-846 (EPA, 1997 and updates), and those described in the laboratory QAMs. The data reduction steps will be documented, signed, and dated by the analyst.

Laboratory qualifiers as described and defined in the laboratory QAMs will include, but are not limited to:

- Concentrations below required reporting limits;
- Estimated concentrations due to poor spike recovery;
- Concentrations of the chemical also found in the laboratory blank; and

- Other sample-specific qualifiers necessary to describe QC conditions.

The laboratories will maintain detailed procedures for laboratory record keeping in order to support the validity of all analytical work. Each data report package submitted to the TEC Project Manager will contain the laboratory's written certification that the requested analytical method was run and that all QA/QC checks were performed. The laboratory program administrator will provide the TEC Project Manager with QC reports of the laboratory's external audits, if appropriate, which will become part of the project file.

6.1.2.2 Laboratory Data Review

The laboratory data review process involves evaluation of both the results of the QC data and the professional judgment of the person(s) conducting the review. This application of technical knowledge and experience to the data evaluation is essential to ensuring that high quality data are generated. Each project laboratory has documented procedures, which are to be followed and must be accessible to all laboratory personnel. The data review is generally conducted in a three-step process at the laboratory prior to submittal:

- Level 1 Analyst/Peer Data Review – The analysts review the quality of their work based on an established set of guidelines. The review will ensure at a minimum that: appropriate preparation, analysis, and SOPs have been followed; analytical results are correct and complete; QC samples are within established control limits; and that documentation is complete (e.g., any anomalies have been documented).

- Level 2 Supervisory Data Review – A supervisor or data review specialist whose function is to provide an independent review of the data package will perform this level of review. This review will also be conducted according to an established set of guidelines (i.e., method requirements and laboratory SOP). The Level 2 review includes a review of the qualitative and quantitative data and review of documented anomalies.

- Level 3 Administrative Data Review – A laboratory QA/QC officer or program administrator performs the final data review, prior to submittal. This level of review provides a total overview of the data package to ensure its consistency and compliance with project requirements.

The project laboratory QA/QC officer or designee will evaluate the quality of the work based on this document and an established set of laboratory guidelines to ensure the following:

- Sample preparation information is correct and complete;
- Analysis information is correct and complete;
- Appropriate procedures have been followed;
- Analytical results are correct and complete;
- Laboratory QC check results are within appropriate QC limits;
- Special sample preparation and analytical requirements have been met;
- Documentation is complete (all anomalies in the preparation and analysis have been documented; holding times are documented); and
- Laboratory qualifiers have been assigned to all samples with data usability limitations.

6.1.2.3 Laboratory Data Deliverables

Upon acceptance of the data by the laboratory QC manager, or designee, deliverables will be generated and submitted to the TEC Project Manager. The contract laboratory will maintain detailed procedures for laboratory record keeping, supporting the validity of all analytical work. Each data report package submitted to the TEC Project Manager will contain the laboratory's written certification that the requested analytical method was run and that all laboratory QC checks were performed. The laboratory program administrator will provide the TEC Project Manager with QC reports of their external audits, if appropriate, which will become part of the project file.

The project laboratory will be required to report analytical results consistently. Analytical results for soils and solid samples will be reported in concentrations of micrograms per kilogram (µg/Kg) or milligrams per kilogram (mg/Kg). Analytical results for water samples will be reported in micrograms per liter (µg/L) or milligrams per liter (mg/L).

6.2 FIELD DOCUMENT CONTROL AND RECORDS MANAGEMENT

Project-specific records that relate to fieldwork performed will be retained for 5 years. These records may include correspondence, COC records, field notes, and reports issued as a result of the work. In addition, records that document the field operations will be retained. This may include equipment performance records, maintenance logs, personnel files, general field procedures, and corrective action reports. Electronic or hard copy records of field operations are acceptable.

6.3 LABORATORY DOCUMENT CONTROL AND RECORDS MANAGEMENT

The laboratory prepares and retains full analytical and QC documentation that can be tracked from initiation to disposal for each sample. The following minimum records should be stored for each project:

- Original work order, COC, and other pertinent documents received with the samples
- Communications between the laboratory, field, and the customer
- Any associated corrective actions
- Laboratory data packages
- GC/MS mass spectra for samples verified with analyst's initials
- Finalized data reports
- Laboratory log books
- GS/MS tune data, as applicable
- Electronic data

The laboratory should also maintain its QAP and related SOPs for the methods performed.

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SECTION 7

ASSESSMENT/OVERSIGHT

7.1 PERFORMANCE AND SYSTEM AUDITS

Proper communication between field personnel, project management personnel, and laboratory personnel will help to ensure that the proper methods and techniques are used throughout the project.

The QA Officer will be responsible for initiating audits, selecting the audit team, and overseeing audit implementation.

The Field Manager will be responsible for supervising and checking that samples are collected and handled in accordance with this QAPP and that documentation of work is adequate and complete.

The project laboratory QA Managers will have the responsibility of ensuring that their analytical laboratory is following in-house performance and performing system audits under their in-house QA/QC guidelines. The laboratory will deal with any irregularities found in the laboratory's performance or system audits immediately. The laboratory QA Manager, or their designee, will also conduct the following internal audits regularly:

- Technical audit including reviews of calibration and equipment monitoring records, laboratory logbooks, maintenance records, and instrument control charts;
- Data quality audit reviews, including all aspects of data collection, reporting, and review; and
- Management systems audits verifying that management and supervisory staff are effectively implementing and monitoring all QC activities necessary to support the laboratory QA program.

The TEC Project Manager is responsible for overseeing that the project performance satisfies the QA objectives as set forth in this document. Reports and technical correspondence will be peer reviewed by qualified individuals before being finalized.

7.2 CORRECTIVE ACTIONS

Audits and other assessments may reveal findings of practices or procedures that do not conform to this QAPP. The following sections describe appropriate corrective actions for the various data management activities.

7.2.1 FIELD CORRECTIVE ACTION

The Field Manager will review the procedures being implemented in the field for consistency with the established protocols. Sample collection, preservation, labeling, etc. will be checked for completeness. Where procedures are not strictly in compliance with the established protocol, the deviations will be field documented and reported to the QA Officer. Corrective actions will be defined and documented, as appropriate, by the Field Manager and reported to the TEC Project Manager and the QA Officer. The documentation will become part of the project file.

7.2.2 LABORATORY CORRECTIVE ACTION

The project laboratory QA Managers will be responsible for the review of the data generated by their laboratory to ensure that all QC samples have been run as specified in the protocol. Recoveries of LCS, surrogates, and MS samples will be reviewed for method accuracy. The RPD of laboratory duplicates and MSD samples will be reviewed for method precision. The results will be evaluated against the laboratory's acceptance limits for the specified analytes and appropriate corrective action taken if warranted.

Laboratory personnel will be alerted that corrective actions are necessary if any of the following occur:

- The QC data is outside the warning or acceptance limits for precision and accuracy established for LCS. The laboratory QA Manager will consult the Project Chemist or the QA Officer to discuss out-of-control data sets.
- Blanks contain contaminants at concentrations above the detection limit.
- Undesirable trends are detected in the LCS or MS percent recoveries, RPDs, or surrogate recoveries.
- Unusual changes in detection limits are observed.

- The laboratory QA Manager detects deficiencies during internal or external audits, or from the results of performance evaluation samples.

If the analyst identifies any nonconformity in the analytical methodologies or QC sample results, the laboratory will implement corrective actions immediately. Specific corrective actions are outlined in each laboratory QAM.

The analyst will review the preparation or extraction procedures for possible errors, check the instrument calibration, evaluate spike and calibration mixes, check instrument sensitivity, and will initially handle corrective action procedures at the bench level. The analyst will immediately notify his/her supervisor of the identified problem and the investigation that is being conducted. If the problem persists or cannot be identified, the matter will be referred to the laboratory supervisor and laboratory QA Manager, and if the data are impacted, the Project Chemist and QA Officer will be provided a corrective action memo for inclusion in the project file.

Corrective action may include, but will not be limited to, the following:

- Reanalyzing suspect samples if holding time criteria permit;
- Retrieving the archived sample for analysis;
- Accepting data with acknowledged level of uncertainty (with consultation);
- Recalibrating analytical instruments;
- Evaluating and attempting to identify data limitations; and
- Resampling.

7.2.3 Corrective Actions Following Data Evaluation

Working with the Project Chemist, the QA Officer will be responsible for reviewing the laboratory data generated for this project and ensuring that all project QA objectives are met. If any nonconformances are found in field procedures, sample collection procedures, field documentation procedures, laboratory analytical and documentation procedures, and data evaluation and quality review procedures, the impact of those nonconformances on the overall project QA objectives will be assessed. Appropriate actions, including reanalysis or resampling, will be recommended to the TEC Project

Manager so that the project objectives can be accomplished. Data deemed unacceptable by the TEC Project Manager, following the implementation of the required corrective action measures, will not be accepted and further follow-up corrective actions will be explored.

7.3 REPORTS

A Data Verification, Validation, and Evaluation Report will be prepared at the end of data collection activities for this project. This report will include discussion of data quality as determined during the data verification, data quality review, and assessment process described in Section 8 of this QAPP.

SECTION 8

DATA REVIEW, VERIFICATION, VALIDATION, AND ASSESSMENT

8.1 DATA REVIEW

All analytical data may be reviewed by the Project QA Manager, Project Chemist, Field Manager, Hydrogeologist, or Risk Assessor as part of the process of preparing the information for use in the risk assessment.

8.2 VALIDATION AND DATA QUALITY REVIEW OF PROJECT ANALYTICAL DATA

Full data validation will be performed on 10% of all analyses. Data from all other analyses will undergo a data quality review. Validation and data quality review will be performed according to the current USEPA functional guidelines for organic and inorganic data review, the USEPA Office of Solid Waste and Emergency Response (OSWER) SOPs for inorganic and organic data review, SW-846 Method requirements, and project-specific requirements specified in this QAPP. Results of the data validation and data quality review will be presented in the Data Validation Report.

8.2.1 DATA QUALITY REVIEW

Data quality review involves a comprehensive check of the laboratory's certified analytical report (CAR) to assess the following: COC compliance; holding time compliance; presence or absence of laboratory contamination as demonstrated by method and field blanks; accuracy and bias as demonstrated by recovery of surrogate spikes, laboratory control samples, and matrix spikes; analytical precision as the RPD of analyte concentration between replicate samples (i.e., laboratory duplicates); sampling precision as the RPD of analyte concentration between field duplicates; calibration performance; and degree of conformance to method requirements and good laboratory practices. Data quality review does not include a review of the raw analytical data.

8.2.2 DATA VALIDATION

Data validation is performed similarly to a data quality review, but it is a comprehensive evaluation of laboratory data by experienced analytical chemists. It involves complete review of all raw data associated with the project samples in a process that includes reconstruction and verification of initial calibrations, and recalculation of sample results from instrument printouts and sample preparation bench sheets.

8.3 DATA VALIDATION REPORT

The Data Validation Report will summarize the performance of the project team in meeting the QA criteria outlined in this QAPP. The Data Validation Report will include, but is not limited to:

- Compliance with this QAPP,
- COC documentation,
- Compliance with technical holding times,
- Instrument calibration,
- Compliance with project-specific reporting limits,
- Field and laboratory QC samples (precision and accuracy),
- Field and method blanks, and
- Discussion of limitations on data usability.

8.4 FINAL DATA QUALITY ASSESSMENT

A final data quality assessment will be performed by the Project Risk Assessor as part of preparing the data for use in the risk assessment or constituent fate and transport modeling process. Any data usability issues identified by the Project Risk Assessor or Hydrogeologist will be communicated to the Project Chemist or Project Field Manager for further investigation and corrective action.

SECTION 9

REFERENCES

Hawaii State Department of Health (HDOH), 2000. Technical Guidance Manual for UST Closure and Release Response. 2^{nd} Edition. Environmental Management Division. March 2000.

HDOH, 2003. Interim Draft: Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater. Environmental Management Division. December 2003.

Massachusetts Department of Environmental Protection (MADEP), 1995. *Guidance for Disposal Site Risk Characterization:* Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, July 1995.

U.S. Environmental Protection Agency (USEPA), 1997. Test Methods for Evaluation of Solid Waste, Physical/Chemical Methods, SW-846. USEPA, Office of Solid Waste, Washington DC, 1997 and updates.

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Table 1-1
Summary of Analytical Program for Subsurface Soil/Rock Samples
Red Hill Bulk Fuel Storage Facility
Pearl Harbor, Hawaii

Sample Description	Sample Type	Matrix	TPH-DRO 8015B	TPH-GRO 8015B	MADEP EPH	MADEP VPH	VOCs 8260B	SVOCs 8270C SIM	Pb 6010B	Tetraethyl Pb ASTM D3341 87M	Comments
Basal Aquifer											
RHMW02*	N	SO	2	2	2	2	2	2	2	2	
RHMW03*	N	SO	2	2	2	2	2	2	2	2	
RHMW04*	N	SO	2	2	2	2	2	2	2	2	
Totals - Environmental samples			6	6	6	6	6	6	6	6	
QC Samples (estimated numbers)											
Duplicates (RHMW06)	FD	SQ	1	1	1	1	1	1	1	1	FD (RHMW02)
Trip Blanks	TB	WQ	-	-	-	-	-	-	-	-	
MS/MSD	MS/SD	SQ	1	1	1	1	1	1	1	1	
Equipment Blanks	EB	WQ	1	1	1	1	1	1	1	1	RHBHEB-1, -2
Totals (QC samples)			3	3	3	3	3	3	3	3	
Grand Total			9	9	9	9	9	9	9	9	

Notes:

* Borings converted into Monitering wells

N	Normal Sample	MS/MSD	Matrix Spike/ Spike Duplicate
SO	Soil	EB	Equipment Blank
FD	Field Duplicate	SQ	Soil Quality Sample
TB	Trip blank	WQ	Water Quality Sample
VPH	Volatile Petroleum Hydrocarbons	MADEP	Massachusetts Department of Environmental Protection
EPH	Extractable Petroleum Hydrocarbons	Pb	Lead
VOC	Volatile Organic Compounds	GRO	Gasoline Range Organics
SVOC	Semi-Volitile Organic Compounds	DRO	Diesel Range Organics
TPH	Total Petroleum Hydrocarbons		

Table 1-2
Summary of Analytical Program for Groundwater Samples
Red Hill Bulk Fuel Storage Facility
Pearl Harbor, Hawaii

																	Field Measurements			
Sample Description	Sample Type	Matrix	TPH-DRO 8015B	TPH-GRO 8015B	VOCs 8260B	SVOC's 8270C SIM	Total Lead 6010B	Tetraethyl Pb ASTM D3341 87M	Dissolved Pb 6010B	MADEP EPH	MADEP VPH	Alkalinity E310.1	Methane RSK-175	Silica, Dissolved EPA370.1/ SM19 4500SID	Anions[1] E300	Cations[2] 6010B	Ferrous Iron	Dissolved Oxygen	Carbon Dioxide	Comments
Round 1																				
RHMW01	N	WG	-	-	-	-	-	-	-	-	-	1	1	-	1	-	1	1	-	
RHMW2254	N	WG	-	-	-	-	-	-	-	-	-	1	1	-	1	-	1	1	1	
Totals - Environmental samples			0	0	0	0	0	0	0	0	0	2	2	0	2	0	2	2	1	
QC Samples*																				
Duplicates (RHMW05)	FD	WQ	-	-	-	-	-	-	-	-	-	1	1	-	1	-	-	-	-	FD (RHMW01)
Trip Blanks	TB	WQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
MS/MSD	MS/SD	WQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Equipment Blanks	EB	WQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total QC samples for Round 1			0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	
Round 2																				
RHMW01	N	WG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
RHMW02	N	WG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
RHMW03	N	WG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
RHMW04	N	WG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
RHMW2254	N	WG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Totals - Environmental samples			5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
QC Samples*																				
Duplicates (RHMW05)	FD	WQ	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-	FD (RHMW01)
Trip Blanks	TB	WQ	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
MS/MSD	MS/SD	WQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Equipment Blanks	EB	WQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total QC samples for Round 2			1	1	2	1	1	1	1	1	1	1	1	1	1	1	0	0	0	
Grand Total (Rounds 1 and 2)			6	6	7	6	6	6	6	6	6	9	9	6	9	6	7	7	6	

Notes

N	Normal Sample	EB	Equipment Blank
FD	Field Duplicate	WG	Groundwater
TB	Trip blank	WQ	Water Quality Sample
Pb	Lead		

1 = Anions by Method E300 include Phosphate, Nitrate, Sulfate, Chloride, and Fluoride
2 = Cations by Method SW846 6010B include Sodium, Magnesium, Calcium, Potassium, and Strontium
* Number of QC samples are estimated

Table 1-3
Summary of Analytical Program for Soil Vapor Samples
Red Hill Bulk Fuel Storage Facility
Pearl Harbor, Hawaii

Sample Description	Sample Type	Matrix	VOCs TO-15	Comments
RHSV01-25	N	GS	1	
RHSV01-45	N	GS	1	
RHSV01-80	N	GS	1	
RHSV14-25	N	GS	1	
RHSV14-45	N	GS	1	
RHSV14-80	N	GS	1	
RHSV16-25	N	GS	1	
RHSV16-45	N	GS	1	
RHSV16-80	N	GS	1	
Totals - Environmental samples			9	
QC Samples (estimated numbers)				
Duplicates	FD	AQ	1	RHSV01-0
Trip Blanks	TB	WQ	-	
MS/MSD	MS/SD	AQ	-	
Equipment Blanks	EB	WQ	-	
Totals - QC samples			1	
Grand Total			10	

N	Normal Sample	MS/MSD
GS	Soil Gas	EB
FD	Field Duplicate	AQ
TB	Trip blank	WQ

Table 2-1
Laboratory Methods Limits of Detection (LOD) and Reporting Limits (RLs)

LABORATORY METHODS Limits of detection (LOD) AND RLs					
Parameter	Method	Matrix	Units	desired LOD	estimated RL/EQL
Metals - ICP					
Lead (total and dissolved)	6010B	W	mg/L	0 00234	0 010
Lead	6010B	S	mg/kg	0 23	0 50
Metals -ASTM D3341 91					
Lead, Tetraethyl	D3341	W	mg/L	0 00100	0 010
Lead Tetraethyl	D3341	S	mg/kg	0 10	1 00
Volatiles - GC/MS					
Acetone	8260B	W	ug/L	3 02	10
Benzene	8260B	W	ug/L	0 25	0 5
Bromobenzene	8260B	W	ug/L	0 18	1
Bromochloromethane	8260B	W	ug/L	0 27	1
Bromodichloromethane	8260B	W	ug/L	0 09	1
Bromoform (tribromomethane)	8260B	W	ug/L	0 23	1
Bromomethane (Methyl bromide)	8260B	W	ug/L	0 78	1
2-Butanone	8260B	W	ug/L	3 50	10
n-Butylbenzene	8260B	W	ug/L	0 32	1
sec-Butylbenzene	8260B	W	ug/L	0 33	1
tert-Butylbenzene	8260B	W	ug/L	0 16	1
Carbon Disulfide	8260B	W	ug/L	0 54	10
Carbon Tetrachloride	8260B	W	ug/L	0 11	0 5
Chlorobenzene	8260B	W	ug/L	0 20	1
Chloroethane	8260B	W	ug/L	0 50	1
Chloroform	8260B	W	ug/L	0 16	1
Chloromethane	8260B	W	ug/L	0 43	1
2-Chlorotoluene	8260B	W	ug/L	0 26	1
4-Chlorotoluene	8260B	W	ug/L	0 22	1
Dibromochloromethane	8260B	W	ug/L	0 24	1
1,2-Dibromo-3-Chloropropane	8260B	W	ug/L	2 84	5
1,2-Dibromoethane	8260B	W	ug/L	0 15	1
Dibromomethane	8260B	W	ug/L	0 22	1
1,2-Dichlorobenzene	8260B	W	ug/L	0 22	1
1,3-Dichlorobenzene	8260B	W	ug/L	0 33	1
1,4-Dichlorobenzene	8260B	W	ug/L	0 36	1
Dichlorodifluoromethane	8260B	W	ug/L	0 34	1
1,1-Dichloroethane	8260B	W	ug/L	0 27	1
1,2-Dichloroethane	8260B	W	ug/L	0 37	0 5
1,1-Dichloroethene	8260B	W	ug/L	0 25	1
c-1,2-Dichloroethene	8260B	W	ug/L	0 43	1
t-1,2-Dichloroethene	8260B	W	ug/L	0 33	1
1,2-Dichloropropane	8260B	W	ug/L	0 36	1
1,3-Dichloropropane	8260B	W	ug/L	0 17	1
2,2-Dichloropropane	8260B	W	ug/L	0 38	1
1,1-Dichloropropene	8260B	W	ug/L	0 24	1
c-1,3-Dichloropropene	8260B	W	ug/L	0 20	0 5
t-1,3-Dichloropropene	8260B	W	ug/L	0 17	0 5
Ethylbenzene	8260B	W	ug/L	0 17	1
2-Hexanone	8260B	W	ug/L	2 97	10
Isopropylbenzene	8260B	W	ug/L	0 16	1
p-Isopropyltoluene	8260B	W	ug/L	0 44	1
Methylene Chloride	8260B	W	ug/L	2 90	10
4-Methyl-2-Pentanone	8260B	W	ug/L	2 92	10
Naphthalene	8260B	W	ug/L	0 57	10
n-Propylbenzene	8260B	W	ug/L	0 25	1
Styrene	8260B	W	ug/L	0 23	1
1,1,1,2-Tetrachloroethane	8260B	W	ug/L	0 13	1
1,1,2,2-Tetrachloroethane	8260B	W	ug/L	0 29	1
Tetrachloroethene	8260B	W	ug/L	0 37	1
Toluene	8260B	W	ug/L	0 11	1
1,2,3-Trichlorobenzene	8260B	W	ug/L	0 47	1
1,2,4-Trichlorobenzene	8260B	W	ug/L	0 37	1
1,1,1-Trichloroethane	8260B	W	ug/L	0 18	1
1,1,2-Trichloroethane	8260B	W	ug/L	0 22	1
Trichloroethene	8260B	W	ug/L	0 24	1
Trichlorofluoromethane	8260B	W	ug/L	0 35	10
1,2,3-Trichloropropane	8260B	W	ug/L	0 33	1
1,2,4-Trimethylbenzene	8260B	W	ug/L	0 21	1
1,3,5-Trimethylbenzene	8260B	W	ug/L	0 25	1
Vinyl Acetate	8260B	W	ug/L	1 84	10
Vinyl Chloride	8260B	W	ug/L	0 26	0 5
p/m-Xylene	8260B	W	ug/L	0 30	1
o-Xylene	8260B	W	ug/L	0 14	1
Methyl-tert-Butyl Ether	8260B	W	ug/L	0 20	1

Table 2-1
Laboratory Methods Limits of Detection (LOD) and Reporting Limits (RLs)

LABORATORY METHODS Limits of detection (LOD) AND RLs					
Parameter	Method	Matrix	Units	desired LOD	estimated RL/EQL
Acetone	8260B	S	ug/kg	11 1	50
Benzene	8260B	S	ug/kg	0 62	5
Bromobenzene	8260B	S	ug/kg	0 78	5
Bromochloromethane	8260B	S	ug/kg	1 23	5
Bromodichloromethane	8260B	S	ug/kg	1 54	5
Bromoform	8260B	S	ug/kg	1 64	5
Bromomethane (Methyl bromide)	8260B	S	ug/kg	3 34	5
2-Butanone	8260B	S	ug/kg	11 22	50
n-Butylbenzene	8260B	S	ug/kg	1 14	5
sec-Butylbenzene	8260B	S	ug/kg	1 16	5
tert-Butylbenzene	8260B	S	ug/kg	1 79	5
Carbon Disulfide	8260B	S	ug/kg	1 46	50
Carbon Tetrachloride	8260B	S	ug/kg	1 43	5
Chlorobenzene	8260B	S	ug/kg	1 33	5
Chloroethane	8260B	S	ug/kg	2 60	5
Chloroform	8260B	S	ug/kg	1 48	5
Chloromethane	8260B	S	ug/kg	2 67	5
2-Chlorotoluene	8260B	S	ug/kg	1 26	5
4-Chlorotoluene	8260B	S	ug/kg	1 20	5
Dibromochloromethane	8260B	S	ug/kg	1 73	5
1,2-Dibromo-3-Chloropropane	8260B	S	ug/kg	5 28	10
1,2-Dibromoethane	8260B	S	ug/kg	1 35	5
Dibromomethane	8260B	S	ug/kg	1 54	5
1,2-Dichlorobenzene	8260B	S	ug/kg	1 39	5
1,3-Dichlorobenzene	8260B	S	ug/kg	1 12	5
1,4-Dichlorobenzene	8260B	S	ug/kg	1 20	5
Dichlorodifluoromethane	8260B	S	ug/kg	1 99	5
1,1-Dichloroethane	8260B	S	ug/kg	1 25	5
1,2-Dichloroethane (EDC)	8260B	S	ug/kg	1 76	5
1,1-Dichloroethene	8260B	S	ug/kg	1 58	5
c-1,2-Dichloroethene	8260B	S	ug/kg	2 61	5
t-1,2-Dichloroethene	8260B	S	ug/kg	0 84	5
1,2-Dichloropropane	8260B	S	ug/kg	2 49	5
1,3-Dichloropropane	8260B	S	ug/kg	1 19	5
2,2-Dichloropropane	8260B	S	ug/kg	1 99	5
1,1-Dichloropropene	8260B	S	ug/kg	1 47	5
c-1,3-Dichloropropene	8260B	S	ug/kg	0 67	5
t-1,3-Dichloropropene	8260B	S	ug/kg	1 12	5
Ethylbenzene	8260B	S	ug/kg	1 00	5
2-Hexanone	8260B	S	ug/kg	4 42	50
Isopropylbenzene	8260B	S	ug/kg	1 04	5
p-Isopropyltoluene	8260B	S	ug/kg	1 26	5
Methylene Chloride	8260B	S	ug/kg	2 78	50
4-Methyl-2-Pentanone	8260B	S	ug/kg	4 4	50
Naphthalene	8260B	S	ug/kg	2 6	50
n-Propylbenzene	8260B	S	ug/kg	1 17	5
Styrene	8260B	S	ug/kg	1 09	5
1,1,1,2-Tetrachloroethane	8260B	S	ug/kg	1 66	5
1,1,2,2-Tetrachloroethane	8260B	S	ug/kg	1 81	5
Tetrachloroethene	8260B	S	ug/kg	1 23	5
Toluene	8260B	S	ug/kg	0 43	5
1,2,3-Trichlorobenzene	8260B	S	ug/kg	2 47	10
1,2,4-Trichlorobenzene	8260B	S	ug/kg	3 86	5
1,1,1-Trichloroethane	8260B	S	ug/kg	1 26	5
1,1,2-Trichloroethane	8260B	S	ug/kg	2 08	5
Trichloroethene	8260B	S	ug/kg	1 52	5
Trichlorofluoromethane	8260B	S	ug/kg	2 09	50
1,2,3-Trichloropropane	8260B	S	ug/kg	2 76	5
1,2,4-Trimethylbenzene	8260B	S	ug/kg	1 20	5
1,3,5-Trimethylbenzene	8260B	S	ug/kg	1 12	5
Vinyl Acetate	8260B	S	ug/kg	2 45	50
Vinyl Chloride	8260B	S	ug/kg	0 98	5
p/m-Xylene	8260B	S	ug/kg	0 87	5
o-Xylene	8260B	S	ug/kg	1 21	5
Methyl-tert-Butyl Ether	8260B	S	ug/kg	1 70	5

Table 2-1

Laboratory Methods Limits of Detection (LOD) and Reporting Limits (RLs)

LABORATORY METHODS Limits of detection (LOD) AND RLs					
Parameter	Method	Matrix	Units	desired LOD	estimated RL/EQL
Semi-Volatiles - GCMS					
Naphthalene	8270C	W	ug/L	1.79	10
Acenapthylene	8270C	W	ug/L	0.86	10
Acenaphthene	8270C	W	ug/L	0.94	10
Anthracene	8270C	W	ug/L	1.15	10
Fluorene	8270C	W	ug/L	1.08	10
Fluoranthene	8270C	W	ug/L	1.07	10
Pyrene	8270C	W	ug/L	1.00	10
Benzo (a) Anthracene	8270C	W	ug/L	0.86	10
Chrysene	8270C	W	ug/L	1.03	10
Benzo (b) Fluoranthene	8270C	W	ug/L	0.75	10
Benzo (k) Fluoranthene	8270C	W	ug/L	1.11	10
Benzo (a) Pyrene	8270C	W	ug/L	0.72	10
Benzo (g,h,i) Perylene	8270C	W	ug/L	0.88	10
Indeno (1,2,3-c,d) Pyrene	8270C	W	ug/L	0.79	10
Dibenz (a,h) Anthracene	8270C	W	ug/L	0.98	10
Naphthalene	8270C	S	mg/kg	0.0920	0.8
Acenaphthylene	8270C	S	mg/kg	0.0985	0.8
Acenaphthene	8270C	S	mg/kg	0.1105	0.8
Fluorene	8270C	S	mg/kg	0.1005	0.8
Phenanthrene	8270C	S	mg/kg	0.1031	0.8
Anthracene	8270C	S	mg/kg	0.1194	0.8
Fluoranthene	8270C	S	mg/kg	0.1098	0.8
Pyrene	8270C	S	mg/kg	0.1307	0.8
Benzo (a) Anthracene	8270C	S	mg/kg	0.1025	0.8
Chrysene	8270C	S	mg/kg	0.0940	0.8
Benzo (b) Fluoranthene	8270C	S	mg/kg	0.0973	0.8
Benzo (k) Fluoranthene	8270C	S	mg/kg	0.1145	0.8
Benzo (a) Pyrene	8270C	S	mg/kg	0.1028	0.7
Indeno (1,2,3-c,d) Pyrene	8270C	S	mg/kg	0.1023	0.8
Dibenz (a,h) Anthracene	8270C	S	mg/kg	0.1074	0.8
Benzo (g,h,i) Perylene	8270C	S	mg/kg	0.1087	0.8
Total Petroleum Hydrocarbons (TPH) - GC					
TPH as gasoline	8015M	W	ug/L	51.1	500
TPH as diesel	8015M	W	ug/L	863	1000
TPH as gasoline	8015M	S	mg/kg	0.126	0.5
TPH as diesel	8015M	S	mg/kg	4.81	5
Extractable and Volatile Total Petroleum Hydrocarbons (TPH)					
Extractable TPH, all ranges	MADEP EPH	W	ug/L	200.0	1000
Volatile TPH, all ranges	MADEP VPH	W	ug/L	10	100
Extractable TPH, all ranges	MADEP EPH	S	mg/kg	20	100
Volatile TPH, all ranges	MADEP VPH	S	mg/kg	0.5	5
Gases					
Methane	RSK-175	W	mg/L	0.127	1
Anions - IC					
Nitrate	300.0	W	mg/L	0.030	0.1
Sulfate	300.0	W	mg/L	0.110	1
General Chemistry					
Alkalinity	310.1	W	mg/L	0.200	1
Field Tests- Chemistry					
Ferrous Iron	SM3500	W	mg/L	0.2	0.05
Dissolved Oxygen	360.1	W	mg/L	1	0.05
Volatiles - GC/MS					
Dichlorodifluoromethane	TO-15	A	uL/L	0.16	0.5
Chloromethane	TO-15	A	uL/L	0.13	0.5
Chloroform	TO-15	A	uL/L	0.17	0.5
Vinyl Chloride	TO-15	A	uL/L	0.16	0.5
Bromomethane	TO-15	A	uL/L	0.38	0.5
Chloroethane	TO-15	A	uL/L	0.19	0.5
Trichlorofluoromethane	TO-15	A	uL/L	0.18	0.5
1,1-Dichloroethene	TO-15	A	uL/L	0.13	0.5
Methylene Chloride	TO-15	A	uL/L	0.14	2
Tetrachloroethene	TO-15	A	uL/L	0.16	0.5
1,1,2-Dichloro-1,2,2-Trifluoroethane	TO-15	A	uL/L	0.18	1
1,1-Dichloroethane	TO-15	A	uL/L	0.16	0.5
1,2-Dichloro-1,1,2,2-Tetrafluoroethane	TO-15	A	uL/L	0.14	2
c-1,2-Dichloroethene	TO-15	A	uL/L	0.19	0.5
1,2-Dichloroethane	TO-15	A	uL/L	0.17	0.5
1,1,1-Trichloroethane	TO-15	A	uL/L	0.17	0.5

Table 2-1

Laboratory Methods Limits of Detection (LOD) and Reporting Limits (RLs)

LABORATORY METHODS Limits of detection (LOD) AND RLs					
Parameter	Method	Matrix	Units	desired LOD	estimated RL/EQL
Benzene	TO-15	A	uL/L	0.15	0.5
Carbon Tetrachloride	TO-15	A	uL/L	0.14	0.5
1,2-Dichloropropane	TO-15	A	uL/L	0.14	0.5
Trichloroethene	TO-15	A	uL/L	0.14	0.5
c-1,3-Dichloropropene	TO-15	A	uL/L	0.16	0.5
t-1,3-Dichloropropene	TO-15	A	uL/L	0.15	0.5
1,2,2-Trichloroethane	TO-15	A	uL/L	0.15	0.5
Toluene	TO-15	A	uL/L	0.17	0.5
Chlorobenzene	TO-15	A	uL/L	0.2	0.5
1,2-Dichlorobenzene	TO-15	A	uL/L	0.2	0.5
Ethylbenzene	TO-15	A	uL/L	0.16	0.5
p/m-Xylenes	TO-15	A	uL/L	0.42	1
Styrene	TO-15	A	uL/L	0.16	1
1,1,2,2-Tetrachloroethane	TO-15	A	uL/L	0.19	0.5
o-Xylene	TO-15	A	uL/L	0.16	0.5
1,3,5-Trimethylbenzene	TO-15	A	uL/L	0.16	0.5
1,2,4-Trimethylbenzene	TO-15	A	uL/L	0.18	0.5
Benzyl Chloride	TO-15	A	uL/L	0.18	0.5
1,3-Dichlorobenzene	TO-15	A	uL/L	0.19	0.5
1,4-Dichlorobenzene	TO-15	A	uL/L	0.18	0.5
1,2-Dibromoethane	TO-15	A	uL/L	0.18	0.5
1,2,4-Trichlorobenzene	TO-15	A	uL/L	0.21	0.5
Hexachloro-1,3-Butadiene	TO-15	A	uL/L	0.18	0.5
Acetonitrile	TO-15	A	uL/L	0.22	1
t-1,2-Dichloroethene	TO-15	A	uL/L	0.18	0.5
2-Butanone	TO-15	A	uL/L	0.15	1
Dibromochloromethane	TO-15	A	uL/L	0.17	0.5
Bromodichloromethane	TO-15	A	uL/L	0.17	0.5
Acetone	TO-15	A	uL/L	0.18	1
Methyl-t-Butyl Ether	TO-15	A	uL/L	0.18	2
4-Methyl-2-Pentanone	TO-15	A	uL/L	0.22	1
Bromoform	TO-15	A	uL/L	0.23	0.5
Carbon Disulfide	TO-15	A	uL/L	0.15	0.5
Vinyl Acetate	TO-15	A	uL/L	0.17	1
2-Hexanone	TO-15	A	uL/L	0.21	1
4-Ethyltoluene	TO-15	A	uL/L	0.18	0.5

TABLE 2-2
Sensitivity Goals
Red Hill Bulk Storage Facility

Method	Analyte	Groundwater (mg/L)	Solid (mg/Kg)
SW-8468260B[1]	Benzene	0.005	0.05
	Toluene	1.0	16
	Ethylbenzene	0.14	0.50
	Xylene	10	23
	MTBE	0.02	0.05
SW-846 8310 or SW-846 8270SIM[1]	Benzo(a)pyrene	0 0002	1.0
	Acenaphthene	0.32	18
	Fluoranthene	0.013	11
	Naphthalene	0.24	41
SW-846 6010B[1]	Lead (total)	0 0056	400
SW-846 8015[1]	Gasoline-range organics	NS	5000
	Diesel-range organics	NS	2000
MADEP VPH[2]	C_5-C_8 aliphatics	0.010	5.0
	C_8-C_{12} aliphatics	0.010	5.0
	C_9-C_{10} aromatics	0.010	5.0
	Total TPH	0.010	5.0
MADEP EPH[3]	C_9-C_{18} aliphatics	0.010	20
	C_{19}-C_{36} aliphatics	0.010	20
	C_{11}-C_{22} aromatics	0.010	20
	Total TPH	0.010	20
ASTM D3341[4]	Tetraethyl lead	0.010	2.0

NS No standard.

[1] Hawaii Administrative Rules, Underground Storage Tanks, Department of Health, Title 11, Chapter 281, and MTBE DOH UST Policy Update dated Oct 16, 1998

[2] MADEP, Final Method for the Determination of Extractable Petroleum Hydrocarbons, May 2004.

[3] MADEP, Final Method for the Determination of Volatile Petroleum Hydrocarbons, May 2004.

[4] ASTM D3311, Standard Method for Lead in Gasoline- Iodine Monochlorine Method, ASTM International.

TABLE 4-1
Sample Containers, Preservatives, and Holding Times
Red Hill Bulk Storage Facility

Analysis	Method	Container[1]	Preservative	Holding Time
Solid				
GRO	8015B	4 or 9 oz Glass Jar[2]	Cool to 4°C	14 days
VPH	MADEP VPH	4 or 9 oz Glass Jar[2]	Cool to 4°C	14 days
DRO	8015B	4 or 9 oz Glass Jar[2]	Cool to 4°C	14/40 days[3]
EPH	MADEP EPH	4 or 9 oz Glass Jar[2]	Cool to 4°C	14/40 days[3]
BTEX/MTBE	8260B	4 or 9 oz Glass Jar[2]	Cool to 4°C	14 days
PAH	8310 or 8270 SIM	4 or 9 oz Glass Jar[2]	Cool to 4°C	14/40 days[3]
Lead	6010B	4 or 9 oz Glass Jar[2]	Cool to 4°C	6 months
Tetraethyl Lead	ASTM D3341	4 or 9 oz Glass Jar[2]	Cool to 4°C	NS
Water Samples				
GRO	8015B	3 – 40 mL Glass Vials, no headspace	HCl to pH<2, cool to 4°C	14 Days
VPH	MADEP VPH	3 – 40 mL Glass Vials, no headspace	HCl to pH<2, cool to 4°C	14 Days
DRO	8015B	2 – 1 L Amber Glass Bottles	HCl to pH<2, cool to 4°C	14/40 days[3]
EPH	MADEP EPH	2 – 1 L Amber Glass Bottles	HCl to pH<2, cool to 4°C	14/40 days[3]
BTEX/MTBE	8260B	3 – 40 mL Glass Vials, no headspace	HCl to pH<2, cool to 4°C	14 Days
PAH	8310	2 – 1 L Amber Glass Bottles	Cool to 4°C	7/40 days[3]
	8270 SIM	2 – 1 L Amber Glass Bottles		
Total Lead	6010B	1 – 250 or 500 mL HDPE	HNO_3 to pH<2, cool to 4°C	6 months
Dissolved Lead		1 – 250 or 500 mL HDPE, field filtered		
Tetraethyl Lead	ASTM D3341	1 - 250 mL HDPE	Cool to 4°C	NS

BTEX Benzene, Toluene, Ethylbenzene, Xylenes
DRO Diesel-range organics
EPH Extractable petroleum hydrocarbons
GRO Gasoline-range organics
MTBE Methyl tert-butyl ether
NS Not specified
PAH Polynuclear aromatic hydrocarbons
VPH Volatile petroleum hydrocarbons

Notes:
1 Double sample volume collected for MS/MSD
2 Multiple tests may be performed from the sample 4 or 9 oz. Jar, so a jar is not needed for each individual test.
3 Number of days from collection until extraction/number of days from time of extraction until analysis.

TABLE 5-1
Laboratory Quality Control Samples
Red Hill Bulk Storage Facility

Method	Method Blanks[1]	Duplicate Analyses[1,2]	MS[1]	LCS[1] (Blank Spike)	Surrogate	Initial Calibration	Initial Calibration Verification	Continuing Calibration Standard
GRO	1/Batch	1/Batch	1/Batch	1/Batch	All Samples	5-point	1/curve	Every 10 samples
VPH	1/Batch	1/Batch	1/Batch	1/Batch	All Samples	5-point	1/curve	Every 10 samples
DRO	1/Batch	1/Batch	1/Batch	1/Batch	All Samples	5-point	1/curve	Every 10 samples
EPH	1/Batch	1/Batch	1/Batch	1/Batch	All Samples	5-point	1/curve	Every 10 samples
BTEX/MTBE	1/Batch	1/Batch	1/Batch	1/Batch	All Samples	5-point	1/curve	Every 12 hours
PAH	1/Batch	1/Batch	1/Batch	1/Batch	All Samples	5-point	1/curve	Every 12 hours
Lead	1/Batch	1/Batch	1/Batch	1/Batch	NA	Instrument Specific	1/curve	Every 10 samples
Tetraethyl Lead	1/Batch	1/Batch	1/Batch	1/Batch	NA	Instrument Specific	1/curve	Every 10 samples

[1] Batch is equivalent to 20, or fewer, samples prepared and anlyzed together with common QC samples.
[2] Duplicate analyses might be laboratory duplicates, LCS/LCSD, and/or MS/MSD.

BTEX Benzene, Toluene, Ethylbenzene, Xylenes
DRO Diesel-range organics
EPH Extractable petroleum hydrocarbons
GRO Gasoline-range organics
LCS Laboratory control sample
MS Matrix spike
MTBE Methyl tert-butyl ether
NA Not Applicable
PAH Polynuclear aromatic hydrocarbons
VPH Volatile petroleum hydrocarbons

Appendix C

Facility Construction History

Appendix C

Red Hill Bulk Fuel Storage Facility Construction

Introduction

This document describes the sequence that was followed in construction of the bulk storage tanks at Red Hill Bulk Storage Facility (RHSF). Portions of this history were excerpted from the *Work Plan, Phase II Investigation, Fleet Industrial Supply Center, Bulk Fuel Storage Facility at Red Hill, September 1999,* prepared by Ogden Environmental and Energy Services (Ogden). The sequence described herein is as depicted on construction drawings for Tanks 1 through 4, but is believed to be generally the same for all 20 tanks. In this document, figures identified by the prefix "2" (e.g., Figure 2-1) refer to figures found within Section 2 of the Work Plan (WP) while figures identified by the prefix "C" (e.g., Figure C-1) refer to figures found only within this appendix. The general layout of the tanks is provided in **Figure 2-12, Figure 2-14, Figure 2-15, Figure 2-16** and **Figure 2-17**.

Construction of the RHSF began late in 1940 and was completed in 1943. The facility incorporates 20 steel underground storage tanks with capacities between 285,000 and 300,000 barrels (BBL). Each tank was constructed onsite and consists of a vertical cylindrical barrel capped with an upper and lower dome. Each tank measures approximately 245 feet in height and 100 feet in diameter, with the top of the upper dome at a depth varying between 100 feet and 200 feet below the existing ground surface (bgs). The bulk tanks were constructed in two parallel rows sloping south by southwest towards Pearl Harbor (**Figure 2-5** and **Figure 2-12**). A network of upper and lower subsurface service tunnels connects the tanks and contains light rail systems, water and electrical facilities, and fuel pipelines. In the lower tunnel, each parallel tank is connected by a short access tunnel, which branches off the main service tunnel and terminates into a face-wall under each tank. Individual tank ancillary piping from each face-wall connects the fuel transmission lines. The fuel pipelines run approximately 2.5 miles from the bulk tanks to a Pearl Harbor pump station. The pump station is used to pump fuel from fuel tankers in Pearl Harbor to the bulk fuel storage facility. The Navy PWC operates a water pumping station situated hydraulically down-gradient within this lower tunnel system. The water pumping station is referred to as the Red Hill Adit No. 3 Water Pumping Station and its location is depicted on **Figure 2-5, Figure 2-6, Figure 2-7, Figure 2-12** and **Figure 2-14**. The water pumping station pumps water from the basal aquifer beneath Red Hill to the Pearl Harbor water distribution system.

Construction of Access Tunnels and Shafts

The initial stage of construction involved the upper and lower access tunnels and shafts. Both access tunnels were constructed between the two rows of tanks. The upper access tunnel was constructed approximately 50 feet from the top of each tank at an elevation even with the top dome / vertical side wall intersection. The base of the lower access tunnel was constructed approximately 18 feet below the bottom of each tank. A branch access tunnel was constructed from both the upper and lower access tunnels to each tank. In the upper tunnel, the branch access tunnel to the upper portion of each tank was constructed so that it intersected the tank in a tangential manner. In the lower tunnel, the access tunnel to each tank was aligned directly beneath the tank in a perpendicular manner and is referred to on the drawings as the lower cross tunnel. The upper and lower tunnels and a (typical) side view of two tanks are depicted on **Figure C-1**.

Along with the upper and lower access tunnels, a temporary vertical shaft was constructed from the ground surface down to the top of the upper dome location for each tank. Each vertical shaft measured 4 feet by 6 feet and was installed for use during the construction process as an access point for removal of rock and for movement of construction materials into the excavation for storage tank construction. After construction was complete, these access shafts were closed. The vertical shaft is depicted on **Figure C-1**.

After construction of the upper access tunnel and the vertical shaft was complete, mining of the upper dome shell was completed. The dome was excavated to form a cap-like excavation for construction of the upper dome. Mining of the upper dome shell is depicted on **Figure C-2**.

Construction of the Upper Dome

After the upper dome shell had been mined to the appropriate dimensions, the steel plate tank lining was installed in the upper dome. The steel plate lining was installed on temporary structural steel supports, which rested on rock. The plate was installed a minimum of 4 feet down from the upper limits of rock excavation to allow sufficient space for reinforced concrete to be placed between the steel plate lining and the rock.

Steel reinforcing was installed above the steel plate between the plate and the rock, and concrete was poured to provide reinforced concrete walls with an interior steel plate lining. Concrete was poured through a pipe, which passed from the ground surface downward through the 4 feet by 6 feet vertical shaft to the upper dome. An opening approximately 14 feet square remained in the upper dome to provide access for construction of the remainder of the tank. Construction of the upper dome is depicted on **Figure C-3**.

Construction of Vertical Shafts Beneath Upper Dome

Following completion of the upper dome, the 4 feet by 6 feet vertical shaft was extended downward to intersect the lower cross tunnel located beneath the tank. The 4 feet by 6 feet vertical shaft was subsequently enlarged to measure approximately 14 feet by 14 feet. Extension of the vertical shafts to the lower cross tunnel is depicted on **Figure C-4**.

Enlargement of Vertical Shafts and Remaining Excavation for Tanks

Following enlargement of the vertical shaft to 14 feet by 14 feet, a pan feeder and conveyor were installed in the lower cross tunnel to carry material from tank excavation to the lower access tunnel for removal to the ground surface. Following installation of the pan feeder, the shaft was enlarged to 30 feet in diameter.

Rock was next excavated for the remaining tank volume by drilling and blasting with the resulting material falling through the 30-foot-diameter center shaft to the pan feeder and conveyor below in the lower cross tunnel. This excavation began immediately beneath the top of the dome and proceeded downward the full height of the tank to the bottom of the tank. This excavation sequence covered the full 100-foot interior diameter of the tank plus approximately 3 feet 9 inches on each side for reinforced concrete. As the excavation process proceeded downward past the bottom of the upper dome and into the vertical portion of the walls at approximately 50 feet from the top of the tank, the rock sidewalls were secured in place with gunite. This sequence of construction is depicted on **Figure C-5**.

Tower and Tank Construction

After excavation of the entire tank volume was complete, the pan feeder and conveyor were removed from the lower cross tunnel. Next, a steel erection tower was installed from the floor of the lower access cross tunnel to the bottom of the top dome of each tank. This erection tower was approximately 220 feet tall and was utilized to support derricks and concrete feed equipment for construction of the remainder of the tank. The erection tower is shown on **Figure C-6**.

A slurry prepared of red clay and water was painted on the gunite sidewalls of the excavation from the bottom of the dome top to the base of the excavation. The slurry served as a bond breaker between the gunite and the concrete that was to be placed between the gunite and the steel tank lining. This process is described later in this section.

Next, the steel plate lining was installed around the base of the tank. An opening approximately 18 feet in diameter was provided in the center base of the tank so that the erection tower could remain in place on the lower cross tunnel floor below. The steel plate was installed approximately 3 feet 9 inches from the gunite-covered rock walls. The steel plate and the gunite served as formwork for the concrete pours. Steel reinforcing was installed between the steel plate and gunite, and concrete was poured in the space. The steel plate was installed in sheets approximately 5 feet by 12 feet. As each row of steel plate was installed, extending the base and then the walls 5 feet further, steel reinforcing was placed and concrete was poured. The wall section was raised in increments of 5 feet around the entire perimeter of the tank.

Each 5 foot by 12 foot steel plate was welded to the next 5 foot by 12 foot plate using a piece of steel angle as backing for the weld. The angle was used only on the horizontal welds; flat stock steel was utilized as backing for the vertical welds. In addition to serving as a backing for the next piece of steel plate to be welded, the angle served as a barrier to inhibit leaks that occur in the steel plate lining from migrating down the outer surface of the steel plate. These angles were part of a leak detection system. Installation of the steel plate and reinforced concrete proceeded from the base of the tank to the bottom of the top dome. The tower and tank construction is depicted on **Figure C-5** and **Figure C-6**.

A large concrete pour was completed beneath the bottom steel plate liner of each tank. The concrete extends from the steel liner to the lower access tunnel floor and provides a foundation for the middle of the tank. This mass concrete foundation is shown in **Figure C-7**. Piping extending through the steel tank liner to the lower access tunnel is encased in this concrete foundation. The size and location of this concrete foundation restrict investigation (drilling) activities beneath the tanks so that drilling must be done into the rock outside the concrete.

Grout Pre-stressing of the Tank

After the steel lining and concrete walls were in place, water was flushed through grout tubes to flush the red clay bond breaker from between the concrete and the gunite. This created a small gap or crack between the gunite and concrete. After the red clay bond breaker had been adequately flushed, cement grout was injected into this gap under high pressures to compress the tank structure from the outside, prestressing the entire tank structure. The degree of prestressing was monitored by strain gauges anchored to the rock and passing through the concrete walls and steel lining to the inside of the tank. The configuration of the grout tubes, bond breaker, grout, and tank wall construction is shown on **Figure C-8**.

Installation of Leak Detection System

The tell-tale leak detection system included eleven 1-1/4-inch diameter steel pipes vertically aligned and evenly spaced around the interior tank wall. The pipes extend from the top of the tank through the bottom of the tank to the lower access cross tunnel for each tank. Each of these pipes is attached to the interior of the tank wall and has a tee branch near each horizontal steel plate seam so that a 1-1/4-inch steel pipe passes through the steel plate immediately above each steel angle section every 5 feet. Each of these 11 pipes has a valve at its termination point in the lower access tunnel.

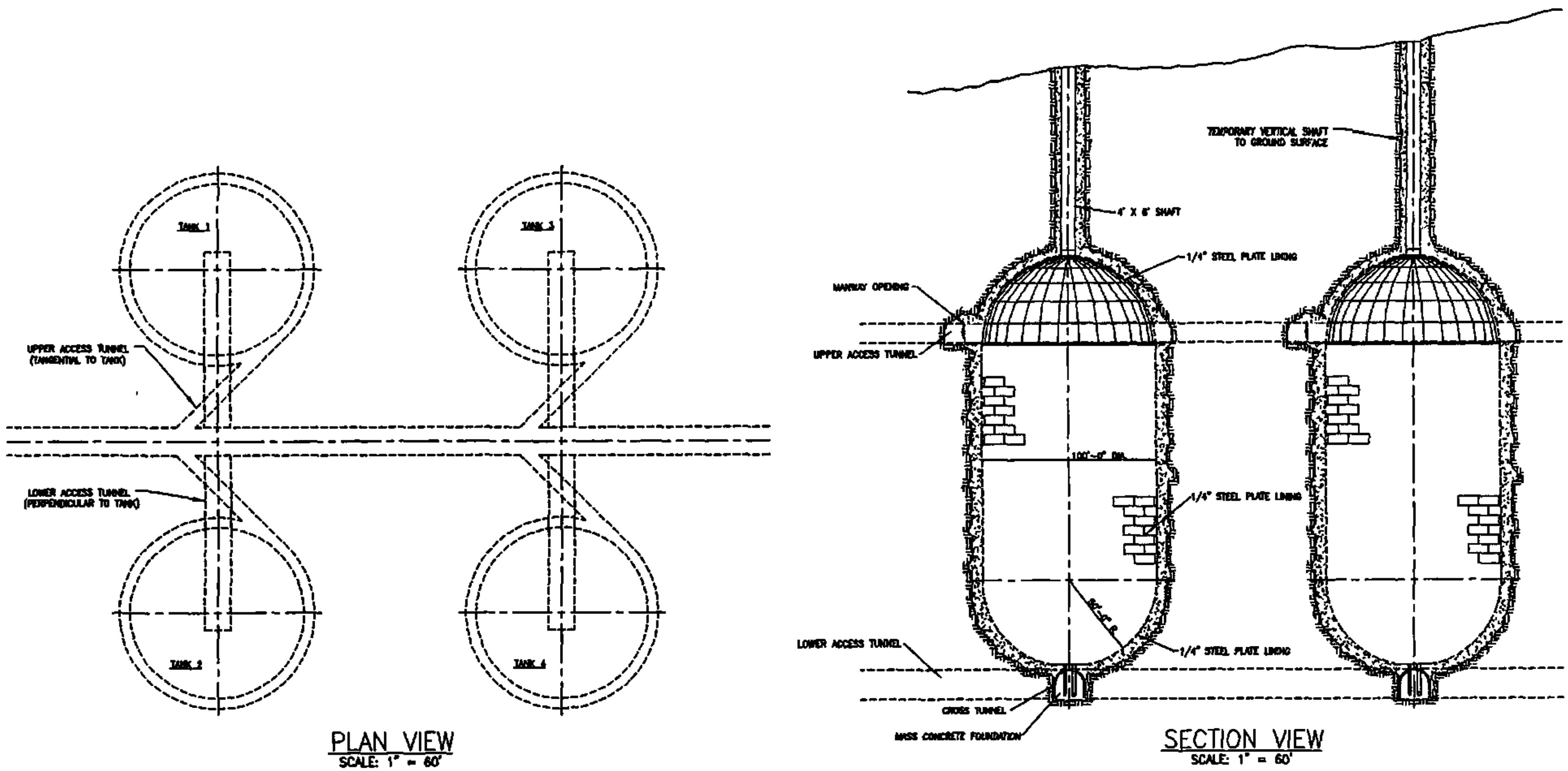
The tell-tale system was designed to function in the following manner. If petroleum leaked through the steel plate tank wall, it would presumably seep down the exterior of the steel plate, between the steel plate and the concrete until it reached one of the horizontal angles. The petroleum would then pond on the horizontal angle until it drained out one of the tell-tale pipe penetrations and into one of the 11 pipes leading to the lower access tunnel. To determine if oil was leaking into one of the tell-tale pipes, the eleven 1-1/4-inch valves in the lower access tunnel were periodically opened to see if any oil drained out. The construction of the tell-tall pipe through the tank wall is shown on **Figure C-8.**

A second function of the tell-tale system was to leak test the tanks after construction was complete. This was done by filling the tanks with water and then injecting air under high pressure into the tell-tale pipes. This would cause air to be forced around the outside steel lining of the tanks so that holes in the steel tank lining could be identified by the appearance of air bubbles within the tank. The water level within the tank would then be lowered until the bubbles stopped and the air leak location was noted. The leak location was then repaired by welders.

A third function of the tell-tale leak detection system was to relieve pressure from the outer tank shell. Should petroleum leak through the steel lining, the oil would flow out the tell-tale system rather than pond outside the tank lining. This prevented petroleum from potentially ponding to significant heights and consequently causing high petroleum pressures outside the tank lining. The high pressures that would result if petroleum accumulated to significant heights outside the wall would be more prone to force the petroleum into fractures in the rock and thereby increase the potential of a petroleum release into the rock.

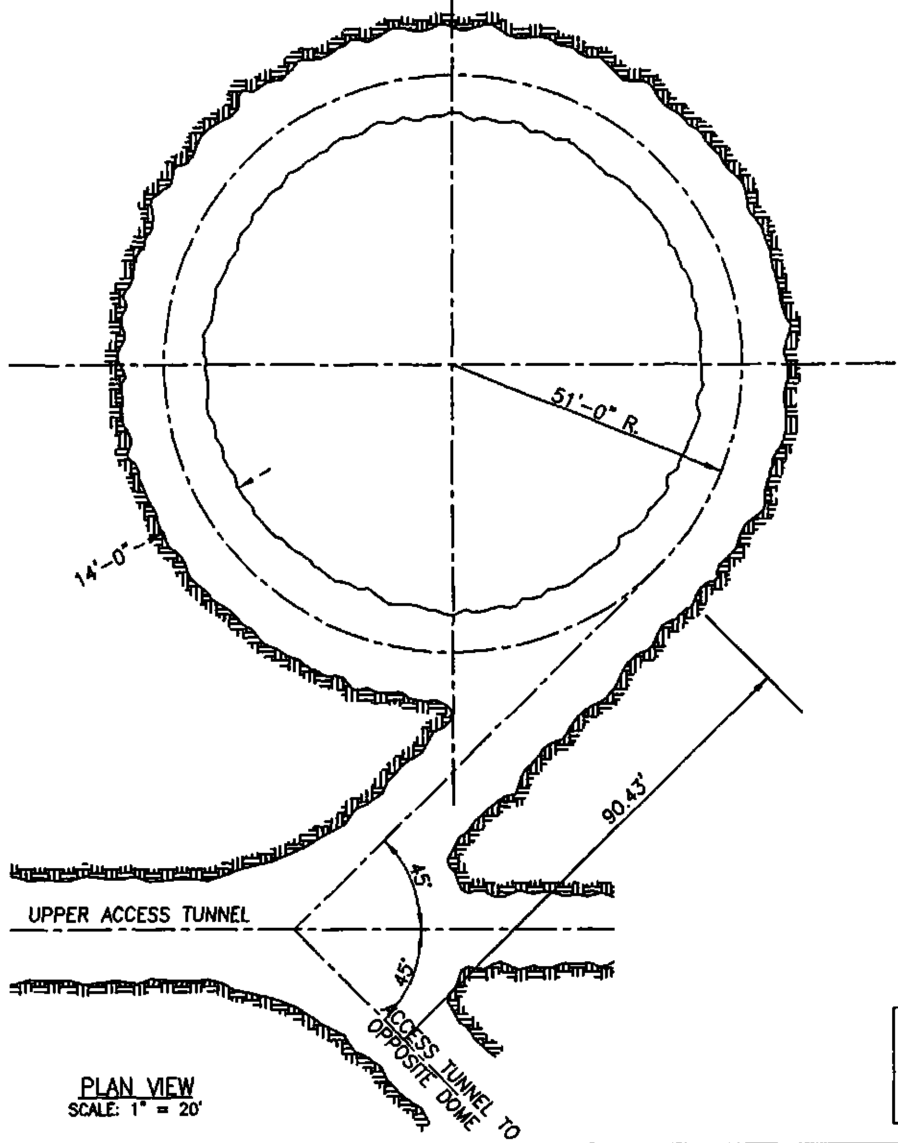
Historical Modifications of Tanks Since Initial Construction

During the 1970s, leaking was noted in the tell-tale detection system for several of the tanks. Subsequent investigations determined that the leaks were occurring where the tell-tale pipes passed through the tank wall and not in the steel tank lining. To remedy the leaking, the tell-tale pipes were removed from Tanks 1 through 16. Although this did solve the problem of the tell-tales pipes leaking, it also eliminated the pressure relief system that was affected by the tell-tale pipes. Therefore, in Tanks 1 through 16, if a leak occurred through the steel tank lining and flowed outside the lining to the base of the tank, petroleum under pressures up to approximately 100 pounds per square inch (psi) could be forced into the surrounding concrete and rock.

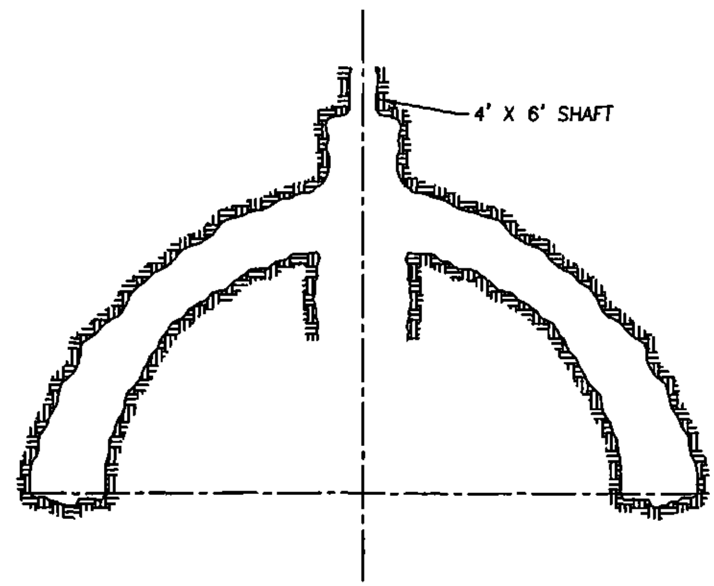


RED HILL BULK FUEL
STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

FIGURE
C-1
GENERAL TANK LAYOUT



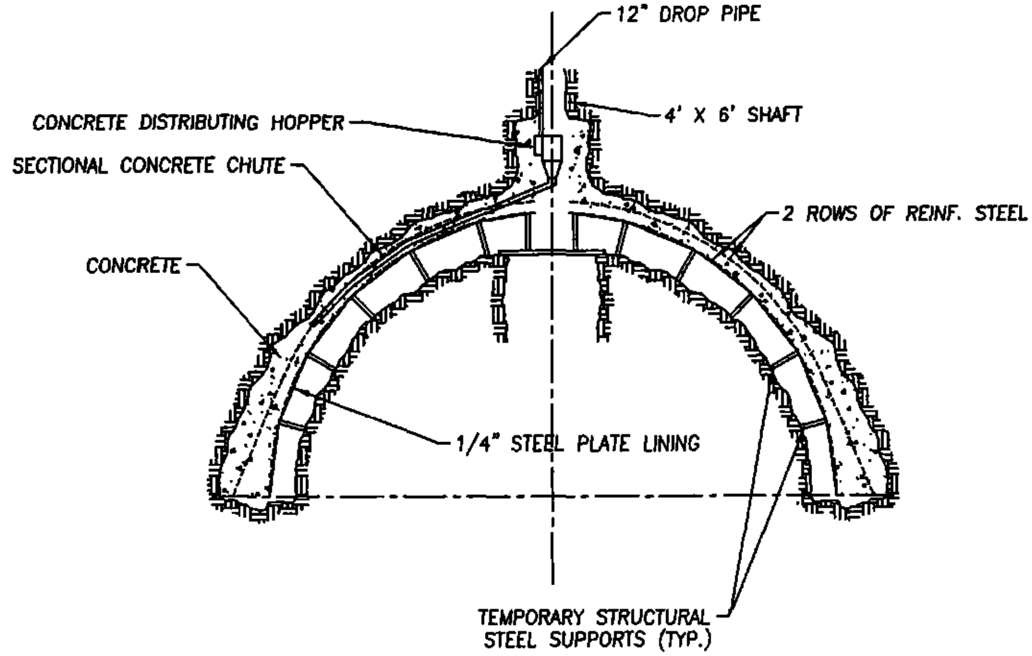
PLAN VIEW
SCALE: 1" = 20'



SECTION
SCALE: 1" = 20'

RED HILL BULK FUEL STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

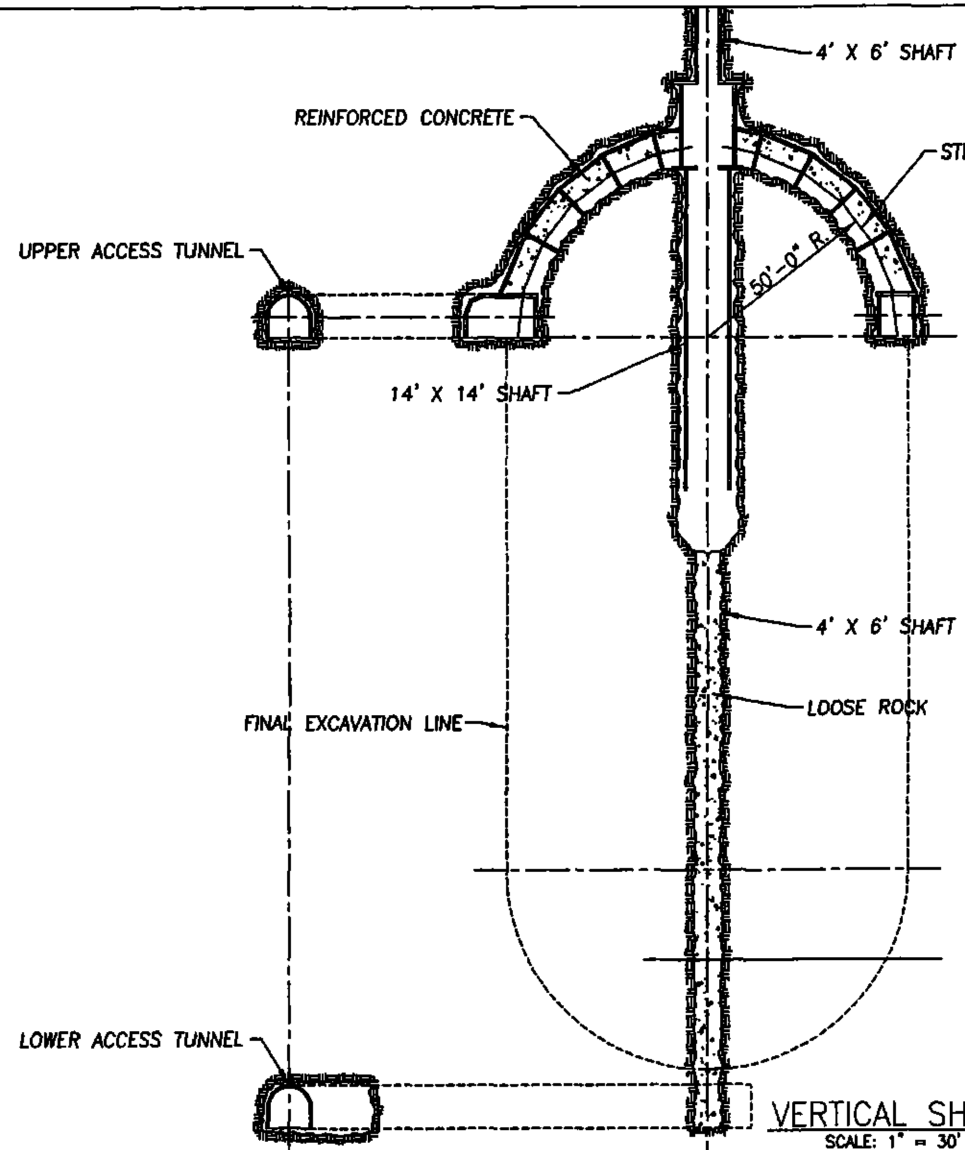
FIGURE
C-2
MINING OF UPPER DOME SHELL



DETAIL UPPER DOME
SCALE: 1" = 20'

RED HILL BULK FUEL STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

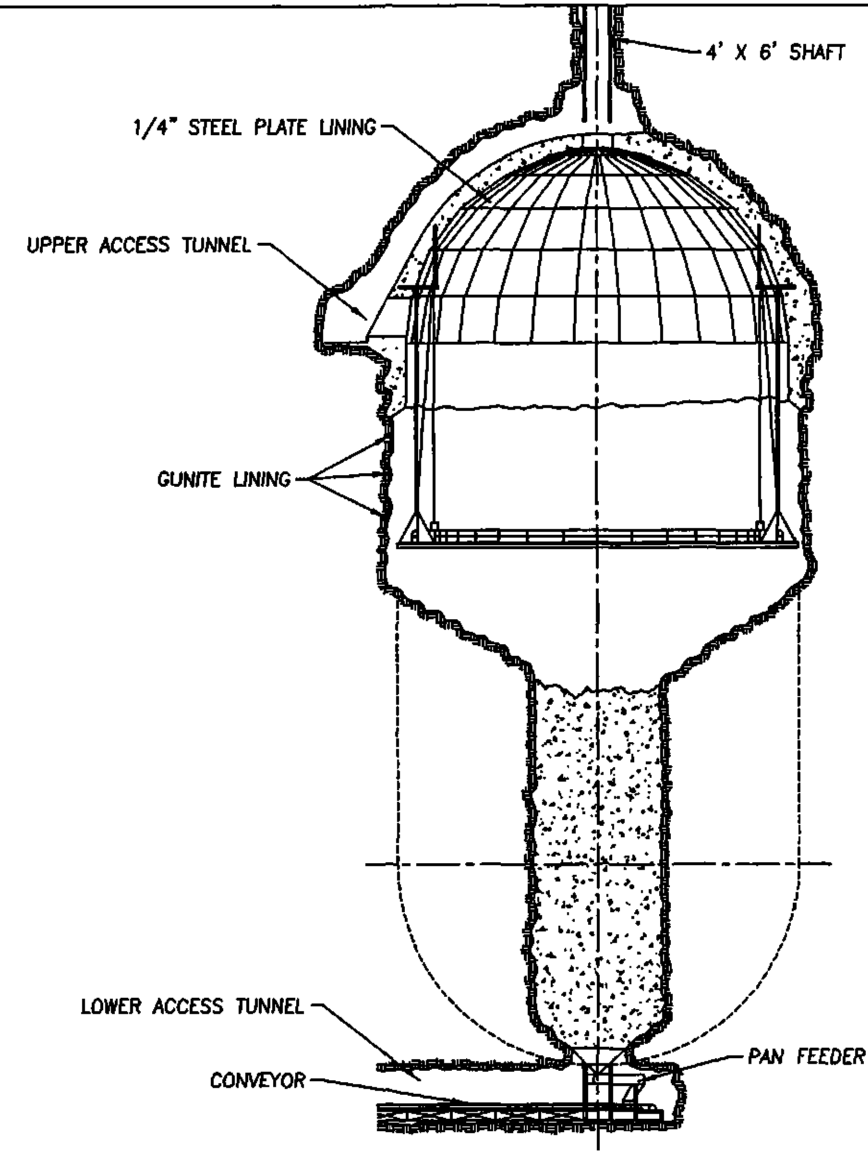
FIGURE C-3
CONSTRUCTION OF UPPER DOME



VERTICAL SHAFT
SCALE: 1" = 30'

RED HILL BULK FUEL STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

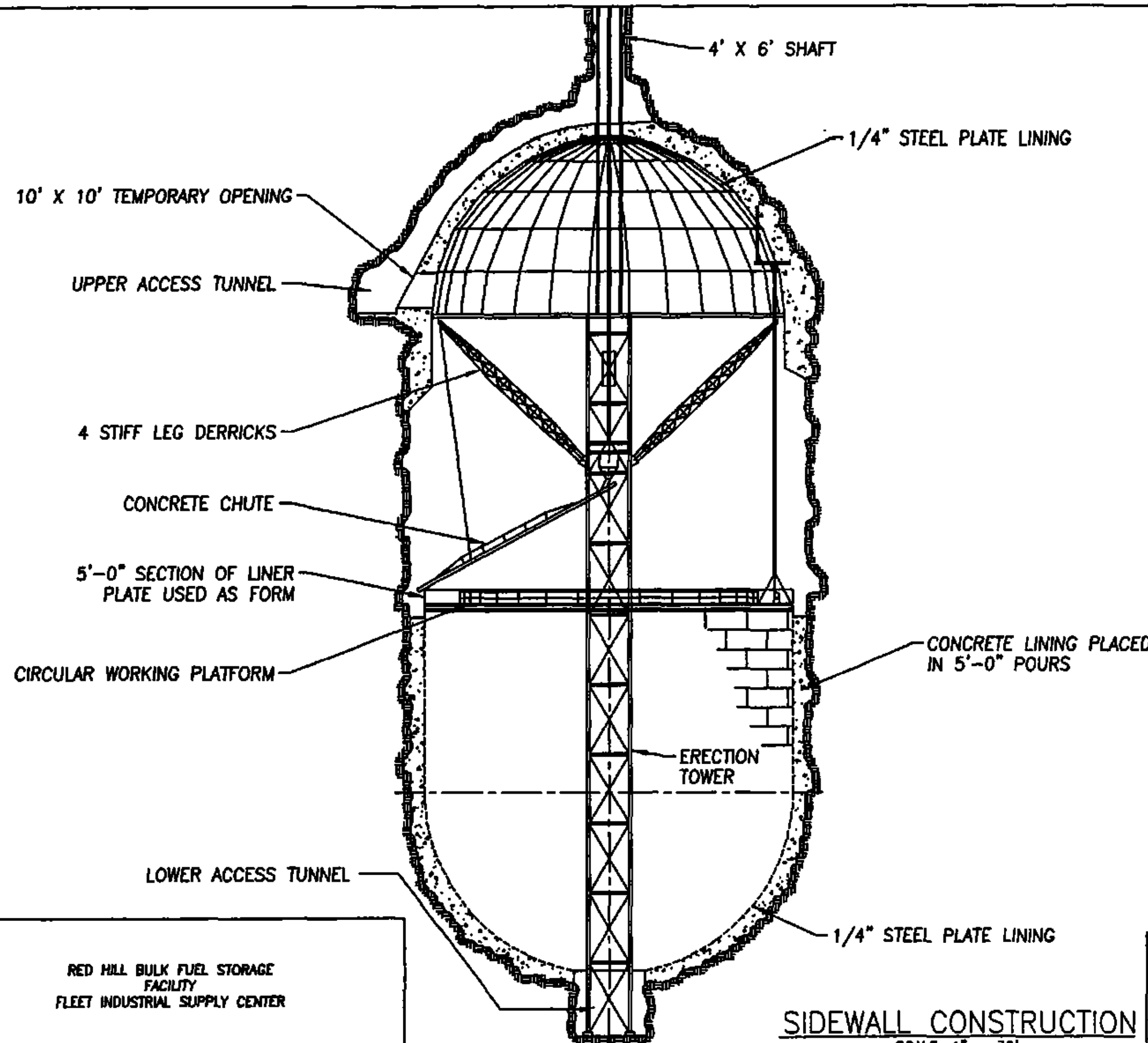
FIGURE
C-4
VERTICAL SHAFT CONSTRUCTION



TANK EXCAVATION
SCALE: 1" = 30'

RED HILL BULK FUEL STORAGE
FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

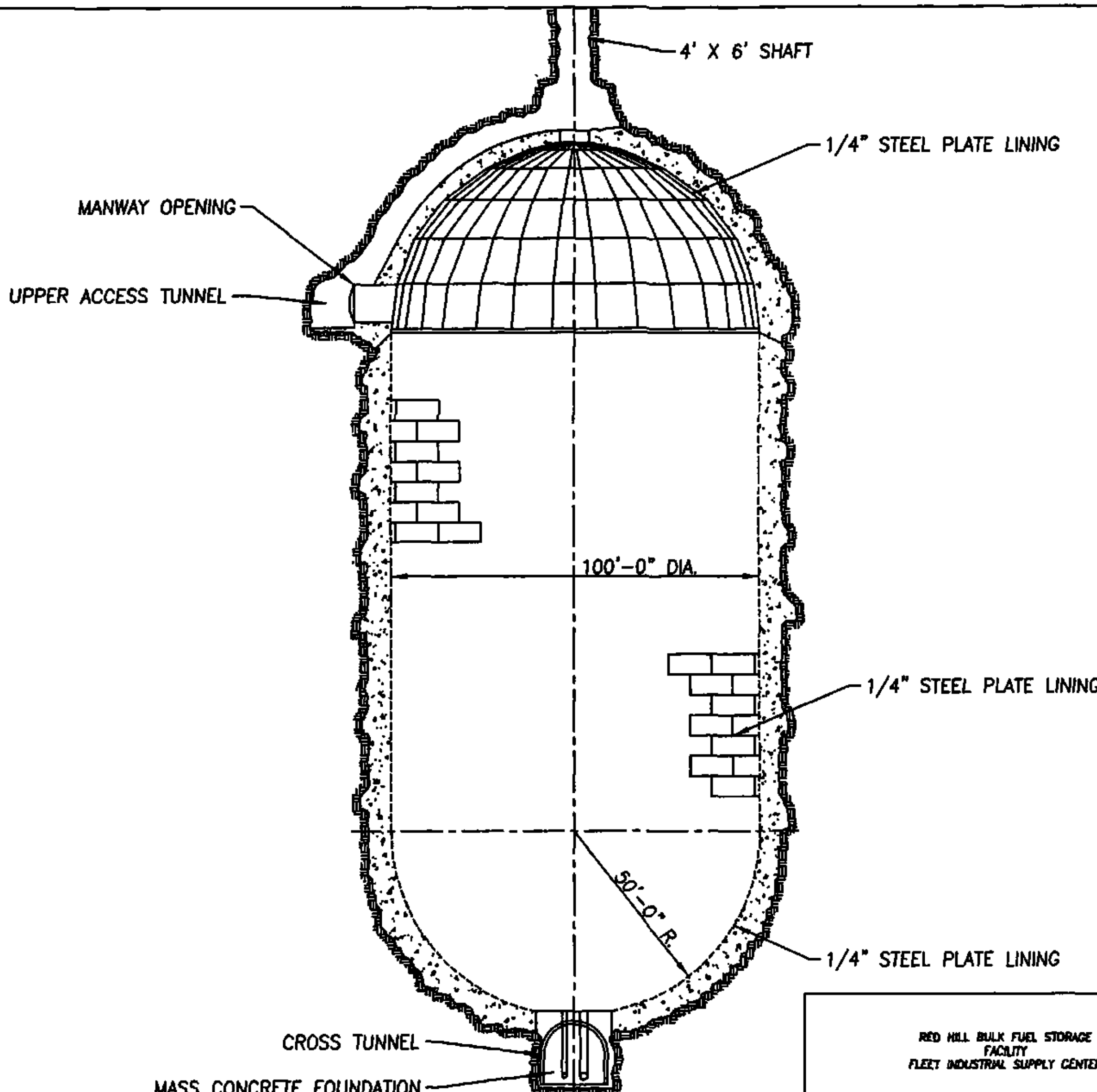
FIGURE
C-5
TANK EXCAVATION



SIDEWALL CONSTRUCTION
SCALE: 1" = 30'

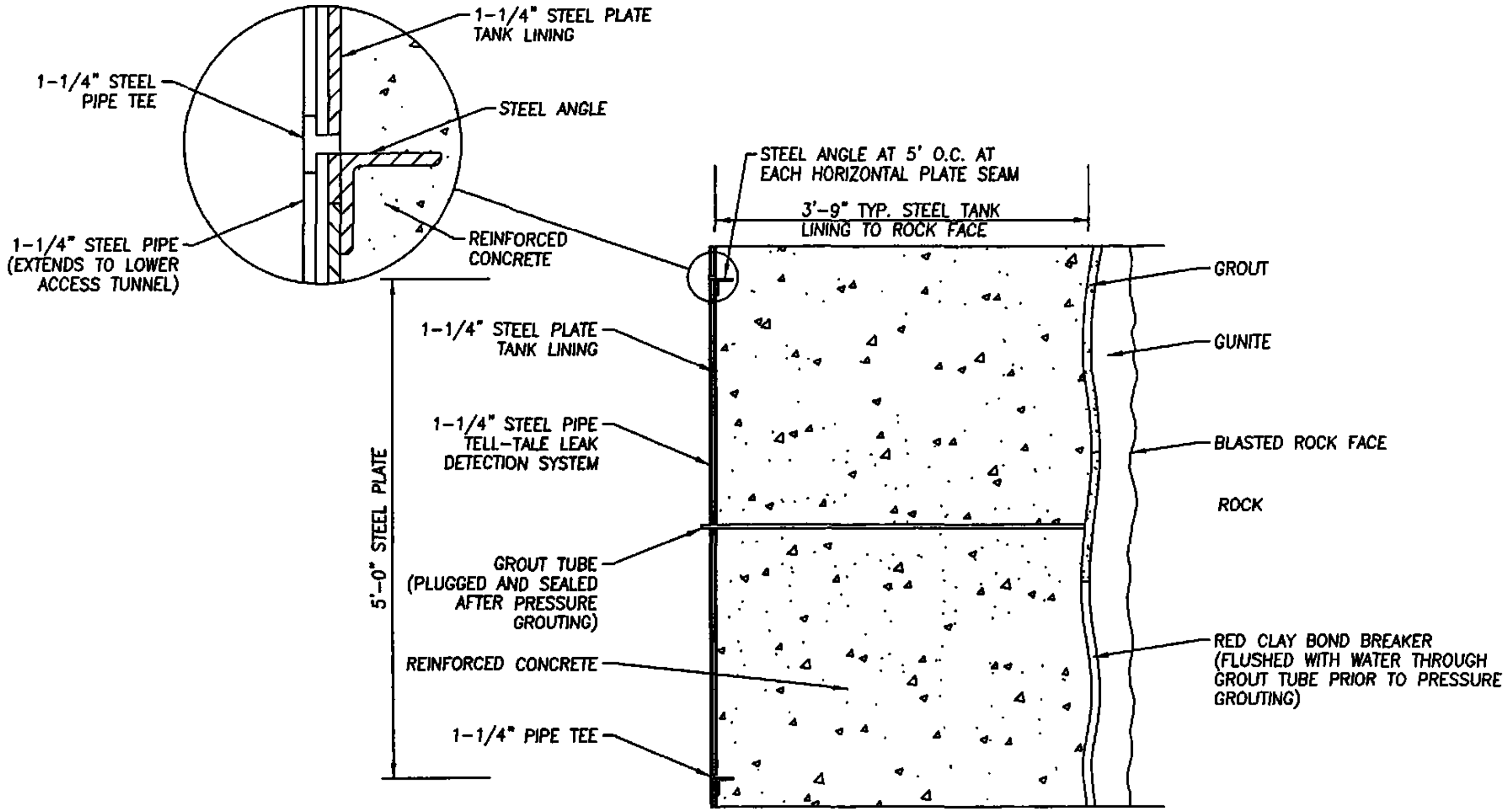
RED HILL BULK FUEL STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

FIGURE
C-6
ERECTION TOWER AND TANK SIDEWALL CONSTRUCTION



RED HILL BULK FUEL STORAGE
FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

FIGURE
C-7
COMPLETED TANK INSTALLATION



WALL SECTION
SCALE: 1" = 1'

RED HILL BULK FUEL STORAGE
FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

FIGURE
C-8
TYPICAL WALL SECTION

Appendix D

Preliminary Risk Evaluation

Indefinite Delivery/Indefinite Quantity Contract
Contract No. N62742-02-1802
CTO No. 0007

PRELIMINARY RISK EVALUATION
PHASE 1, BULK STORAGE FACILITIES RISK ASSESSMENT
US NAVAL SUPPLY CENTER
BULK FUEL STORAGE FACILITY AT RED HILL
OAHU, HAWAII

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LIST OF ACRONYMS

ALISH	Agricultural Lands of Importance to the State of Hawaii
COPCs	Contaminants Of Potential Concern
CSEM	Conceptual Site Exposure Model
DLNR	Department of Land and Natural Resources
DPP	Department of Planning and Permitting
EPA	Environmental Protection Agency
ERA	Ecological Risk Assessment
FISC	Fleet Industrial Supply Center
HDOH	Hawaii Department of Health
LNAPL	Light, Non-Aqueous Phase Liquids
OWDF	Oily Water Disposal Facility
PUC	Primary Urban Center
PWC	Public Works Center
RHBFSF	Red Hill Bulk Fuel Storage Facility
TPH	Total Petroleum Hydrocarbons
TMDLs	Total Maximum Daily Loads
UAA	Use Attainability Analysis
UIC	Underground Injection Control
USFWS	United States Fish and Wildlife Service
USTs	Underground Storage Tanks
VOCs	Volatile Organic Compounds
WP	Work Plan

SECTION 1.0 Preliminary Risk Evaluation

An initial screening level risk assessment was performed for the Red Hill Bulk Fuel Storage Facility (RHBFSF) as part of the Phase II SI Report (Ogden 1999). This assessment was used as a qualitative tool to identify the constituents that were present in environmental media at concentrations of potential concern. The results of the screening level assessment indicated that seven constituents were detected in core samples at concentrations of potential concern: ethylbenzene, methylene chloride, 2-methylnaphthalene, naphthalene, phenanthrene, total petroleum hydrocarbons (TPH) (C10-C28), and unknown hydrocarbon. Three constituents were detected in groundwater at concentrations of potential concern: bis(2-ethylhexyl)phthalate, lead, and TPH (C10-C28). The investigation also indicated the presence petroleum in the form of light, non-aqueous phase liquids (LNAPL) in several slant borings screened approximately 85 to 100 feet above the basal aquifer at the site.

Based on the preliminary risk screening, it was recommended that a comprehensive risk assessment be completed to allow for an accurate assessment of current and potential future risk associated with the RHBFSF. As part of the comprehensive risk assessment a site-specific exposure assessment was recommended to evaluate site data in conjunction with information on the exposure setting to identify potential migration pathways, potential receptor populations, and relevant exposure routes.

The objective of an exposure assessment is to evaluate potential human and environmental exposure to site-related constituents of potential concern. The exposure assessment is conducted to identify the pathways by which human and environmental receptors are potentially exposed and to estimate the magnitude, frequency, and duration of exposure. The process involves four steps:

- characterization of the exposure setting;
- identification of potentially exposed populations;
- identification of potential exposure pathways; and
- quantification of potential exposure.

The exposure assessment evaluates all potential exposure pathways. However, those that are incomplete or irrelevant may be dismissed if the rationale for elimination of a pathway is documented. Risk estimates are generated for those exposure pathways that are considered complete or that may potentially become complete in the future. A quantitative risk assessment typically evaluates an average or median individual risk (i.e., central tendency) and a high-end risk (i.e., reasonable maximum exposure).

SECTION 2.0 Characterization of Exposure Setting and Identification of Potential Receptors

The exposure setting is critical for the identification of both human and ecological receptors. **Section 2.1**, below, presents information relevant to the identification of potential human receptors and **Section 2.2** presents information relevant to the identification of potential ecological receptors in the vicinity of the RHBFSF.

2.1 POTENTIAL HUMAN RECEPTORS

Potential human receptors in the vicinity of the site were identified through evaluation of land use, zoning and groundwater use information, which is summarized below.

2.1.1 Land Use and Zoning

The RHBFSF is located in the Koolau Range, with pipelines extending into the Coastal Plain near Pearl Harbor. The RHBFSF is operated by the Fleet and Industrial Supply Center (FISC) and is secured from public access. The site is part of the Red Hill Naval Reservation.

The RHBFSF lies along the western edge of the Koolau Range. The site specifically lies along a ridge that divides the Halawa Valley and the Moanalua Valley. Please refer to **Figure 2-7** in the Work Plan (WP). The RHBFSF area is located approximately 3 miles northeast of Pearl Harbor and bordered on the south by the Salt Lake volcanic crater. The facility access adits generally exit the lower slopes of the South Halawa Valley. Refer to **Figures 2-12 through 2-14** in the WP for general facility layout.

Land use information indicates that the site is located on urban land that is bordered to the immediate north by forest (refer to **Figure 2-2** land use map in the WP). The Department of Agriculture identified no agricultural lands of importance to the State of Hawaii (ALISH) in the immediate vicinity of the site (refer to **Figure A6-1** ALISH map)).

Current zoning information from the City and County of Honolulu's Department of Planning and Permitting (DPP) indicates that the site is located on federal government land (zoned F1-Military and Federal) with public land located to the immediate north and northeast (zoned P1-Restricted Parkland). The Halawa Correctional Facility is located in the residential area depicted north of the public land (zoned R5- Residential) and is bordered by industrial development to the north and northwest (zoned I2- Industrial) and a quarry to the north and northwest beyond the Halawa Correctional Facility (zoned Ag2- Agricultural). There is a high cliff face with a 100 to 200 feet elevation difference between the Red Hill Naval Reservation and both the industrial area and the Halawa Correctional Facility. The H3 Freeway is located north of the quarry.

A residential development, Moanalua Village, is located immediately adjacent to the Red Hill Naval Reservation to the south and east (zoned R5- Residential). Further south is the Moanalua

Golf Course (zoned P2- General Parkland and R5- Residential), a small section of public land (zoned P1- Restricted Parkland), and the Tripler Army Medical Center (zoned F1- Military and Federal). There is a high cliff face with a 100 to 200 feet elevation difference between the Red Hill Naval Reservation and both Moanalua Village and the Moanalua Golf Course. To the northeast of the site is public land, which is mostly forested (zoned P1- Restricted Parkland), and to the east of the Moanalua Village residential development is Moanalua Valley Park (zoned P2- General Parkland) and then more public land (zoned P1- Restricted Parkland).

A gated residential community with townhouses and apartment buildings is located to the southwest of the site (zoned A2- Apartments), and a public school (Red Hill Elementary School) is also present in this area. The Red Hill Naval Reservation continues to the west and is adjacent to the Coast Guard Reservation, which borders Highway 78 (refer to **Figure 2-3** (GIS zoning figure), **Figure 2-4** (elevation map), and **Figure 2-2**(land use map) in the WP).

The closest residential property is the area zoned for apartment buildings located approximately 305 feet southwest of Tank 2. Red Hill Elementary School is located approximately 1,080 feet southwest of Tank 2. The Moanalua Village residential development is located approximately 880 feet south of Tank 2. The area zoned for apartment buildings is located approximately 2,113 feet southwest of Tank 20 (the tank farthest to the east), and Red Hill Elementary School is located approximately 2,850 feet from Tank 20. The Moanalua Village residential development is located approximately 875 feet south of Tank 20. Refer to **Figure 2-2** and **Figure 2-3** in the WP.

Figure 2-10 in the WP presents the Primary Urban Center (PUC) Development Plan land use map for the PUC west sector, which encompasses the site location. The DPP helps establish, promote, and implement long-range planning programs for Honolulu. The DPP's PUC Development Plan presents a vision and a clear set of planning policies for the area extending from Kahala to Pearl City on Oahu. The PUC Development Plan is designed as a general framework intended to support more detailed planning at the neighborhood level. It provides clear, conceptual, long-range policies for topics of concern to all of the region's communities. Based on review of this anticipated future land use map, the most significant item is that the site is not identified as military land, but is rather identified as industrial property. In addition, the area north of the site to the H3 Freeway and slightly beyond is also identified for industrial land use. This includes the area between the Naval Reservation and the South Halawa Stream, north of the prison, which is currently open land, zoned P1- Restricted Parkland. Moanalua Village remains identified as a lower-density residential neighborhood and the apartment buildings to the southwest of the site are identified as medium and higher-density residential/mixed use.

2.1.2 Groundwater Use

The site is located in the Moanalua portion of the Southern Oahu groundwater flow system. Water flow is estimated to be toward the southwest. Refer to **Figure 2-5** and **Figure 2-6** in the WP. Groundwater is estimated to be located approximately 16.5 feet above msl. Refer to Cross Section **Figure 3-2** and **Figure 3-3** in the WP. The bottom of Tanks 1 and 2 are estimated to be located at 120 feet above msl and the bottoms of Tanks 19 and 20 are estimated to be located 155 feet above msl.

Groundwater is considered a very important natural resource as nearly all of Hawaii's drinking water supply comes from groundwater sources. Groundwater wells in the vicinity of the site are shown on **Figure 2-18** in the WP. The Hawaii Department of Health (HDOH) has identified the site location as being "mauka" or above the underground injection control (UIC) line, indicating that the underlying aquifer is considered a potential drinking water source. In fact, the basal aquifer in the vicinity of the site is used as a source of drinking water by the Navy PWC and supplies the drinking water for the Pearl Harbor Naval Complex. The PWC pumping station (Adit No. 3) is located within the lower tunnel system approximately 0.5 miles to the west of the bulk fuel storage tanks. Refer to **Figure 2-9, Figure 3-2**, and **Figure 3-3** in the WP.

Regular testing of the basal aquifer is conducted by the Public Works Center (PWC) and the HDOH to ensure that the water is maintained within drinking water standards. The analytical program at the PWC pump station addresses volatile organic compounds (VOCs) and other petroleum constituents of concern. No indication of petroleum contamination has been detected in the basal aquifer water samples collected during the periodic monitoring at the PWC pump station. Currently a small business subcontractor has been tasked to perform quarterly groundwater monitoring of the PWC pump station shaft and existing lower tunnel vertical well (MW-V1D). As of the publication of this document, results and findings have not been published.

The 2002 Groundwater Contamination Maps for the State of Hawaii provide information on monitoring data for public drinking water wells where groundwater constituents have been detected and confirmed. Information specific to the Naval PWC pumping station Adit No. 3 was not included in the reported data. However, seven public wells were identified in the vicinity of the site: four wells are located near the junction of the H3 Freeway and Highway 78, and three wells are located near the junction of Highway 78 and Highway 63. The information provided on the constituents detected in these public water wells is summarized in the following table.

Table 2-1
Summary of Monitoring Data on Public Wells[a]

Summary of Monitoring Data on Public Wells[a]				
Map #	**Well Name**	**Use**	**Constituents**	**Date**
Highway 78 & H3				
14	Halawa Plant (Navy)	Drinking Water	Dieldrin	2002
15	BWS Halawa Well 2	Drinking Water	Chlordane Dieldrin	2002 2002
15	BWS Halawa Well 1	Drinking Water	Dieldrin	2002
18	Aiea Well Pump 1	Drinking Water	Dieldrin	2002
18	Aiea Well Pump 2	Drinking Water	Dieldrin	2000
19	Kaamilo Wells	Drinking Water	Dieldrin Dieldrin Perchloroethene	2002 1998 1985
Highway 78 & Highway 63				
5	Kalihi Station Wells	Drinking Water	Dieldrin	2002
9	Kamehameha School Well 1	Inactive	Chlordane Dieldrin	1998 1998
9	Kamehameha School Well 1	Inactive	Chlordane Dieldrin	1997 1996
10	Jonathan Springs Well	Inactive	Chlordane Dieldrin	1995 1995

Source: 2002 Groundwater Contamination Maps for the State of Hawaii.

The information on the public drinking water wells as summarized above does not indicate the presence of petroleum-related constituents in drinking water in the general site vicinity. Refer to **Figure 2-8** in the WP for area wells impacted and non-impacted by contamination.

2.2 Potential Ecological Receptors

Potential ecological receptors were identified through evaluation of information on surface water bodies in the vicinity of the site, threatened and endangered species, and critical habitat.

2.2.1 Surface Water

There are three potentially ecologically important surface water entities in the vicinity of the site. The southern segment of the Halawa Stream is located approximately 665 feet to the north of the site and the northern segment of the Moanalua Stream is located approximately 1,760 feet to the south of the site (refer to **Figure A6-2** (drainage)). The third potentially impacted surface water body is Salt Lake. It is located approximately 5,610 feet to the southwest of the site.

Both the Moanalua and the Halawa Streams are identified on the HDOH list of impaired waters in the State of Hawaii. The Halawa Stream was listed based on the visual assessment of nutrients and turbidity. The HDOH is in the process of developing total maximum daily loads (TMDLs) for the Halawa stream with completion expected in 2005. In addition, the Halawa Stream has been identified as needing additional monitoring and is a candidate for a Use

Attainability Analysis (UAA) as a biological assessment of the stream indicated that it may be impaired. The Environmental Protection Agency's (EPA's) Watershed Assessment Tracking & Environmental Results System indicates that the Halawa stream is 100 percent impaired for aquatic life support. Water impairments are identified as nutrients, pathogens, turbidity, and exotic species. Potential sources of impairment are identified as: urban runoff/storm sewers; other urban runoff; and other natural sources (EPA, 2004).

The South Halawa Stream is concrete lined and channelized and does not support sensitive habitat, according to the Remedial Investigation Phase II, Red Hill Oily Waste Disposal Facility (Earth Tech, 1999). The concrete-lined segment runs for at least 4,200 feet into the valley, along the entire perimeter of the Red Hill Naval Reservation. In addition, there are no stream-gauging stations, rain gauges, or water-quality sampling sites on the South Halawa Stream according to the USGS (2003, 2005). All of the monitoring stations are situated on the North Halawa Stream or the lower Halawa Stream downstream of the convergence of the North and South branches. Because the stream is concrete-lined and is 100 percent impaired for the support of aquatic life, the South Halawa Stream is not considered a potential ecological receptor for this site.

The Moanalua Stream was listed based on the visual assessment of nutrients, turbidity, and trash. The stream is noted to be of medium priority. The EPA's Watershed Assessment Tracking & Environmental Results System indicates that the Moanalua Stream is 100 percent impaired for the support of aquatic life. Water impairments are identified as nutrients, other habitat, pathogens, and turbidity. Potential sources of impairment are identified as: urban runoff/storm sewers; other urban runoff; hydromodification; channelization; habitat modification; removal of riparian vegetation; and natural sources (EPA, 2004). Although the Moanalua Stream is listed as an impaired stream, the purpose of the EPA's 303(d) program is to identify impaired streams, develop TMDLs, remediate the impairments, and return impaired streams to full productivity.

Salt Lake, which is located approximately 5,610 feet to the southwest of the site is also identified as impaired based on the visual assessment of turbidity and trash, and is noted to be of medium priority. Salt Lake is not considered a potential ecological receptor for this site.

2.2.2 Biological Resources

A biological field survey of the Red Hill Naval Reservation was performed during the Phase I Remedial Investigation of the adjacent Red Hill Oily Waste Disposal Facility by Ogden Environmental (Ogden, 1996). The Site is inhabited by: (1) *haole koa (Leucaena leucocephala)* scrub; (2) disturbed habitat, and (3) vegetation communities in developed areas. *Haole koa* scrub grows throughout Oahu, primarily in areas that have been disturbed by grazing or human activities. The scrub community on Red Hill is dominated by *Haole koa,* Guinea grass *(Panicum maximum),* and Chinese violet *(Asystasia gangetica).* The disturbed habitat is comprised of weedy plant species that can withstand frequent disturbance by human activities or natural events. Many of the species in this community are similar to those found in nonnative grasslands. However, disturbed habitats have a greater percentage of non-grass species and are characterized by sparsely covered areas. Developed habitats are those with buildings, paved roads, or other manmade structures with a minimal amount of vegetation. Small areas of lawn and ornamental bushes are often planted in developed areas. Although this vegetation does support some wildlife species, the habitat is very low in quality and is primarily used by introduced, common urban species (Ogden 1996). No native or sensitive species were observed in the area, nor were any expected, as the appropriate habitat was not present.

2.2.3 Threatened & Endangered Species and Critical Habitat

Information on potential threatened and endangered species was requested of the U.S. Fish & Wildlife Service (USFWS), the Department of Land and Natural Resources (DLNR), and the Natural Heritage Program. The DLNR responded with a list of 5 endangered plants and 13 candidate plants. Some of the plants were last observed as long ago as 1927. The most recent observation was 1967. All but five plants were last observed before 1953. In addition, no native or sensitive species were observed in a 1995 biological survey of the area (Ogden, 1996.)

Table 2-2
List of Endangered Species and Candidate Plants

Scientific Name	Common Name	Last Observed	Status
LABORDIA CYRTANDRAE	KAMAKAHALA	1933	Candidate
GARDENIA MANNII	NANU	1933	Candidate
CYANEA CRISPA	'OHA	1933	Endangered
HESPEROMANNIA ARBORESCENS		1933	Endangered
EURYA SANDWICENSIS	ANINI	1933	Candidate
CYRTANDRA PRUINOSA	HA'IWALE	1933	Candidate
GARDENIA MANNII	NANU	1995	Candidate
EURYA SANDWICENSIS	ANINI	1936	Candidate
EXOCARPOS GAUDICHAUDII	HEAU	1936	Candidate
DIELLIA FALCATA		1938	Endangered
HESPEROMANNIA ARBORESCENS		1990	Endangered
PHYLLOSTEGIA HIRSUTA		1927	Candidate
TREMATOLOBELIA SINGULARIS		NA	Candidate
JOINVILLEA ASCENDENS SSP ASCENDENS	'OHE	1967	Candidate
CYANEA GRIMESIANA SSP GRIMESIANA	'OHA	1930	Candidate

Scientific Name	Common Name	Last Observed	Status
MELICOPE LYDGATEI	ALANI	1936	Endangered
CYANEA ACUMINATA	'OHA	1953	Candidate
CHAMAESYCE ROCKII		1983	Candidate

AMEC is awaiting responses from the USFWS and the Natural Heritage Program.

It is not expected that any federal or state-listed threatened or endangered species would occur onsite. Habitats onsite are not considered sensitive and are dominated by introduced species that do not usually support native species. The state-listed Hawaiian short-eared owl *(Asio flammeus sandwichensis)* may occasionally forage onsite, but none was detected during the biological resource survey conducted by Ogden biologists at the nearby (approximately 0.6 miles east) Oily Waste Disposal Facility on February 17, 1995. This survey concluded that other sensitive wildlife species are not expected to occur on or adjacent to the Site because of a lack of appropriate habitat (Ogden 1996).

Other available information on ecological receptors is presented on **Figure A6-3**, Island of Oahu Reserves, and on **Figure A6-4** Ecological Receptors. The information presented on these figures indicates that the site is not located in a known area of critical ecological habitat. Critical habitat that supports the *Elepaio* (a native bird species) is located over 1.2 miles to the northeast and southeast. Critical habitat that supports native plant species (species information is currently unknown) is also located over 1.4 miles to the northeast. Three segments of the Honolulu Watershed Forest Reserve, a segment of the critical habitat for the Elepaio bird, and a portion of a wildlife management area are located over 1.7 miles to the southeast. There are no natural area reserves, preserves, seabird sanctuaries, state monuments, state parks, state park reserves, state waysides, wildlife refuges, hunting areas, or trails located within the vicinity of the site. Information on wetlands indicates that Pearl Harbor, Salt Lake and the streams near the site are identified as wetlands.

Figure A6-5 presents the coastal resources present around Oahu. These resources represent both potential ecological receptors (e.g., whale sanctuaries, marine life conservation districts), and also areas for potential human receptors (e.g., body surfing sites and ocean recreation areas). Because these areas are at least 3 miles from the site, they are not considered to be areas of concern for the site.

SECTION 3.0 Identification of Potential Exposure Pathways

There are four elements used to establish a complete exposure pathway:

1. a source and a mechanism of release to the environment;
2. an environmental transport medium;
3. a point of potential contact between a receptor and the environmental medium (referred to as the exposure point); and
4. an exposure route or uptake mechanism.

The exposure pathway analysis is performed by means of the development of the conceptual site exposure model (CSEM). The CSEM identifies the relationship among sources, release mechanisms, impacted media, exposure routes, exposure points, and receptors potentially affected by constituents present at or released from the site.

Figure 3-4 in the WP depicts the CSEM for the RHBFSF. **Figure 3-2** and **Figure 3-3** (cross sections) in the WP also illustrate aspects of the CSEM. The following discussion describes the CSEM and identifies the exposure pathways that will be evaluated in the Comprehensive Risk Assessment. The text is generally organized by the environmental media to which potential exposure could occur, i.e., air, soil, groundwater, surface waters, and biota.

3.1 PRIMARY SOURCES

The current sources are believed to be the underground storage tanks and the fuel distribution systems (POL piping) specifically associated with the RHBFSF. Hydrogeologic investigations and direct observations indicate that product may be leaking from one or more of the storage tanks and/or piping and possibly pooling beneath the tank facility. Therefore, the underground storage tanks and associated piping could act as primary sources from which petroleum products could be released.

3.2 PATHWAYS

3.2.1 Air

Volatile constituents from any petroleum releases could potentially volatilize at the site of the release and enter the soil pore spaces or basalt bedrock fissures. Any such volatilized constituents could then potentially migrate to a distant location. In addition, product could potentially migrate within basalt bedrock fissures from the location of release to a distant location. At the distant location, volatile constituents could also volatilize into soil pore spaces or basalt bedrock fissures where they could potentially migrate further. Finally, either product or product vapor could migrate via a pathway of preferential flow, such as pipeline or utility corridor backfill, to a distant location, where, again, the product or vapor could enter pore spaces or basalt bedrock fissures and then potentially migrate further.

At a distant location, the vapor could potentially be released into ambient air or into a building by vapor intrusion through the building's flooring. If any of these mechanisms were to occur, an exposure route of interest would be inhalation of petroleum product vapor.

The Comprehensive Risk Assessment will evaluate occupational workers and trespasser/visitors as potential receptors for inhalation of any such vapor within the tunnels. This exposure pathway is not relevant and is considered incomplete for ecological receptors.

The potential for toxic compounds in soil gas originating from beneath the underground storage tanks (USTs) to migrate to nearby surface residential areas is extremely remote and considered insignificant. Nearest residents are more than 300 feet away from the USTs. Toxic compounds would be diluted, would partition to soil and soil moisture, and would be degraded prior to reaching these locations at concentrations of concern. Terrestrial receptors are not expected to be impacted by soil vapor based on similar rationale. The pathway to aquatic receptors is incomplete.

3.2.2 Soil

Any petroleum product vapor that might potentially migrate through basalt bedrock fissures to a distant location could also potentially adsorb onto surface soils if the vapor migrated laterally or vertically through the soil column. If so, the soil could be a potential exposure medium by which human or ecological receptors could come into contact with petroleum constituents. However, volatile petroleum constituents only have moderate affinity for adsorption to soil. Any constituent concentrations in soil at locations distant from the Red Hill Naval Reservation would be expected to be very low. Ingestion, dermal contact, and inhalation of vapor from potentially affected soils by human and terrestrial ecological receptors are considered minor exposure pathways. These exposure pathways are not relevant and are considered incomplete for aquatic ecological receptors.

3.2.3 Groundwater

Any released petroleum product could also potentially migrate within basalt bedrock fissures from the location of release to a distant location where it might contact groundwater. Soluble constituents could become dissolved in the groundwater and migrate further. Also, product could migrate via a pathway of preferential flow, such as pipeline or utility corridor backfill, to a distant location, where, again, the product could contact groundwater. If the constituents contacted groundwater, the groundwater could potentially migrate to the nearby infiltration tunnel that serves the Red Hill Adit Number 3 Water Pumping Station. If this were to occur, the groundwater would be used as a potable water supply.

Residential and occupational receptors could potentially become exposed to petroleum constituents via ingestion and dermal contact with the groundwater and inhalation of volatile constituents that could volatilize during potable water use in the home or workplace. Pathways associated with potential exposures to residential and occupational users of groundwater as a potable drinking water source are considered significant. The exposures to trespassers or visitors who could use the groundwater for potable purposes are considered minor exposure pathways, because their exposure frequencies and durations would be far less than those of residential and occupational receptors. These exposure pathways are not relevant and are considered incomplete for ecological receptors.

Volatile dissolved petroleum constituents in groundwater could volatilize into ambient air or into buildings above the groundwater. Residential and occupational receptors are considered potential receptors for inhalation of any such vapor within buildings. The inhalation of vapor by trespassers or visitors inside buildings is considered a minor exposure pathway; their exposure frequencies and durations would be far less than those of residential and occupational receptors. This exposure pathway is not relevant and is considered incomplete for ecological receptors. Because the dilution of any vapor in ambient air would be significant, inhalation of petroleum constituents in ambient air by any potential human or terrestrial ecological receptors is considered a minor exposure pathway. This exposure pathway is not relevant and is considered incomplete for aquatic ecological receptors.

Groundwater containing dissolved petroleum constituents is not anticipated to surface through seeps above the water table under any circumstance. This exposure pathway is not relevant and is considered incomplete for all receptors. Therefore, this exposure pathway will not be evaluated in the Comprehensive Risk Assessment.

3.2.4 Surface Water

Groundwater containing dissolved petroleum constituents is not anticipated to be released to surface water bodies because the groundwater table is approximately 80 feet below the streambeds in the adjacent valleys. Because of the unlikely release of dissolved petroleum constituents from seeps or groundwater discharges to nearby streams, this exposure pathway is not relevant and is considered incomplete for human and terrestrial ecological receptors.

3.2.5 Biota

Petroleum constituents are not anticipated to be released to surface water. Therefore, any aquatic or terrestrial organisms present there are not anticipated be exposed to contaminants. In addition, none of the soluble petroleum constituents that could potentially be present in a dissolved state in groundwater from the site are bioaccumulative. As such, neither the aquatic biota nor the terrestrial biota, themselves, can be considered exposure media for other human or ecological receptors. Thus, there are no complete exposure pathways for exposures by human or ecological receptors to petroleum constituents that have bioaccumulated in aquatic or terrestrial biota.

Similarly, if any groundwater affected by dissolved petroleum constituents were used as drinking water for animals or to irrigate crops fed to animals, there would be little or no bioaccumulation of the constituents into the crops or the livestock. Thus, there are no complete exposure pathways for exposures by human receptors to petroleum constituents that have bioaccumulated in terrestrial biota from use of groundwater to water livestock or livestock food sources.

3.3 SCREENING LEVEL ECOLOGICAL RISK EVALUATIONS

A screening level ecological risk assessment (ERA) was previously conducted for the Red Hill Oily Water Disposal Facility (OWDF) and was presented in the Phase I RI Report (Ogden 1996). The OWDF is located approximately 0.6 miles northwest of the RHBFSF and the screening level ERA performed for the OWDF is considered representative of the site.

The screening level ERA indicated that the OWDF is located in a partially vegetated industrial area surrounded by developed land. The majority of land comprising the OWDF is either developed or is non-native habitat utilized by common urban species. The biological survey performed of the Red Hill Naval Reservation indicated that the habitat consists of scrub vegetation, disturbed habitat and developed land. All habitats found onsite were of poor quality, were dominated by non-native species, and contained no species with federal or state status. Poor habitat quality is primarily due to habitat alteration and degradation by development. The predominant plant in undeveloped areas is *koa haole*, a large, exotic shrub or small tree that is common throughout dryer lowland areas in Hawaii. Common introduced bird species were observed in the koa haole scrub onsite. With the exception of the Pacific golden-plover, all terrestrial species observed during the survey were non-native, exotic species. The plover is a migratory bird that overwinters in Hawaii, and generally inhabits grassy fields, lawns, mudflats, and sandy beaches. The plover was seen in the concrete channel of Halawa Stream, possibly foraging in the very small flow extant at the time of the survey. The Halawa Stream does not flow year round and is not the preferred habitat of the plover. It is unlikely that this species spends a significant amount of time onsite, due to lack of appropriate habitat. No aquatic ecological receptors were observed in the channelized reach of Halawa Stream.

Three elements create the potential for risk (a) detected concentrations of chemical constituents, (b) ecological receptors linked to assessment endpoints, and (c) potentially complete exposure pathways linking a constituent to a receptor. Constituents and potentially complete pathways were identified at the OWDF. However, all of the receptors identified onsite, with the exception of the Pacific golden-plover, are common, non-native urban species and were deemed to be neither ecologically, nor socially, important receptors and thus not linked to assessment endpoints. The plover is not likely to spend sufficient time foraging onsite for it to be considered a significantly exposed receptor. There is no anticipated future use of the OWDF as a re-introduction site for either special status species or native Hawaiian flora and fauna. Therefore, there would be a minimal possibility for current or future adverse effects to special status species due to OWDF-related contaminants.

The screening level ERA concluded that due to the lack of significant receptors, there was a minimal possibility for current or future adverse effects to sensitive species due to OWDF-related chemicals. This conclusion also holds for the Red Hill Bulk Fuel Storage Facility since potential ecological receptors at the site would be considered representative of those observed at the ODWF.

3.4 CONCLUSIONS AND RECOMMENDATIONS

Based on the evaluations presented above, the Comprehensive Risk Assessment will evaluate the following:

1. The current risk to potable water wells in the vicinity of the Site
   (a) Ingestion of potable water by residential and occupational users
   (b) Dermal contact with potable water by residential and occupational users
   (c) Inhalation of volatile constituents released during use of potable water by residential and occupational users

2. Underground tunnels at the Red Hill Naval Reservation.
   (a) Inhalation of volatile constituents in tunnel by occupational workers and visitors/trespassers

3. Concentrations of contaminant of potential concern (COPCs) at monitoring points (3 onsite monitoring wells) that can be expected to present a future risk.

The results of the fate and transport modeling will be used to estimate constituent concentrations at the point of exposure for use in the Comprehensive Risk Assessment. The CSEM is presented as Figure 3-4 in the WP and summarizes the results of the refined exposure assessment.

SECTION 4.0 References

Earth Tech Inc., 1999. Draft Report Phase II Remedial Investigation, Red Hill Oily Waste Disposal Facility, January 1999.

Ogden Environmental and Energy Services Company, Inc. (Ogden). 1996. Phase I Remedial Investigation Report. Red Hill Oily Waste Disposal Facility. Fleet and Industrial Supply Center, Pearl Harbor, Oahu, Hawaii. Volume I, Technical Report. Prepared for the Department of the Navy. Pacific Division. Contract No. N62742-88-D-0032, Delivery Order 0012. January 1996.

Ogden, 1999. Environmental and Energy Services, Co., Inc., 1999. Initial Phase II Site Characterization Report, Fleet Industrial Supply Center, Bulk Storage Facility at Red Hill (Draft). March, 1999.

U.S. Environmental Protection Agency (EPA). 2004. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual. (Part E, Supplemental Guidance. for Dermal Risk Assessment). Final. EPA/540/R/99/005. OSWER 9285.7-02EP. PB99-963312. July 2004.

USGS. 2003. Rainfall, Streamflow, and Water-Quality Data During Stormwater Monitoring, Halawa Stream Drainage Basin, Oahu, Hawaii, July 1, 2002 to June 30, 2003. Open File Report 03-331.

USGS. 2005. Site Inventory for Hawaii. http://nwis.waterdata.usgs.gov/hi/nwis

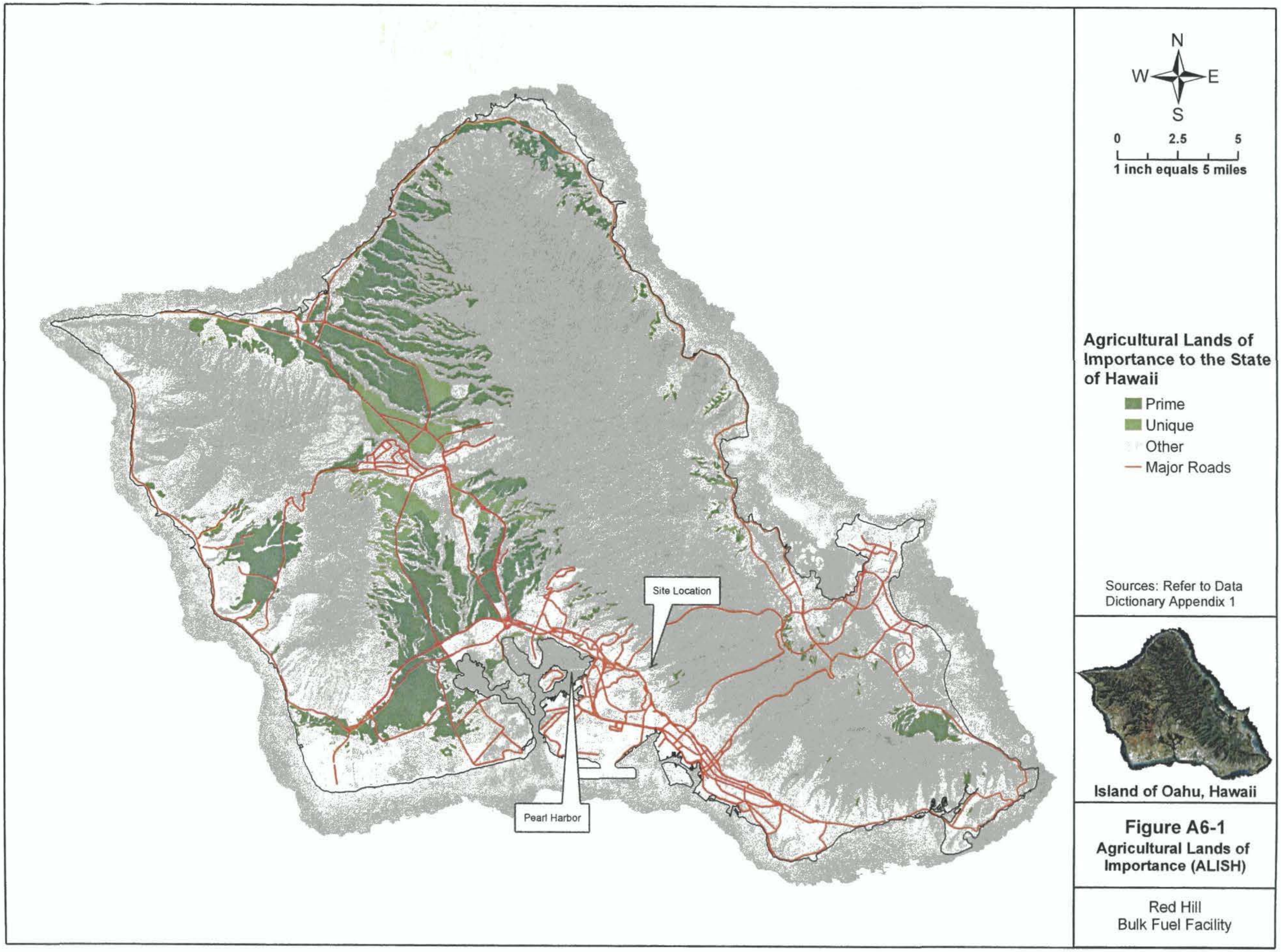


Figure A6-1
Agricultural Lands of Importance (ALISH)

Red Hill
Bulk Fuel Facility

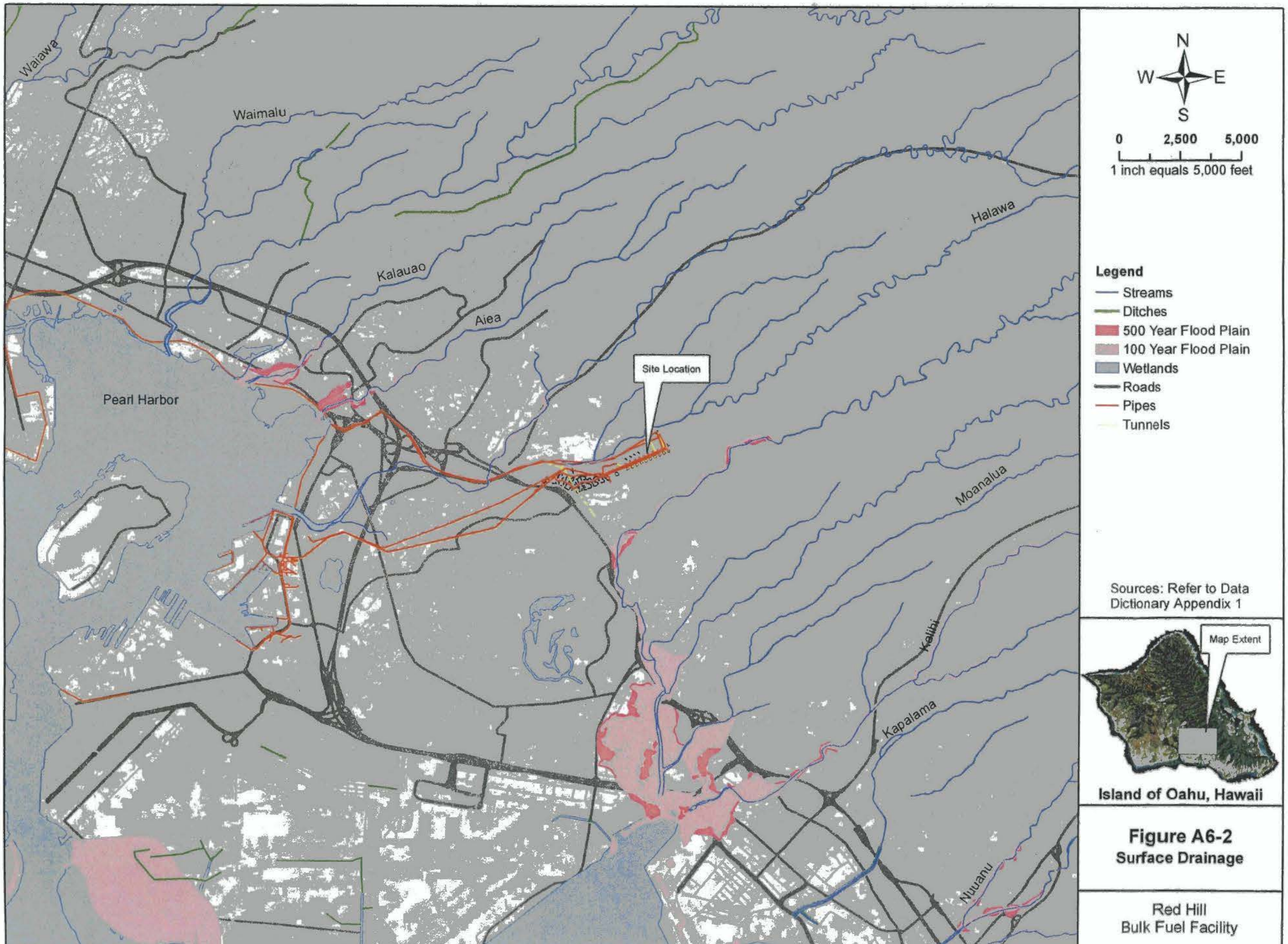


Figure A6-2
Surface Drainage

Red Hill
Bulk Fuel Facility

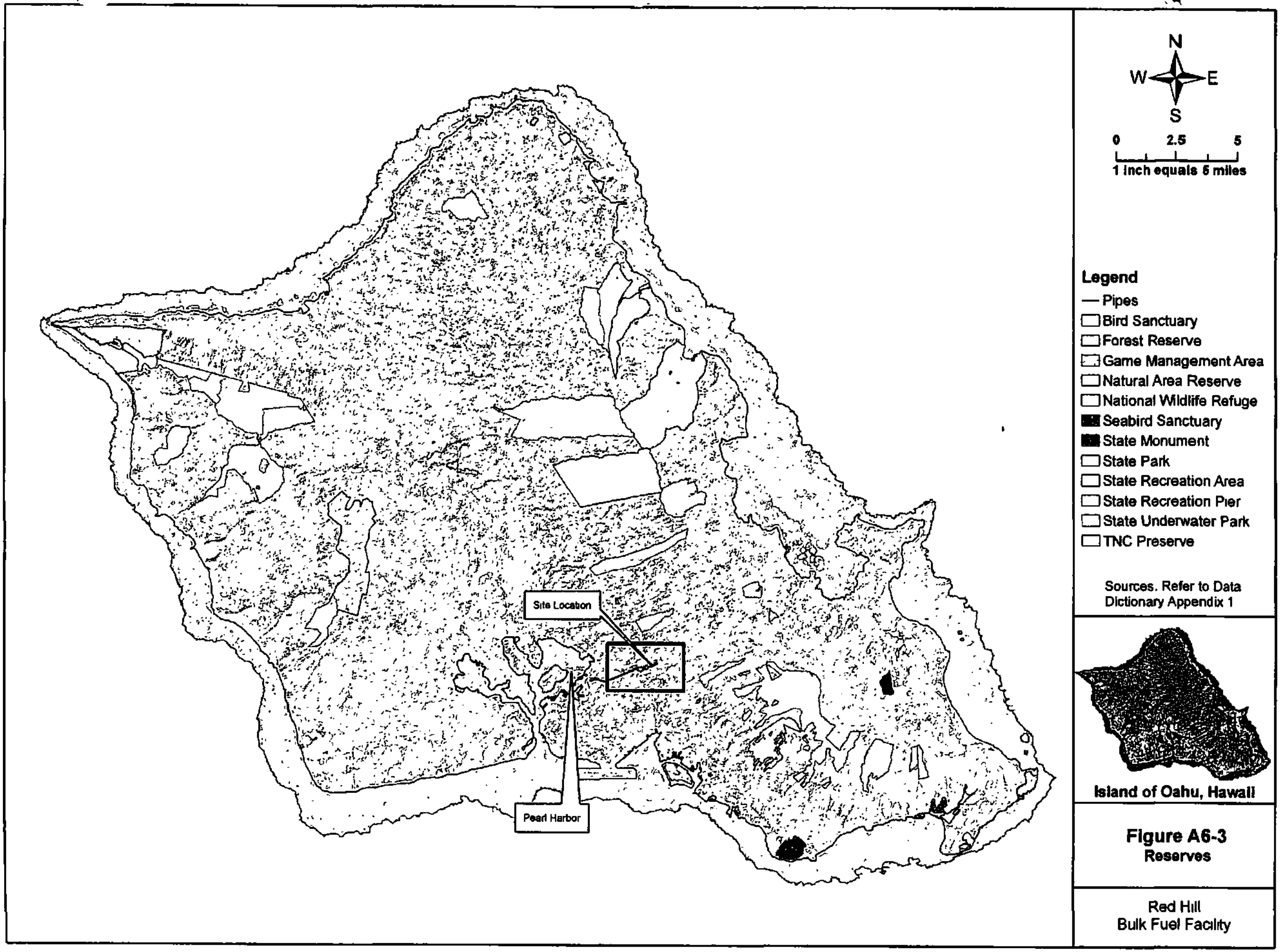


Figure A6-3
Reserves

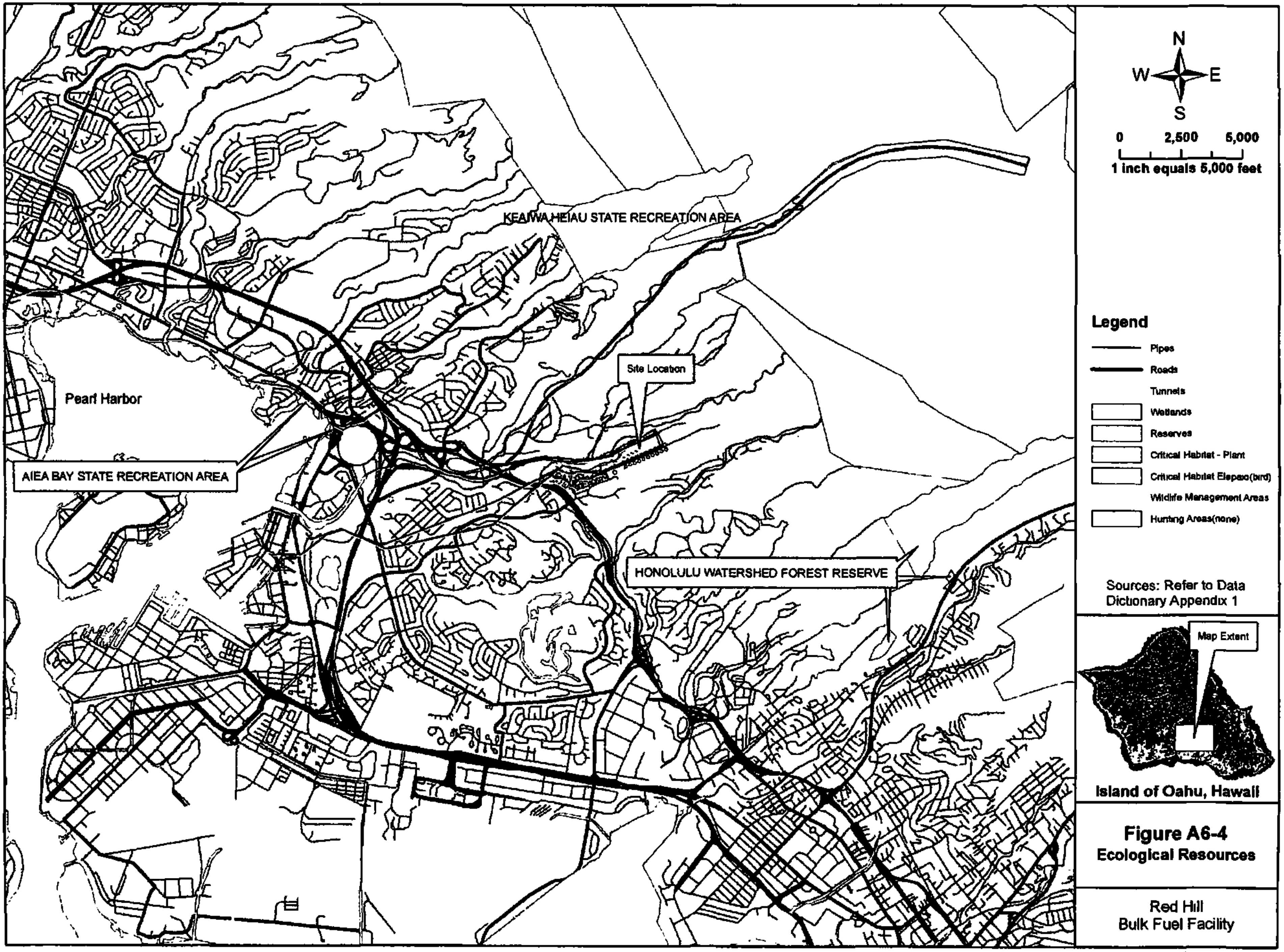


Figure A6-4
Ecological Resources

Red Hill
Bulk Fuel Facility

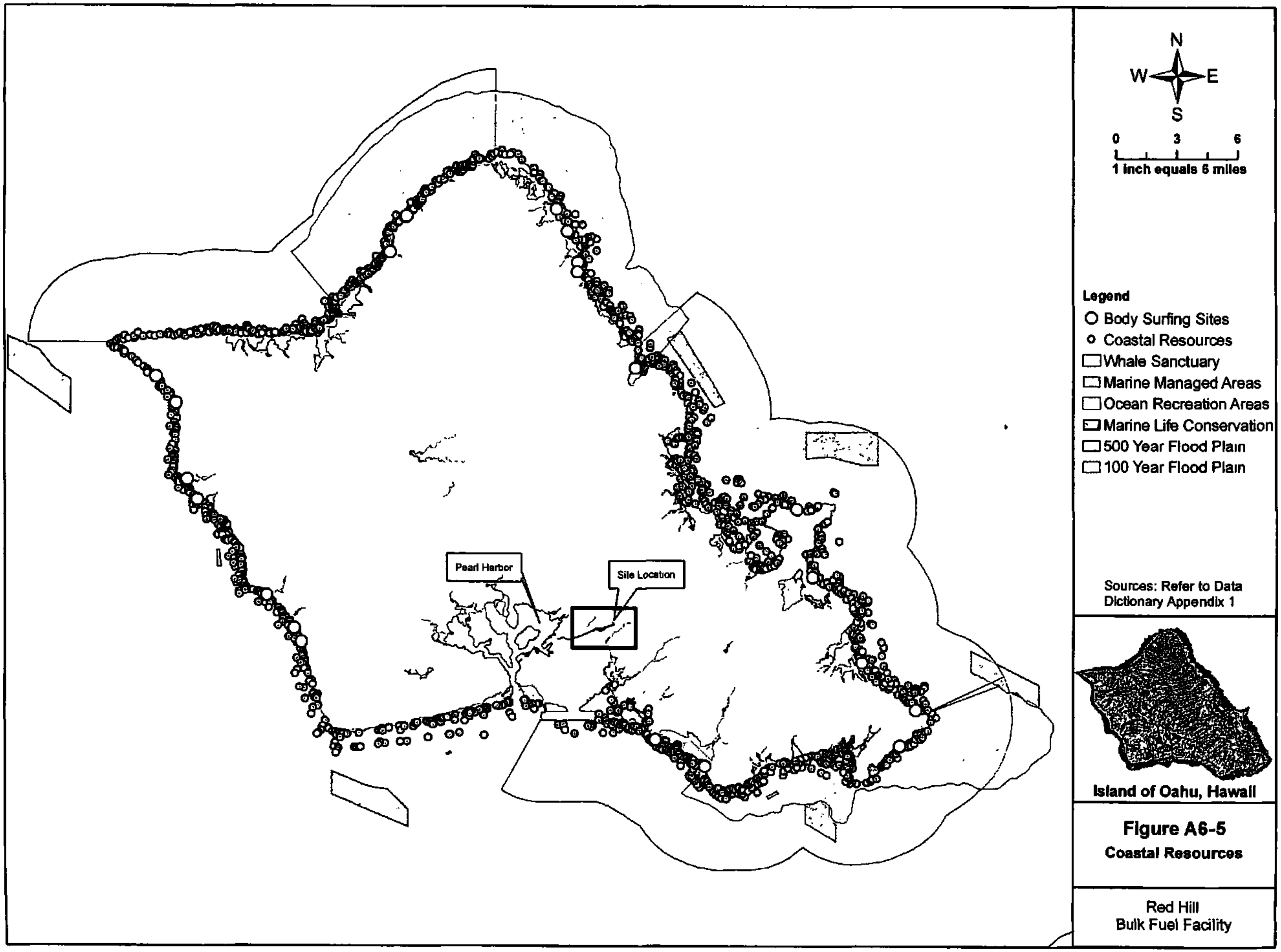


Figure A6-5
Coastal Resources

Red Hill
Bulk Fuel Facility

Appendix E

Regulatory Correspondence

OCT 10 2003

LINDA LINGLE
GOVERNOR OF HAWAII

COPY

STATE OF HAWAII
DEPARTMENT OF HEALTH
P.O. BOX 3378
HONOLULU, HAWAII 96801-3378

In reply, please refer to:

October 10, 2003 U10018RT

Mr. Darren Uchima
Navy Region Hawaii
Regional Environmental Department, N465
517 Russell Avenue, Suite 110
Pearl Harbor, Hawaii 96860-1884

Dear Mr. Uchima:

SUBJECT: Red Hill Tank Complex
Facility ID No. 9-102271 / Release ID Nos. 990051, 010011 and 020028

The Department of Health (DOH) would like to thank you for the presentation and tour of the Red Hill Tank Complex on August 12, 2003. As stated in our letter of July 21, 2003, a comprehensive Tier III Risk Assessment is requested for the Red Hill Tank Complex in accordance with 5.4.4 of our *"Technical Guidance Manual for Underground Storage Tank Closure and Release Response, 2nd Edition (TGM),"* and Appendix 5-H of the TGM, *Format for a Risk Assessment Report*. We recommend that your consultant contact toxicologist Barbara Brooks or ecological risk assessor Clarence Callahan of DOH's Hazard Evaluation and Emergency Response Office to ensure that your Tier III Risk Assessment is prepared according to DOH standards.

Due to the uncertainties regarding petroleum releases from the facility, the following is also strongly recommended:

1. Comprehensive site conceptual model, including a fate and transport model for contamination from the facility, flow modelling to receptors, and contingency plan to protect the Navy's Halawa Adit No. 3 Drinking Water Pumping Station.

2. As stated in our letter of July 21, 2003, scale maps and figures identifying the precise location and distance of the groundwater extraction points to the tanks and piping of the Red Hill Tank Complex are required in your next quarterly progress report. Your e-mail message sent on July 7, 2003 stated that Figure 1-2 of the submitted *"Red Hill Bulk Fuel Storage Facility Investigation Report, Volume I of III,"* would satisfy this request. Unfortunately, Figure 1-2 does not indicate the location or presence of piping connected to the 20 underground storage tanks (USTs) of the Red Hill Tank Complex in relation to the groundwater extraction points, or the Red Hill Adit No. 3 Water Pumping Station, or the pipelines which connect the facility to Pearl Harbor, Hickam Air Force Base, the former Barbers Point Naval Air Station,

Mr. Darren Uchima
October 10, 2003
Page 2

or any other facilities. DOH defines a UST system as the UST plus all connected piping. This information is required and will be critical to your planned Tier III Risk Assessment for the facility.

3. As stated in our letters of April 4, 2003 and July 21, 2003, the Red Hill Tank Complex is a confirmed UST release site and the Navy is required to submit quarterly release response reports to this office every 90 days. These reports must include groundwater monitoring data from the wells installed within the facility. As these are groundwater monitoring wells and not drinking water wells, analytical results, including minimum detection limits and reporting results, should be submitted for the following chemical constituents: benzene, toluene, ethylbenzene, xylenes, MtBE, benzo(a)pyrene, acenaphthene, fluoranthene, naphthalene, and total lead. If additional analyses are performed, please include the results in a separate table.

4. We are aware that DOH's Safe Drinking Water Branch requires comprehensive testing of the Navy's Adit No. 3 Drinking Water Pumping Station every three years. Due to the fact that 100 million to 200 million gallons of jet fuel and fuel oil are stored in the Red Hill Tank Complex, this office recommends quarterly testing of the Adit No. 3 Drinking Water Pumping Station for the following chemical constituents: benzene, toluene, ethylbenzene, xylenes, MtBE, benzo(a)pyrene, acenaphthene, naphthalene, and total dissolved lead. In addition, DOH requests a written description of the method of collection for drinking water samples at the Adit No. 3 Drinking Water Pumping Station.

5. Copies of any documentation of engineering investigations of structural integrity or leakage of Red Hill Tank Complex.

6. Installation of a leak detection system for each of the 20 field-constructed USTs in the Red Hill Tank Complex.

If you have any questions regarding this letter, please contact Mr. Richard Takaba of our Underground Storage Tank Section at (808) 586-4226.

Sincerely,

STEVEN Y.K. CHANG, P.E., CHIEF
Solid and Hazardous Waste Branch

c: Matt Small, U.S. EPA Region 9
Barbara Brooks, Hazard Evaluation and Emergency Response Office
Clarence Callahan, Hazard Evaluation and Emergency Response Office
William Wong, Safe Drinking Water Branch

Appendix F

Auxiliary Maps, Report Excerpts, Existing Boring Logs, and Well Completion Diagrams

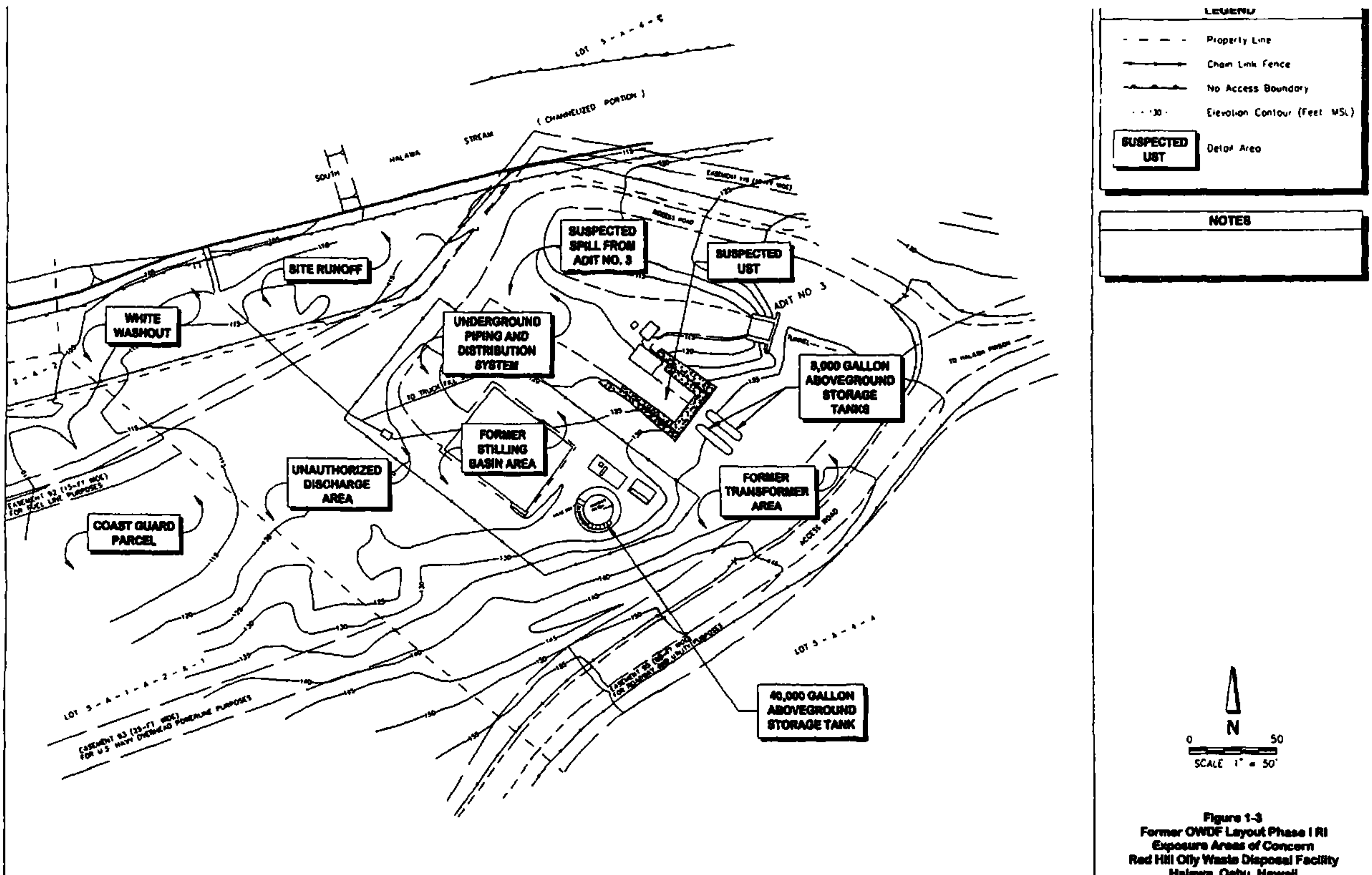
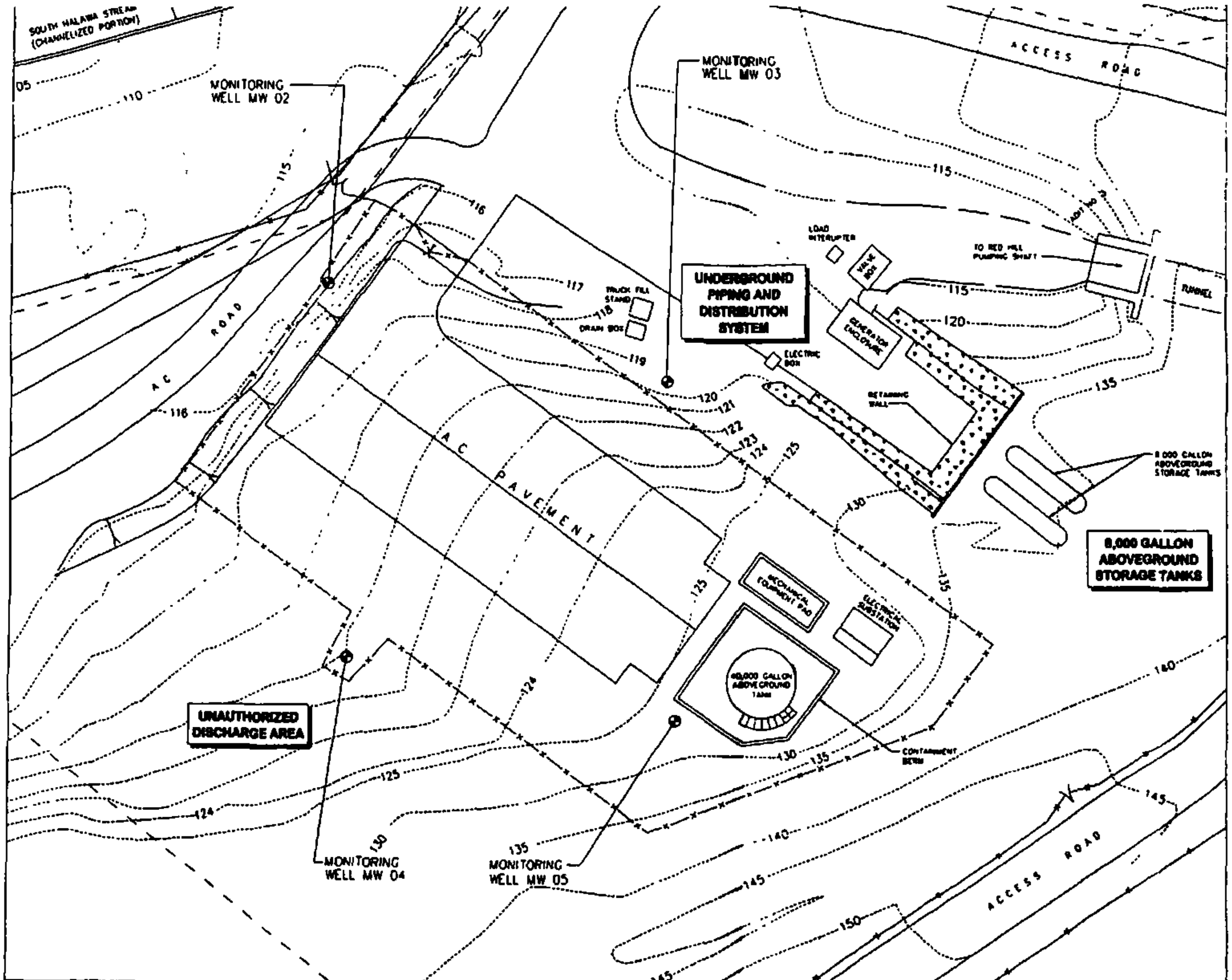


Figure 1-3
Former OWDF Layout Phase I RI
Exposure Areas of Concern
Red Hill Oily Waste Disposal Facility
Halawa, Oahu, Hawaii

Filename \CLEAN\25260-CT034_RedHill\Figures\General\RH-Former Facility Layout.Dwg 07SEPT98



LEGEND

— — —	Property Line
—x—x—	Chain Link Fence
---- 130 ----	Elevation Contour (Feet MSL)
⊕	Perched Groundwater Monitoring Well
UNAUTHORIZED DISCHARGE AREA	Phase II RI Area of Concern

NOTES

1. All Contours In Feet, MSL
2. Source Ogden 1996 OHM 1996 Towill Survey, 1998

Figure 1-4
OWDF Layout, Phase II RI
Exposure Areas of Concern
Red Hill Oily Waste Disposal Facility
Halawa, Oahu, Hawaii

Filename \CLEAN\25280-CTO34_Redhill\Figures\General\RI-Exposure Areas of Concern.Dwg 07SEP199

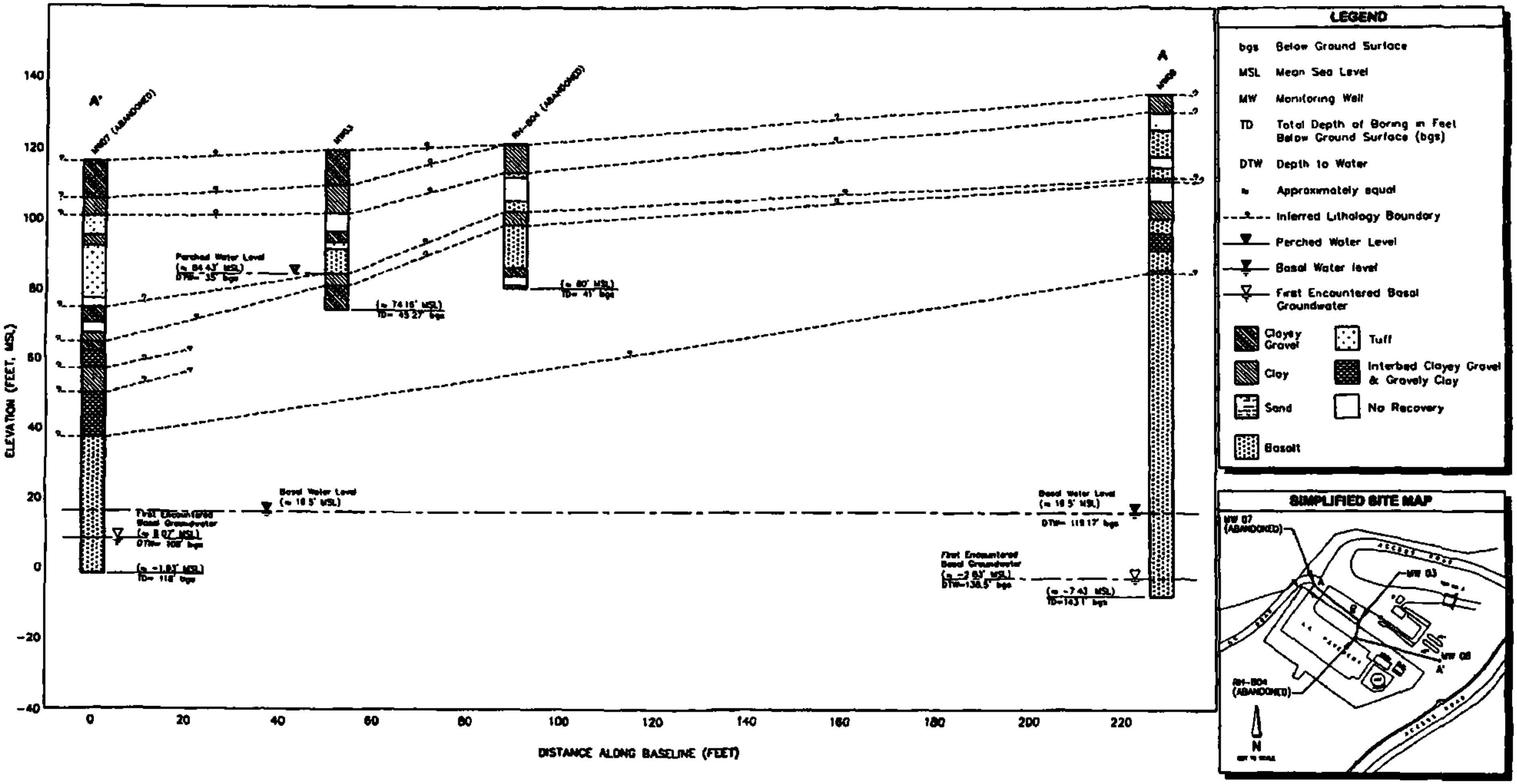


Figure 3-2
Geologic Cross Section A-A'
Red Hill Oily Waste Disposal Facility
Halawa, Oahu, Hawaii

Filename \CLEAN\25260-CTO34_RedHill\Figures\General\RH-CS_A-A.Dwg 07SEP'99

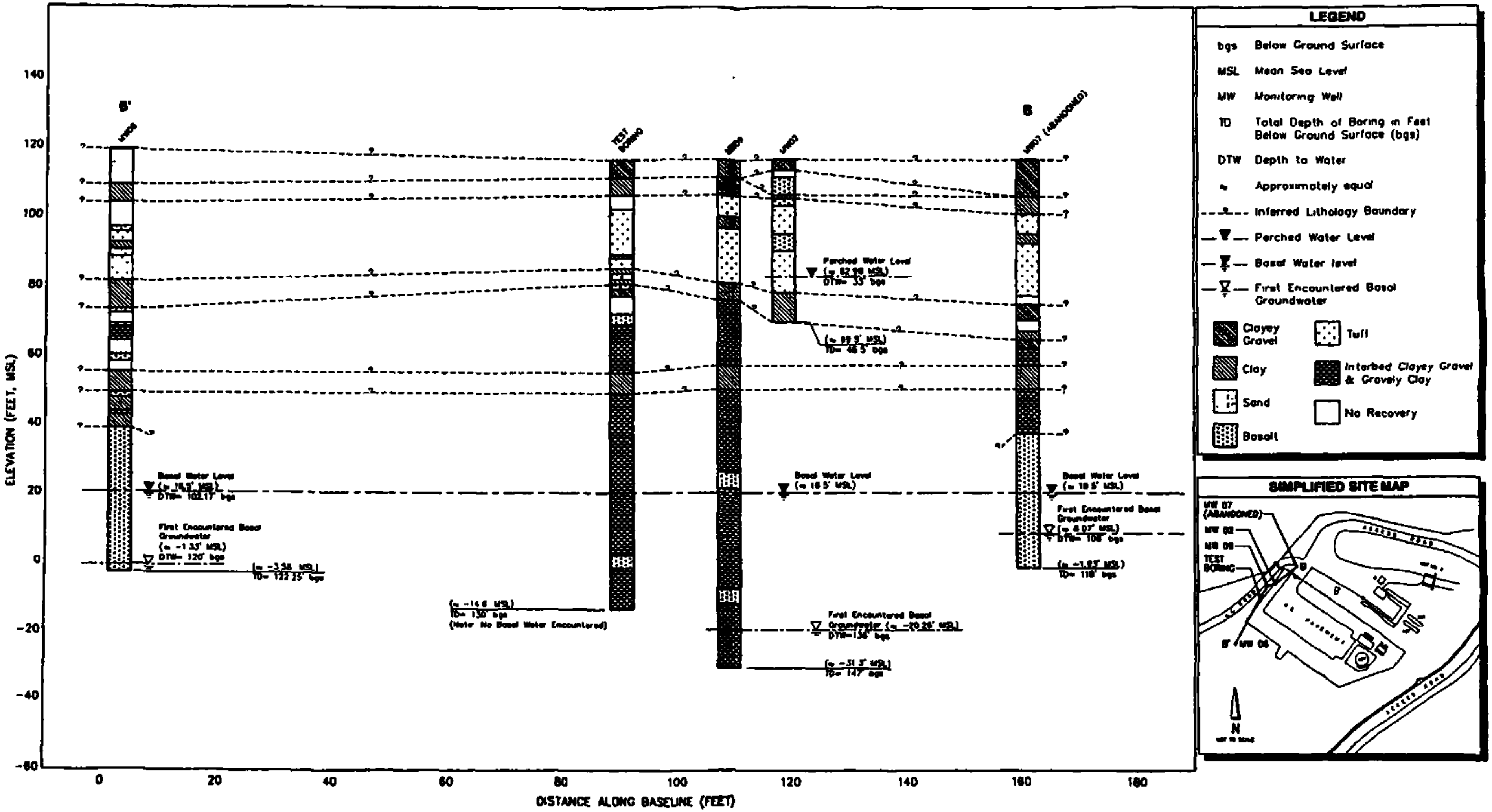
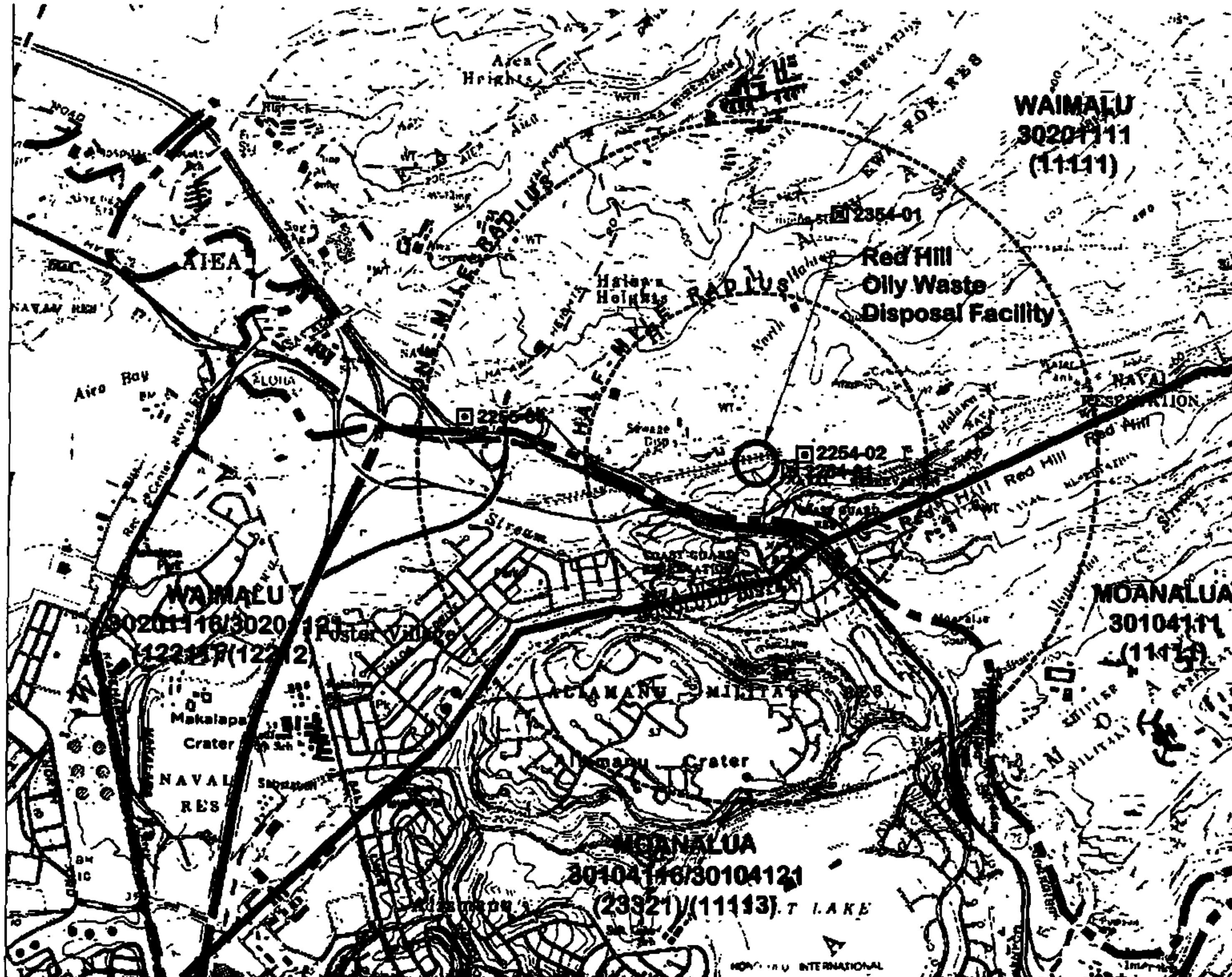


Figure 3-3
Geologic Cross Section B-B'
Red Hill Oily Waste Disposal Facility
Halawa, Oahu, Hawaii

Filename \CLEAN\25260-CTO34_RedHill\Figures\General\RH-CS_B-B Dwg 07SEP789



LEGEND

━━━	Aquifer System Boundary
━ ━ ━	Aquifer Type Boundary
30201111	Aquifer Code
(11111)	Status Code
2255-33 ⊡	Observation Well
2254-01 ⊠	Water Pumping Station

NOTES

1 Sources: Mink & Lau (1990), DLNR (1998), USGS (1983)

Figure 3-4
Offsite Monitoring Wells Within a
One Mile Radius and OWDF Site Designation,
State of Hawaii Aquifer Classification
Red Hill Oily Waste Disposal Facility
Halawa, Oahu, Hawaii

Table 3-1 Aquifer and Status Codes for Oahu, Hawaii

Aquifer Code[1]				Status Code[2]	
Code[1]	Sector	System	Type	Code[2]	Aquifer used
30104116	01 Honolulu	04 Moanalua	116 Basal Unconfined Sedimentary	23321	Potential use neither drink nor ecologically important moderate salinity, replaceable with high vulnerability to contamination
30104111	01 Honolulu	04 Moanalua	111 Basal Unconfined Flank	11111	Currently used drinking fresh water, irreplaceable with high vulnerability to contamination
30104121	01 Honolulu	04 Moanalua	121 Basal Confined Flank	11113	Currently used drinking fresh water, irreplaceable with low vulnerability to contamination
30201116	02 Pearl Harbor	01 Waimalu	116 Basal Unconfined Sedimentary	12211	Currently used ecologically important low salinity, irreplaceable with high vulnerability to contamination
30201121	02 Pearl Harbor	01 Waimalu	121 Basal Confined Flank	12212	Currently used ecologically important low salinity, irreplaceable with high vulnerability to contamination
30201111	02 Pearl Harbor	01 Waimalu	111 Basal Unconfined Flank	11111	Currently used drinking fresh water, irreplaceable with high vulnerability to contamination

[1] Aquifer Code = Island+Aquifer sector+Aquifer System+Aquifer Type

3	Oahu Island
01	Honolulu Sector
04	Moanalua Aquifer System
111	Basal Unconfined Flank

[2]Status Code (Groundwater)

Development Stage	Utility	Salinity (mg/l CL-)	Uniqueness	Vulnerability to Contamination
1 Currently used	1 Drinking	1 Fresh (<250)	1 Irreplaceable	1 High
2 Potential use	2 Ecologically important	2 Low (250-1000)	2 Replaceable	2 Moderate
3 No potential use	3 Neither	3 Moderate (1000-5000)		3 Low
		4 High (5000-15000)		4 None
		5 Seawater (>15000)		

Table 3-2 Offsite Water Supply Wells Within A One Mile Radius, Red Hill OWDF

Well ID	Well Name	Latitude	Longitude	Owner	Well Type	Ground Surface Elevation (feet MSL)	Well Depth (feet)
2253-01	Red Hill	212248	1575334	N/A	N/A	256	275
2254-01	Halawa Red Hill	212225	1575430	US Navy	Tunnel	200	210
2254-02	Halawa	212226	1575427	US Navy	N/A	158	164
2354-01	Halawa Shaft	212305	1575426	BWS	Tunnel	165	183

Continued

Well ID	Well Name	Listed Use	Initial Head (feet MSL)	Head (feet MSL)	Geology	Bottom of Hole (feet MSL)	Latest Head (feet MSL)
2253-01	Red Hill	UNU	21 4	N/A	TKB	-19	N/A
2254-01	Halawa Red Hill	MUN	23 6	N/A	TKB	-10	N/A
2254-02	Halawa	OTH	12 1	N/A	TKB	-6	N/A
2354-01	Halawa Shaft	MUN	N/A	N/A	TKB	-18	N/A

Notes
BWS City and County of Honolulu Board of Water Supply
MSL Mean Sea Level
MUN Municipal Water Supply
N/A Not Available
OTH Other
TKB Tertiary Koolau Basalt
UNU Unused
Source *State of Hawaii Department of Land and Natural Resources Water Commission Water Supply Well Database*

(((

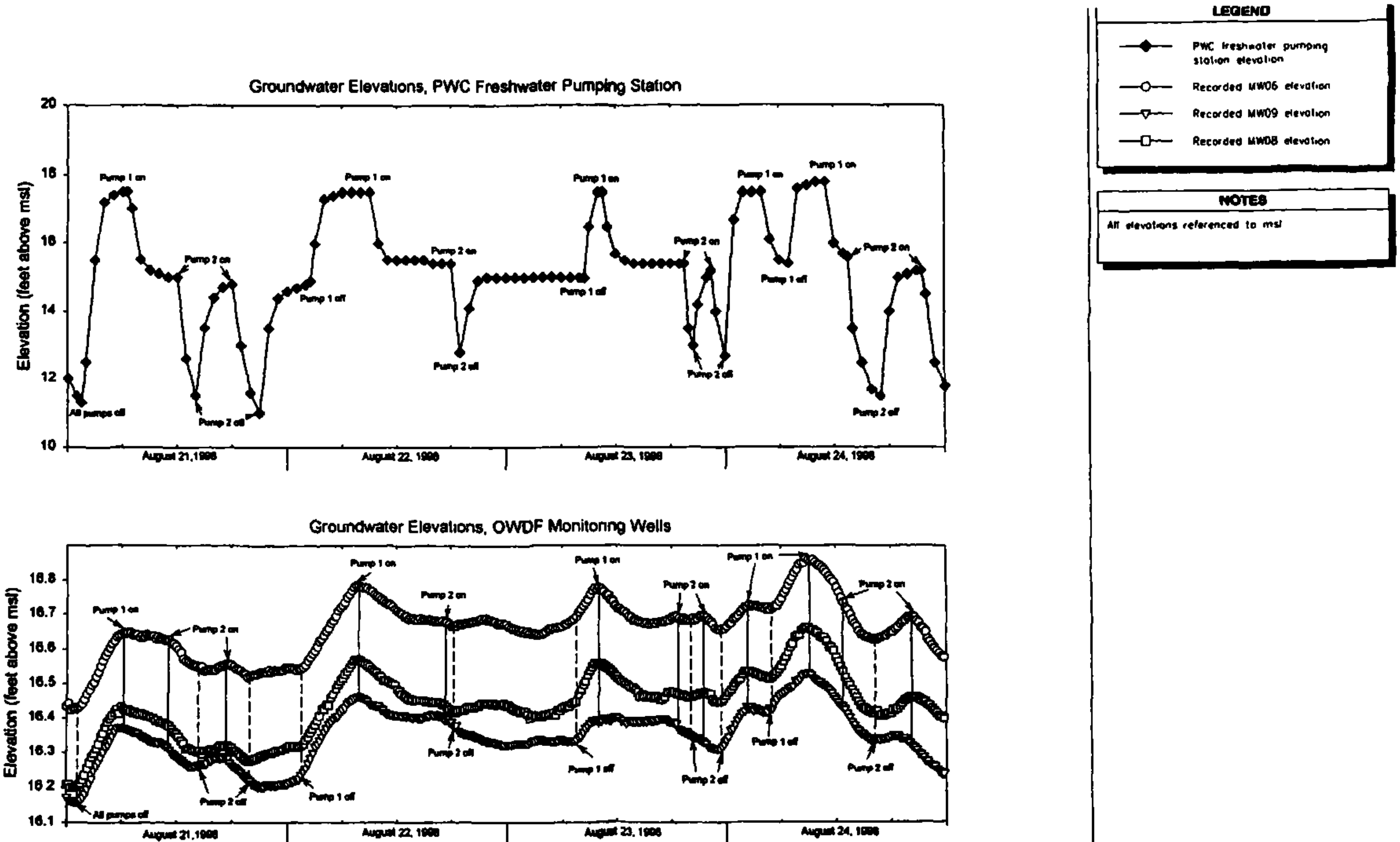
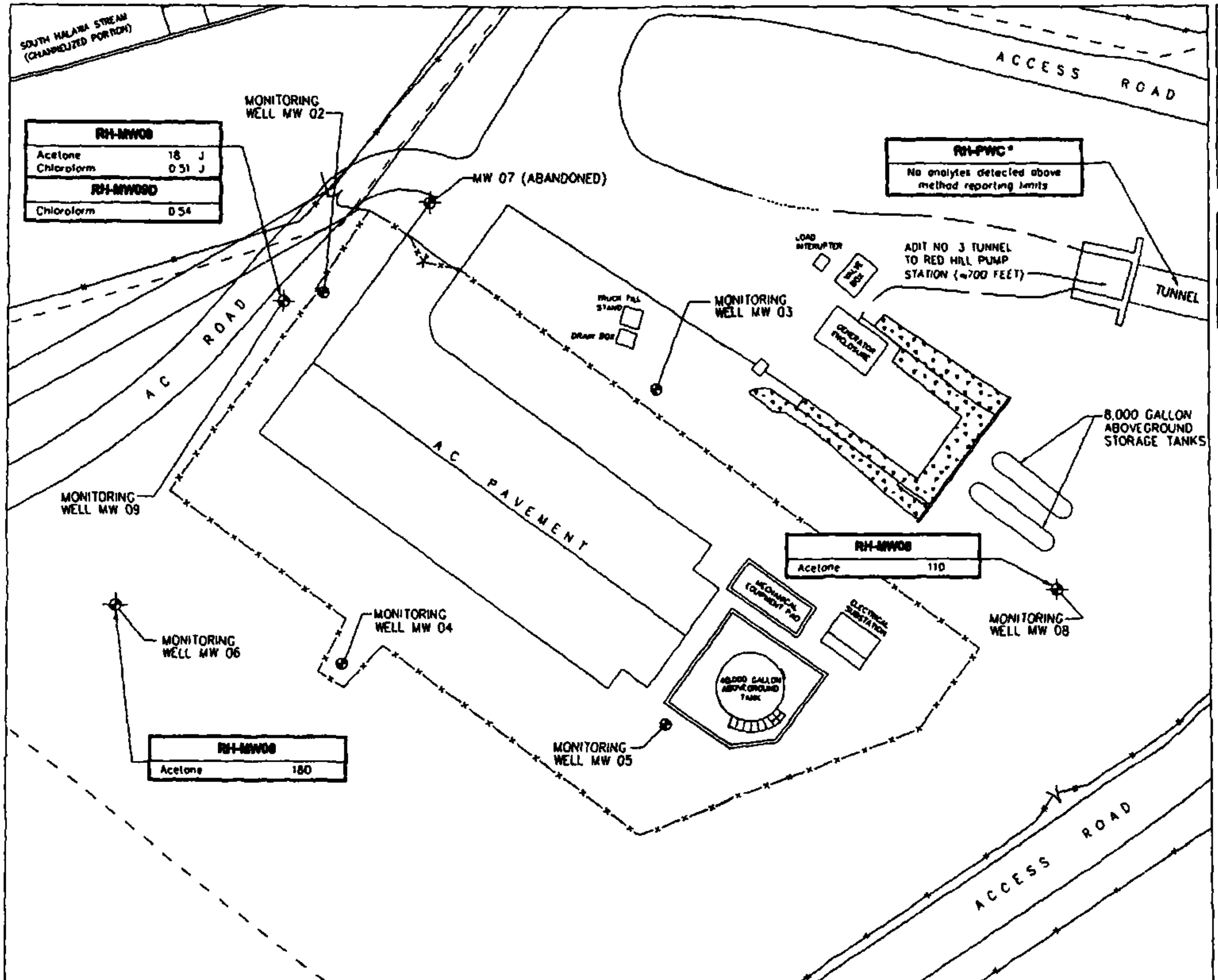


Figure 3-6
Basal Groundwater Surface Elevations
From August 21, 1998 to August 24, 1998
Red Hill Oily Waste Disposal Facility
Halawa, Oahu, Hawaii

Filename \CLEAN\23260-C1034_RedHill\Figures\Basal-Perched\RH-Basal Ground-water Surface Elevations.Dwg 07SEP98



LEGEND

— — —	Property Line
-x-x-x-	Chain Link Fence
⊕	Basal Aquifer Monitoring Wells
●	Perched Groundwater Monitoring Wells

NOTES

1. All concentrations in µg/L
2. * Sample collected from PWC Red Hill Fresh Water Pumping Station

Filename \CLEAN\25280-CT034_RedHill\Figures\Basal-Perched\RH-Basal_Detects.Dwg 07SEP198

Figure 4-9
Compounds Detected in First Round Basal Groundwater Samples
Red Hill Oily Waste Disposal Facility
Halawa, Oahu, Hawaii

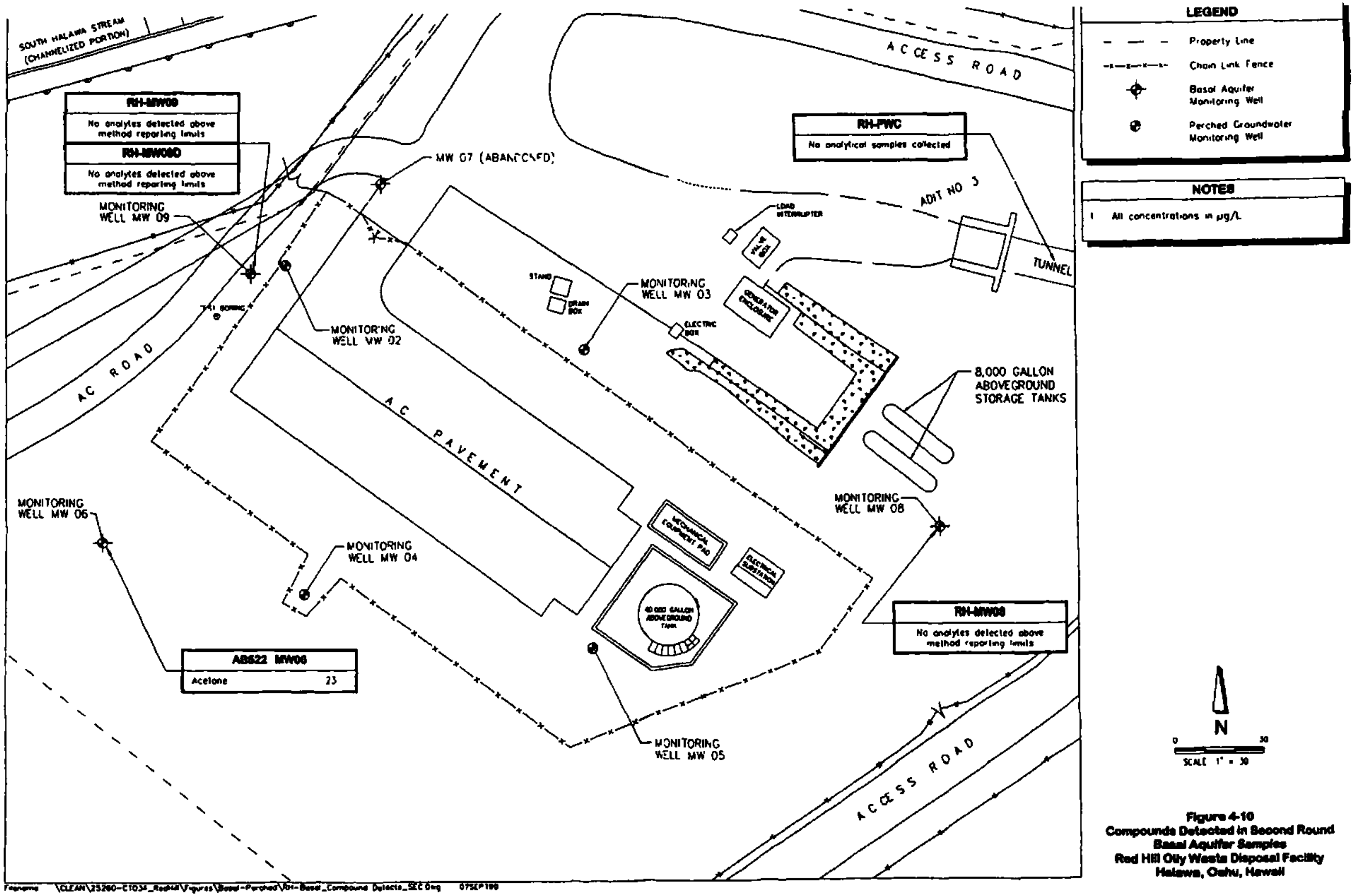
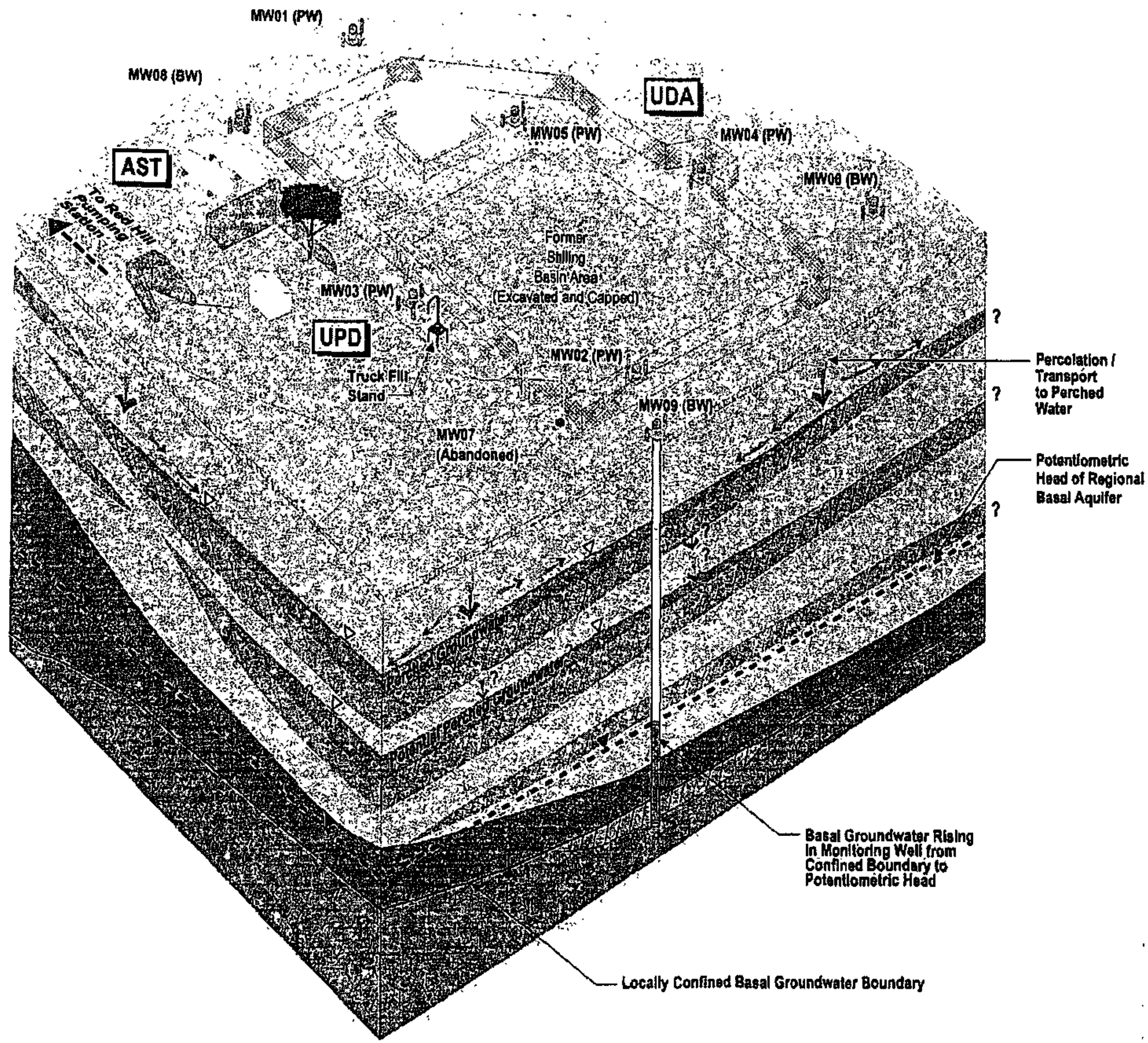


Figure 4-10
Compounds Detected in Second Round Basal Aquifer Samples
Red Hill Oily Waste Disposal Facility
Halawa, Oahu, Hawaii



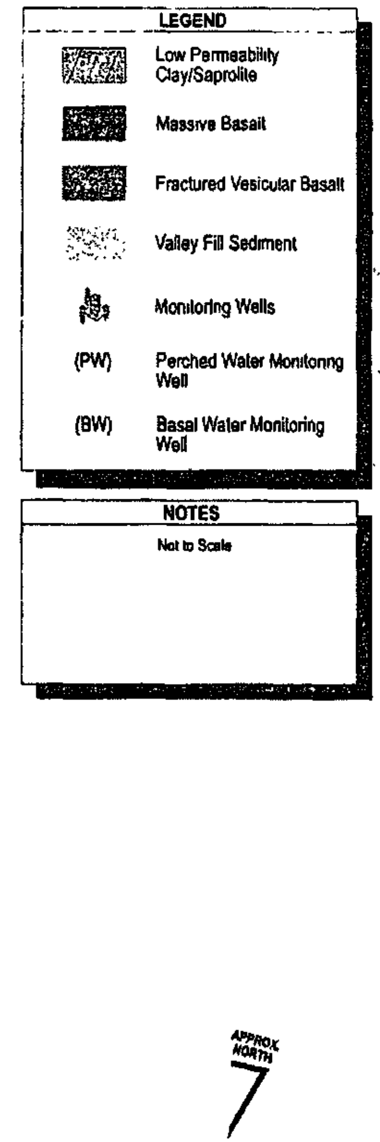


Figure 3-10
Hydrogeologic Setting
Red Hill Oily Waste Disposal Facility
Halawa, Oahu, Hawaii

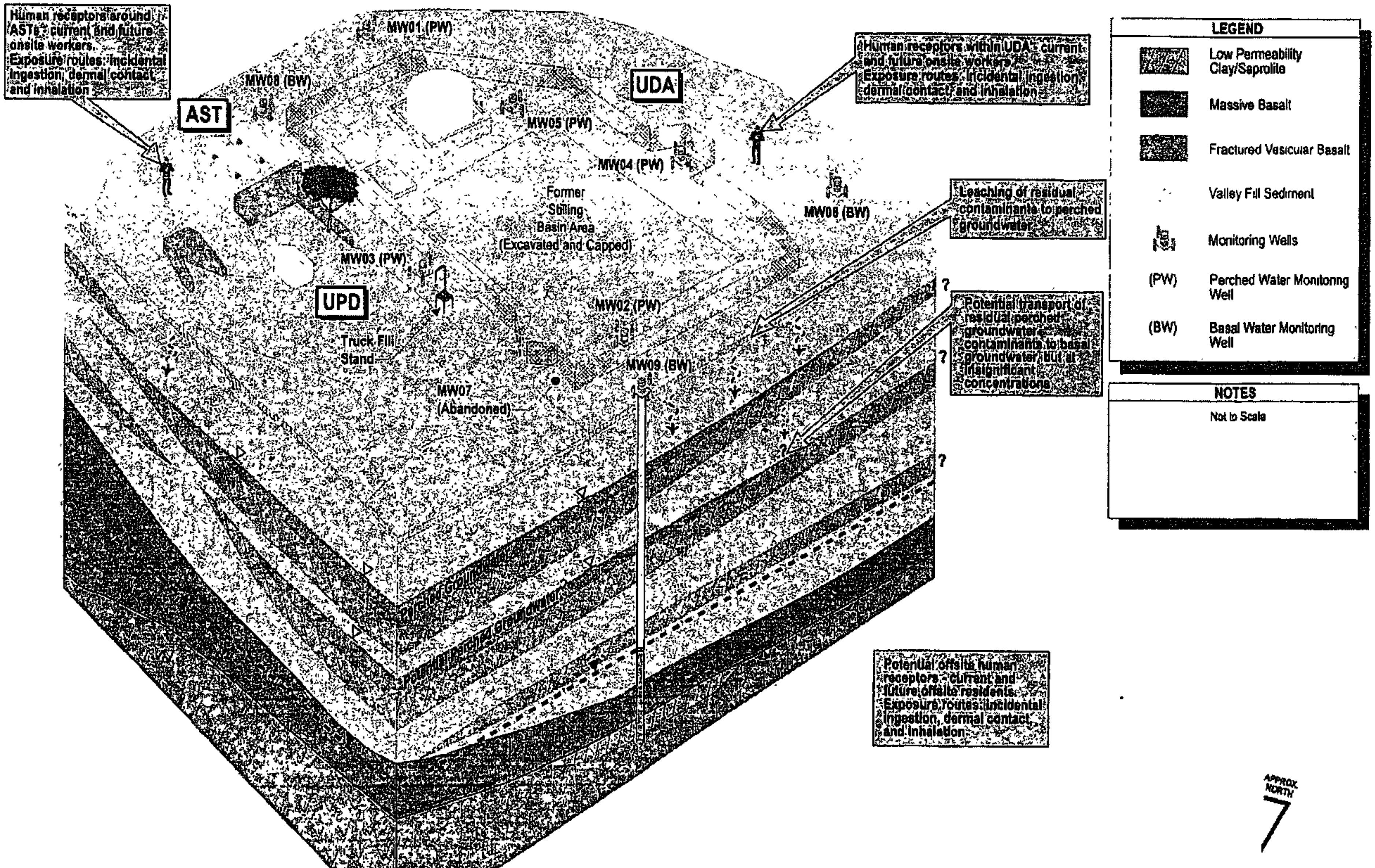


Figure 6-1
Conceptual Site Model
Red Hill Oily Waste Disposal Facility
Halawa, Oahu, Hawaii

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-01
Project No. CTO 0229

LOCATION: Tank 1	ELEVATION: 102.66		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 02/08/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: 124.20
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
102.66 — 0	1	300		80		Concrete 0-2' over fine coarse sand, slightly fine gravel and silt; odor	
102.01 / 101.70	2	103.7	RH-BR-1-S01	29		Concrete fragments with metal and core 2.5-3.7'; odor Small vesicles; 10YR 2/2	
100.77 / 100.38	3	573	RH-BR-1-S02	80		Concrete 7.3-7.35'; small to medium vesicles 7.36-8.8'; strong odor; 10YR 2/2	
— 10	4	185		100		Small to medium vesicles; odor; 10YR 2/2 to 3/1	
99.61	5	235.5		103		Small to medium vesicles; no odor; 10YR 3/1	
98.62	6	204.8		100		Small vesicles; no odor; 10YR 2/2 to 2/1	
97.90	7	38.9		100		Small vesicles; grout seams 20-22.9'; no odor; 10YR 2/1 to 5YR 3/2	
— 20 / 96.60	8	301		100		Small vesicles; grout seams 24.05-26'; no odor; 10YR 2/2 to 5YR 3/3	
95.93	9	NM		90		Small to medium vesicles; no odor; 10YR 2/2	
94.58 — 30	10	147.1		113		Small to medium vesicles; grout seams throughout; no odor; 10 YR 3/1 to 5YR 3/2	
93.39	11	164.3		102		Small to medium vesicles; grout seams throughout; no odor; 5YR 3/2 to 10YR 3/1	
92.23 — 40	12	76.2		106		Small to large vesicles; grout seams 40-40.4 and 42.25-43.95'; no odor; 10YR 3/1 to 2/1	
90.94	13	48.7		94		Small to large vesicles; grout seams 45.3-46.1, 47.3-48.95, and 49.05 -49.8'; no odor; 10YR 3/1 to 5YR 3/2	
89.56 — 50	14	116		102		Small to medium vesicles; no odor; 5YR 3/2 to 10YR 3/1	
88.27	15	266		100		Small to large vesicles; odor; 10YR 3/1	
86.95 — 60	16	453	RH-BR-1-S03 RH-BR-1-D09 RH-BR-1-S04	100		Small to large vesicles; strong odor; 10YR 3/1	
85.63	17	192		98		Small to large vesicles; grout seams 67.3-67.45'; strong odor; 10YR 3/1	
84.26 — 70	18	478		102		Small to large vesicles; strong odor; 10YR 3/1	
82.96	19	NM		87		Small to large vesicles; odor; 10YR 3/1	

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-01
Project No. CTO 0229

LOCATION: Tank 1	ELEVATION: 102.66		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 02/08/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: 124.20
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
81.62 / 80	20	48.5		102		Small to medium vesicles; no odor; 10YR 3/1	
80.45	21	NM		94		Small to large vesicles; grout seams 87.35-87.95'; no odor; 5YR 3/2 to 10YR 3/1	
79.13 / 90	22	59.2		111		Small to medium vesicles; grout seams 90.9-92.45 and 93.1-93.35'; no odor; 10YR 3/1 to 5YR 3/2	
77.92	23	43		86		Small to medium vesicles; no odor; 10YR 3/1	
76.55 / 100	24	43.7		95		Small to large vesicles; silty clay in fractures 104.2-104.8'; no odor; 10YR 3/1	
75.35	25	115.3		111		Small to large vesicles; no odor; 10YR 3/1	
74.14 / 110	26	222.7		79		Small to medium vesicles; silty clay in vesicles; no odor; 10YR 3/1	
72.84	27	151.7		119		Small to large vesicles; silty clay in some vesicles; no odor; 10YR 3/1	
71.73 / 120	28	118.5		100		Small to large vesicles; silty clay noted in few vesicles and most fractures; no odor; 10YR 3/1	
70.44	29	542		98		Small to medium vesicles; silty clay in fractures and vesicles; no odor; 10YR 3/1	
69.09 / 130			RH-BR-1-S05			B-01 terminated at 129.7'	
140							
150							

Corrected elevations are provided for angle borings.

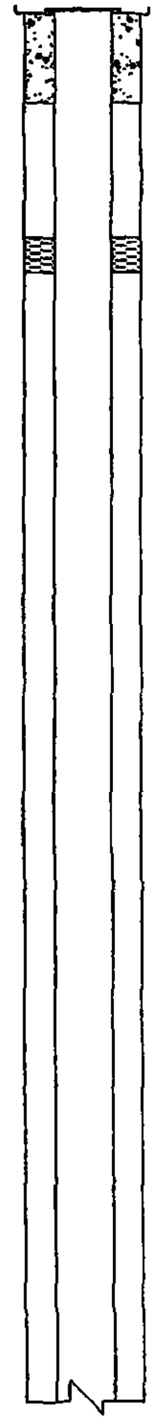
This information pertains only to this boring and should not be interpreted as being indicitive of the site.

DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 02/05/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
102.31 — 0					
101.66	1	135		100	Concrete 0-2' over fine coarse sand, slightly fine gravel and silt; slight odor
	2	71.8	RH-BR-2-S01	88	Concrete and wood fragments 2.5-3.3', concrete 3.3-4.5, small and large vesicles 4.6- 6.3'; no odor; 10YR 3/1
100.55					
100.40	3	105		83	
99.93	4	131.9		106	Small to medium vesicles; no odor; 10YR 2/2
— 10	5	NM		97	Small to large vesicles; grout seam 8.4-8.6'; no odor; 10YR 2/2
99.05	6	60		104	Small to medium vesicles; grout seams at 9.4, 9.5, and 12.5'; no odor; 10YR 2/2
97.78	7	45.3		103	Small to medium vesicles; grout seams throughout; no odor; 5YR 3/2 to 10YR 2/2
97.03 — 20	8	10		100	Small to medium vesicles; grout seams throughout; no odor; 5YR 3/2; 10YR 2/2
96.38	9	171		108	Small to medium vesicles; grout seams 20.4-20.95, 21.8, 22.1-22.6, and 22.9'; no odor; 5YR 3/2 to 10YR 2/2
95.45	10	59.1		98	Small to medium vesicles; grout seams 23.55-23.9 and 25.35-25.65'; no odor; 10YR 3/1
— 30					Primarily small to large vesicles; grout seams 29.2-31.7'; no odor; 10YR 3/1 to 2/2
94.08	11	115.2		100	Small to medium vesicles; grout seams 31.8-33.6'; no odor; 10YR 2/1 to 2/2 to 5YR 3/2
92.73	12	28.3		102	Small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
— 40					
91.41					
91.39	13	NM		100	Small vesicles; no odor; 10YR 2/1 to 3/1
	14	85.1		100	Small to medium vesicles; grout seams 44.15-44.25, 44.65-45.8, and 46.3-46.65'; no odor; 10YR 3/1 to 5YR 3/2
90.04	15	2.3		100	Small vesicles; grout seams 49.1-50.05 and 51.15-51.6'; no odor; 10YR 2/2 to 5YR 3/2
— 50					
88.95	16	57		100	Small to medium vesicles; no odor; 10YR 2/2 to 3/1
87.71	17	80		100	Small vesicles; grout seams 56.4-56.55 and 61.2-61.6'; no odor; 10YR 3/1 to 2/2
— 60					
86.37	18	53.3		100	Small vesicles; grout seams 62.45 and 66.4-66.5'; no odor; 10YR 3/1 to 2/2
85.10	19	23		98	Small to medium vesicles; grout seams 66.85-67.75, 68, 68.8-69.65, and 71.6-70.5'; no odor; 10YR 2/2 to 3/1
— 70					
83.73	20	28.3		102	Small to medium vesicles; grout seams 73.05, 73.7-74.25, 74.4-74.85, 75.4, 76.05, and 76.15-76'; no odor; 10YR 2/2 to 3/1
82.41					

Graphic Log

WELL CONSTRUCTION



Corrected elevations are provided for angle borings.

This information pertains only to th ring and sh not be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-02
Project No. CTO 0229

LOCATION: Tank 2	ELEVATION: 102.31		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 02/05/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
	21	34.1		94		Small to medium vesicles; grout seams 76.9-77.55, 78.8- 79.8, 80.15-80.45, and 81-81.2'; no odor; 10YR 3/1 to 5YR 3/2	
80							
81.09	22	30.4		100		Small to medium vesicles; grout seams 82-82.5'; no odor; 5YR 3/2 to 10YR 2/2	
79.74	23	74.7		100		Small to large vesicles; slight odor; 10YR 3/1 to 2/2	
90			RH-BR-2-S02				
78.42	24	34.0		102		Small to medium vesicles; grout seams throughout; no odor; 10YR 3/1 to 2/2	
77.10	25	41.3		82		Small to medium vesicles; grout seams 97.4-98.1'; no odor; 10YR 3/1 to 5YR 3/2	
100							
75.81							
75.47	26	29.8		100		Small vesicles; no odor; 5YR 3/2 to 10YR 3/1	
	27	58.1		108		Small to primarily medium vesicles; no odor; 10YR 3/1	
74.51	28	23.0		96		Small to medium vesicles; no odor; 10YR 3/1 to 5YR 3/2	
110							
73.22	29	32.0		88		Small to medium vesicles; no odor; 10YR 3/1 to 5YR 3/2	
71.98							
71.80	30	36.1		143		Small to medium vesicles; no odor; 10YR 3/1 to 5YR 3/2	
	31	21.2		87			
71.02	32	56.3	RH-BR-2-S03	80		Small to medium vesicle; no odor; 10YR 3/1 to 5YR 3/2	
120						Small to medium vesicles; no odor; 5YR 3/2 to 10YR 3/1	
69.62							
						B-02 terminated at 126.3'	
130							
140							
150							

Corrected elevations are provided for angle borings.

This information pertains only to this boring and should not be interpreted as being indicative of the site.

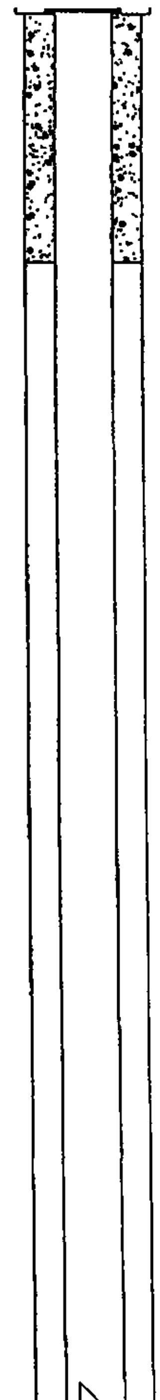
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-03
Project No. CTO 0229

LOCATION: Tank 3		ELEVATION: 102.72			
DRILLER: Salisbury & Associates, Inc.		DATE DRILLED: 01/31/01		LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill		DEPTH TO WATER>		FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (Inch): 1 1/2				

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
102.72 (0)	1	214		59		Concrete 0-1.6' over fine to coarse sand with slight fine gravel and silt; slight odor
102.02	2	65	RH-BR-3-S01	43		Sand 2.7-3.3'; concrete 3.3-7.4'; partially filled cavity 6.0-7.4'; no odor
100.81	3	244.6		140		Small to medium vesicles; slight odor; 10YR 3/1
100.68	4	151.2		106		Primarily small to medium vesicles; slight odor; 10YR 3/1
100.21	5	346		100		Small to medium vesicles; no odor; 10YR 3/2
100.03 (10)	6	228		73		Small to medium vesicles; grout seams 10.4 and 11.25-12'; no odor; 10YR 2/2
99.07	7	240.7		126		Small to large vesicles; grout seams throughout; no odor; 10YR 2/2
98.09 (20)	8	327		100		Small to large vesicles; grout seams 17.9-20.5, 21.1-21.35, and 21.9-22.2'; no odor; 10YR 2/2 to 3/1
96.79	9	51.2		109		Small to medium vesicles; grout seams 23.15 and 24.8-27.6'; no odor; 10YR 3/1 to 2/2
95.58 (30)	10	82.6		104		Primarily small to medium vesicles; grout seams though out; no odor; 10YR 2/2
94.28	11	62.9		94		Small to medium vesicles; grout seams 33, 34-35.45, and 37.5-38.75'; no odor; 5YR 3/2 to 10YR 2/2
92.94 (40)	12	84.3		98		Small to medium vesicles; grout seams 37.8-38.7 and 40.1-41.35'; no odor; 10YR 2/2 to 5YR 3/2
91.62	13	189.2		100		Primarily small to medium vesicles; grout seams 43.45, 44.1, and 44.5'; slight odor; 10YR 2/2
90.48 (50)	14	82.9	RH-BR-3-S02	100		Small to medium vesicles; grout seams 47.45-47.7, 49.3- 49.5, 49.75-49.95, and 51.4-51.55'; no odor; 10YR 2/2 to 5YR 3/2
89.13	15	40.1		100		Small to medium vesicles; grout seams 52.5, 54, 55.55-55.7, and 57-57.5'; no odor; 5YR 3/2
87.79	16	9.9		74		Small to medium vesicles; grout seams 59.4-60.2'; no odor; 5YR 3/2 to 10YR 3/1
86.91 (60)	17	66.7		96		Small to medium vesicles; grout seams 61.1-62.3, 63-63.5, 64.3, 65.2, 65.6, and 66.1-66.5'; no odor; 10YR 3/1 to 2/2
85.51	18	71.4		98		Small to medium vesicles; grout seams 67.1-71'; no odor; 5YR 3/2 to 10YR 3/1
84.32 (70)	19	15.6		102		Small to medium vesicles; grout seams 71-71.7, 74.15, and 75.5'; no odor; 5YR 3/2 to 10YR 3/1
83.18	20	50.1		94		Small to medium vesicles; grout seams 75.5-75.85

WELL CONSTRUCTION



This information pertains only to this boring and s... ...ot be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

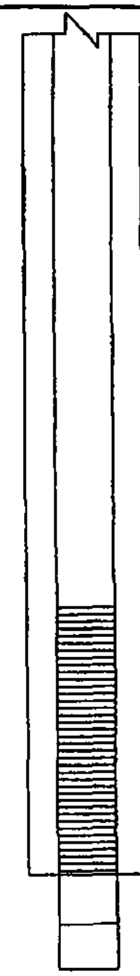
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-03
Project No. CTO 0229

LOCATION: Tank 3	ELEVATION: 102.72
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/31/01 — LOGGED BY: Gary Gleason
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER> FIRST: NA — COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
						and 78.15'; no odor; 5YR 3/2 to 10YR 2/2
81.86 — 80	21	2.6		102		Small to medium vesicles; grout seam 83.3'; no odor; 10YR 2/2
80.54	22	50.8		100		Small to medium vesicles; grout seam 88.95'; no odor; 10YR 3/1 to 5YR 3/2
79.19 — 90	23	72.9		104		Small to medium vesicles; grout seams 93.5-93.6 and 93.8'; no odor; 5YR 3/2
77.87	24	8.7		93		Small to medium vesicles; grout seams 97-97.25'; no odor; 5YR 3/2 to 10YR 2/2
76.68 — 100	25	NM		47		Small to large vesicles; grout seams 101.1-102 and 102.5-102.6'; no odor; 10YR 2/2 to 5YR 3/2
75.18	26	4.4		107		Small to large vesicles; grout seams 106.1-106.6 and 109.4-110.6'; no odor; 5YR 3/2 to 10YR 2/2
74.09 — 110	27	38.1		93		Small to large vesicles; grout seams throughout; no odor; 10YR 2/2
73.76	28	16.1		100		Small to large vesicles; grout seams 111.9-114.85'; no odor; 5YR 3/2 to 10YR 2/2
72.46	29	3.0		85		Small to medium vesicles; no odor; 5YR 3/2 to 10YR 3/1
71.77 — 120	30	7.8		50		Small to medium vesicles; grout seam 120.3'; no odor; 10YR 3/1 to 5YR 3/2
70.32	31	33.3	RH-BR-3-S03	34		Small to medium vesicles; grout seam 125.65'; no odor; 10YR 3/1 to 5YR
69.02 — 130						B-03 terminated at 130.2'
— 140						
— 150						

WELL CONSTRUCTION



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Corrected elevations are provided for angle borings.

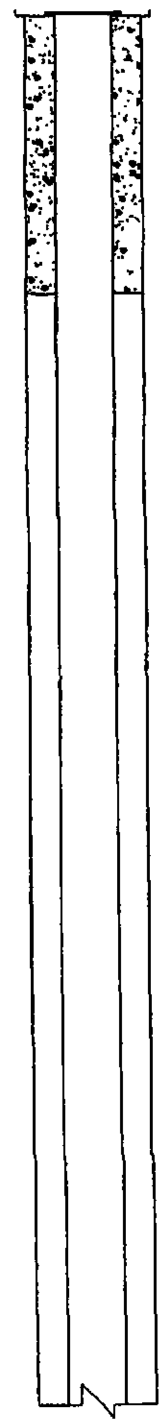
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-04
Project No. CTO 0229

LOCATION: Tank 4	ELEVATION: 102.62		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/29/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)		Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
102.62	0	1	5.6		100	Concrete over fine to coarse sand with slight fine gravel and silt; no odor
101.97		2	95	RH-BR-4-S01	44	Concrete 2.5-3.8'; small to medium vesicles 3.8-7'; odor; 10YR 2/2
100.81		3	294		83	Fine to coarse sand with slight fine gravel, rock fragments, and silt; odor; 10YR 3/1
100.50		4	180	RH-BR-4-S02	100	Small to medium vesicles; odor; 10YR 3/1
99.72	10	5	103		89	Small to medium vesicles; slight odor; 10YR 3/1 to 5YR 3/2
98.58		6	225		100	Small to medium vesicles; odor; 10YR 3/1 to 5YR 3/2
98.43		7	48		100	Small to large vesicles; grout seams 19.9-20.15, 18.5, and 17.95'; no odor; 5YR 3/2 to 10YR 3/1
97.11	20	8	308		95	Small to large vesicles; grout seams 24.95-25.5'; no odor; 10YR 3/1
95.97		9	308		108	Small to primarily large vesicles; grout seams 25.4-27.8'; no odor; 10YR 3/1
94.73	30	10	NM		100	Small to primarily large vesicles; grout seams 30.05-30.15, 30.55, and 33.25-33.35'; no odor; 10YR 3/1
93.38		11	191		100	Small to primarily large vesicles; grout seams 36.55, 38.05-38.15, 39.85-40, and 40.5'; no odor; 10YR 3/1
92.14	40	12	465		100	Small to medium vesicles; grout seams 40.5-40.8'; no odor; 10YR 3/1
90.82		13	465		98	Small to large vesicles; grout seams 47.05, 48.05-48.7, and 50.4'; no odor; 10YR 3/1 to 5YR 3/2
89.45	50	14	120.1		100	Small to medium vesicles; grout seams 51.9-52.1 and 54.7'; no odor; 10YR 2/2
88.13		15	47.1		100	Small to medium vesicles; grout seams 59.35-59.5 and 59.95'; no odor; 10YR 2/2
86.81	60	16	465		81	Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/2
85.43		17	37.5		121	Small to medium vesicles; grout seams 68.85, 69.75-69.9, 69.97, and 70.7'; no odor; 10YR 2/2 to 5YR 3/2
84.32	70	18	46.5		100	Small to medium vesicles; grout seams 71.15, 72.65-71.55, and 75.9-73.75'; no odor; 5YR 3/2 to 10YR 2/2
82.98		19	51.7		100	Small to medium vesicles; grout seams 75.9-78.3 and

WELL CONSTRUCTION



This information pertains only to this boring and ... ot be interpreted as being indicative of the site.

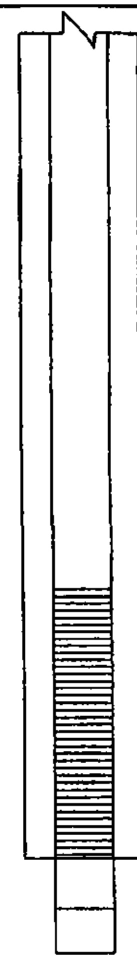
Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility	**Boring/Monitoring Well No.** B-04
CLIENT: PACNAVFACENGCOM	**Project No.** CTO 0229

LOCATION: Tank 4	ELEVATION: 102.62		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/29/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
					79.45-80'; no odor; 10YR 2/2
81.66 (80)	20	66.1		98	Small to medium vesicles; grout seams 83.9-83.95 and 84. 45'; no odor; 10YR 3/2 to 5YR 3/2
80.28					
79.92	21	14.2		140	Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/2
(90)	22	112.2		100	Small to medium vesicles; grout seams 87.7-89.8, 90.95- 91.45, 91.9, and 92.7'; no odor; 10YR 2/2 to 3/1
78.60					
78.34	23	NM		27	Small to medium vesicles; no odor; 10YR 3/1
	24	41.7		98	Small to large vesicles with primarily medium vesicles; 93.85-93.95, 94.3-94.5, and 96.1'; no odor; 10YR 3/1 to 2/2
77.18 (100)	25	50.7		104	Small to medium vesicles; grout seam 99.8'; no odor; 10YR 3/1 to 5YR 3/2
75.88	26	53.2		98	Small to medium vesicles; no odor; 10YR 2/2 to 3/1
74.51 (110)	27	74.3		70	Small to large vesicles; no odor; 10YR 3/1 to 2/2
73.22	28	96.4		100	Small to large vesicles; grout seams 113.6-114.15'; no odor; 10YR 3/1
71.87 (120)	29	45.4		100	Primarily small to medium vesicles; grout seam 122.35'; no odor; 10YR 3/1
70.55	30	91.6	RH-BR-4-S03 RH-BR-4-D08	100	Small vesicles; no odor; 10YR 3/1
69.21 (130)					B-04 terminated at 129.1'
(140)					
(150)					

WELL CONSTRUCTION



This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-05
Project No. CTO 0229

LOCATION: Tank 5	ELEVATION: 105.98	
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/24/01	LOGGED BY: Gary Gleason
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA / COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2	

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
105.98 — 0	1	19.5		67		Concrete 0-2' over fine to coarse sand with slighty fine gravel and rock fragments; no odor	
105.20	2	46		28		Concrete 3.0 to 3.9' over small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2	
104.01	3	72	RH-BR-5-S01	100		Small to large vesicles; grout seams 7.6-8.9, 9.15-10.3, 10.9-11.35, and 12.25'; slight odor; 10YR 2/2	
10							
102.80	4	63.1	RH-BR-5-S02	98		Small to primarily large vesicles; grout seams 13.4-14, 14.3-14.7, and 15.5-15.7'; odor; 10YR 2/2	
101.43	5	46		104		Small to primarily large vesicles; grout seams 20.95-22.25'; slight odor; 10YR 2/2 to 3/1	
20							
100.13 / 99.85	6	14.3		109		Small to large vesicles with primarily medium vesicles; no odor; 10YR 3/1	
	7	142.8		98		Small to large vesicles; grout seams 26.7-26.9'; no odor; 10YR 3/1 to 5YR 3/2	
98.47 / 98.06 — 30	8	14.2		100		Small to medium vesicles; grout seams 30.15-30.6'; no odor; 5YR 3/2	
	9	23.3		98		Small to large vesicles; grout seams 34.15-34.4'; no odor; 5YR 3/2 to 10YR 2/2	
96.90	10	75.6		104		Large to small vesicles; no odor; 10YR 2/2 to 5YR 3/2	
95.60 — 40	11	55		91		Small to medium vesicles; grout seams 42.45-43.3 and 43.75-44.2'; no odor; 5YR 3/2 to 10YR 2/1	
94.44	12	14.9		100		Small to primarily large vesicles; grout seams 49.45-50'; no odor; 10YR 2/1 to 3/1	
93.04 — 50	13	52		108		Small to primarily large vesicles; no odor; 10YR 3/1	
91.80	14	262	RH-BR-5-S03	92		Few small to primarily large vesicles; no odor; 10YR 3/1	
90.43 — 60	15	308		104		Few small to primarily large vesicles; no odor; 10YR 3/1	
89.16	16	308		100		Small to large vesicles; grout seams 67.35-68.8'; no odor; 10YR 3/1 to 5YR 3/2	
87.81 — 70	17	68		67		Small to primarily large vesicles; no odor; 5YR 3/2 to 10YR 2/2	
86.41 / 86.21	18	26		325		Small to large vesicles; no odor; 10YR 2/2 to 5YR 3/2	

Corrected elevations are provided for angle borings.

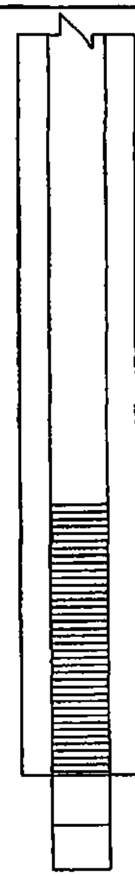
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-05
Project No. CTO 0229

LOCATION: Tank 5	ELEVATION: 105.98		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/24/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
85.79	19	8.5		100	Small to medium vesicles; no odor; 5YR 3/2
80	20	36		92	Small to very large vesicles; no odor; 5YR 3/2 to 10YR 3/1
84.45	21	78		106	Small to large vesicles; grout seams 83.2-83.45 and 86.75-86.9'; no odor; 10YR 3/1
83.15	22	12		77	Five small to primarily large vesicles; grout seams 90.4-90.5'; no odor; 10YR 3/1
90					
81.81	23	35.9		134	Few small to primarily large vesicles; grout seam 94.25'; no odor; 10YR 3/1 to 2/2
80.82	24	12		108	Small to large vesicles; grout seams 97.05 and 97.2'; no odor; 10YR 3/1
79.81 / 100	25	31		82	Primarily small to medium vesicles; grout seams 102.9 and 103-103.25'; no odor; 10YR 3/1 to 5YR 3/2 to 10YR 2/2
78.39	26	21		38	Small to medium vesicles; grout seams 106.9-107 and 107. 75'; no odor; 10YR 2/2 to 5YR 3/2
110 / 77.10					
77.04	27	9		100	Small to medium vesicles; no odor; 5YR 3/2
76.47	28	308	RH-BR-5-S04	100	Small vesicles; no odor; 5YR 3/2
	29	173	RH-BR-5-S05	100	Small to medium vesicles; no odor; 10YR 2/2 to 3/1
75.13 / 120	30	104		94	Small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
73.81					B-05 terminated at 124.3'
130					
140					
150					

WELL CONSTRUCTION



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Corrected elevations are provided for angle borings.

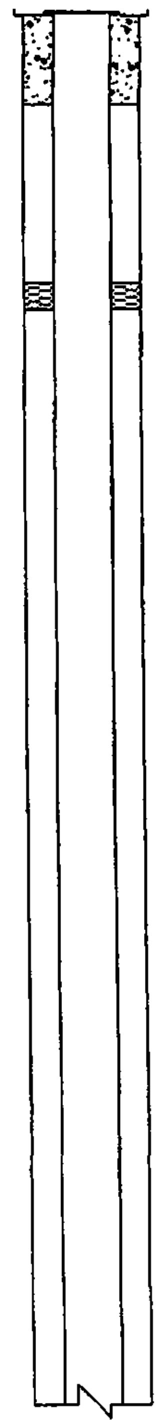
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-06
Project No. CTO 0229

LOCATION: Tank 6	ELEVATION: 105.68
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/19/01 — LOGGED BY: Gary Gleason
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER> FIRST: NA — COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2

Corrected Elevation/ Boring Length (ft)		Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
105.68 105.16	0	1	78	RH-BR-6-S01(L) RH-BR-6-S01(S)	100	Concrete 0-0.5'; strong odor
		2	132	RH-BR-6-S02	20	Concrete over fine to coarse sand with fine gravel; strong odor; product present
103.87 103.45		3	0.6		81	Concrete 7-7.5'; primarily small to medium vesicles 7.5- 8.6'; odor; 10 YR 2/1 to 5YR 3/2
		4	0		89	
102.76	10	5	163		100	Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/1
101.41						Small to medium vesicles; slight odor; 5YR 3/2 to 10YR 2/2
101.38		6	47		400	Small to medium vesicles; no odor; 10YR 2/2
100.63		7	191		93	Small to medium vesicles; odor; 5YR 3/2 to 10YR 2/1
100.06	20	8	121	RH-BR-6-S03 RH-BR-6-D07	100	Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/1
		9	21		98	Small to primarily medium vesicles; grout seams 24.95-24.45'; no odor; 10YR 2/1 to 2/2
98.92		10	40		98	Small to medium vesicles; grout seams 26.15-27.6, 29, and 30.05'; strong odor; 10YR 2/2 to 2/1
97.68	30	11	65		70	Small to primarily large vesicles; odor; 10YR 2/1
96.03	40	12	42		98	Small to large vesicles; grout seams 37.3-38.05 and 40.9-41.45'; slight odor; 10YR 2/2
94.65		13	66.7		105	Primarily small to medium vesicles; grout seams 42.95-46.9'; odor; 10YR 2/2
93.54	50	14	40		96	Small to medium vesicles; grout seams 46.9-47.25'; odor; 10YR 2/2 to 5YR 3/2
92.14		15	65		100	Small to medium vesicles; grout seams 52.7-53, 53.55-53.85, and 56.9-57.1'; odor; 10YR 2/2 to 2/1
90.80	60	16	26		96	Small to medium vesicles; grout seams 57.9-59.5, 59.9, and 60.65'; no odor; 5YR 3/2 to 10YR 2/2
89.40		17	16		98	Small to large vesicles; grout seams 63.35, 65.4-65.9, 66.1-66.35, and 68.1'; no odor; 10YR 2/2
88.03	70	18	25		102	Small to large vesicles; grout seams 68.7 and 71.1-71.3'; no odor; 10YR 2/2
86.79		19	25		83	Medium to primarily large vesicles; no odor; 10YR 2/2
85.57						

WELL CONSTRUCTION



Corrected elevations are provided for angle borings.

This information pertains only to this boring and sh... not be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-06
Project No. CTO 0229

LOCATION: Tank 6	ELEVATION: 105.68		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/19/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
	20	0.3		120	Small to large vesicles; no odor; 10YR 2/2 to 2/1
84.43	21	16.8		102	Small to medium vesicles; grout seams 82-82.3'; no odor; 10YR 2/1 to 5YR 3/2
83.14	22	30.1		92	Small to medium vesicles; grout seams 88.2-90.4, 91.05- 91.55, and 91.8'; no odor; 5YR 3/2 to 10YR 2/1
81.82	23	10.1		111	Small to medium vesicles; grout seam 91.75'; no odor; 10YR 2/1 to 5YR 3/2
80.60	24	3		98	Small to large vesicles; no odor; 5YR 3/2 to 10YR 3/1
79.23	25	0.9		106	Small to large vesicles; no odor; no odor; 10YR 3/1
77.96	26	17.8		100	Small to large vesicles; no odor; 10YR 3/1 to 5YR 3/2
76.61	27	12.2		95	Primarily small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/1
75.19	28	3.3		21	Small vesicles; no odor; 5YR 3/2
73.82	29	0		68	Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/2
73.17	30	15	RH-BR-6-S04	250	Small to medium vesicles; no odor; 10YR 2/2
72.91	31	10		100	
					B-06 terminated at 126.6'

WELL CONSTRUCTION

This information pertains only to this boring and sh[...]not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

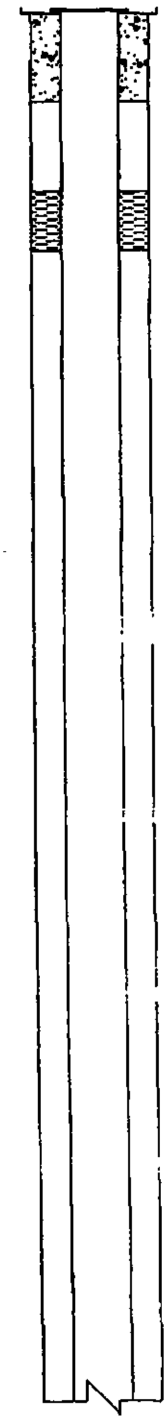
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-07
Project No. CTO 0229

LOCATION: Tank 7	ELEVATION: 113.96		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/17/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
113.96 (0) / 113.44	1	1.8	RH-BR-7-S01	100	Concrete 0-0.5'; over fine to coarse sand with fine gravel 0.5-2'; odor
	2	0.7		36	Basalt; slight odor
111.71	3	NM		47	
(10)	4	NM		65	Small to medium vesicles; slight odor; 5YR 3/2
110.52 / 110.41	5	0		100	Primarily small to medium vesicles; no odor; 5YR 3/2
	6	0		97	Small to medium vesicles; grout seams 16.3-17.2'; no odor; 10YR 2/2
109.41	7	0		106	Small to medium vesicles; grout seams throughout; no odor; 10YR 2/2
(20) / 108.09	8	NM		84	Small to large vesicles; grout seams 22.7-24.4 and 25.1-25.4'; no odor; 10YR 2/1
107.26	9	110	RH-BR-7-S02	81	Small to large vesicles; grout seams 25.9-27.45, 28, 28.95, and 29.9-30.7'; odor; 10YR 2/1
(30) / 105.65	10	57		124	Small to medium vesicles; grout seams throughout; odor; 10YR 2/1
104.80	11	0		100	Small to large vesicles; grout seams 35.7, 35.8-36.4, and 38.75'; no odor; 10YR 2/1 to 3/1
103.48 (40)	12	26.5		102	Small to large vesicles; odor; 10YR 3/1
102.13	13	12.2		100	Medium to primarily large vesicles; no odor; 10YR 3/1
100.79 (50)	14	0.6		102	Small to large vesicles; no odor; 10YR 3/1
99.47	15	0		100	Small to medium vesicles; grout seams 59.95-60.95'; no odor; 10YR 3/1 to 2/1 to 2/2
98.09 (60)	16	0		96	Small to large vesicles; no odor; 10YR 2/2
96.72	17	0		104	Small to large vesicles; no odor; 10YR 3/1 to 2/1 to 2/2
(70) 95.43	18	0.2		95	Small to medium vesicles; no odor; 10YR 2/2
94.89	19	0.3		102	Small to medium vesicles; grout seams 76.65-76.9 and 77.5'; no odor; 10YR 2/2

WELL CONSTRUCTION



This information pertains only to this boring and should not be interpreted as being indicitive of the site.

Corrected elevations are provided for angle borings.

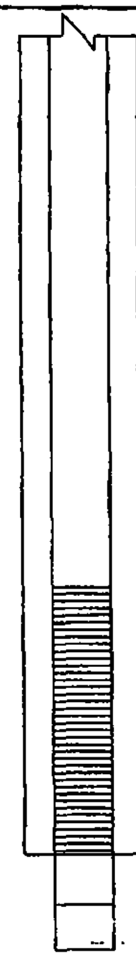
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-07
Project No. CTO 0229

LOCATION: Tank 7	ELEVATION: 113.96		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/17/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (Inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
93.59	20	0.3		98	Small to medium vesicles; grout seams 79.3, 81-81.6, and 82'; no odor; 10YR 2/2
92.53	21	0.4		102	Small to large vesicles; grout seams 83.9-84.5, 85.45, 85.2-85.35, 87, and 87.8'; no odor; 10YR 2/2 to 3/1
91.24	22	0.6		98	Small to large vesicles; grout seams 89.55, 91.1-91.5, and 91.8-92'; no odor; 10YR 3/1 to 2/2
89.86	23	6.6	RH-BR-7-S03	100	Small to large vesicles; odor; 5YR 3/2
88.52	24	0		98	Small to medium vesicles; grout seams 98.45-99.15, 99.3- 99.7, 100.7, 100.9-101, 101.45-101.5, and 102.35-102.7'; no odor; 10YR 2/2 to 2/1
87.35	25	9.6	RH-BR-7-S04	100	Small to medium vesicles; grout seams 102.5-103.45, 103. 85-105.2, and 105.5-107'; odor; 10YR 2/1
86.06	26	41		104	Small to large vesicles; grout seams 111.6-112.8'; odor; 10YR 2/1
84.77	27	15.2	RH-BR-7-S05	100	Small to medium vesicles; grout seams 112.8-114, 114.15- 114.9, 115.6-116, and 116.3-118'; odor; 10YR 2/1 to 2/2
83.42	28	15.4		100	Small to medium vesicles; grout seams 118-119.4'; odor; 10YR 2/2
82.90	29	36.9		100	Small to medium vesicles; grout seams 120.4-121, 121.25- 122.1, 122.25-122.85, 123.2, and 123.8-125.7'; odor; 10YR 2/1
81.56	30	26		68	Small to medium vesicles; grout seams 125.2-127.05; odor; 10YR 2/1 to 2/2
80.60					B-07 terminated at 128.9'

WELL CONSTRUCTION



This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

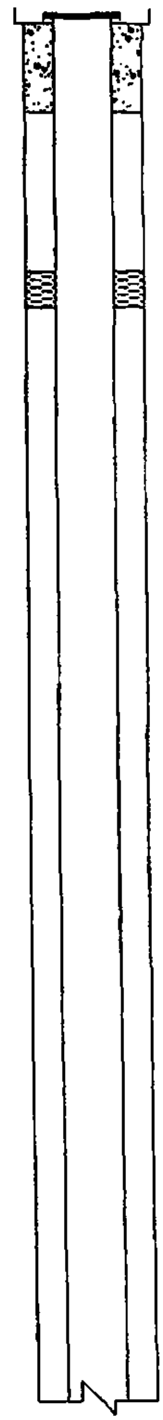
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-08
Project No. CTO 0229

LOCATION: Tank 8	ELEVATION: 113.67		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/15/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
113.67 / 0					
113.13	1	2.5	RH-BR-8-S01	100	Concrete 0-0.5'; over fine to coarse sand with slight fine gravel 0.5-2.1'; odor
112.56	2	3.4		59	Basalt; odor
	3	NM		82	Small to medium vesicles; no odor; 5YR 3/2
111.52	4	NM		100	Small to primarily medium vesicles; no odor; 5YR 3/2
110.93 / 10	5	0		96	Small to medium vesicles; no odor; 5YR 3/2
109.53	6	NM		100	Primarily small to medium vesicles; grout seams 16.7-17. 9 and 18.75'; no odor; 5YR 3/2
108.80 / 20	7	NM		92	Small to primarily large vesicles; grout seams 18.8, 20.2, and 21.15-22.1'; no odor; 10YR 2/2
107.51	8	0		124	Small to primarily large vesicles; no odor; 10YR 2/2
106.35 / 30	9	0		100	Small to primarily large vesicles; no odor; 10YR 2/2
104.97	10	0		100	Small to large vesicles with primarily medium vesicles; no odor; 10YR 2/2
103.68					
103.20 / 40	11	0		100	Small to medium vesicles; clinker zone from 40.45-41.25'; 5YR 3/2
					Clinker zone
102.33	12	0		96	Small to medium vesicles; no odor; 5YR 3/2
100.96 / 50	13	0		100	Medium to large vesicles; grout seams 50.6-50.9 and 53.5'; no odor; 5YR 3/2
99.64	14	0		100	Medium to large vesicles; grout seams 56.85 and 59.2-59.3'; no odor; 10YR 2/2
98.32 / 60	15	0		100	Small to medium vesicles; grout seams 59-62.2, 63.3, and 63.95'; no odor; 10YR 2/2
96.98	16	0		98	Primarily small to large vesicles; grout seam 69.5'; no odor; 5YR 3/2
95.60 / 70	17	0		102	Medium to large vesicles; no odor; 10YR 2/2
94.28	18	0		87	Small to large vesicles; no odor; 5YR 3/2

WELL CONSTRUCTION



Corrected elevations are provided for angle borings.

This information pertains only to this boring and cannot be interpreted as being indicitive of the site.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-08
Project No. CTO 0229

LOCATION: Tank 8	ELEVATION: 113.67		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 01/15/01	LOGGED BY: Gary Gleason	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
93.17	19	0	RH-BR-8-S02	94	Small to medium vesicles; grout seams 80.8-81.55'; no odor; 5YR 3/2
92.45	20	0		100	Primarily small to medium vesicles; grout seams 83.25-83.35 and 86.3-86.6'; no odor; 5YR 3/2
91.26	21	0		96	Primarily small to medium vesicles; grout seams 87.5-90'; no odor; 5YR 3/2
89.91	22	0		102	Small to large vesicles; no odor; 10YR 3/1
88.75	23	0		98	Small to primarily large vesicles; no odor; 10YR 3/1 to 5YR 3/2
87.37	24	0		102	Small to large vesicles; no odor; 5YR 3/2 to 10YR 3/1
86.03	25	0		100	Small to medium vesicles; no odor; 10YR 3/1
84.66	26	0	RH-BR-8-S03	98	Small to medium vesicles; no odor; 10YR 3/1
83.31	27	0		102	Small to medium vesicles; grout seams 119.45-119.95'; no odor; 10YR 3/1 to 5YR 3/2
81.99	28	0		100	Small to medium vesicles; grout seams 122.4-123.05'; no odor; 5YR 3/2 to 10YR 3/1
80.75					B-08 terminated at 127.2'

Boring length scale (ft): 80, 90, 100, 110, 120, 130, 140, 150

WELL CONSTRUCTION

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B09A
Project No. CTO 0229

LOCATION: Tank 09	ELEVATION: 113.94		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 10/26/98	LOGGED BY: Fermin Esquibell	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 11	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
113.94 — 0	1			57		Concrete 0-2.5' over fine to coarse sand with fine gravel and silt 2.5-3.2'; basalt 3.2'	
113.27	2		B09A-1	94		Basalt; medium gray	
	3			96			
111.86 — 10	4			104		Basalt; medium dark gray; grout seams 18.3-19.3'	
110.01 — 20	5			100		Basalt; medium dark gray; grout seams 20.9-22.0 and 23.3-25.6'	
108.12 — 30	6			103		Basalt; medium gray; grout seams 29-33 and 33.6-34.7'	
106.23 — 40	7			95		Basalt; dark gray	
104.27 — 50	8			101		Basalt; greenish black from 50 to 50.7 '	
102.40 — 60	9			87		Basalt; medium gray; grout seam 61.5'	
	10			71			
— 70	11			97			
99.42	12			117		Basalt; 5YR 2/1	

Corrected elevations are provided for angle borings.

This information pertains only to this boring and ... not be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B09A
Project No. CTO 0229

LOCATION: Tank 09	ELEVATION: 113.94		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 10/26/98	LOGGED BY: Fermin Esquibell	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 11	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)		Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
98.87	80	13			107		Basalt; grayish black; grout seam 83-83.2'	
97.76		14			100		Basalt; grayish black; grout seam 84.8'	
96.73	90	15			89		Basalt; grayish black	
95.83		16		B09A-2	106		Basalt; dark gray	
94.86	100						Original B09A terminated at 98.3'; re-drilled and new boring terminates at 100'	
	110							
	120							
	130							
	140							
	150							

This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

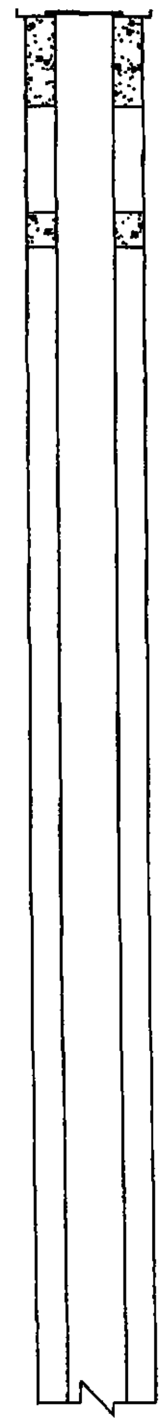
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-10
Project No. CTO 0229

LOCATION: Tank 10	ELEVATION: 113.71		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 1/8/01	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
113.71 / 0	1			64	Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5; basalt 2.5'; no odor
112.26					
111.85	2	0		87	Medium vesicles; no odor; 10YR 2/2
111.46	3	0		100	Medium vesicles; no odor; 5YR 3/2
10	4	0		89	Large vesicles; grout seams 9.3, 9.7, and 10.7-11.7'; no odor; 10YR 2/2
110.29					
109.96	5	0		100	Large vesicles; no odor; 10YR 2/2
109.65	6	0		108	Large vesicles; no odor; 10YR 2/2
109.34	7	0		108	Large vesicles; no odor; 10YR 2/2
	8	0		97	Large vesicles; grout seam 17.0'; no odor; 10YR 2/2
108.53					
108.20 / 20	9	0		92	Medium vesicles; no odor; 10YR 2/2
	10	0		102	Medium vesicles; no odor; 10YR 2/2
107.08					
106.93	11	0		100	Small vesicles; grout seam 26.1'; no odor; 10YR 2/2
	12	0		98	Small vesicles; no odor; 10YR 2/2
105.82 / 30					
105.40	13	0		100	Large vesicles; no odor; 10YR 2/2
	14	0		100	Medium vesicles; grout seam 36.3-37.1'; no odor; 10YR 2/2
104.11	15	0		102	Medium vesicles; grout seam 37.1-41.2'; no odor; 5YR 3/2
40					
102.84	16	0		100	Large vesicles; no odor; 10YR 2/2
101.55	17	0		100	Medium vesicles; grout seams 47.6-49.0 and 51.5'; no odor; 10YR 2/2
50					
100.30	18	0		100	Large vesicles; grout seam 54.2';no odor; 10YR 2/2
98.96	19	0		100	Medium vesicles; grout seam 59'; no odor; 10YR 2/2
97.77 / 60			RH-BR-10-S01		
97.40	20	0		100	Medium vesicles; grout seam 66.3'; clinker zone 63-64.7'; no odor; 10YR 2/2
					Clinker zone
96.52	21	0		106	Large vesicles; grout seam 66.4-68'; no odor; 10YR 2/2
95.31 / 70	22	0		116	Medium vesicles; grout seam 73.7-75.2'; no odor; 10YR 2/2
94.14	23	0		87	Medium vesicles; grout seam 75.6-77.7'; no odor;

WELL CONSTRUCTION



Corrected elevations are provided for angle borings.

This information pertains only to this boring and should not be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-10
Project No. CTO 0229

LOCATION: Tank 10	ELEVATION: 113.71
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 1/8/01 — LOGGED BY: Lance Williams
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER> FIRST: NA — COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2

Corrected Elevation/	Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
							10YR 2/2	
92.80	80	24	0		102		Medium vesicles; grout steam 81.4-83.6'; no odor; 10YR 2/2	
91.53		25	0		100		Large vesicles; no odor; 10YR 2/2	
90.18	90	26	0		102		Large vesicles; no odor; 10YR 2/2	
88.92		27	0		100		Large vesicles; no odor; 10YR 2/2	
87.54	100	28	0	RH-BR-10-S01	86		Medium vesicles; no odor; 10YR 2/2	
86.09		29	0		94		Medium vesicles; no odor; 10YR 2/2	
84.77	110							
84.61		30	0		95		Medium vesicles; grout seam 112-112.6'; clinker zone 112.45-114.25'; no odor; 10YR 2/2	
83.95							Clinker zone	
83.64		31	0		100		Clinker zone Large vesicles; grout seams 116.4-116.8 and 117.35'; clinker zone 115-130.7'; no odor; 10YR 2/2	
82.32	120	32	0		92		Small to medium vesicles; clinker zone 122.5-123.1'; no odor; 10YR 2/2	
				RH-BR-10-S03				
80.97		33	0		10		Medium vesicles; no odor; 10YR 2/2	
79.88	130						BR-10 terminated at 130.7'	
	140							
	150							

This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-11
Project No. CTO 0229

LOCATION: Tank 11	ELEVATION: 117.98		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/15/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)		Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
117.98	0	1	NM		53	Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5'; basalt 2.5'; slight odor
116.95		2	14.1	RH-BR-11-S01	100	Basalt; strong odor
116.56		3	NM		60	Concrete and wood recovered; strong odor
116.43		4	NM		114	Concrete and wood recovered; strong odor
116.07		5	12.0		14	Wood recovered; slight odor
115.70		6	17.0		100	Medium vesicles; strong odor; 10YR 2/2
115.52	10	7	19.4	RH-BR-11-S02	100	Medium vesicles; sheen on rock; strong odor; 10YR 2/2
115.31		8	19.8		104	Medium vesicles; strong odor; 10YR 2/2
114.07		9	2.7		100	Medium vesicles; no odor; 10YR 2/2
112.73	20	10	3.1	RH-MW-11 (FP)	95	Large vesicles; slight odor; 10YR 2/2
111.67		11	4.0		100	Medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
110.32	30	12	2.3		45	Large vesicles; no odor; 5YR 3/2
108.09	40	13	9.8		102	Medium vesicles; slight odor; 10YR 2/2
106.77		14	0.0		98	Medium vesicles; slight odor; 10YR 2/2
105.43	50	15	0.5		100	Small vesicles; no odor; 10YR 2/2
104.11		16	0.2		102	Medium vesicles; no odor; 10YR 2/2
102.79	60	17	0.2		72	Medium vesicles; no odor; 10YR 2/2
101.75		18	24.3		96	Large vesicles; strong odor; 5YR 3/2
	70			RH-BR-11-S03		
99.01		20	3.9		90	Medium vesicles; no odor; 5YR 3/2
98.23		21	2.8		100	Large vesicles; no odor; 10YR 2/2

WELL CONSTRUCTION

Corrected elevations are provided for angle borings.

This information pertains only to this boring and ...ot be interpreted as being indicative of the site.

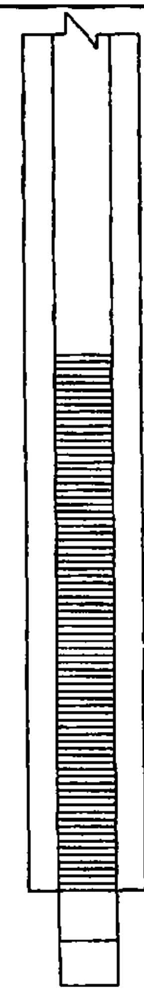
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-11
Project No. CTO 0229

LOCATION: Tank 11	ELEVATION: 117.98		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/15/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
96.91 — 80	22	21.4		39		Medium vesicles; grout seam 86.5'; strong odor; 10YR 2/2
95.46			RH-BR-11-S04			
	23			20		Medium vesicles; no odor; 10YR 2/2
94.82 — 90	24	55.8		96		Large vesicles; grout seams 90.2, 91.4, and 94.8'; strong odor; 10YR 2/2
93.42	25	80.3	RH-BR-11-S05	93		Large vesicles; strong odor; 10YR 2/2
92.59						
92.28	19	7.9		100		Large vesicles; strong odor; 5YR 3/2
100	26	3.5		106		Large vesicles; grout seam 101.1'; no odor; 10YR 2/2
91.06	27	1.6		93		Medium vesicles; no odor; 10YR 2/2
89.67 — 110	28			104		Large vesicles; no odor; 10YR 2/2
88.35	29	0.5		43		Small vesicles; no odor; 10YR 2/2
86.53 — 120	30					Medium vesicles; no odor; 10YR 2/2
84.85	31			17		Small vesicles; no odor; 10YR 2/2
84.07 — 130						B-11 terminated at 131.0'
140						
150						

WELL CONSTRUCTION



This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

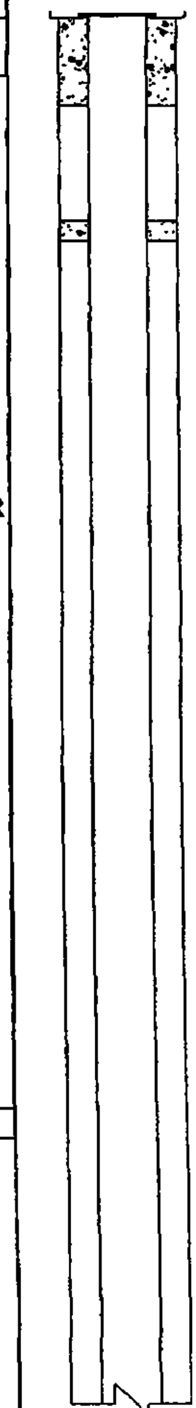
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-12
Project No. CTO 0229

LOCATION: Tank 12	ELEVATION: 117.71		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/12/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Depth	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
117.71	0	1	NM		100	Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5'; basalt 2.5'; no odor
116.52						
116.05		2	1.6		56	Medium vesicles; slight odor; 10YR 2/2
115.74		3	0.6		92	Small vesicles; strong odor; 10YR 2/2
115.43		4	0.3	RH-BR-12-S01	100	Medium vesicles; slight odor; 10YR 2/2
	10	5	1.0		100	Small vesicles; no odor; 10YR 2/2
114.45		6	1.3		89	Grout seam 16.8-17.0'; no odor; 10YR 2/2
113.31		7	1.2		102	Small vesicles; grout seam 17.0-18.2'; no odor; 10YR 2/2
112.04	20	8	1.5		96	Small vesicles; grout seam 22.9-26.9'; no odor; 10YR 2/2
110.75		9	1.3		106	Small vesicles; grout seam throughout; no odor; 10YR 2/2
109.51	30	10	26.0	RH-BR-12-S02	102	Small vesicles; strong odor; 10YR 2/2
108.21		11	2.8		100	Small vesicles; grout seam throughout; strong odor; 10YR 2/2
106.92	40	12	2.2		102	Large vesicles; grout seam 46'; slight odor; 10YR 2/2
105.65		13	1.8		100	Medium vesicles; grout seam 47.8 and 49.5-50.4'; slight odor; 10YR 2/2
104.33	50	14			96	Small vesicles; no odor; 10YR 2/2
102.96		15	1.9		100	Medium vesicles; strong odor; 10YR 2/2
101.92	60					Clinker zone 61-62'
101.61		16	17.3	RH-BR-12-S03	98	Grout seam 65'; slight odor; 10YR 2/2
100.24		17	1.0		100	Small vesicles; no odor; 10YR 2/2
	70					
98.87		18	0.1		90	Medium vesicles; no odor; 10YR 2/2
97.86		19	0.1		100	Small vesicles; no odor; 10YR 2/2

WELL CONSTRUCTION



This information pertains only to this boring and s[illegible]ot be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

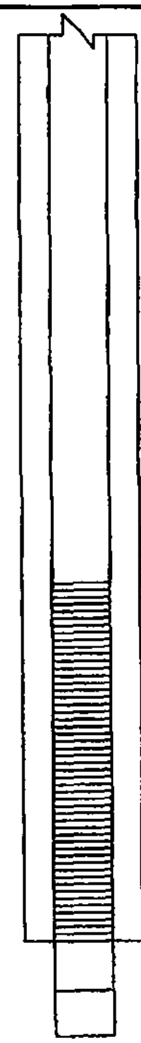
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-12
Project No. CTO 0229

LOCATION: Tank 12	ELEVATION: 117.71		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/12/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)		Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
97.55	80	20	2.2		102		Small vesicles; no odor; 10YR 2/2
96.23		21	0.0		92		Medium vesicles; no odor; 10YR 2/2
94.88	90	22	NM		100		Medium vesicles; no odor; 10YR 2/2
93.64		23	0.1		111		Medium vesicles; no odor; 10YR 2/2
92.42	100	24	0.0		100		Medium vesicles; no odor; 10YR 2/2
91.18		25	0.0	RH-BR-12-S04 RH-BR-12-D06	100		Large vesicles; no odor; 10YR 2/2
89.78	110	26	0.7		102		Medium vesicles; slight odor; 10YR 2/2
88.46		27	1.9		102		Large vesicles; odor; 10YR 2/2
87.12	120	28	26.4	RH-BR-12-S05	98		Medium vesicles; slight odor; 10YR 2/2
85.72		29	1.9		100		Medium vesicles; no odor; 10YR 2/2
84.50	130	30	0.8		100		Small vesicles; no odor; 10YR 2/2
83.13							B-12 terminated at 133.6'
	140						
	150						

WELL CONSTRUCTION



This information pertains only to this boring and sho ot be interpreted as being indicitive of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-13
Project No. CTO 0229

LOCATION: Tank 13	ELEVATION: 121.95	
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/8/00	LOGGED BY: Lance Williams
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA / COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2	

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
121.95 — 0	1	NM		100		Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5; basalt 2.5'; odor; sheen on drill water	
120.92							
120.50	2	179.2		4		Small vesicles; strong odor; 10YR 5/3	
119.98	3	83.2		73		Small vesicles; strong odor; 10YR 3/1	
119.88	4	92.9	RH-BR-13-S04	100		Large vesicles; strong odor; 10YR 2/2	
119.72	5	10.7		100		Sample was obtained from adjacent boring	
— 10		4.4				Large vesicles; no odor; 10YR 2/2	
118.46	6	6.4		100		Medium vesicles; no odor; 10YR 2/2	
117.84	7	6.7		68		Large vesicles; no odor; 10YR 2/2	
116.77 — 20						Lava tube 20-22.8'	
115.84	8	5.7		91		Large vesicles; no odor; 10YR 2/2	
114.50 — 30	9	7.0		100		Medium vesicles; no odor; 10YR 2/2	
113.20	10	7.4		100		Large vesicles; no odor; 10YR 2/2	
111.91 — 40	11	6.8		104		Large vesicles; no odor; 10YR 2/2	
110.72	12	3.3		64		Large vesicles; no odor; 10YR 2/2	
109.81	13	4.4		113		Medium vesicles; no odor; 10YR 2/2	
108.67 — 50	14	2.3		102		Medium vesicles; no odor; 10YR 2/2	
107.35	15	5.9		93		Small vesicles; no odor; 5YR 2.5/2	
105.96 — 60	16	7.1		100		Small vesicles; no odor; 5YR 2.5/2	
104.97	17	5.5		102		Medium vesicles; no odor; 10YR 2/2	
103.65 — 70	18	5.3	RH-BR-13-S01 RH-BR-13-D05	94		Medium vesicles; no odor; 10YR 2/2	
102.25	19	6.8		100		Medium vesicles; no odor; 10YR 2/2	

Corrected elevations are provided for angle borings.

This information pertains only to this boring and s... ...ot be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-13
Project No. CTO 0229

LOCATION: Tank 13	ELEVATION: 121.95		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/8/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
100.93 / 80	20	7.0		84		Small vesicles; no odor; 10YR 2/2 to 5YR 2.5/2	
99.33	21	5.8		98		Small vesicles; no odor; 10YR 2/2	
90 / 97.96	22	7.8		102		Medium vesicles; no odor; 10YR 2/2	
96.66	23	5.5		96		Small vesicles; no odor; 10YR 2/2	
100			RH-BR-13-S02				
95.29	24	6.8		100		Medium vesicles; no odor; 5YR 2.5/2	
93.95	25	6.7		104		Large vesicles; no odor; 10YR 2/2	
110 / 92.65	26	5.7		94		Medium vesicles; no odor; 10YR 2/2	
91.41	27	5.0		100		Small vesicles; no odor; 10YR 2/2	
120 / 90.09	28	5.1		104		Small vesicles; no odor; 10YR 2/2	
			RH-BR-13-S03				
88.80	29	1.9		100		Small vesicles; no odor; 10YR 2/2	
130 / 87.50						B-13 terminated at 133.1'	
140							
150							

Corrected elevations are provided for angle borings.

This information pertains only to this boring and should not be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-14
Project No. CTO 0229

LOCATION: Tank 14	ELEVATION: 121.75		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/05/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
121.75 — 0	1			13		Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5'; basalt 2.5'	
	2			75			
119.60							
119.11 — 10	3	0.0		95		Medium vesicles; 10YR 3/1	
	4	0.0		100		Medium vesicles; grout seam 13.2'; 10YR 3/1 to 2/2	
117.76	5	0.0		100		Medium vesicles; 10YR 3/1	
116.50 — 20	6	0.0		102		Medium vesicles; grout seams 23.4-25'; 10YR 2/2	
115.18	7	2.0		98		Small vesicles; grout seams 26.7-28.3 and 30.4'; 10YR 2/2	
113.80 — 30	8	6.2		98		Medium vesicles; grout seams 31.5-33.5 and 34.9'; 10YR 3/2	
112.43	9	9.8	RH-BR-14-S01	102		Large vesicles; grout seams throughout; 10YR 3/2	
111.11 — 40	10	10.8		102		Medium vesicles; 10YR 3/1	
109.82	11	4.7		100		Medium vesicles; 10YR 3/1	
108.52 — 50	12	2.0		100		Grout seam 55.7'; 10YR 2/2	
107.20	13	2.0		100		Small vesicles; grout seam 57.1'; 10YR 3/2	
105.86 — 60	14	1.6	RH-BR-14-S02 RH-BR-14-D04	92		Small vesicles, 10YR 2/2	
104.51	15	0.6		113		Medium vesicles; grout seam 67.2, 68, 68.7, and 69.7-70.8'; 10YR 2/1	
103.35 — 70	16	NM		100		Medium vesicles; grout seam 72'; 10YR 3/2	
102.03	17	1.6	RH-BR-14-S03	98		Large vesicles; 10YR 2/2	

Corrected elevations are provided for angle borings.

This information pertains only to this boring and ...ot be interpreted as being indicitive of the site.

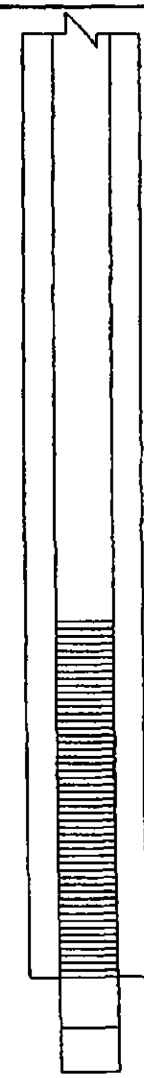
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-14
Project No. CTO 0229

LOCATION: Tank 14	ELEVATION: 121.75		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/05/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)		Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
100.66	80	18	2.0		102	Medium vesicles; 10YR 2/2
99.49		19	19.8		100	Medium vesicles; grout seam 90.2-91.2'; 10YR 2/2
98.15	90	20	19.7		100	Small vesicles; grout seams throughout; 10YR 2/2; heavy staining on core
96.83		21	44.4	RH-BR-14-S04	100	Large vesicles; grout seam 100.4'; 10YR 2/2
95.51	100	22	9.1		100	Small vesicles; hydrocarbon odor and stain; 10YR 2/2
94.16		23	3.9		100	Medium vesicles; grout seam 109.3-110.7'; hydrocarbon odor and stain; 10YR 2/2
92.81	110	24	2.0		100	Small vesicles; hydrocarbon odor and stain; 10YR 2/2
91.47		25	NA	RH-BR-14-S05	102	Medium vesicles; hydrocarbon odor and sheen; 10YR 2/2
90.20	120	26	2.0		96	Large vesicles; hydrocarbon odor and sheen; 10YR 2/2
88.83 88.60		27	2.0		85	Large vesicles; hydrocarbon odor and sheen; 10YR 2/2 Lava tube 128.1-129.2'
87.22 86.55	130	28	68.4		100	Medium vesicles; 10YR 2/2
						B-14 terminated at 136.0'
	140					
	150					

WELL CONSTRUCTION

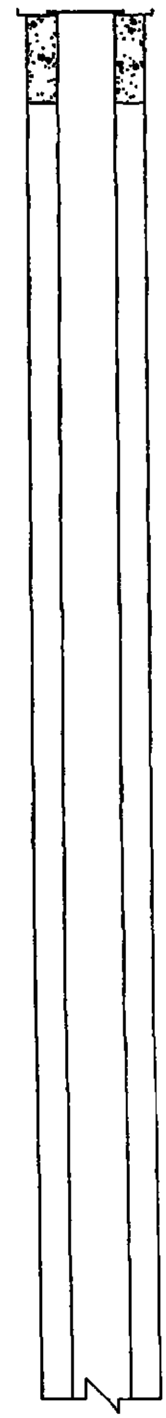


This information pertains only to this boring and should not be interpreted as being indicitive of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility **Boring/Monitoring Well No.** B-15
CLIENT: PACNAVFACENGCOM **Project No.** CTO 0229

LOCATION: Tank 15	ELEVATION: 125.88		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/02/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 13	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
125.88 — 0	1	NM		51		Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5'; basalt 2.5'	
	2			30			
124.13	3			120			
123.68	4	0		100		Medium vesicles; 10YR 2/2	
— 10	5	0.2		100		Medium vesicles; 10YR 2/2	
123.00							
122.75	6	0		100		Clinker zone 12.8-13.9; 10YR 2/2	
	7	0		93		Medium vesicles; grout seam 15.3-15.9'; 5YR 3/2	
121.85							
121.49	8	1.0		69		Small vesicles; 5YR 3/2	
— 20	9	1.2		98		Small vesicles; 5YR 3/2	
120.55	10	0.4		95		Medium vesicles; 10YR 2/2	
119.60	11	1.6		96		Medium vesicle; 10YR 2/2	
— 30							
18.39	12	1.2		95		Medium vesicles; 10YR 2/2	
117.89	13	1.4		94		Large vesicles; 10YR 2/2	
116.79 — 40	14	1.2		100		Medium vesicles; 10YR 2/2	
115.65	15	1.2		106		Medium vesicles; 10YR 2/2	
114.52 — 50	16	0.2		98		Small vesicles; 10YR 2/2	
113.51	17	1.2		100		Small vesicles; 10YR 2/2	
112.14 — 60	18	1.0	RH-BR-15-S01 RH-BR-15-D03	70		Small vesicles; 10YR 2/2	
111.15	19			96		Medium vesicles; 10YR 2/2	
109.98 — 70	20	1.4		100		Medium vesicles; grout seam 75.4-75.9'; 10YR 2/2	
08.81	21	0.9		100		Medium vesicles; grout seam 75.9-77'; 10YR 2/2	

Corrected elevations are provided for angle borings.

This information pertains only to this boring and should not be interpreted as being indicative of the site.

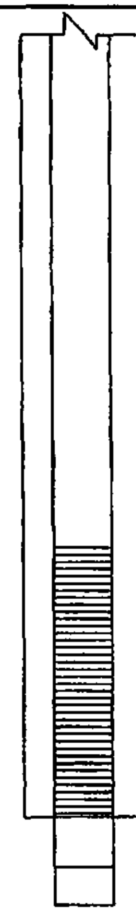
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-15
Project No. CTO 0229

LOCATION: Tank 15	ELEVATION: 125.88		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 12/02/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 13	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
80						
107.64	22	1.2		100		Medium vesicles; 10YR 2/2
106.49	23	1.2	RH-BR-15-S02	104		Small vesicles; 10YR 2/2
90						
105.27	24	0.9		100		Medium vesicles; 10YR 2/2
104.24	25	1.2		100		Small vesicles; 5YR 2.5/1
100						
103.09	26	1.4		100		Small vesicles; 5YR 2.5/1
101.95	27	1.0		100		Small vesicles; 5YR 2.5/1
110						
100.75	28	1.2		100		Small vesicles; 5YR 2.5/1
			RH-BR-15-S03			
99.58	29	1.2		100		Small vesicles; 5YR 2.5/1
120						
98.41	30	0.6		100		Medium vesicles; 5YR 2.5/1
97.45						B-15 terminated at 126.4'
130						
140						
150						

WELL CONSTRUCTION



This information pertains only to this boring and should not be interpreted as being indicitive of the site.

Corrected elevations are provided for angle borings.

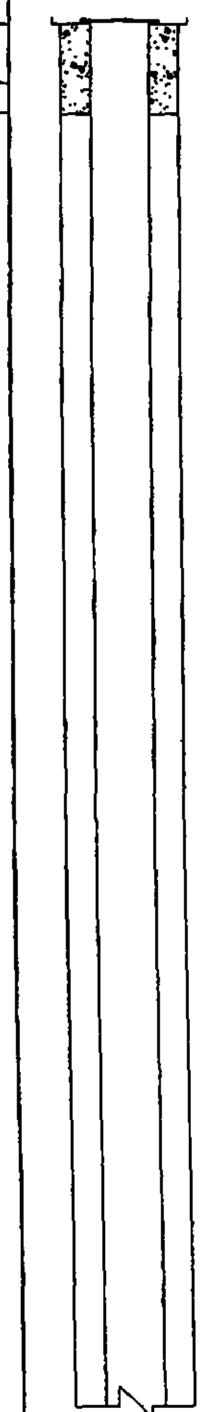
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B16A
Project No. CTO 0229

LOCATION: Tank 16A	ELEVATION: 125.70		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 10/21/98	LOGGED BY: Fermin Esquibell	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 11	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
125.70 — 0	1			69	Concrete 0-2' over grout 2-3.8'; basalt 3.8'; medium gray
125.32	2			86	Grout
124.98					Basalt; medium gray
124.25	3			103	Basalt; very dark gray
— 10					
123.30	4			108	Basalt; gray
— 20					
121.45	5			104	Basalt; grayish black
— 30					
119.56	6			90	Basalt; medium gray
— 40					
117.65	7			104	Basalt; dark, greenish gray
— 50					
115.70	8			93	Basalt; dark, reddish brown
— 60					
113.76	9			88	Basalt; medium dark gray
	10			103	
— 70					
110.91					

WELL CONSTRUCTION

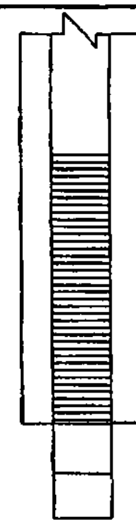


Corrected elevations are provided for angle borings.

This information pertains only to this boring and ... ot be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility		**Boring/Monitoring Well No.** B16A	
CLIENT: PACNAVFACENGCOM		**Project No.** CTO 0229	
LOCATION: Tank 16A		ELEVATION: 125.70	
DRILLER: Salisbury & Associates, Inc.		DATE DRILLED: 10/21/98	LOGGED BY: Fermin Esquibell
DRILL RIG: SAITECH EH5, Portable Core Drill		DEPTH TO WATER>	FIRST: NA / COMPL.: NA
BORING ANGLE: 11	WELL DIAMETER (inch): 2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
	11			102		Grout seam 81-81.8'	
80							
109.72			BR16A-4 B16A-DUP			Basalt; brownish black; grout seam 84-85.6'	
109.05	12			89		Basalt; medium dark gray	
90							
107.62	13			100		Basalt; medium gray	
106.81	14			91		Basalt; dusky, yellowish brown	
100			BR16A-5				
105.70						B16A terminated at 104.8'	
110							
120							
130							
140							
150							



This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-17
Project No. CTO 0229

LOCATION: Tank 17	ELEVATION: 129.75			
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 11/07/00	LOGGED BY: Lance Williams		
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA	
BORING ANGLE: 13	WELL DIAMETER (inch): 1 1/2			

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
129.75 / 0	1	11.2		40		Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5'; basalt 2.5'	
129.19						Basalt	
128.11	2	17.4		96		Medium vesicles; 10YR 2/1	
10			RH-BR-17-S01				
127.03	3	10.7		100		Medium vesicles; 5YR 2.5/2	
125.99	4	10.1		98		Medium vesicles; 10YR 3/2	
20							
124.78	5	10.7		102		Medium vesicles; 10YR 3/1	
123.65	6	10.1		100		Medium vesicles; 10YR 3/2	
30							
122.53	7	10.4		100		Medium vesicles; 10YR 3/1	
			RH-BR-17-S02 RH-BR-17-D02				
121.40	8	9.8		100		Medium vesicles; 5YR 3/2	
40							
120.28	9	10.7		78		Medium vesicles; 5YR 3/2	
119.16	10	10.3		100		Medium vesicles; 10YR 3/1	
50							
118.03	11	10.6		100		Medium vesicles; 10YR 3/1	
116.91	12	10.5		100		Medium vesicles; grout seam 59.1'; 5YR 2.5/1	
60							
115.78	13	10.7		100		Medium vesicles; 10YR 2/1	
114.86	14	10.6	RH-BR-17-S03	100		Medium vesicles; 5YR 2.5/1	
113.98 / 70	15	10.7		100		Medium vesicles; grout seam 72.8'; 5YR 3/1	
112.92	16	NM		100		Medium vesicles; 5YR 3/1	
112.81	17	10.3		98		Medium vesicles; 10YR 2/2	

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

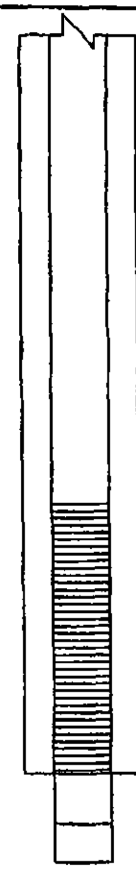
Boring/Monitoring Well No. B-17
Project No. CTO 0229

LOCATION: Tank 17	ELEVATION: 129.75
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 11/07/00 — LOGGED BY: Lance Williams
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER> FIRST: NA — COMPL.: NA
BORING ANGLE: 13	WELL DIAMETER (inch): 1 1/2

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
112.09	18	10.7		100	Medium vesicles; 10YR 3/1
111.35					
110.97	19	83.2		100	Medium vesicles; 10YR 3/1
110.61	20	10.7		81	Medium vesicles; 10YR 3/1
	21	7.7		100	Medium vesicles; 10YR 3/1
109.44	22	95.1		100	Medium vesicles; 10YR 3/1
108.25	23	14.1		100	Medium vesicles; 10YR 2/2
107.08	24	11.5		90	Large vesicles; 10YR 2/1
105.93	25	NM		267	Large vesicles; 10YR 2/1
105.86	26	7.0		104	Large vesicles; 10YR 2/1
104.74	27	7.0		100	Large vesicles; 10YR 2/2
103.95					
103.79	28	NM		100	Clinker zone; 10YR 2/1
103.50	29	7.8		100	Clinker zone; 10YR 2/1
103.21	30			77	Clinker zone; 10YR 2/1
102.78	31			81	Clinker zone; 10YR 2/1
	32	NM		121	Large vesicles; 10YR 2/1
101.81					
					B-17 terminated at 124.2'

Boring length scale: 80, 90, 100, 110, 120, 130, 140, 150

WELL CONSTRUCTION



This information pertains only to this boring and should not be interpreted as being indicative of the site.

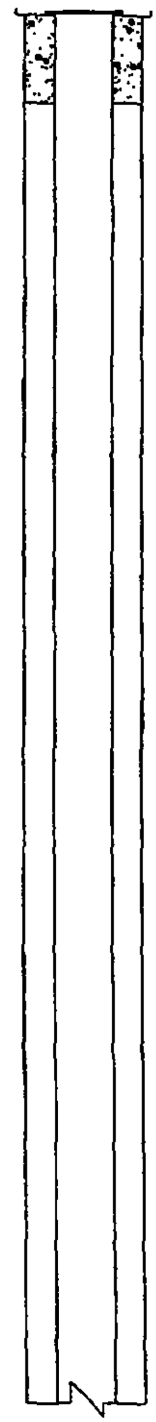
Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-18
Project No. CTO 0229

LOCATION: Tank 18	ELEVATION: 129.58		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 11/02/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 13	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
129.58 — 0 128.97	1			70		Concrete 0-2.7'; over fine to coarse sand with fine gravel and silt 2-2.5'; basalt 2.5'; 5YR 2.5/2; no odor Sand	
128.03	2 3	10.1		33 111		Basalt; no odor; 5YR 2.5/2	
127.17 — 10	4	12.3		98		Basalt; no odor; 5YR 2.5/2	
125.98	5	10.7		102		Basalt; no odor; 10YR 2/1	
124.83 — 20	6	10.8		100		Grout seams 21.9, 22.1, and 22.8'; no odor; 10YR 2/1	
123.66	7	18.1		100		Basalt; no odor; 10YR 2/1	
122.52 — 30	8	10.8		102		Basalt; no odor; 10YR 2/1 to 5YR 3/2	
121.39	9	10.7		102		Basalt; no odor; 5YR 3/2	
120.22 — 40	10	10.6		100		Basalt; slight odor; 5YR 3/2	
119.08	11	12.3		100		Basalt; no odor; 5YR 3/2	
117.91 — 50	12	10.4		100		Basalt; no odor; 5YR 3/2	
116.74	13	10.5		94		Basalt; no odor; 5YR 3/2 to 10YR 2/1	
115.59 — 60	14	10.7		106		Basalt; no odor; 10YR 2/1	
114.49	15	11.3		100		Basalt; no odor; 10YR 2/1	
113.32 — 70	16	10.7		93		Basalt; no odor; 10YR 2/2	
112.33	17	8.6		93		Basalt; no odor; 10YR 2/1	



Corrected elevations are provided for angle borings.

This information pertains only to this boring and ... not be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-18
Project No. CTO 0229

LOCATION: Tank 18	ELEVATION: 129.58		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 11/02/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 13	WELL DIAMETER (inch): 1 1/2		

This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
80							
111.22	18	9.4	RH-BR-18-S01	98		Grout seam 86.5'; no odor; 10YR 3/2	
110.03	19	12.4		116		Small vesicles; no odor; 10YR 3/2	
109.47 / 90	20	9.2		104		Small vesicles; no odor; 10YR 3/1	
108.35	21	10.4		100		Small vesicles; no odor; 10YR 3/1	
107.24 / 100	22	10.4		150		Small vesicles; no odor; 10YR 3/1	
107.15	23	10.7		100		Small vesicles; no odor; 10YR 3/2	
105.98	24	9.8	RH-BR-18-S02	100		Large vesicles; grout seam 106.6'; no odor; 10YR 3/2	
104.79 / 110	25	10.3		100		Large vesicles; no odor; 5YR 3/1	
103.71						Clinker Zone	
103.60	26	10.7	RH-BR-18-S03 RH-BR-18-D01	87		Large vesicles; no odor; 10YR 3/2	
102.25 / 120	27	125.8		111		Large vesicles; no odor; 10YR 3/2	
101.24						B-18 terminated at 126'	
130							
140							
150							

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility	**Boring/Monitoring Well No.** B-19
CLIENT: PACNAVFACENGCOM	**Project No.** CTO 0229
LOCATION: Tank 19	ELEVATION: 133.68
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 11/22/00 — LOGGED BY: Lance Williams
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER> FIRST: NA — COMPL.: 113.1'
BORING ANGLE: 13	WELL DIAMETER (inch): 1 1/2

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
133.68 — 0						Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5; basalt 2.5'; 10YR 3/2; clinker zone 0-51.4'	
133.12							
132.22						Clinker zone	
132.11	2			160		Small vesicles; 10YR 2/2; clinker zone	
131.59	3			30		Clinker zone; 10YR 2/2	
— 10	4	13.5		55		Clinker zone; 10YR 2/2	
130.94	5	14.0		42		Clinker zone; 10YR 2/2	
130.40	6	10.4		104		Medium vesicles; 10YR 3/1; clinker zone	
129.83	7	10.6		100		Clinker zone; 10YR 2/2	
— 20							
128.64	8	10.4		100		Clinker zone; 5YR 3/4	
127.97	9	8.9		52		Clinker zone; 5YR 3/4	
127.36	10	10.1		85		Large vesicles; clinker zone; 10YR 3/2	
— 30							
126.28	11	NM		77		Clinker zone; 5YR 3/4	
125.99	12	10.0		82		Clinker zone; 5YR 3/4	
125.60	13	10.7		133		Clinker zone; 5YR 3/4	
125.38	14	7.7		76		Clinker zone; 5YR 3/4	
124.66 — 40	15	94.7		97		Clinker zone; odor; 5YR 3/4	
124.01						Clinker zone	
123.78	16	47.8	RH-BR-19-S01	100		Medium vesicles; 10YR 3/2; clinker zone end 45.0'; odor	
123.04							
122.79	17	10.7		109		Medium vesicles; 10YR 3/2; clinker zone	
122.61	18	NM		100		Medium vesicles; 10YR 3/2; clinker zone	
122.25 — 50	19	50.4		87		Medium vesicles; 10YR 3/2; clinker zone	
122.12	20	8.3		100		Medium vesicles; 10YR 3/2; clinker zone	
121.85	21	131		100		Small vesicles; slight odor; 10YR 2/2	
121.29	22	111		100		Small vesicles; slight odor; 10YR 2/2	
	23	0.0		100		Small vesicles; no odor; 10YR 2/1	
120.12 — 60	24	154		100		Small vesicles; slight odor; 10YR 2/2	
119.60	25	175	RH-BR-19-S02	90		Medium vesicles; strong odor; 10YR 2/2	
118.43	26	167		104		Medium vesicles; no odor; 10YR 2/2	
— 70							
117.26	27	200		81		Small vesicles; no odor; 10YR 2/2	
116.34							

This information pertains only to this boring and s... ...ot be interpreted as being indicitive of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-19
Project No. CTO 0229

LOCATION: Tank 19	ELEVATION: 133.68		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 11/22/00	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: 113.1'
BORING ANGLE: 13	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
115.71 / 80	28	25		75		Medium vesicles; no odor; 10YR 2/2	
	29	334		102		Small vesicles; no odor; 10YR 2/2	
114.56	30	189		100		Large vesicles; no odor; 10YR 2/2	
113.39 / 90	31	630		104		Large vesicles; no odor; 10YR 2/2	
112.87	32	667	RH-BR-19-S03	117		Medium vesicles; no odor; 10YR 2/2	
112.33	33			69		Large vesicles; no odor; 10YR 2/2	
111.97	34			88		Small vesicles; no odor; 10YR 2/2	
111.41 / 100	35	NM		102		Large vesicles; no odor; 10YR 2/2	
110.94	36	NM		100		Large vesicles; no odor; 10YR 2/2	
109.09 / 110	37	350		102		Large vesicles; no odor; 10YR 2/2	
107.99	38	582		121		Large vesicles; no odor; 10YR 2/2	
107.45	39	406	RH-BR-19-S04	104		Large vesicles; no odor; 10YR 2/2	
106.44 / 120						BR-19 terminated at 121.1'	
130							
140							
150							

Corrected elevations are provided for angle borings.

This information pertains only to this boring and should not be interpreted as being indicative of the site.

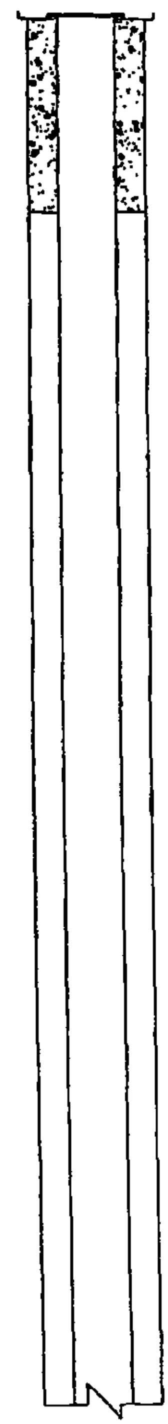
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-20
Project No. CTO 0229

LOCATION: Tank 20	ELEVATION: 133.54		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 3/2/01	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
133.54 — 0	1	75.1		84	Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5'; basalt 2.5'; strong odor
132.89	2		RH-BR-20-S01	24	Medium vesicles; no odor; 10YR 2/2
131.60	3	375		40	Small vesicles; strong odor; 10YR 2/2
— 10	4		RH-BR-20-S02	85	
130.56	5			100	Small vesicles; no odor; 10YR 2/2
129.43	6			109	Medium vesicles; no odor; 10YR 2/2
128.26 — 20	7			177	Small vesicles; no odor; 5YR 3/2
127.92	8			84	Small vesicles; grout seam 22.7-25.2'; no odor; 5YR 3/2 to 10YR 2/2
126.32	9			98	Small vesicles; no odor; 10YR 2/2 to 5YR 3/2
— 30					
124.95	10			111	Small vesicles; no odor; 10YR 2/2
124.25	11			90	Medium vesicles; no odor; 10YR 2/2
122.90 — 40	12			113	Medium vesicles; no odor; 10YR 2/2
121.71	13			100	Small vesicles; no odor; 5YR 3/2
121.35	14			100	Small vesicles; no odor; 10YR 2/2
120.50 — 50	15			96	Large vesicles; grout seam 52.3'; no odor; 10YR 2/2
119.10	16			98	Medium vesicles; grout seam 58'; no odor; 10YR 2/2
117.75 — 60	17			90	Large vesicles; grout seams 61.3-64.3 and 65.5'; no odor; 10YR 2/2
116.46	18			111	Medium vesicles; no odor; 10YR 2/2
115.24 — 70					Small vesicles; no odor; 5YR 2/2
115.01	19			52	Clinker zone 71.6-73.6'
114.15	20			98	Small vesicles; grout seam 75.0-79.1'; no odor; 10YR 2/2

WELL CONSTRUCTION



Corrected elevations are provided for angle borings.

This information pertains only to this boring and s...t be interpreted as being indicative of the site.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-20
Project No. CTO 0229

LOCATION: Tank 20	ELEVATION: 133.54		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 3/2/01	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: NA	COMPL.: NA
BORING ANGLE: 15	WELL DIAMETER (inch): 1 1/2		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
113.04					
112.42 (80)	21			62	Small vesicles; grout seam 79.4'; no odor; 10YR 2/2
	22			66	Small vesicles; grout seam 81.7-81.9'; no odor; 10YR 2/2
111.44	23			100	Small vesicles; no odor; 5YR 3/2
110.40 (90)	24			103	Small vesicles; no odor; 5YR 3/2
109.65	25			96	Small vesicles; no odor; 10YR 2/2
108.95	26			69	Small vesicles; no odor; 10YR 2/2
108.54	27			31	Small vesicles; no odor; 10YR 2/2
107.87	28			73	Small vesicles; no odor; 10YR 2/2
107.48 (100)	29			100	Small vesicles; no odor; 10YR 2/2
107.30	30			32	Small vesicles; no odor; 5YR 3/2
106.65	31	NM	RH-BR-20-S03	50	Small vesicles; no odor; 5YR 3/2
106.03	32	NM		97	Large vesicles; no odor; 10YR 2/2
105.25	33			53	Small vesicles; no odor; 10YR 2/2
104.76 (110)	34			29	Small vesicles; no odor; 10YR 2/2
103.88	35			125	Small vesicles; no odor; 10YR 2/2
103.67	36	467		112	Small vesicles; no odor; 10YR 2/2
103.47	37			80	Medium vesicles; no odor; 10YR 2/2
102.30 (120)	38	629		75	Large vesicles; no odor; 10YR 2/2
100.98	39	420		147	Large vesicles; no odor; 10YR 2/2
100.49					BR-20 terminated at 127.7'
(130)					
(140)					
(150)					

WELL CONSTRUCTION

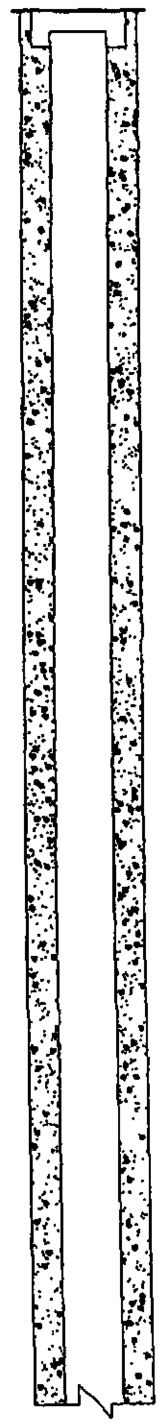
This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility	**Boring/Monitoring Well No.** B-V1D
CLIENT: PACNAVFACENGCOM	**Project No.** CTO 0229
LOCATION: V1D - Basal Aquifer	ELEVATION: 102.56
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 2/13/01 — LOGGED BY: Lance Williams
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER> FIRST: 86.0 — COMPL.: 86.1
BORING ANGLE: 90	WELL DIAMETER (inch): 1"

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
102.56 — 0	1	NM		100	Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5; basalt 2.5'; no odor
102.06	2	172		83	Small to large vesicles; no odor; 10YR 3/1
98.56		NM			
	3	NM		71	Small to medium vesicles; no odor; 10YR 3/1 to 2/1
95.36		99.2			
94.16	4	NM		0	Small vesicles; no odor; 5YR 3/2 to 10YR 2/2
93.66	5	NM		33	Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/2
91.76 — 10	6			100	
	7	124		105	Small to large vesicles; no odor; 10YR 2/2
	8			93	Small to large vesicles; no odor; 10YR 2/2 to 3/2
86.06	9	NM		96	Primarily small to medium vesicles; no odor; 10YR 2/2
81.66 — 20	10	NM		100	Small to primarily large vesicles; no odor; 10YR 2/2 to 5YR 3/2 to 10YR 3/1
76.26	11	3.2		100	Small to large vesicles; no odor; 10YR 3/1 to 5YR 3/2
71.26 — 30	12	10.8		100	Small to medium vesicles; no odor; 5YR 3/2 to 10YR 3/1
66.16	13	NM		102	Small to large vesicles; no odor; 5YR 3/2 to 10YR 3/1
60.96 — 40	14	NM		100	Small to large vesicles; no odor; 10YR 2/2 to 5YR 3/2
57.26					
56.91	15	NM		98	Small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
					Void
53.06 — 50	16	NM		98	Small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
48.06	17	1.0		89	Small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
43.36 — 60	18	6.9		100	Small to large vesicles; no odor; 10YR 3/1 to 2/2 to 5YR 3/2
38.36	19	1.8		83	Small to large vesicles; no odor; 10YR 2/5 to 5YR 3/2
34.26 — 70	20	0.0		92	Small to medium vesicles; no odor; 10YR 2/1 to 2/2 tp 5YR 3/2
29.16	21	0.0	RH-BR-V1D-S01	102	Small vesicles; no odor; 10YR 2/1

WELL CONSTRUCTION



This information pertains only to this boring and [n]ot be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-V1D
Project No. CTO 0229

LOCATION: V1D - Basal Aquifer	ELEVATION: 102.56		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 2/13/01	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: 86.0	COMPL.: 86.1
BORING ANGLE: 90	WELL DIAMETER (inch): 1"		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION	WELL CONSTRUCTION
24.06	22	0		100		Medium vesicles; no odor; 10YR 2/2	
18.86	23	0.0	RH-BR-V1D-S02	106		Medium vesicles; no odor; 10YR 2/2	
15.66	24	0.0		96		Large vesicles; no odor; 10YR 2/1	
10.16 / 9.56	25	0.0		86		Small vesicles; no odor; 10YR 2/2	
						Clinker zone 93-100'	
6.56 / 4.96	26	0.0		56		Medium vesicles; clinker zone; no odor; 10YR 2/1	
4.96	27	0.0	RH-BR-V1D-S03	50		Medium vesicles; clinker zone; no odor; 10YR 2/2	
2.56						Clinker zone	
						B-V1D terminated at 100.0'	

Depth scale: 80, 90, 100, 110, 120, 130, 140, 150

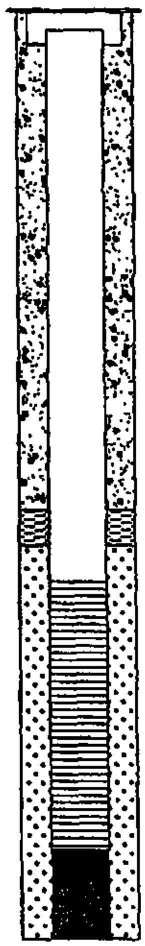
This information pertains only to this boring and should not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility	**Boring/Monitoring Well No.** B-V2S
CLIENT: PACNAVFACENGCOM	**Project No.** CTO 0229
LOCATION: V2S - Monitor Above Basal Aquifer	ELEVATION: 102.56
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 2/20/01 — LOGGED BY: Lance Williams
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER> FIRST: NA — COMPL.: NA
BORING ANGLE: 90	WELL DIAMETER (inch): 1 1/2

Corrected Elevation/ Boring Length (ft)		Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
102.56	0	1	0.0		33		Concrete 0-2' over fine to coarse sand with fine gravel
101.06		2	0		100		and silt 2-2.5'; basalt 2.5'; no odor
99.16		3	0.0		95		Medium vesicles; no odor; 10YR 2/2
97.06			0.0				Small vesicles; no odor; 10YR 2/2
95.36		4	0.0		112		Small vesicles; no odor; 10YR 2/2
		5	0.0		92		Medium vesicles; no odor; 10YR 2/2
91.46	10			RH-BR-V2S-S01			
		6	0.0		100		Medium vesicles; no odor; 10YR 2/2
89.16		7	0.0		91		Medium vesicles; no odor; 5YR 3/2
84.17		8	0.0		90		Large vesicles; no odor; 10YR 2/2
	20			RH-BR-V2S-S02			
77.86		9	0.0		100		Large vesicles; no odor; 10YR 2/2
75.16		10	0.0		93		Small vesicles; no odor; 10YR 2/1 to 5YR 3/2
72.26	30						Clinker zone
70.56		11	0.0		83		Small vesicles; no odor; 5YR 3/2
67.06		12	0.0		89		Medium vesicles; no odor; 10YR 2/2
62.36	40	13	0.0		94		Small vesicles; no odor; 10YR 2/2
58.96		14	0.0	RH-BR-V2S-S03	96		Small vesicles; no odor; 5YR 3/2
54.06		15	NM		NA		Small vesicles; no odor; 5YR 3/2
50.56	50						B-V2S terminated at 52.0'
	60						
	70						

WELL CONSTRUCTION



Corrected elevations are provided for angle borings.

This information pertains only to this boring and ...st be interpreted as being indicative of the site.

Appendix G

FISC Specifications for GIS Data Presented in Phase SOW

GIS and Data Management
For the FISC Red Hill Environmental Investigation

Task Description

The Red Hill Environmental Investigation will produce an array of digital data including surface and subsurface data. The contractor should provide data in a format that will be most usable to FISC and PWC.

The objective of the digital deliverables is to provide FISC and PWC archive sets of geospatial project data and metadata to reside on their GIS systems for future work and integration. The geospatial project data should be provided so that FISC and PWC will be able to use the data in their GIS systems with a minimal amount of conversion and reformatting, etc. FISC utilizes GeoMedia Professional 5.2, GeoMedia WebMap Professional 5.2, GeoMeida Transportation 5.2, and an Oracle 8i database backend for its GIS. PWC utilizes an ESRI ArcInfo, Arc IMS, ArcView (versions 8 and 3.2) and an Oracle backend database for its GIS.

The contractor will also create a digital, three dimensional, site plan using ArcGIS and MVS. The Red Hill facility GIS will incorporate existing data (drawings, logs, etc), future drilling activities and future geophysical surveys.

Deliverables

1) Provide a data integration and development plan for coordination, including a detailed timeline for delivery of Phase 1 data and the model to FISC and PWC.

2) Provide GIS and geospatial project data produced as part of this phase in Geomedia Warehouse Database format, and in Personal Geodatabase or Shapefile format.
Data in this section includes:

- i. Geophysical survey data compiled or created for Phase 1
- ii. Sampling data compiled or created for Phase 1
- iii. Any future physical survey data collected by the contractor for Phase 1
- iv. Any GIS data layers produced as part of the Phase 1 including digitized paper maps, digital topographic data, bore hole logs, etc.;
- v. Digital Fuel tank boring logs
- vi. Digital Fuel tank models

3) The contractor will purchase one (1) node locked copy of FME Intergraph suite for conversion of the ESRI geodatabase to a Geomedia warehouse database format. The contractor shall complete and test the conversion of the delivered data files in GeoMedia prior to its delivery. The node locked-licensed copy of FME Intergraph suite shall be transferred to FISC after completion of the contract.

4) Provide MVS Project/ArcGIS 3D data files including ArcGrid surface interpolations and Tin layers if used to develop the 3D model.

5) The contractor will provide Open Flight (.flt) and VRML versions of the finished 3D model. Client should be advised that functionality such as volume rendering is not supported in VRML.

6) Provide MVS 4DIM (4D Interactive Model) and free viewing software.

7) Provide full FGDC compliant metadata files for data in XML (.xml) and text (.txt) formats.

Assumptions

1) Navy will provide any available and applicable digital geographic data relating to the Red Hill site for use by the contractor.

2) Geographic coordinates or survey information will be provided for all borings, drillings, and surveys.

3) 3-D Model is to include 2 new vertical wells installed during Phase 1.

4) 3-D Model is to include Geophysical survey from Phase 1.

5) All data provided will be in NAD 83, Hawaii Zone 3, meters.

6) The contractor will provide a data dictionary to be applied to project data files.

7) Data files will be produced and delivered using federal Spatial Data Standards (SDS) where applicable.

Appendix H

Standard Operating Procedures

IDW MANAGEMENT

1.0 PURPOSE

This standard operating procedure (SOP) describes the activities and responsibilities of the U.S. Navy PACDIV IRP with regard to management of investigation-derived waste. The purpose of this procedure is to provide guidance for the minimization, handling, labeling, temporary storage, and inventory of investigation-derived waste (IDW) generated under the IRP. This SOP will also apply to personal protective equipment (PPE), sampling equipment, decontamination fluids, non-IDW trash, non-indigenous IDW, and hazardous waste generated during implementation of removal or remedial actions. The information presented will be used to prepare and implement Work Plans (WP) and Field Sampling Plans (FSP) for IDW-related field activities. Results from implementation of WPs and FSPs will then be used to develop and implement final IDW Disposal Plans (DPs).

2.0 SCOPE

This document applies to all IRP personnel involved in the development and implementation of WPs and FSPs that include the generation of IDW.

This procedure was developed to serve as management-approved professional guidance for the management of IDW generated under the IRP. It focuses on the requirements for minimizing, segregating, handling, labeling, storing, and inventorying IDW in the field. Certain drum inventory requirements related to the screening, sampling, classification, and disposal of IDW are also noted in this procedure.

This procedure is not intended to obviate the need for professional judgment that may arise in unspecified or unforeseen circumstances. Moreover, specific guidance from local regulatory agencies must be obtained and acted upon. Deviations from this procedure in planning or executing planned activities must be approved by the Technical Director/QA Program Manager and documented.

3.0 DEFINITIONS

3.1 INVESTIGATION-DERIVED WASTE

Investigation-derived waste (IDW) consists of all materials generated during site investigation that may be contaminated with chemicals of concern. IDW may consist of many types of potentially contaminated materials, including but not limited to, PPE; disposable sampling and decontamination equipment; investigation-derived soil, sludge, and sediment; well development and purge water; and decontamination fluids.

3.2 PERSONAL PROTECTIVE EQUIPMENT

PPE, as defined in this procedure, refers to all disposable materials used to protect personnel from contact with potentially contaminated site media, such as inner and outer gloves, Tyvek® suits and overboots, and disposable respirator cartridges. Non-consumable items such as steel-toe boots, respirators, and hard hats are not included in this procedure.

3.3 DISPOSABLE SAMPLING EQUIPMENT

Disposable sampling equipment consists of all single-use equipment that may have come in contact with potentially contaminated site media, including sample bailers, Draeger® air monitoring tubes, used soil sampling trowels and spatulas, plastic drop cloths, plastic bags and bucket liners, and sample containers from field analytical test kits.

3.4 INVESTIGATION-DERIVED SOIL, SLUDGE, AND SEDIMENT

Investigation-derived soil consists of all potentially contaminated soil that is disturbed as part of site investigation activities. The most commonly encountered form of IDW soil is drill cuttings brought to the ground surface by drilling. Other forms of disturbed soil, including trenching spoils and excess soil remaining from surface sampling, should not be stored as IDW. Excavated soil should be returned to its source, if site conditions permit.

Investigation-derived sludge consists of all potentially contaminated sludge materials generated or disturbed during site investigation activities. Generated sludge may consist of drilling mud used or created during intrusive activities. Other sludge may include solvents or petroleum-based materials encountered at the bottom of storage tanks and grease traps.

Investigation-derived sediment consists of all potentially contaminated sediments that are generated or disturbed during site investigation activities. Generated sediments may include solids that settle out of suspension from well development, purge, or decontamination water (see Definitions 3.5 and 3.6) while stored in 55-gallon drums or during sample filtration. Disturbed sediments may also consist of catch basin sediments or excess sediment from surface water activities.

3.5 Well Development and Purge Water

Development water consists of ground water withdrawn from newly installed monitoring wells in preparation for well purging or pump testing. Monitoring well development methods are discussed in SOP I-C-2, *Monitoring Well Development*.

Purge water consists of ground water that is removed from monitoring wells immediately prior to sampling. Well purging methods are discussed in SOP I-C-3, *Monitoring Well Sampling*. Ground water derived during aquifer testing shall be addressed on a site-specific basis. Procedures for handling ground water generated during aquifer testing shall be included in the DOT/DO Work Plan or equivalent document.

3.6 Decontamination Fluids

Decontamination fluids consist of all fluids used in decontamination procedures conducted during site investigation activities. These fluids consist of wash water, rinse water and solvents used for the decontamination of non-consumable PPE, sampling equipment, and drilling equipment. Decontamination procedures are discussed in SOP I-F, *Equipment Decontamination*.

3.7 Non-IDW Trash

Non-IDW trash is all waste materials such as waste paper, drink containers, food, and packaging generated in the support zone that have not come in contact with potentially contaminated site media.

3.8 Non-Indigenous IDW

Non-indigenous IDW consists of all waste materials from offsite sources that are generated in the transition or contamination reduction zones and have not come in contact with potentially contaminated site media. Non-indigenous IDW includes materials such as PPE from "clean" field activities (e.g., field blank generation, water sampling events); and refuse from monitoring well installation (e.g., unused sections of well casing, used bentonite buckets, sand bags, and cement bags).

3.9 RCRA Hazardous Waste

Under the Resource Conservation and Recovery Act (RCRA), a solid waste that is not excluded from regulation is defined as hazardous if (1) it is listed as a hazardous waste in Chapter 40, Code of Federal Regulations (CFR), Parts 261.31 through 261.33; (2) it exhibits any of four hazardous characteristics: ignitability, corrosivity, reactivity, or toxicity (as determined using the Toxicity Characteristic Leachate Procedure [TCLP]); or, (3) it is subject to certain mixture rules (EPA 1992). If IDW is determined to be RCRA hazardous waste, then RCRA storage, transportation, and disposal requirements may apply.

3.10 Land Disposal Restrictions (LDR)

Land disposal, as defined in RCRA, is any placement of RCRA hazardous waste on the land in a waste pile, landfill, impoundment, well, land treatment area, etc. LDRs are regulatory restrictions placed on land disposal, including pre-treatment standards, engineered containment, capacity constraints, and reporting and permitting requirements.

3.11 Area of Contamination (AOC)

The United States Environmental Protection Agency (EPA) considers the area of contamination (AOC) to be a single land-based disposal unit, usually a "landfill," and includes non-discrete land areas in which there is generally dispersed contamination (EPA 1991). Note that storing IDW in a container (i.e., portable storage devices such as drums and tanks) within the AOC and returning it to its source, whether RCRA hazardous or not, does not trigger RCRA LDRs. In addition, sampling and direct replacement of wastes within an AOC do <u>not</u> constitute land disposal (EPA 1992).

4.0 RESPONSIBILITIES

The CTO/DO Manager is responsible for preparing WPs and FSPs in compliance with this procedure, and is responsible for documenting instances of non-compliance.

The Field Managers are responsible for implementing this IDW procedure and for ensuring that all project field personnel follow it.

The Technical Director/QA Program Manager is responsible for conducting audits to ensure that this procedure is being utilized throughout the U.S. Navy PACDIV IRP, and in accordance with the U.S. Navy PACDIV IRP.

5.0 PROCEDURES

The procedures for IDW management in the field are described below in Sections 5.1 to 5.5. The implementation of these procedures requires CTO/DO Managers, Field Managers, and their designates to perform the following tasks:

- Minimize IDW as it is generated
- Segregate IDW by matrix and source location
- Apply suitable procedures for IDW drum handling and labeling
- Apply protective methods for IDW drum storage
- Prepare an IDW drum inventory
- Update and report changes to the IDW drum inventory

5.1 IDW Minimization

Field Managers and their designates shall minimize the generation of onsite IDW to reduce the need for special storage or disposal requirements that may result in substantial additional costs and provide little or no reduction in site risks (EPA 1992). The volume of IDW shall be reduced by applying minimization practices throughout the course of site investigation activities. These minimization strategies include substitution of biodegradable raw materials; using low-volume IDW-generating drilling techniques; where possible, returning excess material to the source location; use of disposable sampling equipment versus generating more decontamination fluids from reusable sampling equipment; use of bucket and drum liners; and separating trash from IDW.

Material substitution consists of selecting materials that degrade readily or have reduced potential for chemical impacts to the site and the environment. An example of this practice is the use of biodegradable detergents (e.g., Alconox® or non-phosphate detergents) for decontamination of non-consumable PPE and sampling equipment. In addition, field equipment decontamination can be conducted using isopropyl alcohol rather than hexane or other solvents (for most analytes of concern), to reduce the potential onsite chemical impacts of the decontamination solvent. Decontamination solvents shall be selected carefully so that the solvents, and their known decomposition products, are not potentially RCRA hazardous waste.

Drilling methods that minimize potential IDW generation should be given priority. Hollow stem auger and air rotary methods should be selected, where feasible, over mud rotary methods. Mud rotary drilling produces waste drilling mud, while hollow stem and air rotary drilling methods produce relatively low volumes of soil waste. Small diameter borings and cores shall be used when soil is the only matrix to be sampled at the boring location; the installation of monitoring wells requires the use of larger diameter borings.

Soil, sludge, or sediment removed from borings, containment areas, and shallow test trenches shall be returned to the source immediately after sampling and/or geological logging of the soils (EPA 1991, 1992). Immediate replacement of solid waste in the source location during investigation activities avoids RCRA land disposal restrictions (LDRs), which permit movement of IDW within the same area of contamination (AOC) without considering land disposal to have occurred, even if the IDW is later determined to contain RCRA hazardous material (EPA 1991). For projects conducted in the Hawaiian Islands, it is recommended that soil IDW from borings and trenches less than 10 feet deep and not penetrating into a saturated layer be placed on polyethylene sheeting (e.g., Visqueen®) during excavation. Following excavation, the soil IDW shall be replaced into the boring or trench and compacted. Soil IDW from borings or trenches deeper than 10 feet or that penetrate into a saturated layer shall be contained in drums.

The quantity of decontamination rinse water generated can be reduced by using dedicated and disposable sampling equipment such as plastic bailers, trowels, and drum thiefs, that do not require decontaminating. In general, decontamination fluids, and well development and purge water, should not be minimized because the integrity of the associated analytical data may be affected.

The storage of visibly soiled PPE and disposable sampling equipment IDW shall be minimized by implementing decontamination procedures. If, based upon the best professional judgment of the Field Manager, the PPE and disposable sampling equipment can be rendered non-hazardous after decontamination, then the PPE and disposable sampling equipment shall be double-bagged and disposed of offsite as municipal waste (EPA 1991, 1992).

Bucket liners can be used in the decontamination program to reduce the volume of solid IDW generated and reduce costs on larger projects. The plastic bucket liners can be crushed into a smaller volume than the buckets, and only a small number of plastic decontamination buckets are required for the entire project. The larger, heavy-duty, 55-gallon drum liners can be used for heavily contaminated IDW to provide secondary containment, and reduce the costs of disposal and drum recycling. Drum liners may extend the containment life of the drums in severe climates and will reduce the costs of cleaning out the drums prior to recycling.

All waste materials generated in the support zone are considered non-IDW trash. To minimize the total volume of IDW, all trash shall be separated from IDW, sealed in garbage bags, and properly disposed of offsite as municipal waste.

Excess cement, sand, and bentonite grout prepared for monitoring well construction shall be kept to a minimum. Well construction shall be observed by Field Managers to ensure that a sufficient, but not excessive, volume of grout is prepared. Some excess grout may be produced. Unused grout (that should not come in contact with potentially contaminated soil or ground water) shall be considered non-hazardous trash and shall be disposed of offsite by the drilling subcontractor. Surplus materials from monitoring well installation, such as scrap PVC sections, used bentonite buckets, and cement/sand bags that do not come in contact with potentially contaminated soil, shall be considered non-IDW trash and shall be disposed of offsite by the drilling subcontractor.

IDW generated from the use of field analytical test kits consists of those parts of the kit that have come into contact with potentially contaminated site media, and used or excess extracting solvents and other reagents. Potentially contaminated solid test kit IDW shall be contained in plastic bags and stored with PPE or disposable sampling equipment IDW from the same source area as soil material used for the analyses. The small volumes of waste solvents, reagents, and water samples used in field test kits should be segregated, and disposed of accordingly (based upon the characteristics of the solvents as described in this SOP). Most other test kit materials should be considered non-IDW trash, and be disposed of as municipal waste.

5.2 Segregation of IDW by Matrix and Location

To facilitate subsequent IDW screening, sampling, classification and/or disposal, IDW shall generally be segregated by matrix and source location at the time it is generated. Each drum of solid IDW shall be completely filled, when possible. For liquid IDW, drums should be left with headspace of approximately 5% by volume to allow for expansion of the liquid and potential volatile contaminants. IDW from only one matrix shall be stored in a single drum (e.g., soil, water or PPE shall not be mixed in one drum). In general, IDW from separate sources should not be combined in a single drum.

It is possible that monitoring well development and purge water will contain suspended solids which will settle to the bottom of the storage drum as sediment. Significant observations on the turbidity or sediment load of the development or purge water shall be included in the logbook and reported in attachments to the quarterly drum inventory report (see SOP III-D, *Logbooks* and Section 5.5). To avoid having mixed matrices in a single drum (i.e., sediment and water), it may be necessary to decant the liquids into a separate drum, after the sediments have settled out. This segregation may be accomplished during subsequent IDW sampling activities or during consolidation in a holding tank prior to disposal in the sanitary sewer. Disposal of liquid IDW into the sanitary sewer shall only occur if approved by the Navy Public Works Center. As always, appropriate precautions shall be taken to ensure worker protection during these activities.

Potentially contaminated well construction materials shall be placed in a separate drum. No soil, sediment, sludge, or liquid IDW shall be placed in drums with potentially contaminated waste well construction materials, and potentially contaminated well construction materials from separate monitoring wells shall not be commingled.

Potentially hazardous PPE and disposable sampling equipment shall be stored in drums separate from other IDW. PPE from generally clean field activities, such as water sampling, shall be segregated from visibly soiled PPE, double-bagged and disposed of offsite as municipal waste. Disposable sampling equipment from activities such as soil, sediment, and sludge sampling includes plastic sheeting used as liner material in containment areas around drilling rigs and waste storage areas; disposable sampling equipment; and soiled decontamination equipment. If, according to the Field Manager's best professional judgment, the visibly soiled PPE can be decontaminated and rendered nonhazardous, then the decontaminated PPE shall be double-bagged and disposed of offsite as municipal waste (EPA 1991, 1992). PPE and disposable sampling equipment generated on separate days in the field may be combined in a single drum, provided clean and visibly soiled IDW are segregated as discussed above.

Decontamination fluids shall be stored in drums separate from other IDW. If practical, decontamination fluids generated from different sources should not be stored in the same drum. If decontamination fluids generated over several days or from different sources are stored in a single drum, information about the dates and IDW sources represented in the drum shall be recorded. This information shall be noted in the field notebook, on the drum label (see Section 5.3), and in the drum inventory (see Section 5.5).

Part of IDW segregation by the Field Manager and designated personnel should include separating the liquid and sediment portions of the equipment decontamination fluid present in the containment unit used by the drilling or excavation field crew. The contents of this unit normally consist of turbid decontamination fluid above a layer of predominantly coarse-grained sediment. When the contents of the containment unit are to be removed for storage in IDW drums, the field crew shall be instructed by the Field Manager to place as much of the liquid into drums as possible and transfer the remaining solids into separate drums. Observations of the turbidity and sediment load of the liquid IDW should be noted in the field notebook, on the drum label (see Section 5.3), and in attachments to the drum inventory (see Section 5.5). It is likely that decontamination fluids will contain minor amounts of suspended solids that will settle out of suspension to become sediment at the bottom of IDW storage drums. As noted above, it may be necessary to segregate the drummed water from sediment during subsequent IDW sampling or disposal activities.

5.3 Drum Handling and Labeling

Drum handling consists of those actions necessary to prepare an IDW drum for labeling. Drum labeling consists of those actions required to legibly and permanently identify the contents of an IDW drum.

5.3.1 Drum Handling

The drums used for containing IDW shall be approved by the United States Department of Transportation (DOT HM-181 1990). The drums shall be made of steel or plastic, have a 55-gallon capacity, be completely painted or opaque, and have removable lids (i.e., type 17-H or United Nations Code 1A2 or 1H2). New steel drums are preferred over recycled drums. For short-term storage of liquid IDW prior to discharge, double-walled bulk steel or plastic storage tanks may be used. For this scenario, consideration must be given to the scheduling and cost-effectiveness of this type of bulk storage, treatment, and discharge system versus longer-term drum storage.

The Guam Environmental Protection Agency (GEPA) may require double-walled drums or other secondary containment for the storage of liquid IDW. For long-term IDW storage at other project locations, the DOT-approved drums with removable lids are recommended. The integrity of the foam or rubber sealing ring located on the underside of some drum lids shall be verified prior to sealing drums containing IDW liquids. If the ring is only partially attached to the drum lid, or if a portion of the ring is missing, select another drum lid with a sealing ring that is in sound condition.

To prepare IDW drums for labeling, the outer wall surfaces and drum lids shall be wiped clean of all material that may prevent legible and permanent labeling. If potentially contaminated material adheres to the outer surface of a drum, that material shall be wiped from the drum, and the paper towel or rag used to remove the material shall be segregated with visibly soiled PPE and disposable sampling equipment. All IDW drums shall be labeled and placed on pallets prior to storage (see Section 5.4).

5.3.2 Drum Labeling

Proper labeling of IDW drums is essential to the success and cost-effectiveness of subsequent waste screening and disposal activities. Labels shall be permanent and descriptive to facilitate correlation of field analytical data with the contents of individual IDW drums. All IDW drums must be labeled using the three distinct labeling methods described below to ensure durability of the information. These three methods are completing and affixing preprinted U.S. NAVY PACDIV IRP labels; marking information on drum surfaces with paint; and affixing aluminum tags to the drum. Use of the preprinted labels, painted labeling, and aluminum tags is mandatory. These methods are described below.

5.3.2.1 Preprinted Labels

Two preprinted U.S. NAVY PACDIV IRP drum labels shall be completed as described below. Both labels shall be sealed in separate heavy-duty, clear plastic bags to prevent moisture damage. One label shall be on the outside of the drum with the label data facing outward. The bag shall be affixed to the drum at the midpoint of the drum height using a sufficient quantity of adhesive tape (e.g., duct tape, packing/strapping tape) to enable the bag to remain on the drum as long as possible during storage. A second copy of the preprinted label shall be prepared, sealed in a plastic bag, affixed to the underside of the drum lid, and sealed inside the drum. If appropriate, a third label may be prepared and placed in the plastic bag, behind the outside label and facing the drum. The use of two or more preprinted labels for IDW drum identification purposes should be considered as a short-term backup to the information on the aluminum tags discussed below.

Two different types of preprinted labels are available for IDW drums generated in Hawaii and Guam under the U.S. NAVY PACDIV IRP. Attachment 1 to this procedure shows the label that shall be used for all IDW drums generated during U.S. NAVY PACDIV IRP projects in the Hawaiian Islands. Attachment 2 shows the label that shall be used for all IDW drums generated during U.S. NAVY PACDIV IRP projects in Guam. The required information is the same for both labels except for the different preprinted Navy "Information Contacts" for each island group. The requested information shall be printed legibly on the drum labels in black, indelible ink. Instructions for entering the required drum-specific information for each label field are presented below:

CTO/DO #: Enter the four-digit number of the CTO/DO for the project during which the IDW was generated. Include any initial zeroes in the CTO/DO number (e.g., CTO/DO 0047);

Activity-Site: Enter the name of the Navy activity responsible for the project site (e.g., NSC, PWC) and the name of the site where the project is taking place (e.g., Orote, Landfill, Building 18);

Boring/Well/Trench #: Enter the identification number of the source of the contents of the drum. Cross out the names of the sources provided in the field title that do not apply. For example, if the source is Soil Boring #1, cross out "Well/Trench" and enter "SB-1" in the field;

(_ _ _ _ - _ _ - D _ _ _): Enter the drum identification number according to the convention described below.

(x x x x - A A - D z z z);

where xxxx represents the four-digit CTO/DO number;

AA represents the unique site identifier assigned by the CTO/DO Manager for multiple site CTO/DOs (e.g., for CTO/DO 0047, OW denotes Old Westpac, OR denotes Orote);

D represents a drum identification number; and

zzz the sequential drum number for the site, beginning with 001.

Date Collected: Enter the date the IDW was generated and placed in the drum. If IDW was generated over a number of days, enter the start and end dates for the period.

Contents: Enter an "√" in the box corresponding to the type of IDW placed in the drum. For "Soil" and "Water," use the line provided to record observations on the condition of the drum contents (e.g., diesel odor, high turbidity, specific liquid IDW type). Check "Solid Waste" for PPE and indicate that PPE is present in the drum. Check "Other" for disposable sampling equipment and potentially contaminated monitoring well construction materials, and indicate the type of waste on the line provided.

Project Type: Enter an "√" in the box corresponding to the type of investigation. Choices are Remedial Investigation (RI), RCRA Facility Inspection (RFI), Underground Storage Tank (UST), and Other. If "Other" is specified, indicate the type of project in the "Comments" area, as described below.

Comments: Enter any additional information regarding the drum contents that will assist individuals who will characterize and dispose of the contents of the drum. "Other" project types include Site Inspection (SI), Feasibility Study (FS), Removal/Remedial Action, and Emergency Response activity. In addition, use this space on the label to complete any descriptions that were too large to fit in preceding label fields such as the turbidity of decontamination water, or the site activities from which the PPE was generated.

It is essential that all relevant information recorded on individual drum labels be repeated in the field notebook for later development of the drum inventory data base (see Section 5.5 and SOP III-D, *Logbooks*).

5.3.2.2 Painted Labels

The second method for labeling drums is to paint label information directly on the outer surface of the drum. At a minimum, the information placed on the drum shall include the CTO/DO number, the drum number (following the numbering convention given above), the source identification type and number, the type of IDW, the generation date(s), and the telephone number provided at the bottom of the preprinted label appropriate for the project location. The drum surface shall be dry and free of material that could prevent legible labeling. Label information shall be confined to the upper two-thirds of the total drum height. The top surface of the drum lid may be used as an additional labeling area, but this area should only be used in addition to the upper two-thirds of the sides of the drum. The printing on the drum shall be large enough to be easily legible. Yellow, white, or red paint markers (oil-based enamel paint) that are non-photodegradable are recommended to provide maximum durability and contrast with the drum surface.

5.3.2.3 Aluminum Tags

The third method for labeling drums is to affix an aluminum tag to the drum with neatly printed information that shall consist of the CTO/DO number, the drum identification number, the type of contents, the generation date(s), the source identification number, and the telephone number provided at the bottom of the appropriate preprinted label. Attachment 3 to this procedure presents an example of the aluminum tag, which shall measure approximately 1 inch by 3 inches, or larger. When a ball point pen is used to fill out the aluminum tag, the information is permanently recorded as indentations on the tag. A fine ball point pen shall be used, and block-printed lettering is required for legibility. Indentations on the tag shall be sufficiently deep to be legible after the label has been exposed to weathering for an extended period.

Aluminum tags shall be completed after the drum has been sealed. The tags shall be affixed to the drum using a wire which passes through predrilled holes in the label and shall be wrapped around the bolt used to seal the drum lid. The wire is the most likely part of the aluminum tag to decay during exposure. Use of plastic insulated, copper-core electrical wire of appropriate diameter is recommended if long-term exposure to severe weathering is anticipated.

5.4 Drum Storage

Drum storage procedures shall be implemented to minimize potential human contact with the stored IDW and prevent extreme weathering of the stored drums. All IDW drums shall be placed upright on pallets before the drums are stored. RCRA storage requirements include the following: containers shall be in good condition and closed during storage; wastes shall be compatible with containers; storage areas shall have a containment system; and spills or leaks shall be removed as necessary. However, until the IDW is conclusively determined to be an RCRA hazardous waste, the CTO/DO Manager shall manage the IDW in a protective manner, and not necessarily in accordance with these listed RCRA storage requirements (EPA 1992). In general, drums of IDW shall be stored within the area of contamination (AOC) so that RCRA land disposal restrictions (LDRs) will not apply in future, if onsite disposal is an option. If the IDW is determined to be RCRA hazardous waste, then RCRA storage, transportation, and disposal requirements may apply including a limited 90-day storage permit exemption period prior to required disposal. The AOC concept does not affect the approach for managing IDW that did not come from the AOC, such as PPE, decontamination equipment and fluids, and ground water. If RCRA hazardous, these wastes must be drummed and disposed of offsite (EPA 1991).

Drums shall be stored onsite within the AOC prior to disposal, except as directed by RCRA requirements for removal when professional judgment suggests the IDW may pose an immediate or permanent public endangerment (EPA 1991). All IDW drums generated during field activities at a single AOC shall be placed together in a secure, fenced area onsite to prevent access to the drums by unauthorized personnel. When a secure area is not available, drums shall be placed in an area of the site with the least volume of human traffic; at a minimum, plastic sheeting (or individual drum covers) and yellow caution tape shall be placed around the stored drums. Drums from projects involving multiple AOCs shall remain at the respective source areas where the IDW was generated. IDW should not be transferred offsite for storage elsewhere, except under rare circumstances, such as the lack of a secure storage area onsite.

Proper drum storage practices shall be implemented to minimize damage to the drums from weathering and possible exposure to humans of the environment. When possible, drums shall be stored in dry, shaded areas and covered with impervious plastic sheeting or tarpaulin material. Every effort shall be made to protect the preprinted drum labels from direct exposure to sunlight, which causes ink on the labels to fade. In addition, drums shall be stored in areas that are not prone to flooding. The impervious drum covers shall be appropriately secured to prevent dislodging by the wind. It may be possible to obtain impervious plastic covers designed to fit over individual drums; however, the labeling information shall be repeated on the outside of these opaque covers.

Drums in storage shall be placed with sufficient space between rows of drum pallets and shall not be stacked, such that authorized personnel may access all drums for inspection. Proper placement will also render subsequent IDW screening, sampling, and disposal more efficient. It is recommended that IDW drums be segregated in separate rows/areas by matrix (i.e., soil, liquid or PPE/other).

If repeated visits are made to the project site, the IDW drums shall be inspected to clear encroaching vegetation, check the condition and integrity of each drum, check and replace aluminum tags as necessary, and replace or restore the tarpaulin covers.

5.5 DRUM INVENTORY

Accurate preparation of an IDW drum inventory is essential to all subsequent activities associated with IDW drum tracking and disposal. An inventory shall be prepared for each project in which IDW is generated, stored, and disposed of.

The drum inventory information in shall include 11 elements that identify drum contents and indicate their fate.

5.5.1 Navy Activity (Generator)/Site Name

Inventory data shall include the Navy activity and the site name where the IDW was generated (e.g., NSC Pearl/Red Hill, NSC Pearl/PWC Gas Station, NAVMAG Headquarters/USTs, etc.).

5.5.2 CTO/DO Number

Inventory data shall include the four-digit CTO/DO number associated with each drum (e.g., 0089).

5.5.3 Drum Number

The drum number assigned to each drum shall be included in the inventory data base. Drum numbers shall adhere to the numbering convention presented in Section 5.3.2 (e.g., 0091-LF-D006).

5.5.4 Storage Location Prior to Disposal

The storage location of each drum prior to disposal shall be included in the inventory (e.g., Building 394 Battery Disassembly Area, or Adjacent to West end of Building 54).

5.5.5 Origin of Contents

The source identification of the contents of each IDW drum shall be specified in the inventory (e.g., soil boring number, monitoring well number, sediment sampling location, or the multiple sources for PPE- or rinse water-generating activities).

5.5.6 IDW Type

Inventory data shall include the type of IDW in each drum (e.g., soil, PPE, disposable sampling equipment, sludge, sediment, development water, steam cleaning water, decontamination rinse water).

5.5.7 Waste Volume

The amount of waste in each drum shall be specified in the inventory as a percentage of the total drum volume or an estimated percentage-filled level (e.g., 95% maximum for liquid IDW).

5.5.8 Recommended Analytical Methods and Test Results Compared with Applicable Regulatory Standards

The EPA analytical methods recommended to adequately characterize IDW contained in each drum will be summarized in a tabular format (e.g., TCLP Metals, TCLP Benzene, 8080 Pesticides, 8015 Mod. BTEX, Total Cadmium, etc.) and attached to the quarterly IDW drum inventory report (see Attachment 4).

5.5.9 Recommended or Actual Disposition of IDW Drum Contents

The recommended means of IDW disposal for each drum shall be summarized in a tabular format (e.g., Offsite, Encapsulated Onsite, Treatment/Sewer, Offsite Incinerator) and attached to the quarterly IDW drum inventory report (see Attachment 4). Additional narrative discussion of the rationale for the recommended disposal option shall be attached to the quarterly IDW drum inventory report as data become available.

5.5.10 Generation Date

Inventory data shall include the date IDW was placed in each drum. If a drum contains IDW generated over more than one day, the start date for the period shall be specified in dd-Mon-yy format. This date is not to be confused with an RCRA hazardous waste accumulation date (40 CFR 262).

5.5.11 Expected Disposal Date

The date each drum is expected to be disposed of shall be specified as part of the inventory in Mon-yy format. This date is for informational purposes only for the Navy, and shall not be considered contractually binding.

5.5.12 Actual Disposal Date

The actual drum disposal date occurs at the time of onsite disposal, or acceptance by the offsite treatment or disposal facility. It shall only be entered in the drum inventory data base when such a date is available in dd-Mon-yy format.

In order to provide information for all 11 of the inventory elements for the quarterly inventory report described above and summarized in Attachment 4, the main source of information will be provided by CTO/DO Managers.

The recommended analytical test methods along with actual test results compared with applicable regulatory standards will be provided by CTO/DO Managers to the PMO when such data are available. Recommended disposal options or actual disposition of the IDW drum contents will also be provided by CTO/DO Managers as data becomes available. The U.S. NAVY PACDIV IRP PMO will forward all IDW data to the Navy as attachments to the quarterly IDW drum inventory report. This information constitutes the results of preparing and implementing an IDW screening, sampling, classification, and disposal program for each site.

6.0 RECORDS

The CTO/DO Manager is responsible for completing and updating the site-specific IDW drum inventory spreadsheet and submitting it as needed. The CTO/DO Manager is also responsible for submitting backup documentation to the PMO about the analytical methods recommended to adequately characterize the IDW in each drum (see Section 5.5.8). In addition, actual site or drum sampling results shall be forwarded to the PMO, along with a comparison to the applicable regulatory standards, for inclusion as attachments to the quarterly IDW drum inventory. As necessary, the backup documentation to the quarterly IDW drum inventory report shall also include the recommended means for IDW disposal for each drum (see Section 5.5.9). After disposal, the actual means and/or location of disposal shall be indicated in tabular format with supporting narrative.

Field Managers and designates are responsible for documenting all IDW-related field activities in the field notebook, including most elements of the IDW drum inventory spreadsheet. The correct methods for developing and maintaining a field notebook are presented in SOP III-D, *Logbooks*.

Upon receipt of analytical data from the investigation, an IDW Disposal Plan shall be prepared that will include the following:

- Criteria for selecting disposal options
- Possible disposal options
- A comparison between analytical data for each drum of IDW and the comparative criteria
- The disposal option selected for each drum of IDW

Guidance related to preparing an IDW Disposal Plan is presented in the generic IDW Disposal Plans for Hawaii (*Disposal Plan for Management of Investigation-Derived Waste, Hawaii* (Ogden 1995)) and Guam (*Generic IDW Screening, Sampling, Analysis, and Disposal Plan for Various Guam Naval Installations* (Ogden 1994)). The IDW Disposal Plan must be approved by the Navy RPM and, in some cases, pertinent regulatory agencies. It must also be amended following each phase of field work. IDW disposal plans shall be prepared by the CTO/DO Manager and shall be in place prior to initiating field work.

7.0 HEALTH AND SAFETY

A site-specific health and safety plan shall be prepared by the CTO/DO Manager or their designee.

8.0 REFERENCES

Department of Transportation (DOT). 1990. Transporting Hazardous Materials (HM-181). December 21.

EPA. 1991. Management of Investigative-Derived Wastes During Site Inspections. U.S. Environmental Protection Agency/540/G-91/009. May.

EPA. 1992. Guide to Management of Investigative-Derived Wastes. Quick Reference Guide. U.S. Environmental Protection Agency: 9345.3-03FS. January.

Ogden, 1995. Disposal Plan for Management of Investigation-Derived Waster, Hawaii.

Ogden, 1994. Generic IDW Screening, Sampling, Analysis, and Disposal Plan.

9.0 ATTACHMENTS

1. Example Hawaii Drum Label
2. Example Guam Drum Label
3. Example Aluminum Tag
4. Example Format – Quarterly IDW Drum Inventory Updates

Attachment I-A-7-1

Drum Label - Hawaiian Islands IDW

Contract #: N62742-90-D-0019

CTO #: ______________

ACTIVITY SITE: ______________________

BORING/WELL/TRENCH #:

(___ - __ - D ___)

DATE COLLECTED

CONTENTS: (please ✓ and explain)

Soil ______________________

Water ______________________

Solid Waste ______________________

Other ______________________

PROJECT TYPE

☐ RI ☐ RFI ☐ UST ☐ Other

COMMENTS: ______________________

FOR INFORMATION CONTACT

Name: PACNAVFACENGCOM

Address: Pearl Harbor, HI 96860-7300

Telephone: 808/471-0701

Attachment I-A-7-2

Drum Label - Guam IDW

Contract #: N62742-90-D-0019

CTO #: ______________

ACTIVITY SITE: ______________________

BORING/WELL/TRENCH #:

(____-___-D____)

DATE COLLECTED

CONTENTS: (please ✓ and explain)

Soil ______________________

Water ______________________

Solid Waste ______________________

Other ______________________

PROJECT TYPE

☐ RI ☐ RFI ☐ UST ☐ Other

COMMENTS: ______________________

____

____

____

____

____

FOR INFORMATION CONTACT:

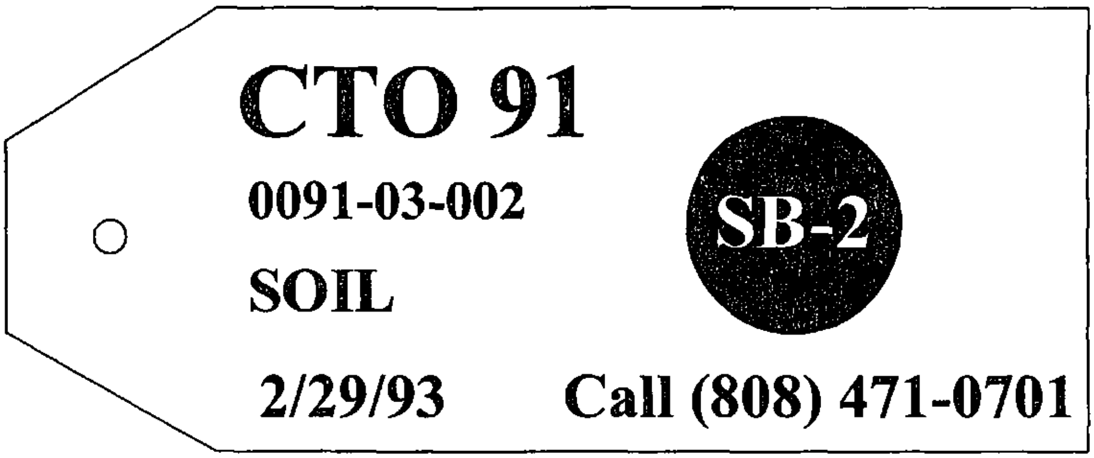
Name: Commanding Officer
U.S. Navy Public Works Center, Guam

Address: PSC 455-Box 195
FPO AP 96540-2937

Telephone: 011-671/339-4100

Attachment I-A-7-3

Drum Label - Aluminum Tag



Attachment I-A-7-4
Quarterly IDW Drum Inventory Updates
Table A4-1

Navy Activity / Site Name (Generator Site)	CTO Number (0bbb)	Drum Number (xxxx-AA-Dzzz)	Drum Storage Location	Origin of Contents (Source ID #)	IDW Type	Waste Volume (Fill level %)	Waste Generation Date (dd-Mon-yy)	Expected Disposal Date (Mon-yy)	Actual Disposal Date (dd-Mon-yy)
NSC Pearl Harbor/ Landfill	0068	0068-LF-D001	NSC, Bldg 7	SB-1	Soil Cuttings	100	16-Dec-92	Dec-93	Na
		0068-LF-D002	NA	MW-1 MW-2 MW-3	Purge Water	75	20-Dec-92	Jul 93	26-Jul-93
		0068-LF-D003	NA	MW-1 MW-2 MW-3	Decon Water	95	20-Dec-92	Jul-93	26-Jul-93
		0068-LF-D004	NSC, Bldg 16	SB-1 SB-2 SB-3 SB-4 MW-1 MW-2 MW-3	PPE	50	16-Dec-92	Oct-93	NA
NAVSTA Guam/ Drum Storage	0047	0047-DS-001	Hazmat Storage Area	SB-1 SB-2	Soil Cuttings	100	18-Feb-93	Sep-93	NA

NA = Not Applicable

SOIL GAS SURVEY

1.0 PURPOSE

This standard operating procedure (SOP) describes recommended soil gas surveying procedures for use by U.S. Navy PACDIV IRP personnel. It is likely that soil gas surveys conducted under the U.S. Navy PACDIV IRP will be conducted by subcontractors. This procedure should be used to provide guidance to U.S. Navy PACDIV IRP field personnel in providing subcontractor oversight.

2.0 SCOPE

This document applies to all U.S. Navy PACDIV IRP personnel involved with managing or participating in soil gas survey activities.

This procedure has been developed to serve as management-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in planning, or executing planned activities must be approved by both the CTO/DO Manager and the Technical Director/QA Program Manager.

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

The CTO/DO Manager is responsible for ensuring that the soil gas survey activities conducted during the U.S. Navy PACDIV IRP are in compliance with this procedure. The CTO/DO Manager is also responsible for ensuring that the soil gas survey is conducted under the supervision of an U.S. Navy PACDIV IRP representative. It is recommended that supervisory personnel have a thorough understanding of the principles of soil gas and the physical characteristics of the vadose zone. This should be determined in consultation with the Technical Director/QA Program Manager. To a certain extent, adequate understanding of the physical characteristics of the vadose zone by field supervisory personnel is site specific and is subject to the judgment of the Technical Director/QA Manager.

The Field Manager is responsible for ensuring that all project field staff are familiar with these procedures.

The Technical Director/QA Program Manager is responsible for conducting evaluations to ensure that these procedures are being utilized appropriately throughout the U.S. Navy PACDIV IRP.

5.0 PROCEDURES

5.1 BACKGROUND INFORMATION

The soil gas survey is a semi-quantitative technique for evaluating the distribution of contaminants in soil gas. The resulting data can be used to qualitatively evaluate the potential for, and extent of, certain types of contamination in soil and ground water.

The use of soil gas surveying to locate potential source areas of subsurface contamination is based on aqueous phase/vapor phase equilibrium in the subsurface. Because of their relatively low solubilities and high vapor pressures, volatile organic compounds (VOCs) have a tendency to partition from the aqueous phase into the soil vapor phase. Certain semivolatile compounds also behave in this manner. Generally speaking, an organic compound with a relatively high Henry's law constant (i.e., the ratio of a compound's vapor pressure to its solubility in water) is likely to partition from soil or ground water into soil gas. The presence of VOCs in shallow soil gas depends on the following factors: (1) the volatilization of VOCs from soil or ground water into the soil gas, (2) the presence of a chemical gradient in soil gas between the contaminant source and the ground surface, and (3) the physical properties of the soil. If VOCs are present in the soil gas in large enough quantities, they can be detected during a soil gas survey.

Fixed gas (i.e., O_2 and N_2) and biogenic gas (i.e., CO_2, CH_4, N_2O, and H_2S) data obtained during a soil gas survey also provides an indication of potential subsurface contamination. A concurrent increase in carbon dioxide and decrease in oxygen often indicates increased chemical or biological breakdown of organic compounds. This phenomenon is usually associated with the degradation of petroleum hydrocarbons;

however, moisture content, natural organic content, and reduction/oxidation (redox) conditions in the soil can also affect fixed gas/biogenic gas ratios.

In most cases, soil gas surveys performed under the U.S. Navy PACDIV IRP will be conducted by subcontractors. U.S. Navy PACDIV IRP personnel will be responsible for recommending the subcontractor and directing their performance onsite.

Each soil gas subcontractor shall possess the necessary sample collection and analytical instruments to perform the survey. The field methods employed by the subcontractor must be in compliance with the methods listed in this procedure. The methods and equipment proposed for use by the subcontractor should be evaluated prior to awarding the job. The individual responsible for recommending selection of the subcontractor shall evaluate the subcontractor to determine if compliance with this procedure is possible. If not, another subcontractor shall be recommended. Alternatively, project-specific data quality objectives shall be evaluated and modified, if appropriate, in a manner such that this procedure can generally be followed.

5.2 Equipment

The following types of equipment are generally required to conduct the soil gas survey:

- Hydraulic driving/hammering system designed to drill through pavement and install or remove sampling probes
- Stainless steel drive points
- Tubing, pumps, and vials, for collecting and preparing soil gas and/or ground-water samples
- Oilless air pump and evacuation chamber for collecting the required volumes of ambient air or soil gas at atmospheric pressure

Analytical instrumentation and chemical supplies may include the following:

- Varian 3400, Hewlett-Packard 5890, and SRI 8610 gas chromatographs (GCs)
- Computer-based data management and GC integration systems

- A combination of Electron Capture Detector (ECD), Flame Ionization Detector (FID), and other detectors as necessary

- UHP grade compressed analytical gases (nitrogen, helium, hydrogen, air)

- Analytical standards for priority pollutants, gaseous hydrocarbons, and fixed/biogenic gases.

- High resolution megabore, packed, and capillary gas chromatographic columns

- Fittings, tools, plumbing, and glass syringes required for normal GC operation

5.3 Selection of Sampling Locations and Analyses

The design of a soil gas survey program depends on the objectives of the program and the types of contaminants anticipated to be present. The following items shall be considered when designing a soil gas program.

- **Number of Samples.** This depends upon the extent of anticipated contamination, the size of the site, and the selected sample spacing.

- **Soil Types Expected to be Encountered (if known).** The lithology of the subsurface must be considered when determining sampling locations, distance between samples, and sampling depth.

- **Depth of Samples.** This will depend on the type of contamination, the depth to ground water, and the objectives of the survey. For instance, evaluation of surface contamination may require only a 3- to 5-foot sampling depth whereas evaluation of deeper soil gas quality may require penetration to 20 feet. Samples may also be collected at several discrete intervals to provide a depth profile. Some flexibility exists in choosing a sampling depth or depths; however, once chosen, consistency across the site should be attempted.

- **Distance Between Samples.** For detecting the limits of plumes, spacing may be 50 to 100 feet or greater. Around a buried tank, spacing may be a few feet. The relative air permeability of the soil type(s) present must also be considered. Soils with low air permeabilities (i.e., clays) may require closer sample spacing.

Spacing should be selected based on the objective(s) of the survey, subsurface conditions, and the nature of the target compounds. These factors shall be addressed in the project-specific Work Plan or Field Sampling Plan.

- **Sampling Point Selection**. Large spills, leaks, or plumes are often sampled on a predetermined sampling grid. Initial surveys may be random or based on real-time field data. Location access may also be an important factor.

- **Objectives of the Survey**. If plume definition is the objective, probe locations should be established to define the down-gradient and lateral extent of the VOCs in soil vapor. If source delineation is the objective, probes should be located in proximity to suspected source areas. In either case, some sampling points should be included within the known plume area and well outside contaminated areas in order to provide a basis for correlation and comparison to background levels of VOCs.

- **Timing of Sampling**. Probe locations can be sampled in stages to meet the objectives of the survey. The first stage of sampling may involve widespread spacing of the probes. Later sampling should focus on areas where VOCs were detected during the first stage of sampling to define the lateral extent of soil gas contaminants, or delineate a source area. Later sampling events should include some overlap with earlier sampling points in order to provide a basis for correlation between data sets.

- **Selection of Analytes**. In general, only contaminants with relatively high Henry's law constants are amenable to detection using soil gas. However, biodegradative breakdown products (CO_2, O_2, and CH_4) of less volatile contaminants can be used to evaluate certain semivolatile and non-volatile compounds. Analysis should focus on known indicator compounds at the site. The more analytes selected, the fewer locations that can be sampled in a day. Analytes should be selected to sample the compounds necessary to meet the objectives of the study and to maximize the number of locations sampled in a given period of time.

5.4 SAMPLING PROCEDURES

5.4.1 Soil Gas Sampling

The soil gas probes are inserted into the ground using a hydraulic ram, pneumatic hammer, or other similar device. When the soil gas probe is at the desired sampling depth, a section of inert, silicon tubing is fitted to the top of the probe and connected to an air withdrawal system. The air withdrawal system is used to apply a vacuum to the system and draw soil gas from the surrounding formation into the probe. The system must be pumped for a sufficient amount of time to allow all of the atmospheric air to be removed and ensure that a representative soil gas sample can be obtained. The amount of air to be removed is proportional to the volume of the sampling probe. A air tight seal must be maintained around the soil gas probe at the ground surface to help prevent possible short circuiting from ambient air diluting soil vapor gas concentrations. Purging of approximately 1.5 volumes permits removal of atmospheric air from the system with a minimum disturbance of the soil gas around the probe tip. Unlike purging of a ground-water monitoring well, purging of a soil gas probe should remove only the ambient air in the system. If a vacuum pump is used, vacuum pressure and time required to purge the prescribed volume of gas from each probe shall be recorded to permit estimation of relative soil permeabilities. When purging is complete, the air withdrawals are ended and the sampling system is allowed to return to atmospheric pressure. A 10 cc soil gas sample is then withdrawn from the system using a glass syringe inserted through the silicon tubing. Other methods of sample withdrawal are acceptable as long as approval is obtained from the CTO/DO Manager and Technical Director/QA Program Manager.

Soil gas samples should not contact potentially sorbing materials such as the pump diaphragm or soft tubing. All components of the sampling system should be checked randomly for contamination by drawing atmospheric air through the system, subjecting it to analysis, and comparing the resulting chromatogram with that of ambient air. Pre-cleaned probes shall be used for each sample location in order to minimize the possibility of cross-contamination among sampling locations. Sampling components, such as the probes, shall be cleaned using steam or pressurized water and detergent at the conclusion of each day and shall be cleaned immediately after use with a portable sprayer as described in SOP I-F, *Equipment Decontamination*. Sections of drill steel can be reused only if GC analyses indicate that no residual contamination is present. Sampling syringes can be decontaminated and reused only if GC analyses indicate no residual contamination. Drive points placed at the ends of the steel sampling tubes are dedicated to one sample location. Note that this SOP assumes that syringe sampling will be conducted. If other sampling techniques are preferred or required, they shall be documented in the project-specific Work Plan or FSP.

As part of the sampling procedure, probe locations shall be recorded on a site map in accordance with the procedures defined in SOP I-I, *Land Surveying*. In addition, field data forms (and chain-of-custody forms, if necessary) shall be used to record observations regarding vapor sampling and probe installation. These field data forms may include, but are not limited to, vacuum pressures corresponding to steady flow, time required for the sampling system to reach atmospheric pressure, sampling depth, volume of soil gas extracted, soil characteristics, and procedures which are necessary to drive sampling probes to the target depth.

Duplicate soil vapor samples can be collected by connecting dedicated sections of polyethylene tubing to a low-volume vacuum pump and filling a Tedlar bag or evacuated cylinder. The pump is purged between sample locations and is checked for residual VOC contamination either by onsite GC analysis or by collecting field "blanks" which are submitted to a laboratory. Gas containers are normally transferred under chain-of-custody procedures to a commercial laboratory where they are analyzed according to the specified methods. The percentage of duplicates submitted for laboratory analysis depends on project-specific objectives and regulatory specifications that shall be defined in the Work Plan or FSP.

5.5 Analytical Procedures

To preserve the integrity of the soil gas sample, each sample shall be analyzed within 15 minutes of collection. The 10 cc soil gas samples or ground-water samples can be subsampled according to the requirements of the analytical method, and duplicates shall be periodically injected into the GC for documentation of reproducibility. The number of required injections depends on the reproducibility of results as well as the success in separating individual compounds during a single GC run. Difficulties associated with peak separation shall be minimized by the use of compound-specific detectors, columns, and temperature programs. As previously indicated, this SOP assumes that an on-site laboratory will be used. If it is necessary to send samples to a fixed laboratory, then this shall be documented in the work plan.

Analytes are identified by their respective elution times through the selected columns and detectors. Retention or elution times shall be compared with external standards injected in a gaseous phase. Analyte concentrations are estimated by comparing the detector response for a known concentration of the external standard with the detector response for the sample. Calibration curves shall be computer-generated by plotting the detector response for external standards against a range of analyte concentrations. Each calibration curve shall include at least three standards to establish the analytical range. All samples shall be quantified within this analytical range. Samples outside the calibration range shall be diluted with ambient air and re-analyzed. The detector response shall be checked periodically during the survey to ensure that the calibration curves are accurate. Blanks shall be run at least once for every 20 samples and after "hot" samples with concentrations outside the calibration range. A QC standard containing concentrations in the middle range of those expected at the site shall be run at least once for every 20 samples, or at a minimum of once per day. Analysis of duplicate samples is also recommended for assessment of method precision. In addition, a minimum of two ambient air samples shall be collected over the course each day and analyzed for background concentrations of target compounds.

Although preliminary results are often available in the field, all chromatograms generated during soil gas surveying or water screening shall be subsequently reviewed by the chemists to ensure that computer identification and quantification of analytes are correct. Target analytes are normally selected during the early stages of a soil gas or ground-water investigation; however, "unidentified" peaks which appear during the course of a field investigation can sometimes be tentatively identified by reproducing the chromatographic conditions at a later time. Second column confirmation of GC analytes can also be performed if stipulated by project objectives.

The following procedures may be employed during soil gas investigations:

- High-volume sampling syringes can be decontaminated by washing with a mild detergent, followed by rinsing with analyte-free water, and drying at a minimum temperature of 90°C for a minimum of 1 hour.

- Subsampling and microliter GC syringes may be solvent rinsed, dried, purged with an inert gas, and checked for contamination by immediate injection into the appropriate gas chromatograph

- External standards are either prepared from analytical-quality neat chemicals (diluted with an appropriate solvent and stored in 25 ml vials) or obtained as mixtures of commercially prepared gases

- Detector response to analytes is documented over a 50- to 100-fold range of concentrations to check the linearity of detector response to analytes

- Septa on the GC column injectors are replaced daily to minimize the possibility of carrier gas leaks (only zero-grade or UHP gases are used for chromatography)

- All analytical data (e.g., chromatographs, calibration curves, integration reports) shall be stored on computer disk and reviewed by a second chemist

6.0 DOCUMENTATION/RECORDS

Each soil gas sampling event shall be documented by the subcontractor in a bound logbook or appropriate field log sheets. The following information shall be recorded for each soil gas sampling event:

- Sample number

- Project name and number

- Sample location and depth

- Date and time

- Name(s) of sampling personnel

- Site location

- Miscellaneous observations

- Analytical equipment utilized (e.g., GC, column, detector, etc.)

Other documentation will be recorded on a daily basis in the bound field notebook, and will include:

- Calibration results and
- Blank measurement results.

The original field records will be placed in the project files immediately upon completion of field work. Subcontractors shall prepare a detailed report summarizing the methodologies used during the survey, the results obtained, and an interpretation of the results. This report will be incorporated into the site characterization report or equivalent document.

7.0 HEALTH AND SAFETY

Soil gas surveyors are considered task specific workers and, therefore, must meet all requirements of said workers for health and safety reasons. In addition, adherence to safe work practices as outlined in the site-specific Health and Safety Plan (HSP) is required.

Analyses should be conducted in a location that will not contaminate analytical equipment nor expose the public or analyst to unacceptable levels of contaminants. "Detector" and "vent" outlets should be vented through a combustion furnace (>1,500°F), an activated charcoal filter, or to an external atmosphere not endangering the general public. If anticipated conditions warrant a real/time immediate response instrument such as an OVA, PID, HNU, Thermo, or Draeger or Sensidyne tubes, it should be used to monitor the atmosphere.

When real/time instrument response exceeds the Permissible Exposure Limit (PEL), or the more conservative threshold limit value (TLV), appropriate previously defined PPE will be donned and alternate arrangements to ensure analytical personnel safety shall be considered. If safe alternatives are not achievable, the soil gas survey will be discontinued immediately.

When there is a danger of leakage from sample or gas standards containing hazardous materials and reagents, they should be stored outside of the workplace occupied by the analyst in a manner consistent with storage of hazardous or compressed gases and in a configuration such that the public will not be endangered by exposure.

In addition to the aforementioned precautions, the following safe work practices will be employed:

Chemical Hazards Associated With Soil Gas Survey

- Avoid skin contact with and/or incidental ingestion of solvents.
- Utilize PPE as deemed necessary while collecting samples and performing analyses.
- Refer to Manufacturer Safety Data Sheets (MSDSs), safety personnel, and/or consult sampling personnel regarding appropriate safety measures.
- Take necessary precautions when handling reagents and samples.

Physical Hazards Associated With Soil Gas Survey:

- To avoid possible back strain associated with sample collection, use the large muscles of the legs, not the back, when retrieving soil gas probes.
- To avoid heat/cold stress as a result of exposure to extreme temperature and PPE, drink electrolyte replacement fluids (1-2 cups/hour is recommended) and, in cases of extreme cold, wear fitted insulating clothing.
- Be aware of restricted mobility due to the wearing of PPE.

8.0 REFERENCES

U.S. EPA Environmental Response Team. 1988. Response Engineering and Analytical Contract Standard Operating Procedures. U.S. EPA, Research Triangle Park, NC.

U.S. EPA. 1991. Soil Vapor Extraction Technology: Reference Handbook. February.

SOP I-I, *Land Surveying*

9.0 ATTACHMENTS

None.

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MONITORING WELL INSTALLATION

1.0 PURPOSE

This standard operating procedure (SOP) establishes the installation of methods to be used by U.S. Navy PACDIV IRP personnel during the installation of ground-water monitoring wells. It describes the components of monitoring well design and installation and sets forth the rationale for use of various well installation techniques in specific situations.

The onsite hydrogeologist/engineer is expected to obtain a description of the lithologic samples obtained during the excavation and construction of a monitoring well. These data are often required to provide guidance regarding the installation of specific components of the monitoring well. Guidance for lithologic sample collection and sample description is contained within SOP I-B-1, *Soil Sampling*.

Throughout this procedure, it should be understood that operations are likely to be conducted in the presence of hazardous materials. Implicit to all discussions herein are health and safety and decontamination procedures.

2.0 SCOPE

This SOP should be followed during the design, construction, and abandonment of monitoring wells at IRP sites.

The SOP shall serve as Navy-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in the planning or execution of activities must be documented in the project Field Sampling Plan (FSP) or approved by the Technical Director/QA Program Manager and documented in the project file.

3.0 DEFINITIONS

3.1 Filter Pack

Sand or gravel that is smooth, uniform, clean, well-rounded, and siliceous. It is placed in the annulus of the well between the borehole wall and the well screen to prevent formation materials from entering the well and to stabilize the adjacent formation.

3.2 Annulus

The down hole space between the borehole wall and the well casing and screen.

3.3 Grout

A fluid mixture of cement and water of a consistency that can be forced through a pipe and emplaced in the annular space between the borehole and casing to form an impermeable seal. Various additives, such as sand, bentonite, and polymers, may be included in the mixture to meet certain requirements.

3.4 Sieve Analysis

Determination of the particle-size distribution of a soil, sediment, or rock by measuring the percentage of the particles that will pass through standard sieves of various sizes.

4.0 RESPONSIBILITIES

CTO/DO Managers are responsible for issuing Quality Assurance Project and Field Sampling Plans that reflect the procedures and specifications presented in this procedure. Well construction specifications and sampling equipment shall comply with the guidelines established in this procedure unless deviations have been approved by the CTO/DO Manager and the Technical Director/QA Program Manager.

The Field Manager is responsible for ensuring that procedures and specifications are implemented in the field. The qualifications for the Field Manager include a degree in geology, hydrogeology, or civil/geotechnical/environmental engineering with at least 2 years of field experience in the installation of monitoring wells.

The Technical Director/QA Program Manager is responsible for ensuring overall compliance with this procedure.

All U.S. Navy PACDIV IRP field personnel are responsible for adhering to these procedures to the maximum degree practicable.

It is the responsibility of the Field Manager to directly supervise the installation of a monitoring well and ensure that the procedures are conducted according to the protocol set forth in this procedure.

Individual municipalities, county agencies, and possibly state regulatory agencies enforce regulations that may include well construction and installation requirements. The CTO/DO Manager shall be familiar with current local and state regulations, and ensure that these regulations are followed. Additionally, it should be recognized that regulations are subject to constant revision. Every effort should be made to stay informed of these changes through contact with the agencies that oversee work in specific project areas, prior to initiation of field activities.

5.0 PROCEDURES

5.1 BACKGROUND INFORMATION

The primary objectives of installing a monitoring well at a site are to observe ground-water levels and flow conditions, to obtain samples for determining ground-water quality, and to evaluate the hydraulic properties of water-bearing strata. To achieve these objectives, it is necessary to satisfy the following criteria:

1. Construct the well with minimum disturbance to the formation.

2. Construct the well with materials that are compatible with the anticipated geochemical environment.

3. Properly complete the well in the desired zone.

4. Adequately seal the well with materials that will not interfere with the collection of representative water samples.

5. Sufficiently develop the well to remove drilling fluids or other additives or conditions associated with drilling, and provide unobstructed flow to the well.

An understanding of site geology and hydrogeology, and a knowledge of contaminant transport in subsurface materials are required to properly design and construct monitoring wells.

A significant difference between monitoring wells and production or "water" wells is that the intake section of monitoring wells is often purposely completed in a zone of poor water quality and/or poor yield. The quality of water entering a monitoring well can vary from drinking water to a hazardous waste or leachate. In contrast, production wells are normally designed to efficiently obtain water from highly productive zones containing good quality water. The screen of a monitoring well often extends only a short length (typically 10 feet or less) to monitor hydraulic conditions within, and obtain water samples from, selected water-bearing intervals. In contrast, water wells are often designed to obtain economic quantities of water from multiple zones of water-bearing strata.

5.2 Monitoring Well Design Considerations

The following information was compiled from a number of technical references. For additional information related to monitoring well installation consult the references listed in Section 8.0 (e.g., Driscoll 1987, USEPA 1992, etc.)

5.2.1 Well Placement

The location of a monitoring well shall be selected according to the purpose of the monitoring program, which will vary among different sites and may include detection of contaminants in ground water, verification of contaminant migration predictions, the monitoring of leachate at a landfill site, remediation of a contaminated site, or simply reassurance to regulators that ground-water quality at a site is being monitored. Each of these purposes will require a specialized array of monitoring locations and completion intervals, and a specific sampling program. The monitoring well network shall, therefore, be designed to satisfy the needs of the particular situation.

Positioning of a monitoring well in a contaminant flow path for a monitoring effort must be determined on the basis of the interpretation of preliminary data. These data shall be sufficient to facilitate identification of potential contaminant sources. Consideration must also be given to site history, topography, climate, surface hydrology, and the location of nearby pumping wells.

The layout of the ground-water monitoring network shall be designed following preliminary evaluation of the approximate direction of ground-water flow. A minimum of three wells is necessary to estimate local hydraulic gradients. Ideally, at least one well will be located hydraulically upgradient, and two or more wells strategically located hydraulically downgradient of each potential contaminant source. Determination of the horizontal and vertical extent of a contaminant plume is often an iterative process requiring the installation and sampling of wells in several phases.

In order to immediately detect releases from a hazardous waste site, monitoring wells should be installed hydraulically downgradient and as close as physically possible to the areas of suspected contamination. Additional monitoring wells should be located based on the interception of potential ground-water flow paths and direction of contaminant migration.

The placement of ground-water monitoring wells shall also consider the three-dimensional nature of ground-water flow. Significant vertical gradients and heterogeneous and/or anisotropic hydraulic conditions may exist at a site. Thus, the direction of ground-water flow may not necessarily coincide with the apparent horizontal gradient observed by the triangulation provided by three monitoring wells. The completion intervals of existing wells shall also be determined prior to the calculation of ground-water gradient directions. If the monitoring well network is located near existing, active well fields, near tidal zones, or near ephemeral surface water (canals, dry river beds), temporal/seasonal ground-water flow conditions should be considered.

5.2.2 Well Depth and Screened Interval

A detailed understanding of the site stratigraphy, including both horizontal and vertical extent of geologic formations, is necessary to identify zones of different permeabilities, and discontinuities such as bedding planes, fractures, or solution channels. It is in the more permeable zones that ground-water flow and/or contaminant transport beneath the site preferentially occur. Equally important is the identification of relatively low permeability zones which may impede migration of contaminants. The occurrence and movement of ground water in the subsurface is closely related to lithology. Thus, geologic conditions will influence the location, design, and methods used to locate and install monitoring wells.

The depth of a monitoring well is determined by the depth of one or more water-bearing zones that are to be monitored. For example, if preliminary soil borings indicate that multiple water-bearing zones are present at a site, and it is believed that zones other than the uppermost zone may be impacted by surface contamination, a well should be completed in each individual water-bearing zone encountered. Where two or more saturated zones occur beneath a site, and the intent of the monitoring program is to monitor water quality in the lower zone, the monitoring well will generally require surface casing to isolate the upper water-bearing zone from the deeper zone, prior to drilling into the deeper zone.

In multiple aquifer systems, highly variable conditions may occur. For example, an overlying unconfined aquifer may be contaminated, whereas the underlying confined aquifer may not contain contaminants. Extreme care should be exercised to ensure that the installation/completion of monitoring wells does not cause cross-contamination of the aquifers. In these cases, it may be preferable to install surface casing through the contaminated aquifer to minimize the possibility of cross-contamination to the lower aquifer system.

Characteristics of lithologic materials encountered at the site, such as the degree of consolidation and grain size, also influence the type of well completion. In unconsolidated alluvial deposits, screened well intakes are typically used. An emplaced filter pack, consisting of well-sorted, clean, inert silica sand with a grain size and well screen slot size appropriate for the formation, is typically used to filter out fine-grained materials present within formations encountered in the borehole. Where permeable consolidated formations are present, casing may be extended through overlying unconsolidated deposits and the well completed with a section of open borehole in the consolidated water-bearing zone. Even in these cases, however, fine-grained materials may enter the well through fractures, and if severe enough, an artificial filter pack and screened intake may be required. Also, many regulatory agencies require a screened interval installed with filter pack for all well completions.

Placement of the screened interval depends primarily on two factors: the interval to be monitored and type of contaminants. The desired interval to be monitored shall dictate the interval to be screened. From the site characterization, it should be determined which stratigraphic horizons represent potential pathways for contaminant migration. Short screened sections provide more specific data on the vertical distribution of contaminants and hydraulic head, while long screen intervals can result in a cumulative dilution of contamination in one zone with uncontaminated ground water in another zone as well as less specific information on hydraulic head. In addition, a long screened interval could potentially create vertical conduits that may result in cross-contamination.

Prior to well installation, consideration must be given to the type of contaminants involved. Contaminants that have a density less than water migrate differently than contaminants with a density equal to or greater than water. For example, given a situation where the contaminant in an unconfined aquifer has a density lower than water, such as diesel or gasoline, it is important to ensure that the screened interval of the well extends above the maximum seasonal elevation of the water table. Doing so facilitates an accurate determination of apparent thickness of free product in a monitoring well. In general, when monitoring the upper portions of an unconfined aquifer, the screen shall extend 3 to 5 feet above the highest anticipated level of the water table.

Conversely, if the contaminant of concern has a density higher than water, such as trichloroethene (TCE), the screened interval of one or more monitoring wells should be installed just above the lower confining bed of a potentially impacted aquifer. TCE may be transported at high concentration as a dense, nonaqueous phase liquid (DNAPL) near the source area and migrate along the top of a confining bed at the base of an impacted aquifer.

Special attention must be given to interpretation of site stratigraphy when assessing DNAPL, particularly with respect to dipping beds, as it is possible for DNAPLs to effectively move hydraulically upgradient if low permeability perching horizons dip in a direction opposite to the hydraulic gradient. This type of situation is important to consider when selecting monitoring well locations.

If time and budget allow, conventional borehole geophysical methods and continuous cores of soil samples should be correlated to yield a more complete stratigraphic characterization. A continuous profile of borehole conditions is compared to field observations and is used to select screened intervals.

5.2.3 Well Permitting

All wells shall be permitted in accordance with the regulations of the jurisdiction where well installation is occurring if this is Navy policy for the region of activity. Local authorities should be contacted prior to establishing well construction requirements for the project.

The permit procedure may require permit fees, site inspections, and an application signed by a registered professional geologist or engineer. Field schedules and budgets may be impacted by the permit requirements. The driller may also be required by law to be licensed and bonded. Documentation that all legal requirements have been met must be provided to the appropriate agencies prior to the installation of a monitoring well.

5.3 SELECTION OF DRILLING METHOD

Monitoring well installation at hazardous waste sites may involve drilling through or near hazardous materials, in areas where the extent of contamination is unknown, or through more than one geologic material or aquifer. Use of any drilling method at a hazardous waste site involves an element of risk related to the potential spread of contamination or creation of a pathway through which contaminants can migrate. Selection of a method most appropriate for site-specific conditions is essential to minimize these risks. Table I-C-1-1 provides an interpretation of how geologic conditions may influence the selection of a particular drilling method.

Most drill rigs use gasoline or diesel fuel, as well as hydraulic fluid during operation. Because these fluids are all potential contaminants, it is important to protect the drill hole and immediate area from these substances. Whenever leaking fluid from the drill rig is detected, drilling operations shall cease as soon as practical following stabilization of the drill stem, and the rig moved to a safe area to be repaired.

The following sections discuss commonly used drilling methods and their applicability to installation of monitoring wells. Regardless of the drilling method selected, all drilling

Table 1-C-1-1

RELATIVE PERFORMANCE OF DIFFERENT DRILLING METHODS IN VARIOUS TYPES OF GEOLOGIC FORMATIONS COMMONLY UTILIZED DRILLING METHODS

Type of Formation	Auger-Hollow Stem	Rotary Bucket Auger*	Rotary with Fluids (foam, mud)*	Air Rotary	Air Rotary with Casing Hammer	Down the Hole Air Hammer	Dual Tube/ Casing Hammer	Coring	Reverse Rotary with Fluids*	Reverse Rotary with Dual Tube
Loose sand and gravel	G	P	P-G	NR	E	NR	E	NR	P-E	E
Loose boulders in alluvium	P	P-G	G	NR	E	NR	P	NR	P	G
Clay, silt	E	G	E	NR	E	NR	E	P-G	E	E
Shale	P	NR	E	P	E	NR	NR	E	E	E
Sandstone	P	NR	G	E	NR	NR	NR	E	G	E
Limestone with chert	NR	NR	G	E	NR	E	NR	E	G	G
Limestone with and without fractures	NR	NR	G-E	E	NR	E	NR	E	P-E	E
Limestone, cavernous	NR	NR	P-G	P-G	NR	E	NR	E	NR	E
Dolomite	NR	NR	E	E	NR	E	NR	E	E	E
Basalts-thin layers in sedimentary rocks	P	NR	G	E	NR	NR	NR	E	G	E
Tuff	P	NR	G	E	NR	E	NR	E	G	G
Basalts-thick layers	NR	NR	P	G	NR	E	NR	E	G	G
Basalts-highly fractured	NR	NR	NR	P	NR	G	NR	E	NR	G
Metamorphic Rocks	NR	NR	NR-P	G	NR	E	NR	E	G	G
Granite	NR	NR	NR-P	E	NR	E	NR	E	G	G

NR = Not Recommended
G = Good
P = Poor
E = Excellent

* Cannot be used for analytical soil sampling

equipment shall be decontaminated using procedures described in SOP I-F, *Equipment Decontamination*. These procedures shall be followed before use and between borehole locations to prevent cross-contamination. In addition to selecting the proper drilling technique, other precautions shall be taken to prevent distribution of any existing contaminants throughout the borehole.

5.3.1 Hollow-stem Continuous-flight Auger

Hollow-stem continuous flight auger (HSA) is the most frequently employed method used in the environmental industry for the drilling and installation of shallow monitoring wells in unconsolidated materials. Drilling with HSA is possible in loose sand and gravel, loose boulders in alluvium, clay, silt, shale, and sandstone. HSA drilling is usually limited to unconsolidated materials and depths of approximately 150 to 200 feet. HSA drill rigs are mobile, relatively inexpensive to operate, generally cause minimal disturbance to the subsurface materials, and have the additional advantage of not introducing drilling fluids (e.g., air, mud, or foam) to the formation.

Another advantage of the HSA method is that undisturbed samples are obtained by driving a split spoon sampler below the lead auger. Soil samples can usually be easily collected in this manner with a minimum of tripping sampling tools into and out of the hole.

Moreover, in the HSA drilling method the well is constructed inside the hollow-stem augers as the augers are gradually removed from the ground. This method decreases the possibility of the borehole collapsing before the well is installed. Hollow-stem augers shall have a nominal outside auger-flight diameter of 10 to 12 inches and a minimum inside diameter of 8 inches. Larger inside diameter auger flights are sometimes available. Well casing diameter is usually limited to 4 inches or less when using the HSA method. The difference between the inner diameter of the auger and the outer diameter of the well casing shall be at least 4 inches (i.e., a minimum 2-inch annular space) to permit effective placement of filter pack, bentonite seal, and grout without bridging.

5.3.2 Rotary Bucket Auger

Rotary bucket auger drilling, or bucket auger drilling (BAD), utilizes a large-diameter bucket auger to excavate earth materials. Excavated material is collected in a cylindrical bucket that has auger-type cutting blades on the bottom of the bucket. The bucket is attached to the lower end of a kelly bar that passes through, and is rotated by, a large ring gear that serves as a rotary table.

The kelly bar is square in cross-section and consists of two or more lengths of square steel tubing, with each successive length of tubing telescoped inside the previous length. This design permits boring to a depth several times the collapsed length of the kelly bar before having to add a length of drill rod between the kelly and the bucket. In drilling with the telescoping kelly, the bucket is typically lifted and dumped without disconnecting, thereby speeding up the process when drilling deep holes. Depths of 75 to 100 feet are achievable with most telescoping kellys. It is possible to construct wells more than 250 feet deep by this method, although depths of 50 to 150 feet are more typical.

The BAD technique is most effective in semi-consolidated or clayey formations that stand open without caving. Drilling through unconsolidated materials within the saturated zone is difficult, but not impossible if the hole is kept full of water or mud (see direct rotary methods with foam or mud). Drilling mud may be necessary, particularly in loose formations consisting of unconsolidated fine- to medium-grained sands and silts. In the right conditions, a bucket auger bit will remove a cylinder of material 12 to 24 inches deep with each run. Therefore, samples obtained by the BAD method are representative of the formation being drilled, unless sloughing or caving of the borehole walls has occurred.

Boreholes drilled with the BAD technique generally range from 18 to 48 inches in diameter. Because of the large diameter of the borehole drilled with this technique, and the common need to add either water or mud to maintain the borehole in unconsolidated, near-surface deposits, it is recommended that this method be used only for the installation of surface casing through the first water-bearing unit at a hazardous waste site.

5.3.3 Direct Rotary with Foam or Mud

Direct rotary drilling (DRD) techniques involve the use of various types of drilling fluids which typically include air, foam, and mud. In each of the DRD methods, drilling fluids are circulated down through the inside of the drilling pipe, into the borehole, and then up through the annulus between the drilling pipe and the borehole wall during drilling to carry drill cuttings up to the surface. The drilling fluids may also be used for stabilizing the borehole wall, which may be especially useful in unconsolidated, caving formations. In this section, the DRD method and its use with either foam or mud are discussed.

A variety of bit types may be used with each of these drilling fluids, depending on the type of formational material encountered; however, the tri-cone or roller bit is typically used. The drilling bit is attached directly to a heavy section of drill pipe called a drill collar, which is attached to help keep the borehole straight. The drill collar is in turn attached to the drill pipe and the kelly.

General types of drilling fluids available for use with the DRD method include water with clay additives, water with polymeric additives, water with clay and polymeric additives, and foams (comprised of air or water, surfactants, and occasionally clays or polymers). The drilling fluid density may be adjusted during drilling to improve or resume circulation within the borehole, or to attempt to stabilize the borehole wall. A major problem with the addition of these fluids is that it is almost impossible to estimate the amount introduced into the formation through the saturated and unsaturated zones. Additionally, it is also very difficult to estimate the magnitude and duration of the impact to ground-water quality by the use of these fluids.

The drilling fluids and associated cuttings shall be not be allowed to flow over the site unrestricted. A downhole circulation system, or fluid diversion system shall be used to keep the fluids and cuttings contained in a reasonable manner, yet still allow the collection of grab samples for lithologic identification.

While in some geologic situations DRD may be the most efficient method of drilling a borehole, potential problems associated with the drilling fluids usually make DRD a last resort drilling technique for environmental purposes, one that should be avoided whenever possible.

<u>Potential Problems of DRD with Foam or Mud</u>

- The chemistry of the drilling fluid could adversely affect the chemistry of ground-water samples, soil samples, or the efficiency of the well (when using mud).
- Bentonite muds reduce the effective porosity of the formation around the well, thereby compromising the estimates of well recovery. Bentonite may also affect ground-water pH. Additives to adjust viscosity and density may

introduce contaminants to the system or force irrecoverable quantities of mud into the formation.

- Some organic polymers and compounds provide an environment for bacterial growth which, in turn, reduces the reliability of sampling results.
- Uncontained drilling foam and/or muds may create unsafe working conditions at the surface around the rig.

Solutions

- DRD should only be utilized as a last resort.
- The hydrogeologist should make certain that the fluids used will not affect the chemistry of the soil samples and ground-water samples. One possibility is to collect samples of the drilling fluid for laboratory analysis.
- The hydrogeologist shall keep track of the amount of water and fluids introduced to the borehole, in order to purge this quantity during well development.
- Provisions to contain drilling muds and foam need to be discussed in the drilling contractor scope of work.

5.3.4 Air Rotary and Air Rotary With Casing Hammer

Air rotary drilling (ARD) and air rotary with casing hammer (ARC) force air down the drill pipe and back up the borehole to remove drill cuttings in the same manner as direct rotary drilling with foam or mud. Without casing hammer, the use of ARD techniques is best suited to hard-rock formations where the borehole will stand open on its own and circulation loss is not a major concern. ARC is most useful in unconsolidated sediments of all types due to the use of a hardened steel casing that is driven behind the bit with a pneumatic casing hammer to keep the hole open. A combination of these two drilling techniques is very useful where unconsolidated overburden overlies consolidated rock. In this case, the casing hammer attachment would be used to set the surface casing at the top of the consolidated formation while continuing with ARD. As a well is being installed or the hole is being abandoned, the casing can be retrieved to be used on another hole, or left in place to serve as surface casing.

Air from the compressor shall be filtered to ensure that oil or hydraulic fluid is not introduced into the soils and/or ground-water system to be monitored. In addition, foam or hydrocarbon-based lubricating joint compounds for the drill rods shall not be used with any rotary drilling method due to the potential for introduction of contaminants into the native materials and/or ground water. Teflon®-based joint lubricating compounds that are typically mixed with vegetable oil are available for this purpose.

Potential Problems of ARD and ARC

- In the case of sampling with a split-spoon sampler to collect soil samples for laboratory analysis, the high pressure air from inside the drill pipe can cause volatilization of contaminants from the soils beneath the bit in unconsolidated sediments. If installing deep wells or boreholes, this problem may not be avoidable.
- Fine-grained saturated materials that may cause surging and heaving problems are common in many coastal areas. Heaving sediments may cause problems during sampling and well installation when drilling with ARD.
- Rocks and other drill cuttings may be ejected from the borehole at high velocities, creating a secondary hazard around the rig.

Solutions

- ARD and ARC should not be used for soil sampling in shallow, unconsolidated situations where a hollow-stem auger rig could used as effectively.
- One method to compensate for heaving and surging aquifer materials is to overdrill the borehole by 5 or 10 feet to provide space for heaving sediments to fill in while well completion is being performed.
- Another method to control heaving sands is to add clean water to a level above the water table to create a downward pressure on the heaving materials. This

additional volume of water added should also be extracted during well development.

- Drill rigs shall be equipped with cyclones or equivalent devices designed to contain formation projectiles.

5.3.5 Dual Tube Casing Hammer With Reverse Air Circulation

Dual tube casing hammer with reverse air circulation (DTCH) is useful in unconsolidated sediments, but is most effective as a method for drilling through thick sequences of materials such as coarse-grained sands and gravels. The DTCH system operates by simultaneously driving a pair of heavy gauge steel pipes into the ground while using high pressure reverse air circulation to blow air down the annulus of the two pipes and bring air and unconsolidated lithologic materials out through the inside of the inner pipe. The method does not employ a typical bit in that the formational materials are neither ground up, sliced up, nor cut into pieces. Instead, the bit consists of a special shoe that is used to funnel materials either into, or away from, the inner pipe, depending on whether the formational material is fine- or coarse-grained, respectively.

Typically, the method can drill through 200 feet of gravel in a day with relative ease. The inside diameter of the inner pipe is about 6 inches, with the borehole diameter being about 10 inches. Cobbles with long axes of up to 6 inches come up through the inner pipe easily. Larger conglomerate clasts must be either pushed aside or broken up using the pneumatic hammer to drive the heavy shoe down onto the clast.

Conversely, the method works poorly in clay-rich materials. The shoe acts as a large cookie cutter, forcing a plug of clay into the inner pipe which then must be forced to the surface and physically removed from the diverter/shoe assembly with the hammer. This method should probably be avoided where large thicknesses of clay are expected to be encountered in the subsurface.

Typically, the DTCH method can drill to approximately 200 feet with standard equipment. Deeper holes will likely require a larger air volume for circulation via an additional compressor hooked up to the drilling rig. Additionally, a variation of the DTCH called "triple tube" can be used to install larger diameter wells to depths of about 200 feet depending upon the site. This method can also be used to supply a temporary surface casing to avoid cross-contamination of deeper zones while extending the boring to greater depths.

Potential Problems of DTCH

- In the case of soil sampling with a split-spoon sampler to collect samples for laboratory analysis, the high pressure air from inside the drill pipe can cause volatilization of contaminants from the soils beneath the bit in unconsolidated sediments. If installing deep wells or boreholes, this problem may not be avoidable.

Solutions

- DTCH should not be used for sampling soil in shallow, unconsolidated situations where a hollow-stem auger rig could used as effectively.

5.4 MONITORING WELL DESIGN PROCEDURES

The designs of typical ground-water monitoring wells are depicted in Figures I-C-1-1 and I-C-1-2. A discussion of the design of the individual components of a typical monitoring well is given in the following subsections.

5.4.1 Pre-installation Design Drawing

A pre-installation design drawing shall be developed after the borehole for the well has been completed and well-specific lithologic and hydrologic information are available. The pre-design drawing shall identify the anticipated depth of the well, the locations of the top and bottom of the screened interval, the anticipated top of the filter pack, the anticipated top of the bentonite seal, and the locations of centralizers (if applicable). In addition, the volumes of sand, bentonite, and grout anticipated to be placed in the annular space of the well shall be calculated. The drawing shall be maintained as documentation of the well design.

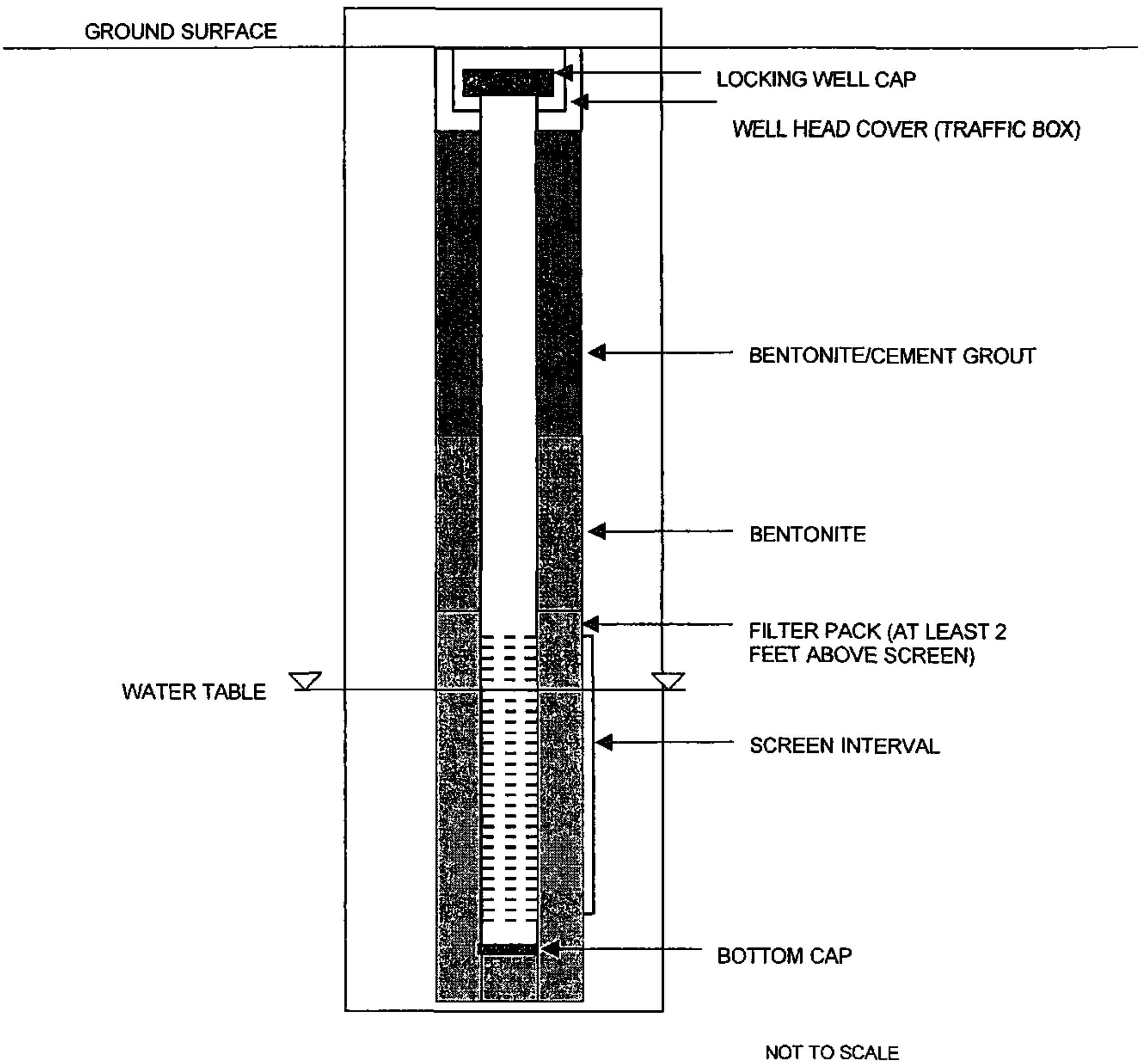


Figure I-C-1-1
General Cross Section of Monitoring Well
Unconfined Water Bearing Zone

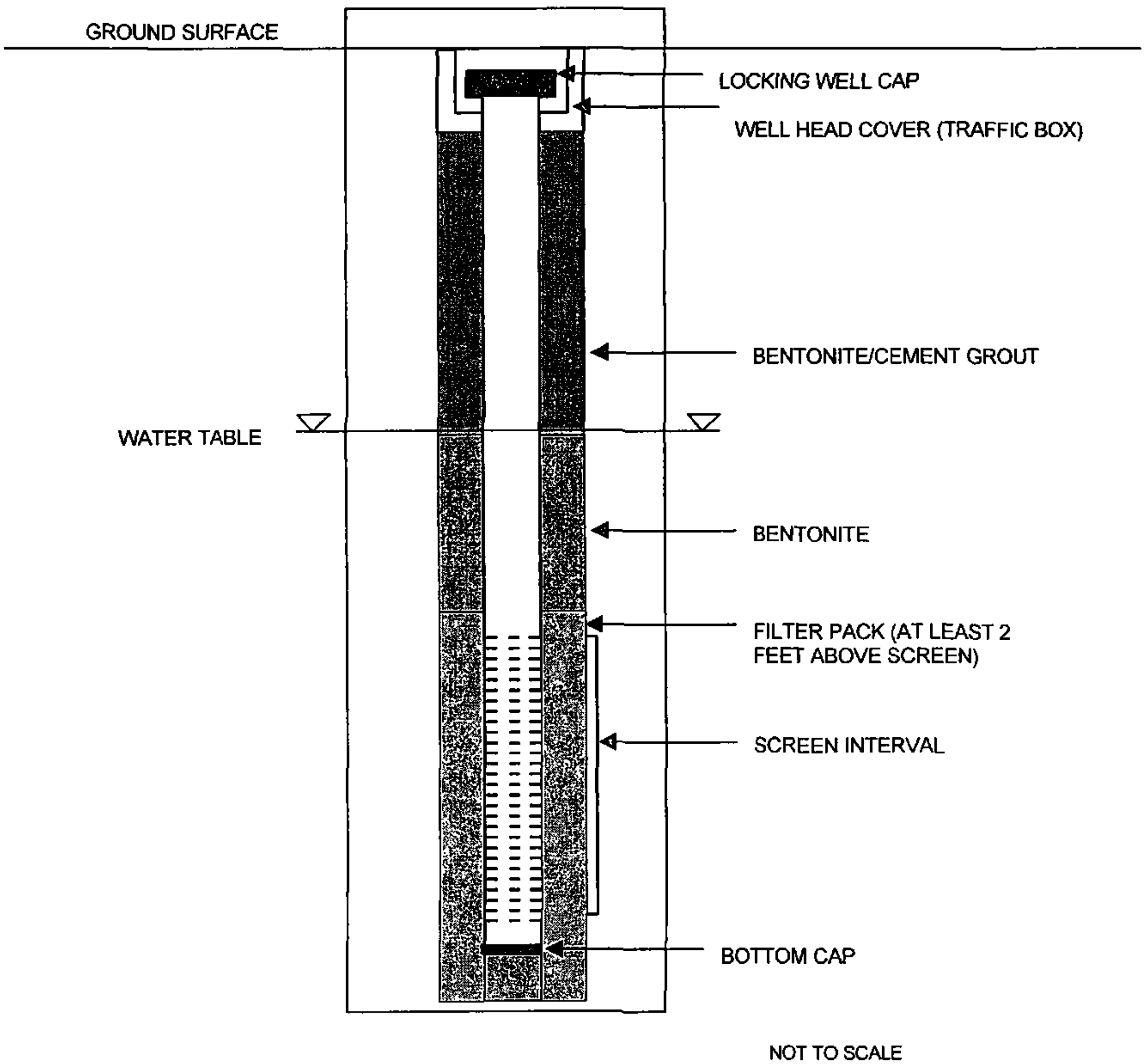


Figure I-C-1-2
General Cross Section of Monitoring Well
Confined Water Bearing Zone

5.4.2 Casing Selection

The cased section of a monitoring well is a pipe without slots or openings which is installed to prevent the well from directly accessing formations above the screened interval. The casing isolates the screened interval.

The selection of appropriate casing materials must take into account several site-specific factors such as (1) geology, (2) geochemistry, (3) well depth, (4) size and type of equipment to be used in the well, and (5) the types and concentrations of suspected contaminants. In addition, several other logistical factors must also be considered, including drilling method, cost, and availability.

Typical casing materials are composed of PVC, CPVC, fiberglass reinforced plastic (FRP), Teflon® (PTFE), galvanized steel, carbon steel, Type 304 stainless steel, and Type 316 stainless steel. Casing materials must be compatible with the environment into which they will be placed. Metallic casings are most subject to corrosion, while thermoplastic casings are most subject to chemical degradation. Some thermoplastic materials are susceptible to sorption and desorption of chemicals. The extent to which these processes occur is related to water quality, the concentration of contaminants, and the type of casing materials. Casing material must be chosen with a knowledge of the existing or anticipated ground-water chemistry. Table I-C-1-2 presents the relative compatibilities of some typical casing materials.

Besides chemical compatibility, a second consideration for specification of casing materials is the depth of the monitoring well. Well installations greater than 150 feet deep require casing materials of greater structural strength. In the case of PVC casing, Schedule 80 PVC rather than Schedule 40 may be required to prevent over-stressing of the casing couplings. Some thermo-plastic materials may be adversely affected by the build-up of heat during grout setup.

Regardless of the type of casing materials, only flush-threaded couplings are to be used. Flush-threaded couplings ensure that no screws, mechanical adapters, glues, or solvents are necessary to join individual sections. Steel conductor casing shall be welded at the

Table I-C-1-2

RELATIVE CHEMICAL COMPATIBILITY OF RIGID WELL-CASING MATERIAL

	PVC(1) 1	Galvanized Steel	Carbon Steel	Low-Carbon Steel	Stainless(2) Steel 304	Stainless(2) Steel 316	Teflon®*
Buffered weak acid	100	56	51	59	97	100	100
Weak acid	98	59	43	47	96	100	100
Mineral acid/high solids	100	48	57	60	80	82	100
Aqueous/organic mixtures	64	69	73	73	98	100	100
Percent overall rating(3)	*91*	*58*	*56*	*59*	*93*	*96*	*100*

* Trademark of E.I. DuPont de Nemours

Preliminary Ranking of Rigid Materials

Teflon®
Stainless Steel 316
Stainless Steel 304
PVC
Low-carbon Steel
Galvanized Steel
Carbon Steel

Notes:

(1) PVC casing shall not be installed in a ground-water environment containing chlorinated solvent or other destructive contaminants where the concentration of organics is greater than 1 ppm, and where the desired detection limit is less than 25 ppb.

(2) Type 316 stainless steel screen and/or casing shall be used rather than type 306 when conditions are unknown and the lifespan of the monitoring well is to be greater than 5 years, or where the pH is less than 4.5, or where chloride concentration is greater than 1,000 ppm.

(3) Overall rating based on scale of 0 to 100 with 0 being least compatible and 100 being the most compatible.

joints and the joint shall be at least as thick as the thickness of the casing wall. The weld shall be fully penetrating and shall meet the standards of the American Welding Society. Outside steel collars may be used to increase the strength of the welded joint. Teflon® tape shall not be used on PVC or stainless steel casing joints because it reduces the tensile strength of the joints.

The selection of an appropriate casing diameter is also important. The inner diameter (ID) shall be 4 inches or greater to allow better access to the well and more rigorous well development than is commonly possible with smaller diameter wells. Wells with casing smaller than 4-inch ID shall only be installed with the approval of the Technical Director/QA Program Manager. Wells greater than 150 feet in depth may require diameters larger than 4 inches to ensure that development and sampling equipment can be moved easily through the well. In addition, wells designed for ground-water extraction shall have a casing diameter large enough to accommodate a pump capable of achieving the appropriate pumping rate. The borehole in which the well is to be installed shall be a minimum of 4 inches larger in diameter than the outer diameter (OD) of the well casing.

5.4.3 Well Screen Selection

The screened section of the monitoring well allows ground water to flow freely into the well, while retarding movement of fine-grained lithologic materials into the well. When designing a well screen, consider important factors such as type of well screen material, length of the screened section, location of the screened section, the intake opening (slot) size, the type of intake opening, and size of filter pack to be utilized.

These five factors directly affect the performance of the monitoring well and are evaluated in the selection of an appropriate screen: (1) chemical resistance/interference, (2) screen length, (3) screen placement, (4) intended use of well (e.g., long-term ground-water extracted) and (5) intake opening size.

Selection of a screen material that provides chemical resistance and minimizes interference follows the same basic procedures as the selection of an appropriate casing material (see Table I-C-1-2). Some typical screen materials consist of PVC, CPVC, Teflon®, Type 304 stainless steel, and Type 316 stainless steel. Again, only flush-threaded couplings are to be used. Screen sections constructed of different metals in the same well may cause electrochemical reactions that could rapidly degrade the casing or screen;

therefore, this type of composite well construction shall not be used. In addition, wells intended for long-term ground-water extraction shall be constructed with well screen rather than slotted casing for facilitating redevelopment.

Selection of the screen length depends on its primary use(s). Most monitoring wells function as both ground-water sampling points and piezometers. Shorter screened sections provide more specific data on vertically distributed contaminants, hydraulic head, and flow, and are generally preferred to longer screened lengths. Saturated sections in ground-water monitoring wells shall be limited to between 5 and 10 feet in length. However, longer intervals may be justified in certain circumstances with approval of the Technical Director/QA Program Manager.

Placement of the screened interval within a ground-water monitoring well depends primarily upon two factors: the discrete interval and the type of contaminants to be monitored. The location of the discrete interval to be monitored will dictate the location of the screened interval within a monitoring well. However, the characteristics of the contaminants to be monitored (i.e., light, non-aqueous phase liquid; dense, non-aqueous phase liquid, etc.) must also be considered when choosing placement of the screened interval.

An additional consideration in the design of the screened section of the well is the hydraulic characteristics of the water-bearing zone that is to be monitored (i.e., confined or unconfined). If an unconfined zone is being monitored for contaminants that are less dense than water (e.g., gasoline, diesel, waste oil), 3 to 5 feet of screened interval should be placed above the highest level of the water table to allow for evaluation of fluctuations in water level and ensure that contaminant phases less dense than water can be observed. Conversely, if an unconfined zone is being monitored for contaminants that are denser than water (e.g., chlorinated solvents, PCBs), approximately 5 feet of screened interval (maximum) should be placed just above the confining unit at the base of the water-bearing zone to facilitate detection of the dense-phase contaminants. In the case of a confined water-bearing zone, a maximum screened interval of approximately 5 feet should be used.

Selection of an appropriate intake opening size is critical to the performance of the monitoring well and to the integrity of ground-water samples obtained from the well. The size of the intake openings can only be determined following the selection of an appropriate filter pack, which itself is selected based upon the grain-size of the formation. An intake size is generally designed to hold back between 85 to 100% of the filter pack material. Figure I-C-1-3 can be used to select appropriate intake opening sizes. The screen slots shall be factory-made (or formed), and shall be inwardly enlarging slots. This design helps prevent clogging of the screen slots.

5.4.4 Filter Pack Design

Filter pack material shall be clean and chemically stable within the monitoring well environment to minimize addition to, or sorption from, the ground water. Filter pack shall meet the following minimum specifications:

- Filter pack material shall be at least 95% silica, consisting of hard, durable grains that have been washed until free of dust and contamination, and graded.
- Filter pack material shall not be angular and non-uniform such that it will bridge in the annular space, leaving a void or poorly packed materials that can consolidate or settle after construction.
- Filter pack shall be selected to meet the grading specification determined from sieve analysis of the geologic formation to be screened, if available.
- Filter pack material shall be commercially packaged in bags that prevent the entrance of contaminants, and allow proper handling, delivery, and storage at the monitoring well site. Material delivered in broken bags shall not be used for monitoring well construction.

In investigations where there are limited data on site conditions prior to monitoring well installation, the filter pack size will be selected prior to field activities on the basis of available lithologic data. Finer filter pack sizes will be utilized if fine-grained formations are anticipated to be present, while coarser-grained filter packs will be used in coarser lithologies and consolidated formations.

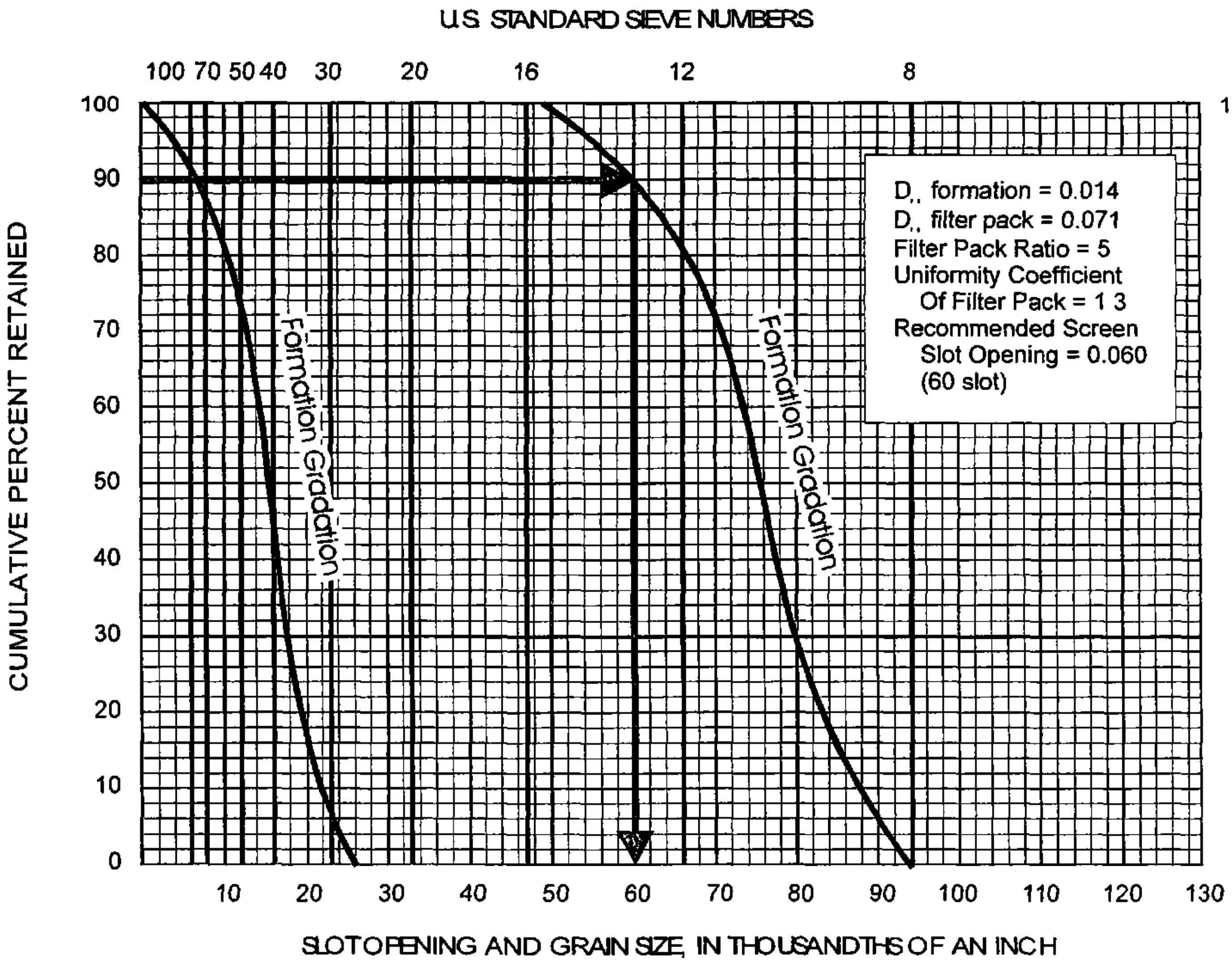


Figure I-C-1-3
Selecting Well Intake Slot Size Based on Filter Pack Grain Size

In investigations where sieve analysis data exist for a site prior to field activities, selection of a proper filter pack will be based primarily upon the grain size of the formation materials to be monitored. The sieve data for the finest lithology identified in the interval to be monitored shall be used for establishing filter pack size. The EPA recommends that filter pack grain size be selected by multiplying the 70% retained grain size of the formation materials by a factor between 4 and 6. A factor of 4 is used if the formation materials are fine-grained and uniform, and a factor of 6 is used if the formation materials are coarse-grained and non-uniform. In any case, the actual filter pack used should fall within the area defined by these two curves. An example of this technique is presented in Figure I-C-1-4.

5.4.5 Annular Seal

The annular seal is placed directly above the filter pack in the annulus between the borehole and the well casing. The annular space must be sealed to prevent the migration of water and contaminants through the annulus. The annular seal is also intended to hydraulically and chemically isolate discrete water-bearing zones.

Typically, annular seals consist of two discrete sections. The first section, known as the transition seal, consists of a pure sodium bentonite seal. This seal is generally no less than 3 feet thick and is emplaced directly over the top of the filter pack. Typical materials for the seal consist of granular sodium bentonite, or sodium bentonite pellets or chips.

The second section of the annular seal typically contains a grout slurry which completely fills the remaining annular space from the bentonite seal to just below the ground surface. Grout consists of either, sodium bentonite and Portland cement slurry or a neat cement slurry. Special consideration should be given to the selection of annular seal material for wells installed in coastal areas where ground water may contain elevated concentrations of sulfates. In this situation, a sulfate resistant grout should be used to prolong the usefulness of the well.

5.4.6 Surface Completion

The surface of the well shall be completed using either an above-grade (monument) style, or a flush-to-grade (traffic box) style. In either case, the protection of the well head at

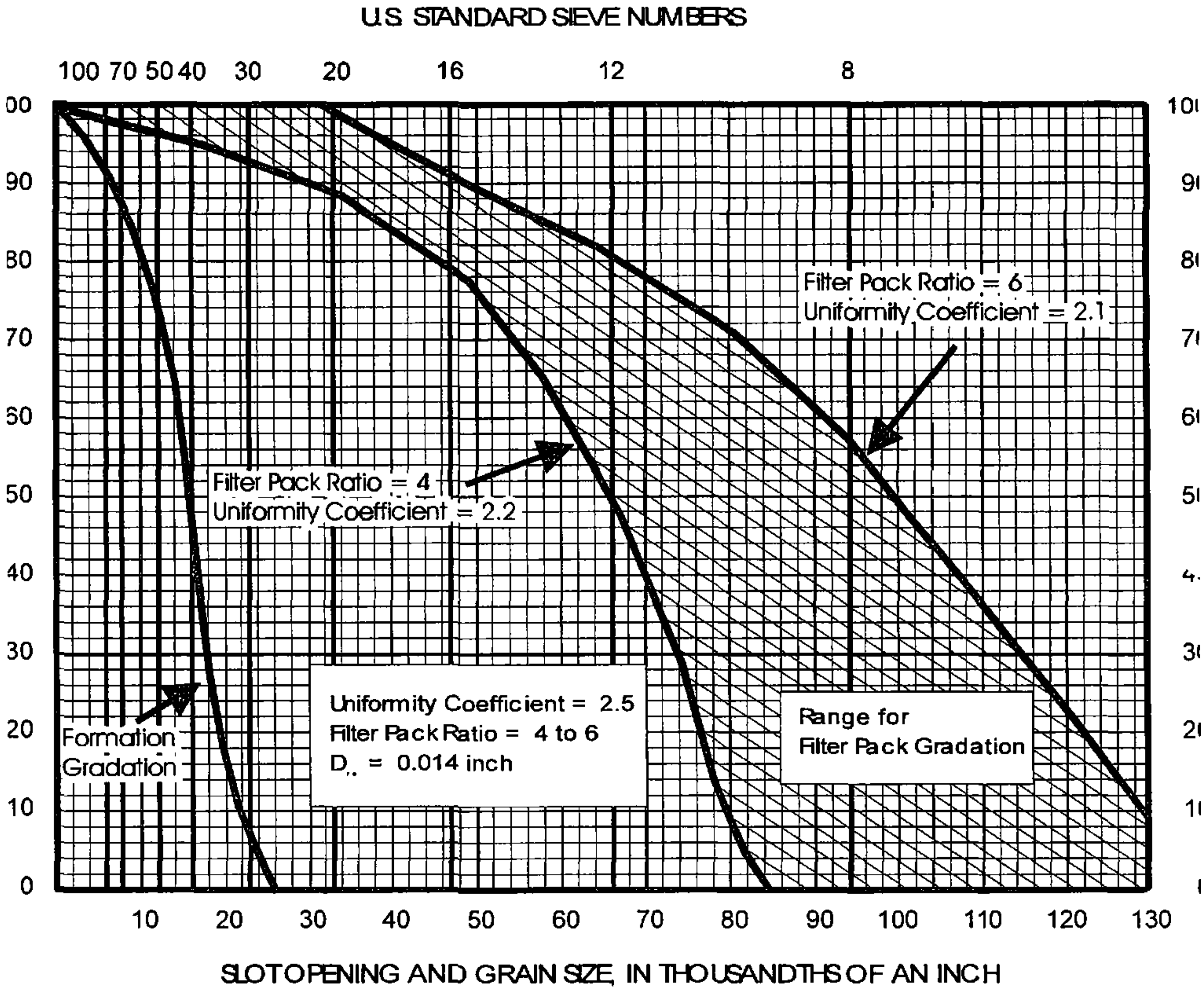


Figure I-C-1-4
Filter Pack Design Criteria

land surface is accomplished by means of a surface seal of concrete and a metal completion box surrounding the well casing. The surface seal serves to prevent infiltration of surface water and unauthorized entry, and where necessary, to provide protection from vehicular traffic.

5.5 MONITORING WELL INSTALLATION TECHNIQUES

The following general procedures describe the installation of ground-water monitoring wells are described.

5.5.1 General Casing and Screen Installation Techniques

Following completion of the borehole, the Field Manager or designate measure the total depth of the hole will first be measured to ensure that the desired depth has been attained. The lengths of casing and screen shall also be measured. These measurements shall be made with an accuracy of 0.01 feet using either a fiberglass or steel tape measure.

Installation of the casing and screen is normally accomplished by emplacing them into the well as an integral unit. Prior to installation, individual lengths of the well casing and screen shall be decontaminated according to the methods described in SOP I-F, *Equipment Decontamination*, unless the casing and screen were certified clean by the manufacturer to have been properly precleaned at the factory and sealed in plastic. Following decontamination, each length shall be inspected to ensure that damaged or otherwise unsuitable sections are not used.

To ensure even distribution of filter pack, bentonite seal, and grout materials around the well within the borehole, the casing and screen shall be suspended with a threaded hoisting plug and not allowed to rest on the bottom of the boring unless the installation is less than 30 feet deep.

5.5.2 Centralizers

Centralizers shall be installed at the top and bottom of screened sections when using the air or mud rotary techniques for well installation. Centralizers also shall be placed at 20- to 40-foot intervals on blank casing; the Field Manager will determine the spacing according to the depth of the well. Align the centralizers from top to bottom of the casing so that they do not interfere with the insertion and removal of the tremie pipe. All devices used to affix centralizers to the casing shall not puncture the casing or contaminate the ground water with which they come in contact. Centralizers shall be constructed of stainless steel.

5.5.3 Filter Pack Installation

Prior to addition of any filter pack material, cover the top of the well casing to prevent filter pack material from entering it.

The filter pack is usually installed through hollow-stem augers, conductor casing, or a tremie pipe depending on the drilling technique used. However, if depth to the bottom of the screened interval is less than 10 feet, and lithologic materials are sufficiently consolidated to preclude the possibility of hole collapse, the filter pack may be poured into the annular space of the well from the ground surface. This procedure applies to any drilling method.

During installation, measure the level of the top of the filter pack periodically to ensure that no bridging has occurred, and to determine the depth to the top of the filter pack. Be sure that the filter pack encloses the entire length of screened section. For wells less than 100 feet in total depth, the filter pack shall generally extend to 2 feet above the top of the screened section of the well. For wells greater than 100 feet in total depth, an additional 1 foot of filter pack may be emplaced above the screen for each 100 feet of well depth.

Following the installation of the filter pack, a surge block or large bailer shall be placed into and removed from the casing for approximately 10 minutes to set and compact the filter pack and to begin well development. Then, the level of the filter pack shall be checked again. Add more filter pack material according to the procedures described above if any settling of the filter pack has occurred. After emplacement, the volume of filter pack material placed in the well shall be noted, recorded in the well completion record (Figure I-C-1-5), and compared to the calculated volume of filter pack that was expected to have been used.

JOB NO ____________ WELL NO. ____________ HYDROGEOLOGIST. ____________

CLIENT ____________ DRILLER: ____________

WELL LOCATION: ____________ DATE/TIME· ____________

DETAILS OF CONSTRUCTION

Date Completed ______

Borehole Diameter (in.) ______

Type and Size of Casing (in.) ______

Type and Size of Screen (in.) ______

Screen Perforation Diameter (in) ______

Screen Length (ft.) ______

Centralizer Depths (ft) ______

Completion Technique

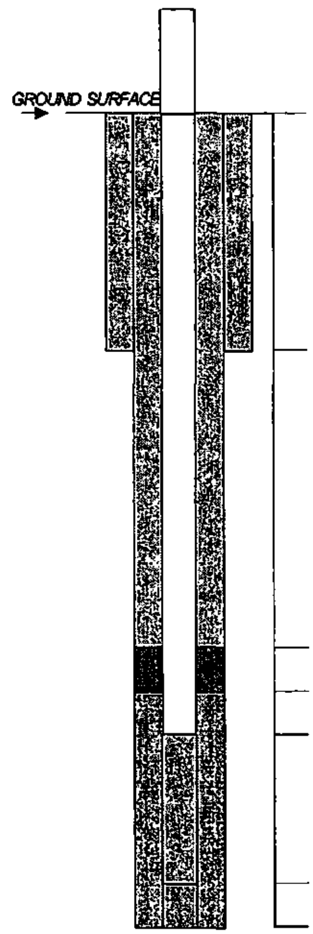
1. Type of Filter Pack and Placement Method ______
2. Type of Bentonite and Placement Method ______
3. Type of Grout Mixture and Placement Method ______

Description of Potential Problems With Well

______

Development Technique

______



Well Head Elevation ______

Ground Surface Elev ______

Well Head Completion Method ______

Drilling Method/Rig Type ______

Surface Casing: Type ______ Diameter ______ Length ______

MATERIALS

Cement (sks) ______

Filter Pack Material (ft ^{3}) ______

Casing Material (ft) ______

Bentonite (ft ^{3}) ______

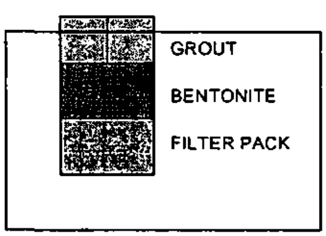
Top of Bentonite Seal ______ ft

Top of Filter Pack ______ ft

Top of Screen ______ ft

Bottom of Screen ______ ft

Bottom of Hole ______ ft



NOTE ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

Figure I-C-1-5
Well Completion Record

5.5.4 Annular Seal Installation

The sodium bentonite transition seal shall have a minimum thickness of 3 feet. It may be constructed of powdered, granular, or pelletal bentonite, and may be emplaced as a dry solid, powder, or slurry. Use only sodium bentonite manufactured specifically for use in the drilling and construction of water wells. Typically, granular or pelletized bentonite is emplaced dry. Powdered bentonite is usually mixed with potable water to produce a slurry. Depending on the type of installation method, the bentonite may be emplaced through the hollow-stem augers, conductor casing, or tremie pipe.

In dry form, the bentonite shall be placed directly on the top of the filter pack. After emplacing each 1-foot-thick layer of dry bentonite in the well, approximately 5 gallons of water of known chemical quality shall be added to hydrate the bentonite. A minimum of 15 minutes shall be allowed for hydration of the bentonite seal once it is completely installed.

When emplacing the bentonite in slurry form, take care to ensure that the bentonite is thoroughly mixed, with no visible lumps to ensure the proper consistency. Then place a 1-foot layer of fine-grained silica sand over the top of the filter pack. This fine-grained sand layer will prevent invasion of the filter pack by the bentonite slurry.

Following the emplacement of the transition bentonite seal, the remaining annular seal shall be emplaced. The annular seal shall be a slurry consisting of 7 to 9 gallons of water per 94-pound bag of Portland cement Type I or II and a minimum of 3 to 5% bentonite (1/4 to 1/2 bags of bentonite powder per five bags of Portland cement). The slurry may be emplaced through a hollow-stem auger, conductor casing, or tremie pipe, depending on the method of installation. The grout shall be thoroughly mixed to ensure the proper consistency with no visible lumps of dehydrated powder. The rates at which the augers or pipe are withdrawn and the slurry added will be such that the level of the grout within the well annulus is just below the lowermost auger or pipe.

If a tremie pipe is used, emplace the annular grout seal shall be emplaced by pumping through a pipe with a minimum 1-inch ID, in one continuous pour, from the top of the transition seal to the ground surface. The bottom of the tremie pipe shall be placed about 5 to 10 feet above the transition seal, depending on the stability of the hole and impact velocity of the grout.

A tremie pipe is not required for annular seals less than 10 feet from the ground surface to the top of the transition seal or for grouting within dual wall drill strings or hollow-stem augers. The volume of grout seal material placed in the well shall be measured, recorded in the well construction log, and compared with the calculated volume. The slurry shall extend from the top of the bentonite seal to a depth of approximately 2 feet below ground surface.

5.5.5 Annular Seal "Set Time" and Setting

Let the annular grout seal set at least 12 hours before disturbing the casing or well so that separations or breaks cannot occur between the seal and the casing, or between the seal and the borehole. Development of the well is prohibited until the grout seal has set. Likewise, the concrete slab, traffic box, and/or casing riser of the surface completion shall not be poured/constructed until the grout seal has set. Top off any settlement of the grout seal shall be as soon as possible after it occurs. Record all pertinent data on the well construction log.

5.5.6 Surface Completion

The surface of a ground-water monitoring well shall be either an above-ground completion or as a flush-to-ground completion. Regardless of the method, each monitoring well shall have, at a minimum, a casing cap, concrete slab and annular seal, and a locking protective casing or locking vault.

In an above-ground completion, the protective casing or monument is installed around the top of the well casing within a cement surface seal. A 2-foot-long by 2-foot-wide cement pad with a minimum thickness of 3 inches is constructed around the protective casing. Type 1 Portland cement, which meets the requirements of CLASS A standards, is used for the surface seal. The monument shall be inspected prior to installation to ensure that no oils, coatings, or chemicals are present. Once installed, the monument shall be maintained in a plumb position with 2 to 3 inches of clearance between the top of the well casing and the lid of the monument. The monument shall extend at least 18 inches above grade and at least 12 inches below grade. In areas where frost heaving is considered a factor, the casing shall extend below the frost depth. A minimum of three concrete-filled posts shall be constructed around the well to protect it from vehicular damage.

Inside the monument, two permanent survey marks approximately 0.25 inches apart shall be cut or scribed into the top of the well casing and the well shall also be permanently marked with its identification number. The top of the well casing shall be covered with a slip cap or locking cap to prevent debris from entering the well. The monument shall be fitted with a case-hardened lock to prevent unauthorized entry.

In a flush-to-ground completion, the protective casing or traffic box is installed around the top of the well casing which has been cut off slightly below grade. The traffic box has a lid that is held firmly in place by bolts and has a flexible O-ring or rubber gasket to prevent water from entering the box. The traffic box is set within a cement surface seal slightly above grade to deflect surface water flow away from the well. The surface seal extends to a minimum of 4 inches from the outer rim of the traffic box. Type 1 Portland cement, which meets the requirements of CLASS A standard, is used for the surface seal. The traffic box shall be inspected prior to installation to ensure that no oils, coatings, or chemicals are present. Once installed, the traffic box shall be maintained in a level position that leaves 2 to 3 inches of clearance between the top of the well casing and the lid of the traffic box.

Two permanent survey marks shall be cut into the top of the well casing approximately 0.25 inches apart and the well shall also be permanently marked with its identification number. The top of the well casing shall be covered with a lockable cap to prevent debris from entering the well. The lockable cap shall also be fitted with a case-hardened lock to prevent unauthorized entry.

5.5.7 Installation of Surface Casing

The use of surface casing may be required to minimize the potential for cross-contamination of different hydrogeologic zones within the subsurface of a site. The depth of placement of the surface casing shall be based on site-specific geologic knowledge obtained from lithologic samples collected in situ during the drilling of the well boring.

If a surface casing is to be installed permanently along with the well, it shall be grouted in place. The borehole shall be of sufficient diameter that a tremie or grout pipe can be easily placed between the borehole wall and the outside of the surface casing. After the desired placement depth is reached and the drilling tools are removed from the borehole, the casing shall be lowered into the borehole and centered. The bottom of the surface casing may be plugged or driven into the sediment at the base of the borehole to keep grout from entering the casing if necessary.

Grout shall be installed through the tremie pipe and pumped from the bottom of the casing to ground surface. As the grout is being placed, the tremie pipe shall be raised slowly to avoid excessive back pressure and potential clogging of the tremie pipe. After the grout has been allowed to set for at least 24 hours, drilling and subsequent well installation can continue. It must be noted that the required time to set before continuing drilling depends on the volume of grout emplaced; the more grout used, the longer the delay time.

5.5.8 Shallow Well Completion

Due to the occurrence of shallow ground water in some areas, there are some instances when the top of the screened interval must be placed at a depth so shallow that it is impossible to install the well using the typical design for annular materials (i.e., 2 feet above the screen for filter pack followed by a 3-foot thickness of bentonite seal). In cases where the top of the screen must be placed between 4 and 6 feet below ground surface, the following design alteration shall be used:

- The filter pack shall be placed 1 foot above the top of the screened interval.
- A minimum of 3 feet of bentonite seal shall be placed above the filter pack.
- The remainder of annular space shall be filled with a 3% to 5% bentonite-cement grout.

In no case shall the top of the screen be brought higher than 4 feet below ground surface because it is difficult to install a reliable annular seal at these shallow depths.

5.5.9 Method-specific Well Installation Techniques

The following sections describe well installation techniques for ground-water monitoring at hazardous waste sites. Included are sections on troubleshooting common problems encountered when using each technique and potential solutions to the problems.

5.5.9.1 Hollow-stem Auger

General methods of well installation using the hollow-stem auger technique are listed below.

- Complete a pre-installation design in accordance with Section 5.4.1.
- Prior to well installation, properly decontaminate and measure the well screen, cap, and casing to ensure accurate placement of well casing and screen. Mark the well casing near the ground surface to signal the drillers where the casing should be placed.
- Remember that wells are constructed within the augers as the augers are removed from the ground.
- The diameter of the well casing constructed within an HSA is limited to 4 inches. **Note:** The difference between the inner diameter of the HSA and outer diameter of the well casing must be at least 4 inches to permit effective placement of filter pack, bentonite seal, and grout.
- Remove the inner rod and hammer quickly, measure the depth of the borehole, and place the well screen and casing quickly into the auger to the desired depth. **Note:** the well screen and casing shall be suspended in hole by the use of a hoisting bail in order to ensure proper depth and plumb construction. This may not be necessary for wells less than 30 feet in depth.
- Prior to addition of filter pack, cover the top of the well casing to prevent filter pack material from entering it.
- The hollow-stem augers acts as tremie pipe for placement of filter pack, bentonite, and grout.
- Slowly pour the filter pack between the inside of the auger and the outside of the well casing.
- While the filter pack material is being poured, incrementally withdraw the auger. The rate of auger withdrawal and filter pack placement shall allow for

the top of the filter pack level to be consistently just below the lead auger. In general, the augers should be withdrawn in increments of 2 to 3 feet. **Note:** The level of the top of the filter pack shall be constantly tagged with a measuring tape during emplacement of the filter pack.

- Surge the well shall to consolidate the filter pack; add more if settlement occurs.

- Emplace bentonite pellets or chips through the HSA. Tag level of the bentonite periodically to ensure accurate placement. For each foot of bentonite seal installed in an unsaturated completion, pour 5 gallons of water of known chemical quality into the well to hydrate the bentonite. If the bentonite seal is less than 10 feet below ground surface and the borehole is stable, the bentonite may be emplaced directly from the top of the borehole rather than through the HSA.

- Immediately after pouring the bentonite seal, emplace a grout seal through the HSA from the top of the bentonite seal to within 2 feet of ground surface. The grout shall be emplaced from bottom to top in one continuous pour. If the top of the bentonite seal is less than 10 feet below ground surface and the borehole is not subject to collapse, the grout may be emplaced directly from the top of the borehole. The composition of the grout is detailed in Section 5.4.5.

- Construct an above- or below-ground well head.

Potential Problems and Solutions

1. Bridging Filter Pack or Bentonite Seal

Bridging filter pack or bentonite can create unwanted void spaces or lock the well casing within the hollow stem auger.

Solutions for "Avoidance" of Locked Well Casing

- Carefully tag the filter pack level and keep it just below the lead auger, while the auger is inched up and sand is slowly added.

- Use an auger with a larger inner diameter.
- Use filter pack materials with a larger grain size.
- Add water of known chemical quality while pouring the sand filter pack. Try this only in cases where the filter pack is very fine.

Solutions for Unlocking Well Casing From Augers

- Gently hold the casing in place while lifting and twisting the auger (do not force).
- Insert the surge block into the casing and gently surge the water column if bridge is below water table.
- Add water in between the well and auger if the sand bridge is above the water table.
- Attach an air compressor to a tremie pipe then gently blow the bridge away.
- Completely remove the casing and screen and reinstall the well.
- Never drive the casing out of the auger with a hammer because this will break the casing.

2. Heaving, Surging Materials

Fine-grained saturated materials that may cause surging problems are common in coastal areas. Heaving sediments may cause problems when drilling with HSA.

Solutions for Heaving Sediments

- Overdrill the borehole by 5 or 10 feet to provide space for heaving sediments to fill in while well installation is begun. Begin placement of filter pack as soon possible. Add it quickly until overdrilled space is filled.
- Add clean water to a level above the water table to create a downward pressure on the heaving materials. The volume of water added shall be recorded on the well installation log and extracted during well development.

- Drill an initial pilot borehole and sample with a 6-inch-diameter auger. The 6-inch auger may be fitted with plastic or metal core catcher on the lead auger, which will allow for soil sampling and prevent sediments from entering augers. After the total sampling depth is reached, the 6-inch auger is removed and 10-inch diameter augers are substituted to ream out the borehole. The lead auger shall be fitted with a tapered stainless steel plug. At a depth below the desired total depth of the well. Use the sampling hammer and center rod to knock out the stainless steel plug. Then well installation can be completed.

5.5.9.2 Direct Rotary with Foam or Mud

General well installation techniques using direct rotary with foam or mud are listed below.

- Complete a pre-installation design in accordance with Section 5.4.1.

- Prior to well installation, measure the well screen, cap, and casing to ensure accurate placement of well casing and screen. Place mark on the portion of the well casing near ground surface to identify to the drillers where the casing should be placed. Place centralizers on the well casing and screen as discussed in Section 5.5.2.

- With DRD techniques, wells are constructed in the borehole after the bit and drill pipe are removed from the hole. For mud rotary drilling, the mud must first be thinned sufficiently prior to removal of the bit and drill pipe from the hole. The purpose of thinning the mud is to allow a faster and more accurate placement of the annular materials within the borehole balances the density of the borehole fluids so they more closely match the density of the fluids used to install the filter pack and bentonite seal, and reduces the potential for annular materials to be washed out of the borehole through the tremie.

- After the bit and drill pipe are retrieved from the hole as smoothly and quickly as possible, measure the total depth of the hole to verify its depth and to check its stability.

- Suspend the well screen and casing in the hole by the use of hoisting bail in order to ensure proper depth and a plumb construction. This may be unnecessary on wells whose depth is less than 30 feet. Place the casing and screen in the hole as fast as is safely possible to minimize the time that the borehole stays open.

- Prior to addition of filter pack, cover the top of the well casing to prevent filter pack material from entering the well casing.

- Use a tremie pipe for placement of filter pack, bentonite, and grout. The filter pack and bentonite seal should also be emplaced as soon as possible to avoid potential collapse of the hole.

- Slowly pour the filter pack into the tremie pipe to avoid bridging within the tremie pipe at the water table. The level of the top of the filter pack shall be constantly tagged with measuring tape as the filter pack is being emplaced.

- Make the bentonite seal at least 3 feet thick. It should consist of bentonite pellets or chips emplaced through the tremie pipe. Tag the level of the bentonite periodically to ensure accurate placement. If the bentonite seal is less than 10 feet below ground surface and the borehole is stable, the bentonite may be placed directly from the top of the borehole rather than through the tremie pipe.

- Immediately after pouring the bentonite seal, emplace a grout seal through the tremie pipe from the top of the bentonite seal to within 2 feet of ground surface. The grout shall be placed from bottom to top in one continuous pour. If the top of the bentonite seal is less than 10 feet below ground surface, and the borehole is not subject to collapse and is not filled with drilling fluid, the grout may be placed directly from the top of the borehole. The composition of the grout is detailed in Section 5.4.5.

- Construct an above- or below-ground well head.

Potential Problems and Solutions

1. Bridging Filter Pack or Bentonite Seal

Bridging filter pack or bentonite can create unwanted void spaces that may collapse in the future.

Solution

Controlled pouring of the annular materials is the best defense against bridging. In the case of mud rotary, however, it may be necessary to perform emplacement of the filter pack and bentonite chips or pellets through the borehole without the aid of a tremie pipe. For wells greater than 10 feet deep, the approval of the Technical Director/QA Program Manager must be obtained.

5.5.9.3 Air Rotary and Air Rotary With Casing Hammer

General well installation techniques using air rotary (ARD) or air rotary with casing hammer (ARC) are listed below.

- Prepare a pre-installation design.
- Prior to well installation, properly decontaminate and measure the well screen, cap, and casing to ensure the accurate placement of well casing and screen.
- Remember that with ARD techniques, wells are constructed in the borehole after the bit and drill pipe are removed from the hole. With ARC, the driven casing remains in the ground and is slowly withdrawn as well installation proceeds.
- After the bit and drill pipe are retrieved from the hole as smoothly and quickly as possible, measure the total depth of the hole to verify its depth and to check its borehole stability.
- To ensure proper depth and a plumb construction, suspend the well screen and casing in the hole using a hoisting bail. Place the casing and screen in the borehole as fast as is safely possible to minimize the time that the hole stays open, particularly for ARD.

- Before adding filter pack, cover the top of the well casing to prevent filter pack material from entering it.

- For ARD, use a tremie pipe for placement of filter pack, bentonite, and grout. The filter pack and bentonite seal should be emplaced as soon as possible to avoid potential collapse of the hole. For ARC, the annular materials can in most cases be placed directly between the driven casing and the well casing. A tremie pipe is advisable if very exacting placement is required.

- For ARD, place the tremie pipe within 2 feet of the interval where the filter pack is to be placed. Slowly pour the filter pack into the tremie pipe to avoid bridging within the tremie pipe at the water table. The tremie pipe shall be slowly withdrawn during placement.

- Periodically tag the level of the top of the filter pack with measuring tape while the filter pack is being emplaced. Install bentonite in a similar manner.

- For ARC, pour the filter pack slowly between the well casing and driven casing. The driven casing shall be withdrawn periodically while the filter pack is being emplaced. Withdraw the driven casing in increments no greater than 2 to 3 feet.

- For ARD, emplace bentonite pellets or chips through the tremie pipe to a minimum thickness of 3 feet. Tag the level of the bentonite periodically to ensure accurate placement. For each foot of bentonite seal installed in an unsaturated completion, 5 gallons of water of known chemical quality into the well to hydrate the bentonite. If the bentonite seal is less than 10 feet below ground surface and the borehole is stable, the bentonite may be emplaced directly from the top of the borehole rather than through the tremie pipe. For ARC, emplace the bentonite between the well casing and the driven casing while the driven casing is being withdrawn.

- Emplace a grout seal through the tremie pipe for the ARD method or through the driven casing in the ARC method. Emplace the grout from the top of the bentonite seal to within 2 feet of ground surface. The driven casing or tremie pipe shall be withdrawn as the grout is placed. The grout shall be emplaced from bottom to top in one continuous pour following placement of the bentonite seal. If the top of the bentonite seal is less than 10 feet below ground surface and the borehole is not subject to collapse, emplace the grout directly from the top of the borehole. The composition of the grout is detailed in Section 5.4.5.

- Construct an above- or below-ground well head.

<u>Potential Drilling Problems</u>

1. Bridging Filter Pack or Bentonite Seal

Bridging filter pack or bentonite can create unwanted void spaces that may collapse in the future.

Solutions

Controlled pouring of the annular materials is the best defense against bridging.

2. Heaving Sediment

Fine-grained saturated materials that may cause heaving problems are common in coastal areas. Difficulties caused by heaving sediments may create problems when drilling with ARC. Heaving sediments cannot be drilled using ARD techniques.

Solutions for Heaving Sediments

- Overdrill the borehole by 5 or 10 feet to provide space for heaving sediments to fill in while well completion is begun.

- Add clean water to a level above the water table to create a downward pressure on the heaving materials. The volume of water added should be extracted during well development.

- Heaving sands may also be controlled by first removing the drill pipe from the hole, then constructing an air lift line made from the tremie pipe. If there is sufficient water above the heaving sands, an air line connected approximately

10 feet from the bottom of the tremie pipe can be used to air lift out the fine-grained sediments at the base of the casing.

- Begin placement of filter pack as soon as possible and add it quickly until the overdrilled space is filled.

5.5.9.4 Dual Tube Casing Hammer With Reverse Air Circulation

General well installation techniques using dual tube casing hammer with reverse air circulation are listed below.

- Prepare a pre-installation design.

- Prior to well installation, measure the well screen, cap, and casing to ensure accurate depth placement of well casing and screen. Place a mark near the top of the casing to identify to the drillers the proper position to place the casing and screen.

- Like hollow-stem auger drilling techniques, wells are constructed within the dual tube pipe as the pipe is removed from the ground.

- Prior to setting the casing and screen in the hole, verify total depth of the hole by measuring it and check for surging materials. Suspend the well screen and casing in the hole using of a hoisting bail in order to ensure proper depth and plumb construction.

- Prior to addition of filter pack, cover the top of the well casing to prevent filter pack material from entering the well casing.

- The inner pipe of the dual tube assembly shall act as tremie pipe for placement of filter pack, bentonite, and grout.

- Slowly pour the filter pack between the inside of the augers and the outside of the well casing to avoid potential bridging of the annular materials. While the filter pack material is being poured, the dual tube pipe shall be incrementally withdrawn. The rate of pipe withdrawal and filter pack emplacement shall allow for the top of the filter pack level to be consistently just below the shoe of the dual tube assembly. The level of the top of the filter pack shall be constantly tagged with measuring tape.

- Use bentonite pellets or chips to construct the well, shall be a minimum of 3 feet thick, and shall also be emplaced through the dual tube assembly. For each foot of bentonite seal installed in an unsaturated completion, 5 gallons of water of known chemical quality shall be poured into the well to hydrate the bentonite. Tag the level of the bentonite periodically to ensure accurate emplacement. If the bentonite seal is less than 10 feet below ground surface and the borehole is stable, the bentonite may be emplaced directly from the top of the borehole rather than through the tremie pipe.

- Emplace a grout seal through the dual tube assembly from the top of the bentonite seal to within 2 feet of ground surface. The grout shall be emplaced from bottom to top in one continuous pour immediately following emplacement of the bentonite seal. If the top of the bentonite seal is less than 10 feet below ground surface, the grout may be emplaced directly from the top of the borehole. The composition of the grout is detailed in Section 5.4.5.

- Construct an above- or below-ground well head shall be constructed.

Potential Problems and Solutions

1. Bridging Filter Pack or Bentonite Seal

Bridging filter pack or bentonite can create unwanted void spaces or lock the well casing and dual tube pipe together.

Solutions for "Avoidance" of Locked Well Casing

- Tag carefully and always keep the filter pack just below the shoe while inching the dual tube assembly up and slowly adding sand.

- Use a smaller diameter well casing.

- Use a filler pack with a larger grain size.

- Add water while pouring the sand filter pack. Avoid this unless absolutely necessary.

Solutions for Unlocking Well Casing From Dual Tube Pipe

- Insert a surge block into casing and gently surge the water column, if the bridge is below water table.
- Add water in between the well and piping if the sand bridge is above the water table.
- Attach an air compressor to a tremie pipe and gently blow the bridge away.

2. Heaving, Surging Materials

Fine-grained saturated materials that may cause surging problems are common in coastal areas. Heaving sediments may cause problems when drilling with dual tube casing hammer.

Solutions for Heaving Sediments

- Overdrill the borehole by 5 or 10 feet to provide space for heaving sediments to fill in while well completion is begun.
- Add clean water to a level above the water table to create a downward pressure on the heaving materials. The volume of water added should be extracted during well development.
- Removing the drill pipe from the hole, then construct an air lift line made from the tremie pipe. If there is sufficient water above the heaving sands, an air line connected approximately 10 feet from the bottom of the tremie pipe can be used to air lift out the fine grained sediments at the base of the casing.
- Begin emplacement of the filter pack as soon as possible and add it quickly until the overdrilled space is filled.

5.5.10 Well Construction Record Keeping Procedures

A written well construction record (Figure I-C-1-5) detailing the timing, amount of materials, and methods of installation/construction for each step of monitoring well construction shall be prepared during construction of each monitoring well by the Field Manager or designate. Construction records shall be kept in a hard-bound field notebook dedicated to the CTO/DO. An "as-built" drawing illustrating the placement location and amounts of all materials used in construction of each monitoring well shall be prepared in the field at the time of construction. The well construction record shall be filled out with indelible ink. Construction records shall include the date/time and quantities of materials used at each of the following stages of monitoring well construction, including:

- Drilling
    1) Drill rig type
    2) Drilling method/coring method
    3) Drill bit/core barrel diameter (hole diameter)
    4) Drill company, driller, helper(s)
    5) Field geologist, supervising geologist
    6) Dates/times start and finish drilling hole, interval drilling rates
    7) Total depth of hole
    8) Drilling location, surveyed ground elevation
    9) Inclination of hole from horizontal
- Borehole abandonment - type, volume, and surface seal
- Casing material - type
- Casing decontamination - document process and equipment used
- Casing diameter - nominal inner diameter of casing

- Screen material

    1) Type

    2) Top and bottom of section as actually installed

    3) Length

    4) *Slot type, size, shape*

    5) Type of bottom plug and/or cap used

- Filter pack material

    1) Composition and size gradation

    2) Manufacturer

    3) Actual volume and depth of top and bottom of filter pack

    4) Calculated volume versus actual volume used and explanation of discrepancies

- Transition seal

    1) Composition and depth of top and bottom of seal

    2) Size (or gradation) or material used (e.g., pellets, granulated, or powdered)

    3) Time allowed for hydration prior to emplacement of annular grout slurry seal

- Annular slurry seal

    1) Date and time of beginning and completion of annular seal

    2) Type and actual volume of seal

    3) Calculated volume versus actual volume and explanation of discrepancies

4) Set time allowed prior to commencement of additional work

- Surface completion

  1) Type of construction

  2) Nature of materials used for surface completion

  3) Date/time of completion

5.5.11 Well Location

Each monitoring well location shall be surveyed by a registered land surveyor for exact horizontal location to the nearest 0.5 foot, and exact vertical location to the nearest 0.01 foot, referenced to mean sea level (MSL) or Mean Low Low Water (MLLW). The vertical elevation shall be surveyed between the two notches cut in the top of the well casing, which is the point from which all water level measurements shall be made. The elevation of the ground or top of the concrete slab adjacent to the monitoring well shall also be surveyed, to the nearest 0.01 foot.

5.6 WELL ABANDONMENT/DESTRUCTION

Once a monitoring well is no longer needed as part of an investigation, or has been damaged to the extent that it cannot be repaired, it is essential that it be properly abandoned. The proper abandonment of a monitoring well ensures that the underlying ground-water supply is protected and preserved. In addition, proper well abandonment eliminates a potential physical hazard and liability. An additional permit and/or inspection may be required for abandonment.

The standard procedures for the abandonment of a ground-water monitoring well apply to the hollow-stem auger drilling method. This type of installation was chosen because it is the primary method of abandoning ground-water monitoring wells.

The first step in abandoning a ground-water monitoring well is to remove the surface completion from around the top of the well casing. This is normally accomplished using a jack-hammer to break the surface cement seal and then removing the monument or traffic box. When the surface seal and the well head cover have been removed, the well shall be overdrilled to its total depth using hollow-stem augers. Once the total depth of the well has been reached, the casing and screen shall be removed from the borehole. The borehole shall then be completely backfilled with a grout seal. Typically, the grout seal is emplaced as a slurry of Portland cement grout, which contains a minimum of 3 to 5% bentonite as described in Section 5.4.5. When mixing the slurry, care must be taken to ensure that the bentonite is mixed according to the manufacturer's specifications to ensure the proper consistency.

The slurry shall be emplaced through the hollow-stem augers. The rates at which the augers are withdrawn and the slurry is added shall be such that the level of the slurry within the borehole is just below the lead auger. The borehole seal shall extend from the total depth of the borehole to a depth of approximately 1 foot below ground surface. The surface shall then be repaired to prior conditions and grade.

If the monitoring well casing cannot be pulled or drilled out, the well casing shall be perforated adjacent to the saturated zones so that the annular space and any nearby voids can be filled with sealing material.

The perforated well or borehole shall be filled from the bottom up with an appropriate sealing material, such as neat cement. The neat cement shall be injected under pressure to force it into the annular space, nearby voids, and filter pack. Pressure shall be applied for a sufficient time to allow the cementing mixture to set.

After the cement has hardened, a hole shall be excavated around the well with a backhoe to an approximate depth of 6 feet. The uppermost portion of the casing shall be removed, (if still in place), and a cement cap poured on top of the abandoned well and the remaining portion of the excavation backfilled with sealing material.

5.7 Vapor Extraction/Monitoring Wells

Vapor extraction/monitoring wells have most of the same design and installation considerations and procedures as for ground-water monitoring wells, with the exception that they are screened in the unsaturated zone. Vapor extraction/monitoring wells generally shall not be screened over an interval greater than 20 feet and shall not be screened over two or more lithologies that have air permeabilities that differ by more than one order of magnitude. Vapor extraction/monitoring wells shall be installed using drilling techniques that do not require drilling fluids other than filtered air. Vapor monitoring wells may have casing inner diameters of 2 inches or less while extraction wells shall generally have casing inner diameters of at least 4 inches. The design of vapor extraction/monitoring wells is dependent upon many site-specific factors, such as the depth of contamination, soil conditions, geology, depth to ground water, etc. As a result, specifics related to the design of these wells shall be included in the CTO/DO Work Plan, Field Sampling Plan, or Plans and Specifications.

5.8 Drive Points

An alternative to conventional monitoring well construction is, under limited conditions, the use of drive points. These consist of slotted steel pipe that is pushed, hammered, or hydraulically jetted into the ground. A filter pack is not constructed around the screen, so the width of the screen openings must be sufficiently small to prevent the passage of significant quantities of sediment into the well during the withdrawal of water for sampling. In some instances, the drive points are used only as piezometers.

Drive points are commonly used in hazardous waste investigations to sample ambient soil gases in the vadose zone. It is often possible to extend the drive point below the water table to collect water samples. In some instances, permits may be required, because the drive points are considered in some jurisdictions to be equivalent to a temporary monitoring well.

5.9 Hydropunch Sampling

Another alternative to conventional monitoring well construction is the use of a discrete ground-water sampling device known as a Hydropunch™. The Hydropunch™ tool can be used in conjunction either with a standard drill rig, a cone penetrometer rig, or possibly a vehicle capable of driving vapor probes to sample ground water and non-aqueous phase liquid in unconsolidated formations. The Hydropunch™ tool is constructed of a stainless steel drive point, a perforated section of Teflon® pipe for a sample intake, and a stainless steel sample chamber. The tool is 55.5 inches long, 2 inches in outer diameter, and weighs roughly 24 pounds.

Ideally, a standard HSA drill rig is used to drill a pilot hole to a depth just above the desired sampling depth. The Hydropunch™ tool is then hydraulically pushed or driven

4 to 5 feet through the saturated zone at each sampling location. As the tool is advanced, the sample intake screen remains pristine within the watertight stainless steel chamber. When the desired sampling interval is reached, the steel sampling chamber is unscrewed and withdrawn 1 to several feet, depending on how discrete a sampling interval is needed. This exposes the intake screen to the ground water. Under hydrostatic pressure, ground water flows through the intake screen and fills the sample chamber, without aeration or agitation occurring. The drive cone, which is attached to the base of the screen, will remain in place by soil friction.

The pointed shape of the sampler and its smooth exterior surface prevent downward transport of surrounding soil and ground water as the tool is advanced. Once in place, the intake screen will be sealed from ground water above and below the interval being sampled, because the exterior is flush of the Hydropunch™ tool against the surrounding soil wall. Additionally, as the tool is advanced, the sample intake screen is retained within the steel watertight sample chamber.

A stainless steel or Teflon® bailer with a bottom check valve is lowered into the sample chamber to collect the ground-water sample. Ground water is then decanted at ground surface from the bailer into the appropriate sample containers.

6.0 RECORDS

Monitoring well location, design and construction shall be recorded in the field notebook for the CTO/DO and on a well completion record form (Figure I-C-1-5). The field operations manager should provide a copy of this form to the CTO/DO Manager for the project files. The CTO/DO Manager or designee shall review all well construction logs on a minimum monthly basis.

7.0 HEALTH AND SAFETY

During monitoring well installation, subcontractors in direct contact with potentially contaminated media shall wear the proper personal protective equipment (PPE) as outlined in the site-specific Health and Safety Plan (HSP). Failure to comply will result in disciplinary action.

If circumstances warrant, a real-time immediate response instrument such as a Miniram Dust Monitor, OVA, HNU, Thermo, Draeger® or Sensidyne tubes, or explosimeter, should be used to monitor the work area. When real/time instrument response exceeds the Permissible Exposure Limit (PEL), personnel shall don the appropriate PPE and alternate control measures to ensure personnel safety. If safe control measures are not achievable, field activities shall be discontinued immediately.

Depending upon the type of contaminant expected, the following safe work practices will be employed:

Particulate or Metal Compounds

1. Avoid skin contact with and/or incidental ingestion of soil cuttings.
2. Utilize protective clothing, steel-toed boots, gloves, hearing protection, and safety glasses as warranted.

Volatile Organic Compounds:

1. Stand upwind of the boring, and/or use respiratory protection to avoid breathing constituents venting from the boring.
2. Periodically survey the work area and personnel breathing zone with a flame ionization detector/photoionization detector (FID/PID) during drilling activities.
3. If monitoring results indicate organic vapors that exceed action levels as specified in the HSP, installation activities may need to be conducted in Level C protection. At a minimum, skin protection will be required by use of Tyvek® or other media that is protective against the media being encountered.

Flammable or Explosive Conditions:

1. Monitor explosive gases as continuously as possible using an explosimeter and oxygen meter.
2. Place all ignition sources upwind or crosswind of the borehole.

3. If explosive gases exceed the designated action levels as specified in the site-specific HSP, cease operations and evaluate conditions.

Physical Hazards Associated With Well Installation:

1. To avoid lifting injuries associated with hollow-stem auger use and general well installation practices, use the large muscles of the legs, not the back.
2. Stay clear of all moving equipment and avoid wearing loose fitting clothing.
3. When using pocket knives for cutting purposes, cut away from self.
4. To avoid slip/trip/fall conditions as a result of drilling activities, keep the area clear of excess soil cuttings and use textured boots/boot cover bottoms in muddy areas.
5. To avoid heat/cold stress as a result of exposure to extreme temperatures and PPE, drink electrolyte replacement fluids (1-2 cups/hour is recommended) and, in cases of extreme cold, wear fitted insulating clothing.
6. Be aware of restricted mobility caused by the wearing of PPE.

8.0 REFERENCES

California Department of Health Services. 1990. "Technical Standards for the Design and Construction of Monitoring Wells and Piezometers at Hazardous Waste Sites." August.

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USEPA. 1987. A Compendium of Superfund Field Operations Methods. U.S. Environmental Protection Agency/540/P-87/001.

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USEPA. 1992. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, U.S. Environmental Protection Agency/530/R-93/001, November.

SOP I-B-1, *Soil Sampling*;

SOP I-B-4, *Surface Water Sampling*

SOP I-F, *Equipment Decontamination*

9.0 ATTACHMENTS

None.

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MONITORING WELL DEVELOPMENT

1.0 PURPOSE

This section describes the standard operating procedures (SOP) for monitoring well development to be used by U.S. Navy PACDIV IRP personnel.

2.0 SCOPE

This document applies to all U.S. Navy PACDIV IRP personnel involved in monitoring well development activities.

This procedure shall serve as management-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in the planning or execution of activities must be approved by the CTO/DO Manager and the Technical Director/QA Program Manager.

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

The CTO/DO Manager is responsible for ensuring that these monitoring well development procedures are followed during projects conducted under the U.S. Navy PACDIV IRP.

The Field Manager is responsible for ensuring that all project field staff follow these procedures.

The Technical Director/QA Program Manager is responsible for conducting evaluations to ensure that these procedures are being followed throughout the U.S. Navy PACDIV IRP.

5.0 PROCEDURE

5.1 INTRODUCTION

Well development procedures are crucial in preparing a well for sampling. They enhance the flow of ground water from the formation into the well and remove the clay, silt, and other fines from the formation so that produced water will not be turbid or contain suspended matter that can interfere with chemical analyses. A monitoring well should be a "transparent" window into the aquifer from which samples can be collected that are truly representative of the quality of water that is moving through the formation.

The goal of well development is to restore the area adjacent to a well to its natural condition by correcting damage to the formation during the drilling process. Well development shall accomplish the following tasks:

- Remove a filter cake or any drilling fluid within the borehole and that invades the formation.
- Remove fine-grained material from the filter pack.
- Increase the porosity and permeability of the native formation immediately adjacent to the filter pack.

Well development shall not occur until 24 hours after the completion of well installation to allow the annular seal to fully set up.

5.2 FACTORS AFFECTING MONITORING WELL DEVELOPMENT

5.2.1 Type of Geologic Materials

Different types of geologic materials are developed more effectively by using certain development methods. Where permeability is greater, water moves more easily into and out of the formation and development is accomplished more quickly. Highly stratified deposits are effectively developed by methods that concentrate on distinct portions of the formation. If development is performed unevenly, a ground-water sample will likely be more representative of the permeable zones. In uniform deposits, development methods that apply powerful surging forces over the entire screened interval will produce satisfactory results.

5.2.2 Design and Completion of the Well

Because the filter pack reduces the amount of energy reaching the borehole wall, it must be as thin as possible if the development procedures are to be effective in removing fine particulate material from the interface between the filter pack and natural formation. Conversely, the filter pack must be thick enough to ensure a good distribution of the filter-pack material during emplacement. The rule of thumb is that filter pack material must be at least 2 inches thick.

The screen slot size must be appropriate for the geologic material and filter pack material in order for development to be effective. If slot size is too large, the removal of too much sediment may cause settlement of overlying materials and sediment accumulation in the casing. When screen openings are too small, full development may not be possible and well yield will be below the potential of the formation. Additionally, incomplete development coupled with a narrow slot size can lead to blockage of the screen openings.

5.2.3 Drilling Method

The drilling method influences development procedure. Typical problems associated with specific drilling methods include the following:

- If a mud rotary method is used, a mudcake builds up on the borehole wall and must be removed during the development process.
- If drilling fluid additives have been used, the development process must attempt to remove all fluids that have infiltrated into the native formation.
- If driven casing or hollow-stem auger methods have been used, the interface between the casing or auger flights and the natural formation may have been smeared with fine particulate matter that must be removed during the development process.

- If an air rotary method has been used in rock formations, fine particulate matter is likely to build up on the borehole walls and may plug pore spaces, bedding planes, and other permeable zones. These openings must be restored during the development process.

5.3 PREPARATION

In preparing for monitoring well development, development logs for any other monitoring wells in the vicinity should be reviewed to determine the general permeability of the water-bearing formation and the appropriate development method.

Depth to ground water and information from the well construction log should be used in calculating of the required quantity of water to be removed. The distance between the equilibrated water level and the bottom of screen is the saturated section. The saturated section (feet) multiplied by the unit well volume per foot (gallons/linear foot) equals the gallons required to remove one total well volume of water. The unit well volume is the sum of the casing volume and the filter-pack pore volume, both of which depend upon casing and borehole diameter and the porosity of the filter pack material. Well volume for wells can be calculated using Table I-C-2-1 and Table I-C-2-2.

Table I-C-2-1*

Casing Volume

Casing Diameter (inches)	Volume (gallon/linear foot)
2	0.16
4	0.65
6	1.47

Table I-C-2-2*

Filter Pack Pore Volume

Casing Diameter (inches)	Borehole Diameter (inches)	Volume[a] (gallon/linear foot)
2	6	0.52
2	8	0.98
4	10	1.37
4	12	2.09
6	12	1.76

* The above two volumes must be added together to obtain one unit well volume.
[a] Assumes a porosity of 40% for filter pack.

5.4 DECONTAMINATION

The purpose of decontamination of development equipment is to prevent cross-contamination between monitoring wells. A steam-cleaner, if available, shall be used to decontaminate development equipment. The equipment shall be cleaned away from the monitoring well in such a fashion that decontamination effluent can be intercepted and drummed.

A triple rinse decontamination procedure is acceptable for equipment such as bailers or if access to a steam cleaner is not possible. See SOP I-F, *Equipment Decontamination.*

During well development, visqueen shall be placed around the well to prevent contamination at ground surface. This sheeting shall be properly disposed of after each use.

5.5 WELL DEVELOPMENT MONITORING

Throughout the well development process, a development record shall be maintained using the form presented in Attachment 1. The record should include the following information:

- General
  1) Well name/number and location
  2) Date, time, and weather conditions
  3) Names of personnel involved
- Development volume
  1) Initial and final water level
  2) Casing total depth and diameter
  3) Borehole diameter
  4) Casing volume, filter pack pore volume, total well volume
  5) Volume of water to be evacuated
  6) Method and rate of removal
  7) Appearance of water before and after development
- Monitoring data for each sample point
  1) Date, time, elapsed time
  2) Cumulative gallons removed, removal method, removal rate
  3) Temperature, pH, specific conductivity, turbidity, dissolved oxygen, and redox potential

Part of the well development procedure shall consist of acquisition and analysis of water samples at appropriate intervals considering the total quantity of water to be removed. Conductivity, pH, temperature, dissolved oxygen, and redox potential shall be measured in each sample, and turbidity shall be measured using a turbidity meter. Sampling shall occur on a periodic basis during development and at least one sample shall be obtained after removal of each well volume. At the time each sample is analyzed, the cumulative water removed, the clock time, and the time elapsed during development should be recorded and flow rate calculated. Development shall continue until turbidity stabilizes at or below 5 nephelometric units or at least three borehole volumes have been removed. If three successive parameters have stabilized (values within 10% of each other) and turbidity is low, well development may cease. If stabilization has not been attained, if turbidity remains high, or if the well does not readily yield water, development shall continue for a reasonable time.

The discussion of well development in special situations such as low yield formations and 2-inch wells is described in Section 5.7.

5.6 Methods of Monitoring Well Development

The methods available for the development of monitoring wells have been inherited from production well practices. Methods include (1) mechanical surging with a surge block or swab, and (2) surge pumping. Development methods using air or jetting of water into the well are generally inappropriate for development of monitoring wells due to the potential for affecting water quality.

All development water must be containerized and appropriately labeled, unless it is permissible to discharge onsite. All development efforts must utilize mechanical surging or surge pumping, followed by bailing or ground-water removal with a pump. More detailed descriptions of appropriate development methods are presented below.

Mechanical Surging and Bailing

For mechanical surging and bailing, a surge block or swab is operated either manually or by a drill rig. The surge block or swab should be vented and be of sufficient weight to free fall through the water in the well and create a vigorous outward surge. The equipment lifting the tool must be strong enough to extract it rapidly. A bailer is then used to remove fine-grained sediment and ground water from the well.

Methodologies:

1. Properly decontaminate all equipment entering well.

2. Record the static water level and the total well depth.

3. Lower surge block or swab to top of the screened interval.

4. Operate in a pumping action with a typical stroke of approximately 3 feet.

5. Gradually work the surging downward through the screened interval during each cycle.

6. Surge for approximately 10 to 15 minutes per cycle.

7. Remove surge block and attach bailer in its place.

8. Bail to remove fines loosened by surging until water appears clear.

9. Repeat the cycle of surging and bailing at least three times or until turbidity is reduced and stabilization of water quality parameters occurs.

10. The surging shall initially be gentle and the energy of the action should gradually increase during the development process.

The advantages (+) and disadvantages (–) of this method are listed below:

+ It reverses the direction of flow, reduces bridging between large particles; the inflow then moves the fine material into the well for withdrawal.

+ It affects the entire screened interval.

+ It effectively removes fines from the formation and the filter pack.

– It may cause upward movement of water in the filter pack that could disrupt the seal.

– Potential exists for damaging a screen with a tight-fitting surge block or with long surge strokes.

Surge Pumping

Methodologies:

1. Properly decontaminate all equipment entering well.

2. Record the static water level and the total well depth.

3. Lower a submersible pump or air lift pump without a check valve to a depth within 1 to 2 feet of the bottom of the screened section.

4. Start pumping and increase discharge rate to maximum capacity (overpumping), causing rapid drawdown of water in the well.

5. Periodically stop and start pump, allowing the water in the drop pipe to fall back into the well and surge the formation (backwashing), thus loosening particulates.

6. The pump intake shall be moved up the screened interval in increments appropriate to the total screen length.

7. At each pump position, the well shall be pumped, overpumped, and backwashed alternately until satisfactory development as been attained as demonstrated by reduction in turbidity and stabilization of water quality parameters.

The advantages (+) and disadvantages (–) of this method are listed below:

+ Reversing the direction of flow reduces bridging between large particles, and the inflow then moves the fine material into the well for withdrawal.

+ It effectively removes fines from the formation and filter pack.

– The pump position or suction line must be changed to cover the entire screen length.

– Submersible pumps suitable to perform these operations may not be available for small diameter (2 inches or less) monitoring wells.

- It is not possible to remove sediment from the well unless particle size is small enough to move through pump.

For additional information on well development, consult the references included in Section 8.0 of this SOP.

5.7 SPECIAL SITUATIONS

5.7.1 Development of Low Yield Wells

Development procedures for monitoring wells in low-yield (<0.25 gpm) water-bearing zones are somewhat limited. Due to the low hydraulic conductivity of the materials, surging of water in and out of the well casing is difficult. Also, when the well is pumped, the entry rate of water is inadequate to remove fines from the well bore and the gravel pack. Additionally, the process may be lengthy because the well can be easily pumped dry and the water level will be very slow to recover.

The procedures for mechanical surging and bailing shall be followed for low yield wells. During surging and bailing, wells in low yield formations should be drawn down to total depth twice if possible. Development can be terminated, however, if the well does not exhibit 80% recovery after 3 hours have passed.

5.7.2 Development of 2-inch Wells

It is easier to develop monitoring wells that are large in diameter than it is to develop small diameter wells. Mechanical surging or bailing techniques that are effective in large diameter wells are much less effective when used in wells 2 inches or less in diameter. Equipment to develop small diameter wells are available on a limited basis and mechanical surge blocks and bailers have a high potential for damaging a small diameter well. As a result, the CTO/DO Manager shall obtain approval from the Technical Director/QA Program Manager prior to installing ground-water monitoring wells with inside diameters of 2 inches or less.

Two-inch or smaller diameter wells should be developed by surging with a specially designed hand-operated surge block or by pumping with a bladder or air-lift pump.

Information related to development of wells 2 inches or less in diameter shall be included in the CTO/DO Work Plan or Field Sampling Plan.

6.0 RECORDS

Well development information should be documented in indelible ink on well development monitoring forms (Attachment I-C-2-1.) Copies of this information shall be sent to the CTO/DO Manager and to the project files. The CTO/DO Manager shall review all well development logs on a minimum monthly basis.

7.0 HEALTH AND SAFETY

Standard Health and Safety (H&S) practices shall be observed according to the site-specific Health and Safety Plan (HSP). Prior monitoring should have determined contaminant concentrations and thus established the required level of personal protective equipment (PPE).

Suggested minimum protection during well development activities shall include inner disposable vinyl gloves, outer chemical protective nitrile gloves, rubberized steel-toed boots, and an ANSI-Standard hard hat. Half-face respirators and cartridges and Tyvek® suits may be necessary depending on the contaminant concentrations, and shall always be available onsite.

Depending upon the type of contaminant expected or determined in previous sampling efforts, the following safe work practices will be employed:

<u>Particulate or Metal Compounds</u>

1. Avoid skin contact with and/or incidental ingestion of purge water.

2. Wear long sleeved protective gloves and splash protection (i.e., Saranex or splash suits and face shields) as warranted.

<u>Volatile Organic Compounds</u>

1. Avoid breathing constituents venting from the well by approaching upwind, and/or by use of respiratory protection.

2. Presurvey the well head-space with a flame ionization detector/photoionization detector (FID/PID) prior to sampling.

3. If monitoring results indicate organic vapors that exceed action levels as specified in the HSP, sampling activities may need to be conducted in Level C protection. At a minimum, skin protection will be required by use of Tyvek® or other media that protects against the media being encountered.

Physical Hazards Associated With Well Development

1. To avoid lifting injuries associated with pump and bailers retrieval, use large muscles of the legs, not the back.

2. Stay clear of all moving equipment and avoid wearing loose fitting clothing.

3. When using pocket knives for cutting purposes, cut away from self.

4. To avoid slip/trip/fall (wet) conditions as a result of pump discharge, use textured boots/boot cover bottoms.

5. To avoid heat/cold stress as a result of exposure to extreme temperatures and PPE, drink electrolyte replacement fluids (1-2 cups/hour is recommended) and, in cases of extreme cold, wear fitted insulating clothing.

6. Be aware of restricted mobility due to the wearing of PPE.

8.0 REFERENCES

Driscoll, F.G. 1987. Ground Water and Wells. Published by Johnson Division, St. Paul, Minnesota.

USEPA. 1992. RCRA, Ground Water Monitoring Technical Enforcement Guidance Document. U.S. Environmental Protection Agency/530/R-93/001. November.

U.S. EPA Environmental Response Team. 1988. Response Engineering and Analytical Contract Standard Operating Procedures. U.S. EPA, Research Triangle Park, NC.

SOP I-F, *Equipment Decontamination*

9.0 ATTACHMENTS

1. Well Development Record

Attachment 1-C-2-1
Well Development Record

PROJECT		WELL	NO.
JOB NO	SITE	PREPARED BY	

WELL DEVELOPMENT LOG

METHOD		REMARKS
OVERPUMPAGE ________	INITIAL WATER LEVEL ________	
BAILER ________	FINAL WATER LEVEL ________	
SURGE BLOCK ________	CAPACITY OF CASING (GALLONS/LINEAR FOOT) 2" = 0 16 4" = 0.65 6" = 1 47	VOLUME BETWEEN CASING AND HOLE (GALLONS/LINEAR FOOT) (ASSUMING 40% POROSITY) 2" CASING AND 6" HOLE - 0 52 2" CASING AND 8" HOLE - 0 98 4" CASING AND 10" HOLE = 1 37 4" CASING AND 12" HOLE - 2.09
AIR LIFT ________		
OTHER ________		

HOLE DIAMETER d_h = ____

WELL CASING INSIDE DIAMETER $d_w ID$ = ____

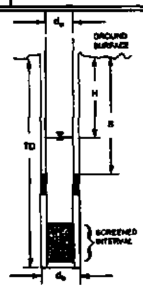
OUTSIDE DIAMETER $d_w OD$ = ____

DEPTH TO: WATER LEVEL H = ____

BASE OF SEAL S = ____

BASE OF WELL TD = ____

EST. FILTER PACK POROSITY P = ____



WELL VOLUME CALCULATION

CASING VOLUME = $V_c = \pi\left(\frac{d_w ID}{2}\right)^2 (TD - H) = 3\,14\left(\frac{\quad}{2}\right)^2(\_\_\_ - \_\_\_) = \_\_\_$

FILTER PACK PORE VOLUME = $V_f = \pi\left[\left(\frac{d_h}{2}\right)^2 - \left(\frac{d_w OD}{2}\right)^2\right]\left(TD - (S \text{ or } H^*)\right)(P) = \_\_\_$

(*if S > H, use S, if S < H, use H)

$= 3\,14\left[\left(\frac{\quad}{2}\right)^2 - \left(\frac{\quad}{2}\right)^2\right](\_\_\_ - \_\_\_)(\_\_\_) = \_\_\_$

TOTAL WELL VOLUME = $VT = Vc + Vf$ = ____ + ____ = ____ ft^3 x 7 48 = ____ gal

DEVELOPMENT LOG:

DATE	TIME BEGIN/END	METHOD	ELAPSED TIME	FLOW RATE (gpm)	CUMULATIVE WATER REMOVED GALLONS	WATER QUALITY: pH	TEMP	CONDUC-TIVITY	D O *	REDOX	TURBID-ITY	COMMENTS

* = Dissolved Oxygen

MONITORING WELL SAMPLING

1.0 PURPOSE

This standard operating procedure (SOP) describes the monitoring well sampling procedures to be used by U.S. Navy PACDIV IRP personnel.

2.0 SCOPE

This document applies to all U.S. Navy PACDIV IRP personnel involved in ground-water and sampling activities.

This procedure shall serve as management-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in planning or in the execution of planned activities must be approved by the CTO/DO Manager and Technical Director/QA Program Manager.

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

The CTO/DO Manager is responsible for ensuring that these standard ground-water sampling activities are followed during projects conducted under the U.S. Navy PACDIV IRP.

The Field Manager is responsible for ensuring that all project field staff follow these procedures.

The Technical Director/QA Program Manager is responsible for conducting evaluations to ensure that these procedures are being followed throughout the U.S. Navy PACDIV IRP.

Minimum qualifications for sampling personnel are that one individual in the field team shall have a minimum of 6 months of experience with sampling monitoring wells.

It is the responsibility of the field sampler and/or task manager to directly supervise the ground-water sampling procedures and ensure that they are conducted according to proper protocol as described within this procedure, and to record all pertinent data collected during sampling. If deviations from the procedure are required because of anomalous field conditions, they must first be approved by the Technical Director/QA Program Manager and then documented in the field logbook and associated report or equivalent document.

5.0 PROCEDURE

5.1 PURPOSE

This procedure establishes the method for sampling ground-water monitoring wells for water-borne contaminants and general ground-water chemistry. The objective is to obtain ground-water samples of aquifer conditions with as little alteration of water chemistry as possible.

5.2 PREPARATION

5.2.1 Site Background Information

A thorough understanding of the purposes of the sampling event shall be established prior to commencing field activities. A review of all available data obtained from the site and pertinent to the water sampling shall also be conducted. Available well history data to be reviewed shall include, but not be limited to, well locations, sampling history, purging rates, turbidity problems, previously used purging methods, well installation methods, well completion records, well development methods, previous analytical results, presence of an immiscible phase, historical water levels, and general hydrogeologic conditions.

Previous ground-water development and sampling logs give a good indication of well purging rates and the types of problems that may be encountered during sampling, such as excessive turbidity and low well yield. They may also indicate where dedicated pumps are placed in the water column. To help minimize the potential for cross-contamination, well purging and sampling, and water level measurement collection shall proceed from the least contaminated to the most contaminated as indicated in previous analytical results. This order may be changed in the field if conditions warrant, particularly if dedicated sampling equipment is used. A review of prior sampling procedures and results may also identify which purging and sampling techniques are appropriate for the parameters to be tested under a given set of field conditions.

5.2.2 Ground-Water Analysis Selection

The requisite field and laboratory analyses shall be established prior to performing water sampling. The types and numbers of quality assurance/quality control (QA/QC) samples to be collected (refer to SOP III-B, *Field QC Samples*) shall be decided, as shall the type and volume of sample preservatives, the number of sample containers (e.g., coolers), and the quantity of ice or other chilling materials. The sampling personnel shall ensure that the appropriate number of properly sized sample containers are brought to the site, including extras in case of breakage or unexpected field conditions. A written Analytical Plan shall be prepared prior to the sampling event and included in the project specific sampling and analysis plan.

5.3 GROUND-WATER SAMPLING PROCEDURES

Ground-water sampling procedures at a site shall include: (1) measurement of well depth to ground water, (2) assessment of the presence or absence of an immiscible phase, (3) assessment of purge parameter stabilization, (4) purging of static water within the well and well bore, and (5) obtaining a ground-water sample. Each step is discussed in sequence below. Depending upon specific field conditions, additional steps may be necessary. As a rule, at least 24 hours should separate well development and well sampling events.

5.3.1 Measurement of Static Water Level Elevation

The depth to standing water and the total depth of the well shall be measured to the nearest 0.01 foot to provide baseline hydrologic data, to calculate the volume of water in the well, and to provide information on the integrity of the well (e.g., identification of siltation problems). Each well shall be marked with a permanent, easily identified reference point for water level measurements whose location and elevation have been surveyed.

Before purging well, water levels should be measured in all of the wells within the zone of influence of the well being purged. Water levels should be measured twice in quick succession and each measurement recorded. This will provide a water level database that describes water levels across the site at one time (a synoptic sampling). The water level in each well shall also be measured immediately prior to well purging.

The device used to measure the water level surface and depth of the well shall be sufficiently sensitive and accurate so that a measurement to the nearest 0.01 foot can be obtained reliably. An electronic water level meter will usually be appropriate for this measurement; however, when the ground water within a particular well is highly contaminated, an inexpensive weighted tape measure can be used to determine well depth to prevent adsorption of contaminants onto the meter tape. The presence of light, non-aqueous phase liquids (LNAPLs) and/or dense, non-aqueous phase liquids (DNAPLs) in a well requires measurement of the elevation of the top and the bottom of the product, generally using an interface probe. Water levels in such wells must then be corrected for density effects to accurately determine the elevation of the water table.

5.3.2 Decontamination of Equipment

A decontamination station shall be established before beginning sampling. The station shall consist of an area of at least 4 feet by 2 feet covered with plastic sheeting and be located upwind of the well being sampled. The station shall be large enough to fit the appropriate number of wash and rinse buckets, and have sufficient room to place equipment after decontamination. One central cleaning area may be used throughout the entire sampling event. The area around the well being sampled shall also be covered with plastic sheeting to prevent spillage. Further details are presented in SOP I-F, *Equipment Decontamination.*

Each piece of equipment shall be decontaminated prior to entering the well. Decontamination shall also be conducted prior to the start of sampling at a site, even if the equipment is known to have been decontaminated subsequent to its last usage. This precaution is taken to minimize the potential for cross-contamination. Additionally, each piece of equipment used at the site shall be decontaminated prior to leaving the site. Dedicated sampling equipment need only be decontaminated prior to installation within the well. Clean sampling equipment shall not be placed directly on the ground or other contaminated surfaces prior to insertion into the well. Dedicated sampling equipment that has been certified by the manufacturer as being decontaminated can be placed in the well without onsite decontamination.

5.3.3 Detection of Immiscible Phase Layers

The following steps for detecting the presence of LNAPL and DNAPL shall be completed before the well is evacuated for conventional sampling:

1. Sample the headspace in the well head immediately after the well is opened for organic vapors using either a photoionization detector (PID) or an organic vapor analyzer (OVA), and record measurements.

2. Lower an interface probe into the well to determine the existence of any immiscible layer(s), LNAPL and/or DNAPL, and record measurements.

3. Confirm the presence or absence of an immiscible phase by slowly lowering a clear bailer to the appropriate depth, then visually observing the results after sample recovery.

4. In rare instances such as when very viscous product is present, it may be necessary to utilize hydrocarbon- and water-sensitive paste for measurement of LNAPL thickness. This is accomplished by smearing adjacent, thin layers of both hydrocarbon- and water-sensitive pastes along a steel measuring tape and inserting the tape into the well. An engineering tape showing tenths and hundredths of feet is required. Record depth to water, as shown by the mark on the water-sensitive paste, and depth to product, as shown by the mark on product-sensitive paste. In wells where the approximate depth to water and product thickness are not known, it is best to apply both pastes to the tape over a fairly long interval (5 feet or more). Under these conditions, measurements are obtained by trial and error, and may require several insertions and retrievals of the tape before product and water are encountered by the paste covered interval of the tape. In wells where approximate depths of air-product and product-water interfaces are known, pastes may be applied over shorter intervals. Water depth measurements

should not be used in preparation of water-table contour maps until they are corrected for depression by the product.

If the well contains an immiscible phase, it may be desirable to sample this phase separately. Immiscible phase sampling procedures are presented in Sections 5.3.5.1 and 5.3.5.2. It may also not be meaningful to conduct water sample analysis of water obtained from a well containing LNAPLs or DNAPLs. The CTO/DO Manager and U.S. Navy PACDIV IRP Technical Director shall be consulted if this situation is encountered.

5.3.4 Purging Equipment and Use

The water present in a well prior to sampling may not be representative of *in situ* ground-water quality and shall be removed prior to sampling. All ground-water removed from potentially contaminated wells shall be handled in accordance with the investigation-derived waste (IDW) handling procedures described in SOP I-A-7, *IDW Management*.

Purging shall be accomplished by removing ground water from the well at low flow rates using a pump. According to the USEPA (1992), the rate at which ground water is removed from the well during purging ideally should be less than 0.2 to 0.3 L/min. The USEPA further states that wells should be purged at rates below those used to develop the well to prevent further development of the well, to prevent damage to the well, and to avoid disturbing accumulated corrosion or reaction products in the well. The USEPA also indicates that wells should be purged at or below their recovery rate so that migration of water in the formation above the well screen does not occur.

Realistically, the purge rate should be low enough that substantial drawdown in the well does not occur during purging. A low purge rate also will reduce the possibility of stripping VOCs from the water, and will reduce the likelihood of mobilizing colloids in the subsurface that are immobile under natural flow conditions.

The sampler shall ensure that purging does not cause formation water to cascade down the sides of the well screen. Wells shall not be purged to dryness if recharge causes the formation water to cascade down the sides of the screen, as this will cause an accelerated loss of volatiles. This problem should be anticipated; water shall be purged from the well at a rate that does not cause recharge water to be excessively agitated unless an extremely slow recharging well is encountered where complete evacuation is unavoidable.

In high yield wells (wells that exhibit 80% recovery in less than 2 hours), purging shall be conducted at relatively low flow rates and shall remove water from the entire screened interval of the well to ensure that fresh water from the formation is present throughout the entire saturated interval. In general, the intake of the purge pump shall be placed 2 to 3 feet below the air-water interface within the well to allow purging and at the same time minimize disturbance/overdevelopment of the screened interval in the well. During the well purging procedure, water level and/or product level measurements shall be collected to assess the hydraulic effects of purging. The well can then be sampled when it recovers sufficiently to provide enough water for the analytical parameters specified.

For low yield wells (those that exhibit less than 80% recovery in less than 2 hours), one borehole volume of water shall be removed. The well then shall be allowed to recover sufficiently to provide enough water for the specified analytical parameters, and sampled.

Water samples shall be evaluated on a regular basis during well evacuation and analyzed in the field preferably using in-line devices for temperature, pH, specific conductivity, dissolved oxygen, Redox potential, and turbidity. At least four to six readings shall be taken during the purging process. These parameters are measured to demonstrate that the natural character of the formation waters has been restored. Purging shall be considered complete when two or three consecutive field parameter measurements stabilize within approximately 10%. This criterion may not be applicable to temperature if a submersible pump is used during purging due to the heating of the water by the pump motor. All information obtained during the purging and sampling process shall be entered into a ground-water sampling log (Figure I-C-3-1). All blanks on this field log shall be completed during field sampling.

In cases where an LNAPL has been detected in the monitoring well, a stilling tube of a minimum diameter of 2 inches shall be inserted into the well prior to well purging. The stilling tube shall be composed of a material that meets the performance guidelines for sampling devices. The stilling tube shall be inserted into the well to a depth that allows ground water from the screened interval to be purged and sampled, but that is below the upper portion of the screened interval where the LNAPL is entering the well screen. The goal is to sample the aqueous phase (ground water) while preventing the LNAPL from entering the sampling device. To achieve this goal, the stilling tube must be inserted into the well in a manner that prevents the LNAPL from entering the stilling tube. One method

Figure 1-C-3-1

GROUND-WATER SAMPLING LOG

WELL NO ____________ LOCATION: ________ PROJECT NO: ____________

DATE: __________ TIME: __________ CLIMATIC CONDITIONS: ______________

STATIC WATER LEVEL: ____________ TOTAL DEPTH: ______________

WELL PURGING LENGTH OF SATURATED ZONE: ____________ LINEAR FEET

VOLUME OF WATER TO BE EVACUATED: ____________ GALS /LINEAR FT. X

LINEAR FT. OF SATURATION X CASING VOLUMES = ____ GALS.

METHOD OF REMOVAL: ____________ PUMPING RATE: ________

WELL PURGE DATA:

DATE/ TIME	GALLONS REMOVED	pH	SP. COND	D.O	REDOX	TURBIDITY

SAMPLE WITHDRAWAL METHOD: ______________________

APPEARANCE OF SAMPLE COLOR ______________________

TURBIDITY ______________________

SEDIMENT ______________________

OTHER ______________________

LABORATORY ANALYSIS PARAMETERS AND PRESERVATIVES ______________________

NUMBER AND TYPES OF SAMPLE CONTAINERS USED. ______________________

SAMPLE IDENTIFICATION NUMBER(S) ______________________

DECONTAMINATION PROCEDURES: ______________________

NOTES: ______________________

SAMPLED BY ______________________

SAMPLES DELIVERED TO: ______________ TRANSPORTERS ______________

DATE: ______________ TIME: ______________

CAPACITY OF CASING (GALLONS/LINEAR FOOT)
2"-0.16•4"-0.65•6"-1.47•8"-2.61•10"-4.08•12"-5.87

of doing this is to cover the end of the stilling tube with a membrane or material that will be ruptured by the weight of the pump. A piece of aluminum foil can be placed over the end of the stilling tube. The stilling tube is lowered slowly into the well to the appropriate depth and then attached firmly to the top of the well casing. When the pump is inserted, the weight of the pump breaks the foil covering the end of the tube, and the well can be purged and sampled from below the LNAPL layer. The membrane or material that is used to cover the end of the stilling tube must be fastened firmly so that it remains attached to the stilling tube when ruptured. Moreover, the membrane or material must retain its integrity after it is ruptured. Pieces of the membrane or material must not fall off of the stilling tube into the well. Although aluminum foil is mentioned in this discussion as an example of a material that can be used to cover the end of the tube, a more chemically inert material may be required, based on the site-specific situation. Stilling tubes shall be thoroughly decontaminated prior to each use. Ground water removed during purging shall be collected and stored onsite until its disposition is determined based upon laboratory analytical results. Storage shall be in secured containers such as DOT-approved drums. Containers of purge water shall be labeled with the standard U.S. Navy PACDIV IRP IDW label.

The following paragraphs list available purging equipment and methods for their use.

5.3.4.1 Bailers and Pumps

1. **Submersible Pump:** A stainless steel submersible pump may be utilized for the purging of both shallow and deep wells prior to sampling the ground water for volatile, semivolatile, and non-volatile constituents. For wells over 200 feet deep, the submersible pump is one of the few technologies available to feasibly accomplish purging under any yield conditions. For shallow wells with low yields, submersible pumps are generally inappropriate due to overpumpage of the wells (<1 gallon per minute), which causes increased aeration of the water within the well.

   Prior to the placement of the pump in the well, the pump and discharge tubing shall be steam cleaned or otherwise decontaminated. The submersible pump shall be equipped with an anti-backflow check valve to limit the amount of water that will flow back down the drop pipe into the well. The pump intake shall be placed approximately 2 to 3 feet below the air-water interface within the well and maintained in that position during purging. Additionally, when the pump is being pulled out of the well subsequent to purging, care shall be taken to avoid dumping water within the drop pipe and pump stages back into the well.

2. **Bladder Pump:** A stainless steel and/or Teflon® bladder pump can be utilized for purging and sampling wells up to 200 feet in depth for volatile, semivolatile, and non-volatile constituents. Additionally, the bladder pump can be utilized for purging and obtaining ground-water samples overlain by a LNAPL layer as long as care is taken not to draw the product layer into the bladder pump. Use of the bladder pump is most effective in low to moderate yield wells where the pump can cause depression of the water table and allow significant inflow of fresh formation water.

   The bladder pump can be operated by either compressed dry nitrogen or compressed dry air depending upon availability. Note that the driving gas utilized must be dry to avoid damage to the bladder pump control box. Decontamination of the bladder pump must be accomplished prior to use. Once purging is complete, the samples can be collected directly from the bladder pump.

3. **Centrifugal or Diaphragm Pump:** A centrifugal or diaphram pump may be utilized to purge a well if the water level is within 20 feet of ground surface. A new or properly decontaminated hose is lowered into the well and water withdrawn at a rate that does not cause excessive well drawdown. The hose bottom shall be placed approximately 2 to 3 feet below the air-water interface and maintained in that position during purging.

4. **Air Lift Pump:** Air lift pumps are not appropriate for purging or sampling.

5. **Bailer:** Using a bailer to purge a well should be avoided because it can result in overdevelopment of the well and create excessive purge rates. If a bailer must be used, the bailer, bailer wire, and reel must be decontaminated as described in Section 5.3.2 prior to its use. Teflon®-coated cable mounted on a reel is recommended for lowering the bailer in and out of the well.

The bailer shall be lowered below the water level of the well with as little disturbance of the water as possible to minimize aeration of the water in the well. One way to gauge the depth of water on the reel is to mark the depth to water on the bailer wire with a stainless steel clip. In this manner, less time is spent trying to identify the water level in the well. Use of bailers for purging monitoring wells shall be approved in advance by the Technical Director/QA Program Manager.

5.3.5 Monitor Well Sampling Methodologies

5.3.5.1 Sampling Light, Non-Aqueous Phase Liquids (LNAPL)

LNAPL, if present, must be collected prior to any purging activities. The sampling device shall generally consist of a dedicated or disposable bailer equipped with a bottom-discharging device. The bailer shall be lowered slowly until contact is made with the surface of the LNAPL, and lowered to a depth less than that of the immiscible fluid/water interface depth as determined by measurement with the interface probe. The bailer shall then be allowed to fill with the LNAPL and retrieved.

When sampling LNAPLs, bailers should never be dropped into a well and should be removed from the well in a manner that causes as little agitation of the sample as possible. For example, the bailer should not be removed in a jerky fashion or be allowed to continually bang against the well casing as it is raised. When using bailers to collect LNAPL samples for inorganic analyses, the bailer shall be composed of fluorocarbon resin. Bailers used to collect LNAPL samples for organic analyses shall be constructed of stainless steel. The cable used to raise and lower the bailer shall be composed of an inert material (e.g., stainless steel) or coated with an inert material (e.g., PTFE).

5.3.5.2 Sampling Dense, Non-Aqueous Phase Liquids (DNAPL)

DNAPL shall be collected prior to any purging activities. The best method for collecting DNAPL is to use a double check valve, stainless steel bailer, or a Kemmerer (discrete interval) sampler. The sample shall be collected by slow, controlled lowering of the bailer to the bottom of the well, activation of the closing device, and retrieval.

5.3.5.3 Ground-Water Sampling Methodology

The well shall be sampled when ground-water within it is representative of aquifer conditions and after it has recovered sufficiently to provide enough volume for the ground-water sampling parameters. A period of no more than 2 hours shall elapse between purging and sampling to prevent ground-water interaction with the casing and atmosphere. This may not be possible with a slowly recharging well. Water level shall be measured and recorded prior to sampling to demonstrate the degree of recovery of the well. Sampling equipment (e.g., especially bailers) shall never be dropped into the well, because this could cause aeration of the water upon impact. Additionally, the sampling methodology utilized shall allow for the collection of a ground-water sample in as undisturbed a condition as possible, minimizing the potential for volatilization or aeration. This includes minimizing agitation and aeration during transfer to sample containers.

Sampling equipment shall be constructed of inert material. Equipment with neoprene fittings, PVC bailers, tygon tubing, silicon rubber bladders, neoprene impellers, polyethylene, and viton is not acceptable. If bailers are used, an inert cable/chain (e.g., fluorocarbon resin-coated wire or single strand stainless steel wire) shall be used to raise and lower the bailer. Generally, bladder and submersible pumps are acceptable sampling devices for all analytical parameters. Dedicated equipment is highly recommended for all sampling programs. The following text describes sampling methods utilizing submersible pumps, bladder pumps and bailers.

1. **Submersible Pumps:** When operated under low-flow rate conditions (100 to 300 ml/minute or less) submersible pumps are as effective as bladder pumps in acquiring samples for volatile organic analysis as well as other analytes. The submersible pump must be specifically designed for ground-water sampling (i.e., pump composed of stainless steel and PTFE, sample discharge lines composed of PTFE) and must have a controller mechanism allowing flow of the required low flow rate. The pump rate must be adjusted so that flow is continuous and does not pulsate to avoid aeration and agitation within the sample discharge lines. The pump shall be run for several minutes at the low flow rate used for sampling to ensure that the ground water in the lines was obtained at the low flow rate. Higher pumping rates than 100 to 300 ml/minute may be used when collecting

samples to be analyzed for non-volatile constituents, if significant drawdown does not occur.

2. **Bladder Pumps:** A gas-operated Teflon® or stainless steel bladder pump with adjustable flow control and equipped with Teflon®-lined tubing can be effectively utilized to collect a ground-water sample and is considered to be the best overall device for sampling inorganic and organic constituents. Positive gas displacement bladder pumps shall be operated in a continuous manner so that they minimize discharge pulsation that can aerate samples in the return tube or upon discharge. If a bladder pump is utilized for the well purging process, the same bladder pump can also be utilized for sample collection after purging is complete.

   Before the compressor is started, several precautions must be taken. First, position the gas operated compressor downwind of the well cap. Second, ground the engine block. This can be done by connecting a wire (with clips on either end) to the engine and to a stake that has been hammered into the ground. Third, make sure the purge water exiting the well is collected into a drum or bucket. Finally, connect the red compression hose from the well cap to the control box. Do not connect the compression hose from the compressor to the control box until after the engine has been started.

   When all precautions are completed and the engine has been started, connect the compression hose to the control box. Slowly adjust the control knobs so as to discharge water in the shortest amount of time but maintaining a near constant flow. This does not mean that the compressor must be set so as to discharge the water as hard as possible. The optimal setting is one that produces the largest volume of purge water per minute (not per purge cycle) while maintaining a near constant flow rate.

   Prior to sampling, the flow rate (purge rate) must be adjusted to yield 100 to 300 milliliter (ml) per minute. Avoid settings that produce pulsating streams of water instead of a steady stream. The pump shall be operated at this low flow rate for several minutes to ensure that the ground water being sampled is being withdrawn at the low extraction rate. The flow rate of 100 ml/minute must be obtained so as not to cause fluctuation in pH, pH-sensitive analytes, and the loss of volatile constituents. Higher flow rates can be used once the samples for the analysis of volatile components have been collected. At no time shall the sample flow rate exceed the flow rate used while purging. The natural conditions of the ground-water shall be preserved, as defined by pH, DO, specific conductivity and redox.

For those samples requiring filtration, it is recommended that an in-line high capacity filter be used after all nonfiltered samples have been collected.

3. **Bailers:** A single- or double-check valve Teflon® or stainless steel bailer equipped with a bottom discharging device can be utilized to collect ground-water samples. Bailers have a number of disadvantages, however, including a tendency to alter the chemistry of ground-water samples due to degassing, volatilization, and aeration; the possibility of creating high ground-water entrance velocities; differences in operator techniques resulting in variable samples; and difficulty in determining where in the water column the sample was collected. Bailers therefore shall be used for ground-water sampling only when other types of sampling devices cannot be utilized for technical or logistical reasons. The use of bailers for ground-water sampling shall be approved in advance by the Technical Director/QA Program Manager.

   The bailer shall be thoroughly decontaminated before being lowered into the well if they are not disposable bailers sealed in plastic. Two to three rinse samples shall be collected and discharged prior to acquisition of the actual sample. Each time the bailer is lowered to the water table, it shall be lowered in such a way as to minimize disturbance and aeration of the water column within the well.

   The preferred alternative when using bailers for sampling is to use disposable Teflon® bailers equipped with bottom-discharging devices. Use of disposable bailers reduces decontamination time and limits the potential for cross-contamination.

5.3.6 Sample Handling and Preservation

Many of the chemical constituents and physiochemical parameters to be measured or evaluated during ground-water monitoring programs are chemically unstable, therefore samples must be preserved. The U.S. Environmental Protection Agency document entitled *Test Methods for Evaluating Solid Waste – Physical/Chemical Methods (SW-846)*, includes a discussion of appropriate sample preservation procedures. In addition, SW-846 specifies the sample containers that shall be used for each constituent or common set of parameters. In general, check with specific laboratory requirements prior to obtaining field samples. In many cases, the laboratory will supply the necessary sample bottles and required preservatives. In some cases, the field team may add preservatives in the field.

Improper sample handling may alter the analytical results of the sample. Therefore, samples shall be transferred in the field from the sampling equipment directly into the container that has been prepared specifically for that analysis or set of compatible parameters as described in the CTO/DO-specific Quality Assurance Project Plan. It is not an acceptable practice for samples to be composited in a common container in the field and then split in the laboratory, or poured first into a wide mouth container and then transferred into smaller containers.

Ground-water samples shall be collected and placed in their proper containers in the order of decreasing volatility and increasing stability. A preferred collection order for some common ground-water parameters is:

- Volatile organic constituents (VOCs) and total organic halogens (TOX)
- Dissolved gases, total organic carbon (TOC), total fuel hydrocarbons
- Semivolatile organics, pesticides
- Total metals, general minerals (unfiltered)
- Dissolved metals, general minerals (filtered)
- Phenols

- Cyanide
- Sulfate and chloride
- Turbidity
- Nitrate and ammonia
- Radionuclides

When sampling for VOCs, water samples shall be collected in vials or containers specifically designed to prevent loss of VOCs from the sample. These vials shall be provided by an analytical laboratory, preferably by the laboratory that will perform the analysis. Ground water from the sampling device shall be collected in vials by allowing the ground water to slowly flow along the sides of the vial. Sampling equipment shall not touch the interior of the vial. The vial shall be filled above the top of the vial to form a positive meniscus with no overflow. No headspace shall be present in the sample container once the container has been capped. This can be checked by inverting the bottle once the sample is collected and tapping the side of the vial to dislodge air bubbles. Sometimes it is not possible to collect a sample without air bubbles, particularly water that is aerated. In these cases, the investigator shall note the problem to account for possible error. Cooling samples may also produce headspace, but this will typically disappear once the sample is warmed prior to analysis. In addition, if the samples are shipped by air, air bubbles form most of the time. Field logs and laboratory analysis reports shall note any headspace in the sample container(s) at the time of receipt by the laboratory, as well as at the time the sample was first transferred to the sample container at the wellhead.

5.3.6.1 Special Handling Considerations

Samples requiring analysis for organics shall not be filtered. Samples shall not be transferred from one container to another because this could cause aeration or a loss of organic material onto the walls of the container. Total organic halogens (TOX) and total organic carbon (TOC) samples shall be handled and analyzed in the same manner as VOC samples.

Ground-water samples to be analyzed for metals shall be obtained sequentially. One sample shall be obtained directly from the pump and be unfiltered. The second sample shall be filtered through a 0.45-micron membrane in-line filter, transferred to a container, preserved with nitric acid to a pH less than 2, and analyzed for dissolved metals. Remember to include a filter blank for each lot of filters used and always record the lot number of the filters. In addition, allow at least 500 ml of effluent to flow through the filter prior to sampling. Any difference in concentration between the total and dissolved fractions may be attributed to the original metallic ion content of the particles and adsorption of ions onto the particles.

5.3.6.2 Field Sampling Preservation

Samples should be preserved immediately upon collection. Ideally, sample jars contain preservatives of known concentration and volume during the initial filling of the jar to a predetermined final sample volume. For example, metals require storage in aqueous media at pH of 2 or less. Typically, 0.5 ml of 1:1 nitric acid added to 500 ml of ground water will produce a pH less than 2.0. Certain matrices that have alkaline pH (greater than 7) may require more preservative than is typically required. An early assessment of preservation techniques, such as the use of pH strips after initial preservation, may therefore be appropriate. It should be noted that introduction of preservatives will dilute samples, and may require normalization of results. Guidance for the preservation of environmental samples can be found in the EPA "Handbook for Sampling and Sample Preservation of Water and Wastewater:" (EPA 1982). Additional guidance can be found in other EPA documents (EPA 1992, EPA 1995.)

5.3.6.3 Field Sampling Log

A ground-water sampling log (Figure I-C-3-1) shall document the following:

- Identification of well
- Well depth
- Static water level depth and measurement technique
- Presence of immiscible layers and detection method
- Well yield

- Purge volume and pumping rate
- Time that the well was purged
- Collection method for immiscible layers
- Sample identification numbers
- Well evacuation procedure/equipment
- Sample withdrawal procedure/equipment
- Date and time of collection
- Well sampling sequence
- Types of sample containers used and sample identification numbers
- Preservative(s) used
- Parameters requested for analysis
- Field analysis data
- Sample distribution and transporter
- Field observations on sampling event;
- Name of collector
- Climatic conditions including air temperature

6.0 RECORDS

Information collected during ground-water sampling should be documented on the ground-water sampling log form in indelible ink (Figure I-C-3-1.) Copies of this information shall be sent to the CTO/DO Manager and to the project files. The CTO/DO Manager or designee shall review all ground-water sampling forms on a minimum monthly basis.

7.0 HEALTH AND SAFETY

Depending upon the site-specific contaminants, various protective programs must be implemented prior to sampling the first well. The site-specific Health and Safety Plan (HSP) should be reviewed paying particular attention to the control measures planned for the well sampling tasks. Preliminary area monitoring of sampling wells should be conducted to determine the potential hazard to sampling personnel. If significant contamination is observed, contact with potential contaminants in both vapor phase and liquid matrix shall be minimized through the use of respirators and disposable clothing.

Depending upon the type of contaminant expected or determined in previous sampling efforts, the following safe work practices shall be employed:

Particulate or Metal Compounds

1. Avoid skin contact with and/or incidental ingestion of purge water.

2. Wear long-sleeved protective gloves and splash protection (i.e., Saranex or splash suits and face shields) as warranted.

3. Use of eye protection and gloves when handling acid or caustic preservatives.

Volatile Organic Compounds

1. Avoid breathing constituents venting from the well by approaching upwind, and/or by use of respiratory protection.

2. Presurvey the well head-space with a flame ionization detector/photoionization detector (FID/PID) prior to sampling.

3. If monitoring results indicate organic vapors that exceed action levels as specified in the HSP, sampling activities may need to be conducted in Level C protection. At a minimum, skin protection will be required by use of Tyvek® or other media that is protective against the media being encountered.

Physical Hazards Associated With Well Sampling:

1. To avoid lifting injuries associated with pump and bailers retrieval, use large muscles of the legs, not the back.

2. Stay clear of all moving equipment and avoid wearing loose fitting clothing.

3. When using pocket knives for cutting purposes, cut away from self.

4. To avoid slip/trip/fall (wet) conditions as a result of pump discharge, use textured boots/boot cover bottoms.

5. To avoid heat/cold stress as a result of exposure to extreme temperatures and PPE, drink electrolyte replacement fluids (1-2 cups/hour is recommended) and, in cases of extreme cold, wear fitted insulating clothing.

6. Be aware of restricted mobility due to the wearing of PPE.

In addition, standard health and safety practices should be observed according to the site-specific HSP. Suggested minimum protection during well sampling activities shall include inner disposable vinyl gloves, outer chemical-protective nitrile gloves, rubberized steel-toed boots, and an ANSI-Standard hard hat. Half-face respirators and cartridges and Tyvek® suits may be necessary depending on the contaminant concentrations, and shall always be available onsite.

8.0 REFERENCES

EPA. 1982. Handbook for Sampling and Sample Preservation of Water and Wastewater. EPA-600/4-82-029. September 1982.

NJDEP. 1986. Field Sampling Procedures Manual. New Jersey Department of Environmental Protection.

SOP I-A-7, *IDW Management*

SOP I-F, *Equipment Decontamination*

SOP III-B, *Field QC Samples*

USEPA. 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document.

USEPA. 1992. RCRA Ground-Water Monitoring: Draft Technical Enforcement Guidance Document.

USEPA. 1995 and as revised. Test Methods for Evaluating Solid Waste–Physical/Chemical Methods (SW-846). January 1995.

USEPA. 1994a and as revised. Contract Laboratory Program (CLP) Statement of Work (SOW) for Organic Analysis.

USEPA. 1994b and as revised. Contract Laboratory Program (CLP) Statement of Work (SOW) for Inorganics Analysis.

U.S. EPA Environmental Response Team. 1988. Response Engineering and Analytical Contract Standard Operating Procedures. U.S. EPA, Research Triangle Park, NC.

9.0 ATTACHMENTS

None.

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AQUIFER TESTS

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to establish standard methods by which U.S. Navy PACDIV IRP personnel should conduct aquifer tests.

2.0 SCOPE

This procedure applies to all Navy PACDIV IRP personnel involved in the conduct and preliminary interpretation of aquifer tests. It is not intended to be a comprehensive documentation of aquifer test analysis.

This procedure shall serve as management-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in the planning or execution of activities must be approved by the CTO/DO Manager and Technical Director/QA Program Manager.

3.0 DEFINITIONS

3.1 HYDRAULIC CONDUCTIVITY

The rate of flow through a unit area cross section under a unit hydraulic gradient, at the prevailing temperature. Hydraulic conductivity is typically reported as feet per day (reduced from $ft^3/day/ft^2$). In the Systems International system, the units are typically $m^3/day/m^2$ or m/day. The letter "K" is typically used to denote hydraulic conductivity.

3.2 TRANSMISSIVITY

Transmissivity (T) is the product of the hydraulic conductivity (K) and saturated aquifer thickness (b) and is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Transmissivity values are given in area per time units, typically gallons/day/ft or ft^2/day in the English system; in the SI, transmissivity is given in $m^3/day/m$ or m^2/day.

3.3 STORAGE COEFFICIENT

The volume of water an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in head. Storage coefficient (S) is unitless, and is applied only to confined aquifers. Typical values of storage coefficients range from 10^{-3} to 10^{-5}.

3.4 SPECIFIC YIELD

The ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity to the volume of that mass. Specific yield (S_y) is applied to unconfined aquifers only. Typical values of specific yield are 10^{-1} to 10^{-3}.

3.5 CONFINED AQUIFER

An aquifer situated between two layers having very low hydraulic conductivity. The water level in a well in a confined aquifer usually rises above the top of the aquifer.

3.6 UNCONFINED AQUIFER

An unconfined aquifer is also known as a water-table aquifer and is an aquifer in which the water table forms the upper boundary. The water level in an unconfined aquifer lies at the water table.

3.7 SKIN EFFECTS

An increase or decrease in measured hydraulic conductivity caused by drill cuttings or fluids accumulating along the wall of the boring.

3.8 HYDRAULIC BOUNDARIES

A geologic or hydrologic feature that affects the movement or distribution of ground water.

3.9 DELAYED YIELD

Water that drains vertically downward from the newly created unsaturated zone during an unconfined aquifer test after the water table has been lowered from its initial level.

3.10 Observation Well

A well drilled in a selected location for the purpose of observing parameters such as water levels and water quality.

3.11 Pumping Well

A well from which water is withdrawn by pumping in order to evaluate aquifer characteristics by monitoring the response to pumping in the pumping or observation wells.

3.12 Well-bore Storage Effects (Casing Effects)

The delayed drawdown response observed in the initial phases of a pump test due to removal of water from storage in the well casing and filter pack.

4.0 RESPONSIBILITIES

The CTO/DO Manager is responsible for selecting the appropriate aquifer test procedures based on the objectives of the test. The CTO/DO Manager is also responsible for ensuring that the site-specific sampling plan defines test methods clearly.

The Technical Director/QA Program Manager is responsible for conducting evaluations to ensure that these procedures are being followed throughout the U.S. Navy PACDIV IRP.

The Field Manager is responsible for supervising the test in the field. Qualifications for the Field Manager for aquifer testing include a degree in geology, hydrogeology, hydrology, or civil/environmental engineering with 2 years of experience in conducting aquifer tests and interpreting the results. The Field Manager is also responsible for assuring appropriate documentation and containment of potentially hazardous waste generated during testing.

5.0 PROCEDURES

5.1 Constant Discharge Aquifer Pumping Tests

Constant discharge pumping tests are commonly performed at hazardous waste sites to estimate the hydraulic conductivity, transmissivity, specific yield, and/or storativity of an aquifer. These data assist in analyzing contaminant fate and transport and site remediation options. A wide variety of aquifer test methods and aquifer conditions (e.g., confined, unconfined, leaky, etc.) exist and each test must consider both the goals of the test and site conditions.

Pumping tests that are properly designed and implemented can evaluate well efficiency and detect hydraulic boundaries, vertical leakage, or delayed yield effects, and allow assessment of hydraulic conductivity and storativity.

The proper design and implementation of a pumping test requires knowledge of the hydrogeologic setting. Information required prior to the design of the test includes:

- Objectives of the pumping test
- Location of observation and pumping wells
- Climatic conditions
- Screened intervals of all wells
- Installation and completion methods ("as-builts")
- Generalized hydrogeologic conditions
- Regional ground-water flow direction
- Boundary conditions
- Existence of improperly completed or developed wells
- Presence of pumping or irrigation
- Potential for the capture of insoluble or dissolved contaminants
- Hydraulic conductivity estimate for aquifer
- Presence and location of confining layers
- Potential well water disposal problems

- Potential for tidal effects

- Previous sampling results and development records.

The pumping test interpretation method is based upon an analytical solution that considers well and site conditions. The hydraulic response of the aquifer is compared to a theoretical analytical response. Different analytical solutions exist for unconfined and confined aquifers, each taking into account assumptions about test and aquifer conditions. It is important to document the assumptions applied to the interpretation of a particular test. It is beyond the scope of this procedure to provide a detailed explanation of aquifer testing analytical solutions. Several texts that address pumping test theory are included in Section 8.0, References.

Constant discharge pumping tests provide results that are more representative of aquifer characteristics than those provided by slug tests; however, pumping tests require greater effort and expense. In general, slug testing should be used only in situations where hydraulic conductivity is sufficiently low to preclude a pumping testing.

5.1.1 Interferences and Potential Problems

The conditions that exist at a site during the performance of a pumping test are often far from ideal. Hydrogeologic factors that may be encountered at a site include:

- Localized or regional pumping

- Barometric effects

- Tidal effects

- Aquifer compression (e.g., trains, traffic)

- Boundary effects

- Recharge effects

- Leakage from underlying or overlying aquifers

- Heterogeneous and anisotropic aquifers.

Many of these potential complications may be detected during the pre-test period, or anticipated from an examination of existing hydrogeological data.

Information about the location, completion, and development of the pumping and observation wells may be useful in evaluating potential complications. Complicating factors may include:

- Partially penetrating wells
- Improperly completed or developed wells
- Low-permeability conditions that may lead to well-bore storage effects, well dewatering, or slow responding observations wells
- Wells completed within aquitards, possibly designed to evaluate the pressure response and leakage into adjacent aquifers
- Potential skin effects caused by well bore conditions.

5.1.2 Pumping Test Planning

Prior to implementation of the pumping test, the following should be considered:

1. Monitoring pre-test and post-test water levels (preferably for at least 3 days). Ground-water systems are rarely static and localized conditions such as nearby pumping wells, tidal effects, barometric effects, variable recharge conditions, and other "non-ideal" conditions are likely to be present at a site.

2. The performance of a long-term, constant discharge pumping test should consider the volume of water that will be generated during the test, and storage, treatment, and disposal methods for the water generated during the test. If free product is present within the vicinity of the pumping well, an oil/water separator shall be included as part of the ground-water treatment process.

3. Observation well design, location and installation.

4. Use of subcontractors for installing and operating pumping equipment during constant discharge pumping tests.

5. Selection of pumping equipment.

6. Pump placement in well.

7. Staff scheduling, security and safety during overnight aquifer testing.

8. Consider how equipment will be decontaminated (SOP I-F, *Equipment Decontamination*) and how potentially contaminated water will be handled (SOP I-A-7, *IDW Management*.) Select, a well containing uncontaminated ground water for pump testing. Water derived from a potentially contaminated well may have to be temporarily stored onsite. Once the analytical results are obtained, the disposition of the water can be determined. In some instances, flammable/explosive fluids and gases may be collected and onsite storage procedures must allow for the hazards of storing these substances. If possible, avoid aquifer tests of highly contaminated wells.

5.1.3 Field Procedures

5.1.3.1 Preparation

1. Review the site work plan, and become familiar with information about the wells to be tested, e.g., depth to water, well depth, aquifer hydraulic conductivity, distances between pumping and observation wells, and anticipated drawdown.

2. Check out the operation of all field equipment. A data logger shall be used for all aquifer testing unless other methods are approved by the Technical Director/QA Program Manager. Ensure that the electronic data-logger is fully charged. Calibrate the electronic data-logger and transducers at measured depths in a container of water. Always bring additional transducers in case of malfunctions. Calibrate the flow meter at several known discharge rates. Ensure that the calibration is linear in the anticipated test range. Have pH and conductivity meters onsite to assess water quality periodically during the pumping test.

3. Assemble a sufficient number of field pumping test forms.

4. Ensure that the pumping well has been properly developed prior to testing.

5. If a flow meter is not operating properly, calibrate an orifice weir, bucket, or other type of water measuring device to accurately measure and monitor discharge from the pumping well.

6. Have sufficient lengths of pipe on hand to transport the discharge from the pumping well to a holding tank or to a discharge point well beyond the influence of the expected cone of depression.

7. Install a gate valve on the discharge pipe to control the pumping rate.

8. Install an outlet at the well head to obtain water quality samples during the pumping test.

9. Install a check valve on the pump so water cannot flow back into the well after the pump is shut off.

10. Install transducers in wells, making sure to secure them firmly at the well head and allow sufficient depth for drawdown (generally 5 to 10 feet below the water surface in the well). Measure the depth to the transducer and ensure that the transducer is not placed at a depth below the water surface beyond its range (this will ruin the transducer).

11. Arrange for treatment, special storage and handling, or a discharge permit before contaminated water can be pumped.

Pre-test water levels at the test site shall be monitored for at least 3 days prior to performance of the test. A continuous-recording device is recommended. This information allows researchers to determine the barometric efficiency of the aquifer when comparing with barometric readings at the site. It helps to determine if the aquifer is experiencing variations in head with time due to tidal influences or recharge or pumping in the nearby area.

If barometric pressure is found to significantly affect water levels in the aquifer, then changes in barometric pressure should be recorded during the test (preferably using an onsite barometer) in order to "correct water" levels for fluctuations that may occur because of changing atmospheric conditions. Trends in pre-test water levels can then be projected for the duration of the test. Correcting water levels during the test produce results that are representative of the hydraulic response of the aquifer caused by pumping of the test well in the absence of atmospheric pressure changes.

The influence of ocean tides or localized pumping can mask the water level response to the pumping test. Water levels can be corrected for the effect of ocean tides by adding or subtracting values of tidal fluctuation from the response of the pumping. Pumping test data can be corrected for the effect of localized pumping if the pumping response prior to the test is known and predictable over the duration of the drawdown and recovery phases of the test. Non-rhythmic and "unique" water-level fluctuations may be difficult to resolve and substantial hydrologic judgment is required to properly interpret the data.

5.1.3.2 Step Drawdown Test

Prior to initiating a constant discharge pumping test, a step drawdown test shall be conducted. The purpose of the step drawdown test is to estimate the greatest flow rate that may be sustained during a long-term test. The step drawdown test is typically conducted over a 4- to 8-hour period prior to commencing the constant discharge test.

To correctly assess the maximum yield of the well, the well must be pumped at discharge rates varying from relatively low to the maximum rate that the well can produce. The discharge increments for each step shall be distributed as evenly as possible through the range of well yields. Four steps should be utilized for the test. Each step shall last approximately 2 hours depending on the response of water levels to pumping. Water level recovery following the test shall be measured for approximately 8 hours.

Water levels shall be measured periodically during the step test within the pumping well and within observation wells that may be used during the constant discharge test. For each step increment, levels within the pumping well shall be measured on the same time basis as that used for the beginning of the constant discharge test (i.e., approximately on a logarithmic basis). Observation wells may be measured using a longer time scale since the primary reason for measurement is to assess whether the aquifer responds to pumpage rather than to gather data for quantitative analysis. Water levels shall also be measured during the recovery phase of the step test.

Prior to initiating the constant discharge test, the data from the step drawdown test shall be analyzed to identify the appropriate discharge rate for the longer term test. The generated drawdown versus time data shall be plotted on a semilogarithmic graph and the sustainable discharge rate shall be determined from this graph by projecting the straight line formed by each data set for each step increment to the longer pumping times associated with the constant discharge test. Based on the projected drawdowns associated with these longer time periods and the amount of drawdown available in the pumping well, the optimum pumping rate can be determined. The step drawdown data can also be evaluated more quantitatively using methods described by Birsoy and Summers (1980) and Lohman (1982).

5.1.3.3 Constant Discharge Pumping Test

Time Intervals

After the pumping well has fully recovered from the step drawdown test, the constant discharge pumping test may begin (typically 24 hours after step drawdown testing). At the beginning of the test, the discharge rate shall be set as quickly and accurately as possible. The water levels in the pumping well and observation wells shall be recorded using a data logger according to the following schedules:

Table I-C-4-1

PUMPING WELL MEASUREMENTS

Elapsed Time Since Start of Test (Minutes)	Intervals Between Measurements (Minutes)
0-10	.5-1
10-15	1
15-60	5
60-300	30
300-1440	60
1440-termination	480

Note: Similar time intervals shall be used during water level recovery, with short time intervals at the start of recovery.

Table I-C-4-2

OBSERVATION WELL MEASUREMENTS

Elapsed Time Since Start or Stop of Test (Minutes)	Intervals Between Measurements (Minutes)
0-60	2
60-120	5
120-240	10
240-360	30
360-1440	60
1440-termination	480

During the early part of the test, at least one person shall be stationed at the pumping well and at least one other shall handle other pump test logistics. Readings at the wells need not be taken simultaneously. It is very important that depth to water readings be measured accurately and readings be recorded at the exact time measured. Pressure transducers and electronic data-loggers must be used to record water levels in the pumping well and nearby observation wells. Manual checks of the depth to water shall be performed to verify the pressure transducer measurements. In some instances, the pressure transducer may be unstable and "drifting" may occur.

During a pumping test, the following data must be recorded on the aquifer test data form (Attachment 1):

1. Site identification - CTO/DO number, site name, well identification number, indication as to whether the well is an observation or pumping well

2. Location - The location of the well in which water level measurements are being taken

3. Distance from Pumping Well - Distance the observation well is from the pumping well in feet

4. Personnel - The company and individual conducting the pump test

5. Test Start Date - The date when the pumping test began

6. Test Start Time - Time, using 24-hour clock, at which a field measurement was taken, e.g., 10:30 hours for 10:30 a.m., and 13:50 hours for 1:50 p.m.

7. Test End Date - Same as above

8. Test End Time - Same as above

9. Depth to water in feet and to an accuracy of 0.01 feet, in the pumping well at the beginning of the pump test

10. Depth to water in feet and to an accuracy of 0.01 feet, in the observation well at the beginning of the pump test

11. Depth of pressure transducers

12. Average Pumping Rate - Summation of all entries recorded in the pumping rate (gal/min) column divided by the total number of pumping rate readings

13. Measurement Methods - Type of instrument used to measure depth-to-water (this may include steel tape, electric sounding probes, Stevens recorders, or pressure transducers)

14. Comments - Appropriate observations or information including notes on sampling

15. Actual time test started

16. Elapsed Time - Time elapsed since the start of pumping in minutes

17. Depth to Water - Depth to water, in feet, tenths and hundredths of feet, in the observation well at the time of the water level measurement

18. Pumping Rate - Flow rate of pump measured from an orifice weir, flow meter, container, or other type of water measuring device in gallons per minute

Water Chemistry Measurements

During the pumping test, portable field-grade water testing equipment should be used to measure at periodic intervals. The pH, electrical conductivity, and temperature of the water. These parameters are used to qualitatively evaluate aquifer conditions. Water testing equipment shall be recalibrated during the pump test on a predetermined schedule with known calibration standards.

Test Duration

The duration of the test depends on the properties of the aquifer that the project seeks to characterize. The duration may be determined by plotting the drawdown data on both log-log and semi-log graphs and preliminarily evaluating it during the pump test. Doing this allows possible identification of recharge boundaries or permeability barriers that might be further evaluated with a longer pump test. Optimally, flow conditions should approach steady state where the observed drawdowns reach near-constant values prior to terminating the test.

The minimum time necessary for the test is indicated on the semi-log graph when the log-time versus drawdown for the most distant observation well plots as a straight line (assuming $u < 0.01$) (Jacob's). Longer tests tend to produce more reliable results. Longer tests are usually necessary for unconfined aquifers to allow evaluation of delayed yield effects. A pumping duration of 24 to 72 hours is desirable, followed by a similar period of monitoring the recovery of the water level.

A knowledge of the local hydrogeology, combined with a clear understanding of the overall project objectives should be considered in selecting duration of the test and the effect of boundary conditions. There is little need to continue the test once the increase in drawdown in all observation wells becomes insignificantly small. However, delayed yield effects and boundary effects may be observed with continued pumping.

Recovery

Once the pump has been shut down, the recovering water levels shall be recorded in the same manner and using the same time intervals as were used during the beginning of the constant discharge test (i.e., at approximately logarithmic time intervals). Recovery shall be monitored for a period corresponding to the length of the pumping portion of the test or when water levels have recovered to 95% of their original level. Any tidal and barometric monitoring shall be continued during the recovery portion of the test.

5.1.3.4 Post Operation

The following activities shall be performed after completion of water level recovery measurements:

1. Decontaminate and/or dispose of equipment as listed in SOP I-F, *Equipment Decontamination*.
2. For the electronic data-logger, use the following procedures:
    a) Stop logging sequence.
    b) Print data, or
    c) Save memory at the end of the day's activities.
3. Replace testing equipment in storage containers.
4. Check sampling equipment and supplies. Repair or replace all broken or damaged equipment.
5. Replace expendable items.
6. Return equipment to Equipment Manager and report incidents of malfunctions or damage.
7. Review field forms for completeness.
8. Interpret slug or aquifer test field results with Project Hydrogeologist and/or CTO/DO Manager. Analyze data using an appropriate analytical solution.

5.1.4 Pumping Test Interpretation

There are several accepted methods for determining aquifer properties such as transmissivity, storativity, and hydraulic conductivity. Kruseman and de Ridder (1990) and Freeze and Cherry (1979) present methods of interpretation. However, the appropriate method depends on the characteristics of the aquifer being tested (e.g., confined, unconfined, leaky confining layer). When reviewing pumping test data, both log-log and semi-log plots of drawdown with time shall be generated. However, log-log plots cannot be used for quantitative analysis of data obtained from the pumping well.

The interpretation of pumping test data attempts to match or duplicate the observed field response with a theoretical water level response to pumping. Aquifer parameters can be estimated on the basis of such a match, using commercially available software such as AQTESOLV.

A range of aquifer parameter values are likely to occur at a site; for example, hydraulic conductivities are typically log normally distributed. The estimate of the values may vary with the interpretation method. It is important to verify that the assumptions used to derive a particular method of solution are reasonable in view of the test conditions. For example, for a confined aquifer, storativity values should be less than 0.005.

5.1.5 Quality Assurance/Quality Control

All gauges, transducers, flowmeters, etc., used in conducting pumping tests shall be calibrated before use at the site. Copies of the documentation of instrumentation calibration should be obtained and filed with the test data records. The calibration records shall consist of laboratory measurements and, if necessary, any onsite zero adjustment and/or calibration performed. Where possible, all flow and measurement meters should be checked onsite using a container of measured volume and a stopwatch. The accuracy of the meters must be verified before testing proceeds. The water levels measured by a pressure transducer-based data logger must also be verified by manual measurements.

5.2 Slug Tests

5.2.1 Scope and Application

A common procedure for single-well hydraulic testing is a slug test. A slug test is restricted in application because it is a measure of the well and near-well hydrogeologic conditions. The results of the test provide an order of magnitude estimate of the horizontal hydraulic conductivity of the aquifer, and are most useful in low-permeability materials. Storativity cannot be determined very accurately using this method.

5.2.2 Method Summary

A slug test involves the instantaneous injection or withdrawal of a mass (slug) of water or object displacing a known volume of water into or from a well and measuring the induced water level fluctuation.

The primary advantages of using slug tests to estimate hydraulic conductivities are that (1) estimates can be made *in situ*, thereby avoiding errors incurred in laboratory testing of disturbed soil samples; (2) tests can be performed quickly at relatively low cost because only one observation well is required; and (3) the hydraulic conductivity of small discrete portions of an aquifer can be estimated (e.g., sand layers in a clay). Estimates of storativity or specific storage cannot be reliably established from slug tests. Slug tests should be used only to evaluate water-bearing zones with relatively low hydraulic conductivities. In addition, slug testing shall always be conducted with a data logger coupled to a pressure transducer.

5.2.3 Interferences and Potential Problems

The zone of investigation covered by a slug test is limited to the immediate vicinity of the well bore. Thus, interpretation of the test may be strongly influenced by the hydraulic properties of the well casing, filter pack, and borehole, and may possibly reflect variations in well development. When possible, consistent methods of well construction and development shall be used at a site to minimize the potential for variation in slug test results.

A slug test may be affected by problems associated with pump tests. Refer to Section 5.1.1 for further discussion.

Water levels within a borehole will often oscillate rapidly after the introduction/withdrawal of a slug volume. This does not indicate a problem with performance of the slug test. If a well is screened above and below the water table, a slug injection method will tend to store water in the filter pack and yield a higher estimate of hydraulic conductivity than would be expected. In these cases, the slug withdrawal method may yield more accurate data.

5.2.4 Field Procedures

5.2.4.1 Preparation

Office Procedures

1. Review the Work Plan and the procedure, including well construction, development, and sampling information on the wells to be tested.

2. Review the operator's manual provided with the electronic data-logger.

3. Verify the displacement volume of the slug. This may be accomplished by accurately measuring the dimensions of a solid displacement slug or by accurately measuring the volume of water discharge from a liquid slug.

4. Check out and ensure the proper operation of all field equipment. Ensure that the electronic data-logger is fully charged. Test the electronic data-logger using a container of water (e.g., sink, bucket of water). Additional transducers should be brought to the site in case of malfunctions.

5. Assemble a sufficient number of field forms to complete the field assignment.

6. Assemble the appropriate testing equipment.

Equipment List

The following equipment is needed to perform slug tests. All of the equipment shall be decontaminated and tested prior to commencing field activities.

- Tape measure (subdivided into tenths of feet)

- Water pressure transducer
- Electric water level indicator or steel tape (subdivided into hundredths of feet)
- Electronic data-logger
- Solid or liquid slug of a known volume (stainless steel, PVC, and ABS plastic are appropriate construction materials)
- Watch or stopwatch with second hand
- Semi-log graph paper
- Water proof ink pen and logbook
- Temperature/pH/electrical conductivity meter (optional)
- Appropriate references and calculator
- Electrical tape
- Health and safety equipment as required.

Data Form

The slug test data form shall be used to record observations. All entries shall be made in indelible ink. The form shall include the following data:

1. Site identification - identification number assigned to the site and the well.
2. Date - the date when the test data were collected: year, month, day (e.g., 960901 for September 1, 1996).
3. Slug Volume (ft^3) - manufacturer's specification for the known volume or displacement of the slug device.
4. Logger - identifies the company or person responsible for performing the field measurements.

5. Test Method - either injected (dropped) or withdrawn (pulled out) from the monitoring well

6. Comments - Appropriate observations or information for which no other blanks are provided.

7. Depth to water (ft) - Depth of water recorded to 0.01 feet.

8. Configuration of the data logger (e.g., sample rate, duration, transducer type, etc.).

5.2.4.2 Performing the Slug Test

The following procedures may be used to collect and report slug test data. They may be modified to reflect specific site conditions:

1. The electronic data-logger and pressure transducer to store all data internally or on computer diskettes or tape. Transfer the data to a computer for analysis. Keep a computer printout of the data in the field as documentation.

2. Decontaminate the transducer and cable.

3. Collect initial water level measurements from monitoring wells in an upgradient to downgradient sequence, if possible.

4. Before beginning a slug test, record information and enter it into the electronic data-logger. The type of information will vary depending on the model used. Consult the operator's manual for the proper data entry sequence.

5. Test wells from least contaminated to most contaminated, if possible.

6. Determine the static water level in a well by measuring the depth to water periodically for several minutes.

7. Cover sharp edges of the well casing with duct tape to protect the transducer cables.

8. Install the transducer and cable in the well to a depth below the target drawdown estimated for the test but at least 2 feet from the bottom of the well. Be sure this

depth of submergence is within the design range stamped on the transducer. Temporarily tape the transducer cable to the well to keep the transducer at constant depth.

9. Connect the transducer cable to the electronic data-logger.

10. Enter the initial water level and transducer design range into the recording device according to the manufacturer's instructions (the transducer design range will be stamped on the side of the transducer). Compare manual and pressure transducer measurements to check that the transducer is operational and accurate. Thermal drift may occur until the transducer equilibrates with the water in a well. Record the initial water level on the recording device.

11. "Instantaneously" introduce or remove a known volume (slug) of water to the well. The preferred test method is to introduce a solid cylinder of known volume to displace and raise the water level. Let the water level restabilize and remove the cylinder. It is important to remove or add the volumes as quickly as possible because the analysis assumes an "instantaneous" change in volume is created in the well.

12. With the moment of volume addition or removal assigned time zero, measure and record the depth to water and the time using the data logger. The number of depth-time measurements necessary to complete the test are variable and can be determined from previous aquifer tests or evaluations. It is critical to make as many measurements as possible in the early part of the test.

13. Continue measuring and recording depth-time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to clearly show a trend on a semi-log plot of time versus depth.

14. Retrieve the slug (if applicable) and follow appropriate decontamination procedures.

The time required for a slug test to be completed is a function of the volume of the slug, the hydraulic conductivity of the formation, and the type of well completion. The slug volume should be large enough that a sufficient number of water level measurements can be made before the water level returns to equilibrium conditions. The length of the test may range from less than a minute to several hours.

If the well is to be used as a monitoring well, precautions should be taken to ensure that the well is not contaminated by material introduced into the well. If water is added to the monitoring well, it should be from an uncontaminated source and transported in a clean container. Bailers or measuring devices shall be cleaned prior to the test. If tests are performed on more than one monitoring well, care must be taken to avoid cross-contamination of the wells.

Slug tests shall be conducted on relatively undisturbed wells. If a test is conducted on a well that has recently been pumped for water sampling purposes, the measured water level must be within 0.1 foot of the static water level prior to testing.

5.2.4.3 Post Operations

Decontaminate and/or dispose of equipment according to SOP I-F, *Equipment Decontamination.*

For the electronic data-logger, implement the following procedure:

1. Stop logging sequence.
2. Print the data if available.
3. Save the data and disconnect the battery at the end of the day's activities.
4. Inventory sampling equipment and supplies. Repair or replace all broken or damaged equipment.
5. Replace expendable items.
6. Return equipment to the Equipment Manager and report incidents of malfunctions or damage.
7. Review field forms for completeness.

8. Interpret slug test field results with the Project Hydrogeologist and the CTO/DO Manager. Analyze the slug test using appropriate software packages or graphical solutions.

9. Send data-logger or pressure transducers to factory for recalibration, if needed.

5.2.5 Slug Test Interpretation

The results of slug tests should be viewed as order of magnitude estimates of hydraulic conductivity and should not be performed as a substitute for constant discharge pump tests. The interpretation of the water level response usually requires a number of simplifying assumptions, and the physical properties of the well casing and filter pack are rarely included in the analysis. A limited number of test interpretation methodologies exist. The following two approaches are most commonly used:

1. Cooper et al. Method

   A more physically based model for the slug test was developed by the U.S. Geological Survey. It involves a curve-fitting procedure that may not always produce a unique fit and is the only method discussed herein to produce an estimate of specific storage.

2. Bouwer and Rice Method

   This is a popular approach to the interpretation of slug test data obtained from unconfined aquifers. It is a graphical method and relatively straightforward to apply.

5.2.6 QA/QC

Similar to pumping test analysis. Refer to Section 5.1.5.

6.0 RECORD KEEPING REQUIREMENTS

All data collected in the field shall be maintained onsite during field activities, and then transferred to the office project files upon completion of the aquifer test(s). Computerized data (e.g., from data loggers) shall be stored in ASCII format. The CTO/DO Manager or designee shall review all aquifer test forms upon completion of the aquifer test(s).

7.0 HEALTH AND SAFETY

Standard Health and Safety (H&S) practices should be observed as stated in the site-specific Health and Safety Plan (HSP). Prior monitoring should have determined contaminant concentrations and, thus established any required personal protective equipment (PPE).

Suggested minimum protection during aquifer test activities shall include inner disposable vinyl gloves, outer chemical protective nitrile gloves, rubberized steel-toed boots, and an ANSI-Standard hard hat. Half-face respirators and cartridges and Tyvek® suits may be necessary depending on the contaminant concentrations and shall always be available onsite.

Depending upon the type of contaminant expected or determined in previous sampling efforts, the following safe work practices will be employed:

7.1 PARTICULATE OR METAL COMPOUNDS

1. Avoid skin contact with and/or incidental ingestion of water.

2. Wear long-sleeved protective gloves and splash protection (i.e., Saranex or splash suits and face shields) as warranted.

7.2 VOLATILE ORGANIC COMPOUNDS

1. Avoid breathing constituents venting from the tanks by approaching upwind, and/or by use of respiratory protection.

2. Survey the well head-space and the personnel breathing zone with a flame ionization detector/photoionization detector (FID/PID) prior to and during sampling.

3. If monitoring results indicate organic vapors that exceed action levels as specified in the site-specific HSP, sampling activities may need to be conducted in Level C protection. At a minimum, skin protection will be required by use of Tyvek or other media that is protective against the media being encountered.

7.3 Flammable or Explosive Conditions

1. Periodically monitor flammable or explosive gases using an explosimeter and oxygen meter.

2. All ignition sources should be placed upwind or crosswind of the well or borehole (i.e., generators).

3. If explosive gases exceed the designated action levels as specified in the site-specific HSP, cease operations and evaluate conditions.

7.4 Physical Hazards Associated With Aquifer Testing

1. To avoid back injuries associated with moving generators and pumps, always use two people and the large muscles of the legs, not the back.

2. To avoid slip/trip/fall (wet) conditions as a result of leaking pumps or discharge, use textured boots/boot cover bottoms.

3. To minimize fire/explosion hazards, the following guidelines should be followed:

   - Monitoring equipment, such as explosimeters, should be used to detect flammable/explosive atmospheres.

   - All potential ignition sources should be kept out of the work area.

   - Two generators must be kept onsite and gassed up alternately when the engines are cool—the filling of generators with fuel while they are running is strictly prohibited.

   - At least one ABC- or BC-rated fire extinguisher must be kept within 75 feet of the work area to prevent the spread of small fires should they occur.

4. Conduct all work being performed at night in areas where lighting equals or exceeds five foot-candles.

5. All personnel should avoid climbing on tanks as much as possible to eliminate the possibility of injuries due to falls.

6. To avoid heat/cold stress as a result of exposure to extreme temperatures and PPE, drink electrolyte replacement fluids (1-2 cups/hour is recommended) and, in cases of extreme cold, wear fitted insulating clothing.

7. Be aware of restricted mobility due to the wearing of PPE.

8.0 REFERENCES

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9.0 ATTACHMENTS

1. Constant Discharge Pumping Test/Aquifer Test Data Form

Attachment I-C-4-1

AQUIFER TEST DATA FORM

AQUIFER TEST DATA FORM

PROJECT NAME: ________________ PROJECT NUMBER: ____________ WELL NUMBER: ____________
LOCATION: ________________ DATE: ____________ HYDROGEOLOGIST: ________________
PUMPED WELL NO. _____ DISTANCE FROM PUMPING WELL: ________ TYPE OF TEST: ______ TEST NO. __________
MEASURING EQUIPMENT ______________________ TYPE AND DEPTH OF PUMP ________________

Time Data **Pump on: Date___Time ___( )** **Pump off: Date___Time___( )** **Duration of aquifer test:** **Pumping___Recovery____**					**Water Level Data** **Static Water Level______________** **Measuring Point_______________** **Elevation of measuring point_______**				**Discharge Data**	**Water Quality Data**			**Comments on factors affecting test data**
Date	Clock Time	Time since pump started t (min)	Time since pump stopped t (min)	Vt	Depth of Water (feet)	Pressure (PSI)	Accumulated Drawdown (feet)	Corrected Drawdown s (feet)	Flow Rate (gpm)	pH	Specific Conduc-tivity	Temp (°C)	

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EQUIPMENT DECONTAMINATION

1.0 PURPOSE

The standard operating procedure (SOP) describes methods of equipment decontamination for use during site activities at U.S. Navy PACDIV IRP sites.

2.0 SCOPE

These procedures shall be followed during decontamination of field equipment used to sample environmental media.

This procedure shall serve as management-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in the planning or execution of activities must be approved by the CTO/DO Manager and Technical Director/QA Program Manager.

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

The Field Manager is responsible for ensuring that all field equipment is decontaminated according to this procedure.

The CTO/DO Manager is responsible for identifying instances of non-compliance with this procedure and ensuring that decontamination activities are in compliance with this procedure.

The Technical Director/QA Program Manager is responsible for ensuring that decontamination activities conducted during all CTO/DOs are in compliance with this procedure.

5.0 PROCEDURES

Decontamination of equipment used in soil/sediment sampling, ground-water monitoring, well drilling and well development, as well as equipment used to sample ground water, surface water, sediment, waste, wipe, asbestos, and unsaturated zone is necessary to prevent cross-contamination and to maintain the highest integrity possible in collected samples. Planning a decontamination program requires consideration of the following factors:

- The location where the decontamination procedures will be conducted
- The types of equipment requiring decontamination
- The frequency of equipment decontamination
- The cleaning technique and types of cleaning solutions appropriate to the contaminants of concern
- The method for containing the residual contaminants and wash water from the decontamination process
- The use of a quality control measure to determine the effectiveness of the decontamination procedure

This subsection describes standards for decontamination, including the techniques to be used, frequency of decontamination, cleaning solutions, and effectiveness.

5.1 DECONTAMINATION AREA

An appropriate location for the decontamination area at a site shall be selected on the basis of the ability to control access to the area, the ability to control residual material removed from equipment, the need to store clean equipment, and the ability to restrict access to the area being investigated. The decontamination area shall be located an adequate distance away and upwind from potential contaminant sources to avoid contamination of clean equipment.

5.2 TYPES OF EQUIPMENT

Drilling equipment that must be decontaminated includes drill bits, auger sections, drill-string tools, drill rods, split barrel samplers, tremie pipes, clamps, hand tools, and steel cable. Decontamination of monitoring well development and ground-water sampling equipment includes submersible pumps, bailers, interface probes, water level meters, bladder pumps, air lift pumps, peristaltic pumps, and lysimeters. Other sampling equipment that requires decontamination includes, but is not limited to, hand trowels, hand augers, slide hammer samplers, shovels, stainless steel spoons and bowls, soil sample liners and caps, wipe sampling templates, COLIWASA samplers, and dippers. Equipment with a porous surface, such as rope, cloth hoses, and wooden blocks, cannot be thoroughly decontaminated and shall be properly disposed of after one use.

5.3 FREQUENCY OF EQUIPMENT DECONTAMINATION

Down-hole drilling equipment and equipment used in monitoring well development and purging shall be decontaminated prior to initial use and between each borehole or well. However, down-hole drilling equipment may require more frequent cleaning to prevent cross-contamination between vertical zones within a single borehole. When drilling through a shallow contaminated zone and installing a surface casing to seal off the contaminated zone, the drilling tools shall be decontaminated prior to drilling deeper. Ground-water sampling shall be initiated by sampling ground water from the monitoring well where the least contamination is suspected. All ground-water, surface water, and soil sampling devices shall be decontaminated prior to initial use and between collection of each sample to prevent the possible introduction of contaminants into successive samples.

5.4 CLEANING SOLUTIONS AND TECHNIQUES

Decontamination can be accomplished using a variety of techniques and fluids. The preferred method of decontaminating major equipment such as drill bits, augers, drill string, pump drop-pipe, etc., is steam cleaning. Steam cleaning is accomplished using a portable, high pressure steam cleaner equipped with a pressure hose and fittings. For this method, equipment shall be thoroughly steam washed and rinsed with potable tap water to remove particulates and contaminants.

A rinse decontamination procedure is acceptable for equipment such as bailers, water level meters, new and re-used soil sample liners, and hand tools. The decontamination procedure shall consist of the following: (1) wash with a non-phosphate detergent (alconox, liquinox, or other suitable detergent) and potable water solution, (2) rinse in a bath with potable water, (3) spray with isopropyl alcohol, (4) rinse in a bath with deionized or distilled water, and (5) spray with deionized or distilled water. If possible, equipment shall be disassembled prior to cleaning. A second wash should be added at the beginning of the process if equipment is very soiled.

Decontaminating submersible pumps requires additional effort because internal surfaces become contaminated during usage. These pumps shall be decontaminated by washing and rinsing the outside surfaces using the procedure described for small equipment or by steam cleaning. The internal surfaces shall be decontaminated by recirculating fluids through the pump while it is operating. This recirculation can be done using a relatively long (typically 4 feet) large diameter pipe (4-inch or greater) equipped with a bottom cap. The pipe shall be filled with the decontamination fluids, the pump placed within the capped pipe, and the pump operated while recirculating the fluids back into the pipe. The decontamination sequence shall include (1) detergent and potable water, (2) potable water rinse, (3) potable water rinse, and (4) deionized water rinse. The decontamination fluids shall be changed after each decontamination cycle.

Solvents other than isopropyl alcohol may be used, depending upon the contaminants involved. For example, if polychlorinated biphenyls (PCBs) or chlorinated pesticides are contaminants of concern, hexane may be used as the decontamination solvent. However, if samples are also to be analyzed for volatile organics, hexane shall not be used. In addition, some decontamination solvents have health effects that must be considered. Decontamination water shall consist of distilled or deionized water. Steam-distilled water shall not be used in the decontamination process as this type of water usually contains elevated concentrations of metals. Decontamination solvents to be used during field activities will be specified in CTO/DO Work Plans or Quality Assurance Project Plans (QAPPs).

Equipment used for measuring field parameters such as pH, temperature, specific conductivity, and turbidity shall be rinsed with deionized or distilled water after each measurement. New, unused soil sample liners and caps will also be washed with a fresh detergent solution and rinsed with potable water followed by distilled or deionized water to remove any dirt or cutting oils that may be on them prior to use.

5.5 CONTAINMENT OF RESIDUAL CONTAMINANTS AND CLEANING SOLUTIONS

A decontamination program for equipment exposed to potentially hazardous materials requires a provision for catchment and disposal of the contaminated material, cleaning solution, and wash water.

When contaminated material and cleaning fluids must be contained from heavy equipment such as drill rigs and support vehicles, the area must be properly floored, preferably with a concrete pad that slopes toward a sump pit. If a concrete pad is impractical, planking can be used to construct solid flooring that is then covered by a nonporous surface and sloped toward a collection sump. If the decontamination area lacks a collection sump, plastic sheeting and blocks or other objects shall be used to create a bermed area for collection of equipment decontamination water. Items such as auger flights, which can be placed on metal stands or other similar equipment, should be situated on this equipment during decontamination to prevent contact with fluids generated by previous equipment decontamination. Clean equipment should be stored in a separate location to prevent recontamination. Decontamination fluids contained within the bermed area shall be collected and stored in secured containers as described below.

Catchment of fluids from the decontamination of lighter-weight drilling equipment and hand-held sampling devices shall be accomplished using wash buckets or tubs. The decontamination fluids shall be collected and stored onsite in secured containers such as DOT-approved drums until their disposition is determined by laboratory analytical results. Containers shall be labeled in accordance with SOP I-A-7, *IDW Management*.

5.6 EFFECTIVENESS OF DECONTAMINATION PROCEDURES

A decontamination program must incorporate quality control measures to determine the effectiveness of cleaning methods. Quality control measures typically include collection of equipment rinsate samples or wipe testing. Equipment rinsates consist of analyte-free water that has been poured over or through the sample collection equipment after its final decontamination rinse. Wipe testing is performed by wiping a cloth over the surface of the equipment after cleaning. Further descriptions of these samples and their required frequency of collection is provided in SOP III-B, *Field QC Samples (Water, Soil)*. These quality control measures provide "after-the fact" information that may be useful in determining whether or not cleaning methods were effective in removing the contaminants of concern.

6.0 RECORDS

The decontamination process shall be described in the field logbook.

7.0 HEALTH AND SAFETY

It is the responsibility of the Onsite Health and Safety Coordinator (OHSC) to set up the site zones (i.e., exclusion, transition, and clean) and decontamination areas. Generally the decontamination area is located within the transition zone, upwind of intrusive activities, and serves as the area where both personnel and equipment are washed to minimize the spread of contamination into the clean zone. For equipment, a series of buckets are set up on a visqueen-lined bermed area. Separate spray bottles containing isopropyl alcohol (or alternative cleaning solvent as described in the CTO/DO Work Plan or Field Sampling Plan) and distilled water are used for final rinsing of equipment. Depending on the nature of the hazards and the site location, decontamination of heavy equipment such as augers, pump drop pipe, and vehicles may be accomplished using a variety of techniques.

Personnel responsible for equipment decontamination must wear the PPE specified in the site- specific Health and Safety Plan (HSP). Generally this includes at a minimum Tyvek® coveralls, steel-toed boots with boot covers or steel-toed rubber boots, safety glasses, ANSI-Standard hard hats, and hearing protection (if heavy equipment is in operation). It should be noted that air monitoring by the OHSC may result in an upgrade to the use of half-face respirators and cartridges in the decontamination area; therefore, this equipment must be available onsite. If safe alternatives are not achievable, site activities will be discontinued immediately.

In addition to the aforementioned precautions, the following safe work practices will be employed:

Chemical Hazards Associated With Equipment Decontamination

1. Avoid skin contact with and/or incidental ingestion of decontamination solutions and water.

2. Utilize PPE as specified in the site-specific HSP to maximize splash protection.

3. Refer to material safety data sheets (MSDSs), safety personnel, and/or consult sampling personnel regarding appropriate safety measures (i.e., handling, PPE - skin, respiratory, etc.).

4. Take necessary precautions when handling detergents and reagents.

Physical Hazards Associated With Equipment Decontamination

1. To avoid possible back strain, it is recommended that the decontamination area be raised 1 to 2 feet above ground level.

2. To avoid heat stress, over exertion, and exhaustion, it is a recommended that equipment decontamination be rotated among all site personnel.

3. Take necessary precautions when handling field sampling equipment.

8.0 REFERENCES

SOP I-A-7, IDW Management

SOP III-B, Field QC Samples (Water, Soil).

U.S. EPA Environmental Response Team. 1988. Response Engineering and Analytical Contract Standard Operating Procedures. U.S. EPA, Research Triangle Park, NC.

9.0 ATTACHMENTS

None.

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LAND SURVEYING

1.0 PURPOSE

This standard operating procedure (SOP) sets forth protocols for acquiring land surveying data to facilitate the location and mapping of geologic, hydrologic, geotechnical data, and analytical sampling points and to establish topographic control over project sites.

2.0 SCOPE

This procedure applies to all personnel involved in acquiring and presenting land surveying data on U.S. Navy PACDIV IRP sites.

This procedure shall serve as management-approved guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in the planning, or execution of activities, must be approved by both the CTO/DO Manager and by the Technical Director/QA Program Manager.

3.0 DEFINITIONS

3.1 Boundary Survey

Boundary surveys are conducted by Certified Land Surveyors in order to delineate a legal property line for a site or section of a site.

4.0 RESPONSIBILITIES

CTO/DO Managers are responsible for determining the appropriate land surveying protocols for the project and ensuring this SOP is properly implemented.

The Field Manager (FM) is responsible for ensuring that the appropriate protocols are conducted according to this SOP and the project-specific sampling plan. In virtually all cases, these procedures will be conducted by subcontractors. The FM is responsible for overseeing the activities of the subcontractor and ensuring that sampling points and topographic features are properly surveyed.

5.0 PROCEDURES

Land surveying will be conducted by a subcontractor with oversight by the U.S. Navy. The procedures listed below shall be followed during land surveying conducted under the U.S. Navy PACDIV IRP.

- All surveying work shall be performed under the direct supervision of a land surveyor registered in the state or territory in which the work is being performed.

- Survey instruments shall be inspected and calibrated by an authorized manufacturer's representative in accordance with the manufacturer's specifications regarding procedures and frequencies. At a minimum, instruments shall have been calibrated no more than 6 months prior to the start of the survey work.

- Standards for all survey work shall be in accordance with National Oceanic and Atmospheric Administration (NOAA) standards and at the minimum accuracy standards set forth below. The horizontal accuracy for location of all grid intersection and planimetric features shall be (±) 0.1 feet. The horizontal accuracy for boundary surveys shall be one in ten thousand feet (1:10,000). The vertical accuracy for ground surface elevations shall be (±) 0.1 feet. Bench mark elevation accuracy and elevation of other permanent features, including monitoring well heads, shall be (±) 0.01 feet.

- Surveys shall be referenced to the local established coordinate systems and all elevations and bench marks established shall be based on United States Geological Survey (USGS) datum, 1929 general adjustment.

- Surveyed points shall be referenced to Mean Sea Level (Lower Low Water Level).

- Appropriate horizontal and vertical control points shall be jointly determined prior to the start of survey activities. If discrepancies in the survey (e.g., anomalous water level elevations) are observed, the surveyor may be required to verify the survey by comparison to a known survey mark. If necessary, a verification survey may be conducted by a qualified third party.

- All field notes, sketches and drawings shall clearly identify the horizontal and vertical control points by number designation, description, coordinates and elevations. All surveyed locations shall be mapped using a base map or other site mapping specified by the CTO/DO Manager.
- All surveys shall begin and end at the designated horizontal and vertical control points to determine the degree of accuracy of the surveys.
- Iron pins used to mark control points shall be made of reinforcement steel or an equivalent material and shall be 18 inches long with a minimum diameter of 5/8 inch. Pins shall be driven to a depth of 18 inches into the soil.
- Stakes used to mark survey lines and points shall be made from 3-foot lengths of 2-inch by 2-inch lumber and pointed at one end. They shall be clearly marked with brightly colored weatherproof flagging and paint.
- The point on a monitoring well casing that is surveyed shall be clearly marked by filing grooves into the casing on either side of the surveyed point.

6.0 RECORDS

Field notes shall be recorded daily by the surveyor using generally accepted practices. The data shall be neat, legible and easily reproducible. Copies of the surveyor's field notes and calculation forms generated during the work shall be obtained and placed in the project files.

Surveyor's field notes shall, at a minimum, clearly indicate:

- The date of the survey
- General weather conditions
- The name of the surveying firm
- The names and job titles of personnel performing the survey work

- Equipment used, including serial numbers
- Field book designations, including page numbers.

Drawings and calculations submitted by the surveyor shall be signed, sealed and certified by a land surveyor registered in the state or territory in which the work was done.

Dated records of land surveying equipment calibration shall be provided by the surveyor and placed in the project files. Equipment serial numbers shall be provided in the calibration records.

7.0 HEALTH AND SAFETY

The site-specific health and safety plan shall be followed by all field personnel.

8.0 REFERENCES

None.

9.0 ATTACHMENTS

None.

LABORATORY QC SAMPLES (WATER, SOIL)

1.0 PURPOSE

This section sets forth the standard operating procedure (SOP) for identifying the number and type of laboratory Quality Control (QC) samples that will be analyzed during each CTO/DO associated with the U.S. Navy PACDIV IRP. Laboratory QC analyses serve as a check on the precision and accuracy of analytical methods and instrumentation and potential contamination that may occur during laboratory sample preparation and analyses. Laboratory QC analyses include but are not limited to blank, duplicate, surrogate, blank spike, laboratory control sample, and matrix spike/ matrix spike duplicate analyses. These laboratory QC analyses are discussed in general below.

2.0 SCOPE

This procedure applies to all laboratory analytical activities conducted during the IRP Program.

This procedure shall serve as management-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in the planning or the execution of activities must be approved by the CTO/DO Manager and Technical Director/QA Program Manager.

3.0 DEFINITIONS

3.1 PRECISION

A measure of the agreement, i.e., reproducibility, among individual measurements of the same property, under prescribed similar conditions. Precision is measured by relative percent difference (RPD).

3.2 Relative Percent Difference (RPD)

A measure of precision which is based on the mean of two values from related analyses and is reported as an absolute value. It is calculated using the following formula:

$$RPD = | S - D | / [(S + D)/2] \times 100\%$$

where S = original sample result

D = duplicate sample result

3.3 Laboratory Blank

A clean sample provided by the laboratory that is analyzed to monitor contamination during laboratory analysis. Also called a method blank, reagent blank, or preparation blank. The same matrix must be used for the laboratory blank as for site samples.

3.4 Duplicate

A duplicate is a split sample that is analyzed to determine laboratory precision for a particular matrix.

3.5 Matrix Spike

A quality control sample where a known amount of analyte is added to a site sample, then analyzed, for the purpose of determining efficiency of recovery for that type of matrix.

3.6 Blank Spikes and Laboratory Control Samples

Blank spikes and laboratory control samples consist of reagent water or clean soil/sand that has been spiked with known amounts of specific analytes and is carried through the entire analytical procedure with the samples. The term blank spike is used in reference to organic analyses, whereas the laboratory control sample is used in reference to inorganic analyses; however, they are basically the same.

3.7 Surrogates

Surrogates are organic compounds that have similar characteristics and behavior as the target analytes but are either not naturally occurring (such as deuterated surrogates for gas chromatography/mass spectrometry (GC/MS) analyses) or are not expected to be naturally occurring in the analyzed samples. Surrogates are added to every blank, sample, matrix spike, matrix spike duplicate, and standard, and are used to evaluate analytical efficiency of the analytical method by measuring percent recovery. Surrogates are normally added prior to extraction to portions of samples that will be analyzed for all GC, GC/MS, and high-performance liquid chromatography (HPLC) methods.

3.8 Quality Control (QC) Levels

Pacific Division Naval Facilities Engineering Command (PACDIV) QC Levels A, B, C, D, and E (formerly defined by the Naval Energy and Environmental Support Activity (NEESA 1988)). PACDIV QC Levels A, B, C, D, and E correspond closely with USEPA QC Levels I, II, III, IV, and V, respectively. Level D QC is appropriate to use for laboratory analysis for sites where cleanup decisions will be based on risk assessment; sites on or eligible for the National Priorities List (NPL) will also have laboratory analyses conducted at Level D QC. The QC level selected for laboratory analyses for many sites, therefore, will be PACDIV Level D. Other QC levels may be appropriate for certain types of samples or analyses; criteria for selection of the appropriate QC level for individual projects and field work activities are discussed in SOP I-A-8, *Data Validation Planning and Coordination.*

4.0 RESPONSIBILITIES

The CTO/DO QA Coordinators and the Laboratory Manager are responsible for identifying instances of non-compliance with this procedure and ensuring that future laboratory analytical activities are in compliance with it.

The Technical Director/QA Program Manager is responsible for ensuring that sample analytical activities during all CTO/DOs are in compliance with this procedure.

5.0 PROCEDURES

Laboratory QC checks include all types of samples specified in the requested analytical methods, such as the analysis of laboratory blank, duplicate, and matrix spike samples. Types of QC samples are discussed in general below. The procedures presented below are minimum requirements; QC requirements of each analytical method must also be followed, and take precedence over this SOP.

5.1 Laboratory Blanks

Laboratory blank samples are analyzed to assess the degree to which laboratory contamination by reagent or method preparation may have affected sample analytical results. At a minimum, one laboratory blank will be analyzed per matrix per analytical method for each batch of at most 20 samples.

In evaluating the blank results, all blank data are reviewed to identify any compounds detected in the blanks. The laboratory shall be contacted to discuss detection of analytes in blank samples only in the event of unusual contamination, but not for common laboratory contaminants at low levels. The following compounds are considered to be common laboratory contaminants: acetone, methylene chloride, 2-butanone, and common phthalate esters. The data for samples analyzed during the same time period as the blank is then evaluated to identify the presence of any contaminants found in the blanks. The presence of the blank contaminants found in associated samples is then evaluated to avoid potential misinterpretation of actual sample constituents. Briefly, as discussed in the data validation SOPs, any analyte detected in both the sample and the associated blank is qualified as not detected if the sample concentration is less than 5 times the blank concentration (5x rule). For common laboratory contaminants (methylene chloride, acetone, toluene, 2-butanone, and common phthalate esters), a 10x rule applies.

5.2 Duplicates

Laboratory duplicates are analyzed to evaluate the reproducibility, or precision, of the analytical procedures for a given sample. Results of duplicate analyses are reported as the RPD, which is calculated by dividing the absolute value of the difference in concentration between the duplicate and original sample analyses by the arithmetic mean of their concentrations and multiplying the result by 100. One duplicate sample is analyzed for each batch of at most 20 samples analyzed of similar matrix. Duplicate analyses are normally performed on sample portions analyzed for inorganic constituents. For organic analyses, duplicate analyses are performed on matrix spike samples (see Section 5.3 of this procedure).

5.3 Matrix Spikes/Matrix Spike Duplicates

Matrix spike (MS) analyses are conducted by the laboratory to assess the accuracy of specific analytical methods and to provide information on the effect of the sample matrix on the analytical methodology. Spike analyses are performed by adding compounds of known concentration to a sample, an unspiked portion of which has previously been analyzed or is concurrently analyzed; spikes are representative target compounds for each analytical method performed. The spiked sample is reanalyzed and the original and the spiked sample results are compared. One matrix spike is analyzed for each batch of at most 20 samples of similar matrix. Since MS samples only provide information about the specific sample matrix used for the spike, MS analyses should be performed for each type of matrix collected.

For the matrix spike duplicate (MSD), a separate sample is separately spiked and analyzed. As discussed in Section 5.2, results of matrix spike duplicate analyses are reported the RPD, which is calculated by dividing the difference in concentration between the matrix spike duplicate and the matrix spike sample analyses by the arithmetic mean of their concentrations. One matrix spike duplicate analysis is required for at most each 20 samples of similar matrix.

5.4 Blank Spikes, Surrogates, and Laboratory Control Samples

Blank spikes, surrogates, and laboratory control samples are used to demonstrate that the laboratory process for sample preparation and analysis is under control.

Analytes selected for spiking of blank spikes and laboratory control samples are usually the same compounds used to spike MS/MSD samples and are representative target compounds.

At least two pesticides should be used as surrogates when pesticide analyses are being performed, and one polychlorinated biphenyl (PCB) when PCBs are analyzed. For wet chemistry methods, a single spike of an appropriate control for each method may be used for laboratory control sample analyses (i.e., cyanide, a control standard of sodium cyanide from a source other than that used for calibration may be spiked into water samples and analyzed with the water samples). For metals, at least three metals typically analyzed by inductively coupled plasma (ICP) must be monitored, and each element analyzed by graphite furnace atomic absorption and cold-vapor atomic absorption needs to be monitored. Blank spikes and laboratory control samples should be analyzed at a frequency of 1 per batch of at most 20 samples analyzed of similar matrix. Surrogates are required to be analyzed with all samples analyzed for volatile organics, base/neutral-acid extractables, and pesticides/PCBs.

6.0 RECORDS

Records of laboratory QC samples analyzed during IRP CTO/DO activities will be maintained on laboratory bench sheets, raw data sheets, in the laboratory computerized data system, and on QC summary forms as requested. These QC summary forms will be provided in the laboratory analytical reports and laboratory data packages transmitted for each IRP CTO/DO.

7.0 HEALTH AND SAFETY

Applicable to laboratory personnel only.

8.0 REFERENCES

NEESA. 1988. Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program. NEESA 20.2-047B. June.

NFESC. 1996. Navy Installation Restoration Laboratory Quality Assurance Guide. February.

SOP I-A-8, *Data Validation Planning and Coordination*

9.0 ATTACHMENTS

None.

FIELD QC SAMPLES (WATER, SOIL)

1.0 PURPOSE

This standard operating procedure (SOP) describes the number and types of field Quality Control (QC) samples that will be collected during U.S. Navy PACDIV IRP site field work.

2.0 SCOPE

This procedure applies to all site sample collection activities conducted during the IRP Program.

This procedure shall serve as management-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in the planning or execution of activities must be approved by the CTO/DO Manager and IRP Technical Director/QA Program Manager.

3.0 DEFINITIONS

3.1 TRIP BLANK

Trip blanks are samples that originate from ASTM Type II analyte-free water taken from the laboratory to the sampling site and returned to the laboratory with samples to be analyzed for volatile organic compounds.

3.2 EQUIPMENT RINSATE SAMPLES

An equipment rinsate (i.e., "decontamination rinsate," or "equipment blank") sample consists of analyte-free water that has been poured over or through the sample collection equipment after its final decontamination rinse. Analytical results of equipment rinsate samples are used to access equipment cleanliness and the effectiveness of the decontamination process.

3.3 FIELD BLANKS

Field blanks are samples of the source water used as the final decontamination rinse water of sampling equipment, and should be from the same source water as used to generate the equipment rinsate sample.

3.4 FIELD DUPLICATE

A field duplicate is a second sample taken from the same source at the same time and analyzed under identical conditions to assist in evaluating sample variance. There are two types of field duplicates: replicates and collocates. Replicates are identical samples that have typically been homogenized, while collocates are samples collected next to each other (e.g., laterally or vertically, in separate containers, and not homogenized).

3.5 REFERENCE SAMPLES

Reference samples are samples taken from media similar to site media, but that are collected outside the zone of contamination, usually offsite.

3.6 QUALITY CONTROL (QC) LEVELS

Pacific Division Naval Facilities Engineering Command (PACDIV) QC Levels A, B, C, D, and E (formerly defined by the Naval Energy and Environmental Support Activity (NEESA 1988)). PACDIV QC Levels A, B, C, D, and E correspond closely with USEPA QC Levels I, II, III, IV, and V, respectively. Level D QC is appropriate to use for laboratory analysis for sites where cleanup decisions will be based on risk assessment; sites on or eligible for the National Priorities List (NPL) will also have laboratory analyses conducted at Level D QC. The QC level selected for laboratory analyses for many sites, therefore, will be PACDIV Level D. Other QC levels may be appropriate for certain types of samples or analyses; criteria for selection of the appropriate QC level for individual projects and field work activities are discussed in SOP I-A-8, *Data Validation Planning and Coordination.*

4.0 RESPONSIBILITIES

The Field Manager, the CTO/DO Manager, and the Technical Director/QA Program Manager are responsible for ensuring that field QC samples are collected and analyzed according to this procedure. The Laboratory Manager is responsible for ensuring that field QC samples are analyzed according to the specifications of the project Statement of Work and the analytical methods used.

5.0 PROCEDURES

Field QC checks may include submission of trip blank, equipment rinsate, field blank, duplicate, and reference samples to the laboratory. Suggested frequency and types of QC check samples are discussed in the following guidance documents: *RCRA Technical Enforcement Guidance Document*, Section 4.6.1 (EPA 1986); the use and frequency of these field QC samples should be incorporated as appropriate. Types of field QC samples are discussed in general below. The frequency at which field QC samples should be collected for each QC level is provided in Table III-B-1.

The use of performance evaluation (PE) samples is discussed in SOP III-G, *Performance Evaluation Procedures.*

5.1 TRIP BLANKS

Trip blanks are prepared by the laboratory using organic-free water. They are sent by the laboratory to the field.

Trip blanks shall be placed in sample coolers by the laboratory prior to transport to the site so that they accompany the samples throughout the sample collection/handling/transport process. Once prepared, trip blanks should not be opened until they reach the laboratory. One set of two 40 milliliter vials will form a trip blank and will accompany each cooler containing samples to be analyzed for volatile organics (VOCs) by methods such as CLP VOCs, 8010/601, 8020/602, 8240/624, and modified 8015 (only if purge and trap analysis is performed, e.g., for gasoline, not for extraction and analysis for diesel fuel). Trip blanks will be analyzed for VOCs only (EPA 1987). Results of trip blank analyses are used to assess whether samples have been contaminated by VOCs during sample handling and transport to the laboratory.

Because trip banks are typically not analyzed for in tissue samples, they are not required for tissue sampling programs.

Table III-B-1

FIELD QC SAMPLES PER SAMPLING EVENT

Type of Sample	Level C Metal	Level C Organic	Level D Metal	Level D Organic	Level E Metal	Level E Organic
Trip blank (for volatiles only)	NA[1]	1/cooler	NA[1]	1/cooler	NA[1]	1/cooler
Equipment rinsate[2]	1/day	1/day	1/day	1/day	1/day	1/day
Field blank	1/decontamination water source/event/for all QC levels and all analytes					
Field duplicates[3]	10%	10%	10%	10%	5%	5%

Background samples at least 1/sample media/sample event[4]

Notes:
[1]NA means not applicable.
[2]Samples are collected daily; however, only samples from every other day are analyzed. Other samples are held and analyzed only if evidence of contamination exists.
[3]The duplicate must be taken from the same sample that will become the laboratory matrix/spike duplicate for organics or for the sample used as a duplicate in inorganic analysis.
[4]Sample event is defined from the time sampling personnel arrive at the site until they leave the site for more than a period of one week; the use of controlled-lot source water makes one sample per lot rather than per event an option.

Source: Naval Energy and Environmental Support Activity (NEESA), 1988. Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program. NEESA 20.2-047B. June.

5.2 EQUIPMENT RINSATE SAMPLES

Equipment rinsate samples are collected by pumping the source water over and/or through the decontaminated sampling equipment. This runoff water is collected into the sample containers directly, or with the use of a funnel if necessary. The source water may be poured by use of an electric or hand submersible pump by tipping the jug of water upside down, or by use of a stopcock and gravity.

One equipment rinsate sample shall be collected per day per sampling technique utilized that day (NEESA 1988 and EPA 1986). Initially, rinsate samples from every other day will be analyzed (NEESA 1988). The samples will be analyzed for the same parameters for which samples collected utilizing a particular sampling method were analyzed. If analytes pertinent to the project are found in the rinsates, the remaining rinsate samples will be analyzed unless holding times have been exceeded. If no analytes are found in any rinsate samples, the frequency of analysis may be decreased from every other day to weekly. Results of rinsate samples are used to determine whether equipment decontamination was effective.

When disposable or dedicated sampling equipment is utilized, only one equipment rinsate sample will be collected per equipment lot or project phase. Disposable and/or dedicated sampling equipment may include stainless steel bowls or trowels that will be used for collection of only one soil sample, disposable bailers for ground-water sampling, dedicated submersible pumps for ground-water sampling, or other such equipment. These disposable and/or dedicated sampling equipment are typically pre-cleaned and individually wrapped by the manufacturer prior to delivery to the site. In this case, the equipment rinsate sample is used to provide verification that contaminants are not being introduced to the samples via sampling equipment.

Sampling devices (e.g., gloved hands, dip nets, or traps) for collection of tissue samples are generally non-intrusive into the organisms collected, so equipment rinsate samples will not be collected as long as the devices have been properly cleaned following SOP I-F, *Equipment Decontamination*, and the devices appear clean.

5.3 FIELD BLANKS

Field blanks are collected simply by pouring the source water into sample containers.

Field blanks, consisting of samples of the source water used as the final decontamination rinse water, will be analyzed to assess whether the wash or rinse water contained contaminants that may have been carried over into the site samples.

The final decontamination rinse water source, the field blank source water, and equipment rinsate source water should all be from the same purified water source. Tap water used for steam cleaning augers or used in the initial decontamination buckets need not be collected and analyzed as a field blank, because augers typically do not touch the actual samples and because the final decontamination rinse water should be from a purified source.

Field blanks are collected at a frequency of one per sampling event per each source of water for all levels of QC. A sampling event is considered to be from the time sampling personnel arrive at a site until they leave for more than a week. Field blanks will be analyzed for the same analyses as the samples collected during the period that the water sources are being used for decontamination. If the same lot of the water source is used, a field blank needs to be collected only once per lot.

5.4 FIELD DUPLICATES

Field duplicates consist of either collocated or replicate samples. Collocated samples will be collected from adjacent locations or liners or water samples collected from the same well at the same time; these provide information on the entire sample measurement system, including sampling, analysis, and non-homogeneities of the media sampled. Alternatively, replicates may be collected. Replicates are collected at the same time (e.g., homogenized or split samples), and provide information for various points in the analytical process. Sampling error can be approximated by the inclusion of collocated and replicated versions of the same sample.

Field duplicates for ground water and surface water samples will generally consist of replicates. Field duplicates for soil samples will consist primarily of collocates. Soil field duplicates that are to be analyzed for volatile constituents will consist only of collocates; no soil samples that are to be analyzed for volatiles will be replicated (i.e., homogenized or otherwise processed or split) in the field. A separate sample will be collected to provide duplicates for non-volatile analyses. The sample may be homogenized and split in the field to form an original and duplicate (replicate) sample, or an additional volume into a separate sample container may be collected to form a duplicate (collocate) sample. Alternatively, replicates may be formed by homogenization in the laboratory. Duplicates will be analyzed for the same analytical parameters as their associated original sample.

Field duplicates for biological tissue samples will consist of splits of the original sample. Twice the required volume of organisms for one sample will be collected and placed into one foodgrade self-sealing bag. The sample will later be homogenized in the laboratory and split, producing an original and a replicate sample. Replicates will be analyzed for the same analytical parameters as their associated original samples.

5.5 Reference Samples

Reference sampling is conducted to distinguish site-related contamination from naturally occurring or other non-site related levels of chemicals, i.e., to assess background levels. There are two types of background levels of chemicals:

- Naturally occurring levels, which are concentrations of chemicals present in the environment that have not been influenced by humans (e.g., iron, aluminum)

- Anthropogenic levels, which are concentrations of chemicals that are present in the environment due to human-made, non-site sources (e.g., industry, automobiles)

Reference samples will be collected for each medium sampled at a site. Site-specific conditions will dictate the number of reference samples necessary to characterize background concentrations of contaminants of concern. However, at least one reference sample from each medium will be collected during each sampling event at a site. The samples will be analyzed for all the analytes for which site samples of that medium are analyzed for. Background analysis, especially for metals, should be performed to assess the typical naturally occurring levels.

At least one reference sample will be collected for each biological species collected at a site. It may be difficult to find a nearby offsite location similar enough to the project site that has the same biological species available for offsite reference sample collection. Therefore, reference sample locations may need to be more distant from the site than for soil or water offsite reference samples. Collection methods will be identical for site and reference samples.

6.0 RECORDS

Records of the collection of field QC samples should be kept in the sample logbook by the methods discussed in SOP III-E *Record Keeping, Sample Labeling, and Chain-of-Custody*.

7.0 HEALTH AND SAFETY

The CTO/DO-specific Health and Safety Plan shall be followed when collecting or working with potentially hazardous environmental samples.

8.0 REFERENCES

EPA. 1987. Data Quality Objectives for Remedial Response Activities: Development Process

NEESA. 1988. Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program, NEESA 20.2-047B, June.

EPA. 1992. RCRA Technical Enforcement Guidance Document.

SOP I-F-1, *Equipment Decontamination*

9.0 ATTACHMENTS

None.

FIELD QC SAMPLES (AIR)

1.0 PURPOSE

This procedure describes the standard quality control (QC) and quality assurance (QA) procedures for air monitoring field samples.

2.0 SCOPE

The field QA/QC procedures presented herein will be employed by U.S. NAVY PACDIV IRP personnel when undertaking air monitoring/sampling site investigations or assessments. Specific guidance for collecting field QC samples will be addressed in project-specific planning documents.

This procedure shall serve as management-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in the planning or execution of activities must be approved by the CTO/DO Manager and Technical Director/QA Program Manager.

3.0 DEFINITIONS

3.1 QUALITY ASSURANCE

A system of activities whose purpose is to provide assurance that the overall quality control job is in fact being done effectively. The system involves a continuing evaluation of the accuracy and effectiveness of the overall quality control program with a view to having corrective measures initiated where necessary. For a specific service, this involves verifications, audits, and the evaluation of the quality factors that affect the specification and use of the service.

3.2 QUALITY CONTROL

The overall purpose of the system of activities is to provide a quality service that meets the needs of users, and facilitates the use of such a system. The aim of quality control is to provide quality that is satisfactory, adequate, dependable, and economic. The overall system involves integrating the quality aspects of several related steps including:

- The proper specification of what is wanted
- Commitment to meet the full intent of the specification
- Inspection to determine whether the resulting service is in accordance with specifications
- Review of usage to provide revision of the specification

4.0 RESPONSIBILITIES

The CTO/DO Manager is responsible for ensuring that the air monitoring and sampling QA/QC activities are followed during projects conducted under the U.S. NAVY PACDIV IRP. These QA/QC activities will be implemented in accordance with the Quality Assurance Project Plan for the respective CTO/DO activity.

The Field Program Manager is responsible for ensuring that all project field staff follow these procedures. The Laboratory Manager is responsible for ensuring that field QC samples are analyzed according to the specifications of the project Statement of Work and the analytical methods used.

The Technical Director/QA Program Manager is responsible for conducting audits to ensure that these procedures are being followed throughout the U.S. NAVY PACDIV IRP. In addition, air quality personnel are responsible for the performance of audits at respective CTO/DO air monitoring sites.

5.0 PROCEDURE

U.S. NAVY PACDIV IRP air monitoring programs for airborne pollutants consist of complex activities using monitoring equipment and laboratory analysis techniques. This approach is necessary to accurately quantify concentrations of airborne pollutants in ambient air. Therefore, it is critical that one ensures and maintains a high-quality program, by implementing the appropriate QA/QC program elements.

Many people confuse the terms quality assurance and quality control (QA/QC). Both activities are concerned with maintaining consistent and verifiable quality in each element of the program. Strictly speaking, quality control (QC) applies to measures taken, on an ongoing basis, by personnel involved in producing the primary output of the activity. These actions are taken to maintain performance parameters within acceptable levels. An example of a quality control activity is a routine zero/span calibration check of a monitoring instrument by the responsible operating technician.

Quality assurance, on the other hand, refers to checks or tests performed by personnel other than the primary operators to verify that the performance parameters have, in fact, been maintained within acceptable limits. Examples of quality assurance activities are performing a quarterly audit of monitoring instruments and checking output data for "out-of-limits" values. In the discussion that follows, QA/QC is used as a general term to encompass both QA and QC activities.

To meet monitoring objectives a rigorous QA/QC effort is necessary during the operation of a U.S. NAVY PACDIV IRP site air monitoring program. Major QA/QC elements that should be implemented during the operational phase of an air monitoring program include QA/QC management, sample QA/QC, analytical QA/QC, and data reduction QA/QC.

QA management involves implementing project-specific task order administrative procedures to control QA/QC functions. The potential for, and types of, quality problems vary depending on the activity: sampling, analysis, or data reduction. Therefore, individual QA/QC requirements must be developed for each of these activities. Summaries of typical sampling and analysis frequencies, QA/QC requirements, and calibration requirements for sampling and analysis instrumentation are presented in Tables III-C-1 and III-C-2, respectively. Data recording procedures to be specified in the air sampling activity include: (1) periodic readings of the temperature, flow, volumes, and other parameters; (2) documentation of meteorological conditions at appropriate time points; (3) documentation of instrument operating variables (i.e., resin cartridge number); (4) documentation of any upset conditions such as sudden leakage or pressure surges; and (5) documentation of calibration or maintenance activities. A logbook for the overall field program in which sampling descriptions, meteorological data, and upset conditions are documented should be maintained. In addition, a sampling data sheet should be prepared for each sample or set of samples in which the periodic readings and instrument parameters are recorded. Certain measurements such as filter numbers and weights or impinger volumes which are required for analytical purposes may be recorded on a separate sheet with provisions for recording subsequent analytical data on the same sheet. Separate maintenance and calibration logbooks should be maintained for each sampling/monitoring instrument. In most cases, sampling data forms specific for a given CTO/DO must be prepared because of difference in the sampling design between CTO/DOs.

Table III-C-1

TYPICAL SAMPLING/ANALYSIS FREQUENCIES FOR QC SAMPLES (AIR)

Type of Sample*	Description	Typical Frequency
Field Blanks	Collection media shipped to the field and exposed to the sampling environment, recapped or reclosed without a volume of air passing into or through them.	At least one per day or one per each sample batch up to 10% of sample total.
Laboratory Blanks	Unexposed media that do not go to the field but are analyzed by the laboratory to confirm that analyte(s) of concern are not present.	At least one per day or one per each sample batch up to 10% of sample total.
Trip Blanks	Collection media shipped to the field, remains unopened or unexposed to the test environment and is returned to the laboratory.	At least one per shipment container.
Spiked Samples	Media to which a known amount of the analyte(s) of interest have been added by the laboratory and shipped to the filed for use.	At least one per batch up to 10% of sample total.
Collocated Samples	Air samples collected immediately adjacent to each other in the same time period.	At least one per matrix in each sampler array matrix up to 10% of sample total.
Instrument Calibration Standards	Calibration devices or material traceable to known certified standards.	Test at least twice daily at beginning and ending of sampling period.

* Specification of the manner in which these types of samples are collected shall be described within the specific CTO/DO Work Plan or Field Sampling Plan.

Table III-C-2

CALIBRATION REQUIREMENTS FOR FIELD AIR SAMPLING AND ANALYSIS INSTRUMENTATION

Device	Parameter Calibrated	Method of Calibration	Approximate Frequency	Comments
Sampling Instrumentation				
Sampling flow rate measurement device	Flow rate	Flow calibration kit; primary standard film calibrator; calibration flow meter; dry test meter	Depends on sampler; generally immediately prior to and after sampling event	
Sample volume measurement device (usually a dry test meter)	Total volume	Wet test meter or any appropriate volume standard	Depends on sampler; generally immediately prior to and after sampling event	Must be determined at known atmospheric pressure and temperature. Flow rate should be similar to that used for sampling.
Analytical Instruments				
Continuous monitors (i.e. FID, PID, FPD, etc.)	Response	Use standard concentrations	Daily or more frequently, if required	Test atmosphere should be referenced to primary standard (i.e., NIST, SRM, or CRM*). Flow/pressure conditions should duplicate sampling process.
Field Gas Chromatographic Instruments	Column performance and response retention time for each analyte	Injection of standard using the same process as for sample injection	Daily or more frequently, if required	Standard composition should be checked against primary standards if available

Table III-C-2 (continued)

CALIBRATION REQUIREMENTS FOR FIELD AIR SAMPLING AND ANALYSIS INSTRUMENTATION

Device	Parameter Calibrated	Method of Calibration	Approximate Frequency	Comments
GC/MS	Response and retention time for each analyte	Same as for other gas chromatographic instruments	Same as for other chromatographic gas instruments	Same as for other gas chromatographic instruments
GC/MS	Mass spectral resolution and tuning parameters	(a) Introduction of perfluoro-compound directly into MS. (b) Injection of tuning standard (i.e., bromo-fluorbenzene) into GC	Daily	Selection of tuning standards will be dependent on type of analysis being performed

NIST - National Institute of Standards and Technology
SRM - Standard Reference Material
CRM - Certified Reference Material

In addition to site-specific air sampler(s) and meteorological station parameters, the monitored area or locale elevation (i.e., feet above mean sea level) should be noted; and data for the following meteorological parameters taken/recorded every four hours; ambient air temperature, relative humidity, and barometric pressure. The two former values are obtained with a field or pocket type thermo-hygrometer; barometric pressure values may be obtained form either a nearby National Weather Service station or an airport that measures/records this parameter.

Sample labeling, preservation, storage, and transport procedures should be specified, and these procedures should be carefully explained to field personnel prior to sampling to ensure proper implementation. Sample labels, prepared in advance, should include sufficient information to associate the sample with a particular data sheet as well as the overall program record notebook. In general, each sample should be given a unique identification number with a prefix describing the type of sample.

Sample preservation, storage, and transport procedures must be appropriate for the type of analyses required. Particulate samples generally should be placed in air-tight containers and stored in the dark to minimize analyte degradation. Resin cartridges and impingers generally require more attention, because of analyte instability in the matrix, and should be shipped to the laboratory on the same day that the sample was collected for analysis. These sample types should be placed in airtight, glass containers and stored at subambient temperatures until analysis. Exposure to solvents must be avoided for resin cartridges during all stages of handling in order to avoid sample contamination. Air samples collected in Tedlar bags should be placed within an opaque plastic bag (i.e., plastic garbage can bag) and then placed in a cardboard box with blue ice for shipment to the laboratory on the same day that the sample was collected for analysis.

Chain-of-custody forms are required. The objective of the chain-of-custody procedure is to document the movement of a sample from collection until analysis to ensure its integrity.

5.1 ROUTINE QA/QC CHECKS

The field air monitoring program should incorporate the following four-component approach for routine quality control and assurance checks:

- Use collocated (i.e., two separate ambient air samples collected side-by-side at the same sampling location) samples for precision checks.
- Use blanks (i.e., field and trip blanks) for ambient locale and shipping container contamination checks.
- Use analytical standards and equipment calibrations for accuracy checks.
- Perform data review for internal consistency.

During each air monitoring program, one station with two sets of collocated air samplers should be used in accordance with siting criteria. The goal should be to obtain at least 10% of collocated samples for each monitoring network. The analytical results from the collocated air samples should be used to assess the precision and overall homogeneity of the samples, including the influence of the combined field and analytical procedures.

The purpose for collecting sample blanks (i.e., field blank) is to document that extraneous concentrations of the target analyte(s) are not introduced into the collection medium simply by handling or working with it in a normal, routine fashion. Generally, one field blank per collection medium per day is sufficient to demonstrate that the levels of target analyte(s) found in the normal handling of the media in the field. In some instance, where the field environment is known to have high levels of contaminants, collecting more field blanks may be deemed appropriate. However, those requirements should be identified in the Field Sampling Plan. The frequency of field blanks collected for a particular project is project-specific and should be presented in detail in the Work Plan or Field Sampling Plan.

The exact procedure for collecting field blanks is specific to each type of medium. However, the general concept is to handle the field blank media in exactly the same fashion as the media used for actual sample collection except no sample volume of air is moved through the media. For example, glass sorbent tubes used for field blank are shipped, labeled, have their ends broken open, are placed in the sampling mechanism, removed from the sampling mechanism, capped, logged, and packed for shipment in an identical manner to the sorbent tubes used to collect air samples. The difference is that no air is pulled through the field blank sorbent tubes. Attachment B lists general procedures for collecting field blank for some of the collection media.

Canisters (Summa-stainless steel, SilcoCan-fused silica/stainless steel) used for ambient air sampling purposes should be tested to determine vacuum/pressure condition before and after sampling. Evacuated canisters should undergo two separate tests. First the canister is checked with a vacuum gauge to determine negative pressure and then the attached critical flow orifice that is used to control flow during the prescribed sampling interval, is tested with a rotometer. Canisters used with a positive displacement sampling pump (i.e., canister at atmospheric pressure at the start of the sampling period and then pressurized under constant flow pump conditions to approximately two atmospheres) should be tested for pressure conditions with a pressure gauge. Additionally, the sample pump flow rate should be determined with either a film calibrator or a flowmeter kit and stopwatch.

A vacuum/pressure gauge known to be free of contaminants is attached to the fitting upstream of the canister's main valve. The main valve is then opened and the gauge is read to confirm that the evacuated canister has maintained the same vacuum reading, within ±5%, reported by the laboratory or provider of the canister. The same method is used by the laboratory to confirm the fill of a pressurized canister. The canister should be within ±5% of the pressure valve reported by the field crew. Canisters outside the gauge error margin should be flagged as suspect and their data should be qualified accordingly.

5.2 Periodic QA/QC Checks

Periodic field QA/QC checks should be implemented to supplement the more frequent routine QC checks required by the project. These periodic checks will serve to determine compliance with siting and operating criteria and should be made after the specific CTO/DO air monitoring plan is in full operation. The periodic QA/QC checks should include air matrix spiked samples, instrument performance audits of the air monitoring and meteorological equipment, and system audits.

The accuracy of sample analysis can be routinely checked by submitting spiked and blank gas samples as part of the laboratory analysis package. Spiked samples should contain a known concentration of some of the same compounds for which the laboratory is performing analysis. Blank samples are collection media that have no measurable amounts of the substance(s) of interest. The analysis of spiked and blank samples should be reported along with the normal samples collected during the project.

Instrument performance audits conducted on air sampling and meteorological measurement equipment are to be conducted by qualified air quality technicians who are not directly involved in the routine operation of the air monitoring activity. In addition, the auditing equipment used to conduct the tests must be independent and different from that used to calibrate or maintain the air monitoring instrumentation. The audited instruments are challenged with known input values (e.g. air flow rates, electrical signals, timing mechanisms, temperature environments, etc.) and the instrument's observed response to the known inputs is reported.

The system audit provides an onsite qualitative evaluation of the installation of air sampler array and the meteorological monitoring station. The system audit documents the following:

Table III-C-3

COMMON FIELD BLANK COLLECTION PROCEDURES (AIR)

Media	Field Blank Collection Procedure
Glass Sorbent Tubes	The tubes are removed from their shipping package and labeled as if they were to be used to collect samples. The tube ends are snapped off and the tubes are placed in the sampler mechanism (e.g., personal sampling pump or flow control device). Without turning on the sampler mechanism, the tubes are then removed, capped, logged, and placed in the shipping container along with regular samples for transport to the laboratory. Analysis of the field blank tubes is identical to the tubes used to collect air samples.
Filters	The filters to be used as field blanks are removed from their shipping package and tagged or labeled along with the filters intended for sample collection. They are installed in the filter holder, attached to the sampling mechanism (pump), removed without turning on the sampling mechanism, placed in a protective envelope, logged on the appropriate form, and shipped along with regular samples to the laboratory for analysis. (Note: many filter media come preloaded in individual cassettes with capped ends. If filter cassettes are used, field blank procedures similar to those described for sorbent tubes will apply.)
Liquid Impingers	The impinger solution is placed in the impinger as it would be under normal sampling procedures. Without moving a volume of air through the impinger, an aliquot of solution (5-10 ml) is transferred into a shipment bottle, labeled, logged, and packaged for shipment to the laboratory along with the exposed sample impinger solutions.
Tedlar® Bags	The empty bags intended for field blanks are removed form the shipping package and labeled as if they are to be used for normal sample collection. The field blank bags are then filled with ultra pure nitrogen, logged, and packaged for shipment to the laboratory along with normally collected air samples.
Summa® Canisters	The canisters intended for field blanks are removed form the shipping container and labeled as if they are to be used for normal sample collection. The field blank canisters are then filled with ultra pure nitrogen, logged, and packaged for shipment to the laboratory along with canisters used for normally collected air samples.

- General physical condition and operability of the air sampling and meteorological instrumentation.

- Operational QC procedures in use (calibrations, single-point checks, instrument operation check lists, documentation)

- Instrument siting and exposure criteria

- Data acquisition, validation, and reporting procedures

The frequency of periodic QA/QC checks depends on the duration of the project. Where a long-term (i.e., 6 to 12 months, or more) project is in effect, the periodic QA/QC checks should be performed quarterly. For short-term projects lasting only a few weeks or less an initial QA/QC check at the beginning followed by a final check and project's end is sufficient.

Any problems or discrepancies discovered during the performance and system audits are documented in a report and discussed with the respective CTO/DO Manager who will initiate the required corrective actions.

5.3 Laboratory QA/QC Program

Laboratory analytical techniques must properly identify the sample components and accurately and precisely measure concentrations. This requires the preconcentration and/or storage of air samples. Therefore, methods chosen for time-integrated monitoring usually involve a longer analytical time period, more sophisticated equipment, and more rigorous QA procedures. Canister sampling includes replicate analyses and duplicate canisters to assess analytical and sampling precision. Analysis of co-located duplicate samples with laboratories is desirable to check laboratory analytical performance.

Laboratory QC methods for a U.S. Navy PACDIV IRP site must include the requirements noted in Section 3.0 of the *Navy Installation Restoration Laboratory Quality Assurance Guide (Interim Guidance Document)* (NFESC 1996). For air monitoring projects, these requirements should address the following elements: laboratory control samples, matrix spikes/matrix spike duplicates, duplicates, blanks, surrogates, other laboratory QC samples, field QC samples, internal standards, calibration standards, and canister cleanup and certification. Inter-laboratory analysis of duplicate or collated samples is desirable to check laboratory analytical performance.

6.0 RECORDS

Field QA/QC Samples (Air) shall be documented as prescribed in the respective U.S. NAVY PACDIV IRP CTO/DO and/or associated Air Monitoring Plan. These items shall be sent to the CTO/DO Manager and the project files.

7.0 HEALTH AND SAFETY

The CTO/DO-specific Health and Safety Plan shall be followed when collecting or working with potentially hazardous environmental samples.

8.0 REFERENCES

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USEPA. 1987. "Compendium Method TO-12: Method for the Determination of Non-Methane Organic Compounds (NMOC) in Ambient Air Using Cryogenic Preconcentration and Direct Flame Ionization Detection," Quality Assurance Division, Research Triangle Park, NC.

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USEPA. 1988. "Compendium Method TO-14: The Determination of Volatile Organic Compounds in Ambient Air Using Summa Passivated Canister Sampling and Gas Chromatographic Analysis," Quality Assurance Division, Research Triangle Park, NC.

USEPA. 1989. "Air/Superfund National Technical Guidance Study Series, Volume IV-Procedures for Dispersion Modeling and Air Monitoring for Superfund Air Pathway Analysis," EPA-450/1-89-004, Section 3, Office of Air Quality Planning and Standards, Research Triangle Park, NC.

USEPA. 1989. "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV - Meteorological Measurements," EPA-600/4-90-003, Research Triangle Park, NC.

9.0 ATTACHMENTS

None.

LOGBOOKS

1.0 PURPOSE

This standard operating procedure (SOP) describes the activities and responsibilities of the U.S. Navy PACDIV IRP organization pertaining to the identification, use, and control of logbooks and associated field data records.

2.0 SCOPE

This document applies to all U.S. NAVY PACDIV IRP personnel involved with the use and control of logbooks and associated records pertaining to quality-related activities.

This procedure shall serve as management-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in the planning or execution of activities must be approved by the CTO/DO Manager and Technical Director/QA Program Manager.

3.0 DEFINITIONS

3.1 LOGBOOK

A bound field notebook with consecutively numbered, water-repellent pages that is clearly identified with the name of the affected activity, the person assigned responsibility for maintenance of the logbook, and the beginning and ending dates of the entries.

3.2 DATA FORM

A predetermined format utilized for recording field data that may become, by reference, a part of the logbook. For example: soil boring logs, trenching logs, surface soil sampling logs, ground-water sample logs, and well construction logs are data forms.

4.0 RESPONSIBILITIES

The CTO/DO Manager is responsible for determining which team members shall record information in field logbooks and for obtaining and maintaining control of the required logbooks. The Field Manager is responsible for ensuring that the logbook is completed properly and daily. The Field Manager is also responsible for submitting copies to the CTO/DO Manager, who is responsible for filing it and submitting a copy to the Navy (if required by the CTO/DO Statement of Work).

The logbook user is responsible for recording pertinent data into the logbook to satisfy project requirements and for attesting to the accuracy of the entries by dated signature. The logbook user is also responsible for safeguard of the logbook while having custody of it.

The Technical Director/QA Program Manager or designee is responsible for reviewing logbook entries to determine compliance with this procedure and to ensure that the entries are adequate to meet the project requirements.

5.0 PROCEDURE

The field logbook serves as the primary record of field activities. Entries shall be made chronologically and in sufficient detail to allow the writer or a knowledgeable reviewer to reconstruct the applicable events. The logbook shall be stored in a clean location and used only when outer gloves used for personal protective equipment have been removed.

Individual data forms may be generated to provide systematic data collection documentation. Entries on these forms shall meet the same requirements as entries in the logbook and shall be referenced in the applicable logbook entry. Individual data forms shall reference the applicable logbook and page number. At a minimum, names of all samples collected shall be included in the logbook even if recorded elsewhere.

All field descriptions and observations are entered into the logbook, as described in Attachment 1, using indelible black ink.

Typical information to be entered includes, but is not limited to, the following:

- Date and time of all onsite activities
- Site location and description
- Weather conditions

- Field work documentation
- Descriptions of and rationale for approved deviations from the Work Plan or Field Sampling Plan
- Field instrumentation readings
- Personnel present
- Photograph references
- Sample locations
- Sample EPA number and sample identification, as described in SOP I-A-9, *Sample Naming*
- Sample naming
- Field QC sample information
- Field descriptions, equipment used, and field activities accomplished to reconstruct field operations
- Meeting information
- Important times and dates of telephone conversations, correspondence, or deliverables
- Field calculations
- PPE level
- Calibration records
- Subcontractors present
- Equipment decontamination procedures and effectiveness

The logbook shall reference data maintained in other logs, forms, etc. Entry errors shall be corrected by drawing a single line through the incorrect entry, then initialing and dating this change. An explanation for the correction should be entered if the correction is for more than just a mistake.

Each entry or group of entries shall be signed or initialed by the person making the entry at least at the end of each day.

Logbook page numbers shall be entered on each page to facilitate identification of photocopies.

If a person's initials are used for identification, or if uncommon acronyms are used, these should be identified on a page at the beginning of the logbook.

At least weekly and preferably daily, the preparer shall photocopy and retain the pages completed during that session for backup. This will prevent loss of a large amount of information if the logbook is lost.

A technical review of each logbook shall be performed by a knowledgeable individual such as the Field Manager, CTO/DO Manager, or QC Supervisor, at a frequency commensurate with the level of activity (weekly is suggested, or at a minimum monthly. These reviews shall be documented by the dated signature of the reviewer on the last page or page immediately following the material reviewed.

6.0 RECORDS

The field logbook shall be retained as a permanent project record. If a particular CTO/DO requires submittal of photocopies of logbooks, this shall be performed as required. The field logbook shall be reviewed by the CTO/DO Manager on at least a monthly basis.

7.0 HEALTH AND SAFETY

In order to keep the logbook clean, it should be stored in a clean location and used only when outer gloves used for personal protective equipment have been removed.

8.0 REFERENCES

SOP I-A-9, *Sample Naming*

U.S. Navy PACDIV IRP, Quality Assurance Management Plan.

9.0 ATTACHMENTS

1. Description of Logbook Entries

Attachment 1

DESCRIPTION OF LOGBOOK ENTRIES

Logbook entries shall contain the following information, as applicable, for each activity recorded. Some of these details may be entered on data forms as described previously.

Name of Activity	For example, Asbestos Bulk Sampling, Charcoal Canister Sampling, Aquifer Testing.
Task Team Members and Equipment	Name all members on the field team involved in the specified activity. List equipment used by serial number or other unique identification, including calibration information.
Activity Location	Indicate location of sampling area as indicated in the Field Sampling Plan.
Weather	Indicate general weather and precipitation conditions.
Level of Personal Protective Equipment	The level of personal protective equipment (PPE), e.g., Level D, should be recorded.
Methods	Indicate method or procedure number employed for the activity.
Sample Numbers	Indicate the unique numbers associated with the physical samples. Identify QC samples.
Sample Type and Volume	Indicate the medium, container type, preservative, and the volume for each sample.
Time and Date	Record the time and date when the activity was performed (e.g., 0830/08/OCT/89). Use the 24-hour clock for recording the time and two digits for recording the day of the month and the year.
Analyses	Indicate the appropriate code for analyses to be performed on each sample, as specified in the Field Sampling Plan.
Field Measurements	Indicate measurements and field instrument readings taken during the activity.
Chain of Custody and Distribution	Indicate chain-of-custody for each sample collected and indicate to whom samples are transferred and the destination.

References

If appropriate, indicate references to other logs or forms, drawings or photographs employed in the activity.

Narrative (including time and location)

Create a factual, chronological record of the team's activities throughout the day, including the time and location of each activity. Include descriptions of any general problems encountered and their resolution. Provide the names and affiliations of non-field team personnel who visit the site, request changes in activity, impact to the work schedule, requested information, or observe team activities. Record any visual or other observations relevant to the activity, the contamination source, or the sample itself.

It should be emphasized that logbook entries are for recording data and chronologies of events. The logbook author must include observations and descriptive notations, taking care to be objective and recording no opinions or subjective comments unless appropriate.

Recorded by

Include the signature of the individual responsible for the entries contained in the logbook and referenced forms.

Checked by

Include the signature of the individual who performs the review of the completed entries.

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RECORD KEEPING, SAMPLE LABELING, AND CHAIN-OF-CUSTODY PROCEDURES

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to establish standard protocols for all U.S. Navy PACDIV IRP field personnel for use in maintaining field and sampling activity records, writing sample logs, labeling samples, ensuring that proper sample custody procedures are utilized, and completing chain-of-custody/analytical request forms.

2.0 SCOPE

This procedure shall apply to all sample collection conducted during U.S. NAVY PACDIV IRP activities.

This procedure shall serve as management-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in the planning or the execution of activities must be approved by the CTO/DO Manager and Technical Director/QA Program Manager.

3.0 DEFINITIONS

3.1 LOGBOOK

A bound field notebook with consecutively numbered, water-repellent pages that is clearly identified with the name of the affected activity, the person assigned responsibility for maintenance of the logbook, and the beginning and ending dates of the entries.

3.2 CHAIN-OF-CUSTODY (COC)

Documentation of the process of custody control. Custody control includes possession of a sample from the time of its collection in the field to its receipt by the analytical laboratory, and through analysis and storage prior to disposal.

3.3 CTO/DO LABORATORY COORDINATOR

The person for each CTO/DO who is the main point of contact with the Laboratory Project Manager. This may or may not be the CTO/DO QC Coordinator.

4.0 RESPONSIBILITIES

U.S. NAVY PACDIV IRP field personnel are responsible for following these procedures during conduct of sampling activities. U.S. NAVY PACDIV IRP CTO/DO field personnel are responsible for recording pertinent data into the logbook to satisfy project requirements and for attesting to the accuracy of the entries by dated signature.

The Field Program Manager is responsible for ensuring that all field personnel follow these procedures. The CTO/DO Laboratory Coordinator is responsible for verifying that the COC/Analytical Request Forms have been completed properly and match the sampling and analytical plan. The CTO/DO Manager or CTO/DO Laboratory Coordinator is responsible for notifying the laboratory, data managers, and data validators in writing if analytical request changes are required as a corrective action. These small changes are different from change orders, which involve changes to the scope of the subcontract with the laboratory and must be made in accordance with a respective contract (e.g., CLEAN, RAC.)

The CTO/DO Manager is responsible for determining which team members shall record information in the field logbook and for checking sample logbooks and chain-of-custody forms to ensure compliance with these procedures.

The Laboratory Project Manager or Sample Control Department Manager is responsible for reporting any sample documentation or chain-of-custody problems to the CTO/DO Manager or CTO/DO Laboratory Coordinator within 24 hours of sample receipt.

The Technical Director/QA Program Manager is responsible for evaluating project compliance with these procedures. The Technical Director/QA Program Manager, or designee, is responsible for reviewing logbook entries, sample labeling, and chain-of-custody records to ensure that all are adequate to meet project requirements.

5.0 PROCEDURES

Standards for documenting field activities, labeling the samples, documenting sample custody, and completing chain-of-custody/analytical request forms are provided in this procedure. The standards presented in this section shall be followed to ensure that samples collected are maintained for their intended purpose and that the conditions encountered during field activities are documented.

5.1 RECORD KEEPING

The field logbook serves as the primary record of field activities. Entries shall be made chronologically and in sufficient detail to allow the writer or a knowledgeable reviewer to reconstruct each day's events. Field logs such as soil boring logs and ground-water sampling logs will also be used. These procedures are described in SOP III-D, *Logbooks*.

5.2 SAMPLE LABELING

A sample label with adhesive backing shall be affixed to each individual sample container. Clear tape shall be placed over each label (preferably prior to sampling) to prevent the labels from tearing off, falling off, being smeared, and to prevent loss of information on the label. The following information shall be recorded with a waterproof marker on each label:

- Project name or number (optional)
- EPA sample number
- Date and time of collection
- Sampler's initials
- Matrix (optional)
- Sample preservatives (if applicable)
- Analysis to be performed on sample (typically for water samples only)*. This shall be identified by the method number or name identified in the subcontract with the laboratory. For water samples, a separate container is typically used

for each separate test method, whereas with soil samples, all analyses are typically performed on the soil obtained from one sample container. In order to avoid lengthy lists on each container and confusion, soil sample containers typically don't list every analysis to be performed.

These labels may be obtained from the analytical laboratory or printed from a computer file onto adhesive labels.

5.3 CUSTODY PROCEDURES

For samples intended for chemical analysis, sample custody procedures shall be followed through collection, transfer, analysis, and disposal to ensure that the integrity of the samples is maintained. Custody of samples shall be maintained in accordance with EPA chain-of-custody guidelines as prescribed in EPA *NEIC Policies and Procedures,* National Enforcement Investigations Center, Denver, Colorado, revised May 1986; EPA *RCRA Ground Water Monitoring Technical Enforcement Guidance Document* (TEGD), *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA OSWER Directive 9355 3-01), Appendix 2 of the *Technical Guidance Manual for Solid Waste Water Quality Assessment Test (SWAT) Proposals and Reports,* and *Test Methods for Evaluating Solid Waste* (EPA SW-846). A description of sample custody procedures is provided below.

5.3.1 Sample Collection Custody Procedures

According to EPA *NEIC Policies and Procedures,* a sample is considered to be in custody if:

- It is in one's actual physical possession or view
- It is in one's physical possession and has not been tampered with (i.e., it is under lock or official seal)
- It is retained in a secured area with restricted access
- It is placed in a container and secured with an official seal such that the sample cannot be reached without breaking the seal

Custody seals shall be placed on sample containers immediately after sample collection and on shipping coolers if the cooler is to be removed from the sampler's custody. Custody seals will be placed in such a manner that they must be broken to open the containers or coolers. The custody seals shall be labeled with the following information:

- Sampler's name or initials
- Date and time that the sample/cooler was sealed.

These seals are designed to enable detection of sample tampering. An example of a custody seal is shown in Attachment III-E-1.

Field personnel shall also log individual samples onto carbon copy chain-of-custody forms when a sample is collected. These forms may also serve as the request for analyses. Procedures for completing these forms are discussed in Section 5.4 indicating sample EPA number, matrix, date and time of collection, number of containers, analytical methods to be performed on the sample, and preservatives added (if any). The samplers will also sign the COC form signifying that they were the personnel who collected the samples. The COC form shall accompany the samples from the field to the laboratory. When a cooler is ready for shipment to the analytical laboratory, the person delivering the samples for transport will sign and indicate the date and time on the accompanying COC form. One copy of the COC form will be retained by the sampler and the remaining copies of the COC form shall be placed inside a self-sealing bag and taped to the inside of the cooler. Each cooler must be associated with a unique COC form. Whenever a transfer of custody takes place, both parties shall sign and date the accompanying carbon copy COC forms, and the individual relinquishing the samples shall retain a copy of each form. One exception is when the samples are shipped; the delivery service personnel will not sign or receive a copy because they do not open the coolers. The laboratory shall attach copies of the completed COC forms to the reports containing the results of the analytical tests. An example COC form is provided in Attachment 2.

5.3.2 Laboratory Custody Procedures

The following are custody procedures to be followed by an independent laboratory receiving samples for chemical analysis; the procedures in their laboratory Quality Assurance Plan (LQAP) must follow these same procedures. A designated sample custodian shall take custody of all samples upon their arrival at the analytical laboratory. The custodian shall inspect all sample labels and COC forms to ensure that the information is consistent, and that each is properly completed. The custodian will also measure the temperature of the samples in the coolers upon arrival. The custodian shall also note the condition of the samples including:

- if the samples show signs of damage or tampering
- if the containers are broken or leaking
- if headspace is present in sample vials
- proper preservation of samples (made by pH measurement, except VOCs and purgeable TPH). The pH of these samples will be checked by the laboratory analyst after the sample aliquot has been removed from the vial for analysis.
- if any sample holding times have been exceeded

All of the above information shall be documented on a sample receipt sheet by the custodian.

Any discrepancy or improper preservation shall be noted by the laboratory as an out-of-control event and shall be documented on an out-of-control form with corrective action taken. The out-of-control form shall be signed and dated by the sample control custodian and any other persons responsible for corrective action. An example of an out-of-control form is included as Attachment III-E-4.

The custodian shall then assign a unique laboratory number to each sample and distribute the samples to secured storage areas maintained at 4°C. The unique laboratory number for each sample, the EPA sample number, the client name, date and time received, analysis due date, and storage shall also be manually logged onto a sample receipt record and later entered into the laboratory's computerized data management system. The custodian shall also sign the shipping bill and maintain a copy.

Laboratory personnel shall be responsible for the care and custody of samples from the time of their receipt at the laboratory through their exhaustion or disposal. Samples should be logged in and out on internal laboratory COC forms each time they are removed from storage for extraction or analysis.

5.4 Completing Chain-of-Custody/Analytical Request Forms

COC form/analytical request completion procedures are crucial in properly transferring the custody and responsibility of samples from field personnel to the laboratory. This form also is important for accurately and concisely requesting analyses for each sample; it is essentially a release order from the analysis subcontract.

Attachment III-E-2 is an example of a generic COC/analytical request form that may be used by field personnel. Multiple copies may be tailored to each project so that much of the information described below need not be handwritten each time. Attachment III-E-3 is an example of a completed site-specific COC/analytical request form, with box numbers identified and discussed in text below.

Box 1 **Project Manager:** This name shall be the name that will appear on the report. Do not write the name of the Project Coordinator or point of contact for the project instead of the CTO/DO manager.

Project Name: Write it as it is to appear on the report.

Project Number: Write it as it is to appear on the report. It shall include the project number, task number, and general ledger section code. The laboratory subcontract number should also be included.

Box 2 **Bill to**: List the name and address of the person/company to bill only if it is not in the subcontract with the laboratory.

Box 3 **Sample Disposal Instructions:** These instructions will be stated in the Basic Ordering Agreement (BOA) or each CTO/DO statement of work with each laboratory.

Shipment Method: State the method of shipment, e.g., hand carry; air courier via FED EX, AIR BORNE or DHL.

Comment: This area shall be used by the field team to communicate observations, potential hazards, or limitations that may have occurred in the field or additional information regarding analysis. For example: a specific metals list, explanation of Mod 8015, Mod 8015 + Kerosene, samples expected to contain high analyte concentrations.

Box 4 **Cooler Number:** This will be written somewhere on the inside or outside of the cooler and shall be included on the COC. Some laboratories attach this number to the trip blank identification which helps track VOA samples. If a number is not on the cooler, field personnel shall assign a number, write it on the cooler, and write it on the COC.

QC Level: Enter the reporting/QC requirements, e.g., PACDIV QC Level C, D, or E.

Turn around time (TAT): TAT for contract work will be determined by a sample delivery group (SDG) which may be formed over a 14-day period, not to exceed 20 samples. Standard turnaround time once the SDG has been completed is 35 calendar days from receipt of the last sample in the SDG. Entering NORMAL or STANDARD in this field will be acceptable. If quicker TAT is required, it shall be in the subcontract with the laboratory and reiterated on each COC to remind the laboratory.

Box 5 **Type of containers:** The type of container used, e.g., 1 liter glass amber, for a given parameter in that column.

Preservatives: Field personnel must indicate on the COC the correct preservative used for the analysis requested. Indicate the pH of the sample (if tested) in case there are buffering conditions found in the sample matrix.

Box 6 **EPA number:** Five-character alpha-numeric identifier to be used by the laboratory to identify samples. The use of this identifier is important since the labs are restricted to the number of characters they are able to use. See SOP I-A-9, *Sample Naming*.

Description (sample identification): This name will be determined by the location and description of the sample, as described in SOP I-A-9, *Sample*

Naming. This sample identification should not be submitted to the laboratory, but should be left blank. If a computer COC version is used, the sample identification can be input but printed with this block black. A cross-referenced list of EPA number and sample identification must be maintained separately.

Date Collected: Collection date must be recorded in order to track the holding time of the sample. Note: For trip blanks, record the date it was placed in company with samples.

Time Collected: When collecting samples, record the time the sample is first collected. Use of the 24-hour military clock will avoid a.m. or p.m. designations; e.g., 1815 instead of 6:15 p.m. Record local time; the laboratory is responsible for calculating holding times to local time (Guam is 17 hours ahead of California during daylight savings time).

Lab Identification: This is for laboratory use only.

Box 7 **Matrix and QC:** Identify the matrix: e.g., water, soil, air, tissue, fresh water sediment, marine sediment, or product. If a sample is expected to contain high analyte concentrations, e.g., a tank bottom sludge or distinct product layer, notify the laboratory in the comment section. Mark an "X" for the sample(s) that have extra volume for laboratory QC matrix spike/matrix spike duplicate (MS/MSD) purposes. The sample provided for MS/MSD purposes is usually a field duplicate.

Box 8 **Analytical Parameters:** Enter the parameter by descriptor and the method number desired. For example, Attachment 3 shows OLM01.8V as a column heading; this includes the CLP revision number and an indicator of the analytical category. When requesting metals that are modifications of the standard lists, define the list in the comment section. This would not be necessary when requesting standard list metals such as priority pollutant metals (PPM), target compound list from ILM03.0, and Title 22 metals which are groups of metals commonly requested and should not cause any confusion as to what metals are being analyzed. Whenever possible, list the parameters as they appear in the laboratory subcontract to maintain consistency and avoid confusion.

In the boxes below the analytical parameter, indicate the number of containers collected for each parameter by marking an "X". If more than one container is used for a sample, write a number in the desired box to indicate a request for analysis and to indicate the number of containers sent for that analysis.

Box 9 **Sampler's Signature:** The person who collected samples must sign here.

Relinquished By: This space shall contain the signature of the person who turned over the custody of the samples to a second party other than an express mail carrier such as FEDEX, DHL or Air Borne Express.

Received By: Typically, this is signed by a representative of the receiving laboratory. Or, this signature could be from a field crew member who delivered the samples in person from the field to the laboratory. A courier such as Federal Express or DHL does not sign this because they do not open the coolers. It must also be used by the prime contracting laboratory when samples are to be sent to a subcontractor.

Relinquished By: In the case of subcontracting, the primary laboratory will sign the Relinquished By space and fill out an additional COC to accompany the samples being subcontracted.

Received By (Laboratory): This space is for the final destination, e.g., at a subcontracted laboratory.

Box 10 **Lab Number and Questions:** This box is to be filled in by the laboratory only.

Box 11 **Control Number:** This number is the "COC" followed by the first EPA number in that cooler, or contained on that COC. This control number must be unique, i.e., never used twice. Record the date the COC is completed. It should be the same date the samples are collected.

Box 12 **Total No. of Containers/row:** Sum the number of containers in that row.

Box 13 **Total No. of Containers/column:** Sum the number of containers in that column. Because COC forms contain different formats based upon who produced the form, not all of the information listed in items 1 to 13 may be recorded. However, as much of this information as possible shall be included.

COC forms tailored to each CTO/DO can be drafted and printed onto multi-ply forms. This eliminates the need to rewrite the analytical methods column headers each time. It also eliminates the need to write the project manager, name, and number; QC Level; TAT; and the same general comments each time.

Complete one COC form per cooler. Whenever possible, place all VOA vials into one cooler in order to reduce the number of trip blanks. Complete all sections and be sure to sign and date the COC form. One copy of the COC form must remain with the field personnel.

6.0 RECORDS

The COC/analytical request form shall be faxed approximately daily to the CTO/DO Laboratory Coordinator for verification of accuracy. Following the completion of sampling activities, the sample logbook and COC forms will be transmitted to the CTO/DO Manager for storage in project files. The CTO/DO Manager shall review COC forms on a monthly basis at a minimum. The data validators shall receive a copy also. The original COC/analytical request form shall be submitted by the laboratory along with the data delivered. Any changes to the analytical requests that are required shall be made in writing to the laboratory. A copy of this written change shall be sent to the data validators and placed in the project files. The reason for the change shall be included in the project files so that recurring problems can be easily identified.

7.0 HEALTH AND SAFETY

Not applicable.

8.0 REFERENCES

State of California Water Resources Control Board. 1988. Technical Guidance Manual for Solid Waste Water Quality Assessment Test (SWAT) Proposals and Reports.

USEPA. 1986. EPA NEIC Policies and Procedures, National Enforcement Investigations Center, Denver, Colorado.

USEPA. 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA USWER Directive 9355 3-01).

USEPA. 1992. RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD).

USEPA. 1995 and as updated. Test Methods for Evaluating Solid Waste (SW-846), Third edition.

9.0 ATTACHMENTS

1. Chain-of-Custody Seal
2. Generic Chain-of-Custody/Analytical Request Form
3. Sample Completed Chain-of-Custody/Analytical Request Form
4. Sample Out-of-Control Form

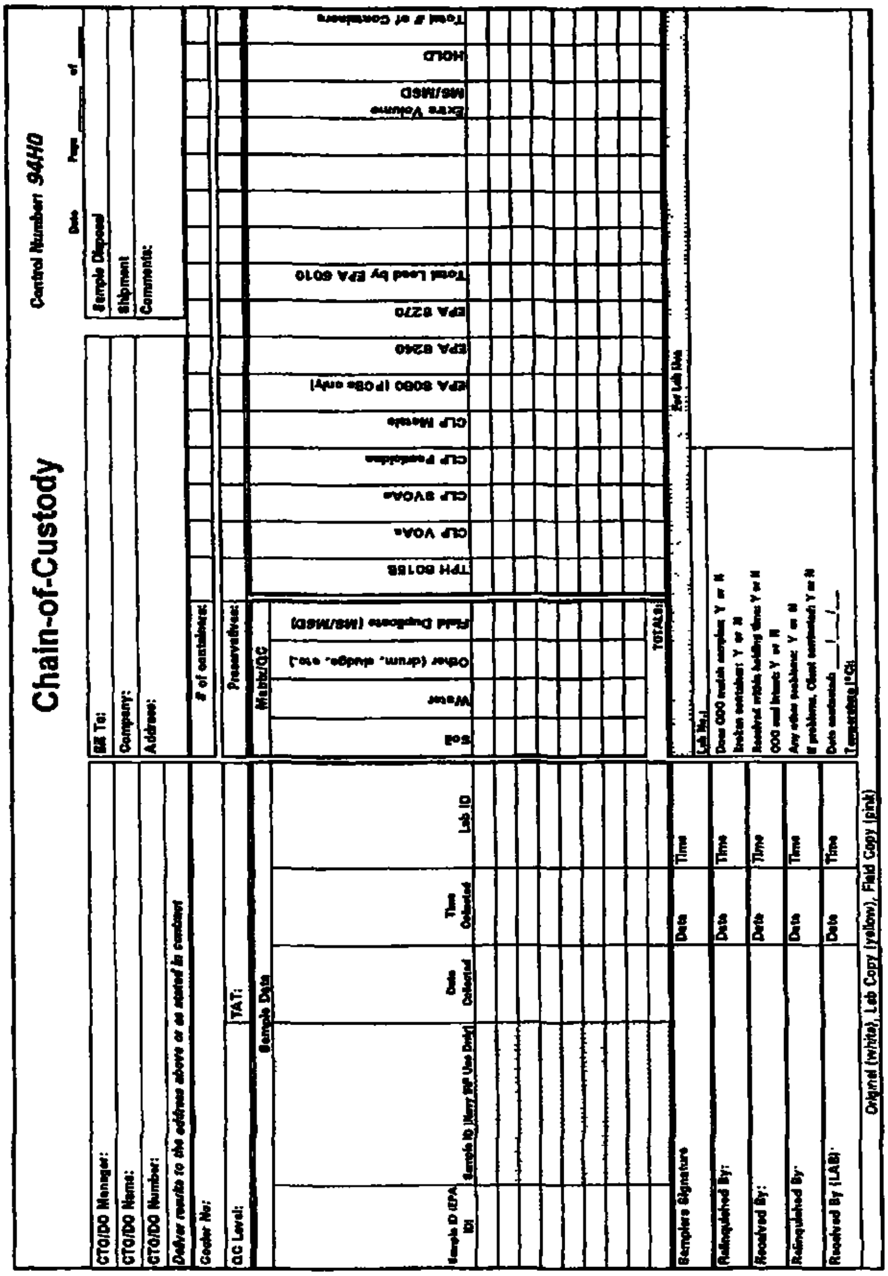
Attachment III-E-1

CHAIN-OF-CUSTODY SEAL

<table>
<tr><td rowspan="3">[LABORATORY]</td><td>SAMPLE NO</td><td>DATE</td><td>SEAL BROKEN BY</td></tr>
<tr><td colspan="2">SIGNATURE</td><td>DATE</td></tr>
<tr><td colspan="3">PRINT NAME AND TITLE (Inspector, Analyst or Technician</td></tr>
</table>

Attachment III-E-2

GENERIC CHAIN-OF-CUSTODY/ANALYTICAL REQUEST FORM



Attachment III-E-3

SAMPLE COMPLETED CHAIN-OF-CUSTODY/ ANALYTICAL REQUEST FORM

Chain-of-Custody

11 Control Number: 96H0HC205

Date 9/ 3/ 98 Page 1 of 1

1

CTO/DO Manager:	Joe Smith
CTO/DO Name:	Former Navy Landfill
CTO/DO Number:	CTO 0250
Deliver results to the address above or as stated in contract	

2

Bill To:	CLEAN/RAC Contractor
Company:	company name
Address:	Oahu, Hawaii

3

Sample Disposal	by lab
Shipment Method:	Express Courier
Comments:	PACDIV Level D, Measure Cooler Temperature at Lab

4 Cooler No: 413

QC Level: PACDIV Level D TAT: Normal - per contract

6 Sample ID (EPA ID)	Sample ID (Navy IRP Use Only)	Date Collected	Time Collected	Lab ID	7 Matrix/QC: Soil	Water	Other (drum, sludge, etc.)	Field Duplicate (MS/MSD)	8 TPH 8015B	CLP VOAs	CLP SVOAs	CLP Pesticides	CLP Metals	EPA 8080 (PCBs only)	EPA 8240	EPA 8270	Total Lead by EPA 6010					Extra Volume MS/MSD	HOLD	12 Total # of Containers
				5 container # (water):					1	2	2	1	2	1								2		
				Preservatives:					HCL	HCL			HNO3											
HC205		9/6/98	9:35		X				X	X	X	X	X	X										1
HC206		9/6/98	9:50		X				X	X	X	X	X	X										1
HC207		9/6/98	10:15		X				X	X	X	X	X	X										1
HC208		9/6/98	10:25		X				X	X	X	X	X	X										1
HC209		9/6/98	10:45		X				X	X	X	X	X	X										1
HC210		9/6/98	10:55			X		X		X														2
HC211		9/6/98	12:50			X			X	X	X	X	X	X										9
					13			TOTALS:	6	8	7	6	7	6										16

9

Samplers Signature	Date	Time
Relinquished By:	Date	Time
Received By:	Date	Time
Relinquished By:	Date	Time
Received By (LAB):	Date	Time

10 For Lab Use

Lab No.:
Does COC match samples: Y or N
Broken container: Y or N
Received within holding time: Y or N
COC seal intact: Y or N
Any other problems: Y or N
If problems, Client contacted: Y or N
Date contacted: __/__/__
Temperature (°C):

Original (white), Lab Copy (yellow), Field Copy (pink)

Attachment III-E-4

SAMPLE OUT-OF-CONTROL FORM

OUT OF CONTROL FORM	Status	Date	Initial
	Noted OOC		
	Submit for CA*		
	Resubmit for CA*		
	Completed		

Date Recognized:		By.	
Dated Occurred:		Matrix	
Parameter (Test Code):		Method	
Analyst:		Supervisor:	
1. Type of Event (Check all that apply)		2 Corrective Action (CA)* (Check all that apply)	
	Calibration Corr. Coefficient <0.995		Repeat calibration
	%RSD>20%		Made new standards
	Blank >MDL		Reran analysis
	Does not meet criteria:		Sample(s) redigested and rerun
	Spike		Sample(s) reextracted and rerun
	Duplicate		Recalculated
	LCS		Cleaned system
	Calibration Verification		Ran standard additions
	Standard Additions		Notified
	MS/MSD		Other (please explain)
	BS/BSD		
	Surrogate Recovery		
	Calculations Error		
	Holding Times Missed		
	Other (Please explain	Comments:	

Samples Affected (List by Accession AND Sample No.)

3. Results of Corrective Action
☐ Return to Control (indicated with)
☐ Corrective Actions Not Successful - DATA IS TO BE FLAGGED with ____________

Analyst.	Date
Supervisor:	Date:
QA Department.	Date:

SAMPLE HANDLING, STORAGE, AND SHIPPING

1.0 PURPOSE

This standard operating procedure (SOP) sets forth the methods for use by U.S. Navy PACDIV IRP field personnel engaged in handling, storing, and transporting samples.

2.0 SCOPE

This procedure applies to all samples, and sample containers handled, stored, shipped, or otherwise transported during Navy PACDIV IRP CTO/DO Activities.

This procedure shall serve as management-approved professional guidance for the U.S. Navy PACDIV IRP. It is not intended to obviate the need for professional judgment that may arise in unforeseen circumstances. Deviations from this procedure in planning or in the execution of planned activities must be approved by the CTO/DO Manager and Technical Director/QA Program Manager.

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

The Field Manager is responsible for ensuring that all samples are shipped according to this procedure.

The CTO/DO Manager and the Laboratory Project Manager are responsible for identifying instances of non-compliance with this procedure and ensuring that future sample transport activities are in compliance with this procedure.

The U.S. NAVY PACDIV IRP Technical Director is responsible for ensuring that sample handling, storage, and transport activities conducted during all CTO/DOs are in compliance with this procedure.

5.0 PROCEDURE

5.1 HANDLING AND STORAGE

Immediately following collection, all samples will be labeled according to the procedures in SOP III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody Procedures*. The lids of the containers shall not be sealed with duct tape, but may be covered with custody seals or placed directly into self-sealing bags. The sample containers shall be placed in an insulated cooler with frozen gel packs (such as "blue ice") or ice in double, sealed self-sealing bags. Samples should occupy the lower portion of the cooler, while the ice should occupy the upper portion. Styrofoam pads shall be placed on the bottom and top (and optionally on the sides) of the inside of the cooler. An absorbent material (e.g., proper absorbent cloth material) shall be placed on the bottom of the cooler to contain liquids in case of spillage. All empty space between sample containers shall be filled with Styrofoam "peanuts" or other appropriate material. Prior to shipping, glass sample containers should be wrapped on the sides, tops, and bottoms with bubble wrap or other appropriate padding and/or surrounded by Styrofoam to prevent breakage during transport. All glass containers for water samples must be packed in a upright position, never stacked or on their sides. Prior to shipment, the ice or cold packs in the coolers shall be replaced so that samples will be maintained as close to 4°C as possible from the time of collection through transport of the samples to the analytical laboratory. Samples shall be shipped within 24 hours or on a schedule allowing the laboratory to meet holding times for analyses. The procedures for maintaining sample temperatures at 4°C, pertains to all field samples.

5.2 SHIPPING

All appropriate U.S. Department of Transportation (DOT) regulations (e.g., 49 Code of Federal Regulations (CFR), Parts 171-179) shall be followed in shipment of air, soil, water, and other samples. Elements of these procedures are summarized below.

In Hawaii, soil sample shipments are typically brought to the courier at the airport where a United States Department of Agriculture (USDA) representative is contacted by the courier to make an inspection. Alternatively, U.S. Navy PACDIV IRP has received approval from the USDA to ship soil samples, and has received a stamp that can be used to facilitate shipment. In this way, the USDA does not need to inspect each soil sample shipment. Water sample shipments do not need to be inspected by the USDA. Custody seals are to be placed on each container (see Section 5.1, *Handling and Storage*) to ensure proper chain-of-custody control in the event coolers are opened for inspection.

In Guam, the courier picks up shipments at each site provided that arrangements have been made regarding pick-up time and location. Alternatively, shipments can be delivered directly to the courier at the airport. USDA inspection occurs outside of Guam.

5.2.1 Hazardous Materials Shipment

Field personnel must state whether any sample is suspected to be a hazardous material. A sample should be assumed to be hazardous unless enough evidence exists to indicate it is nonhazardous. If not suspected to be hazardous, shipments may be made as described in the Section 5.2.2 for non-hazardous materials. If hazardous, the procedures summarized below must be followed.

Any substance or material that is capable of posing an unreasonable risk to life, health, or property when transported is classified as hazardous. Hazardous materials identification should be performed by checking the list of dangerous goods for that particular mode of transportation. If not on that list, materials can be classified by checking the Hazardous Materials Table (49 CFR 172.102 including Appendix A) or by determining if the material meets the definition of any hazard class or division (49 CFR Part 173), as listed in Attachment 2.

All persons offering for shipment any hazardous material <u>must</u> be properly trained in the appropriate regulations, as required by HM-126F, Training for Safe Transportation of Hazardous Materials. The training covers loading, unloading, handling, storing, and transporting of hazardous materials, as well as emergency preparedness in the case of accidents. Carriers such as commercial couriers must also be trained. Modes of shipment include air, highway, rail, and water.

When shipping hazardous materials, including bulk chemicals or samples suspected of being hazardous, the proper shipping papers (49 CFR 172 Subpart C), package marking (49 CFR 172 Subpart D), labeling (49 CFR 172 Subpart E), placarding (49 CFR 172 Subpart F, generally for carriers), and packaging must be used. Attachment III-F-1 shows an example of proper package markings. A copy of 49 CFR should be referred to each time a hazardous material/potentially hazardous samples are shipped.

According to Section 2.7 of the International Air Transport Association (IATA) Dangerous Goods Regulations publication, very small quantities of certain dangerous goods may be transported without certain marking and documentation requirements as described in 49 CFR Part 172. However, other labeling and packing requirements must still be followed. Attachment III-F-2 shows the volume or weight for different classes of substances. A "Dangerous Goods in Excepted Quantities" label must be completed and attached to the associated shipping cooler (Attachment 3). Certain dangerous goods are not allowed on certain airlines in any quantity.

As stated in item 4 of Attachment 4, the Hazardous Materials Regulations do not apply to hydrochloric acid (HCl), nitric acid (HNO_3), sulfuric acid (H_2SO_4), and sodium hydroxide (NaOH) added to water samples if their pH or percentage by weight criteria are met. These samples may be shipped as non-hazardous materials as discussed below.

5.2.2 Non-hazardous Materials Shipment

If the samples are suspected to be nonhazardous, based on previous site sample results, field screening results, or visual observations, if applicable, then samples may be shipped as nonhazardous.

When a cooler is ready for shipment to the laboratory, two copies of the chain-of-custody form shall be placed inside a self-sealing bag and taped to the inside of an insulated cooler. The coolers will then be sealed with waterproof tape and labeled "Fragile," "This-End-Up" (or directional arrows pointing up), or other appropriate notices. Chain-of-custody seals will be placed on the coolers as discussed in SOP III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody Procedures.*

5.2.3 Shipments from Outside the Continental United States

Shipment of sample coolers to the U.S. from locations outside the continental U.S. is controlled by the USDA and is subject to their inspection and regulation. Documentation is required to prove that the receiving analytical laboratory is certified by the USDA to receive and properly dispose of soil; this is called a "USDA Soil Import Permit." In addition, all sample coolers must be inspected by a USDA representative, affixed with a label indicating that the coolers contain environmental samples, and shipping forms stamped by the USDA inspector prior to shipment. In addition, samples shipped from

U.S. territorial possessions or foreign countries must be cleared by the U.S. Customs Service upon entry into the United States. As long as the commercial invoice is properly completed (see below), shipments typically pass through U.S. Customs without the need to open coolers for inspection.

Completion and use of proper paperwork will, in most cases, minimize or eliminate the need of the USDA and U.S. Customs to inspect the contents. Attachment III-F-5 shows an example of how paperwork may be placed on the outside of coolers for nonhazardous materials. For hazardous materials, refer to Section 5.2.1.

In summary, the paperwork listed below should be taped to the outside of the coolers to assist sample shipments. If a shipment is made up of multiple pieces (e.g., more than one cooler), the paperwork need be attached only to one cooler, provided that the courier agrees. All other coolers in the shipment need only be taped and have address and chain-of-custody seals affixed.

1. **Courier Shipping Form & Commercial Invoice** - See Attachments III-F-6, III-F-7, and III-F-8 for examples of the information to be included on these forms. Both forms should be placed inside a clear plastic adhesive-backed pouch which adheres to the package (typically supplied by the courier) and placed on the cooler lid as shown in Attachment 5.

2. **Soil Import Permit and USDA Letter** (soil only) - See Attachments III-F-9 and III-F-10 for examples. The laboratory shall supply these documents prior to mobilization. The USDA in Hawaii often <u>does</u> stop shipments of soil without these documents. The 2" x 2" USDA label (described below), the USDA letter, and soil impact permit should be stapled together and placed inside a clear plastic pouch. Clear plastic adhesive-backed pouches which adhere to the package are typically supplied by the courier.

   The Soil Import Permit label should be supplied by the laboratory. Original labels are preferred, but copies of this label which are cut out to the 2" x 2" dimensions are acceptable. Placing one label as shown in Attachment 5 (covered with clear packing tape) and one stapled to the actual permit is suggested.

Water samples are not controlled by the USDA, so the requirements for soil listed above do not apply.

3. **Chain-of-Custody Seals**. Seals should be supplied by the laboratory. CTO/DO personnel must sign and date these; at least two seals should be placed in such a manner that they stick to both the cooler lid and body. Placing the seals over the tape (as shown in Attachment 5), then covering it with clear packing tape, is suggested. This prevents the seal from coming loose and enables detection of tampering.

4. **Address Label**. A label stating the destination (laboratory address) should be affixed to each cooler.

5. **Special Requirements for Hazardous Materials** - see Section 5.2.1.

Upon receipt of sample coolers at the laboratory, the sample custodian shall inspect the sample containers as discussed in SOP III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody Procedures*. The samples shall then be either immediately extracted and/or analyzed, or stored in a refrigerated storage area until they are removed for extraction and/or analysis. Whenever the samples are not being extracted or analyzed, they shall be returned to refrigerated storage.

6.0 RECORDS

Records shall be maintained as required by implementing these procedures.

7.0 HEALTH AND SAFETY

1. Avoid lifting heavy coolers with back muscles; instead, use leg muscles or dollies.

2. Wear proper gloves, such as blue nitrile, latex, etc., as defined in the site-specific project Health and Safety Plan, when handling sample containers to avoid contacting any materials that may have spilled out of the sample containers.

8.0 REFERENCES

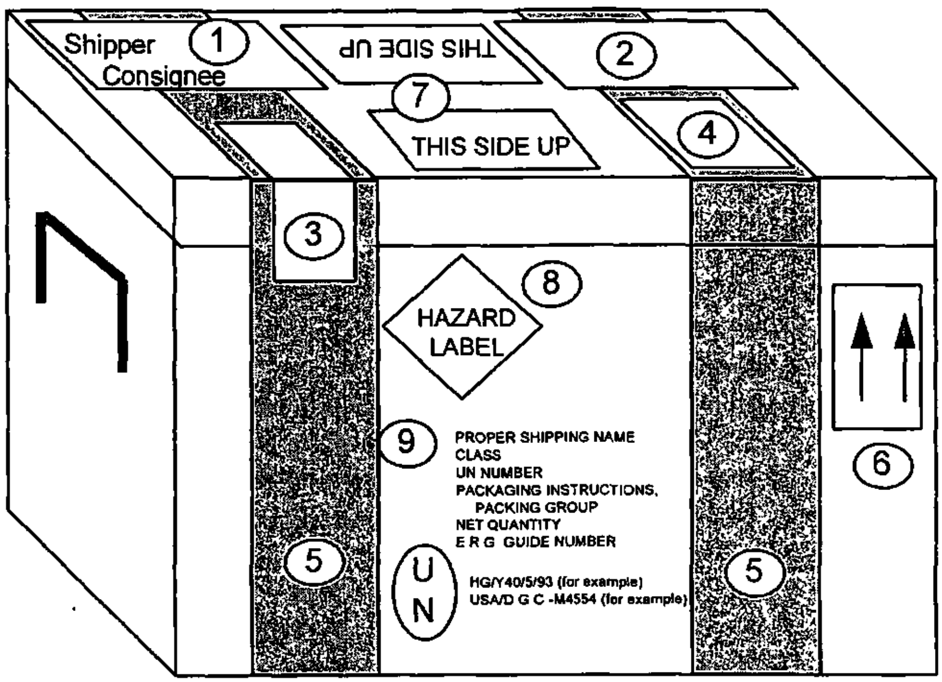
SOP III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody Procedures*

9.0 ATTACHMENTS

1. Example Package Marking
2. Packing Groups
3. Label for Dangerous Goods in Excepted Quantities
4. SW-846 Preservative Exception
5. Sample Cooler Marking Figure
6. Example Courier Form
7. Commercial Invoice - Soil
8. Commercial Invoice - Water
9. Soil Import Permit
10. Soil Samples Restricted Entry Labels

Attachment III-F-1

EXAMPLE HAZARDOUS MATERIAL PACKAGE MARKING



(1) AIR BILL/COMMERCIAL INVOICE
(2) USDA PERMIT (Letter to Laboratory from USDA)
(3) CUSTODY SEAL
(4) USDA 2" X 2" SOIL IMPORT PERMIT
(5) WATERPROOF STRAPPING TAPE
(6) DIRECTION ARROWS STICKER - TWO REQUIRED
(7) THIS SIDE UP STICKERS
(8) HAZARD LABEL
(9) HAZARDOUS MATERIAL INFORMATION
(10) PACKAGE SPECIFICATIONS

Attachment III-F-2

PACKING GROUPS

PACKING GROUP OF THE SUBSTANCE	PACKING GROUP 1		PACKING GROUP II		PACKING GROUP III	
CLASS or DIVISION of PRIMARY or SUBSIDIARY RISK	Packagings		Packagings		Packagings	
	Inner	Outer	Inner	Outer	Inner	Outer
1: Explosives	Forbidden (Note A)					
2.1 Flammable Gas	Forbidden (Note B)					
2.2. Non-Flammable, non-toxic gas	See Notes A and B					
2.3 Toxic gas	Forbidden (Note A)					
3. Flammable liquid	30 mL	300 mL	30 mL	500 mL	30 mL	1 L
4.1 Self-reactive substances	Forbidden		Forbidden		Forbidden	
4.1 Other flammable solids	Forbidden		30 g	500 g	30 g	1 kg
4.2: Pyrophoric substances	Forbidden		Not Applicable		Not Applicable	
4.2 Spontaneously combustible substances	Not Applicable		30 g	500 g	30 g	1 kg
4.3 Water reactive substances	Forbidden		30 g or 30 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
5.1 Oxidizers	Forbidden		30 g or 30 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
5.2. Organic peroxides (Note C)	See Note A		30 g or 30 mL	500 g or 250 mL	Not Applicable	
6.1 Poisons - Inhalation toxicity	Forbidden		1 g or 1 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
6.1 Poisons - oral toxicity	1 g or 1 mL	300 g or 300 mL	1 g or 1 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
6.1 Poisons - dermal toxicity	1 g or 1 mL	300 g or 300 mL	1 g or 1 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
6.2. Infectious substances	Forbidden (Note A)					
7. Radioactive material (Note D)	Forbidden (Note A)					
8. Corrosive materials	Forbidden		30 g or 30 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
9 Magnetized materials	Forbidden (Note A)					
9: Other miscellaneous materials (Note E)	Forbidden		30 g or 30 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L

Note A: *Packing groups are not used for this class or division*

Note B: *For inner packagings, the quantity contained in receptacle with a water capacity of 30 mL. For outer packagings, the sum of the water capacities of all the inner packagings contained must not exceed 1 L*

Note C: *Applies only to Organic Peroxides when contained in a chemical kit, first aid kit or polyester resin kit*

Note D: *See 6 1 4 1, 6 1 4 2 and 6 2 1 1 through 6 2.1.7, radioactive material in excepted packages*

Note E: *For substances in Class 9 for which no packing group is indicated in the List of Dangerous Goods, Packing Group II quantities must be used*

Attachment III-F-3

LABEL FOR DANGEROUS GOODS IN EXCEPTED QUANTITIES

DANGEROUS GOODS IN EXCEPTED QUANTITIES

This package contains dangerous goods in excepted small quantities and is in all respects in compliance with the applicable international and national government regulations and the IATA Dangerous Goods Regulations

____
Signature of Shipper

__________________ __________________
Title Date

____

____
Name and address of Shipper

This package contains substance(s) in Class(es)
(check applicable box(es))

Class.	2	3	4	5	6	8	9
	☐	☐	☐	☐	☐	☐	☐

and the applicable UN Numbers are

Attachment III-F-4

PRESERVATIVE EXCEPTION

Measurement	Vol. Req. (mL)	Container[2]	Preservative [3,4]	Holding Time[5]
MBAS	250	P,G	Cool, 4°C	48 Hours
NTA	50	P,G	Cool, 4°C	24 Hours

1. More specific instructions for preservation and sampling are found with each procedure as detailed in this manual. A general discussion on sampling water and industrial wastewater may be found in ASTM, Part 31, p. 72-82 (1976) Method D-3370.

2. Plastic (P) or Glass (G). For metals, polyethylene with a polypropylene cap (no liner) is preferred.

3. Sample preservation should be performed immediately upon sample collection For composite samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.

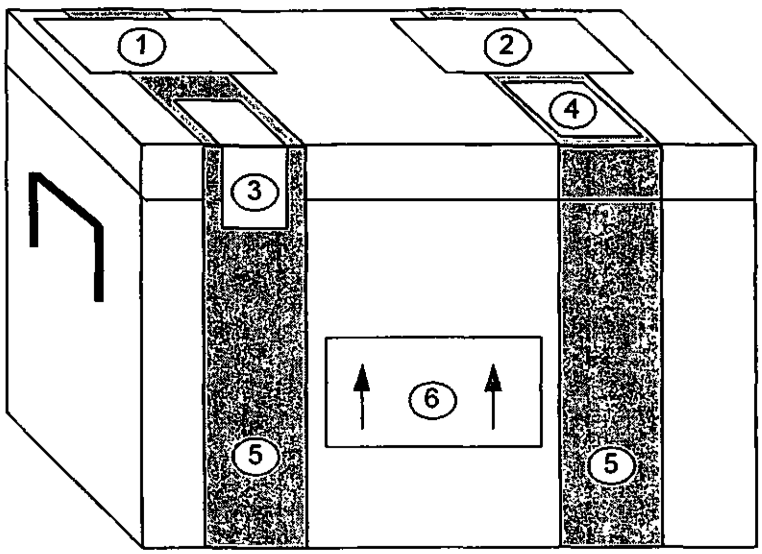
4. When any sample is to be shipped by common carrier or sent through the United States Mail, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172). The person offering such material for transportation is responsible for ensuring such compliance. for the preservation requirements of Table 1, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentration of 0.04% by weight or less (pH about 1 96 or greater); Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or grater); Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

5. Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of sample under study are stable for the longer time, and has received a variance from the Regional Administrator. Some samples may not be stable for the maximum time period given in the table. A permittee, or monitoring laboratory, is obligated to hold the sample for a shorter time if knowledge exists to show this is necessary to maintain sample stability.

6. *Should only be used in the presence of residual chlorine.*

Attachment III-F-5

NON-HAZARDOUS MATERIAL COOLER MARKING FIGURE FOR SHIPMENT FROM OUTSIDE THE CONTINENTAL UNITED STATES



1 AIR BILL/COMMERCIAL INVOICE
2 USDA PERMIT (Letter to Laboratory from USDA)
3 CUSTODY SEAL
4 USDA 2" X 2" SOIL IMPORT PERMIT
5 WATERPROOF STRAPPING TAPE
6 DIRECTION ARROWS STICKER - TWO REQUIRED

Attachment III-F-6

EXAMPLE COURIER FORM

FedEx. USA Airbill 8017048556l9 0200 Sender's Copy

1 From (please print and press hard)
Account Number
Sender's FedEx Account Number
Sender's Name Joe Smith Phone (808) 545-2462
Company OGDEN ENVIRONMENTAL/CRC ACCT
Address 680 IWILEI RD STE 660
City HONOLULU State HI ZIP 96817

2 Your Internal Billing Reference Information

3 To (please print and press hard)
Recipient's Name Sample Receipt Phone Lab Phone #
Company Lab Name
Address Lab Address
City State ZIP
For HOLD at FedEx Location check here
For Saturday Delivery check here

4a Express Package Service
4b Express Freight Service
5 Packaging
6 Special Handling
7 Payment
8 Release Signature

Questions?
Call 1·800·Go·FedEx (800)463-3339

The World On Time

Attachment III-F-7

COMMERCIAL INVOICE - SOIL

DATE OF EXPORTATION 1/1/94	EXPORT REFERENCES (i e., order no., invoice no., etc.) <CTO #>
SHIPPER/EXPORTER (complete name and address) Joe Smith Ogden c/o <hotel name> <hotel address>	CONSIGNEE Sample Receipt <Lab Name> <Lab Address>
COUNTRY OF EXPORT Guam, USA	IMPORTER - IF OTHER THAN CONSIGNEE
COUNTRY OF ORIGIN OF GOODS Guam, USA	
COUNTRY OF ULTIMATE DESTINATION USA	

INTERNATIONAL AIR WAYBILL NO. (NOTE All shipments must be accompanied by a Federal Express International Air Waybill)

MARKS/NOS	NO OF PKGS	TYPE OF PACKAGING	FULL DESCRIPTION OF GOODS	QTY	UNIT OF MEASURE	WEIGHT	UNIT VALUE	TOTAL VALUE
	3	coolers	Soil samples for laboratory analysis only				$1 00	$3.00
	TOTAL NO OF PKGS					TOTAL WEIGHT		TOTAL INVOICE VALUE
	3							$3 00

Check one
☐ F O B.
☐ C&F
☐ C I F

THESE COMMODITIES ARE LICENSED FOR THE ULTIMATE DESTINATION SHOWN
DIVERSION CONTRARY TO UNITED STATES LAW IS PROHIBITED

I DECLARE ALL THE INFORMATION CONTAINED IN THIS INVOICE TO BE TRUE AND CORRECT

SIGNATURE OF SHIPPER/EXPORTER (Type name and title and sign)

Name/Title	Signature	Date
Joe Smith, Ogden	Joe Smith	1/1/94

Attachment III-F-8

COMMERCIAL INVOICE - WATER

DATE OF EXPORTATION 1/1/94	EXPORT REFERENCES (i e., order no., invoice no., etc.) <CJO #>
SHIPPER/EXPORTER (complete name and address) Joe Smith Ogden c/o <hotel name> <hotel address>	CONSIGNEE Sample Receipt <Lab Name> <Lab Address>
COUNTRY OF EXPORT Guam, USA	IMPORTER - IF OTHER THAN CONSIGNEE
COUNTRY OF ORIGIN OF GOODS Guam, USA	
COUNTRY OF ULTIMATE DESTINATION USA	

INTERNATIONAL AIR WAYBILL NO. (NOTE: All shipments must be accompanied by a Federal Express International Air Waybill)

MARKS/NOS	NO OF PKGS	TYPE OF PACKAGING	FULL DESCRIPTION OF GOODS	QTY	UNIT OF MEASURE	WEIGHT	UNIT VALUE	TOTAL VALUE
	3	coolers	Water samples for laboratory analysis only				$1.00	$3 00
	TOTAL NO OF PKGS					TOTAL WEIGHT		TOTAL INVOICE VALUE
	3							$3 00

Check one
☐ F O B
☐ C&F
☐ C I F.

THESE COMMODITIES ARE LICENSED FOR THE ULTIMATE DESTINATION SHOWN
DIVERSION CONTRARY TO UNITED STATES LAW IS PROHIBITED.

I DECLARE ALL THE INFORMATION CONTAINED IN THIS INVOICE TO BE TRUE AND CORRECT

SIGNATURE OF SHIPPER/EXPORTER (Type name and title and sign)

Name/Title	Signature	Date
Joe Smith, Ogden	Joe Smith	1/1/94

SOIL IMPORT PERMIT
Attachment III-F-9

UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE PROGRAMS

COMPLIANCE AGREEMENT

1. NAME AND MAILING ADDRESS OF PERSON OR FIRM	2. LOCATION
Ogden Environmental & Energy Service Co 680 Iwilei Road, Suite 660 Honolulu, HI 96817	680 Iwilei Road, Suite 660 Honolulu, HI 96817 Telephone: 545-2462 Fax: 528-5379

3. REGULATED ARTICLE(S)
Foreign soil samples destined to approved laboratories in the Continental United States transiting through Honolulu International Airport and military facilities on Oahu, Hawaii.

4. APPLICABLE FEDERAL QUARANTINE(S) OR REGULATIONS
7 CFR 330.300

6. I/We agree to the following:

See the attached Addendum, Foreign Soil Samples Destined To Approved Laboratories In The Continental United States Transiting Through Honolulu International Airport And Military Facilities On Oahu, Hawaii

THIS COMPLIANCE AGREEMENT IS VALID FOR 2 YEARS FROM THE DATE OF ISSUANCE
For renewal, call our office at 861-8446 or Fax 861-8450.

EXPIRATION DATE: SEPTEMBER 30, 2000

7. SIGNATURE	8. TITLE	9. DATE SIGNED
Betsy D. Quspaugh	Air & Hazardous Waste Group Manager	9/9/98

The affixing of the signatures below will validate this agreement which shall remain in effect until canceled, but may be revised as necessary or revoked for noncompliance.	10. AGREEMENT NO. OAHU-ST-002 11. DATE OF AGREEMENT September 2, 1998

12. PPQ OFFICIAL (Name and Title) Michael M. Jodoi, Supervisor, Satellite Operations	13. ADDRESS USDA, APHIS, PPQ 3375 Koapaka Street, Suite G330 Honolulu, HI 96819
14. SIGNATURE Michael M. Jodoi	
15. STATE AGENCY OFFICIAL (Name and Title) N/A	16. ADDRESS N/A
17. SIGNATURE N/A	

PPQ FORM 519 REPLACES PPQ 274, 519, 560, AND AQI 83, WHICH ARE OBSOLETE
AUG. 1977

Attachment III-F-10

SOIL SAMPLES RESTRICTED ENTRY LABELS

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE
HYATTSVILLE, MARYLAND 20782

SOIL SAMPLES
RESTRICTED ENTRY

The material contained in this package
is imported under authority of the
Federal Plant Pest Act of May 23, 1957

For release without treatment if
addressee is currently listed as
approved by Plant Protection and
Quarantine.

PPQ FORM 550 *Edition of 12/77 may be used*
(JAN 83)

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE
HYATTSVILLE, MARYLAND 20782

SOIL SAMPLES
RESTRICTED ENTRY

The material contained in this package
is imported under authority of the
Federal Plant Pest Act of May 23, 1957

For release without treatment if
addressee is currently listed as
approved by Plant Protection and
Quarantine.

PPQ FORM 550 *Edition of 12/77 may be used*
(JAN 83)

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE
HYATTSVILLE, MARYLAND 20782

SOIL SAMPLES
RESTRICTED ENTRY

The material contained in this package
is imported under authority of the
Federal Plant Pest Act of May 23, 1957

For release without treatment if
addressee is currently listed as
approved by Plant Protection and
Quarantine.

PPQ FORM 550 *Edition of 12/77 may be used*
(JAN 83)

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PERFORMANCE EVALUATION SAMPLES

1.0 PURPOSE

This section sets forth the standard operating procedure (SOP) for using performance evaluation (PE) samples on U.S. Navy PACDIV IRP sampling projects. PE samples are used to assess analytical accuracy in the laboratory during the time frame that project samples are analyzed, for a given method.

2.0 SCOPE

This procedure applies to all sample collection projects that have specified the use of PE samples. The use of PE samples is recommended for all medium and large projects, especially for laboratories that have not been used extensively or that have experienced quality control problems, and for particular analyses for which identification or assessment of magnitude (concentration) has been, or is expected to be, difficult.

3.0 DEFINITIONS

3.1 PERFORMANCE EVALUATION (PE) SAMPLE

A PE sample is defined as a sample prepared by a vendor/supplier that contains a certified spiked concentration of a certain analyte(s). This sample is shipped to the analytical laboratory along with other site samples and analyzed. It should be double blind, i.e., the identity of the PE sample, analytes, and analyte concentrations are unknown to the laboratory. In order to serve as a double blind PR sample, it is important that the sample, to the extent practical, mimic actual field samples in terms of the number, type, and concentration of contaminants, and the sample matrix composition. Results reported by the laboratory for each analyte are compared to the certified concentrations supplied by the PE sample vendor, which measures the performance of the laboratory for that particular analytical method. PE samples are available for many analytes and at different concentrations. The water matrix is the most commonly used matrix for project-specific PE samples. Use of the soil matrix for PE samples is more difficult to interpret because of widely different soil types, which may affect contaminant extraction efficiency (unless soil from the site itself is effectively homogenized and spiked, and if field heterogeneity has been quantified. Non-native soils used for PE sample spiking would need to mimic site soil physical characteristics).

4.0 RESPONSIBILITIES

The CTO/DO Manager, along with the Technical Director/QA Program Manager, is responsible for deciding whether to include PE samples in the scope of work, while the CTO/DO laboratory coordinator and CTO/DO Manager are responsible for ordering the PE sample. Shipping the PE sample blind to the laboratory is the responsibility of the field sampling personnel and Field Manager. Interpretation of the analytical results associated with PE samples and implementing corrective actions associated with questionable results (if necessary) is the responsibility of the CTO/DO Manager or their designee.

5.0 PROCEDURES

PE samples shall be obtained from a vendor/supplier for the analyte(s) of interest. For example, if only a subset of analytes from an analytical category are suspected, the PE sample need only be spiked with these (e.g., benzene and trichloroethene from the volatile organic compounds analytical category may be the only compounds of concern for a specific CTO/DO).

The concentration of interest shall also be specified. If site samples are expected to be at low concentrations, it is better to specify that a low concentration of the analytes be spiked into the PE sample. Generally, spikes at 2 to 3 times the reporting limit and near the regulatory action level (if any) are useful for water samples to verify the reporting limits provided by the laboratory, while spikes greater than 5 times the reporting limit are more useful for assessing the recovery of compounds that are expected to be present at a site. Soil PE samples are more difficult to interpret because of widely different soil types which may affect contaminant extraction efficiency (unless soil from the site itself is spiked), so these should be spiked with concentrations at least five times the reporting limit.

The PE samples shall be ordered from a qualified vendor far enough in advance that it can be prepared, then shipped to the field site a day or two prior to shipping it back to the laboratory along with other site samples. Care must be taken to ensure PE samples do not exceed their shelf time. It may be necessary to send the vendor sample containers that will be used for the project so that the laboratory cannot distinguish between sample containers and identify which sample is the PE sample. The vendor shall be responsible for adding the proper volume and type of preservative to each container. The PE samples shall be shipped overnight on ice and immediately placed in the sample stream. The date and time of the preparation of the PE samples are not evaluated.

The PE sample shall be labeled similarly to other field samples so that the laboratory cannot distinguish which sample is the PE sample. Sample naming, labeling, handling, and shipping are discussed in SOP Numbers I-A-7, *IDW Management*; and III-F, *Sampling Handling, Storage, and Shipping Procedures*. If it is necessary to send a PE sample to the laboratory in advance of field sampling (this is not normally recommended), enough volume must be provided for the laboratory to use as a matrix spike/matrix spike duplicate (MS/MSD) sample also.

PE samples shall be submitted to the laboratory and analyzed as close to the beginning of a project as possible (e.g., within the first week of a one to two month field sampling effort). This should allow sufficient time for the PE sample results to be evaluated, and appropriate corrective actions to be implemented. The evaluation should consist of comparing the analytical results for each compound to the corresponding certified concentrations supplied by the vendor. For water samples, the laboratory should be capable of identifying each of the compounds present in the PE sample and detecting these compounds at concentrations within the acceptable range specified by the vendor. Due to potential matrix interference problems associated with soil samples, it may be sufficient for the laboratory to simply identify the presence of a particular suite of analytes (i.e., the laboratory may not be capable of detecting the analytes within the acceptance criteria specified). The evaluation methodology for PE samples shall be documented into the project-specific planning documents (e.g., Work Plan, QAPP, etc.).

If the results reported by the laboratory are not found to be acceptable (i.e., the correct identity and concentration are not reported), appropriate corrective action shall be taken. Initially, the findings of the PE sample evaluation shall be submitted to the laboratory along with a request for an explanation for PE sample analysis failure. The analytical laboratory shall prepare a description of corrective actions, as necessary, that either have, or will be, taken to remedy the problem. If the laboratory cannot provide sufficient explanation for the problems, then another PE sample can be submitted for specific analysis for analytes of concern. The additional PE sample result will be used to verify that corrective action was taken. This will, of course, depend on whether the field sampling efforts are still occurring. Timely reporting of the PE results will be required, as well as early assessment of the PE sample results to ensure that additional PE samples can be submitted if problems are identified. If deemed necessary by the Technical Director/QA Program Manager, the laboratory can be audited to help confirm that they are capable of conducting the required analysis. Finally, if necessary, the laboratory can be suspended from conducting analysis for a particular method, or for the entire project.

6.0 RECORDS

Field sampling personnel shall label, package, and ship the PE sample similarly to other site samples. The certified value for each analyte and the acceptable range of results provided by the vendor/supplier shall be retained and used to compare to actual results reported. The results of the evaluation shall be included in the associated deliverable (e.g., Remedial Investigation Report, Remediation Verification Report, etc.).

7.0 HEALTH AND SAFETY

Field personnel shall follow the same health and safety procedures that apply to routine sample handling and shipping practices.

8.0 REFERENCES

None.

9.0 ATTACHMENTS

None.