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INTERIM MEASURE WORK PLAN FOR MONITORED NATURAL ATTENUATION PILOT TEST SOLID WASTE MANAGEMENT UNIT 17 (SWMU 17) ZONE H CNC CHARLESTON SC
8/17/2001
CH2M HILL

INTERIM MEASURE WORK PLAN

Monitored Natural Attenuation Pilot Test

SWMU 17. Zone H

Charleston Naval Complex
North Charleston, South Carolina

SUBMITTED TO
U.S. Navy Southern Division
Naval Facilities Engineering Command

CH2M-Jones

August 2001

Contract N62467-99-C-0960

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CH2MHILL

August 17, 2001

Mr. David Scaturo
Division of Hazardous and Infectious Wastes
South Carolina Department of Health and
Environmental Control
Bureau of Land and Waste Management
2600 Bull Street
Columbia, SC 29201

Re: Interim Measure Work Plan (Revision 0), Monitored Natural Attenuation Pilot Test – SWMU 17, Zone H

Dear Mr. Scaturo:

Enclosed please find four copies of the Interim Measure Work Plan (Revision 0), Monitored Natural Attenuation Pilot Test – SWMU 17, Zone H of the Charleston Naval Complex (CNC). This report has been prepared pursuant to agreements by the CNC BRAC Cleanup Team for completing the RCRA Corrective Action process.

The principal author of this document is Rebecca Carovillano. Please contact her at 303/771-0900, extension 5078, if you have any questions or comments..

Sincerely,

CH2M HILL

Dean Williamson, P.E.

cc: Rob Harrell/Navy, w/att
Gary Foster/CH2M HILL, w/att

INTERIM MEASURE WORK PLAN

Monitored Natural Attenuation Pilot Test
SWMU 17, Zone H

Charleston Naval Complex
North Charleston, South Carolina

SUBMITTED TO
U.S. Navy Southern Division
Naval Facilities Engineering Command

PREPARED BY
CH2M-Jones

August 2001

Revision 0
Contract N62467-99-C-0960
158814.ZH.PR.09

Certification Page for Interim Measure Work Plan – SWMU 17, Zone H

Monitored Natural Attenuation Pilot Test

I, Dean Williamson, certify that this report has been prepared under my direct supervision. The data and information are, to the best of my knowledge, accurate and correct, and the report has been prepared in accordance with current standards of practice for engineering.

South Carolina

Temporary Permit No. T2000342

Dean Williamson, P.E.

8/10/2001

Date

SOUTH CAROLINA
CH2M HILL, INC.
No.: C00201
CERTIFICATE OF AUTHORIZATION

Contents

Acronyms and Abbreviations

BCT	BRAC Cleanup Team
BRAC	Base Realignment and Closure
CA	Corrective Action
CMS	Corrective Measures Study
CNC	Charleston Naval Complex
COC	chemical of concern
COPC	chemical of potential concern
DNAPL	dense non-aqueous phase liquid
DOT	Department of Transportation
DPT	direct-push technology
EnSafe	EnSafe Inc.
EPA	U.S. Environmental Protection Agency
ft bls	feet below land surface
ft/d	feet per day
HAZWOPER	Hazardous Waste Operations and Emergency Response
HSWA	Hazardous and Solid Waste Amendments
IDW	investigation-derived waste
IM	interim measure
LNAPL	light non-aqueous phase liquid
m/m	meter per meter
µg/L	microgram per liter
MCL	maximum contaminant level
MCS	media cleanup standard
MNA	monitored natural attenuation
NAPL	non-aqueous phase liquid
NAVBASE	Naval Base
NAVFACENGCOM	Southern Division Naval Facilities Engineering Command
OSWER	Office of Solid Waste and Emergency Response
PVC	polyvinyl chloride

RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SCDHEC	South Carolina Department of Health and Environmental Control
SOP	standard operating procedure
SVOC	semivolatile organic compound
SWMU	solid waste management unit
USBP	United States Border Patrol
USGS	United States Geological Survey
VOC	volatile organic compound

Section 1.0

1.0 Introduction

In 1993, Naval Base (NAVBASE) Charleston was added to the list of bases scheduled for closure as part of the Defense Base Realignment and Closure (BRAC) Act, which regulates closure and transition of property to the community. The Charleston Naval Complex (CNC) was formed as a result of the dis-establishment of the Charleston Naval Shipyard and NAVBASE on April 1, 1996.

CNC Corrective Action (CA) activities are being conducted under the Resource Conservation and Recovery Act (RCRA); the South Carolina Department of Health and Environmental Control (SCDHEC) is the lead agency for CA activities at the site. All RCRA CA activities are performed in accordance with the Final Permit (Permit No. SCO 170 022 560).

In April 2000, CH2M-Jones was awarded a contract to provide environmental investigation and remediation services at CNC. This work plan has been prepared by CH2M-Jones to document the basis for a Monitored Natural Attenuation (MNA) Pilot Test at Solid Waste Management Unit (SMWU) 17 in Zone H of the CNC.

1.1 Introduction

CH2M-Jones has prepared this MNA Pilot Test Work Plan on behalf of the Southern Division Naval Facilities Engineering Command (NAVFACENGCOM) to comply with the RCRA Hazardous and Solid Waste Amendments (HSWA) Permit requirements for closure of the CNC facility.

This Pilot Test Work Plan presents the scope of work for the MNA of chemicals of concern (COCs) in groundwater at SWMU 17. Specifically, this Pilot Test Work Plan presents a description of the SWMU 17 study area, a summary of the extent of groundwater contamination, a description of the MNA technology and the technical approach that will be used, methods for monitoring MNA effectiveness, and a proposed project implementation schedule.

1.2 Purpose of the MNA Pilot Test Work Plan

The general purpose of this Pilot Test is to assess the effectiveness of MNA as a groundwater remedial alternative. Specifically, the main objectives are to assess the effectiveness of MNA in order to accomplish the following objectives:

- Reduce the mass of COCs in SWMU 17 groundwater
- Reduce the concentrations of COCs in SWMU 17 groundwater below the applicable media cleanup standards (MCSs) within a suitable timeframe
- Control migration and/or reduce the extent of the dissolved COCs groundwater plume in the SWMU 17 area

If this study indicates that MNA is feasible for aquifer remediation, it will be added to the upcoming Corrective Measures Study (CMS) alternatives analysis for consideration as a final remedy.

1.3 Organization of the MNA Pilot Test Work Plan

This MNA Pilot Test Work Plan consists of the following eight sections, including this introductory section:

1.0 Introduction —Presents the purpose of and background information on the work plan.

2.0 SWMU 17 Site Description —Provides a site description of the SWMU 17 study area, including a summary of the extent of groundwater contamination and site hydrogeologic conditions.

3.0 Remedial Objectives —Discusses the overall remedial objectives at SWMU 17.

4.0 MNA Technology Description —Presents generic information about the processes of the MNA technology, description of source controls to be used in conjunction with MNA, and how MNA is demonstrated to be occurring.

5.0 Pilot Study Technical Approach and Methodology —Presents the proposed MNA approach at SWMU 17, proposed new monitoring well locations, and the analytical parameter list to be used for monitoring the effectiveness of MNA.

6.0 Project Schedule —Presents the proposed schedule for implementation of field work, groundwater monitoring, and submission of project deliverables.

7.0 Investigation-Derived Waste —Discusses the methods to be used for handling soil cuttings, development water, and other investigation-derived waste (IDW) generated as part of this pilot test.

8.0 References —Lists the references used in this document.

All tables and figures appear at the end of their respective sections.

Section 2.0

2.0 SWMU 17 Site Description

SWMU 17, shown in Figure 2-1, is located at Building FBM 61 within Zone H of the CNC. FBM 61 is the former Fleet Ballistic Missile Training Center that was used by the Navy from 1962 until June 1996. It is leased by the United States Border Patrol (USBP) and is used as a law enforcement training facility.

The zoning for SWMU 17, as applied by the City of North Charleston, is B-2, which is a zoning type that allows for various commercial business activities but does not provide for long-term or permanent residential use. The CNC Reuse Plan designates the future land use of this area for government offices and a training campus. The USBP's use of this area for law enforcement training is compatible with the zoning and future land use provided for in the Reuse Plan.

2.1 Current Nature and Extent of Contamination

Site investigation activities have occurred in five separate phases since 1994. Soil sample collection and groundwater monitoring well installation methods are detailed in the *Final RCRA Facility Investigation (RFI) Report for Zone H* (EnSafe Inc. [EnSafe]/Allen & Hoshall, 1996).

Sources of contamination at SWMU 17 were previously described in detail in the CMS Work Plan prepared by CH2M-Jones (2001a) and are shown in Figure 2-2. A detailed summary of previous investigations was also provided in the CMS Work Plan.

The RFI Addendum (EnSafe, 2000) included the following summary of the general origins and extent of key contaminants, which serves as an overall conceptual site model regarding sources of contamination and current status:

> *PCB and diesel fuel oil from activities in and around FBM 61 have entered soil and groundwater at the site. PCB contamination is the result of transformer fluid leaks in the paved courtyard area on the north side of the building. Aroclor-1260 is the main PCB contaminant exceeding screening levels in soil. Chlorinated benzenes are also present as contaminants associated with the leaking transformer dielectric fluid. Leaking transformer fluids pooled on the surface or in pavement subgrade materials northwest of what is now the storage area, and migrated vertically until accumulating in the saturated zone as a DNAPL in the*

area immediately surrounding well 017002. The DNAPL found at well 017002 is persistent but not great in thickness (0.10 ft, 01/00). The DNAPL accumulation appears static but is a continuing source of dissolved phase constituents such as the chlorinated benzene compounds. Although there have been some PCB detections in groundwater, chlorobenzene is the most widespread contaminant in groundwater related to the dielectric fluid and has migrated north and south of the building area.

Diesel fuel leaking from UST FBM 61-1 and the buried boiler fuel pipeline likely contributed to the spread of PCB contaminants in soil. Residual diesel fuel from the pipeline leak is present as LNAPL in the storage addition area. LNAPLs at FBM 61 have not migrated from the source area and are relatively immobile under existing site groundwater gradients. However, the LNAPLs continue to be a source of dissolved phase constituents. Soluble phase fuel constituents are present in shallow groundwater beneath the paved courtyard and storage addition, and in the area around the pipeline between the storage addition and the boiler fuel storage AST [above-ground storage tank]. Moderate pumping of the temporary wells during development and sampling created a noticeable increase in LNAPL measured in SWMU 17 wells. This implies that the LNAPLs may be induced to move by low pumping of the aquifer.

The low permeability clayey sediments of Qm1 effectively isolate the basal sand (Qs1) of the surficial aquifer beneath SWMU 17 which has not been impacted by contaminants in near surface soils and shallow groundwater.

A total of 10 shallow groundwater monitoring wells were installed in 1994 and 1998 to a typical depth of about 15 feet below land surface (ft bls). In 1998, one deep monitoring well was installed to a depth of 44 ft bls at SWMU 17. In 1999, 27 temporary wells were installed to a depth of approximately 15 ft bls using direct-push technology (DPT). These wells were installed to investigate other potential sources of contamination at SWMU 17 and to better delineate the extent of specific contaminants in groundwater. Figure 2-3 shows groundwater monitoring wells and DPT locations.

A risk assessment for SWMU 17 was performed and documented in the Zone H RFI Addendum (EnSafe, 2000) for chemicals of potential concern (COPCs) identified in the preliminary screening process. According to the RFI and risk assessment, environmental media at SWMU 17 that have been impacted include surface and subsurface soils and groundwater. Potential offsite impacts were evaluated as part of the fate and transport analysis; it was concluded that offsite sediment or surface water impacts were not occurring at the present time and are not anticipated to occur in the future. There are no sediments or surface water associated with SWMU 17; therefore, these media do not need to be remediated or considered in the CMS.

COCs for surface soil, subsurface soil and groundwater were evaluated and documented in the CMS Work Plan (CH2M-Jones, 2001a). MCSs based on risk were proposed in the CMS Work Plan for the COCs. Based on the COC evaluation, risk assessment and remedial action objectives (RAOs), the COCs for groundwater and associated MCSs, along with the upper and lower range of concentrations detected during the site investigation activities, are presented in Table 2-1.

Current sources of groundwater contamination at SWMU 17 exist in the form of subsurface soil concentrations of COCs that may leach to the groundwater and localized areas of light non-aqueous phase liquid (LNAPL) and dense non-aqueous phase liquid (DNAPL) in the shallow aquifer. Figure 2-4 illustrates the extent of non-aqueous phase liquid (NAPL) and contamination in subsurface soil and groundwater, relative to MCSs. For this figure, the chemical that has the greatest lateral extent across the site has been selected for each media. Accordingly, Aroclor-1260 is shown for soils, and chlorobenzene is shown for groundwater.

An Interim Measure Work Plan (CH2M-Jones, May 2001b) was prepared to address the removal of surface soils that exceed the industrial MCS for Aroclor-1260 and the removal of NAPL from existing monitoring wells.

2.2 Hydrogeology Overview

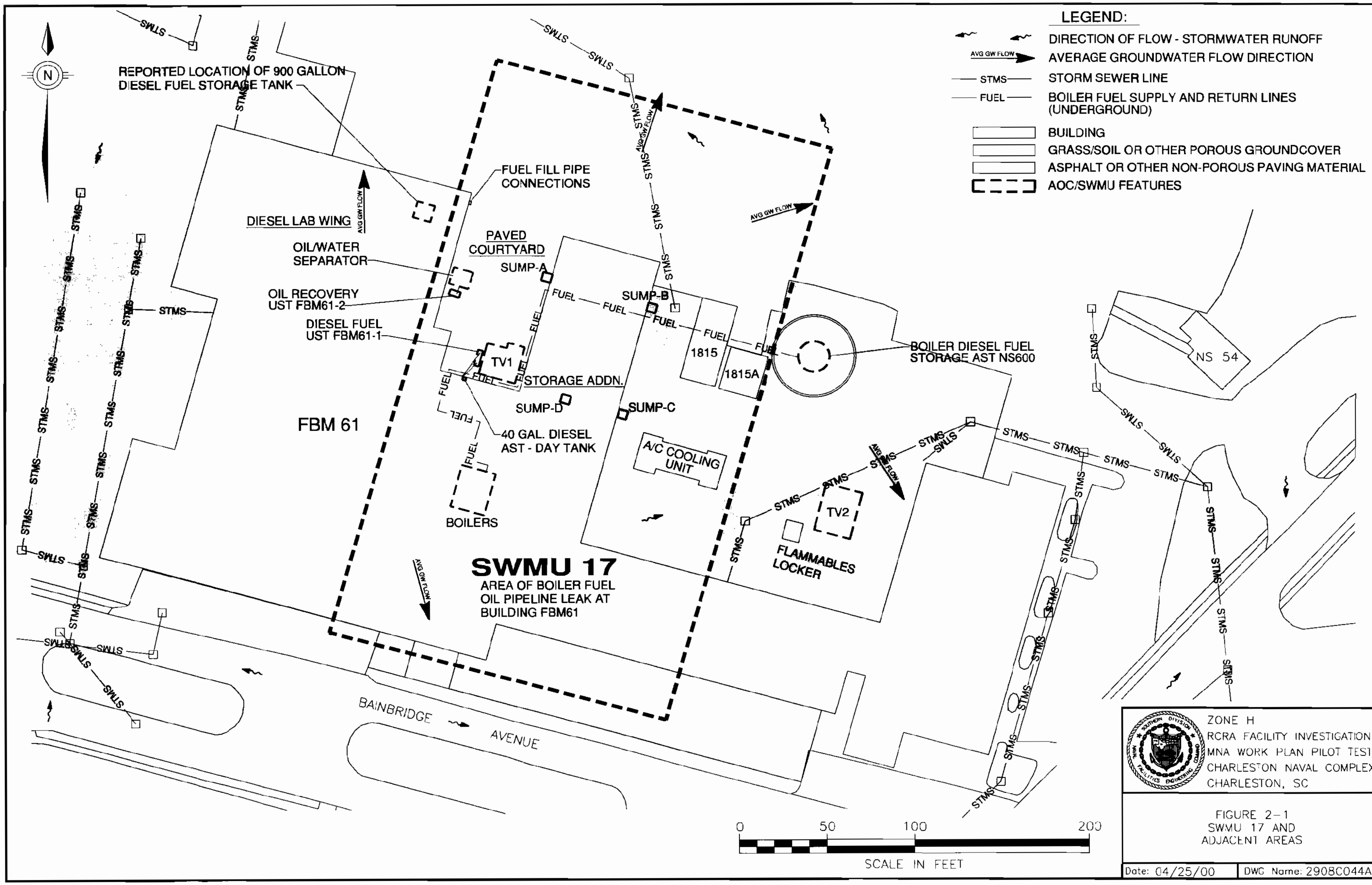
Soil samples collected from SWMU 17 borings indicate that the site geology consists of unconsolidated Quaternary coastal sediments. The sediments consist of interbedded silty sands and marsh clays. The sands and clays contain an unconfined (water table) aquifer system. The water table is approximately 5 ft bls at SWMU 17, and the interbedded sands and clays range from 5 to 15 feet in thickness. Beneath this aquifer lies an organic clayey silt that appears to be laterally continuous at SWMU 17 since it is detected in the bottom portions of all of the groundwater wells installed at the site. This clay unit is approximately 15 feet thick in the one well that fully penetrated it, and is likely to provide an effective barrier in preventing shallow groundwater contamination from reaching the deeper aquifer that lies beneath the clay.

The shallow groundwater flow direction has been assessed to flow from a groundwater high in the west of the SWMU 17 area towards the north, east, and south. Groundwater elevations measured in December 1999 are shown in Figure 2-5. Based on the results of a study performed by the United States Geological Survey (USGS) that involved computer model simulations of groundwater flow, CNC hydraulic conductivities range from 3 to 8 feet per day (ft/d). A hydraulic conductivity of 4 ft/d is appropriate for SWMU 17, based on the model results. The average hydraulic gradient at the SWMU 17 site is considered to be 0.01 meter per meter (m/m).

TABLE 2-1
Groundwater MCSs/RAOs for SWMU 17
MNA Pilot Test Work Plan, SWMU 17, Zone H, Charleston Naval Complex

	Minimum Detected Concentration	Maximum Detected Concentration	Proposed MCS	MCL	Explanation	RGOs Based on Noncarcinogenic Risks HI=0.1	HI=1	HI=3
COC	(µg/L)	(µg/L)	(µg/L)	(µg/L)		(µg/L)	(µg/L)	(µg/L)
Aroclor-1260	2.3	520	0.5	0.5	MCL is proposed cleanup goal.	NA	NA	NA
Benzene	2	130	5	5	MCL is proposed cleanup goal.	NA	NA	NA
Chlorobenzene	0.78	6,900	110	NA	Not a carcinogen; cleanup goal for HI=1 is 110 µg/L.	11	110	330
2-chlorophenol	5	18	30	NA	Not a carcinogen; cleanup goal for HI=1 is 30 µg/L.	3	30	90
1,3-dichlorobenzene	2	1,400	600	600#	MCL is proposed cleanup goal.	0.6	6	17
1,4-dichlorobenzene	1	2,700	75	75	MCL is proposed cleanup goal.	NA	NA	NA
Naphthalane	6	33	6.2	NA	Not a carcinogen; cleanup goal for HI=1 is 6.2 µg/L.	0.62	6.2	19
1,2,4-trichlorobenzene	1	1,400	70	70	MCL is proposed cleanup goal.	19	190	570

#	Value for 1,3-dichlorobenzene is based on 1,2-dichlorobenzene
HI	Hazard index
NA	Not applicable (not a carcinogen)


LEGEND:
DIRECTION OF FLOW - STORMWATER RUNOFF
AVERAGE GROUNDWATER FLOW DIRECTION
STMS — STORM SEWER LINE
FUEL — BOILER FUEL SUPPLY AND RETURN LINES (UNDERGROUND)
BUILDING
GRASS/SOIL OR OTHER POROUS GROUNDCOVER
ASPHALT OR OTHER NON-POROUS PAVING MATERIAL
AOC/SWMU FEATURES
REPORTED LOCATION OF 900 GALLON DIESEL FUEL STORAGE TANK
FUEL FILL PIPE CONNECTIONS
DIESEL LAB WING
PAVED COURTYARD
OIL/WATER SEPARATOR
OIL RECOVERY UST FBM61-2
DIESEL FUEL UST FBM61-1
SUMP-A
SUMP-B
SUMP-C
SUMP-D
TV1
TV2
STORAGE ADDN.
40 GAL. DIESEL AST - DAY TANK
BOILERS
FBM 61
1815
1815A
BOILER DIESEL FUEL STORAGE AST NS600
NS 54
A/C COOLING UNIT
FLAMMABLES LOCKER
SWMU 17
AREA OF BOILER FUEL OIL PIPELINE LEAK AT BUILDING FBM61
AVG GW FLOW
BAINBRIDGE AVENUE
0 50 100 200
SCALE IN FEET
ZONE H
RCRA FACILITY INVESTIGATION
MNA WORK PLAN PILOT TEST
CHARLESTON NAVAL COMPLEX
CHARLESTON, SC
FIGURE 2-1
SWMU 17 AND ADJACENT AREAS
Date: 04/25/00
DWG Name: 2908C044A

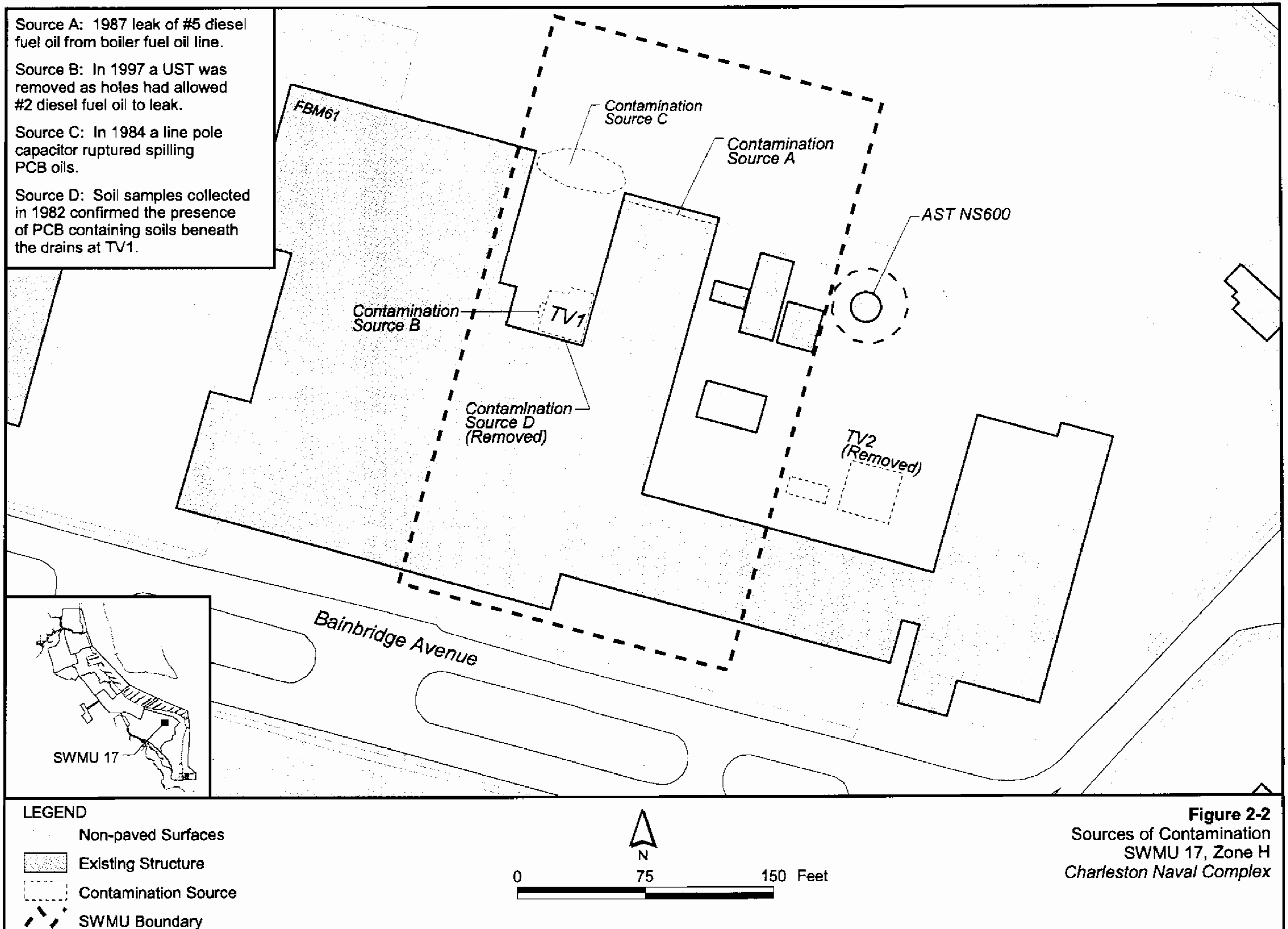


Figure 2-2
Sources of Contamination
SWMU 17, Zone H
Charleston Naval Complex

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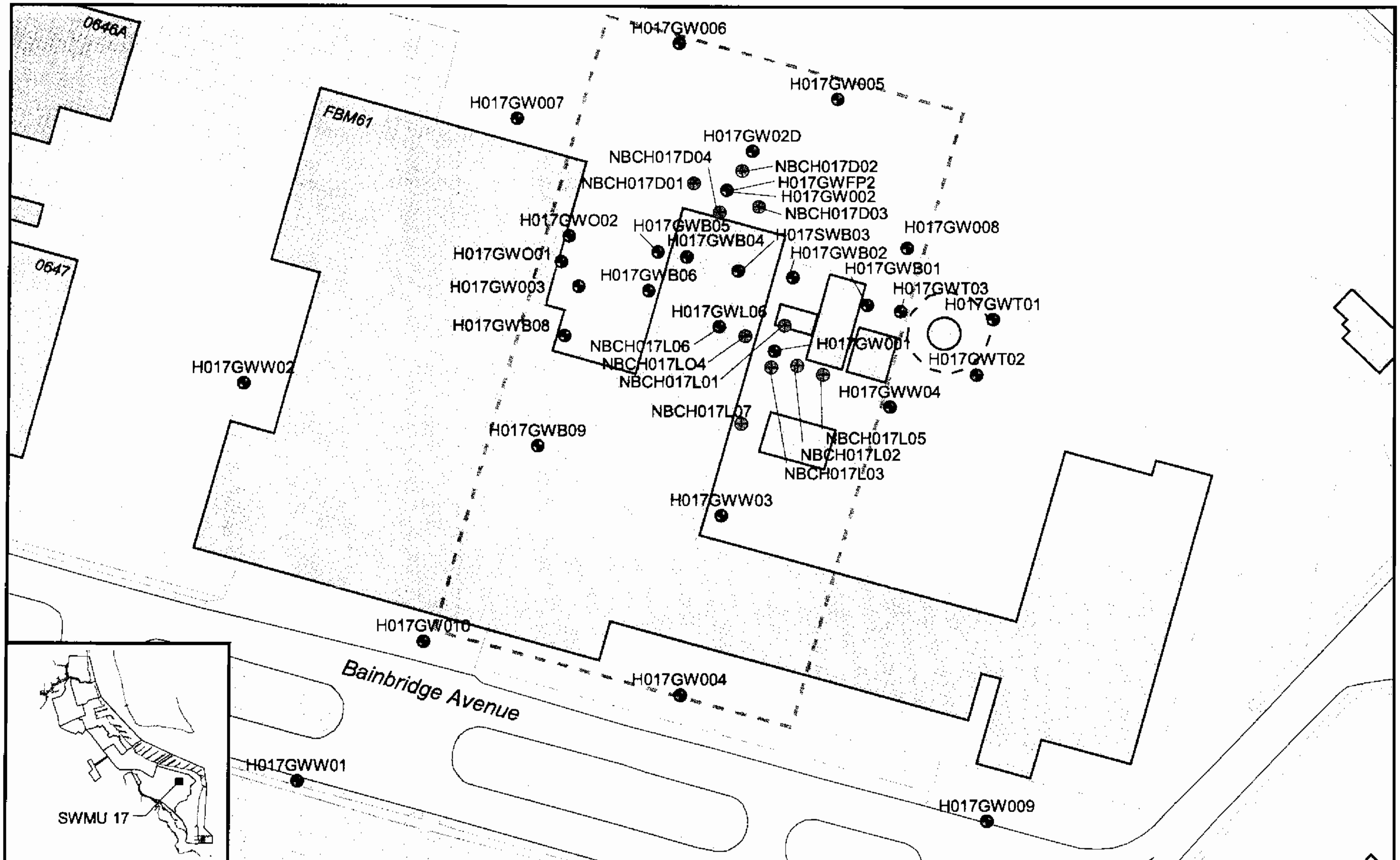

LEGEND
- Groundwater Probe
- Groundwater Well
- SWMU Boundary

N

0 75 150 Feet

Figure 2-3
Groundwater Well and Probe
Location Map
SWMU 17, Zone H
Charleston Naval Complex

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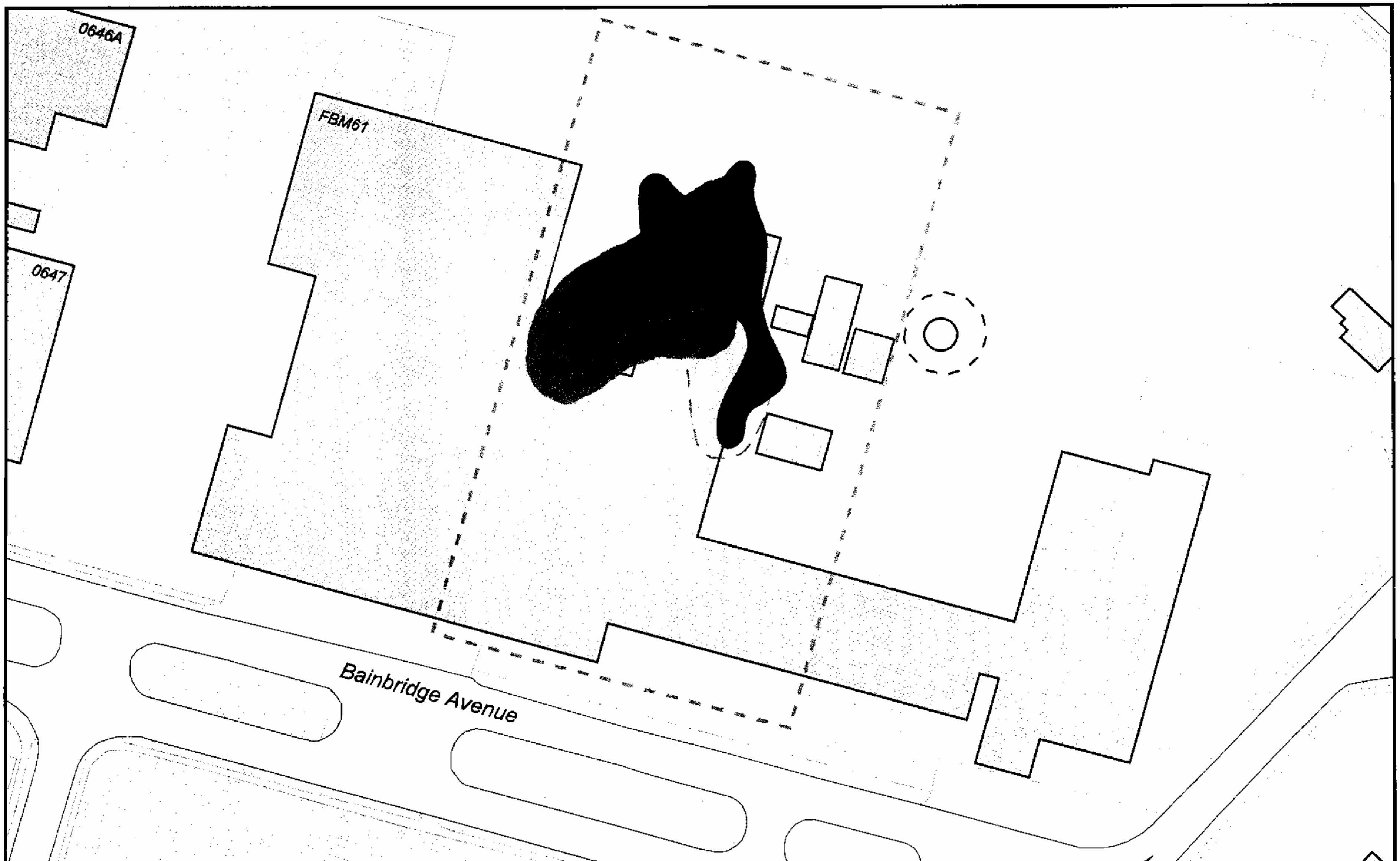


LEGEND:

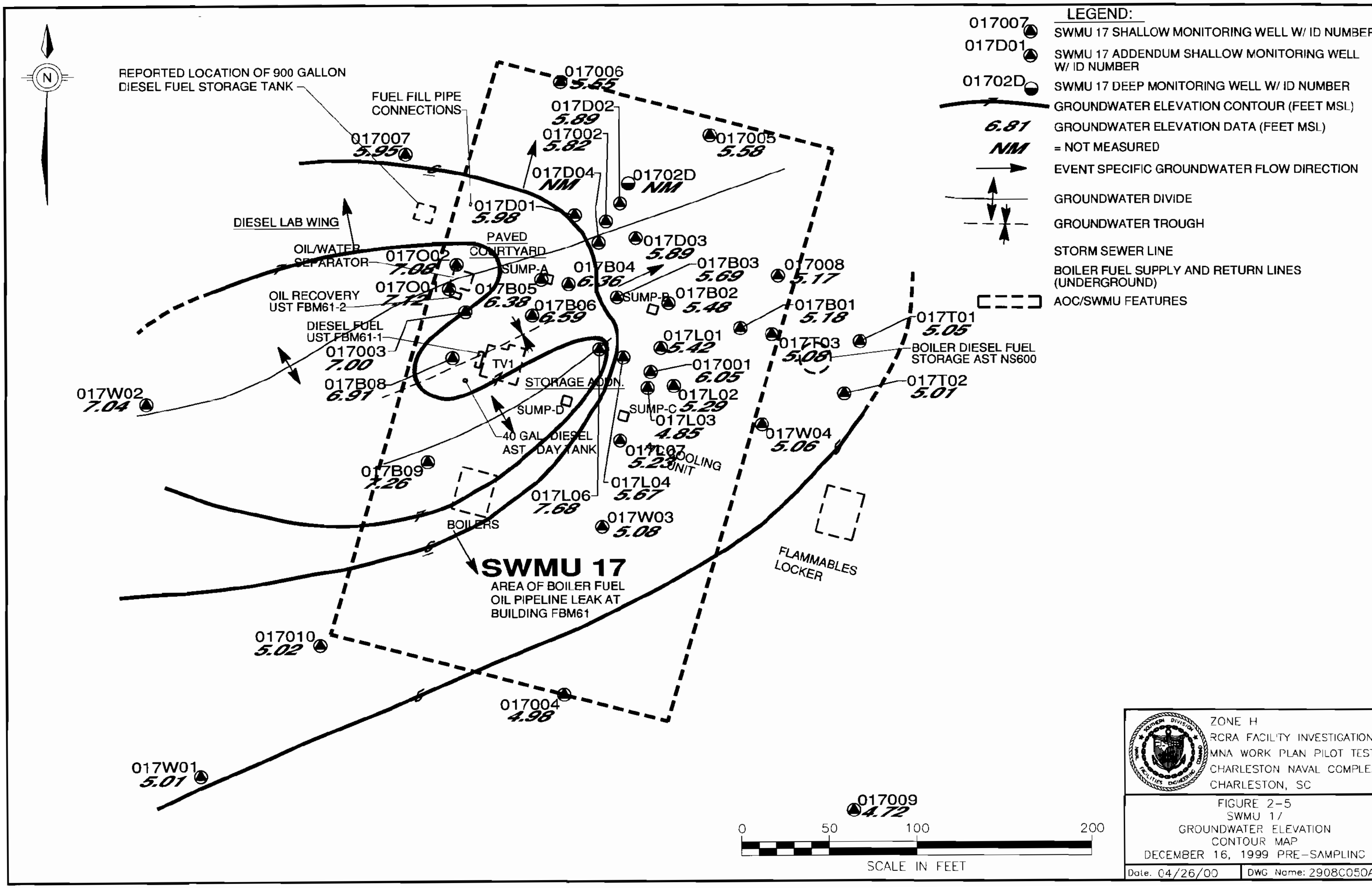
- Area that Exceeds Soil MCSs for Future Unrestricted Land Use
- Area that Exceeds Groundwater MCSs
- Area where Groundwater Concentration may exceed MCSs based on occurrence of NAPL
- SWMU Boundary

N

0 75 150 Feet

Figure 2-4
Composite Showing Extent of Contamination
In Subsurface Soil and Groundwater
That Exceed MCSs
SWMU 17, Zone H
Charleston Naval Complex

File Path: C:\18gis\CNC\cnc_swmu17_cms.apr, Date: 8 May 2001 18:06, User: ASPOSATO


LEGEND:
017007 SWMU 17 SHALLOW MONITORING WELL W/ ID NUMBER
017D01 SWMU 17 ADDENDUM SHALLOW MONITORING WELL W/ ID NUMBER
01702D SWMU 17 DEEP MONITORING WELL W/ ID NUMBER
GROUNDWATER ELEVATION CONTOUR (FEET MSL)
6.81 GROUNDWATER ELEVATION DATA (FEET MSL)
NM = NOT MEASURED
EVENT SPECIFIC GROUNDWATER FLOW DIRECTION
GROUNDWATER DIVIDE
GROUNDWATER TROUGH
STORM SEWER LINE
BOILER FUEL SUPPLY AND RETURN LINES (UNDERGROUND)
AOC/SWMU FEATURES
N
REPORTED LOCATION OF 900 GALLON DIESEL FUEL STORAGE TANK
FUEL FILL PIPE CONNECTIONS
DIESEL LAB WING
OIL/WATER SEPARATOR
OIL RECOVERY UST FBM61-2
DIESEL FUEL UST FBM61-1
PAVED COURTYARD
SUMP-A
SUMP-B
SUMP-C
SUMP-D
TV1
STORAGE ADDN.
40 GAL DIESEL AST DAY TANK
COOLING UNIT
BOILERS
BOILER DIESEL FUEL STORAGE AST NS600
FLAMMABLES LOCKER
SWMU 17
AREA OF BOILER FUEL OIL PIPELINE LEAK AT BUILDING FBM61
017006 5.55
017D02 5.89
017002 5.82
017005 5.58
017007 5.95
017D04 NM
01702D NM
017D01 5.98
017D03 5.89
017O02 7.08
017O01 7.12
017B04 6.36
017B03 5.69
017008 5.17
017B05 6.38
017B06 6.59
017B02 5.48
017B01 5.18
017T01 5.05
017L01 5.42
017T03 5.08
017003 7.00
017001 6.05
017B08 6.91
017L02 5.29
017T02 5.01
017W02 7.04
017L03 4.85
017W04 5.06
017L07 5.23
017B09 7.26
017L04 5.67
017L06 7.68
017W03 5.08
017010 5.02
017004 4.98
017W01 5.01
017009 4.72
6
0 50 100 200
SCALE IN FEET
ZONE H
RCRA FACILITY INVESTIGATION
MNA WORK PLAN PILOT TEST
CHARLESTON NAVAL COMPLEX
CHARLESTON, SC
FIGURE 2-5
SWMU 17
GROUNDWATER ELEVATION CONTOUR MAP
DECEMBER 16, 1999 PRE-SAMPLING
Date: 04/26/00
DWG Name: 2908C050A

Section 3.0

3.0 Remedial Objectives

This section discusses how the objective of the MNA pilot test fits into the overall RAOs for SWMU 17 and outlines MCSs for groundwater at SWMU 17. In addition, this section discusses how MNA will be evaluated in conjunction with groundwater contaminant source controls.

3.1 Remedial Action Objectives

The RAO for groundwater at SWMU 17 is outlined in the CMS Work Plan (CH2M-Jones, 2001a) as follows:

> *Protection and Restoration of Beneficial Use: The RAOs for groundwater are to prevent ingestion and direct/dermal contact with groundwater having unacceptable carcinogenic or non-carcinogenic risk, and to restore the aquifer to beneficial use.*

This MNA Pilot Study Work Plan has been developed such that natural attenuation can be evaluated with regard to addressing the RAO for groundwater.

3.2 Media Cleanup Standards

The proposed MCSs for groundwater at SWMU 17 are discussed in the CMS Work Plan and are presented in Table 2-1 of this document. Achieving these MCSs is accepted as demonstrating that the RAOs have been achieved. Achieving these goals should promote the protection of human health and the environment, while at the same time achieving compliance with applicable state and federal standards.

A specific objective of the MNA pilot study is to evaluate whether MNA has the potential to reduce concentrations of COCs to levels equivalent to or below the MCSs. However, it is likely that further data will be required beyond the timeframe of the MNA pilot study to determine whether natural attenuation can reduce the concentration of COCs to maximum contaminant levels (MCLs).

Section 4.0

4.0 MNA Technology Description

This section describes the processes of natural attenuation which act to remediate organic compounds in groundwater. The MNA technology has been applied at many field sites across the United States, and the effectiveness of the technology has been documented by quantitative field demonstrations in numerous publications. The U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17P on the use of MNA considers MNA "to be an alternative means of achieving remediation objectives that may be appropriate for specific, well documented site circumstances (EPA, 1999)."

All groundwater COCs except Aroclor-1260 are considered to be compounds which may potentially undergo natural attenuation. Aroclor-1260 is known to be recalcitrant to biodegradation and is not very soluble in water. As a result, it is the only groundwater COC that will not be addressed by MNA. However, after implementation of a proposed interim measure (IM) for NAPL removal (i.e., using a vacuum truck to remove NAPL from the aquifer), it is expected that the concentration of Aroclor-1260 should decline significantly, potentially below the proposed MCS because of its low solubility in water. In the event that this does not occur, further evaluation of remedial alternatives for PCBs will be conducted.

4.1 Natural Attenuation Processes Overview

The environmental fate and transport of an organic compound in groundwater is controlled by the compound's physical and chemical properties, as well as the physical, chemical, and biological nature of the subsurface media through which the contaminant is migrating. Several processes are known to cause a reduction in the concentration and/or mass of a contaminant dissolved in groundwater. Those processes that result in the reduction of a contaminant concentration but not of the total contaminant mass are termed nondestructive and include hydrodynamic dispersion, sorption, dilution, and volatilization. Those processes that result in the degradation of contaminants are referred to as destructive and include biodegradation and abiotic degradation mechanisms.

Biodegradation is generally the dominant destructive attenuation process acting on a contaminant, depending on the type of contaminant and the availability of electron donors or carbon sources. Abiotic degradation processes (e.g., hydrolysis) are also known to degrade chlorinated solvents; where biodegradation is not occurring, these may be the only destructive processes operating. However, the rates of abiotic processes are generally slow relative to rates of biodegradation for most contaminants.

Natural attenuation results from the integration of all the attenuation processes. Where the attenuation processes are sufficiently rapid, the size of the contaminant plume and mass of contaminants dissolved in groundwater may stabilize or decline.

4.2 Biodegradation

Microorganisms in the subsurface environment may degrade a variety of organic compounds, including the petroleum hydrocarbons and chlorinated organic compounds that are SWMU 17 groundwater COCs (except Aroclor-1260). To carry out their functions, microorganisms require a carbon source, electron donors and acceptors, and water and mineral nutrients. Many organic compounds, including petroleum hydrocarbons and certain chlorinated compounds, are degraded or transformed by microorganisms through use as an electron donor. This process is known as direct biological oxidation.

Direct biological oxidation processes may occur aerobically (in the presence of oxygen) or anaerobically (without oxygen), often at the same time in different parts of the dissolved contaminant plume. During direct biological oxidation, dissolved oxygen is generally consumed rapidly in the center of dissolved organic contaminant plumes and converts the area into an anoxic zone. Under these conditions anaerobic bacteria start to utilize nitrate, sulfate, iron, and carbon dioxide for anaerobic metabolism.

The reduction/oxidation (redox) environment is very important in determining the biodegradation mechanism which may occur. Oxygen is the electron acceptor for aerobic metabolism. Nitrate, ferric iron, sulfate, and carbon dioxide can also be electron acceptors for anaerobic biodegradation pathways. After dissolved oxygen has been depleted and as the redox environment becomes more reducing, nitrate is used as an electron acceptor, followed by ferric iron, sulfate, and carbon dioxide. An example of biodegradation under various electron acceptor and redox conditions (Suthersan, 1997) is presented as Table 4-1 for benzene.

Biodegradation of some chlorinated compounds may involve the chlorinated compound serving as an electron acceptor. When a chlorinated compound acts as an electron acceptor, the chlorinated compound will be reduced via reductive dechlorination. Reductive dechlorination only occurs when the environment becomes sufficiently reduced and when sufficient electron donors are present.

Chlorinated compounds may also undergo biodegradation via aerobic or anaerobic cometabolism. Cometabolism requires the presence of a suitable primary substrate such as toluene, phenol, or methane. For cometabolism to be to be effective, the primary substrate must be present at higher concentrations than the chlorinated compound.

Chlorinated benzenes occur as four different groundwater COCs at SWMU 17. Studies indicate that chlorinated benzenes are biodegradable under aerobic and anaerobic conditions, and exhibit biodegradation behaviors similar to those of chlorinated ethenes. Evidence suggests that chlorobenzene and polychlorinated benzenes, up to and including tetrachlorobenzene, may undergo biodegradation under aerobic conditions (Spain, 1997). For highly chlorinated benzenes (including trichlorobenzenes), the most likely biodegradation mechanism is reductive dechlorination in anaerobic environments (Herrington et al., 2000). Herrington et al. indicates that as highly chlorinated benzenes are dechlorinated, the daughter products become more resistant to further reductive dechlorination, but become increasingly amenable to aerobic biodegradation.

The likely potential degradation mechanisms for the COCs in groundwater at SWMU 17 are summarized in Table 4-2.

4.3 Groundwater Contaminant Source Control

The MNA pilot study is intended to evaluate the potential for natural attenuation processes to function as a groundwater remediation mechanism for COCs at SWMU 17. It is likely that for natural attenuation processes to be fully successful in reducing COCs concentrations below MCSs, the sources of contaminants to groundwater will have to be controlled. Sources of groundwater contaminants still occur at SWMU 17 in the subsurface soils, as discussed in Section 2.1. In addition, localized areas of LNAPL and DNAPL occur in the shallow aquifer at SWMU 17 creating a source for contaminants to enter the groundwater.

The IM Work Plan (CH2M-Jones, 2001b) addresses the removal of LNAPL and DNAPL from the aquifer by pumping with a vacuum truck from existing monitoring wells. It is proposed that this source control work described in the interim measure work plan be undertaken concurrently with the MNA pilot study. After the removal of NAPL with the vacuum truck, it is possible that natural attenuation will degrade any residual NAPL remaining in the aquifer.

Control of other potential sources of contaminants to groundwater in the subsurface soils will be addressed as part of the CMS.

Because the building at SWMU 17 is in active use, a passive in situ technology, such as MNA, is desirable because it will minimize disturbances to onsite activities.

4.4 Demonstrating Natural Attenuation

Three main lines of evidence can be used to demonstrate that natural attenuation processes are occurring at a site at a rate sufficient to remediate dissolved contaminant plumes. The three lines of evidence are described below:

1. Historical data showing plume stabilization and/or loss of contaminant mass over time. This line of evidence involves using contaminant monitoring data to show that the contaminant plume is shrinking, stable, or expanding at a rate slower than that predicted by conservative groundwater seepage velocity calculations.
2. Chemical and geochemical analytical data, including:
   (a) Depletion of electron acceptors and donors
   (b) Increasing metabolic by-product concentrations
   (c) Decreasing parent compound concentrations
   (d) Increasing daughter compound concentrations
3. Microbiological data that support the occurrence of biodegradation.

The first line of evidence is valuable because it shows that the contaminant plume is being attenuated. The second line of evidence is used to show that contaminant mass is being destroyed, not just being diluted or sorbed to the aquifer matrix. The third line evidence, microbiological laboratory or field data, can be used to show that indigenous biota are capable of degrading site contaminants. The microcosm study is the must common technique used for this purpose. Microcosm studies are only necessary when estimates of biodegradation rates could not be obtained using the other lines of evidence or when the specific mechanism of degradation is not known.

The first two lines of evidence will be used to demonstrate MNA at SWMU 17 during the MNA pilot study. The third line of evidence will only be used if the first two lines of evidence do not provide sufficient data to evaluate biodegradation rates, or if there is uncertainty regarding the biodegradation mechanism for any of the COCs.

TABLE 4-1
Benzene Biodegradation
MNA Pilot Test Work Plan, SWMU 17, Zone H, Charleston Naval Complex

Redox Potential	Reaction Type	Electron Acceptors	By-Products
> 300 mV	Aerobic	O_2	CO_2, H_2O
↓	Denitrification	NO_3^-	NO_2^-, N_2, CO_2, H_2O
	Valence reduction	Mn(IV)	Mn(II), CO_2, H_2O
	Valence reduction	Fe(III)	Fe(II), CO_2, H^+
	Sulfate reduction	SO_4^{2-}	S_2^-, CO_2, H_2O
< 300 mV	Methanogenesis	CO_2	CO_2, CH_4

Source: Suthersan, 1997

TABLE 4-2
Potential Degradation Mechanisms for Groundwater COCs at SWMU 17
MNA Pilot Test Work Plan, SWMU 17, Zone H, Charleston Naval Complex

Groundwater Contaminant of Concern	Potential Degradation Mechanism
Benzene	Direct Biological Oxidation
Chlorobenzene	Direct Biological Oxidation, Reductive Dechlorination, Cometabolism
2-chlorophenol	Reductive dechlorination, Direct Oxidation, Cometabolism
1,3-dichlorobenzene	Direct Biological Oxidation, Reductive Dechlorination, Cometabolism
1,4-dichlorobenzene	Direct Biological Oxidation, Reductive Dechlorination, Cometabolism
Naphthalene	Direct Biological Oxidation, Cometabolism
1,2,4-trichlorobenzene	Reductive Dechlorination, Direct Biological Oxidation, Cometabolism

Based on: Wiedemeier *et al* (1999), Suthersan (1997), and Spain (1997)

Section 5.0

5.0 Pilot Study Technical Approach and Methodology

This section discusses the technical approach for evaluating MNA at SWMU 17, the field methods to be used, the frequency of groundwater sampling, and the parameter list to be used for monitoring of natural attenuation.

5.1 MNA Evaluation Approach

CH2M-Jones proposes to evaluate the effectiveness of natural attenuation to remediate the groundwater COCs at SWMU 17 with the exception of Aroclor-1260. The MNA evaluation approach will involve the following main steps, which are listed below and described in detail in subsequent sections:

1. Install approximately two additional monitoring wells to provide sufficient data for monitoring of natural attenuation at SWMU 17
2. Determine direction and rate of groundwater flow
3. Measure the current baseline concentrations of groundwater COCs, inorganic electron acceptors and metabolic by-products
4. Monitor the concentrations of groundwater COCs, inorganic electron acceptors, and metabolic by-products
5. Demonstrate that natural attenuation processes are occurring at SWMU 17 and estimate biodegradation rates for the COCs
6. Use the results of Steps 2 and 5 to compare the rate of contaminant transport to the rate of biodegradation
7. Based on the results of Step 6 and the pilot study objectives (Section 1.2), evaluate whether natural attenuation is a viable option for remediation of groundwater at SWMU 17

5.2 Monitoring Well Installation

The evaluation of natural attenuation requires analytical data to be collected from: (a) the source area or most contaminated portion of the aquifer (e.g., adjacent to where

NAPL exists), (b) downgradient from the source area but still in the dissolved contaminant plume, (c) downgradient from the dissolved contaminant plume, and (d) upgradient and lateral locations that are not affected by the plume. A number of wells exist at SWMU 17 (see Figure 2-3) which can be utilized for the collection of the required analytical data. However, approximately two additional monitoring wells will be installed to provide sufficient monitoring locations for analytical data to be collected from each of the four areas of the plume listed above.

Prior to the installation of the two new monitoring wells, groundwater elevation measurements will be made in all existing monitoring wells at the SWMU 17 and an up-to-date potentiometric surface map created to confirm groundwater flow directions and gradients. This will allow for the optimal location of the two new monitoring wells. The proposed locations for the two new monitoring wells, discussed below and shown in Figure 5-1, will be confirmed following the development of the up-to-date potentiometric surface map.

- One new well (designated H017GW011) will be installed approximately 40 ft to the northwest of existing monitoring well H017GW002 to allow for groundwater within the dissolved contaminant plume hydraulically downgradient of the NAPL to be monitored
- One new well (designated H017GW012) will be installed approximately 40 ft to the west-northwest of H017GW005 to allow for groundwater hydraulically downgradient of the dissolved contaminant plume to be monitored

The wells will be installed by a Hazardous Waste Operations and Emergency Response (HAZWOPER)-trained drilling vendor, under the direct supervision of the CH2M-Jones site hydrogeologist. Well borings will be advanced using appropriate drilling techniques.

The well boring at each new well location will be lithologically logged to assist in well screen placement and to refine the site hydrogeologic conceptual model. The drill rig, tools, and equipment will be properly decontaminated between borings using the procedures described in the approved sampling and analysis portion of the *Final Comprehensive Sampling and Analysis Plan, Volume II* (EnSafe, 1996). Protocols for well installation, well development, sampling, and sample handling will also comply with requirements of EPA Environmental Services Division *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual* (EPA, 1996).

The wells will be constructed of 2-inch inside diameter flush-threaded Schedule 40 polyvinyl chloride (PVC). New well installation depths and screen lengths will be comparable to those of the existing monitor wells in the shallow aquifer (approximately 15 ft bls). Exact depths and screen lengths will be determined in the field, based on the lithologic log recovered during each boring. The elevation and location of the new wells will be surveyed after installation.

The wells will be developed at least 48 hours after installation to clean out any sediments from the well and to create a suitable filter pack around the well screen. Monitoring well borings, well installation and development will be performed in accordance with the Field Sampling Plan (EnSafe, 1996). Selected Standard Operating Procedures (SOPs) for field work in EPA Region IV will also be referenced and utilized as necessary to address updates in applicable technologies and procedures.

Appropriate permits and approvals will be obtained from SCDHEC for all permanent well locations, in accordance with South Carolina Well Standards and Regulations (R.61-71), prior to mobilizing for the field effort.

5.3 Direction and Rate of Groundwater Flow

Following the installation of the new monitoring wells, groundwater elevations will be measured in all wells at SWMU 17 and a potentiometric surface plan prepared. This potentiometric surface plan will be used to assess groundwater flow directions and gradients. Hydraulic conductivity data used in the USGS groundwater flow model for the CNC, hydraulic gradient data, and estimates of the aquifer effective porosity will be used to assess the groundwater flow velocity at SWMU 17.

During each groundwater monitoring event (Step 4, Section 5.5), groundwater elevations will be monitored and assessed for any seasonal changes in groundwater gradients or flow directions.

5.4 Measurement of Baseline Concentrations of COCs and Natural Attenuation Parameters

A groundwater sampling event will be performed approximately three weeks after the new wells have been installed to provide baseline concentrations of geochemical natural attenuation parameters and COCs using selected existing monitor wells and the new wells installed during this study. The proposed groundwater sampling locations (total of 12 wells) are shown on Figure 5-2. The proposed sampling locations have been selected to provide data from the four main areas of the plume listed in Section 5.2.

Chemical analysis of groundwater samples will be conducted using EPA SW-846 Methods for RCRA monitoring. The proposed analytical parameter list for monitoring natural attenuation conditions will measure the concentrations of electron acceptors and donors, metabolic byproducts, parent and daughter compounds. The parent compounds are the groundwater COCs (except Aroclor-1260) which will be assessed by analyzing volatile organic compound (VOC) and semivolatile organic compound (SVOC) concentrations. This will also provide a baseline of the distribution of COCs. The chemical analyses to be undertaken for the MNA baseline study are presented in Table 5-1.

Groundwater samples will be collected in accordance with the Field Sampling Plan (EnSafe, 1996). Selected SOPs for field work in EPA Region IV will also be referenced and utilized as necessary to address updates in applicable technologies and procedures.

5.5 Monitoring of Concentrations of COCs and Natural Attenuation Parameters

The biodegradation of organic compounds brings about measurable changes in the chemistry of groundwater in the affected area. By measuring these changes it is possible to document and evaluate natural attenuation.

After the baseline sampling, which is discussed in Section 5.4, has been completed, additional groundwater sampling events will be performed to monitor the concentrations of COCs and natural attenuation parameters. During the pilot test, it is proposed that groundwater sampling events be performed every six months (biannually) for a one year period (total of two sampling events) to provide data for evaluation of natural attenuation as a remediation alternative.

The rates at which microbes degrade the COCs in groundwater at SWMU 17 will be site-specific. For this reason, it is difficult to predict the amount of time required for the pilot test to obtain sufficient data to conclusively evaluate natural attenuation as a remediation alternative at SWMU 17. Experience at other similar sites indicates that a one-year duration of the pilot test with biannual sampling events is likely to provide sufficient data to evaluate natural attenuation. However, if the groundwater data collected during the first six months is considered sufficient to demonstrate the effectiveness of MNA in remediating groundwater, CH2M-Jones will discuss, with the BRAC Cleanup Team (BCT), the recommendation of MNA as a viable remediation alternative for groundwater at SWMU 17. Likewise, if the groundwater data collected during the first six months is considered to clearly demonstrate that MNA is not likely to be effective in remediating groundwater, CH2M-Jones will discuss, with the BCT, the feasibility of stopping the pilot study and implementing an alternative groundwater remediation technology.

The proposed groundwater sampling locations for the biannual sampling events are the same as those for the baseline sampling event (shown on Figure 5-2). Chemical analysis of groundwater samples will be conducted using EPA SW-846 Methods for RCRA monitoring. The proposed analytical parameter list for monitoring natural attenuation conditions is the same as the parameters selected for the baseline sampling event (see Table 5-1).

Groundwater samples will be collected in accordance with the Field Sampling Plan (EnSafe, 1996). Selected SOPs for field work in EPA Region IV will also be referenced and utilized as necessary to address updates in applicable technologies and procedures.

Water levels will be measured in all SWMU 17 area wells during each sampling event to provide additional potentiometric data. The potentiometric data will be used to refine the site hydrogeologic model, assess any seasonal changes in groundwater flow, and to document the groundwater flow conditions during the pilot test.

5.6 Demonstration of Natural Attenuation and Estimation of Biodegradation Rates

As discussed in Section 4.4, there are three lines of evidence used to demonstrate MNA. The first two lines of evidence, historical analytical data showing plume stabilization and loss of contaminant mass, and attenuation parameter analytical data collected as part of the MNA pilot study will be used to demonstrate that natural attenuation processes are occurring at SWMU 17. The third line of evidence, microbiological studies, will only be used if the historical analytical data and analytical data collected during the MNA pilot study do not provide sufficient data for the demonstration of biodegradation or estimation of biodegradation rates.

The historical data collected at SWMU 17 during the RFI investigations and data collected during the MNA pilot study will be presented visually (e.g., isopleth plume maps for COCs, daughter products, and electron acceptors) and/or statistically (e.g., Mann-Whitney U test or Mann-Kendall test) to document plume stabilization and loss of contaminant mass. The measured concentration of the natural attenuation parameters will be used to evaluate the relative importance of the different biodegradation mechanisms and electron acceptors for the COCs by estimating the biodegradation capacity. This evaluation will be extended to estimate the mass of COCs degraded by each biodegradation mechanism.

If microbiological studies are required to demonstrate MNA for specific COCs (e.g., chlorinated benzenes), then a laboratory microcosm study will be considered. Aquifer material samples will be collected from the boreholes during the installation of the new wells and maintained under field conditions to be used in a laboratory microcosm study if deemed necessary.

The groundwater monitoring data will be used to estimate the rates of biodegradation of the groundwater COCs. Experience has shown that biodegradation rates of petroleum hydrocarbons and chlorinated organic compounds are adequately described by a first-order decay model. There are four recognized approaches which can be used to estimate first-order biodegradation rate constants: (a) using conservative tracers, (b) steady-state equilibrium method, (c) mass balance methods, and (d) graphical method. At least two of these methods will be used to estimate biodegradation rates of the COCs in groundwater at SWMU 17.

For the chlorinated groundwater COCs, it may first be necessary to demonstrate that biodegradation via reductive dechlorination is occurring. This involves assessing the groundwater monitoring data for redox processes and daughter product concentration changes as groundwater flow down gradient. This preliminary screening process for reductive dechlorination is well documented by Wiedemeier et al. (1999). Reductive dechlorination may be an important biodegradation process for 2-chlorophenol. The chlorinated benzene COCs are more likely to be biodegraded via oxidative pathways, so screening for reductive chlorination may not be necessary for these COCs.

5.7 Comparison of Rate of COCs Transport to Rate of Biodegradation

The rate of transport of the COCs and the rate of biodegradation will be compared to assess whether the distribution of the dissolved contaminant plume and the mass of contaminants are stabilized, reducing or expanding. The comparison will be made using the BIOSCREEN model which is a simple spreadsheet based analytical model. The use of BIOSCREEN will also allow an estimate of the maximum stabilized plume length, and an estimate of the time required for MNA to reduce the concentration of COCs to the MCSs.

The BIOSCREEN model simulates groundwater flow, a fully penetrating vertical plane source orientated perpendicular to groundwater flow, linear isotherm sorption, three-dimensional dispersion and first-order decay biodegradation. Groundwater flow input parameters for the BIOSCREEN model will be taken from those determined in Step 2 (Section 5.3) of the MNA evaluation approach. Sorption and dispersion input parameters will be estimated based on published values and experience at other sites for the COCs. The first-order decay rate constants for input into BIOSCREEN will be taken from the values estimated in Step 6 (Section 5.5) of the MNA evaluation approach.

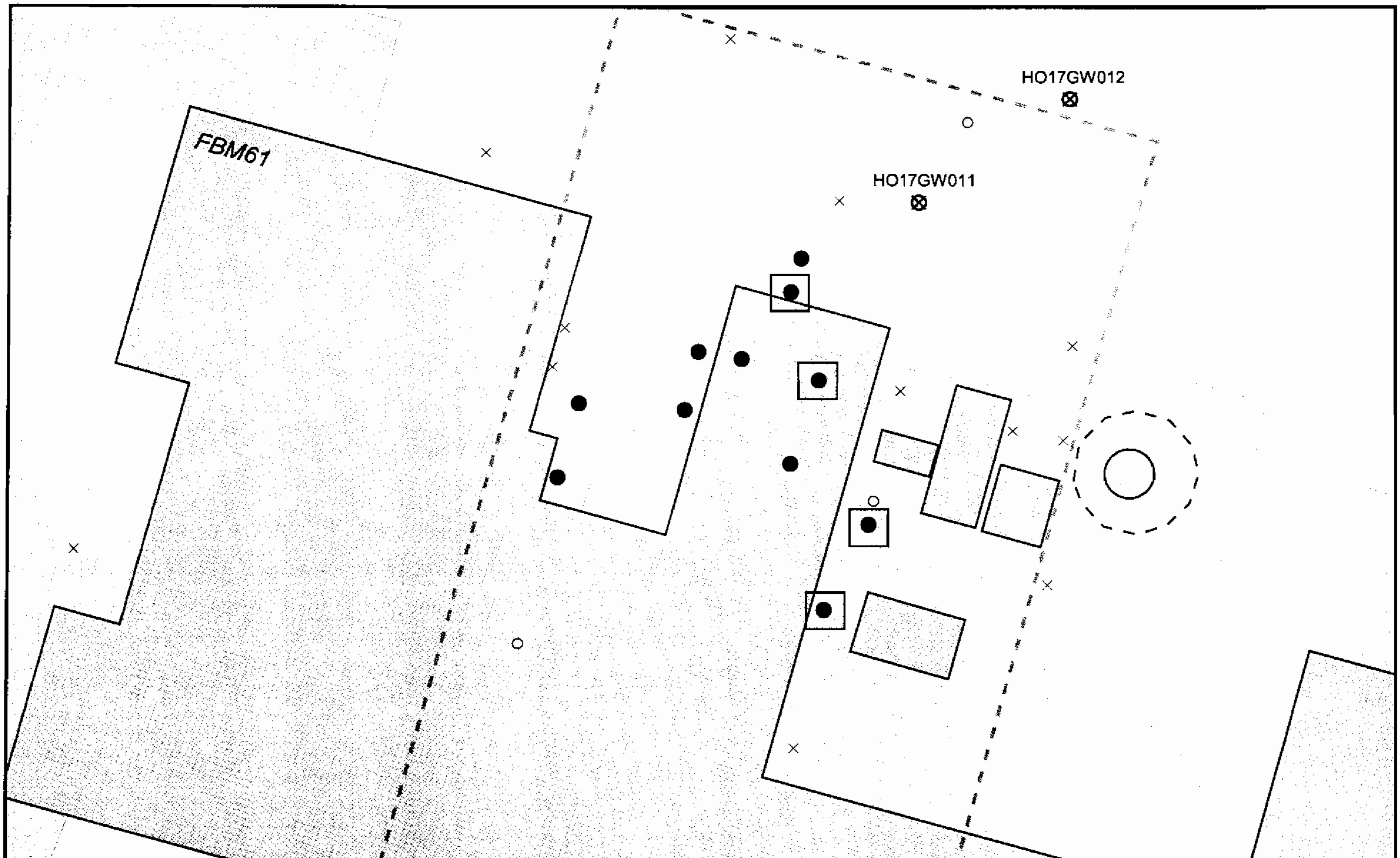
5.8 Evaluation of MNA as a Viable Remediation Alternative

Based on Steps 1 to 6 of the MNA evaluation, an assessment will be made as to whether MNA is a viable remediation alternative. This assessment will take into account whether MNA will meet the RAOs, and if so, whether the RAOs will be met within a reasonable timeframe.

The findings of the MNA evaluation will be discussed with the BCT. The MNA evaluation will be documented in a MNA Pilot Test Report which will be submitted to SCDHEC following the completion of the evaluation. A full list of the MNA Pilot Test deliverables and schedule for submission to SCDHEC is provided in Section 6.2.

TABLE 5-1
Proposed Groundwater Monitoring Parameters for the MNA Pilot Test
MNA Pilot Test Work Plan, SWMU 17, Zone H, Charleston Naval Complex

Analytical Parameter	Analysis Method	Baseline Monitoring	Biannual Monitoring
	Geochemical Parameters		
Carbonate Species (Alkalinity, carbonate, bicarbonate)	EPA 310.1	X	X
Chloride	SW9056	X	X
Nitrate/Nitrite	SW9056	X	X
Sulfate	SW9056	X	X
Sulfide	SW9030	X	X
Major Cations	SW6010B	X	X
TDS	EPA 160.1	X	X
TOC	SW9060	X	X
pH	Field	X	X
Electrical Conductivity	Field	X	X
Oxidation-Reduction Potential	Field	X	X
Temperature	Field	X	X
Turbidity	Field	X	X
	Dissolved Gases		
Methane/Carbon Dioxide	EPA 0003C	X	X
Hydrogen	ASTM D1945	X	X
Oxygen	Field	X	X
	Dissolved Metals		
Iron II (filtered)	EPA 200.7	X	X
Manganese II (filtered)	EPA 200.7	X	X
	COCs		
VOCs	SW 8260B	X	X
SVOCs	SW 8270C	X	X



LEGEND:
Groundwater Sample Locations
● Concentration > MCS
○ Concentration < MCS
X Not Detected
● Where NAPL Occurs
⊗ Proposed Monitoring Well Location
Area that exceeds Groundwater MCSs
/ v Area where Groundwater Concentration may exceed MCSs based on occurrence of NAPL

N

0 50 100 Feet

Figure 5-1
Proposed New Monitoring Well Locations
SWMU 17, Zone H
Charleston Naval Complex

File Path: C:\18gis\CNC\cnc_swmu17_cms.apr, Date: 3 May 2001 15:39, User: ASPOSATO

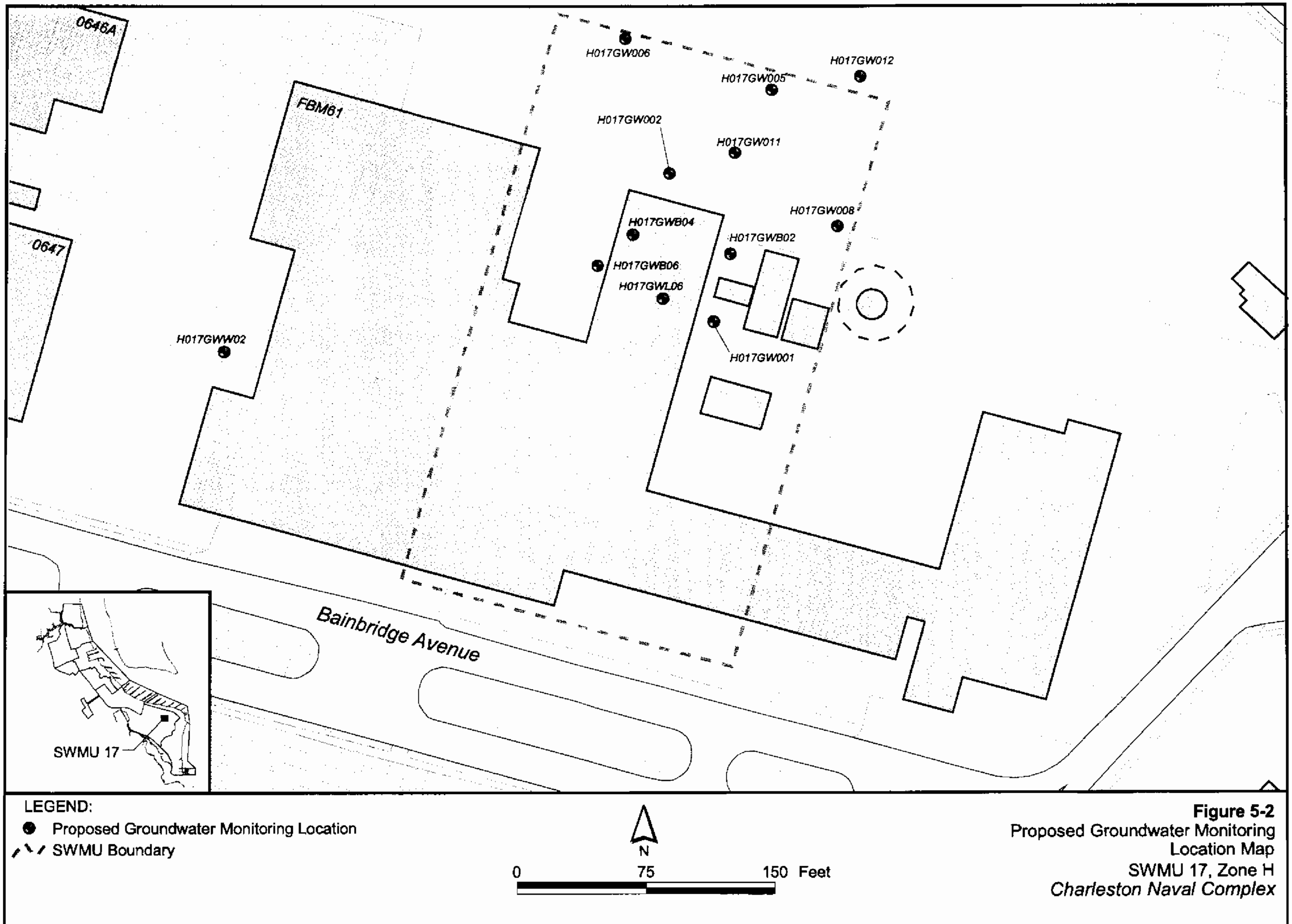


Figure 5-2
Proposed Groundwater Monitoring Location Map
SWMU 17, Zone H
Charleston Naval Complex

File Path: C:\18gis\CNC\cnc_swmu17_cms.apr, Date: 3 May 2001 13:42, User: ASPOSATO

Section 6.0

6.0 Project Schedule

This section presents a conceptualized schedule for implementation of the pilot test, based on elapsed calendar days after receipt of Final MNA Work Plan approval from SCDHEC.

6.1 Field Work and MNA Evaluation

The field work will be initiated within 30 days after Final MNA Work Plan approval. Anticipated milestone tasks for the fieldwork and MNA assessment are outlined as follows:

- Measurement of groundwater elevations and production of an up-to-date potentiometric surface plan – 30 days after SCDHEC approval of Work Plan
- New Monitor Well Installation and Development —14 days after completion of potentiometric surface map
- Baseline Groundwater Monitoring— 21 days after installation and development of new monitoring wells
- First Quarterly Groundwater Monitoring Event – 3 months after baseline groundwater monitoring
- Subsequent Quarterly Groundwater Monitoring Events —3 months after previous groundwater monitoring event
- Estimate of Biodegradation Rates - 21 days after receipt of the last set of analytical data from Quarterly Groundwater Monitoring
- Comparison of Contaminant Transport Rates and Biodegradation Rates – 21 days after completion of Estimate of Biodegradation Rates
- Final Evaluation of MNA —30 days after completion of Comparison of Contaminant Transport Rates and Biodegradation Rates

6.2 Deliverables

The proposed schedule for project deliverables is based on the assumptions made for completion of field work, groundwater monitoring and evaluation of MNA described in Section 6.1. Target dates for key deliverables are summarized below:

- Revision 1 Work Plan/ Response to DHEC Comments—30 days after receipt of SCDHEC comments on Draft Work Plan
- Interim Progress Reports —30 days after receipt of analytical data for each sampling event
- Draft MNA Pilot Test Report —90 days after receipt of the analytical data from the final Groundwater Monitoring Event
- Response to SCDHEC comments on Draft MNA Pilot Test Report —30 days after receipt of comments
- Final MNA Pilot Test Report —30 days after comments/responses are finalized

Section 7.0

7.0 Investigation-Derived Waste

During field activities, a certain amount of IDW will be generated in association with personal protection, monitor well installation and development, and groundwater sampling activities. The majority of the soil cuttings generated is expected to be below applicable disposal criteria, because new well installation is occurring downgradient of the source areas. Every effort will be made to minimize the amount of IDW generated during this work.

At each new well location, soil cuttings, development water and groundwater purge water will be containerized separately in closed Department of Transportation (DOT) 55-gallon steel drums, staged on pallets near each new well. The drums will each be labeled with the date of generation, type of waste, and associated monitoring well identification number. The analytical results obtained for each well will be used to determine the proper disposal option for the associated wastes.

Section 8.0

8.0 References

CH2M-Jones. *CMS Work Plan, SWMU 17, Zone H, Charleston Naval Complex.* Revision 1. May, 2001a.

CH2M-Jones. *Interim Measure Work Plan, Soil Removal at SWMU 17 (Zone H), Charleston Naval Complex*. Revision 0. May, 2001b.

EnSafe Inc. *Final Comprehensive Sampling and Analysis Plan, Volume II.* Revision 2. July 30, 1996.

EnSafe/Allen & Hoshall. *Final RCRA Facility Investigation Report for Zone H Naval Base Charleston*. Prepared for the Department of the Navy, Southern Division Naval Facilities Engineering Command: Charleston, SC. Contract N62467-89-D0318. July 1996.

EnSafe Inc. *RCRA Facility Investigation Addendum*. NAVBASE Charleston. 2000.

Herrington et al. Natural Attenuation of Chlorinated Benzenes at a Former Disposal Site. 175-184. Proceedings of the Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds. Monterey, CA. May 22-25, 2000.

Spain, J. *Synthetic Chemicals with Potential for Natural Attenuation*. Bioremediation Journal 1(1):1-9. 1997.

Suthersan, S. S. *Remediation Engineering Design Concepts*. CRC Press, Inc. 1997.

U.S. Environmental Protection Agency (EPA), *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual.* Region IV Environmental Services Division. 1996.

U.S. Environmental Protection Agency (EPA), *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.* Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17P. April 1999.

Wiedemeier, T.H., Rifai, H.S., Newell, C.J., and Wilson, J.T. *Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface*. John Wiley & Sons. 1999.

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EnSafe Inc. *Final Comprehensive Sampling and Analysis Plan, Volume II.* Revision 2. July 30, 1996.

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EnSafe Inc. *RCRA Facility Investigation Addendum.* NAVBASE Charleston. 2000.

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Spain, J. *Synthetic Chemicals with Potential for Natural Attenuation.* Bioremediation Journal 1(1):1-9. 1997.

Suthersan, S. S. *Remediation Engineering Design Concepts.* CRC Press, Inc. 1997.

U.S. Environmental Protection Agency (EPA), *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual.* Region IV Environmental Services Division. 1996.

U.S. Environmental Protection Agency (EPA), *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.* Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17P. April 1999.

Wiedemeier, T.H., Rifai, H.S., Newell, C.J., and Wilson, J.T. *Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface.* John Wiley & Sons. 1999.