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CORRECTIVE MEASURES STUDY WORK PLAN AREA OF CONCERN 723 (AOC 723) ZONE E CNC CHARLESTON SC

11/1/2004

ENSAFE

CMS REPORT AND PILOT STUDY WORK PLAN

AOC 723, Zone E

Charleston Naval Complex
North Charleston, South Carolina

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

CH2M Jones

November 2004

Contract N62467-99-C-0960

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AOC 723, Zone E

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Revision 0
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158814.ZE.PR.29

Certification Page for Corrective Measures Study Report/Pilot Study Work Plan (Revision 0) – AOC 723, Zone E

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

Permit No. 21428

Dean Williamson

Dean Williamson, P.E.

11/18/2004

Date

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Appendices

Acronyms and Abbreviations

AOC	area of concern
BEQ	benzo(a)pyrene equivalents
BRAC	Base Realignment and Closure Act
CA	corrective action
CMS	corrective measures study
CNC	Charleston Naval Complex
COC	chemical of concern
COPC	chemical of potential concern
CSAP	Comprehensive Sampling and Analysis Plan
CVOC	chlorinated volatile organic compound
DCE	dichloroethylene
DHE	Dehalococcoides etheneogenes
DO	dissolved oxygen
EnSafe	EnSafe, Inc.
EPA	U.S. Environmental Protection Agency
ERD	Enhanced reductive dechlorination
Excel	Excel Apparatus Services, Inc.
ft bls	feet below land surface
ft msl	feet mean sea level
HI	Hazard Index
ILCR	Incremental Lifetime Cancer Risk
LUC	land use control
LUCMP	land use control management plan
µg/L	microgram per liter
mg/kg	milligram per kilogram
ml/g	milliliters per gram
MCL	maximum contaminant level

Acronyms and Abbreviations, Continued

MCS	media cleanup standard
MEE	methane, ethane, and ethene
MNA	monitored natural attenuation
NAVBASE	Naval Base
OSWER	Office of Solid Waste and Emergency Response
ORP	oxidation reduction potential
PCE	tetrachloroethene
PCR	Polymerase Chain Reaction
PLFA	phospholipid fatty acid
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RGO	remedial goal option
SCDHEC	South Carolina Department of Health and Environmental Control
SSL	soil screening level
SVOC	semivolatile organic compound
TCE	trichloroethylene
TOC	total organic carbon
UIC	underground injection control
VFA	volatile fatty acid
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 Act (BRAC), 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.

Corrective Action (CA) activities are being conducted under the Resource Conservation and Recovery Act (RCRA) with the South Carolina Department of Health and Environmental Control (SCDHEC) as the lead agency for CA activities at the CNC. All RCRA CA activities are performed in accordance with the Final Permit (Permit No. SC0 170 022 560).

The Navy/EnSafe Inc. (EnSafe) team conducted RCRA Facility Investigations (RFIs) during the 1990s at the CNC. The CNC was divided into 12 study zones. The RFI for Zone E was initially conducted during 1995-1997. At the time of the Zone E RFI, Area of Concern (AOC) 723 had not been identified as an AOC. After the Zone E RFI was completed, the presence of this former paint booth became known and it was identified as an AOC. In April 2000, CH2M-Jones was awarded a contract to provide environmental investigation and remediation services at the CNC.

A RCRA Facility Assessment (RFA) and RFI Work Plan for AOC 723 were prepared by the Navy/CH2M-Jones team and submitted to SCDHEC during May 2003. The RFA and RFI Work Plan were approved by SCDHEC during July 2003. The RFA identified volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and metals as chemicals of potential concern (COPCs) in soil and groundwater. The RFI Work Plan recommended soil and groundwater sampling for the COPCs as part of the RFI.

Soil and groundwater sampling activities associated with the RFI were conducted during July 2003 and October 2003, respectively.

An RFI report addendum and a corrective measures study (CMS) work plan for AOC 723 were subsequently prepared by CH2M-Jones to complete the RFI process and initiate the CMS process (CH2M-Jones, 2004). The responses to SCDHEC comments on the *RFI Report Addendum and CMS Work Plan, Revision 0,* were submitted in July 2004.

The *RFI Report Addendum and CMS Work Plan* presented the remedial action objectives (RAOs) and media cleanup standards (MCSs) proposed for AOC 723. This CMS report has been prepared by CH2M-Jones to complete the next stage of the CMS process for AOC 723.

1.1 Corrective Measures Study Report Purpose and Scope

This CMS report evaluates corrective measure alternatives for surface soil impacted by arsenic, trichloroethylene (TCE), and benzo(a)pyrene equivalents (BEQs); subsurface soil impacted by TCE and BEQs; shallow groundwater impacted by antimony and TCE; and deep groundwater impacted by cis-1,2-dichloroethylene (cis-1,2-DCE), TCE, and vinyl chloride at AOC 723 in Zone E. These chemicals were identified as chemicals of concern (COCs) in the *RFI Report Addendum and CMS Work Plan, Revision 0,* for AOC 723.

This CMS report identifies a set of corrective measure alternatives that are considered to be technically appropriate for addressing soil and groundwater contamination, evaluates the alternatives using standard criteria from U.S. Environmental Protection Agency (EPA) RCRA guidance, and selects a recommended (preferred) corrective measure alternative for the site.

1.2 Background

This section of the CMS report presents background information on the facility, site history, and a summary of the nature and extent of COCs at the site. This information is essential to the understanding of the remedial goal options (RGOs), MCSs, and ultimately the evaluation of corrective measure alternatives for AOC 723. Additional information on the site and hydrogeology in the Zone E area of the CNC is provided in the *Zone E RFI Report, Revision 0* (EnSafe, 1997).

AOC 723 – Former Paint Booth

AOC 723 is a former paint booth in the southwestern corner of Building 177. Building 177 was built in 1955 and is a five-story structural steel-framed building with metal siding. It is located at 1865B Avenue B, at the corner of Fourth Street and Avenue B. An abandoned rail line enters the northern end of the building, where the flooring is partially brick. The remainder of the building has concrete flooring. A review of the historical engineering drawings indicates that a cleaning and degreasing room and an oven room were next to the paint booth.

The western half of Building 177 was previously used for parts cleaning. Currently Excel Apparatus Services, Inc. (Excel) uses the AOC 723 area for maintenance activities in support of the Detyens Shipyards. These activities include repairing electrical and electronic equipment, parts cleaning, paint stripping, paint spraying, electric motor rebuilding, machining metal parts, and treatment of aluminum components in a corrosion inhibitor bath (Iridite treatment). Engineering drawings prepared by the Navy during 1954 show the presence of several floor drains that may have been used to collect and convey wastes from the paint booth operation. This area of Zone E is zoned M2 (industrial).

The location of AOC 723 in Zone E is shown in Figure 1-1. Figure 1-2 shows an aerial photograph of the site.

1.3 Summary of Site Conditions

1.3.1 Summary of Hydrogeologic Setting at AOC 723

AOC 723 is located in the northwestern portion of Zone E at the CNC, where the surface topography is relatively flat and elevations range between approximately 12 feet above mean sea level (ft msl) to approximately 6 ft msl near the Cooper River waterfront. Because the area is highly industrialized, surface water runoff is largely controlled by a system of stormwater sewers that discharge to the Cooper River.

1.3.1.1 Surface Geology

Due to the extensive surface soil disturbance at the CNC during the history of its operations, the soils from land surface to depths of approximately 6 feet are typically a mixture of artificial fill and native sediments. The extent of fill material present varies extensively, but in the vicinity of the site, undifferentiated clay, sand, gravel, dredged material and construction debris may be present at or near the land surface. In undisturbed areas, surface deposits consist of Quaternary age (Holocene epoch to recent) fine-grained sands and clays typical of a coastal plain environment, repeatedly reworked by marine and river water erosion prior to development by man.

1.3.1.2 Subsurface Geology

The Zone E RFI included the installation of soil borings and more than 185 monitoring wells, from which geologic information was collected to develop geologic cross sections. The data indicate that Quaternary (Pleistocene to Holocene) and Tertiary age unconsolidated sediments were encountered in the subsurface. The lowermost unit encountered is the Tertiary age Ashley Formation, which is a member of the Mid-Tertiary age Cooper Group. Overlying the Ashley Formation are younger upper Tertiary and Quaternary age deposits, which are in turn overlain by the Holocene to recent surface soils.

The Ashley Formation occurs at depths of approximately 16 to 43 feet below land surface (ft bls), except in the northern portion of Zone E, where it dips downward to the north. In the remainder of Zone E, the top of the Ashley Formation is gently rolling and slopes gently downward to the east toward the Cooper River, with measured thickness approaching 40 feet. The Ashley Formation is comprised of brown to olive marine silts with varying amounts of clay, phosphatic sand, and microfossils. The consistency of the Ashley Formation is generally dense to stiff and plastic, with low vertical permeability.

In most areas of Zone E, the Ashley Formation is unconformably overlain by marine lagoon deposits of the Marks Head Formation, consisting of undifferentiated Tertiary age silts, clays and phosphatic sands of 2 to 15 feet in thickness.

The overlying Quaternary age deposits are back barrier and near shore shelf deposits from various past marine transgressions, with subsequent reworking by erosion and redeposition. The result is a sequence is approximately 15 to 85 feet thick at the CNC and is comprised mainly of Pleistocene age Wando Formation sands, silts, and clays, with varying amounts of organic matter, including peat.

At AOC 723, the Ashley Formation occurs at a depth of approximately 29 ft bls, based upon a boring completed during the installation of nearby well E563GW04D in November 2002. This boring log is provided in Appendix A. The Ashley Formation at AOC 723 is overlain by several feet of undifferentiated Upper Tertiary age silt and sand, which is overlain by approximately 21 feet of interbedded clays and fine to medium-grained sands, which is overlain by about 4 feet of fill to the land surface.

1.3.1.3 Hydrogeology

The shallow aquifer system at AOC 723 is an unconfined water table aquifer occurring within the Quaternary sediments. The underlying low-permeability Ashley Formation member acts as an aquitard for the shallow aquifer system and as a confining unit for deeper geologic units. The Cooper River acts as a regional discharge boundary for the aquifer to the east. The average saturated aquifer thickness in the AOC 723 area is approximately 25 feet, based on water level measurements in monitoring wells.

Regionally in Zone E, the shallow groundwater flows to the east, toward the Cooper River. Because a significant portion of Zone E is along the riverfront, the Cooper River is a major discharge boundary for the shallow aquifer system. However, because of extensive subsurface disturbances and the presence of underground utility lines and subsurface heterogeneities, the local groundwater flow direction at any specific site may vary significantly from the regional flow direction.

Locally at AOC 723, shallow groundwater generally flows in a northeast direction, as indicated in potentiometric surface map (see Figure 1-3). Shallow groundwater is encountered at approximately 5 ft bls. At AOC 723, the shallow surficial aquifer is comprised of two permeable zones. A shallow permeable zone extends from land surface down to approximately 11 ft bls to 13 ft bls. Shallow wells at the site are screened in this zone. A clay layer extends from approximately 13 ft bls to 20 ft bls, below which a deeper permeable zone is encountered down to the Ashley Formation. Deep wells at AOC 723 are screened beneath the intermediate clay layer in this deeper permeable zone.

The hydraulic conductivity of the shallow aquifer is approximately 10 feet/day. Based on the hydraulic gradients in the shallow portion of the surficial aquifer shown on Figure 1-3 (approximately 0.0044 foot/feet) and an assumed effective porosity of 0.40, a groundwater flow rate of 0.11 feet/day or 40 feet/year is calculated for the site.

Figure 1-4 shows the hydraulic gradients of the deeper portion of the shallow aquifer at the site. The deep groundwater flow is in the east to southeasterly direction near AOC 723.

The hydraulic conductivity of the deep aquifer is approximately 10 feet/day. Based on the hydraulic gradients in the deep portion of the surficial aquifer shown in Figure 1-3 (approximately 0.0044 foot/feet) and an assumed effective porosity of 0.40, a groundwater flow rate of 0.11 feet/day or 40 feet/year is calculated for the site.

The migration rate of organic chemicals in groundwater would be slower than the groundwater migration rate due to retardation effects resulting from interactions between the dissolved contaminants and aquifer media. A retardation factor (R) can be calculated from the expression:

R = 1 + [Pb * Kp/Pe], where

Pb = the bulk density of soil (1.6 to 1.8 grams/cm3)

Kp = the soil partition coefficient (estimated as organic carbon partition coefficient * percent total organic carbon [TOC]), and

Pe = effective porosity

Table 1-1 shows the values of the retardation factors calculated using the above formula and values from the EPA Soil Screening Guidance: Technical Background Document (EPA, 1996).

Using the average Zone E subsurface soil TOC of 1.7 percent and an organic carbon partition coefficient of 35 milliliters per gram (ml/g) for cis-1,2-DCE, a retardation factor of 3.52 can be calculated for the shallow aquifer. Based on this retardation factor, the cis-1,2-DCE migration rate in groundwater at the site would be estimated at approximately 11.33 feet/year.

Using the average Zone E subsurface soil TOC of 1.7 percent and an organic carbon partition coefficient of 166 ml/g for TCE, a retardation factor of 13 can be calculated for the shallow aquifer. Based on this retardation factor, the TCE migration rate in groundwater at the site would be estimated at approximately 3 feet/year.

Using the average Zone E subsurface soil TOC of 1.7 percent and an organic carbon partition coefficient of 18.6 ml/g for vinyl chloride, a retardation factor of 2.3 can be calculated for the shallow aquifer. Based on this retardation factor, the vinyl chloride migration rate in groundwater at the site would be estimated at approximately 17 feet/year.

1.3.2 Chemical of Concern Distribution in Soil and Groundwater

1.3.2.1 Chemicals of Concern Identified in the RFI Report Addendum and CMS Work Plan

COCs identified in the *RFI Report Addendum and CMS Work Plan, Revision 0* (CH2M-Jones, 2004) for soil at AOC 723 are arsenic, TCE, and BEQs for surface soil and TCE and BEQs for subsurface soil. COCs identified in the *RFI Report Addendum and CMS Work Plan* for groundwater at AOC 723 are antimony and TCE in shallow groundwater and cis-1,2-DCE, TCE, and vinyl chloride in deep groundwater.

1.3.2.2 Chemical of Concern Distribution in Soil

Figure 1-5 shows the soil sampling locations where surface and subsurface soil COCs were detected above screening criteria.

Surface Soil

Arsenic in surface soil exceeds the unrestricted land use criterion of 0.43 milligram per kilogram (mg/kg) and the Zone E maximum surface soil background concentration of 68 mg/kg at E723SB008 (at 106 mg/kg).

The average TCE concentration in surface soil samples is 0.35 mg/kg. This value is below the paved site-specific soil screening level (SSL) value of 2.17 mg/kg and above the unpaved site-specific SSL of 0.195 mg/kg. Only two individual samples (at boring locations E723SB003 and E723SB005) exceeded the unpaved SSL; both of these borings are located beneath Building 177. The average TCE concentration in surface soil samples collected from unpaved locations is 0.0029 mg/kg, well below the unpaved SSL value. BEQs in surface soil exceed the CNC base-wide reference concentration of 1.304 mg/kg at E723SB003 (at 2.19 mg/kg), E723SB008 (at 3.08 mg/kg), and E723SB009 (at 3.68 mg/kg).

Subsurface Soil

The average TCE concentration in subsurface soil samples is 0.0097 mg/kg, well below the unpaved site-specific SSL of 0.195 mg/kg. No individual subsurface soil samples exceeded the unpaved SSL. Thus, subsurface soil poses no leaching risk for TCE under the paved or unpaved land use scenarios.

BEQs in subsurface soil exceed the CNC base-wide reference concentration of 1.304 mg/kg at E723SB008 (at 2.63 mg/kg).

1.3.2.3 Chemical of Concern Distribution in Groundwater

Figure 1-6 shows groundwater COC exceedances detected in monitoring wells at AOC 723 for antimony, cis-1,2-DCE, TCE, and vinyl chloride.

Shallow Groundwater

TCE is the only chlorinated VOC (CVOC) in shallow groundwater. Exceedances of the TCE maximum contaminant level (MCL) of 5 micrograms per liter (µg /L) were detected in shallow wells E723GW001 and E563GW004 during the October 2003 sampling event, at 7.7 µg/L and 258 µg/L, respectively. The previous TCE detection in E563GW004 from the July 2003 sampling event was 71.3 µg/L, which is also above the MCL.

The lateral extent of TCE contamination appears to be localized in the area immediately downgradient (northeast) of AOC 723. Analytical data from upgradient well E569GW005 and wells from AOC 563 farther downgradient of AOC 723 indicate that TCE in shallow groundwater is localized near E563GW004. Based on the slow migration rate of TCE estimated for the shallow aquifer (about 3 feet/year), the TCE plume is not expected to present a significant migration risk while the corrective measures are being implemented at this site.

Deep Groundwater

Exceedances of the TCE, cis-1,2-DCE, and vinyl chloride MCLs were detected in only one deep groundwater well at the site, E563GW04D. A TCE concentration of 1,880 µg/L, a cis-1,2-DCE concentration of 169 µg/L, and a vinyl chloride concentration of 17.7 µg/L were detected in this well during the October 2003 sampling event. CVOC contamination in deep groundwater appears to be localized.

Table 1-2 shows historical detections of these COCs in groundwater at AOC 723.

1.4 Overall Approach for Selecting Candidate Corrective Measure Alternatives for AOC 723

Because of the small size of the AOC 723 site and the relatively low levels of contamination in surface soil and groundwater, the list of practicable remedial alternatives for this site are limited.

Because all of Zone E will undergo land use controls (LUCs) and the exceedances of screening criteria for arsenic and TCE in surface soil and BEQs in surface and subsurface soils are isolated, LUCs will be considered as a presumptive remedy for surface and subsurface soils. As noted above, the only soil samples that exceeded the site-specific paved SSL for TCE are under the concrete floor of Building 177. Thus, the current land use conditions are protective for soil leaching; LUCs to maintain the presence of the building or pavement in the future are suitable for addressing soils at AOC 723.

A comparison of the soil removal alternative to the LUCs at several other sites at the CNC has consistently shown that the LUC alternative is adequately protective of human health and the environment, less costly than soil excavation, and a feasible alternative. Therefore, LUCs will be considered as a presumptive remedy for soils at this site. LUCs will preclude the property from being used for residential use, as well as require that the existing pavement cover in the area of soil exceedances of the SSL at the site be maintained.

Based on previous evaluations for addressing relatively low levels of VOCs in groundwater at the CNC, the two remedies that are likely to be most cost effective for the groundwater are as follows:

- Monitored Natural Attenuation (MNA) with LUCs, and
- Enhanced In Situ Anaerobic Biodegradation of CVOCs with LUCs.

1.5 Report Organization

This CMS report consists of the following sections, including this introductory section:

1.0 Introduction—Presents the purpose of and background information relating to this CMS report.

2.0 Remedial Goal Objectives and Evaluation Criteria—Defines the RGOs for AOC 723, as well as the criteria used to evaluate the corrective measure alternatives for the site.

3.0 Description of Candidate Corrective Measure Alternatives—Describes each of the candidate corrective measure alternatives for addressing CVOCs in groundwater.

4.0 Evaluation and Comparison of Corrective Measure Alternatives—Evaluates each alternative relative to standard criteria, then compares the alternatives and the degree to which they meet or achieve the evaluation criteria.

5.0 Recommended Corrective Measure Alternative—Describes the preferred corrective measure alternative to achieve the MCS and RGOs for CVOCs in groundwater based on a comparison of the alternatives.

6.0 Enhanced In Situ Anaerobic Biodegradation Pilot Study Work Plan—Describes the technical approach and field activities involved in a pilot study intended to enhance groundwater plume delineation and study the aquifer response to the injection of substrate described in Section 5.0.

7.0 References—Lists the references used in this document.

Appendix A contains Figure A-1, which is a boring log for monitoring well E563GW04D.

Appendix B contains the cost estimates developed for the proposed corrective measure alternatives.

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

TABLE 1-1
Calculation of Migration Rates for Groundwater COCs
Corrective Measures Study Report and Pilot Study Work Plan, AOC 723, Zone E, Charleston Naval Complex

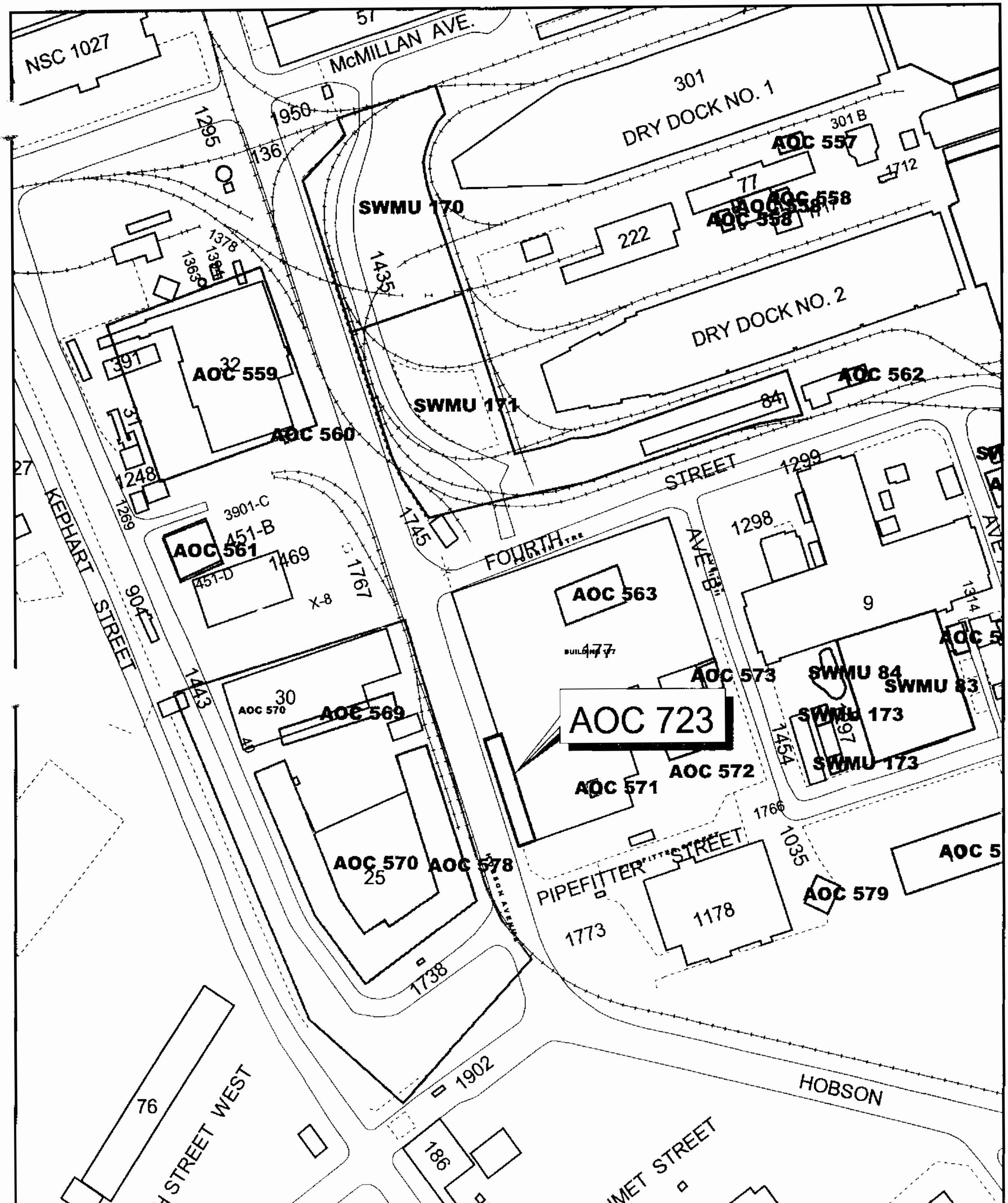
	Soil Organic Carbon/Water Partition Coefficient (Koc)[a] (cm3/g)	Total Organic Carbon (TOC) (g/g)	Soil Partition Coefficient (Kp) (=Koc x TOC) (cm3/g)	Bulk Density of Soil (Pb) (g/cm3)	Effective Porosity (Pe) (unitless)	Retardation factor (R) (unitless)	Groundwater Velocity (V) (feet/year)	Contaminant Migration Rate (V/R)
1-2 Dichloroethylene (1,2-DCE)	35.5	0.017	0.6035	1.7	0.4	3.564875	40	11
Trichloroethylene (TCE)	166	0.017	2.822	1.7	0.4	12.9935	40	3
Vinyl Chloride	18.6	0.017	0.3162	1.7	0.4	2.34385	40	17

Notes:
[a] Source of Koc values is the EPA Region IV Soil Screening Guidance: Technical Background Document (Appendix A, Part 5, Tables 38 and 39)
(g/cm3) grams per cubic centimeter
(cm3/g) cubic centimeter per gram

TABLE 1-2
Historical Detections of Groundwater COCs
Corrective Measures Study Report and Pilot Study Work Plan, AOC 723, Zone E, Charleston Naval Complex

Parameter	Station ID	Sample ID	Result	Qualifier	Date Sampled
Shallow Groundwater			ug/L		
Antimony	E563GW004	563GW004N1	3.28000	U	10/16/2003
	E723GW001	723GW001N1	6.65000	J	10/16/2003
1,2-Dichloroethene (total)	E563GW004	563GW004M4	1.20000	J	11/22/2002
	E563GW004	563GW004N1	30.40000	=	10/16/2003
	E723GW001	723GW001N1	5.00000	U	10/16/2003
Trichloroethylene (TCE)	E723GW001	723GW001N1	7.70000	=	10/16/2003
	E563GW004	563GW004M4	71.30000	=	11/22/2002
	E563GW004	563GW004N1	258.00000	=	10/16/2003
Vinyl chloride	E563GW004	563GW004M4	10.00000	U	11/22/2002
	E563GW004	563GW004N1	10.00000	U	10/16/2003
	E723GW001	723GW001N1	10.00000	U	10/16/2003
Deep Groundwater					
Antimony	E563GW04D	563GW04DN1	5.23000	U	10/16/2003
1,2-Dichloroethene (total)	E563GW04D	563GW04DM4	145.00000	=	11/22/2002
1,2-Dichloroethene (total)	E563GW04D	563GW04DN1	169.00000	J	10/16/2003
Trichloroethylene (TCE)	E563GW04D	563GW04DM4	1700.00000	=	11/22/2002
Trichloroethylene (TCE)	E563GW04D	563GW04DN1	1880.00000	=	10/16/2003
Vinyl chloride	E563GW04D	563GW04DM4	200.00000	U	11/22/2002
Vinyl chloride	E563GW04D	563GW04DN1	17.70000	=	10/16/2003

Notes:
μg/L micrograms per liter
U Indicates analyte not detected above laboratory detection limit.
J Indicates an estimated value. A "J" qualifier may signify that the concentration is below the PQL, or that the "J" has been applied as a result of the data validation.



N

0 100 200 Feet

1 inch = 180 feet

Figure 1-1
AOC 723 Site Location
Zone E
Charleston Naval Complex

CH2MHILL

File Path: c:\18gis\cnc\2003proj.apr Date: 05 May 2003 15:05 User: SNAIK1

NOTE: Aerial Photo Date is 1997

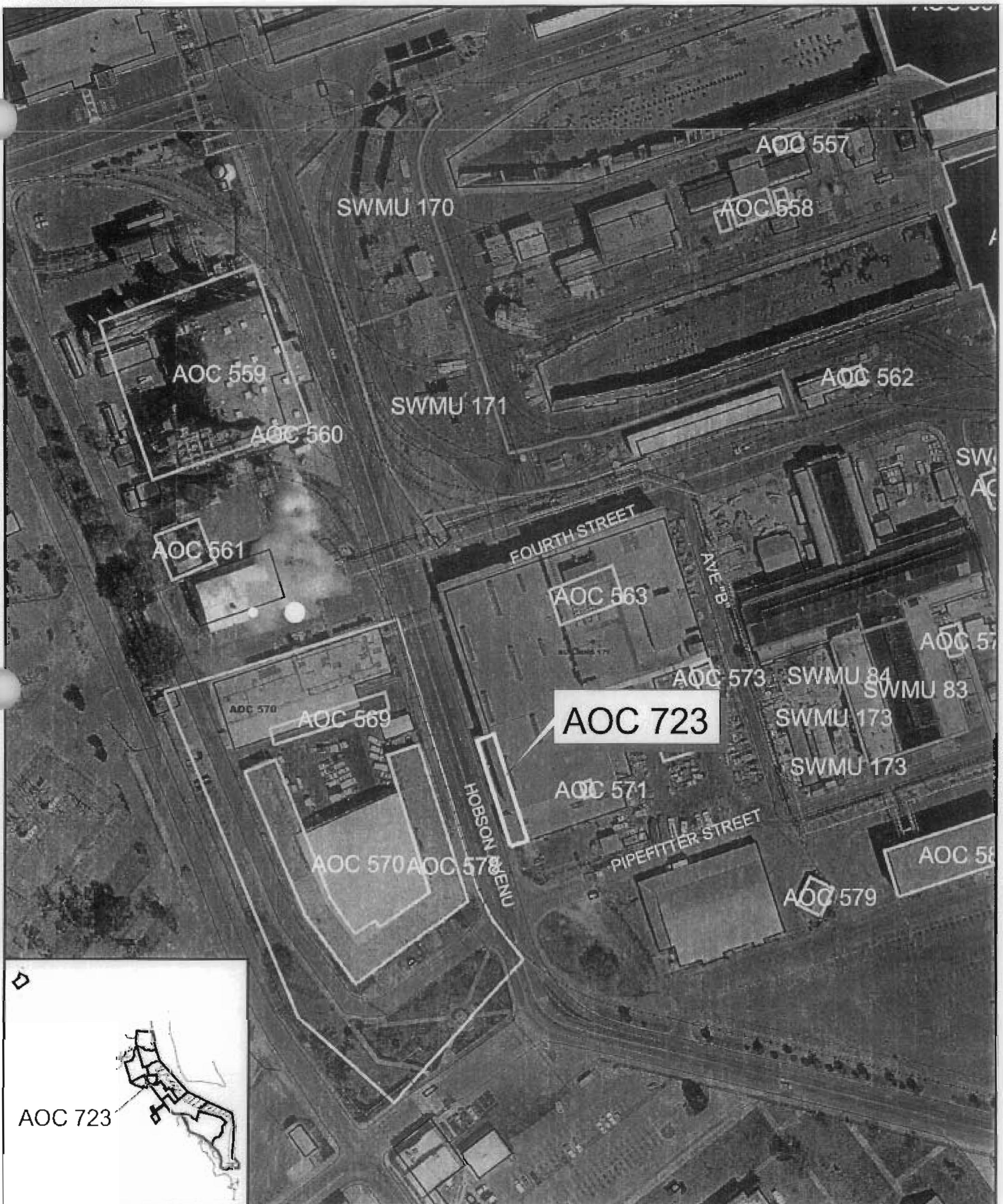


Figure 1-2
Site Map
AOC 723, Zone E
Charleston Naval Complex

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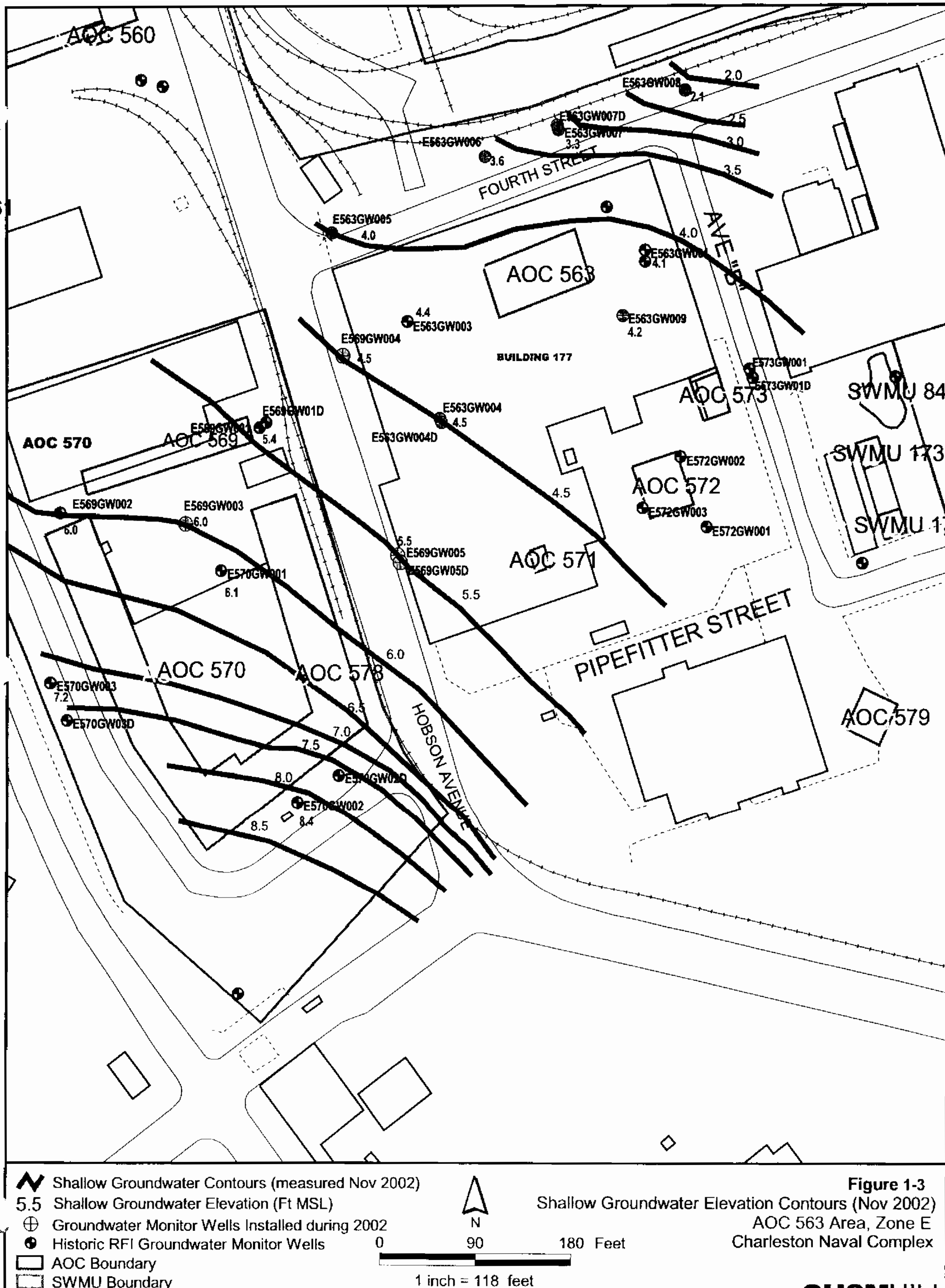

Figure 1-3
Shallow Groundwater Elevation Contours (Nov 2002)
AOC 563 Area, Zone E
Charleston Naval Complex

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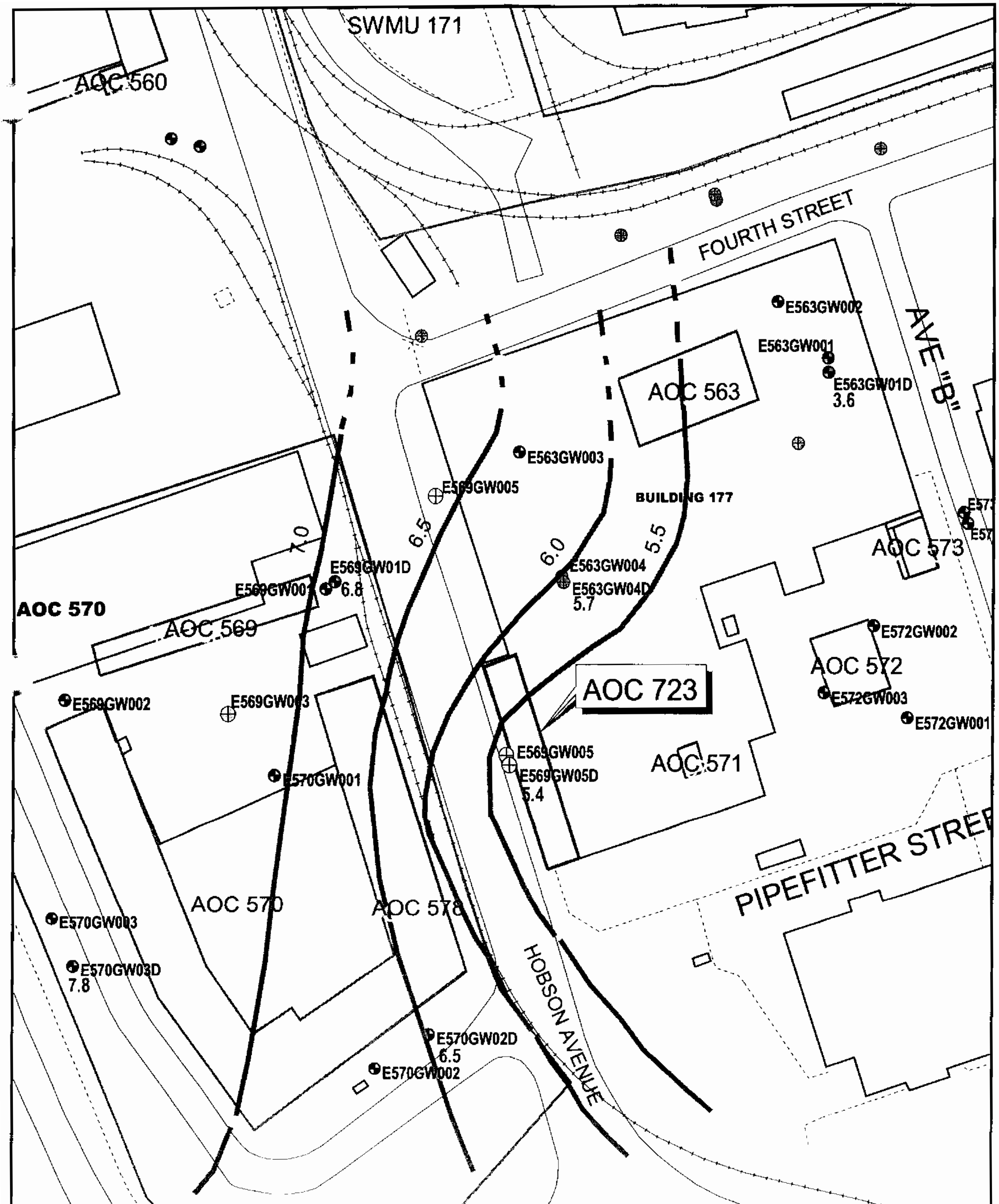

Deep Groundwater Elevation Contours (measured Nov 2002)
.8 Groundwater Elevation (ft above MSL)
⊕ Groundwater Monitor Wells Installed in 2002
Historic RFI Groundwater Monitor Wells
AOC Boundary
SWMU Boundary

N

0 70 140 Feet

1 inch = 94 feet

Figure 1-4
Deep Groundwater Elevation Contours (Nov. 2002)
AOC 723 Area, Zone E
Charleston Naval Complex

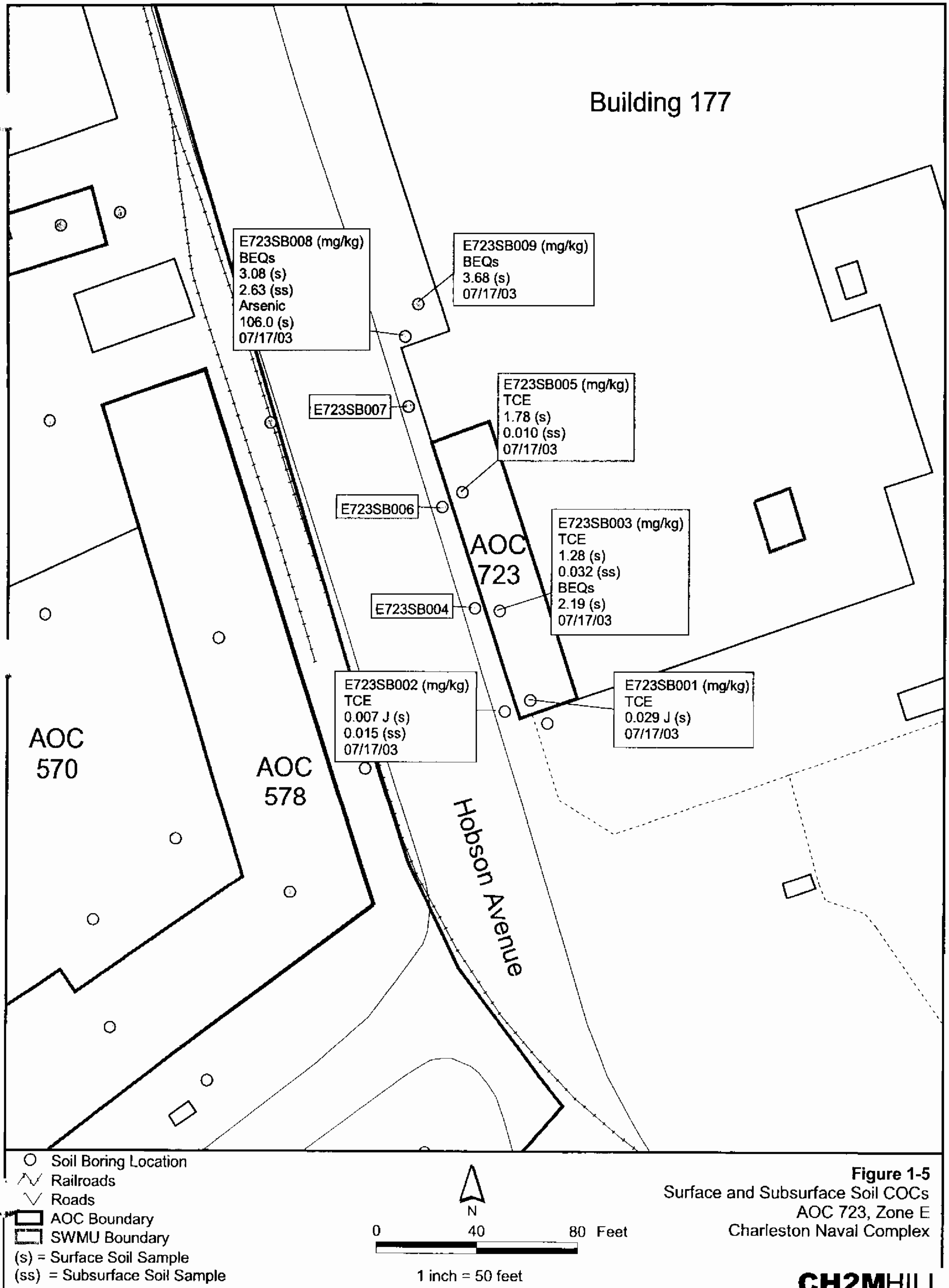

Figure 1-5
Surface and Subsurface Soil COCs
AOC 723, Zone E
Charleston Naval Complex

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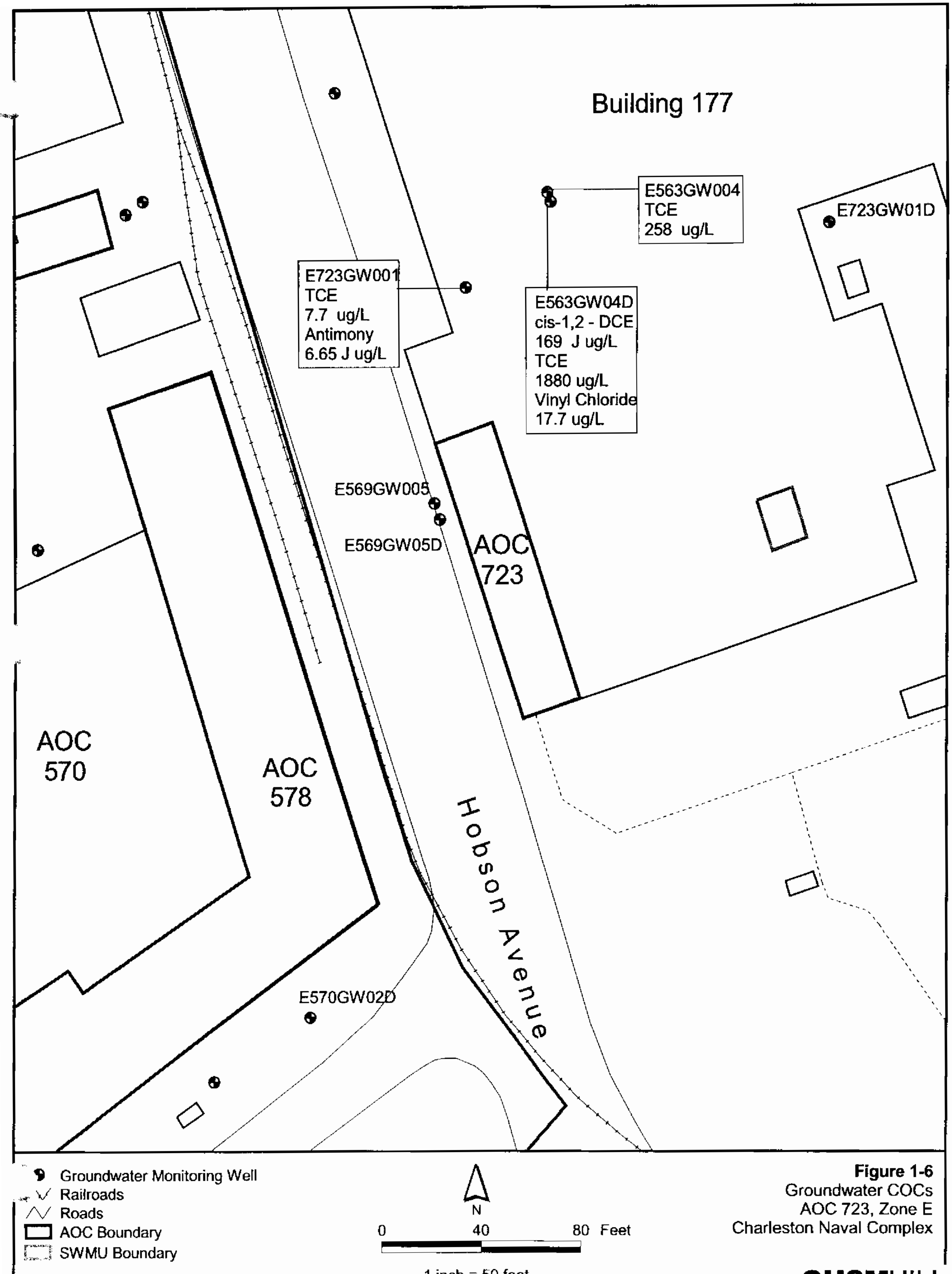


Figure 1-6
Groundwater COCs
AOC 723, Zone E
Charleston Naval Complex

Section 2.0

2.0 Remedial Goal Objectives and Evaluation Criteria

2.1 Remedial Action Objectives

RAOs are medium-specific goals that protect human health and the environment by preventing or reducing exposures under current and future land use conditions. The RAOs identified for the soil and groundwater at AOC 723 are being chosen to prevent ingestion of soil and groundwater containing COCs at unacceptable levels. All of Zone E is expected to undergo LUCs, which will also apply to soils at this site.

2.2 Media Cleanup Standards

Throughout the process of remediating a hazardous waste site, a risk manager uses a progression of increasingly acceptable site-specific media levels in considering remedial alternatives. Under the RCRA program, RGOs and MCSs are developed at the end of the risk assessment in the RFI/Remedial Investigation programs, before completion of the CMS.

RGOs can be based on a variety of criteria, such as specific incremental lifetime cancer risk (ILCR) levels (e.g., 1E-04, 1E-05, or 1E-06), Hazard Index (HI) levels (e.g., 0.1, 1.0, 3.0), or site background concentrations. For a particular RGO, specific MCSs can be determined as target concentration values. Achieving these MCSs is accepted as demonstrating that RGOs and RAOs have been achieved. Achieving these goals should promote the protection of human health and the environment, while achieving compliance with applicable state and federal standards.

The exposure media of concern for AOC 723 are surface soil impacted by arsenic, TCE, and BEQs; subsurface soil impacted by TCE and BEQs; shallow groundwater impacted by antimony and TCE; and deep groundwater impacted by cis-1,2-DCE, TCE, and vinyl chloride. Because this site is located within a highly developed area of the CNC and there are no surface water bodies in the immediate vicinity of the site, ecological exposures were not considered applicable for evaluation.

For the chemicals identified as COCs in soil and groundwater, the following MCSs are proposed:

COC	Target MCS
Soil	
Arsenic	CNC Zone E Maximum Background Arsenic Concentration of 68 mg/kg for surface soil
TCE	Site specific paved SSL for TCE - 2.17 mg/kg
BEQs	CNC Basewide BEQ Reference Concentrations of 1.304 mg/kg for surface soil, and 1.40 mg/kg for subsurface soil
Groundwater	
Antimony	MCL of 6 µg/L
cis-1,2-DCE	MCL for cis-1,2-DCE - 70 µg/L
TCE	MCL for TCE - 5 µg/L
Vinyl Chloride	MCL for Vinyl Chloride - 2 µg/L

2.3 Evaluation Criteria

According to the EPA RCRA CA guidance, corrective measure alternatives should be evaluated using the following five criteria:

1. Protection of human health and the environment.
2. Attainment of MCSs.
3. The control of the source of releases to minimize future releases that may pose a threat to human health and the environment.
4. Compliance with applicable standards for the management of wastes generated by remedial activities.
5. Other factors, including (a) long-term reliability and effectiveness; (b) reduction in toxicity, mobility, or volume of wastes; (c) short-term effectiveness; (d) implementability; and (e) cost.

Each of these criteria is defined in more detail below:

1. **Protection of human health and the environment.** The alternatives will be evaluated on the basis of their ability to protect human health and the environment. The ability of an alternative to achieve this criterion may or may not be independent of its ability to achieve the other criteria. For example, an alternative may be protective of human health, but may not be able to attain the MCSs if the MCSs were not developed based on human health protection factors.

2. **Attainment of MCSs.** The alternatives will be evaluated on the basis of their ability to achieve the MCS defined in this CMS. Another aspect of this criterion is the time frame required to achieve the MCS. Estimates of the time frame for the alternatives to achieve RGOs will be provided.

3. **The control the source of releases.** This criterion deals with the control of releases of contamination from the source (the area in which the contamination originated) and the prevention of future migration to uncontaminated areas.

4. **Compliance with applicable standards for management of wastes.** This criterion deals with the management of wastes derived from implementing the alternatives. Corrective measure alternatives will be designed to comply with all standards for management of wastes. Consequently, this criterion will not be explicitly included in the detailed evaluation presented in the CMS, but such compliance would be incorporated into the cost estimates for which this criterion is relevant.

5. **Other factors.** Five other factors are to be considered if an alternative is found to meet the four criteria described above. These other factors are as follows:

   a. Long-term reliability and effectiveness
   Corrective measure alternatives will be evaluated on the basis of their reliability, and the potential impact should the alternative fail. In other words, a qualitative assessment will be made as to the chance of the alternative's failing and the consequences of that failure.

   b. Reduction in the toxicity, mobility, or volume of wastes
   Alternatives with technologies that reduce the toxicity, mobility, or volume of the contamination will be generally favored over those that do not. Consequently, a qualitative assessment of this factor will be performed for each alternative.

   c. Short-term effectiveness
   Alternatives will be evaluated on the basis of the risk they create during the implementation of the remedy. Factors that may be considered include fire, explosion, and exposure of workers to hazardous substances.

   d. Implementability
   The alternatives will be evaluated for their implementability by considering any difficulties associated with conducting the alternatives (such as the construction disturbances they may create), operation of the alternatives, and the availability of equipment and resources to implement the technologies comprising the alternatives.

e. Cost

A net present value of each alternative will be developed. These cost estimates will be used for the relative evaluation of the alternatives, not to bid or budget the work. The estimates will be based on information available at the time of the CMS and on a conceptual design of the alternative. They will be "order-of-magnitude" estimates with a generally expected accuracy of -50 percent to +100 percent for the scope of action described for each alternative. The estimates will be categorized into capital costs and operations and maintenance costs for each alternative.

Section 3.0

3.0 Description of Candidate Corrective Measure Alternatives

3.1 Introduction

As indicated in Section 2.0, because all of Zone E will undergo LUCs, the exceedances of screening criteria for the COCs in surface and subsurface soil are isolated, and the majority of the exceedance locations are under the paved floor of Building 177, LUCs are being chosen as the presumptive remedy for soils. Therefore, no evaluation or comparison of corrective measure alternatives for surface and subsurface soils have been described in this report.

Currently available groundwater remedial technologies were screened for applicability to the contaminants and physical conditions present at AOC 723, with only the most viable technologies known for effective treatment of CVOCs in groundwater selected for alternatives analysis. The CVOC exceedances in shallow groundwater are found mainly in the vicinity of wells E723GW001 and E563GW004, and near well E563GW04D in deep groundwater.

Two presumptive remedies will be considered for site groundwater in the CMS:

- MNA with LUCs, and
- Enhanced In Situ Anaerobic Biodegradation of CVOCs with LUCs.

This section describes each alternative in more detail.

3.2 Alternative 1: Monitored Natural Attenuation with Land Use Controls

3.2.1 Description of Alternative

Alternative 1 will allow the CVOCs to continue to attenuate naturally in the subsurface, with periodic monitoring of groundwater concentrations until the MCSs are reached, and will impose LUCs (such as a deed restriction) to restrict the installation of drinking water wells.

There is no indication from historical site activities that a release of antimony has taken place at the site, and analytical results from site wells indicate a single exceedance over the MCL in one shallow well. None of the other shallow wells near AOC 723 show antimony exceedances of the MCL, indicating the absence of widespread groundwater contamination from antimony in this area. The presence of antimony in shallow groundwater will be monitored annually in the short term, and if significant concentrations above the MCL are noticed, corrective measures will be implemented if warranted. Currently, no active corrective measures are proposed for the presence of antimony in shallow groundwater at AOC 723. During groundwater monitoring, both filtered and unfiltered samples will be analyzed for antimony to assess whether particulates in groundwater samples are affecting the results. Low-flow purge methods will be used and, if necessary, the monitoring wells will be redeveloped to assist in obtaining low turbidity groundwater samples.

The collective effort of natural processes present in the aquifer, including volatilization, hydrolysis, dilution, dispersion, adsorption, and biotic and abiotic degradation, that reduce CVOC concentrations is termed natural attenuation. MNA is a careful evaluation of natural attenuation mechanisms using monitoring. EPA has issued an Office of Solid Waste and Emergency Response (OSWER) Final Directive on Monitored Natural Attenuation (EPA, 1999), in which it recognizes that MNA is appropriate as a remedial approach, "where it can be demonstrated capable of achieving a site's remedial objectives within a time frame that is reasonable compared to that offered by other methods, and where it meets the applicable remedy selection criteria for that particular OSWER program." EPA clearly states its expectation that "monitored natural attenuation will be most appropriate when used in conjunction with active remediation measures (e.g., source control) or as a follow-up to active remediation measures that already have been implemented."

The low concentrations of CVOCs in groundwater indicate that a significant source area with high-level contamination is not present. Therefore, no source area treatment technologies are needed at this site.

Under the natural attenuation alternative, the CVOC plume would be evaluated using a monitoring system designed to track the plume location and concentrations. Monitoring data would be compared to the predicted transport and fate of the CVOCs to check the accuracy of these predictions. In general, the MNA alternative consists of three major features:

- A designed monitoring program,
- A tracking and data evaluation program, and

- A contingency response plan in the event that the monitoring indicates downgradient migration of dissolved CVOCs.

The MNA alternative would be implemented in conjunction with a long-term monitoring plan. The purpose of the plan is to monitor plume migration over time and to verify that natural attenuation is occurring. The plan would specify existing wells located within, upgradient to, crossgradient to, and downgradient from the plume.

Two existing shallow monitoring wells (E723GW001 and E563GW004) and one existing deep monitoring well E563GW04D will be monitored to assess natural attenuation. Additional shallow and deep monitoring wells are needed in order to better verify the boundaries of the shallow and deep CVOC plumes. Three additional shallow and four deep monitoring wells will be installed to delineate the plume boundaries. These wells will be identified as E723GW002, E723GW02D, E723GW003, E723GW004, E723GW04D, E723GW005 and E723GW05D. The proposed locations of these new wells are shown on Figure 3-1. Additional monitoring wells may be needed if this delineation effort indicates the possibility of the plume extending farther downgradient from the proposed new wells. These additional monitoring wells will be included for MNA monitoring.

In addition to laboratory analysis for CVOCs, field measurements such as dissolved oxygen (DO), oxidation reduction potential (ORP), and turbidity would continue to be monitored. Additional parameters, such as ferrous iron, common cations and anions, and dissolved ethene, ethane, and methane, might also be monitored occasionally, if additional information on these parameters is needed. The data would provide ongoing characterization of plume extent, groundwater quality, hydraulic gradients, ORP indicators, and indicators of biological degradation products of the CVOCs. As shown on the Zone E groundwater potentiometric surface map from 2002 (see Figure 1-3), hydraulic gradients across the site are quite low, and contaminant migration rates are on the order of a few feet per year towards the Cooper River.

It is expected that the CVOC plume will slowly decrease in concentration as a result of natural attenuation. Additional contingency remedies would be considered if natural attenuation indicates low performance, as evidenced by increasing trends for total CVOC concentrations at the downgradient edge of the plume that significantly increase potential exposures or related risks. Existing data indicate that this scenario is not likely.

LUCs, such as deed restrictions, would be implemented to restrict the installation of drinking water wells at AOC 723. Such LUCs could be removed after CVOC concentrations have reduced to MCLs or lower. LUCs are currently planned for AOC 723, as well as the remainder of the Zone E industrial area.

3.2.2 Key Uncertainties

The uncertainties for the MNA alternative are not significant. Key uncertainties include monitoring well network effectiveness and confirming plume stability (that it is effectively biodegrading and not migrating). The existing monitoring well network is currently generally adequate to delineate the general extent of VOC contamination in the vicinity of SWMU 723 and Building 177. Continued water level measurements during the routine groundwater quality monitoring events will be utilized to determine whether any changes to the monitoring network, such as the addition of wells, are required. Uncertainties regarding plume stability will be determined during the continued monitoring of the plume and during the demonstration that contamination is not detected in the downgradient wells.

3.2.3 Other Considerations

LUCs restricting the use of groundwater at the site will be necessary during the MNA period until MCLs are achieved. The LUCs will also address the exposure pathways for arsenic and TCE in surface soil and BEQs in surface and subsurface soils.

3.3 Alternative 2: Enhanced In Situ Anaerobic Biodegradation of Chlorinated Volatile Organic Compounds with Land Use Controls

3.3.1 Description of Alternative

3.3.1.1 Technology Description

CVOCs have been shown to be biodegradable, primarily under anaerobic condition. The main CVOC biodegradation mechanism in anaerobic environments is reductive dechlorination, which involves the sequential replacement of chlorine atoms on the alkene molecule by hydrogen atoms.

In anaerobic reductive dechlorination, a carbon atom in the chlorinated solvent accepts an electron from an electron donor (reduction), causing the release of a chlorine atom (dechlorination). The more chlorine atoms a compound has, the more oxidized its carbon is, and therefore the more susceptible it is to reductive dechlorination. This results in sequential dechlorination of a contaminant. The general reductive dechlorination process results in the formation of breakdown products as detailed below:

TCE ⇒ DCE ⇒ vinyl chloride ⇒ ethene

The chlorinated ethenes serve as electron acceptors in these degradation reactions. This process is referred to as dehalorespiration. Organic carbon compounds such as sugars, alcohols, and fatty acids serve as electron donors.

Enhanced reductive dechlorination (ERD) would involve implementing more active measures in areas of elevated TCE concentration to accelerate the naturally occurring process. For anaerobic biodegradation to be successful, adequate quantities of electron donors, electron acceptors, and nutrients must come in contact with the active microbial consortia and the target contaminants. Not all natural groundwater systems have the essential microbiological organisms needed to achieve complete reductive dechlorination of tetrachloroethene (PCE) and TCE to ethene. One group of bacteria, *Dehalococcoides ethenogenes* (DHE), has been found to be capable of complete dechlorination. At some sites, the addition of a microbiological consortium containing DHE may be an alternative to improve the degree of reductive dechlorination achieved.

Hydrogen is the electron donor used by DHE and other micro-organisms in dehalorespiration. The hydrogen is released by the anaerobic fermentation of organic carbon. Other microbes, such as methanogens, compete with dehalorespiring bacteria for available hydrogen.

A commonly used approach for achieving ERD is biostimulation, which is providing a fermentable substance into the groundwater. Commonly used substrates include Hydrogen Release Compound® (a proprietary lactate polymer), molasses, lactate, and other readily biodegradable materials. Indigenous anaerobic microorganisms ferment these organic chemicals, resulting in the release of hydrogen. The hydrogen can then be used by organisms capable of dechlorinating CVOCs.

The addition of a substrate or other enhancements can be achieved through injection in conventional wells or by inserting the material(s) directly into the aquifer using direct-push technologies. The effectiveness of any enhancement or anaerobic reductive dechlorination is dependent on the ability to supply the rate-limiting reagent directly to the microorganisms and the presence of the appropriate microbes and hydrogeologic conditions.

At some sites, the activity of naturally occurring microorganisms is significantly reduced or potentially inhibited because of site geochemical conditions. This method of bioaugmentation may also be applicable if the appropriate bacteria are not present. Bioaugmentation involves the injection of a known microbial consortia of chlorinated solvent-degrading bacteria. Bioaugmentation with selected known chlorinated solvent-degrading consortia has been shown to be capable of completing dechlorination to ethene at a limited number of sites. Complete dechlorination has occurred at these sites when bioaugmentation with microbial cultures known to be capable of complete dechlorination has been employed. Bioaugmentation is considered potentially applicable in these special cases and can be evaluated through laboratory microcosm study or pilot testing.

It should be noted that the presence of DHE, a bacterium shown to be capable of completely dechlorinating TCE, has been confirmed at AOC 607, at which an in situ biodegradation pilot test is occurring. Thus, it is likely that the native subsurface bacterial population at AOC 723 also has the necessary bacteria to allow in situ biodegradation to be effective.

3.3.2 Conceptual Approach to Implementing Enhanced Reductive Dechlorination

For the purpose of evaluating this alternative, it is assumed that one of the more widely effective substrates, such as lactate, would be a suitable electron donor and that it would be injected via conventional wells. If necessary, the system could also be bioaugmented with a commercially available bacterial consortium known to contain DHE however, as noted above, DHE have been shown to be present at the CNC and bioaugmentation will likely be unnecessary.

For this alternative, it is assumed that potassium lactate ($C_3H_5KO_3$) would be injected into several injection wells. Additional monitoring wells would be installed first to ensure that optimal locations for injections are available. Groundwater would be monitored downgradient of the injection wells to assess the effectiveness of this approach. Four additional shallow and three deep monitoring wells (E723GW002, E723GW02D, E723GW003, E723GW004, E723GW04D, E723005 and E723GW05D) screened in the shallow and deep intervals of the surficial aquifer will be installed as shown on Figure 3-1 and used to evaluate the optimal injection well locations and system performance.

Lactate was selected as the presumed electron donor since it is an easily fermented substrate that has been effectively used at many sites and is easy to inject. Lactate solutions are easily handled and there is no health risk, since lactate exists naturally in the body and is used as a flavoring salt for food. Typically lactate can sustain fermentation for approximately 10 to 45 days once injected. The length of time required between injections depends on a variety of site-specific factors. For this application, it is assumed that up to nine injections of lactate per well will be performed annually for the first year, followed by up to six injections per year for another year.

Monitoring will be used to evaluate the impact on dissolved CVOC concentrations and the distribution and fermentation effects of lactate following the initial injection. Information obtained during the injection and performance monitoring period will be used to further enhance the design of future injection events. Parameters monitored would include field parameters (DO, ORP, pH, temperature), VOCs, volatile fatty acids (VFAs), alkalinity, dissolved iron, and related geochemical parameters.

It is expected that if this process is found to be effective, it would achieve a significant amount of reduction in VOC concentrations over the first several years in which it is implemented, with a declining amount of additional benefit in later years, once the portions of the residual plume that are amenable to this technology have been effectively treated. For this reason, an implementation period for the ERD process of up to 2 years has been assumed. However, the ERD process and LUCs would continue as long as necessary to be adequately protective of human health and the environment. Groundwater monitoring would also continue during the period after implementation of ERD, until CVOC concentrations are sustained below their respective MCLs.

3.3.3 Key Uncertainties

Key uncertainties for implementing ERD at AOC 723 include identification of an effective substrate that maximizes the degree of reductive dechlorination achieved and whether the natural bacterial consortium present at the site can achieve complete reductive dechlorination.

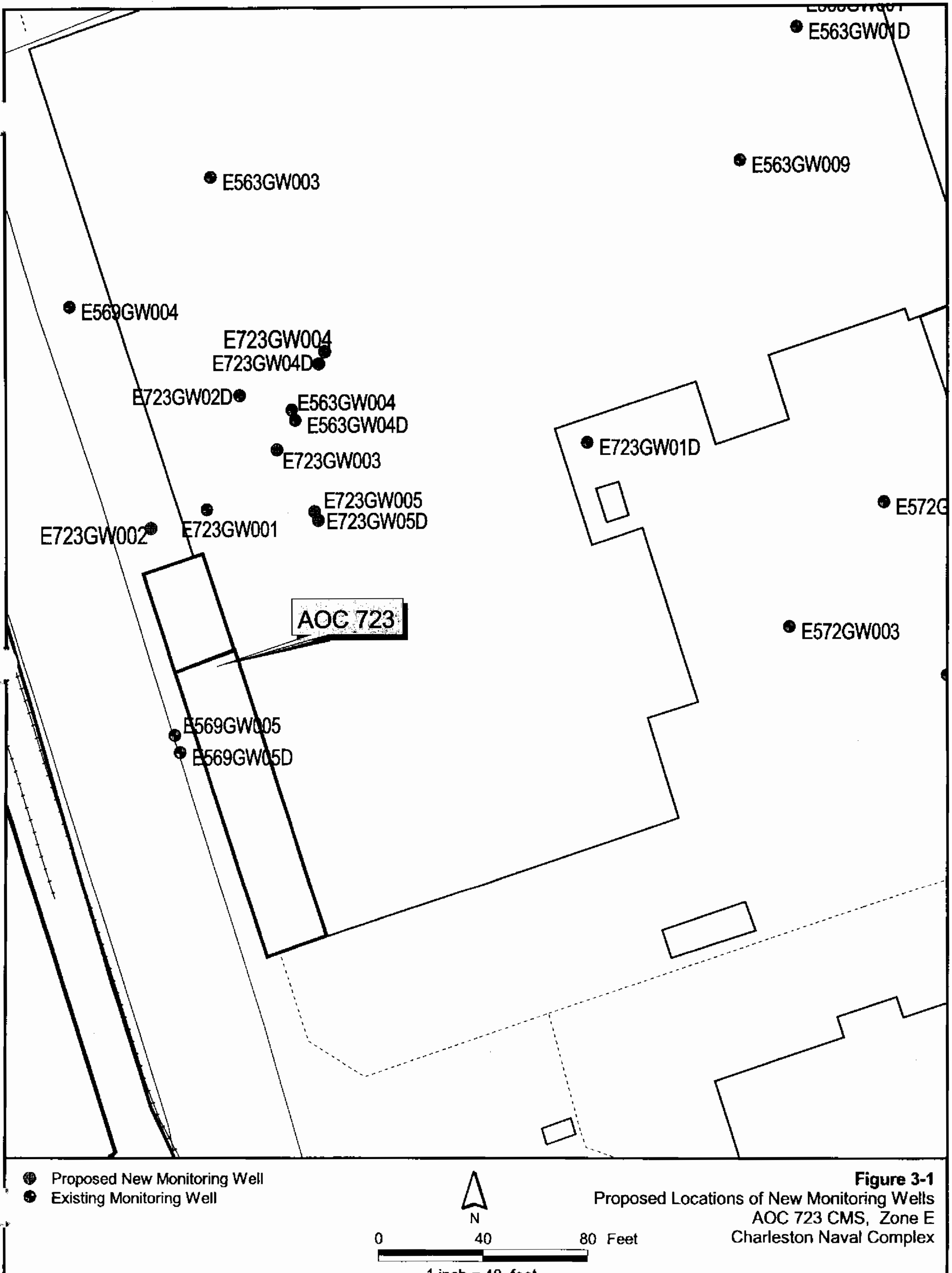


Figure 3-1
Proposed Locations of New Monitoring Wells
AOC 723 CMS, Zone E
Charleston Naval Complex

CH2MHILL

File Path: c:\18gis\cnc\cnc-egis.apr, Date: 22 Nov 2004 15:05, User: SNAIK1, EGIS: Charleston Naval Complex - Figure 3-1 Proposed Locations of New Monitoring Wells

Section 4.0

4.0 Evaluation and Comparison of Corrective Measure Alternatives

The two corrective measure alternatives were evaluated relative to the evaluation criteria previously described in Section 2.0 and then subjected to a comparative evaluation. A cost estimate for each alternative was also developed; the assumptions and unit costs used for these estimates are included in Appendix B.

4.1 Alternative 1: Monitored Natural Attenuation with Land Use Controls

The assumptions for Alternative 1 include the following:

- A base-wide land use control management plan (LUCMP) will be developed for the CNC. The plan will allow for restrictions on the use of groundwater at AOC 723 and other areas. The plan will be developed outside the scope of this CMS.

  Periodic groundwater monitoring will be performed until results indicate that the natural attenuation is considered complete and CVOC concentrations are below MCLs, estimated to be no more than 5 years at this site. Samples will be collected from 10 existing monitoring wells (shallow wells E723GW001, E723GW002, E723GW003, E723GW004, E723GW005, E563GW004 and deep wells E563GW04D, E723GW02D, E723GW03D and E723GW04D) on an annual basis, and the samples will be analyzed for CVOCs. Selected MNA parameters will be analyzed, as needed, in the groundwater samples. Standard field parameters (DO, ORP, turbidity, temperature) will be monitored in all wells. For cost estimating purposes, monitoring will be planned for a 20-year period. Table 4-1 shows the wells to be sampled and the sampling parameters.

4.1.1 Protection of Human Health and the Environment

Alternative 1 is effective at protecting human health because it uses LUCs to prevent the ingestion of, and direct contact with, groundwater. Based on the slow migration rate of TCE (estimated at 3 feet/year), it is likely that this plume will naturally attenuate before representing a threat to the Cooper River.

4.1.2 Attainment of Media Cleanup Standard

Alternative 1 is expected to eventually attain the MCS. The time frame required to achieve MCLs in all wells is difficult to predict. Given the relatively low concentrations present and low migration rates, this is estimated to between 10 and 20 years.

4.1.3 Control the Source of Releases

There are no ongoing sources of release identified at AOC 723; therefore, this issue is not applicable.

4.1.4 Compliance with Applicable Standards for the Management of Generated Wastes

Alternative 1 does not generate any wastes that require special management. The primary generated waste would be purge water from monitoring wells, which is easily managed to applicable standards.

4.1.5 Other Factors (a) Long-term Reliability and Effectiveness

Alternative 1 has adequate long-term reliability and effectiveness. However, if monitoring well sampling results indicated that unexpected migration of the groundwater plume had occurred, additional corrective measures would likely be necessary.

4.1.6 Other Factors (b) Reduction in the Toxicity, Mobility, or Volume of Wastes

Alternative 1 relies on natural attenuation to reduce the toxicity, mobility, and volume of the contaminated groundwater.

4.1.7 Other Factors (c) Short-term Effectiveness

Through the implementation of LUCs, Alternative 1 has short-term effectiveness in preventing ingestion of, or contact with, the contaminated groundwater. No significant short-term risks would be created using this alternative.

4.1.8 Other Factors (d) Implementability

Alternative 1 is easily implemented since it requires only the implementation of LUCs and an appropriate monitoring well program.

4.1.9 Other Factors (e) Cost

Although Alternative 1 is more expensive than Alternative 2, it is easier to implement since it requires no construction of treatment facilities or disposal of wastes. The significant cost component of this alternative is groundwater monitoring.

Using the assumptions described earlier, the total present value of this alternative is $204,000.

4.2 Alternative 2: Enhanced In Situ Anaerobic Biodegradation of Chlorinated Volatile Organic Compounds with Land Use Controls

A presumptive approach of enhanced in situ aerobic biodegradation (via ERD) using one of the more widely effective substrates, such as lactate, was assumed for this alternative. The following additional assumptions were made:

- A base-wide LUCMP will be developed for the CNC. The plan will allow for restrictions on the use of groundwater at AOC 723 and other areas. The plan will be developed outside the scope of this CMS.
- Based on groundwater CVOC concentrations detected in the proposed new wells, the substrate will be injected into appropriately chosen injection wells. At the present time, the injections are planned at the two proposed new shallow wells, E723GW002 and E723GW003, and one proposed new deep well, E723GW02D. Samples will be collected from up to four shallow and three deep additional groundwater wells on an annual basis and analyzed for COCs. The number of wells will be modified during the CMS phase, if necessary, based on the contaminant concentrations detected after completion of the injection phase. Selected MNA parameters will be analyzed, as needed, in the groundwater samples. Standard field parameters (DO, ORP, turbidity, temperature) will also be monitored.

Table 4-1 shows the wells to be sampled and the sampling parameters.

4.2.1 Protection of Human Health and the Environment

Alternative 2 is effective at protecting human health and the environment because it uses LUCs to prevent the ingestion of, and direct contact with, groundwater during the time period when groundwater CVOC concentrations are greater than the MCS.

4.2.2 Attainment of Media Cleanup Standard

Alternative 2 is expected to eventually attain the MCS. The time frame required to achieve MCLs in all wells is difficult to predict. Given the relatively low concentrations present and low migration rates and assuming that anaerobic biodegradation can be effectively stimulated, this is estimated to be between 5 and 15 years.

4.2.3 Control the Source of Releases

There are no ongoing sources of release identified at AOC 723; therefore, this issue is not applicable.

4.2.4 Compliance with Applicable Waste Management Standards

This approach will generate minimal waste during implementation, limited to solid waste associated with well drilling and well development and purge water. Soil cuttings from monitoring well installation will be sampled and analyzed for waste characterization parameters prior to acceptance from a permitted facility. Liquid wastes will be disposed of in accordance with applicable standards.

4.2.5 Other Factors (a) Long-term Reliability and Effectiveness

Alternative 2 has long-term reliability because of the implementation of LUCs and permanent biodegradation of the COCs.

4.2.6 Other Factors (b) Reduction in the Toxicity, Mobility, or Volume of Wastes

Alternative 2 reduces the toxicity, mobility, and volume of the contaminated groundwater via biodegradation.

4.2.7 Other Factors (c) Short-term Effectiveness

Because of the implementation of LUCs, this alternative will have short-term effectiveness in preventing ingestion of, or contact with, the contaminated groundwater. No unmanageable hazards would be created during its implementation.

4.2.8 Other Factors (d) Implementability

This alternative is relatively easily implemented.

4.2.9 Other Factors (e) Cost

Appendix B presents the overall cost estimate for implementing this remedy. Alternative 2 is cheaper than Alternative 1. The total present value of Alternative 2 is $183,000.

4.3 Comparative Evaluation of Corrective Measure Alternatives

Each corrective measure alternative's overall ability to meet the evaluation criteria is described above. In Table 4-2, a comparative evaluation of the degree to which each alternative meets a particular criteria is presented.

TABLE 4-1
Sampling and Analysis Schemes for CMS Alternatives 1 and 2
Corrective Measures Study Report and Pilot Study Work Plan, AOC 723, Zone E, Charleston Naval Complex

Monitoring Well ID	Sampling Parameters
CMS ALTERNATIVE 1 (MNA) (Years 0-20)	
E723GW001 E723GW002 E723GW003 E723GW004 E723GW005 E563GW004 E563GW04D E723GW02D E723GW04D E723GW05D	Field Measurement—DO, ORP, pH, temperature, turbidity, and specific conductance Offsite Laboratory Analysis—VOCs
CMS ALTERNATIVE 2 (ERD)	
Baseline Characterization Sampling and Analysis	
E723GW001	VOCs
E563GW004	VOCs
E563GW04D	VOCs
E723GW002 (new well)	VOCs, dissolved iron and manganese (field filtered), sulfate/sulfide, TOC, DHE (via Real Time PCR), phospholipid fatty acids (PLFAs), volatile fatty acids (VFAs), MEE, alkalinity
E723GW003 (new well)	VOCs, dissolved iron and manganese (field filtered), sulfate/sulfide, TOC, DHE (via Real Time PCR), phospholipid fatty acids (PLFAs), volatile fatty acids (VFAs), MEE, alkalinity
E723GW004 (new well)	VOCs
E723GW005 (new well)	VOCs
E723GW02D (new well)	VOCs, dissolved iron and manganese (field filtered), sulfate/sulfide, TOC, DHE (via Real Time PCR), phospholipid fatty acids (PLFAs), volatile fatty acids (VFAs), MEE, alkalinity
E273GW03D (new well)	VOCs
E723GW04D (new well)	VOCs
E723GW05D (new well)	VOCs
Post-Injection Monitoring for CMS Alternative 2 (YEARS 1 AND 2)	
Quarterly Sampling Parameters (Months 3, 6, 9, and 12)	
E723GW002, E723GW003 and E723GW02D	DO, ORP, pH, temperature, and specific conductance VOCs Methane, ethane, and ethene (MEE) Volatile fatty acids (VFA)

TABLE 4-1
Sampling and Analysis Schemes for CMS Alternatives 1 and 2
Corrective Measures Study Report and Pilot Study Work Plan, AOC 723, Zone E, Charleston Naval Complex

Monitoring Well ID	Sampling Parameters
	Total Organic Carbon (TOC)
Additional Parameters (one time after injection)	
E723GW002, E723GW003 and E723GW03D	All Monthly Parameters (see above), antimony
	Sulfate
	Sulfide
	Dissolved iron (field filtered)
	Dissolved manganese (field filtered)
	Alkalinity
	DHE
	PLFAs
Long-term Monitoring for CMS Alternative 2 (Years 3-8)	
E723GW001, E723GW002, E723GW003, E723GW004, E723GW005, E563GW004	CVOCs (TCE, 1,2-DCE, Vinyl Chloride)
E563GW04D, E723GW02D, E723GW04D, and E723GW05D	

TABLE 4-2
Detailed Analysis of Source Control Corrective Measure Alternatives
Corrective Measures Study Report and Pilot Study Work Plan, AOC 723, Zone E, Charleston Naval Complex

Evaluation Criteria	Alternative 1: Monitored Natural Attenuation and LUCs	Alternative 2: Enhanced In Situ Anaerobic Biodegradation of CVOCs and LUCs
Protection Of Human Health and the Environment	Process will be protective of human health and the environment.	Process will be protective of human health and the environment.
Attainment of Media Cleanup Standards	Alternative can potentially significantly reduce VOC concentrations at site; however, it is not expected to achieve MCSs throughout the entire plume.	Alternative can potentially significantly reduce VOC concentrations at site; however, it is not expected to achieve MCSs throughout the entire plume.
Control of the Source of Release	No release source identified. Therefore, this is not applicable.	No release source identified. Therefore, this is not applicable.
Compliance with Applicable Waste Management Standards	Not expected to accumulate significant quantities of waste requiring management.	Not expected to accumulate significant quantities of waste requiring management.
Long-Term Reliability and Effectiveness		
Magnitude of Residual Risk	Minimal residual risk due to LUCs, gradual reduction of potential risk within areas of elevated VOC concentration in groundwater	Minimal residual risk due to LUCs, significant reduction of potential risk within areas of elevated VOC concentration in groundwater.
Adequacy of Reliability of Controls	Expected to provide adequate control over the long term.	Expected to provide adequate control over the long term.
Reduction of Toxicity, Mobility, or Volume of Wastes		
Amount of Hazardous Materials Anticipated to be Destroyed/Treated	If properly implemented, the alternative is expected to reduce volume and mass of CVOCs.	If properly implemented, the alternative is expected to reduce volume and mass of CVOCs.

TABLE 4-2
Detailed Analysis of Source Control Corrective Measure Alternatives
Corrective Measures Study Report and Pilot Study Work Plan, AOC 723, Zone E, Charleston Naval Complex

Evaluation Criteria	Alternative 1: Monitored Natural Attenuation and LUCs	Alternative 2: Enhanced In Situ Anaerobic Biodegradation of CVOCs and LUCs
Degree and Quantity of Reduction	Low to moderate. Alternative has the long-term potential to decrease dissolved contaminant concentration.	Moderate. Process is expected to reduce CVOC contaminant concentrations.
Irreversibility of Reduction	High. Biodegradation of CVOCs via reductive dechlorination is irreversible.	High. Biodegradation of CVOCs from groundwater is irreversible.
Type and Quantity of Treatment Residuals	Minimal treatment residuals is anticipated.	Minimal treatment residuals is anticipated.
Preference for Treatment as a Principal Element	Natural treatment is a component of this alternative.	Treatment is the principal component of this alternative.
Short-Term Effectiveness		
Protection of Workers During Remedial Action Construction	Implementation poses a low degree of safety and health hazards to workers. Requires a Site Health and Safety Plan.	Implementation poses a minimal degree of safety and health hazards to workers. Requires a Site Health and Safety Plan.
Protection of Community During Remedial Action	Implementation poses a minimal degree of safety or health hazards to the CNC community.	Implementation poses a minimal degree of safety or health hazards to the CNC community.
(Short-Term Effectiveness)		
Environmental Impacts of Remedial Action	Process should not create adverse impacts on the environment.	Process should not create adverse impacts on the environment.
Implementability		
Technical Feasibility	High. Except for the new innovative analytical techniques, process uses conventional and readily available technology.	High. Except for the new innovative analytical techniques, process uses conventional and readily available technology.

TABLE 4-2
Detailed Analysis of Source Control Corrective Measure Alternatives
Corrective Measures Study Report and Pilot Study Work Plan, AOC 723, Zone E, Charleston Naval Complex

Evaluation Criteria	Alternative 1: Monitored Natural Attenuation and LUCs	Alternative 2: Enhanced In Situ Anaerobic Biodegradation of CVOCs and LUCs
Administrative Feasibility	High. Few major administrative issues.	High. Will require UIC permit. Pilot test will be required as part of the design process.
Estimated Costs[a]		
Capital Cost	$57,700	$71,400
Annual O&M Cost	$10,000 (Years 1-20)	$32,000 (Years 1-2)[b] $10,000 (Years 3-8)
Total Cost	$204,000	$183,000

[a] Order-of-magnitude level cost estimates with expected accuracy of plus 50 to minus 30 percent.

[b] Assumes 3.2 percent discount rate, 2-year operation period, and annual sampling for 6 additional years.

[c] Assumes 3.2 percent discount rate and annual sampling for 20 years.

Section 5.0

5.0 Recommended Corrective Measure Alternative

Two corrective measure alternatives were evaluated for groundwater COCs using the criteria described in Section 2.0 of this CMS report: 1) Alternative 1: MNA with LUCs, 2) and Alternative 2: Enhanced In Situ Anaerobic Biodegradation of CVOCs with LUCs.

The RAOs identified for groundwater at AOC 723 are: 1) to prevent ingestion and direct/dermal contact with groundwater or surface soil having unacceptable carcinogenic or noncarcinogenic risk; 2) to prevent migration to offsite areas; and 3) to restore the aquifer to beneficial use.

Based on the alternative evaluations and RAOs for the site and current uncertainties associated with each alternative, the preferred corrective measure alternative is Alternative 2: Enhanced In Situ Anaerobic Biodegradation of CVOCs with LUCs. Alternative 2 is cheaper than Alternative 1 and is expected to result in a more rapid site closure.

An LUCMP is being developed for the industrial areas of the CNC, and AOC 723 will be added to the plan. The LUCMP will limit future site activities to those that would limit exposure to groundwater. Current data indicate that the contaminants are not migrating significantly, and based on historical detections of these contaminants in groundwater, are expected to continue not to migrate noticeably. The expected reliability of this alternative is good. Should monitoring data indicate that this alternative is not as effective as expected, additional measures could be safely implemented.

In order to best assess optimal operational conditions for the ERD technology at AOC 723, a pilot test is recommended. During the pilot test, one or more test injection wells and additional monitoring wells will be installed, several injections of a substrate, such as lactate, will be performed, and the aquifer's response to the presence of the substrate will be monitored to assess overall system performance. After the pilot test has determined the effectiveness of the approach, full-scale implementation will proceed. A pilot test work plan is provided in Section 6.

Section 6.0

6.0 Enhanced In Situ Anaerobic Biodegradation Pilot Study Work Plan

6.1 Pilot Study Objectives and Goals

The purpose of the pilot study is to evaluate the viability of using ERD techniques to enhance the bioremediation of CVOCs in the shallow and deep portions of the surficial aquifer at AOC 723. The primary goals of the pilot study are to:

- Assess the effectiveness of lactate as an organic substrate (electron donor) for the site;
- Assess the degree to which the naturally present bacterial consortium in the aquifer can effectively anaerobically degrade TCE and its daughter products; and
- Determine the required frequency of injection, necessary dosage of substrate, approximate radius of influence of the injection well, and overall substrate migration rate within the aquifer in this area.

This information will allow the overall viability and costs for full scale implementation to be better determined.

6.2 Pilot Study Approach

Key activities for the pilot study will include:

1. Baseline characterization (sampling and analysis) of microbiological and geochemical indicators and groundwater VOC concentrations, and
2. Implementation of substrate injection pilot test with post-injection monitoring.

Each of these key activities are described further in the following subsections.

6.2.1 Baseline Characterization Sampling and Analysis

Although the site has been well-characterized for the purposes of the RFI and understanding the nature and extent of contamination, additional specific sampling will enhance the understanding regarding the amenability of the site to the ERD process, nature of the native microbiological consortium at the site, and current VOC concentrations. The installation of additional wells has also been proposed to better delineate the extent of groundwater CVOC contamination. The proposed sampling and analysis includes groundwater analysis for VOCs, plus several recently developed analyses to assess the general nature of the native site bacteria.

Some recent studies have indicated that the presence of a unique bacteria species (DHE) in the aquifer may indicate that the native bacterial consortium at a site may be able to completely dechlorinate TCE to ethene. DHE is unique in that it is an obligate dehalorespiring bacteria. It uses chlorinated ethene solvents exclusively as its terminal electron acceptors and is one of the few bacteria identified that can anaerobically dechlorinate TCE to vinyl chloride and then to ethene. Sampling and analysis of site groundwater and aquifer material to assess the presence of DHE will be conducted prior to implementation of the substrate injection pilot test. If naturally present in the aquifer, DHE bacteria may allow for the complete anaerobic dechlorination of TCE without requiring the addition of supplemental bacteria. Recent sampling conducted at AOC 607 at the CNC has confirmed the natural presence of DHE bacteria in the subsurface, and it is quite likely that it is available in the subsurface at AOC 723 also.

The presence of DHE bacteria can be detected using several DNA test methods developed in recent years, such as the Polymerase Chain Reaction (PCR), whereby traces of DNA, specific only to microbes of interest, are amplified from environmental samples such that they can be identified. This approach does not allow for specific quantification of the existing and present microbial population. However, a recently-developed analytical method (Real Time PCR) allows for quantification of the number of microbes detected, as well as their identification. CH2M-Jones proposes to perform Real Time PCR tests on groundwater and soil samples as part of the baseline testing to assess the presence and number of DHE organisms at AOC 723. This analysis is conducted commercially by only a few laboratories. CH2M-Jones proposes to use Microbial Insights, Inc. in Knoxville, TN, for conducting this analysis.

In addition to testing for DHE using Real Time PCR, CH2M-Jones proposes to conduct analysis of soil and groundwater samples for phospholipid fatty acid (PLFA) content. PLFAs are an important component in the metabolism of the cell. They degrade extremely quickly once a bacteria dies. Analysis for PFLAs provides a quantitative means to measure viable microbial biomass, overall bacterial community composition, and nutritional status. The PFLA analysis provides significant information regarding the overall composition of native bacterial consortium present in an aquifer. CH2M-Jones proposes to use Microbial Insights for PFLA analysis.

In addition to the Real Time PCR and PFLA analyses, groundwater samples will be collected from three existing wells (E723GW001, E563GW004 and E563GW04D) and analyzed for VOCs, field parameters (DO, ORP, temperature, pH, conductance), sulfate/sulfide, dissolved iron and manganese, VFAs, and alkalinity. Table 4-1 shows the proposed wells for sampling and the parameters to be analyzed. Data from these analyses will provide a baseline against which the effectiveness of the pilot test can be compared.

6.2.2 Substrate Injection Pilot Test and Post-Injection Monitoring

6.2.2.1 Overview of Pilot Test Approach

The initial step in the pilot test will be the installation of additional shallow and deep monitoring wells to assist in a more complete delineation of the CVOC contamination in groundwater, as well as to provide optimal locations for lactate injections. The proposed wells are shown on Figure 3-1. These new wells and the existing wells at AOC 723 will be sampled for CVOCs in order to determine the extent of groundwater contamination. Based on the fairly low levels of contamination observed during the RFI, it does not appear that a source area with high levels of CVOCs is present at the site, and it is unlikely that the plume extends beyond the boundaries formed by the proposed new monitoring well locations.

The overall approach to the pilot test will involve injection of a fermentable substrate into the shallow aquifer via two shallow wells (E723GW002 and E723GW003) and one deep well E723GW02D, located upgradient of wells E723GW001, E563GW004 and E563GW04D, the three wells exhibiting CVOC concentrations above the MCL. The response of the aquifer and groundwater quality will be measured downgradient of the injection (in wells E723GW001, E563GW004 and E563GW04D) to assess changes in overall biological activity and degree of biodegradation of the CVOCs.

Because native bacteria often require an acclimation period before they adjust to a change in conditions, it may take between 3 to 6 months before the level of effectiveness of the substrate injection can be adequately assessed. During this period, groundwater monitoring will be performed to assess the response of aquifer to the injection of substrate. It is expected that several injections of substrate will be required during this period to maintain or achieve the desired reducing conditions.

6.2.2.2 Target Treatment Area

The area exhibiting the highest groundwater concentrations of CVOCs in the shallow interval of the surficial aquifer includes monitoring wells E723GW001, E563GW004 and E563GW04D, as depicted on Figure 3-1. The extent of the CVOC plume in the shallow aquifer is currently estimated to be fairly small and centered around the area between wells E723GW001 and E563GW004, and this area is the current estimated boundary of the target treatment area. If the sampling at the proposed new wells indicates a wider area of groundwater contamination than currently estimated, the target treatment area will be expanded and lactate injections will be conducted in more of the remaining wells at the site.

6.2.2.3 Monitoring Well Design

New monitoring wells E723GW002, E723GW003 and E723GW02D will be installed approximately 10 to 12 feet upgradient of wells E723GW001, E563GW004 and E563GW04D, respectively. Additional shallow and deep well pairs E723GW004/E723GW04D and E723GW005/723GW05D will be installed as shown on Figure 3-1 to assist in delineating groundwater contamination in the shallow and deep zones of the shallow aquifer. The monitoring wells will be constructed of 2-inch PVC casing with 5 feet of 0.01-inch slotted well screen. The wells will be screened at the same interval as the existing shallow and deep wells at the site (from 3 to 13 ft bls for shallow well E563GW001 and from 18 to 28 ft bls for deep well E563GW04D).

All standard well installation requests and well construction methods will be followed, per SCDHEC requirements.

6.2.2.4 Substrate Selection

Because of its widespread success at many sites, lactate is the substrate selected to stimulate reductive dechlorination for this pilot test. Lactate is a naturally occurring organic compound often used in food as a preservative. There are no toxicity or health risks associated with lactate.

Injection of lactate into the aquifer stimulates the ERD process because as it ferments, it releases hydrogen gas, which is used as the electron donor by many bacteria, especially those involved in the anaerobic biodegradation of chlorinated solvents, such as Dehalococcoides. Lactate typically first degrades to pyruvate, releasing a molecule of hydrogen. Pyruvate then typically degrades to acetate, releasing another molecule of hydrogen. Thus, one molecule of lactate can provide two molecules of hydrogen, which then become available for dehalorepiring bacteria.

A solution of potassium lactate will be used for this pilot test. Potassium lactate is typically available as a 60 percent solution, shipped in standard 55-gallon drums.

6.2.2.5 Injection Process

Prior to injection, the potassium lactate solution will be diluted with tap water to an approximately 1 to 5 percent lactate solution. Approximately 200 gallons of this lactate solution will be pumped into the well. A small, low pressure pump will be used to deliver the lactate solution to the injection well. Following the lactate injection, approximately 20 gallons of clean water will be injected to flush the wells and push the lactate solution out into the aquifer.

Based on the observed downgradient effects of the injection, the volume of lactate injected during subsequent injections may be modified (increased upwards or downwards) to satisfy the biological demand observed in the aquifer.

6.3 Permitting

6.3.1 SCDHEC Well Installation Request

In accordance with R.61-79.265 Subpart F of the South Carolina Hazardous Waste Management Regulations and R.61-71 of the South Carolina Well Standards and Regulations, a request for the advancement of any additional monitoring wells or Geoprobe borings is required to be submitted to SCDHEC 2 weeks prior to the scheduled activity. The written request describes the purpose of the monitoring wells, injection wells and Geoprobe boring activities and consists of construction details, if required, as well as a map depicting the proposed locations.

6.3.2 SCDHEC Underground Injection Control Permit Application

An underground injection control (UIC) permit addendum to the original Zone A UIC permit (No. 538) will be prepared and submitted to SCDHEC for approval. The abbreviated addendum will include a description of the enhanced in situ anaerobic biodegradation technology, injection method, and site figure depicting the injection and monitoring well locations. Fieldwork consisting of substrate injection will be initiated after the UIC permit application is approved by SCDHEC.

6.3.3 Post-Injection Monitoring

Monitoring will be performed on a monthly basis starting after the initial injection event. After the first month, field parameters (DO, ORP, temperature, pH, conductance), VFAs, and TOC will be measured in both pilot test monitoring wells to assess the degree to which the aquifer quality is responding to the injection. After the second month and continuing on through the target 6-month monitoring period, these parameters, plus VOCs and additional parameters, will be analyzed. Table 4-2 provides the post-injection monitoring schedule.

CVOCs, TOC, and VFAs are key parameters that will be used to evaluate the effectiveness of the lactate injections. Dissolved gases will also be evaluated to assess dechlorination to ethene and ethane, the availability of hydrogen, and the presence of methane. The presence of methane demonstrates strong anaerobic conditions. The increase in biodegradation may stimulate bacteria growth, thereby increasing the dissolved iron, manganese, and sulfide in the groundwater. These parameters will be monitored during the period monitoring events, every other month, starting 2 months after the initial injection.

Secondary performance monitoring events for parameters that can be measured with field instruments will be completed monthly following the initial injection. In addition to the VFA results, trends in decreasing TOC and increasing ORP levels will be used to schedule additional lactate injections. DO and ORP results will also be used to evaluate the degree of reducing conditions achieved in the aquifer.

6.3.3.1 Groundwater Monitoring Procedures

Groundwater monitoring will be completed using a low-flow groundwater sampling technique to collect accurate field parameters (particularly DO and ORP) and less disturbed groundwater samples for the evaluation of dissolved gases. The intake of the low-flow pump will be placed in the middle of the screened interval and purging will continue until the basic groundwater parameters stabilize (pH, temperature, and specific conductance) or until the well has been purged for 30 minutes.

The groundwater analysis will follow the procedures found in the approved Comprehensive Sampling and Analysis Plan (CSAP) portion of the RFI Work Plan (EnSafe, Inc./Allen & Hoshall, 1994). The CSAP outlines all monitoring procedures to be performed during the interim measure to characterize the environmental setting, source, and releases of hazardous constituents. In addition, the CSAP includes the Quality Assurance Plan (QAP) and Data Management Plan (DMP) to verify that all information and data are valid and properly documented. Unless otherwise noted, the sampling strategy and procedures will be performed in accordance with the EPA Environmental Services Division *Standard Operating Procedures and Quality Assurance Manual* (ESDSOPQAM) (1996).

Section 7.0

7.0 References

CH2M-Jones. *RFI Report Addendum and CMS Work Plan, AOC 723, Zone E, Charleston Naval Complex, Revision ,1.* August 2004.

EnSafe Inc. *Zone E RFI Report, Revision 0, NAVBASE Charleston.* November 1997.

EnSafe/Allen & Hoshall. *Final RCRA Facility Assessment, Naval Base Charleston.* June 1995.

South Carolina Department of Health and Environmental Control, Final RCRA Part B Permit No. SC0 170 022 560.

U.S. Environmental Protection Agency (EPA). Draft Final OSWER Directive on Monitored Natural Attenuation. 1997.

U.S. Environmental Protection Agency (EPA). Soil Screening Guidance: Technical Background Document, EPA/540/R-95/128. July 1996.

Appendix A

CH2MHILL

PROJECT NUMBER	WELL NUMBER	
158814	E563GW04D	SHEET 1 OF 1

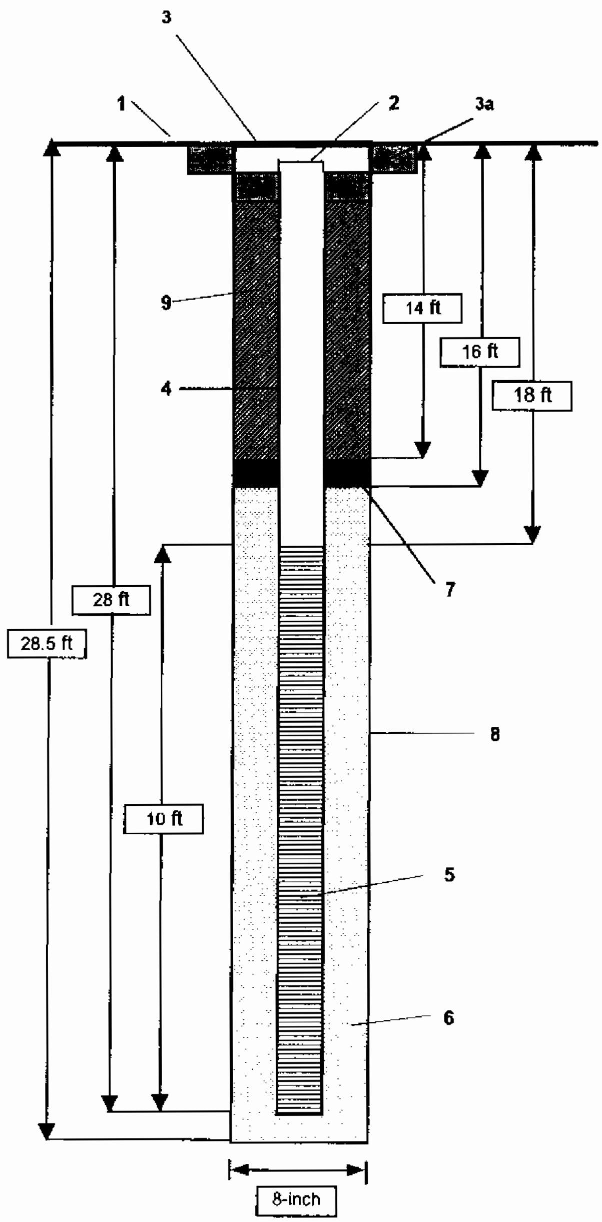
WELL COMPLETION DIAGRAM

PROJECT : AOC 563, ZONE E Charleston Naval Commplex — LOCATION : Charleston, South Carolina

DRILLING CONTRACTOR : Prosonic Corporation License # 14: (Richard Mooney-Driller) — NORTHING:

DRILLING METHOD AND EQUIPMENT USI Mobil Drill Rig/ 8-inch Hollow Stem Augers — EASTING:

WATER LEVELS : START : 11-12-02 END: 11-20-02 LOGGER : Andrew O'Conor



1- Ground elevation at well	
2- Top of casing elevation	
3- Protective cover type	8-ich dia. flush mount manhole vault
a) concrete pad dimensions	2 ft x 2 ft x 6-inches deep
4- Dia./type of well casing	2-inch inside diameter schedule 40 PVC
5- Type/slot size of screen	0.010-inch dia. machine slotted PVC
6- Type filter pack	20/30 Sieve Size Silica Sand
7- Type of seal	3/8-inch bentonite pellets
8- Borehole diameter	8-inch
9- Grout	Portland

Note: Diagram not to scale.

Appendix B

COMPARISON OF TOTAL COST OF REMEDIAL SOLUTIONS
Source Control Alternatives

Site: Charleston Naval Complex **Base Year:** 2004
Location: AOC 723
Phase: Corrective Measures Study Addendum

	Alternative Number 1 **Monitored Natural Attenuation**	Alternative Number 2 **Enhanced In-Situ Anaerobic Biodegradation**	
Total Project Duration (Years)	2	2	
Capital Cost	$57,700	$71,400	
Annual O&M Cost - Present Worth	$10,000	$32,000 $10,000	(Years 1 and 2) (Years3-8)
Total Present Worth of Alternative	$204,000	$183,000	

Disclaimer: The information in this cost estimate is based on the best available information regarding the anticipated scope of the remedial alternatives. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative.
This is an order-of-magnitude cost estimate that is expected to be within -30 to +50 percent of the actual project costs.

Alternative 1: **Monitoring/Natural Attenuation**

COST ESTIMATE SUMMARY

Site: Charleston Naval Complex

Description: Monitoring/natural attenuation of the surficial aquifer.

Location: AOC 723
Phase: Corrective Measures Study
Base Year: 2004
Date:

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Monitoring Well Installation	8	EA		$28,800	7 new monitoring wells installed
Monitoring/Natural Attenuation Work Plan					
Groundwater Contingency Plan					
Labor - Project Manager	6	HR	$125	$750	
Labor - Engineer/Hydrogeologist	24	HR	$90	$2,160	
Labor - Editor	8	HR	$65	$520	
Labor - CAD Technician	8	HR	$65	$520	
Monitoring/Natural Attenuation Groundwater Sample Collection Event	1	EA	$6,500	$6,500	Sample 6 Existing Monitoring Wells
SUBTOTAL				**$39,250**	
Land Use Controls	1	EA	$5,000	$5,000	
Project Management	5%	of	$39,250	$1,963	
Technical Support	5%	of	$39,250	$1,963	
Construction Management	0%	of	$39,250	$0	
Subcontractor General Requirements	5%	of	$39,250	$1,963	
SUBTOTAL				**$50,138**	
Contingency	15%	of	$50,138	$7,521	
TOTAL CAPITAL COST				**$57,700**	

OPERATIONS AND MAINTENANCE COST

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Annual Groundwater Sample Collection Event	1	EA	$6,500	$6,500	
Land Use Controls	1	EA	$1,100	$1,100	
Annual Report					
Labor - Project Manager	4	HR	$125	$500	
Labor - Engineer/Hydrogeologist	12	HR	$90	$1,080	
Labor - Editor	4	HR	$65	$260	
Labor - CAD Technician	4	HR	$65	$260	
SUBTOTAL				**$9,700**	
TOTAL ANNUAL O&M COST				**$10,000**	

Alternative 1: **Monitoring/Natural Attenuation** | **COST ESTIMATE SUMMARY** 1/9/2004

Site: Charleston Naval Complex

Description: Monitoring/natural attenuation of the surficial aquifer.

ocation: AOC 723
ase: Corrective Measures Study
Base Year: 2004
Date:

PRESENT VALUE ANALYSIS

Discount Rate = 3.2%

End Year	COST TYPE	TOTAL COST	TOTAL COST PER YEAR	TOTAL PRESENT WORTH	NOTES
1	FIRST YEAR CAPITAL COST	$57,700	$57,700	$57,700	
1 - 5	ANNUAL O&M COST (Year 1 - 5)	$10,000	$10,000	$146,061	Containment for 20 Years
6 - 20	ANNUAL O&M COST (Year 6 - 20)	$10,000	$10,000		Annual Sampling
				$203,761	
	TOTAL PRESENT WORTH OF ALTERNATIVE			**$204,000**	

SOURCE INFORMATION

1. United States Environmental Protection Agency. July 2000. A Guide to Preparing and Documenting Cost Estimates During the Feasibility Study. EPA 540-R-00-002. (USEPA, 2000).

Alternative 2: **Enhanced In Situ Anaerobic Biodegradation using $C_3H_5KO_3$** **COST ESTIMATE SUMMARY**

Site: Charleston Naval Complex
Location: AOC 723
Phase: Corrective Measures Study Addendum
Base Year: 2004

Description: Potassium lactate injection in the deep interval of the surficial aquifer.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Baseline Groundwater Sample Collection Event	1	EA	$16,200	$16,200	Sample 6 Proposed Monitoring Wells, 8 Injection Wells, and 4 Soil Samples
Monitoring Well Installation	1	EA	$28,800	$28,800	4 shallow and 3 deep Monitoring Wells
SUBTOTAL				**$45,000**	
Potassium Lactate Injection					Six injection events separated by 2 months Assume 230 gallons of 2% $C_3H_5KO_3$ injected solution in each well during each injection event. 6 drums @ 600 pounds of material per drum for both events
Potassium Lactate	3,000	LB	$1.20	$3,588	
Shipping - Potassium Lactate	1	LS	$700	$700	600 pounds per drum
Potassium Bromide Tracer Sodium Bicarbonate Buffer	1	LS	$500.00	$500	
Equipment					Two Injection Events One week each
$C_3H_5KO_3$ Mix System w/ 230 gal Tank	0	EA	$1,000	$0	
PPE	2	Event	$200	$400	
Generator	0	EA	$500	$0	
Decon Equipment/Waste Handling Materials	2	Event	$500	$1,000	
Steam Cleaner	0	EA	$1,200	$0	
Miscellaneous Materials/Supplies	2	Event	$500	$1,000	
SUBTOTAL				**$52,188**	
Project Management	5%	of	$52,188	$2,609	
Remedial Design	10%	of	$52,188	$5,219	
Construction Management	2%	of	$52,188	$1,044	
Subcontractor General Requirements	2%	of	$52,188	$1,044	
SUBTOTAL				**$62,104**	
Contingency	15%	of	$62,104	$9,316	
TOTAL CAPITAL COST				**$71,400**	

11/29/2004

Alternative 2: **Enhanced In Situ Anaerobic Biodegradation using $C_3H_5KO_3$** **COST ESTIMATE SUMMARY**

Site: Charleston Naval Complex
Location: AOC 723
Phase: Corrective Measures Study Addendum
Base Year: 2004

Description: Potassium lactate injection in the deep interval of the surficial aquifer.

OPERATIONS AND MAINTENANCE COST

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Performance Monitoring	1	EA	$20,300	$20,300	Annual Cost
Field (Secondary) Performance Monitoring Event	4	EA	$1,200	$4,800	Quarterly Sampling
Annual Report					
Labor - Project Manager	12	HR	$125	$1,500	
Labor - Engineer/Hydrogeologist	32	HR	$90	$2,880	
Labor - Editor	12	HR	$65	$780	
Labor - CAD Technician	24	HR	$65	$1,560	
SUBTOTAL				**$31,820**	
TOTAL ANNUAL O&M COST				**$32,000**	

PRESENT VALUE ANALYSIS

Discount Rate = 3.2%

End Year	COST TYPE	TOTAL COST	TOTAL COST PER YEAR	TOTAL PRESENT VALUE	NOTES
1	FIRST YEAR CAPITAL COST	$71,400	$71,400	$71,400	
1	ANNUAL O&M COST (Year 1)	$32,000	$32,000	$111,583	
2	ANNUAL O&M COST (Year 2)	$32,000	$32,000		Annual Sampling Event
				$182,983	
	TOTAL PRESENT WORTH OF ALTERNATIVE			**$183,000**	

SOURCE INFORMATION

Element: Land Use Controls
Alternatives: 1 and 2

COST ESTIMATE SUMMARY

Site: Charleston Naval Complex
Location: AOC 723
Phase: Corrective Measures Study
Base Year: 2004

Description: Implementation of base-wide land use management plan to put instituional controls in place to restrict site use to commercial/industrial.

Assumes this site is part of a multi-site implementation, and costs are shared among all the sites.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Deed Restrictions - Attorney	4	hour	$200	$800	
Record Deed	4	each	$500	$2,000	
LUC Implementation	24	hours	$75	$1,800	
SUBTOTAL				**$4,600**	
Project Management	10%		$4,600	$460	USEPA 2000, p. 5-13, <$100K
Remedial Design	0%		$0	$0	Not applicable.
Construction Management	0%		$460	$0	Not applicable.
SUBTOTAL				**$460**	
TOTAL CAPITAL COST				**$5,000**	

OPERATIONS AND MAINTENANCE COST

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Annual Evaluation	12	hour	$75	$900	
SUBTOTAL				$900	
Allowance for Misc. Items	20%		$900	$180	
SUBTOTAL				$1,080	
TOTAL ANNUAL O&M COST				**$1,100**	

SOURCE INFORMATION

1. United States Environmental Protection Agency. July 2000. A Guide to Preparing and Documenting Cost Estimates During the Feasibility Study. EPA 540-R-00-002. (USEPA, 2000).

Element: **Monitoring Well Installation**

Alternatives: **1 and 2**

Site: Charleston Naval Complex
Location: AOC 723
Phase: Corrective Measures Study Addendum
Base Year: 2004

WORK STATEMENT

Monitoring well installation to evaluate performance of corrective measure alternative

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Monitoring Well Installation - Rotasonic Drilling	150	LF	$28.75	$4,313	Prosonic historical price
Monitoring Well Screen and Riser Installation (2-inch, SCH 40 PVC, 0.02-inch slot)	150	LF	$34.50	$5,175	New Well Installation - 4 shallow and 3 deep wells
Mobilization/Demobilization	1	EA	$1,150	$1,150	Prosonic
Project Submittals	1	LS	$300	$300	Prosonic
Well Development Labor	7	HR	$143.75	$1,006	Prosonic
Decontamination - Drill Rig	7	EA	$173	$1,208	Prosonic
IDW Management	1	EA	$575	$575	Prosonic
Site Restoration	1	EA	$230	$230	Prosonic
55-Gallon Drum for Drill Cuttings	65	EA	$86	$5,606	7.33 cf/drum
55-Gallon Drums for Development H_2O	7	EA	$86	$604	Assumes 1 Drum/Well
Transport and Dispose Development Water	385	GAL	$0.30	$116	Assumes Non-Hazardous Waste
Dispose Well Cuttings	23	TON	$35	$794	Assumes Non-Hazardous Waste
Waste Characterization Well Cuttings	1	EA	$518	$518	TCLP - VOCs and Metals
Waste Characterization Well Development Water	1	EA	$1,300	$1,300	TCLP, Ignitability, Reactivity, Corrosivity
PPE and PID Rental	1	Week	$500	$500	
SUBTOTAL				**$23,393**	

Element: **Monitoring Well Installation**

Alternatives: **1 and 2**

Site: Charleston Naval Complex
Location: AOC 723
Phase: Corrective Measures Study Addendum
Base Year: 2004

WORK STATEMENT

Monitoring well installation to evaluate performance of corrective measure alternative

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Project Management	5%	of	$23,393	$1,170	
Technical Support	5%	of	$23,393	$1,170	
Construction Management	10%	of	$23,393	$2,339	
Subcontractor General Requirements	3%	of	$23,393	$702	
SUBTOTAL				**$28,773**	
TOTAL UNIT COST				**$28,800**	

OPERATIONS AND MAINTENANCE COST

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
TOTAL ANNUAL O&M COST				**$0**	

Source of Cost Data

1. Sources are as noted in cost table.

Element: **Sample Collection and Laboratory Costs - Monitoring/Natural Attenuation**
Alternatives: **1**

Site: Charleston Naval Complex	**Prepared By:**	**Checked By:**	
Location: AOC 723	**Date:**	**Date:**	
Phase: Corrective Measures Study			
Base Year: 2004			

WORK STATEMENT

Costs associated with annual sample collection, shipment and analysis for monitoring/natural attenuation alternative.
Eight wells included in assessment.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Equipment & Labor per Year					
					Various Laboratory Estimates 7 New Wells plus 3 Existing Wells, 3 Extra QA/QC Samples, Includes Data Validation
Sample Analyses					
VOCs (EPA 8260 - Level III)	13	SAMPLE	$132	$1,716	
Alkalinity	8	SAMPLE	$12	$96	
Ferrous Iron	8	SAMPLE	$20	$160	
Methane	8	SAMPLE	$120	$960	
DO, ORP, pH, Temperature and specific conductance	1	events	$0	$0	Labor and equipment costs included below
Sampling Supplies	1	EA	$200	$200	
Groundwater Sampling Equipment Rental	1	WK	$1,000	$1,000	Includes MultiRAE, Horiba Meter and Peristaltic Pump
Sample Shipment	1	EA	$200	$200	CH2M-Jones Estimate
Labor - Technicians	32	HR	$55	$1,760	2 hrs/well, 2 people
SUBTOTAL				**$6,092**	
Project Management	2%	of	$6,092	$122	
Technical Support	2%	of	$6,092	$122	
Construction Management	0%	of	$6,092	$0	
Subcontractor General Requirements	2%	of	$6,092	$122	
SUBTOTAL				**$6,458**	
TOTAL COST -ANNUAL EVENT				**$6,500**	

Source of Cost Data

1. Analytical Bid Form - Charleston Naval Complex - Level III

Element:	**Injection Well Installation**
Alternative:	**2**

Site:	Charleston Naval Complex
Location:	AOC 723
Phase:	Corrective Measures Study Addendum
Base Year:	2004

WORK STATEMENT

Injection well installation for electron donor delivery

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Injection Well Installation - Rotasonic Drilling	150	LF	$28.75	$4,313	Prosonic Injection - 7 Wells 4 at 15 ft, 3 @ 30 ft bls
Injection Well Screen and Riser Installation (2-inch, SCH 40 PVC, 0.02-inch slot)	150	LF	$34.50	$5,175	
Mobilization/Demobilization	1	EA	$1,150	$1,150	Prosonic
Project Submittals	0	LS	$288	$0	Prosonic
Well Development Labor	8	HR	$143.75	$1,150	Prosonic
Decontamination - Drill Rig	8	EA	$173	$1,380	Prosonic
IDW Management	1	EA	$575	$575	Prosonic
Site Restoration	0	EA	$230	$0	Prosonic
55-Gallon Drum for Drill Cuttings	43	EA	$86	$3,709	7.33 cf/drum
55-Gallon Drums for Development H_2O	8	EA	$86	$690	Assumes 1 Drum/Well
Transport and Dispose Development Water	440	GAL	$0.30	$132	Assumes Non-Hazardous Waste
Dispose Well Cuttings	15	TON	$35	$529	Assumes Non-Hazardous Waste
Waste Characterization Well Cuttings	0	EA	$518	$0	TCLP - VOCs and Metals
Waste Characterization Well Development Water	0	EA	$1,300	$0	TCLP, Ignitability, Reactivity, Corrosivity
PPE and PID Rental	1	Week	$500	$500	
SUBTOTAL				**$0**	

Element: **Injection Well Installation**

Alternative: **2**

Site: Charleston Naval Complex
Location: AOC 723
Phase: Corrective Measures Study Addendum
Base Year: 2004

WORK STATEMENT

Injection well installation for electron donor delivery

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Project Management	5%	of	$0	$0	
Technical Support	5%	of	$0	$0	
Construction Management	10%	of	$0	$0	
Subcontractor General Requirements	3%	of	$0	$0	
SUBTOTAL				**$0**	
TOTAL UNIT COST				**$0**	

OPERATIONS AND MAINTENANCE COST

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
TOTAL ANNUAL O&M COST				**$0**	

Source of Cost Data

1. Sources are as noted in cost table.

Element: Sample Collection and Laboratory Costs - Baseline Event
Alternatives: 2

Site: Charleston Naval Complex
Location: AOC 723
Phase: Corrective Measures Study
Base Year: 2004

WORK STATEMENT

Costs associated with soil and water sample collection, shipment and analysis to establish a baseline concentration for evaluation of anaerobic biodegradation performance.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Soil Analyses					
Dehalococcoides Ethenogenes	3	SAMPLE	$250	$750	Microbial Insights Est
Phospholipid Fatty Acids	3	SAMPLE	$250	$750	Microbial Insights Est
Total Organic Carbon	3	SAMPLE	$25	$75	
SUBTOTAL				$1,575	
Groundwater Analyses					
Sample Analysis					3 Existing Monitoring Wells 7 New Monitoring Wells
(VOCs - EPA 8260 - Level III)	13	SAMPLE	$132	$1,716	3 extra QA/QC samples
Iron II	10	SAMPLE	$20	$200	
Iron III (calculated)	10	SAMPLE	$0	$0	
Manganese	10	SAMPLE	$20	$200	
Sulfate	10	SAMPLE	$20	$200	
Sulfide	10	SAMPLE	$20	$200	
Total Organic Carbon	10	SAMPLE	$25	$250	
Alkalinity	10	SAMPLE	$15	$150	
Dehalococcoides Ethenogenes	3	SAMPLE	$250	$750	Microbial Insights Est
Phospholipid Fatty Acids	3	SAMPLE	$250	$750	Microbial Insights Est
SUBTOTAL				$4,416	
Equipment & Labor					
Sampling Supplies	1	EA	$500	$500	
Groundwater Sampling					Includes YSI 6500 and Bladder
Equipment Rental	1	WK	$500	$500	Pump
Sample Shipment	1	EA	$300	$300	CH2M HILL Estimate
Labor - Technicians	60	HR	$80	$4,800	3 hrs/well for 10 wells, 2 people
SUBTOTAL				$6,100	
Data Validation	14	HR	$100	$1,400	
Data Management	14	HR	$100	$1,400	
Project Management	10%	of	$4,416	$442	
Technical Support	10%	of	$4,416	$442	
Construction Management	0%	of	$4,416	$0	
Subcontractor General Requirements	10%	of	$4,416	$442	
SUBTOTAL				$4,125	
TOTAL UNIT COST - INITIAL YEAR OF MONITORING				$16,200	

OPERATION AND MAINTENANCE COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
SUBTOTAL				$0	
Contingency	20%		$0	$0	
SUBTOTAL				$0	
TOTAL O&M COST				$0	

Source of Cost Data

1. Analytical Bid Form - Charleston Naval Complex - Level III

Element: **Sample Collection and Laboratory Costs**
Alternatives: 1

Site:	Charleston Naval Complex	**Prepared By:**	**Checked By:**
Location:	AOC 723	**Date:**	**Date:**
Phase:	Corrective Measures Study		
Base Year:	2004		

WORK STATEMENT

POST-INJECTION SAMPLING
Costs associated with water sample collection, shipment and analysis on a per event and per well basis to evaluate enhanced anaerobic bioremediation performance.
Costs include various indicators during lactate injection period

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Equipment & Labor					
Sample Analysis					
(VOCs - EPA 8260 - Level II)	24	SAMPLE	$110	$2,640	6 Existing Wells, 4 events
Methane, Ethane, Ethene (MEE)	12	SAMPLE	$75	$900	For 3 injection wells for 4 events
Alkalinity	12	SAMPLE	$15	$180	For 3 injection wells for 4 events
Dissolved Iron	3	SAMPLE	$20	$60	For 3 injection wells for 1 events
Dissolved Manganese	3	SAMPLE	$20	$60	For 3 injection wells for 1 events
Total Organic Carbon	24	SAMPLE	$25	$600	For 6 injection wells for 4 events
DHE	3	SAMPLE	$350	$1,050	For 3 injection wells for 1 events
PLFAs	3	SAMPLE	$250	$750	For 3 injection wells for 1 events
Sampling Supplies	9	events	$200	$1,800	For 4 events
DO, ORP, pH, Temperature and specific conductance	4	events	$0	$0	Labor and equipment costs included below
Groundwater Sampling Equipment Rental	4	weekly events	$1,000	$4,000	Includes MultiRAE, Horiba Meter and Peristaltic Pump
Sample Shipment	9	LS	$200	$1,800	CH2M-Jones Estimate
Labor - Technicians	48	HR	$55	$2,640	2 hrs/well, 2 people; 3 wells
Labor - Site Superintendent	32	HR	$40	$1,280	
Labor - Field Engineer	32	HR	$30	$960	
Labor - Procurement Manager	8	HR	$30	$240	
SUBTOTAL				**$18,960**	
Project Management	3%	of	$18,960	$569	
Technical Support	3%	of	$18,960	$569	
Construction Management	0%	of	$18,960	$0	
Subcontract Procurement	1%	of	$18,960	$190	
SUBTOTAL				**$20,287**	
TOTAL UNIT COST - INITIAL YEAR OF MONITORING				**$20,300**	

Source of Cost Data

1. Analytical Bid Form - Charleston Naval Complex - Level III

Element: **Field Monitoring**
Alternatives: **1 and 2**

Site: Charleston Naval Complex
Location: AOC 723
Phase: Corrective Measures Study
Base Year: 2004

WORK STATEMENT

Costs associated with field monitoring on a per event basis to evaluate corrective measure alternative performance.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Equipment & Labor per Event					
Dissolved Oxygen	10	SAMPLE	$0	$0	
Temperature	10	SAMPLE	$0	$0	
pH	10	SAMPLE	$0	$0	10 Wells
Eh or ORP	10	SAMPLE	$0	$0	
Chemical Oxygen Demand	10	SAMPLE	$0	$0	
Conductivity	10	SAMPLE	$0	$0	
Groundwater Sampling Equipment Rental	1	DAY	$300	$300	Includes Field Testing Equipment
Sample Shipment	0	EA	$200	$0	CH2M-Jones Estimate
Labor - Technicians	16	HR	$55	$880	1 Day, 2 Technicians
SUBTOTAL				**$1,180**	
Project Management	0%	of	$1,180	$0	
Technical Support	0%	of	$1,180	$0	
Construction Management	0%	of	$1,180	$0	
Subcontractor General Requirements	0%	of	$1,180	$0	
SUBTOTAL				**$1,180**	
TOTAL UNIT COST				**$1,200**	

OPERATION AND MAINTENANCE COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
SUBTOTAL				$0	
Contingency	20%		$0	$0	
SUBTOTAL				$0	
TOTAL O&M COST				**$0**	

Source of Cost Data

Element: Present Worth Analysis
Alternative: Monitoring/Natural Attenuation

Site: Charleston Naval Complex
Location: AOC 723
Phase: Corrective Measures Study
Base Year: 2004

WORK STATEMENT

Calculation of alternative present worth. Assumes total present value earns interest for an entire year (12 months), compound annually.
Discount Rate 3.2%

Present Worth Analysis

Elapsed Time	Year	Discount Factor at 3.2%	Capital Cost	O&M Cost	Total Cost	Total PV Capital Costs at 3.2%	Total PV O&M Costs at 3.2%	Total PV Costs at 3.2%	Balance of Interest Bearing Account at 3.2%
0	2002	1.000	$ 57,700		$ 57,700	$ 57,700	$ -	$ 57,700	$ 150,735
1	2003	0.969		$ 10,000	$ 10,000	$ -	$ 9,690	$ 9,690	$ 140,735
2	2004	0.939		$ 10,000	$ 10,000	$ -	$ 9,389	$ 9,389	$ 130,735
3	2005	0.910		$ 10,000	$ 10,000	$ -	$ 9,098	$ 9,098	$ 120,735
4	2006	0.882		$ 10,000	$ 10,000	$ -	$ 8,816	$ 8,816	$ 110,735
5	2007	0.854		$ 10,000	$ 10,000	$ -	$ 8,543	$ 8,543	$ 100,735
6	2008	0.828		$ 10,000	$ 10,000	$ -	$ 8,278	$ 8,278	$ 90,735
7	2009	0.802		$ 10,000	$ 10,000	$ -	$ 8,021	$ 8,021	$ 80,735
8	2010	0.777		$ 10,000	$ 10,000	$ -	$ 7,773	$ 7,773	$ 70,735
9	2011	0.753		$ 10,000	$ 10,000	$ -	$ 7,532	$ 7,532	$ 60,735
10	2012	0.730		$ 10,000	$ 10,000	$ -	$ 7,298	$ 7,298	$ 50,735
11	2013	0.707		$ 10,000	$ 10,000	$ -	$ 7,072	$ 7,072	$ 40,735
12	2014	0.685		$ 10,000	$ 10,000	$ -	$ 6,852	$ 6,852	$ 30,735
13	2015	0.664		$ 10,000	$ 10,000	$ -	$ 6,640	$ 6,640	$ 20,735
14	2016	0.643		$ 10,000	$ 10,000	$ -	$ 6,434	$ 6,434	$ 10,735
15	2017	0.623		$ 10,000	$ 10,000	$ -	$ 6,235	$ 6,235	$ 735
16	2018	0.604		$ 10,000	$ 10,000	$ -	$ 6,041	$ 6,041	$ (9,265)
17	2019	0.585		$ 10,000	$ 10,000	$ -	$ 5,854	$ 5,854	$ (19,265)
18	2020	0.567		$ 10,000	$ 10,000	$ -	$ 5,672	$ 5,672	$ (29,265)
19	2021	0.550		$ 10,000	$ 10,000	$ -	$ 5,496	$ 5,496	$ (39,265)
20	2022	0.533		$ 10,000	$ 10,000	$ -	$ 5,326	$ 5,326	$ (49,265)
Total Alternative			$ 57,700	$ 200,000	$ 257,700	$ 57,700	$ 146,061	$ 203,761	

Element:	**Present Worth Analysis**
Alternative:	**Enhanced In Situ Anaerobic Biodegradation using $C_3H_5KO_3$**

Site: Charleston Naval Complex
Location: AOC 723
Phase: Corrective Measures Study
Base Year: 2004

Prepared By:
Date:

Checked By:
Date:

WORK STATEMENT

Calculation of alternative present worth. Assumes total present value earns interest for an entire year (12 months), compound annually.

Discount Rate 3.2%

Present Worth Analysis

Elapsed Time	Year	Discount Factor at 3.2%	Capital Cost	O&M Cost	Total Cost	Total PV Capital Costs at 3.2%	Total PV O&M Costs at 3.2%	Total PV Costs at 3.2%	Balance of Interest Bearing Account at 3.2%
0	2002	1.000	$ 71,400		$ 71,400	$ 71,400	$ -	$ 71,400	$ 115,154
1	2003	0.969		$ 32,000	$ 32,000	$ -	$ 31,008	$ 31,008	$ 83,154
2	2004	0.939		$ 32,000	$ 32,000	$ -	$ 30,046	$ 30,046	$ 51,154
3	2005	0.910		$ 10,000	$ 10,000	$ -	$ 9,098	$ 9,098	$ 41,154
4	2006	0.882		$ 10,000	$ 10,000	$ -	$ 8,816	$ 8,816	$ 31,154
5	2007	0.854		$ 10,000	$ 10,000	$ -	$ 8,543	$ 8,543	$ 21,154
6	2008	0.828		$ 10,000	$ 10,000	$ -	$ 8,278	$ 8,278	$ 11,154
7	2009	0.802		$ 10,000	$ 10,000	$ -	$ 8,021	$ 8,021	$ 1,154
8	2010	0.777		$ 10,000	$ 10,000	$ -	$ 7,773	$ 7,773	$ (8,846)
9	2011	0.753		$ -	$ -	$ -	$ -	$ -	$ (8,846)
10	2012	0.730		$ -	$ -	$ -	$ -	$ -	$ (8,846)
11	2013	0.707		$ -	$ -	$ -	$ -	$ -	$ (8,846)
12	2014	0.685		$ -	$ -	$ -	$ -	$ -	$ (8,846)
13	2015	0.664		$ -	$ -	$ -	$ -	$ -	$ (8,846)
14	2016	0.643		$ -	$ -	$ -	$ -	$ -	$ (8,846)
15	2017	0.623		$ -	$ -	$ -	$ -	$ -	$ (8,846)
16	2018	0.604		$ -	$ -	$ -	$ -	$ -	$ (8,846)
17	2019	0.585		$ -	$ -	$ -	$ -	$ -	$ (8,846)
18	2020	0.567		$ -	$ -	$ -	$ -	$ -	$ (8,846)
19	2021	0.550		$ -	$ -	$ -	$ -	$ -	$ (8,846)
20	2022	0.533		$ -	$ -	$ -	$ -	$ -	$ (8,846)
Total Alternative			$ 71,400	$ 124,000	$ 195,400	$ 71,400	$ 111,583	$ 182,983	