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Focused Feasibility Study Report

for

Operable Unit 3
Naval Air Warfare Center
(NAWC)

Warminster, Pennsylvania

Northern Division
Naval Facilities Engineering Command

Contract Number N62472-90-D-1298

Contract Task Order 0159

August 1994

Halliburton NUS
CORPORATION

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R-06-94-24

FOCUSED FEASIBILITY STUDY REPORT
FOR
OPERABLE UNIT 3
NAVAL AIR WARFARE CENTER (NAWC)
WARMINSTER, PENNSYLVANIA

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
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EXECUTIVE SUMMARY

This Focused Feasibility Study (FFS) for Operable Unit 3 (OU-3) at the Naval Air Warfare Center (NAWC) located in Warminster, Pennsylvania has been prepared for the Northern Division, Naval Facilities Engineering Command as authorized under Contract Task Order No. 0159 under Contract N62472-90-D-1298. This work is part of the Navy's Installation Restoration Program (IRP), which is designed to identify contamination of Navy and Marine Corps facilities resulting from past operations and to institute corrective measures, as needed. This report also serves to meet the requirements of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA).

PURPOSE

The purpose of this FFS is to present remedial alternatives for OU-3, which is defined as any groundwater in overburden and shallow bedrock that has been contaminated due to hazardous substance releases attributable to Area C at NAWC Warminster. The Remedial Investigation (RI) report for OU-3 at NAWC Warminster identifies the known nature and extent of contaminated groundwater attributable to Area C in overburden and shallow bedrock aquifers and identifies an unacceptable risk to human health associated with this groundwater. Based on information in the RI report, it has further been determined that a remedial alternative for OU-3 can be selected at this time. This FFS has been prepared as part of the final remedy selection process for OU-3.

REMEDIAL ACTION OBJECTIVES

Contaminated groundwater attributable to Area C in overburden and shallow bedrock aquifers, identified as OU-3, presents an unacceptable risk to human health (see baseline Risk Assessment discussion within the RI report). The general objective of the remedy for OU-3 is to eliminate unacceptable risk associated with exposure (or potential exposure) to groundwater contaminants attributable to Area C in overburden and shallow bedrock aquifers.

The available RI information provides an adequate basis for selecting a final remedy to meet the remedial objectives for OU-3. The remedial objectives for OU-3 are as follows:

- Minimize migration of contaminated groundwater attributable to Area C in overburden and shallow bedrock aquifers.

- Restore affected aquifers to the cleanup goals as required by Applicable or Relevant and Appropriate Requirements (ARARs).

A remedy with these objectives is considered to be a final remedy.

REMEDIAL ALTERNATIVES DEVELOPMENT

The FFS was prepared based on data obtained during previous investigations at NAWC Warminster, using EPA Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (October 1988), the revised National Oil and Hazardous Substances Pollution Contingency Plan (NCP of 1990), EPA Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites (December 1988), and the Navy/Marine Corps Installation Restoration Program (February 1992).

Based on the site problems and the remedial response objectives, general response actions and the associated technologies were identified. The technologies were screened for effectiveness, implementability, and relative cost. Remedial alternatives were assembled using the technologies that passed the screening. In addition, CERCLA and the NCP require that "No Action" be evaluated as a baseline alternative. The alternatives that were assembled are briefly described below:

- **Alternative 1: No Action with Groundwater Monitoring**. Under this alternative, no remedial action would be undertaken to address contaminated groundwater attributable to Area C in overburden and shallow bedrock aquifers. Monitoring of groundwater in overburden and shallow bedrock aquifers would be conducted for 30 years.

- **Alternative 2: Groundwater Extraction, Onsite Treatment at Area C, and Discharge to Surface Water in the Vicinity of Area C**. Under this alternative, contaminated groundwater in overburden and shallow bedrock aquifers would be extracted using a series of extraction wells. The extracted groundwater would be pumped to an onsite treatment system located within Area C. The treatment system is projected to include at a minimum line injection of hydrogen peroxide, filtration, and carbon adsorption. This approach would be effective in reducing the

toxicity, mobility, and volume of groundwater contaminants associated with Area C. Upon meeting effluent limits consistent with NPDES requirements, the treated water would be discharged to an unnamed intermittent tributary of Little Neshaminy Creek that drains north from Kirk Road.

- **Alternative 3: Groundwater Extraction, Onsite Treatment at Area C, and Discharge to Surface Water at Area A System Outfall**. Under this alternative, contaminated groundwater in overburden and shallow bedrock aquifers would be extracted using a series of extraction wells. The extracted groundwater would be pumped to an onsite treatment system located within Area C. The treatment system is projected to include at a minimum line injection of hydrogen peroxide, filtration, and carbon adsorption. This approach would be effective in reducing the toxicity, mobility, and volume of groundwater contaminants associated with Area C. Upon meeting effluent limits consistent with NPDES requirements, the treated water would be discharged to an unnamed tributary of Little Neshaminy Creek via the existing outfall along Bristol Road.

- **Alternative 4: Groundwater Extraction, Treatment at Area A, and Discharge to Surface Water at Area A System Outfall**. Under this alternative, contaminated groundwater in overburden and shallow bedrock aquifers would be extracted using a series of extraction wells. The extracted groundwater would be pumped to a treatment system located in Area A. Treatment would either be at the facilities to be constructed to address groundwater contamination at Areas A or B under the ongoing response action for OU-1, or by a separate treatment system located within Area A. The Area A/B treatment facility is part of a separate interim remedial action which is designed to accommodate a range of groundwater compositions. The facility will include filtration, precipitation, neutralization, air stripping, and activated carbon adsorption.

  The separate treatment system is projected to include at a minimum line injection of hydrogen peroxide, filtration, and carbon adsorption. Both approaches would be equally effective in reducing the toxicity, mobility, and volume of groundwater contaminants associated with Area C. Upon meeting effluent limits consistent with NPDES requirements, the treated water would be discharged to an unnamed tributary of Little Neshaminy Creek via the existing outfall along Bristol Road.

EVALUATION OF REMEDIAL ALTERNATIVES

The three remedial alternatives were evaluated using seven of the nine criteria specified in the NCP and EPA guidance document previously identified. These criteria include overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. The remaining two criteria, state acceptance and community acceptance, will be evaluated following comment on the RI/FFS reports and Proposed Plan for OU-3 and will be addressed in the Record of Decision (ROD) once a final action decision occurs.

The comparative analysis summarizing the evaluation of these criteria is included in Section 5.0.

The cost estimates for the remedial alternatives are as follows:

Alternative	Capital Cost	Annual Cost	Present Worth
1: No Action with Groundwater Monitoring	$69,696	$116,000	$1,853,000
2: Groundwater Extraction, Treatment At Area C, and Discharge to Surface Water in the Vicinity of Area C	$1,545,393	$229,629	$5,075,000
3: Groundwater Extraction, Treatment at Area C, and Discharge to Surface Water at Area A System Outfall	$1,839,690	$220,075	$5,224,000
4: Groundwater Extraction, Treatment at Area A, and Discharge to Surface Water at Area A System Outfall	$1,186,852 - $1,782,904	$244,444 - $214,729	$4,944,000 - $5,084,000

In view of the accuracy of the estimates provided herein, the costs for Alternatives 2 and 4 are essentially the same. Alternative 3 is slightly higher but still comparable, with respect to cost. Decisions with respect to the selection of an alternative should be based on other considerations, such as the need for potential future expansion which was not considered for Alternative 2 or 3, but is considered in Alternative 4, or the potential for more highly contaminated groundwater to be discovered at Area C, or the potential for Area C to be remediated more quickly than the 30-year period used for the cost analyses presented herein.

An integrated approach which reflects the needs of the entire site is preferable. Until the ongoing remedial investigation activities are complete, the precise alternative which best meets the needs of the site and the community cannot be identified.

1.0 INTRODUCTION

1.1 PURPOSE OF REPORT

In response to Contract Task Order No. 159 under Contract N62472-90-D-1298, Halliburton NUS Corporation is submitting this Focused Feasibility Study (FFS) report to address contaminated groundwater in overburden and shallow bedrock attributable to "Area C" of the Naval Air Warfare Center (NAWC) (formerly the Naval Air Development Center), located in Warminster, Pennsylvania. Figure 1-1 shows the general location of NAWC Warminster, while Figure 1-2 shows the location of Area C within the base. CTO 159 is part of the Comprehensive Long-Term Environmental Action Navy (CLEAN), Contract Number N62472-90-D-1298 which is part of the Navy's Installation Restoration Program (IRP). The IRP is designed to identify contamination of Navy and Marine Corps facilities resulting from past operations and to institute corrective measures as needed. CTO 159 is being administered by the Naval Facilities Engineering Command, Northern Division (NAVFAC). This report also serves to meet the requirements of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA).

IRP activities are typically performed in four distinct phases. The first phase consists of a Preliminary Assessment (PA) followed by the second phase which is a Site Inspection (SI). The third phase is a Remedial Investigation/Feasibility Study (RI/FS), which is intended to characterize physical and chemical parameters and risks associated with the facility. The fourth phase consists of Remedial Action designed to control and mitigate contamination. This report is prepared under Phase III IRP activities.

The purpose of this FFS is to present remedial alternatives for OU-3, which is defined as any groundwater in overburden and shallow bedrock aquifers that has been contaminated due to hazardous substance releases by NAWC Warminster in Area C. Area C includes Site 8, a former fire training area; Site 4, an inactive landfill; and the area bounded by Site 8, Site 4, the NAWC property line, and the main runway (see Figure 1-3). The Remedial Investigation (RI) report for OU-3 at NAWC Warminster (prepared by Halliburton NUS and issued concurrently with this document in August 1994) identifies the known nature and extent of contaminated groundwater in overburden and shallow bedrock aquifers at Area C and evaluates risks to human health associated with this groundwater. Based on information in the RI report, it has further been determined that a remedial alternative for OU-3 can be selected at this time. This FFS has been prepared as part of the remedy selection process for OU-3.

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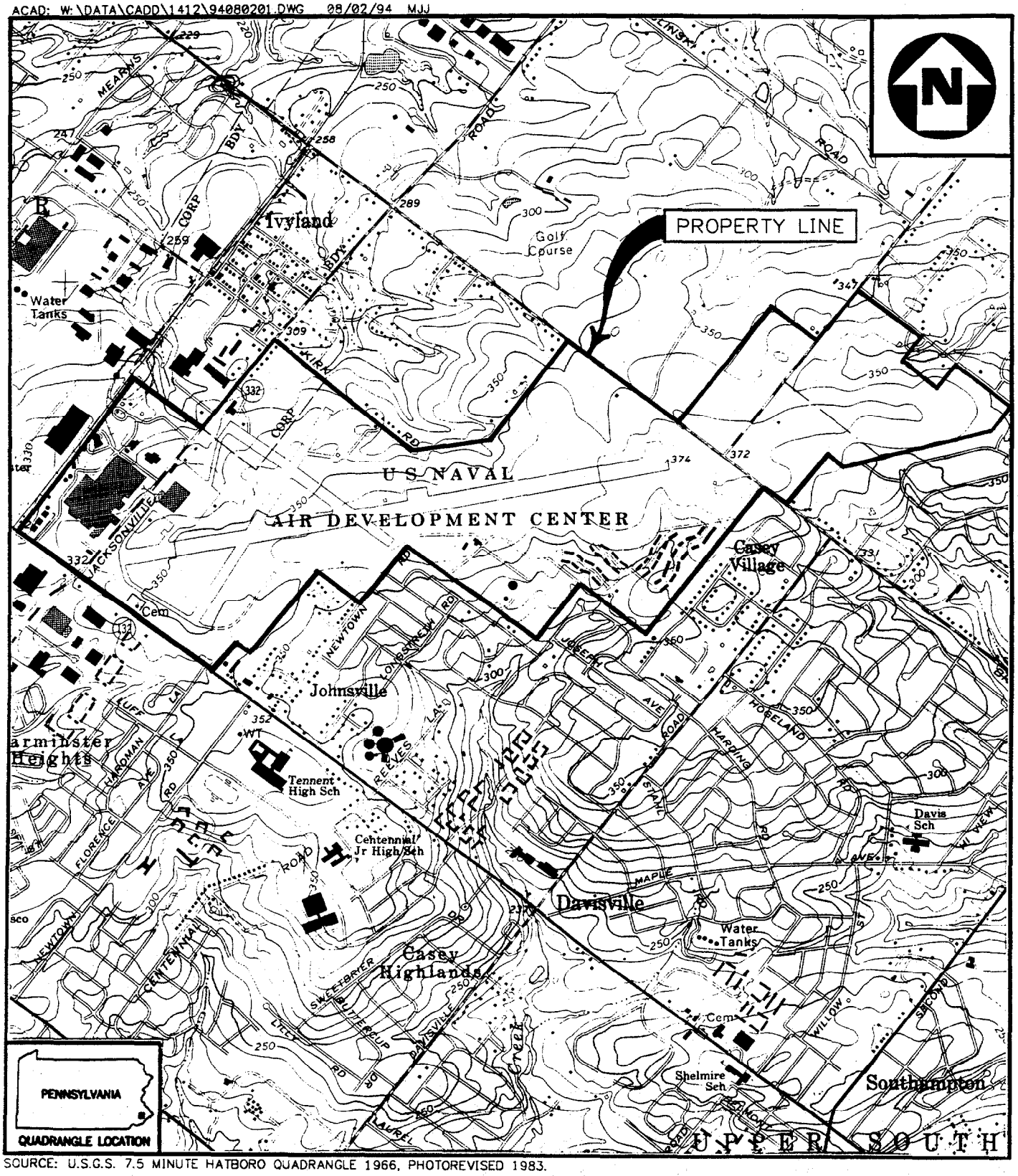

SOURCE: U.S.G.S. 7.5 MINUTE HATBORO QUADRANGLE 1966, PHOTOREVISED 1983.

SITE LOCATION MAP
NAWC WARMINSTER, PA

0 2000 4000
SCALE IN FEET

FIGURE 1-1

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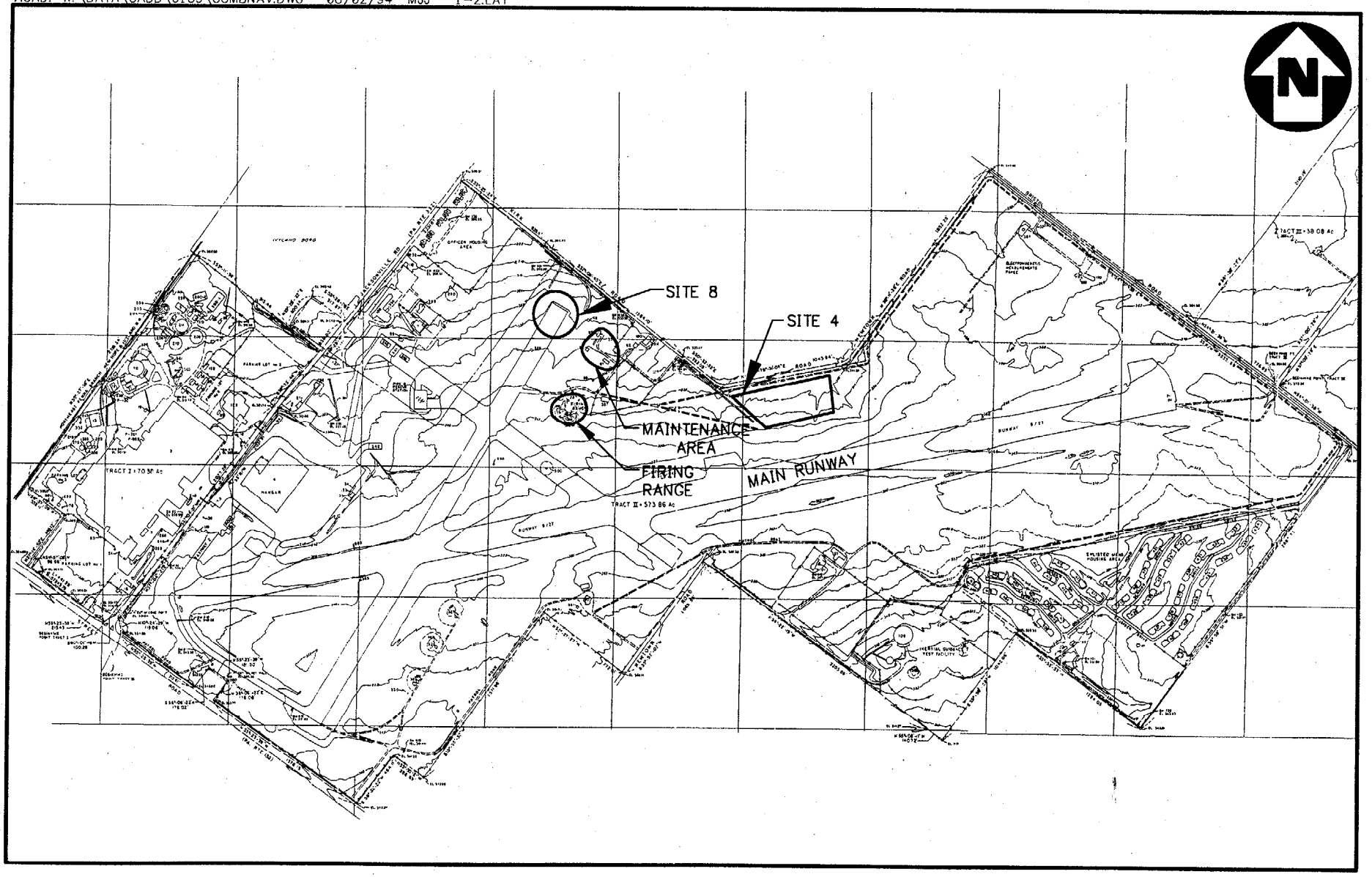

FIGURE 1-2

AREA C
GENERAL SITE LOCATION
NAWC WARMINSTER, PA
NOT TO SCALE

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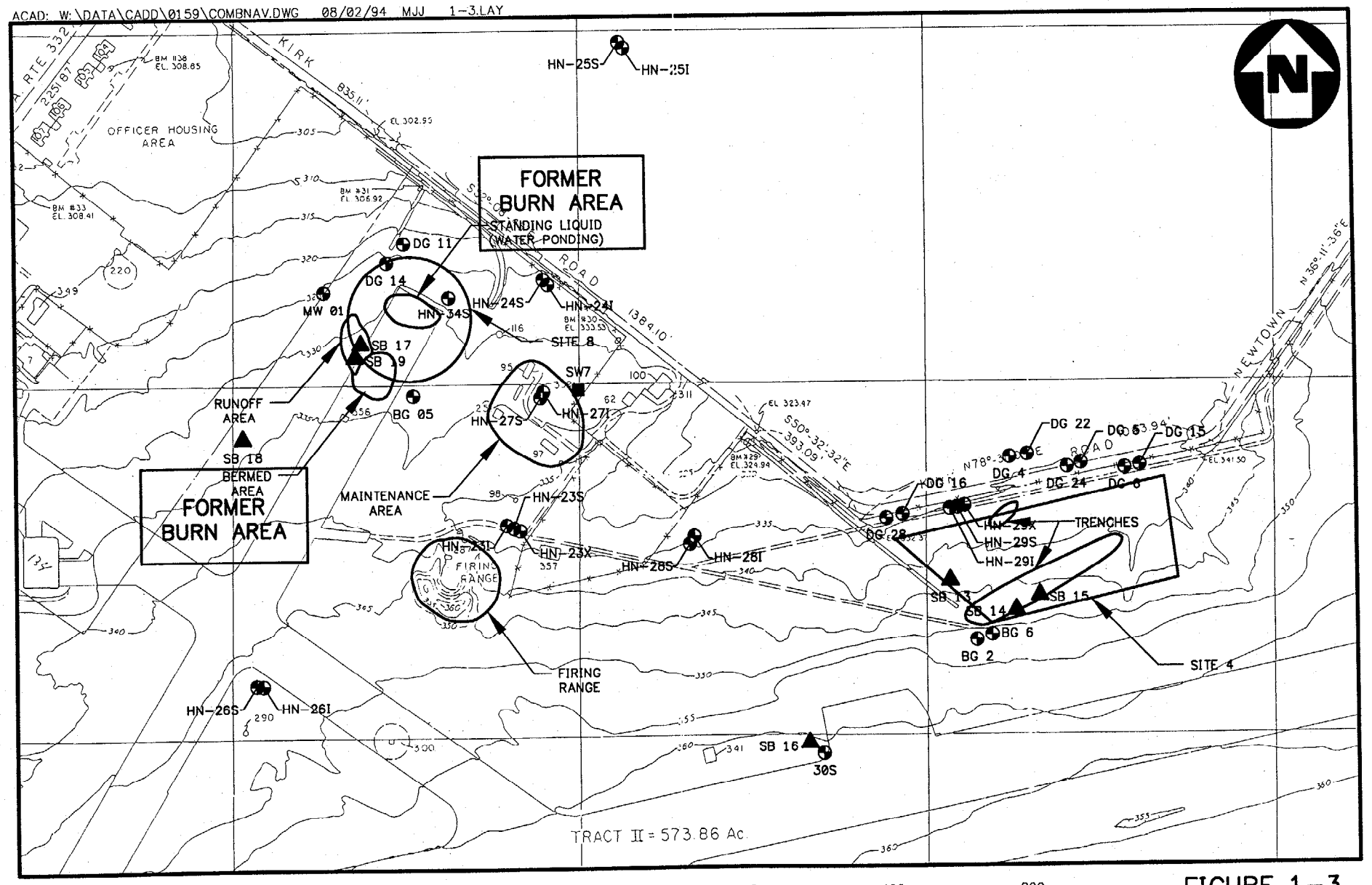

FIGURE 1-3

AREA C
(SITES 4, 8 AND MISCELLANOUS AREAS)
PRESENT/HISTORIC SITE FEATURES
NAWC WARMINSTER, PA

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feasibility studies for other areas (i.e., Area D) and for other media affected by the facility (including groundwater in deeper bedrock aquifers) will be performed upon completion of additional RI work. These feasibility studies will be performed to facilitate the selection of additional remedial actions necessary to protect human health and the environment.

1.2 ORGANIZATION OF REPORT

This report presents the remedial alternatives for groundwater contamination in overburden and shallow bedrock aquifers attributable to Area C at NAWC Warminster.

- Section 2.0 discusses remedial action objectives, Applicable or Relevant and Appropriate Requirements (ARARs) pertaining to groundwater at Area C, and the identification and screening of technologies.
- Section 3.0 presents the development of remedial alternatives.
- Section 4.0 presents the detailed analysis of each remedial alternative.
- Section 5.0 presents a comparative analysis of the remedial alternatives.
- Appendix A contains conceptual design calculations for remedial alternatives.
- Appendix B contains detailed cost estimates for remedial alternatives.

The RI report for OU-3 (Halliburton NUS, 1994) contains a description of the facility, regional and local hydrogeology, groundwater use, the known nature and extent of overburden and shallow bedrock groundwater contamination at Area C, and a risk assessment for this groundwater. The elements are part of the RI report and are not repeated here.

This FFS was prepared using EPA Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (OSWER Directive 9355.3-01, October 1988), the revised National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300, March 1990), EPA Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites (OSWER Directive 9283.1-2, December 1988), and the Navy/Marine Corps Installation Restoration Manual (February 1992).

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

2.1 INTRODUCTION

In this section, the following four actions of the Focused Feasibility Study (FFS) procedure are performed:

- Establish remedial action objectives (Section 2.3).
- Identify general response actions to meet remedial objectives, including no action (Section 2.4).
- Identify remedial technologies and process options under each general response action with emphasis on permanent solutions (Section 2.5).
- Screen remedial technologies and process options based on effectiveness and implementability considerations (Section 2.5).

2.2 BACKGROUND INFORMATION

Investigative work by Halliburton NUS at the Naval Air Warfare Center (NAWC) located in Warminster, Pennsylvania has identified a plume of tetrachloroethylene (commonly referred to as perchloroethylene or PCE) that appears to originate on NAWC property, and extends off of NAWC property. The plume exists within overburden and shallow bedrock underlying an area to the east of Site 8, a former fire training area, and to the north of an active maintenance area. Samples collected from monitoring and private wells in downgradient, off-base areas indicate that PCE contamination in shallow bedrock aquifers exists at least several hundred feet north of NAWC property.

PCE levels have been measured as high as 29 μg/L in groundwater samples collected on site and as high as 31 μg/L in groundwater samples collected off of NAWC property (see Figure 2-1). The Maximum Contaminant Level (MCL) that has been established for PCE is 5 μg/L. A risk assessment has been completed, and indicates that unacceptable risks are posed to current potential offsite residents by the PCE levels. Potential future residential exposure to groundwater may result in unacceptable risks due to PCE, antimony, arsenic beryllium, thallium and manganese. The arsenic, antimony, beryllium, and manganese concentrations in Area C appear to be background levels. The thallium was detected in only one of

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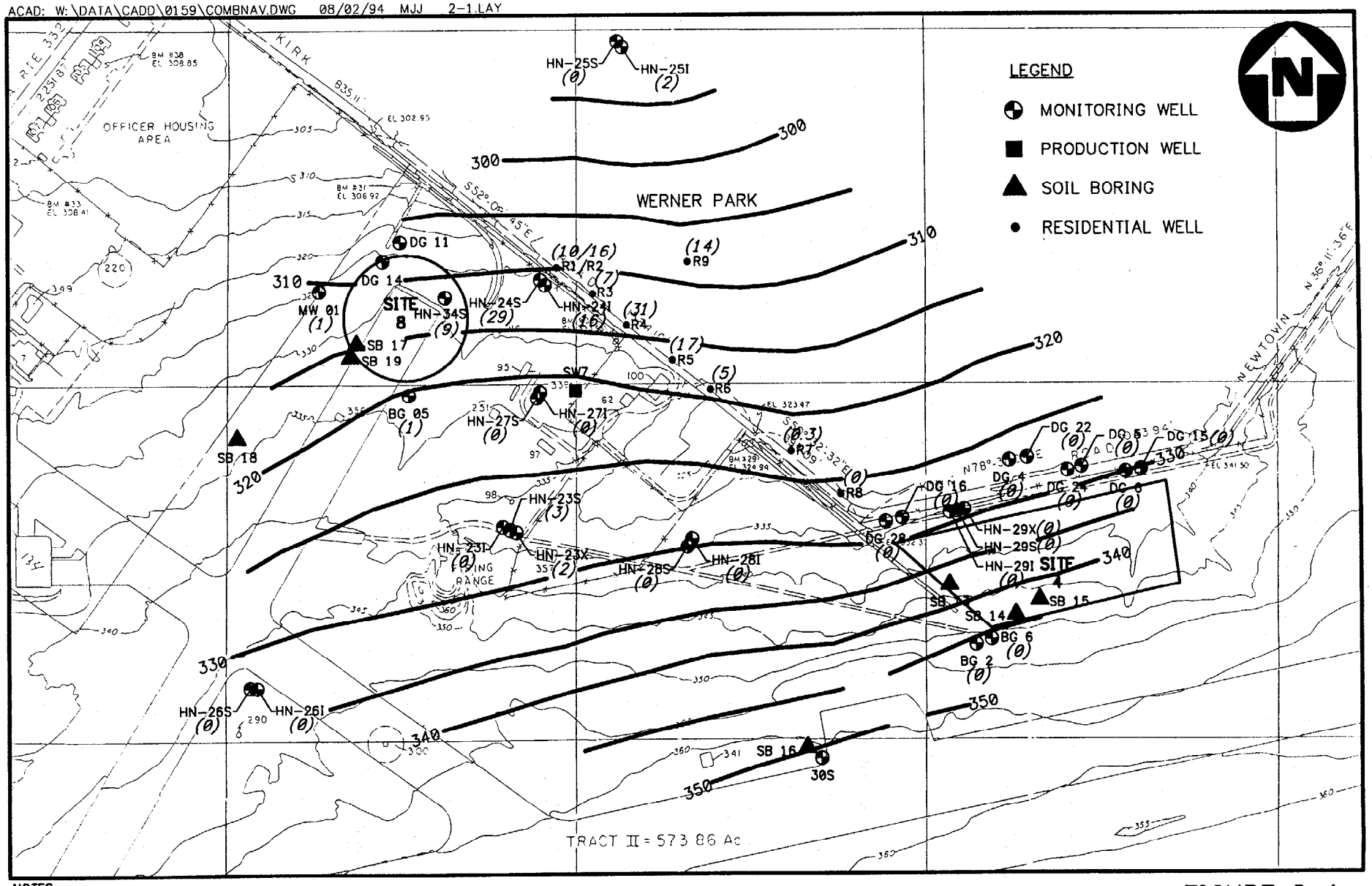

NOTES:

1. POTENTIOMETRIC SURFACE IS REPORTED IN FEET ABOVE MEAN SEA LEVEL
2. PCE CONCENTRATIONS ARE REPORTED IN µG/l.

0 400 800
SCALE IN FEET

FIGURE 2-1

AREA C
SHALLOW GROUNDWATER
PCE CONCENTRATIONS AND POTENTIOMETRIC SURFACE
NAWC WARMINSTER, PA

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34 sampling points and may not be site-related; however the data is inconclusive in this regard.

With respect to hydrogeology and lithology, Area C appears to be substantially similar to Area A, located to the south and east. Approximately 10 feet of overburden overlies alternating beds of sandstone, siltstone, and mudstone, which generally dip to the north-northwest. The bedrock changes gradationally from a highly weathered condition near the surface to unweathered, variably fractured strata. The hydrogeology and lithology is discussed in more detail in the OU-3 RI Report (Halliburton NUS, 1994).

A summary of selected analytical data that impacts treatment system design, as excerpted from the RI report, is included as Table 2-1. The sample point locations are shown in Figure 1-3.

2.3 REMEDIAL ACTION OBJECTIVES

Contaminated groundwater attributable to Area C in overburden and shallow bedrock aquifers, identified as OU-3, presents an unacceptable risk to human health (see baseline Risk Assessment discussion within the RI report). The general objective of the remedy for OU-3 is to eliminate unacceptable risk associated with exposure (or potential exposure) to groundwater contaminants attributable to Area C in overburden and shallow bedrock aquifers.

Based on information in the RI report, the nature and extent of contaminated groundwater in overburden and shallow bedrock aquifers attributable to Area C at NAWC Warminster is reasonably well defined. Consequently, the available RI information provides an adequate basis for selecting a remedial alternative to minimize the migration of NAWC Warminster-related contaminants in the overburden and shallow bedrock aquifers and to initiate restoration of affected aquifers.

The remedial objectives for OU-3 are therefore summarized as follows:

- Minimize migration of contaminated groundwater attributable to Area C at NAWC Warminster in overburden and shallow bedrock aquifers.

- Restore affected aquifers to the cleanup goals set in the Record of Decision (ROD) process.

A remedy with these objectives is considered an final remedy. Alternatives for this final remedy are developed in this FFS.

TABLE 2-1

GROUNDWATER MONITORING DATA 1994
AREA C
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

Well	pH S.U.	Spec. Cond. umho/cm²	Calcium		Iron		Magnesium		Manganese		Aluminum		Arsenic		Chromium		Mercury		PCE
			Total	Filtered	Total	Filtered	Total	Filtered	Total	Filtered	Total	Filtered	Total	Filtered	Total	Filtered	Total	Filtered	
BG-2	4.75	240	11,900	11,500	5,650	13,700	5,130	5,020	451	452	ND	372	ND	ND	ND	ND	ND	ND	ND
BG-5		210	15,000	13,800	107	ND	4,710	4,330	66.2	ND	121	ND	ND	ND	ND	ND	ND	ND	ND
BG-6	5.42	290	15,200	9,070	3,130	ND	5,450	2,790	89.9	27.4	8,370	ND	5.9	ND	ND	ND	0.17	0.33	ND
MW-01		240	20,100	20,000	1,040	ND	5,240	4,970	140	ND	668	ND	ND	ND	ND	ND	ND	ND	1
MW-02			19,900	19,700	864	ND	5,040	4,990	131	ND	481	ND	ND	ND	ND	ND	ND	ND	2
DG-4	8.17	380	27,000	28,300	35,200	18,200	6,820	7,150	1,030	1,060	366	ND	3.2	ND	ND	ND	0.13	ND	ND
DG-5	8.28	420	60,100	56,400	12,500	1,620	12,000	11,200	1,180	1.080	999	ND	3.2	ND	8	ND	ND	ND	ND
DG-6	5.14	540	56,300	58,600	17,300	11,500	8,980	9,330	547	553	639	ND	ND	ND	ND	ND	0.15	ND	ND
DG-14		220	16,900	ND	ND	4,980	4,850	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DG-15	4.93	560	67,700	64,000	ND	17.7	10,900	10,300	1,720	1,380	169	ND	3.1	ND	ND	ND	ND	ND	ND
DG-16	5.43	520	51,700	53,000	590	ND	16,800	17,200	20.2	3.5	383	ND	4.4	ND	ND	ND	ND	ND	ND
DG-22	8.08	420	50,700	49,400	ND	ND	12,200	12,000	106	27.6	79.2	ND	ND	ND	ND	ND	ND	ND	ND
DG-24	7.97	420	64,900	63,500	204	ND	9,500	9,390	165	61.5	171	ND	ND	ND	ND	ND	ND	ND	ND
DG-28	5.39	360	30,100	33,700	572	ND	10,600	11,900	81	1.4	453	ND	ND	ND	ND	ND	ND	ND	ND
HN23-S	7.03	300	28,300	26,700	ND	ND	7,620	7,220	13.6	1.6	171	ND	ND	ND	ND	ND	ND	ND	3
HN23-I	7.68	330	25,300	25,000	ND	9.1	15,600	15,600	ND	ND	104	ND	3.2	ND	ND	ND	ND	ND	ND
HN23-X	8.5	440	38,600	35,900	12,500	5.	19,900	15,800	651	446	11,600	ND	3.5	ND	13.4	ND	ND	ND	2
HN24-S	7.95	470	48,400	46,300	ND	ND	17,900	17,300	22.4	20.2	138	ND	4.1	ND	ND	ND	ND	ND	29
HN24-I	8.06	470	35,400	35,100	ND	557	12,100	12,000	15.2	25.7	ND	ND	5.2	5.4	ND	ND	ND	ND	16
HN24-X			36,400	35,000	513	ND	12,400	12,000	26.6	13.5	393	ND	7.1	5.4	ND	ND	ND	ND	16
HN25-S	8.08	360	35,900	30,200	3,150	ND	6,820	5,260	354	60.3	6,920	ND	5	ND	14	ND	0.22	ND	ND
HN25-I	7.8	340	38,700	35,200	1,090	ND	9,980	9,110	235	183	677	ND	ND	ND	ND	ND	0.2	ND	2
HN26-S		240	18,500	18,900	1,770	ND	6,980	6,850	266	57.6	2,100	ND	ND	ND	7.5	ND	ND	ND	ND

TABLE 2-1 (Continued)
GROUNDWATER MONITORING DATA 1994
AREA C
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

Well	pH S.U.	Spec. Cond. umho/cm^2	Calcium		Iron		Magnesium		Manganese		Aluminum		Arsenic		Chromium		Mercury		PCE
			Total	Filtered	Total	Filtered	Total	Filtered	Total	Filtered	Total	Filtered	Total	Filtered	Total	Filtered	Total	Filtered	
HN26-I		360	21,200	22,300	ND	ND	12,700	13,200	ND	ND	131	ND	ND	ND	ND	ND	ND	ND	ND
HN27-S		360	16,600	16,700	ND	ND	7,270	7,290	14.7	11.5	83.9	ND	ND	ND	ND	ND	ND	ND	ND
HN27-I		400	31,800	31,800	238	ND	13,300	13,100	85.2	68.1	189	ND	ND	ND	ND	ND	ND	ND	ND
HN28-S	4.96	380	23,200	22,100	1,400	44	10,200	9,520	46	18.4	2,340	ND	13.6	10.9	ND	ND	ND	ND	ND
HN28-I	5.34	440	35,600	33,000	576	263	12,900	12,100	719	653	60.2	ND	3.9	ND	ND	ND	ND	ND	ND
HN28-X			33,800	31,900	293	183	13,600	12,800	578	545	45.9	ND	ND	ND	ND	ND	ND	ND	ND
HN29-S	7.44	480	54,500	51,100	ND	ND	15,200	14,200	67.6	28.1	225	ND	3	ND	ND	ND	ND	ND	ND
HN29-I	8.62	370	33,500	32,800	276	175	13,500	13,200	575	563	ND	ND	3.5	ND	ND	ND	ND	ND	ND
HN29-X	8.03	540	43,500	41,900	15,400	26.8	33,700	28,000	1,840	12.3	20,900	ND	6.6	ND	15.5	ND	ND	ND	ND
HN34-S		390	39,900	35,000	337	ND	14,100	12,300	26.1	9.4	200	ND	ND	ND	ND	ND	ND	ND	ND
HN34-X			27,800	28,600	ND	ND	7,570	7,810	13.5	4.4	99.5	ND	5.4	3.7	ND	ND	ND	ND	ND
Sum	153	11,490	1,174,700	1,133,370	114,740	46,301	381,690	360,080	11,276	7,368	58,277	372.0	83.9	25.4	58.4	0.0	0.9	0.3	81
Average	7.0	383	34,550	33,334	3,375	1,362	11,226	10,591	332	217	1,714	10.9	2.5	0.7	1.7	0.0	0.0	0.0	2
Std. Dev.	1.4	96	14,929	14,584	7,199	4,170	5,581	4,889	471	360	4,155	62.9	3.0	2.2	4.3	0.0	0.1	0.1	6

Duplicate samples as follows:

MW-01/MW-02
HN23-S/HN34-X
HN28-X/HN29-I
HN24-I/HN24-X

Note: ND = not detectable
All units in μg/L unless otherwise noted.

2.3.1 Applicable or Relevant and Appropriate Requirements (ARARs)

Tables 2-2 and 2-3 present a summary of potential Federal and state ARARs for any remedial actions undertaken for OU-3 at NAWC Warminster.

The definition of ARARs is as follows:

- Any standard, requirement, criterion, or limitation under federal environmental law.

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

One of the primary concerns during the development of remedial action alternatives for hazardous waste sites under CERCLA or "Superfund" is the degree of human health and environmental protection afforded by a given remedy. Section 121 of CERCLA requires that primary consideration be given to remedial alternatives that attain or exceed ARARs. The purpose of this requirement is to make CERCLA response actions consistent with other pertinent Federal and state environmental requirements.

Definitions of the two types of ARARs, as well as other "to be considered" (TBC) criteria, are given below:

- Applicable Requirements means those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that directly and fully address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

- Relevant and Appropriate Requirements means those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law, while not "applicable," address problems or situations sufficiently similar (relevant) to those encountered at the CERCLA site, that their use is well suited (appropriate) to the particular site.

- "To Be Considered" (TBC) Criteria are non-promulgated, non-enforceable guidelines or criteria that may be useful for developing remedial action, or necessary for determining what is protective to human health and/or the environment. Examples of TBC criteria include EPA Drinking Water Health Advisories, Carcinogenic Potency Factors, and Reference Doses.

TABLE 2-2

POTENTIAL FEDERAL ARARs
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

Requirements	Rationale
CONTAMINANT-SPECIFIC	
Safe Drinking Water Act (42 USC 300) MCLs, SMCLs (40 CFR Part 143) and MCLGs (40 CFR Part 141)	Remedial actions may include groundwater cleanup to MCLs, MCLGs, and/or SMCLs
Clean Water Act (33 USC 1251-1376) Federal Ambient Water Quality Criteria (AWQCs) (40 CFR 131)	Remedial actions may result in surface water discharges that could impact aquatic life
Clean Air Act (42 USC 7401)	
National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50)	Remedial alternatives may result in emissions to the atmosphere
National Emission Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR 61.60-61.71)	Remedial alternatives may result in hazardous chemical emissions
New Source Performance Standards (NSPS) (40 CFR Part 60)	Remedial alternatives may result in emissions to the atmosphere
Air Emissions for Non-attainment Areas (OSWER Directive 9355.0-28)	Remedial alternatives may result in air emissions
Reference Doses (RfDs), EPA Office of Research and Development Cancer Slope Factors, EPA Environmental Criteria and Assessment Office, EPA Carcinogen Assessment Group Health Advisories, EPA Office of Drinking Water Health Effects Assessments	Considered in the human health risk assessment
Threshold Limit Values, American Conference of Governmental Industrial Hygienists	May be applicable to air concentrations during remedial activities
Identification and Listing of Hazardous Wastes (40 CFR Part 261)	Remedial alternatives may result in the generation of hazardous wastes
LOCATION-SPECIFIC	
Federal Protection of Wetlands Executive Order (E.O. 11990)	Wetland or floodplain resources may be affected by remedial action
Endangered Species Act of 1978 (16 USC 1531) (40 CFR 502)	Considered in the environmental assessment
Fish and Wildlife Coordination Act of 1980 (16 USC 661) Fish and Wildlife Conservation Act (16 USC 2901) Fish and Wildlife Improvement Act of 1978 (16 USC 742a)	Remedial alternatives may affect fish and wildlife habitat
Groundwater Protection Strategy (EPA, 1984)	Remedial alternatives may be determined by specific category
Executive Order on Floodplain Management (E.O. 11988)	Floodplain resources may be affected by remedial action

TABLE 2-2 (Continued)
POTENTIAL FEDERAL ARARs
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

Requirements	Rationale
ACTION-SPECIFIC	
Hazardous Waste Generator Requirements (40 CFR Part 262)	Standards applicable to generators of hazardous wastes that may be generated during remedial action
Hazardous Waste Transportation Requirements (40 CFR Part 263)	Remedial alternatives may require transportation of hazardous materials off site for treatment/disposal
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, or Disposal (TSD) Facilities (40 CFR Part 264) Interim Status Standards for Owners and Operators of Hazardous Waste or TSD Facilities (40 CFR Part 264)	Remedial alternatives may involve hazardous waste treatment, storage, and disposal facilities
Land Disposal Restrictions (40 CFR Part 268)	Standards for the land disposal of hazardous wastes
Criteria for Classification of Solid Waste Disposal Facilities and Practices (40 CFR Part 257)	Establishes criteria for use in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health and thereby constitute prohibited open dumps.
Department of Transportation (DOT) Rules for Hazard Materials Transport (49 CFR) Parts 107, 171-179)	Remedial alternatives may include transport of waste for offsite treatment and disposal
National Environmental Policy Act	Requires consideration of environmental effects due to Federal actions
Clean Water Act (40 CFR Part 122) National Pollutant Discharge Elimination System (NPDES)	Remedial actions may involve discharge to surface waters
Clean Air Act (42 USC 7401) NAAQS (40 CFR Parts 50 and 53), NESHAPs (40 CFR Part 61), and NSPS (40 CFR Part 60)	Treatment technologies for emissions to air (incineration, surface impoundments, waste piles, landfills, and sources of fugitive emissions)
Occupational Safety and Health Act (29 USC 651-678)	Regulates worker health and safety
Revised Procedures for Planning and Implementing Offsite Actions (OSWER Directive 9834.11)	Establishes procedures for offsite response actions

TABLE 2-3

POTENTIAL STATE ARARs
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

Requirements	Rationale
CONTAMINANT-SPECIFIC	
State Water Quality Standards (25 PA Code, Chapter 93)	Remedial actions may include discharge to surface waters
State Air Pollution Regulations (25 PA Code, Chapters 121-143)	Remedial actions may include technologies with atmospheric emissions
State Water Quality Toxics Management Strategy (25 PA Code, Chapter 16)	Remedial actions may include discharge to surface waters
State Safe Drinking Water Regulations (25 PA Code, Chapter 109)	State MCLs and treatment technologies
PADER Groundwater Protection Strategy (February 1992)	Remedial actions may need to address nondegradation of groundwater quality
LOCATION-SPECIFIC	
State Water Quality Standards (25 PA Code, Chapter 93.9)	Specific water uses that are protective of particular streams
ACTION-SPECIFIC	
State Hazardous Waste Management (25 PA Code, Article VII)	Remedial actions may include treating, storing, and disposing of hazardous wastes
State Solid Waste Disposal Regulations (25 PA Code, Chapter 75)	Remedial actions may include treating, storing, and disposing of solid wastes
State Pollutant Discharge Elimination System (NPDES) Rules 25 PA Code, Chapter 92)	Remedial actions may include discharge to surface waters
State Wastewater Treatment Requirements (25 PA Code, Chapter 95)	Remedial actions may include treatment and discharge to surface waters
State Industrial Waste Management Regulations (25 PA Code, Chapter 97)	Remedial actions may include treatment and discharge to surface waters
State Special Water Pollution Regulations (25 PA Code, Chapter 101)	Applicable for permitted solid waste disposal facilities
State Erosion Control Regulations (25 PA Code, Chapter 102)	Soil disturbance during proposed remedial actions may require erosion and sedimentation control measures
State Hazardous Substances Transportation Regulations PA Code Title 13 (Flammable Liquids and Flammable Solids) and Title 15 (Oxidizing Materials, Poisons, and Corrosive Liquids)	Applicable to wastes generated during a remedial action that would be shipped off site for analysis, treatment, or disposal
State General Provisions (25 PA Code, Chapter 91)	Standards for the reinjection of treated groundwater
State Construction, Modification, Reactivation and Operation of Sources Regulations (25 PA Code, Chapter 127)	Standards for the operation of air pollution controls at a potential source
State Stormwater Management Act (Act No. 167)	Requires measures to control stormwater runoff during remedial alternatives or development of land
State Hazardous Waste Regulations (25 PA Code, Chapter 264)	Establishes procedures to measure the background groundwater quality

Section 121(d)(4) of CERCLA allows the selection of a remedial alternative that will not attain all ARARs if any of six conditions for a waiver of ARARs exist. These conditions are as follows: (1) the remedial action is an interim measure whereby the final remedy will attain the ARAR upon completion; (2) compliance will result in greater risk to human health and the environment than other options; (3) compliance is technically impracticable; (4) an alternative remedial action will attain the equivalent of the ARAR; (5) for state requirements, the state has not consistently applied the requirement in similar circumstances; or (6) compliance with the ARAR will not provide a balance between protecting public health, welfare, and the environment at the facility with the availability of Fund money for response at other facilities (fund balancing).

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

- Contaminant Specific: Health-/risk-based numerical values or methodologies that establish concentration or discharge limits for particular contaminants. Examples of contaminant-specific ARARs include Maximum Contaminant Levels (MCLs) and Clean Water Act (CWA) water quality criteria. Contaminant-specific ARARs govern the extent of site cleanup.

- Location Specific: Restrictions based on the concentration of hazardous substances or the conduct of activities in specific locations. These may restrict or preclude certain remedial actions or may apply only to certain portions of site. Examples of location-specific ARARs include RCRA location requirements and floodplain management requirements. Location-specific ARARs pertain to special site features.

- Action Specific: Technology- or activity-based controls or restrictions on activities related to management of hazardous waste. Action-specific ARARs pertain to implementing a given remedy.

2.3.1.1 Contaminant-Specific ARARs and TBCs

This section presents a summary of Federal and state contaminant-specific ARARs and TBC criteria of potential concern in the case of OU-3. All ARARs and TBC criteria provide some medium-specific guidance on "acceptable" or "permissible" concentrations of contaminants. Table 2-4 contains regulatory requirements and dose response parameters for contaminants of concern at NAWC Warminster.

The Safe Drinking Water Act (SDWA) promulgated National Primary Drinking Water Standard Maximum Contaminant Levels (MCLs) (40 CFR Part 141). MCLs are enforceable standards for contaminants in public

TABLE 2-4

FEDERAL REGULATORY REQUIREMENTS AND DOSE RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN AT AREA C NAWC WARMINSTER BUCKS COUNTY, PENNSYLVANIA

Chemical	Safe Drinking Water Act[1][2][10] (mg/L)		Health Advisory[3] (mg/L)	Reference Dose[4][6][11] (mg/kg/day)		Cancer Slope Factor[4][5][11] $(mg/kg/day)^{-1}$		Weight of Evidence [4][11][15]	Ambient Water Quality Criteria[6] (mg/L)	
	MCL	MCLG		Oral	Inhalation	Oral	Inhalation		Water & Fish	Fish Only
Tetrachloroethene	0.005	0	1-Day/Child: 2.0 10-Day/Child: 2.0 Longer-Term/Child: 1.0 Longer-Term/Adult: 5.0	1×10^{-2}	NA	[14] 5.1×10^{-2}	[14] 1.8×10^{-3}	[14] B2	0.0008	0.00885
Acetone	NA	NA	NA	1×10^{-1}	NA	NA	NA	D	NA	NA
Toluene	1.0	1.0	1-Day/Child: 20.0 10-Day/Child: 2.0 Longer-Term/Child: 2.0 Longer-Term/Adult: 7.0 Lifetime: 1.0	2×10^{-1}	1×10^{-1}	NA	NA	D	14.3	424
Diethylphthalate	NA	NA	Lifetime: 5.0	8×10^{-1}	NA	NA	NA	D	350	1,800
Di-n-butyl phthalate	NA	NA	NA	1×10^{-1}	NA	NA	NA	D	NA	NA
Endosulfan II	NA	NA	NA	5×10^{-5}	NA	NA	NA	D	NA	NA
Antimony	0.006	0.006	1-Day/Child: 0.01 10-Day/Child: 0.01 Longer-Term/Child: 0.01 Longer-Term/Adult: 0.015 Lifetime: 0.003	4×10^{-4}	NA	NA	NA	D	0.146	45
Arsenic	0.05	NA	NA	3×10^{-4}	NA	1.75×10^{0}	5.0×10^{1}	A	0.0000022	0.000018

TABLE 2-4 (Continued)
FEDERAL REGULATORY REQUIREMENTS AND DOSE RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN AT AREA C
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

Chemical	*Safe Drinking Water Act*[1][2][10] (mg/L)		Health Advisory[3] (mg/L)	Reference Dose[4][6][11] (mg/kg/day)		Cancer Slope Factor[4][5][11] $(mg/kg/day)^{-1}$		Weight of Evidence[4][11][15]	Ambient Water Quality Criteria[6] (mg/L)	
	MCL	MCLG		Oral	Inhalation	Oral	Inhalation		Water & Fish	Fish Only
Barium	2.0	2.0	Lifetime: 2.0	7×10^{-2}	1.4×10^{-4}	NA	NA	NA	NA	NA
Beryllium	0.004	0.004	1-Day/Child: 30 10-Day/Child: 30 Longer-Term/Child: 4 Longer-Term/Adult: 20	5×10^{-3}	NA	4.3	8.4	B2	0.0000068	0.000117
Cadmium	0.005	0.005	1-Day/Child: 0.04 10-Day/Child: 0.04 Longer-Term/Child: 0.005 Longer-Term/Adult: 0.02 Lifetime: 0.005	5×10^{-4}	NA	NA	6.1×10^{0}	B1	0.010	NA
Chromium (*total*)	0.1	0.1	1-Day/Child: 1.0 10-Day/Child: 1.0 Longer-Term/Child: 0.2 Longer-Term/Adult: 0.8 Lifetime: 0.1	1×10^{-0}(tri) 5×10^{-3} (hex)	NA	NA	4×10^{1} (hex)	D (tri) A (hex, inhalation)	hex (0.050) *Tri* (170)	hex (NA) *Tri* (3,433)
Cobalt	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copper	1.3	1.3	NA	NA	NA	NA	NA	D	1.3	NA
Lead	0.015[8]	0	NA	NA	NA	NA	NA	B2	0.050	NA
Manganese	NA	NA	NA	Food: 1.04×10^{-1} Water: 5.0×10^{-3}	1.1×10^{-4}	NA	NA	D	0.050	0.100

TABLE 2-4 (Continued)
FEDERAL REGULATORY REQUIREMENTS AND DOSE RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN AT AREA C
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

Chemical	Safe Drinking Water Act[1][2][10] (mg/L)		Health Advisory[3] (mg/L)	Reference Dose[4][6][11] (mg/kg/day)		Cancer Slope Factor[4][5][11] $(mg/kg/day)^{-1}$		Weight of Evidence[4][11][15]	Ambient Water Quality Criteria[6] (mg/L)	
	MCL	MCLG		Oral	Inhalation	Oral	Inhalation		Water & Fish	Fish Only
Mercury	0.002	0.002	Longer-Term/Adult: 0.002 Lifetime: 0.002	3×10^{-4}	8.6×10^{-5}	NA	NA	D	1.4×10^{-4}	1.5×10^{-4}
Thallium	0.002	0.000 5	1-Day/Child: 0.007 10-Day/Child: 0.007 Longer-Term/Child: 0.007 Longer-Term/Adult: 0.02 Lifetime: 0.0004	7.0×10^{-5}	NA	NA	NA	D	0.013	0.048
Vanadium	NA	NA	NA	7×10^{-3}	NA	NA	NA	NA	NA	NA
Zinc	5.0[13]	NA	1-Day/Child: 6 10-Day/Child: 6 Longer-Term/Child: 3 Longer-Term/Adult: 12 Lifetime: 2	3×10^{-1}	NA	NA	NA	D	NA	NA

* Proposed
NA Not Available

(1) Safe Drinking Water Act, 40 CFR 141/142/143.
(2) EPA, 1990a.
(3) EPA, 1992a.
(4) IRIS February, 1993.
(5) EPA, 1992b
(6) EPA, 1990b. Based on protection of human health.
(7) Calculated from LD_{LO}.
(8) Action level, EPA, 1991b.
(9) RfD has been revoked pending review of carcinogenicity.
(10) EPA, 1991a.
(11) Heast, 1992 Annual
(12) Memorandum on Carcinogenicity of Benzo(a)pyrene and PAHs, Pei-Fing Hurst, March 22, 1991
(13) Secondary MCL
(14) Heast, 1991 Annual
(15) IRIS, April 1994

drinking water supply systems. They consider not only health factors but also the economic and technical feasibility of removing a contaminant from a water supply system. Secondary MCLs (SMCLs) (40 CFR Part 143) are not enforceable but are intended as guidelines for contaminants that may adversely affect the aesthetic quality of drinking water, such as taste, odor, color, and appearance, and may deter public acceptance of drinking water provided by public water systems.

The SDWA also established Maximum Contaminant Level Goals (MCLGs) for several organic and inorganic compounds in drinking water. MCLGs are set at levels of no known or anticipated adverse health effects, with an adequate margin of safety. The NCP [40 CFR Part 300.430(e)(2)(i)] states that MCLGs that are set at levels above zero shall be attained by remedial actions for groundwaters or surface waters that are current or potential sources of drinking water (where the MCLGs are relevant and appropriate under the circumstances of the release based on the factors in Section 300.400(g)(2) of the NCP). If an MCLG is found not to be relevant and appropriate, the corresponding MCL shall be achieved where relevant and appropriate to the circumstances of the release. For MCLGs that are set at zero, the MCL promulgated for that contaminant under the SDWA shall be attained by the remedial actions. In cases involving multiple contaminants or pathways where attainment of chemical-specific ARARs will result in a cumulative cancer risk in excess of 10^{-4}, criteria in paragraph (e)(2)(i)(A) of Section 300.430 (i.e., risk-based criteria) may be considered when determining the cleanup level to be attained. The NCP explains that cleanup levels set at zero (generally the case for carcinogens) are not appropriate because CERCLA does not require complete elimination of risk and because "true zero" cannot be detected.

SDWA requirements may be relevant and appropriate to remedial actions involving groundwater. Table 2-4 contains available Federal SDWA standards for the elements/compounds of concern identified during the previous studies conducted at NAWC Warminster.

EPA Health Advisories are nonenforceable guidelines (TBCs) developed by the EPA Office of Drinking Water for chemicals that may be intermittently encountered in public water supply systems. Health advisories are available for short-term, longer-term, and lifetime exposures for a 10-kg child and/or a 70-kg adult. Health advisories may be pertinent for remedial actions involving groundwater, especially for contaminants that are not regulated under the SDWA.

The Clean Water Act (CWA) sets EPA Ambient Water Quality Criteria (AWQCs) that are non-enforceable guidelines developed for pollutants in surface waters pursuant to Section 304(a)(1) of the Clean Water Act. Although AWQCs are not legally enforceable, they have been used by many states to develop enforceable water quality standards; they should be considered as potential ARARs, as specified by CERCLA. AWQCs are available for the protection of human health from exposure to contaminants in drinking water as well as

from ingestion of aquatic biota and for the protection of freshwater and saltwater aquatic life. AWQCs may be considered for actions that involve groundwater treatment and/or discharge to nearby surface waters.

Reference Dose (RfD), as defined in the EPA Integrated Risk Information System (IRIS), is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs are developed for chronic and/or subchronic human exposure to hazardous chemicals and are based on the assumption that thresholds exist for certain toxic effects. The RfD is usually expressed as an acceptable dose (mg) per unit body weight (kg) per unit time (day). The RfD is derived by dividing the no-observed-adverse effect level (NOAEL) or the lowest-observed-adverse effect level (LOAEL) by an uncertainty factor (UF) times a modifying factor (MF). The use of uncertainty factors and modifying factors is discussed in the EPA, Office of Research and Development (ORD) Health Effects Assessment Summary Tables, Fourth Quarter FY1989 [October 1989-ORD(RD-689)] (EPA, 1989a). RfDs are TBCs for NAWC Warminster.

Cancer Slope Factors (CSFs) are used for estimating the lifetime probability (assumed 70-year lifespan) of human receptors contracting cancer as a result of exposure to known or suspected carcinogens. These factors are generally reported in units of kg-day/mg and are derived through an assumed low dosage linear relationship and an extrapolation from high to low dose responses determined from human or animal studies. Cancer risk and CSFs are most commonly estimated through the use of a linearized multistage mathematical extrapolation model applied to animal bioassay results. The value used in reporting the slope factor is the upper 95 percent confidence limit. CSFs are TBCs for NAWC Warminster.

The Clean Air Act (CAA) (42 USC 7401) consists of three programs or requirements that may be ARARs: National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50), National Emission Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR Part 61), and New Source Performance Standards (NSPS) (40 CFR Part 60). NESHAPs, which are emission standards for source types (i.e., industrial categories) that emit hazardous air pollutants, are not likely to be applicable or relevant and appropriate for NAWC Warminster because they were developed for a specific source.

EPA requires the attainment and maintenance of primary and secondary NAAQS, shown in Table 2-5, to protect public health and public welfare, respectively. These standards are not source specific but rather are national limitations on ambient air quality. States are responsible for assuring compliance with the NAAQS. Requirements in an EPA-approved State Implementation Plan (SIP) for the implementation, maintenance, and enforcement of NAAQS are potential ARARs.

TABLE 2-5

CLEAN AIR ACT - NATIONAL AMBIENT AIR QUALITY STANDARDS
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

Parameter	Primary Standard ($\mu g/m^3$)	Secondary Standard ($\mu g/m^3$)
Carbon monoxide	10,000 (8-hour)[1] 40,000 (1-hour)[1]	NA
Lead	1.5 (90-day)[2]	1.5 (90-day)[2]
Nitrogen oxides	100 (1-year)[3]	100 (1-year)[3]
Ozone	235 (1-hour)[1]	235 (1-hour)[1]
Particulate matter (expressed as PM-10)	150 (24-hour)[1] 50 (1-year)[3]	150 (24-hour)[1] 50 (1-year)[3]
Sulfur Dioxide	365 (24-hour)[1] 80 (1-year)[3]	1,300 (3-hour)[1]

Primary: Protection of public health
Secondary: Protection of public welfare

(1) Maximum concentration not to be exceeded more than once per year
(2) Maximum arithmetic mean averaged over a calendar quarter
(3) Annual arithmetic mean

NSPS are established for new sources of air emissions to ensure that the new stationary sources minimize emissions. These standards are for categories of stationary sources that cause or contribute to air pollution that may endanger public health or welfare. Standards are based upon the best demonstrated technology (BDT). NSPS are generally not applicable to CERCLA remedial actions but may be relevant and appropriate to NAWC Warminster if the pollutant(s) emitted (e.g., from an air stripping tower) and the technology employed during the cleanup action are sufficiently similar to the pollutant and source category regulated by an NSPS and are well suited to the circumstances at the site.

Hazardous Waste Identification and Listing Regulations (40 CFR Part 261) defines those solid wastes which are subject to regulation as hazardous waste under 40 CFR Parts 262 to 265 and Parts 124, 270, and 271.

OSWER Directive 9355.0-28 is a TBC that guides the control of air emissions from air strippers at Superfund groundwater remediation sites. For sites located in areas that are not attaining the NAAQS for ozone, add-on emission controls are required for an air stripper with an actual emission rate in excess of 3 pounds per hour or 15 pounds per day, or a potential (i.e., calculated) rate of 10 tons per year of total volatile organic compounds. This TBC may be relevant and appropriate in meeting risk management guidelines because NAWC Warminster is located in an area that is not attaining the NAAQS for ozone.

Pennsylvania Safe Drinking Water Regulations (PA Code, Title, 25 Chapter 109) sets forth drinking water quality standards at least as stringent as the National Primary Drinking Water Regulations. MCLs that are promulgated by the EPA are automatically incorporated into the Pennsylvania SDWA. If an MCL does not exist for a contaminant, the Pennsylvania SDWA require the maximum allowable concentration to be determined in the following order: (1) the concentration that EPA has proposed to set or is considering setting as a primary MCL for the contaminant; (2) the concentration associated with a lifetime cancer risk of 10^{-6} for carcinogenic contaminants or the lifetime drinking water health advisory concentration for noncarcinogenic contaminants, provided that this concentration is equal to or greater than the practical quantitation level and the level achievable through the use of available treatment technology; or (3) the lowest concentration achievable considering the practical quantitation level and available treatment technology.

Pennsylvania Water Quality Toxics Management Strategy (PA Code, Title 25, Chapter 16) is the water quality toxics management strategy and contains water quality criteria for toxics. Values for elements/compounds are shown in Table 2-6.

Pennsylvania Water Quality Standards (PA Code, Title 25, Chapter 93) set forth state water quality standards. The standards are based upon water uses that are to be protected and will be considered by the

TABLE 2-6

PENNSYLVANIA WATER QUALITY STANDARDS AND AMBIENT WATER QUALITY CRITERIA
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

Parameter	Water Quality Standard[1]	Ambient Water Quality Criteria for Protection of Aquatic Life[2] (μg/L)		Ambient Water Quality Criteria for Protection of Human Health[2] (μg/L)
		Continuous Concentration	Maximum Concentration	
Antimony	NP	0.056	0.11	10
Arsenic	NP	190	360	0.02
Barium	NP	NP	NP	NP
Beryllium	NP	219	1,095	NA
Cadmium	NP	1.3[3]	4.6[3]	10
Chromium (Total)	NP	243[3]	1,963[3]	170,050
Cobalt	NP	NP	NP	NP
Copper	NP	13[3]	20[3]	1,000
Iron	1.5 mg/L (total); 0.3 mg/L (diss.)	NP	NP	NP
Lead	NP	3.8[3]	99[3]	50
Manganese	1.0 mg/L	NP	NP	NP
Mercury	NP	0.012	2.4	0.144
Thallium	NP	13	65	2
Vanadium	NP	NP	NP	NP
Zinc	NP	119[3]	132[3]	5,000
Tetrachloroethene	NP	139	695	0.7
Acetone	NP	NP	NP	NP
Toluene	NP	330	1,650	7,000
Diethylphthalate	NP	800	4,000	20,000
Di-n-butylphthalate	NP	NP	NP	NP
Endosulfan II	NP	0.056	0.11	0.9[6]

NP Not promulgated

(1) 25 PA Code, Chapter 93
(2) 25 PA Code Chapter 16
(3) Based on assumed hardness of 115 mg/L
(4) Total halomethanes
(5) Total dichlorobenzenes
(6) For alpha or beta endosulfan

Pennsylvania Department of Environmental Resources (PADER) in its regulation of discharges to surface water. The standards may be applicable for actions involving the discharge of pollutants to surface water.

Table 2-6 provides state Water Quality Standards applicable to surface waters near NAWC Warminster (Southampton Creek, Little Neshaminy Creek, and their unnamed tributaries).

Pennsylvania Air Pollution Control Regulations (PA Code, Title 25, Chapters 121 through 143) govern air emissions from remedial actions. The regulations provide for the control and prevention of air pollutants and guidance for the design and operation of air pollution sources. Potential sources of air pollution at the site may include onsite remedial actions that involve air stripping. Pennsylvania has adopted the NAAQS presented in Table 2-5 and has air quality standards for five additional constituents as shown in Table 2-7.

PADER Groundwater Protection Strategy is a guideline (TBC) for achieving nondegradation of groundwater quality through use of best demonstrated control technologies.

2.3.1.2 Location-Specific ARARs and TBCs

Federal Protection of Wetlands Executive Order (E.O. 11990) requires Federal agencies, in carrying out their responsibilities, to take action to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. According to the published definition of national wetlands, Federal Register 40 CFR Appendix C, several small areas of palustrine forested wetlands are present along intermittent tributaries to Little Neshaminy Creek or Southampton Creek. This ARAR has been retained in the event that wetland areas may be affected.

The Endangered Species Act of 1978 (16 USC 1531) (40 CFR Part 502) provides for consideration of the impacts on endangered and threatened species and their critical habitats. This act requires federal agencies, in consultation with the Secretary of the Interior, to ensure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any endangered or threatened species or adversely affect its critical habitat. A review of the available information indicates that no state or Federally listed endangered or threatened species are known to permanently or seasonally reside in the vicinity of NAWC Warminster. For this reason, the Endangered Species Act of 1978 is not applicable or relevant and appropriate to actions taken at the site.

The Fish and Wildlife Coordination Act (16 USC 661) provides for consideration of the impacts on wetlands and protected habitats. The act requires that federal agencies, before issuing a permit or undertaking Federal action for the modification of any body of water, consult with the appropriate state agency exercising

TABLE 2-7

PENNSYLVANIA AMBIENT AIR QUALITY STANDARDS
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

Parameter	Standard
Settled particulate	0.8 $mg/cm^2/mo$ (1-year average) 1.5 $mg/cm^2/mo$ (30-day average)
Beryllium	0.01 $\mu g/m^3$ (30-day average)
Sulfates (as H_2SO_4)	10 $\mu g/m^3$ (30-day average) 30 $\mu g/m^3$ (24-hour average)
Fluorides (total soluble as HF)	5 $\mu g/m^3$ (24-hour average)
Hydrogen sulfide	0.005 ppm (24-hour average) 0.1 ppm (1-hour average)

Source Code: PA Code Title 25, Chapter 131

jurisdiction over wildlife resources to conserve those resources. Consultation with the United States Fish and Wildlife Service is also required.

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

EPA's Groundwater Protection Strategy (EPA, 1984) policy is to protect groundwater for its highest present or potential beneficial use. This policy (TBC) will be incorporated into future regulatory amendments. The strategy designates three categories of groundwater:

- Class I - Special Groundwaters: Waters that are highly vulnerable to contamination and are either irreplaceable or ecologically vital sources of drinking water.

- Class II - Current and Potential Sources of Drinking Water and Waters Having Other Beneficial Uses: Waters that are currently used or that are potentially available.

- Class III - Groundwater Not a Potential Source of Drinking Water and of Limited Beneficial Use. Class III groundwater units are further subdivided into two subclasses.

  - Subclass IIIA includes groundwater units that are highly to intermediately interconnected to adjacent groundwater units of a higher class and/or surface waters. They may, as a result, be contributing to the degradation of the adjacent waters. They may be managed at a similar level as Class II groundwaters, depending upon the potential for producing adverse effects on the quality of adjacent waters.

  - Subclass IIIB is restricted to groundwater characterized by a low degree of interconnection to adjacent surface waters or other groundwater units of a higher class within the Classification Review Area. These groundwaters are naturally isolated from sources of drinking waters in such a way that there is little potential for producing adverse effects on quality. They have low resource values outside of mining or waste disposal.

Groundwater beneath and adjacent to NAWC Warminster is designated as a Class II aquifer.

Federal Floodplain Management Executive Order (E.O. 11988) requires Federal agencies to evaluate the potential effects of actions they may take in a floodplain to avoid, to the extent possible, the adverse impacts associated with direct and indirect development of a floodplain.

Pennsylvania Water Quality Standards (25 PA Code 93.9) contains specific water uses that are protective of particular streams.

2.3.1.3 Action-Specific ARARs and TBCs

RCRA Subtitle C regulates the treatment, storage, and disposal of hazardous waste from its generation until its ultimate disposal. In general, RCRA Subtitle C requirements for the treatment, storage, or disposal of hazardous waste will be applicable if

- The waste is a listed or characteristic waste under RCRA.
- The waste was treated, stored, or disposed (as defined in 40 CFR 260.10) after the effective date of the RCRA requirements under consideration.
- The activity at the CERCLA site constitutes current treatment, storage, or disposal as defined by RCRA.

RCRA Subtitle C requirements may be relevant and appropriate when the waste is sufficiently similar to a hazardous waste and/or the onsite remedial action constitutes treatment, storage, or disposal, and the particular RCRA requirement is well suited to the circumstances of the contaminant release and site. RCRA Subtitle C requirements may also be relevant and appropriate when the remedial action constitutes generation of a hazardous waste. Onsite activities, mandated by a Federally ordered Superfund cleanup, must comply with the substantiative requirements of RCRA Subtitle C but not with the administrative requirements (i.e., permits) of RCRA. All RCRA Subtitle C requirements must be met if the cleanup is not under Federal order and/or when the hazardous waste moves off site.

The following requirements included in the RCRA Subtitle C regulations may pertain to the NAWC Warminster:

- Hazardous waste generator requirements (40 CFR Part 262).
- Transportation requirements (40 CFR Part 263).
- Standards for owners and operators of hazardous waste treatment, storage, and disposal (TSD) facilities (40 CFR Part 264).

- Interim status standards for owners and operators of hazardous waste TSD facilities (40 CFR Part 265).

- Land Disposal Restrictions (40 CFR Part 268)

A generator that treats, stores, or disposes of hazardous waste on site must comply with RCRA Standards Applicable to Generators of Hazardous Waste (40 CFR Part 262). These standards include manifest, pre-transport (i.e., packaging, labeling, placarding), recordkeeping, and reporting requirements. The standards are applicable to actions taken at NAWC Warminster that constitute generation of a hazardous waste (e.g., generation of groundwater treatment residues that may be hazardous).

Standards Applicable to Transporters of Hazardous Waste (40 CFR Part 263) are applicable to offsite transportation of hazardous waste from NAWC Warminster. These regulations include requirements for compliance with the manifest and recordkeeping systems and requirements for immediate action and cleanup of hazardous waste discharges (spills) during transportation. Transporters must also have a Pennsylvania transporter permit.

Standards for Owners and Operators of Hazardous Waste TSD Facilities (40 CFR Part 264) are applicable to remedial actions taken at NAWC Warminster and to offsite facilities receiving hazardous waste from the site for treatment and/or disposal and have a RCRA Part B permit. Onsite facilities must also have a RCRA Part B permit if the site is not a Federally ordered CERCLA cleanup. Standards for TSDFs include requirements for preparedness and prevention, releases from solid waste management units (i.e., corrective action requirements), closure and post-closure care, use and management of containers, and design and operating standards for tank systems, surface impoundments, waste piles, landfills, and incinerators.

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

Placement of hazardous waste into underground injection wells constitutes "land disposal" under the LDRs. Furthermore, RCRA Section 3020(a) bans hazardous waste disposal by underground injection into or above an underground source of drinking water. RCRA Section 3020(b), however, exempts from the ban all reinjections of treated contaminated groundwater into such formations undertaken as part of a CERCLA Section 104 or 106 response action, or a RCRA corrective action, if the following conditions are met:

- The contaminated groundwater is treated to substantially reduce hazardous constituents prior to such injection.

- The response action or corrective action is sufficient to protect human health and the environment upon completion.

Therefore, the LDR requirements may not be applicable or relevant and appropriate to reinjection of treated groundwater at NAWC Warminster.

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

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

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

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

OSWER Directive 9834.11 establishes procedures for planning and implementing offsite response actions.

Pennsylvania Stormwater Management Act (Act No. 167) requires measures to control stormwater runoff during remedial alternatives or development of land.

Pennsylvania Special Water Pollution Regulations (PA Code, Title 25, Chapter 101) establish a procedure for mandatory notification of downstream users in the case of an accident in which a toxic substance enters surface waters. These regulations also specify bonding requirements for solid waste facilities that would ensure closure of a permitted site in a manner that would abate or prevent water pollution. The regulations may be applicable for remedial actions that include onsite treatment of solid waste.

Pennsylvania Hazardous Substances Transportation Regulations (PA Code, Title 13 and Title 15) govern the transport of flammable liquids and solids, oxidizing materials, poisons, and corrosive liquids. These regulations may be applicable to certain wastes that are shipped off site for laboratory analysis, treatment, or disposal. These regulations are generally equivalent to Federal DOT regulations.

Pennsylvania Hazardous Waste Management Regulations (PA Code, Title 25, Article VII) essentially parallel RCRA Subtitle C hazardous waste management regulations. Similar to RCRA Subtitle C regulations, Pennsylvania regulations include requirements for the following:

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

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

The corrective action program requirements of Chapter 264 (Section 264.100) require contaminated groundwater to be remediated to background levels. This regulation also establishes procedures to measure background groundwater quality. As stated in the regulation, groundwater remedial actions may be terminated when it can be demonstrated that concentration levels of hazardous constituents in the monitoring wells have remained at background levels for a period of three consecutive years.

Pennsylvania NPDES Rules (PA Code, Title 25, Chapter 92) govern point-source discharges to Pennsylvania waters. The rules include requirements for permits, permit applications, permit conditions, and monitoring. These rules may be applicable for remedial actions involving a discharge to surface water. To the extent that Pennsylvania water quality criteria and standards, waste-water treatment requirements, industrial waste treatment, and special water pollution control regulations (PA Code, Title 25, Chapters 16, 93, 95, 97, and 101) pertain to a discharge for which an NPDES permit is required, the provisions of these chapters govern if their application produces a more stringent effluent limitation than would be produced by application of Federal standards. The Pennsylvania NPDES rules are generally equivalent to the federal standards. Effluent limits for the OU-1 interim groundwater extraction and treatment system are presented in Table 2-8. It is expected that similar limits would be established for any discharges to surface water related to the OU-3 remedial action.

TABLE 2-8

EFFLUENT QUALITY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
INTERIM REMEDIAL ACTION
OU-1 GROUNDWATER PUMP-AND-TREAT SYSTEM
NAVAL AIR WARFARE CENTER
WARMINSTER, PENNSYLVANIA

Constituent	Units	Average Monthly	Instantaneous Maximum
Flow	Monitor Only		
pH	Standard Units	6.0 - 9.0	
Total Suspended Solids	mg/L	30	75
Cadmium	μg/L	1.6	4.0
Copper	μg/L	9.5	24.0
Lead	μg/L	4.3	11.0
Zinc	μg/L	63	158
Arsenic	μg/L	0.11	0.28
$Chromium^{6+}$	μg/L	9.3	23.0
Aluminum	μg/L	750	1,875
Total Iron	μg/L	1,440	3,600
Dissolved Iron	μg/L	450	1,125
Total Manganese	μg/L	1,500	3,750
Mercury	μg/L	0.018	0.045
Carbon Tetrachloride	μg/L	1.7	4.3
Tetrachloroethene	μg/L	4.0	10.0
Trichloroethene	μg/L	17	43.0
Vinyl chloride	μg/L	0.11	0.28
1,1-Dichloroethylene	μg/L	0.34	0.85

Note 1: Limits apply to a flow of 130 gallons per minute.

Note 2: Limits shown were excerpted from internal memo, Nancy Krickman to Steve O'Neil, dated March 31, 1994, issued within PADER's Conshohocken office.

Note 3: Limits for arsenic, vinyl chloride and 1,1-dichloroethylene will be enforced at detection limits, per telephone conversation with Nancy Krickman on June 21, 1994.

Pennsylvania General Provisions (PA Code, Title 25, Chapter 91) are general provisions that are applicable if treated groundwater reinjection is a component of the remediation. If reinjection is done off site, it will be necessary to obtain a water quality management permit (Section 91.21). If the reinjection is done on site, then the substantive requirements of Chapter 91 must be met, but a permit would not be required.

Pennsylvania Wastewater Treatment Regulations (PA Code, Title 25, Chapter 95) are regulations that are required to maintain water quality and include treatment requirements, effluent limitations based on best practical control technologies, and waste-load allocations for pollutants for which minimum treatment requirements have not been established. These regulations will be applicable for remedial actions that include a discharge to surface water.

Pennsylvania Construction, Modification, Reactivation, and Operation of Sources Regulations (PA Code, Title 25, Chapter 127) regulate the construction, modification, or reactivation of an air contaminant source as well as the installation of an air cleaning device on an air contamination source. Remedial actions used to remove volatile contaminants from the groundwater at NAWC Warminster are subject to plan approval review under Chapter 127. The various air quality permitting criteria are site specific. Depending on site conditions, air pollution controls may be required for an air stripper at NAWC Warminster.

Pennsylvania Solid Waste Disposal Regulations (PA Code 25, Chapter 75) regulate the disposal of solid wastes including municipal and industrial materials. The regulations set operating and permitting standards for disposal areas and characterize waste materials to achieve proper disposal. Any remedial actions resulting in the generation of waste material for onsite or offsite disposal are governed by these regulations.

Pennsylvania Industrial Waste Management Regulations (PA Code 25, Chapter 97) regulate the disposal of industrial waste materials. The regulation characterizes wastes and sets permitting and disposal standards. Remedial activities resulting in the generation of industrial waste such as wastewater treatment plant sludges are regulated under this statute.

Pennsylvania Erosion Control Regulations (PA Code 25, Chapter 102) regulate earthwork and construction that may result in the erosion of soils and sedimentation and pollution of surface wastes. Remedial activities on site that may include soil excavation for remediation or construction are subject to these regulations.

2.3.2 Remedial Action Levels

The remedial action levels for each contaminant of concern shall be the background concentration of that contaminant (the Pennsylvania ARAR under PA Code Sections 264.90-264.100).

2.4 GENERAL RESPONSE ACTIONS

Using the general response actions developed for NAWC Warminster, future sections will identify the types of technologies (e.g., physical treatments) and process options (e.g., activated carbon adsorption, ambient-temperature air stripping, high-temperature steam stripping) associated with these technologies. These will be screened for technical implementability, and a representative process option will be selected for applicable and implementable technologies. The selected process options will then be assembled into remedial alternatives. Listed below are the six general response actions that were identified for OU-3.

- No Action
- Institutional Controls
- Removal
- Containment
- In-situ Treatment
- Treatment

2.5 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

This stage of the FFS consists of the following steps:

- Identifying remedial technologies and process options based on remedial action objectives and general response actions.
- Screening technologies for technical implementability and effectiveness.
- Evaluating process options considered to be implementable.

2.5.1 Initial Identification and Screening of Technologies and Options

In this step, potentially applicable technology types and process options are identified based on the remedial action objectives and the general response actions. This list of technologies and process options is reduced by evaluating the options with respect to technical implementability. This is accomplished by using available information from the RI site characterization on contaminant types and concentrations and onsite characteristics to screen out technologies and process options that cannot be effectively implemented at the site.

A summary of the initial screening of technologies and process options is presented in Table 2-9.

TABLE 2-9

INITIAL SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

General Response Action Component	Remedial Technology	Process Option	Description	Screening Comments
No Action	None	Not applicable	No remedial actions taken	Required as a baseline consideration by NCP
Institutional Controls	Access restrictions	Deed restrictions	Groundwater use in the area of groundwater contamination would involve restrictions on wells	Potentially applicable
	Monitoring	Groundwater monitoring	Periodic monitoring of offsite wells and onsite monitoring wells in the areas of groundwater contamination	Potentially applicable
Removal	Extraction	Extraction wells	A series of pumping wells to extract contaminated groundwater	Potentially applicable
	Subsurface drains	Interceptor trenches	Perforated pipe in trenches backfilled with porous media to collect groundwater	Potentially applicable for overburden aquifer; however, not applicable for bedrock aquifer
Containment	Capping	Capping of soil surface with impervious material	Surface soil to be capped with impervious material to prevent infiltration and leaching of soil contaminants to groundwater	Not applicable; does not meet objective of minimizing migration of contaminated overburden and shallow bedrock groundwater
	Vertical barriers	Slurry wall/grout curtain	Soil/bentonite or cement grout mixture injected into trenches/borings to create curtain impervious to groundwater flow	Potentially applicable for overburden aquifer; not applicable for fractured bedrock of shallow bedrock aquifer

TABLE 2-9 (Continued)
INITIAL SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

General Response Action Component	Remedial Technology	Process Option	Description	Screening Comments
Disposal	Surface water discharge	Direct discharge of water to local stream or river	Collected/treated groundwater discharged to tributary of Little Neshaminy or Southampton Creek	Potentially applicable
	Discharge to existing wastewater treatment plant	Indirect discharge of water through existing wastewater treatment plant	Collected/treated groundwater discharged to existing wastewater treatment plant	Potentially applicable
	Subsurface discharge (re-injection)	Injection wells	Collected/treated groundwater injected into ground through a series of wells	Potentially applicable
	Spray irrigation	Discharge to surface soil for infiltration	Collected/treated groundwater sprayed to surface for evaporation/infiltration	Potentially applicable
	Water reuse	Reuse for drinking water or industrial purposes	Collected/treated groundwater used to supplement NAWC Warminster water supply	Not applicable; NAWC Warminster has an adequate supply of water for drinking and industrial purposes
In Situ Treatment	Biological	Aerobic	Degradation of organics using microorganisms in an aerobic environment	Potentially applicable for organic contaminants
	Air sparging	Aeration	Air forced under pressure through soils below the water table	Not applicable due to nature of impacted aquifer (fractured bedrock)

TABLE 2-9 (Continued)
INITIAL SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

General Response Action Component	Remedial Technology	Process Option	Description	Screening Comments
Treatment	Biological	Aerobic	Aerobic degradation of organics using microorganisms, nutrients, and an oxygen source	Potentially applicable to organic contaminants; not applicable to inorganics
		Anaerobic	Anaerobic degradation of organics using microorganisms	Not applicable to primary organic contaminants. Degradation product of PCE and TCE is vinyl chloride. Not applicable to inorganics.
	Chemical/physical	Coagulation - flocculation/ precipitation	Removal of heavy metals by adding agents to reduce solubility and encourage precipitation of contaminants	Potentially applicable to inorganic contaminants; not applicable to primary organic contaminants
		Oxidation - reduction	Manipulation of oxidation or reduction state of a compound to alter its characteristics	Not applicable to site-related contaminants
		Chlorination	Disinfection of water using chlorine compounds	Not applicable; combining organics and chlorine may produce trihalomethane
		Neutralization	Addition of acidic or basic compounds to alter the pH of a solution	Potentially applicable; may be required for all discharge technologies
		Air stripping	Mixing groundwater with large volumes of air in a packed column to promote the transfer of VOCs to the air	Potentially applicable; Not applicable for inorganic contaminants

TABLE 2-9 (Continued)
INITIAL SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

General Response Action Component	Remedial Technology	Process Option	Description	Screening Comments
Treatment	Chemical/physical	Steam stripping	Mixing groundwater with large volumes of steam in a packed column to promote transfer of VOCs to steam for condensation	Not applicable for organic components at concentrations detected; will not be applicable for inorganic contaminants
		Carbon adsorption	Adsorption of contaminants onto activated carbon by passing water through carbon column	Potentially applicable for organic contaminants; may not be effective for inorganic contaminants
		Reverse osmosis	Use of high pressure to force water through a membrane, leaving contaminants behind	Not applicable to primary organic contaminants. Potentially applicable for inorganic contaminants.
		Ion exchange	Contaminated water is passed through a resin bed where ions are exchanged between resin and water	Not applicable to primary organic contaminants. Potentially applicable for inorganic contaminants.
		UV/ozonation/ hydrogen peroxide	The enhanced oxidation of a compound to carbon dioxide and water	Potentially applicable for organic contaminants; not applicable to inorganic contaminants
		Solvent extraction	Extracting organic contaminants using a characteristic solvent	Not applicable to site contaminants
		Filtration	Removal of suspended solids using a granular bed or other means	Potentially applicable for pretreatment or removal of particulates

2.5.2 Screening of Technologies and Process Options Which Passed Initial Screening

Further screening of the technologies and process options that passed the initial screening can be applied in accordance with EPA guidance for feasibility studies. Three criteria are used to eliminate from further consideration any technologies and process options that are undesirable regarding effectiveness, implementability, and cost. These criteria are defined as follows:

- Effectiveness
  - Protection of human health and environment; reduction in toxicity, mobility, and volume, and permanence of solution.
  - Ability of the technology to handle the estimated areas or volumes of contaminated medium.
  - Ability of the technology to meet the remediation goals identified in the remedial action objectives.
  - Technical reliability (innovative versus well proven) with respect to contaminants and site conditions.
- Implementability
  - Overall technical feasibility at the site
  - Availability of vendors, mobile units, storage and disposal services, etc.
  - Administrative feasibility
  - Special long-term maintenance and operation requirements
- Cost
  - Capital cost
  - Operation and maintenance (O&M) costs

All of the items listed under each criterion may not apply directly to each technology; therefore, each item will only be addressed where appropriate.

The initial screening evaluation generally focuses on effectiveness and implementability with less effort directed at cost evaluations. Technologies whose use would be precluded by waste characteristics are screened and eliminated from further consideration. At this stage, no technologies will be eliminated based

on cost. A process option within a technology category, however, may not be carried through if an equally effective process option under that technology is available at a lower cost. Each technology presented in this section is not intended to necessarily stand alone because it may be subsequently combined with other processes into remedial action alternatives.

For each technology, at least one representative process is selected to more effectively facilitate the subsequent development and evaluation of alternatives without limiting flexibility during the development of remedial alternatives. The remainder of this section presents the technologies and process options that were considered.

2.5.2.1 No Action

The no-action scenario is considered to provide a baseline level to which other remedial technologies and alternatives can be compared. Under this scenario, no removal or treatment of contaminants in the groundwater would occur.

Effectiveness. The no-action option would not achieve the remedial action objectives. Over time, the degree of contamination in the groundwater may decrease through natural attenuation and dilution provided that the sources of contamination are eliminated. The rate of decrease in contaminant levels is difficult to predict at NAWC Warminster due to the nature of the aquifer (fractured bedrock). Long-term, periodic groundwater monitoring would be required to assess the ability of the aquifer to naturally lower contaminant levels through flushing.

The no-action option would not minimize plume migration or initiate aquifer restoration. The no-action scenario would not provide any protection of uncontaminated groundwater because the plume would continue to migrate into downgradient areas.

Implementability. There are no implementability considerations associated with the no-action scenario.

Cost. Because no action would be taken at the site, there would be no capital or annual O&M costs.

Conclusion. Retain no action as a baseline as required by CERCLA.

2.5.2.2 Institutional Controls

Access Restrictions

Institutional controls may include access restrictions for preventing access to groundwater such as regulatory prohibitions, zoning regulations, and local ordinances.

Effectiveness. Access restrictions would not reduce the toxicity, mobility, or volume of contaminants in the groundwater. Access restrictions would also not provide any additional protection of the environment because the plume may continue to spread into uncontaminated or lesser contaminated areas. Access restrictions would, however, reduce the potential risk to human health associated with ingestion/inhalation of contaminated groundwater.

Implementability. Land-use restrictions are currently in place at NAWC Warminster. However, most of the base is to be closed in the near future and associated with the closure will be the transfer of ownership of various areas of the base to other parties. After NAWC property is transferred to other parties, land use restrictions such as zoning or deed restrictions would be necessary to prevent exposure to contaminated groundwater underlying NAWC property. Currently, there are no such restrictions on private property in the area, and such restrictions would be difficult to enforce. Accordingly, the implementability of land use restrictions is questionable.

Cost. Because only administrative actions would be taken, capital and O&M costs would be low.

Conclusion. Since the implementability of institutional controls is questionable, these controls cannot be depended on at this time to prevent the exposure of concern.

Groundwater Monitoring

Periodic groundwater monitoring throughout the area of potential groundwater contamination would be used to evaluate migration of contaminants and the potential for contamination of the onsite drinking water supply and nearby residential, municipal, and commercial wells.

Effectiveness. Groundwater monitoring would not reduce the toxicity, mobility, or volume of contaminants in the groundwater. Also, monitoring would not provide any additional protection of the environment because the plume may continue to spread into uncontaminated or lesser contaminated areas. Monitoring would allow establishment of a trend in contaminant levels to evaluate whether contaminant levels are

increasing, decreasing, or stable. Monitoring will also be helpful in measuring and evaluating the effectiveness of groundwater remediation.

Implementability. A groundwater monitoring program could be readily implemented at NAWC Warminster.

Cost. Because only groundwater monitoring would be conducted, capital and O&M costs would be low.

Conclusion. Retain monitoring for further consideration.

2.5.2.3 Removal Technologies

The treatment technologies discussed require that the groundwater be brought to the surface for treatment or disposal. Two process options are potentially applicable for this purpose: extraction using a pumping well system and subsurface drains using interceptor or collection trenches.

Extraction Wells

The extraction option uses a pumping well system, composed of a series of wells completed in shallow bedrock, that can be used to capture contaminated groundwater for treatment. The wells used in the capture system would be designed and located to provide optimum efficiency in capturing contaminated groundwater while minimizing the collection of uncontaminated groundwater.

Effectiveness. The effectiveness of a pumping well system depends largely on the extent of contamination and the geology and hydrogeology at the site. The effectiveness of a pumping well system will depend on the ability of individual wells to intersect fractures within the bedrock and effectively capture groundwater flow in selected areas requiring treatment.

A capture system for groundwater at NAWC Warminster would stop further migration of onsite contaminated groundwater from the source into downgradient areas.

Implementability. Groundwater extraction through a pumping well system can be readily implemented at NAWC Warminster. The technology uses readily available equipment and techniques and has been proven effective in similar situations. Implementation of this technology would require long-term operation and maintenance. Maintenance may require periodic replacement of mechanical components and well flushing to remove fine-grained material that may clog extraction wells.

Cost. Capital and O&M costs are relatively low.

Conclusion. Retain groundwater extraction for further evaluation.

Subsurface Drains

Subsurface drains (e.g., french drains) can be used as preventive measures (leachate collection) and/or as abatement measures (interceptor trenches). Construction of subsurface drains involves digging a trench or system of trenches below the water table. The excavated trench is then backfilled with permeable material such as gravel or crushed rock. Collection pipes and pumps are used for water removal. Subsurface drains or trenches function similarly to a continuum of extraction wells; that is, they create a continuous zone of depression that runs the length of the drainage trench.

Effectiveness. Subsurface drains can control further contamination by reducing contact between groundwater and contaminated soils. This technology can also control migration of a shallow contaminated plume. The use of collection trenches for the extraction of groundwater has been most effective in low-permeability media where wells are not effective. Collection trenches could be effective in capturing some of the groundwater in overburden deposits but would not be effective in capturing contaminated groundwater that extends into the underlying bedrock aquifers. At NAWC Warminster, where the overburden and shallow bedrock are hydraulically connected and transmit water, a pumping well system may be more efficient in capturing and extracting contaminated groundwater than collection trenches, although some combination of collection trenches and extraction wells could potentially be used.

Implementability. The amount of excavation required for implementation of collection trenches is dependent on the area of remediation and the depth to groundwater, which varies throughout the site. Trenches for groundwater collection would require extensive excavation as well as disposal of any contaminated soil from the trench. French drains are normally not constructed much deeper than 40 feet below the ground surface and are not effective in extracting groundwater contaminants below 60 feet. Since the depth of groundwater contamination extends to a depth of at least 120 feet in the shallow bedrock aquifer, the construction of such trenches would not be feasible.

Cost. Capital cost for subsurface drains would be moderate. O&M costs would be low.

Conclusion. Because of implementability concerns, subsurface drains are eliminated from further consideration for collection of groundwater.

2.5.2.4 Containment

Slurry Wall/Grout Curtain

The placement of a vertical barrier to groundwater migration can be effective in limiting the inflow of uncontaminated groundwater into a contaminant source and in controlling the spread of contaminated groundwater. A slurry wall consists of a mixture of soil, bentonite clay, and water that is placed into an excavated trench or bored holes. A grout wall is similar, utilizing a grout or cement component instead of bentonite clay.

Effectiveness. Both a slurry wall and a grout curtain can be effective at limiting the flow of groundwater in a particular area. The technologies do not allow for the reduction in existing contamination. This technology does not address the vertical component of groundwater migration and would not be effective in limiting migration between the overburden, shallow bedrock, and semi-artesian aquifers at the site.

Implementability. The construction of a slurry wall/grout curtain could be readily implemented in the overburden soils at NAWC Warminster by excavating trenches or drilling a series of adjacent soil borings. Implementation of this technology into the shallow bedrock beneath the soil overburden may prove difficult, due to the depth of contamination in the shallow bedrock.

Cost. The capital and O&M costs for this technology in the overburden aquifer are expected to be low. Extending this technology into the underlying bedrock would increase costs significantly.

Conclusions. This technology will not be retained for further consideration. The utility of this technology at greater depths is limited because of construction difficulties. Additionally, this technology would only be effective if implemented in areas where vertical migration of groundwater was not a concern.

2.5.2.5 Disposal Technologies

Extracted groundwater must eventually be disposed when brought to the surface. The available disposal options include discharge to offsite surface water, discharge to the existing NAWC Warminster wastewater treatment plant, discharge to the existing Warminster Municipal Authority (WMA) wastewater treatment plant, discharge to groundwater, and spray irrigation.

Discharge to Offsite Surface Water and Wastewater Treatment Plant

The discharge of groundwater to surface water bodies at NAWC Warminster is applicable for the disposal of extracted treated groundwater. Intermittent tributaries of Little Neshaminy Creek are located immediately to the north of the facility and Area C. NAWC Warminster discharges treated wastewater to a perennial stream tributary of Little Neshaminy Creek located approximately 6,000 feet from the existing wastewater treatment plant (WWTP). Direct discharge to these tributaries would require an NPDES permit, which would set limits of contaminant concentration and flow rates of the discharged water.

Indirect discharge of groundwater through an existing POTW such as the Warminster Municipal Authority (WMA) WWTP or the NAWC Warminster WWTP following pretreatment, as required, are potential disposal methods for extracted groundwater. However, the NAWC Warminster WWTP is to be removed from service as part of the base realignment activities. The utilization of the WMA WWTP as a receptor for treated groundwater was rejected at a public meeting addressing mitigation of groundwater contamination at Areas A and B. Influent flow rate and contaminant concentration are the potential limiting factors for this disposal option.

Effectiveness. Direct discharge to Little Neshaminy Creek (or its tributaries) is a potentially effective means of disposing of the volumes of water generated by the groundwater extraction systems. The outfall capacity of the NAWC Warminster WWTP would not limit the flow rate at which groundwater can be disposed. The outfall is currently discharging about 60,000 gallons per day, and reportedly has the capacity to discharge 1.3 million gallons per day. Thus, utilization of the existing NAWC Warminster WWTP outfall will effectively handle the necessary volumes of water anticipated from groundwater extraction. If public reaction was more favorable, indirect discharge to the WMA WWTP would also be an effective means to dispose of pretreated groundwater.

Implementability. Direct discharge to surface water, which would require installation of underground piping from the groundwater treatment system to surface water, is implementable. Disposal to the WMA or NAWC Warminster WWTP is not implementable due to unfavorable public reaction and facility shutdown, respectively.

Cost. Capital costs for the direct disposal of groundwater to surface water are expected to be low, as are the O&M costs.

Conclusion. Retain discharge to surface water for further consideration. Eliminate discharge to the WMA and NAWC Warminster WWTP from further consideration.

Discharge to Groundwater

Subsurface discharge involves the use of injection wells to reinject treated groundwater into the aquifers or infiltration basins to allow gravity drainage of treated groundwater into the aquifer. Underground injection wells can be coupled with extraction wells to create a closed system in which pumping and injection rates balance one another. Alternately reinjection can occur at a remote location or a deeper location (open system).

Effectiveness. Subsurface discharge is an effective means of disposing of the volumes of water generated by the groundwater pumping/treatment system. Injection wells can offer the advantage of decreasing groundwater remediation time in a close-loop system design by increasing the groundwater flow rate through the aquifer. Infiltration basins would not be effective during the winter months due to freezing problems.

Implementability. Installation of a well system for underground injection is implementable; however, achieving a closed system within the fractured bedrock at the site may be difficult. Creating a closed system with extraction and reinjection wells would significantly increase the flow rate for treatment. Reinjected water that is not captured by the extraction wells could potentially force contaminated groundwater into lesser contaminated areas. Periodic groundwater monitoring would help to assess whether or not this condition is occurring. Remote or deep injection could offset the potential for dispersing the plume at Area C; however, care would be necessary that reinjection would not disturb existing plumes at other locations. Remote injection would minimize the flow required for plume containment. Infiltration basins would be implementable providing there is sufficient uncontaminated land available that has the proper drainage characteristics. Subsurface discharge would require that groundwater be treated to either action or background levels prior to reinjection.

Underground injection of water may require a state permit, depending on whether it occurs on site or off site. The permit would set limitations on contaminant concentrations, and possibly flow rates, of disposed water.

Cost. The capital and O&M costs for subsurface discharge are high compared with those for surface water discharge.

Conclusion. Because the costs for subsurface discharge are high compared to other disposal options, and because implementation/control of this option can be difficult in a fractured bedrock aquifer, subsurface discharge (reinjection and infiltration basins) will be eliminated from further consideration.

Spray Irrigation

Spray irrigation involves the discharge of treated/untreated groundwater to the soil surface after spraying into the air. This technology allows for the volatilization of VOCs and promotes recharge of the aquifer.

Effectiveness. Spray irrigation is suitable for the volatilization of some VOCs. It is not effective for the removal of less volatile VOCs or inorganic compounds such as heavy metals. The technology allows for the recharge of an aquifer and can be used to encourage flow into a groundwater extraction system.

Implementability. Spray irrigation would be partially effective for the disposal of treated groundwater for the facility. Treatment before disposal may be required to reduce the discharge of contaminants. Parameters involved in implementing this technology include flow rate, contaminant concentration, and available sorptive capacity of site soils. The soils at the facility must have the ability to infiltrate the sprayed groundwater so that surface water runoff is not generated. Soil characteristics at the facility may not allow sufficient discharge volume, potentially making other disposal techniques, such as surface water discharge, more applicable. Freezing problems are likely in the winter, both from the perspective of equipment freezing and ground freezing (stops infiltration).

Cost. The capital and O&M costs for this technology are expected to be low. Piping must be constructed to route water from the source wells to the spray area. If the system is coupled with a treatment system, capital O&M costs are expected to be moderate.

Conclusion. Because spray irrigation offers no significant advantages over the other disposal options and may be difficult to implement year-round, it will be eliminated from further consideration.

2.5.2.6 In-Situ Treatment Technologies

Contaminated groundwater may be treated in situ (i.e., in place). The in-situ treatment process that passed initial screening is aerobic biodegradation.

Aerobic Biodegradation

In-situ biodegradation is a relatively new technology that has been primarily used to treat petroleum hydrocarbons. In-situ biodegradation treatment involves the stimulation of indigenous microbial populations and/or the inoculation of the subsurface with cultured species possessing specialized metabolic capabilities for the particular waste. The objective of this technology is to accelerate the biodegradation process by

optimizing the organisms' environment. This typically involves setting up a flow pattern using a number of pumping wells and reinjection points to disperse microorganisms, oxygen, and nutrients throughout the hydrogeologic formation.

A conventional biological treatment technology, such as activated sludge, is often incorporated into the circulation system, which provides additional treatment as well as a microbe-rich, nutrient-rich solution. The solution is recharged into the subsurface to enhance microbial growth.

Quantifiable characteristics needed to assess the in-situ biodegradability of a particular waste include

- Microorganisms present at the site
- Aquifer properties (dissolved oxygen content, pH, temperature, etc.)
- Biodegradation products (particularly hazardous ones)
- Biodegradability of the waste (half-life, rate constants)

Effectiveness. Halogenated solvents such as PCE are very persistent under aerobic conditions (Wilson et al., 1986). Some laboratory studies suggest that biodegradation of halogenated compounds such as PCE does not occur under aerobic conditions (Bouwer et al., 1981).

In-situ biodegradation would not be effective for inorganic contaminants.

Implementability. Implementation of this technology is possible but would be complex and would require highly skilled personnel due to the need to maintain proper environmental conditions. Injection of toxic aromatic compounds into the aquifer, however, in order to facilitate in-situ biodegradation, may be feasible but may not be acceptable, and in-situ biodegradation technology using other compounds, such as methane, has not been developed. A number of vendors offer biological treatment technology, although none to date have demonstrated a full-scale system for biodegradation of all halogenated contaminants in groundwater (Bonk, 1992). Aerobic biodegradation may require increasing the oxygen content in the groundwater. In addition, the acclimation time of the microbial culture to the waste must be estimated because long periods of acclimation to subsurface pollutants may be required before biodegradation can occur. Because no full-scale systems have been demonstrated, scale-up problems, environmental impacts, and long-term equipment operation and maintenance requirements cannot be fully assessed at this time.

Cost. The capital and O&M costs for in-situ aerobic treatment are low compared to the other treatment technologies.

Conclusion. Because full-scale systems for biodegradation of PCE and other site contaminants are not commercially available at this time, in-situ aerobic treatment will be eliminated from further consideration. In addition, the process is not effective for inorganics.

2.5.2.7 Treatment Technologies

In this section, only primary treatment technologies for the removal of the contaminants will be discussed. Discussion of secondary treatment technologies that may be required for water conditioning before or after primary treatment, such as filtration or sedimentation for the removal of suspended solids, will be included as part of the primary technology sections.

Aerobic Biodegradation

Biological treatment uses microorganisms, primarily bacteria, actinomycetes, and fungi, to break down hazardous organic compounds into nontoxic or less toxic forms. Aerobically, microorganisms have the potential to completely oxidize organic substances into carbon dioxide and water. The fundamentals of biological treatment involve the following:

- Demonstrated biodegradability of the waste using either acclimated, indigenous (native) microorganisms or exogenous cultured species.
- Maintenance of optimal environmental conditions such as temperature and pH.
- Maintenance of essential nutrients such as phosphorus and nitrogen.

Although a wide variety of organic substances have been efficiently biodegraded with existing technologies, certain classes of organic compounds show resistance to microbial attack and are biodegraded very slowly or only partially. Halogenated solvents such as PCE are very persistent in oxygenated waters (Wilson et al., 1986). Although some laboratory studies suggest that biodegradation of halogenated compounds such as PCE does not occur under aerobic conditions (Bouwer et al., 1981), recent laboratory work has indicated that microorganisms that oxidize methane and propane can co-oxidize TCE and a variety of other halogenated organic compounds (Fogel et al., 1986; Strand and Shippert, 1986; and Henry and Grbic-Galic, 1986).

Typical aerobic biological treatment systems include activated sludge processes and various forms of fixed-film bioreactors. In activated sludge processes, a suspended aerobic microbial culture is used to treat the incoming contaminated water. The aerobic environment is produced through the use of diffused or

mechanical aeration. At the end of the reaction period, the resulting flocculent slurry of microorganisms is removed from the aeration tank, usually by sedimentation, and a portion of the mass is recycled and the remaining mass (sludge) wasted. The four basic activated sludge process configurations are nominal plug flow, continuous flow, complete mix, and sequential batch reactor.

In fixed-film bioreactors, organisms grow as a film on an immobile support such as rock or plastic media. Organisms are continuously sloughed off by the fluid stream and must be removed by a final settler. Common types of fixed-film reactors include packed towers and rotating-disc reactors as well as various modifications of these two configurations.

In addition to these fixed-film reactors, a third type of biological treatment, Biological Activated Carbon (BAC), is currently being investigated. BAC involves growing microorganisms on a packed carbon bed or a fluidized carbon bed (Voice, 1990). This type of system provides the benefit of contaminant removal through both biodegradation and adsorption. Research at this time is currently focused on the removal of petroleum hydrocarbons from groundwater; petroleum hydrocarbons are relatively easily biodegraded compared to chlorinated solvents such as PCE and TCE (Voice, 1990).

Effectiveness. Although researchers have demonstrated the biodegradation of PCE in aerobic systems in the laboratory, PCE biological treatment systems in the field have not been demonstrated. The co-metabolism process does not appear to be effective for PCE (Wilson, 1992). Due to the innovative nature of this technology, bench- and pilot-scale studies would be needed to determine the effectiveness of aerobic biodegradation for the groundwater contaminants at NAWC Warminster.

Implementation. Aerobic biodegradation processes could be implemented on site. A number of vendors offer biological treatment technology, although none have demonstrated a full-scale system for biodegradation of NAWC Warminster contaminants at this time (Bonk, 1992). Implementation considerations include the disposal of biomass sludge produced and the potential release of organics into the air. Because no full-scale systems have been demonstrated, however, scale-up problems and long-term equipment operation and maintenance requirements cannot be fully assessed.

Cost. The capital and O&M costs for aerobic treatment are low to moderate compared to the other treatment technologies.

Conclusion. Because full-scale systems for biodegradation of the primary groundwater contaminants (i.e., PCE) are not commercially available at this time, aerobic treatment will be eliminated for further consideration.

Air Stripping

Air stripping is a proven technology well suited for the removal of VOCs from contaminated water. This aeration process promotes mass transfer of VOCs from the aqueous phase to the gas phase as defined by Henry's Law. In general, air stripping is used for volatile compounds with a Henry's Law constant greater or equal to 3.0 atm-L/mole (Camp, Dresser and McKee Incorporated, 1985). Removal efficiencies of VOCs typically range from 50 percent to more than 99 percent depending on the operating parameters (i.e., air-to-water ratio), as well as the physical properties of the organic compound(s).

The countercurrent packed tower is the most commonly used air stripping configuration. Water is distributed over the top of the unit while air is forced upward through the bottom. Loosely fitted packing material serves to increase the air/water interface area to provide maximum mass transfer. Key factors that influence process performance include air-to-water ratio, type of packing material, operating temperature, surface hydraulic loading, and contact time.

Effectiveness. Air stripping is a well-proven, reliable technology that would be effective for removing the primary VOCs from groundwater at NAWC Warminster. Theoretically, removal efficiencies greater than 99.99 percent could be achieved for these contaminants. It would not be effective for semivolatile organics or inorganics. Since air stripping only removes the contaminants from the water and concentrates them in the off-gas, the off-gas may have to be subsequently treated by other means, such as granular activated carbon adsorption, catalytic oxidation, or thermal destruction.

Implementability. Air stripping would be readily implementable at the site. There are a sufficient number of vendors that provide air-stripping technology. Control of off-gas emissions would be required. An exemption from air treatment requirements may be obtained, depending on the VOC concentrations in the off-gas and air flow rate. One of the maintenance considerations for air stripping is channeling of the flow resulting from clogging of the packing material. Common causes of clogging include oils, suspended solids, high iron concentrations, and slightly soluble salts such as calcium carbonate. High levels of any of these substances would require pretreatment. At NAWC Warminster, provisions may be needed for chemical precipitation of iron and manganese and removal of suspended solids.

Cost. Capital costs are low, and O&M costs range from low to moderate, depending on influent contaminant concentrations and the degree of removal required.

Conclusion. Retain air stripping as a representative process option for physical/chemical treatment.

Activated Carbon Adsorption

Activated carbon adsorption is a frequently applied technology for the removal of organic compounds from contaminated water. Activated carbon will adsorb many organic compounds to some extent but is most effective for the less polar and less soluble organic compounds. Removal efficiency of more than 99 percent can be achieved depending on the type of organic solute and system operating parameters, such as retention time and carbon replacement frequency. The fundamental principle behind activated carbon treatment involves the physical attraction of organic solute molecules to exchange sites on the internal pore surface areas of the specially treated (activated) carbon grains. As water is filtered through the adsorbent, the organic molecules eventually occupy all of the surface sites on the carbon grains. The exhausted carbon must then be either regenerated or disposed according to Federal (RCRA) and state regulations.

Typical activated carbon adsorption treatment systems include gravity flow or pressure flow columns in series and/or parallel configurations with backwashing capability. Granular activated carbon is generally used in these systems. Common flow rates range from 0.5 to 5.0 gpm/feet^2. Factors such as pH and temperature of the influent, empty bed contact time, surface area/volume ratio of the activated carbon, and solubility of the organic compound will affect the carbon adsorption process.

Effectiveness. Carbon adsorption is a well-proven, reliable technology that would be effective for removing most of the organics from groundwater at NAWC Warminster. Removal efficiencies as high as 99 percent could potentially be achieved for most of these contaminants. Carbon adsorption would not be as effective for removal of compounds with properties such as vinyl chloride, however, because removal efficiencies are expected to be significantly lower for these compounds. As activated carbon only concentrates the contaminants, the spent carbon would have to be subsequently disposed in a hazardous waste landfill or regenerated.

Implementation. Carbon adsorption would be readily implementable at NAWC Warminster. There are a sufficient number of vendors that provide carbon adsorption units. Implementation factors include planning for disposal or regeneration (on site or off site) of the exhausted carbon. Thermal, steam, and solvent treatments are the most common types of regeneration technologies. Furthermore, pretreatment (e.g., filtration, precipitation) may be required if the influent has a total solids concentrations greater than 50 mg/L, oil and grease concentrations greater than 10 mg/L, or calcium or magnesium concentrations greater than 500 mg/L to prevent clogging and high pressure drops (Berkowitz et al., 1978; and EPA, 1986). At NAWC Warminster, filtration may be needed ahead of the activated carbon adsorbers to ensure maximum carbon life cycle.

Cost. Capital costs are low, and O&M costs range from low to moderate, depending on the carbon usage rate, which is a function of influent contaminant concentrations.

Conclusion. Retain carbon adsorption for further consideration.

Ion Exchange

Ion exchange resins are insoluble solids containing fixed cations or anions capable of reversible exchange with mobile ions of the same charge in solutions with which they are brought into contact. The ion exchange resins will eventually be exhausted and must be regenerated. The regeneration waste will contain the ions removed at much higher concentrations than in the influent and must be further treated and/or disposed of.

Effectiveness. Ion exchange is effective for the removal of soluble metals and anions such as halides, sulfates, and nitrates. It removes metals to low concentrations, but not as low as certain limits shown in Table 2-8 which approach, or are below detection limits. If treatment for these parameters were to be necessary, ion exchange would not be effective.

Implementability. Ion exchange would be readily implementable at NAWC Warminster. There are many vendors that provide ion exchange units. The upper influent concentration limit for exchangeable ions for efficient operations is approximately 2,500 mg/L. Influent suspended solids must be very low, otherwise the resin bed could be fouled or plugged. Some organics, especially aromatics, can be irreversibly adsorbed by the resin, resulting in decreased capacity.

Cost. Capital costs are low to moderate and O&M costs range from low to high, depending on the frequency of regeneration required, which is a function of influent contaminant concentrations and effluent quality requirements.

Conclusion. Ion exchange is eliminated from further evaluation as a polishing step based on performance limitations.

Reverse Osmosis

Reverse osmosis uses a semi-permeable barrier that will pass only certain components of a solution. The membrane is permeable to water but impermeable to most dissolved substances, both organic and inorganic. The driving force is an applied pressure gradient. Reverse osmosis produces a concentrated

solution (for further treatment or disposal) and a dilute stream of purified water. In groundwater treatment systems, the concentrated solution (or reject) is typically about 25 percent of forward flow.

Effectiveness. Reverse osmosis may be used to concentrate dilute solutions of many inorganic and organic solutes. Reverse osmosis reduces excess dissolved solids, reduces or removes many organics and metals, and produces almost turbidity-free water.

Implementability. Reverse osmosis would be readily implementable. Pretreatment may be required to optimize pH and filter out suspended solids. However, the further treatment or disposal of the reject stream would be required.

Cost. Capital and O&M costs are typically moderate. However in this case, they would be high because of the reject management issue.

Conclusion. Reverse osmosis is eliminated from further evaluation based on cost of ancillary treatment processes.

Ozone/Ultraviolet Light Radiation (Ozone/UV)/Hydrogen Peroxide

Ozone/UV/hydrogen peroxide processes use a controlled combination of either ozone or hydrogen peroxide and ultraviolet light to induce photochemical oxidation of organic compounds. Ozone has been used extensively in Europe for purification, disinfection, and odor control of drinking water. Ozone alone has the ability to break down some organics but has generally proven to be an ineffective oxidant of halogenated organics under conditions normally used for drinking water treatment or for disinfecting wastewaters (i.e., 1 to 10 mg/L concentration levels and 5- to 10-minute contact times) (Brenton et al., 1986; and Arienti et al., 1986). Oxidation of organic species to carbon dioxide, water, etc., however, is possible if the ozone dosage and contact times are sufficiently high (EPA, 1987).

Ultraviolet (UV) radiation is electromagnetic energy whose wavelengths fall between those of visible light and X-ray radiation on the electromagnetic spectrum. UV energy is capable of breaking down or rearranging a molecular structure, depending on the dissociation energies of the chemical bonds within the structure (EPA, 1987). The combination of ultraviolet radiation with ozone or hydrogen peroxide treatment results in the oxidation of organic contaminants at a rate many times faster than that obtained from applying UV light alone (McShea et al., 1987).

A typical continuous-flow hydrogen peroxide/ozone/UV system consists of an oxygen or air source, an ozone generator or hydrogen peroxide feed system, a UV/oxidation reactor, and an ozone decomposer. Flow patterns and configurations are designed to maximize exposure of the wastewater to the UV radiation, which is supplied by an arrangement of UV lamps. Typical reactor designs range from mechanically agitated reactors to spray, packed, and tray-type towers. Reactor gases are passed through a catalytic ozone decomposer, which converts remaining ozone to oxygen and destroys any volatiles. The gases are then discharged or recycled.

Effectiveness. Hydrogen peroxide/ozone/UV technology has effectively oxidized halogenated organics, benzene derivatives, and various aliphatics (McShea et al., 1987). PCE has been reduced from levels of 20 ppm to less than 5 ppb (McShea et al., 1987). This process is considered an innovative technology; only a few commercial systems have been installed and tested. Bench- and pilot-scale treatability studies would therefore need to be conducted to determine the actual effectiveness and cost of applying this process to the contaminants in the groundwater at NAWC Warminster.

Implementation. Hydrogen peroxide/ozone/UV technology should be implementable. Only a few vendors, however, currently offer this technology. Implementation may involve pretreatment of influents containing high concentrations of suspended solids. With this treatment, no toxics are emitted to the atmosphere or adsorbed onto media that require further treatment or disposal.

Cost. Capital and O&M costs are moderate.

Conclusion. Air stripping and carbon adsorption were chosen as representative process options for treatment because these processes are more proven in the field than hydrogen peroxide/ozone/UV. However, hydrogen peroxide/ozone/UV will be retained for further consideration because this innovative technology could be considered during remedial design. The selection of treatment process options during the FS will depend on design contaminant concentrations and compliance with air regulations and standards.

Filtration

Filtration is a process using a porous medium to remove suspended solids from a liquid. It is valuable in wastewater treatment as a pre-treatment to remove suspended solids before other treatment processes and for the final cleaning or polishing of treated effluent. It is effective in removing organic and inorganic contaminants (particularly metals) that are bound to suspended solids in groundwater, often reducing the need for further treatment of these contaminants.

Liquid filtration may be accomplished by numerous methods including screens, fibrous fabrics (paper or cloth), or beds of granular material. Flow through a filter can be encouraged by pressure on the inlet side or by drawing a vacuum on the filter outlet.

Effectiveness. This technology is widely used for the removal of suspended materials from liquids. Filtering systems can be staged to progressively remove smaller materials; many system variations have been designed to reduce clogging and provide easy maintenance.

Filtration is especially useful in reducing contaminant levels of metals and organic compounds that are bound to suspended solid materials. These compounds may not easily be removed by other treatment methods such as aeration or carbon filtration, making filtration an advisable pre-treatment step for these technologies. It should be noted, however, that conventional filtration is not effective in removing dissolved contaminants but is readily applicable to suspended solids.

Implementation. Filtration systems are commercially available from a wide variety of manufacturers and can be readily ordered to almost any specification. For groundwater treatment, the primary use of a filtration system will be for the removal of suspended material before further treatment and possibly as a final treatment before discharge from a treatment system. Filter media will occasionally have to be replaced or regenerated, potentially resulting in the generation of sludges requiring specialized disposal because of contaminant content.

Cost. Capital costs for filtration are low, as are O&M costs. O&M costs may elevate slightly if frequent turbidity in the pumped groundwater requires additional filter maintenance.

Conclusion. Filtration will be retained as a process option for groundwater treatment.

Coagulation-Flocculation/Precipitation

Coagulation-flocculation/precipitation are liquid treatment processes that involve the addition of compounds or chemical reagents that bind to suspended materials and to each other, and to form insoluble salts with the compounds to be removed from solution, encouraging the creation of particles that are too large to remain in suspension and resulting in the precipitation or settling of suspended material. The technology is useful as a pretreatment step for removing contaminants such as heavy metals or semivolatile organics that are be tightly bound to suspended materials.

Effectiveness. Coagulation-flocculation/precipitation is useful for the conversion of soluble metals to an insoluble form, and for the removal of suspended materials from a liquid. It is not effective in the removal of dissolved contaminants such as VOCs. As stated, the technology is also useful as a pretreatment step for removing contaminants bound to suspended solids.

Implementation. This technology is widely used in liquid treatment and is readily available commercially. The use of such a system may require the construction of piping and tanks if a self-contained unit is not commercially available. As with filtration, excessive suspended solids in the raw water may require added maintenance and can result in the generation of sludges requiring specialized disposal because of contaminant content.

Cost. The capital costs and O&M costs are expected to be low. The presence of high amounts of suspended solids may necessitate additional system maintenance.

Conclusion. Coagulation-flocculation/precipitation will be retained as a process option for groundwater treatment.

Neutralization

Neutralization is a treatment process for altering the pH or acidity/alkalinity of a solution. When ionic salts are present in water, some water molecules break into ionic constituents H^+ and OH^-. Neutralization is a process by which the relative concentrations of H^+ and OH^- ions are balanced. This is generally accomplished by adding acidic compounds (H^+) to balance alkaline solutions (OH^-) or vice-versa.

Effectiveness. Neutralization is an easily accomplished means of balancing or changing the pH of a solution. The process is best performed in a well-mixed system. A thorough analysis of the waste to be treated is advisable to avoid the creation of compounds more toxic than the original compounds and to ensure that incompatible compounds are not introduced into the system. The technology is particularly useful as a pretreatment step for pH adjustment before other treatment steps that require altered pH levels for optimum efficiency. Neutralization is also frequently used as a finishing step prior to discharge of a treated liquid.

Implementation. Neutralization technology is easily implemented; it is widely used and commercially available. Limited construction is necessary to include neutralization equipment as a step in a treatment system.

Cost. The capital O&M costs for neutralization are expected to be low.

Conclusion. Neutralization will be retained as a process option for wastewater treatment.

2.5.3 Summary of Final Screening of Technologies and Process Options

The evaluations of technologies and process options, based on effectiveness, implementability, and cost, are summarized in Table 2-10. In this table, the technologies are organized according to the general response actions developed in Section 2.3. Where appropriate, the ability of the technology to achieve the remedial action objectives developed in Section 2.2 is summarized under the "Effectiveness" column in the table. Technologies and process options are retained or eliminated for further consideration in the "Conclusion" column of this table.

The technologies and process options to be further considered in this report are as follows:

- No Action
- Groundwater Monitoring
- Extraction wells
- Discharge to surface water
- Treatment Technologies
  - Air stripping
  - Activated carbon absorption
  - Photochemical oxidation (ozone/UV/hydrogen peroxide)
  - Filtration
  - Coagulation/flocculation/precipitation
  - Neutralization

TABLE 2-10

FINAL SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

General Response Action Component	Remedial Technology	Process Option	Effectiveness	Implementability	Cost	Conclusion
No Action	None	Not applicable	Does not provide any additional reduction in the toxicity, mobility, or volume of contaminants	Readily implemented.	No capital and O&M costs.	Retain as a baseline.
Institutional Controls	Access to groundwater restrictions	Zoning regulations, local ordinances, etc.	Does not provide any additional reduction in the toxicity, mobility, or volume of contaminants.	Restrictions may not be implementable.	Negligible capital and O&M costs. Administrative costs only.	Eliminate from further consideration
	Monitoring	Groundwater monitoring	Does not provide any additional reduction in the toxicity, mobility, or volume of contaminants.	Readily implemented.	Low capital and O&M costs.	Retain for further consideration
Removal	Extraction	Extraction wells	Effective for the collection of groundwater in overburden and bedrock.	Readily implemented.	Low capital and O&M costs.	Retain for further consideration
	Subsurface Drains	Interceptor trenches	Effective for the collection of groundwater in overburden.	Readily implemented for overburden groundwater collection only.	Moderate capital and low O&M costs.	Eliminate from further consideration
Containment	Slurry wall/grout curtain	Impermeable vertical barrier	Does not provide reduction of existing contamination levels. Partially effective for overburden aquifer only.	Readily implemented for shallow depths only.	Low capital and O&M costs for shallow depths. Significantly higher for deeper depths.	Eliminate from further consideration

TABLE 2-10 (Continued)
FINAL SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

General Response Action Component	Remedial Technology	Process Option	Effectiveness	Implementability	Cost	Conclusion
Disposal	Surface water discharge	Direct discharge to intermediate tributaries of Little Neshaminy Creek north of the facility.	Effective means of disposal.	Implementable. May require pretreatment.	Moderate capital and O&M costs.	Retain for further consideration
		Direct discharge to intermediate tributaries of Southampton Creek south of the facility.	Effective means of disposal.	Implementable. May require pretreatment.	Moderate capital and O&M costs.	Retain for further consideration
	Discharge to WWTP	Discharge to WMA or NAWC Warminster wastewater treatment plant.	Effective means of disposal.	Readily Implementable. May require pretreatment plant.	Low to Moderate capital and O&M costs.	Retain for further consideration
	Subsurface discharge	Reinjection wells	Effective means of disposal. May reduce remediation time.	Implementable for over burden. Pretreatment required.	Capital and O&M costs higher than surface discharge.	Eliminate from further consideration
	Spray irrigation	Spray irrigation jets	Effective means of disposal with verification of pumping rate and soil permeability.	Readily Implementable. May require pretreatment.	Low capital and O&M costs.	Eliminate from further consideration
In-situ Treatment	Biological	Aerobic	Potentially partially effective. Not effective for inorganics.	Not adequately demonstrated pilot- or full-scale for contaminants of concern.	Low capital and O&M costs.	Eliminate from further consideration

TABLE 2-10 (Continued)
FINAL SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS
NAWC WARMINSTER
BUCKS COUNTY, PENNSYLVANIA

General Response Action Component	Remedial Technology	Process Option	Effectiveness	Implementability	Cost	Conclusion
Treatment	Biological	Aerobic	Potentially partially effective.	Not adequately demonstrated pilot- or full-scale for contaminants of concern.	Low to moderate capital and O&M costs.	Eliminate from further consideration
	Chemical/physical	Air Stripping	Effective for primary organic contaminants.	Readily implemented, off gas treatment may be required.	Low capital cost. Low to moderate O&M costs.	Retain for further consideration.
		Activated Carbon Adsorption	Effective for organic contaminants.	Readily implementable.	Low capital cost. Low to moderate O&M costs.	Retain for further consideration.
		Photochemical Oxidation (UV/Ozonation/ Hydrogen peroxide)	Effective for primary organic contaminants.	Implementable. Few vendors and commercial installations.	Moderate capital and O&M costs.	Retain for further consideration as innovative technology.
		Filtration	Effective for removal of suspended solids.	Readily implementable.	Low capital and O&M costs.	Retain for further consideration
		Coagulation/ Flocculation/ Precipitation	Effective for removal of suspended solids.	Readily implementable.	Low capital and O&M costs.	Retain for further consideration
		Neutralization	Effective pH adjustment for pre- or post-treatment.	Readily implementable.	Low capital and O&M costs.	Retain for further consideration

3.0 DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

3.1 DEVELOPMENT OF REMEDIAL ALTERNATIVES

The purpose of this section is to develop and screen groundwater remedial alternatives based on technologies and process options that passed the final screening in Section 2.4. The alternatives developed in this section include the following:

- Alternative 1: No Action with Groundwater Monitoring.
- Alternative 2: Groundwater Extraction, Onsite Treatment at Area C, and Discharge to Surface Water in the Vicinity of Area C.
- Alternative 3: Groundwater Extraction, Treatment at Area C, and Discharge to Surface Water at Area A System Outfall.
- Alternative 4: Groundwater Extraction, Treatment at Area A, and Discharge to Surface Water at Area A System Outfall.

3.1.1 Alternative 1: No Action with Groundwater Monitoring

Under this alternative, no remedial action would be undertaken to address contaminated groundwater attributable to Area C at NAWC Warminster in overburden and shallow bedrock aquifers. Instead, additional studies necessary to identify the full name and extent of contaminated groundwater in overburden and shallow bedrock aquifers in the vicinity of Area C would be conducted as part of continuing RIs addressing the facility. In addition to these studies, monitoring of groundwater in overburden and shallow bedrock aquifers would be conducted for 30 years.

3.1.2 Alternative 2: Groundwater Extraction, Treatment at Area C and Discharge to Surface Water in the Vicinity of Area C

Under this alternative, contaminated groundwater in overburden and shallow bedrock aquifers attributable to Area C at NAWC Warminster would be extracted using a series of extraction wells. The extraction system would be designed to restore contaminated groundwater in the overburden and shallow bedrock aquifers

attributable to Area C to remedial action levels (see Section 2.3.2). The extraction wells would be located as necessary to maximize the effectiveness of the system.

3.1.2.1 Technical Approach Groundwater Extraction and Treatment

Based on the findings of the OU-3 Remedial Investigation, significant site-related groundwater impacts are confined to a limited area near the northern edge of Area C, close to but not directly downgradient of Site 8. The plume consists of low level PCE contamination, ranging in concentration to 31 μg/L in the wells sampled within and downgradient of Area C. The source of the contamination is not defined at this point, and will be further investigated during the upcoming Phase III RI. Arsenic, manganese, antimony, and beryllium are also present, but are naturally occurring and appear to be present within background ranges for these compounds. Thallium also contributed to the calculated risks; however, this chemical was detected at only one location, and it's presence/status as a site-related contaminant is questionable.

A parameter of concern from a treated water discharge perspective is arsenic, based on the very low effluent limitation provided for this parameter (see Table 2-8). The effluent limit for this parameter will be below detection levels for either of the treatment alternatives presented herein; the compliance level will be the detection limit.

Low (background) levels of arsenic were detected in groundwater during the OU-3 field investigation. Eleven of 23 wells had low level detections of total arsenic (overall average 2 μg/L), while only 2 of 23 had positive detections for dissolved arsenic. No pattern of arsenic presence was noted within Area C, with the highest detection of arsenic found in a well that is not associated with any known disposal area (Cluster 28, Well HN-28S), and background arsenic concentrations were comparable to downgradient concentrations. Regional USGS background water quality data for the Stockton Formation also indicates that low concentrations of arsenic occur naturally.

In view of the fact that samples from almost all of the monitoring wells were nondetect for dissolved arsenic, and since particulate arsenic can be expected to be reduced during pretreatment/filtration operations, it is reasonable to expect that the arsenic levels will be below detection levels. Discharges to surface waters will be monitored for arsenic, and if concentrations generally exceed discharge requirements, the system can be adapted as needed to reduce the arsenic levels. For example, the outfall could be extended to a larger receiving stream if consistent compliance quality effluent is not produced.

Based on these considerations, the technical approaches to treatment of groundwater at Area C considers only PCE and iron removal. Iron removal is included as pretreatment to assure that the PCE treatment process operates smoothly.

3.1.2.2 Extraction Well System

For remedial alternatives evaluation and cost estimation purposes, a groundwater extraction system design was prepared for Area C. The extraction system consists of a line of wells located along the downgradient (northern) edge of Area C, within the lateral boundaries of the plume. Based on aquifer characteristics determined during the OU-3 field investigation and on general aquifer characteristics used for the recent interim groundwater extraction and treatment design for OU-1, a series of eight extraction wells pumping at an average rate of 6.5 gpm per well was estimated to be necessary to meet the objectives of the remedy. Each well was assumed to be 6 inches in diameter and approximately 120 feet deep each, which corresponds to the maximum observed depth of contamination to date.

Well locations will be spaced approximately 80 feet apart (normal to the groundwater flow direction) and will be placed along a line that is oriented parallel to the base boundary and at an angle to the groundwater flow direction. The extraction well locations are shown in Figure 3-1, along with the plume containment boundary. For the extraction system design, the capture zone width at the midpoint of the extraction system is 800 feet, expanding outward to a maximum width of 1,600 feet further to the south (upgradient). The maximum downgradient limit of the extraction system's capture zone is approximately 200 feet from the line of wells, to the north.

The hydraulic characteristics of the Stockton Formation in Area C are not well defined at this time. Accordingly, the extraction system design should be regarded as a conceptual design only, subject to revision once the aquifer characteristics are better defined. In particular, the downgradient extent of the capture zone of the FS extraction system design cannot be accurately predicted. The need to add offsite extraction well locations to capture the offsite portion of the plume should be evaluated once more data is evaluated, and the extraction system design modified as appropriate in the final design process, if groundwater extraction and treatment is the selected remedial alternative.

Groundwater extraction system design calculations are included in Appendix A.

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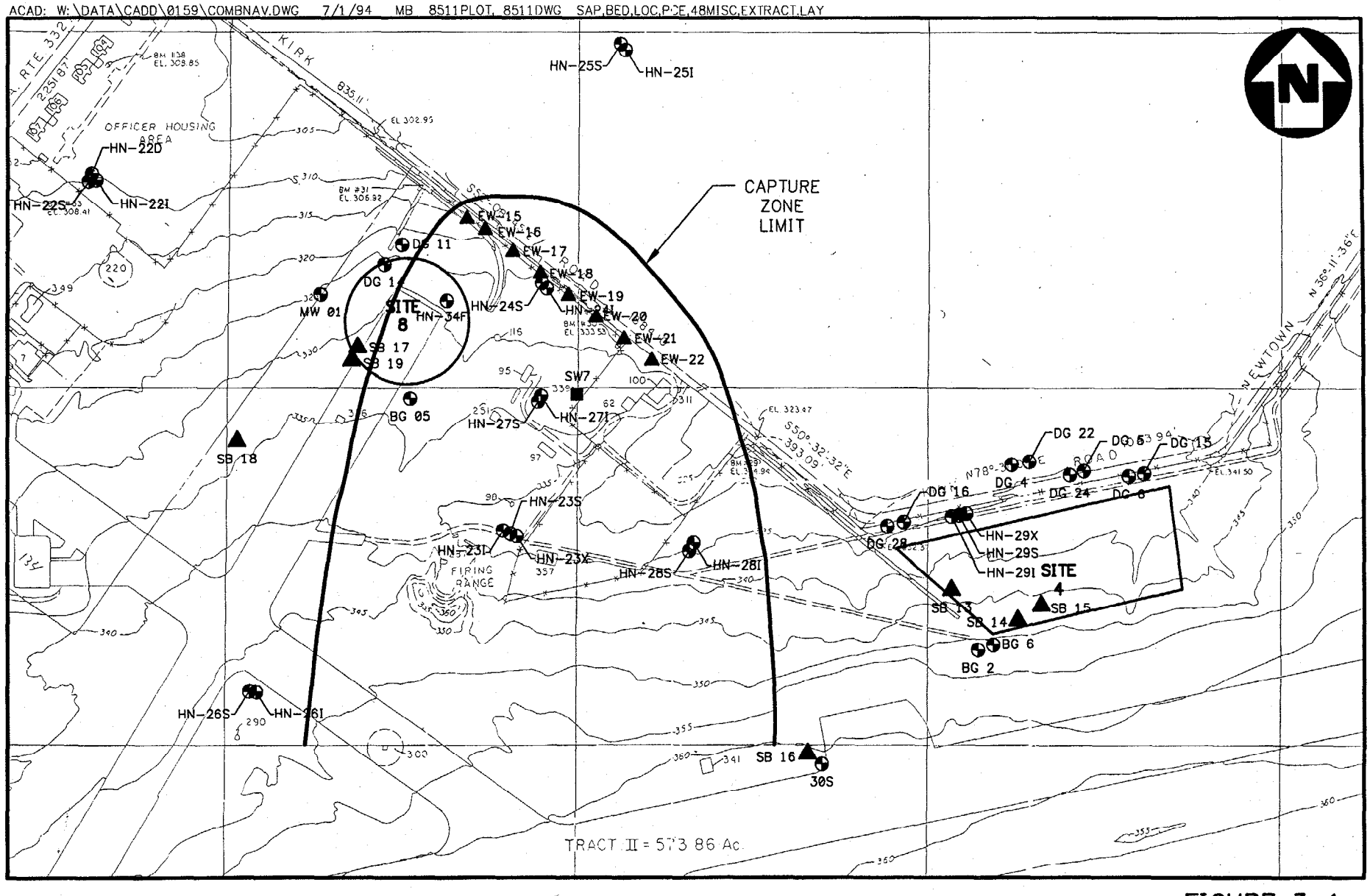

FIGURE 3-1

EXTRACTION WELL LOCATIONS
NAWC WARMINSTER, PA

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3.1.2.3 Treatment System

The extracted groundwater from Area C would be pumped to an adjacent treatment plant within Area C. Treatment would consist of line injection of hydrogen peroxide to convert soluble ferrous iron to insoluble ferric iron, filtration to remove suspended solids and precipitated iron, and carbon adsorption to remove organics. A slight pH drop is associated with the precipitation of iron; however, it would not be sufficient to require a neutralization step. Air stripping has been considered and eliminated as a treatment technology for this alternative. PADER requires the application of Best Available Technology to air stripper emissions on remediation projects, regardless of emissions. For vapor phase carbon to be effective, the air stream must be heated to reduce relative humidity sufficiently that the carbon can be used cost effectively. The low levels of volatile organics and the cost of the ancillary processes make air stripping an unattractive alternative. In view of these considerations, air stripping was eliminated as a treatment alternative. Photochemical oxidation is alternate treatment technology that could be considered subject to verification by treatability testing. However, for cost estimating purposes, activated carbon treatment has been used.

The discharge would be required to meet Pennsylvania NPDES requirements which consider both the flow and quality of the discharge. The discharge limits that would be imposed by the Pennsylvania Department of Environmental Resources (PADER) in an NPDES Permit are expected to be similar to those shown in Table 2-8. Treated water would be discharged to an unnamed intermittent tributary of Little Neshaminy Creek that begins near the western terminus of the extraction well field, on the other side of Kirk Road (see Figure 3-2) or further downstream of this point.

A collector drain system would collect the water removed from the ground and convey it by gravity to an in-ground sump from which it would be pumped to the treatment plant. Figure 3-3 shows a schematic flow diagram of the proposed treatment system.

Treatment plant influent concentrations were based on an average concentration of PCE in Area C of 6 μg/L, with an assumed influent total suspended solids (TSS) of 10 mg/L. Effluent limitations were assumed to be those indicated in Table 2-8. The flow rate used was a projected 52 gpm (see Appendix A).

Based on the estimated initial influent concentrations, the assumed effluent concentrations, and the projected flow rate, unit processes were determined to remove both organic and inorganic contaminants. Filtration was selected to remove suspended solids and to prevent sediments from interfering with the functioning of the downstream processes. Carbon adsorption was selected to remove PCE. Conceptual design calculations are provided in Appendix A.

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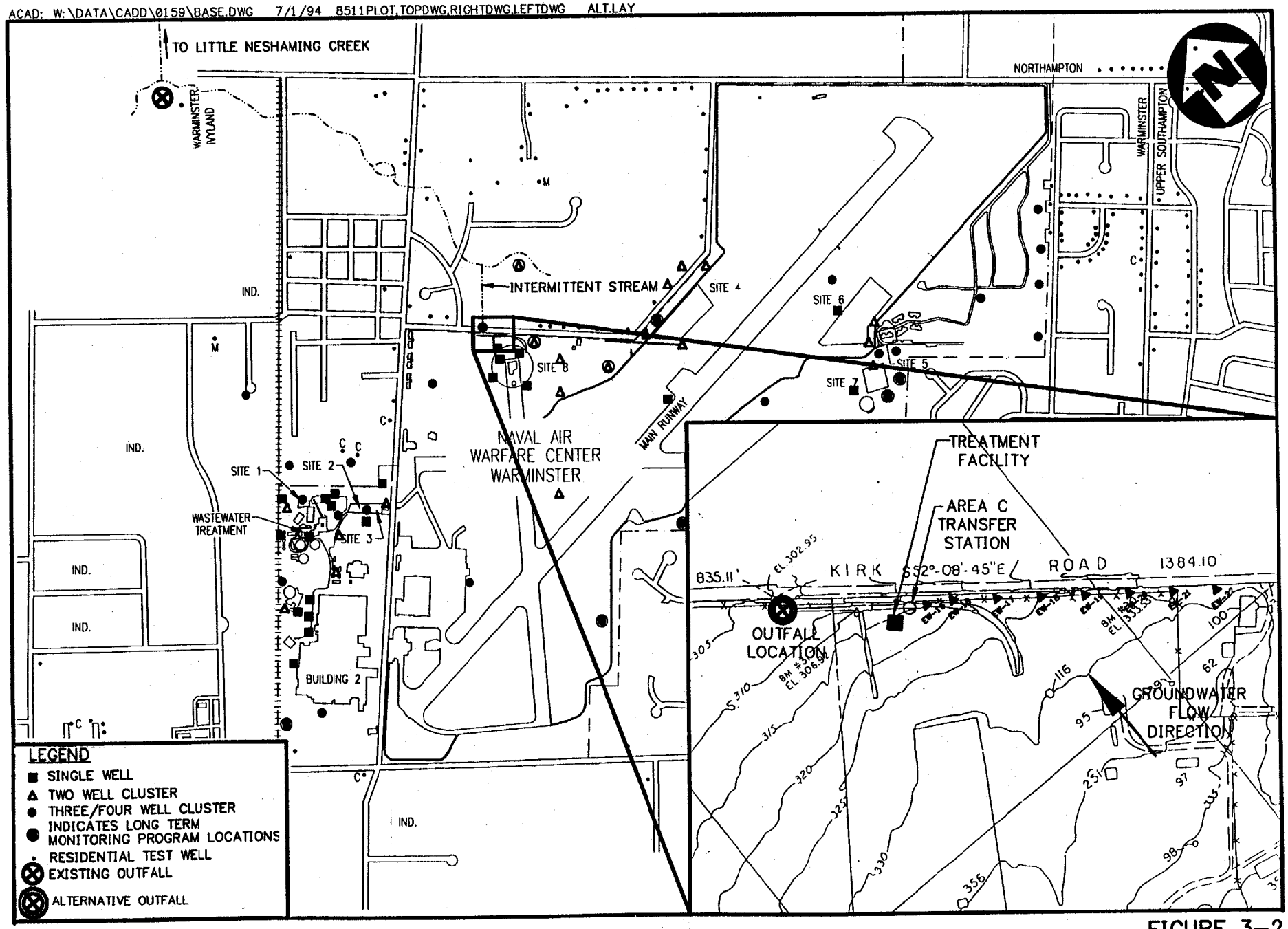

FIGURE 3-2

ALTERNATIVE 2: PLAN
NAWC WARMINSTER, PA

Halliburton NUS CORPORATION

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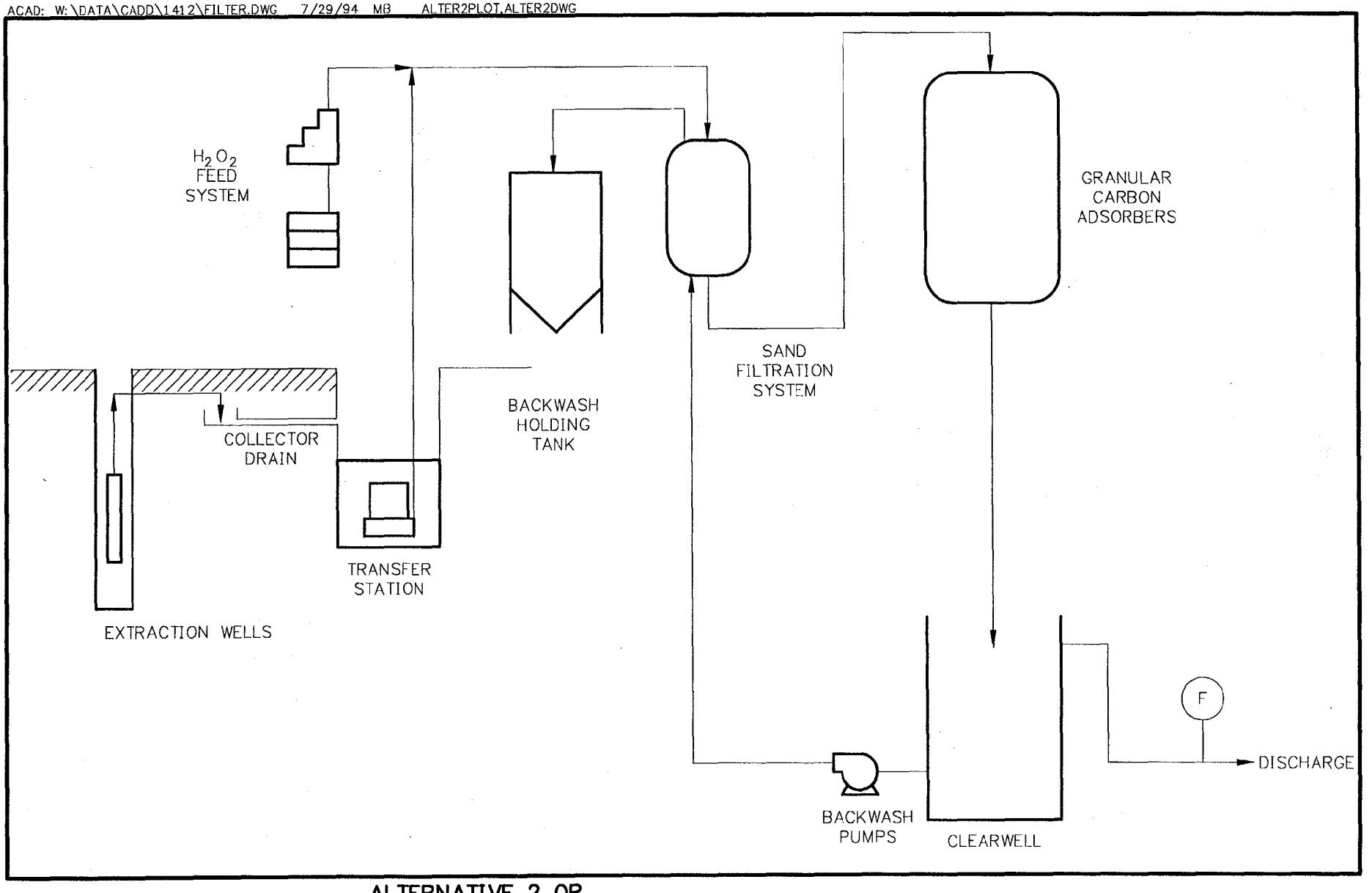

ALTERNATIVE 2 OR
ALTERNATIVE 4 (SEPARATE TREATMENT SYSTEM)
TREATMENT SYSTEM
FLOW DIAGRAM
NAWC WARMINSTER, PA

FIGURE 3-3

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3.1.3 Alternative 3: Groundwater Extraction, Treatment at Area C, and Discharge to Surface Water at Area A System Outfall

This alternative is the same as Alternative 2 (discussed in Section 3.1.2), except that it would utilize the existing outfall which discharges to a perennial stream along Bristol Road (see Figure 3-2). Groundwater would be transferred by pumping to Area A and combining the treated discharge with the treated discharge from the Area A facility (see Figures 3-4 and 3-5). The point of connection to the outfall would be at the chlorine contact chamber, or the Area C transfer line could intersect with the outfall line at some closer intermediate point.

The discharge would be required to meet Pennsylvania NPDES requirements which consider both the flow and quality of the discharge. The discharge limits that would be imposed by the Pennsylvania Department of Environmental Resources (PADER) in an NPDES Permit are expected to be similar to those shown in Table 2-8.

3.1.4 Alternative 4: Groundwater Extraction, Treatment at Area A, and Discharge to Surface Water at Area A System Outfall

Under this alternative, overburden and shallow bedrock groundwater within the facility boundary would be extracted using a series of extraction wells. The conceptual extraction systems are the same as for the Alternative 2, discussed in Section 3.1.2.

The extracted groundwater would be conveyed to the treatment facility which has been designed to treat plumes in Areas A and B (see Figures 3-4 and 3-6) with some additional capacity, or to a separate treatment system which could be within the same building or within a separate structure. Treatment at the facility designed to treat the plumes in Areas A and B will include air stripping to remove volatile organics, precipitation/filtration to remove metals, and carbon adsorption to remove semivolatile organics. Emissions from the air stripper would be treated by vapor-phase carbon adsorption.

The discharge would be required to meet Pennsylvania NPDES requirements which consider both the flow and quality of the discharge. The discharge limits that would be imposed by the Pennsylvania Department of Environmental Resources (PADER) in an NPDES Permit are expected to be similar to those shown in Table 2-8. Treated water would be discharged to the existing outfall on an unnamed tributary of Little Neshaminy Creek (see Figure 3-2).

Available capacity of the treatment facility is an important consideration. The facility to be constructed for the treatment of extracted groundwater flows from Areas A and B is based on a design flow rate of 130 gpm.

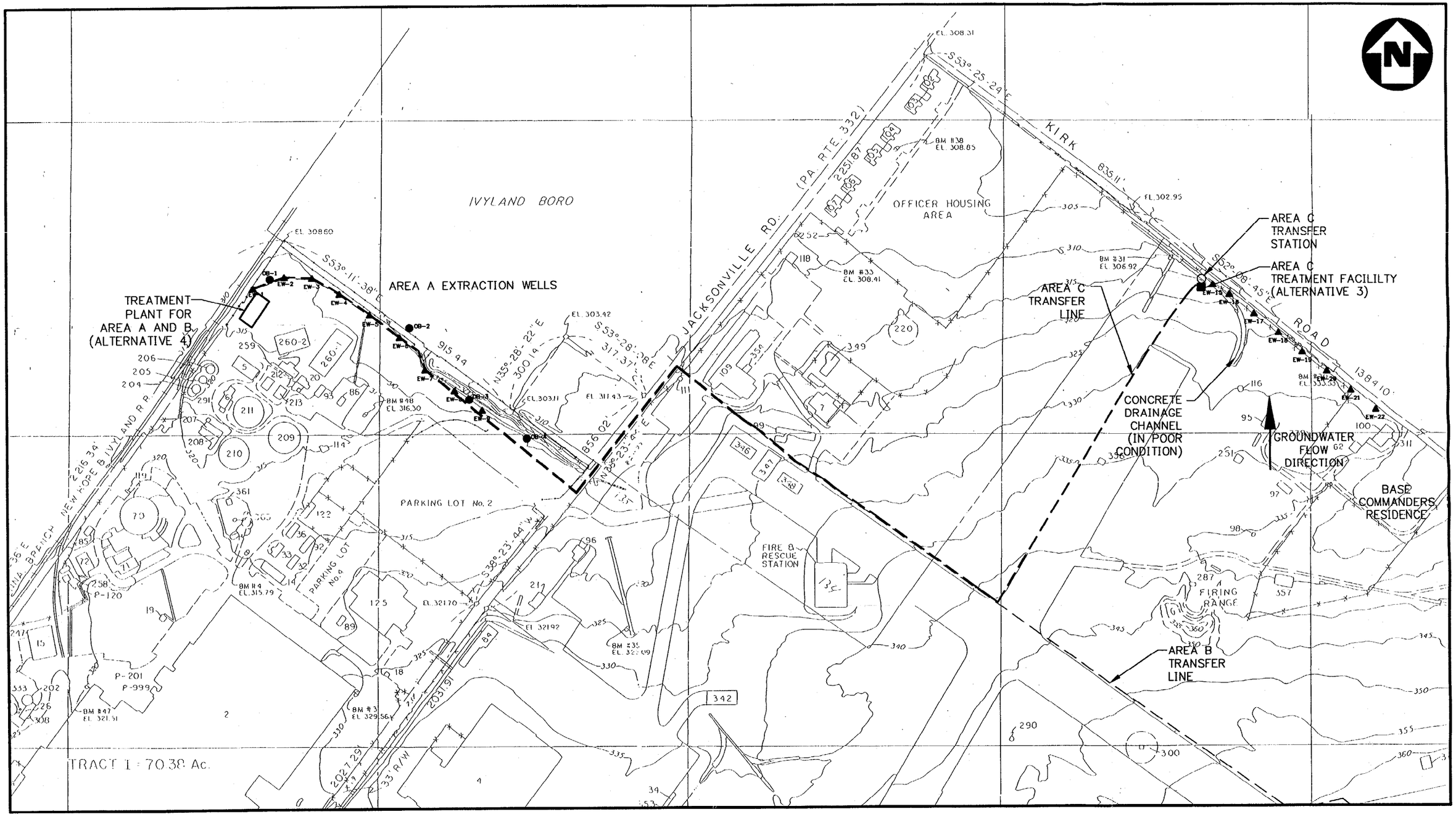

FIGURE 3-4

ALTERNATIVE 3 OR 4
EXTRACTION WELLS AND TRANSFER LINE
NAWC WARMINSTER, PA

0 300 600
SCALE IN FEET

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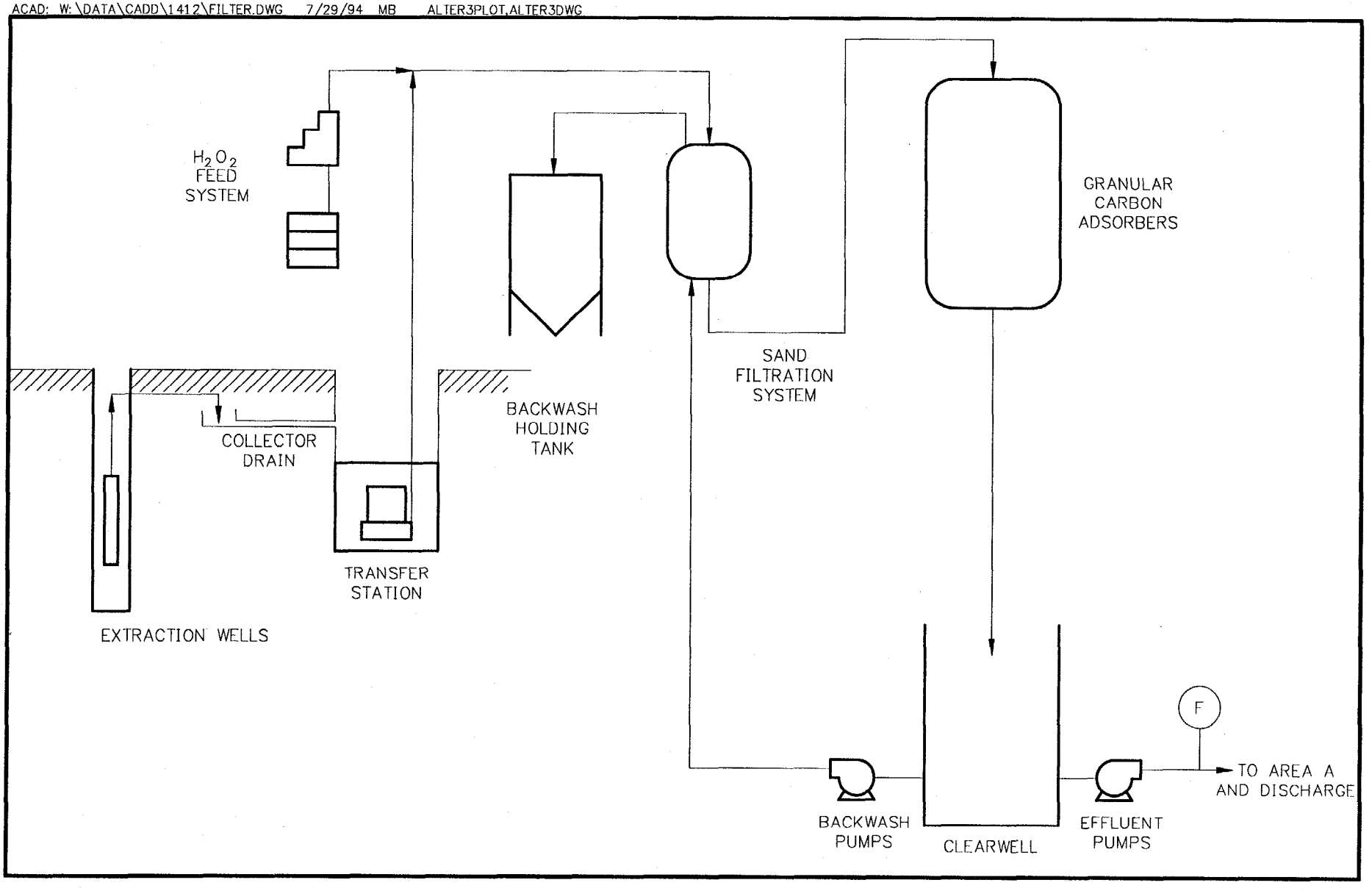

ALTERNATIVE 3
TREATMENT SYSTEM
FLOW DIAGRAM
NAWC WARMINSTER, PA

FIGURE 3-5

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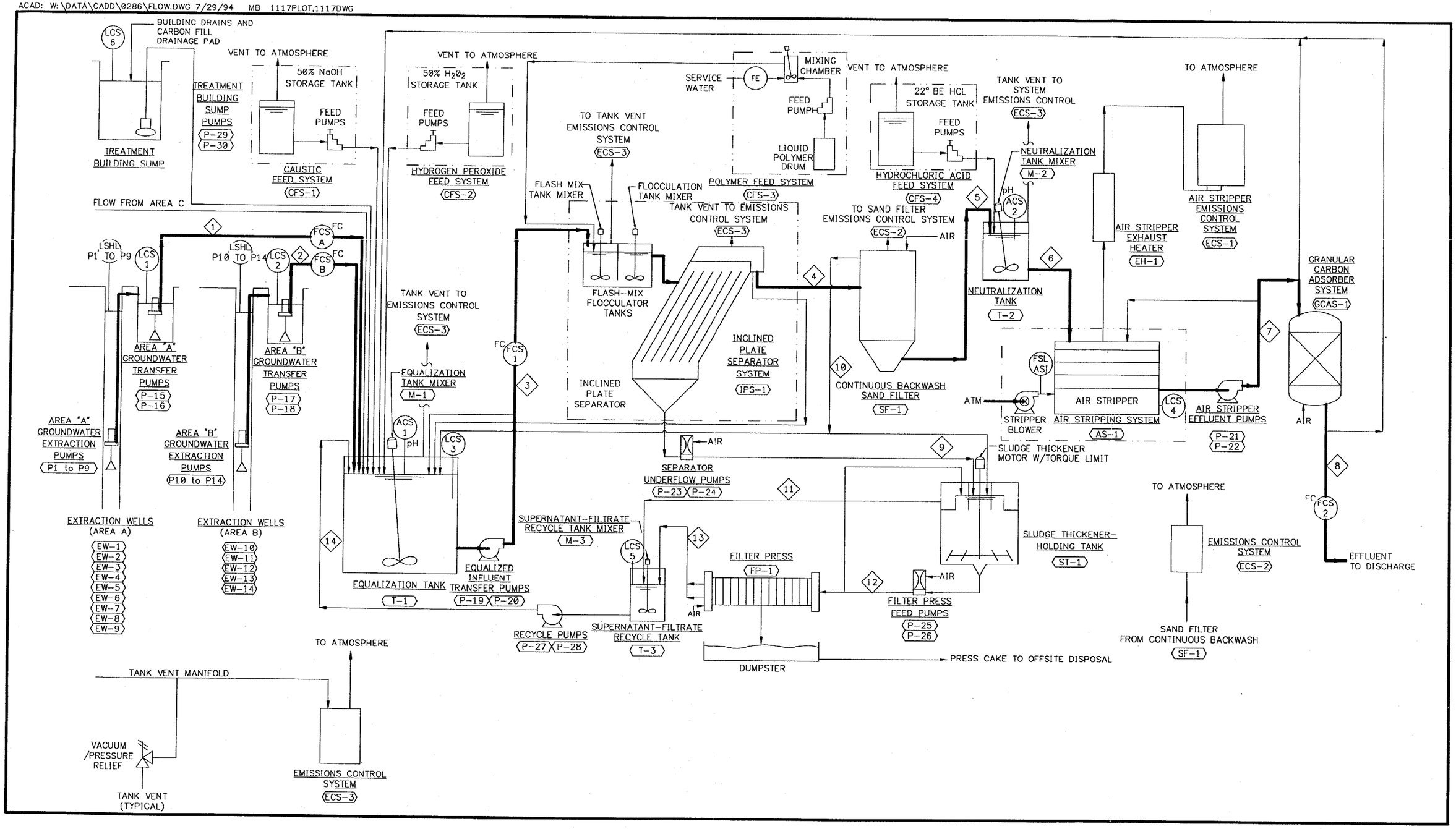

ALTERNATIVE 4
(COMMON TREATMENT SYSTEM)
AREA A TREATMENT FACILITY
PROCESS FLOW DIAGRAM
NAWC WARMINSTER, PA

FIGURE 3-6

Halliburton NUS CORPORATION

R-06-94-24

0007 B02Z

The flows from Areas A and B are projected to be 86 gpm combined. This leaves 44 gpm reserved capacity.

The design limiting unit process in the system is the air stripper, which is rated at 130 gpm. An additional 52 gpm from Area C would result in a flow of 138 gpm. However, the air stripper has an actual capacity that is greater than the rating. In this case, the air stripper has a capacity of about 160 gpm. Therefore, operating at 138 gpm would not impact performance and would allow a 15 percent margin of safety. Impacts would be with respect to operating costs.

If a separate treatment facility is constructed at Area A, it would be similar to that shown on Figure 3-3. The groundwater from Area C would be treated in a separate treatment system at Area A. The purpose of this alternative, if exercised, would be to preserve the treatment capacity of the facility that is planned for the treatment of groundwater extracted from Areas A and B. This alternative would result in two treatment facilities, one for treating groundwater with higher levels of contaminants (from Area A), and a simpler facility for treating the groundwater from Area C. Both facilities would treat to a level sufficient to meet ARARs.

3.2 SCREENING OF REMEDIAL ALTERNATIVES

All technologies and process options that were combined into the remedial alternatives that were found to be effective and implementable are presented in Section 2.5.2. Therefore, further screening of alternatives, based on effectiveness, implementability, and cost, is not necessary to reduce the number of alternatives for detailed analysis. All of the alternatives previously developed in Section 3.1 will be retained for detailed analysis in Section 4.0. The alternatives are as follows:

- Alternative 1: No Action with Groundwater Monitoring
- Alternative 2: Groundwater Extraction, Treatment at Area C, and Discharge to Surface Water in the Vicinity of Area C
- Alternative 3: Groundwater Extraction, Treatment at Area C, and Discharge to Surface Water at Area A System Outfall
- Alternative 4: Groundwater Extraction, Treatment at Area A, and Discharge to Surface Water at Area A System Outfall

4.0 DETAILED ANALYSIS OF ALTERNATIVES

Detailed analysis of alternatives will be conducted in accordance with the "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA" (EPA, 1988) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), including the February 1990 revisions. In conformance with the NCP, seven of the following nine criteria will be used for the detailed analysis:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost
- State acceptance (not evaluated at this time)
- Community acceptance (not evaluated at this time)

State acceptance and community acceptance will be evaluated by addressing comments received after the FFS has been reviewed by the Pennsylvania Department of Environmental Resources, local townships and authorities, and the public.

Achievement of the groundwater remedial action objectives for OU-3 are evaluated for each alternative under the Overall Protection of Human Health and the Environment criterion.

Overall Protection of Human Health and the Environment: The primary requirement is that remedial actions are protective of human health and the environment. A remedy is protective if it adequately eliminates, reduces, or controls all current and potential site risks posed through each exposure pathway at the site. At sites where hazardous substances remain without engineering or institutional controls, after the remedy is implemented, the remedy must allow for unrestricted use and unlimited exposure for human and environmental receptors. Alternatively, adequate engineering controls, institutional controls, or some combination of the two must be implemented to control exposure and thereby ensure reliable protection over time. In addition, implementation of a remedy cannot result in unacceptable short-term risks or cross-media impacts on human health and the environment.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs): Compliance with ARARs is one of the statutory requirements for remedy selection. Alternatives are developed and refined throughout the FFS process to ensure that they will meet all of the respective ARARs or that there is a good rationale for waiving an ARAR. During the detailed analysis, information on Federal and state action-specific ARARs will be assembled along with previously identified contaminant-specific and location-specific ARARs. Alternatives will be refined as necessary to ensure compliance with these requirements.

Long-term Effectiveness and Permanence: This criterion reflects CERCLA's emphasis on implementing remedies that will insure protection of human health and the environment in the future, as well as in the near term. In evaluating alternatives for their long-term effectiveness and the degree of permanence they afford, the analysis will focus on residual risks present at the site after the completion of the remedial action. The analysis will include consideration of the following:

- Degree or threat posed by the hazardous substances remaining at the site.
- Adequacy of any controls (e.g., engineering and institutional controls) used to manage the hazardous substances remaining at the site.
- Reliability of those controls.
- Potential impacts on human health and the environment, should the remedy fail, based on assumptions included in the reasonable maximum exposure scenario.

Reduction of Toxicity, Mobility, or Volume through Treatment: This criterion addresses the statutory preference for remedies that employ treatment as a principal element by ensuring that the relative performance of the treatment alternatives in reducing the toxicity, mobility, or volume will be assessed. Specifically, the analysis will examine the magnitude, significance, and irreversibility of reductions.

Short-term Effectiveness: This criterion examines the short-term impacts of the alternative (i.e., impacts during construction and implementation) on the neighboring community, workers, or surrounding environment. This includes potential threats to human health and the environment associated with the removal, treatment, and transportation of hazardous substances. The potential cross-media impacts of the remedy and the time to achieve protection of human health and the environment will also be analyzed.

Implementability: Implementability considerations include the technical and administrative feasibility of the alternatives, as well as the availability of goods and services (e.g., treatment, storage, or disposal capacity)

on which the viability of the alternative depends. Implementability considerations often affect the timing of various remedial alternatives (e.g., limitations on the season in which the remedy can be implemented, the number and complexity of material handling steps, the need to obtain permits, and the need to secure technical services). Onsite activities must comply with the substantive portions of applicable permitting regulations.

Cost: Cost includes all capital costs and annual operation and maintenance (O&M) costs incurred over the life of the project. The focus during detailed analysis is on the present worth of these costs. Costs are used to select the most cost-effective alternative that will achieve the remedial action objectives.

State Acceptance: This criterion, which is an ongoing concern throughout the remedial process, reflects the statutory requirement to provide substantial and meaningful state involvement. State comments may be addressed during the development of the FFS, as appropriate, although formal state comments usually will not be received until after the state has reviewed the draft FFS and draft Proposed Plan prior to the public comment period. This criterion will not be used for detailed analysis of alternatives in the FFS.

Community Acceptance: This criterion refers to the community's comments on the remedial alternatives under consideration, where "community" is broadly defined to include all interested parties. These comments are taken into account throughout the FFS process. However, only preliminary assessment of community acceptance can be conducted during the development of the FFS, since formal public comment will not be received until after the public comment period for the FFS is held. This criterion will not be used for detailed analysis in the FFS.

4.1 ALTERNATIVE 1: NO ACTION WITH GROUNDWATER MONITORING

4.1.1 Description

Under this alternative, no remedial action would be undertaken to address contaminated groundwater attributable to Area C in overburden and shallow bedrock aquifers. Monitoring of groundwater in overburden and shallow bedrock aquifers would be conducted for 30 years.

4.1.2 Overall Protection of Human Health and the Environment

This alternative would delay the implementation of actions necessary to meet the remedial action objectives in the case of OU-3. The selection of a remedy addressing contaminated groundwater would not be initiated

until completion of the studies necessary to fully identify the nature and extent of contaminated groundwater attributable to Area C.

4.1.3 Compliance with ARARs

Since no action would be taken under this alternative, there would be no ARARs.

4.1.4 Long-Term Effectiveness and Permanence

This alternative does not involve remedial action that would pose a risk to human health or the environment during implementation would not be effective. Groundwater contaminants would continue to migrate and would present unacceptable risks to human health.

4.1.5 Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative does not employ treatment to reduce the toxicity, mobility, or volume of contaminated groundwater in overburden and shallow bedrock aquifers.

4.1.6 Short-Term Effectiveness

This alternative does not involve remedial action that would pose a risk to human health and the environment during implementation. Groundwater contaminants would continue to migrate and would present potential unacceptable risks to human health.

4.1.7 Implementability

Since no remedial action will be taken, this criterion is not applicable. Groundwater monitoring can be performed using existing monitoring wells. Additional wells, if needed, could be readily installed.

4.1.8 Cost

The estimated costs for this alternative are as follows:

- Estimated capital cost: $69,696
- Estimated annual cost: $116,000
- Estimated 30-year present worth: $1,853,000

The present-worth cost estimate of this alternative is based on a 30-year period of quarterly monitoring. Detailed costs are presented in Appendix B.

4.2 ALTERNATIVE 2: GROUNDWATER EXTRACTION, ONSITE TREATMENT AT AREA C AND DISCHARGE TO SURFACE WATER IN THE VICINITY OF AREA C

4.2.1 Description

Under this alternative, contaminated groundwater in overburden and shallow bedrock aquifers would be extracted using a series of extraction wells. The extraction wells would be located as necessary to maximize the effectiveness of the system. The extracted groundwater would be pumped to an onsite treatment system constructed specifically to treat groundwater. Treatment would be at a treatment system located within Area C. The treatment system would consist of line injection of hydrogen peroxide to convert soluble ferrous iron to insoluble ferric iron, filtration to remove suspended solids and precipitated iron, and carbon adsorption to remove organics. This approach would be effective in reducing the toxicity, mobility, and volume of groundwater contaminants associated with Area C. Upon meeting effluent limits consistent with NPDES requirements, the treated water would be discharged to an unnamed intermittent tributary of Little Neshaminy Creek that drains north from Kirk Road.

This alternative would incorporate the sampling of 1) observation wells constructed for the purpose of observing the performance of the extraction well system, 2) monitoring wells which are appropriate for observing extraction well performance and 3) extraction wells. For cost estimation purposes, it was assumed that a total of 24 wells would be sampled and that sampling would be conducted on a quarterly basis for 30 years. Groundwater samples would be analyzed for metals and volatile organics. Once a reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis.

4.2.2 Overall Protection of Human Health and the Environment

This alternative would protect both human health and the environment by reducing groundwater contaminants to levels which do not present an unacceptable risk.

4.2.3 Compliance with ARARs

Under this alternative, it is unknown whether discharge of treated groundwater to the unnamed tributary of Little Neshaminy Creek north of Kirk Road could meet NPDES requirements regarding flow rate and/or effluent quality. Otherwise, this alternative is expected to meet all ARARs.

4.2.4 Long-Term Effectiveness and Permanence

This alternative would be effective with respect to long-term effectiveness and permanence. To ensure this effectiveness for all contaminated groundwater attributable to NAWC, this alternative provides for conserving the capacity of the treatment plant designed to meet the remediation needs for OU-1, to the extent necessary.

4.2.5 Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative would be effective in reducing the toxicity, mobility and volume of groundwater contaminants associated with Area C through treatment.

The treatment system would generate residuals such as sludge and spent activated carbon that would require further treatment or disposal. It is assumed that dewatered sludge would be disposed of as a non-hazardous waste and that spent activated carbon would be regenerated by a vendor of the carbon.

4.2.6 Short-Term Effectiveness

There would be no additional risks to the general public or the environment during implementation of this alternative. Workers would be required to wear protective equipment during activities where they may be exposed to hazardous materials.

4.2.7 Implementability

The technologies proposed for groundwater extraction and treatment are demonstrated and commercially available. These systems are reliable if properly maintained. The treatment plant discharge would be subject to monitoring requirements which would be imposed by the NPDES permit.

This alternative includes the discharge of the treated groundwater to an intermittent, unnamed tributary of Little Neshaminy Creek located immediately north of Kirk Road (see Figure 3-2). This discharge would be

required to meet NPDES requirements which consider the flow rate and effluent quality of the discharge. It is unknown whether the discharge could meet these requirements, which have not been established at this time.

4.2.8 Cost

The estimated costs for this alternative are as follows:

- Estimated capital costs: $1,545,393
- Estimated annual costs: $229,629
- Estimated 30-year present worth: $5,075,000

The present worth cost estimate of this alternative is based on a 30-year operation period for the groundwater extraction and treatment system. Detailed costs are presented in Appendix B.

4.3 ALTERNATIVE 3: GROUNDWATER EXTRACTION, ONSITE TREATMENT AT AREA C AND DISCHARGE TO SURFACE WATER AT AREA A SYSTEM OUTFALL

4.3.1 Description

Under this alternative, contaminated groundwater in overburden and shallow bedrock aquifers would be extracted using a series of extraction wells. The extraction wells would be located as necessary to maximize the effectiveness of the system. The extracted groundwater would be pumped to an onsite treatment system constructed specifically to treat groundwater. Treatment would be at a treatment system located within Area C. The treatment system would consist of line injection of hydrogen peroxide to convert soluble ferrous iron to insoluble ferric iron, filtration to remove suspended solids and precipitated iron, and carbon adsorption to remove organics. This approach would be effective in reducing the toxicity, mobility, and volume of groundwater contaminants associated with Area C. Upon meeting effluent limits consistent with NPDES requirements, the treated water would be discharged to an unnamed tributary of Little Neshaminy Creek via the existing outfall along Bristol Road.

This alternative would incorporate the sampling of 1) observation wells constructed for the purpose of observing the performance of the extraction well system, 2) monitoring wells which are appropriate for observing extraction well performance and 3) extraction wells. For cost estimation purposes, it was assumed that a total of 24 wells would be sampled and that sampling would be conducted on a quarterly basis for 30 years. Groundwater samples would be analyzed for metals and volatile organics. Once a

reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis.

4.3.2 Overall Protection of Human Health and the Environment

This alternative would protect both human health and the environment by reducing groundwater contaminants to levels which do not present an unacceptable risk.

4.3.3 Compliance with ARARs

Under this alternative, compliance with ARARs for discharge of treated water and for air emissions is expected to be achieved.

4.3.4 Long-Term Effectiveness and Permanence

This alternative would be effective with respect to long-term effectiveness and permanence. To ensure this effectiveness for all contaminated groundwater attributable to NAWC, this alternative provides for conserving the capacity of the treatment plant designed to meet the remediation needs for OU-1, to the extent necessary.

4.3.5 Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative would be effective in reducing the toxicity, mobility and volume of groundwater contaminants associated with Area C through treatment.

The treatment system would generate residuals such as sludge and spent activated carbon that would require further treatment or disposal. It is assumed that dewatered sludge would be disposed of as a non-hazardous waste and that spent activated carbon would be regenerated by a vendor of the carbon.

4.3.6 Short-Term Effectiveness

There would be no additional risks to the general public or the environment during implementation of this alternative. Workers would be required to wear protective equipment during activities where they may be exposed to hazardous materials.

4.3.7 Implementability

The technologies proposed for groundwater extraction and treatment are demonstrated and commercially available. These systems are reliable if properly maintained. The treatment plant discharge would be subject to monitoring requirements which would be imposed by the NPDES permit.

This alternative includes the discharge of the treated groundwater to the existing outfall of the NAWC Wastewater Treatment Plant (WWTP), which discharges to an unnamed tributary of Little Neshaminy Creek at a point located along Bristol Road (see Figure 3-2). Adequate capacity is available per an existing NPDES permit for the NAWC WWTP outfall to accommodate this treated groundwater. This discharge would be required to meet NPDES requirements which consider the flow rate and effluent quality of the discharge.

4.3.8 Cost

The estimated costs for this alternative are as follows:

- Estimated capital costs: $1,839,690
- Estimated annual costs: $220,075
- Estimated 30-year present worth: $5,224,000

The present worth cost estimate of this alternative is based on a 30-year operation period for the groundwater extraction and treatment system. Detailed costs are presented in Appendix B.

4.4 ALTERNATIVE 4: GROUNDWATER EXTRACTION, TREATMENT AT AREA A AND DISCHARGE TO SURFACE WATER AT AREA A SYSTEM OUTFALL

4.4.1 Description

Under this alternative, contaminated groundwater in overburden and shallow bedrock aquifers would be extracted using a series of extraction wells. The extraction wells would be located as necessary to maximize the effectiveness of the system. The extracted groundwater would be pumped to an onsite treatment system constructed specifically to treat groundwater.

Treatment would either be at the facilities to be constructed to address groundwater contamination at Areas A or B, or by separate treatment systems located within Area A. The former facility is part of a separate interim remedial action which is designed to accommodate a range of groundwater compositions.

The facility will include filtration for removal of precipitated metal salts and other suspended solids, coagulation/flocculation/precipitation, for removal of dissolved metals, neutralization of pH control, air stripping for removal of volatile organics, and activated carbon adsorption for removal of semivolatile organics.

The separate treatment system would consist of line injection of hydrogen peroxide to convert soluble ferrous iron to insoluble ferric iron, filtration to remove suspended solids and precipitated iron, and carbon adsorption to remove organics. Both approaches would be equally effective in reducing the toxicity, mobility, and volume of groundwater contaminants associated with Area C. Upon meeting effluent limits consistent with NPDES requirements, the treated water would be discharged to an unnamed tributary of Little Neshaminy Creek via the existing outfall along Bristol Road.

This alternative would incorporate the sampling of 1) observation wells constructed for the purpose of observing the performance of the extraction well system, 2) monitoring wells which are appropriate for observing extraction well performance and 3) extraction wells. For cost estimation purposes, it was assumed that a total of 24 wells would be sampled and that sampling would be conducted on a quarterly basis for 30 years. Groundwater samples would be analyzed for metals and volatile organics. Once a reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis.

4.4.2 Overall Protection of Human Health and the Environment

This alternative would protect both human health and the environment by reducing groundwater contaminants to levels which do not present an unacceptable risk.

4.4.3 Compliance with ARARs

Under this alternative, compliance with ARARs for discharge of treated water and for air emissions is expected to be achieved.

4.4.4 Long-Term Effectiveness and Permanence

This alternative would be effective with respect to long-term effectiveness and permanence. To ensure this effectiveness for all contaminated groundwater attributable to NAWC, this alternative provides for conserving the capacity of the treatment plant designed to meet the needs for OU-1, to the extent necessary.

4.4.5 Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative would be equally effective in reducing the toxicity, mobility and volume of groundwater contaminants associated with Area C through treatment.

Either treatment system would generate residuals such as sludge and spent activated carbon that would require further treatment or disposal. It is assumed that dewatered sludge would be disposed of as a non-hazardous waste and that spent activated carbon would be regenerated by a vendor of the carbon.

4.4.6 Short-Term Effectiveness

There would be no additional risks to the general public or the environment during implementation of this alternative. Workers would be required to wear protective equipment during activities where they may be exposed to hazardous materials.

4.4.7 Implementability

The technologies proposed for groundwater extraction and treatment are demonstrated and commercially available. These systems are reliable if properly maintained. The treatment plant discharge would be subject to monitoring requirements which would be imposed by the NPDES permit.

This alternative includes the discharge of the treated groundwater to the existing outfall of the NAWC WWTP, which discharges to an unnamed tributary of Little Neshaminy Creek at a point located along Bristol Road (see Figure 3-2). Adequate capacity is available per an exiting NPDES permit for the NAWC WWTP outfall to accommodate this treated groundwater. This discharge would be required to meet NPDES requirements which consider the flow rate and effluent quality of the discharge.

4.4.8 Cost

The estimated costs for this alternative are as follows:

- Estimated capital costs: $1,186,852 $1,782,904
- Estimated annual costs: $244,444 $214,729
- Estimated 30-year present worth: $4,944,000 $5,084,000

The present worth cost estimate of this alternative is based on a 30-year operation period for the groundwater extraction and treatment system. Detailed costs are presented in Appendix B.

4.5 SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

A summary of the detailed analyses for the alternatives for Area C discussed herein is provided in Table 4-1.

TABLE 4-1

SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES
NAWC WARMINSTER

Criterion	Alternative 1: No Action with Groundwater Monitoring	Alternative 2: Groundwater Extraction, Treatment at Area C, and Discharge to Surface Water in the Vicinity of Area C	Alternative 3: Groundwater Extraction, Treatment at Area C, and Discharge to Surface Water at Area A System Outfall	Alternative 4: Groundwater Extraction, Treatment at Area A, and Discharge to Surface Water at Area A System Outfall
Overall Protection of Human Health and the Environment	Would delay implementation of action needed to meet remedial objectives. Would not meet remedial objective of minimizing further contaminant migration.	Would minimize migration of contaminants in overburden and shallow bedrock aquifers.	Would minimize migration of contaminants in overburden and shallow bedrock aquifers.	Would minimize migration of contaminants in overburden and shallow bedrock aquifers.
Compliance with ARARs	No ARARs.	It is unknown whether discharge of treated groundwater to the unnamed tributary of Little Neshaminy Creek north of Kirk Road could meet NPDES requirements regarding flow rate and/or effluent quality. No location-specific ARARs.	ARARs for discharge of treated water are expected to be achieved. No location-specific ARARs.	ARARs for discharge of treated water are expected to be achieved. No location-specific ARARs.
Long-Term Effectiveness and Permanence	Delaying remedial action would result in additional contaminant migration and could possibly prolong time required to restore aquifers of concern.	Would initiate process of minimizing contaminant migration in overburden and shallow bedrock aquifers as soon as possible. Initiation of pumping and treatment may reduce the time necessary to restore the affected aquifers. Provides for conserving the capacity of the treatment plant designed to meet the remediation needs of OU-1, to the extent necessary. Long-term monitoring and O&M required.	Would initiate process of minimizing contaminant migration in overburden and shallow bedrock aquifers as soon as possible. Initiation of pumping and treatment may reduce the time necessary to restore the affected aquifers. Provides for conserving the capacity of the treatment plant designed to meet the remediation needs of OU-1, to the extent necessary Long-term monitoring and O&M required.	Would initiate process of minimizing contaminant migration in overburden and shallow bedrock aquifers as soon as possible. Initiation of pumping and treatment may reduce the time necessary to restore the affected aquifers. Provides for conserving the capacity of the treatment plant designed to meet the remediation needs of OU-1, to the extent necessary. Long-term monitoring and O&M required.

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TABLE 4-1 (Continued)
SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES
NAWC WARMINSTER

Criterion	Alternative 1: No Action with Groundwater Monitoring	Alternative 2: Groundwater Extraction, Treatment at Area C, and Discharge to Surface Water in the Vicinity of Area C	Alternative 3: Groundwater Extraction, Treatment at Area C, and Discharge to Surface Water at Area A System Outfall	Alternative 4: Groundwater Extraction, Treatment at Area A, and Discharge to Surface Water at Area A System Outfall
Reduction of Toxicity, Mobility, or Volume through Treatment	No treatment employed to reduce toxicity, mobility, or volume.	Volume and toxicity reduced by extraction and treatment. Treatment system would generate residuals that would require further treatment/ disposal.	Volume and toxicity reduced by extraction and treatment. Treatment system would generate residuals that would require further treatment/ disposal.	Volume and toxicity reduced by extraction and treatment. Treatment system would generate residuals that would require further treatment/ disposal.
Short-Term Effectiveness	No remedial action that would pose a risk to human health or the environment.	No additional risks to general public or environment during implementation. Workers would need protective equipment if exposed to hazardous materials.	No additional risks to general public or environment during implementation. Workers would need protective equipment if exposed to hazardous materials.	No additional risks to general public or environment during implementation. Workers would need protective equipment if exposed to hazardous materials.
Implementability	Not applicable, since no remedial action taken.	The NPDES requirements for an Area C discharge point have not been specified. Accordingly, implementability is unknown.	All technologies and process options are demonstrated and commercially available.	All technologies and process options are demonstrated and commercially available.
Costs	Capital: $69,696 Annual: $116,000 Present Worth: $1,853,000	Capital: $1,545,393 Annual: $229,629 Present Worth: $5,075,000	Capital: $1,839,690 Annual: $220,075 Present Worth: $5,224,000	Capital: $1,186,852 - $1,782,904 Annual: $244,444 - $214,729 Present Worth: $4,944,000 - $5,084,000

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5.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

In the following analysis, the alternatives are evaluated in relation to one another for each of the evaluation criteria that were used for detailed analysis, except for state acceptance and community acceptance. State and community acceptance are to be addressed in the ROD following comments on the FFS report and the Proposed Plan for OU-3. The purpose of this analysis is to identify the relative advantages and disadvantages of each alternative.

5.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Under Alternative 1, a remedial action addressing contaminated groundwater would not be initiated. Accordingly, this alternative would not be protective of human health and the environment.

Alternatives 2, 3, and 4 would both protect human health and the environment by minimizing the migration of groundwater contaminants in the overburden and shallow bedrock aquifers and initiating the restoration of overburden, shallow bedrock, and as a result, deeper bedrock aquifers.

5.2 COMPLIANCE WITH ARARs

Since no action would be taken under Alternative 1, there would be no ARARs.

Under Alternatives 3, and 4 ARARs for discharge of treated water and air emissions (as applicable) are expected to be met. Under Alternative 2 it is unknown whether the discharge would meet ARARs since the NPDES requirements for the point of discharge are unknown.

5.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Since no action would be taken under Alternative 1, there is no long-term effectiveness benefit to this alternative. Alternatives 2, 3, and 4 would reduce the time necessary to restore affected aquifers relative to Alternative 1 and thus would be more effective over the long term.

Alternatives 2, 3, and 4 require groundwater monitoring to evaluate the effectiveness of the alternatives. Operation and maintenance of the treatment plants and monitoring of the treated discharges would be required for these alternatives.

5.4 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT

Alternative 1 does not reduce toxicity, mobility, or volume of contaminated groundwater in the overburden and shallow bedrock aquifers.

Alternatives 2, 3, and 4 would reduce the volume and toxicity of contaminated groundwater. Migration of groundwater in the overburden and shallow bedrock aquifers would be contained by the extraction systems. The treatment systems for these alternatives would generate residuals that would require further treatment or disposal.

5.5 SHORT-TERM EFFECTIVENESS

Under Alternative 1, groundwater contaminants would continue to migrate and would present potential unacceptable risks to human health. There would be no additional risks to the public or the environment under Alternatives 2, 3, and 4.

For Alternatives 2, 3, and 4, workers would be required to wear protective equipment during activities where they may be exposed to hazardous materials.

5.6 IMPLEMENTABILITY

No remedial activity is included under Alternative 1.

For Alternatives 2, 3, and 4, the remedial technologies proposed for groundwater extraction and treatment are all demonstrated and commercially available. Under Alternative 2, it is unknown whether discharge of treated groundwater to the unnamed tributary of Little Neshaminy Creek north of Kirk Road could meet NPDES requirements regarding flow rate and/or effluent quality. Otherwise, Alternatives 2, 3, and 4 are expected to meet all ARARs.

If contaminated groundwater is found in overburden or shallow bedrock aquifers outside Area C, additional extraction wells or treatment units could be installed as part of RD/RA activities for OU-3 to provide a remedy for additional contaminated groundwater of concern.

5.7 COSTS

The costs estimates for the remedial alternatives are as follows:

Alternative	Capital Cost	Annual Cost	Present Worth
1: No Action with Groundwater Monitoring	$69,696	$116,000	$1,853,000
2: Groundwater Extraction, Treatment At Area C, and Discharge to Surface Water in the Vicinity of Area C	$1,545,393	$229,629	$5,075,000
3: Groundwater Extraction, Treatment at Area C, and Discharge to Surface Water at Area A System Outfall	$1,839,690	$220,075	$5,224,000
4: Groundwater Extraction, Treatment at Area A, and Discharge to Surface Water at Area A System Outfall	$1,186,852 - $1,782,904	$244,444 - $214,729	$4,944,000 - $5,084,000

5.8 CONCLUSIONS

In view of the accuracy of the estimates provided herein, the costs for Alternatives 2 and 4 are essentially the same. Alternative 3 is higher but still comparable, with respect to cost. Decisions with respect to the selection of an alternative should be based on other considerations, such as the need for potential future expansion which was not considered for Alternative 2 or 3, but is considered in Alternative 4, or the potential for more highly contaminated groundwater to be discovered at Area C, or the potential for Area C to be remediated more quickly than the 30-year period used for the cost analyses presented herein.

An integrated approach which reflects the needs of the entire site is preferable. Until the ongoing remedial investigation activities are complete, the precise alternative which best meets the needs of the site and the community cannot be identified.

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APPENDIX A

CALCULATIONS

CLIENT	JOB NUMBER
Navy	0286

SUBJECT: CLEAN CTO 139, Interim GW Extraction System, Area C

BASED ON	DRAWING NUMBER

BY	CHECKED BY	APPROVED BY	DATE
JPO	AWK		7/26/94

Area C Interim GW Extraction System Design

Methodology

- Use assumptions from Areas A/B interim design regarding aquifer T (shallow portion of aquifer)
- Use measured gradient of 0.03 (from WL data)
- Use plume width of 800' (normal to gw flow direction) @ midpoint of line of extraction wells (From sampling)
- Assume wells will be installed along downgradient edge of affected portion of Area C (PCE ≥ 5ug/L)
- Calculate Q required for containment (need Q for aquifer width 2x plume width @ line of wells, 800' x 2 = 1600')
- Assume plume/recovery well depths of 120' (confining layer @ 120' in cluster 24, upward vertical gradient expected below this will limit depth of plume)
- Assume gw extraction from bedrock will effectively contain plume, including any contamination in overburden

Required Q

$T = 208\ ft^2/day$ (From Area A/B interim design)

$i = 0.03$

$w = 1600'$

✓ $Q = Tiw = 9984\ ft^3/day = 52\ gpm$

CLIENT		JOB NUMBER	
Navy		0286	
SUBJECT	CTO 139 Interim GW Extraction System, Area C		
BASED ON		DRAWING NUMBER	
BY JPO	CHECKED BY AWK	APPROVED BY	DATE 7/26/94

Extraction Well Pumping Rates

Assuming: A well diameter of 0.8 ft (including gravel pack)
: $T = 208\ ft^2/day$
$S = 0.0004$ (from pumping test)
Time required to reach steady-state drawdown is approximately 2 weeks

Using: A pumping test simulation program by Walton (1987)

The following drawdowns were predicted (for a single well):

- @ 5.8 gpm, ~7.9' (Need 9 wells)
- @ 6.5 gpm, ~8.8' (Need 8 wells)

Well Spacings

Based on Javandel & Tsang (1986), the optimum well spacing (d) for a line of 4 or more wells is:

$$d = 1.2Q/\pi T'$$

- @ 5.8 gpm (1116.6 ft^3/day), d = 68'
- @ 6.5 gpm (1251.3 ft^3/day), d = 77'

CLIENT		JOB NUMBER	
Navy		0286	
SUBJECT			
CTO 139 Interim GW Extraction System, Area C			
BASED ON		DRAWING NUMBER	
BY	CHECKED BY	APPROVED BY	DATE
JPO	AWK		7/26/94

Cumulative Drawdown Effects

- Maximum effects will be seen in center well of a line of equally spaced wells

For 5.8 gpm, max dd (w/ 9 wells) =

$= 7.9' + 2(3.25') + 2(2.6') + 2(2.25') + 2(2.0')$

✓ $= 28.1'$

For 6.5 gpm, max dd (w/ 8 wells) =

$= 8.8' + 2(3.5') + 2(2.8') + 2(2.4') + 2.1'$

✓ $= 28.3'$

Use 8 wells @ 6.5 gpm/well, spaced 77' apart (normal to gw flow direction) along NAWC border where plume exists (see map)

- Will produce capture zone 800' wide @ midpoint of extraction system.

Capture zone width along line formed by residential well w/ 5 ug/L PCE, SW7, and BG 05 (280' ± upgradient of midpoint of extraction system

$w' = 2([Q/2Ti] - [Q/2\pi Ti][\tan^{-1} y/x])$, where

$y = 1/2$ capture zone width @ x

x = distance upgradient from midpoint of extract.

for $y/x = 1.9$,

✓ $w' = 1048'$, $y = 524'$, $x = 276'$

CLIENT	JOB NUMBER
Navy	0286

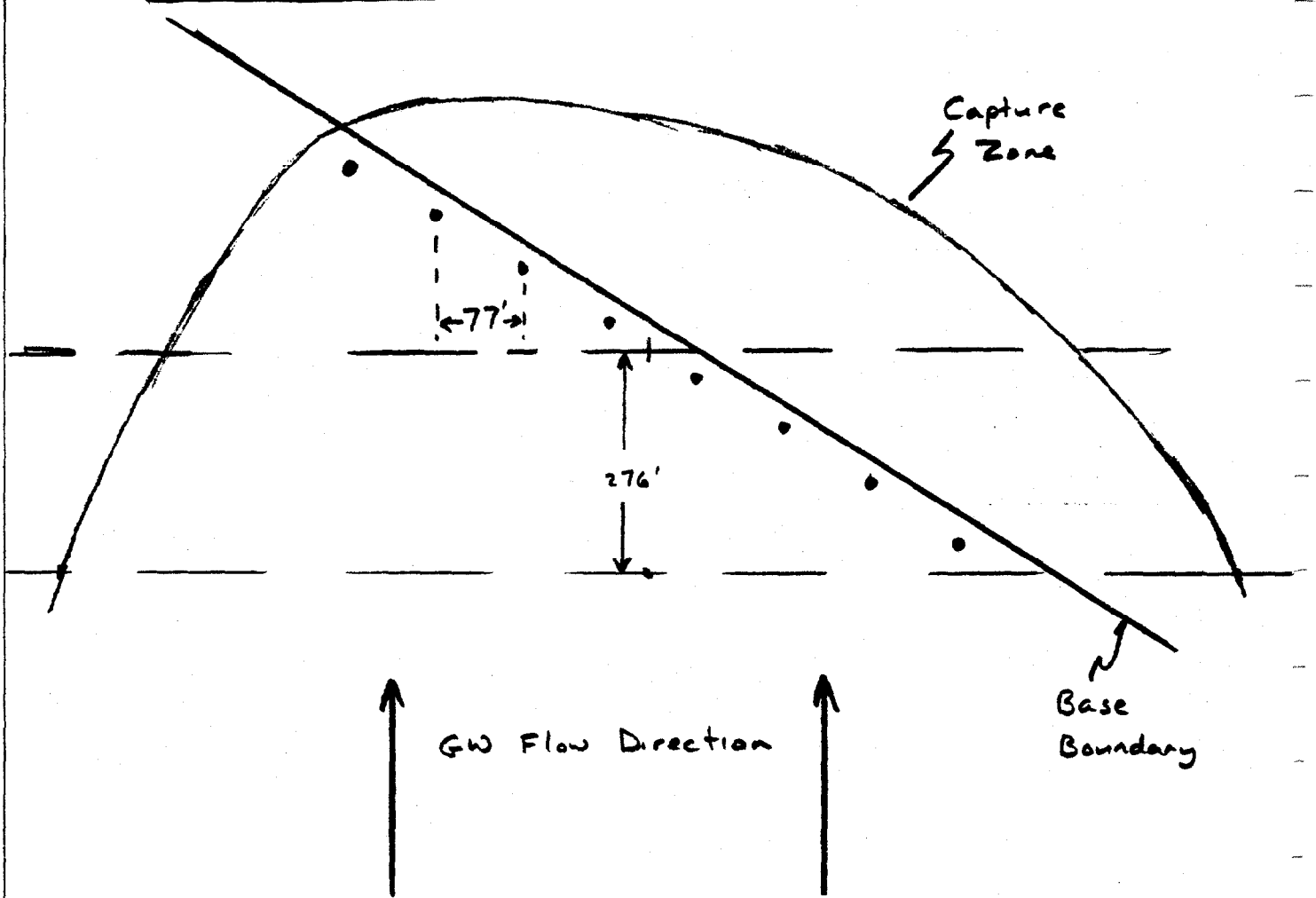
SUBJECT: CTO 139 Interim GW Extraction System, Area C

BASED ON	DRAWING NUMBER

BY	CHECKED BY	APPROVED BY	DATE
JPO	AWK		7/26/94

@ line 276' from midpoint of extraction system, capture zone width is 1,048'

Well Schematic



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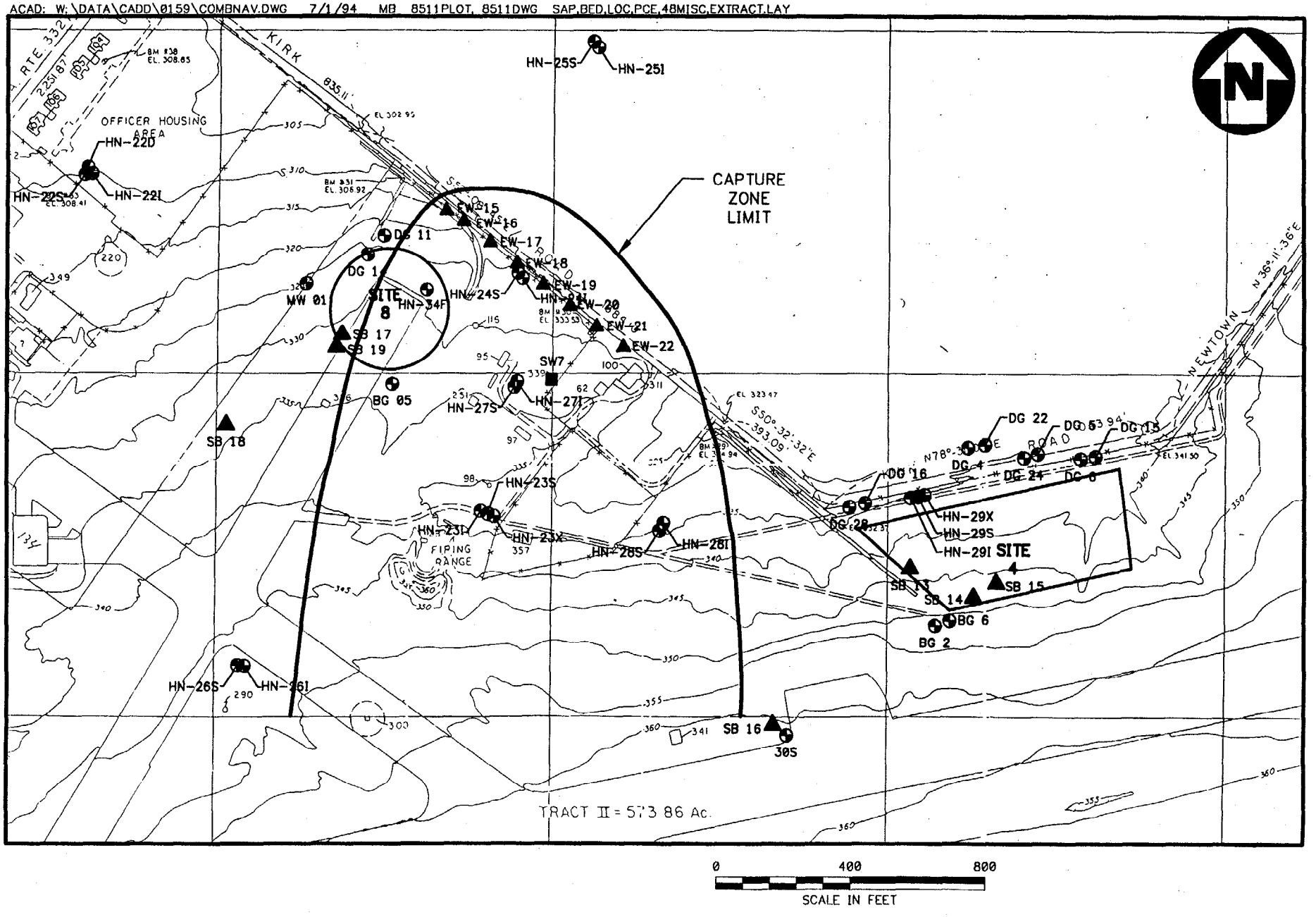

EXTRACTION WELL LOCATIONS
NAWC WARMINSTER, PA

Halliburton NUS CORPORATION

DATA BASE:

AQUIFER HORIZ. HYDR. COND. (GPD/SQ FT)= 14.10
AQUIFER VERT. HYDR. COND. (GPD/SQ FT)= 1.410
AQUIFER THICKNESS (FT)= 110.00
ARTESIAN AQUIFER STORATIVITY (DIM)= 4.0000D-04
WATER TABLE STORATIVITY (DIM)= 0.0004
PRODUCT. WELL EFFECTIVE RADIUS (FT)= 0.400
TOP OF AQUIFER DEPTH (FT)= 0.00
BASE OF AQUIFER DEPTH (FT)= 110.00
INITIAL WATER LEVEL DEPTH (FT)= 0.00
INFINITE AQUIFER SYSTEM

COMPUTATION RESULTS:

PRODUCTION WELL DISCHARGE RATE (GPM)= 5.80

TIME-DRAWDOWN OR WATER LEVEL VALUES (FT)

	SELECTED DISTANCES (FT)					
TIME(MIN)	0.40	63.40	159.24	400.00	1004.75	2523.83
0.11	0.16	0.00	0.00	0.00	0.00	0.00
0.18	0.25	0.00	0.00	0.00	0.00	0.00
0.28	0.39	0.00	0.00	0.00	0.00	0.00
0.44	0.59	0.00	0.00	0.00	0.00	0.00
0.70	0.88	0.00	0.00	0.00	0.00	0.00
1.11	1.28	0.00	0.00	0.00	0.00	0.00
1.76	1.79	0.01	0.00	0.00	0.00	0.00
2.79	2.39	0.04	0.00	0.00	0.00	0.00
4.42	3.04	0.09	0.00	0.00	0.00	0.00
7.01	3.66	0.18	0.01	0.00	0.00	0.00
11.11	4.20	0.31	0.03	0.00	0.00	0.00
17.61	4.63	0.48	0.07	0.00	0.00	0.00
27.91	4.96	0.66	0.14	0.00	0.00	0.00
44.24	5.23	0.85	0.24	0.01	0.00	0.00
70.11	5.46	1.04	0.36	0.03	0.00	0.00
111.11	5.67	1.22	0.50	0.07	0.00	0.00
176.11	5.86	1.39	0.65	0.12	0.00	0.00
279.11	6.04	1.56	0.80	0.20	0.01	0.00
442.36	6.22	1.72	0.95	0.30	0.02	0.00
701.09	6.40	1.89	1.11	0.41	0.04	0.00
1111.15	6.58	2.06	1.27	0.55	0.08	0.00
1761.05	6.77	2.24	1.45	0.70	0.14	0.00
2791.08	6.96	2.43	1.63	0.86	0.24	0.01
4423.56	7.16	2.62	1.82	1.04	0.36	0.03
7010.88	7.37	2.82	2.01	1.22	0.50	0.06
11111.49	7.57	3.01	2.21	1.41	0.67	0.13
17610.53	7.78	3.21	2.40	1.61	0.84	0.23
20000.00	7.85	3.28	2.47	1.67	0.90	0.26

TIME AFTER PUMPING STARTED(MIN)=20000.00

DISTANCE-DRAWDOWN OR WATER LEVEL VALUES AT END OF PUMPING PERIOD

NODE NO	RADIUS(FT)	DRAWDOWN OR WATER LEVEL (FT)
2	0.40	7.85
3	0.63	7.42
4	1.00	7.00
5	1.59	6.58
6	2.52	6.16
7	4.00	5.75
8	6.34	5.33
9	10.05	4.92
10	15.92	4.50
11	25.24	4.09
12	40.00	3.68
13	63.40	3.28
14	100.48	2.87
15	159.24	2.47
16	252.38	2.06
17	400.00	1.67
18	633.96	1.27
19	1004.75	0.90
20	1592.43	0.55
21	2523.83	0.26
22	4000.00	0.08
23	6339.57	0.01

DATA BASE:

AQUIFER HORIZ. HYDR. COND. (GPD/SQ FT)= 14.10
AQUIFER VERT. HYDR. COND. (GPD/SQ FT)= 1.410
AQUIFER THICKNESS (FT)= 110.00
ARTESIAN AQUIFER STORATIVITY (DIM)= 4.0000D-04
WATER TABLE STORATIVITY (DIM)= 0.0004
PRODUCT. WELL EFFECTIVE RADIUS (FT)= 0.400
TOP OF AQUIFER DEPTH (FT)= 0.00
BASE OF AQUIFER DEPTH (FT)= 110.00
INITIAL WATER LEVEL DEPTH (FT)= 0.00
INFINITE AQUIFER SYSTEM

COMPUTATION RESULTS:

PRODUCTION WELL DISCHARGE RATE (GPM)= 6.50

TIME-DRAWDOWN OR WATER LEVEL VALUES (FT)

	SELECTED DISTANCES (FT)					
TIME(MIN)	0.40	63.40	159.24	400.00	1004.75	2523.83
0.11	0.18	0.00	0.00	0.00	0.00	0.00
0.18	0.28	0.00	0.00	0.00	0.00	0.00
0.28	0.44	0.00	0.00	0.00	0.00	0.00
0.44	0.66	0.00	0.00	0.00	0.00	0.00
0.70	0.99	0.00	0.00	0.00	0.00	0.00
1.11	1.43	0.00	0.00	0.00	0.00	0.00
1.76	2.00	0.01	0.00	0.00	0.00	0.00
2.79	2.68	0.04	0.00	0.00	0.00	0.00
4.42	3.41	0.10	0.00	0.00	0.00	0.00
7.01	4.11	0.20	0.01	0.00	0.00	0.00
11.11	4.72	0.35	0.03	0.00	0.00	0.00
17.61	5.20	0.54	0.08	0.00	0.00	0.00
27.91	5.57	0.74	0.15	0.00	0.00	0.00
44.24	5.87	0.95	0.27	0.01	0.00	0.00
70.11	6.14	1.16	0.41	0.03	0.00	0.00
111.11	6.37	1.36	0.56	0.07	0.00	0.00
176.11	6.59	1.56	0.73	0.14	0.00	0.00
279.11	6.80	1.75	0.90	0.22	0.01	0.00
442.36	7.00	1.93	1.07	0.33	0.02	0.00
701.09	7.20	2.12	1.24	0.46	0.04	0.00
1111.15	7.40	2.31	1.43	0.61	0.09	0.00
1761.05	7.61	2.52	1.62	0.78	0.16	0.00
2791.08	7.83	2.72	1.83	0.97	0.27	0.01
4423.56	8.06	2.94	2.04	1.16	0.40	0.03
7010.88	8.29	3.16	2.25	1.37	0.56	0.07
11111.49	8.53	3.38	2.48	1.58	0.75	0.15
17610.53	8.76	3.61	2.70	1.80	0.94	0.25
20000.00	8.84	3.68	2.77	1.87	1.00	0.29

TIME AFTER PUMPING STARTED(MIN)=20000.00

DISTANCE-DRAWDOWN OR WATER LEVEL VALUES AT END OF PUMPING PERIOD

NODE NO	RADIUS(FT)	DRAWDOWN OR WATER LEVEL (FT)
2	0.40	8.84
3	0.63	8.36
4	1.00	7.88
5	1.59	7.40
6	2.52	6.93
7	4.00	6.46
8	6.34	5.99
9	10.05	5.52
10	15.92	5.06
11	25.24	4.60
12	40.00	4.14
13	63.40	3.68
14	100.48	3.22
15	159.24	2.77
16	252.38	2.32
17	400.00	1.87
18	633.96	1.43
19	1004.75	1.00
20	1592.43	0.61
21	2523.83	0.29
22	4000.00	0.09
23	6339.57	0.01

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* File name:   EG&G-2                      Server: IIISI                    *
* Directory:                                                                *
* Description:                                                              *
*              June 7, 1994                        8:23am                   *
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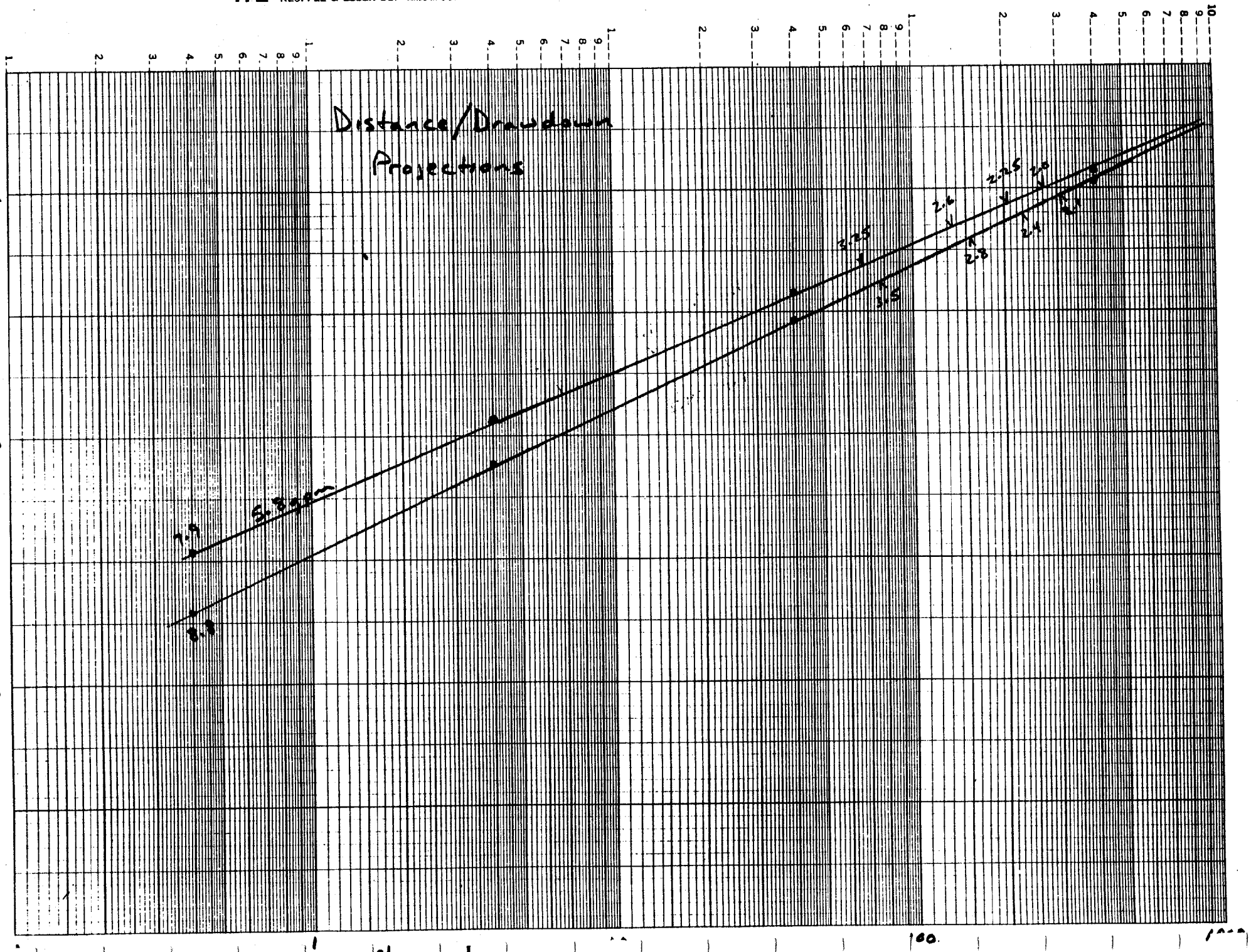
K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6010



CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT	JOB NUMBER
NAWC Warminster	1412-1000
SUBJECT: Area C - FFS	
BASED ON	DRAWING NUMBER

BY	CHECKED BY	APPROVED BY	DATE
DGO	JLG 07/29/94		7/29/94

Alternative 2, Alternative 3: Groundwater Extraction Treatment & Discharge to Surface Waters (except Treatment @ facility for Area A & B) & Alternative 4.

1. Assume oxidation of both iron & manganese occurs.

$$2\,Fe^{2+} + H_2O_2 + 4(OH^-) \rightarrow 2\,Fe(OH)_3$$
$$Mn^{2+} + H_2O_2 + 2(OH^-) \rightarrow MnO_2 + 2H_2O$$

	gmw	Conc ug/l	Conc M	NaOH req'd Stoich Mult.	NaOH req'd conc M	NaOH req'd conc mg/l	H_2O_2 req'd Stoich Mult	H_2O_2 req'd conc M	H_2O_2 req'd conc mg/l
Fe	55.8	1362	2.44×10^{-5}	2	1.88×10^{-5}	2	0.5	1.22×10^{-5}	0.41
Mn	54.9	217	3.95×10^{-6}	2	7.9×10^{-6}	0.3	1	3.95×10^{-6}	0.13
Total						2.3			0.53
Daily (lb/d)						1.4			0.33

Assume no caustic addition needed, pH will be slightly reduced

2. Oxidation of Humic Materials

Information is sketchy so use conservative assumptions
Expect 10% of humic materials to be oxidized - TOC ≈ 10 mg/l
Assume the oxidizable fraction is comparable to phenol.

$$C_6H_6O + 14\,H_2O_2 \rightarrow 6\,CO_2 + 17\,H_2O$$

CLIENT		JOB NUMBER	
NAWC Warminster		1412 - 1000	
SUBJECT			
Area C FFS			
BASED ON		DRAWING NUMBER	
BY	CHECKED BY	APPROVED BY	DATE
DGO	JIG 07/29/94		7/29/94

	gmw	Conc mg/l	Conc M	H_2O_2 stoich Mult	Req'd Conc M	Req'd Conc mg/l
Phenol	94	1	1.1×10^{-5}	14	2×10^{-4}	5.2
Daily (lb/d)						3.3

@ 50% H_2O_2 need $\frac{1}{0.5}\frac{(3.3+0.3)}{10\ lb/gal.} = 0.72\ \frac{gal}{d}$ or 112 ml/hr.

3. TSS.

$2Fe^{2+} + H_2O_2 + 4(OH^-) \rightarrow 2Fe(OH)_3$

1 mg/l Fe^{2+} results in 1.9 mg/l $Fe(OH)_3$

$Mn^{2+} + H_2O_2 + 2(OH^-) \rightarrow MnO_2 + 2H_2O$

1 mg/l Mn^{2+} results in 1.6 mg/l MnO_2

1.3 mg/l Fe → 2.6 mg/l TSS
0.2 mg/l Mn → 0.3 mg/l TSS

2.9 mg/l TSS

Initial TSS (from wells) 10 mg/l
Total TSS 13 mg/l

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT: NAWC Warminster		JOB NUMBER: 1412-1000	
SUBJECT: Area C - FFS			
BASED ON		DRAWING NUMBER	
BY: DGO	CHECKED BY: JLG 07/04/94	APPROVED BY	DATE: 7/29/94

6 Sludge Volume

Sludge solids - 2%

$$\text{Unit Vol} = \frac{1}{0.02} \times \frac{1}{8.6} = 5.8 \text{ gal / lb solids}$$

Daily solids = 8.34 × (flow in million gallons/d) × TSS (efficiency)

= 8.34 × 0.075 × 13 (0.9) = 7.3 lb/d.

Daily Volume = 7.3 × 6 = 44 gal/d @ 2% TSS

Say dispose 600 gal every 2 wks

7. Carbon Utilization

Avg PCE = 6 ug/l
Peak PCE = 15 ug/l (estimated)

Carbon utilization PCE = 0.0047 lb carbon /1000 gal groundwater

TOC = 10 mg/l (assumed) - also assume all TOC is humic cpds (naturally occuring)

carbon utilization (humics) ≈ same as for phenol

≈ 2.3 lb carbon / 1000 gal groundwater

Humic compounds govern carbon utilization rate

CLIENT	JOB NUMBER		
NAWC Warminster			
SUBJECT: Area C - FFS			
BASED ON	DRAWING NUMBER		
BY: DGO	CHECKED BY: JCG 07/29/94	APPROVED BY	DATE: 7/29/94

4. Sand Filter - 20 - 40 mesh sand

$$\text{Area} = \frac{Q}{\text{Area Loading}} = \frac{52 \text{ gpm}}{5 \text{ gpm/sf}} = 10 \text{ sf}$$

Two filter vessels 3 ft Ø in parallel

Actual filter area = 14 sf

Actual Loading = 3.7 gpm/sf avg, 7.4 gpm/sf max (one filter in backwash)

Backwash Rate Required = 15 gpm/sf

Use the clearwell to hold the backwash and add a backwash pump

5. Backwash Tank

Maximum backwash time: 10 min

Backwash with extracted groundwater and accumulated treated water in clearwell

Backwash flow = 7 sf × 15 gpm/sf = 105 gpm

Backwash vol = 10 × 105 = 1050 gal

Say a 1500 gal conical bottom holding tank / thickener with provisions for decanting

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT: NAWC Warminster	JOB NUMBER: 1412-1000
SUBJECT: Area C - FFS	
BASED ON:	DRAWING NUMBER:
BY: DGO	CHECKED BY: JLG 07/29/94
APPROVED BY:	DATE:

Carbon Usage $= 2.3 \times \frac{75000 \text{ gpd}}{1000 \text{ gal}} = 172$ lb/d.

Vessel Ø $= \frac{52 \text{ gpm}}{1.5 \text{ gpm/sf}} = 35$ sf 6 or 7' Ø ok

For a 7' vessel get 8624 lb GAC or 50d /charge

APPENDIX B

COST ESTIMATES

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
No Action
Alternative No. 1
(NAWEC3)
6/29/94

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
1) Monitoring Wells	600	LF	80.00				48000				48000	5 @ 120'
							48000	0	0	0	48000	
Burden @ 30% of Labor Cost									0		0	
Labor @ 10% of Labor Cost									0		0	
Material @ 10% of Material Cost								0			0	
SubContract @ 10% of Sub. Cost							4800				4800	
Total Direct Cost							52800	0	0	0	52800	
Indirects @ 75% of Total Direct Labor Cost									0		0	
Profit @ 10% of Total Direct Cost											5280	
Total Field Cost											58080	
Contingency @ 20% of Total Field Cost											11616	
TOTAL COST THIS PAGE											69696	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
No Action
Alternate No. 1
(O&MECGW3) 6/29/94

Annual Costs

ITEM	ITEM $ QUARTERLY SAMPLING	NOTES
1. Sampling	44000.00	24 groundwater samples 100 manhours per sampling period (quarterly) plus travel, living & shipping costs.
2. Analysis	64000.00	35 groundwater samples, per sampling period. (inc. blank & duplicate) Metals, VOCs
3. Reporting	8000.00	40 manhours per report plus other direct costs
TOTAL ANNUAL COST	116000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 30

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
No Action
Alternate No. 1
(PWANEC3) 6/29/94
1853

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	69.7											
2. O & M COSTS		116										
3. ANNUAL COSTS	69.7	116	116	116	116	116	116	116	116	116	116	116
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	70	110	105	100	95	91	87	82	79	75	71	68

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	116	116	116	116	116	116	116	116	116	116	116	116
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	65	61	59	56	53	51	48	46	44	42	40	38

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	116	116	116	116	116	116	116	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	36	34	33	31	30	28	27	1853

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Onsite Treatment Area "C",
Discharge To Adjacent Intermittent Stream
Alternate No. 2
(NAWCE2aS)

7/29/94

SUMMARY

Item	Sub.	Mat.	Labor	Equip.	
1) SITE PREPARATION	0	4200	9600	9000	22800
2) EQUIPMENT	201600	283800	22800	16000	524200
3) PIPING & INSTRUMENTATION	0	75004	40928	81	116013
4) FOUNDATION & STRUCTURAL	22500	19000	29100	1400	72000
5) ELECTRICAL	0	81080	84135	0	165215
	224100	463084	186563	26481	900228
Burden @ 30% of Labor Cost			55969		55969
Labor @ 10% of Labor Cost			18656		18656
Material @ 10% of Material Cost		46308			46308
Subcontract @ 10% of Sub. Cost	22410				22410
Total Direct Cost	246510	509392	261188	26481	1043572
Indirects @ 75% of Total Direct Labor Cost			195891		195891
Profit @ 10% Total Direct Cost					104357
Total Field Cost					1343820
Contingency @ 20% of Total Field Cost					201573
Total Cost This Page					1545393

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Onsite Treatment Area "C",
Discharge To Adjacent Intermittent Stream
Alternate No. 2
(NAWCEC2a)

7/29/94

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
SITE PREPARATION												
1) Mobilization/Demobilization		LS			3000.00	3000.00			3000	3000	6000	
2) Clearing And Grubbing	2	AC			3000.00	3000.00			6000	6000	12000	
3) Access Road	600	SY		7.00	1.00			4200	600		4800	
							0	4200	9600	9000	22800	
EQUIPMENT												
1) Extraction Wells	960		160.00				153600				153600	8 @ 120'
2) Monitoring Wells	600		80.00				48000				48000	5 @ 120'
3) Extraction Well Pumps	8			2200.00	400.00			17600	3200		20800	6.5 gpm
4) Area "C" Transfer Pumps	2			2800.00	400.00			5600	800		6400	52 gpm @ 50' tdh
5) Sand Filters	2			30000.00	3000.00	3000.00		60000	6000	6000	72000	3' dia.
6) Backwash Holding Tank	1			3000.00	400.00			3000	400		3400	1500 gallon
7) Backwash Pumps	2			2800.00	400.00			5600	800		6400	52 gpm @ 50' tdh
8) Hydrogen Peroxide Feed System	1			6000.00	1000.00			6000	1000		7000	
9) Activated Carbon Adsorber	2			90000.00	5000.00	5000.00		180000	10000	10000	200000	7' dia.
10) Effluent Tank	1			6000.00	600.00			6000	600		6600	4000 gallon
							201600	283800	22800	16000	524200	
PIPING & INSTRUMENTATION												
1) Area C Extraction Wells To Transfer Sump												
A) Piping												
a) 1-1/2"	960	LF		9.75	5.25			9360	5040		14400	
b) 4"	700	LF		4.00	3.00			2800	2100		4900	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	700	LF		1.00	8.25	5.80		700	5775		6475	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	700	LF		1.24	1.80			868	1260		2128	
D) Revegetation	7	MSF		50.00	11.00	9.00		350	77	63	490	
2) Area C Transfer Sump To Trmt. System												
A) Piping												
a) 3" C.S	100	LF		7.00	2.50			700	250		950	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	100	LF		1.00	8.25	5.80		100	825		925	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	100	LF		1.24	1.80			124	180		304	
D) Revegetation	1	MSF		50.00	11.00	9.00		50	11	9	70	
3) Effluent Disc. Line To Stream												
A) Piping												
a) 6" C.S.	300	LF		12.00	5.00			3600	1500		5100	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	300	LF		1.00	8.25	5.80		300	2475		2775	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	300	LF		1.24	1.80			372	540		912	
D) Revegetation	1	MSF		50.00	11.00	9.00		50	11	9	70	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Onsite Treatment Area "C",
Discharge To Adjacent Intermittent Stream
Alternate No. 2
(NAWCEC2a)

7/29/94

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
4) Treatment Plant Piping												
a) 1/2"	100	LF		3.50	1.50			350	150		500	
b) 3"	200	LF		19.50	10.50			3900	2100		6000	
5) Plug Valves												
a) 1-1/2"	8			110.00	20.00			880	160		1040	
b) 3"	2			280.00	90.00			560	180		740	
c) 4"	4			350.00	120.00			1400	480		1880	
6) Check Valves												
a) 1-1/2"	8			95.00	20.00			760	160		920	
b) 3"	4			130.00	46.00			520	184		704	
7) Ball Valves - 1/2"	18			45.00	15.00			810	270		1080	
8) Level Control System	11			4000.00	1500.00			44000	16500		60500	
9) Pressure Gauges	14			175.00	50.00			2450	700		3150	
							0	75004	40928	81	116013	
FOUNDATION & STRUCTURAL												
1) Area C Sump	1	LS		5000.00	2500.00			5000	2500		7500	
2) Treatment Building	900	SF	25.00				22500				22500	30' x 30'
3) Treatment Building Foundation	70	CY		200.00	380.00	20.00		14000	26600	1400	42000	
							22500	19000	29100	1400	72000	
ELECTRICAL												
1) MCC												
a) #1 Starter	14			1300.00	220.00			18200	3080		21280	
b) Distribution Transformer	1			5000.00	800.00			5000	800		5800	
2) Conduit, Cable, Control	14			1200.00	2200.00			16800	30800		47600	
3) Conduit, Cable, Motor	14			1000.00	2000.00			14000	28000		42000	
4) Control Panel	9			1000.00	150.00			9000	1350		10350	
5) Instrument Control Loop	9			500.00	700.00			4500	6300		10800	
6) Grounding	14			250.00	250.00			3500	3500		7000	
7) Miscellaneous Wiring	14			500.00	500.00			7000	7000		14000	
8) Fire Alarm	900	SF		.50	.80			450	720		1170	
9) Security	900	SF		.70	.65			630	585		1215	
10) Outdoor Lighting		LS		2000.00	2000.00			2000	2000		4000	
							0	81080	84135	0	165215	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Onsite Treatment Area "C"
Discharge To Adjacent Intermittent Stream
Alternate No. 2
(O&MEGW2a)
7/29/94

Annual Costs

ITEM	ITEM $ QUARTERLY SAMPLING	NOTES
1. Sampling	44000.00	24 groundwater samples 100 manhours per sampling period (quarterly) plus travel, living & shipping costs.
2. Analysis	64000.00	35 groundwater samples, per sampling period. (inc. blank & duplicate) Metals, VOCs
3. Reporting	8000.00	40 manhours per report plus other direct costs
4. NPDES Analysis	12000.00	2 samples per month Metals, VOCs
5. NPDES Reporting	7000.00	4 manhours per report
TOTAL ANNUAL COST	135000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 30

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Onsite Treatment Area "C"
Discharge To Adjacent Intermittent Stream
Alternate No. 2
(O&MEG2a1)
7/29/94

Annual Costs - (24 hr/day - 365 days/year)

ITEM	QTY	UNIT	UNIT$	ITEM $	NOTE
1. Energy					
a. Electric	137179	Kw-hr	.065	$8917	Treatment Plan
2. Maintenance				$30400	3% of Capital
3. Operator				$8000	1 Hour/Day
4. Chemical					
a. Hydrogen Peroxide	2410	LB	.70	$1687	
5. Activated Carbon					
a. Liquid	18250	LB	2.50	$45625	
6. Sludge Disposal					
a. Hauling	26	LD	200.00	$5200	
TOTAL ANNUAL COSTS				$94629	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C' Extraction & Collection System
Onsite Treatment Area "C"
Discharge To Adjacent Intermittent Stream
Alternate No. 2
(PWANEC2a) 7/29/94
5075

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	1545.4											
2. O & M COSTS		229.6										
3. ANNUAL COSTS	1545.4	229.6	229.6	229.6	229.6	229.6	229.6	229.6	229.6	229.6	229.6	229.6
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	1545	219	208	198	189	180	171	163	155	148	141	134

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	229.6	229.6	229.6	229.6	229.6	229.6	229.6	229.6	229.6	229.6	229.6	229.6
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	128	122	116	110	105	100	96	91	87	82	79	75

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	229.6	229.6	229.6	229.6	229.6	229.6	229.6	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	71	68	65	62	59	56	53	5075

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Onsite Treatment Area "C",
Pump To Area "A" For Discharge
Alternate No. 3
(NAWCE2bS)
Page 1 of 3
7/29/94

SUMMARY

Item	Sub.	Mat.	Labor	Equip.	
1) SITE PREPARATION	0	4200	9600	9000	22800
2) EQUIPMENT	201600	294800	24000	16000	536400
3) PIPING & INSTRUMENTATION	12600	118762	92595	459	224416
4) FOUNDATION & STRUCTURAL	22500	19000	29100	1400	72000
5) ELECTRICAL	0	89580	94475	0	184055
	236700	526342	249770	26859	1039671
Burden @ 30% of Labor Cost			74931		74931
Labor @ 10% of Labor Cost			24977		24977
Material @ 10% of Material Cost		52634			52634
Subcontract @ 10% of Sub. Cost	23670				23670
Total Direct Cost	260370	578976	349678	26859	1215883
Indirects @ 75% of Total Direct Labor Cost			262259		262259
Profit @ 10% Total Direct Cost					121588
Total Field Cost					1599730
Contingency @ 20% of Total Field Cost					239960
Total Cost This Page					1839690

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Onsite Treatment Area "C",
Pump To Area "A" For Discharge
Alternate No. 3
(NAWCEC2b)

7/29/94

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
SITE PREPARATION												
1) Mobilization/Demobilization		LS			3000.00	3000.00			3000	3000	6000	
2) Clearing And Grubbing	2	AC			3000.00	3000.00			6000	6000	12000	
3) Access Road	600	SY		7.00	1.00			4200	600		4800	
							0	4200	9600	9000	22800	
EQUIPMENT												
1) Extraction Wells	960		160.00				153600				153600	8 @ 120'
2) Monitoring Wells	600		80.00				48000				48000	5 @ 120'
3) Extraction Well Pumps	8			2200.00	400.00			17600	3200		20800	6.5 gpm
4) Area "C" Transfer Pumps	2			2800.00	400.00			5600	800		6400	52 gpm @ 50' tdh
5) Sand Filters	2			30000.00	3000.00	3000.00		60000	6000	6000	72000	3' dia.
6) Backwash Holding Tank	1			3000.00	400.00			3000	400		3400	1500 gallon
7) Backwash Pumps	2			2800.00	400.00			5600	800		6400	52 gpm @ 50' tdh
8) Hydrogen Peroxide Feed System	1			6000.00	1000.00			6000	1000		7000	
9) Activated Carbon Adsorber	2			90000.00	5000.00	5000.00		180000	10000	10000	200000	7' dia.
10) Effluent Tank	1			6000.00	600.00			6000	600		6600	4000 gallon
11) Area "A" Transfer Pumps	2			5500.00	600.00			11000	1200		12200	100 gpm @ 220' tdh
							201600	294800	24000	16000	536400	
PIPING & INSTRUMENTATION												
1) Area C Extraction Wells To Transfer Sump												
A) Piping												
a) 1-1/2"	960	LF		9.75	5.25			9360	5040		14400	
b) 4"	700	LF		4.00	3.00			2800	2100		4900	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	700	LF		1.00	8.25	5.80		700	5775		6475	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	700	LF		1.24	1.80			868	1260		2128	
D) Revegetation	7	MSF		50.00	11.00	9.00		350	77	63	490	
2) Area C Transfer Sump To Trmt. System												
A) Piping												
a) 3" C.S	100	LF		7.00	2.50			700	250		950	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	100	LF		1.00	8.25	5.80		100	825		925	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	100	LF		1.24	1.80			124	180		304	
D) Revegetation	1	MSF		50.00	11.00	9.00		50	11	9	70	
3) Area "C" Effluent To Area "A"												
A) Piping												
a) 3" C.S.	4250	LF		7.00	2.50			29750	10625		40375	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	4250	LF		1.00	8.25	5.80		4250	35063		39313	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	4250	LF		1.24	1.80			5270	7650		12920	
D) Revegetation	43	MSF		50.00	11.00	9.00		2150	473	387	3010	
E) Jacksonville Road Boring	60	LF	210.00				12600				12600	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Onsite Treatment Area "C",
Pump To Area "A" For Discharge
Alternate No. 3
(NAWCEC2b)

7/29/94

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
4) Treatment Plant Piping												
a) 1/2"	100	LF		3.50	1.50			350	150		500	
b) 3"	200	LF		19.50	10.50			3900	2100		6000	
5) Plug Valves												
a) 1-1/2"	8			110.00	20.00			880	160		1040	
b) 3"	4			280.00	90.00			1120	360		1480	
c) 4"	8			350.00	120.00			2800	960		3760	
6) Check Valves												
a) 1-1/2"	8			95.00	20.00			760	160		920	
b) 3"	6			130.00	46.00			780	276		1056	
7) Ball Valves - 1/2"	20			45.00	15.00			900	300		1200	
8) Level Control System	12			4000.00	1500.00			48000	18000		66000	
9) Pressure Gauges	16			175.00	50.00			2800	800		3600	
							12600	118762	92595	459	224416	
FOUNDATION & STRUCTURAL												
1) Area C Sump	1	LS		5000.00	2500.00			5000	2500		7500	
2) Treatment Building	900	SF	25.00				22500				22500	30' x 30'
3) Treatment Building Foundation	70	CY		200.00	380.00	20.00		14000	26600	1400	42000	
							22500	19000	29100	1400	72000	
ELECTRICAL												
1) MCC												
a) #1 Starter	16			1300.00	220.00			20800	3520		24320	
b) Distribution Transformer	1			5000.00	800.00			5000	800		5800	
2) Conduit, Cable, Control	16			1200.00	2200.00			19200	35200		54400	
3) Conduit, Cable, Motor	16			1000.00	2000.00			16000	32000		48000	
4) Control Panel	9			1000.00	150.00			9000	1350		10350	
5) Instrument Control Loop	9			500.00	700.00			4500	6300		10800	
6) Grounding	16			250.00	250.00			4000	4000		8000	
7) Miscellaneous Wiring	16			500.00	500.00			8000	8000		16000	
8) Fire Alarm	900	SF		.50	.80			450	720		1170	
9) Security	900	SF		.70	.65			630	585		1215	
10) Outdoor Lighting		LS		2000.00	2000.00			2000	2000		4000	
							0	89580	94475	0	184055	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Onsite Treatment Area "C"
Pump To Area "A" For Discharge
Alternate No. 3
(O&MEGW2b)
7/29/94

Annual Costs

ITEM	ITEM $ QUARTERLY SAMPLING	NOTES
1. Sampling	44000.00	24 groundwater samples 100 manhours per sampling period (quarterly) plus travel, living & shipping costs.
2. Analysis	64000.00	35 groundwater samples, per sampling period. (inc. blank & duplicate) Metals, VOCs
3. Reporting	8000.00	40 manhours per report plus other direct costs
4. NPDES Analysis	.00	Incl. in NPDES Monitoring For Area A & B Treatment
5. NPDES Reporting	.00	Incl. in NPDES Monitoring For Area A & B Treatment
TOTAL ANNUAL COST	116000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 30

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Onsite Treatment Area "C"
Pump To Area "A" For Discharge
Alternate No. 3
(O&MEG2b1)
7/29/94

Annual Costs - (24 hr/day - 365 days/year)

ITEM	QTY	UNIT	UNIT$	ITEM $	NOTE
1. Energy					
a. Electric	202502	Kw-hr	.065	$13163	Treatment Plar
2. Maintenance				$35600	3% of Capital
3. Operator				$8000	1 Hour/Day
4. Chemical					
a. Hydrogen Peroxide	2410	LB	.70	$1687	
5. Activated Carbon					
a. Liquid	18250	LB	2.50	$45625	
6. Sludge Disposal					
a. Hauling	26	LD	200.00	$5200	
TOTAL ANNUAL COSTS				$104075	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C' Extraction & Collection System
Onsite Treatment Area "C"
Pump To Area "A" For Discharge
Alternate No. 3
(PWANEC2b) 7/29/94
5224

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	1839.7											
2. O & M COSTS		220.1										
3. ANNUAL COSTS	1839.7	220.1	220.1	220.1	220.1	220.1	220.1	220.1	220.1	220.1	220.1	220.1
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	1840	210	200	190	181	173	164	156	149	142	135	129

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	220.1	220.1	220.1	220.1	220.1	220.1	220.1	220.1	220.1	220.1	220.1	220.1
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	123	117	111	106	101	96	92	87	83	79	75	72

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	220.1	220.1	220.1	220.1	220.1	220.1	220.1	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	68	65	62	59	56	53	51	5224

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Treatment Area "A"
Use Facilities For Treatment of Groundwater
In Area "A" And Area "B"
Alternate No. 4 - Option 1
(NAWC2c1S)

7/29/94

SUMMARY

Item	Sub.	Mat.	Labor	Equip.	
1) SITE PREPARATION	0	0	9000	9000	18000
2) EQUIPMENT	201600	23600	4000	0	229200
3) PIPING & INSTRUMENTATION	12600	113608	95170	450	221828
4) FOUNDATION & STRUCTURAL	0	5000	2500	0	7500
5) ELECTRICAL	0	95000	72900	0	167900
	214200	237208	183570	9450	644428
Burden @ 30% of Labor Cost			55071		55071
Labor @ 10% of Labor Cost			18357		18357
Material @ 10% of Material Cost		23721			23721
Subcontract @ 10% of Sub. Cost	21420				21420
Total Direct Cost	235620	260929	256998	9450	762997
Indirects @ 75% of Total Direct Labor Cost			192749		192749
Profit @ 10% Total Direct Cost					76300
Total Field Cost					1032045
Contingency @ 20% of Total Field Cost					154807
Total Cost This Page					1186852

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Treatment Area "A"
Use Facilities For Treatment Of Groundwater
In Area "A" And Area "B"
Alternate No. 4 - Option 1
(NAWCE2c1)

7/29/94

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
SITE PREPARATION												
1) Mobilization/Demobilization		LS			3000.00	3000.00			3000	3000	6000	
2) Clearing And Grubbing	2	AC			3000.00	3000.00			6000	6000	12000	
							0	0	9000	9000	18000	
EQUIPMENT												
1) Extraction Wells	960		160.00				153600				153600	8 @ 120'
2) Monitoring Wells	600		80.00				48000				48000	5 @ 120'
3) Extraction Well Pumps	8			2200.00	400.00			17600	3200		20800	6.5 gpm
4) Area "C" Transfer Pumps	2			3000.00	400.00			6000	800		6800	100 gpm @ 130' tdh
							201600	23600	4000	0	229200	
PIPING & INSTRUMENTATION												
1) Area C Extraction Wells To Transfer Sump												
A) Piping												
a) 1-1/2"	960	LF		9.75	5.25			9360	5040		14400	
b) 4"	700	LF		4.00	3.00			2800	2100		4900	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	700	LF		1.00	8.25	5.80		700	5775		6475	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	700	LF		1.24	1.80			868	1260		2128	
D) Revegetation	7	MSF		50.00	11.00	9.00		350	77	63	490	
2) Area C Transfer Sump To Equal. Tank												
A) Piping												
a) 3"/6" Double Walled Pipe	4250	LF		10.00	5.00			42500	21250		63750	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	4250	LF		1.00	8.25	5.80		4250	35063		39313	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	4250	LF		1.24	1.80			5270	7650		12920	
D) Revegetation	43	MSF		50.00	11.00	9.00		2150	473	387	3010	
E) Jacksonville Road Boring	60	LF	210.00				12600				12600	
3) Plug Valves												
a) 1-1/2"	8			110.00	20.00			880	160		1040	
b) 3"	2			280.00	90.00			560	180		740	
c) 4"	2			350.00	120.00			700	240		940	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Treatment Area "A"
Use Facilities For Treatment Of Groundwater
In Area "A" And Area "B"
Alternate No. 4 - Option 1
(NAWCE2c1)

7/29/94

Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
4) Check Valves												
a) 1-1/2"	8			95.00	20.00			760	160		920	
b) 3"	2			130.00	46.00			260	92		352	
5) Ball Valves - 1/2"	10			45.00	15.00			450	150		600	
6) Level Control System	10			4000.00	1500.00			40000	15000		55000	
7) Pressure Gauges	10			175.00	50.00			1750	500		2250	
							12600	113608	95170	450	221828	
FOUNDATION & STRUCTURAL												
1) Area C Sump	1	LS		5000.00	2500.00			5000	2500		7500	
							0	5000	2500	0	7500	
ELECTRICAL												
1) MCC												
a) #1 Starter	10			1300.00	220.00			13000	2200		15200	
c) Distribution Transformer	1			5000.00	800.00			5000	800		5800	
2) Conduit, Cable, Control	10			1200.00	2200.00			12000	22000		34000	
3) Conduit, Cable, Motor	10			1000.00	2000.00			10000	20000		30000	
4) Leak Detection Monitor	4250	LF		8.00	3.00			34000	12750		46750	
5) Control Panel	9			1000.00	150.00			9000	1350		10350	
6) Instrument Control Loop	9			500.00	700.00			4500	6300		10800	
7) Grounding	10			250.00	250.00			2500	2500		5000	
8) Miscellaneous Wiring	10			500.00	500.00			5000	5000		10000	
							0	95000	72900	0	167900	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Treatment Area "A"
Use Facilities For Treatment Of Groundwater
In Area "A" And Area "B"
Alternate No. 4 - Option 1
(O&MEG2c1)
7/29/94

Annual Costs

ITEM	ITEM $ QUARTERLY SAMPLING	NOTES
1. Sampling	44000.00	24 groundwater samples 100 manhours per sampling period (quarterly) plus travel, living & shipping costs.
2. Analysis	64000.00	35 groundwater samples, per sampling period. (inc. blank & duplicate) Metals, VOCs
3. Reporting	8000.00	40 manhours per report plus other direct costs
4. NPDES Analysis	.00	Incl. in NPDES Monitoring For Area A & B Treatment
5. NPDES Reporting	.00	Incl. in NPDES Monitoring For Area A & B Treatment
TOTAL ANNUAL COST	116000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 30

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C" Extraction & Collection System
Treatment Area "A"
Use Facilities For Treatment Of Groundwater
In Area "A" And Area "B"
Alternate No. 4 - Option 1
(O&ME2c1a)
7/29/94

Annual Costs - (24 hr/day - 365 days/year)

ITEM	QTY	UNIT	UNIT$	ITEM $	NOTES
1. Energy					
a. Electric	273408	Kw-hr	.065	$17772	Treatment Plan
2. Maintenance				$22900	3% of Capital
3. Operator	0	EA.	.00	$0	Operated By Ma Trmt. Plant Ope
4. Chemical					
a. Caustic Soda	22	TON	400.00	$8800	
b. Polymer	260	LB	2.50	$650	
c. Hydrochloric Acid	8	TON	100.00	$800	
d. Hydrogen Peroxide	1752	LB	.70	$1226	
5. Activated Carbon					
a. Liquid	16686	LB	2.50	$41715	
b. Vapor	11527	LB	3.00	$34581	
TOTAL ANNUAL COSTS				$128444	

NAVAL AIR WARFARE CENTER
Warminster, Pennsylvania
Area "C' Extraction & Collection System
Treatment Area "A"
Use Facilities For Treatment Of Groundwater
In Area "A" And Area "B"
Alternate No. 4 - Option 1
(PWANE2c1) 7/29/94
4944

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	1186.9											
2. O & M COSTS		244.4										
3. ANNUAL COSTS	1186.9	244.4	244.4	244.4	244.4	244.4	244.4	244.4	244.4	244.4	244.4	244.4
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	1187	233	222	211	201	192	182	174	165	158	150	143

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	244.4	244.4	244.4	244.4	244.4	244.4	244.4	244.4	244.4	244.4	244.4	244.4
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	136	130	123	118	112	107	102	97	92	88	84	80

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	244.4	244.4	244.4	244.4	244.4	244.4	244.4	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	76	72	69	65	62	59	56	4944

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SUMMARY

Item	Sub.	Mat.	Labor	Equip.	
1) SITE PREPARATION	0	4200	9600	9000	22800
2) EQUIPMENT	201600	289200	23200	16000	530000
3) PIPING & INSTRUMENTATION	12600	110998	88901	450	212949
4) FOUNDATION & STRUCTURAL	25000	21000	32900	1600	80500
5) ELECTRICAL	0	81080	84135	0	165215
	239200	506478	238736	27050	1011464
Burden @ 30% of Labor Cost			71621		71621
Labor @ 10% of Labor Cost			23874		23874
Material @ 10% of Material Cost		50648			50648
Subcontract @ 10% of Sub. Cost	23920				23920
Total Direct Cost	263120	557126	334230	27050	1181526
Indirects @ 75% of Total Direct Labor Cost			250673		250673
Profit @ 10% Total Direct Cost					118153
Total Field Cost					1550352
Contingency @ 20% of Total Field Cost					232553
Total Cost This Page					1782904

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Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
SITE PREPARATION												
1) Mobilization/Demobilization		LS			3000.00	3000.00			3000	3000	6000	
2) Clearing And Grubbing	2	AC			3000.00	3000.00			6000	6000	12000	
3) Access Road	600	SY		7.00	1.00			4200	600		4800	
							0	4200	9600	9000	22800	
EQUIPMENT												
1) Extraction Wells	960		160.00				153600				153600	8 @ 120'
2) Monitoring Wells	600		80.00				48000				48000	5 @ 120'
3) Extraction Well Pumps	8			2200.00	400.00			17600	3200		20800	6.5 gpm
4) Area "A" Transfer Pumps	2			5500.00	600.00			11000	1200		12200	100 gpm @ 220' tdh
5) Sand Filters	2			30000.00	3000.00	3000.00		60000	6000	6000	72000	3' dia.
6) Backwash Holding Tank	1			3000.00	400.00			3000	400		3400	1500 gallon
7) Backwash Pumps	2			2800.00	400.00			5600	800		6400	52 gpm @ 50' tdh
8) Hydrogen Peroxide Feed System	1			6000.00	1000.00			6000	1000		7000	
9) Activated Carbon Adsorber	2			90000.00	5000.00	5000.00		180000	10000	10000	200000	7' dia.
10) Effluent Tank	1			6000.00	600.00			6000	600		6600	4000 gallon
							201600	289200	23200	16000	530000	
PIPING & INSTRUMENTATION												
1) Area C Extraction Wells To Transfer Sump												
A) Piping												
a) 1-1/2"	960	LF		9.75	5.25			9360	5040		14400	
b) 4"	700	LF		4.00	3.00			2800	2100		4900	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	700	LF		1.00	8.25	5.80		700	5775		6475	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	700	LF		1.24	1.80			868	1260		2128	
D) Revegetation	7	MSF		50.00	11.00	9.00		350	77	63	490	
2) Area "C" Transfer Sump To Area "A"												
A) Piping												
a) 3" C.S.	4250	LF		7.00	2.50			29750	10625		40375	
B) Excavation, Backfill, Compaction												
a) 2' Wide x 5' Deep	4250	LF		1.00	8.25	5.80		4250	35063		39313	
C) Pipe Bedding												
a) 2' Wide (1 Layer)	4250	LF		1.24	1.80			5270	7650		12920	
D) Revegetation	43	MSF		50.00	11.00	9.00		2150	473	387	3010	
E) Jacksonville Road Boring	60	LF	210.00				12600				12600	

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Item	Qty	Unit	Unit Cost Sub.	Unit Cost Mat.	Unit Cost Labor	Unit Cost Equip.	Total Cost Sub.	Total Cost Mat.	Total Cost Labor	Total Cost Equip.	Total Direct Cost	Comments
3) Treatment Plant Piping												
a) 1/2"	100	LF		3.50	1.50			350	150		500	
b) 3"	200	LF		19.50	10.50			3900	2100		6000	
4) Plug Valves												
a) 1-1/2"	8			110.00	20.00			880	160		1040	
b) 3"	2			280.00	90.00			560	180		740	
c) 4"	4			350.00	120.00			1400	480		1880	
5) Check Valves												
a) 1-1/2"	8			95.00	20.00			760	160		920	
b) 3"	3			130.00	46.00			390	138		528	
6) Ball Valves - 1/2"	18			45.00	15.00			810	270		1080	
7) Level Control System	11			4000.00	1500.00			44000	16500		60500	
8) Pressure Gauges	14			175.00	50.00			2450	700		3150	
							12600	110998	88901	450	212949	
FOUNDATION & STRUCTURAL												
1) Area C Sump	1	LS		5000.00	2500.00			5000	2500		7500	
2) Treatment Building Addition	1000	SF	25.00				25000				25000	20' x 50'
3) Treatment Building Foundation	80	CY		200.00	380.00	20.00		16000	30400	1600	48000	
							25000	21000	32900	1600	80500	
ELECTRICAL												
1) MCC												
a) #1 Starter	14			1300.00	220.00			18200	3080		21280	
b) Distribution Transformer	1			5000.00	800.00			5000	800		5800	
2) Conduit, Cable, Control	14			1200.00	2200.00			16800	30800		47600	
3) Conduit, Cable, Motor	14			1000.00	2000.00			14000	28000		42000	
4) Control Panel	9			1000.00	150.00			9000	1350		10350	
5) Instrument Control Loop	9			500.00	700.00			4500	6300		10800	
6) Grounding	14			250.00	250.00			3500	3500		7000	
7) Miscellaneous Wiring	14			500.00	500.00			7000	7000		14000	
8) Fire Alarm	900	SF		.50	.80			450	720		1170	
9) Security	900	SF		.70	.65			630	585		1215	
10) Outdoor Lighting		LS		2000.00	2000.00			2000	2000		4000	
							0	81080	84135	0	165215	

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Annual Costs

ITEM	ITEM $ QUARTERLY SAMPLING	NOTES
1. Sampling	44000.00	24 groundwater samples 100 manhours per sampling period (quarterly) plus travel, living & shipping costs.
2. Analysis	64000.00	35 groundwater samples, per sampling period. (inc. blank & duplicate) Metals, VOCs
3. Reporting	8000.00	40 manhours per report plus other direct costs
4. NPDES Analysis	.00	Incl. in NPDES Monitoring For Area A & B Treatment
5. NPDES Reporting	.00	Incl. in NPDES Monitoring For Area A & B Treatment
TOTAL ANNUAL COST	116000.00	Post Remedial monitoring will be performed quarterly for years 1 thru 30

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Annual Costs - (24 hr/day - 365 days/year)

ITEM	QTY	UNIT	UNIT$	ITEM $	NOTES
1. Energy					
a. Electric	137179	Kw-hr	.065	$8917	Treatment Plan
2. Maintenance				$34500	3% of Capital C
3. Operator				$8000	1 Hour/Day
4. Chemical					
a. Hydrogen Peroxide	2410	LB	.70	$1687	
5. Activated Carbon					
a. Liquid	18250	LB	2.50	$45625	
6. Sludge Disposal					
a. Hauling	26	LD	200.00	$5200	
TOTAL ANNUAL COSTS				$98729	

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5084

PRESENT WORTH ANALYSIS

COST/YEAR COST OCCURS ($000'S)

COST COMPONENT	0	1	2	3	4	5	6	7	8	9	10	11
1. CAPITAL COST	1782.9											
2. O & M COSTS		214.7										
3. ANNUAL COSTS	1782.9	214.7	214.7	214.7	214.7	214.7	214.7	214.7	214.7	214.7	214.7	214.7
4. ANNUAL DISCOUNT RATE=5%	1	.952	.907	.864	.823	.784	.746	.711	.677	.645	.614	.585
PRESENT WORTH =	1783	204	195	186	177	168	160	153	145	138	132	126

	12	13	14	15	16	17	18	19	20	21	22	23
O & M COSTS	214.7	214.7	214.7	214.7	214.7	214.7	214.7	214.7	214.7	214.7	214.7	214.7
ANNUAL DISCOUNT RATE=5%	.557	.53	.505	.481	.458	.436	.416	.396	.377	.359	.342	.326
PRESENT WORTH =	120	114	108	103	98	94	89	85	81	77	73	70

	24	25	26	27	28	29	30	TOTAL PRESENT WORTH (000'S)
O & M COSTS	214.7	214.7	214.7	214.7	214.7	214.7	214.7	
ANNUAL DISCOUNT RATE=5%	.31	.295	.281	.268	.255	.243	.231	
PRESENT WORTH =	67	63	60	58	55	52	50	5084