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# REMEDIAL DECISION DOCUMENT
# FOR
# REMEDIAL ACTION AT THE NAVY FUEL FARM
# AT
# NAVAL AIR STATION JOINT RESERVE BASE (NASJRB) WILLOW GROVE
# HORSHAM TOWNSHIP, PENNSYLVANIA

Contract No. N62472-92-D-1296
Contract Task Order No. 0074

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Final - *Remedial Decision Document for Remedial Action at the Navy Fuel Farm, Naval Air Station Joint Reserve Base (NAS/JRB) Willow Grove, Horsham Township, Pennsylvania.*

EA CTO Manager: Carl Reitenbach

In compliance with EA's Quality Procedures for review of deliverables outlined in the Quality Management Plan, this final deliverable has been reviewed for quality by the undersigned Senior Technical Reviewer(s). The information presented in this report/deliverable has been prepared in accordance with the approved Implementation Plan for the Contract Task Order (CTO) and reflects a proper presentation of the data and/or the conclusions drawn and/or the analyses or design completed during the conduct of the work. This statement is based upon the standards identified in the CTO and/or the standard of care existing at the time of preparation.

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20 August 1997

REMEDIAL DECISION DOCUMENT
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Contract No. N62472-92-D-1296
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20 August 1997
FINAL
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# 1. INTRODUCTION

This Remedial Decision Document (RDD) for the Navy Fuel Farm facility, Naval Air Station Joint Reserve Base (NASJRB), Willow Grove, Horsham Township, Pennsylvania has been prepared for Northern Division, Naval Facilities Engineering Command under Contract No. N62472-92-D-1296, Contract Task Order (CTO) No. 0074.

## 1.1 PURPOSE

The purpose of this RDD is to document the evaluation of alternatives available to recover light non-aqueous phase liquid (LNAPL) hydrocarbons in the subsurface at the Navy Fuel Farm facility and the selection of the preferred remedial alternative as recommended in the *Final Pilot Study Report for the Product Recovery Pilot System at the Navy Fuel Farm Facility, Naval Air Station Willow Grove, Horsham Township, Pennsylvania* (EA 1996). As a result, this RDD is based on the results and conclusions of the 32-month Pilot Study (March 1994 - October 1996) which included evaluation of a vacuum enhanced LNAPL recovery pilot system, one passive LNAPL skimming device, and two automated LNAPL skimming pumps. The pilot study also evaluated the applicability of soil vapor extraction (SVE) .

## 1.2 ORGANIZATION OF THE REPORT

This report is divided into six chapters. Chapter 1 is the Introduction and includes a summary of the Pilot Study scope of work. Chapter 2 describes the Navy Fuel Farm facility and includes a summary of the site setting, characteristics, and history. Chapter 3 contains a summary of potential risks to public health and the environment based on current site conditions and Chapter 4 summarizes the Pilot Study results and conclusions. An analysis of remedial alternatives considered and associated costs are included in Chapter 5. Chapter 6 presents the preferred remedial action and an estimate of the associated cost of implementation.

## 1.3 PILOT STUDY SCOPE OF WORK

The Pilot Study was conducted in accordance with the *Work Plan for Pilot-Scale Testing of Free-Product Recovery and Aquifer Air Sparging* (EA, 1993a). The scope of work outlined in the work plan included two phases:

**Phase I - LNAPL Recovery**

- Installation of a pilot LNAPL recovery system at well NFFW-2R and initiation of LNAPL recovery by water table depression and vacuum enhanced pumping at well NFFW-2R; and

- Installation of automated LNAPL skimming pumps in wells NFFW-6 and NFFW-19 to assess the potential for continuous LNAPL yield without depressing the water-table.

**Phase II - Source and Residual Hydrocarbon Reduction**

- Evaluation of the effectiveness of SVE in combination with Aquifer Air Sparging (AAS) including the installation and operation of a 14 trench/24 well SVE/AAS pilot system to remediate residual phase hydrocarbons in the zone of water-table fluctuations.

Phase II of the scope of work was changed during the pilot study to substitute a two-part SVE field test for the SVE/AAS evaluation. This change was made because of concerns that SVE/AAS would not be appropriate due to the occurrence of LNAPL throughout the site. The occurrence of LNAPL is closely, if not exclusively, related to water-table fluctuations in the shallow bedrock fracture zone. Air sparging does not address LNAPL in this setting. Removal of LNAPL is substantially more cost effective than dissolved-phase remediation. Therefore, this change in scope allowed the LNAPL recovery portion (Phase I) of the pilot study to be extended and as a result accomplish more remediation during the course of the pilot study than would be gained by conducting the SVE/AAS evaluation. This change was authorized in a NAVFAC Record of Change letter dated 27 January 1995. The Record of Change letter included provisions for the evaluation of small scale SVE testing during high and low water table periods (spring and summer) at 3 existing monitoring wells.

Activities conducted during the Pilot Study included the following:

- gauging site monitoring wells to assess the nature and extent of LNAPL,
- evaluating the effectiveness of vacuum-enhanced LNAPL recovery,
- sampling of the pilot system ground-water effluent to demonstrate treatment prior to discharge to the sanitary sewer
- monitoring of the air emissions to evaluate the performance of the air treatment system.

Conclusions are presented in the *Final Pilot Study Report for the Product Recovery Pilot System at the Navy Fuel Farm Facility, Naval Air Station Willow Grove, Horsham Township, Pennsylvania* (EA 1996).

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AAS | Aquifer Air Sparging |
| ARF | Air Reserve Facility |
| AST | Above Ground Storage Tank |
| BTEX | Benzene, Toluene, Ethylbenzene, Xylenes |
| cfm | cubic feet per minute |
| cm | centimeters |
| CPOC | Constituents of Potential Concern |
| CTO | Contract Task Order |
| EA | EA Engineering, Science, and Technology |
| EPA | Environmental Protection Agency |
| ft | feet |
| GAC | Granular Activated Carbon |
| gal | gallon |
| gpm | gallons per minute |
| Hg | Mercury |
| HP | Horsepower |
| in. | inch |
| IR | Installation Restoration |
| JP-4 | Jet Propulsion Fuel #4 |
| JP-5 | Jet Propulsion Fuel #5 |
| kg | kilogram |
| L | Litre |
| lbs | pounds |
| LNAPL | Light Non-Aqueous Phase Liquid |
| LEL | Lower Explosive Limit |
| MCL | Maximum Contaminant Level |
| MEK | Methyl Ethyl Ketone |
| $\mu$g | microgram |
| msl | mean sea level |
| NASJRB | Naval Air Station Joint Reserve Base |
| NAVFAC | Naval Facilities Engineering Command |
| Nos. | Numbers |
| OVA | Organic Vapor Analyzer |

## ACRONYMS AND ABBREVIATIONS (Cont.)

| | |
|---|---|
| PAANG | Pennsylvania Air National Guard |
| ppmv | parts per million volume |
| psi | pounds per square inch |
| PVC | Polyvinyl Chloride |
| RDD | Remedial Decision Document |
| sec | second |
| SVE | Soil Vapor Extraction |
| TOC | Top of Casing |
| TPH | Total Petroleum Hydrocarbons |
| UST | Underground Storage Tank |
| VOC | Volatile Organic Compounds |

# 2. AREA DESCRIPTION

## 2.1 SITE SETTING

The Navy Fuel Farm is located along the north side of Privet Road and immediately south of the Pennsylvania Air National Guard (PAANG) portion of the Air Reserve Facility (ARF) at NASJRB Willow Grove. Figure 2-1 is a site location map and Figure 2-2 is a site plan of the Navy Fuel Farm. The Navy Fuel Farm and a portion of the adjoining property to the north, occupied by PAANG (Buildings 345 and 340), constitute the area requiring remedial efforts and include the area within which the pilot study was conducted. The Navy Fuel Farm is bordered on all sides by NASJRB grounds. Located to the north of the Navy Fuel Farm are ARF Buildings 330, 340, and 345. Several other base facilities exist within 1,000 ft of the site. The Navy Fuel Farm is approximately 2 acres in area and consists of three aboveground storage tanks (ASTs), associated aboveground piping, and building Nos. 119 and 81.

The topography of the Navy Fuel Farm area is characterized as flat and gently sloping to the north-northwest. There is a slight downgrade at the north end of the facility which encourages runoff to flow northeast into the catchment basin or the adjacent drainage ditch.

Several buried utilities including water, electric, sewer, telephone, and product piping exist on and adjacent to the Navy Fuel Farm grounds.

## 2.2 SITE GEOLOGY

Soil cover at the Navy Fuel Farm varies in thickness from 6 to 21 ft. In general, soil depth increases from south to north, reflecting the dip of the underlying bedrock strata. The northeast edge of the site is underlain by soil types belonging to the Readington Silt Loam group; the remainder of the site is covered with fill material. The site-specific shallow stratigraphy is comprised primarily of silty clay and clayey silt with varying amounts of sand and little gravel. The high proportion of clay in the soil leads to reduced permeability and slow infiltration rates (EA 1996).

Unconsolidated materials at the site are underlain by the Middle Arkosic Member of the Late Triassic Stockton Formation. This member consists of interbedded red shale, siltstone, and gray-tan, medium-grained, arkosic sandstone which was deposited as part of coalescing fluvial channel system. Red shale and siltstone are predominant along the south edge of the site, whereas the arkosic sandstone underlies the remainder of the site.

Depth to competent rock ranges from 6 ft in areas where soil was removed during site construction activities (typically in areas underlain by sandstone) to 20 ft in areas underlain by shale or siltstone. Relict bedding structure within soil is often present as a zone several feet thick and overlying shale or siltstone units. Regional bedrock formation dip ranges from 5 to 15 degrees with strike to the north-northwest (Rima *et al.* 1962). Rock beds vary in thickness,

often pinching out or grading into other facies, making interpretation of stratigraphic correlation difficult.

Regionally, small displacement normal faults trending northeast-southwest are present throughout the unit. Two sets of vertical joints, roughly parallel and perpendicular to the bedding strike direction, are well developed. A third set of joints, though not as well expressed as the first two, trends northwest-southeast (Rima *et al.* 1962).

## 2.3 SITE HYDROGEOLOGY

The depth to static ground water at the site on 13 January 1997 ranged from approximately 11 ft (well NFFW-4) to 25 ft (well NFFW-20) below grade. However, water levels in the monitoring wells fluctuate several feet annually due to seasonal influences. In most cases, ground water is observed within bedrock fractures or within the weathered zone immediately overlying competent rock. Static water levels not only reflect the regional potentiometric surface but also the composite head resulting from the different water-yielding zones that the wells intercept. For this reason, water levels may show marked differences in nearby wells depending on the number, location and size of fractures intercepted by each well.

Based upon several rounds of well gauging, ground-water flow at the Navy Fuel Farm is predominantly to the north, as illustrated in Figure 2-3. However, because flow is primarily through fractures within the bedrock or weathered bedrock, localized flow direction may vary. Ground-water flow through the arkosic sandstone is more rapid than through the shale/siltstone as evidenced by more rapid recharge rates during well development and purging prior to sampling. This may be due to the greater size and density of the fractures present within the sandstone.

Using the Neuman Method for numerical characterization of unconfined aquifers, the average hydraulic conductivity, as derived from pumping test data at wells NFFW-2R, NFFW-8, NFFW-12, NFFW-14, and NFFW-16 (EA 1991), was estimated at $4.05 \times 10^{-5}$ cm/sec. The average ground-water velocity has been estimated at 30 ft/year, assuming an effective porosity of 7 percent and a hydraulic gradient of 0.029 ft/ft (EA 1991). Aquifer tests conducted during low water table conditions have indicated that the wells are low yielding, typically 0-2 gal per minute (EA 1991).

## 2.4 HISTORY OF FUEL STORAGE AND PRODUCT RELEASES AT THE NAVY FUEL FARM

From 1950 to 1991, two partially buried 210,000-gal JP-4/JP-5 aviation fuel tanks (Tank Nos. 115 and 116) were located at the site. A 500-gal underground waste oil tank and an underground diesel fuel tank were also located at the southwestern corner of the site. Figure 2-4 is a site map of the Navy Fuel Farm prior to 1991.

In 1986, a spill occurred when Tank 115 was overfilled and fuel was released from the vent pipe onto the ground. The event was attributed to faulty gauges which registered less fuel than was actually present. During this same year, a utility trench was excavated along the western boundary of the site but work discontinued when LNAPL was observed floating on the water within the trench. The area where the LNAPL was discovered is immediately adjacent to a former drywell. The drywell accepted water which was periodically siphoned from the bottom of the fuel tanks.

In March 1989, JP-5 jet fuel was detected emanating from two patches of dead grass on the west side of Tank 115. Heavy rains flushed this fuel into the ditch on the north side of the site. Navy personnel responded with the placement of sorbant material in the ditch and adjacent to Tank 115. With this evidence of tank leakage, it was decided to empty and remove the two main fuel tanks (Tank Nos. 115 and 116). Removal of these tanks occurred in 1991. Also during this time, the waste oil and diesel fuel underground storage tanks (USTs) were removed. Inspection of the waste oil tank during removal revealed the tank was not intact as holes up to 1-in. in diameter were reported.

Subsequent to the completion of removal activities, a new AST system was installed to the east of the former tank field location. In order to accommodate the newly constructed Navy Fuel Farm, Building No. 157 was removed. The new tank system at the Navy Fuel Farm consists of aboveground steel tanks set in a concrete berm. The Navy Fuel Farm is currently inactive.

## 2.5 COMPARISON OF ANALYTICAL RESULTS TO REGULATORY GUIDANCE CRITERIA

Several previous investigations have been conducted at the Navy Fuel Farm. The Navy intends to pursue the transfer of the Navy Fuel Farm from the Installation Restoration (IR) Program to the Commonwealth of Pennsylvania's UST/AST program. As discussed in the following sections, several VOC including methylene chloride and 2-butanone have been reported in soil samples collected at the Navy Fuel Farm. As a result, additional characterization of this site is planned to evaluate if non-petroleum constituents of potential concern (COPC) are present. This additional site characterization includes soil and ground-water sampling and will be conducted during the Summer of 1997. If non-petroleum COPC are present, they could be addressed separately from the petroleum related remedial action and may not prevent the Fuel Farm from being regulated under the Pennsylvania UST/AST program. Therefore, this section presents a comparison of the results of soil and ground-water sampling and analysis to the guidance criteria established by Pennsylvania's Land Recycling Program (Pennsylvania 1995).

### 2.5.1 Soil Samples

Soil samples in the vicinity of the fuel farm were first collected in March 1989 as part of an investigation to assess potential subsurface hydrocarbon contamination in areas planned for

future construction (EA 1989). At that time a total of 24 soil samples were collected from 18 borings installed around Building 340 (Figure 2-5). The samples were analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX). None of the samples collected contained individual BTEX components exceeding the guidance criteria (EA 1991).

Also in 1989 as part of additional investigations at the Navy Fuel Farm 4 soil samples were collected during the installation of three monitoring wells and one soil boring (EA 1989). The samples were analyzed for several volatile organic compounds (VOC) and base neutral extractable organic compounds. Only 1 of the 4 samples collected contained VOC concentrations exceeding the regulatory guidance criteria. Methylene chloride and 2-butanone (or methyl ethyl ketone [MEK]) were reported in the soil sample collected from monitoring well NFFW-7. Methylene chloride was present at a concentration of 2,300 $\mu$g/kg and the guidance criteria is 500 $\mu$g/kg. The concentration of 2-butanone was 88 $\mu$g/kg and the guidance criteria is 50 $\mu$g/kg (EA 1990).

Additional soil samples were collected in April 1991 during the installation of four monitoring wells and analyzed for BTEX (EA 1991). Of the four samples collected, only 1 sample contained a concentration of any analyte exceeding the regulatory guidance criteria. The sample collected from monitoring well NFFW-8 had a total xylene concentration of 290,000 $\mu$g/kg compared to a guidance criteria of 5,000 $\mu$g/kg (EA 1991).

### 2.5.2 Ground-Water Samples

A total of 36 ground-water samples were collected from selected monitoring wells on 5 occasions from June 1989 through June 1993. Of the 23 ground-water samples collected prior to June 1993, 8 samples contained concentrations of benzene in excess of the 5 $\mu$g/L guidance criteria with concentrations ranging from 10 to 990 $\mu$g/L. These wells were NFFW-1, 2 (two samples), 7 (two samples), 9, 13 and 16. None of the other analytes tested exceeded the guidance criteria. It should be noted that several wells were not sampled due to the occurrence of LNAPL (EA 1993a).

During the most recent, June 1993, sampling event 5 of the 13 ground-water samples collected contained benzene concentrations in excess of the 5 $\mu$g/L guidance criteria with concentrations ranging from 6-67 $\mu$g/L. These wells were NFFW-5, 9, 11, 17, and 19. Benzene was the only analyte to exceed the guidance criteria. During this event, wells NFFW-1, 2R, 6, 7, 12, 13, 14, and 16 were not sampled due to the presence of LNAPL (EA 1993a).

Ground-water samples were also collected from well NFFW-2R during the pilot study. A total of seven samples were collected between April 1995 and July 1996 and analyzed for BTEX, naphthalene, and total petroleum hydrocarbons (TPH). Each sample exceeded the 5 $\mu$g/L benzene and 20 $\mu$g/L naphthalene guidance criteria.

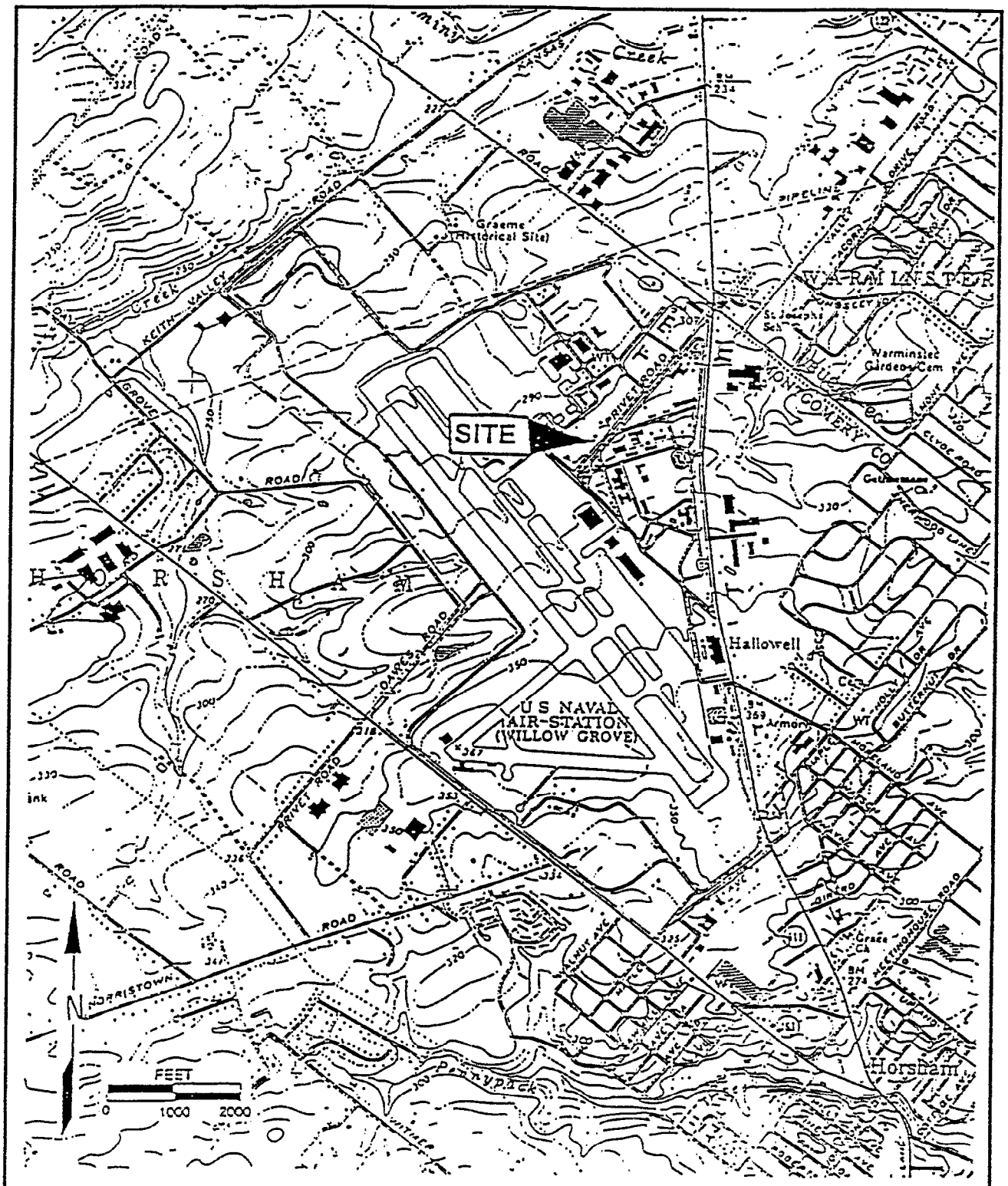


**Figure 2-1. Site Location Map, Navy Fuel Farm Facility, Naval Air Station Joint Reserve Base, Willow Grove, Pennsylvania.**

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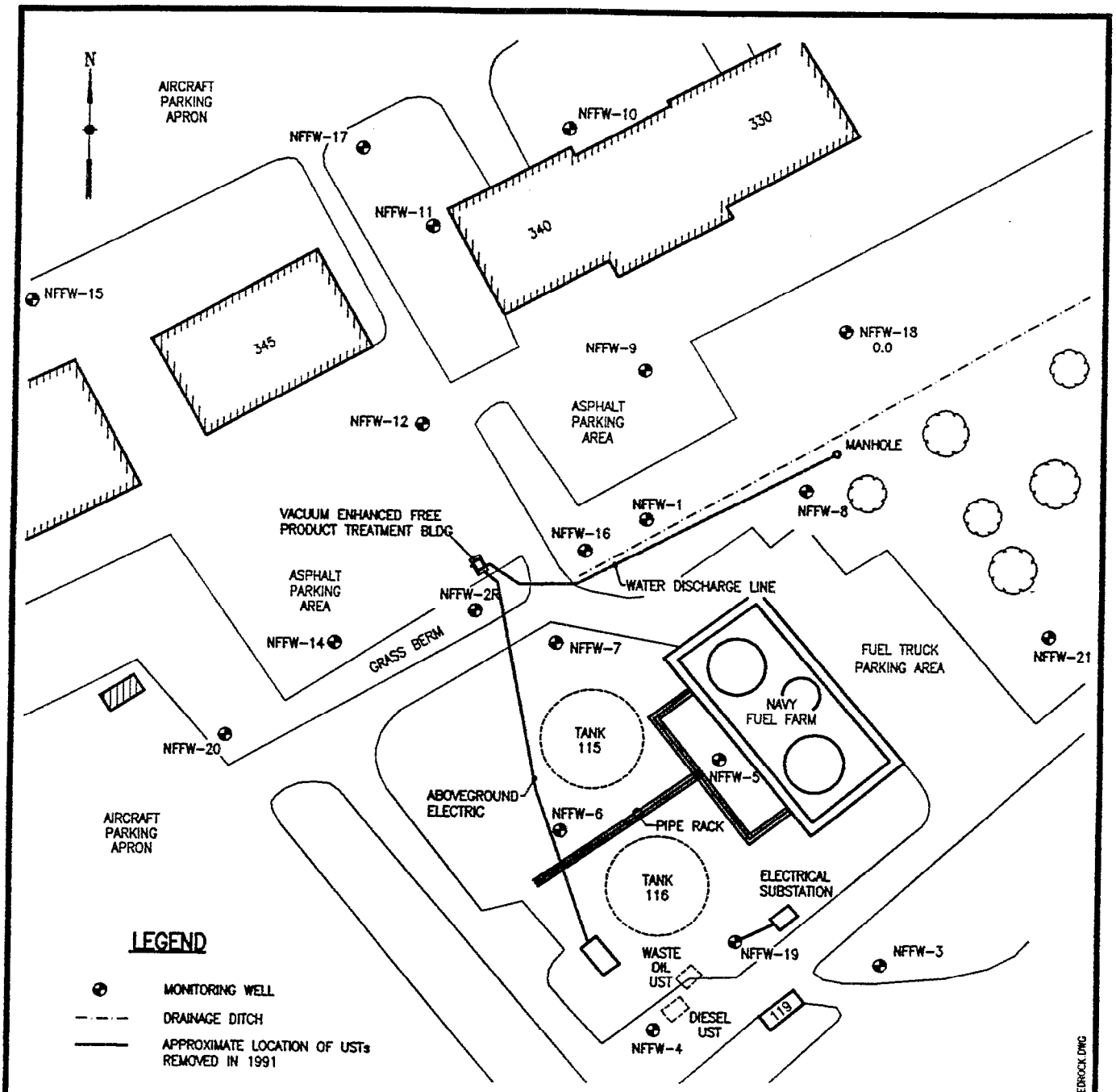


NOTE:

BASE MAP DEVELOPED FROM EA FIELD MEASUREMENTS AND SITE PLAN DEVELOPED BY EA (1993). NO AS-BUILT DRAWINGS OF NEW FUEL FARM FACILITY WERE AVAILABLE FROM NAVY PERSONNEL PRIOR TO DEVELOPMENT OF BASE MAP. BASE MAP IS INTENDED AS A REFERENCE ONLY. ANY DECISIONS MADE BASED ON THE CONTENT OF THIS MAP ARE THE SOLE RESPONSIBILITY OF THE USER.

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NAVY FUEL FARM FACILITY
NAVAL AIR STATION JOINT RESERVE BASE
WILLOW GROVE, PENNSYLVANIA

SITE PLAN

| PROJECT MGR | DESIGNED BY | DRAWN BY | CHECKED BY | SCALE | DATE | PROJECT NO | FIGURE |
|---|---|---|---|---|---|---|---|
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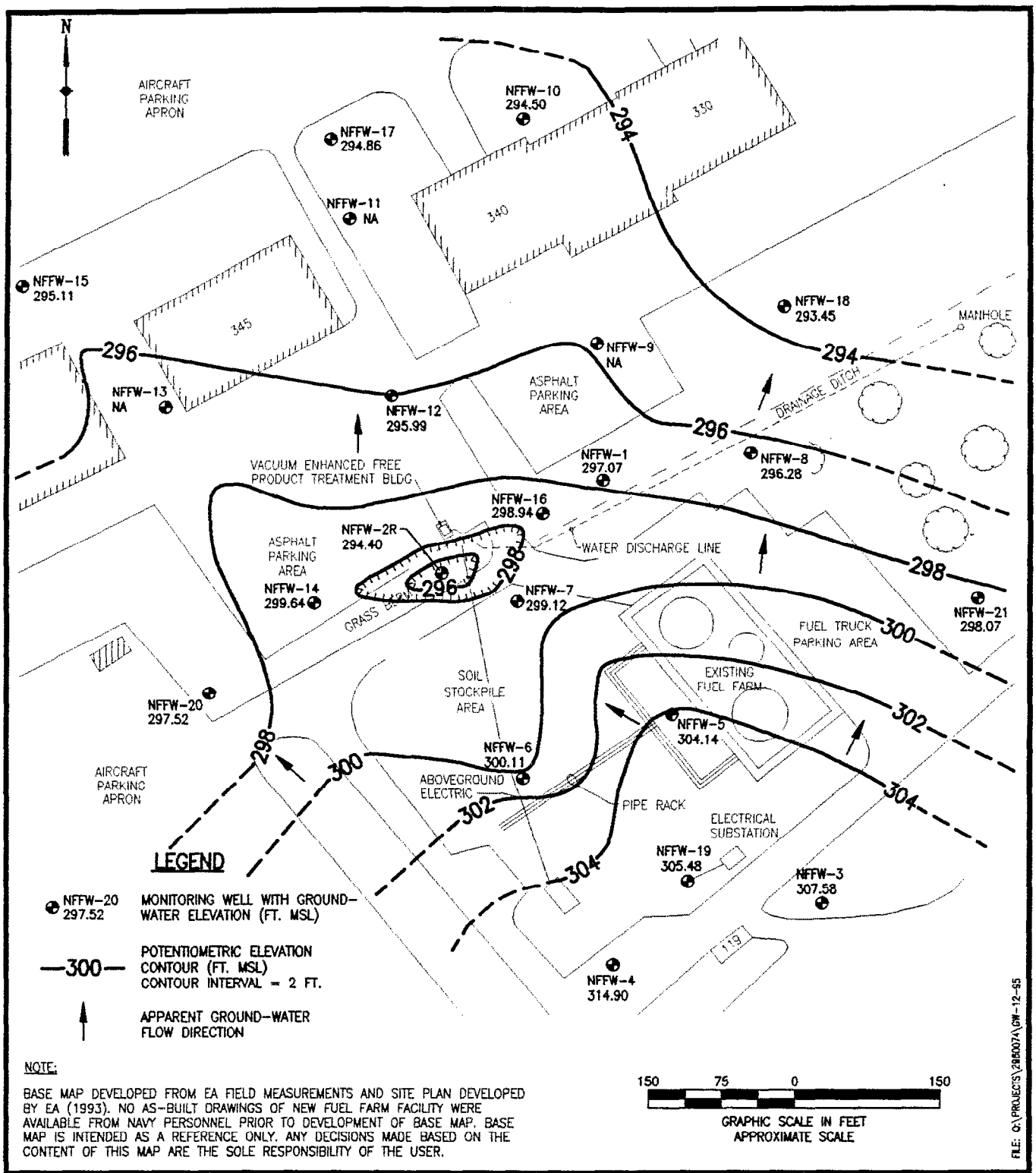


NOTE:

BASE MAP DEVELOPED FROM EA FIELD MEASUREMENTS AND SITE PLAN DEVELOPED BY EA (1993). NO AS-BUILT DRAWINGS OF NEW FUEL FARM FACILITY WERE AVAILABLE FROM NAVY PERSONNEL PRIOR TO DEVELOPMENT OF BASE MAP. BASE MAP IS INTENDED AS A REFERENCE ONLY. ANY DECISIONS MADE BASED ON THE CONTENT OF THIS MAP ARE THE SOLE RESPONSIBILITY OF THE USER.

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NAVY FUEL FARM FACILITY
NAVAL AIR STATION JOINT RESERVE BASE
WILLOW GROVE, PENNSYLVANIA

POTENTIOMETRIC SURFACE
8 DECEMBER 1995

| PROJECT MGR | DESIGNED BY | DRAWN BY | CHECKED BY | SCALE | DATE | PROJECT NO | FIGURE |
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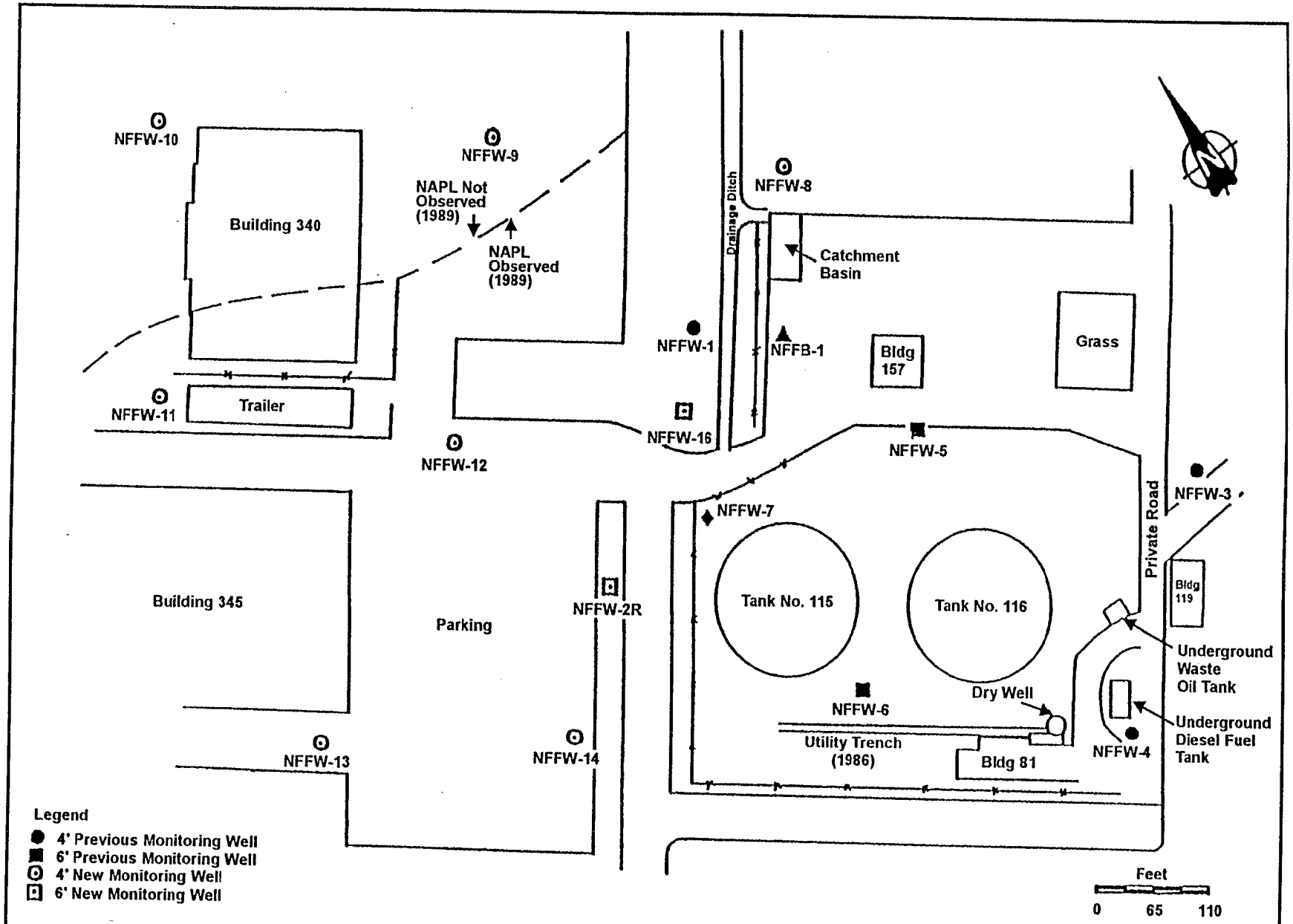


Figure 2-4. Site Plan Showing Relevant Site Features, Prior to 1991.
Navy Fuel Farm Facility, Naval Air Station Joint Reserve Base, Willow Grove, Horsham Township, Pennsylvania.

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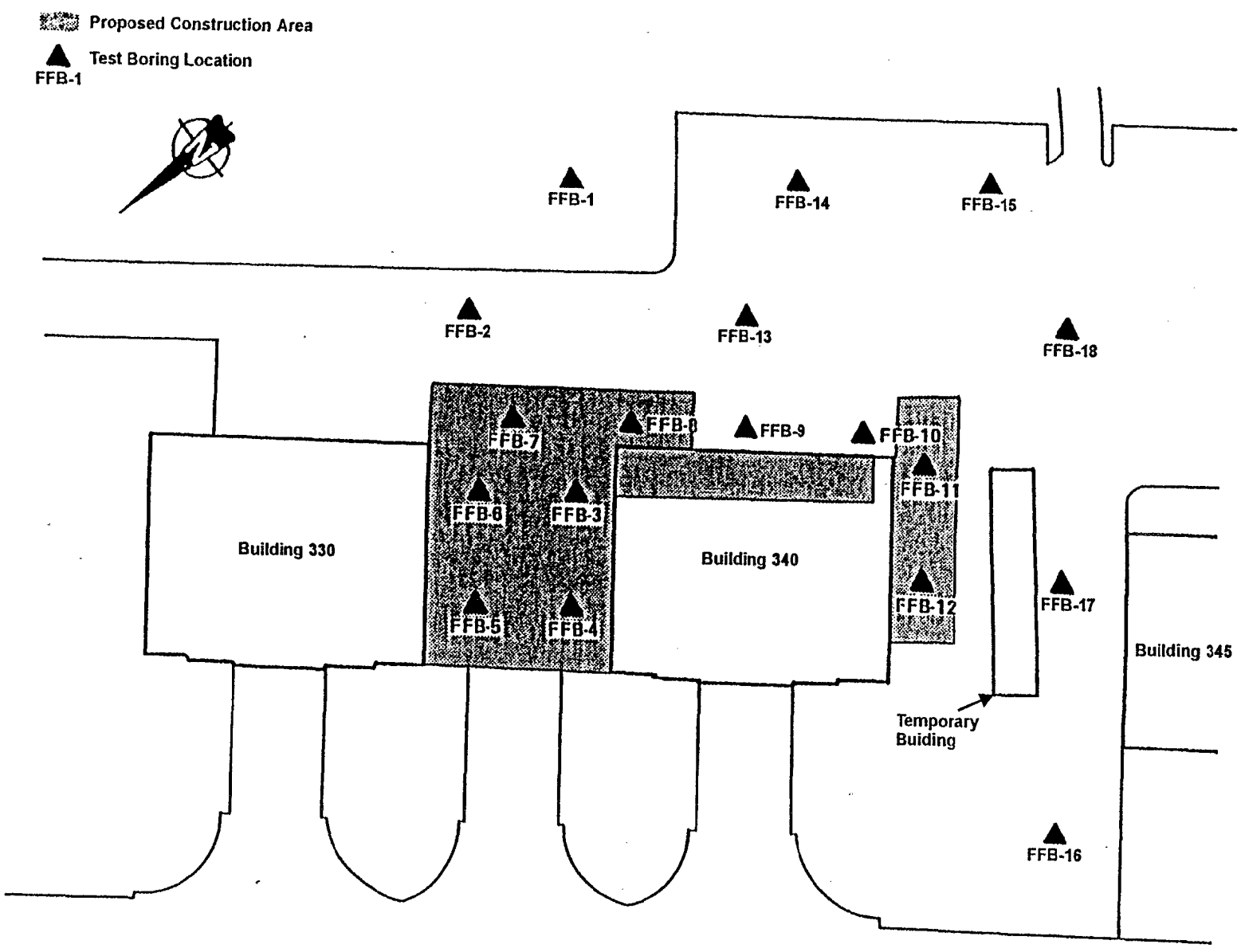


Figure 2-5. Location of Soil Borings Installed in March 1989.
Navy Fuel Farm Facility, Naval Air Station Joint Reserve Base, Willow Grove, Horsham Township, Pennsylvania.

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# 3. RISK EVALUATION

The purpose of this section is to briefly summarize the potential threats to human health and the environment associated with the Navy Fuel Farm. This was accomplished by identifing several potential exposure pathways, reviewing the available analytical data, and assessing whether exposure occurs under current site usage.

Human health exposure pathways identified include:

- ground-water ingestion and inhalation,
- dermal contact, ingestion, and inhalation of soil and water by construction personnel during site construction activities,
- surface soil ingestion.

As discussed in Section 2.5, the results of historic soil and ground-water samples collected during previous investigations conducted at the Navy Fuel Farm were compared to guidance criteria established by Pennsylvania's Land Recycling Program, Technical Guidance, July 1995 (Pennsylvania 1995). Specifically, soil sample results were compared to the most conservative criteria, soil to ground-water pathway, and ground-water sample results were compared to the aquifer ingestion criteria. Several COPC exceeded these criteria in subsurface soil and ground-water samples.

The Stockton Formation underlies the NASJRB Willow Grove, including the Navy Fuel Farm. This formation consists of two aquifers, the water table aquifer and the confined middle member. The Navy Fuel Farm is adversly impacting the quality of the water table aquifer, however, the water table aquifer is not used as a drinking water source. As a result, the potential for exposure to impacted ground water through ingestion or inhalation is expected to be minimal.

No surface soil samples have been collected at the Navy Fuel Farm. However, all soil sample depths were selected based on screening with a photoionization detector (PID). Based on the PID screening, surficial soil in the area of NFFW-7 may have been impacted. This soil was removed during the removal of tanks 115 and 116 in 1991. As a result, the potential for future exposure through surface soil ingestion is expected to be minimal.

Construction activities represent one scenario in which exposure to impacted soil and ground water may occur. However, exposure could be minimized by monitoring and the use of appropriate personal protective equipment during construction activities.

Because the COPC exist in the subsurface, the impacts to the environment are also expected to be minimal. The likely potential exposure is through discharge of LNAPL or ground water to surface water, however, this has not been observed. The nearest potential location of

discharge is approximately 2,000 ft away.

In summary, the potential for exposure to COPC is minimal; therefore, the potential for risks to human health and the environment is expected to be minimal.

# 4. PILOT STUDY RESULTS AND CONCLUSIONS

## 4.1 Summary of Pilot Study Results

During the 32-month pilot period (March 1994 - October 1996) the LNAPL recovery pilot system at well NFFW-2R was operated both with and without vacuum-enhancement. The total volume of LNAPL recovered was 1,513 gal and 1,435,392 gal of ground water was pumped. Additionally, the equivalent of approximately 401 gal of LNAPL was recovered in the vapor-phase through vacuum-enhanced operation, for a total LNAPL recovery of 1,914 gal.

Automated skimming operations recovered a total of 1.86 and 0.00 gal of LNAPL from wells NFFW-6 and NFFW-19, respectively. Passive LNAPL skimming recovered a total of 55.11 and 14.32 gal of LNAPL from wells NFFW-14 and NFFW-16, respectively. Small amounts of LNAPL were also recovered through hand bailing at wells NFFW-1, NFFW-7, NFFW-12, and NFFW-20. LNAPL skimming and hand bailing recovered a total of 86.32 gal of LNAPL or approximately 6% of the 1,513.09 gal of LNAPL recovered during the pilot study. LNAPL recovery during the pilot study is summarized in Table 4-1.

## 4.2 Occurrence and Distribution of LNAPL

Significant amounts of LNAPL remain in the subsurface at the Navy Fuel Farm and the occurrence of LNAPL in wells is related to the water-table elevations. During periods of a high water elevations, LNAPL is present sporadically in a few wells. However, during periods of low or falling water table elevations, LNAPL is found throughout the Navy Fuel Farm. LNAPL was observed in a 4.6 acre area bounded by monitoring wells NFFW-19, NFFW-6, NFFW-20, NFFW-12, and NFFW-8 excluding NFFW-5.

LNAPL tends to be present in monitoring wells when the water-table elevation is in the fractured rock zone and not when the water table elevation is in the overburden. The relationship between water elevation and LNAPL recovery is illustrated for well NFFW-2R in Figures 4-1 and 4-2. These figures compare instantaneous and cumulative LNAPL recovery and water-table elevation, respectively. Figures 4-1 and 4-2 illustrate that LNAPL recovery is greatest during periods of low water-table elevation and virtually no LNAPL is recovered during periods of high water-table elevations. In addition, both figures reveal that the optimum water-table elevation for LNAPL recovery at well NFFW-2R falls in the approximate range of 285 to 292 ft above mean seal level (msl); approximately 30 to 23 ft below top-of-casing (TOC). One possible explanation for the relationship between the water-table elevation and the occurrence and recoverability of LNAPL in the monitoring wells is that the LNAPL is present in the rock fractures and flows into the wells during periods of low water-table elevation. However, during periods of high water-table elevation, the LNAPL becomes hydraulically isolated from the well. The result is that the LNAPL cannot enter the well and, therefore, no LNAPL is observed in the well during periods of a high water table

## 4.3 LNAPL Recovery without Vacuum Enhancement

LNAPL recovery without vacuum enhancement was successful when the water table was depressed. While operating the recovery system at NFFW-2R without vacuum enhancement from July 1994 to July 1995, the average LNAPL recovery rate was 2.5 gal per day at a ground-water pumping rate of 0.3 gal per minute. However, the fluctuation of the water table had a large influence on the rate of LNAPL recovery. In addition to the absence of LNAPL when the water-table elevation was high, heavy rainfalls also affected LNAPL recovery. Heavy rainfalls often increased recharge that raised the water-table elevation faster than the water-table depression pump (rated at 7 gpm) could maintain the depressed water-table. As a result, the recovery pump would become submerged. The ground-water pumping rate needed to maintain the desired drawdown in NFFW-2R during periods of high water-table elevation is estimated at 10-15 gpm, based on results of a rate check conducted in March 1996.

Furthermore, recovery was also limited during drought periods when the LNAPL/water interface dropped below the level of the recovery pump intake. The option of deepening the wells was considered, however, because of the potential to cross-contaminate the lower portion of the Stockton Formation, which is utilized as a water supply, this option was ruled out.

Depending on the monitoring well, the pilot study reports limited success in skimming of LNAPL. Typically, both automated skimming and hand bailing are effective methods of recovering LNAPL in the immediate area of the well but do not create a significant capture zone. Based on the hand bailing and automated skimming results, the automated skimmers were not deployed in the proper wells. Manual bailing of LNAPL from NFFW-14 and NFFW-16 recovered 55 gal and 14.32 gal respectively. The hand bailing results indicate that automated bailing should also be effective. Based on the available information at the start of the pilot study, automated skimming systems were installed in NFFW-6 and NFFW-19. However, the amount of LNAPL recovered from wells NFFW-6 and NFFW-19 (1.86 gal and 0 gal respectively) did not justify the effort of installing the automated skimmers. The automated skimmer from NFFW-19 was subsequently moved to NFFW-14, but high water-table elevations limited LNAPL recovery. However, 12 gal of LNAPL were recovered in 1996 through the use of the automated skimmer at well NFFW-14 representing nearly a 25 percent increase in recovery over the same period in 1995.

## 4.4 Vacuum Enhanced LNAPL Recovery

Vacuum enhanced LNAPL recovery was also hampered by the fluctuations in the water table. For much of the time that vacuum enhanced recovery was conducted, the LNAPL/water interface was below the level of the recovery pump intake. As a result, during the August-November 1995 time period, most of the hydrocarbons recovered during the vacuum enhanced recovery operations were recovered in the vapor-phase. The equivalent of approximately 4.1 gal per day was recovered in the vapor phase compared to 0.24 gal per day of LNAPL. Comparing the amount of LNAPL recovered during the July 1994-July 1995 period of

recovery without vacuum-enhancement and the August-November 1995 period of vacuum-enhanced recovery; vacuum-enhanced recovery resulted in a 64 percent increase in hydrocarbon recovery when vapor-phase recovery is considered.

Vacuum-enhanced recovery also increased the LNAPL recovery rate during the June 1994 vacuum-enhanced recovery operations when compared to the 30 March-3 June 1994 recovery operations without vacuum-enhancement. Approximately 9.7 gal per day of LNAPL was recovered without vacuum-enhancement as compared to 19.9 gal per day with vacuum-enhancement. This is a 105 percent increase in LNAPL recovery using vacuum-enhanced recovery. However, the June 1994 vacuum-enhanced recovery operations were of too short a duration to draw conclusions about the long-term effectiveness of vacuum-enhanced recovery.

Based on each period of vacuum-enhanced recovery operations, water-table fluctuations had a large impact on the amount of LNAPL recovered. As discussed above, deepening of NFFW-2R is not recommended. However, when the water-table elevation fell below the recovery pump intake, vacuum-enhanced recovery did result in the removal of significant amounts of hydrocarbons which would not have been recovered otherwise. In addition, oxygen is typically the limiting factor for subsurface biological activity and the biodegradability of petroleum products is well documented. Therefore, it is likely that vacuum-enhanced recovery will stimulate biological degradation of residual-phase petroleum hydrocarbons in the vadose zone.

## 4.5 Soil Vapor Extraction Testing

Based on the results of two sets of SVE tests, SVE appears to be of limited use as a remedial option for this site. This is a result of the small radial influences observed, low vapor flow rates, and low vapor phase hydrocarbon recovery rates. The results from the April 1994 test (high water-table conditions) indicate hydrocarbon recovery rates between approximately 11.5 and 28.5 lbs/day are attainable for wells NFFW-7 and NFFW-16, respectively. During the July 1995 test (low water-table conditions) recovery rates for the same two wells were less than 1.0 lb/day. However, as with vacuum-enhanced recovery, SVE would result in the removal of some residual phase hydrocarbons which would not otherwise be recovered and would stimulate biodegradation of the residual phase petroleum hydrocarbons.

## 4.6 Pilot Study Conclusions

Based on the results of the pilot study, the following conclusions can be made. These form the basis for the recommended remedial action presented in Chapter 6.

- Based on a comparison of the analytical results from previous investigations to the Pennsylvania guidance criteria, the remedial action objectives at the Navy Fuel Farm should include source reduction through recovery of LNAPL and ground-water remediation.

- Significant amounts of LNAPL remain at the Navy Fuel Farm. Recoverable amounts of LNAPL have been gauged in wells NFFW-1, NFFW-2R, NFFW-7, NFFW-14, NFFW-16, and NFFW-20.

- LNAPL occurrence in wells is directly related to water-table elevation. During periods of high water-table elevation, LNAPL is present in only a few monitoring wells. During periods of low water-table elevation, the occurrence of LNAPL increases, both in areal extent and in thickness of the LNAPL layer observed in the monitoring wells.

- Recovery of the LNAPL is limited by the hydrogeology of the site. In particular, the LNAPL appears to be present in the fractures of the bedrock and becomes isolated from the site wells during periods of high water-table elevation. The water-table fluctuates seasonally and with rainfall events. The large and relatively rapid fluctuations (up to 24 ft) make maintaining the pump intake at the proper level very difficult.

- LNAPL recovery using water-table depression without vacuum-enhancement was an effective method of recovery. Automated skimming of LNAPL was not an effective method of recovery.

- LNAPL recovery using vacuum-enhanced recovery was limited due to both high and low water table elevations resulting in the LNAPL/water interface being either above or below the level of the intake of the recovery pump during portions of the periods that vacuum-enhanced recovery was tested. However, when vapor-phase recovery of LNAPL is accounted for, vacuum-enhanced recovery did increase the amount of petroleum hydrocarbons recovered.

- Because of small radius of influence and low vapor recovery rates, SVE is only marginally effective at the Navy Fuel Farm.

FIGURE 4-1

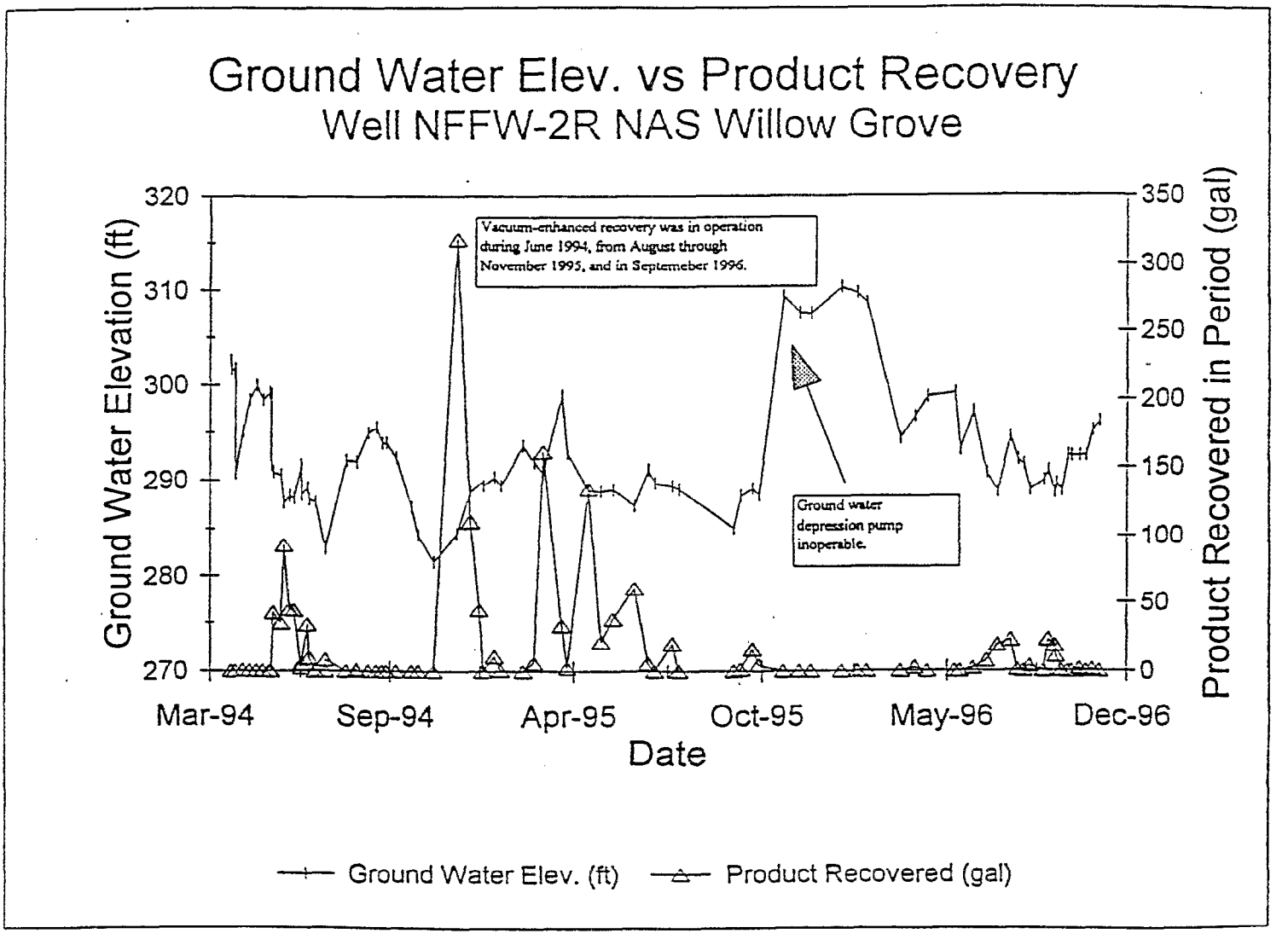
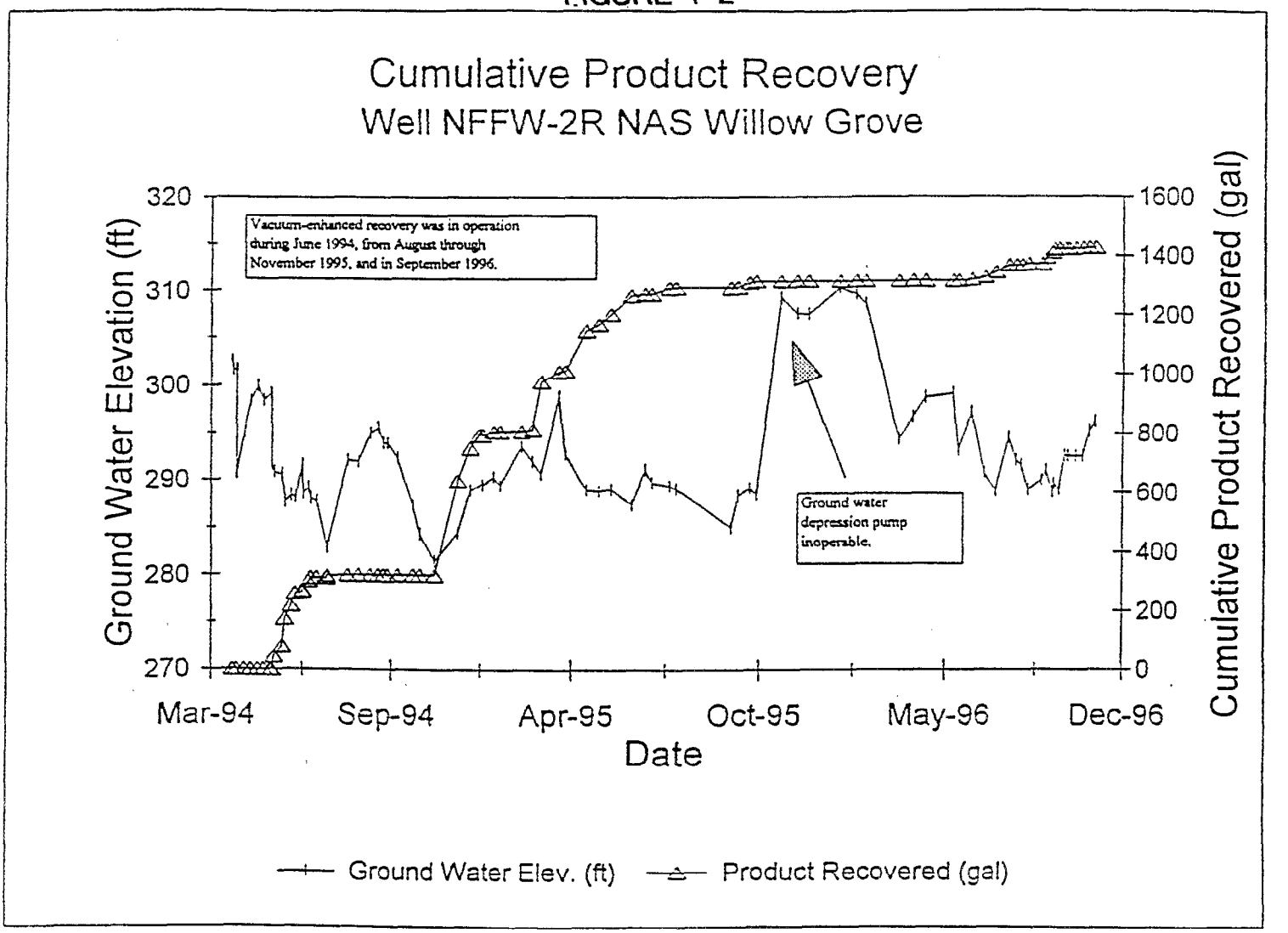

Ground Water Elev. vs Product Recovery
Well NFFW-2R NAS Willow Grove
Ground Water Elevation (ft)
320
310
300
290
280
270
Product Recovered in Period (gal)
350
300
250
200
150
100
50
0
Vacuum-enhanced recovery was in operation during June 1994, from August through November 1995, and in Septemeber 1996.
Ground water depression pump inoperable.
Mar-94
Sep-94
Apr-95
Oct-95
May-96
Dec-96
Date
Ground Water Elev. (ft)
Product Recovered (gal)

FIGURE 4-2


Cumulative Product Recovery
Well NFFW-2R NAS Willow Grove
Vacuum-enhanced recovery was in operation during June 1994, from August through November 1995, and in September 1996.
Ground water depression pump inoperable.
Ground Water Elevation (ft)
320
310
300
290
280
270
Cumulative Product Recovered (gal)
1600
1400
1200
1000
800
600
400
200
0
Mar-94
Sep-94
Apr-95
Oct-95
May-96
Dec-96
Date
Ground Water Elev. (ft)
Product Recovered (gal)

# TABLE 4-1 SUMMARY OF LNAPL RECOVERY

## NAVY FUEL FARM FACILITY
## NAVAL AIR STATION JOINT RESERVE BASE, WILLOW GROVE
## HORSHAM TOWNSHIP, PENNSYLVANIA

| Well No. | Cumulative Product Recovered (gal)* |
|---|---|
| NFFW-1 | 0.25 |
| NFFW-2R | 1427.02/400.83 |
| NFFW-6 | 1.86 |
| NFFW-7 | 2.00 |
| NFFW-12 | 0.25 |
| NFFW-14 | 67.29 |
| NFFW-16 | 14.32 |
| NFFW-19 | 0.00 |
| NFFW-20 | 0.35 |
| **TOTAL** | **1513.09/400.83** |

Note: * Where two numbers appear (1312.75/378), the first number references product recovered as liquid-phase and the second number estimates the liquid equivalent of product recovered via vapor-phase during vacuum enhanced free product recovery. Vacuum enhanced free product recovery from well NFFW-2R began on 17 August 1995 and has been operated on an intermittent basis.

# 5. EVALUATION OF REMEDIAL ALTERNATIVES

As stated in Chapter 4, the remedial action objective at the Navy Fuel Farm is source reduction through the recovery of LNAPL and ground-water remediation. Based on the results of the pilot study and in order to meet this objective the following options for LNAPL recovery were considered for the full-scale remedial system in addition to the recommended alternative of water table depression and vacuum enhancement on a year round basis:

- no further action
- LNAPL vacuum-enhanced recovery using water-table depression operating all year
- LNAPL recovery using water-table depression without vacuum-enhancement operated only during periods of low water-table elevations
- LNAPL recovery using vacuum-enhanced recovery when conditions are favorable and only water table depression when conditions for vacuum-enhanced recovery are not favorable
- bioslurping

The no further action option does not meet the remedial action objective and is therefore not applicable. As a result, it will not be further discussed. Each remaining option would include expansion of the recovery efforts to include new wells installed in the vicinity of NFFW-2R, NFFW-14 and NFFW-16, except bioslurping which would require additional extraction points due to the anticipated minimal radius of influence as evidenced by the results of SVE tests. Furthermore, each option would be supplemented by a bailing program to recover LNAPL that occurs intermittently at other site wells. The following discusses the advantages and disadvantages of each option. Approximate design, construction and operation and maintenance costs are also provided and summarized on Table 5-1.

## 5.1 LNAPL Vacuum-Enhanced Recovery

The advantages to operating a full scale vacuum-enhanced recovery system include the increased rate of LNAPL recovery; recovery of vapor-phase hydrocarbons during periods when the water-table elevation falls below the well; reduction of residual-phase hydrocarbons; treatment of dissolved-phase hydrocarbons; and increased biodegradation. All of these advantages result in a decreased duration for remediation as compared to the water-table depression only design.

The disadvantages include the cost of treating the air emissions and the increased water flow rates. In addition, to accommodate the water flow rates that would result from expanding the system, larger water table depression pumps and water treatment equipment will be required.

Treatment of the air emissions is an expensive part of the vacuum enhanced recovery system. The recovery rate of vapor phase hydrocarbons varies with the water-table elevation and the amount of LNAPL in the well. This makes selection of an off-gas treatment technology difficult. For example, when vapor-phase concentrations are high as is the case when the water table is low, the cost of carbon treatment is prohibitive; conversely, when vapor-phase concentrations are low, the cost of providing supplemental fuel for the thermal oxidizer is also expensive. The thermal oxidizer currently at the site is large enough to handle the increased air flow from additional wells. The operating costs of the thermal oxidizer can be decreased by adding a heat exchanger and/or a catalytic oxidizer option to the thermal oxidizer. These features will reduce the amount of supplemental fuel required to treat the air emissions.

As shown on Table 5-1, the approximate cost for design of this option ranges from $25,000 to $30,000 with construction costs in the range of $320,000 to $510,000. This assumes installation of three new wells, purchasing the existing thermal oxidizer, installing new ground-water treatment units, and equipping the system with telemetry. Average annual operation and maintenance costs are estimated to range between $72,000 and $120,000.

## 5.2 LNAPL Recovery Using Water Table Depression Without Vacuum-Enhancement Operated Only During Periods of Low Water Table Elevations

This option would operate only during periods of low water table elevation. This option would recover significant amounts of LNAPL at the lowest cost. The disadvantage is that during periods of high water table elevation no remediation would be accomplished.

Several additions to the current system would be required to expand recovery operations. Three new larger diameter wells would be installed, new ground-water depression pumps would be required, and the water treatment system would need to be expanded to add larger carbon adsorption units to accommodate the increased water flow.

The approximate cost for design of this option ranges from $20,000 to $25,000 with construction costs in the range of $250,000 to $420,000. Additionally, average annual operation and maintenance costs are estimated to range between $40,000 and $60,000. Approximate cost ranges for this option are also summarized on Table 5-1.

## 5.3 LNAPL Recovery Using Vacuum-Enhanced Recovery when Conditions are Favorable and Only Water Table Depression When Conditions for Vacuum Enhanced Recovery are not Favorable

When conditions are favorable, selective use of vacuum-enhancement would increase the LNAPL recovery rate and allow remediation to continue when the LNAPL/water interface drops below the well. Remediation of the residual phase and increased biodegradation would also occur. However, this option does not optimize LNAPL recovery during times of high water-table, but does minimize the cost of supplemental fuel for offgas treatment.

The approximate cost for design of this option ranges from $25,000 to $30,000 with construction costs in the range of $320,000 to $510,000. Average annual operation and maintenance costs are estimated to range between $55,000 and $65,000. These cost ranges are summarized on Table 5-1.

## 5.4 Bioslurping

Conceptually, bioslurping and vacuum enhanced recovery are the same remedial technology. Both options extract LNAPL, ground water, and soil vapor. The difference is that bioslurping uses a vacuum pump to withdraw liquids and vapors from the extraction well. Vacuum pumps are limited to one atmosphere of pressure (33 ft of water). Therefore, accounting for head losses, after the LNAPL/water interface dropped more than 20-25 ft below the ground surface, bioslurping would not be able to extract liquids. While the extraction of LNAPL and a ground water/soil vapor mixture may allow recovery from depths greater than 20-25 ft, an advantage of bioslurping is that it minimizes the amount of water pumped. However, due to the large water table fluctuation at this site, placement of the intake in a bioslurping system would be well below the water table during much of the year and the amount of water pumped may not be decreased. Therefore, bioslurping is not an appropriate technology at this site because of the large range of ground-water pumping rates. Because bioslurping, using a single vacuum pump, is not appropriate, costs have not been estimated.

# TABLE 5-1 COST COMPARISON SUMMARY - REMEDIAL ALTERNATIVES

## NAVY FUEL FARM FACILITY
## NAVAL AIR STATION JOINT RESERVE BASE, WILLOW GROVE
## HORSHAM TOWNSHIP, PENNSYLVANIA

| Remedial Option | Approximate Design Cost | Approximate Construction Cost | Approximate Operation and Maintenance Cost (Annual) |
|---|---|---|---|
| LNAPL Vacuum-Enhanced Recovery Using Water-Table Depression Operating All Year | $25,000-30,000 | $320,000-510,000 | $72,000-120,000 |
| LNAPL Recovery Using Water-Table Depression Without Vacuum-Enhancement Operated Only During Periods of Low Water-Table Elevations | $20,000-25,000 | $250,000-420,000 | $40,000-60,000 |
| LNAPL Recovery Using Vacuum-Enhanced Recovery when Conditions are Favorable and Only Ground-Water Table-Depression when Conditions for Vacuum-Enhanced Recovery are Not Favorable | $25,000-30,000 | $320,000-510,000 | $55,000-65,000 |

# 6. RECOMMENDED REMEDIAL ACTION

Based on the results of the pilot study and to most effectively meet the remedial action objective at the Navy Fuel Farm of source reduction through the recovery of LNAPL and ground-water remediation, year round operation of an LNAPL recovery system using water-table depression and vacuum-enhancement is recommended. This recommendation allows recovery of LNAPL to be conducted during periods of low and high water-table elevations at a cost which is in the same order of magnitude as the other options considered and presented in Chapter 5.

The following items should be incorporated into the design of the full scale remedial system.

- Install new 6-in. or 8-in. diameter recovery wells in the vicinity of wells NFFW-14 and NFFW-16 to accommodate dual pumping systems.

- Expand the vacuum-enhanced recovery system to include the two new wells along with existing well NFFW-2R. Install dual pumping systems in each well that are amenable to vacuum-enhanced operation within the range of water table elevation fluctuations observed during the pilot study. It is anticipated that the three LNAPL pumps currently in use at the Fuel Farm can also be utilized as part of the final design; however, three new ground-water pumps will be required. Also install variable speed drives and pressure transducers on each pump. This will allow manipulation of pumping rates in relation to water-table elevations in order to maintain the desired level of drawdown. Expected flow rate is <1-15 gpm per well.

- Install individual underground lines (LNAPL, ground-water and SVE) to each recovery well along with underground electrical service.

- Upgrade the ground-water treatment system to accommodate a flow rate of up to 45 gpm. This could be accomplished by installing two new 1,000 pound high pressure carbon treatment vessels. These units along with the ground-water system controls should be placed in a new non-explosion proof enclosure. The existing explosion proof enclosure will continue to house the existing vacuum portion of the system and will also provide equipment and material storage space. It should be noted that air stripping is not recommended due to the low carbon usage during the pilot study and because Pennsylvania Regulations (25 PA Code Chapter 127) require treatment of air emissions.

- Upgrade the water discharge line to 6-in diameter PVC pipe or larger and install below ground.

- Install telemetry to allow for remote monitoring of the entire system. This will enable a timely response to any system malfunctions that may occur.

## REFERENCES


EA. 1989. Draft Report, Environmental Test Boring Investigation at the Navy Fuel Farm, NAS Willow Grove, Horsham Township, Pennsylvania. June.

EA. 1990. Final Report, Site Inspection Studies at NAS Willow Grove, Horsham Township, Pennsylvania. Volumes I and II. May.

EA. 1991. Final Interim Report on Investigations at the Navy Fuel Farm, NAS Willow Grove, November 1990 - July 1991. November.

EA. 1993a. Final Report of Interim Site Investigations, Navy Fuel Farm - Willow Grove NAS. September.

EA. 1993b. Final Work Plan for Pilot-Scale Testing of Free-Product Recovery and Aquifer Air Sparging at the Navy Fuel Farm Facility - NAS Willow Grove. November.

EA. 1996. Final Pilot Study Report for the Product Recovery Pilot System at the Navy Fuel Farm Facility, Naval Air Station Willow Grove, Horsham Township, Pennsylvania November.

Pennsylvania Land Recycling Program, Technical Guidance, 18 July 1995.

Rima, D.R., H. Meisles, and S. Longwill. 1962. Geology and Hydrology of the Stockton Formation in Southeastern Pennsylvania. Bulletin W-14, Pennsylvania Topographic and Geologic Survey. 111 pp.

Title 25 - Pennsylvania Code Chapter 245 Subchapter D, Storage Tanks; Corrective Action. August. Commonwealth of Pennsylvania, Environmental Quality Board (EQB 1993).