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DEFENSE LOGISTICS AGENCY

THE MEMPHIS DEPOT
TENNESSEE

ADMINISTRATIVE RECORD
COVER SHEET

AR File Number 17

JOB No. 11-8531-01
CONTRACT No. DACA 87-88-C-0082

LAW ENVIRONMENTAL

DEFENSE DEPOT MEMPHIS, TENNESSEE (DDMT)
REMEDIAL INVESTIGATION
FINAL REPORT

FOR

U.S. ARMY CORPS OF ENGINEERS
HUNTSVILLE, DIVISION

HUNTSVILLE, ALABAMA

AUGUST 1990

LAW ENVIRONMENTAL, INC.

GOVERNMENT SERVICES DIVISION
114 TOWNPARK DRIVE, 4TH FLOOR
KENNESAW, GEORGIA 30144-5599
404-499-6800

September 26, 1990

Department of the Army
Corps of Engineers, Huntsville Division
P.O. Box 1600
Huntsville, AL 35807-4301

Attention: Mr. David Hasley
Project Manager

Subject: Slip pages for DDMT Final RI Report
Contract No. DACA87-88-C-0082
LEGS Project No. 11-8531-01

Dear Mr. Hasley:

The enclosed pages for the Final RI Report and the Final RI Report Appendices have modified to address comments from CEHND, dated 11 September, 1990. Please insert these replacement pages in the appropriate documents. The distribution list of these pages has been included on the following page for your convenience.

If you have any further questions regarding the Final Report, please do not hesitate to call us at 404/499-6800.

Sincerely,

Frank W. Thomas

Frank W. Thomas, P.G.
Project Manager

Thomas L. Richardson, P.E.
Project Principal

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August 24, 1990

U.S. Army Corps of Engineers
Huntsville Division
P. O. Box 1600
Huntsville, AL 35807-4301

Attention: Mr. David Hasley
Project Manager

Subject: Final Remedial Investigation Report
Defense Depot Memphis (DDMT)
Project No. 11-8531-01
Contract No. DACA87-88-C-0082

Dear Mr. Hasley:

Law Environmental, Inc. is pleased to submit the Final Remedial Investigation Report for the DDMT project. The report is distributed in accordance with the Project Scope of Work. The distribution is repeated on the following page for your convenience.

If you have any questions regarding the Final Report, please do not hesitate to call us at 404/499-6800.

Sincerely,

Laura M. Smith
Laura M. Smith
Risk Assessment Manager

Frank W. Thomas
Frank W. Thomas, P.G.
Project Geologist

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Project Principal

Encl.

LMS/tc

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REMEDIAL INVESTIGATION FINAL REPORT

DEFENSE DEPOT MEMPHIS, TENNESSEE (DDMT)

Contract Number DACA87-88-C-0082
LEGS Job Number 11-8531-01

Prepared for:

United States Army Corps of Engineers
Huntsville Division
106 Wynn Drive
Huntsville, Alabama 35807

Submitted by:

Law Environmental, Inc.
Government Services Division
114 TownPark Drive
Kennesaw, Georgia 30144

August, 1990

TABLE OF CONTENTS

PAGE NO.

TABLE OF CONTENTS
(Continued)

PAGE NO.

5.0 CONTAMINANT FATE AND TRANSPORT

6.0 BASELINE RISK ASSESSMENT

TABLE OF CONTENTS
(Continued)

7.0 SUMMARY AND CONCLUSIONS

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF TABLES
(Continued)

LIST OF TABLES
(CONTINUED)

APPENDICES

EXECUTIVE SUMMARY

Purpose

The purpose of the Remedial Investigation/Feasibility Study (RI/FS) at Defense Depot Memphis, Tennessee (DDMT) was to confirm the presence or absence of contamination, to evaluate the extent and significance of detected contamination, and to formulate remedial action recommendations, as appropriate. The RI/FS is a continuing part of the Department of Defense Installation Restoration Program (IRP). The IRP is a systematic examination of Department of Defense facilities where the effects of past hazardous material storage or waste disposal may be of concern. This report presents the results of the Remedial Investigation.

Site Description and Background

Defense Depot Memphis, Tennessee (DDMT) is situated on 642 acres of federal land in the City of Memphis, Shelby County, Tennessee. The Depot lies in the south central section of Memphis, four miles southeast of the Central Business District and one mile north of Memphis International Airport. DDMT is set in a mixed residential, commercial and industrial land use area. DDMT consists of two sections: Dunn Field, an open storage area about sixty acres in size, and the main installation, which is intensely developed.

As a major field installation of the Defense Logistics Agency, DDMT warehouses and distributes an extensive inventory of supplies utilized by U.S. military services and federal agencies. These supplies span a broad range of commodities including clothing, food, medical supplies, electronic equipment, petroleum products and industrial chemicals. Due to the nature of its mission and the large supply volumes handled, some items were spilled, leaked or disposed of within installation boundaries during the last forty-eight years.

A review of installation file data and other records suggests that as many as 77 waste disposal sites, spill locations and other items of potential environmental concern exist at the facility. Much of DDMT's waste disposal was conducted in past years at Dunn Field. Some loss of stored materials through spillage or leaks also occurred at the main installation.

Investigative Program

This Remedial Investigation is the second of three principal activities comprising the Remedial Investigation/Feasibility Study (RI/FS) process: Phase I included the preparation and issuance of the RI/FS Work Plans (April 1989). These plans summarized known conditions at DDMT and the results of previously conducted studies. The plans also provided project specific guidance for sampling, analysis, data management and health/safety measures.

Phase II, the Remedial Investigation, focuses on the installation, its activities, the study area's environmental setting and the facility's environmental data collection, sample analyses, data evaluation, and a Risk Assessment.

Phase III, the Feasibility Study, will consist of the development, screening, evaluation and final selection of preferred remedial action alternatives.

Contamination Extent and Source

Dunn Field Ground Water

The ground-water quality investigation at Dunn Field revealed elevated (above background and ARARs) levels of chlorinated volatile organic compounds and metals in the Fluvial aquifer both on the installation and beyond the installation boundaries. The investigation indicates that the plume of contaminated ground water has migrated in a generally west and northwest direction. The contamination source is probably associated with the waste material burial trenches in Dunn Field. The western extent of the plume is not defined. In other areas, the plume appears to be defined by wells with low or nondetected levels of organics and background levels of metals.

Soils analyzed from the soil test borings in Phase II at Dunn Field contained low levels of chlorinated volatile organics within the confining unit at STB-6 and in the Memphis Sand aquifer in STB-6 and STB-8. This contamination may have resulted from downward migration of these constituents from the overlying Fluvial aquifer. However, the possibility also exists that the contamination may have been transported from the overlying aquifer during drilling operations.

Two monitoring wells were screened in the Memphis Sand aquifer. A fairly high level of acetone contamination was detected in MW-37. The source of acetone is unknown, since this was not a significant contaminant in the Fluvial aquifer. No other significant contamination was detected in either Memphis Sand monitoring well.

Main Installation Ground Water

At the main installation, generally low levels of metals and chlorinated volatile organics were detected in two areas of the Fluvial aquifer. The first area is located near Lake Danielson (MW-25 and MW-26), and the second in the southwest corner of the installation (MW-21, MW-22 and MW-39). The source of this contamination has not been determined; however, analysis of surface soils showed the presence of tetrachlorethene and trichloroethene at Buildings 770, 757, 629 and T273, which are in the vicinity of the aforementioned wells. Due to the high mobility of these compounds, the surface soil contamination could contribute to the ground-water contamination.

The complex Fluvial aquifer flow regime suggests that a portion of Fluvial aquifer flow at the main installation is controlled by a sink or channel-like feature incised in the underlying confining unit. The two wells installed in the deepest known reach of the Fluvial aquifer (MW-34 and MW-38) were relatively free of the contaminants, suggesting that contamination is not currently accumulating in that area.

Surface Soils

The surface soil investigation focused on probable or known "hot spots" at twelve separate areas at the main installation and Dunn Field. Surface soils were found to be contaminated by solvents, organic compounds, and/or metals at all sampling locations. Several of the samples were contaminated with pesticides and polycyclic aromatic hydrocarbons (PAHs). The six most contaminated areas were located at the main installation. Those areas are listed below, along with the suspected source of contamination:

	Site	Suspected Source of Contamination
1.	DRMR Yard	Leaking drums
2.	Building 629	Spills swept or hosed out of doors at Building 629
3.	Building T-273 at golf course	Cleaning of pesticide application equipment
4.	Building 1088	General spillage from paint shop and/or cleaning operations
5.	Open Storage Area	Leakage from railroad tank cars on Tracks #3 and #4
6.	Building 770	General spillage from maintenance shop and waste oil storage drums

The extent of contamination was not fully defined in any area.

Surface Water and Sediment

The surface water investigations in Phase I and Phase II detected low levels of organic compounds, metals and pesticides. The sediment investigation in Phase I detected appreciable levels of pesticides and herbicides in the golf course pond and in Lake Danielson.

Major Findings

One consideration of the risk assessment involves potential migration of contamination from the water table aquifer into the underlying Memphis Sand aquifer (the major drinking water supply for the city of Memphis). Studies in the Memphis area have indicated the potential for this leakage. Results from this investigation indicate that the confining unit is thick and extensive in the northern portion of Dunn Field, but is less so and perhaps non-existent in some areas of the Main Installation. Estimates of potential risks from drinking water exposures were examined in the risk assessment and do not predict unacceptable risks via these exposure pathways under currently existing conditions. Key properties of the confining unit relating to contaminant migration have not been fully determined. Further investigation of this migration potential and of the off-base contamination is recommended.

The high levels of contamination in the surface soils can be controlled by access restrictions and dust control measures. However, the installation may eventually wish to utilize these areas, thus increasing the potential health risk and the need for remediation. On-site risk associated with surface water contamination in Lake Danielson and the golf course pond is low because of generally low contaminant levels and current fishing and swimming restrictions. While the surface water contamination leaving the installation is reduced by dilution, there is a potential risk to off-site populations via fish ingestion. The lake and pond sediment contamination is significant, as it may serve as a reservoir of off-site contamination.

17 21

1.0 INTRODUCTION

1.1 GENERAL

Defense Depot Memphis, Tennessee (DDMT) is a major field installation of the Defense Logistics Agency (DLA), U.S. Department of Defense (DOD). Due to the requirements of its primary mission, providing material support to all U.S. military services and some civil agencies, DDMT has been engaged in a variety of operations dealing with hazardous substance transportation, shipment and disposal.

DOD developed the Installation Restoration Program (IRP) in 1981 to evaluate and remediate the effects of past hazardous waste management and disposal practices at its facilities and to comply with provisions of the Comprehensive Environmental Response, Compensation and Liability Act, as amended. All DOD facilities will be examined under the IRP.

A Remedial Investigation and Feasibility Study (RI/FS) are in progress at DDMT as a continuing part of the IRP. The RI/FS effort is managed and contracted on behalf of DLA by the Huntsville Division, U.S. Army Corps of Engineers (CEHND). CEHND retained Law Environmental, Inc. Government Services Division (LEGS) to perform the DDMT RI/FS.

1.2 PURPOSE

The RI/FS has been undertaken to assess the hazardous substance contamination, to examine the migration potential of detected contaminants, to evaluate the significance of detected constituents, and to formulate appropriate remedial recommendations.

1.3 SITE BACKGROUND

The site background information utilized to develop, scope and perform the Remedial Investigation at DDMT is summarized in this section.

1.3.1 Site Description

Defense Depot Memphis, Tennessee (DDMT) is situated on 642 acres of land, in Shelby County, Memphis, Tennessee, in the extreme southwestern portion of the state. DDMT is approximately five miles east of the Mississippi River and just northeast of the Interstate 240, Interstate 55 junction.

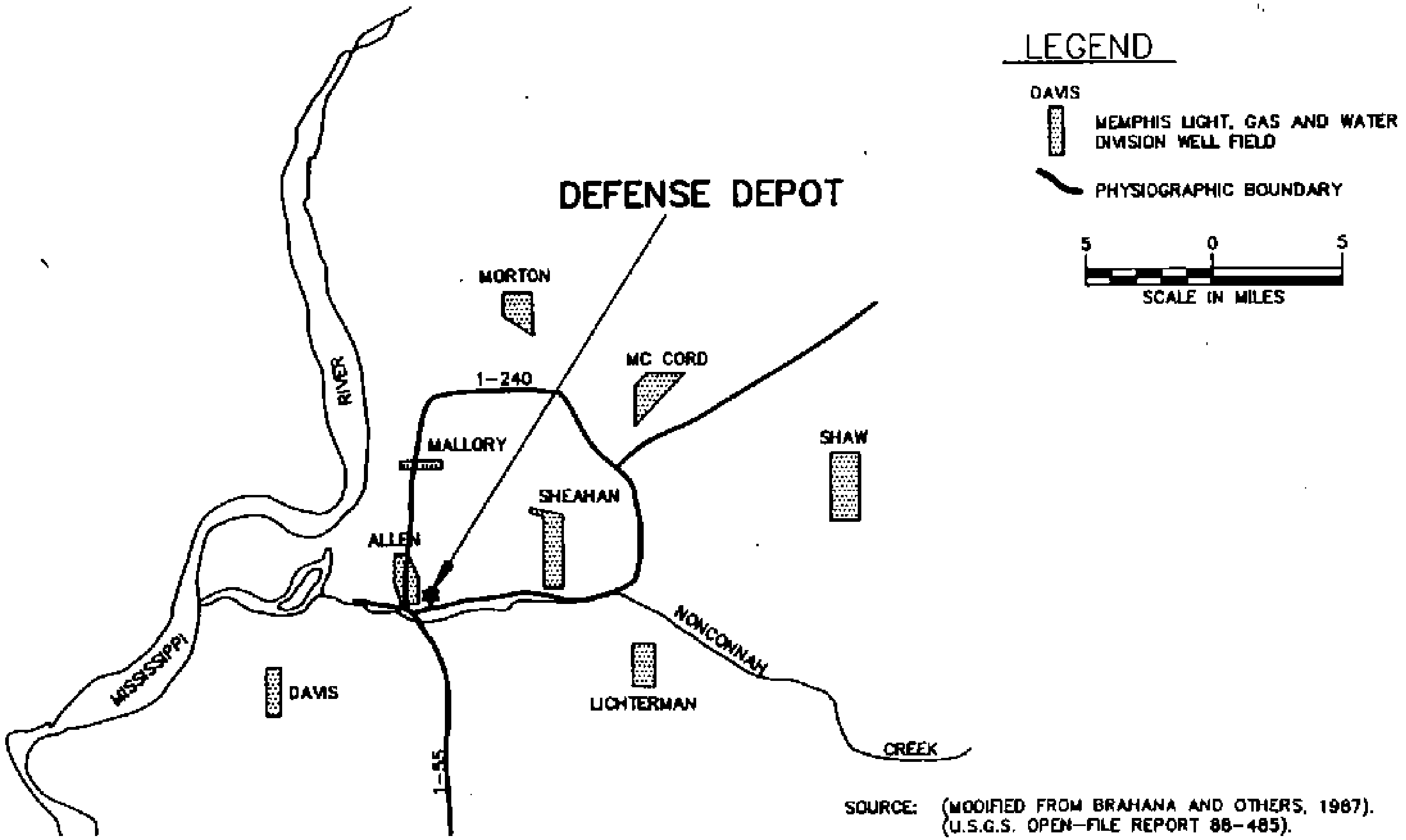
The Depot lies in the south central section of Memphis, approximately four miles southeast of the Central Business District and one mile northwest of Memphis International Airport. Airways Boulevard borders the Depot on the east and provides primary access to the installation. Dunn Avenue, Ball Road and Perry Road serve as the northern, southern and western boundaries, respectively. Figure 1-1 shows the installation's location with respect to the Memphis area.

As a major field installation of the Defense Logistics Agency (DLA), Defense Depot Memphis warehouses and distributes supplies common to all U.S. military services and some civil agencies, primarily in the southeastern United States, Puerto Rico and Panama area, and also includes some worldwide shipments. The depot's mission is to receive, store, maintain and ship items which are centrally managed by the Defense Logistics Agency, which is responsible for supplying and servicing the United States military. Stocked items include food, clothing, electronic equipment, petroleum products, construction materials, industrial, medical and general supplies.

FIGURE 1-1

DEFENSE DEPOT MEMPHIS, TENNESSEE SITE LOCATION MAP

DEFENSE DEPOT MEMPHIS, TENNESSEE



SOURCE: (MODIFIED FROM BRAHANA AND OTHERS, 1987).
(U.S.G.S. OPEN-FILE REPORT 88-485).
(GEOLOGIC MAP OF TN, 1966)

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Approximately four million line items are received and shipped by the depot annually; it ships about 155,000 tons of goods a year. In-stock inventory at the depot is worth more than $1.4 billion; annual issues to the military are nearly $1.0 billion.

The Defense Depot Memphis employs approximately 2,200 civilians and sixteen military personnel; the depot's annual payroll is $49.9 million. The total annual contribution of the Depot to the area's economy is more than $127 million (from 1989 installation information).

The installation consists of 110 buildings, 26 miles of railroad track and 28 miles of paved streets. It has about 5.5 million square feet of covered storage space, and approximately 6.0 million square feet of open storage space. The land and buildings are owned by the U.S. Army and are leased by DLA. Figure 1-2 illustrates the significant installation features.

1.3.2 Site History

Construction of the Defense Depot Memphis began in June 1941 and was completed in May 1942 on land bought from the Goodman family for $225,000. The site was previously used as a cotton field. Operation of DDMT began January, 1942.

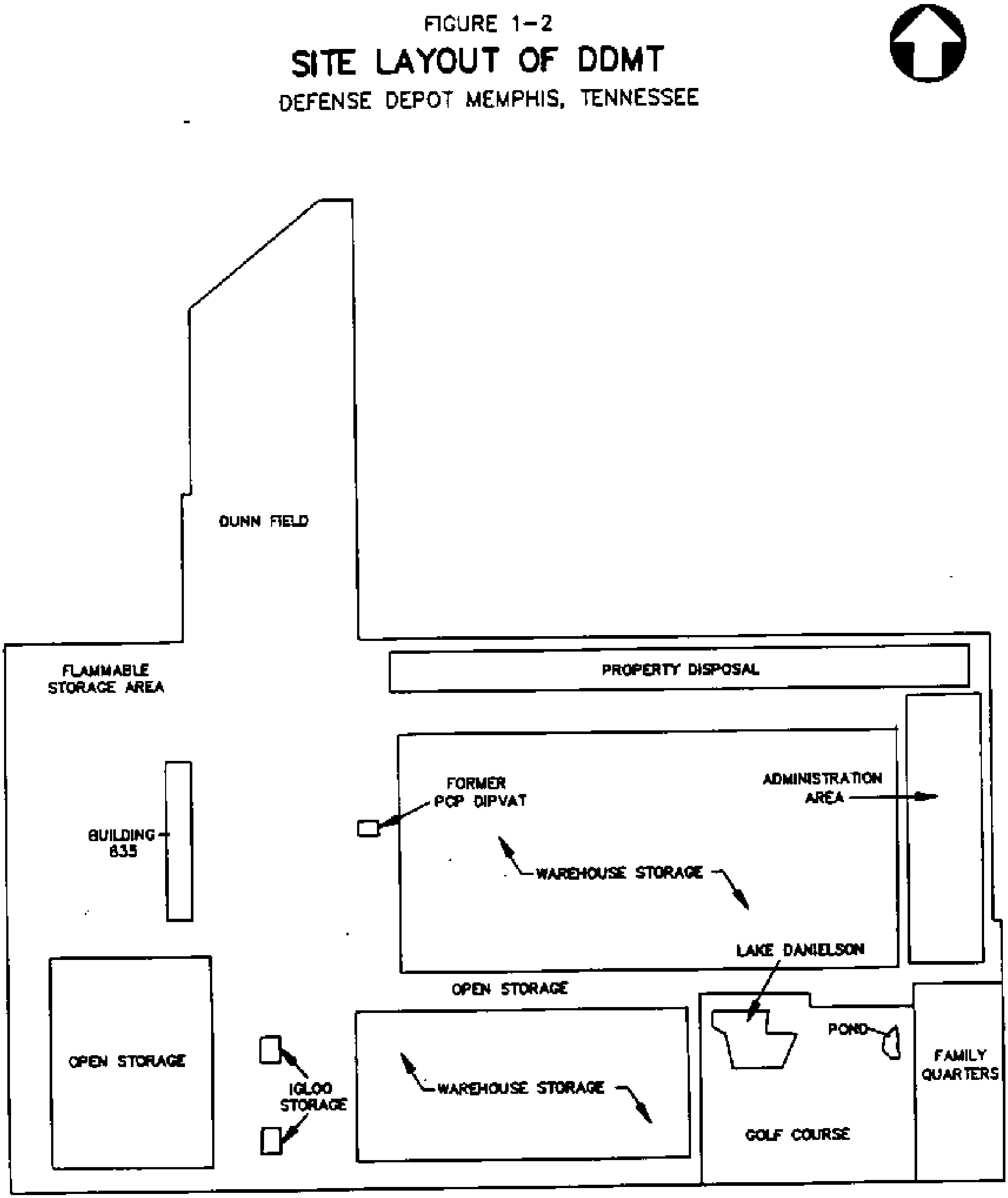
The initial mission and functions of DDMT were to supply, provide stock control, storage and maintenance services for the Army Engineer, Chemical and Quartermaster Corps. During World War II, the Depot served as an internment center for 800 prisoners of war. The Depot also performed supply missions for the signal and Ordnance Corps.

In 1963 the installation was chosen by the Defense Supply Agency (DSA), currently the DLA, to be a principal distribution center for a complete range of DSA commodities. On January 1, 1964

FIGURE 1-2

SITE LAYOUT OF DDMT

DEFENSE DEPOT MEMPHIS, TENNESSEE



SOURCE: GEOHYDROLOGIC STUDY NO. 38-26-0195-83, DDM, MEMPHIS, TN, 21 JUNE - 2 JULY, 1982.

SCALE: 1"~1000'

the U.S. Army released the installation to DSA and the installation became the Defense Depot Memphis. DLA is responsible to the Secretary of Defense for providing services and supplies used in common by all the military services.

Several other organizations are co-located at DDMT and report directly to DLA. These include Defense Industrial Plane Equipment Center (DIPEC), Defense Reutilization Marketing Region (DRMR), Defense Reutilization Marketing Organization (DRMO), Defense Logistics Agency (DLA), Customer Supply Assistance Center, Defense Contract Administrative Services (DCAS), and DLA Systems Automation Center (DSAC).

As host activity, DDMT provides administrative support to the DLA co-located activities. Services include accounting, personnel and travel arrangements.

1.3.3 Previous Investigations

In conformance with DOD policies, a number of technical studies have been performed at DDMT to assist DLA in its continuing mission requirements. The technical studies reviewed and utilized in support of this Remedial Investigation include the following general categories:

1) Industrial Hygiene
2) Facility Planning
3) Regulatory Compliance Consultation
4) Surface Water Quality
5) Ground Water Quality
6) Waste Management Assessment
7) Hazardous Waste Remediation

Most of the studies were performed internally by the U.S. Army Environmental Hygiene Agency (USAEHA) or the U.S. Army Toxic and

Hazardous Materials Agency (USATHMA). A few were projects conducted by consultants or Architect - Engineer (AE) firms under contract to DLA. The previous investigations known to Law Environmental, Inc. utilized in support of this Remedial Investigation include the following:

- Harland Bartholomew & Associates, Inc. , July 1988. Master Plan, Defense Depot Memphis, Tennessee.
- O.H. Materials Company, Summary Report: Feb. 1986. On-site Remedial Activities at Defense Depot Memphis, Tennessee.
- Phoenix Environmental Consultants, Inc., January, 1984. Environmental Assessment for Hazardous Materials Mission Expansion.
- Defense Depot Memphis Tennessee, 1982. Draft Spill Prevention Control and Countermeasures Plan. Facilities Engineering Division, DDMT.
- U.S. Army Environmental Hygiene Agency, December, 1986. Ground Water Consultation No. 39-26-0815-87. Aberdeen Proving Ground, MD. 21010.
- U.S. Army Environmental Hygiene Agency, March, 1986. Water Quality Biological Study No. 32-24-0733-86. Aberdeen Proving Ground, MD. 21010.
- U.S. Army Environmental Hygiene Agency, July 1982. Geohydrologic Study No. 38-26-0195-83. Aberdeen Proving Ground, MD. 21010.
- U.S. Army Toxic and Hazardous Materials Agency, March, 1981. Installation Assessment of Defense Depot Memphis Tennessee. Aberdeen Proving Ground, MD. 21010.

- Defense Logistics Agency, 1 October, 1980. Defense Depot Memphis, Master Plan Component Analysis of Existing Facilities.
- U.S. Army Environmental Hygiene Agency, August 1977. Environmental Impact Assessment. Consultation visit No. 21-1443-78, Defense Depot Memphis, Memphis, Tennessee.
- U.S. Army Environmental Hygiene Agency, August 1975. Environmental Survey No. 99-012-76, Defense Depot Memphis, Tennessee.
- U.S. Army Environmental Hygiene Agency, January 1978. Environmental Assessments of Existing Operations at DLA Installations. Survey No. 24-1443-78.
- Defense Supply Agency, 1978. Defense Depot Memphis. Safety & Health Office (DDMT-GE) Industrial Hygienca Survey No. 78-002: Asbestos Rebagging & Rewarehousing by Kennedy Contracting Company.
- U.S. Army Environmental Hygiene Agency, August, 1977. Waste Management Consultation No. 26-1443-78, Defense Depot Memphis, Tennessee. Aberdeen Proving Ground, MD. 21010.
- U.S. Army Environmental Hygiene Agency, May 1977. Hazardous Waste Management Survey No. 26-0020-78, Defense Depot Memphis Memphis, Tennessee. Aberdeen Proving Ground, MD. 21010.
- U.S. Army Environmental Hygiene Agency, September, 1977. Industrial Hygiene Special Study Survey No. 556-35-0127-80, Evaluation of Hazardous Material Warehouse, Defense Depot Memphis, Memphis, Tennessee. Aberdeen Proving Ground, MD. 21010.

- U.S. Army Environmental Hygiene Agency, August, 1977. Waste Management Consultation No. 26-1443-78, Defense Depot Memphis, Memphis, Tennessee. Aberdeen Proving Ground, MD. 21010.
- U.S. Army Environmental Hygiene Agency, May 1977. Hazardous Waste Management Survey No. 26-0020-78, Defense Depot Memphis, Memphis, Tennessee. Aberdeen Proving Ground, MD. 21010.
- U.S. Army Environmental Hygiene Agency, May 1980. Hazardous Waste Management Consultation No. 37-26-0113-81. Defense Depot Memphis, Memphis, Tennessee. Aberdeen Proving Ground, MD. 21010.
- U.S. Army Environmental Hygiene Agency, June 1977. Industrial Hygiene Survey No. 23-022-70. Defense Depot Memphis, Memphis, Tennessee.
- U.S. Army Environmental Hygiene Agency, October 1969. Industrial Hygiene Survey No. 23-022-70. Defense Depot Memphis, Memphis, Tennessee. Edgewood Arsenal, MD. 21010.
- U.S. Army Environmental Hygiene Agency, June 1973. Industrial Hygiene Survey No. 35-049-73/74. Defense Depot Memphis, Memphis, Tennessee. Aberdeen Proving Ground, MD. 21010.
- U.S. Army Environmental Hygiene Agency, June 1977. Radiation Protection Survey No. 62-0431-77. Defense Depot Memphis, Memphis, Tennessee.
- U.S. Army Environmental Hygiene Agency, October 1974. Entomological Survey No. 44-PO9-75. Defense Depot Memphis, Memphis, Tennessee.
- U.S. Army Environmental Hygiene Agency, October 1979. Installation Pest Management Program Review No. 16-62-0589-90. Defense Depot Memphis, Memphis, Tennessee. Aberdeen Proving Ground, MD. 21010.

- U.S. Army Environmental Hygiene Agency, November 1978. Installation Pest Management Program Review No. 16-62-0541-79. Defense Depot Memphis, Memphis, Tennessee. Aberdeen Proving Ground, MD. 21010.

- U.S. Army Environmental Hygiene Agency, September 1977. Installation Pest Management Program Review No. 62-0577-78. Defense Depot Memphis, Memphis, Tennessee.

- U.S. Army Environmental Hygiene Agency, November 1978. Installation Pest Resistance Study (ES) No. 18-62-0542-79, Defense Depot Memphis, Memphis, Tennessee.

- U.S. Army Environmental Hygiene Agency, November 1973. Entomological Survey No. 44-015-74, Defense Depot Memphis, Memphis, Tennessee.

- U.S. Army Environmental Hygiene Agency, September 1976. Installation Pest Management Program Review No. 62-0544-77. Defense Depot Memphis, Memphis, Tennessee.

Past and recent facility use conditions were reviewed to determine the following:

1) Potential Contamination Sources
2) What impact, if any, past/current conditions could have on RI/FS project goals.
3) What constraints, if any, existing site conditions of concern could place on planned facility monitoring and sampling efforts.
4) What effects, if any, existing site conditions of concern could exert on the interpretation of project monitoring and analytical data.

1.4 REPORT ORGANIZATION

The organization of this Remedial Investigation report is generally consistent with the "Suggested RI Report Format" described in OSWER Directive 9355:3-01, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, October 1988. The report has been subdivided into the following sections:

1.0 INTRODUCTION. Discusses the investigation purpose, general information, site description and installation history.

2.0 STUDY AREA INVESTIGATION. Describes the scope of the study, field data collection methods and related information.

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA. Discusses the results of the field activities and the characterization of surface features, soils, surface water, sediments, geology and hydrogeologic units.

4.0 NATURE AND EXTENT OF CONTAMINATION. Describes the types of and levels of contaminants detected.

5.0 CONTAMINANT FATE AND TRANSPORT. Discusses potential contaminant migration pathways, contaminant migration factors and anticipated persistence in the environment.

6.0 QUANTITATIVE RISK ASSESSMENT. Evaluates quantitatively the site-related impacts on public health and the environment.

7.0 SUMMARY AND CONCLUSIONS. Summarizes the results of Sections 4.0, 5.0 and 6.0, above, and presents conclusions and data limitations.

2.0 STUDY AREA INVESTIGATION

2.1 GENERAL

This section of the Remedial Investigation report summarizes the data sources, methods and field data collection procedures utilized to obtain the information required for study area characterization. Supplemental information is included in the appendices and a discussion of study results is presented in subsequent sections of this report.

The study has been organized into three phases:

- Phase I Scoping. This phase of work consists of an initial site visit, installation and published information collection, work plan preparation and a preliminary evaluation of remedial alternatives. This effort was performed in order to learn the types and quality of data available, what additional data was required to evaluate site conditions, to avoid duplication of past studies and to provide guidance for this investigation. The available data review focused on background information relative to the nature and extent of contamination, as well as previous remedial response actions initiated by DLA. The hydrogeologic and environmental data collected in earlier studies was particularly important. The information sources consulted during Phase I included:

    1. Published data
        - U.S. Army Environmental Hygiene Agency
        - U.S. Army Corps of Engineers, Memphis
        - U.S. Army Toxic and Hazardous Materials Agency
        - U.S. Geological Survey, Water Resources Division
        - U.S. Department of Agriculture, Soil Conservation Service

Tennessee Division of Geology
Memphis and Shelby County Health Department
Memphis Light, Gas and Water Division (MLGW)
Various Consultants (to USACOE, DLA or DDMT)

2. File data
Defense Depot Memphis Tennessee
U.S. Army Corps of Engineers
U.S. Geological Survey, Water Resources Division

3. Personnel interviews
U.S. Geological survey, Water Resources Division
Memphis Light, Gas and Water Division
Defense Depot Memphis, Tennessee

Following a detailed data review, a summary of the installation's environmental setting, past and present waste management practices, a conceptual site model, proposed ARARs and preliminary remedial alternatives evaluation were prepared. Site specific Work Plans were developed to guide the collection of field data, data management, data interpretation and employee safety requirements. The term "work plan" in this context refers to five separate volumes including:

Volume I	Introduction - Review of Available Data Soil Boring and Environmental Quality Information
Volume II	Monitoring Well Installation Plan
Volume III	Sampling and Analysis Plan
Volume IV	Data Management Plan
Volume V	Safety, Health and Emergency Response Plan

The project's execution was guided by the detailed procedures and methods described in the Work Plan documents.

- Phase II, Remedial Investigation. This phase of work consisted of the execution of all site characterization efforts including data collection activities, sampling, analytical procedures, data evaluation, a Risk Assessment and the preparation of a Remedial Investigation report. The following subsections of this document describe the project's Phase II activities in detail.

- Phase III, Feasibility Study. This optional phase of the project includes the identification, screening and evaluation of remedial action alternatives and the preparation of a Feasibility Study report. The Feasibility Study results are presented in a separate document.

2.2 DATA COLLECTION

Phase II, the Remedial Investigation, included the collection of regional and study area information utilized to characterize the site. During Phase I Scoping the mustard/lewsite burial site was determined to be a significant concern (reference Figure 4-1). It was decided that sampling of this site would be done by the U.S. Army Technical Escort Unit (TEU). The sampling of this site (if done) will be a separate study and is not included as part of this RI report. A description of each field data collection effort follows.

2.2.1 Surface Features

The study area's surface features (natural and man made) were investigated by on-site visual reconnaissance, U.S. Army Corps of Engineers historical (comparative) aerial imagery, U.S. Geological Survey 7.5 Minute Series Topographic Quadrangle maps and installation topographic maps prepared by U.S Army Corps of Engineers, Mobile District, dated February 1989. The surface feature information review results are presented in Subsection 3.1.1 of this report.

2.2.2 Contaminant Source Investigations

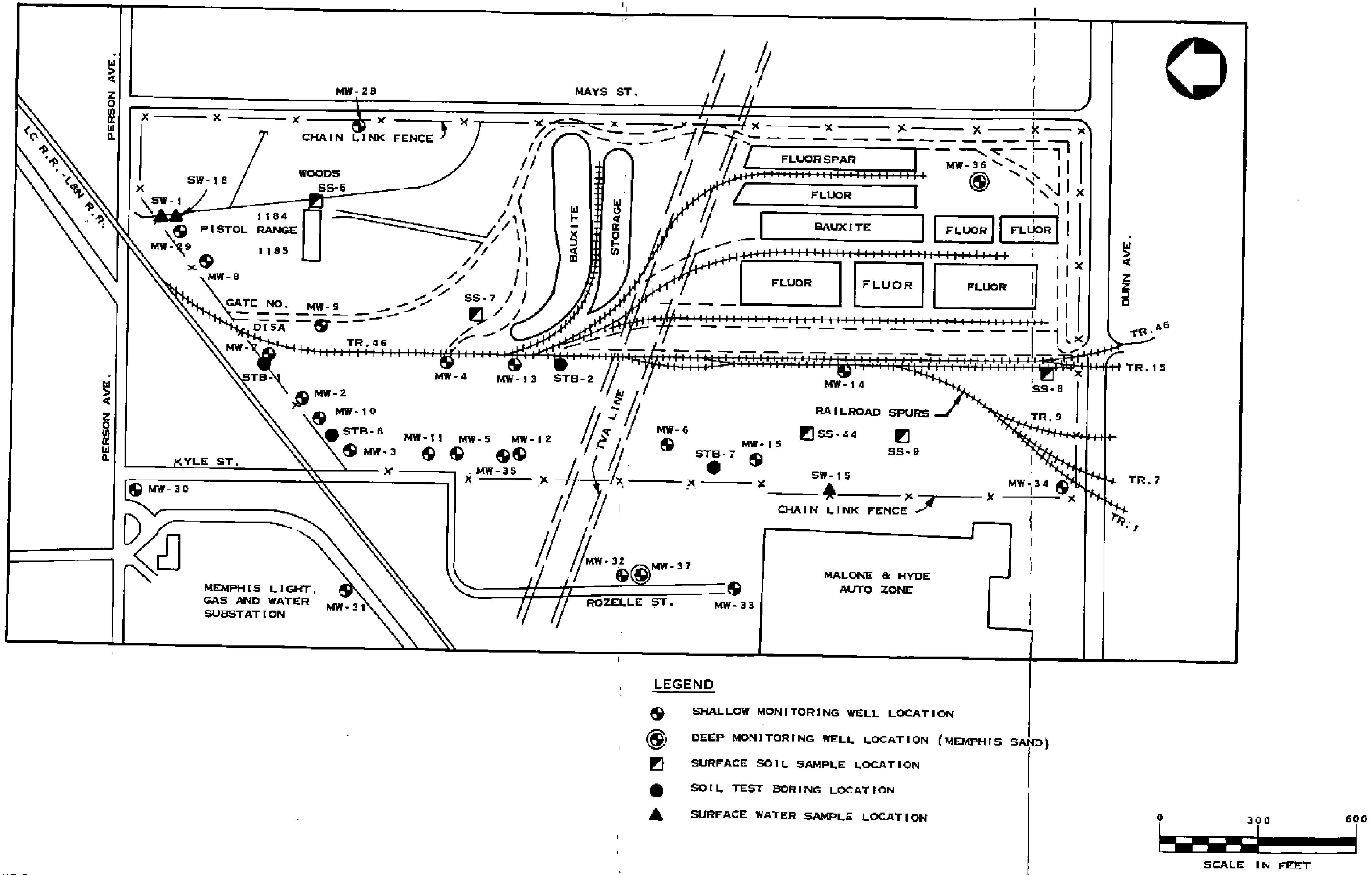
Study area contaminant sources were investigated by visual reconnaissance, interviews with DDMT personnel, installation file data and internal technical studies and consultations. The internal technical documents were produced by the U.S. Army Environmental Hygiene Agency and the U.S. Army Toxic and Hazardous Materials Agency. A list of the previously completed studies describing DDMT's contaminant sources known by Law Environmental, Inc. is presented in Subsection 1.3.3 of this report. The contaminant source information was reviewed and is included in Section 4 of this report.

Analytical data was obtained from surface and subsurface samples collected at DDMT. This data was used to determine if past and present activities at the installation have contributed significant amounts of contamination to the environment. The investigation of the surface features included surface soils, water and sediments. The subsurface investigation focused on ground water and soils.

2.2.3 Surface Water and Sediments Investigations

Installation surface waters were sampled at ten locations in April 1989 and six locations in January 1990. Site sediments were sampled at five locations in April 1989. Three sediment sampling points are located in Lake Danielson and two are located in the Golf Course pond. The approximate locations of the surface water and sediment sample collection points are illustrated on Figures 2-1 and 2-2a through 2-2d. The procedures utilized to collect the samples are given in Appendix A. The sampling effort was supervised in the field by an experienced, qualified chemist. The analytical results are described in Subsections 4.2.3 and 4.2.4 of this report.

FIGURE 2-1
MONITORING LOCATIONS AT DUNN FIELD DEFENSE DEPOT AND OFFSITE MONITORING LOCATIONS
MEMPHIS, TENNESSEE



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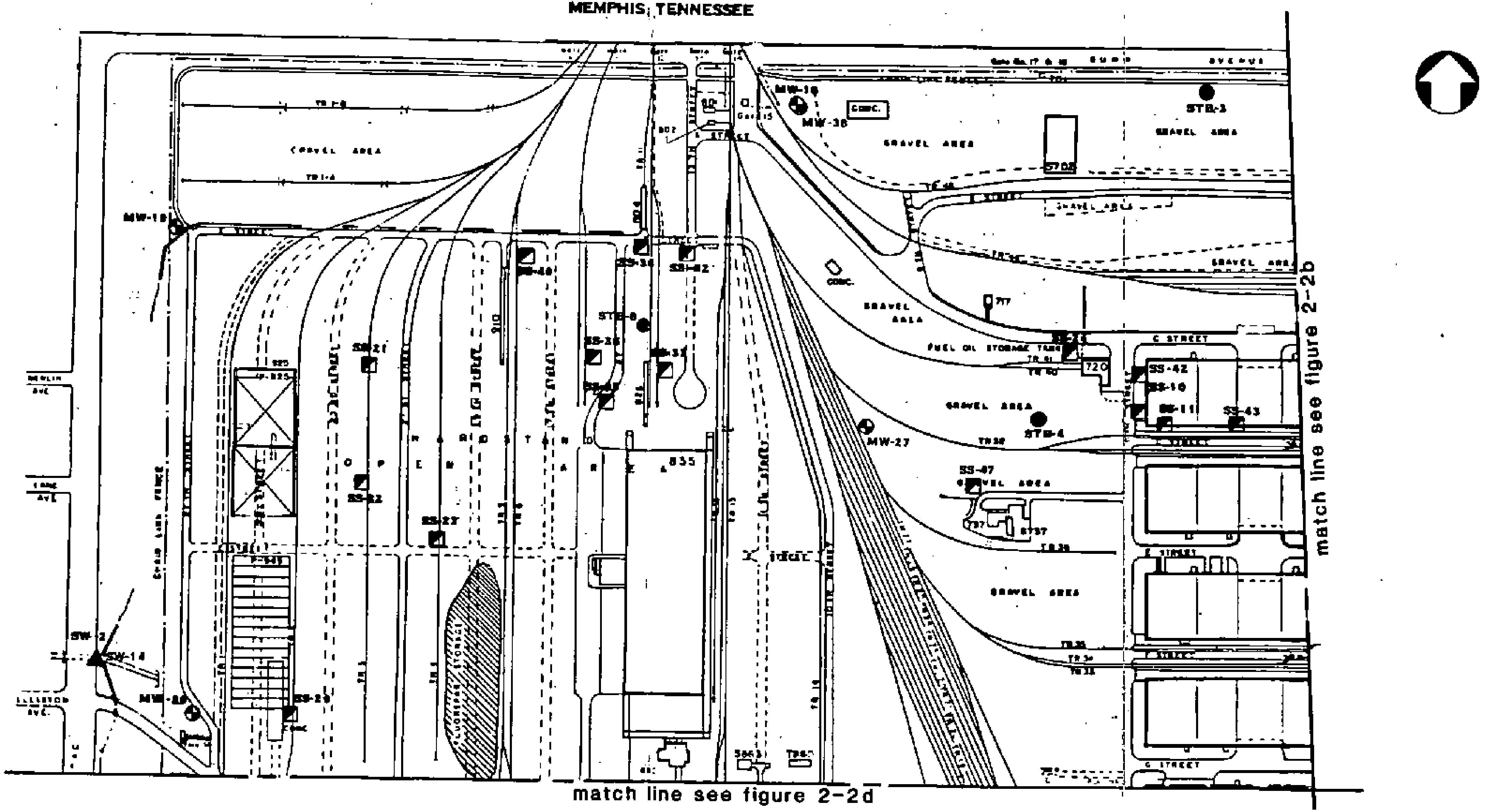
17 37

FIGURE 2-2a

MONITORING LOCATIONS AT THE MAIN INSTALLATION DEFENSE DEPOT

MEMPHIS, TENNESSEE



LEGEND

- ● MONITORING WELL
- ◪ SURFACE SOIL SAMPLE SITE
- ● SOIL TEST BORING
- ▲ SURFACE WATER SAMPLE SITE

SOURCE: DEFENSE DEPOT LAYOUT PLAN
FACILITIES ENGINEERING DIVISION
REVISION DATE: 3 JAN 1985

0 200 600
SCALE IN FEET

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FIGURE 2-2b

MONITORING LOCATIONS AT THE MAIN INSTALLATION DEFENSE DEPOT

MEMPHIS, TENNESSEE

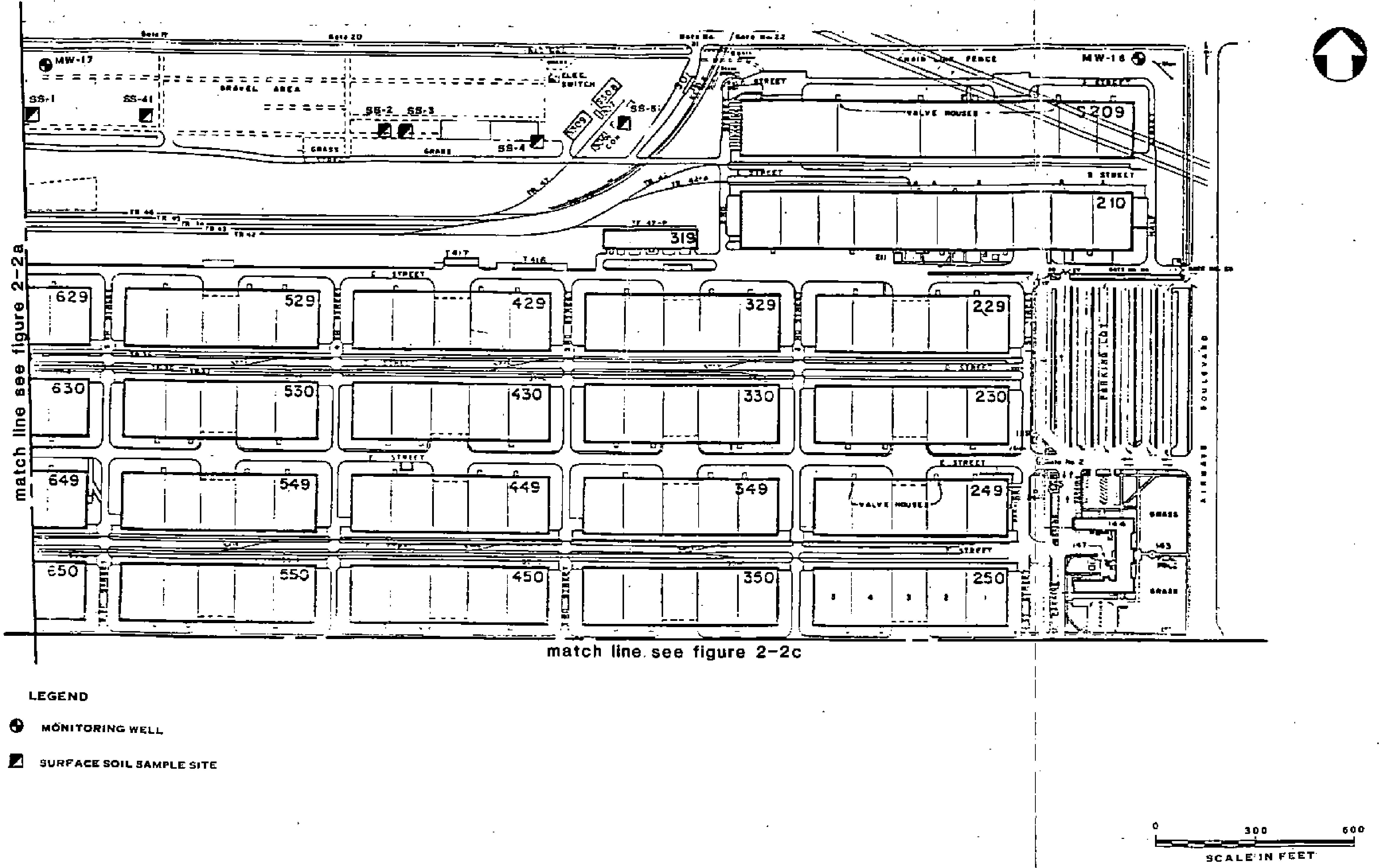

FIGURE 2-2c

MONITORING LOCATIONS AT THE MAIN INSTALLATION DEFENSE DEPOT

MEMPHIS, TENNESSEE

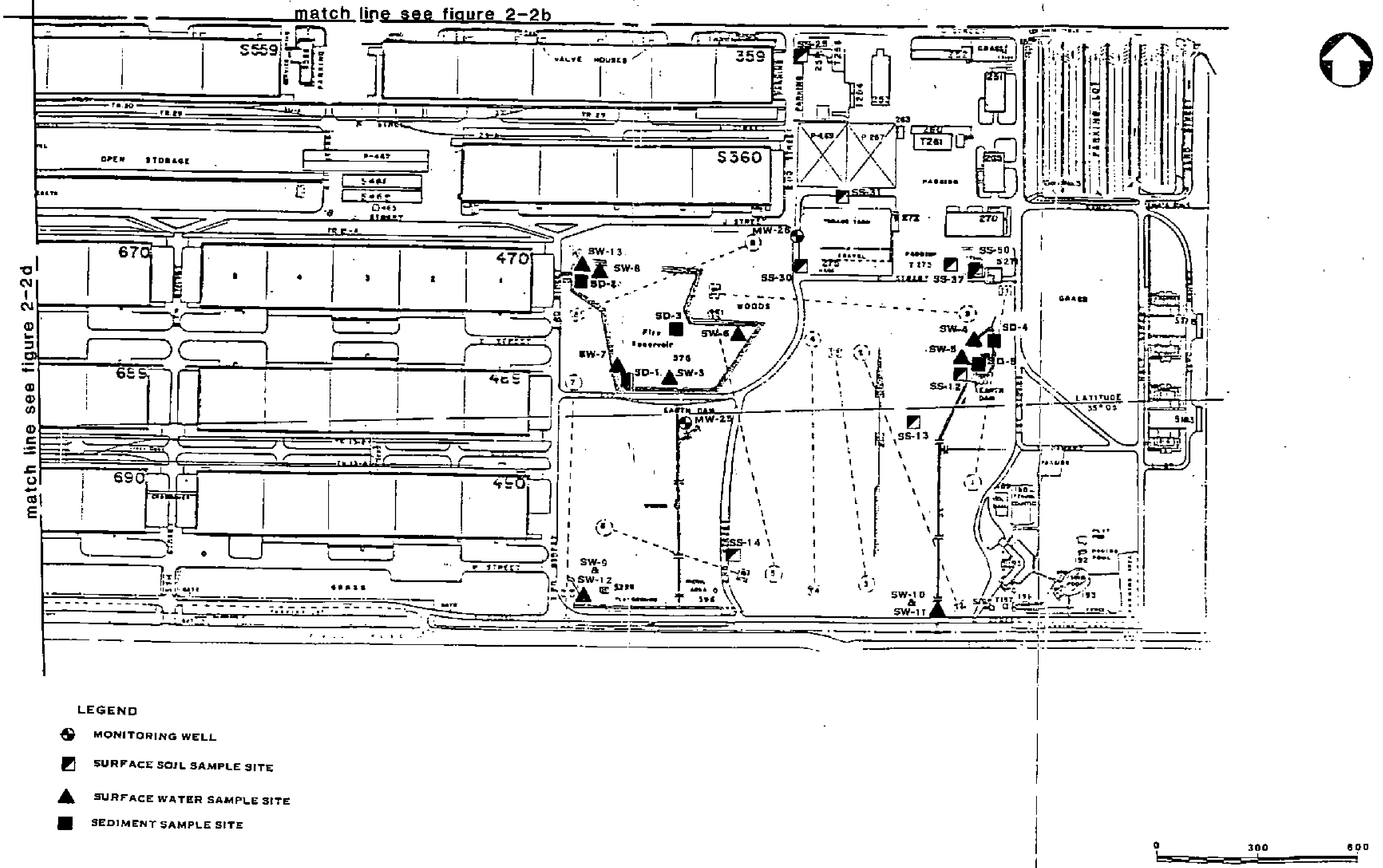

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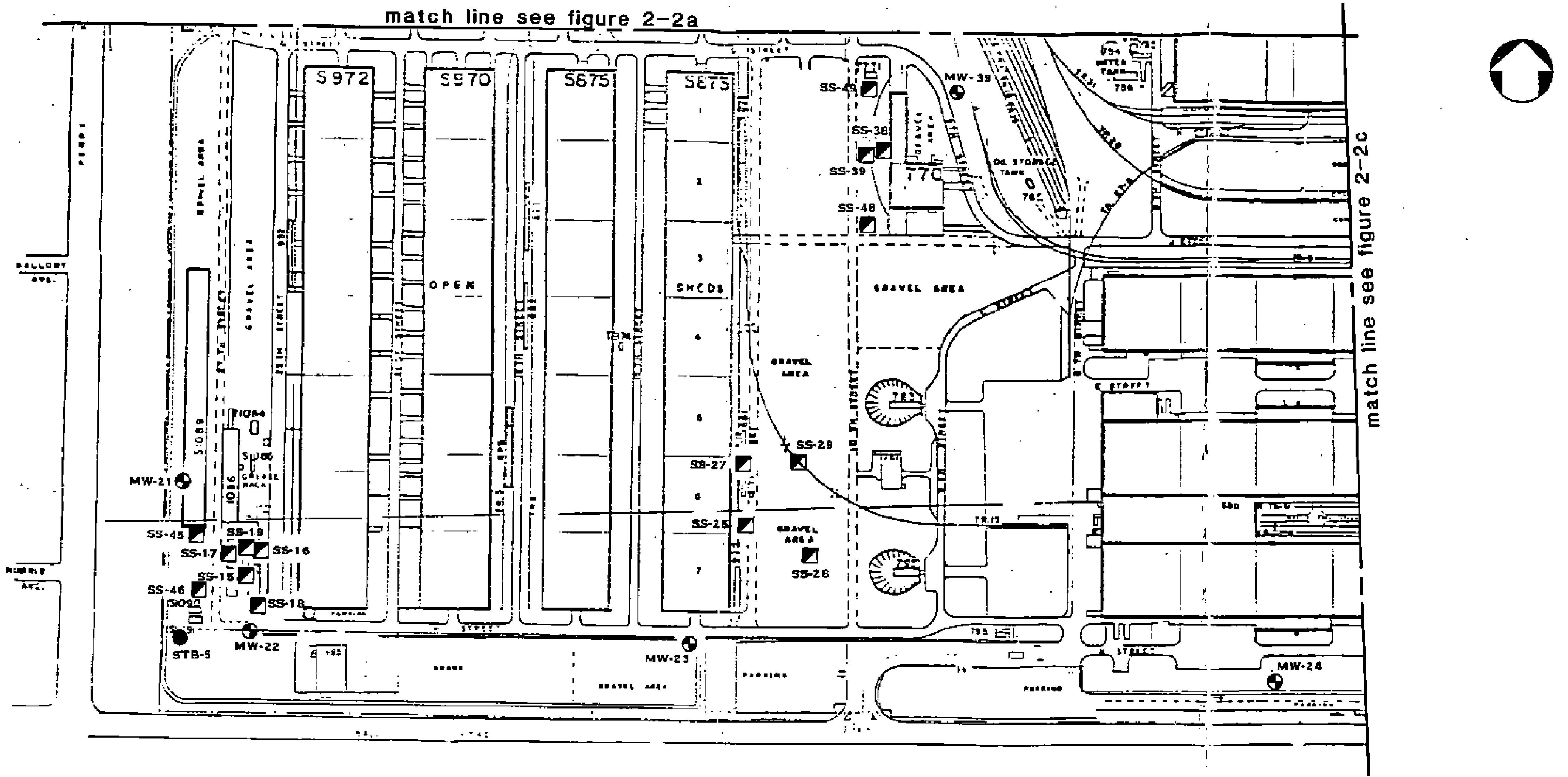
FIGURE 2-2d
MONITORING LOCATIONS AT THE MAIN INSTALLATION DEFENSE DEPOT
MEMPHIS, TENNESSEE



LEGEND

- ● MONITORING WELL
- ◪ SURFACE SOIL SAMPLE SITE
- ● SOIL TEST BORING

0 300 600
SCALE IN FEET

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2.2.4 Geological Investigations

To aid in determining the contaminant's migration rate and extent, the geologic and hydrogeologic features of the area were investigated. All points of investigation are shown on Figures 2-1 and 2-2a through 2-2d. The geology study area was initially investigated by reviewing the existing geologic information described in Subsection 2.1 (Scoping). The geologic information that was collected for the RI was carefully reviewed and evaluated with respect to overall project objectives. The results of the geological investigation are described in Subsection 3.1.5 of this report.

The site specific investigation encompassed two phases of field data collection. During Phase I of the RI, five stratigraphic test borings (STB-1 through STB-5) were completed. These borings ranged in depth from 80 to 105 feet. In addition to the test borings, 18 monitoring wells were installed into the saturated portion of the Fluvial deposits aquifer. All but three wells were installed using Hollow Stem Augers (HSA). MW-16, MW-18 and MW-27 were installed using mud rotary techniques. Appendix A describes the two drilling techniques used at DDMT.

Two monitoring wells (MW-18 and MW-27) were inadvertently screened into the unsaturated portion of the Fluvial deposits. MW-18 was screened in the capillary fringe of the aquifer, thus no water would flow into the well for sampling. During the installation of MW-27, a clay unit, thought to be the Jackson/upper Claiborne confining unit, was encountered at 96.0 feet. The boring was terminated and the well was installed at the top of this clay unit. The final geologic interpretation (Figure 3-7) indicates that the clay is a lens within the Fluvial deposits. Both of these wells were advanced using mud rotary techniques. The introduction of mud into the boring caused difficulty in determining when the saturated zone has been penetrated.

The deep (220 feet) stratigraphic test borings and twelve monitoring wells were completed in Phase II of the RI. Ten of the wells were screened in the Fluvial deposits aquifer. Two of the wells, MW-36 and MW-37, were installed as Type III monitoring wells. Descriptions of Type II and Type III wells are given in Appendix A (Section A.5).

Monitoring wells in the Fluvial deposits aquifer range in depth from 54 (MW-29) to 158 (MW-34) feet below grade and the measured water levels vary from 37 (MW-29) to 145.7 (MW-34) feet below ground surface.

All field work was performed under the supervision of a qualified geologist. Test boring records were prepared describing the subsurface conditions encountered at each drilling location and are included in Appendix B. Drilling procedures are described in Appendix A. Eighty soil samples were subjected to soil mechanics laboratory identification and characterization testing. Test results are summarized in Table 3-3 and the laboratory data is included in Appendix C.

2.2.5 Surface Soils

The quality of DDMT's surface soils was investigated by collecting 40 surface soil samples in Phase I of the RI and 10 surface soil samples in Phase II. Sampling locations were selected with respect to past area use or contaminant source proximity. Surface soil sampling locations are tabulated on Table 2-1. Analytical information is included in Section 4.

2.2.6 Subsurface Soils

The quality of DDMT's vadose zone materials was investigated in Phase I by collecting and analyzing three soil samples from each of the five shallow stratigraphic test borings.

Soil samples were selected from various depth intervals for analytical testing. The depth at which each sample was taken is given in Table 2-2. Sample intervals were chosen based upon adjacent contaminant sources and/or likely contaminant migration pathways. For example, a boring location was selected to be as close as possible to a likely contaminant source. Sample depths

TABLE 2-1

SURFACE SOIL SAMPLING LOCATIONS

SAMPLE TYPE AND NUMBER	LOCATION	DEPTH	FIGURE NUMBER
SS-1	PDO YARD 150, south of MW-17	1-2"	2-2b
SS-2	PDO YARD	surface	2-2b
SS-3	PDO YARD hazardous material storage Post # Y-50-29-67-AA Drums of cleaning compound solvent	surface	2-2b
SS-4	PDO YARD north of B street; south of Post # Y-50-34-67-AA In drainage ditch	surface	2-2b
SS-5	PDO YARD southern most cement bin; west of Bldg. S209; east of Bldg. 308	surface	2-2b
SS-6	DUNN FIELD junction of drainage pipe and and concrete ditch; east of Bldg. 1184	surface	2-1
SS-7	DUNN FIELD burn area; north of road north of bauxite storage	1.0'	2-1
SS-8	DUNN FIELD 100' south of gate on Dunn Ave.; 20' west of rr track # 15; beneath oil drums	surface	2-1
SS-9	DUNN FIELD 75' west of western fence; 500' north of Dunn Ave.	surface	2-1
SS-10	HAZARDOUS MATERIAL STORAGE southwest corner of Bldg. 629; along ramp on 6th street	0.5'	2-2a

SS-11	HAZARDOUS MATERIAL STORAGE west end of Bldg. 629; below door # 11	0.5'	2-2a
SS-12	GOLF COURSE south end of fish pond; 3' south of water-edge	0.2'	2-2c
SS-13	GOLF COURSE 200' southwest of fish pond	surface	2-2c
SS-14	GOLF COURSE 3' east of 2nd street; 300' north of N street	surface	2-2c
SS-15	PAINT AREA west side of Bldg. 1088 beneath metal dust collector	0.2'	2-2d
SS-16	PAINT AREA north end of Bldg. 1087 east side of driveway and doorway	0.2'	2-2d
SS-17	PAINT AREA/SAND BLAST AREA northwest corner of Bldg. 1088 just west of emergency exit door	0.2'	2-2d
SS-18	PAINT AREA south end of Bldg. 1087 east side of driveway	0.2'	2-2d
SS-19	PAINT AREA northwest corner of Bldg. 1087	0.2'	2-2d
SS-20	P-949 AREA south end of new fabric structure; 5' east of concrete slab		2-2a
SS-21	HARDSTAND OPEN AREA 300' south of B street; 2' east of rr track # 3	0.5'	2-2a
SS-22	HARDSTAND OPEN AREA 600' south of B street; 2' west of rr track # 3	0.5'	2-2a
SS-23	HARDSTAND OPEN AREA 2' east of rr track # 4	0.5'	2-2a

SS-24	FUEL OIL STORAGE TANK west of Bldg. 720; beneath diesel fuel tank	0.5'	2-2a
SS-25	MOGAS STATION southeast corner of G and 2nd street; 2' west of tank valves	1.0'	2-2c
SS-26	RECOUPMENT AREA 20' east of Bldg. 873; south end of bin # 6	1.0'	2-2d
SS-27	RECOUPMENT AREA 20' east of Bldg. 873; north end of bin # 6	1.0'	2-2d
SS-28	RECOUPMENT AREA 150' east of Bldg. 873; centered on bin # 7	1.0'	2-2d
SS-29	RECOUPMENT AREA 125' east of Bldg. 873; 20' south of rr track # 3	1.0'	2-2d
SS-30	CAFETERIA OLD TRANSFORMER STORAGE YARD 3' southwest of southwest corner	1.0'	2-2c
SS-31	CAFETERIA OLD TRANSFORMER STORAGE YARD 2' north of north end of Bldg.; very center of building	1.0'	2-2c
SS-32	HARDSTAND OPEN AREA 30' south of B street; centered between rr track # 11 & 12	1.0'	2-2a
SS-33	HARDSTAND OPEN AREA 75' north of the northwest corner of new hazardous material storage building	1.0'	2-2a
SS-34	HARDSTAND OPEN AREA 20' south of B street; directly south of 804	1.0'	2-2a
SS-35	HARDSTAND OPEN AREA northwest corner of the new hazardous material storage building	1.0'	2-2a

SS-36	HARDSTAND OPEN AREA 300' south of B street; 3' east of rr track # 8	1.0'	2-2a
SS-37	OLD PESTICIDE STORAGE AREA in flower bed between putting green and Bldg. T-273	1.0'	2-2c
SS-38	BLDG. 770 50' north of south end of Bldg. 770; 10' west of building at inlet to underground tank	surface	2-2d
SS-39	BLDG. 770 50' north of south end of Bldg. 770; 55' west of building; beneath two garbage bins filled with oil filters, cans of hydraulic fluid, and anti-freeze	surface	2-2d
SS-40	HARDSTAND OPEN AREA 100' south of B street; centrally between 17th street and rr track # 7; transformer storage area	0.2'	2-2a
SS-41	PDO YARD Due south of Gate 19; 10' north of gravel Road	surface	2-2b
SS-42	HAZARDOUS MATERIAL STORAGE west end of Bldg. 629	surface	2-2a
SS-43	HAZARDOUS MATERIAL STORAGE south side of Bldg. 629 200' East of SS-11	surface	2-2a
SS-44	DUNN FIELD	surface	2-1
SS-45	PAINT AREA south east corner of Bldg. S1089	surface	2-2d
SS-46	PAINT AREA just north of S1090 and just west of Bldg. 880	surface	2-2d
SS-47	BLDG. 737 north west corner of bldg, in the gravel	surface	2-2a

SS-48	BLDG. 770 north east corner of J & 10th St. intersection	surface	2-2d
SS-49	BLDG. 770 north west corner of bldg. 2'from storm drain	surface	2-2d
SS-50	OLD PESTICIDE STORAGE AREA beside storm drain at southeast corner of bldg. T-273	surface	2-2c

TABLE 2-2

SOIL TEST BORINGS

SAMPLE NUMBER		LOCATION	SAMPLING DEPTHS	FIGURE NUMBER
STB-1	#1	DUNN FIELD	25.5'	2-1
	#2		62.5'	
	#3		73.5'	
STB-2	#1	DUNN FIELD	10.0'	2-1
	#2		17.5'	
	#3		67.5	
STB-3	#1	PDO YARD	21.0'	2-2a
	#2		26.0'	
	#3		93.5'	
STB-4	#1	OLD DIP VAT DRIP AREA	19.0'	2-2a
	#2		26.0'	
	#3		102.0'	
STB-5	#1	NORTHWEST CORNER OF MAIN INSTALLATION	16.0'	2-2d
	#2		78.0'	
	#3		83.0'	
STB-6	#1	NORTHWEST CORNER OF DUNN FIELD	71.5'	2-1
	#2		76.0'	
	#3		86.0'	
	#4		181.0'	
STB-7	#1	WEST EDGE OF DUNN FIELD	71.0'	2-1
	#2		76.0'	
	#3		91.0'	
	#4		170.0'	
STB-8	#1	MAIN INSTALLATION NORTH OF BUILDING 835	92.0'	2-2a
	#2		97.0'	
	#3		127.0'	
	#4		212.0'	

were chosen to permit the collection of samples at elevations just below a likely source's burial/spill point and within potential migration pathways, above the saturated zone.

Potential contamination of the confining unit and the Memphis Sand aquifer was investigated in Phase II by collecting four soil samples from each of the three stratigraphic test borings. The samples from these borings were selected at the following depths: (1) top of confining unit (i.e. bottom of Fluvial deposits); (2) and (3) both samples collected from within the confining unit; and (4) the top of Memphis Sand aquifer. The results of the subsurface soil quality investigation are presented in Section 4.

2.2.7 Ground-Water Investigation

The quality of the ground water was investigated in three inter-related tasks: a review of the available ground-water data (described in Subsection 2.1), performance of eight stratigraphic test borings to further describe aquifer characteristics, and the installation of monitoring wells. A total of thirty ground-water quality monitoring wells were installed into the study area's Fluvial deposits aquifer and two monitoring wells into the Memphis Sand aquifer.

The monitoring well installation effort provided data describing the site's deep and shallow hydrogeologic units. Individual well water levels were used for the development of generalized water table maps illustrating the Fluvial deposits saturated zone's upper surface. In addition, field hydraulic conductivity tests were performed in thirty of the monitoring wells to obtain aquifer conductivity data.

Ground-water quality monitoring well installation records are contained in Appendix D. Field hydraulic conductivity test records are included in Appendix F. The results of the ground-water investigation are included in Subsection 3.1.6, Hydrogeology.

2.2.8 Study Area Land Utilization

The study area's land use was determined by visual reconnaissance and from the previous investigations (Section 1.3.3).

2.2.8.1 Demographics - The Defense Depot Memphis, Tennessee is located in the southern portion of the city of Memphis. The following information is for the total Memphis Standard Metropolitan Statistical Area (SMSA) city area:

1980 CENSUS DATA FOR MEMPHIS METROPOLITAN AREA

	1980 Census	1988 Estimate	1993 Projection
Total Population	646,356	652,875	659,441
Total Households	230,474	244,545	253,588
Av. Household Size	2.8	2.6	2.6
Av. Household Income	$17,983	$29,187	$36,505
Median House. Income	$14,157	$21,606	$26,368

DDMT is surrounded by zip codes 38114 and 38106. Census data for the area immediately surrounding the facility is summarized below.

1980 CENSUS DATA FOR ZIP CODE 38114

	1980 Census	1988 Estimate	1993 Projection
Total Population	47,781	47,109	46,587
Total Households	15,502	16,315	16,562
Av. Household Size	3.1	2.9	2.8
Av. Household Income	$12,954	$19,398	$23,506
Median House. Income	$10,467	$14,524	$17,621

1980 CENSUS DATA FOR ZIP CODE 38106

	1980 Census	1988 Estimate	1993 Projection
Total Population	46,686	43,956	43,108
Total Households	14,588	14,214	14,312
Av. Household Size	3.2	3.1	3.0
Av. Household Income	$11,569	$16,461	$19,873
Median House. Income	$ 8,756	$11,239	$13,083

The 1988 estimated median age for the populations surrounding the DDMT is 29.5 with 25% of the population under the age of 15 and 11% over the age of 65. Females make up 54% of the population. Most of the residents have lived in the area less than five years or more than fifteen years (D & B, 1989). Two additional zip codes are within one mile of DDMT, but no census data was available for these codes (38132 and 38131) (City of Memphis, 1989).

2.2.8.2 Land Use - The following summary was obtained from Harland, Bartholomew and Associates, 1988.

2.2.8.2.1 Adjacent Land Use - Defense Depot Memphis is located in south central Memphis in an area of widely varying uses. To the north of the Depot are the Lines of the Frisco Railroad and Illinois Central Gulf Railroad. A number of large industrial and warehousing operations are located along the rail lines in this area including Kellogg Company, Laramie Tires, Lanigan Storage and Van Company, the Kroger Company, National Manufacturing Company, Incorporated and United Uniforms. A triangular area immediately to the north of the Depot along Dunn Road also contains several industrial firms. Formerly a residential neighborhood, the area is characterized by small commercial and manufacturing uses with a few single family residences.

Airways Boulevard is the most heavily traveled thoroughfare in the vicinity and is developed with numerous small, commercial establishments, particularly from the Depot southward to the Airways interchange with Interstate 240. Businesses along Airways are typical of highway commercial districts and include convenience stores, liquor stores, restaurants, used car dealers and service stations. Other commercial establishments are located to the north, south and west of the Depot. Most are small groceries or convenience stores which serve their immediate neighborhoods.

The Depot is surrounded by residential development. The housing stock ranges from modern, brick, ranch style homes located on wide tree-shaded streets to small, frame houses built a half century ago, many of which are in poor condition. Several large, multi-family developments are in the area, ranging from an older apartment complex (Castalia Heights Apartments), located north of the Depot along Carver Avenue and Keltner Circle, to a newly constructed development (Orchid Manor), located to the south of the Depot on Ball Road.

Institutional uses include numerous small church buildings scattered throughout the residential neighborhoods. There are several schools located in the area: Alcy Road Elementary to the south of the Depot; Norris Elementary, Dunn Elementary, Corry Junior High, Hamilton High, Hamilton Junior High, and Hamilton Elementary to the west; Magnolia Elementary to the northeast; and Charjean Elementary and Airways Junior High to the east. Five cemetaries are located near the Depot: Anshei-Sphard, located directly across Airways Boulevard; Baron Hirsch, located to the northwest on Rozelle Street; and Calvary, Forest Hill, and Temple Israel in the vicinity of Person Avenue and Bellevue Boulevard, west of the Depot. Memphis Light, Gas, and Water Division operates a large substation to the northwest of the Depot along Person Avenue.

Two neighborhood parks are in the immediate vicinity of the Depot. Alcy Samuels Park is located on Alcy Road to the south of the Depot. Lincoln Park is located on Person Avenue to the west of the Depot.

Most of the land surrounding the Depot is intensely developed. However, three relatively large, undeveloped sites exist in the general area. The largest is located to the north of the Depot at Person Avenue and Rozelle Street. Other areas are located south of the Depot along Ball Road and Ketchum Road in the vicinity of the Orchid Manor Apartments, and east of the Depot on Dwight Street.

2.2.8.2.2 Land Use Controls - In Memphis and Shelby County, zoning controls and subdivision requirements are under the jurisdiction of the Office of Planning and Development (OPD). The Depot property itself is zoned I-L or Light Industrial. This designation extends to several contiguous parcels east of the Depot along Airways in the vicinity of the Kellogg plant westward past Rozelle Street. Several smaller areas adjacent to those mentioned above are zoned I-H, Heavy Industrial.

Commercially zoned areas predominate along Airways Boulevard from the Depot southward to the Airways intersection with Interstate 240. Other commercially zoned areas exist along Castalia, Hearst, and Ragan north of the Depot, and along Alcy and Ketchum south of the Depot.

The great majority of the remaining land in the vicinity of the Depot is zoned for single-family or duplex residential. However, several large parcels have been zoned to allow multi-family developments particularly to the north of the Depot in the Castalia Heights area; to the west of the Depot on Dunn Avenue near Lincoln Park; to the south of the Depot along Alcy and Ketchum roads; and to the east of the Depot along Airways, Dwight, Pecan, and Ketchum.

2.2.9 Ecology

2.2.9.1 Introduction - Study area ecological information, required in the consideration of potential contaminant receptors (Subsection 6.2 of the Risk Assessment) was obtained from published sources.

2.2.9.2 Surface Waters - The DDMT facility has two main surface water features: Lake Danielson and the golf course pond. Both bodies of water are located in the southeastern quadrant of the facility. These waters are currently unsuitable for recreational purposes and serve primarily as drainage reservoirs. Drainage channels on the facility and in neighboring areas drain either to Cane Creek, northwest of DDMT, or to Nonconnah Creek, south of DDMT. Cane Creek also eventually drains to Nonconnah Creek, at a point several miles southwest of DDMT. In turn, Nonconnah Creek empties to Lake McKellar, which is part of the Mississippi River system.

Tennessee Water Quality Standards define uses of waters which are in the public interest. The uses for waters include:

1) sources of water supply for domestic and industrial purposes;
2) propagation and maintenance of fish and other desirable aquatic life;
3) recreation in and on the waters;
4) stock watering and irrigation;
5) navigation;
6) generation of power;
7) the enjoyment of scenic and aesthetic qualities of waters.

Under the Tennessee Water Quality Control Act, when waters are classified for more than one use, the most stringent criteria will be applicable. In addition, waters designated as wet weather conveyances (natural watercourses) shall be protective of wildlife and humans that may come in contact with them and maintain standards applicable to all downstream waters.

Nonconnah Creek and Cane Creek have been classified for the following stream uses: propagation of and maintenance of fish and other aquatic species; livestock and wildlife watering; and irrigation. In addition, the portion of Cane Creek flowing near the DDMT facility is classified for recreation. The most stringent criteria which is applicable protects fish and aquatic life and states that the waters shall not contain toxic substances which cause death or serious illness to aquatic biota and reference criteria promulgated under the Clean Water Act and Safe Drinking Water Act (SDWA) (Tennessee Water Quality Board, 1987). SDWA levels are given in Section 6 and compared with contaminant levels detected in the surface waters at DDMT.

2.2.9.3 Flora - Most of the facility is restructured surfaces with little observable vegetation. The unsurfaced areas have native Bermuda grass and some deciduous black oak (Quercus velutina). Some decorative plant species have been used in landscaping the housing area, golf course, administrative areas and the lake (SPCC, 1987).

2.2.9.4 Fauna - No threatened or endangered species associated with the Memphis area have been sighted on the DDMT facility. The most prevalent forms of animal life are pests such as roaches, rats and mosquitos. Lake Danielson has been stocked in the past with bass (Micropterus sp.) and bluegill (Lepomis sp.) and also contains catfish (Letalurus sp.). Dunn Field is a large open area with mature oak trees and grass. Several additional species have been noted at Dunn Field which include squirrels (Sciurus niger), the red fox (Vulpes vulpes fulva), mourning doves (Zenaidura macroura), quail (Colinuus virginianus) and turtles (Terrpaene carolina) (SPCC, 1987).

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

3.1 PHYSICAL CHARACTERISTICS

The individual tasks performed to support this study (refer to Section 2.0) collected a substantial volume of study area physical characterization information. The results of physical characterization data evaluation are presented in this section. Supplemental information such as boring logs, field hydraulic conductivity testing data, etc. are included in the Appendices.

3.1.1 Surface Features

Defense Depot Memphis, Tennessee (DDMT) is divided into two separate areas, Dunn Field and the main installation, each with its own distinct land surface and use-related features.

Dunn Field lies just north of the main installation and Dunn Avenue, and consists of approximately sixty-four acres of undeveloped land. Dunn Field is unpaved; about one-half the area is grassed. A few large deciduous trees are present in the north-central part of the field. An arc-shaped ridgeline separates the field's two northern quadrants. In the northeast quadrant of the field, the areas surrounding the former pesticide/herbicide storage shed (Building 1184) and the former burn area are level and grassed. In the northwest quadrant of the field, the waste, chemical and hazardous materials disposal zone is a level to gently sloping grassed area. The southwest quadrant of the field is a grassed, gently sloping area. The southeast quadrant is a level zone utilized for both covered and uncovered bulk materials storage.

Dunn Field's topographic expression is that of a level to gently rolling open area. It appears to slope to the east and west from the bauxite piles in the center of the field. Surface elevations range from a low of 273 feet, National Geodetic Vertical Datum of 1929 (NGVD), at the north outfall/installation boundary fenceline, to 315 feet NGVD, (325 feet NGVD atop the bauxite storage piles) in the field's approximate center. Maximum local relief is about twenty-five feet at the pistol range bullet stop.

The main installation consists primarily (approximately 57%) of highly developed, urbanized land. Most of the main installation's land area has been graded, paved and built up. Some of the few remaining undeveloped areas are utilized for open storage of various materials equipment. The only significant grassed and treed area is the golf course, located in the main installation's southeast sector. The main installation's topographic expression is that of nearly level expanse. Surface elevations range from approximately 316 feet, NGVD in the DRMO storage yard adjacent to Dunn Avenue to 267 feet, NGVD in the low area below Lake Danielson's earthen dam. Maximum local relief is approximately twenty feet, measured across the lake's earthen dam.

3.1.2 Meteorology

Meteorological conditions in a study area may exert an influence over the generation and migration of waste-related contamination. These conditions are also an important factor to be considered during the evaluation of contaminant migration potential (Subsection 5.3). Information describing study area meteorological conditions was obtained from various U.S. Geological Survey reports and from the Climatic Atlas of the United States, National Oceanic and Atmospheric Administration, (NOAA) 1983.

The study area is located in the west Tennessee Climatic Division of the United States (NOAA, 1981). This Division experiences a typical continental type of climate with humid, warm summers and cold winters. The Memphis area receives an annual average of fifty inches of precipitation (thirty year period of record). Total annual rainfall was reported to vary from 30.54 inches (1941) to 76.85 inches (1957). Normally, precipitation is heaviest during the winter and early spring. A second, less significant rainfall period develops as thundershowers during late spring and early summer. The one year, twenty-four hour rainfall value for the study area is reported to be 3.4 inches (Rainfall Frequency Atlas of the United States, US Department of Commerce, Weather Bureau Technical Paper 40, May 1961).

The net annual precipitation estimated for the Memphis area is nine inches, based on NOAA (1983) data. The estimate is a high value, suggesting that a strong leachate generation and contamination migration potential exists. The estimate of net precipitation does not consider evapotranspiration which varies considerably, according to season. The estimate was performed in a manner consistent with 40 CFR Part 300, Appendix A.

3.1.3 Surface Water Hydrology

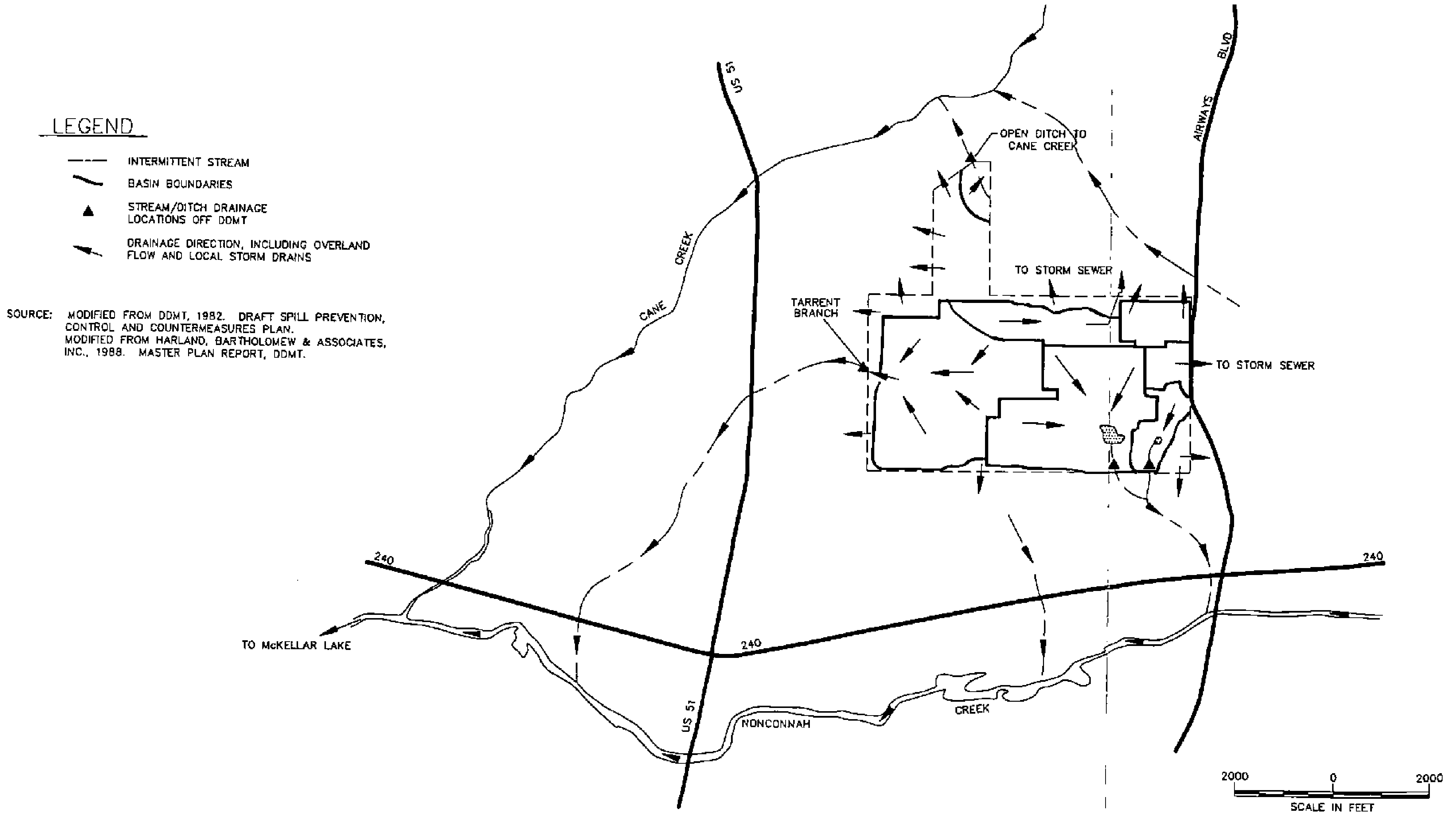
3.1.3.1 Installation Drainage - Installation surface drainage is accomplished by overland flow to swales, ditches, concrete-lined channels and an efficient storm drainage system. Figure 3-1 illustrates the study area's surface drainage features, installation drainage areas, outfalls and local streams.

Most of the study area, including the main installation and Dunn Field, is generally level with, or above, surrounding terrain. Therefore, DDMT receives little or no runoff from adjacent areas. Where exposed, undisturbed installation surface soils are predominantly grassed, fine-grained semicohesive materials which tend to promote large volumes of rapid runoff. Paved and built-up sections of the installation also tend to generate significant amounts of runoff.

FIGURE 3-1

STUDY AREA SURFACE DRAINAGE

DEFENSE DEPOT MEMPHIS, TENNESSEE



SOURCE: MODIFIED FROM DDMT, 1982. DRAFT SPILL PREVENTION, CONTROL AND COUNTERMEASURES PLAN.
MODIFIED FROM HARLAND, BARTHOLOMEW & ASSOCIATES, INC., 1988. MASTER PLAN REPORT, DDMT.

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The majority of Dunn Field's drainage (Figure 3-1) is achieved by overland flow to the adjacent properties to the north and west. The northeast quadrant drains to the east, to a concrete-lined channel, or to the adjacent properties to the north. The concrete lined channel consists of two separate segments which join approximately two hundred feet north of Building 1184. Both channel segments convey adjacent residential neighborhood stormwater through the northeast quadrant of Dunn Field. The concrete-lined channel directs flow northward to Cane Creek, a tributary of Nonconnah Creek.

The main installation's surface drainage is achieved by overland flow to a storm drainage system. The main installation has been divided into several small "drainage basins" (Figure 3-1). The primary drainage directions and outfall locations are to the west (Tarrent Branch), to the east (unnamed ephemeral stream) and to the south (unnamed ephemeral stream). Surface drainage is directed via these alignments to Nonconnah Creek, approximately three-quarters of a mile south of DDMT. Nonconnah Creek drains into Lake McKellar, a Mississippi River tributary.

Stormwater collected from the roof of Building 995 is discharged locally to a French drain.

3.1.3.2 Installation Surface Waters - All of the ditches, channels or drainage alignments within DDMT's boundaries convey seasonal (or wet weather) flow. Frequently, they are completely dry.

Two permanent surface waters exist at DDMT. The largest body of water is Lake Danielson, about four acres in size. Lake Danielson receives a significant amount of installation stormwater runoff, primarily from the area in which Buildings 470, 489, 490, 689, and 690 are located. Lake overflow is discharged through a drop inlet at the dam through a concrete-lined channel, to a culvert extending beneath N Street and Ball Road. The smaller surface water is the golf course pond. It receives runoff from the surrounding golf course, Buildings 249, 250, 251, 265, 270, 271 and the south parking lot. Pond overflow is directed to a culvert extending beneath N Street and Ball Road. Stormwater flow is then directed to Nonconnah Creek via unnamed tributaries.

3.1.3.3 Flood Potential - DDMT's surface elevations (276-316 feet, NGVD) are well above the average Mississippi River alluvial valley flood levels (185-230 feet, NGVD). Furthermore, the installation's land mass is at least equal to, or slightly higher than adjacent properties. Therefore, it is unlikely that any installation property would be subject to inundation, even for short periods of time. During the performance of Phase I field data collection activities, the study area experienced six inches of continual precipitation during the weekend of February 18-19, 1989. Despite the intense sustained rainfall, no installation areas were subjected to flooding.

3.1.4 Surface Soils

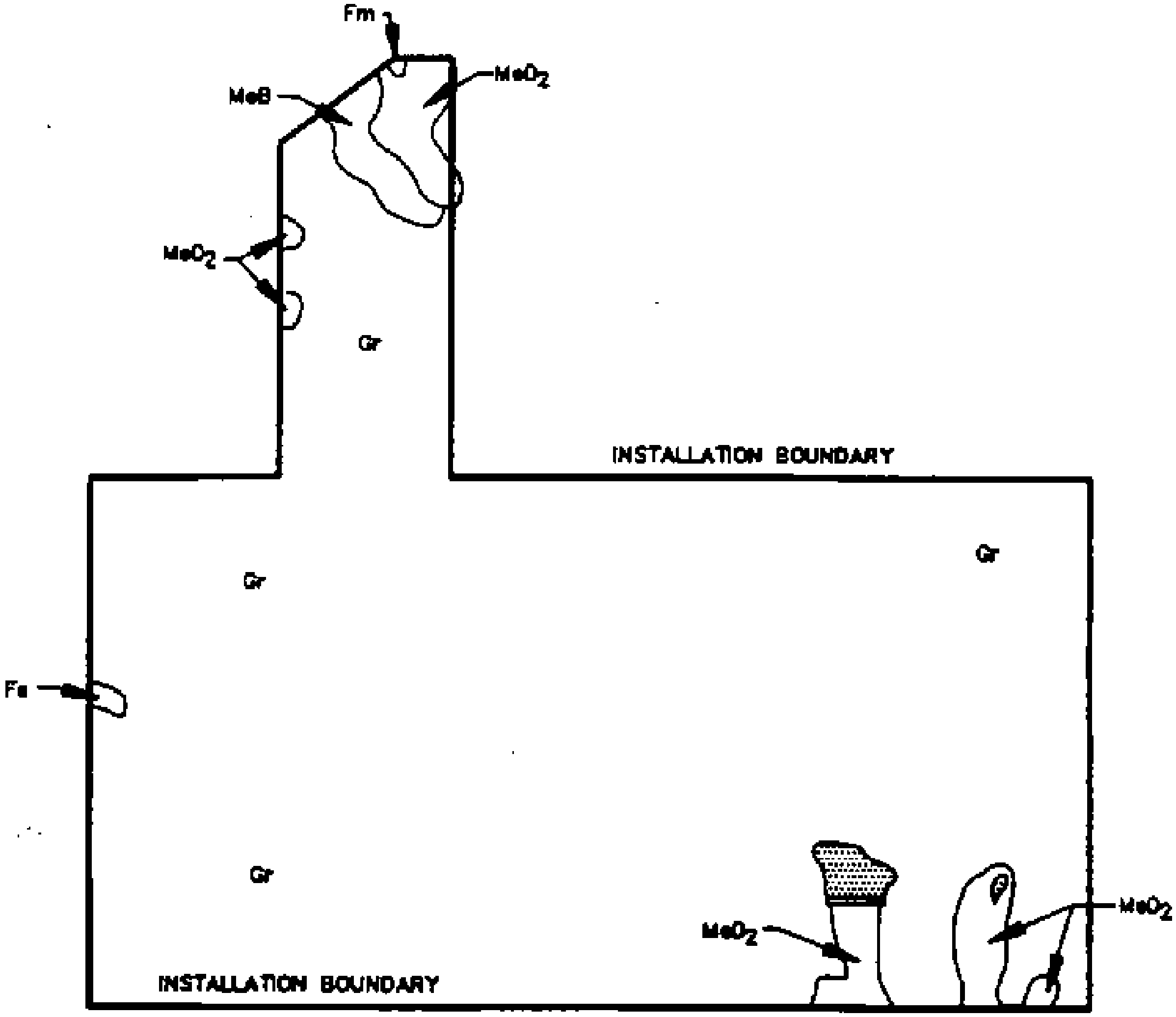
According to information furnished by the U.S. Department of Agriculture, Soil Conservation Service (1970), five distinct surface soil units have been mapped in the study area. The distribution of these units relative to the installation is illustrated on Figure 3-2. A brief description of each unit follows:

- Falaya Silt Loam (Fm). This soil unit may have originally developed as a narrow strip of alluvium occupying a bench above a stream channel. The unit has been mapped on a small portion of northern Dunn Field. It is generally described as a silt loam, poorly to moderately drained, possesses a shallow water table and typically low to moderate permeabilities.

FIGURE 3-2

STUDY AREA SURFACE SOILS

DEFENSE DEPOT MEMPHIS, TENNESSEE



SOURCE: MODIFIED FROM USDA, SOIL CONSERVATION SERVICE, 1970.

LEGEND

Fm	FALAYA SILT LOAM
Fe	FILLED LAND--SILTY
Gr	GRADED LAND
MeB	MEMPHIS SILT LOAM
MeO$_2$	MEMPHIS SILT LOAM

1000 0 1000

SCALE IN FEET

- Filled land-silty (Fs). This soil unit has been artificially developed as a result of backfilling a small portion of the main installation's west boundary. It consists of a mixture of generally silty soils. Unit characteristics are estimated to include poor to moderate drainage and low permeabilities.

- Graded land (Gr). This soil unit has been artificially developed from silty native upland materials as a result of numerous site use modifications throughout the installation's operational history. It generally consists of silty sandy clay or clayey sandy silt, but may include coarser materials, construction material and demolition debris locally. The unit's permeability is reported to be highly variable; potential use constraints are uncertain. It is significant to this study as it occupies more than ninety percent of the installation's land area. 47 of the surface soil samples were collected from this unit.

- Memphis silt loam (MeB). This unit has developed in silty native upland materials on low hilltops, benches and adjacent gradual slopes. The unit is described as a silt loam or silty clay loam. It is well drained and possesses low to moderate permeabilities. This unit is significant because of its location in north Dunn Field with respect to burial areas and because this unit probably represents "pre-development" surface soil conditions.

- Memphis silt loam (MeD2). This unit has developed in silty native upland material on intermediate slopes and benches. It is described as a silt loam or a silty clay loam. It is deep, well drained and possesses low to moderate permeabilities. The unit is significant because of its Dunn Field location and because this soil likely represents "pre-development" conditions at DDMT. Surface soil samples SS-12, SS-13, and SS-14 were collected from this unit.

Table 3-1 summarizes the engineering use data for each soil unit mapped in the installation study area. USDA texture, Unified Soil Classification System symbols, estimated permeability and likely use constraints are described for each of the five soil units.

3.1.5 Geology

3.1.5.1 Regional Geology

3.1.5.1.1 Physiography - The Memphis, Tennessee area straddles two major subdivisions of the Atlantic Coastal Plain Physiographic Province (Figure 3-3). The western Memphis urban area lies within the Mississippi Alluvial Plain subdivision, which is characterized by Fluvial depositional features including young/recently deposited point bars, natural levees and abandoned channels.

DDMT and eastern Memphis are situated within the Gulf Coastal Plain subdivision. The area is characterized by dissected loess covered uplands and are generally lacking distinct features. The erosion-controlled land surface appears nearly level to markedly rolling and the visual perspective offers little spatial variation. Local slopes range from level to approximately ten percent. The study area elevations average 300 feet, NGVD. Locally, relief is due to erosion or stream channel development and seldom exceeds thirty feet.

Generally, Gulf Coastal Plain drainage systems are well developed and the region is classified as being in a late youthful stage of dissection. The uplands tend to be low with respect to major streams and the valleys are relatively shallow. Most principal

TABLE 3-1
STUDY AREA SOIL UNITS

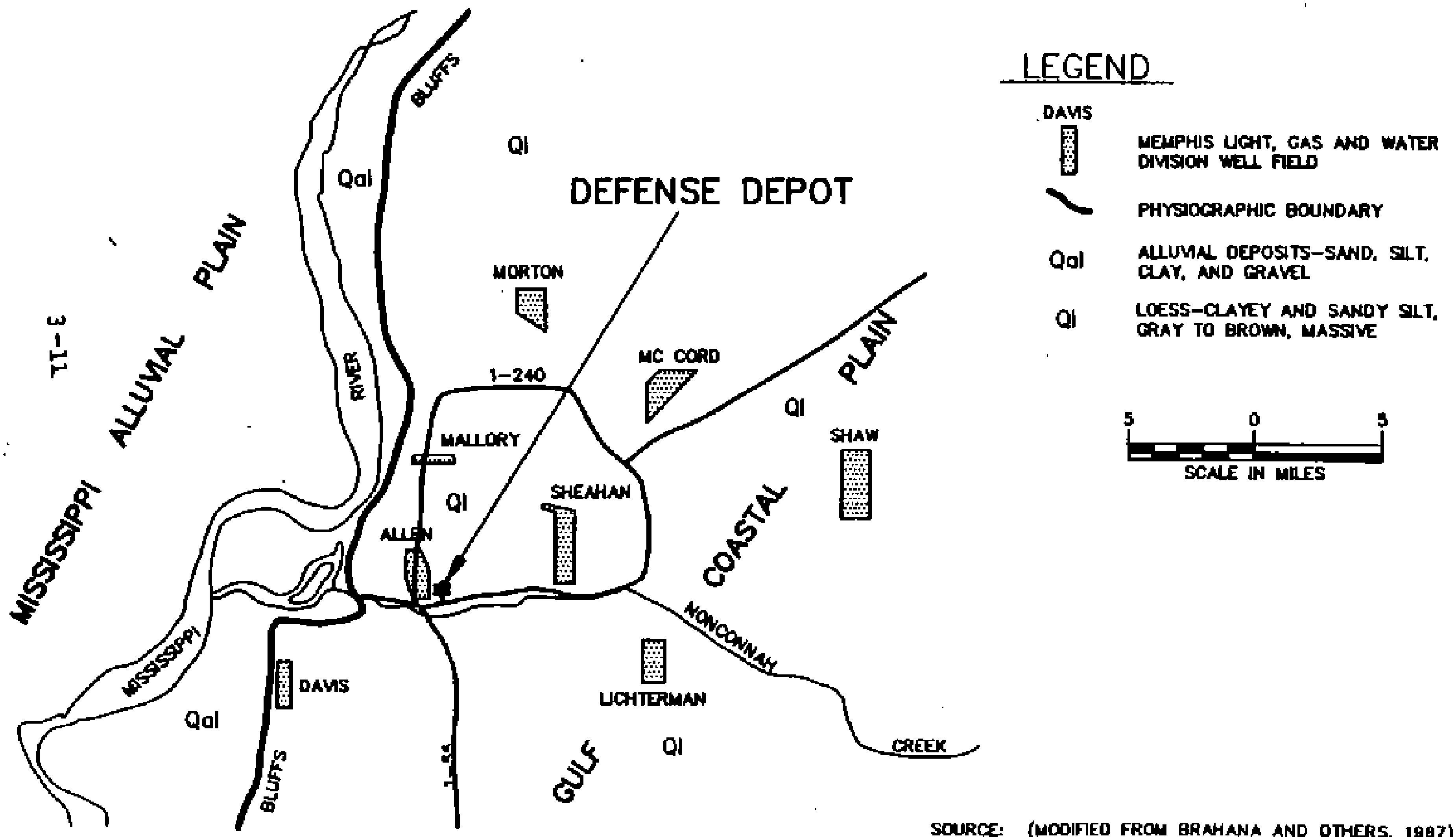
MAP SYMBOL	UNIT DESCRIPTION	USDA TEXTURE (Major Fraction)	TYPICAL THICKNESS (inches)	UNIFIED CLASSIFICATION SYSTEM (Major Fraction)	PERMEABILITY (inches/Hour)	CONSTRUCTION OR USE CONSTRAINTS
Fm	Falaya Silt Loam	Silt loam or silty clay loam	60	ML, CL	0.63 - 2.0	Seasonal wetness and high water table. Occasional flooding.
Fx	Filled land-silty	Silty fill (mixed)	36-60	ML	0.63 - 2.0	Uncertain
Gr	Graded Land	Silty sandy clay, clayey sandy silt	36	SP-SM, ML, CL	Varies	Uncertain
MeB	Memphis silt loam, 2-5% slopes	Silt loam or silty clay loam	100	ML, CL, ML-CL	0.63 - 2.0	Erosion Potential
MeD2	Memphis silt loam, 8-12% slopes, eroded	Silt loam or silty clay loam	100	ML, CL, ML-CL	0.63 - 2.0	Slopes; severe erosion hazards.

Source: Modified from USDA, Soil Conservation Service, 1970

FIGURE 3-3

GEOLOGIC MAP OF MEMPHIS AREA WITH THE MAJOR PHYSIOGRAPHIC SUBDIVISIONS AND LOCATIONS OF MEMPHIS LIGHT, GAS AND WATER DIVISION WELL FIELDS

DEFENSE DEPOT MEMPHIS, TENNESSEE



SOURCE: (MODIFIED FROM BRAHANA AND OTHERS, 1987).
(U.S.G.S. OPEN-FILE REPORT 88-485).
(GEOLOGIC MAP OF TN, 1966).

streams have low gradients and occupy broad alluviated and terraced valleys (Nonconnah Creek). Secondary streams have developed narrow V-shaped valleys in fine-grained soils.

3.1.5.1.2 Geologic Setting - The Memphis area is situated within a major structural feature termed the Mississippi embayment. This area is described as a youthful to mature, belted coastal plain. The principal river in the area is the Mississippi River; the major tributaries are the Wolf River, the Loosachatchie River, and Nonconnah Creek (Graham and Parks, 1986).

The Mississippi embayment is a structural reentrant extending into the North American craton from the Gulf of Mexico north to Cairo, Illinois. The embayment is a wedge-shaped, downwarped structure composed of stratified sediments. It begins inland as a thin accumulation of clastic materials, thickening substantially at the Gulf of Mexico. Late and post-Cretaceous strata fill the trough. Formation of the Mississippi embayment began in the latest Mesozoic period with the onset of renewed subsidence of the underlying Reelfoot rift. The axis of the trough (N50°E) roughly parallels the present course of the Mississippi River. The embayment experienced its greatest subsidence during Early Tertiary time and has been tectonically stable since its emergence during the widespread uplift of the continent in Neogene time.

The New Madrid seismic zone (NMSZ) lies at the northern end of the Mississippi embayment and is the most seismically active area in the central and eastern United States. Three great earthquakes occurred in this area in 1811 and 1812, and over 2500 microearthquakes have been recorded since 1974. Johnston and Nava (1985) have estimated a recurrence interval for great earthquakes in the Memphis area to be 425-675 years and a recurrence interval of 70 years for moderate earthquakes.

3.1.5.1.3 Geologic Units - Information describing major regional geologic units was obtained from Wells (1933); Moore (1965); Nyman (1965) and Graham and Parks (1986). Table 3-2 summarizes the regionally important post-Cretaceous study area geologic units and their hydrologic significance. Figure 3-3 is a regional geologic map illustrating the distribution of surficial geologic units.

The Quaternary and Tertiary strata in the Memphis area are composed of loosely consolidated deposits of marine, Fluvial, fluvioglacial and deltaic sediments. In Tennessee, unconsolidated sediments (Cretaceous through Quaternary) reach their maximum thickness at Memphis, where they range from 2700 to 3000 feet thick.

Cyclic Pleistocene glaciation has been directly or indirectly responsible for the origin, character, and distribution of virtually all of the Quaternary deposits and formation in the Mississippi embayment. Although continental ice sheets did not actually extend into the Lower Mississippi valley area, they nevertheless were responsible for deranging preglacial drainage and creating the southward-trending river and valley which subsequently has carried large volumes of glacial meltwater and outwash. Equally important controls were exerted by the cyclic glaciation in the form of major changes in base levels of erosion and deposition and the form of climatic changes (Saucier, 1974).

The following geologic units have been identified in the study area:

3.1.5.1.3.1 Alluvium - Alluvial deposits consisting of Holocene and Pleistocene sand, gravel, silt and clay have been deposited in the channel systems and flood plains of modern streams. Alluvial deposits may reach their maximum thickness of 175 feet in the valleys of primary streams (Mississippi River). At other locations, the unit seldom exceeds fifty feet in thickness. Although a significant unit within the region, no Alluvial deposits were encountered at DDMT.

TABLE 3-2

DDMT STUDY AREA
GEOLOGIC STRATA

[ALLUVIUM IS SHOWN HERE IN THE CONVENTIONAL POSITION AS THE YOUNGEST STRATIGRAPHIC UNIT. ACTUALLY IT ALMOST NOWHERE OVERLIES THE LOESS BUT MAY OVERLIE ANY OF THE OLDER STRATIGRAPHIC UNITS]

SYSTEM	SERIES	GROUP	STRATIGRAPHIC UNIT	THICKNESS (feet)	LITHOLOGY AND HYDROLOGIC SIGNIFICANCE
QUATERNARY	HOLOCENE AND PLEISTOCENE		ALLUVIUM	0-175	SAND, GRAVEL, SILT, AND CLAY. UNDERLIES THE MISSISSIPPI ALLUVIAL PLAIN AND ALLUVIAL PLAINS OF STREAMS IN THE GULF COASTAL PLAIN. THICKEST BENEATH THE ALLUVIAL PLAIN, WHERE COMMONLY BETWEEN 100 AND 150 FEET THICK; GENERALLY LESS THAN 50 FEET THICK ELSEWHERE. PROVIDES WATER TO DOMESTIC, FARM, INDUSTRIAL, AND IRRIGATION WELLS IN THE MISSISSIPPI ALLUVIAL PLAIN.
	PLEISTOCENE		LOESS	0-65	SILT, SILTY CLAY, AND MINOR SAND. PRINCIPAL UNIT AT THE SURFACE IN UPLAND AREAS OF THE GULF COASTAL PLAIN. THICKEST ON THE BLUFFS THAT BORDER THE MISSISSIPPI ALLUVIAL PLAIN; THINNER EASTWARD FROM THE BLUFFS. TENDS TO RETARD DOWNWARD MOVEMENT OF WATER PROVIDING RECHARGE TO THE FLUVIAL DEPOSITS.
QUATERNARY AND TERTIARY (?)	PLEISTOCENE AND PLIOCENE (?)		FLUVIAL DEPOSITS (terrace deposits)	0-100	SAND, GRAVEL, MINOR CLAY AND FERRUGINOUS SANDSTONE. GENERALLY UNDERLIE THE LOESS IN UPLAND AREAS, BUT ARE LOCALLY ABSENT. THICKNESS VARIES GREATLY BECAUSE OF EROSIONAL SURFACES AT TOP AND BASE. PROVIDES WATER TO MANY DOMESTIC AND FARM WELLS IN RURAL AREAS.
TERTIARY	EOCENE	— ? — CLAIBORNE	JACKSON FORMATION AND UPPER PART OF CLAIBORNE GROUP, INCLUDES COCKFIELD AND COOK MOUNTAIN FORMATIONS (CAPPING CLAY)	0-360	CLAY, SILT, SAND, AND LIGNITE. BECAUSE OF SIMILARITIES IN LITHOLOGY, THE JACKSON FORMATION AND UPPER PART OF THE CLAIBORNE GROUP CANNOT BE RELIABLY SUBDIVIDED BASED ON AVAILABLE INFORMATION. MOST OF THE PRESERVED SEQUENCE IS THE COCKFIELD AND COOK MOUNTAIN FORMATIONS UNDIVIDED, BUT LOCALLY THE COCKFIELD MAY BE OVERLAIN BY THE JACKSON FORMATION. SERVES AS THE UPPER CONFINING BED FOR THE MEMPHIS SAND.
			MEMPHIS SAND ("500-FOOT" SAND)	500-890	SAND, CLAY, AND MINOR LIGNITE. THICK BODY OF SAND WITH LENSES OF CLAY AT VARIOUS STRATIGRAPHIC HORIZONS AND MINOR LIGNITE. THICKEST IN THE SOUTHWESTERN PART OF THE MEMPHIS AREA; THINNEST IN THE NORTHEASTERN PART. PRINCIPAL AQUIFER PROVIDING WATER FOR MUNICIPAL AND INDUSTRIAL SUPPLIES EAST OF THE MISSISSIPPI RIVER; SOLE SOURCE OF WATER FOR THE CITY OF MEMPHIS.
	— ? —	WILCOX	FLOUR ISLAND FORMATION	160-310	CLAY, SILT, SAND, AND LIGNITE. CONSISTS PRIMARILY OF SILTY CLAYS AND SANDY SILTS WITH LENSES AND INTERBEDS OF FINE SAND AND LIGNITES. SERVES AS THE LOWER CONFINING BED FOR THE MEMPHIS SAND AND THE UPPER CONFINING BED FOR THE FORT PILLOW SAND.
			FORT PILLOW SAND ("1400-FOOT" SAND)	125-305	SAND WITH MINOR CLAY AND LIGNITE. SAND IS FINE TO MEDIUM. THICKEST IN THE SOUTHWESTERN PART OF THE MEMPHIS AREA; THINNEST IN THE NORTHERN AND NORTHEASTERN PARTS. ONCE THE SECOND PRINCIPAL AQUIFER SUPPLING THE CITY OF MEMPHIS; STILL USED BY AN INDUSTRY. PRINCIPAL AQUIFER PROVIDING WATER FOR MUNICIPAL AND INDUSTRIAL SUPPLIES WEST OF THE MISSISSIPPI RIVER.
	PALEOCENE		OLD BREASTWORKS FORMATION	180-350	CLAY, SILT, SAND LIGNITE. CONSISTS PRIMARILY OF SILTY CLAYS AND CLAYEY SILTS WITH LENSES AND INTERBEDS OF FINE SAND AND LIGNITE. SERVES AS THE LOWER CONFINING BED FOR THE FORT PILLOW SAND, ALONG WITH THE UNDERLYING PORTERS CREEK CLAY AND CLAYTON FORMATION OF THE MIDWAY GROUP.

SOURCE: MODIFIED FROM GRAHAM AND PARKS, 1986

3.1.5.1.3.2 Loess - Loess is a semi-cohesive eolian deposit composed of silt, silty clay, silty fine sand or mixtures thereof. It mantles the ground surface over wide areas of the central United States. It typically occurs above the Alluvial (terrace) deposits and is thickest along the bluffs overlooking the Mississippi Alluvial Plain. Its maximum thickness is reported to be on the order of 65 feet; it thins considerably toward the east. Locally it may contain thin, discontinuous fine sandy layers enclosed within silts and silty clays.

3.1.5.1.3.3 Fluvial (Terrace) Deposits - Quaternary and possibly Pliocene age Fluvial deposits occur beneath the uplands and valley slopes of the Gulf Coastal Plain and are the remnants of ancient alluvial deposits of either present streams or an ancient drainage system. The Fluvial deposits consist primarily of sand and gravel with minor lenses of clay and thin layers of iron-oxide cemented sandstone or conglomerate. Reported thickness of the Fluvial deposits ranges from 0 to 100 feet. The thickness is highly variable because of erosional surfaces at both the top and the base of this unit. Locally, in the Memphis area, the Fluvial deposits may be absent (Graham and Parks, 1986).

3.1.5.1.3.4 Jackson Formation/Upper Claiborne Group - The Late Eocene Jackson Formation and upper part of the Claiborne Group lie beneath the Fluvial (terrace) deposits. Because of lithologic similarities, the Jackson Formation and upper part of the Claiborne Group cannot be reliably subdivided in the subsurface of the Memphis area. These units include strata of the Cockfiled and Cook Mountain Formations undivided in the upper part of the Claiborne Group, and locally, of the Jackson Formation. The Jackson/upper Claiborne unit consists primarily of clay, silt and fine sand with minor lenses of lignite. Within this unit sediments are lenticular, and locally individual beds may not be areally extensive. The clays are predominantly of the montmorillonite type. The thickness of the Jackson/upper Claiborne unit is highly variable in the Memphis urban area, ranging from 0 to 360 feet with aggregate thickness of clay beds ranging from 0 to 250 feet (Hart, 1989a).

3.1.5.1.3.5 Memphis Sand ("500-foot sand") - The widespread terrace deposits of the Memphis Sand were deposited during Middle Eocene time when streams carried extensive quantities of sand and gravel into the Mississippi embayment area. The Memphis Sand unit is composed primarily of thick bedded, white to brown or gray, very fine grained to gravelly, partly argillaceous and micaceous sand. Lignitic clay beds constitute only a small percentage of total thickness. The Memphis Sand ranges from 500 to 890 feet in thickness. It is thinnest in the northeastern part of the Memphis area in northwestern Fayette County, TN, and thickest near the Mississippi River in southwestern Shelby County, TN (Nyman, 1965).

3.1.5.1.3.6 Flour Island Formation - Beneath the Memphis Sand lies the lower Eocene and Paleocene Flour Island Formation. The Flour Island Formation consists primarily of silty clay and sandy silt with lenses of fine sand and lignite that are not areally extensive. The thickness of this formation is variable in the Memphis urban area, ranging from 70 to 240 feet (Nyman, 1965).

3.1.5.1.3.7 Fort Pillow Formation ("1400-foot sand") - The Fort Pillow Sand occurs beneath the Flour Island Formation throughout the Memphis area. It consists primarily of fine to medium sand with some local interbedded clay and lignite. The Fort Pillow Sand ranges from 125 to 305 feet in thickness (Nyman, 1965).

3.1.5.1.3.8 Old Breastworks Formation - The Old Breastworks Formation is the oldest of the Tertiary units identified in the study area. It consists of silty clays and clayey silts with interbeds and lenses of fine sand and lignite. This unit has been reported to range from 180 to 350 feet in thickness.

3.1.5.2 Site Geology - Because soil borings are only considered to be representative of geologic conditions for the exact point where they were advanced, care was taken in the development of subsurface interpretations which may or may not infer the continuity of individual strata between widely spaced borings. Professional judgement was exercised in the interpretations that are depicted on cross-sections and other figures. The geologic conditions encountered at DDMT appear to be consistent with those reported by a number of investigators in the professional technical literature relative to the geologic units underlying Memphis.

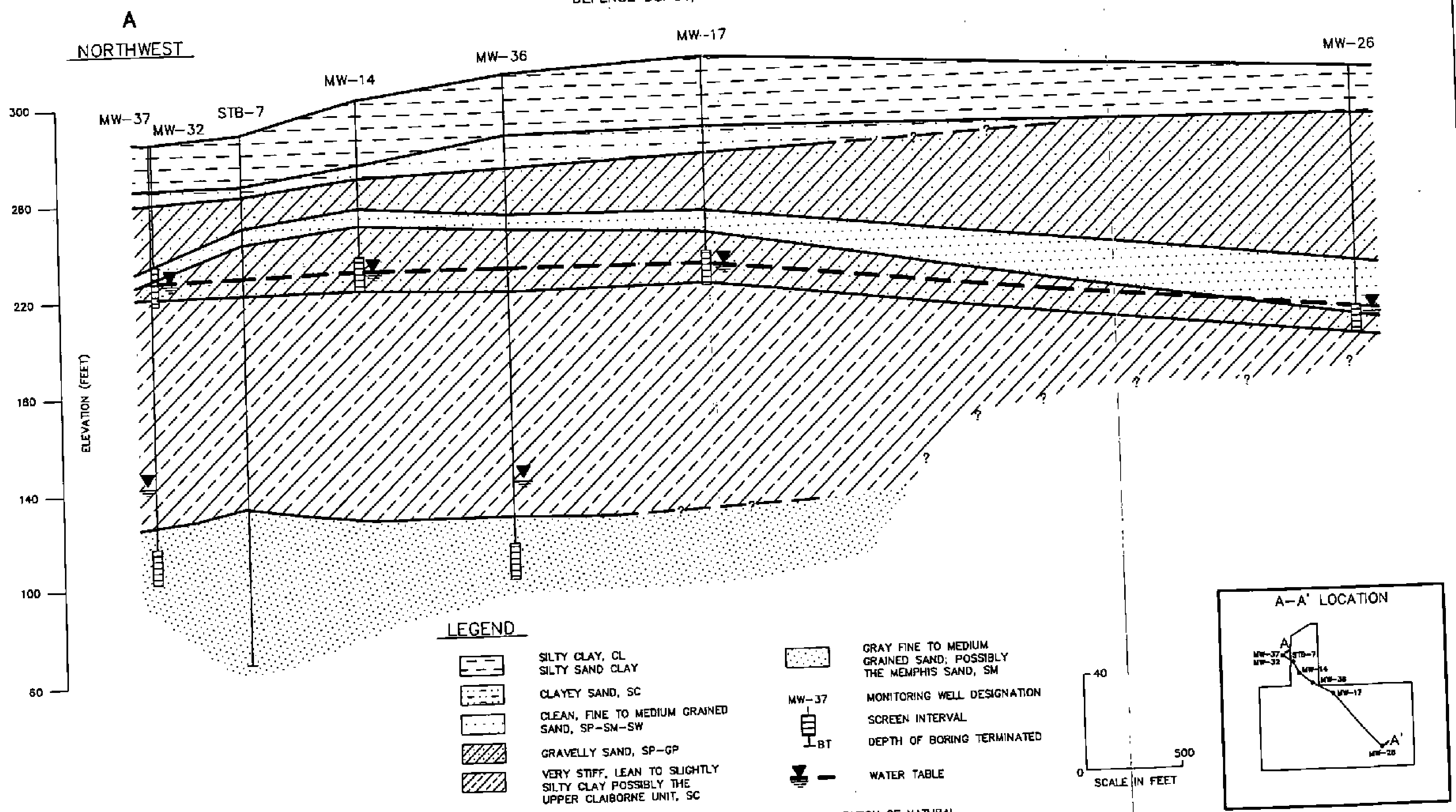
Based on the soil test borings and monitoring wells, five cross-sections have been developed which illustrate the postulated occurrence, attitude and relationships of the geologic units encountered. The cross-sections, Figures 3-4, 3-5, 3-6, 3-7, and 3-8 are generalizations; local variations in subsurface conditions should be expected. Refer to Soil Test Boring Records in Appendix B for descriptions of specific subsurface conditions at individual boring locations. The strata encountered during the drilling portion of this investigation include Loess, Fluvial deposits, Jackson Formation/upper Claiborne Group clays and the Memphis Sands. These geologic units are generally present throughout the Memphis area and are reported to be laterally extensive, although individual formation members may not be correlative over even short distances.

3.1.5.2.1 Loess - The uppermost geologic unit present at or near ground surface in the study area is loess, eolian deposits consisting of brown silty clay, clayey silt and fine sandy clayey silt. The loess was encountered at all drilling locations. This unit is described as a brown to yellowish low plasticity silt (ML) or low plasticity clay (CL). Thin, discontinuous fine grained sand zones may occur locally. The unit was found to range in thickness from six feet at MW-25 to some forty feet at MW-16, MW-17 and MW-20. Five samples were collected from this unit for analysis of their physical properties (Table 3-3). Atterberg Limits analysis

FIGURE 3-4

CROSS-SECTION A-A', NORTHWEST TO SOUTHEAST

DEFENSE DEPOT, MEMPHIS TENNESSEE

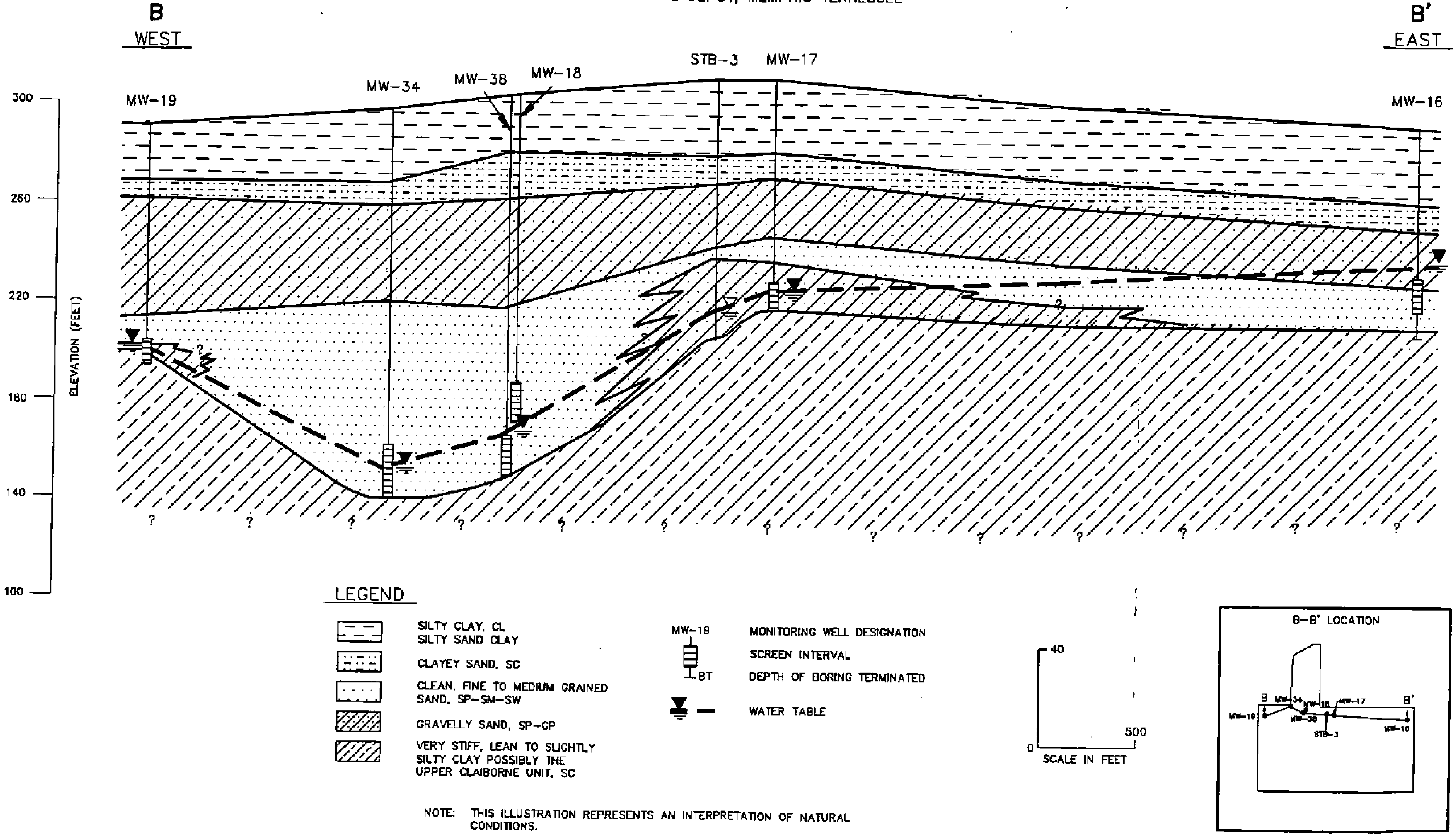


NOTE: THIS ILLUSTRATION REPRESENTS AN INTERPRETATION OF NATURAL CONDITIONS.

FIGURE 3-5

CROSS-SECTION B-B', WEST TO EAST

DEFENSE DEPOT, MEMPHIS TENNESSEE

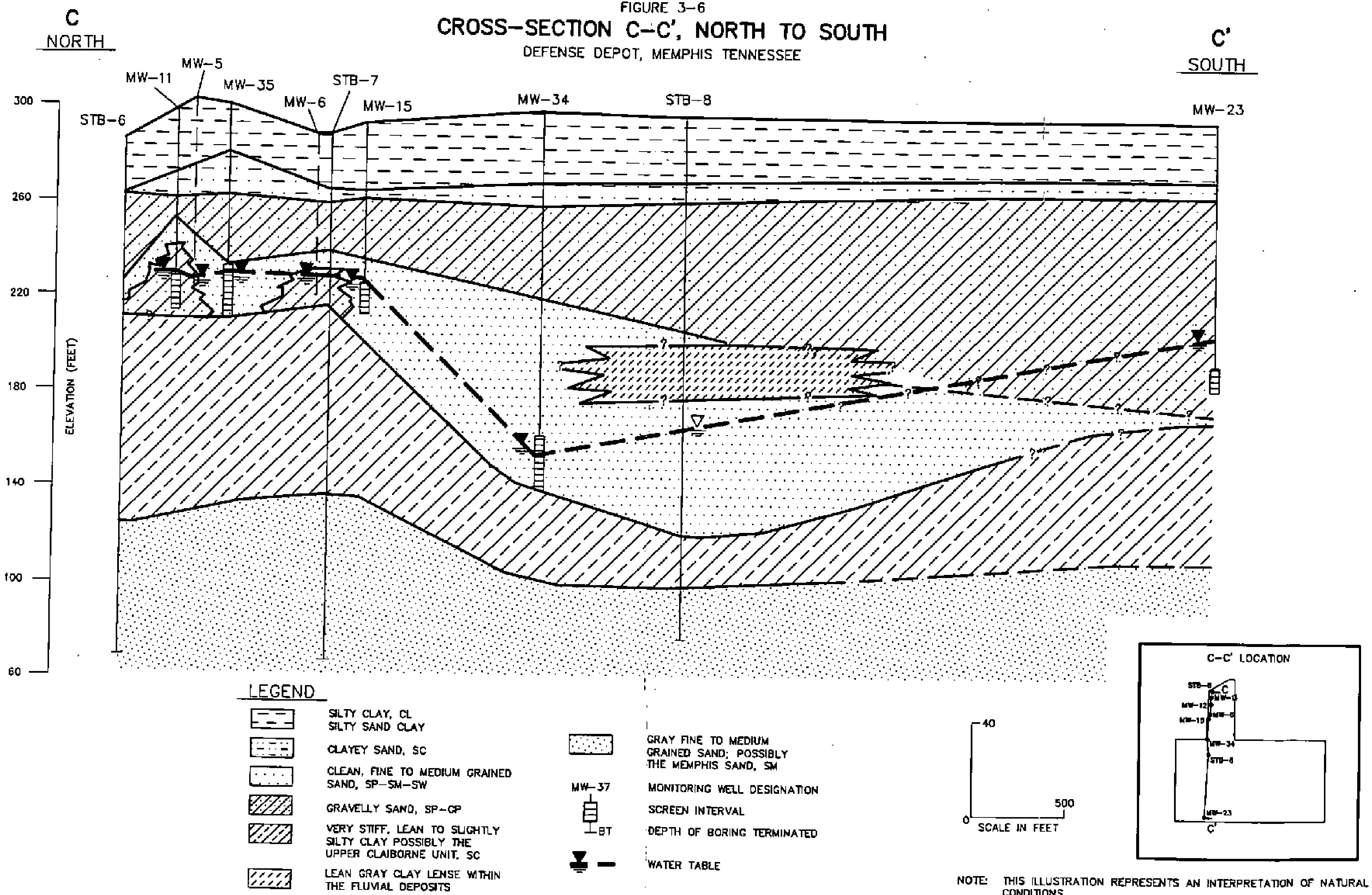


NOTE: THIS ILLUSTRATION REPRESENTS AN INTERPRETATION OF NATURAL CONDITIONS.

FIGURE 3-6

CROSS-SECTION C-C', NORTH TO SOUTH

DEFENSE DEPOT, MEMPHIS TENNESSEE



NOTE: THIS ILLUSTRATION REPRESENTS AN INTERPRETATION OF NATURAL CONDITIONS.

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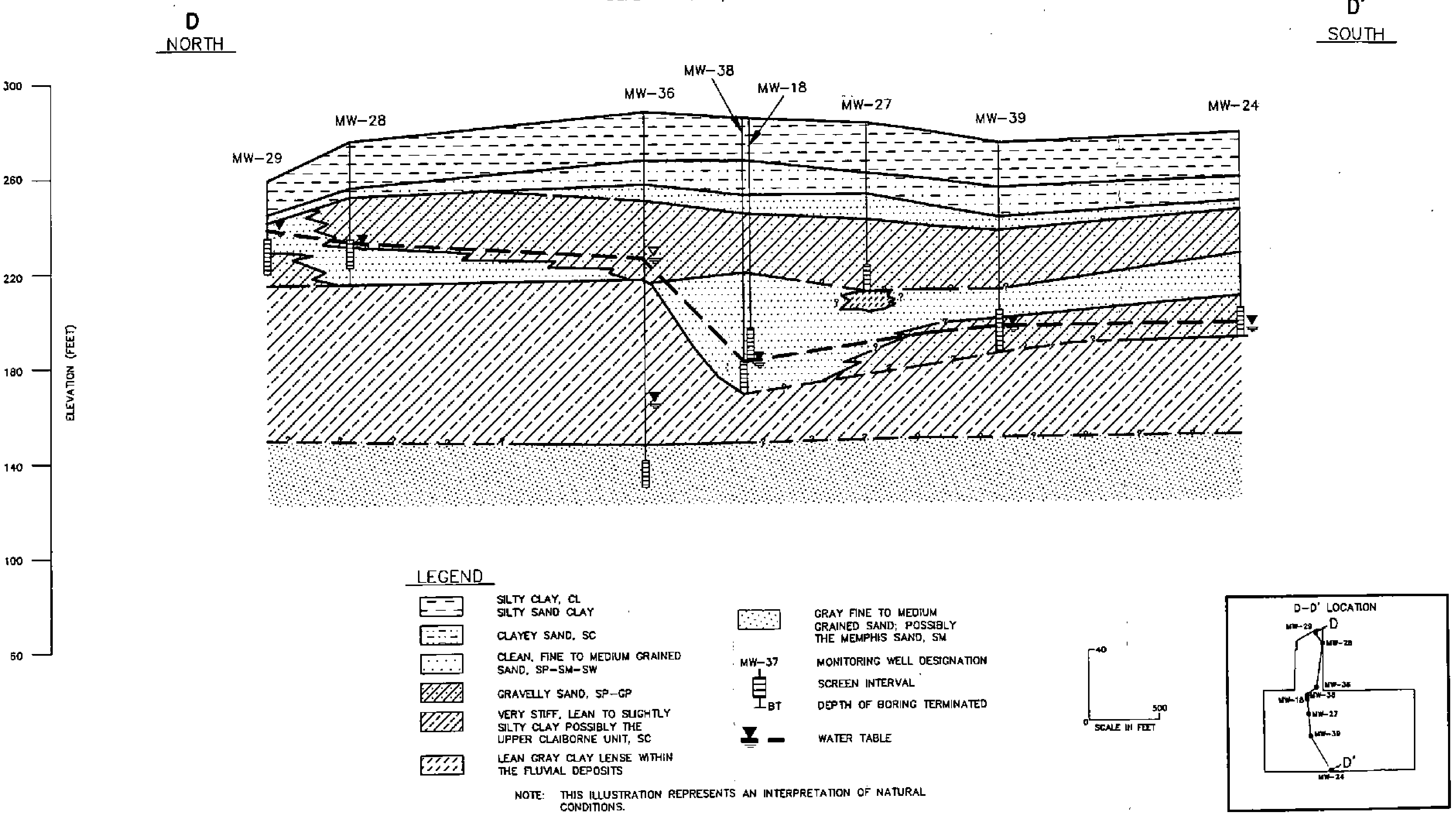
FIGURE 3-7

CROSS-SECTION D-D', NORTH TO SOUTH

DEFENSE DEPOT, MEMPHIS TENNESSEE

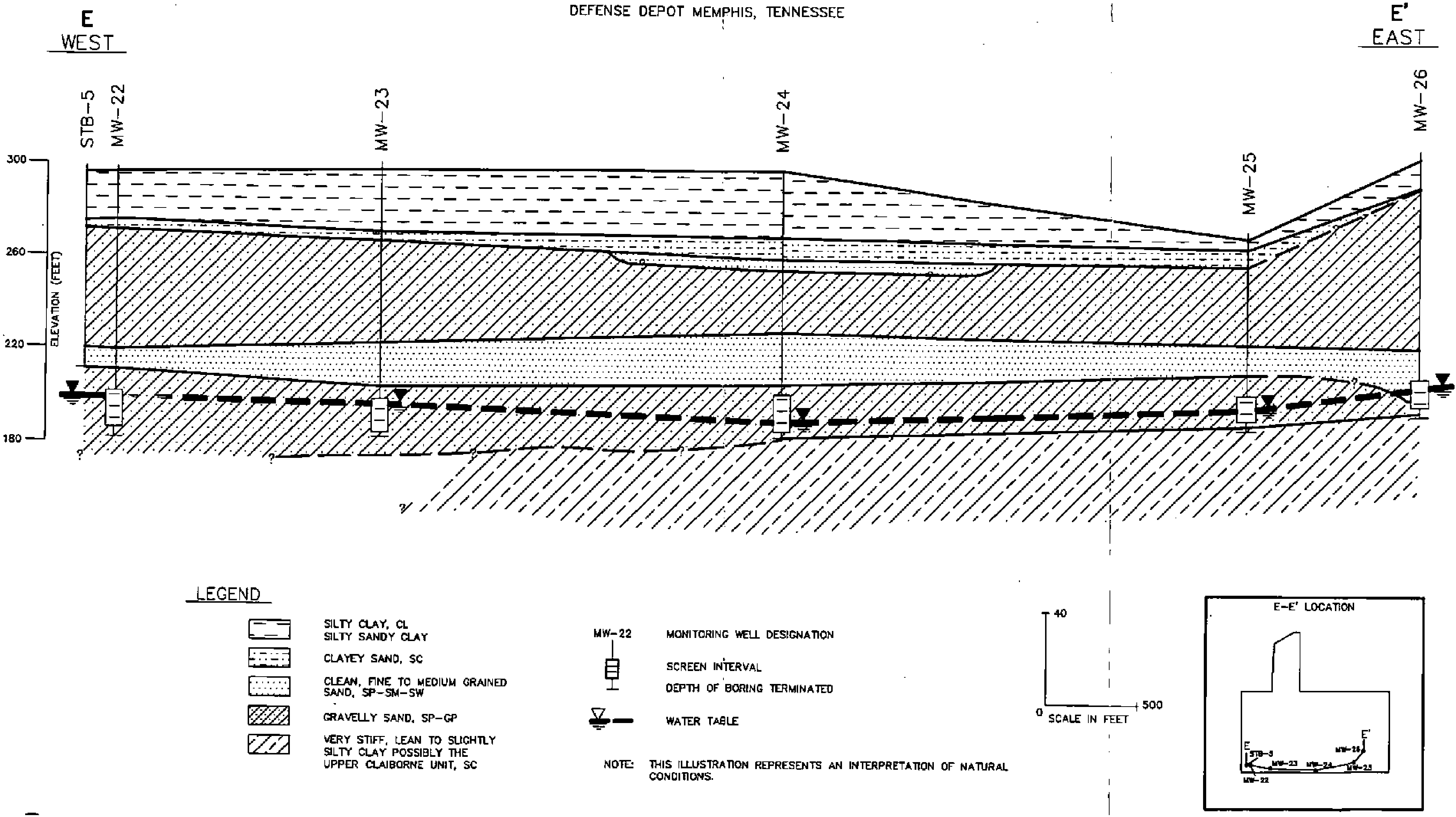


NOTE: THIS ILLUSTRATION REPRESENTS AN INTERPRETATION OF NATURAL CONDITIONS.

FIGURE 3-8

CROSS-SECTION E-E', WEST TO EAST

DEFENSE DEPOT MEMPHIS, TENNESSEE



NOTE: THIS ILLUSTRATION REPRESENTS AN INTERPRETATION OF NATURAL CONDITIONS.

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TABLE 3-3
GEOTECHNICAL LABORATORY TESTING DATA SUMMARY

BORING/WELL NO.	SAMPLE DEPTH, FEET	%PASSING 200 SIEVE	COEFFICIENT OF UNIFORM	LL	PL	PI	MOISTURE CONTENT	UNIFIED SOIL CLASSIFICATION
LOESS:								
MW-12	19.0	98.7	---	38	21	17	24.5	CL
MW-13	15.0	92.6	---	34	19	15	23.7	CL
MW-14	10.0	96.9	---	39	21	18	21.4	CL
MW-26	4.5-6.0	98.5	---	30	22	8	23.1	CL
STB-2	15.0	98.9	---	38	20	18	26.9	CL
FLUVIAL DEPOSITS:								
MW-8	58.5-60.0	4.7	3.0	NP	NP	NP	---	SP-SM
MW-8	63.5-65.0	3.7	3.3	NP	NP	NP	---	SP
MW-9	68.5-70.0	8.1	7.4	NP	NP	NP	---	SW-SM
MW-9	73.5-75.0	3.6	4.0	NP	NP	NP	---	SP
MW-10	63.5-65.0	2.4	2.4	NP	NP	NP	---	SP
MW-10	68.5-70.0	2.8	2.6	NP	NP	NP	---	SP
MW-11	69.0-70.0	3.1	2.3	NP	NP	NP	---	SP
MW-11	73.5-75.0	1.7	2.4	NP	NP	NP	---	SP
MW-12	74.0	1.7	2.3	NP	NP	NP	---	SP
MW-13	80.0	2.1	2.4	NP	NP	NP	---	SP
MW-14	75.0	2.4	10.3	NP	NP	NP	---	SP
MW-15	30.0	31.3	---	41	22	19	18.6	SC
MW-15	60.0	3.0	2.0	NP	NP	NP	---	SP
MW-16	43.5-45.0	10.7	80.8	NP	NP	NP	---	GW-GM
MW-16	63.5-65.0	6.2	3.8	NP	NP	NP	---	SP-SM
MW-17	88.5-90.0	6.8	24.2	NP	NP	NP	---	SP-SM
MW-18	38.4-40.0	30.7	---	40	20	20	16.2	SC
MW-18	138.5-140.0	7.9	2.7	NP	NP	NP	---	SP-SM
MW-19	38.5-40.0	8.7	6.9	NP	NP	NP	---	SW-SM
MW-19	88.5-90.0	7.2	21.9	NP	NP	NP	---	SP-SM
MW-20	43.5-45.0	10.8	9.1	NP	NP	NP	---	SW-SM
MW-20	86.0	12.0	5.4	NP	NP	NP	---	SP-SM
MW-21	33.5-35.0	3.6	2.0	NP	NP	NP	---	SP
MW-21	93.5-95.0	1.3	2.1	NP	NP	NP	---	SP
MW-22	103.5-105.0	2.2	4.5	NP	NP	NP	---	SP
MW-22	108.5-110.0	5.1	7.3	NP	NP	NP	---	SP-SM
MW-23	103.5-105.0	2.5	3.4	NP	NP	NP	---	SP

BORING/WELL NO.	SAMPLE DEPTH, FEET	%PASSING 200 SIEVE	COEFFICIENT OF UNIFORM	LL	PL	PI	MOISTURE CONTENT	UNIFIED SOIL CLASSIFICATION
FLUVIAL DEPOSITS (continued)								
MW-23	108.5-110.0	3.9	2.9	NP	NP	NP	---	SP
MW-24	88.5-90.0	5.2	2.1	NP	NP	NP	---	SP-SM
MW-24	113.5-115.0	3.6	8.0	NP	NP	NP	---	SP
MW-25	7.0	38.5	---	44	20	24	13.2	SC
MW-25	75.0-76.5	2.2	5.0	NP	NP	NP	---	SP
MW-26	105.0-106.5	2.4	4.3	NP	NP	NP	---	SP
MW-27	85.0-86.0	7.5	7.0	NP	NP	NP	---	SW-SM
MW-28	60.0-61.5	0.9	2.3	NP	NP	NP	19.5	SP
MW-29	40.0-41.5	5.1	16.6	NP	NP	NP	15.7	GW-GM
MW-29	55.0-56.5	1.8	2.0	NP	NP	NP	22.3	SP
MW-30	25.0-26.5	11.6	5.1	NP	NP	NP	12.0	SP-SM
MW-30	60.0-61.5	26.6	---	NP	NP	NP	21.8	SM
MW-31	65.0-66.5	0.6	2.2	NP	NP	NP	19.2	SP
MW-31	75.0-76.5	0.7	1.9	NP	NP	NP	21.2	SP
MW-32	35.0-36.5	2.5	2.2	NP	NP	NP	3.2	SP
MW-32	60.0-61.5	13.8	---	NP	NP	NP	15.4	SM
MW-33	50.0-51.5	1.9	2.0	NP	NP	NP	20.8	SP
MW-34	80.0-81.5	42.7	---	27	16	11	17.1	SC
MW-34	156.5-158.0	3.2	2.9	NP	NP	NP	15.4	SP
MW-35	85.5-87.0	1.4	2.7	NP	NP	NP	17.1	SP
MW-38	142.0-143.5	10.4	4.6	NP	NP	NP	21.2	SP-SM
MW-38	152.0-153.5	10.8	3.1	NP	NP	NP	22.5	SP-SM
MW-39	90.0-91.5	14.6	---	NP	NP	NP	16.1	SM
MW-39	110.0-111.5	4.1	9.3	NP	NP	NP	18.8	SP
STB-1	22.5	36.1	---	NP	NP	NP	9.6	SM
STB-1	54.5	1.2	1.9	--	--	--	---	SP
STB-2	44.5	6.0	2.3	NP	NP	NP	---	SP-SM
STB-3	90.0	16.7	---	NP	NP	NP	---	SM
STB-4	43.5-48.5	32.8	---	NP	NP	NP	13.4	SM
STB-4	96.0	1.9	2.9	--	--	--	---	SP
STB-5	78.5-83.5	2.4	2.1	--	--	--	---	SP
STB-5	73.5-78.5	89.2	---	47	20	27	24.9	CL
STB-6	76.5-78.0	90.9	---	57	30	27	29.9	MH
STB-7	66.5-67.0	6.7	2.4	NP	NP	NP	20.5	SP-SM
JACKSON / UPPER CLAIBORNE FORMATION:								
MW-17	93.5-95.0	99.7	---	86	35	51	46.3	CH
MW-27	98.0-99.5	88.0	---	45	18	27	24.0	CL
MW-28	80.0-81.5	93.6	---	50	21	29	26.0	CH
MW-33	60.0-61.5	89.5	---	53	18	35	28.5	CH
MW-35	90.5-92.0	91.7	---	51	21	30	25.5	CH

BORING/WELL NO.	SAMPLE DEPTH, FEET	%PASSING 200 SIEVE	COEFFICIENT OF UNIFORM	LL	PL	PI	MOISTURE CONTENT	UNIFIED SOIL CLASSIFICATION
JACKSON/UPPER CLAIBORNE FORMATION (continued)								
MW-36	110.5-112.0	99.4	---	60	23	37	25.5	CH
MW-37	130.0-131.5	80.9	---	50	20	30	21.1	CH
STB-3	103.5-105.0	89.0	---	50	18	32	23.0	CH
STB-8	136.5-138.0	58.7	---	25	15	10	20.2	CL
MEMPHIS SANDS:								
MW-36	210.0-212.0	14.5	---	NP	NP	NP	27.1	SM
MW-37	170.0-171.5	12.0	3.2	NP	NP	NP	29.4	SP-SM
STB-6	161.5-163.0	14.4	---	NP	NP	NP	18.4	SM
STB-7	185.5-187.0	9.6	4.0	NP	NP	NP	20.1	SP-SM
STB-8	218.5-220.0	18.1	---	NP	NP	NP	21.6	SM

NOTE:		
	LL	Liquid Limit
	PL	Plastic Limit
	PI	Plasticity Limit
	NP	Not Plastic

(liquid limit average = 35 and plasticity index average = 15) and grain size analysis (average 96.8% passing the 200 sieve) indicates a lean clay (CL) classification.

3.1.5.2.2 Fluvial Deposits - Fluvial deposits underlie the loess and were encountered at all drilling locations. The unit is composed of three generalized members which may be traced through the study area:

- Silty clay, silty sandy clay or clayey sand
- Clean, fine to medium grained sand
- Gravelly sand

The upper member is the silty clay, silty sandy clay or clayey sand. It averages approximately five feet in thickness and directly underlies the loess. It thins in the vicinity of Lake Danielson at MW-25 and is not present in MW-26.

Beneath the silty clay, sandy clay/clayey sand are layers of sand and sandy gravel. These layers may alternate, as shown on the cross-sections. A conspicuous pink, white or gray low plasticity clay occurs as a thin discontinuous seam within the gravelly sand sequence. This seam thickens near STB-8, where 35 feet of clay was encountered. MW-27 probably terminated at the top of this clay seam prior to reaching the saturated zone of the aquifer.

The sand layers range from clean to dirty, fine to coarse grained, very well sorted to poorly sorted quartz grains. The upper sand layers are generally a bright orange in color indicating an oxidizing environment. The lower layers are very clean and tan to white in color. The sand layers show a coarsening downwards into a gravelly sand with chert being the primary gravel constituent. Gravel size ranges from small pebble size up to four inches in diameter. The coarsening downward sequences and the lateral facies changes over short distances are indicative of fluvial deposition (Selly, 1986). The Fluvial deposits range in thickness from approximately forty feet at MW-29 to 131 feet at MW-38.

Most of the samples collected for analysis of their physical properties (Table 3-3) were taken from within the Fluvial deposits. The analysis confirmed the primary field classification as poorly sorted sands and gravels (SP).

3.1.5.2.3 Jackson Formation/Upper Claiborne Group - Clayey soils which have been interpreted as the Jackson Formation/upper Claiborne Group was penetrated in STB-6, STB-7, STB-8, MW-36 and MW-37. Ten samples were collected from this unit for physical properties analysis (Table 3-3). Field observations and testing results indicate that this unit is a stiff gray and/or orange, plastic, lean to fat lignitic clay. This member underlies the Fluvial deposits and is a regionally significant confining unit. The maximum thickness of the confining unit was found to be 92 feet in MW-36. This unit appears to be laterally persistent and fairly uniform in thickness throughout most of northern Dunn Field. Starting in the southern portion of Dunn Field and continuing on the northern portion of the main installation, post Eocene erosion of the upper surface of the Jackson/upper Claiborne has resulted in a deep channel-like feature. A channel was indicated by increased depths to the top of the clay unit encountered during drilling operations. A minimum thickness for the clay unit was determined to be 15 feet in STB-8.

3.1.5.2.4 Memphis Sand - The upper portion of the Memphis Sand Formation was encountered during the installation of monitoring wells MW-36 and MW-37 and soil test borings STB-6, STB-7 and STB-8. Five samples were collected from this formation for physical properties analysis (Table 3-3). Results indicate this formation is composed of gray, very fine grained, silty sand.

3.1.6 Hydrogeology

3.1.6.1 Regional Hydrogeology - Information describing groundwater conditions and resources of Shelby County has been obtained from Wells (1933); Moore (1965); Terry et al. (1979) and Graham and Parks (1986). Fluvial aquifer quality information was derived from McMaster and Parks' 1988 report.

3.1.6.1.1 Hydrogeologic Setting - The region's hydrogeologic setting consists of a series of thick, generally unconsolidated sedimentary units deposited in a broad trough or syncline (Mississippi embayment). The trough's greatest depth is defined by its axis. Large-scale sedimentary units deposited within this structural feature tend to thicken from east to west where they reach their greatest accumulation at the axis, and tilt gently southward, following the trough's orientation.

Individual sedimentary sequences have been deposited in the trough, roughly following its physical orientation. The most permeable of these units are identified as aquifers and the least permeable are termed confining units.

3.1.6.1.2 Principal Aquifers - The Memphis area is located within a region where several aquifers of local and regional importance exist. These aquifers are identified in descending order by their geologic names:

- Alluvium
- Fluvial (Terrace) deposits
- Memphis ("500-foot") Sand
- Fort Pillow ("1400-foot") Sand

These aquifers correspond to the geologic units described in subsection 3.1.5 (Geology). The Alluvial aquifer's distribution is limited to the channels of primary streams; therefore, it does not occur at DDMT. The Fluvial deposits, Memphis Sand and Fort Pillow Sand underlie the installation and are discussed in following subsections.

3.1.6.2 Site Hydrogeology - Site specific hydrogeologic conditions were investigated by physical inspection, test borings, groundwater quality monitoring well installation and direct measurement of in-situ hydraulic properties. Individual test and exploration records are contained in the Appendices. The following discussion summarizes the information which is of particular interest to this investigation.

3.1.6.2.1 Loess - The uppermost hydrogeologic unit encountered at DDMT is the loess. While not usually a water-bearing unit, these materials are of interest to this investigation as they tend to limit precipitation infiltration (recharge) to significant underlying aquifers where the loess remains intact and undisturbed. Sandy zones occurring within the loess may become seasonal "perched" water-bearing zones which contain water for short periods of time following rainfall events. Usually, the perched water-bearing zones discharge their ground water to adjacent units in hydraulic communication with them. One USAEHA monitoring well (MW-2) was screened in one of these perched zones. During the installation of several monitoring wells in northern Dunn Field, perched water tables were encountered. The perched zone consisted of a fine sandy layer enclosed within the loess, approximately twenty feet below ground surface.

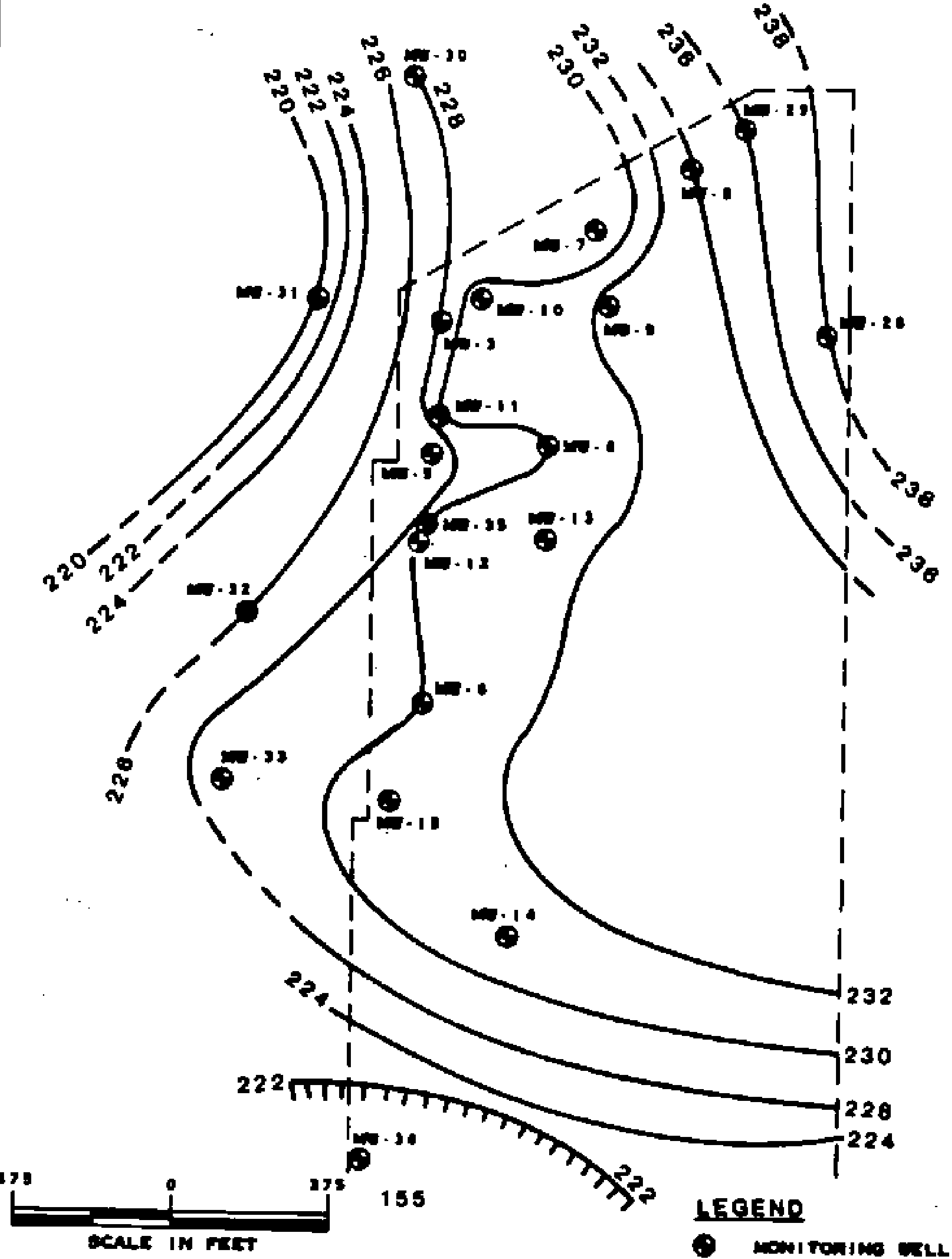
3.1.6.2.2 Fluvial (Terrace) Deposits - Fluvial (Terrace) deposits underlie the loess within the study area. The Fluvial deposits form the site's water table aquifer. It consists of clayey sand, sand, and gravelly sand strata, ranging in thickness 40 feet to 131 feet at DDMT. Recharge to this unit is primarily from the infiltration of rainfall (Graham and Parks, 1986). Discharge from the unit is probably directed toward underlying units in hydraulic communication with the Fluvial deposits.

According to the water levels measured in the monitoring wells, only the base of the unit is saturated. The actual saturated thickness varies from 5.7 feet at monitoring well MW-24 to twenty-three feet at MW-28. The upper surface of the unit's saturated thickness ranges from an elevation of 243 feet, NGVD at MW-16 to a low of 155 feet, NGVD at MW-34. Published seasonal water levels indicates that the ground-water levels fluctuate several feet. However, during Phase I and Phase II of the RI no significant fluctuations were seen in the water levels measured at DDMT.

The study area's water level data was utilized to prepare a water table surface map of the Fluvial deposits underlying DDMT (Figures 3-9 and 3-10). These figures represent an interpolation of the water level information obtained from widely-spaced monitoring wells and is an interpretation of natural conditions on the date of measurement. The figure suggests that two general flow directions exist within the Fluvial deposits at DDMT. In the Dunn Field area, a westerly direction of flow is apparent in the installation's shallow aquifer (Figure 3-9). An average particle velocity of 0.8 ft./day was calculated from information collected from wells in Dunn Field by using the equations of Lohman (1972). A 26% effective porosity was estimated for the Fluvial deposits and an average hydraulic conductivity of 7.6×10^{-3} ft/min was used in the calculations.

At the main installation, a different flow regime is suggested by the water level data (Figure 3-10). The closure of water level contours about MW-34 and STB-8 suggests that ground-water flow in this area is directed toward what may be a "sink" or a buried stream channel. Flow from the "sink" may be directed down, to underlying units in hydraulic communication with the Fluvial deposits. A general west to southwest ground-water flow direction is indicated for the rest of the main installation. However, flow directions may vary over short to moderate distances (several hundred feet). This is due to the probable controlling effect of the upper surface of the confining unit on flow directions within the fluvial aquifer.

FIGURE 3-9
WATER TABLE SURFACE OF FLUVIAL DEPOSITS AT DUNN FIELD JANUARY, 1990
DEFENSE DEPOT, MEMPHIS TENNESSEE



155

LEGEND

⊕ MONITORING WELL LOCATION

——— ISOPLETHS OF EQUAL ELEVATIONS

– – – INFERRED ELEVATIONS

NOTE: THIS ILLUSTRATION REPRESENTS AN INTERPRETATION OF NATURAL CONDITIONS ON THE DATE OF MEASUREMENT.

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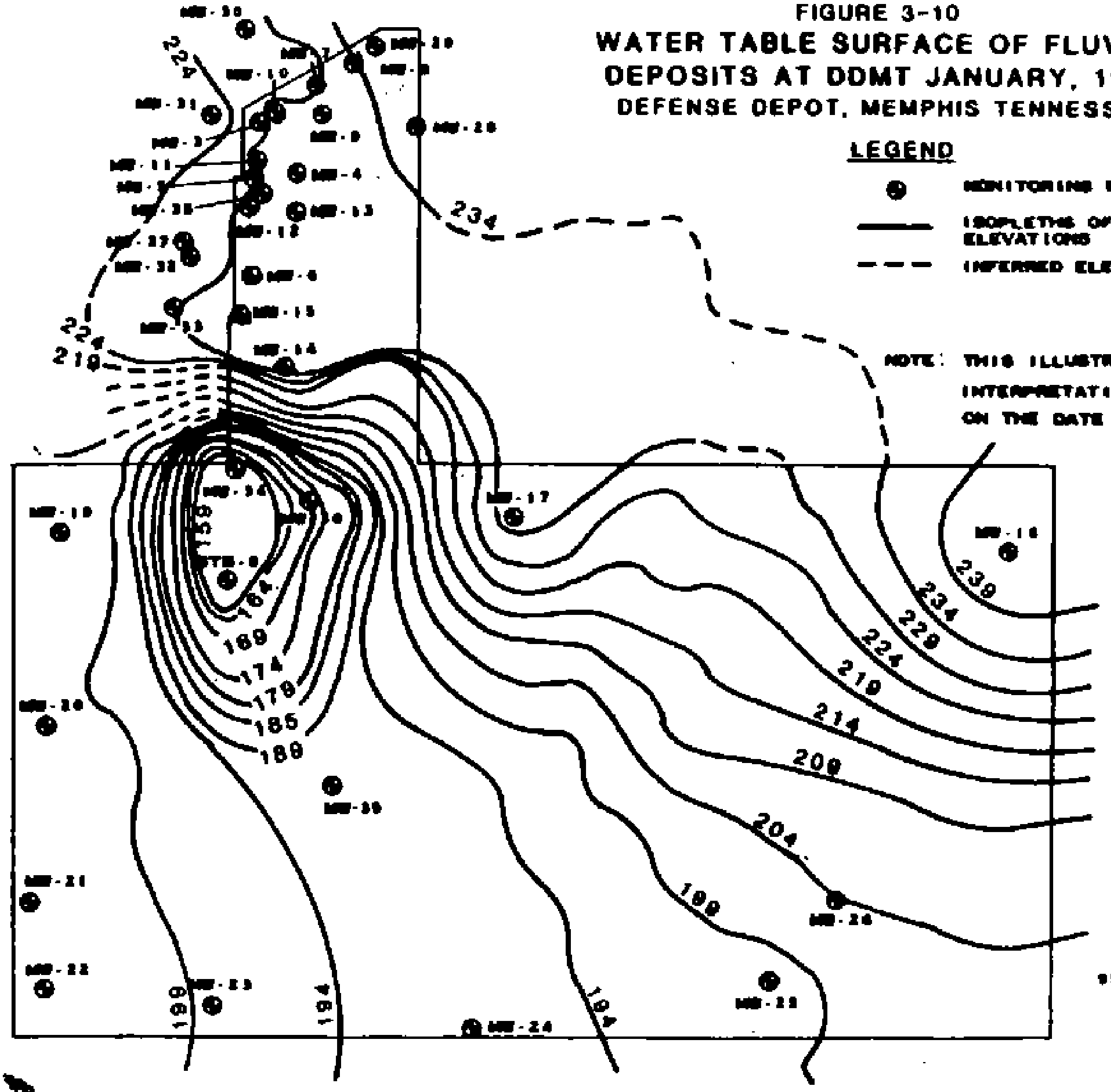
FIGURE 3-10

WATER TABLE SURFACE OF FLUVIAL DEPOSITS AT DDMT JANUARY, 1990
DEFENSE DEPOT, MEMPHIS TENNESSEE



LEGEND

⊕ MONITORING WELL LOCATION

—— ISOPLETHS OF EQUAL ELEVATIONS

– – – INFERRED ELEVATIONS

NOTE: THIS ILLUSTRATION REPRESENTS AN INTERPRETATION OF NATURAL CONDITIONS ON THE DATE OF MEASUREMENT.

950 0 950

SCALE IN FEET

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Site ground water and surface water levels from Cane Creek and Nonconnah Creek were compared in order to evaluate the possibility of ground-water discharge to surface waters at or near DDMT. Based upon the hydrogeologic section (Figure 3-11), it was concluded that the Fluvial deposits do not contribute to local stream base flow in the vicinity of DDMT. It is important to note that this diagram has been constructed by combining all the facies into one strata to diagrammatically represent the Fluvial deposits.

In order to better interpret subsurface conditions, a geologic map of the Fluvial deposits' saturated zone at DDMT was prepared (Figure 3-12). The interpretation shown on this figure supports the presence of a paleo-stream channel in the study area. This is a feature known to be consistent with conditions existing in the region (Wells, 1933; Moore et al., 1965). This figure shows a contouring of in situ permeability values in comparison with a soil classification of the saturated thickness. The figure suggests correlation exists between conductivity test data and the basal unit's sedimentary characteristics.

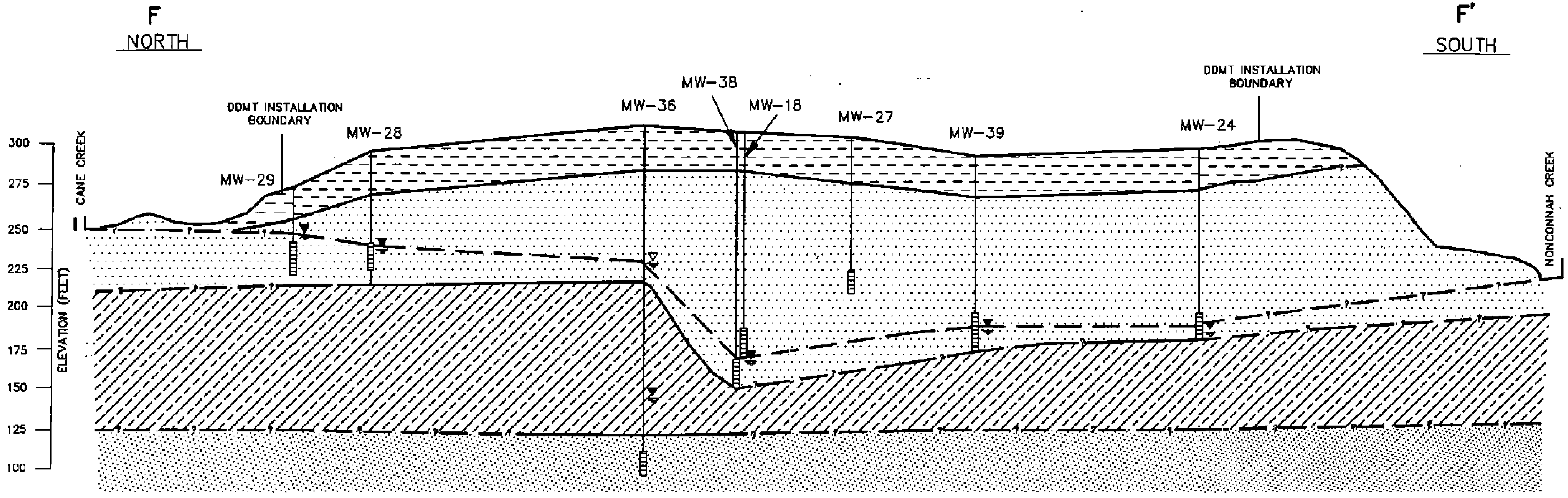
3.1.6.2.3 Jackson Formation/Upper Claiborne Group - The Jackson Formation/upper Claiborne Group was encountered at over half of the monitoring well/soil boring installation locations. The unit is represented in the study area by a distinct gray or orange clay. The unit is significant because it is a regionally important confining bed separating shallow water bearing zones from underlying major aquifers (Nyman, 1965).

The top of the Jackson Formation/upper Claiborne Group at DDMT was contoured in order to interpret the influence this unit has on ground-water flow directions (Figure 3-13). Where encountered, the elevation of the confining unit's upper surface ranges from 223 feet, NGVD at monitoring well MW-14 to 118 feet, NGVD at STB-8. In addition, the elevation of the Jackson/upper Claiborne surface encountered at the Allen Well Field was compared to those

FIGURE 3-11

HYDROGEOLOGIC CROSS-SECTION F-F' NORTH TO SOUTH

DEFENSE DEPOT, MEMPHIS TENNESSEE



LEGEND

▭ LOESS DEPOSITS CL, SC

▭ FLUVIAL DEPOSITS SC-SP-SM SW-GP

▨ JACKSON\UPPER CLAIBORNE FORMATION CH, CL

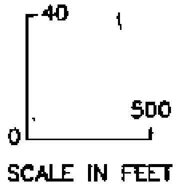
░ MEMPHIS SAND FORMATION SM, SP

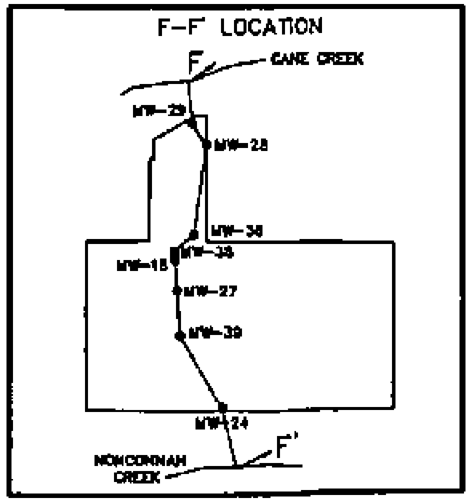
MW-37 MONITORING WELL DESIGNATION

SCREEN INTERVAL

BT DEPTH OF BORING TERMINATED

WATER TABLE





NOTE: THIS ILLUSTRATION REPRESENTS AN INTERPRETATION OF NATURAL CONDITIONS.

FIGURE 3-12
GEOLOGIC MAP OF FLUVIAL DEPOSITS SATURATED THICKNESS WITH UNIT HYDRAULIC CONDUCTIVITIES
DEFENSE DEPOT, MEMPHIS TENNESSEE

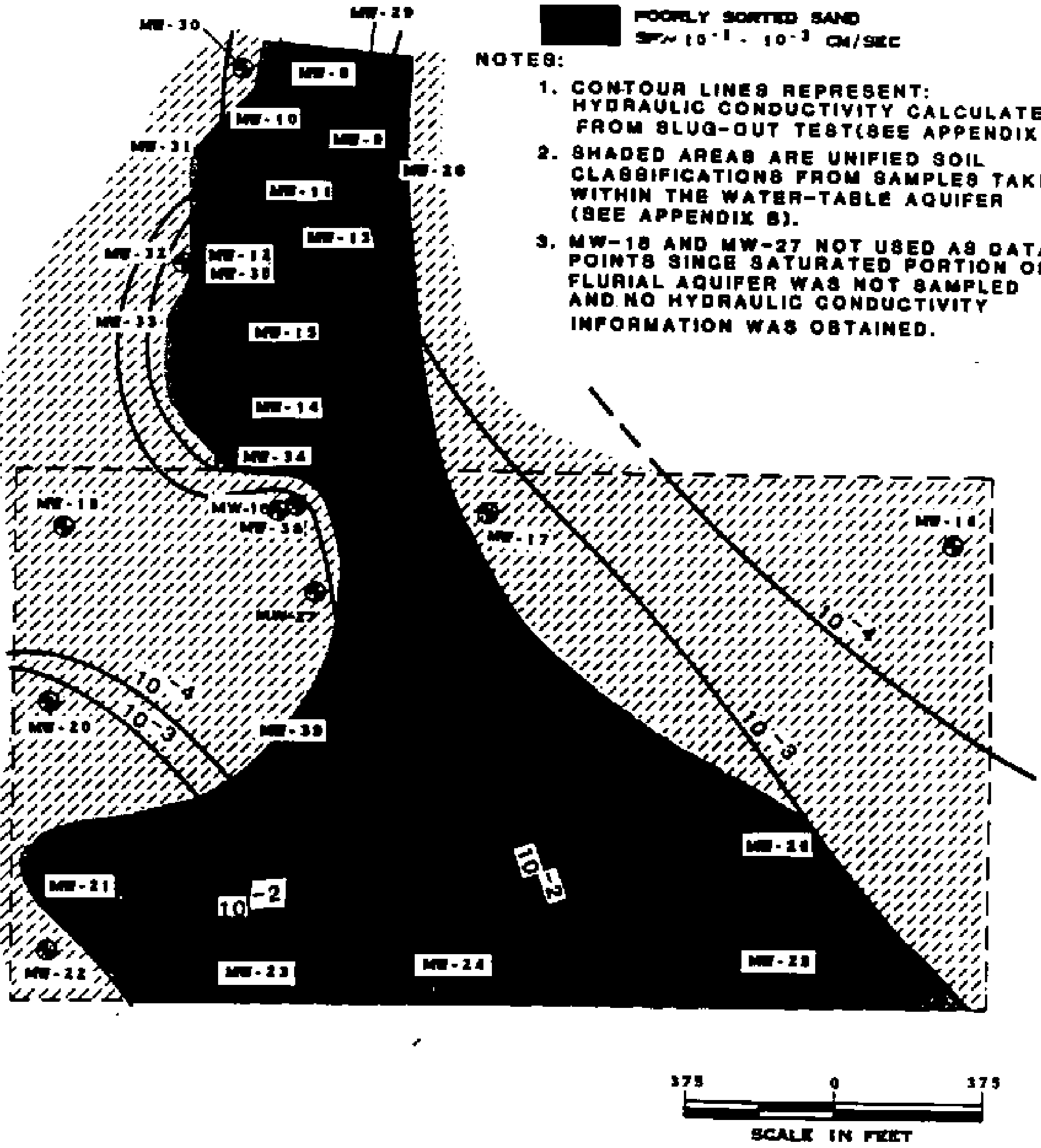
LEGEND

▨ POORLY SORTED SAND WITH SILT & GRAVEL SP-SM:~10^{-3} - 10^{-5} CM/SEC

■ POORLY SORTED SAND SP~10^{-1} - 10^{-3} CM/SEC

NOTES:

1. CONTOUR LINES REPRESENT: HYDRAULIC CONDUCTIVITY CALCULATED FROM SLUG-OUT TEST(SEE APPENDIX E
2. SHADED AREAS ARE UNIFIED SOIL CLASSIFICATIONS FROM SAMPLES TAKEN WITHIN THE WATER-TABLE AQUIFER (SEE APPENDIX 6).
3. MW-18 AND MW-27 NOT USED AS DATA POINTS SINCE SATURATED PORTION OF FLURIAL AQUIFER WAS NOT SAMPLED AND NO HYDRAULIC CONDUCTIVITY INFORMATION WAS OBTAINED.



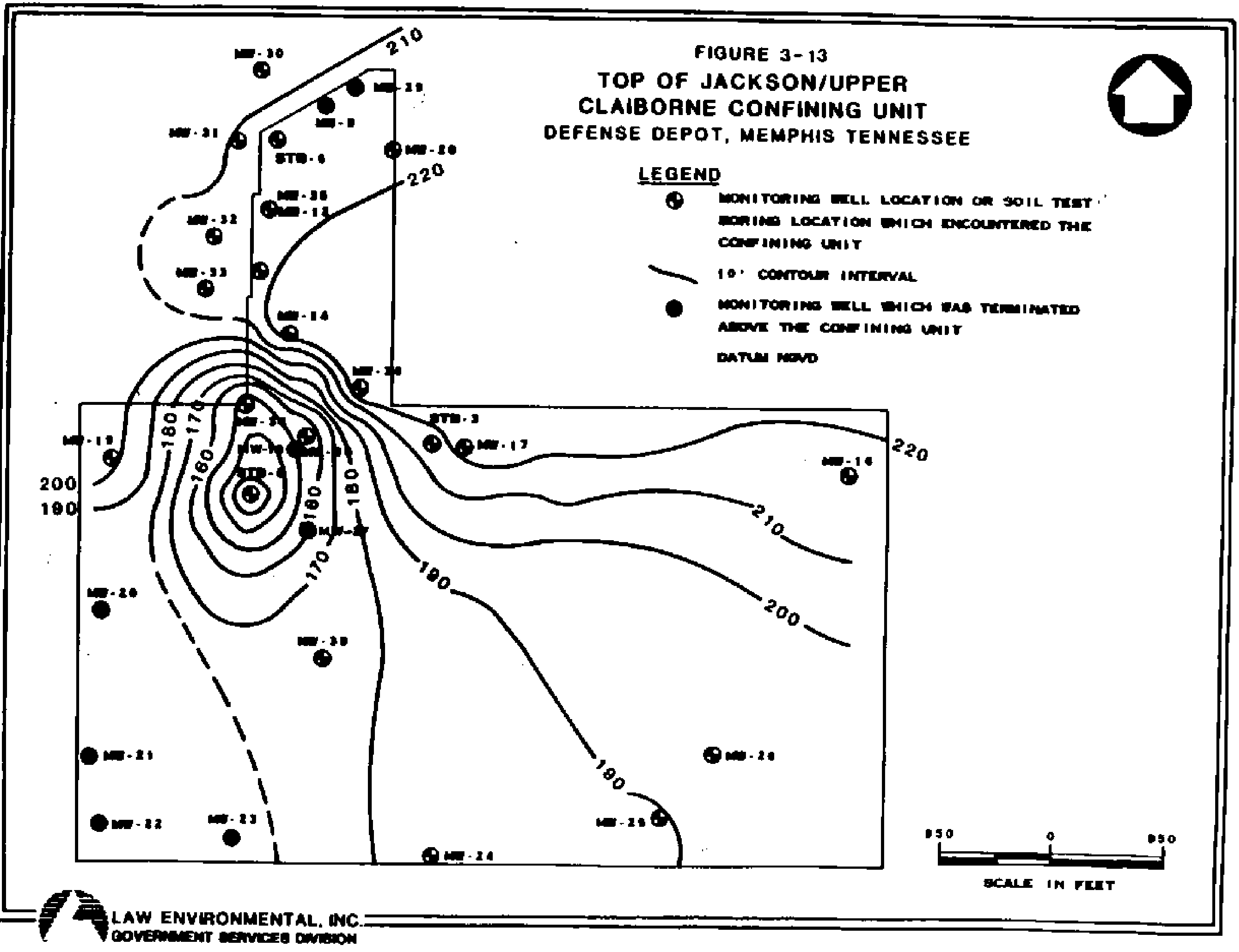


FIGURE 3-13

TOP OF JACKSON/UPPER CLAIBORNE CONFINING UNIT

DEFENSE DEPOT, MEMPHIS TENNESSEE

LEGEND

⊕ MONITORING WELL LOCATION OR SOIL TEST BORING LOCATION WHICH ENCOUNTERED THE CONFINING UNIT

10' CONTOUR INTERVAL

● MONITORING WELL WHICH WAS TERMINATED ABOVE THE CONFINING UNIT

DATUM NGVD

encountered at DDMT. The comparison of elevations is presented in Figure 3-14. The elevation of the Jackson/upper Claiborne's upper surface within the Allen Well Field varies from 182 feet, NGVD at well number 133 to a low of 150 feet, NGVD at well number 138. This comparison indicates that the variation in the top of the confining unit is not atypical for the area. The highly variable nature of this surface is interpreted to be due to post Eocene erosion.

As shown on the study areas' cross-sections (Figures 3-4 through 3-8), the strata in the vicinity of MW-34, MW-38 and STB-8 does not conform to the more pervasive flat-lying conditions. The extreme depth at which the confining unit was encountered at these three locations and the reduced thickness of the unit in STB-8 suggests that the confining unit has been significantly eroded in this area. The continuity and actual thickness of the confining unit in areas not investigated by drilling can only be estimated.

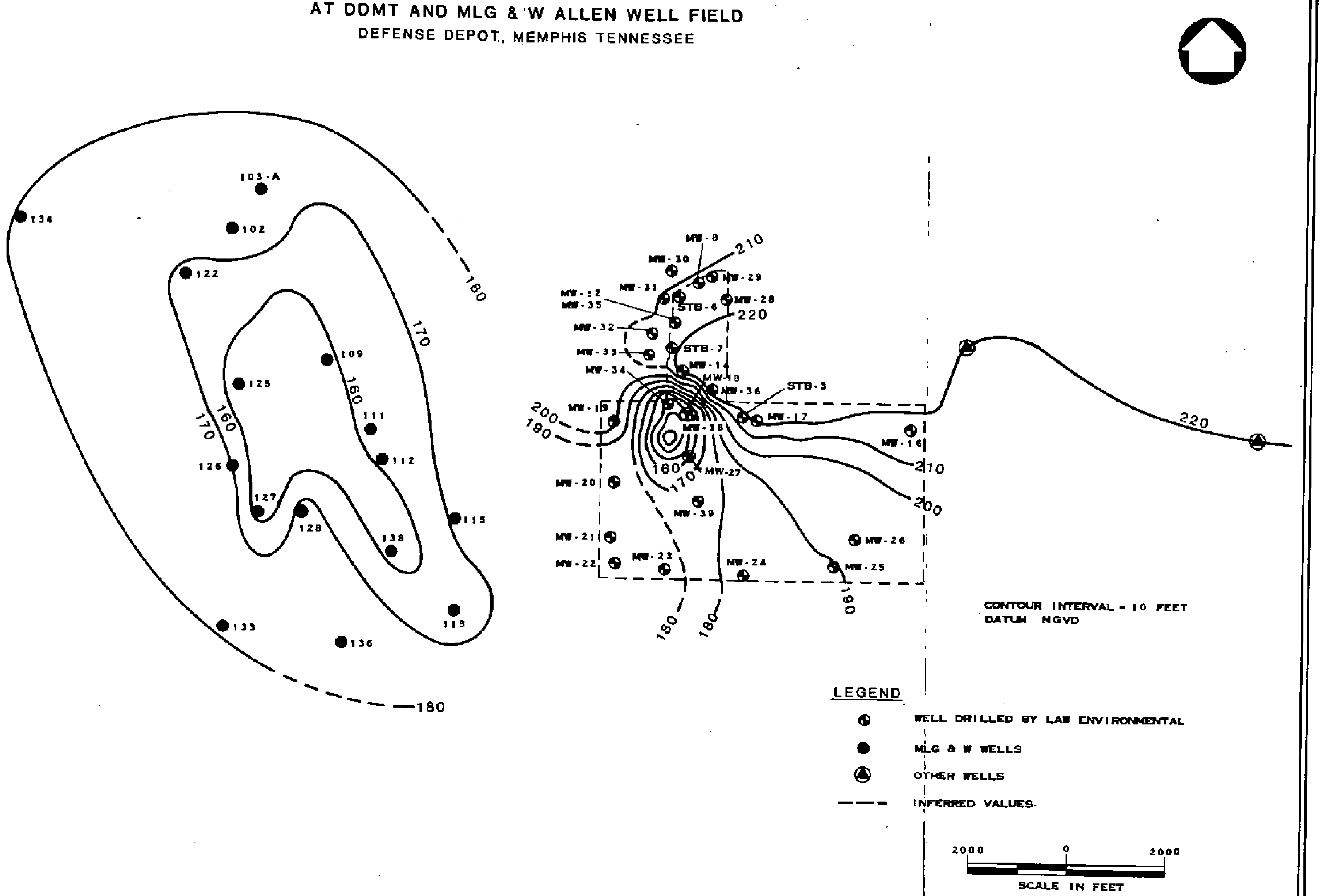
The confining unit was found to be present at every drilling location. However, the thickness and depth of this unit were found to be inconsistent over short distances. Graham and Parks (1986) present several lines of evidence to suggest that the Jackson Formation/upper Claiborne Group is not laterally continuous throughout the Memphis area. In some areas, the Memphis Sand is directly overlain by the Alluvial or Fluvial deposits, permitting the downward vertical leakage from shallow water bearing zones into the regional aquifer. Bell and Nyman (1968, in Graham and Parks, 1986) estimated the quantity of this downward leakage to be on the order of two million gallons per day.

Leakage through the Jackson Formation/upper Claiborne is likely even where it is continuous, due to the significant positive head difference between the two aquifers. The presence of more permeable fine sand and lignitic lens within the confining unit will also increase the rate at which leakage occurs.

FIGURE 3-14

TOP OF JACKSON/UPPER CLAIBORNE CONFINING UNIT AT DDMT AND MLG & W ALLEN WELL FIELD

DEFENSE DEPOT, MEMPHIS TENNESSEE



An estimate of ground-water seepage through the confining unit at Dunn Field has been done. In that area, the borings indicated the confining unit to be relatively thick and to consist of a uniform clay. Permeability of the specific site soils was not determined; therefore, a range of typical values for clayey soils has been assumed. The average interstitial seepage velocity may be estimated by using the equation $V = \frac{K\,h/l}{n^*}$ (Lohman et al., 1972), where:

V = average interstitial velocity
K = average estimated coefficient of permeability; the assumed range is 3×10^{-3} to 3×10^{-5} ft/day ($1\text{x}10^{-6}$ to $1\text{x}10^{-8}$ cm/sec) for tight, plastic clays (from Cedergren, 1989, pp. 31 and 32)
h = difference in hydraulic head between two aquifers(82.7 ft); this information was obtained for the Fluvial aquifer at MW-32 (226.02 NGVD) and the Memphis Sand Aquifer at MW-37 (143.36 NGVD)
l = thickness of the confining unit (75 Ft at MW-37)
h/ l = hydraulic gradient (dimensionless)
n^* = estimated effective porosity (dimensionless), assumed as 0.40 for clays

The calculated range of downward seepage velocities is 8.3×10^{-3} to 8.3×10^{-5} feet per day. This approach indicates that the confining unit in the Dunn Field area would be penetrated by water flow in a time frame from 25 to 2500 years. However, in areas where the confining unit has thinned or where sand or silt beds exist within the clay unit the rate of penetration could be much faster.

3.1.6.2.4 <u>Memphis Sand ("500-foot sand")</u> - The Memphis Sand represents the region's most important source of water resources. This unit was investigated by drilling three deep soil borings and the installation of MW-36 and MW-37 and from published sources.

The Memphis Sand aquifer is reported to underlie all of the Memphis region. At DDMT, the top of this aquifer is approximately 125 to 150 feet, NGVD. The base of the unit is on the order of -750 feet, NGVD, based on interpolation of Moore's (1965) work. The Memphis Sand aquifer contains ground water under strong artesian (confined) conditions. Locally, extensive pumping has lowered water levels considerably. The potentiometric level at MW-36 and MW-37 ranges from 143 to 146 feet, NGVD. Flow in the unit is directed generally westward, toward the Allen Well Field, a major local pumping zone.

The Memphis Sand aquifer is reported to derive most of its recharge from areas where it crops out. The outcrop area forms a wide northeast trending belt several miles east of DDMT. The outcrop belt extends from the east Shelby, Fayette and Hardemen Counties area northeast across much of west Tennessee.

3.1.6.2.5 Fort Pillow Sand - The Fort Pillow Sand (also called the "1400-foot sand") underlies DDMT and the Memphis region at great depth, on the order of 1,400 feet. It is reported to average some two hundred feet thick in the study area. The unit contains ground water under strong artesian (confined) conditions. It derives most of its recharge from its area of outcrop, well east of the study area, and from hydrogeologic units in hydraulic communication with it. The Fort Pillow Sand potentiometric level in the DDMT area was interpolated to be on the order of 180 feet, NGVD in the fall of 1985 (reported in Graham and Parks, 1986).

3.1.6.3 Ground Water Pumpage and Use - The Fluvial deposits provide water to many domestic and farm wells in rural areas of the Gulf Coastal Plain, but none are located within the immediate vicinity of DDMT. The Fluvial deposits have a limited saturated thickness and ground-water levels are subject to fluctuations. Therefore, this unit is not typically a dependable source of water.

The Memphis Sand aquifer currently provides about 95 percent of the water used for municipal and industrial water supplies in the Memphis area. It was first used as a source of water at Memphis in 1886; since then withdrawals have increased in proportion to industrial and population growth. In 1984, municipal and industrial pumpage from the Memphis Sand aquifer in the Memphis area averaged about 180 Mgal/d. The remaining five percent of the water used for municipal and industrial supplies comes from the Fort Pillow Sand (10 Mgal/d in 1984) (Graham and Parks, 1986).

3.2 SUMMARY OF PHYSICAL CHARACTERIZATION INFORMATION

Information compiled and evaluated for this study suggests the following:

- The Dunn Field area is essentially undeveloped. It has slight to moderate relief. The main installation has been extensively developed and is essentially level.

- The study area experiences approximately fifty inches of annual precipitation. Net precipitation was calculated to be some nine inches annually, a value suggesting the potential for generation of leachate and migration of waste-related contamination.

- Few surface water drainage controls are present in Dunn Field. The main installation has an extensive storm water drainage system. Lake Danielson and the golf course pond receive installation surface drainage.

- It is unlikely that DDMT will experience flooding.

- Site surficial soils (loess) are predominantly fine-grained, low permeability materials which promote rapid runoff and limit percolation where they remain intact and undisturbed.

- The study area's shallow aquifer is composed of the Fluvial deposits of which only the lower extent is saturated. The unit's water levels are some thirty-seven to one hundred forty five feet below grade. The unit obtains recharge from precipitation infiltration. A channel or "sink" exists in the Fluvial deposits beneath the main installation.

- The Fluvial deposits are underlain by the Jackson Formation/upper Claiborne Group, a documented confining unit in the study area. The top of this unit may exert an influence over flow directions in the overlying Fluvial deposits. The unit appears to be persistent in the Dunn Field area where the highest concentration of contaminants were found. It both deepens and thins in other areas beneath DDMT. The unit is reported to be thin or completely absent in areas around Memphis, permitting hydraulic communication between shallow and regional aquifers, locally.

- The Memphis Sand aquifer is a regionally significant source of potable water supplies in the Memphis area. This hydrogeologic unit underlies DDMT at a depth of approximately 180 feet and receives most of its recharge from the outcrop area, several miles east of Memphis. Some recharge is derived from overlying or hydraulically communicating units.

- The Fort Pillow Sand aquifer, a second regionally significant aquifer, underlies DDMT at very great depth. It derives most of its recharge from the area of outcrop, several miles east of Memphis.

4.0 NATURE AND EXTENT OF CONTAMINATION

4.1 POTENTIAL CONTAMINATION SOURCES

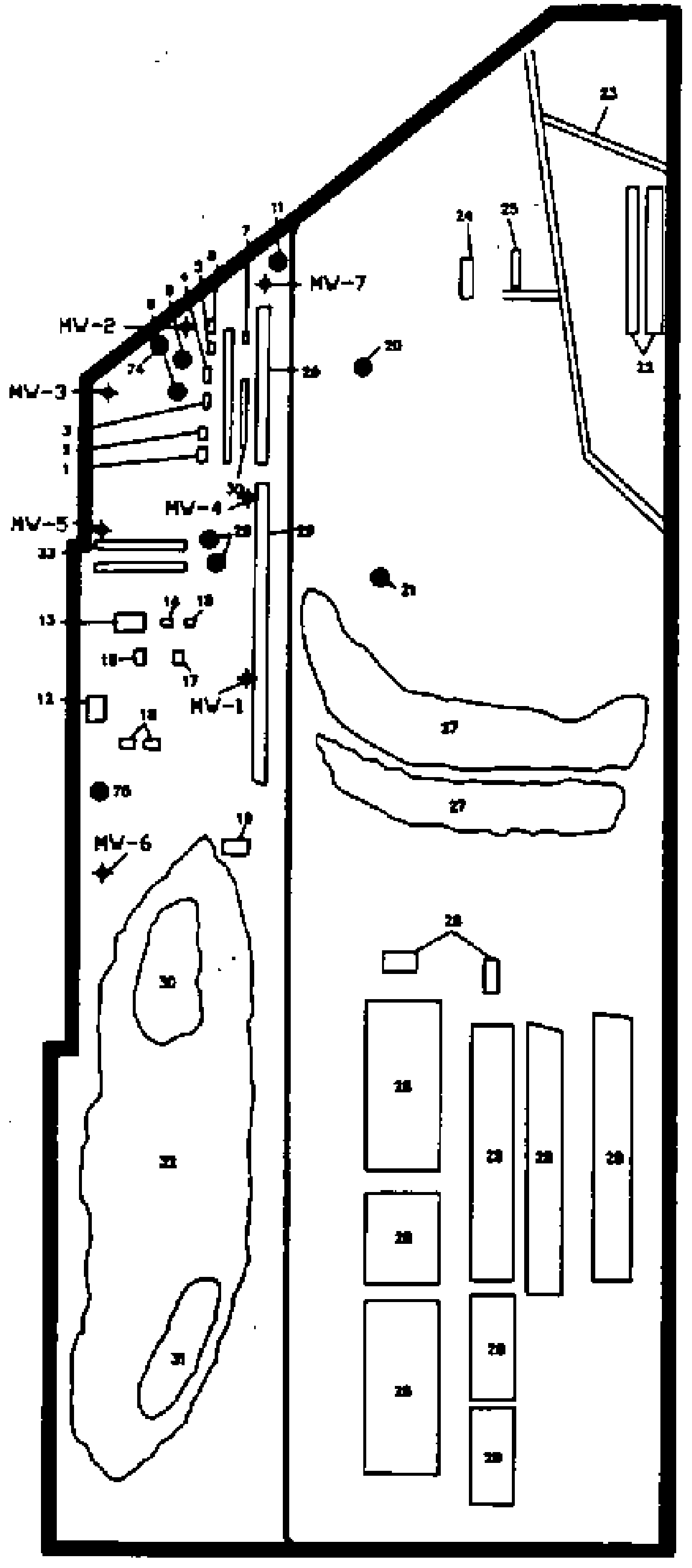
4.1.1 Past Waste Disposal and Storage Areas

The information evaluated under Phases I and II of this project indicates that as a result of DDMT's complex site utilization history, large quantities of industrial chemicals or hazardous materials have been stored, repackaged, shipped or disposed on installation property. In addition, leaks or spills of stored goods or substances used on site have been reported. Past and recent facility use conditions were reviewed as described in subsection 1.3.

The examination of available facility utilization information commenced with the review of Dunn Field material storage and disposal records. A total of thirty-three individual sites were identified at Dunn Field by installation records (Figure 4-1 and Table 4-1). In addition, two other potential contaminant sources were discovered during the execution of field data collection efforts. Site number 74 was encountered during the installation of monitoring well MW-10. Miscellaneous solid waste metal, glass, burned trash and organic matter was encountered from 3.5 to approximately 10 feet below existing grade. Organic vapor emissions from the borehole were on the order of 200 ppm. Site number 75 (Figure 4-1) was encountered during the installation of monitoring well MW-12. Mixed municipal waste (C-Rations, paper, cardboard, etc.) were encountered from six to eighteen feet below grade in what may have been a landfill cell. The zone is very porous; some forty bags of cement were required to grout the well assembly into place. An average of 12 bags of cement was required for other wells of the same type design.

FIGURE 4-1

DUNN FIELD DISPOSAL & STORAGE SITES



✦ AEHA MONITORING WELLS

MAP NUMBERS CORRESPOND TO LOCATIONS ON TABLE 4-1.

SCALE: 1"~350'

SOURCE: US ARMY ENVIRONMENTAL HYGIENE AGENCY, 1982.
GEOHYDROLOGIC STUDY NO. 38-26-0195-83.

TABLE 4-1
DEFENSE DEPOT MEMPHIS TENNESSEE
DUNN FIELD SITES
SUMMARY OF HAZARDOUS MATERIAL USE, STORAGE, AND DISPOSAL SITES
SITE LOCATIONS ARE ILLUSTRATED ON FIGURE 4-1

MAP NO.	LOCATION	MATERIALS/WASTE	QUANTITY, DIMENSIONS OR SIZE	REMARKS
1	NW QUADRANT	MUSTARD AND LEWISITE	NINE TRAINING SETS	DISPOSED IN 1955
2	NW QUADRANT	AMMONIUM HYDROXIDE & GLACIAL ACETIC ACID	7 POUNDS SOLID, 1 GAL. LIQUID	DISPOSED IN 1955
3	NW QUADRANT	VARIOUS CHEMICAL; ORTHO-TOLIDINE DIHYDROCHLORIDE	3,000 QUARTS/5 CU.FT OTD	DISPOSED IN 1955
4	NW QUADRANT	POL AND PAINT	13-55 GAL. DRUMS	---
5	NW QUADRANT	POL AND THINNER	32-55 GAL. DRUMS	DISPOSED IN 1955
6	NW QUADRANT	METHYL BROMIDE	3 CUBIC FEET	DISPOSED IN 1955
7	NW QUADRANT	EYE OINTMENT	40,037 UNITS	DISPOSED IN 1955
8	NW QUADRANT	FUMING NITRIC ACID	1,700 BOTTLES	DISPOSED IN 1954
9	NW QUADRANT	METHYL BROMIDE	3,768 ONE-GALLON CANS	DISPOSED IN 1954
10	NW QUADRANT	ASHES AND METAL WASTE	UNCERTAIN	DISPOSED IN 1955 - (not shown on figure)
11	NW QUADRANT	TRICHLOROACETIC ACID	1,433 ONE-OUNCE BOTTLES	DISPOSED IN 1965
12	NW QUADRANT	SULPHURIC AND HYDROCHLORIC ACIDS	30 PALLETS	DISPOSED IN 1967
13	NW QUADRANT	MIXED CHEMICAL & ACID, DETERGENT, ALUMINUM SULPHATE & SODIUM	32 CUBIC YARDS MIXED CHEMICALS & ACID, 8,100 POUNDS SOLIDS	---
14	NW QUADRANT	SODIUM	ONE PALLET	---
15	NW QUADRANT	SODIUM PHOSPHATE	ONE PALLET	DISPOSED IN 1968
16	NW QUADRANT	ACID	ONE PALLET	DISPOSED IN 1969
17	NW QUADRANT	HERBICIDE, MEDICAL SUPPLIES & CLEANING COMPOUND	UNCERTAIN	DISPOSED IN 1969
18	NW QUADRANT	ACID	UNCERTAIN	---
19	NW QUADRANT	HARDWARE (NUTS & BOLTS)	UNCERTAIN	---
20	NE QUADRANT	ASPHALT	UNCERTAIN	---
21	NE QUADRANT	SANITARY WASTE, CN CANISTERS, & SMOKE POTS	UNCERTAIN	UTILIZED FROM 1955-60
22	NE QUADRANT	XXCC-3 IMPREGNITE	UNCERTAIN	---
23	NE QUADRANT	DRAINAGE DITCHES	---	MAY HAVE REC'D RUNOFF FROM STORAGE & DISPOSAL AREAS
24	PISTOL RANGE	UNKNOWN	UNCERTAIN	LEACHATE OBSERVED APRIL, 1989
25	BUILDING 1184	PESTICIDES & HERBICIDES	UNCERTAIN	CURRENTLY IN USE
26	NE QUADRANT	DRAIN PIPE	UNCERTAIN	--- (not shown on figure)

- continued -

TABLE 4-1
DEFENSE DEPOT MEMPHIS TENNESSEE
DUNN FIELD SITES
SUMMARY OF HAZARDOUS MATERIAL USE, STORAGE, AND DISPOSAL SITES
SITE LOCATIONS ARE ILLUSTRATED ON FIGURE 4-1

MAP NO.	LOCATION	MATERIALS/WASTE	QUANTITY, DIMENSIONS OR SIZE	REMARKS
27	NE QUADRANT	BAUXITE	TWO SEMI-CONTAINED PILES	---
28	SE QUADRANT	FLUORSPAR	TEN BINS	---
29	NW QUADRANT	FOOD SUPPLIES	UNCERTAIN	---
30	SW QUADRANT	FOODS, BURNED CONSTRUCTION DEBRIS	UNCERTAIN	DISPOSED IN 1948
31	SW QUADRANT	VARIOUS COMBUSTIBLES	UNCERTAIN	UTILIZED IN 1946
32	SW QUADRANT	BAUXITE	ONE SEMI-CONTAINED PILE	UTILIZED FROM 1942-72
33	NW QUADRANT	SODIUM, SODIUM PHOSPHATE, ACID, CHLORINATED LIME & MEDICAL SUPPLIES	UNCERTAIN	DISPOSED IN 1970
74	NW QUADRANT	MIXED SOLID WASTE	UNCERTAIN	WASTE ZONE 3.5 TO 10 FEET BELOW GRADE, ENCOUNTERED AT WELL MW-10
75	NW QUADRANT	MUNICIPAL WASTE	UNCERTAIN	WASTE ZONE 6 TO 18 FEET BELOW GRADE, ENCOUNTERED AT WELL MW-12

Site number 24 (Pistol Range) (Figure 4-1) had been identified on installation records as a former training area. However, its use for waste disposal was uncertain. Leachate was observed flowing from the range to a nearby drainage channel in April, 1989. The character and quality of the leachate is unknown. No samples were collected from within the leachate. One soil sample (SS-6) was taken from this area but only metal and pesticides were detected. MW-28 is located due east of the pistol range, MW-29 is due north, and MW-9 is due west. Analytical results of ground water from these three wells are presented in subsection 4.2.1.2.2. No direct correlation can be made from the observed leachate and the constituents detected in the ground water.

Available facility utilization information included U.S. Army Environmental Hygiene Agency (USAEHA) and U.S. Army Toxic and Hazardous Materials Agency (USATHMA) records describing past conditions on the main installation. A total of forty specific locations or conditions of potential environmental concern were noted. The locations of individual sites are illustrated on Figure 4-2. This information is listed on Table 4-2.

4.1.2 Review of Current Hazardous Materials/Waste Management

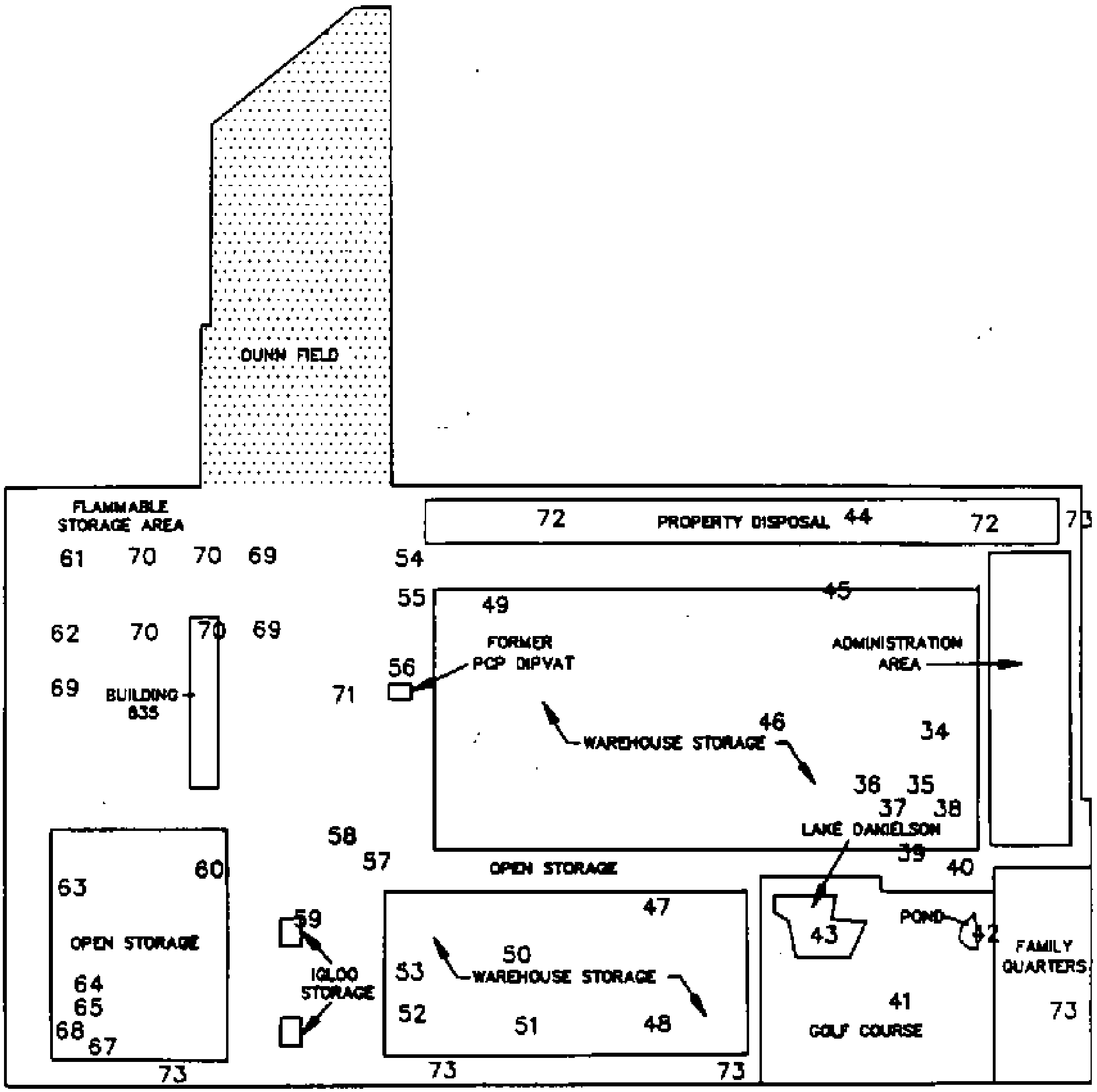
This section is based on the Master Plan Report: Defense Depot Memphis, Tennessee, prepared by Harland Bartholomew and Associates, Inc., July, 1988.

The current utilization of DDMT land resources is illustrated on Figure 4-2.

FIGURE 4-2

MAIN INSTALLATION DISPOSAL & STORAGE SITES

DEFENSE DEPOT MEMPHIS, TENNESSEE



SCALE: 1"~1000'

TABLE 4-2
DEFENSE DEPOT MEMPHIS TENNESSEE
MAIN INSTALLATION
SUMMARY OF HAZARDOUS AND NON-HAZARDOUS MATERIAL USE, STORAGE, AND DISPOSAL SITES
SITE LOCATIONS ARE ILLUSTRATED ON FIGURE 4-2

MAP NO.	LOCATION	MATERIALS/WASTE	QUANTITY, DIMENSIONS OR SIZE	REMARKS
34	BUILDING 249	XXCC-3	UNCERTAIN	STORAGE/HANDLING UNCERTAIN
35	BUILDING 253	POL	50 X 125 FEET	SMALL CONTAINERS
36	BUILDING 257	MOGAS	47,700 GALLONS	TANKS NOT TESTED
37	BUILDING 263	POL	20 X 40 FEET	SMALL CONTAINERS
38	PAD 267	PESTICIDES, HERBICIDES	150 X 200 FEET	BULK LOTS USED ON POST
39	AREA 272	PCBS	100 X 225 FEET	TRANSFORMER LEAKS SUSPECTED
40	BUILDING 273	PESTICIDES, CLEANERS	10 X 50 FEET	---
41	GOLF COURSE	2,4 D M2A1&M4 FLAMETHROWER LIQUID FUELS	20 ACRES	EQUIPMENT TESTING
42	POND	2,4 D	0.5 ACRE	SURFACE APPLICATION
43	LAKE DANIELSON	2,4 D	4 ACRES	SURFACE APPLICATION
44	BUILDING 308	DDT	11,000 - 12,000 GALLONS	SPILLS SUSPECTED
45	BUILDING 319	FLAMMABLES, TOXICS, ETC.	UNCERTAIN	RADIOACTIVE ITEMS REPACKED IN WEST END OF BLDG.
46	BUILDING 359	MEDICAL SUPPLIES & WASTE	30 X 60 FEET	---
47	VICINITY BLDG. 470	UNKNOWN	UNCERTAIN	---
48	VICINITY BLDG. 490	UNKNOWN	200 X 400 FEET	---
49	BUILDING 629	DDT, HERBICIDES, SOLVENTS, OXIDIZER, CORROSIVE, REACTIVE, ETC.	DDT-70 TONS, LARGE QUANTITIES OF BULK LIQUIDS	HYDROFLUORIC ACID SPILL
50	VICINITY BLDG. 689	UNKNOWN	UNCERTAIN	---
51	VICINITY BLDG. 690	UNKNOWN	UNCERTAIN	---
52	VICINITY BLDGS.689-690	UNKNOWN	UNCERTAIN	---
53	BUILDING 689	ALCOHOL, ACETONE, TOLUENE, NAPHTHA, HF	3,000 GALLONS	HYDROFLUORIC ACID SPILL
54	VICINITY 8702	FUELS, MISC. LIQUIDS, WOOD, PAPER	UNKNOWN	UTILIZED 1968-72
55	BUILDING 720	FUEL & CLEANERS DISPENSING	POL-12,000 GALLONS	---
56	BUILDING 737	PCP, DIOXIN, FURAN	@ 600 CUBIC YARDS	METAL SHED,DIPVAT,PUMPHOUSE & UST REMOVED. SOIL CONTAMINATION REMAINS.
57	BUILDING 765	FUEL OIL	---	---
58	BUILDING 770	WASTE OIL AND FUEL OIL	---	---
59	BUILDING 783	FLAMMABLES	---	---
60	BUILDING 873	POL	500,000 GALLONS	CONFIRMED DDE,DDT & ALDRIN CONTAM. EAST OF BLDG.
61/62	BUILDING 949	POL	VARIES	REPLACES X-25

- continued -

TABLE 4-2
DEFENSE DEPOT MEMPHIS TENNESSEE
MAIN INSTALLATION
SUMMARY OF HAZARDOUS AND NON-HAZARDOUS MATERIAL USE, STORAGE, AND DISPOSAL SITES
SITE LOCATIONS ARE ILLUSTRATED ON FIGURE 4-2

MAP NO.	LOCATION	MATERIALS/WASTE	QUANTITY, DIMENSIONS OR SIZE	REMARKS
63	BUILDING 972	FLAMMABLES, SOLVENTS, WASTE OIL, ETC.	UNCERTAIN	LEAKERS" RECOUPED IN 1981 - UNDERGROUND TANK USED
64	BUILDING 1084	DOT, "BANNED PESTICIDES"	---	---
65	BUILDING 1085	POL	SMALL QUANTITIES	VEHICLE GRASE RACK
66	BUILDING 1086	VARIOUS WASTES	UNCERTAIN	---
67	BUILDING 1088	ZINC CHROMATE PRIMER	UNCERTAIN	---
68	BUILDING 1089	ACIDS	UNCERTAIN	ACID LEAKS SUSPECTED
69	AREAS X-13,X-15,X-25	POL, ISOOCTANE, TOLUENE, ACETONE, MEK, NAPHTHA	UNCERTAIN	A FEW LEAKS SUSPECTED
70	RR TRACKS 1,2,3,4,5,6	POL, VARIOUS CHEMICALS	UNCERTAIN	A FEW LEAKS SUSPECTED
71	ALL RR TRACKS	HERBICIDE	UNCERTAIN	HERBICIDE USED TO CLEAR TRACKS
72	PDO YARD	WASTE OIL	UNCERTAIN	USED FOR DUST CONTROL
73	ALL GRASSED AREAS	2,4 D	UNCERTAIN	---

The following hazardous materials are warehoused and issued at DDMT:

1) Flammable Liquids
2) Flammable Solids
3) Corrosives (Acids and Bases)
4) Poisons (A&B) including insecticides
5) Compressed Gases (non-flammable)
6) Compressed Gases (flammable)
7) Class C Explosives
8) Oxidizers
9) Radioactive Materials
10) Other Regulated Material (ORM)

These materials are received as packaged commodities from manufacturers in containers that range in size of up to 55-gallon drum quantities. While in storage, these materials are segregated by hazardous storage compatibility groups to assure optimum safety conditions are met.

Storage

Existing locations of hazardous materials storage at DDMT were summarized in Figures 4-1 and 4-2, and Tables 4-1 and 4-2. Some of the storage locations are areas where surface soil contamination was detected. The following paragraphs describe the past and present conditions at each of the locations (to the extent possible from DDMT records). Those areas will be correlated with the contaminants detected as to being possible sources of surface soil contamination in subsection 4.2.2.2.2.2.

Location	Item
Building 629	Various chemicals (toxics, corrosives, oxidizers)
Building 319	Flammable materials, toxics
Area X-25	Flammable materials
Area X-13, X-15	Anti-Freeze
Building S-873	POL products and overflow chemicals from 629
Building 689	Short-term storage of flammable liquids, for shipping and receiving

Hazardous materials operations at DDMT are increasing. In 1984, DDMT was responsible for 30,000 tons of hazardous material, while in 1987, the amount was about 37,000 tons. Construction of a new hazardous materials warehouse has recently been completed (Bldg. 835) in the northwest quadrant of DDMT. The total area of the building is 141,100 square feet. The building will provide 138,000 square feet of storage area for hazardous materials, with the remainder being used for general office and ancillary activities.

The majority of chemical stock items have been stored in Building 629. This building is constructed on a concrete foundation without floor drains and contains five bays separated by concrete walls and fire doors. Spill booths containing absorbent materials and cleanup equipment are located in each separate area. These booths are marked to preclude incompatible chemicals being placed in the same booth. The capacity of Building 629 is currently inadequate, and overflow chemicals are stored in Building S-873.

Building 319 is the flammable materials storage area and contains mostly alcohols with lesser amounts of other items (ether, pesticides, and solvents). Hazardous materials requiring temperature-controlled environments are also stored in this warehouse, as are pilferable hazardous materials. The building is concrete-bermed and is on a concrete foundation with no floor drains. One mechanically ventilated, separately bermed room in the west end of the building contains cyanide compounds. The building is equipped with explosion-proof lighting and spill booths similar to those in Building 629. Security control at Building 319 is stringent. Building 319 storage is currently being replaced by new hazardous materials warehouse, Building 835.

The X-25 area is a bermed, concrete pad in the open storage area on the northwest side of the installation, where only Class 1 flammable liquids are stored. These liquids are normally stored in 55-gallon drums and include a wide range of industrial grade organic solvents. A third facility on the Building T267 site is a tension roof structure used for general purpose material storage. This structure is currently not in use and the tent is being removed.

A new recoupment facility has recently been constructed immediately south of the new hazardous material warehouse (Building 835). This will replace non-compliance operations in Building S-873. Selected materials that are damaged in transport will be repackaged at this facility for use. Any material that cannot be repackaged must be classified as hazardous material excess and turned over to DRMO. It is the Hazardous Materials Supervisor's responsibility to dispose of the material through salvage or resale.

All open storage of drummed products, except at X-25, will be eliminated. Building 529 is partially utilized for non-compliance storage. An additional 20,000 square feet of material will be relocated from Building 529 to the new warehouse. Materials are currently being transferred from Building 629, 529 and 319.

The Flammable Liquids Holding Area, also known as the "hot house", is where flammable materials are temporarily stored (less than 24 hours) after receipt or before shipping. Typical items in this area include alcohols, ketones, aromatics, and ethers. The "hot house" is located at the northwest corner of Building 689.

4.1.2.1 Hazardous Waste Generation and Disposal - DDMT is a RCRA generator of hazardous wastes in the State of Tennessee, under generator number TN 4210020570. DDMT is a large quantity generator by the State of Tennessee. The sources of hazardous wastes result from the cleanup of small hazardous materials spills, mission stock which has reached expired shelf life, and satellite generation areas. Of the approximately 100,000 hazardous material transfers per year at DDMT, only an estimated 50 per year result in an out-of-container event. More than 90 percent of these events result from packaging failures in transport. The remaining events are attributed to handling at DDMT.

Defense Reutilization and Marketing Region (DRMR) is a tenant activity of DDMT. DRMR supports several installations in the region and is responsible for providing disposal of hazardous material through contractors. The former Defense Property Disposal Office has been redesignated Defense Reutilization and Marketing Office (DRMO). DRMO provides property disposal services and conforming storage facilities for hazardous materials and hazardous wastes generated by DDMT, Memphis Naval Air Station and Air Force Air National Guard. Under the present permit, the time limit for hazardous waste storage is ninety days. The installation is seeking a Part B permit from USEPA which would allow storage for up to 180 days.

Building 308 is where hazardous materials in DRMO's possession are stored. It is a wood-framed tin structure with a concrete floor. A two-foot concrete foundation surrounds the floor to provide secondary containment, except for two doorways. Spill containment and cleanup materials are kept in the building. This storage area will be replaced by the planned DRMO Conforming Storage Facility. The project was first planned for FY 1987 and is still pending a Part B permit. It is to provide a 14,000 square foot storage facility with auxiliary facilities required to accomplish the hazardous materials disposal mission. Recoupment is used as much as possible to minimize losses and to keep waste quantity to a minimum. Cleanup residuals are transferred to DRMO for resale or disposal.

4.1.2.2 PCP Dip Tank - A sampling investigation of the PCP Dip Tank Facility (Building S-737) commenced in August, 1985 when U.S. Army Environmental Hygiene Agency personnel obtained analytical testing results arranged by O.H. Materials Company, Inc., which revealed the presence of high levels of chlorinated isomers of dioxins and furans.

Samples taken of soil beneath the dip vat showed the presence of contamination. O.H. Materials used a portable drill rig to systematically depth sample the area. O.H. Materials, in conjunction with state and federal authorities, determined a target clean-up criteria level of 200 ppb total dioxins and furans.

Although contaminants exceeding the 200 ppb were found at a depth of 27 feet, the U.S. Army, USEPA Region IV, and the State of Tennessee Department of Health and Environment established a ten foot removal depth as appropriate.

The contaminated soil was stored on roll-off containers near Building 670. The roll-off containers have been removed and the soil was disposed of at an approved facility in the spring of 1988.

4.1.2.3 Spill Response - DDMT has instituted spill response and control measures which reduce the probability of significant releases of spilled hazardous material to the environment. The following programs have been implemented to mitigate adverse impacts:

(1) Spill Prevention, Control, and Countermeasures (SPCC) Plan. The plan is designed to improve responses to and decrease the potential for hazardous materials spills.

(2) Installation Spill Contingency Plan (ISCP). The Plan provides specific steps to follow for reporting of a spill, mobilization of the spill response team, and cleanup of a spill. Also included are telephone numbers for emergency services (police, fire department, hospitals, etc.), reportable quantities of hazardous materials, and the responsibilities of the spill response team members.

(3) Personnel Training. The training includes courses for hazardous materials warehouse personnel, spill team members, and management. The training program includes initial orientation; an in-house course, "Introduction to Hazardous Materials--Handling and Storage, Packing and Marking"; certification training for packers, "Defense Packaging of Hazardous Materials for Transportation," which is conducted by the Joint Military Packaging Training Center; and opportunities to take technical courses and attend appropriate seminars outside the DLA system for certain personnel. Safety meetings are conducted once per week. Unannounced drills on safe work practices are conducted monthly by the Safety and Health Office.

(4) Spill Response Vehicle. The vehicle has a variety of spill response equipment for personnel protection (chemical-resistant coveralls, boots, hard-hats, face shields, gloves, respirators, first aid kits, fire extinguishers, etc.), spill control (shovels, absorbents, neutralizing chemicals, etc.), communications, and analysis (explosimeter, oxygen meter, pH paper, etc.) plus other safety gear. In addition to the DDMT vehicle, the City of Memphis Fire Department Hazardous React Team is on call for emergencies at the installation. This team has a national reputation for its hazardous spills response expertise.

4.1.2.4 Explosives - DDMT does not handle significant quantities of ammunition. Small quantities of ammunition confiscated by the FBI were stored in an igloo on the west side of 9th Street. The storage of these materials was not considered to be a significant hazard to personnel or facilities; storage was discontinued in 1989.

The only other explosives on the Depot are flammable materials stored in temporary structures on the west side of the installation. An adequate safety distance is maintained.

4.2 SAMPLING PROGRAM AND ANALYTICAL RESULTS

The following sections discuss the sampling programs and the analytical results for each media inspected during the Remedial Investigation. Ground water, surface water, sediments, surface soil and subsurface soil sampling was done in two phases as discussed in Section 2.

During Phase I, ground water sampling was performed in March and April, 1989, surface and subsurface soils in February, 1989, surface water in May, 1989, and sediments in May, 1989. Phase II surface and subsurface soils were collected in October-November, 1989, and surface and ground water samples were collected in January, 1990. All sampling locations are shown on Figures 2-1 and 2-2a through 2-2d. Surface soil sampling locations are given in Table 2-1. Subsurface soil sampling depths are given in Table 2-2.

4.2.1 Ground Water

All ground-water samples were analyzed for volatile organic compounds (VOCs) (USEPA Method 8240; including xylene), semi-volatile organics (USEPA Method 8270), pesticides/PCBs (USEPA Method 8080), total metals (USEPA Method 6010 including: antimony, arsenic, barium, cadmium, chromium, copper, lead, silver, selenium, nickel and zinc) and mercury (USEPA Method 7470). All of the USEPA methodologies listed above are found in USEPA SW-846, 3rd Edition. All water matrix samples were measured for pH, temperature and specific conductance in the field. This information was recorded on the field Sampling Data sheets which are provided in Appendix A.

4.2.1.1 Background Ground Water Quality - All available information (literature and field studies) indicates that monitoring well MW-16 is located upgradient from the rest of the monitoring wells screened in the Fluvial aquifer at DDMT. Chlorinated volatile organic and metal contamination was detected in the ground water at DDMT. The areas of contamination were located down-gradient from MW-16 (Figure 3-10). The specific contaminants detected will be discussed in the following subsections. The fact that no chlorinated volatile organic contamination was detected in MW-16 supports the reasoning for using this data as background ground water quality. The positive results reported for total metals are likely to be indicative of natural background levels. Samples analyzed from MW-16 in Phase I and Phase II resulted in consistent metals results. However, a variability with respect to time may naturally exist in total metals concentrations. For that reason, it is difficult to discern total metals concentrations above which are considered contamination. Total metals results are discussed as being elevated, rather than necessarily representative of contamination. For comparison purposes, the analytical results from MW-16 have been repeated on all tables presenting Fluvial aquifer groundwater results.

4.2.1.2 Dunn Field Area

4.2.1.2.1 Ground Water Sampling - Phase I ground-water samples were collected in Dunn Field form MW-2 through MW-15. MW-1 through MW-7 are wells that were installed by AEHA in 1985. MW-1 was destroyed prior to the RI field operations and was not accessible for sampling. MW-2 is screened in a perched water table at a depth of 29 feet. Since MW-2 does not penetrate the same aquifer as the other wells, the analytical results can not be directly correlated with the contaminants detected in the Fluvial aquifer. Monitoring wells MW-3 through MW-15 are screened in the Fluvial aquifer. MW-8 through MW-15 were installed during Phase I of the RI.

During Phase I it was discovered that chlorinated volatile organic compounds and metal contamination was present in most of the ground water samples collected from the northwestern portion of Dunn Field. The results indicated possible contaminant migration past the boundaries of Dunn Field. In Phase II, five monitoring wells, MW-30, MW-31, MW-32, MW-33 and MW-37, were installed west of Dunn Field. Except for MW-37, all of the wells are screened in the Fluvial aquifer. MW-37 was installed as a Type III monitoring well and is screened in the Memphis Sand aquifer.

Ground water samples were collected again during Phase II from the same wells as in Phase I, except for MW-2 (perched water-table zone), which was dry at the time of sampling. In addition to these wells, five wells installed in Dunn Field during Phase II were sampled. Four of the new Dunn Field monitoring wells (MW-28, MW-29, MW-34 and MW-35) are screened in the Fluvial aquifer. MW-35 is screened to intercept the bottom of the Fluvial aquifer. MW-36 was installed as a Type III monitoring well and is screened in the Memphis Sand aquifer. The analytical results from both sampling episodes will be discussed in the following sections.

4.2.1.2.2 <u>Dunn Field Area Ground Water Analysis</u> - Analytical results from both Phase I and Phase II indicate that chlorinated volatile organic compound and total metal contamination exists in the Fluvial aquifer at Dunn Field and extending past the western boundary of DDMT. Positive results for Dunn Field ground water along with background data, are given in Table 4-3. For easy reference, Maximum Containment Levels (MCLs) and the State of

TABLE 4-3
POSITIVE RESULTS IN GROUND WATER
DUNN FIELD AREA
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER		Background Well MW16	MCL	STATE OF TN	MW3	MW4	MW5	MW6	MW7	MW8	MW9	MW10	MW11	MW12	MW13	MW14	MW15	MW28	MW29	MW34	MW35	MW30	MW31	MW32	MW33
					DUNN FIELD																	OFF-BASE			
HALOGENATED VOLATILES (ug/l)																									
1,1,1-Trichloroethane	PHASE I	--	200	200	3J	--	--	--	5J	5	--	9	--	--	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			4J	--	--	--	4J	5	--	10	--	--	--	--	--	--	9	--	--	--	5	--	--
1,1,2,2-Tetrachloroethane	PHASE I	--	--	1.7	--	--	--	150	--	--	--	10	73	340D	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	86	--	--	--	8	11	1800D	2J	--	--	--	--	--	--	--	260D	110	--
1,1,2-Trichloroethane	PHASE I	--	--	0.6	--	--	--	7	--	--	--	--	2J	1J	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	4J	--	--	--	--	--	7	--	--	--	--	--	--	--	--	12	5	--
1,1-Dichloroethane	PHASE I	--	--	NA	--	--	--	--	3J	3J	--	3J	--	--	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	--	2J	4J	--	4J	--	--	--	--	--	--	5	--	--	--	--	--	--
1,1-Dichloroethylene	PHASE I	--	7	7	36	--	--	--	61	68	3J	130	--	--	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			47	--	--	--	58	68	2J	160	--	--	--	--	--	--	58	--	--	--	61	--	--
1,2-Dichloroethane	PHASE I	--	5	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	--	--	--	--	3J	--	--	--	--	--	--	--	--	--	--	--	--	--
1,2-Dichloroethylene	PHASE I	--	100/70(a)	350	--	--	3J	270D	--	--	--	6J	520D	180D	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	160	--	--	--	180	61	510D	--	--	2J	--	--	--	1J	--	1100D	110	--
Carbon Tetrachloride	PHASE I	--	5	5	--	5J	4J	77	--	--	7	--	4J	1J	--	1J	10J	--	--	--	--	--	--	--	--
	PHASE II	--			--	10	--	40	--	--	5	3J	5	3J	--	--	17	--	--	--	--	--	11	52	--
Chloroform	PHASE I	--	100(c)	0.19	3J	2J	11	15	6	--	3J	--	6	3J	--	--	4J	--	--	--	--	--	--	--	--
	PHASE II	--			--	7	2J	10	6	--	--	6	11	10	--	--	18	--	--	--	--	--	33	12	--
Methylene chloride	PHASE I	--	--	1500	--	--	--	--	4BJ	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			2J	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tetrachlorethene	PHASE I	--	5	0.8	49	100	210	3	58	58	6	190	--	--	3J	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			74	200D	46	2J	47	54	5	240D	18	33	9	--	--	--	67	--	--	--	86	2J	--
Trichloroethene	PHASE I	--	5	5	25	4J	28	190D	18	21	7	140	380D	1700D	--	--	2J	--	--	--	--	--	--	--	--
	PHASE II	--			35	9	5	120	16	21	4J	390D	81	5100D	--	--	6	--	24	--	61	--	1500D	110	--

TABLE 4-3
POSITIVE RESULTS IN GROUND WATER
DUNN FIELD AREA
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER		Background Well MW16	MCL	STATE OF TN	DUNN FIELD MW3	MW4	MW5	MW6	MW7	MW8	MW9	MW10	MW11	MW12	MW13	MW14	MW15	MW26	MW29	MW34	MW35	OFF-BASE MW30	MW31	MW32	MW33
NONHALOGENATED VOLATILES (ug/l)																									
Acetone	PHASE I	3J	--	NA	--	--	--	34B	3J	--	--	--	1JB	1JB	1JB	2JB	--	--	--	--	--	--	--	--	--
	PHASE II	--			6J	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
NONHALOGENATED SEMIVOLATILES (ug/l)																									
Benzoic acid	PHASE I	--	--	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			3J	3J	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Di-n-butyl phthalate	PHASE I	--	--	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	42	--	--	--	--
N-Nitrosodiphenylamine	PHASE I	2J	--	0.049	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			4BJ	10B	8BJ	5BJ	3BJ	4BJ	3BJ	6BJ	4BJ	7BJ	6BJ	--	5BJ	3BJ	6BJ	--	3BJ	--	--	--	--
bis(2-Ethylhexyl) phthalate	PHASE I	5J	--	1500	8J	7J	6J	5J	5J	5J	8J	13	--	5J	3J	6J	8J	--	--	--	--	--	--	--	--
	PHASE II	3J			7BJ	--	--	--	--	--	--	--	3BJ	--	--	--	--	--	--	--	11J	--	--	--	--
VOLATILE METALS (ug/l)																									
Arsenic	PHASE I	55	50	50	--	--	--	--	--	--	62	85	--	--	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	40			--	--	--	--	--	--	--	150	--	--	--	210	--	--	50	--	--	50	180	--	60
Lead	PHASE I	79	50	50	238N	257N	84N	395N	390N	165N	171N	853N	353N	417N	150N	507N	255N	--	--	--	--	--	--	--	--
	PHASE II	60			90	130	40	70	260	70	--	1000	140	70	40	200	120	80	90	--	--	50	290	120	100
Mercury	PHASE I	--	2	2	1.8	1.1	.6	3.6	1.4	1.7	.8	.7	1.4	.5	1.4	1.8	3.1	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	1	--	1	--	1	--	--	--	2	1	--	--	--	--	--	1	1	--

TABLE 4-3
POSITIVE RESULTS IN GROUND WATER
DUNN FIELD AREA
DEFENSE DEPOT MEMPHIS TENNESSEE

		Background Well			DUNN FIELD																	OFF-BASE			
PARAMETER		MW16	MCL	STATE OF TN	MW3	MW4	MW5	MW6	MW7	MW8	MW9	MW10	MW11	MW12	MW13	MW14	MW15	MW28	MW29	MW34	MW35	MW30	MW31	MW32	MW33
NONVOLATILE METALS (ug/l)																									
Antimony	PHASE I	--	--	NA	45BN	59BN	--	142N	170N	113N	81N	81N	54BN	--	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Barium	PHASE I	218	1000	1000	659N	695N	224N	117N	1030N	994N	416N	1310N	3390N	2010N	416N	3740N	999N	--	--	--	--	--	--	--	--
	PHASE II	410			310	280	200	630	540	350	130	1900	1200	560	220	1500	550	960	410	120	120	600	880	1000	460
Cadmium	PHASE I	--	10	0.0037	--	--	--	6N	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	--	--	--	--	--	--	--	--	--	--	9	9	--	--	--	--	--	--
Chromium (b)	PHASE I	55	50	50	643N	823N	170N	366N	1240N	471N	182N	286N	530N	517N	184N	800N	393N	--	--	--	--	--	--	--	--
	PHASE II	50			60	120	50	40	340	100	10	310	120	40	20	190	110	130	170	--	--	50	260	140	100
Copper	PHASE I	188	1000	1000	345N	438N	78N	213N	856N	304N	138N	613N	643N	454N	180N	592N	400N	--	--	--	--	--	--	--	--
	PHASE II	180			50	80	40	40	210	180	20	910	520	80	50	180	110	60	60	--	--	50	100	50	70
Nickel	PHASE I	29	--	13.4	324N	301N	57N	145N	602N	170N	87N	142N	225N	350N	78N	421N	170N	--	--	--	--	--	--	--	--
	PHASE II	40			40	50	20	30	170	50	--	170	60	40	20	100	60	70	80	--	--	30	130	60	50
Silver	PHASE I	--	50	50	--	--	--	20	--	--	--	--	--	42	11	13	68	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Zinc	PHASE I	116	5000	5000	114N	115N	311N	517N	1910N	745N	304N	1120N	872N	1300N	407N	1640N	662N	--	--	--	--	--	--	--	--
	PHASE II	180			160	170	91	63	450	160	14	1300	230	110	79	430	140	250	210	24	36	160	490	220	230

Shaded numbers indicate levels equal to or above MCL or State of TN guidelines.

MCL - SDWA Maximum Containment Level

STATE OF TN - State of Tennessee Guidance Levels (Non-enforceable)

(a) Trans isomer/Cis isomer

(b) No distinction between Chromium (III) and Chromium (VI)

(c) Total trihalomethanes

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL) but greater than the Instrument Detection Limit (IDL).

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

J = Estimated value less than the sample quantitation limit but greater than zero.

N = Spiked sample recovery not within control limits.

-- = Not detected.

NA = Not Available.

Tennessee guidelines have been included on the tables. The shaded numbers indicate constituent levels that are equal to, or exceed, MCLs and/or State guidelines. These will be compared and discussed in Section 6 of this report. Analytical results from the monitoring wells screened in the Memphis Sand aquifer (MW-36 and MW-37) will be discussed in Subsection 4.2.1.4.

The chlorinated volatile organic compounds that were detected in the Fluvial aquifer during Phase I and Phase II sampling are not naturally occurring compounds. The constituents that were detected include: carbon tetrachloride, chloroform, trichloroethylene, tetrachloroethane, 1,1-dichloroethene, 1,1-dichloroethane, 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane, 1,2-dichloroethene, 1,1,2-trichloroethane and 1,2-dichloroethane. Figure 4-3 shows the known area of organic contaminated ground water in the Dunn Field area.

Chlorinated volatile organic compounds were only detected in two of the wells located west of Dunn Field (MW-31 and MW-32). Both wells were contaminated with the same constituents detected in the wells in Dunn Field. The concentration of the chlorinated volatile organics found in these two wells was also within the same order of magnitudes as levels encountered in the northwest quadrant of Dunn Field.

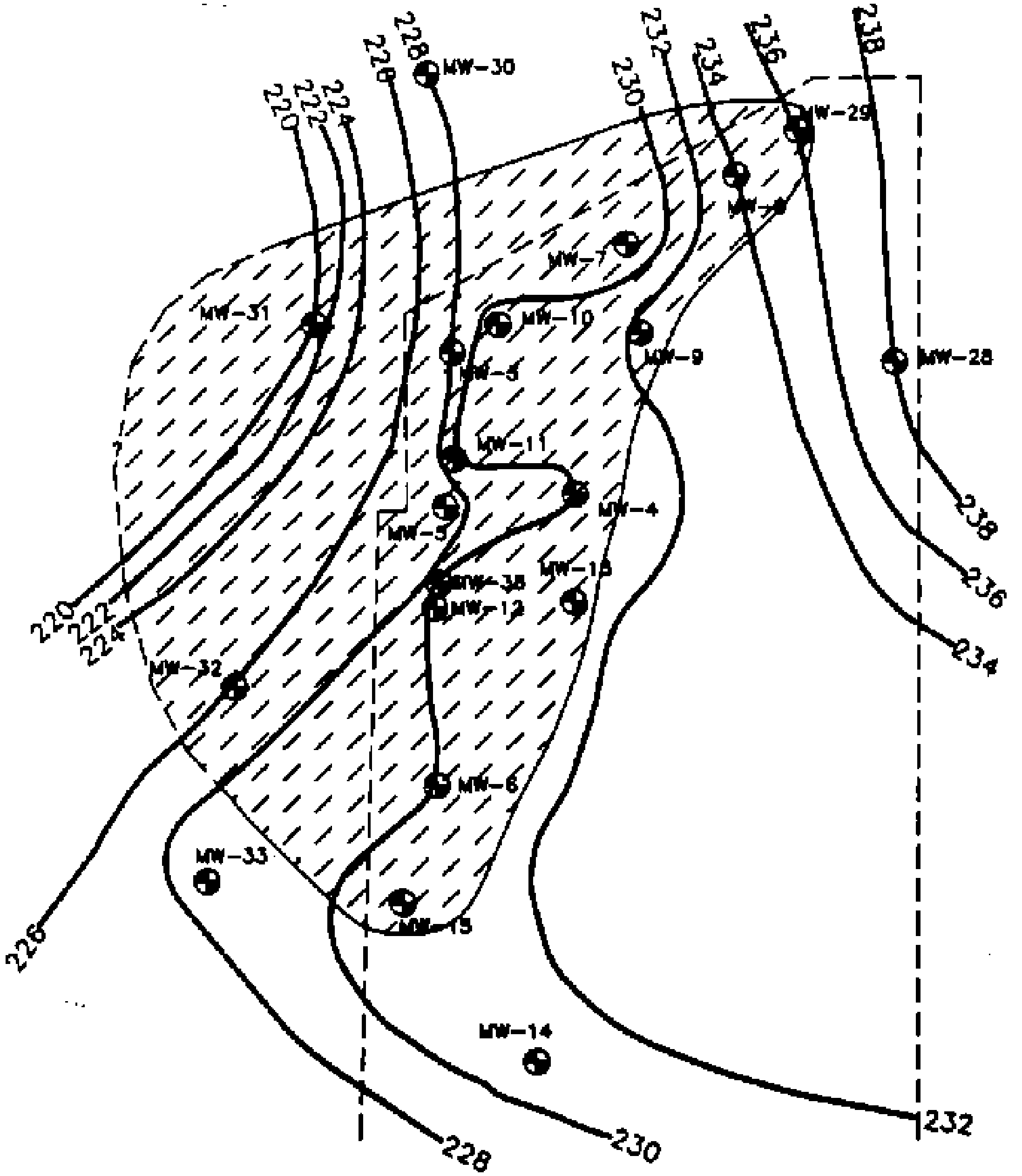
MW-30 and MW-33 (also located west of Dunn Field) did not contain detectable levels of chlorinated volatile organic contaminants at the time of Phase II sampling. These two wells may be used to define the northern and southern extent of the known contaminant plume.

Trichloroethene was the constituent present at the highest levels in samples collected during both Phase I and Phase II. As shown in Table 4-3, the MCL for trichloroethene is 5 ug/l. Trichloroethene was detected at levels ranging from 2 ug/l in MW-15 to 1500

FIGURE 4-3

WATER TABLE SURFACE OF FLUVIAL DEPOSITS AT DUNN FIELD JANUARY, 1990

DEFENSE DEPOT MEMPHIS, TENNESSEE



** SHADED AREA REPRESENTS CHLORINATED VOLATILE ORGANIC CONTAMINATION OF GROUND WATER. EXTENT OF CONTAMINATION IS UNKNOWN AND ALL BOUNDARIES OF THE PLUME HAVE BEEN INFERRED.

NOTE: THIS ILLUSTRATION REPRESENTS AN INTERPRETATION OF NATURAL CONDITIONS ON THE DATE OF MEASUREMENT.

POSITIVE RESULTS FOR ALL CONSTITUENTS DETECTED IN THE FLUVIAL AQUIFER GROUND WATER ARE GIVEN IN TABLE 1-2.

LEGEND

●	MONITORING WELL LOCATION
——	ISOPLETHS OF EQUAL ELEVATIONS
— —	INFERRED ELEVATIONS

375 0 375

SCALE IN FEET

LAW ENVIRONMENTAL INC.
GOVERNMENT SERVICES DIVISION

ug/l in MW-12 in Phase I. Results from Phase II were generally similar to that in Phase I. In Phase II, the levels of trichloroethene ranged from 4 ug/l in MW-9 to 5100 ug/l in MW-12.

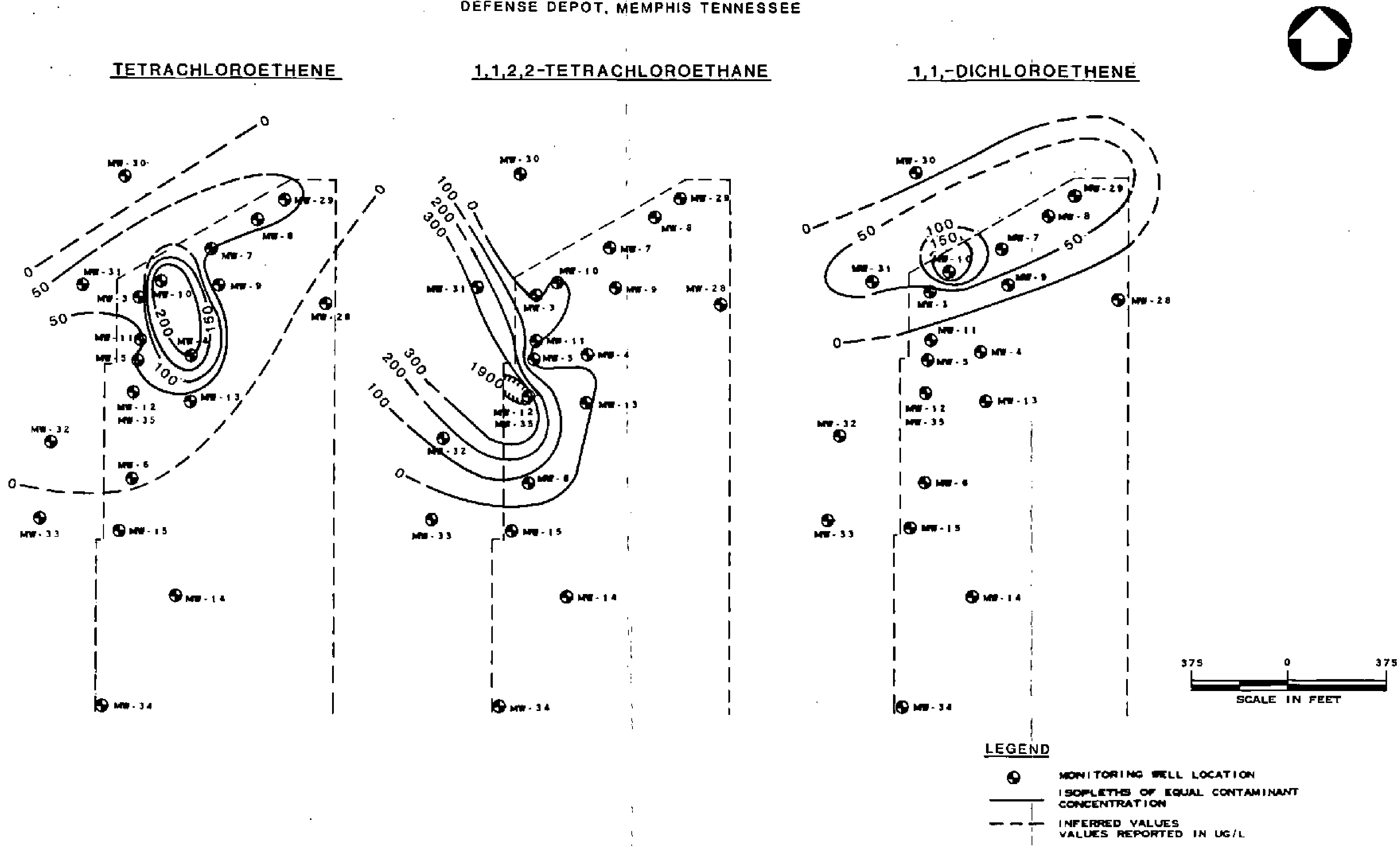
Tetrachloroethene (MCL = 5 ug/l) was another major ground-water contaminant found in both Phase I and Phase II samples. Analytical results from Phase I show tetrachloroethene in most of the northern wells in Dunn Field with levels ranging from 3 ug/l in MW-6 and MW-13 to 190 ug/l in MW-10. Measurements in Phase II obtained similar results with levels ranging from 2 ug/l in MW-6 to 240 ug/l in MW-10. Figure 4-4 presents isopleths for this contaminant based on results from Phase II.

Samples from MW-10, MW-11, MW-12, and MW-6 tested positive for 1,1,2,2-tetrachloroethane in Phase I. In Phase II the same wells, along with MW-13, tested positive for this constituent. The highest concentration levels of 1,1,2,2-tetrachloroethane was found in MW-12 (340 ug/l in Phase I and 1900 ug/l in Phase II). An isopleth of Phase II concentrations of 1,1,2,2-tetrachloroethane is shown on Figure 4-4. Samples from Phase I and Phase II detected 1,1-dichloroethene in MW-3, MW-7, MW-8, MW-9 and MW-10. MW-29 also tested positive in Phase II. Levels of contamination did not change significantly between Phase I and Phase II. Phase II concentrations are shown by an isopleth on Figure 4-4.

Metals were also detected at levels elevated above background in ground-water samples. However, the metals concentrations were generally lower in the wells located west of Dunn Field than in onsite wells. The data indicates metal contamination covering the same general area as the organics, but the rate of contaminant migration may be slower for metals than for the organics.

Chromium, lead and mercury have been identified as constituents of concern (Section 6). Chromium and lead were detected at elevated levels in the majority of the wells. The highest levels detected were: chromium (800 ug/l, MW-7), lead (653 ug/l, MW-10), and mercury (3.6 ug/l, MW-6). The distributions of chromium and lead

FIGURE 4-4
VOLATILE ORGANICS CONTAMINATION EXTENT IN FLUVIAL AQUIFER
DEFENSE DEPOT, MEMPHIS TENNESSEE



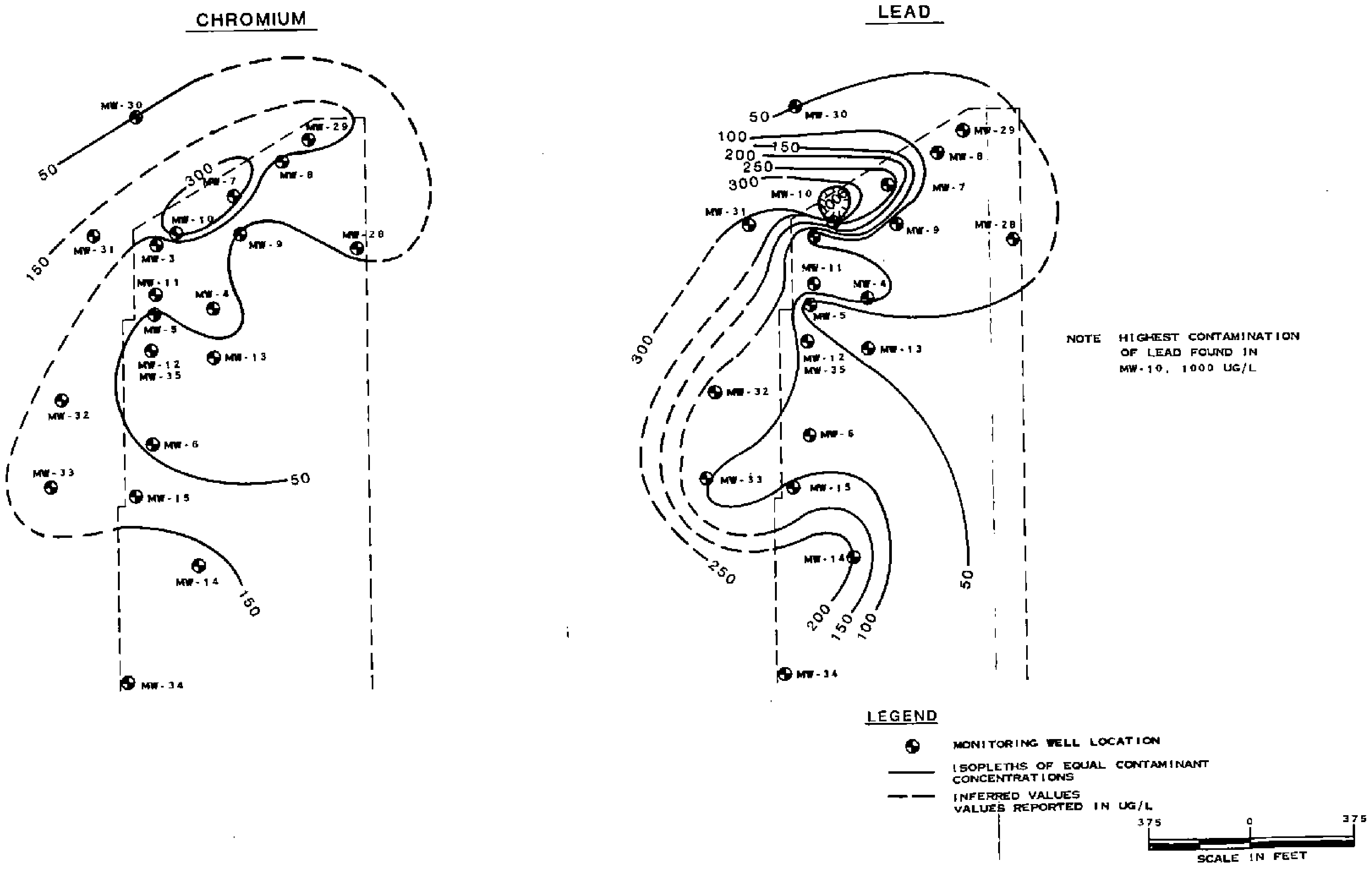
are shown in Figure 4-5. Since most of the detected levels of mercury were below MCLs, and all are very similar in contaminant levels, an isopleth has not been constructed. Arsenic and barium were also identified as contaminants of concern, however, they were less widespread at elevated levels.

Antimony, nickel, silver, and zinc were not identified as constituents of concern but were detected at elevated levels in numerous wells.

MW-2 is screened in a perched water table in the northern part of Dunn Field. USAEHA reports indicate that this well exhibits much greater seasonal variations in water levels than does the Fluvial aquifer. A sample was collected in Phase I, but in Phase II the well was dry and no sample was obtained. Analytical results from this well are given in Table 4-4. Arsenic, lead, cadmium, chromium and nickel were detected at elevated levels in the sample.

In summary, the analytical ground water results indicate that the downgradient wells (west and northwest side of Dunn Field and west of Dunn Field) are contaminated with chlorinated volatile organics and also contain elevated metals. In the east and north, the extent of contamination appears to be defined by "clean" results from MW-28 and MW-30, respectively. However, MW-29 (in the northeast portion of Dunn Field) had low to moderate levels of volatile organic compounds. The southern portion of the plume is approximately defined by low contaminant levels in monitoring wells MW-14 and MW-15. The volatile organic results of the ground water from Dunn Field from both Phase I and Phase II sampling were similar. The minor disrepencies in contaminant levels from Phase I to Phase II could be caused by slight variations in sampling technique, weather or actual fluctuations in contamination. Several sampling episodes will be required before the fluctuations can be evaluated. The level of total metals varied within the range anticipated for this type of analysis. Due to the amount of sediments contained in the sample, total metal results would be expected to fluctuate more than other analytical procedures. Both sets of data agree with the results of the study done by USAEHA

FIGURE 4-5
EXTENT OF ELEVATED METALS IN FLUVIAL AQUIFER
DUNN FIELD
DEFENSE DEPOT, MEMPHIS TENNESSEE



NOTE HIGHEST CONTAMINATION OF LEAD FOUND IN MW-10, 1000 UG/L

TABLE 4-4
POSITIVE RESULTS IN GROUND WATER
DUNN FIELD - PERCHED WATER TABLE
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	MCL	STATE OF TN	PHASE I MW2
NONHALOGENATED VOLATILES (ug/l)			
Acetone	--	NA	3J
NONHALOGENATED SEMIVOLATILES (ug/l)			
bis(2-Ethylhexyl) phthalate	--	1500	5J
VOLATILE METALS (ug/l)			
Arsenic	50	50	100
Lead	50	50	186N
Mercury	2	2	.5
Selenium	--	--	90
NONVOLATILE METALS (ug/l)			
Antimony	--	NA	90N
Barium	1000	1000	475N
Cadmium	10	0.0037	12N
Chromium (a)	50	50	118N
Copper	1000	1000	127N
Nickel	--	13.4	48N
Zinc	5000	5000	299N

Shaded numbers indicate levels equal to or above MCL or State of TN guidelines.

MCL - SDWA Maximum Containment Level

State of TN - State of Tennessee Guidance Levels (non-enforceable)

(a) No distinction between Chromium (III) and Chromium (VI).

J = Estimated value less than the sample quantitation limit, but greater than zero.

N = Spiked sample recovery not within control limits.

NA = Not Available

(USAEHA Ground Water Consultation No. 38-26-0815087, Dec. 1986). The total extent of ground water contamination may not be determined from the available information, but an estimated 75 million gallons of contaminated ground water has been calculated for the known area of contamination. One-dimensional dispersion models have been prepared to calculate the possible western extent of the contaminant plume. These models will be discussed in Section 6 of this report.

Based on the analytical results and the ground water flow direction it appears that the sources of contamination are the burial sites located in Dunn Field. These burial sites were not investigated during this investigation. Therefore, it is not known which sites shown on Figure 4-1 are the actual sources of contamination.

4.2.1.3 Main Installation

4.2.1.3.1 Ground Water Sampling - Ground water samples were collected on the main installation from MW-16, MW-17 and MW-19 through MW-26 during Phase I of the RI. All of the wells are screened in the Fluvial aquifer. MW-18 was inadvertently screened above the saturated portion of the Fluvial aquifer (see subsection 2.2.4), thus no sample was obtained. At the time of Phase I sampling it was thought that MW-27 had a very slow rate of recharge and only a volatile organic compound (VOC) sample was obtained. Additional information was obtained in Phase II, and it was determined that MW-27 was terminated at the top of a clay lens, above the saturated portion of the Fluvial aquifer (See Figure 3-7). In Phase II, no sample was obtained from MW-27 and the VOC sample taken in Phase I probably represents drilling mud that remained in the well and annulus.

Ground water samples were collected again during Phase II from the same monitoring wells along with two additional wells, MW-38 and MW-39, that were installed during Phase II of the RI. Like the other monitoring wells on the main installation, MW-38 and MW-39 are screened in the Fluvial aquifer.

4.2.1.3.2 Main Installation Ground Water Analysis - Analysis of ground water at the main installation in Phase I and Phase II indicate areas of low level chlorinated volatile organic contamination. Total metals, elevated above background levels, were also detected. The analytical results are given in Table 4-5. Contaminants included tetrachloroethene, trichloroethene, carbon tetrachloride and chloroform. Figure 4-6 shows the total volatile organics detected in the ground water of the Fluvial aquifer on the main installation. This section provides a discussion about the level and extent of the ground-water contaminants detected at the main installation and the possible sources.

One of the contaminated areas is located in the southwest portion of DDMT. Phase I and Phase II analytical results show that three wells in this area, MW-21, MW-22, and MW-39, are contaminated with low levels of tetrachloroethene and trichloroethene. Surface spills of paints and solvents that have been used at DDMT could be the contaminant source. Analysis of surface soils (subsection 4.2.2.2) found tetrachlorethene and trichlorethene at Building 770, Building 757 and Building 629. It is likely that all of these sources are contributing to ground-water contamination on the main installation.

The second area of contamination is located in the southeast portion of DDMT in close proximity to Lake Danielson. Phase I and Phase II samples from MW-25 and MW-26 show low level contamination of tetrachloroethene. MW-26 also had low levels of trichloroethene, carbon tetrachloride and chloroform present in both Phase I and Phase II episodes. MW-25 had very low levels of carbon tetrachloride in Phase I, but failed to test positive in Phase II. The contaminant source may be related to the areas mentioned above, but a more likely source could be Building T-273. Surface soil samples collected from this area tested positive for tetrachlorethene and trichlorethene.

TABLE 4-5
POSITIVE RESULTS IN GROUND WATER
MAIN INSTALLATION - FLUVIAL AQUIFER
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	DATE	Background Well MW16	MCL	STATE OF TN	MW17	MW19	MW20	MW21	MW22	MW23	MW24	MW25	MW26	MW38	MW39
HALOGENATED VOLATILES (ug/l)															
Carbon Tetrachloride	PHASE I	--	5	5	--	--	--	--	--	--	--	2J	5J	--	--
	PHASE II	--			--	--	--	--	--	--	--	--	5	--	--
Chloroform	PHASE I	--	100(a)	0.19	--	--	--	--	--	--	--	--	1J	--	--
	PHASE II	--			--	--	--	--	--	--	--	--	2J	--	--
Methylene chloride	PHASE I	--	--	1500	--	--	--	--	--	--	--	--	1BJ	--	--
	PHASE II	--			--	--	--	--	--	--	--	--	--	--	--
Tetrachlorethene	PHASE I	--	5	0.8	--	--	--	39	--	--	--	8	10	--	--
	PHASE II	--			--	--	--	15	2J	--	--	7	5	--	1J
Trichloroethene	PHASE I	--	5	5	--	--	--	--	5J	--	--	--	3J	--	--
	PHASE II	--			--	--	--	2J	11	--	--	--	3J	--	9
NONHALOGENATED VOLATILES (ug/l)															
Acetone	PHASE I	3J	--	NA	3J	--	4J	2J	3J	3J	3J	2BJ	4J	--	--
	PHASE II	--			--	--	--	--	--	--	--	--	--	--	--
NONHALOGENATED SEMIVOLATILES (ug/l)															
Di-n-butyl phthalate	PHASE I	--	--	NA	--	--	3J	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	--	--	--	--	--	--	--	--
Di-n-octyl phthalate	PHASE I	2J	--	NA	--	--	7J	--	--	4J	--	--	3J	--	--
N-Nitrosodiphenylamine	PHASE I	2J	--	0.049	--	--	--	3J	3J	--	2J	.5J	--	--	--
Phenol	PHASE II	--	--	--	--	--	--	--	--	--	--	--	--	--	3J
bis(2-Ethylhexyl) phthalate	PHASE I	5J	--	1500	3J	5J	12J	--	4J	8J	5J	--	9J	--	--
	PHASE II	3J			--	2J	--	--	--	--	--	--	--	--	54

TABLE 4-5
POSITIVE RESULTS IN GROUND WATER
MAIN INSTALLATION - FLUVIAL AQUIFER
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	DATE	Background Well MW16	MCL	STATE OF TN	MW17	MW19	MW20	MW21	MW22	MW23	MW24	MW25	MW26	MW38	MW39
VOLATILE METALS (ug/l)															
Arsenic	PHASE I	55	50	50	324	38	--	--	--	--	--	--	--	--	--
	PHASE II	40			--	--	70	60	200	120	--	--	50	--	--
Lead	PHASE I	79	50	50	205	42	79*	97*	201*	334*	152*	128	--	--	--
	PHASE II	80			--	--	50	110	220	140	--	70	50	--	70
Mercury	PHASE I	--	2	2	6.8	--	.9N	1N	1.4N	1.6N	.4N	1.7	.4N	--	--
	PHASE II	--			--	--	--	1	5	1	--	--	--	--	--
NONVOLATILE METALS (ug/l)															
Antimony	PHASE I	--	--	NA	47B	--	--	--	--	--	--	--	--	--	--
	PHASE II	--			--	--	--	--	--	--	--	60	50	--	--
Barium	PHASE I	218	1000	1000	603	296	247	229	343	567	167	1960	908	--	--
	PHASE II	410			190	310	290	240	380	390	81	410	380	80	130
Cadmium	PHASE I	--	10	0.0037	8	6	11N*	7N*	14N*	15N*	18N*	--	--	--	--
	PHASE II	--			--	--	--	--	7	8	--	--	--	--	--
Chromium (b)	PHASE I	55	50	50	408	17	100	171	616	306	31	337	150	--	--
	PHASE II	50			10	20	90	110	560	150	--	40	30	--	20
Copper	PHASE I	198	1000	1000	322	108	242	148	326	1570	88	209	268	--	--
	PHASE II	180			60	80	130	90	160	230	50	20	40	--	30
Nickel	PHASE I	29	--	13.4	238	--	35	49	110	73	26.	125	58	--	--
	PHASE II	40			--	--	40	40	100	40	--	--	--	--	--
Zinc	PHASE I	116	5000	5000	910	59	150	242	594	413	193	408	400	--	--
	PHASE II	180			180	53	140	190	750	290	170	120	120	23	86

TABLE 4-5
POSITIVE RESULTS IN GROUND WATER
MAIN INSTALLATION - FLUVIAL AQUIFER
DEFENSE DEPOT MEMPHIS TENNESSEE

Shaded numbers indicate levels equal to or above MCL or State of TN guidelines.

MCL - SDWA Maximum Containment Level

State of TN - State of Tennessee Guidance Levels (non-enforceable)

(a) Total trihalomethanes

(b) No distinction between Chromium (III) and Chromium (VI).

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL) but greater than the Instrument Detection Limit (IDL).

B (Organic) = Found in method blank.

J = Estimated value less than the sample quantitation limit but greater than zero.

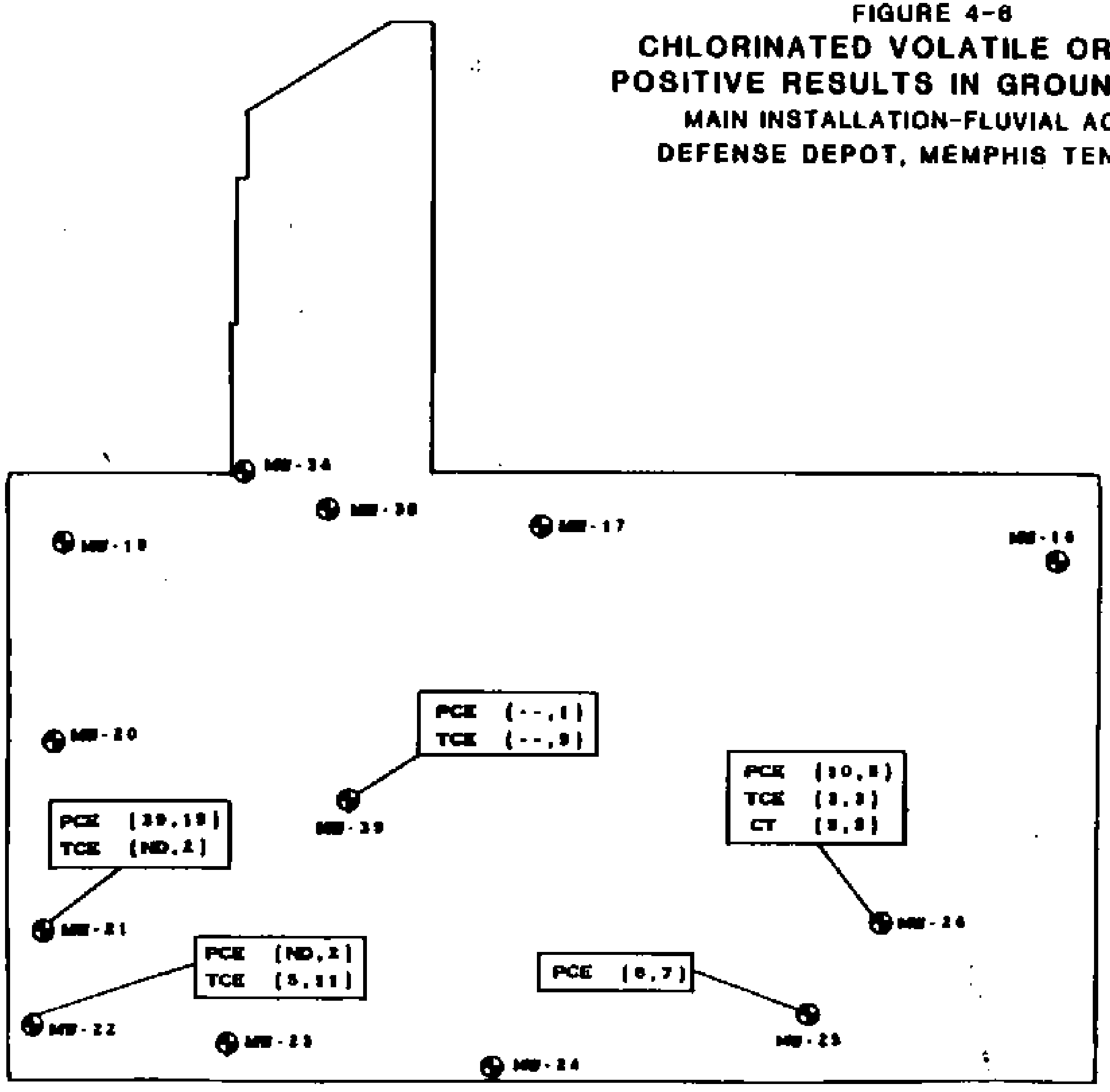
N = Spiked sample recovery not within control limits.

* = Duplicate analysis not within control limits.

-- = Not detected.

NA = Not Available.

FIGURE 4-6
CHLORINATED VOLATILE ORGANICS POSITIVE RESULTS IN GROUND WATER
MAIN INSTALLATION-FLUVIAL AQUIFER
DEFENSE DEPOT, MEMPHIS TENNESSEE



LEGEND

PCE	TETRACHLORETHENE
TCE	TRICHLORETHENE
CT	CARBON TETRACHLORIDE
ND	NOT DETECTED
--	NOT SAMPLED
(39,15)	(PHASE I, PHASE II)

VALUES GIVEN IN UG/L

LAW ENVIRONMENTAL, INC.

Chromium, lead, and mercury were detected at elevated levels over a widespread area. The highest levels were: chromium (616 ug/l, MW-22), lead (334 ug/l, MW-23), and mercury (6.8 ug/l, MW-17). Arsenic and barium were also identified at elevated levels, however, their presence was less widespread.

Other metals were also identified at elevated levels. These included antimony, cadmium, copper, nickel, and zinc.

4.2.1.4 Memphis Sand Ground Water Analysis - To determine if any contamination was migrating through the confining unit into the Memphis Sand aquifer, two Type III monitoring wells were screened into the aquifer during Phase II. MW-36 is located in the southeast corner of Dunn Field. This well was placed upgradient from any suspected contamination. MW-37 is located west of Dunn Field, on Rozelle Street, within the extent of the Fluvial aquifer's contaminant plume. Neither of the two wells contained detectable levels of chlorinated volatile organics and only tested positive for low levels of metals. Positive results for these two samples are given in Table 4-6.

MW-37 did contain acetone at a high level (3500 ug/l). The source of the acetone in the Memphis Sand aquifer is unknown, but does not appear to have originated from Dunn Field. Acetone was not a contaminant of concern in the Fluvial aquifer and there are no recorded buried containers of acetone in Dunn Field. An additional elevated acetone level was detected in a soil sample collected from a soil test boring (STB-6) located in Dunn Field. This sample was obtained approximately 16 feet into the confining unit and had 1100 ug/kg of acetone. See subsection 4.2.2.1.2 for discussion of this sample.

One sampling episode (Phase II) from two wells (MW-36 and MW-37) supplies a limited amount of data. However, a general conclusion can be made that the organic contaminants detected in Fluvial aquifer have not migrated through the confining unit into the

TABLE 4-6
POSITIVE RESULTS IN GROUND WATER
MEMPHIS SAND AQUIFER
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	MCL	STATE OF TN	PHASE II MW36	PHASE II MW37
NONHALOGENATED VOLATILES (ug/l)				
Acetone	--	NA	--	3500D
2-Butanone	--	860	4J	--
4-Methyl-2-pentanone	--	NA	--	8J
NONHALOGENATED SEMIVOLATILES (ug/l)				
N-Nitrosodiphenylamine	--	0.049	3BJ	--
NONVOLATILE METALS (ug/l)				
Barium	1000	1000	410	380
Chromium (a)	50	50	--	20
Copper	1000	1000	10	20
Nickel	--	13.4	--	20
Zinc	5000	5000	73	150

Shaded areas indicate levels equal to or above MCL or State of TN guidelines.

MCL - SDWA Maximum Containment Level

State of TN - State of Tennessee Guidance Levels (non-enforceable)

(a) No distinction between Chromium III and Chromium VI.

D = identified in an analysis at a secondary dilution factor.

J = Estimated value less than the sample quantitation limit, but greater than zero.

-- = Not detected.

NA = Not Available.

Memphis Sand aquifer at detectable levels in Dunn Field. It can not be concluded that this will not occur, or has not already occurred, in areas not investigated during the RI.

4.2.1.5 Quality Control - Ground Water - Quality control (QC) samples collected and analyzed to evaluate ground-water sample data quality consisted of field and laboratory samples. The field QC samples included trip blanks, field duplicates, and rinsates. The laboratory QC samples included method blanks and matrix spikes/matrix spike duplicates (MS/MSDs) for analyses for organic constituents. Surrogate recoveries, where applicable, were also evaluated.

Field duplicate results are only evaluated when the values reported are at least five times the detection limit. Relative percent differences (RPDs) are calculated and used to evaluate sampling precision. Many of the positive results are less than this. Therefore, an evaluation of the MS/MSD data is helpful to assess the precision of the data. The MS/MSD evaluations are presented with the laboratory quality control results discussion. Rinsate samples were collected to aid in the evaluation of the quality of the data and to ascertain if contamination was present due to inadequate cleaning of the sampling equipment.

Some results were eliminated from the data as false positives. N-Nitrosodiphenylamine was found in several method blanks. It is a rare chemical used as rubber vulcanization retardant (Merck Index, 1983), has a poor GC/MS response factor, and is likely to be a laboratory artifact. Also identified as false positives were Bis (2-ethyl hexyl) phthalate found in method blanks (possibly from laboratory use of plastic surgeon gloves) and methylene chloride, acetone, 2-butanone and hexanone (common laboratory solvents), which were all detected in several method blank analyses. Data for these compounds are discounted and will generally not be discussed.

4.2.1.5.1 Quality Control - Dunn Field Ground Water - During Phase I, a field duplicate was collected at monitoring well MW-9, and was labelled MW-9QCD. During Phase II, monitoring well MW-9 was again the site chosen for the collection of the field duplicate sample. Most of the results for the field duplicate samples are below the concentrations needed to properly evaluate RPDs. A few positive values reported are for metal constituents. All of the RPDs for the sample and associated field duplicate are less than 35% for the metals analyses for Phase I and Phase II, except barium from the Phase II duplicate sample. The few calculable RPDs for organic constituents were less than 20%. Evaluation of these results indicates that sampling precision was generally good for the samples collected during Phase I and Phase II sampling at Dunn Field.

The Phase I rinsate sample was taken prior to the sampling of monitoring well MW-9 and was labelled MW-9QCR. Positive results for the organic contaminants acetone, methylene chloride, bis (2-ethyl hexyl) phthalate and toluene are discounted as laboratory artifacts because they were detected concentrations that are less than the method reporting limits and were found in several method blanks. As no other constituents were detected in this rinsate, decontamination procedures utilized during this sampling effort are considered to have been satisfactory and cross contamination between monitoring wells is not likely.

The Phase II rinsate (MW-29R) was reported to contain copper at 10 ug/l and zinc at 47 ug/l. The concentration for copper is at the method detection limit and therefore should not affect the copper results. The zinc value is greater than five times the detection limit and affects the associated zinc results. The Phase II zinc results less than 500 ug/l from the Dunn Field area should be flagged as estimated values. However, the results of these rinsates generally indicate that proper decontamination procedures were used during Phase II sampling effort.

For the sample collected from monitoring well MW-10, MS/MSD were prepared and analyzed during Phase I and II. Phase I recoveries were outside of the control limits for antimony, barium, cadmium, chromium, copper, lead, nickel, and zinc. Post-digestion spike recoveries were all within the control limits, indicating that the laboratory procedures produced the poor MS/MSD results. Phase II MS/MSD data were within the control limits for all metals except silver, selenium, and antimony. Post-digestion spike recoveries for silver were also poor, suggesting a matrix interference for this metal.

The MS/MSD data for the organic constituents were generally within control limits for the Phase I and Phase II sampling episodes. The RPDs for 4-nitrophenol (30%) and pentachlorophenol (50%) were outside of the control limits for Phase I. The recoveries for both of these compounds were at the low end of the acceptable range. Phase II MS/MSD recoveries of 1,1-dichloroethene were outside of the control limits.

Most of the surrogate recoveries were within the control limits specified for the methods. The five of twenty surrogate recoveries for 2-fluorophenol were out-of-control limits for the Phase I samples. This may indicate a negative bias for phenolic compounds for the samples from monitoring wells MW-2, MW-6 and MW-8. In addition, the recovery of the surrogate 2,4,6-tribromophenol for the Phase I samples was low. This suggests a negative bias for phenolic compounds in the samples from monitoring wells MW-2 and MW-6.

The method blanks for all of the analyses performed for Phase I and II samples did not show any indications of major problems in the laboratory sample preparation and analysis. Low concentrations of common laboratory contaminants were noted in many of the method blanks. These values were generally less than the method reporting limits and are not considered to effect data values significantly. However, some constituents detected in field samples are discounted because of their presence in the method blanks.

4.2.1.5.2 <u>Quality Control - Main Installation Ground Water</u> - A field duplicate was collected from the Main Installation from monitoring well MW-17 in both Phase I and Phase II. The only positive results useful for the calculation of RPDs were from the metals analyses. RPDs outside of control limits were obtained during Phase I for arsenic and barium (36% and 89%, respectively). For Phase II, the RPDs for barium and zinc were 125% and 59%, respectively.

The data for the trip blanks and the rinsates did not yield any positive results. Any positive results reported for field samples are therefore not due to shipping and handling exposures for volatile organics or from decontamination procedures for any parameter. The method blanks generated for all the parameters for Phase I and Phase II analyses did not yield any positive results.

The sample from monitoring well MW-24 was chosen for MS/MSD preparation for the Phase I and Phase II sampling effort. The Phase I MS/MSD data suggests that laboratory bias for the metals arsenic, antimony, cadmium, mercury, selenium and silver was present; recoveries were outside the control limits for these metals. The post-digestion recoveries for all of these parameters were within acceptable ranges, indicating that loss during preparation occurred. All of the RPD values were less than 35%, indicating acceptable precision was obtained.

The Phase II MS/MSD results were within control limits for all metals except silver, arsenic, antimony and selenium. The recoveries for these metals were low. The post-digestion recoveries were all within the acceptable range except for silver. All of the RPD values were again less acceptable at less than 35%. A matrix interference may be the cause of the poor recoveries for silver only.

The matrix spike recoveries for all of the organic analyses for Phase I and Phase II were within acceptable ranges. All of the RPD values for the organic analyses were less than 20%. The surrogate recoveries for all of the samples of Phase I and Phase II for all of the organic analyses were within acceptable ranges. The accuracy of the organic analyses for Phase I or Phase II for the Main Installation area appears to be good.

4.2.1.5.3 Quality Control - Memphis Sand Aquifer - A comparison of the results for acetone for monitoring well MW-37 and its field duplicate MW-37QCD (3500 ug/l and 330 ug/l, respectively; RPD = 6%) indicates that the contamination levels are real and are not due to field or laboratory contamination. The RPDs for the other parameters were all within limits except for zinc.

Further evidence that suggests that the reported level of acetone contamination in monitoring well MW-37 is a true value is that the associated rinsate (MW-3QCR) was free of acetone. Rinsate MW-29R contained measurable levels of zinc, and the zinc data for the field samples associated with this rinsate should be flagged as estimated, as discussed in Section 4.4.2.1. The trip blank (BX-9) shipped with the sample from monitoring well MW-37 did not contain acetone or any other volatile organic. The trip blank TB-X3 also did not produce any positive results for volatile organic compounds.

The initial analyses of samples MW-37 and MW-37QCD were accomplished within holding times and did not show the presence of chlorinated volatile organics. However, the acetone level saturated the instrument so that an exact value for acetone for the undiluted sample could not be determined. These samples were reanalyzed after the holding time had expired at a secondary dilution factor. The results reported should be flagged as estimated. The associated method blanks did not have any positive results for any of the analyses performed except zinc. This element was detected in the method blank at approximately six times the reported detection level concentration.

The MS/MSD analyses for MW-37 was performed on MW-32. The sample MW-36 was designated for preparation as an MS/MSD. The metals recoveries for both spiked samples showed problems. The MS/MSD for MW-36 has low recoveries for silver and antimony. The antimony recoveries for MW-36MS and MW-36MSD were only 56% and 46%, and silver only 52% and 50%, respectively. The post-digestion spike results were 92% for antimony and 48% for silver. These results indicate that the silver and antimony values reported for MW-36 are biased low. The matrix spike sample of MW-32 gave low recovery results for silver, antimony, chromium, arsenic, selenium and zinc. The post-digestion spike results were acceptable for all of the elements listed, except for silver. All of the elements listed as low recovery for the MW-32 spike reflect low recovery values for the MW-37 sample results. The RPD values for both MS/MSDs were within acceptable limits.

The organic compound MS/MSD recoveries for MW-32 and MW-36 were within control limits, with the following exceptions. The MS/MSD for MW-32 did not yield acceptable recoveries for the following compounds: phenol, 2-chlorophenol and 4-chloro-3-methylphenol. All of these compounds were below the acceptable range for recoveries. Therefore, the acid extractable compounds for MW-37 may have results that may be biased low. The recovery of all the other organic spiked compounds for both MW-32 and MW-36 were within acceptable ranges. The RPD values for both MS/MSDs were within limits.

Surrogate recoveries for MW-32 matrix spike and duplicate samples were all within quality control limits except for phenol-d5, 2-fluorophenol and 2,4,5-tribromophenol. These surrogates were all below the acceptable ranges and may explain the low spike recoveries. Sample MW-37 surrogate recoveries were all within the quality control limits.

4.2.2 Soils

Numerous soil samples were collected and analyzed during Phase I and Phase II of the RI. Soil samples were collected from surface areas and from the subsurface. The following subsections discuss the analytical results.

All soil samples (surface and subsurface) were analyzed for volatile organics (USEPA Method 8240), semi-volatiles (USEPA Method 8250), pesticides/PCBs (USEPA Method 8080), total metals (USEPA Method 3050/6010), and mercury (USEPA Method 7470). Phase I subsurface soil samples were analyzed for Extraction Procedures Toxicity (EP-TOX) metals using USEPA Method 1310. Subsurface soil samples from Phase II were not analyzed for EP-TOX (as specified in the Scope of Work). All USEPA methodology listed above are found in USEPA SW-846, 3rd Edition.

4.2.2.1 Subsurface Soils

4.2.2.1.1 Subsurface Soil Sampling - Phase I - Phase I subsurface soil samples were obtained utilizing a CME continuous sampler during the advancement of five shallow (80 - 150 feet) stratigraphic soil test borings, STB-1 through STB-5. Three samples were taken from each boring. The selection of the uppermost sample in each boring was based on material discoloration, presence of organic vapors (measured with a Foxboro century 128 OVA) and/or proximity to potential contamination sources. The second sample was to be taken from the top of the saturated zone of the Fluvial aquifer and the third from within the saturated portion of the aquifer. STB-1 and STB-2 are located in Dunn Field and STB-3 through STB-5 are on the main installation. The protocol for sample selection just mentioned was achieved in STB-1, STB-2 and STB-3. Boring STB-4 and STB-5 did not encounter the saturated portion of the Fluvial aquifer and all samples from these two borings were collected from the unsaturated portion of the aquifer. The three samples were labeled 1, 2 and 3 in each boring (example STB-1-1, STB-1-2 and STB-1-3).

Subsurface Soil Analysis - Phase I - Very low levels of contamination were detected in the subsurface soils collected during Phase I of the RI. The analytical results are given in Table 4-7 and the following paragraphs describe the results for each boring. It is important to note that metal analysis for the Phase I samples was done using the EP-TOX method. This method provides information on the level of the constituent that is available for leachate. The only metals detected in the subsurface soils collected in Phase I were low levels of barium and cadmium.

Low levels of methylene chloride were detected in all of the samples. Since it was detected in the method blanks, this probably represents a laboratory contaminant.

STB-1 is located along the northern boundary of Dunn Field. No significant contamination was detected in the samples collected from this boring. Samples STB-1-1 and STB-1-2 were collected from the unsaturated portion of the Fluvial aquifer and STB-1-3 from the saturated portion. STB-1 is located downgradient from MW-8 and MW-7, and upgradient from MW-10. Significant ground-water contamination was detected in each of these wells (subsection 4.2.1.2.2). A vertical, or near vertical, migration pathway from the contaminant source to the ground water is a reasonable assumption for the type of soils encountered at DDMT. This signifies that the contaminants are not moving through the unsaturated portion of the aquifer within the area of STB-1. The non-significant contaminant levels detected from the sample collected from the saturated zone also indicates that the contaminants are not partitioning to the soil matrix within the aquifer, but are staying in solution.

STB-2 is located in the central portion of Dunn Field very near MW-13 and upgradient from MW-12. Low levels of ground-water contamination was detected in MW-13. MW-13 approximately defines the eastern extent of the ground-water contaminant plume. The only

TABLE 4-7
POSITIVE RESULTS IN SUBSURFACE SOILS
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I														
		STB-1-1	STB-1-2	STB-1-3	STB-2-1	STB-2-2	STB-2-3	STB-3-1	STB-3-2	STB-3-3	STB-4-1	STB-4-2	STB-4-3	STB-5-1	STB-5-2	STB-5-3
Depth of Sample:		25.5'	62.5'	73.5'	10.0'	17.5'	67.5'	21.0'	26.0'	63.5'	19.0'	26.0'	102.0'	16.0'	78.0'	83.0'
HALOGENATED VOLATILES ug/kg																
Chloroform	70	--	8	--	--	--	--	--	--	--	--	--	--	--	--	--
Methylene chloride	8600	16B	19B	10B	7B	6B	12B	3J	3J	3J	2J	16B	19B	13B	21B	12B
NONHALOGENATED VOLATILES ug/kg																
2-Butanone	7200	--	--	--	--	--	--	--	--	--	18	--	--	--	--	--
Acetone	590	57	43	20	24B	12B	13B	--	--	30	31	8J	17	18	14B	14
Toluene	14,400	--	--	--	--	--	--	--	--	--	1J	--	--	--	--	--
NONHALOGENATED SEMIVOLATILES ug/kg																
Benzoic acid	na	--	--	--	--	--	58J	--	--	--	--	--	--	--	--	--
bis(2-Ethylhexyl) phthalate	15,000	1200	1200	760J	1100	1900	1600	2000B	670B	910B	610B	1500B	560BJ	450B	440B	320BJ
Di-n-butyl phthalate	na	--	--	--	--	210BJ	100BJ	140BJ	170BJ	120BJ	--	--	--	--	--	--
N-Nitrosodiphenylamine	12.8 - 32	--	--	--	43JB	--	--	--	--	--	--	44J	--	--	--	--
Polynuclear Aromatic Hydrocarbons (PAHs)																
Fluoranthene	-	--	--	--	--	51J	47J	--	--	--	--	--	--	--	--	--
Pyrene	-	--	--	--	--	40J	40J	--	--	--	--	--	--	--	--	--
TOTAL PAHs	0.0028	--	--	--	--	91	87	--	--	--	--	--	--	--	--	--
NONVOLATILE METALS	EPTOX Standard															
Barium (EPTOX in ug/l)	100,000	15	25	58	--	--	--	16	18	49	--	--	25	--	10	--
Cadmium (EPTOX in ug/l)	1000	--	12	5	20	6	--	7	--	--	--	--	--	--	--	--

TABLE 4-7
POSITIVE RESULTS IN SUBSURFACE SOILS
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER Depth of Sample:	STATE OF TN	PHASE II											
		STB-6-1 71.5'	STB-6-2 76.0'	STB-6-3 86.0'	STB-6-4 181.0'	STB-7-1 71.0'	STB-7-2 76.0'	STB-7-3 91.0'	STB-7-4 170.0'	STB-8-1 92.0'	STB-8-2 97.0'	STB-8-3 127.0'	STB-8-4 217.0'
HALOGENATED VOLATILES ug/kg													
1,1,2,2-Tetrachloroethane	1300	240E	12	4J	13	--	--	--	--	--	--	--	--
1,2-Dichloroethane	40	--	--	--	--	--	--	--	--	--	--	--	11
1,2-Dichloroethylene	350	26	--	13	7	--	--	--	--	--	--	--	--
Methylene chloride	8600	21B	16B	6BJ	5JB	5BJ	11B	8B	8	10B	7B	5BJ	5BJ
Trichloroethene	70	4J	--	1J	--	--	--	--	--	--	--	--	--
NONHALOGENATED VOLATILES ug/kg													
2-Butanone	7200	--	--	15	--	--	--	--	--	3BJ	2BJ	2J	--
Acetone	590	210	90	1100D	74	250	86	31	9J	60B	40B	45	28
Toluene	14,400	1J	1J	5J	--	--	5J	--	--	--	3J	--	2J
NONHALOGENATED SEMIVOLATILES ug/kg													
bis(2-Ethylhexyl) phthalate	15,000	500B	280BJ	6400B	590B	1600B	160BJ	1900B	230BJ	520B	250BJ	350BJ	270BJ
Di-n-butyl phthalate	na	--	--	--	--	--	--	78J	--	--	--	--	--
N-Nitrosodiphenylamine	12.8 - 32	--	--	--	--	--	--	--	--	85BJ	55BJ	5BJ	88BJ
PESTICIDES ug/kg													
beta-BHC	2.4 - 6.1	--	--	14Z	--	--	--	--	--	--	--	--	19Z
VOLATILE METALS mg/kg													
Lead	5	6	7	5	9	11	9	7	--	--	6	--	7

TABLE 4-7
POSITIVE RESULTS IN SUBSURFACE SOILS
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER Depth of Sample:	STATE OF TN	PHASE II STB-6-1 71.5'	 STB-6-2 76.0'	 STB-6-3 86.0'	 STB-6-4 181.0'	 STB-7-1 71.0'	 STB-7-2 76.0'	 STB-7-3 91.0'	 STB-7-4 170.0'	 STB-8-1 92.0'	 STB-8-2 97.0'	 STB-8-3 127.0'	 STB-8-4 217.0'
NONVOLATILE METALS mg/kg													
Barium	100	20.7	39.1	42.5	72.7	39.1	51.6	68.6	10.6	3.6	26.1	2.9	14.2
Cadmium	1	--	--	--	--	--	--	--	0.8	--	--	--	--
Chromium (a)	5	9	11	4	5	12	11	8	4	1	8	2	6
Copper	na	3	3	4	5	2	6	8	2	3	5	3	6
Nickel	20	2	--	5	3	3	3	7	3	--	6	--	4
Zinc	na	15.7	11.4	31.2	47.2	12.1	41.3	31	11.9	14	20.5	3.8	11.6

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na – Not Available

State of TN values are only To Be Considered (TBC) guidelines. These are not enforceable clean up levels.

EPTOX Standard - Source: 40 CFR 261 (Appendix 2)

(a) No distinction between Chromium (III) and Chromium (VI).

B (Organic) – Found in method blank.

D – Identified in an analysis at a secondary dilution factor.

E – Concentration exceeds the calibration range of the GC/MS instrument for this specific analysis.

J – Estimated value less than the sample quantitation limit, but greater than zero.

Z – Matrix interference; compound not positively identifiable.

-- = Not detected.

significant contamination detected in STB-2 are the PAHs detected in samples collected from the top of, and within, the saturated zone of the Fluvial aquifer (STB-2-2 and STB-2-3). Significant PAH contamination was detected in surface soil sample SS-7 (subsection 4.2.2.2.2.1), which was collected from an old burn area approximately 300 feet northeast of STB-2. This could suggest that PAH contamination is leaching from the surface and reaching the water table in the Dunn Field area.

STB-3 is located on the main installation in the western portion of the DRMR yard. No significant contamination was detected in the samples collected from this boring. STB-3 is located downgradient from MW-17 and upgradient of MW-38. No significant ground-water contamination was detected in either of the monitoring wells.

STB-4 is located on the main installation in an area previously used as a PCP dip vat area. This activity is no longer in operation and contaminated soils have been excavated and backfilled to a depth of 10-feet. The water table was not encountered during the advancement of this boring and the three samples were collected from the unsaturated portion of the Fluvial deposits. No significant contamination was detected in the samples. The closest monitoring well to STB-3 is MW-39. Only low levels of organic contamination were detected in this well.

STB-5 is located in the southwest corner of the main installation, southwest of Building 1088. This boring did not encounter the water table and the samples were collected from the unsaturated zone of the aquifer. No significant contamination were detected in the samples. Low levels of organic contamination was detected in the ground water at the two closest wells, MW-21 and MW-22. Surface soil samples collected from the area surrounding Building 1088 contained significant PAH, pesticide and PCB contamination (subsection 4.2.2.2.2). The lack of detectable contamination in

STB-5 could suggest one of two things; (1) that the surface contamination is not leaching to the subsurface environment or (2) STB-5 is not in the leachate's pathway.

4.2.2.1.2 Subsurface Soil Sampling - Phase II - Three deep (220 feet) stratigraphic soil test borings (STB-6 through STB-8) were advanced and sampled during Phase II of the RI. Four samples were collected from each boring from split spoon samples. These were labeled in the same manner as was done in Phase I. The samples from the borings were selected to correspond to: (1) the top of the confining unit (i.e. the bottom of the Fluvial aquifer); (2) and (3) within the confining unit; and (4) the top of the Memphis Sand aquifer.

During advancement of the deep borings, the Fluvial aquifer was not cased prior to drilling through the confining unit. Bentonite drilling mud was used to seal the sides of the borings and retard migration of the contaminated ground water in the Fluvial aquifer from entering into lower depths of the boring.

Subsurface Soil Analysis - Phase II - As mentioned above, the selection of samples was different in Phase II than what was done in Phase I of the RI. Phase II results also differ in that the EP-TOX method was not used for metal analysis. In Phase II, the metals lead and chromium were the only ones detected at significant levels. The following paragraphs discuss the analytical results for each boring.

STB-6 is located in the northwest corner of Dunn Field, down-gradient from MW-10 and up-gradient of MW-3. Significant organic contamination was detected in the ground-water samples collected from these two monitoring wells. The same organic contaminants found in the ground water were detected in the soil sample collected from the bottom of the Fluvial aquifer (STB-6-1). Low levels of the organic contaminants were also detected in the two soil samples collected from within the confining unit (STB-6-2 and STB-6-3). The same constituent was detected at low levels in the sample collected from the top of the Memphis Sand aquifer (STB-6-4). The presence of the volatile organic constituents within the confining unit may indicate that they have leached from the Fluvial aquifer into, and through, the confining unit. However, the possibility exists that the contaminants were carried down with the drilling mud and contamination of the samples occurred.

An elevated level of acetone (1100 ug/kg) was detected in STB-6-3. This sample was collected approximately 16 feet into the confining unit and has a higher concentration than the samples collected above it. Whether or not this is a true contaminant or a laboratory contaminant is not known. It is also not known if any correlation exists between this soil sample and the high level of acetone detected in the Memphis Sand aquifer in MW-37 (subsection 4.2.1.4).

STB-7 is located at the western boundary of Dunn Field between MW-6 and MW-15. Low levels or volatile organic ground-water contamination was detected in both monitoring wells. These two wells approximately define the southern boundary of ground-water contaminant plume (Figure 4-3). No detectable levels of contamination were found in soils collected from STB-7.

STB-8 is located in the northwestern portion of the main installation. The nearest monitoring wells are MW-19, MW-38 and MW-39. A low level of volatile organic ground-water contamination was detected only in MW-39 (subsection 4.2.1.3.2). STB-8 is located within the area where the top of the confining unit has been eroded. The total thickness of the confining unit in STB-8 is approximately 15-feet (Section 3). Samples STB-8-1 and STB-8-2 were collected from clay (to sandy clay) lenses within the Fluvial deposits and had no detectable contamination. STB-8-3 was taken from within the confining unit and also had no detectable contamination. However, a low volatile organic level was detected in the sample taken from the Memphis Sand aquifer (STB-8-4). Two reasonable explanations as to the Memphis Sand aquifer contamination can be made; (1) A large un-sampled portion of STB-8 exists between STB-8-3 and STB-8-4 (approximately 90 feet). Since the saturated portion of the Fluvial aquifer was not sampled, it is not known if contamination of ground water is present in this area. If ground-water contamination does exist, the levels detected in STB-8-4 may be cross-contamination caused during drilling. (2) The eroded confining unit could be absent in an area near STB-8, thus allowing the ground-water contaminants on the main installation to enter the Memphis Sand aquifer.

4.2.2.2 Surface Soils - The surface soils were investigated during both phases of RI. This was done to determine if past and current activities at DDMT were contributing hazardous material to the environment. Surface soil samples were collected from various areas at DDMT. The location of each sample is given in Table 2-2. The following sections discuss the analytical results. The analytical results are presented, by areas, where samples were obtained. In the areas where the higher levels of contamination were detected, a diagram has been provided showing the sampling site and contaminant levels. All sampling sites are shown on Figures 2-1 and 2-2a through 2-2d. The health risk associated with the detected soil contaminants will be discussed in Section 6.

4.2.2.2.1 Surface Soil Sampling - During Phase I of the RI, surface soil samples were collected from forty different locations (SS-1 through SS-40). SS-6 through SS-9 were collected in the Dunn Field area. The remaining surface soil samples were collected from the main installation of DDMT.

Ten additional surface soil samples (SS-41 through SS-50) were collected during Phase II to aid in defining the extent of contamination (as will be discussed in the following section). Samples were taken in the same areas as those taken in Phase I. One sample, SS-44, was collected in the Dunn Field area and the other nine were taken on the main installation.

4.2.2.2.2 Surface Soil Analysis

4.2.2.2.2.1 Surface Soil Analysis - Dunn Field - Phase I and Phase II sampling results from Dunn Field surface soil samples are given in Table 4-8. The levels of metals detected in Dunn Field are within ordinary reported limits for soils and do not necessarily indicate contamination from DDMT.

Sample SS-6 was taken in close proximity to the old pistol range in Dunn Field. This building is now used for pesticide storage. The pesticides DDT, DDE and dieldrin were detected at elevated levels in this sample.

SS-7 was collected in the old "burn area" at a depth of approximately one foot. Alpha-chlordane was the only pesticide contaminant detected in this sample. High levels of polynuclear aromatic hydrocarbons (PAHs) compounds were detected. The positive results in this sample and field observations show evidence of buried burned material. Polynuclear aromatics are thermally stable and are often artifacts left as residue when oil, gas or organic materials undergo combustion. This could be the source of PAH contamination discovered in STB-2 (subsection 4.2.2.1.1).

Sample SS-8 was collected in the south central portion of Dunn Field at a site that contained drums of what appeared to be used motor oil. The surrounding ground was discolored from the drums contents. This sample contained low levels of volatile organics including: ethylbenzene, 4-methyl,2-pentanone, xylene and toluene. The pesticide dieldrin was also detected in this sample.

TABLE 4-8
POSITIVE RESULTS IN SURFACE SOILS
DUNN FIELD
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I				PHASE II
		SS6	SS7	SS8	SS9	SS44
HALOGENATED VOLATILES (ug/kg)						
Carbon Tetrachloride	70	--	--	--	--	4J
Methylene chloride	8600	44B	45B	10B	8B	8B
NONHALOGENATED VOLATILES (ug/kg)						
2-Butanone	7200	--	--	19	--	--
2-Hexanone	na	--	--	2J	--	--
4-Methyl-2-pentanone	na	--	--	62	--	--
Acetone	590	8J	7J	120	19	20
Ethylbenzene	154,000	--	--	2J	--	--
Toluene	14,400	1J	2J	6	--	1J
Total xylenes	150	--	3J	14	--	--
NONHALOGENATED SEMIVOLATILES (ug/kg)						
2-Methylnaphthalene	na	--	2600	3600J	--	--
4-Methylphenol	na	--	300J	--	--	--
Benzoic acid	na	--	250J	--	--	--
bis(2-Ethylhexyl) phthalate	15,000	940J	--	--	910	1900B
Dibenzofuran	na	--	11000	--	--	--
N-Nitrosodiphenylamine	12.8 - 32	--	1400J	3200J	--	--
Polynuclear Aromatic Hydrocarbons (PAHs)						
Acenaphthene	.	--	19000	--	--	--
Acenaphthylene	.	--	2000J	--	--	--
Anthracene	.	--	21000	--	--	--
Benzo(a)anthracene	.	--	81000D	--	150J	200J
Benzo(a)pyrene	.	--	68000D	--	130J	150J
Benzo(b)fluoranthene	.	--	68000D	--	300J	300J
Benzo(g,h,i)perylene	.	--	48000D	--	150J	--
Benzo(k)fluoranthene	.	--	28000	--	--	--
Chrysene	.	--	87000D	--	210J	250J
Dibenzo(a,h)anthracene	.	--	26000	--	--	--
Fluoranthene	.	--	220000D	--	340J	510J
Fluorene	.	--	18000	--	--	--
Indeno(1,2,3-cd)pyrene	.	--	44000D	--	120J	--
Naphthalene	.	--	4800	--	--	--
Phenanthrene	.	--	160000D	--	180J	300J
Pyrene	.	--	160000D	2600J	270J	510J
Total PAHs	0.0028	--	1,054,800	2600	1850	2220

TABLE 4-8
POSITIVE RESULTS IN SURFACE SOILS
DUNN FIELD
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I				PHASE II
		SS6	SS7	SS8	SS9	SS44
PESTICIDES (ug/kg)						
4,4'-DDE	na	160D	--	--	--	--
4,4'-DDT	.23 - .58	170D	--	--	--	--
alpha-Chlordane	30	--	1500J	--	--	--
Dieldrin	.0048 - .012	330D	--	480D	64D	--
VOLATILE METALS (mg/kg)						
Arsenic	5	21	35	23	21	--
Lead	5	51	122	459	19	2
Mercury	0.2	0.04	0.06	0.06	0.04	--
NONVOLATILE METALS (mg/kg)						
Barium	100	99.2	105	64.5	70.3	65.2
Cadmium	1	1.6	1	1.1	--	--
Chromium **	5	12	32	--	10	27
Copper	na	32	54	24	18	6
Nickel	20	12	14	9	10	7
Sodium	na	--	--	82B	--	--
Zinc	na	102	114	300	45.1	30.2

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

State of TN values are only To Be Considered (TBC) guidelines. These are not enforceable clean up levels.

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

J = Estimated value less than the sample quantitation limit, but greater than zero.

** = No distinction between Chromium III and Chromium VI.

-- = Not detected.

Sample SS-9 was collected in Phase I from the lowest drainage point in the southwest portion of Dunn Field. SS-44 was collected approximately 200 feet northwest of SS-9. PAHs were detected in both samples at approximately the same levels. Dieldrin was detected in SS-9 and toluene was detected in SS-44.

4.2.2.2.2.2 Surface Soil Analysis - Main Installation

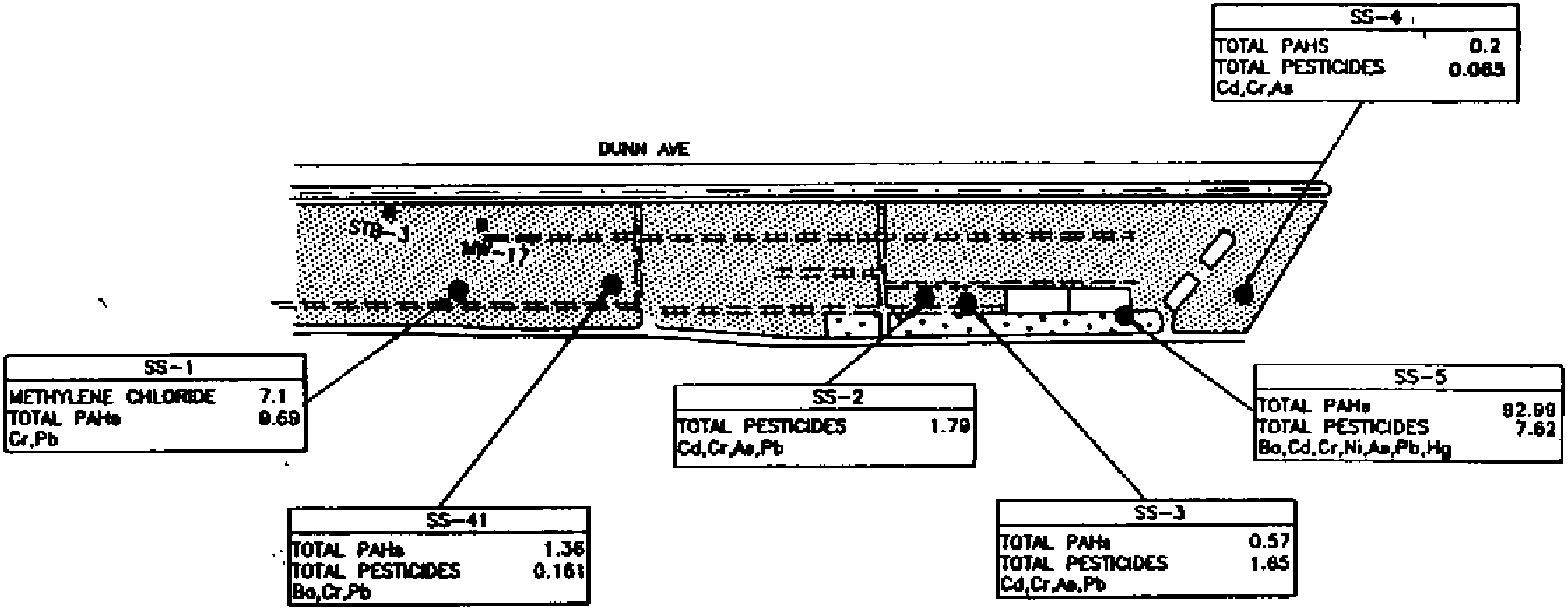
DRMR Yard - Five surface soil samples, SS-1 through SS-5, were collected in the DRMR yard during Phase I and one sample, SS-41, in Phase II. Analytical results of these samples are shown on Figure 4-7 and in Table 4-9. SS-1, SS-5 and SS-41 were the most contaminated samples. All three samples were found to be contaminated with PAHs. SS-1 exhibited higher level of methylene chloride than is usually encountered in a surface soil matrix. SS-5 contained high levels of chromium, copper, lead, silver, and zinc. Zinc, chromium, and lead were detected in SS-41 at high levels along with low levels of the pesticide DDE and toluene.

Building 629 - Building 629 is where toxic, corrosive and oxidizing materials are stored at DDMT. During Phase I of the RI surface soil samples SS-10 and SS-11 were collected adjacent to Building 629. The high levels of contamination reported from these two samples suggested the need for additional sampling in Phase II. Two more samples, SS-42 and SS-43, were collected, several feet away from the building, to provide information on the extent of contamination. Analytical results for these samples are given on Figure 4-8 and in Table 4-10. All of the samples collected from this area are similar in containment nature and levels. PAH contamination is present in all of the samples with SS-42 having the highest level of these constituents. High pesticide (including: DDE, DDT, dieldrin, methoxychlor, gamma-chlordane and beta-BHC) levels were detected in the soil samples from this area along with high levels of metal contamination. The major metal contaminants were lead, zinc (at 1.04% in SS-42), copper and

FIGURE 4-7

SITE LOCATION MAP FOR SURFACE SOILS COLLECTED IN THE DRMR YARD WITH POSITIVE RESULTS EXCEEDING ARARs

DEFENSE DEPOT MEMPHIS, TN



NOTE:

ALL NUMBERS GIVEN ARE IN mg/kg
PAHs = POLYNUCLEAR AROMATIC HYDROCARBONS
METALS LISTED ARE THOSE THAT EXCEED STATE OF TN CRITERIA FOR SOIL.
POSITIVE RESULTS FOR ALL CONSTITUENTS DETECTED IN THE DRMR YARDS SURFACE SOILS ARE GIVEN IN TABLE 1-3.

LEGEND

●	SURFACE SOIL SAMPLING LOCATION
⊕	MONITORING WELL
☐	GRASS
▨	GRAVEL

0 300 600

SCALE IN FEET

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TABLE 4-9
POSITIVE RESULTS IN SURFACE SOILS
DRMR YARD
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I					PHASE II
		SS1	SS2	SS3	SS4	SS5	SS41
HALOGENATED VOLATILES ug/kg							
Methylene chloride	8600	7100B	9B	14B	16B	41B	15B
NONHALOGENATED VOLATILES ug/kg							
Acetone	590	--	--	8J	8J	4J	12
Toluene	14,400	--	8	17	--	2J	13
Total xylenes	150	--	4J	11	--	--	--
NONHALOGENATED SEMIVOLATILES ug/kg							
Benzoic acid	na	840J	--	--	--	230J	--
bis(2-Ethylhexyl) phthalate	15,000	630J	--	--	420J	2900	290BJ
Butyl benzyl phthalate	na	--	--	--	--	4700	--
Dibenzofuran	na	--	--	--	--	290J	--
N-Nitrosodiphenylamine	12.8 - 32	--	--	580J	--	--	--
Polynuclear Aromatic Hydrocarbons (PAHs)							
Acenaphthene	.	--	--	--	--	650J	--
Acenaphthylene	.	--	--	--	--	350J	--
Anthracene	.	6100	--	--	--	2000	--
Benzo(a)anthracene	.	--	--	--	--	8600	120J
Benzo(a)pyrene	.	--	--	--	--	6200	--
Benzo(b)fluoranthene	.	--	--	--	--	8200	210J
Benzo(g,h,i)perylene	.	--	--	--	--	5000	--
Benzo(k)fluoranthene	.	--	--	--	--	7600	--
Chrysene	.	490J	--	--	--	7400	170J
Dibenzo(a,h)anthracene	.	--	--	--	--	2600	--
Fluoranthene	.	--	--	--	100J	15000	370J
Fluorene	.	--	--	--	--	690J	--
Indeno(1,2,3-cd)pyrene	.	--	--	--	--	4000	--
Phenanthrene	.	--	--	--	100J	7700	200J
Pyrene	.	3100	--	570J	--	17000	290J
TOTAL PAHs	0.0028	9,690	--	570	200	92,990	1,380

TABLE 4-9
POSITIVE RESULTS IN SURFACE SOILS
DRMR YARD
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I					PHASE II
		SS1	SS2	SS3	SS4	SS5	SS41
PESTICIDES ug/kg							
4,4'-DDD	na	--	--	--	--	260	--
4,4'-DDE	na	--	290D	250	--	1100D	21
4,4'-DDT	.23 - .58	--	1500D	1400D	--	5900D	130D
beta-BHC	2.4 - 6.1	--	--	--	--	--	10Z
Dieldrin	.0048 - .012	--	--	--	65D	--	--
Endosulfan sulfate	na	--	--	--	--	360	--
VOLATILE METALS mg/kg							
Arsenic	5	4*	18*	28*	33	20	--
Lead	5	66N	96N	129N	22	2420	878
Mercury	0.2	--	0.030	0.030	0.050	0.460	--
NONVOLATILE METALS mg/kg							
Antimony	na	--	--	--	--	22	--
Barium	100	5.8B	43.4	19.2B	97.8	273	311
Cadmium	1	--	4	1.6	1.0	159	0.8
Chromium **	5	15	19	17	14	296	144
Copper	na	246*G	25*G	34*G	26	1590	42
Nickel	20	3.0B	6.0B	3.0B	14	148	6.0
Silver	5	--	--	--	--	2.5	--
Zinc	na	22*	130*	92.4*	80.7	2160	265

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na = Not Available

State of TN values are only To Be Considered (TBC) guidelines. These are not enforceable clean up levels.

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

G = Native analyte > 4 times spike added, therefore acceptance criteria do not apply.

J = Estimated value less than the sample quantitation limit, but greater than zero.

N = Spiked sample recovery not within control limits.

Z = Matrix interference; compound not positively identifiable.

* = Duplicate analysis not within control limits.

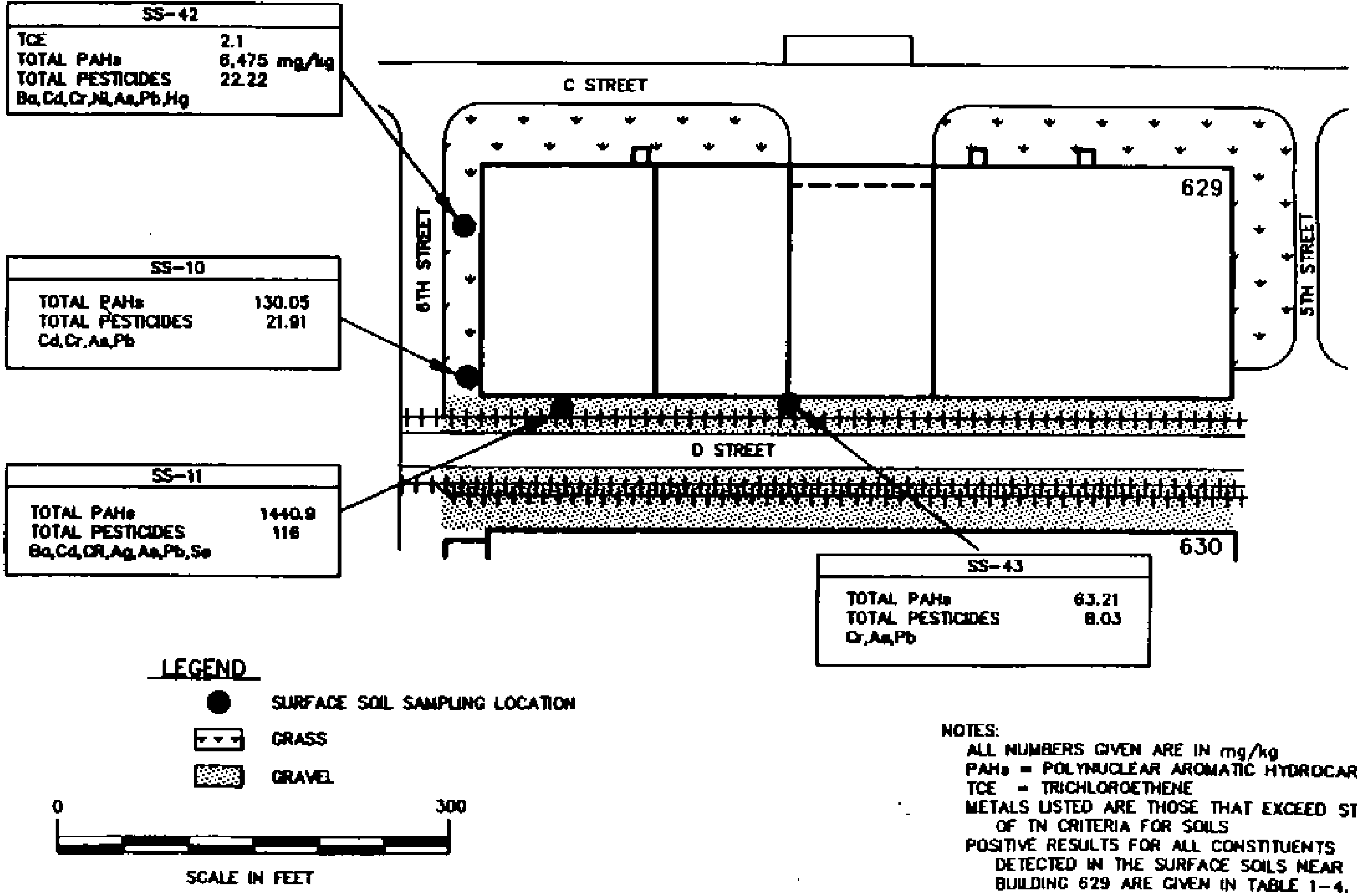
** = No distinction between Chromium (III) and Chromium (VI).

-- = Not detected.

FIGURE 4-8

SITE LOCATION MAP FOR SURFACE SOILS COLLECTED NEAR BUILDING 629 WITH POSITIVE RESULTS EXCEEDING ARARs

DEFENSE DEPOT MEMPHIS, TENNESSEE



LEGEND

- ● SURFACE SOIL SAMPLING LOCATION
- ✓ GRASS
- ▨ GRAVEL

NOTES:
ALL NUMBERS GIVEN ARE IN mg/kg
PAHs = POLYNUCLEAR AROMATIC HYDROCARBONS
TCE = TRICHLOROETHENE
METALS LISTED ARE THOSE THAT EXCEED STATE OF TN CRITERIA FOR SOILS
POSITIVE RESULTS FOR ALL CONSTITUENTS DETECTED IN THE SURFACE SOILS NEAR BUILDING 629 ARE GIVEN IN TABLE 1-4.

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TABLE 4-10
POSITIVE RESULTS IN SURFACE SOILS
BUILDING 629
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I		PHASE II	
		SS10	SS11	SS42	SS43
HALOGENATED VOLATILES ug/kg					
1,1,2-Trichloroethane	1200	--	--	11	--
Methylene chloride	8600	18B	13B	8B	7B
Tetrachloroethene	100	--	--	3J	--
Trichloroethene	70	--	--	2100E	--
NONHALOGENATED VOLATILES ug/kg					
Acetone	590	67	95	24	21
Carbon disulfide	14,400	2J	8	--	--
Toluene	14,400	6J	18	4J	7
HALOGENATED SEMIVOLATILES ug/kg					
Pentachlorophenol	3600	--	--	--	270J
NONHALOGENATED SEMIVOLATILES ug/kg					
bis(2-Ethylhexyl) phthalate	15,000	500J	--	--	1300BJ
Dibenzofuran	na	1300J	9700	24000J	340J
N-Nitrosodiphenylamine	12.8 - 32	510JB	1900JB	--	--
Polynuclear Aromatic Hydrocarbons (PAHs)					
2-Methylnaphthalene	.	500J	2000J	--	--
Acenaphthene	.	2300	20000	64000J	1100J
Acenaphthylene	.	550J	1900J	--	--
Anthracene	.	4400	26000	130000J	1800
Benzo(a)anthracene	.	9500	110000D	970000	5300
Benzo(a)pyrene	.	8300	100000D	450000	5200
Benzo(b)fluoranthene	.	9500	110000D	540000	9300
Benzo(g,h,i)perylene	.	5300	85000D	360000	2900
Benzo(k)fluoranthene	.	10000	92000D	450000	--
Chrysene	.	8900	120000D	620000	6800
Dibenzo(a,h)anthracene	.	1400J	9800	160000	1400
Fluoranthene	.	23000	280000D	860000	9300
Fluorene	.	2600	16000	47000J	880J
Indeno(1,2,3-cd)pyrene	.	4900	72000D	310000	2800
Naphthalene	.	1900	4600	--	130J
Phenanthrene	.	19000	200000D	620000	7000
Pyrene	.	18000	180000D	870000	9300
TOTAL PAHs	0.0028	130,050	1,429,300	6,475,000	63,210

TABLE 4-10
POSITIVE RESULTS IN SURFACE SOILS
BUILDING 629
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I		PHASE II	
		SS10	SS11	SS42	SS43
PESTICIDES ug/kg					
4,4'-DDD	na	2100X	3600	1400JX	320DJ
4,4'-DDE	na	4500D	39000D	9000DJ	2500DJ
4,4'-DDT	.23 - .58	6700D	59000D	7900DJ	710DJ
alpha-Chlordane	na	4000D	--	--	--
beta-BHC	2.4 - 6.1	--	--	1800XZ	--
Dieldrin	.0048 - .012	240	--	--	4500D
Endrin ketone	na	--	12000D	--	--
gamma-Chlordane	30	4000D	2400J	620J	--
Heptachlor	1	120	--	--	--
Heptachlor epoxide	na	250	--	--	--
Methoxychlor	na	--	--	1500J	--
VOLATILE METALS mg/kg					
Arsenic	5	12	20	12	26
Lead	5	61	1680	1120	128
Mercury	0.2	0.080	0.84	1.3	--
NONVOLATILE METALS mg/kg					
Antimony	na	--	68	--	--
Barium	100	57.6	343	108	70.8
Cadmium	1	1.1	6.0	11.8	--
Chromium **	5	24	135	39	15
Copper	na	16	135	705	15
Nickel	20	--	--	367	5.0
Silver	5	3.0	9.0	--	--
Zinc	na	63.4	960	10400	94.8

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na = Not Available

State of TN values are only To Be Considered (TBC) guidelines. These are not enforceable clean up levels.

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL). B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

E = Concentration exceeded the calibration range of the GC/MS instrument.

J = Estimated value less than the sample quantitation limit, but greater than zero.

X = Estimated value due to a confirmed compound which is off-scale in both columns.

** = No distinction between Chromium (III) and Chromium (VI).

-- = Not detected.

mercury. Toluene was detected in all four of the samples. 1,1,2-trichloroethane, tetrachloroethene and trichloroethene were detected in SS-42. The concentration of trichloroethene (2100 ug/kg) reported is a minimum value (the concentration level found in SS-42 exceeded the calibration range of the laboratory instrument). The probable source for the contaminants in this area is from spills that occur on the loading dock or washing out the floors of the building.

Fuel Oil Storage Tank - In Phase I sample SS-24 was collected from beneath the fuel oil storage tank at DDMT. The analytical results for this sample are given in Table 4-11. Pesticides, DDT and dieldrin were detected at low levels. PAHs and toluene were also detected in this sample but, only at quantitation limits.

Golf Course - In Phase I, surface soil samples SS-12, SS-13 and SS-14 were taken from the Golf Course grounds and SS-37 was collected near building T-273. In Phase II one additional sample, SS-50, (also near building T-273) was collected beside a storm drain near building T-273. Analytical results of the Golf Course surface soils are given on Figure 4-9 and in Table 4-12. DDMT records show that Building T-273 was formerly used as a pesticide storage area. High pesticide levels were detected near building T-273 (SS-37) and lower levels in the samples collected on the Golf Course. Low quantities of PAHs were also detected in all of the samples. Very low levels of trichloroethene and tetrachloroethene were detected in SS-37. All of the samples from this area, except SS-50, had detectable levels of toluene.

Building 1088 - During Phase I surface soil samples SS-15, SS-16, SS-17, SS-18 and SS-19 were collected near Buildings 1088 and 1087. Building 1088 is currently the paint shop area at DDMT. Two additional samples, SS-45 and SS-46 were collected form this area in Phase II. Analytical results for the soils near Building 1088 are given on Figure 4-10 and in Table 4-13. All seven soil samples

TABLE 4-11
POSITIVE RESULTS IN SURFACE SOILS
FUEL OIL STORAGE TANK
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE 1 SS24
HALOGENATED VOLATILES (ug/kg)		
Methylene chloride	8600	13B
NONHALOGENATED VOLATILES (ug/kg)		
Acetone	590	58J
Toluene	14,400	5J
NONHALOGENATED SEMIVOLATILES (ug/kg)		
bis(2-Ethylhexyl) phthalate	15,000	470B
N-Nitrosodiphenylamine	12.8 -32	53BJ
Polynuclear Aromatic Hydrocarbons (PAHs)		
Benzo(a)anthracene	.	74J
Benzo(a)pyrene	.	71J
Benzo(b)fluoranthene	.	100J
Benzo(k)fluoranthene	.	80J
Chrysene	.	77J
Fluoranthene	.	200J
Phenanthrene	.	120J
Pyrene	.	140J
Total PAHs	0.0028	862
PESTICIDES (ug/kg)		
4,4'-DDT	0.58	51
Dieldrin	na	130D
Endosulfan-I	74	41Z
VOLATILE METALS (mg/kg)		
Arsenic	5	30
Lead	5	98
Mercury	0.2	0.06

TABLE 4-11
POSITIVE RESULTS IN SURFACE SOILS
FUEL OIL STORAGE TANK
DEFENSE DEPOT MEMPHIS TENNESSEE

		PHASE I
PARAMETER	STATE OF TN	SS24

NONVOLATILE METALS (mg/kg)

Barium	100	67.5
Chromium **	5	26
Copper	na	16
Nickel	20	12
Zinc	na	48.6

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na = Not Available

State of TN values are only To Be Considered (TBC) guidelines.
These are not enforceable clean up levels.

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

J = Estimated value less than the sample quantitation limit,
but greater than zero.

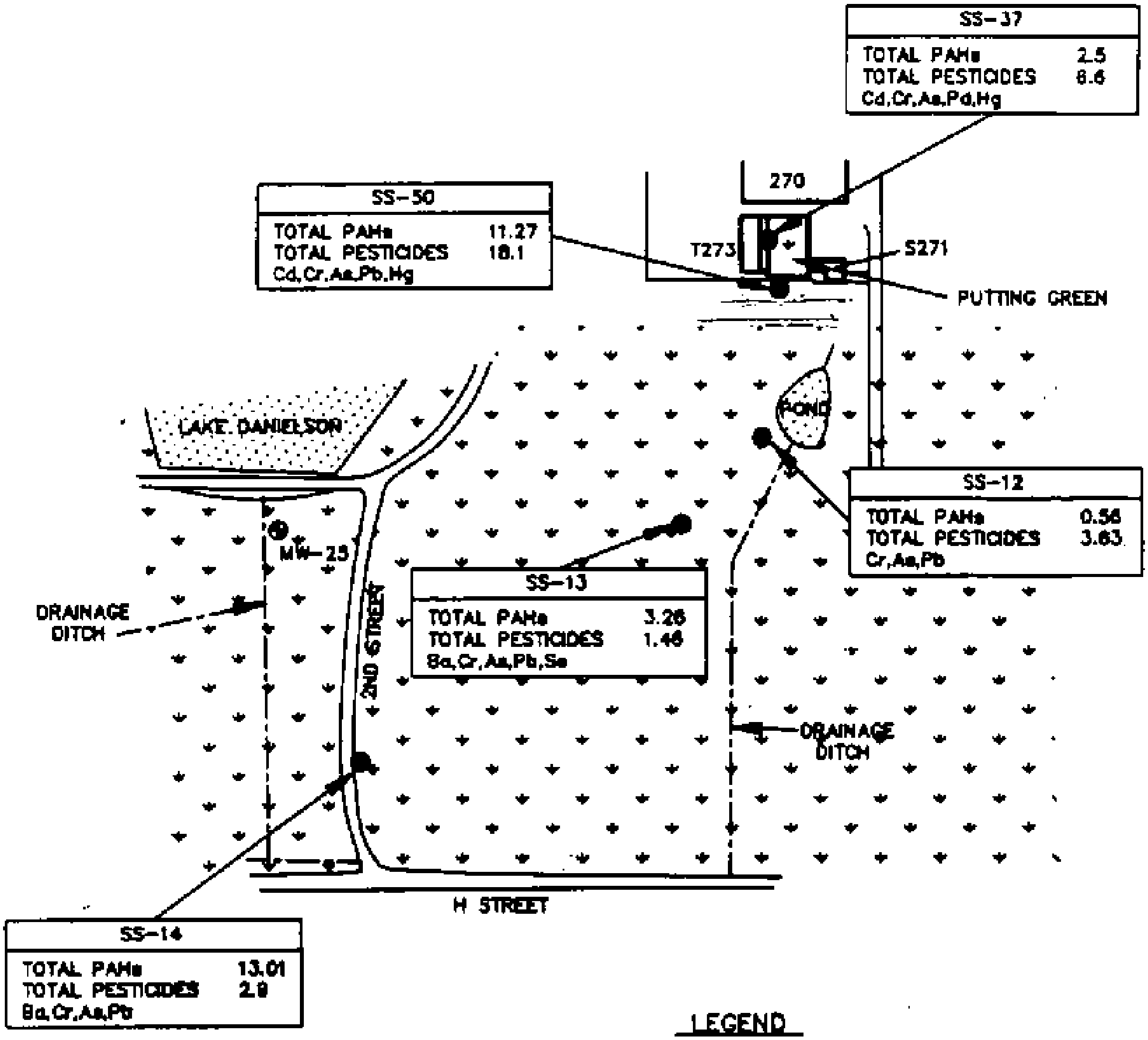
Z = Matrix interference; compound not positively identifiable.

** = No distinction between Chromium (III) and Chromium (VI).

FIGURE 4-9

SITE LOCATION MAP FOR SURFACE SOILS COLLECTED FROM THE GOLF COURSE WITH POSITIVE RESULTS EXCEEDING ARARs

DEFENSE DEPOT MEMPHIS, TENNESSEE



LEGEND

● SURFACE SOIL SAMPLING LOCATION

● MONITORING WELL LOCATION

▨ GRASS

NOTES:
ALL NUMBERS GIVEN ARE IN mg/kg
PAHs = POLYNUCLEAR AROMATIC HYDROCARBONS
TCE = TRICHLOROETHENE
METALS LISTED ARE THOSE THAT EXCEED STATE OF TN CRITERIA FOR SOILS
POSITIVE RESULTS FOR ALL CONSTITUENTS DETECTED IN THE SURFACE SOILS NEAR THE GOLF COURSE ARE GIVEN IN TABLE 1-5.

0 300 600
SCALE IN FEET

TABLE 4-12
POSITIVE RESULTS IN SURFACE SOILS
GOLF COURSE
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I				PHASE II
		SS12	SS13	SS14	SS37	SS50

HALOGENATED VOLATILES ug/kg

Chloroform	70	--	--	2J	--	--
Methylene chloride	8600	14B	21B	15B	13B	16B
Tetrachloroethene	100	--	--	--	2J	--
Trichloroethene	70	--	--	--	4J	--

NONHALOGENATED VOLATILES ug/kg

Acetone	590	9J	38	24	15	22
Toluene	14,400	17	9J	6J	3J	--
Total xylenes	150	--	--	--	8J	--

NONHALOGENATED SEMIVOLATILES ug/kg

bis(2-Ethylhexyl) phthalate	15,000	1500BJ	2200BJ	2700B	710BJ	1700B
N-Nitrosodiphenylamine	12.8 - 32	260J	280J	340J	--	--
Polynuclear Aromatic Hydrocarbons (PAHs)						
Acenaphthene	.	--	--	--	--	200J
Anthracene	.	--	--	280J	--	330J
Benzo(a)anthracene	.	--	270J	920J	--	810J
Benzo(a)pyrene	.	--	340J	930J	--	610J
Benzo(b)fluoranthene	.	--	420J	1100J	620J	1100J
Benzo(g,h,i)perylene	.	--	--	780J	--	--
Benzo(k)fluoranthene	.	--	340J	1100J	--	--
Chrysene	.	--	390J	1200J	--	990J
Fluoranthene	.	330J	630J	2700	780J	2200
Fluorene	.	--	--	--	--	160J
Indeno(1,2,3-cd)pyrene	.	--	--	700J	--	370J
Phenanthrene	.	--	310J	1600J	520J	2000
Pyrene	.	230J	560J	1700J	580J	2500
Total PAHs	0.0028	560	3,260	13,010	2,500	11,270

TABLE 4-12
POSITIVE RESULTS IN SURFACE SOILS
GOLF COURSE
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I				PHASE II
		SS12	SS13	SS14	SS37	SS50
PESTICIDES ug/kg						
4,4'-DDE	na	2000D	340D	--	1200D	4300D
4,4'-DDT	.23 - .58	870	290	--	4000D	3000DJ
Dieldrin	.0048 - .012	760D	630D	2900D	1400D	3800D
Heptachlor	1.0	--	--	--	--	1100Z
Heptachlor epoxide	na	--	--	--	--	340Z
beta-BHC	2.4 - 6.1	--	--	--	--	2500
VOLATILE METALS mg/kg						
Arsenic	5	33	22	41	42	12
Lead	5	80G*	50G*	80G*	71	157
Mercury	0.2	0.15N	0.1N	0.8N	0.32	0.5
NONVOLATILE METALS mg/kg						
Antimony	na	--	--	5.0B	5.0	--
Barium	100	95.8	118	117	76.9	78.4
Cadmium	1	--	--	--	2.0	1.9
Chromium **	5	20G	13G	16G	13	17
Copper	na	34*	21*	26*	18	15
Nickel	20	13*	12*	12*	11	8
Zinc	na	81.2G	89.3G	82.3G	80.4	290

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na = Not Available

State of TN values are only To Be Considered (TBC) guidelines. These are not enforceable clean up levels.

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

G = Native analyte > 4 times spike added, therefore acceptance criteria do not apply.

J = Estimated value less than the sample quantitation limit, but greater than zero.

N = Spiked sample recovery not within control limits.

Z = Matrix interference: compound not positively identifiable.

* = Duplicate analysis not within control limits.

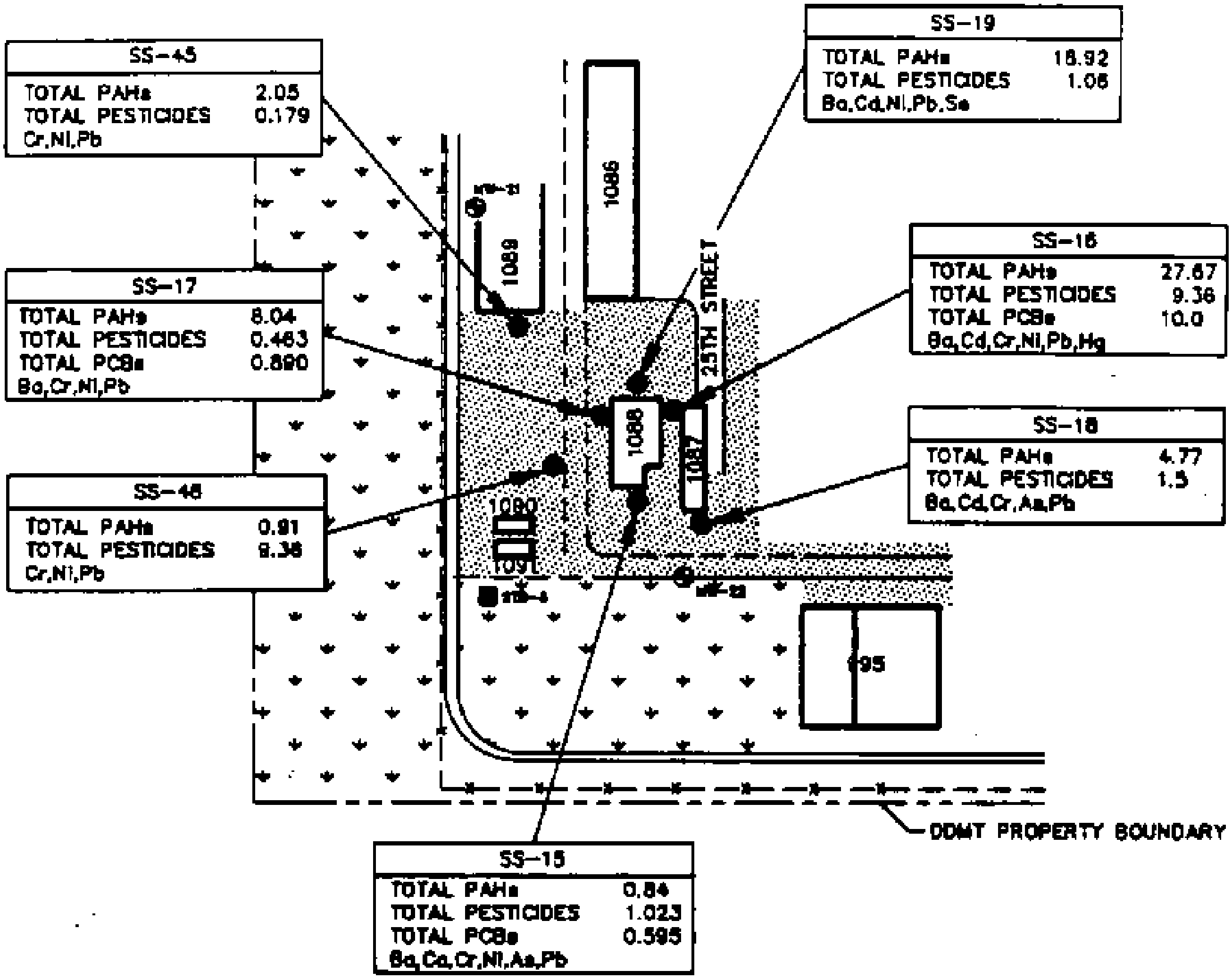
** = No distinction between Chromium (III) and Chromium (VI)

-- = Not detected.

FIGURE 4-10

SITE LOCATION MAP FOR SURFACE SOILS COLLECTED NEAR BUILDING 1088 WITH POSITIVE RESULTS EXCEEDING ARARs

DEFENSE DEPOT MEMPHIS, TENNESSEE



NOTES:
- ALL NUMBERS GIVEN ARE IN mg/kg
- PAHs = POLYNUCLEAR AROMATIC HYDROCARBONS
- METALS LISTED ARE THOSE THAT EXCEED STATE OF TN CRITERIA FOR SOILS
- POSITIVE RESULTS FOR ALL CONSTITUENTS DETECTED IN THE SURFACE SOILS NEAR BUILDING 1088 ARE GIVEN IN TABLE 1-6.

LEGEND

●	SURFACE SOIL SAMPLING LOCATION
■	SOIL TEST BORING LOCATION
⊕	MONITORING WELL LOCATION
☐	GRASS
▨	GRAVEL

0 300
SCALE IN FEET

TABLE 4-13
POSITIVE RESULTS IN SURFACE SOILS
BUILDING 1088
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I					PHASE II	
		SS15	SS16	SS17	SS18	SS19	SS45	SS46
HALOGENATED VOLATILES ug/kg								
Methylene chloride	8600	16B	29B	11B	9B	11B	11B	8B
NONHALOGENATED VOLATILES ug/kg								
Acetone	590	15	17	12B	6BJ	11BJ	13	9J
Toluene	14,400	5J	4J	--	2J	6	2J	--
NONHALOGENATED SEMIVOLATILES ug/kg								
2,4-Dimethylphenol	na	--	--	--	--	720J	--	--
2-Methylphenol	na	--	--	--	--	1100J	--	--
4-Methylphenol	na	--	--	--	--	500J	--	--
Benzoic acid	na	--	--	--	--	320J	--	--
Benzyl alcohol	na	--	--	--	1000J	--	--	--
bis(2-Ethylhexyl) phthalate	15,000	1700B	4300B	600BJ	8100B	--	1200B	1400B
Butyl benzyl phthalate	na	96J	370J	--	--	--	--	--
Dibenzofuran	na	--	--	--	--	210J	--	--
Dimethyl phthalate	na	--	--	--	--	--	160J	--
Di-n-butyl phthalate	na	160J	470J	--	950J	--	--	--
N-Nitrosodiphenylamine	12.8 - 32	150J	590J	--	--	--	--	--
Phenol	na	--	--	--	--	550J	--	--
Polynuclear Aromatic Hydrocarbons (PAHs)								
Acenaphthene	.	--	--	--	--	250J	--	--
Anthracene	.	--	670J	200J	--	260J	--	--
Benzo(a)anthracene	.	--	2100J	620J	--	2200	160J	90J
Benzo(a)pyrene	.	--	1700J	--	370J	1500J	140J	84J
Benzo(b)fluoranthene	.	120J	2400J	1300J	830J	4600	160J	160J
Benzo(g,h,i)perylene	.	--	1400J	840J	--	--	--	--
Benzo(k)fluoranthene	.	100J	2200J	--	--	--	--	--
Chrysene	.	110J	2500J	790J	1000J	2500	220J	130J
Fluoranthene	.	220J	5800	1800J	1300J	3200	340J	210J
Fluorene	.	--	--	--	--	310J	--	--
Indeno(1,2,3-cd)pyrene	.	--	1200J	630J	--	1500J	120J	--
Naphthalene	.	--	--	--	--	480J	--	--
Phenanthrene	.	130J	3000J	760J	780J	2500	210J	120J
Pyrene	.	160J	4700	1100J	860J	2600	440J	250J
Total PAHs	0.0028	840	27,670	8,040	4,770	18,920	2,050	910

TABLE 4-13
POSITIVE RESULTS IN SURFACE SOILS
BUILDING 1088
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I					PHASE II	
		SS15	SS16	SS17	SS18	SS19	SS45	SS46

PESTICIDES ug/kg

PARAMETER	STATE OF TN	SS15	SS16	SS17	SS18	SS19	SS45	SS46
4,4'-DDD	na	45D	250	52D	--	--	--	13J
4,4'-DDE	na	110D	1300D	97D	400D	160	33	27
4,4'-DDT	0.58	450D	7400D	260D	1100D	660	90D	110D
alpha-BHC	1.4-3.5	12Z	--	--	--	--	--	--
alpha-Chlordane	30	--	--	--	--	--	25J	--
beta-BHC	2.4-8.1	26Z	--	43Z	--	--	--	--
delta-BHC	na	--	--	11Z	--	--	--	--
Dieldrin	na	110Z	410Z	--	--	220	--	--
Endosulfan-I	74	19Z	--	--	--	--	--	--
gamma-BHC (Lindane)	0.06	11Z	--	--	--	--	--	--
gamma-Chlordane	30	--	--	--	--	--	31J	--
Heptachlor epoxide	1	69Z	--	--	--	--	--	--

PCBs ug/kg

PARAMETER	STATE OF TN	SS15	SS16	SS17	SS18	SS19	SS45	SS46
Aroclor-1016	na	100Z	--	140Z	--	--	--	--
Aroclor-1221	na	95Z	--	--	--	--	--	--
Aroclor-1232	na	270Z	--	550Z	--	--	--	--
Aroclor-1242	na	130Z	--	200Z	--	--	--	--
Aroclor-1254	na	--	10000D	--	--	--	--	--
Total PCBs	10000	595	10,000	890	--	--	--	--

TOTAL VOLATILE METALS mg/kg

PARAMETER	STATE OF TN	SS15	SS16	SS17	SS18	SS19	SS45	SS46
Arsenic	5	6	--	--	15	--	--	--
Lead	5	2670G*	17500	247	2060	10300	312	166
Mercury	0.2	0.04N	0.26	--	0.06	0.18	--	--
Selenium	1	--	--	--	9	--	--	--

TOTAL NONVOLATILE METALS mg/kg

PARAMETER	STATE OF TN	SS15	SS16	SS17	SS18	SS19	SS45	SS46
Antimony	na	8B	30	--	26	4B	--	--
Barium	100	216	313	109	408	148	85.2	91.8
Cadmium	1	1.9N	23.4	0.7	4.7	4.4	--	--
Chromium **	5	714G	6710	109	8680	2230	138	78
Copper	na	124*	240	72	52	148	116	76
Nickel	20	37*	53	23	16	32	28	24
Silver	5	--	0.8B	--	--	--	--	--
Zinc	na	996G	21000	270	22100	4600	202	146

TABLE 4-13
POSITIVE RESULTS IN SURFACE SOILS
BUILDING 1088
DEFENSE DEPOT MEMPHIS TENNESSEE

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na = Not Available

State of TN values are only To Be Considered (TBC) guidelines. These are not enforceable clean up levels.

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL), but greater than the instrument Detection Limit (IDL).

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

G = Native analyte > 4 times spike added, therefore acceptance criteria do not apply.

J = Estimated value less than the sample quantitation limit, but greater than zero.

N = Spiked sample recovery not within control limts.

Z = Matrix interference; compound not positively identifiable.

* = Duplicate analysis not within control limits.

** = No distinction between Chromium (III) and Chromium (VI)

-- = Not detected.

were contaminated with PAHs, pesticides and PCBs. Pesticides that were detected in this area include: DDE, DDT and gama and alpha chlordane. Metal contamination in these samples were elevated above normal soil levels with chromium, lead and zinc having the highest levels. Toluene was a contaminant in all of the samples except SS-17 and SS-46, but was detected at the quantitation limit.

Open Storage Area - The open storage area is located in the northwest quadrant of the main installation. Three sub-regions of this area were sampled and the analytical results are given on Figure 4-11 and in Table 4-14. In Phase I SS-21, SS-22 and SS-23 were collected along railroad tracks #3 and #4. A variety of contaminants were detected in this area. This is consistent with the reported storage and transport of PCP/PCBs, PAHs, and solvents.

Surface soil samples, SS-32, SS-33, SS-34, SS-35, SS-36 and SS-40, were also collected during Phase I. These samples were collected near Building 835 and are comparatively free of contamination. This apparent lack of contamination may be due to the fact that the area has recently been excavated during the construction of Building 835.

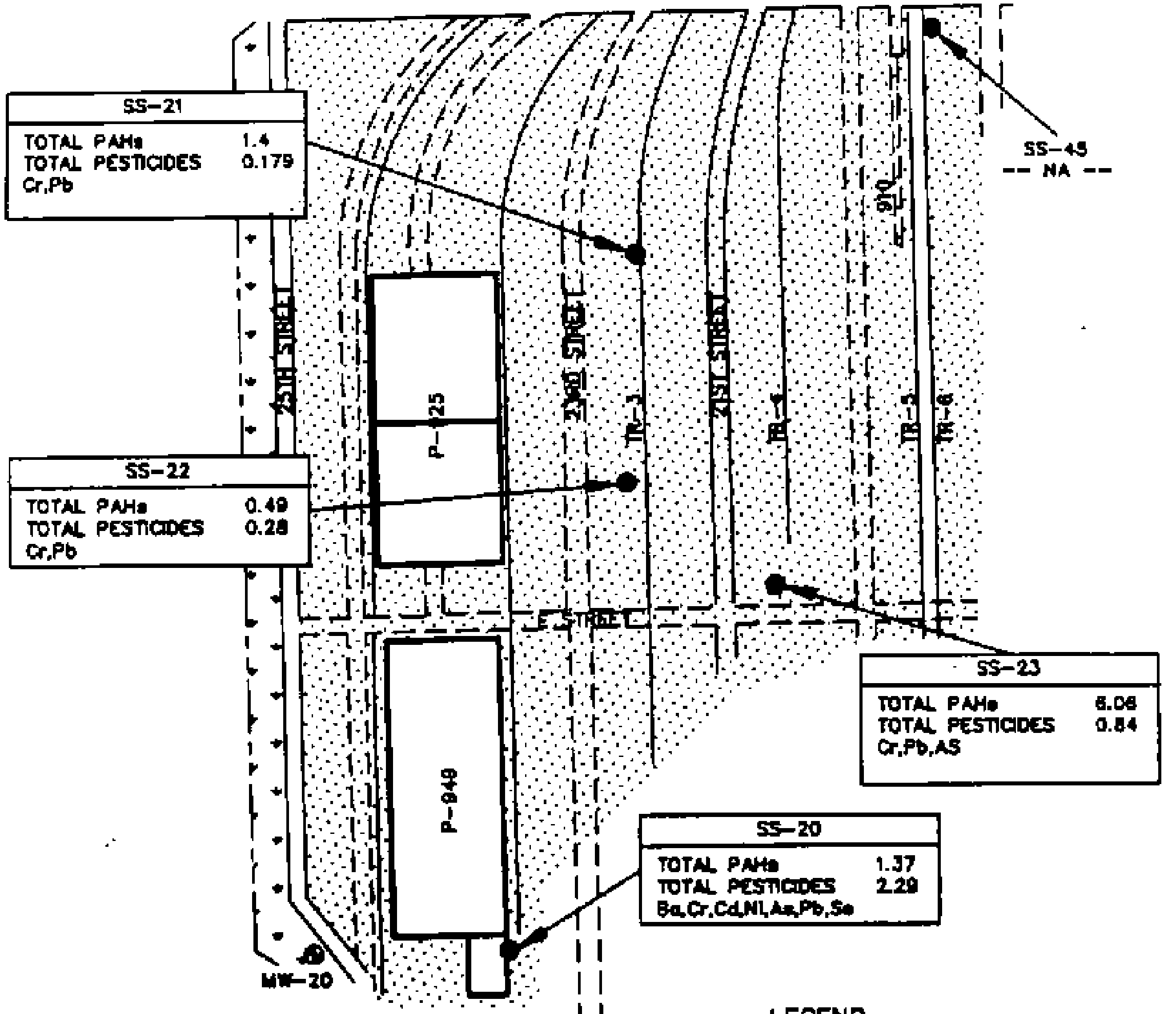
SS-20 was collected west of Building P-949 in an old paint disposal area (Figure 4-11). This sample exhibited high levels of lead, barium, chromium and zinc. Low levels of toluene and PAHs were also detected in this sample.

Gravel Area East of Building S873 - Past activities at Building S873 included use as DDMT's hazardous materials recoupment area. Remediation for pesticide contamination in this area required the removal and backfilling of the upper .5 - 1.0 foot of gravel. For this reason, soil samples, SS-26, SS-27, SS-28 and SS-29, were collected from a depth of one foot during Phase I. Samples from this area did not contain pesticides at detectable levels. Positive results are given in Table 4-15.

FIGURE 4-11

SITE LOCATION MAP FOR SURFACE SOILS COLLECTED FROM THE OPEN STORAGE AREA WITH POSITIVE RESULTS EXCEEDING ARARs

DEFENSE DEPOT MEMPHIS, TENNESSEE



LEGEND

●	SURFACE SOIL SAMPLING LOCATION
⊕	MONITORING WELL LOCATION
⁚⁚	GRASS
▨	GRAVEL

NOTES:
- ALL NUMBERS GIVEN ARE IN mg/kg
- PAHs = POLYNUCLEAR AROMATIC HYDROCARBONS
- TCE = TRICHLOROETHENE
- METALS LISTED ARE THOSE THAT EXCEED STATE OF TN CRITERIA FOR SOILS
- POSITIVE RESULTS FOR ALL CONSTITUENTS DETECTED IN THE SURFACE SOILS NEAR THE HARDSTAND AREA ARE GIVEN IN TABLE 1-7.

0 300 600

SCALE IN FEET

TABLE 4-14
POSITIVE RESULTS IN SURFACE SOILS
OPEN STORAGE AREA
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I									
		SS20	SS21	SS22	SS23	SS32	SS33	SS34	SS35	SS36	SS40
HALOGENATED VOLATILES (ug/kg)											
1,1,2,2-Tetrachloroethane	1300	--	--	--	19	--	--	--	--	--	--
Methylene chloride	8600	18B	20B	20B	50B	6B	8B	11B	8B	13B	9B
Trichloroethene	70	--	--	--	2J	--	--	--	--	--	4J
NONHALOGENATED VOLATILES (ug/kg)											
2-Butanone	7200	--	--	--	--	--	--	--	--	8J	--
Acetone	590	8BJ	6JB	6JB	22	7JB	10JB	13B	11B	23B	31
Benzene	70	--	--	--	4J	--	--	--	--	--	--
Ethylbenzene	154,000	--	--	--	--	--	--	--	--	--	4J
Toluene	14,400	17	12	20	33	3J	2J	6	--	4J	34
Total xylenes	150	1J	--	3J	--	--	--	--	--	--	9
HALOGENATED SEMIVOLATILES (ug/kg)											
Pentachlorophenol	3600	--	310J	--	--	--	--	--	--	--	--
NONHALOGENATED SEMIVOLATILES (ug/kg)											
2-Methylnaphthalene	na	2600	--	--	--	--	--	--	--	--	--
bis(2-Ethylhexyl) phthalate	15,000	2300B	--	470BJ	410BJ	350BJ	320BJ	340BJ	390B	440BJ	--
Benzoic acid	na	--	--	--	--	--	--	--	43J	--	--
N-Nitrosodiphenylamine	12.8 - 32	--	--	--	--	--	49BJ	35BJ	63BJ	--	--

(continued on next page)

TABLE 4-14
POSITIVE RESULTS IN SURFACE SOILS
OPEN STORAGE AREA
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I									
		SS20	SS21	SS22	SS23	SS32	SS33	SS34	SS35	SS36	SS40
Polynuclear Aromatic Hydrocarbons (PAHs)											
Benzo(a)anthracene	.	--	--	--	230J	--	--	--	--	--	--
Benzo(b)fluoranthene	.	350J	500J	290J	600J	--	--	--	--	--	--
Benzo(g,h,i)perylene	.	--	--	--	2100J	--	--	--	--	--	--
Chrysene	.	360J	260J	--	270J	--	--	--	--	--	--
Dibenzo(a,h)anthracene	.	--	--	--	2100J	--	--	--	--	--	--
Fluoranthene	.	--	350J	--	400J	--	--	--	--	--	--
Indeno(1,2,3-cd)pyrene	.	--	--	--	230J	--	--	--	--	--	--
Pyrene	.	660J	290J	200J	360J	--	--	--	--	--	--
Total PAHs	0.0028	776	1,400	490	6,060	--	--	--	--	--	--

PESTICIDES (ug/kg)

4,4'-DDD	na	--	24	--	--	--	--	--	--	--	--
4,4'-DDE	na	490D	150D	50D	85D	--	--	--	--	--	--
4,4'-DDT	.23 - .58	1800D	250D	120D	210D	--	--	--	--	--	--
beta-BHC	2.4 - 6.1	--	53Z	32Z	--	--	--	--	--	--	--
Dieldrin	0048 - .01	--	120D	78D	160D	--	--	--	--	--	--
Endosulfan-I	na	--	--	--	16Z	--	--	--	--	--	--
Toxaphene	70	--	--	--	370Z	--	--	--	--	--	--

TABLE 4-14
POSITIVE RESULTS IN SURFACE SOILS
OPEN STORAGE AREA
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I									
		SS20	SS21	SS22	SS23	SS32	SS33	SS34	SS35	SS36	SS40
PCBs (ug/kg)											
Aroclor-1016	.	--	100Z	--	--	--	--	--	--	--	--
Aroclor-1232	.	--	400Z	--	--	--	--	--	--	--	--
Aroclor-1242	.	--	150Z	--	--	--	--	--	--	--	--
Aroclor-1254	.	--	--	--	220Z	--	--	--	--	--	--
Aroclor-1260	.	--	--	--	320Z	--	--	--	--	--	--
Total PCBs	10000	--	650	--	550	--	--	--	--	--	--
VOLATILE METALS (mg/kg)											
Arsenic	5	15	--	--	23	8	26	8	30	25	21
Lead	5	7680	137	43	112	4	12	4	12	21	19
Mercury	0.2	0.18	0.04	--	0.04	--	0.04	--	0.04	0.04	--
Selenium	1	12	--	--	--	--	--	--	--	--	--
NONVOLATILE METALS (mg/kg)											
Antimony	na	27	8B	--	12	--	4	--	4	--	--
Barium	100	6540	45.2	25.9B	96.9	16.6	60.5	12	126	89.9	22.8
Cadmium	1	5.4	--	--	--	--	--	--	--	--	1
Chromium **	5	16200	115	30	34	10	13	10	13	15	32
Copper	na	41	21	10	30	5	15	4	20	16	10
Nickel	20	24	48	38	9	4	14	4	17	14	4
Silver	5	1.3B	--	--	--	--	--	--	--	--	--
Zinc	na	28200	266	75	167	9.4	46.8	6.9	59.8	53	132

TABLE 4-14

POSITIVE RESULTS IN SURFACE SOILS

OPEN STORAGE AREA

DEFENSE DEPOT MEMPHIS TENNESSEE

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na = Not Available

State of TN values are only To Be Considered (TBC) guidelines. These are not enforceable clean up levels.

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

J = Estimated value less than the sample quantitation limit, but greater than zero.

Z = Matrix interference; compound not positively identifiable.

** = No distinction between Chromium (III) and Chromium (VI)

-- = Not detected.

TABLE 4-15
POSITIVE RESULTS IN SURFACE SOILS
GRAVEL AREA EAST OF S873
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I			
		SS26	SS27	SS28	SS29

HALOGENATED VOLATILES (ug/kg)

PARAMETER	STATE OF TN	SS26	SS27	SS28	SS29
Methylene chloride	8600	23B	12B	4J	4J

NONHALOGENATED VOLATILES (ug/kg)

PARAMETER	STATE OF TN	SS26	SS27	SS28	SS29
Acetone	590	5BJ	3JB	9J	5J
Toluene	14,400	3J	4J	33	1J
Total xylenes	150	--	--	2J	--

NONHALOGENATED SEMIVOLATILES (ug/kg)

PARAMETER	STATE OF TN	SS26	SS27	SS28	SS29
bis(2-Ethylhexyl) phthalate	15,000	440B	320BJ	380BJ	340BJ
Diethyl phthalate	na	77J	--	--	--
Di-n-butyl phthalate	na	44J	--	--	--
N-Nitrosodiphenylamine	12.8 - 32	--	49BJ	--	--
Polynuclear Aromatic Hydrocarbons (PAHs)					
Benzo(a)anthracene	.	45J	--	--	--
Benzo(b)fluoranthene	.	70J	--	--	--
Chrysene	.	44J	--	--	--
Fluoranthene	.	75J	--	--	--
Phenanthrene	.	55J	--	--	--
Pyrene	.	55J	--	--	--
Total PAHs	0.0028	344	--	--	--

VOLATILE METALS (mg/kg)

PARAMETER	STATE OF TN	SS26	SS27	SS28	SS29
Arsenic	5	28	36	17	23
Lead	5	17	13	15	11
Mercury	0.2	0.03	--	0.02	0.03

NONVOLATILE METALS (mg/kg)

PARAMETER	STATE OF TN	SS26	SS27	SS28	SS29
Antimony	na	7	8	5	6
Barium	100	143	105	18.3	18.5
Chromium **	5	16	17	6	10
Copper	na	22	22	5	6
Nickel	20	20	18	5	6
Zinc	na	70.5	67	9	--

TABLE 4-15
POSITIVE RESULTS IN SURFACE SOILS
GRAVEL AREA EAST OF S873
DEFENSE DEPOT MEMPHIS TENNESSEE

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na = Not Available

State of TN values are only To Be Considered (TBC) guidelines. These are not enforceable clean up levels.

B (Organic) = Found in method blank.

J = Estimated value less than the sample quantitation limit, but greater than zero.

** = Not distinction between Chromium (III) and Chromium (VI).

-- = Not detected.

Building 770 - Building 770 is the maintenance shop area at DDMT. During Phase I surface soil SS-38 was collected from the area surrounding the underground waste oil storage tank at Building 770. SS-39 was obtained in the shop waste disposal area. During Phase II samples SS-48 and SS-49 were collected within the same general area. Analytical results are given on Figure 4-12 and in Table 4-16 for the four soil samples. All four samples were contaminated with PAHs, which are indicative of oils or heavy fuel residuals, and with low levels of toluene. SS-38 contained tetrachloroethene, trichloroethene and 1,1,1-trichloroethane. This chlorinated solvent contamination could be indicative of past cleaning solvent disposal practices. SS-48 and SS-49 contained trichloroethylene at the quantitation limit. Pesticides were detected in SS-48 and included DDT, DDE and DDD as well as beta-BHC. The metal levels detected in each sample were normal soil levels.

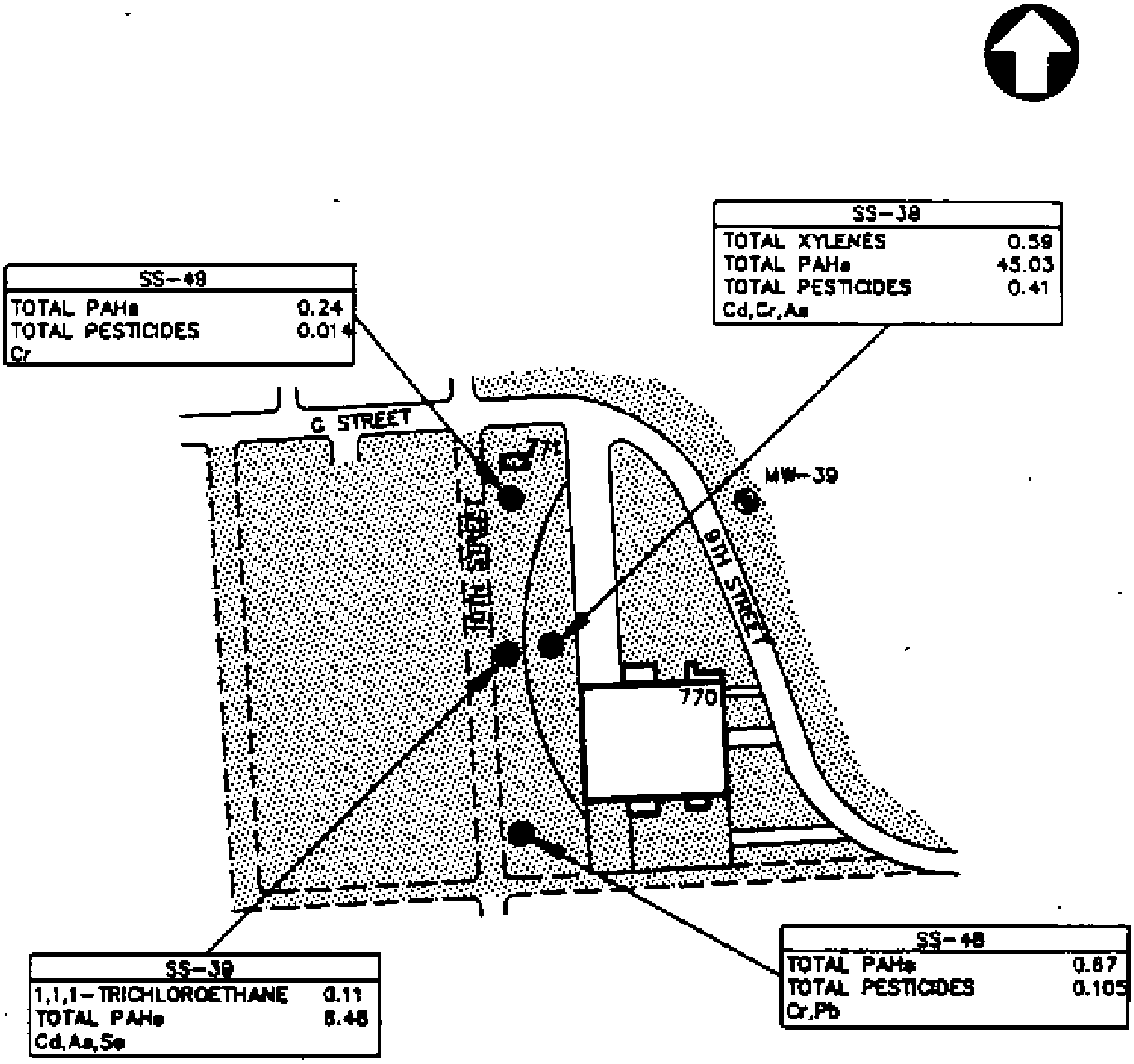
Old Transformer Storage Area - New Cafeteria - Two soil samples, SS-30 and SS-31, were collected in Phase I from where the transformer storage area was located. This area is now occupied by the new cafeteria. Analytical results obtained from the two samples are given in Table 4-17. These samples tested positive for the pesticides DDE and DDT, and low levels of PAHs.

BX Gas Station - SS-25 was collected in Phase I from the BX gas station area. Elevated levels of barium and low levels of PAHs were detected in this sample. The analytical results are given in Table 4-18.

FIGURE 4-12

SITE LOCATION MAP FOR SURFACE SOILS COLLECTED NEAR BUILDING 770 WITH POSITIVE RESULTS EXCEEDING ARARs

DEFENSE DEPOT MEMPHIS, TENNESSEE



SS-49	
TOTAL PAHs	0.24
TOTAL PESTICIDES	0.014
Cr	

SS-38	
TOTAL XYLENES	0.59
TOTAL PAHs	45.03
TOTAL PESTICIDES	0.41
Cd,Cr,As	

SS-39	
1,1,1-TRICHLOROETHANE	0.11
TOTAL PAHs	6.46
Cd,As,Se	

SS-48	
TOTAL PAHs	0.87
TOTAL PESTICIDES	0.105
Cr,Pb	

NOTES:
ALL NUMBERS GIVEN ARE IN mg/kg
PAHs = POLYNUCLEAR AROMATIC HYDROCARBONS
TCE = TRICHLOROETHENE
METALS LISTED ARE THOSE THAT EXCEED STATE OF TN CRITERIA FOR SOILS
POSITIVE RESULTS FOR ALL CONSTITUENTS DETECTED IN THE SURFACE SOILS NEAR BUILDING 770 ARE GIVEN IN TABLE 1-8.

LEGEND

●	SURFACE SOIL SAMPLING LOCATION
⊕	MONITORING WELL LOCATION
▨	GRAVEL

0 300 600
SCALE IN FEET

LAW ENVIRONMENTAL INC.
GOVERNMENT SERVICES DIVISION

TABLE 4-16
POSITIVE RESULTS IN SURFACE SOILS
BUILDING 770
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I		PHASE II	
		SS38	SS39	SS48	SS49

HALOGENATED VOLATILES ug/kg

PARAMETER	STATE OF TN	SS38	SS39	SS48	SS49
1,1,1-Trichloroethane	30,000	110	--	--	--
Methylene chloride	8600	36B	8B	5BJ	6B
Tetrachlorethene	100	31	--	--	--
Trichloroethene	70	--	--	1J	2J

NONHALOGENATED VOLATILES ug/kg

PARAMETER	STATE OF TN	SS38	SS39	SS48	SS49
4-Methyl-2-pentanone	na	--	8J	--	--
Acetone	590	47J	200	51	22
Ethylbenzene	154,000	9J	6	--	--
Toluene	14,400	43	16	13	32
Total xylenes	150	590	53	1J	2J

NONHALOGENATED SEMIVOLATILES ug/kg

PARAMETER	STATE OF TN	SS38	SS39	SS48	SS49
2-Methylnaphthalene	na	610J	4000	--	--
bis(2-Ethylhexyl) phthalate	15,000	4800B	--	340B	160BJ
Dibenzofuran	na	--	350J	--	--
Butyl benzyl phthalate	na	--	1300J	--	--
Di-n-butyl phthalate	na	--	480J	--	--
Polynuclear Aromatic Hydrocarbons (PAHs)					
3-Nitroaniline	.	--	--	--	36J
Benzo(a)anthracene	.	7800	--	80J	--
Benzo(a)pyrene	.	3600J	--	62J	--
Benzo(b)fluoranthene	.	2800J	--	150J	90J
Benzo(k)fluoranthene	.	4600	--	--	--
Chrysene	.	2200J	--	110J	--
Fluoranthene	.	12000	--	160J	66J
Fluorene	.	620J	--	--	--
Indeno(1,2,3-cd)pyrene	.	--	--	53J	--
Naphthalene	.	--	1600J	--	--
Phenanthrene	.	18000	1100J	85J	37J
Pyrene	.	13000	880J	170J	150J
Total PAHs	0.0026	45,030	6,480	670	240

TABLE 4-16
POSITIVE RESULTS IN SURFACE SOILS
BUILDING 770
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I		PHASE II	
		SS38	SS39	SS48	SS49
PESTICIDES ug/kg					
4,4'-DDD	na	--	--	10J	--
4,4'-DDE	na	--	--	17X	--
4,4'-DDT	.23 - .58	--	--	52	--
beta-BHC	2.4 - 6.1	290Z	--	26Z	14Z
gamma-BHC (Lindane)	60	120Z	--	--	--
VOLATILE METALS mg/kg					
Arsenic	5	9	13	--	--
Lead	5	48	24	90	4
Selenium	1	--	15	--	--
NONVOLATILE METALS mg/kg					
Antimony	na	--	17	--	--
Barium	100	20.9B	15.6	19.3	11.7
Cadmium	1	1	3	0.5	0.8
Chromium **	5	10	--	19	6
Copper	na	13	18	10	4
Nickel	20	3	7	6	5
Zinc	na	411	122	55.2	59.4

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na = Not Available

State of TN values are only To Be Considered (TBC) guidelines. These are not enforceable clean up levels.

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).

B (Organic) = Found in method blank.

J = Estimated value less than the sample quantitation limit, but greater than zero.

X = Estimated value due to a confirmed compound which is off-scale in both columns.

Z = Matrix interference; compound not positively identifiable.

** = No distinction between Chromium (III) and Chromium (VI).

-- = Not detected.

TABLE 4-17
POSITIVE RESULTS IN SURFACE SOILS
OLD TRANSFORMER STORAGE YARD (NEW CAFETERIA)
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I	
		SS30	SS31

HALOGENATED VOLATILES (ug/kg)

Methylene chloride	8600	3J	7B

NONHALOGENATED VOLATILES (ug/kg)

Acetone	590	4J	7JB
Toluene	14,400	3J	--

NONHALOGENATED SEMIVOLATILES (ug/kg)

bis(2-Ethylhexyl) phthalate	15,000	350BJ	460B
Polynuclear Aromatic Hydrocarbons (PAHs)			
Benzo(a)anthracene	.	240J	--
Benzo(a)pyrene	.	190J	--
Benzo(b)fluoranthene	.	320J	--
Benzo(g,h,i)perylene	.	230J	--
Chrysene	.	230J	--
Fluoranthene	.	390J	--
Indeno(1,2,3-cd)pyrene	.	180J	--
Phenanthrene	.	210J	--
Pyrene	.	340J	--
Total PAHs	0.0028	2330	--

PESTICIDES (ug/kg)

4,4'-DDE	na	78D	18
4,4'-DDT	.23 - .58	1000D	190D

VOLATILE METALS (mg/kg)

Arsenic	5	19	12
Lead	5	81	5
Mercury	0.2	0.04	0.02

TABLE 4-17
POSITIVE RESULTS IN SURFACE SOILS
OLD TRANSFORMER STORAGE YARD (NEW CAFETERIA)
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I	
		SS30	SS31
NONVOLATILE METALS (mg/kg)			
Antimony	na	4	--
Barium	100	78.1	21.9
Cadmium	1	1	--
Chromium **	5	14	10
Copper	na	22	6
Nickel	20	13	3
Silver	5	0.6	--
Zinc	na	69	11

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na = Not Available.

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These are not enforceable clean up levels.

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

J = Estimated value less than the sample quantitation limit, but greater than zero.

** = No distinction beween Chromium (III) and Chromium (VI).

-- = Not detected.

TABLE 4-18
POSITIVE RESULTS IN SURFACE SOILS
BX GAS STATION
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I
		SS25

HALOGENATED VOLATILES (ug/kg)

Methylene chloride	8600	25B

NONHALOGENATED SEMIVOLATILES (ug/kg)

bis(2-Ethylhexyl) phthalate	15,000	510B
N-Nitrosodiphenylamine	12.8 – 32	56BJ
Polynuclear Aromatic Hydrocarbons (PAHs)		
Benzo(a)anthracene	.	54J
Benzo(a)pyrene	.	53J
Benzo(b)fluoranthene	.	62J
Benzo(g,h,i)perylene	.	58J
Benzo(k)fluoranthene	.	93J
Chrysene	.	76J
Fluoranthene	.	140J
Indeno(1,2,3-cd)pyrene	.	47J
Phenanthrene	.	76J
Pyrene	.	110J
Total PAHs	0.0026	769

PESTICIDES (ug/kg)

Dieldrin	0048 – .012	36D

VOLATILE METALS (mg/kg)

Arsenic	5	25
Lead	5	16
Mercury	0.2	0.03

NONVOLATILE METALS (mg/kg)

Antimony	na	4
Barium	100	130
Chromium **	5	14
Copper	na	20
Nickel	20	19
Zinc	na	57.9

TABLE 4-18
POSITIVE RESULTS IN SURFACE SOILS
BX GAS STATION
DEFENSE DEPOT MEMPHIS TENNESSEE

Shaded areas are values that are equal to or exceed the state of Tennessee soil criteria guidelines.

na = Not Available.

State of TN values are only To Be Considered (TBC) guidelines.
These are not enforceable clean up levels.

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

J = Estimated value less than the sample quantitation limit, but greater than zero.

** = No distinction between Chromium (III) and Chromium (VI).

Building 737 - SS-47 was collected in Phase II near Building 737, (pesticide storage). DDE, DDT, alpha-chlordane and beta-BHC were all detected in this sample at low levels. Toluene and trichloroethene were also detected at quantitation levels. The analytical results for this sample are given in Table 4-19.

4.2.2.3 Quality Control Soils

4.2.2.3.1 Quality Control - Subsurface Soils - For Phase I field duplicates were collected for STB-2-1 and a duplicate for STB-3-1. Concentrations for the parameters tested for in these samples were all at less than five times the detection limits. No RPDs could be calculated. The Phase II field duplicate sample was collected for STB-6-2. The RPD values were within control limits. The trip blanks that were sent with the soil samples from soil borings did not show any volatile organic compound contamination. A rinsate (STB-7-R) was analyzed and contained only low concentrations of zinc.

Acetone and methylene chloride were detected in some of the method blanks analyzed by the laboratory. The amount detected was at very low levels. Low acetone and methylene chloride concentrations in field samples may be discounted as laboratory artifacts. Surrogate recoveries for all the parameters tested during both Phase I and Phase II analyses were within control limits.

The MS/MSD analyses for the Phase I sampling effort were within acceptable limits for all parameters tested. RPDs were acceptable for all of the spiked compounds except 4-nitrophenol (29%) and heptachlor (29%). Overall the precision was good. The MS/MSD results for the Phase II sample SB-8-1 were all within acceptable limits for recovery and precision.

4.2.2.3.2 Surface Soil Quality Control - The high hydrocarbon content present in the surface soil samples from Dunn Field produced problems in the laboratory for the analyses for organic constituents. Surface soil SS-8 required a 53-fold dilution in

TABLE 4-19
POSITIVE RESULTS IN SURFACE SOILS
PESTICIDE STORAGE AREA - BUILDING 737
DEFENSE DEPOT MEMPHIS TENNESSEE

		PHASE II
PARAMETER	STATE OF TN	SS47
HALOGENATED VOLATILES (ug/kg)		
Methylene chloride	8600	6B
Trichloroethene	70	1J
NONHALOGENATED VOLATILES (ug/kg)		
Acetone	590	74
Toluene	14,400	5J
NONHALOGENATED SEMIVOLATILES (ug/kg)		
bis(2-Ethylhexyl) phthalate	15,000	330BJ
Polynuclear Aromatic Hydrocarbons (PAHs)		
Chrysene	.	78J
Benzo(a)anthracene	.	57J
Benzo(a)pyrene	.	46J
Benzo(b)fluoranthene	.	90J
Fluoranthene	.	130J
Indeno(1,2,3-cd)pyrene	.	84J
Phenanthrene	.	72J
Pyrene	.	130J
Total PAHs	0.0028	687
PESTICIDES (ug/kg)		
4,4'-DDE	na	14J
4,4'-DDT	.23 - .58	79DJ
alpha-Chlordane	30	33DJ
beta-BHC	2.4 - 6.1	33XZ
gamma-Chlordane	30	53DJ
Heptachlor epoxide	na	9.1Z
VOLATILE METALS (mg/kg)		
Arsenic	5	19
Lead	5	4

TABLE 4-19

POSITIVE RESULTS IN SURFACE SOILS
PESTICIDE STORAGE AREA - BUILDING 737
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE II SS47
NONVOLATILE METALS (mg/kg)		
Barium	100	30.6
Chromium **	5	9
Copper	na	12
Nickel	20	3
Zinc	na	67

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na = Not Available.

State of TN values are only To Be Considered (TBC) guidelines.
These are not enforceable clean up levels.

** = No distinction between Chromium (III) and Chromium (VI).

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

J = Estimated value less than the sample quantitation limit, but greater than zero.

X = Estimated value due to a confirmed compound which is off-scale in both columns.

Z = Matrix interference; compound not positively identifiable.

order to preclude analytical instrument saturation. Surface soil samples SS-7 and SS-8 had elevated quantitation limits for some compounds due to their hydrocarbon content. Some samples collected from the main installation also required extensive dilution because of the hydrocarbon content. Reporting limits for surface soils SS-38 and SS-39 were elevated for most of the compounds.

Sampling precision appears to have been quite good. All calculable RPDs were less than the goal of 35%. The field duplicate for Phase I was collected with surface soil SS-1 and for Phase II was collected with surface soil SS-50.

4.2.3 Surface Water

The surface waters at DDMT were analyzed during the RI to determine if DDMT activities were contributing hazardous substances to the aquatic environment. Fishing and swimming restrictions are currently in place for Lake Danielson and the golf course pond. Samples were collected from the lake, the pond and several drainage discharge locations surrounding the installation. The following subsections describe the analytical results. The risk to human health and environment will be discussed in Section 6.

All surface water samples were analyzed for the same constituents using the same analytical procedures as was ground water. These methods were listed in subsection 4.2.1.

4.2.3.1 Surface Water Sampling - During Phase I surface water samples SW-3, SW-6, SW-7 and SW-8 were obtained from Lake Danielson. Samples SW-4 and SW-5 were taken from the golf course pond. SW-1 was collected from the drainage ditch in Dunn Field where it crosses DDMT's northern boundary. SW-2 was collected in a drainage ditch at DDMT's western boundary. SW-10 was collected from the golf course pond drainage ditch where it exits the southern DDMT boundary. SW-9 was collected from the drainage ditch located at the southwest corner of the golf course.

An additional six surface water samples (SW-11 through SW-16) were collected in the Phase II investigation. Three of the surface water samples collected were taken from the same location as in Phase I. SW-11 was collected at the location of SW-10, SW-12 at SW-9 and SW-14 at SW-2. SW-13 was collected from the main drainage inlet to Lake Danielson. SW-16 was collected from the drainage ditch in the northern portion of Dunn Field. SW-15 was collected from the drainage ditch on the east side of Dunn Field.

4.2.3.2 Surface Water Analysis

Lake Danielson - SW-3, SW-6, SW-7 and SW-8 were collected from Lake Danielson. The analytical results are given in Table 4-20. The only constituent detected in Lake Danielson that exceeded the Ambient Water Quality Criteria for Aquatic Life was copper. Table 4-20 also shows that bis(2-ethylhexyl) phthalate exceeded the criteria, but this is probably a sampling contaminant and not a constituent in the lake. The only pesticide contamination detected was a low level of DDE found in SW-6. SW-13 was collected at the inlet drain to the lake. Again, no significant contamination was detected at the time of sampling.

Golf Course Pond - SW-4 and SW-5 were collected from the golf course pond. The only contaminant detected exceeding ambient water quality criteria was copper. SW-10 and SW-11 were collected from the drainage ditch along the southern boundary of DDMT. This ditch receives run-off from the pond, and the surrounding golf course. DDE and DDT were detected in both samples. Since no pesticide contamination was detected in the pond it is suspected that recent pesticide applications to the golf course were transported by surface run-off directly to the drainage ditch.

Drainage Ditch - SW-9 and SW-12 were collected from a drainage ditch located in the southwest corner of the golf course. This drainage ditch receives run-off from the surrounding golf course

TABLE 4-20
POSITIVE RESULTS IN SURFACE WATER
MAIN INSTALLATION
DEFENSE DEPOT MEMPHIS TENNESSEE

	Ambient Water Quality Criteria Aquatic Life (fresh)(a)		LAKE DANIELSON							GOLF COURSE POND				DRAINAGE DITCHES	
			LAKE WATER				LAKE INLET	LAKE DRAINAGE		POND WATER		POND DRAINAGE			
PARAMETER	Acute	Chronic	SW3	SW6	SW7	SW8	SW13	SW9	SW12	SW4	SW5	SW10	SW11	SW2	SW14
HALOGENATED VOLATILES (ug/l)															
Methylene chloride	11,000	na	1BJ	--	2BJ	1BJ	--	1BJ	--	--	--	--	--	1BJ	--
NONHALOGENATED VOLATILES (ug/l)															
2-Butanone	na	na	--	--	--	--	--	--	--	--	--	--	--	--	4J
Acetone	na	na	3BJ	--	2BJ	2BJ	--	18B	4J	2BJ	2BJ	1BJ	4J	5BJ	110
Total xylenes	na	na	--	--	--	--	--	--	--	--	--	--	1J	--	--
NONHALOGENATED SEMIVOLATILES (ug/l)															
Benzoic acid	na	na	--	--	--	--	5BJ	--	6BJ	--	--	--	--	--	3BJ
bis(2-Ethylhexyl) phthalate	940	3	3BJ	--	2BJ	3BJ	6BJ	12BJ	3BJ	3BJ	5BJ	7BJ	3J	--	3BJ
Butyl benzyl phthalate	940	3	--	--	--	--	--	--	--	--	--	--	3J	--	--
Di-n-butyl phthalate	940	3	--	--	--	--	--	--	--	--	--	3J	--	--	--
Di-n-octyl phthalate	940	3	--	--	--	--	--	--	--	--	--	3BJ	--	--	--
Fluoranthene	na	na	--	--	--	--	--	--	--	--	--	--	2J	--	--
N-Nitrosodiphenylamine	na	na	--	--	3J	--	--	--	7BJ	--	3J	2J	--	--	--
Pyrene	na	na	--	--	--	--	--	--	--	--	--	3J	3J	--	--
PESTICIDES (ug/l)															
4,4'-DDE	1050	na	--	.21	--	--	--	--	.65D	--	--	.14	.88D	--	--
4,4'-DDT	1.1	0.001	--	--	--	--	--	.16	2.2D	--	--	.27	1.9D	--	--
Endosulfan-I	na	na	--	--	--	--	--	--	--	--	--	--	--	.16Z	--

TABLE 4-20

POSITIVE RESULTS IN SURFACE WATER

MAIN INSTALLATION

DEFENSE DEPOT MEMPHIS TENNESSEE

	Ambient Water Quality Criteria Aquatic Life (fresh)(a)		LAKE DANIELSON							GOLF COURSE POND				DRAINAGE DITCHES	
			LAKE WATER				LAKE INLET	LAKE DRAINAGE		POND WATER		POND DRAINAGE			
PARAMETER	Acute	Chronic	SW3	SW6	SW7	SW8	SW13	SW9	SW12	SW4	SW5	SW10	SW11	SW2	SW14
VOLATILE METALS (ug/l)															
Arsenic	360	190	--	48	41	37	--	47	30	--	--	--	--	--	--
Lead	82	3.2	--	--	--	--	--	295	100	--	--	--	50	--	--
NONVOLATILE METALS (ug/l)															
Barium	na	na	15B	17B	15B	15B	60	60B	98	14B	14B	26B	55	76B	42
Cadmium	na	na	--	--	--	--	--	5	19	--	--	--	--	--	--
Chromium	na	na	--	--	--	--	--	--	20	--	--	--	--	20	10
Copper	18	12	27	24B	20B	19B	--	68	20	46	30	25	30	23B	--
Silver	na	na	--	--	--	--	--	13	--	--	--	--	--	--	--
Zinc	120	110	68	41	32	37	54	400	150	22	22	81	110	29	36

Shaded areas are values that are equal to or exceed either the acute or chronic Ambient Water Quality Criteria Guidelines.

na = Not Available

(a) Source: Integrated Risk Information System (USEPA, 1990); Interim Final RFI Guidance (USEPA, 1989).

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL) but greater than the Instrument Detection Limit (IDL).

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

J = Estimated value less than the sample quantitation limit but greater than zero.

Z = Matrix interference; compound not positively identifiable.

-- = Not detected.

but does not drain Lake Danielson. DDT was detected in both samples at levels exceeding the ambient water criteria. Lead, copper and zinc were also detected at elevated levels.

SW-2 and SW-14 were collected from a drainage ditch located along the western boundary of DDMT. No significant contamination was detected in either sample.

4.2.3.2.2 Surface Water Analysis - Dunn Field - One surface water sample was collected in Phase I of the RI and two in Phase II. Table 4-21 lists the analytical results for Dunn Field surface water.

SW-1 (Phase I) and SW-16 (Phase II) were collected in the drainage ditch at the northern boundary of Dunn Field during Phase I. No elevated levels of constituents were detected in either sample.

SW-15 was collected in Phase II from the drainage ditch at the western boundary of Dunn Field. A very low level of the pesticide dieldrin was detected in this sample.

4.2.3.3 Quality Control - Surface Water - The field duplicate RPDs were generally incalculable due to the low levels detected. The RPD for barium was within control limits, but the RPDs for 4,4'-DDT, 4,4'-DDE, and zinc were not. The trip blanks were contaminated with concentrations of acetone and/or methylene chloride. These data are discounted however, because the associated method blanks were also contaminated with these compounds.

The rinsates for the Phase I and Phase II sampling efforts are identified as SW-3R and SW-10R, respectively. Results for all parameters tested were below the detection limits except for copper (46 ug/l) and zinc (22 ug/l). Copper results for the Phase I sampling effort may be biased high. The zinc contamination in the rinsate may be discounted because the associated method blank also contained zinc.

TABLE 4-21
POSITIVE RESULTS IN SURFACE WATER
DUNN FIELD
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	Ambient Water Quality Criteria Aquatic Life (fresh)(a)		PHASE I	PHASE II	
	Acute	Chronic	SW1	SW15	SW16
HALOGENATED VOLATILES (ug/l)					
Methylene chloride	11,000	na	1BJ	--	--
NONHALOGENATED VOLATILES (ug/l)					
Acetone	na	na	7BJ	18	2J
NONHALOGENATED SEMIVOLATILES (ug/l)					
Benzoic acid	na	na	--	--	3BJ
bis(2-Ethylhexyl) phthalate	940	3	--	--	10BJ
N-Nitrosodiphenylamine	na	na	--	--	5BJ
PESTICIDES (ug/l)					
Dieldrin	na	na	.13	.11	--
VOLATILE METALS (ug/l)					
Lead	82	3.2	--	40	--
NONVOLATILE METALS (ug/l)					
Barium	na	na	91B	77	56
Cadmium	na	na	6	--	--
Copper	18	12	18B	10	--
Zinc	120	110	57	110	140

Shaded areas are values that are equal to or exceed either the acute or chronic Ambient Water Quality Criteria guidelines.

na = Not Available

(a) Source: Integrated Risk Information System (USEPA, 1990); Interim Final RFI Guidance (USEPA, 1989)

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).

B (Organic) = Found in method blank.

J = Estimated value less than the sample quantitation limit, but greater than zero.

-- = Not detected.

The surrogate recoveries for all organic parameters for Phase I and Phase II were within control limits. This shows good accuracy for all of the organic analyses.

The MS/MSD results for the Phase I and Phase II sampling episodes were generally within control limits. The recoveries and RPDs for all of the parameters were within acceptable limits except for the semi-volatile organic RPDs for SW-5 (Phase I) and the silver recovery for SW-106 (Phase II). The semi-volatile RPDs for SW-5 were outside the control limits for the phenol and phenol derivative MS/MSDs. Therefore, the precision for these compounds in the samples taken during the Phase I sampling effort may be poor. The recovery of silver for SW-106 was 62%, which may be due to a matrix interference of laboratory digestion technique. Silver results for the Phase II metals may be biased low.

4.2.4 Sediments

Sediment samples from Lake Danielson and the golf course pond were analyzed to determine if past activities at DDMT had released contamination to the two bodies of water. Contaminants that were not detected in the water column could possibly have been trapped within the sediments.

The sediment samples collected from Lake Danielson and the golf course pond were analyzed following the soil methods described in subsection 4.2.2.

4.2.4.1 Sediment Sampling - Ten sediment samples were collected from Lake Danielson and the golf course pond during Phase I of the RI. Two samples were collected at each location; one from the surface (labeled SD-X-SS) and one at a depth of 9-inches (SD-X-9). SD-1, SD-2 and SD-3 were taken from Lake Danielson. SD-4 and SD-5 were collected from the golf course pond. No sediment samples were collected in Phase II.

4.2.4.2 Sediment Sample Analysis - Analytical results from the sediment samples collected during Phase I of the RI are given on Table 4-22. The sediments collected from Lake Danielson consisted of firm clays. Two of the samples collected from Lake Danielson contained appreciable contamination of the pesticides DDE and DDD. These samples were: SD-1-SS (surface sediment) and SD-3-SS. PAHs were also detected in several of the samples. Two sediment samples taken from the pond contained a much higher level of pesticide and PAHs contamination than found in Lake Danielson.

4.2.4.3 Quality Control Sediment - Two field duplicates were collected from the locations identified as SD-1-SS and SD-1-9. Most of the results for these samples were not above the detection limit, no RPDs could be calculated. Positive results were detected for the pesticides 4,4'-DDE and 4,4-DDT in SD-1-SS. The recoveries and RPDs for these pesticides were outside of the control limits indicating that the results for these compounds should be flagged as estimated. A rinsate was not necessary since the samples were shipped to the laboratory in the individual butyl acetate tubes in which they were collected. Matrix interferences are indicated for the sediments from Lake Danielson. Surrogate recoveries and MS/MSD recoveries and for all of the pesticide analyses were generally outside of the control limits. All other MS/MSD results were within acceptable ranges.

4.2.5 Drilling Mud and Drilling Water

4.2.5.1 Mud and Water Sampling - Several borings were introduced in Phase I and Phase II using mud rotary techniques (see Appendix A). A mud sample was taken from the drilling pit during the installation of MW-18 in Phase I (SBMVD1) and from STB-7 (SBMVDII) during Phase II. A water sample from the fire hydrants used during drilling operations was also collected during both phases of sampling (HYDH201 and HYDH202).

TABLE 4-22
POSITIVE RESULTS IN SEDIMENTS
DEFENSE DEPOT MEMPHIS TENNESSEE

		PHASE I									
		LAKE DANIELSON						GOLF COURSE POND			
PARAMETER	STATE OF TN	SD-1-SS	SD-1-9	SD-2-SS	SD-2-9	SD-3-SS	SD-3-9	SD-4-SS	SD-4-9	SD-5-SS	SD-5-9
HALOGENATED VOLATILES (ug/kg)											
Methylene chloride	8600	42B	38B	22B	22B	28B	22B	27B	29B	14B	25B
NONHALOGENATED VOLATILES (ug/kg)											
Acetone	590	71B	75B	46B	51B	43B	36B	170	140	21	24
2-Butanone	7200	--	3BJ	1BJ	--	--	--	6J	5J	--	--
Toluene	14,400	--	--	--	--	--	--	--	--	--	2J
HALOGENATED SEMIVOLATILES (ug/kg)											
Pentachlorophenol	3600	--	--	--	--	--	--	--	--	270J	--
NONHALOGENATED SEMIVOLATILES (ug/kg)											
bis(2-Ethylhexyl) phthalate	15,000	550	570	580J	530J	760J	640J	710J	630J	710J	710J
Benzoic acid	na	460J	490J	300J	590J	160J	470J	680J	450J	1200J	970J
N-Nitrosodiphenylamine	12.8 - 32	100BJ	--	170BJ	--	270BJ	100BJ	190BJ	--	280BJ	190BJ

(continued on next page)

TABLE 4-22
POSITIVE RESULTS IN SEDIMENTS
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	STATE OF TN	PHASE I									
		LAKE DANIELSON						GOLF COURSE POND			
		SD-1-SS	SD-1-9	SD-2-SS	SD-2-9	SD-3-SS	SD-3-9	SD-4-SS	SD-4-9	SD-5-SS	SD-5-9
Polynuclear Aromatic Hydrocarbons (PAHs)											
Acenaphthene	.	--	--	--	--	--	--	--	--	110J	140J
Anthracene	.	--	--	--	--	--	--	--	--	200J	200J
Benzo(a)anthracene	.	--	--	--	--	230J	--	--	--	1100	680J
Benzo(a)pyrene	.	--	--	--	--	230J	--	--	--	1300	500J
Benzo(b)fluoranthene	.	--	--	--	--	380J	--	--	--	1800	690J
Benzo(g,h,i)perylene	.	--	--	--	--	200J	--	--	--	940	390J
Benzo(k)fluoranthene	.	--	--	--	--	290J	--	--	--	1600	690J
Chrysene	.	--	--	--	--	300J	--	--	--	1400	750J
Dibenzo(a,h)anthracene	.	--	--	--	--	--	--	--	--	330J	140J
Fluoranthene	.	74J	71J	100J	--	700J	--	130J	--	3000	1700
Fluorene	.	--	--	--	--	--	--	--	--	120J	150J
Indeno(1,2,3-cd)pyrene	.	--	--	--	--	210J	--	--	--	900	350J
Phenanthrene	.	--	--	--	--	330J	--	100J	--	1300	1200
Pyrene	.	--	--	--	--	610J	--	100J	--	2400	1400
Total PAHs	0.0028	74	71	100	--	3,460	--	330	--	16,500	8,980

PESTICIDES (ug/kg)

4,4'-DDD	na	47	--	--	--	45	--	190D	280D	3000D	960D
4,4'-DDE	na	36	--	--	--	110D	--	68D	64D	460Z	--
4,4'-DDT	.23 - .58	--	--	--	--	--	--	--	--	2900D	620D
Endosulfan-I	74	--	--	--	--	--	--	--	--	200Z	--

TABLE 4-22
POSITIVE RESULTS IN SEDIMENTS
DEFENSE DEPOT MEMPHIS TENNESSEE

		PHASE I									
		LAKE DANIELSON						GOLF COURSE POND			
PARAMETER	STATE OF TN	SD-1-SS	SD-1-9	SD-2-SS	SD-2-9	SD-3-SS	SD-3-9	SD-4-SS	SD-4-9	SD-5-SS	SD-5-9
VOLATILE METALS (mg/kg)											
Lead	5	--	--	--	--	--	--	5	6	91	55
Mercury	0.2	0.04	0.05	0.05	0.05	--	--	0.05	0.04	0.06	0.04
NONVOLATILE METALS (mg/kg)											
Barium	100	76	88.4	122	110	89.7	99	96	95.2	101	104
Cadmium	1	0.7B	--	--	--	--	--	--	--	0.9B	--
Chromium **	5	13	13	12	10	12	9	13	11	28	21
Copper	na	20	23	18	17	15	16	15	16	28	26
Nickel	20	11	14	14	12	14	13	13	13	14	14
Zinc	na	44.5N	47.8N	50.9N	47.6N	48.8N	45.4N	44.7N	43.2N	80.9N	66.8N

Shaded areas are values that are equal to or exceed the State of Tennessee soil criteria guidelines.

na = Not Available

State of TN values are only To Be Considered (TBC) guidelines. These are not enforceable clean up levels.

B (Inorganic) = Value less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).

B (Organic) = Found in method blank.

D = Identified in an analysis at a secondary dilution factor.

J = Estimated value less than the sample quantitation limit, but greater than zero.

N = Spiked sample recovery not within control limits.

Z = Matrix interference; compound not positively identifiable.

** = No distinction between Chromium (III) and Chromium (VI).

-- = Not detected.

4.2.5.2 Drilling Mud and Drilling Water Analysis - Analytical results for the drilling mud and hydrant samples are given in Table 4-23. Elevated metal constituent levels were detected in both of the mud samples. The high barium levels are to be expected since the bentonite mud used is predominantly made of this constituent. The use of mud during the installation of monitoring wells is not suspected as a source of metal contamination. Based on the analytical results, no correlation can be made between wells in which high levels of metal contamination occurred and the wells that were drilled using mud rotary technique. The water samples collected from the fire hydrant tested positive only for low levels of barium and copper.

TABLE 4-23
POSITIVE RESULTS IN DRILLING WATER AND DRILLING MUD
DEFENSE DEPOT MEMPHIS TENNESSEE

PARAMETER	PHASE I		PHASE II	
	HYDH20-1 (ug/L)	SBMUD-1 (ug/L)	HYDH20-2 (ug/L)	SBMUD-2 (ug/kg)
HALOGENATED VOLATILES				
Bromodichloromethane	3J	--	--	--
Chloroform	3J	--	--	--
Dibromochloromethane	3J	--	2J	--
Methylene chloride	--	1JB	--	55B
NONHALOGENATED VOLATILES				
Acetone	18J	5JB	--	230
2-Butanone	--	1JB	--	--
NONHALOGENATED SEMIVOLATILES				
bis(2-Ethylhexyl) phthalate	--	10,000(ug/kg)	--	4900B
Di-n-butyl phthalate	--	--	--	1600J
N-Nitrosodiphenylamine	--	--	2BJ	--
VOLATILE METALS				
Arsenic	--	955	--	--
Lead	--	1450	--	3000
Mercury	--	5.3	--	--
Selenium	--	369	--	--
NONVOLATILE METALS				
Antimony	--	300	--	--
Barium	50B	6890	18	12200
Cadmium	--	50	--	--
Chromium	--	140	--	3000
Copper	62	1040	20	2000
Nickel	--	789	--	--
Silver	--	26	--	--
Zinc	32	1810	--	18000

B (Organic) = Found in method blank.

J = Estimated value less than the sample quantitation limit, but greater than zero.

-- = Not detected.

5.0 CONTAMINANT FATE AND TRANSPORT

The knowledge of the potential and actual environmental concentrations and types of toxic pollutants is a necessary part of any risk assessment. The potential for exposure to a particular compound or element depends upon whether it can persist in the particular medium of interest. The fate of contaminants and their transport depends upon the site's physical conditions, the characteristics of the source and the extent of the contaminant release. The behavior of the contaminants found in each of the media sampled (ground water, surface water, sediment, surface soil, and subsurface soil) will be discussed with consideration of the various chemical, physical, and/or biological processes that are possible at Defense Depot Memphis, Tennessee. The following topics will be discussed in this Chapter:

- potential routes of migration
- persistence
- migration

5.1 POTENTIAL ROUTES OF CONTAMINANT MIGRATION

Contaminant migration can occur in several ways, depending upon the characteristics of the element or compound in question, the medium in which the element or compound is located, and the type(s) of media in close proximity. Various physical processes may be involved. The transport of pollutants by water to receptors is a central theme because of the importance of water to life, its contribution to the generation of leachate and its ability to mobilize contaminants from source areas. The water solubility of the compound or element will play a significant role in determining what migration route, if any, will be taken. Transformation into a gaseous state (volatilization) or adherence to soil or sediment particles (adsorption) are migration routes. Extraction from sediments or soils (leachipg) or the movement of soil or sediment particles with adsorbed pollutants attached by the movement of water are also possible. Accumulation within the body of aquatic life forms and/or bacteria (bioaccumulation) can also be a pathway from waters, soils, or sediments.

5.1.1 Metals

The migration of metals in the environment is complicated because metals can exist in a variety of forms. For instance, metals can exist in different oxidation states. Metals can also exist as charged particles (i.e. ions in solution) or in a chargeless or neutral state. Metals may combine with other metals or organic chemicals to form many different compounds. In any case, the potential for migration will then depend upon the solubility of these forms in water. Metals in solution will exist in an ionic form; non-ionic forms will precipitate and remain bound to sediments in soil. All of the twelve metals analyzed for were detected in at least one of the four matrices (ground water, surface water, sediment, and soil) sampled. Five of the metals were selected as indicator chemicals because of the concentrations detected at DDMT and the toxicity associated with these metals. These metals are arsenic, barium, chromium, lead, and mercury.

5.1.1.1 Arsenic - Because of its multiple oxidation states and its tendency to form soluble complexes, the geochemistry of arsenic is both intricate and not well characterized. The adsorption of arsenic onto clays, iron oxides, and organic (humic) material is an important transport pathway. Arsenic is also mobile in the aquatic environment; it cycles through water columns, sediments, and biota. The solubility of arsenic varies widely according to the oxidation state. In the natural environment, four oxidation states are possible for arsenic: The (-3) state, the metallic (0) state, the (+3) state, and the (+5) state. The (+3) and (+5) states are common in a variety of complex minerals and in dissolved salts in natural waters. The element most commonly associated with arsenic in nature is sulfur. In all, there are one hundred or more arsenic-bearing minerals known to occur in nature. The oxo acids, arsenious acid (H_3AsO_3) and arsenic acid (H_3AsO_4), are the prevalent forms of arsenic in aerobic (oxygen containing) waters. Arsenic can form complexes with a number of organic compounds, most of which increase its water solubility (Callahan et al., 1979; USEPA, 1983; ATSDR-Arsenic, 1987).

5.1.1.2 Barium - Barium exists in nature as a salt. Several salts including the most common, barite ($BaSO_4$) and witherite ($BaCO_3$), have low solubility, so precipitation into sediments is likely. Due to low vapor pressures and high boiling points, these salts are unlikely to volatilize. Bioaccumulation of barium is not a common migration process except in systems in which the barium concentration exceeds that of calcium and magnesium (USEPA, 1983).

5.1.1.3 Chromium - Chromium exists in two oxidation states in aqueous systems: (+3) and (+6) oxidation states. The hexavalent form is soluble, existing in solution as an anion complex, and is not absorbed to any significant degree by clays or hydrous metal oxides. It is, however, absorbed strongly to activated carbon. Hexavalent chromium is a moderately strong oxidizing agent and reacts with organic or other oxidizable material to form trivalent chromium. Trivalent chromium combines with aqueous hydroxide ion (^-OH) to form insoluble chromium hydroxide ($Cr(OH)_3$). Precipitation of this material is thought to be the dominant transport pathway of chromium in natural waters. Adsorption processes also result in removal of dissolved chromium to the bed sediments. Chromium is bioaccumulated by aquatic organisms and the passage of chromium through the food chain has been documented. Chromium in soil can occur as the insoluble oxide dichromate (Cr_2O_3) and may be aerosolized into the atmosphere or transported to surface waters and ground waters in run-off and leachates (Callahan et al., 1979; USEPA, 1983; ATSDR-Chromium, 1987).

5.1.1.4 Lead - Lead is transferred continuously between air, water and soil. Soil leaching of lead into ground water is determined by the chemical characteristics of the soil. The availability of lead in soils is related to moisture content, soil pH, organic matter, and the concentration of calcium and phosphates. Lead is bioaccumulated in shellfish and plants (Callahan et al., 1979; USEPA, 1983; ATSDR-Lead, 1988). However, increasing pH and calcium ion (Ca^{2+}) concentration diminish the capacity of plants to absorb lead, as Ca^{2+} ions compete with the Pb^{2+} for exchange sites on the soil and root surfaces.

5.1.1.5 Mercury - Mercury's major removal mechanism from a natural system is adsorption onto the surfaces of clay particles and subsequent settling as part of the sediment. The overwhelming majority of any dissolved mercury is removed in this manner within a relatively short time, generally in the immediate vicinity of the source. Much smaller portions of the dissolved mercury are ingested by the aquatic biota or transported by current movement and dilution. Secondary transformations of mercury in the sediments can occur; these include precipitation as mercury sulfide and methylation reactions caused by bacteria. Since mercury itself is not destroyed, these inorganic and organic forms of mercury may then release ionic or metallic mercury into the water column as part of a recycling process. Resuspension of sediments by turbulence or the activity of benthic organisms can also release these compounds of mercury directly into the water column (Callahan et al., 1979; USEPA, 1983; ATSDR-Mercury, 1988).

5.1.2 Volatile Organics

By their nature, the concentrations of volatile organic compounds tend not to remain at constant levels in any of the media under consideration. Only media from which volatilization is hindered would be expected to retain significant amounts. Several of the ground water samples and a few surface and soil boring samples contained measurable levels of toxic volatile organic compounds. Eight indicator chemicals of primary concern due to their prevalence at DDMT and their toxicity are discussed below. These are 1,1-dichloroethene, 1,1,2,2-tetrachloroethane, trichloroethene, tetrachloroethene, methylene chloride, 1,2-dichloroethene, carbon tetrachloride and acetone. Discussions below are based on Callahan et al., 1979, and ATSDR, 1988.

5.1.2.1 1,1-Dichloroethene - Volatilization is the major process whereby 1,1-dichloroethene is removed from the aquatic and soil environment. 1,1-dichloroethene is slightly water soluble. Adsorption onto soils or sediments with high organic content is also possible. 1,1-dichloroethene probably does not bioaccumulate to a significant extent.

5.1.2.2 1,1,2,2-Tetrachloroethane - The primary transport process for 1,1,2,2-tetrachloroethane is volatilization. Because it is slightly soluble in water, leaching is a possible migration pathway. It was detected in ground-water samples, one surface soil sample, and soil samples from STB-6. Bioaccumulation is possible.

5.1.2.3 Trichloroethene - Volatilization is the most important transport process for trichloroethene. As it has been found to be highly mobile in soil, leaching from subsurface soil to ground water is possible. Removal from the atmosphere in rain (wet deposition) is also a likely process, but bioaccumulation potential is low.

5.1.2.4 Tetrachloroethene - While volatilization is the dominant transport mechanism for this compound, leaching into the ground water is also likely. Return to the soil through wet deposition is also likely. Adsorption is not a primary transport mechanism except perhaps in dry soils with high clay content. Leaching into subsurface soil and ground water is likely, but bioaccumulation is not.

5.1.2.5 Methylene Chloride - Volatilization is a transport process for the removal of methylene chloride from aquatic system. Once in the atmosphere methylene chloride can, at high altitudes, react with hydroxyl radicals or undergo photodissociation. Methylene chloride does not readily undergo oxidation or hydrolysis in aquatic systems. Photooxidation should not occur with methylene chloride since this compound does not contain a chromophore that can absorb visible or near UV light. Methylene chloride does not bioaccumulate.

5.1.2.6 1,2-Dichloroethene - Volatilization is the major process for removal of 1,2-dichloroethene from aquatic systems. At high altitudes, 1,2-dichloroethene is attacked by hydroxyl radicals, resulting in degradation products. Photodissociation does not appear to be a significant fate for 1,2-dichloroethene in aquatic systems. Information is not available for this compound to indicate that it would bioaccumulate, biodegrade (microorganism), or adsorb to sediments or solids. 1,2-dichloroethene is also very resistant to hydrolysis.

5.1.2.7 Carbon Tetrachloride - Carbon tetrachloride is volatile and can be expected to leave from aquatic environments when its volatilization is not hindered. Carbon tetrachloride is stable to attach from hydroxyl radicals, and photodissociation in the high altitude atmosphere is slow. Photodissociation in aquatic environments is not significant. Oxidation, sorption, bioaccumulation, bio-transformation, hydrolysis, and biodegradation do not readily occur with carbon tetrachloride.

5.2.1.8 Acetone - Acetone can be expected to volatilize from aquatic media where its volatilization is unhindered, i.e. surface water. However, acetone is very soluble in water and should accumulate in wet soil and ground water if its volatilization is unhindered. Information on the fate of acetone regarding biodegradation, bio-transformation, susceptibility to hydrolysis and oxidation, or sorption to sediments in aquatic environments is not readily available.

5.1.3 Polycyclic Aromatic Hydrocarbons

Of the semivolatile organic compounds analyzed for, only polycyclic aromatic hydrocarbons (PAHs) were found at measurable levels with regularity in soil samples. Several different PAHs were detected. Of these, the three indicator chemicals of primary concern due to their prevalence at DDMT and their toxicity are benzo(a)pyrene, benzo(a)anthracene, and dibenzo(a,h)anthracene. PAHs are semivolatiles. They have low vapor pressures and boiling points greater than 100°C. They are also characterized by their relatively low solubility in water. The primary transport processes are different from those of volatile organics, with adsorption onto soil or other organic matter being most important. Adsorption onto particulates is the primary transport process for PAHs. Adsorption onto mobile soil or sediments is largely responsible for their movement; examples include the erosion of soil and the movement of suspended sediments. Adsorption onto soot particles that can be carried on wind currents and then return to the surface (dry deposition) are the important pathways to and from the atmosphere. Short-term bioaccumulation also occurs but is not important because of the rapid metabolism and excretion of PAHs by most aquatic organisms (Callahan et al., 1979; ATSDR 1987).

5.1.4 Pesticides and PCBs

Pesticides and polychlorinated biphenyls (PCBs) are also classified as semivolatile organic compounds. Volatility is generally of little importance with respect to transport; adsorption and bioaccumulation are much more important. The indicator chemicals of primary concern due to their prevalence at DDMT and their toxicity are dichlorodiphenyltrichloroethane (DDT) and its degradation products dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyldichloroethene (DDE), Dieldrin, and the PCBs.

5.1.4.1 DDT, DDE, and DDD - DDD and DDE are degradation products of DDT; all have generally similar properties. Adsorption onto airborne particulates and sediments are the primary transport pathways that are a result of the relative insolubility of these compounds in water. Removal from the atmosphere through particulate fallout is likely. Bioaccumulation and magnification up through the food chain (bioconcentration) are also important. Volatilization is a possible transport process (Callahan et al., 1979; ATSDR, 1988).

5.1.4.2 Dieldrin - Sorption of dieldrin to soils and sediments is the most prevalent transport pathway, but there is a tendency to bioaccumulate and biomagnify. Co-movement with suspended particulates in water is a likely transport mechanism, but leaching into ground water does not generally occur due to the relatively low solubility of Dieldrin. Volatilization is generally slow for Dieldrin but is relatively high for Aldrin, which is readily converted to Dieldrin. This reaction is probably initiated by UV radiation. It is therefore possible that Aldrin might migrate and then react to form Dieldrin in its new location (Callahan et al., 1979; ATSDR, 1987).

5.1.4.3 Chlordane - Volatilization from aquatic environments, sorption to sediments, and bioaccumulation are important fates for chlordane. Chlordane is photosensitive and should undergo light induced reaction to produce isomers and other products. The biotransformation of chlordane is probably similar to Dieldrin. Chlordane is not unsusceptible to oxidation in aquatic environments, but is somewhat susceptible to hydrolysis, with a half life of 4 years (Callahan et al., 1979; ATSDR, 1988).

5.1.4.4 Heptachlor - A major fate of heptachlor in aquatic systems will be the hydrolysis to 1-hydroxyl chlordane. Heptachlor also shows strong tendencies for bioaccumulation. Sorption to sediments could be an important process for heptachlor that does not undergo hydrolysis. Volatilization is also possible (Callahan et al., 1979; ATSDR, 1988).

5.1.4.5 Beta-Hexachlorocyclohexane (Beta-BHC) - Volatilization, biotransformation and biodegradation appear to be important transport paths for Beta-BHC. Hydrolysis however, does not occur in aquatic systems. Photolysis can occur, but the data supporting photolysis in aquatic systems is conflicting.

5.1.4.6 PCBs - PCBs are prepared in mixtures of different compounds characterized by the number and arrangement of chlorine atoms attached. Different mixtures contain different chlorine to carbon ratios and are called "Aroclors" and usually have a number designation associated with them. All of the PCBs behave in essentially the same manner. Adsorption of PCBs onto soil particles and sediments is the most prevalent transport mechanism. However, bioaccumulation is also likely and results in biomagnification. Although not nearly as prevalent, volatilization and adsorption onto airborne particulates are responsible for spreading PCBs throughout the world; they are redeposited through wet deposition (Callahan et al., 1979).

5.2 CONTAMINANT PERSISTENCE

The persistence of a contaminant in a particular medium will be determined by its resistance to chemical and/or biological changes as well as to the transport mechanisms discussed above. A toxic pollutant may be subject to a variety of chemical reactions depending upon susceptibility to natural radiation and the presence of suitable reactants in the environment. In general, chemical reactions will occur where the oxidation state of one or more of the atoms within the reactants changes. For organic compounds, oxygen is usually the atom whose oxidation state changes, although nitrogen, sulfur, bromine, and chlorine may undergo chemical reaction. The metal atom in inorganic complexes is usually the atom whose oxidation state changes. Reaction with water (hydrolysis) is possible for some compounds. UV radiation can remove an electron from a compound to form a reactive species called a radical in a process known as photolysis. Contaminants can be transformed or degraded through photolysis either directly or indirectly by reaction with other radical species. Metabolism of compounds or elements by microbes and/or aquatic life may result in slight alteration (biotransformation) or significant breakdown (biodegradation) of the contaminant.

5.2.1 Metals

The persistence of the five elements discussed in Subsection 5.1.1 depends upon their rate of transport from the site of interest which, in turn, depends upon their form. As mentioned earlier, metals generally have more than one naturally occurring state and exist in several different chemical forms.

5.2.1.1 Arsenic - The fate of arsenic in the aquatic environment depends largely on prevailing pH and oxidation-reduction conditions. Sediments are the primary sink for arsenic. A number of organisms can metabolize arsenic to form organometallic compounds and thereby increase arsenic mobility in the environment. Arsenic can be reduced and methylated by soil organisms, though the rate at which arsenic is subsequently volatilized may vary according to site conditions. Arsenic in soil is predominantly in soluble forms (Callahan et al., 1979; USEPA, 1983; ATSDR-Arsenic, 1987).

5.2.1.2 Barium - Little information is available concerning the ultimate fate of barium in the environment. As barium is commonly found in soils and in most surface water and ground water, it is assumed to be persistent in these media (USEPA, 1983).

5.2.1.3 Chromium - Hexavalent chromium is the species usually found in industrial wastes; it will eventually be reduced to trivalent chromium by inorganic matters present in water. As discussed in Subsection 5,1.1.3, trivalent chromium reacts with aqueous hydroxide ion to form insoluble chromium hydroxide. Although chromium can react to form a variety of organic complexes, chromium persists in sediments after precipitating out of solution (Callahan et al., 1979; USEPA, 1983; ATSDR-Chromium, 1987).

5.2.1.4 Lead - Lead is present in soils as Pb^{+2} which may precipitate as lead sulfate, hydroxides and carbonates. Lead is extremely persistent in soil and water and the species of lead found is dependent on temperature, pH and the presence of organic matter. Lead is relatively immobile in soils and associates primarily with suspended solids and sediments in aquatic systems. Below pH of 6, $PbSO_4$ (anglesite) is dominant and $PbCO_3$ is most stable at pH values above 7. The hydroxide $Pb(OH)_2$ controls solubility around pH 8, and lead phosphates, of which there are many forms, may control Pb^{2+} solubility at intermediate pH values (Callahan et al., 1979; USEPA, 1983; ATSDR-Lead, 1988).

5.2.1.5 Mercury - The primary sink for mercury release to the environment is sediments. Mercury is able to exist in the natural environment in three oxidation states: as the native element itself, in the (+1) (mercurous) state, and in the (+2) (mercuric) state. The nature of the species which will occur in a given complex or exist in solution depends upon the potential for oxidation or reduction and the pH of the environment. Deposition of mercury in sediments that can cause reduction can result in precipitation of the sulfide. Biotransformation of mercury in the sediments can result in remobilization. An example is dimethyl mercury which has a low solubility in water and is a gas at room temperature; volatilization may occur (Callahan et al., 1979; USEPA, 1983; ATSDR-Mercury, 1988).

5.2.2 Volatile Organics

Chlorinated volatile organic compounds are basically unreactive and are unlikely to undergo chemical or biological transformation unless the medium in which they are contained slows the volatilization process. However, they can undergo either chemical or biological reactions when their concentration is large enough that volatilization and reaction rates can achieve equilibrium. The slight solubility of most volatile organic compounds in water generally results in small but measurable persistence in ground waters where reactions with bacteria can occur (Callahan et al., 1979; ATSDR, 1988).

5.2.2.1 1,1-Dichloroethene - 1,1-Dichloroethene does not undergo measurable photolysis and it is not readily oxidized. 1,1-dichloroethene is also stable toward hydrolysis. 1,1-dichloroethene is slightly soluble in water and can be expected to persist in ground waters.

5.2.2.2 1,1,2,2-Tetrachloroethane - 1,1,2,2-Tetrachloroethane is essentially nonreactive in the atmosphere. In water however, base-catalyzed hydrolysis to form trichloroethene is an important degradation path under aerobic and anaerobic conditions. Anaerobic biodegradation is also to be considered an important loss pathway in water and soils with trichloroethene as the reaction product. With its solubility, persistence in ground water is likely.

5.2.2.3 Trichloroethene - Upon volatilization, trichloroethene reacts readily with hydroxyl radicals in the atmosphere. After leaching to ground water where volatilization is hindered, it is persistent due its solubility. Biodegradation and other chemical reactions are slow and do not contribute measurably to its fate.

5.2.2.4 Tetrachloroethene - Reaction of tetrachloroethene with hydroxyl radicals in the atmosphere is the most likely degradation process for this compound. However, tetrachloroethene is persistent in the atmosphere except during periods of heavy rainfall. This is due to the relative stability of the hydroxyl radical as indicated by its long half-life (approximately 96 days). As volatilization from ground water is hindered, slow biodegradation and hydrolysis processes may occur. However, tetrachloroethene is persistent under such anaerobic conditions.

5.2.2.5 Methylene Chloride - If volatilization is hindered, methylene chloride could expect to be persistent in the ground-water environment. Methylene chloride does not bioaccumulate or biodegrade, or adsorb to sediments.

5.2.2.6 1,2-Dichloroethene - 1,2-Dichloroethene does not bioaccumulate, biodegrade, or adsorb to sediments or solids. It does not undergo hydrolysis, so it should persist in any aquatic media where volatilization is hindered.

5.2.2.7 Carbon Tetrachloride - Carbon tetrachloride is extremely stable and should persist in any aquatic environment where volatilization is hindered.

5.2.2.8 Acetone - Acetone should be expected to persist in ground water because of its solubility in water. Acetone in the soil will either quickly volatilize or probably dissolve in soil water (where volatilization cannot occur).

5.2.3 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are generally amenable to photolysis reactions, subject to rapid degradation upon reaction with strong oxidants, but do not undergo hydrolysis. While oxidation initiated by photolysis is possible for PAHs in solution, it is not a major degradation process because of the minimal amount that exists in these forms. Direct photolysis results in rapid degradation of the minimal amounts that do dissolve. Biodegradation is considered the major transformation process. However, because this process is slow and competing processes (solubilization, oxidation initiated by photolysis, volatilization, etc.) occur only to minimal extents, PAHs are persistent in the soils and sediments in which they adsorb as discussed above (Callahan et al., 1979; ATSDR, 1987).

5.2.4 Pesticides and PCBs

The pesticides and PCBs discussed in subsection 5.1.4 are persistent due to their chemical stability and affinity for organic matter. Although photolysis is a potential loss pathway, it may not be possible if the medium is not exposed to ultraviolet (UV) radiation, as is the case with sediments under deep water and subsurface soils. Biological action is generally the only removal mechanism; however, it may be slow.

5.2.4.1 DDT, DDE, and DDD - Biotransformation of DDT to DDE (aerobic conditions) and/or DDD (anaerobic conditions) is the primary loss mechanism. DDE and DDD do not undergo further degradation, however. Direct photolysis of DDT and DDD is slow, but for DDE it is rapid. Indirect photolysis can occur quickly for all three compounds. Chemical oxidation and hydrolysis are too slow to be competitive. Due to their insolubility, these three compounds are persistent in soils and sediments (Callahan et al., 1979; ATSDR-DDT/DDE/DDD, 1988).

5.2.4.2 Dieldrin - Dieldrin is persistent in soils and sediments and is relatively insoluble in water. Oxidation and hydrolysis are not important factors, and the contribution of oxidation initiated by photolysis is uncertain. It is resistant to biodegradation, although this may be its ultimate fate (Callahan et al., 1979; ATSDR-Aldrin/Dieldrin, 1987).

5.2.4.3 Chlordane - Chlordane is persistent in soils and sediments and is relatively insoluble in water. Hydrolysis, however, is slow. Chlordane should persist in soil, but should be slowly degraded in ground water.

5.2.4.4 Heptachlor - Heptachlor should not persist in the environment since it is easily hydrolyzed and then biotransformed or bioaccumulated.

5.2.4.5 Beta-Hexachlorocyclohexane - Beta-Hexachlorocyclohexane does not hydrolyze. However, it is biotransformed and biodegradable. Beta-hexachlorocyclohexane should persist where these processes are hindered.

5.2.4.6 PCBs - PCBs are resistant to oxidation and hydrolysis. The heavier PCBs may be amenable to oxidation initiated by photolysis, although this is unlikely as they are not generally found in media that are exposed to UV radiation. They are resistant to biodegradation and biotransformation; only those molecules with less than four chlorine atoms are generally susceptible. Due to their insolubility, PCBs are persistent in soils, sediments, and animal tissues (Callahan et al., 1979).

5.3 CONTAMINANT MIGRATION

Typically, landfilled solid waste materials such as those located in Dunn Field are buried in the dry state. Liquid wastes were containerized and the documented fluid spill events were local in nature, involving small quantities. Contamination in the form of leachate is produced by the water saturation of dry solid wastes (USEPA, 1980) by the leakage of corroding liquid waste containers, or by the spillage of fluids at ground surface. Continued waste saturation will mobilize the generated contaminants. The chief source of water at disposal sites is precipitation, a prime component of a site's water balance. Given sufficient data, the likelihood of contamination generation and the quantification of leachate production may be estimated by the water balance method (USEPA, 1980). A calculation of the study area's net precipitation (the amount of rainfall potentially available for infiltration and waste saturation) was nine inches, annually. This value is adequate to both generate and mobilize waste-related contamination at DDMT. If contamination at the available source is mobilized, contaminants will move along the path of least resistance to adjacent receptors. Surface contamination may migrate overland to surface waters via runoff, or may infiltrate into local shallow ground water. Buried waste-related contamination may favor migration to site ground water.

Actual migration routes of contaminants and their rates can be inferred from site physical characterization, contaminant release information and data from chemical analyses of the media that are potentially associated with their fate and transport.

5.3.1 Metals

Leaching and precipitation of indicator metals are likely transport systems as indicated by the presence of metal contamination of the ground water, soils, and sediments. Metals contamination has likely entered the ground water through leaching of the soil. In Dunn Field, the Fluvial aquifer ground-water flow direction is westward. Metals contamination can be expected to migrate with ground water in a westerly direction. The analytical results for the off-post wells support this hypothesis. Shallow aquifer ground-water flow at the main installation is not as well known as are similar conditions at Dunn Field. Shallow aquifer conditions suggests discharge to the underlying regional aquifer in the northwest quadrant of the installation. However, ground-water flow direction in the shallow aquifer in most of the main installation is not well defined.

In summary, metal contaminants can be expected to persist at their present concentrations and to migrate beyond the boundaries of Dunn Field. Main installation metal contaminants will persist at their present concentrations, but should not migrate beyond the border of the base. Contaminant transport to lower aquifer is possible.

5.3.2 Volatile Organics

Volatile chlorinated organic compounds have been detected as surface soil contaminants at both Dunn Field and the main installation. These compounds have also been encountered as subsurface soil contaminants in Dunn Field. The contaminants detected are assumed to occur as an unknown number of localized "hot spots." These compounds are significant to this investigation as they may serve to replenish chlorinated volatile organic compound contamination of the shallow ground-water system through leaching and percolation.

As noted, two areas of contamination were encountered in study area shallow ground water. The largest such zone extends beyond the north and west boundaries of Dunn Field. Contaminant concentrations are sufficiently consistent to permit data contouring at all wells encountering the compounds of interest. Most of the contaminants are denser than water and thus tend to migrate vertically downward. MW-35 was screened in the lower portion of the shallow aquifer adjacent to MW-12, which is screened in the upper portion. Comparison of analytical data from these two wells indicates that although the contamination extends throughout the shallow aquifer, it is not accumulating at higher levels near the bottom of the aquifer.

The volatile chlorinated organics in the shallow aquifer could potentially continue to migrate vertically through the confining unit into the Memphis Sand. Deep soil test boring STB-6 encountered this group of compounds extending through the confining unit underlying the contaminated shallow aquifer. This situation suggests that volatile chlorinated organic compounds may have or may be in the process of migrating from the shallow aquifer at Dunn Field. A review of monitoring well, soil boring, analytical data and current literature describing the likelihood of such a contaminant migration potential may be summarized as follows:

- The volatile chlorinated organic compounds were detected at low levels through the entire sampled section of the confining unit at STB-6.

- Ground-water elevations within the site's shallow aquifer are some eighty feet higher than those noted in Memphis Sand wells at Dunn Field. This difference in head creates a downward flow potential from the shallow aquifer to the Memphis Sand. Occasional pumpage from the nearby Allen Well Field could exacerbate the situation.

- The general class of compounds possesses low solubilities in water and does not readily adsorb on mineral surfaces (Mortland, 1985). These characteristics may enhance the potential for migration.

- The class of encountered contaminants is considered to be persistent and relatively mobile in ground water (Giger and Molnar-Kubica, 1978). Further, Griffin and Roy (1985) classified a number of organic compounds according to their mobility in saturated soil-water systems. The following compounds detected in DDMT ground-water samples may be described as follows:

Compound	Mobility Class
Acetone	Very highly mobile
Methylene Chloride	Very highly mobile
1,1,1-Trichloroethane	Medium mobility
Carbon tetrachloride	Medium mobility
1,1,2,2-Tetrachloride	Medium mobility

- Some organic solvents have been shown to increase clay hydraulic conductivities. This effect was noted especially for acetone, methanol and xylene (Griffin and Roy, 1985).

5.3.3 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) were detected in surface soils at several installation locations. PAHs have apparently not migrated far from their point of introduction. Because of their insoluble nature and strong tendency to adsorb to soils, the leaching of PAHs is not expected. No contamination was observed in any ground-water and surface water samples. The presence of PAHs in sediments from Lake Danielson and the adjacent pond may be attributed to soil containing adsorbed PAHs being transported during surface run-off.

5.3.4 Pesticides and PCBs

While Dieldrin and DDT and their degradation products DDD and DDE were detected in surface soils at several installation locations, PCBs were only detected at two places. It appears that the pesticides and PCBs found at DDMT have not moved very far from their point of application or release to the environment. Adsorption to soil particles is the likely explanation for the persistence of these compounds. The movement of soil particles containing adsorbed pesticides is probably responsible for their presence in sediments in Lake Danielson and the adjacent pond. Their low solubility explains why only low concentrations in a few surface water samples were observed. Leaching to the ground water has probably not occurred.

SECTION 6.0
BASELINE RISK ASSESSMENT

6.1 INTRODUCTION

The purpose of a baseline quantitative risk assessment is to provide an evaluation of the potential threat to human health and the environment in the absence of any remedial action. The objective of the baseline risk assessment is to incorporate data identifying the extent, nature, and potential transport of contaminants with potential exposure pathways and receptors associated with a site, in order to characterize potential human or environmental risks associated with the site.

6.2 PUBLIC HEALTH EVALUATION

6.2.1 Exposure Assessment

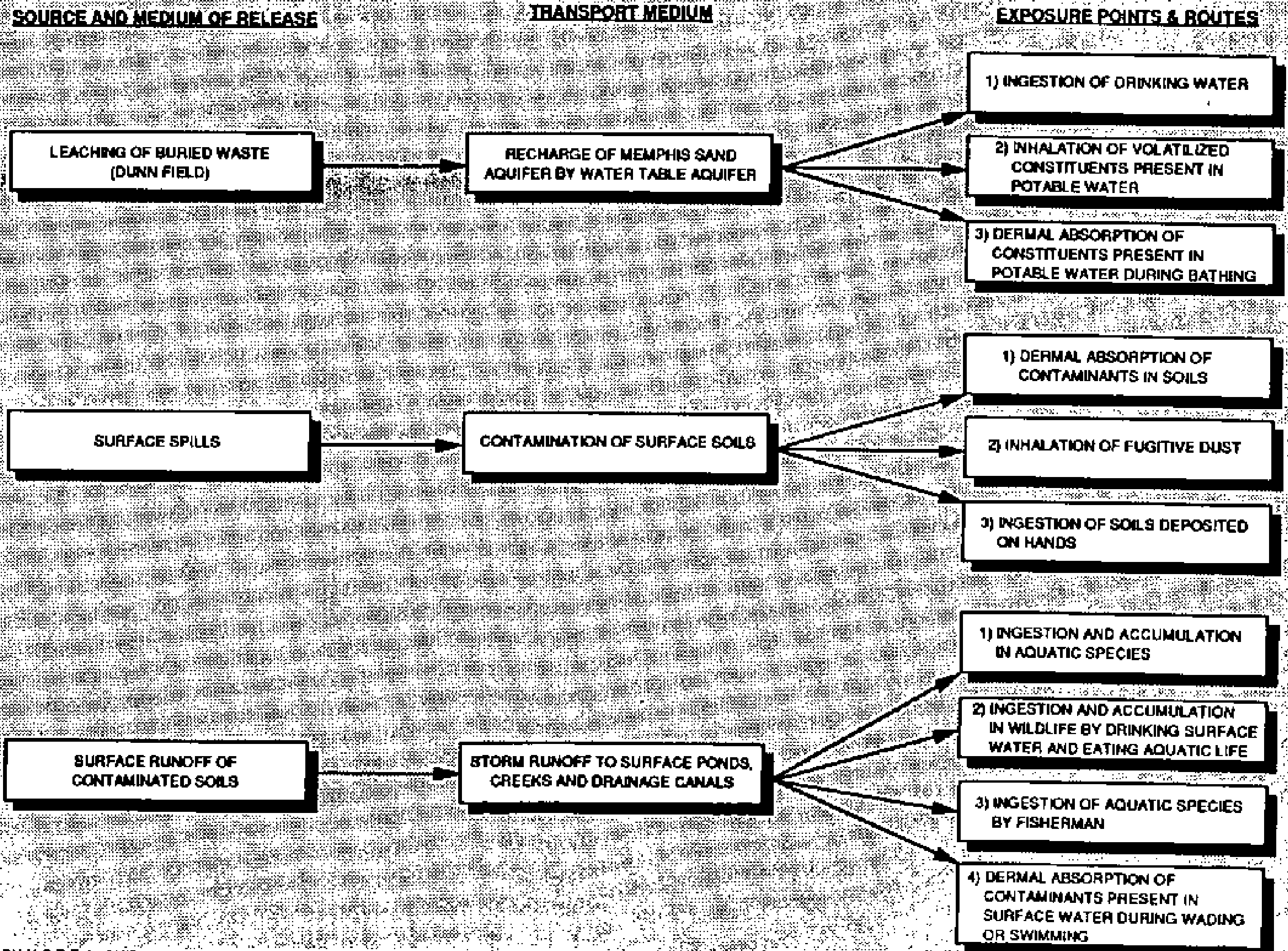
Figure 6-1 presents a conceptual model of potential exposure pathways considered at the DDMT site. The primary environmental exposure pathways associated with DDMT include ingestion, inhalation and dermal absorption of contaminants present in surface soils, ground water, and surface water. A vital potential pathway which is included in the evaluation of this site was the possibility that the shallow aquifer (Fluvial) is interconnected to the Memphis Sand aquifer, which is the source of drinking water for the entire Memphis city area. Contaminants of concern were identified in DDMT monitoring wells screened in the Fluvial or shallow aquifer. Constituents of concern in the Fluvial aquifer have not yet been detected in the Memphis Sand ground-water samples, but were present in some soil borings.

Secondary pathways associated with DDMT include the ingestion of aquatic species which have bioaccumulated contaminants, and dermal absorption of contaminants present in surface ponds, creeks and drainage canals. Surface runoff of soil contaminants present on

FIGURE 6-1

POTENTIAL EXPOSURE PATHWAYS

DEFENSE DEPOT MEMPHIS, TENNESSEE



BASED ON U.S.E.P.A. GUIDANCE FOR CONDUCTING RI/FS UNDER CERCLA, OCTOBER, 1988 the facility drain to either collection basins on the site (Lake Danielson) or off-site via the city storm system. The city storm system is primarily open and above ground in the area neighboring DDMT. City storm drainage eventually drains to either Nonconnah Creek or Cane Creek. Both of these surface waters are classified for fishing use. Also, Lake Danielson has been used for recreational purposes in the past.

6.2.2 Routes of Exposure

There is a potential for contaminants present in the soils to reach human and animal receptors in numerous ways. The routes of primary concern are as follows:

1. Inhalation of soil particulates
2. Ingestion of soil particulates deposited on skin
3. Dermal absorption of contaminants in soils

There is a potential for ground-water constituents to reach receptors via the following routes:

1. Ingestion of ground water (Memphis Sand aquifer only)
2. Dermal contact with potentially contaminated potable water during bathing
3. Inhalation of vapors from volatile contaminants present in potable water, which are emitted during household use

The potential routes of exposure associated with potentially contaminated surface water and surface water sediments include the following:

1. Ingestion of fish and other aquatic life from contaminated lakes and creeks
2. Dermal absorption of contaminants present in surface waters and sediments

Surface water and sediments contained few volatile compounds, which were present only at low concentrations. Therefore, inhalation of vaporized constituents present in surface water was considered an unlikely exposure pathway at DDMT.

6.2.3 Potential Exposure Sources

6.2.3.1 Ground-Water Sources - DDMT is located east of the Allen Well Field, one of six pumping centers owned and operated by the Memphis Light, Gas and Water Division (MLGW). The Allen Well Field draws water from the Memphis Sand aquifer, which is the potable water source for the City of Memphis and most of Shelby County. Studies have implied that "windows" may be present in the confining layer overlying the Memphis Sand aquifer which may allow leakage of contaminants from water table aquifers (Graham and Parks, 1986). It is possible that contaminants migrating from DDMT could reach surrounding water table aquifers and could potentially contaminate the Memphis Sand aquifer. Thirteen of the thirty-three Allen Well Field wells lie within one mile of DDMT (see Figure 6-2).

Analysis in 1988 and 1989 of ground-water samples obtained from wells within the Allen Well Field show no contaminants exceeding drinking water standards. When analyzed during 1988, Wells Numbers. 113, 114, 115, 117, 118, and 138, all of which lie within a one mile radius of DDMT (see Figure 6-2), had no detectable levels of volatile organic chemicals. In 1988, Memphis Light, Gas and Water Division detected low levels of chlorinated solvents in Allen Well Field Wells Numbers 126, 127 and 128. MLGW officials believe the source is an industrial site located close to the three wells and has not considered DDMT as a potential source because DDMT is located more than a mile away from the problem wells. The wells were resampled in 1989 and continued to have detectable levels of chlorinated compounds. All three of the Allen Wells are now closed (MLGW, 1989 and 1990). Table 6-1 shows the contaminants detected in the Allen Wells, as well as the constituents detected in the

FIGURE 6-2

STUDY AREA WATER WELL LOCATIONS

DEFENSE DEPOT MEMPHIS TENNESSEE

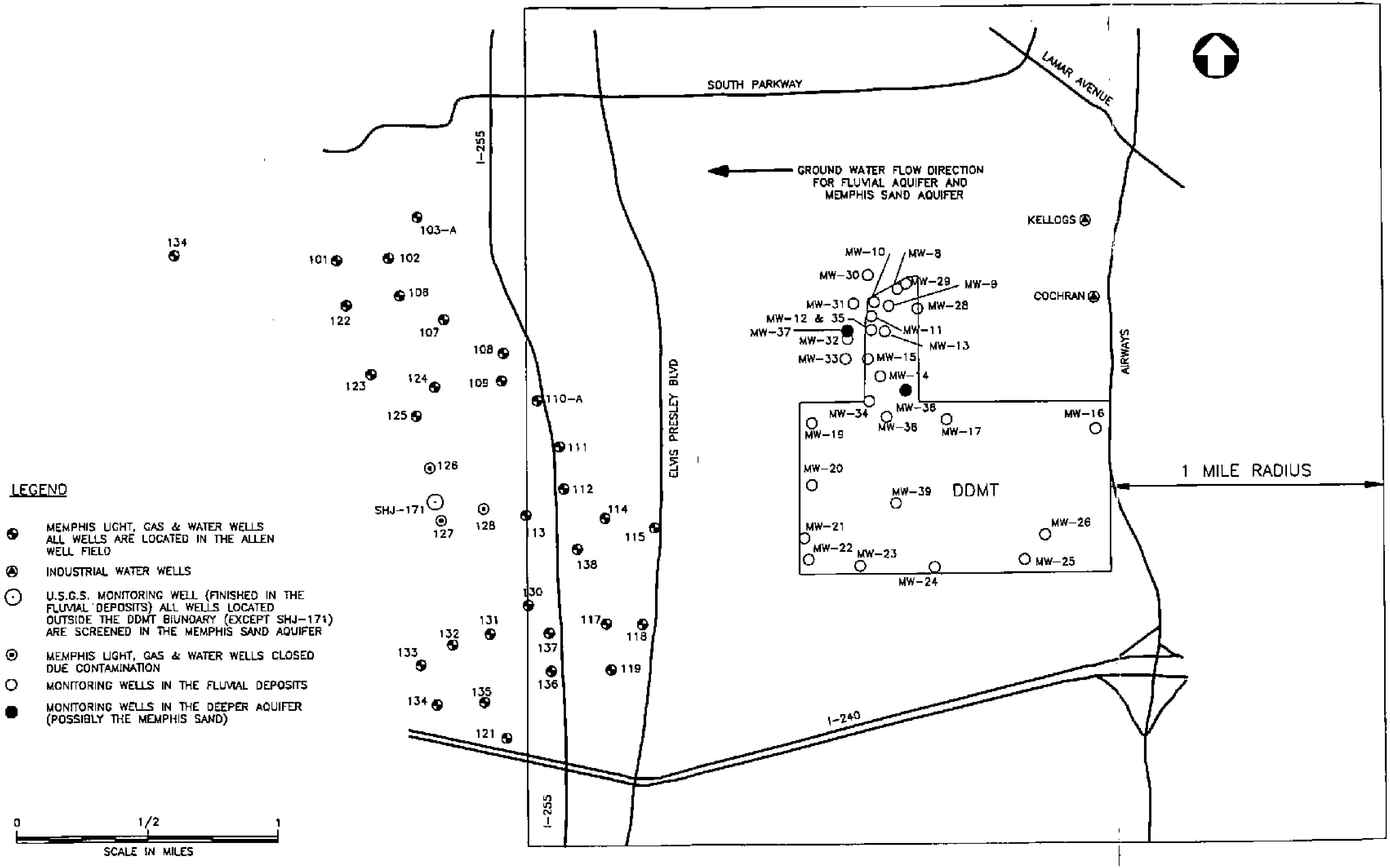


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TABLE 6-1
COMPARISON OF VOLATILE CONTAMINANTS FOUND AT DDMT TO CONTAMINANTS IN CLOSED WELLS AT ALLEN WATER WELL FIELD

CHEMICAL NAME	DDMT Ground-Water Concentrations (PPB)		DDMT Ground-Water Concentrations (PPB)		Closed Wells, Allen Pumping Station			
					Well 126 (PPB)	Well 126 (PPB)	Well 127 (PPB)	Well 128 (PPB)
	Maximum, 4/89	Well Location	Maximum, 1/90	Well Location	8/30/88	6/14/89	8/30/88	8/30/88
VOLATILE ORGANICS:								
Tetrachloroethylene	210	MW-5	240	MW-10	ND	ND	ND	ND
Carbon Tetrachloride	77	MW-6	52	MW-32	ND	ND	ND	ND
Benzene	ND		ND		ND	ND	22.00	0.17
1,1,1-Trichloroethane	9	MW-10	10	MW-10	ND	ND	ND	ND
Chloroform	15	MW-6	33	MW-31	ND	ND	ND	ND
1,1-Dichloroethane	3	MW-10	5	MW-29	0.11	ND	2.86	0.08
1,2-Dichloroethane	ND		3	MW-10	ND	ND	1.94	ND
1,1-Dichloroethylene	130	MW-10	160	MW-10	0.17	ND	0.11	0.16
1,2-Dichloroethylene	520	MW-11	1100	MW-31	0.17	0.15	2.33	0.17
1,1,2-Trichloroethane	7	MW-6	12	MW-31	ND	ND	ND	ND
Trichloroethylene	1700	MW-12	5100	MW-12	1.10	0.95	0.13	ND
1,1,2,2-Tetrachlorethane	340	MW-12	1900	MW-12	ND	ND	ND	ND
Acetone	34	MW-6	3500	MW-37	ND	ND	ND	ND
Vinyl Chloride	ND		ND		ND	ND	0.17	ND
1,2-Dichloropropane	ND		ND		0.92	0.72	ND	ND
2-Methyl-2-Pentenone	ND		8	MW-37	ND	ND	ND	ND
Toluene	1	MW-27	ND		0.90	ND	ND	ND

DDMT monitoring wells. It is important to note that the Allen Wells are screened in the Memphis Sand aquifer. The DDMT well locations shown in Table 6-1 are screened in the Fluvial aquifer.

An analysis of water, dated September 30, 1988, which was taken at the post-chlorination distribution point for the Allen Well Field, revealed low levels of bromodichloromethane, chlorodibromomethane and chloroform (MLGW, 1988). These constituents are common by-products in water which has undergone chlorination (National Research Council, 1987).

The State of Tennessee and the local health department monitor the number of wells in the Memphis area by requiring drilling permits and annual permit renewals for continuous well operation. Figure 6-2 shows the locations of nearby industrial wells. A preliminary well survey of the area within a one mile radius of the depot did not reveal the existence of any private residential wells. Four industrial wells (at Cochran, Kellog, and two at United Refrigeration) are located within a two mile radius, but are not used as potable water sources (Moore, 1988). The Memphis-Shelby County Health Department (MSCHD) has analyzed ground water samples collected from the Cochran (January 30, 1989) and United Refrigeration (October 10, 1988) industrial wells for total phenols, metals, total chlorforms, and nitrates. All three wells were found to have acceptable water quality for the parameters analyzed. All four industrial wells are screened in the Memphis Sand aquifer at depths of approximately 450 to 500 feet (Moore, 1989).

The U.S. Geological Survey has also analyzed selected wells in the Alluvial and Fluvial deposits in the Memphis area. One well, SH: J-171, is physically located near the Allen Water Well Field, and is screened in the Fluvial aquifer at a depth of 71 feet below ground level. The results of analyses for dissolved metals and volatile organic constituents is summarized in Table 6-2. No

TABLE 6-2

USGS FLUVIAL WELL

WELL NAME	DEPTH, FT.	SAMPLE DATE
SH: J-171	71	02-03-87

CONCENTRATIONS OF CONSTITUENTS, (UG/L)

ARSENIC, DISSOLVED	BARIUM, DISSOLVED	CADMIUM, DISSOLVED	CHROMIUM, DISSOLVED	LEAD, DISSOLVED	MERCURY, DISSOLVED	VOLATILE ORGANIC COMPOUNDS
<1	92	2	4	<5	<0.1	<3

USGS, 1988.

levels of metals or volatile organic constituents exceeded drinking water standards for contaminant concentrations (McMaster and Parks, 1988). However, this data is not directly comparable to the data from DDMT monitoring wells, as wells at DDMT were analyzed for total metals, rather than dissolved metals.

In summary, the water well survey associated with the DDMT site assessment did not reveal any shallow aquifer wells (Alluvial or Fluvial) within two miles of DDMT which are used for potable water sources. Therefore, ingestion of potentially contaminated water from the Alluvial or Fluvial aquifers is not considered to be a pathway of exposure.

The primary potential impact of water table contamination would be via leakage through permeable zones in the confining unit, which could allow migration of contamination from the Fluvial deposits to the Memphis Sand aquifer. The potential for this occurrence has been addressed by Graham and Parks, 1986 and Brahana et al., 1987. The Memphis Sand aquifer is the primary water source for the city of Memphis, which has a population of approximately 650,000 people. Analysis of ground water from onsite wells screened in the Memphis Sand Aquifer (MW-36 and MW-37) did not show evidence of contamination with the chlorinated compounds present in the Fluvial aquifer. Low levels were detected in one deep soil test boring located near MW-6. Analysis of wells in the Allen Well Field and SH: J-171 (located less than a mile west of DDMT) during 1988 and 1989 shows no evidence of contaminants which exceed drinking water standards (Brahana, et al., 1987; McMaster and Parks, 1988; MLGW, 1989). Currently, the Allen pumping field is only used on a reserve basis, with use limited primarily to the summer months (MLGW, 1989). Any wells with detectable amounts of Volatile Organic Constituents as measured by gas chromatography methods are promptly closed.

To better assess any potential connection between the Fluvial aquifer at the site and the Memphis Sand Aquifer at Allen Well Field (nearest drinking water exposure point), three potential scenarios of migration were examined:

1. Vertical transport of constituents through a clay confining unit ranging 15 to 75 feet in thickness

2. Lateral transport via the Fluvial aquifer to above the Allen Well Field with the assumption that a "window" exists in the intervening confining unit

3. Lateral transport through a portion of the distance to the Allen Well Field with a "window" in the confining unit encountered in the interim

Monitoring Well MW-37, screened into the Memphis Sand aquifer near Dunn Field provides analytical data control relative to scenario number 1. Well 108, the Allen Well Field well closest to DDMT, provides analytical data control relative to scenarios number 2 and number 3.

Scenario Number 1:

Several methods were used to predict the vertical transport of the most concentrated and potentially mobile constituents, trichloroethylene and 1,1,2,2-tetrachloroethane, through the clay confining unit separating the Fluvial aquifer from the Memphis Sand aquifer. A simple engineering equation (Section 3.1.6.2.3) indicates that ground-water flow through the unit could occur in as little as 25 years. A contaminant transport model, SESOIL from GEMS (SESOIL, 1982), indicates a minimum breakthrough time of approximately 150 years for 1,1,2,2-tetrachloroethane (Appendix J). Estimated concentrations, from the model of contaminant transport through the confining unit was judged too uncertain for use as exposure point concentrations. Therefore, transport rates calculated by the model were not used to estimate concentrations in the Memphis Sand. The SESOIL model was valuable in estimating the retardation of contaminant movement through a low permeability clay, which is not well estimated by the engineering equation previously cited.

Actual site monitoring information confirms the assumption that the confining unit at the site has not been breached. MW-37 shows no evidence of contamination found previously in the Fluvial aquifer. The only major constituent found in MW-37 is acetone (3,500 ug/L), which is not present in the Fluvial aquifer and is not a predicted breakdown product of any of the Fluvial constituents. It is difficult to base any conclusions concerning possible health risks associated with acetone on one sampling episode and one detection incidence.

Scenario Number 2:

Lateral migration via the Fluvial aquifer was estimated using a one dimensional model from USGS and the Donigian Rapid Response model (1983). The assumed parameters used for both models are shown in Appendix J. It was assumed that 35 years have passed since the source began to migrate from the site, because historical records indicate that most solvent material was buried in Dunn Field in 1955. Actual leakage from the source may have occurred more recently, so that the potential migration of the contaminants is overestimated. Both models used TCE and 1,1,2,2-tetrachloroethane as indicator parameters.

Both models estimate that low levels of contamination could arrive at Well 108 of the Allen Well Field within a 35 year period. The USGS model estimated a higher concentration value (TCE = 0.8 ug/l) than the Donigian model. Both models require the assumption of several parameters unavailable from site data.

Actual monitoring data of Well 108 confirms that detectable levels of contaminants have not yet reached the Memphis Sand at the Allen Well Field. Therefore, it appears that, even if low levels of contaminants have reached the area above the Allen Well Field, the clay confining unit separating the two aquifers has sufficiently retarded flow to the Memphis Sand aquifer.

Scenario Number 3:

This scenario is similar to Scenario Number 2. That is, contaminants could be transported via the Fluvial aquifer, pass downward through a "window" in the confining unit, and then be transported laterally through the Memphis Sand to the Allen Well Field. Contamination levels would be reduced within each part of the flow regime. While we have calculated that a contamination plume could extend some distance out in the Fluvial aquifer, it is not feasible to model this complex flow. However, as before, Allen Well Field Well 108 has not shown detectable constituent levels. Thus, contamination from Dunn Field has apparently not affected the Allen Well Field.

Summary:

Scenarios Number 2 and Number 3 are more critical than Scenario Number 1. This is because the permeability of the Fluvial aquifer is several orders of magnitude greater than the clayey confining unit in the vicinity of Dunn Field. Thus, lateral transport via the Fluvial aquifer to a potential window in the confining unit would have a greater effect on the Memphis Sand aquifer. However, this flow scenario is impossible to model accurately based on the unknown conditions (Fluvial aquifer conditions, confining unit extent, etc.) west of Dunn Field.

A worst case estimate for drinking water exposures can be made by predicting that ground water concentrations at the exposure point equal minimum analytical detection limits as measured by acceptable gas chromatography drinking water analysis methods (ATSDR, 1987-1990). This worst case assumes that very low concentrations of contaminants have breached the confining unit and have not yet been detected by sensitive analytical techniques used by Memphis Gas, Light and Water. It also assumes that the low levels of contaminants would go undetected for an extended period of time and that the Allen Well Field would be the sole drinking water source over a lifetime of drinking water exposures. Several sources of drinking water are currently used, so this assumption greatly overestimates potential drinking water exposures. Exposure intake estimates and risk calculations are made in later sections based on this worst case scenario.

6.2.3.2 Surface Water and Sediment Sources - There are two primary surface water sources and several secondary sources located at DDMT. The two primary sources are Lake Danielson and the golf course pond, which are located in the southeastern corner of the facility. Analysis of surface water and sediments indicates a history of contamination from surface run-off following transformer storage and biocide applications in this area. Pesticides previously detected in sediments and fish tissue in samples collected from Lake Danielson and the golf course pond include 4,4'-DDT, dieldrin, chlordane and chlorpyrifos. Questionably high levels of PCBs were also detected in these matrices. Fishing was discontinued at Lake Danielson in 1986 (U.S. Army Environmental Hygiene Agency (USAEHA, 1986b).

Sediment investigations at Lake Danielson and the golf course pond during April 1989 detected metals, some pesticides and numerous polycyclic aromatic hydrocarbons (PAHs). Flame thrower testing and fire protection training has occurred in the vicinity of the golf course pond in past years and is a possible source for the hydrocarbons detected in these surface water sediments during the Phase I sampling episode. No polychlorinated biphenyls (PCBs) were detected during the April 1989 sampling of the sediments or surface water samples collected from Lake Danielson or the golf course pond. Several compounds detected in sediment samples were present as estimated values, were present in trip blanks, or were at levels near background values.

Constituents of potential concern in the golf course pond include polycyclic aromatic hydrocarbons, which were present above laboratory estimated values, and 4,4'-DDT and its degradation products (i.e., 4,4'-DDD and 4,4'-DDE), which were detected in the pond sediments and in one surface water sample downstream with respect to the pond (SW-10). The only constituents detected in the pond water were barium, copper and zinc at or near background levels, and some volatile and semi-volatile organic compounds which are believed to be artifacts of analysis.

The constituents detected at Lake Danielson during April 1989 and January 1990 were similar in identity and levels to those present at the pond. Potential constituents of concern at the lake include arsenic and the degradation products of 4,4'-DDT. In addition, two samples collected down stream from Lake Danielson (SW-9 and SW-12) contained levels of lead, arsenic, and 4,4'-DDT, 4,4'-DDE, silver and zinc, which were above human and aquatic health-based standards for water. Surface water samples SW-9, SW-10, SW-11 and SW-12 were taken at points on the periphery of DDMT from drainage canals carrying water off the facility. SW-10 and SW-11 contained pyrene, 4,4'-DDT, 4,4'-DDE and lead. The pesticide levels detected in the drainage canals increased from the Phase I sampling episode to the Phase II episode.

Surface water sample SW-1 was taken at a point where surface drainage from Dunn Field leaves the facility and travels in a north-northwest direction towards Cane Creek. Dieldrin was detected in this sample at a concentration of 0.13 ug/l. When this point was resampled in January 1990 (SW-16), no dieldrin was detected. Other constituents were present at near background levels or were also present in the trip blank.

Surface water samples SW-2 and SW-4 contained low levels of endosulfan, chromium and acetone. These samples were taken in the northwestern quadrant from a drainage canal directing water off the facility. Chromium was present at a concentration potentially harmful to aquatic life.

An exposure point for residents living in the vicinity of DDMT is via exposure to surface run-off traveling in the city's above ground, open storm canals and creeks. Dermal contact with potentially contaminated water and soil present in Nonconnah Creek are exposure pathways of secondary concern at DDMT, but must be considered in a risk characterization of the DDMT facility. Current storm drain handling capacity on the facility requires upgrading (Harland, Bartholomew and Associates, 1988), with a large quantity of storm water runoff flowing overland during significant precipitation events.

Exposure estimates considering possible off-site exposure via ingestion of fish from and dermal contact with waters from Nonconnah and Cane Creek are included in later sections. Accurate surface water flow estimates were not available. Thus, a conservative estimate of off-base flow was made for use in dilution calculations. This estimate, based on annual precipitation and land surface area for drainage basins, was calculated using the following equation (adapted from USEPA, 1988a):

$Q = C*R*A$

where: Q = Mean flow of surface runoff(ft^3/sec)

c = conversion factor for land use

0.9 = commercial

0.2 = non-commercial

R = total annual rainfall, inches
A = total surface area of drainage basin, ft^2

It was assumed that the Lake Danielson drainage basin would serve as a representative area, as most surface and sediment samples were taken in this basin. This area is approximately half developed and half grass-covered and has an estimated surface area of 217 acres. The mean flow rate of surface runoff (drainage) was estimated at 0.69 ft^3/sec. The mean flow rate of Nonconnah Creek is 47 ft^3/sec. The estimated rate of dilution was calculated with the following equation:

$$C = Ce * Qe/Qt$$

where: C = concentration of substance in stream (mg/L)
Ce= concentration of substance in effluent (mg/L)
Qe= effluent flow rate (ft^3/sec)
Qt= combined effluent and stream flow rate (ft^3/sec)

This equation provides a rough estimate of the concentration of a substance downstream from a point source release into a flowing waterbody after dilution of the substance by the receiving waterbody (USEPA, 1988a).

6.2.3.3 Subsurface Soil Sources - In general, contaminants are limited to surface soils at DDMT. Five soil borings were collected in April 1989 and analyzed, but only samples STB-2-2 and STB-2-3 obtained from Dunn Field had any obvious contaminants. Pyrene (40 and 51 mg/kg, respectively) and fluoranthene (51 and 47 mg/kg, respectively) were detected at depths of 17.5 and approximately 70 feet. The sampling location was near the center of Dunn Field. All values were flagged as estimates by the laboratory. In January 1990, three additional soil borings were collected and sampled.

STB-6 showed evidence of chlorinated hydrocarbons at all four depths, including trace amounts of 1,1,2,2-tetrachloroethane and 1,2-dichloroethylene at 182 feet NGVD.

Exposures to subsurface soils were not considered in estimating intakes as no direct contact with receptors is expected to occur. Subsurface soils could serve as a potential source for groundwater contamination.

Surface Soil Sources - Most of the areas in the main installation are covered with buildings or pavement. The area around Lake Danielson and the golf course are more natural and are well vegetated. Where there is little surface vegetation on the main portion of DDMT, absorption of contaminants present in surface soils via dermal contact, incidental ingestion of soil particulates, and inhalation of fugitive dust and any volatile compounds present in the soils are primary exposure pathways for employees of the DDMT facility. DDMT has a history of surface spills. The presence of surface contaminants has been confirmed during the samplings in April 1989 and January 1990.

Forty surface soil samples were collected in April 1989. Ten additional surface soil samples were collected in January 1990. Surface soil contaminants in the golf course area contained DDT, DDE, dieldrin, heptachlor, beta-BHC, polycyclic aromatic hydrocarbons (PAHs) and some elevated metals. The old transformer storage yard (SS-30 and SS-31) had metals, DDT, DDE and PAHs. The BX Gas Station surface soils had detectable levels of PAHs, dieldrin and metals. All these sites are in the southeastern area of the main facility.

The surface soils around Building 1088 had low levels of PCBs, PAHs, pesticides and elevated metals. Pesticides present included DDT, DDD, DDE, dieldrin, four BHC isomers, chlordane, endosulfan and heptachlor epoxide. PCBs were present at low concentrations at SS-15, SS-16 and SS-17. Metal concentrations in most soil samples in this area exceeded background levels for lead, with SS-16 being extremely high at (17,500 mg/kg). Elevated levels of metals were also present in SS-15, SS-16, SS-18, SS-19, SS-45 and SS-46. The gravel area east of S873 had near background levels of metals and small amounts of phthalates. SS-26 also had low levels of PAHs.

The highest levels of polycyclic aromatic hydrocarbons detected at DDMT were found in surface soils around Building 629. SS-42 (Phase II) had concentrations three to four times greater than SS-11 (Phase I). Concentrations of PAHs in SS-42 and SS-43 approximate 0.05 to 0.1% of the total soil constituents. Many of the PAH compounds are potential human carcinogens and fairly persistent in the environment (ATSDR, 1990). The Building 629 area also had the highest surface soil concentrations of nickel (367 mg/kg) and mercury (1.3 mg/kg). SS-43 had the highest overall soil concentration of dieldrin (4.5 mg/kg). Other constituents detected at Building 629 included DDT, DDE, DDD, beta-BHC, heptachlor, chlordane, dibenzofuran, low levels of chlorinated hydrocarbons and elevated metal concentrations. SS-20 at the hardstand area had high concentrations of zinc, chromium and barium. Other surface samples SS-32, through SS-36 and SS-40, were relatively contaminant-free.

At the PDO yard, SS-41 and SS-5 were clearly the hot spots, with high concentrations of PAHs, chromium, barium, lead, copper, zinc, DDT and its byproducts. Pesticides were also detected in all six samples taken in this area.

Surface sample SS-7, Dunn Field, exhibited high concentrations of PAHs. In general, Dunn Field soil samples had detectable levels of DDT, DDE, chlordane, dieldrin, PAHs, and slightly elevated lead and zinc (SS-8) values. Dunn Field is grass-covered and used sparingly. Therefore, exposures to surface soils at Dunn Field would occur less frequently than on the main part of the facility.

Two potential exposure scenarios for surface soils were examined. Chronic and lifetime risks for career employees were estimated. Because of the open nature of the buildings at the site, indoor soil concentrations (dust) were assumed to equal outdoor concentrations. The subchronic exposure scenario examined exposure potential for construction workers. This scenario assumes an eight hour working day, five days a week, for six months. No onsite air or particulate monitoring has been done, so dust content of the air was assumed to be 10 mg/m^3 (Small, 1984), and the respirable fraction of the dust was estimated as 45% (USEPA, 1988C). Small based his estimate on a review of articles which calculated dust exposures during the use of light and heavy machinery.

In order to estimate exposure intakes for soil exposures, mean concentrations for surface soil constituents detected more than 10% of the time were calculated. Constituents of low toxicity or those potentially contributed by sampling or analysis error were not carried through the risk assessment. When not detected, one-half of the sample quantitation limit for the constituent was used in calculating the arithmetic mean. Chronic and lifetime intakes were calculated using the constituent arithmetic means, while subchronic intakes were calculated using the highest detected concentration.

6.2.4 Potential Human Receptors

Potential human receptors for the DDMT facility include the following:

1. Employees of DDMT
2. Residents and Neighbors of DDMT
3. Residents of Memphis
4. Fishermen and Recreational users ("Waders") of surface waters, including Cane Creek and Nonconnah Creek

DDMT has been utilized as a storage depot and equipment staging facility for the armed forces since the 1940's. The majority of DDMT employees are civilians working during two shifts per work day. The number of employees is estimated to be 2,700 (Chumney, 1989), with a projected future increase of strength to 3,100 (Harland, Bartholomew and Associates, 1988). Thirty-two employees are uniformed military personnel.

All expansion in employment is expected in the civilian sector. Employees would be exposed primarily to contaminants in surficial soils and surface water through the inhalation of fugitive dust or the dermal absorption of constituents deposited on skin. Some incidental ingestion of soil deposited on the hands may be expected to occur.

Land use of the area surrounding DDMT is a mixture of residential and commercial or manufacturing establishments. Population for the two zip code areas around DDMT (38114 and 38106) was 94,468 in the 1980 census, with a projected population of 89,695 in 1993. The average household size was 3.0 and the average household income was $9,612 in 1980. The zip code areas (38114 and 38106) encompass an area which extends 1.5 to 2 miles to the east and north of the facility and up to 4 miles west of DDMT (City of Memphis, 1989). There are several schools within a one-mile radius of DDMT, but no other sensitive subpopulations (i.e., hospitals, nursing homes) are located within one mile.

There are eight permanent residences located within the depot boundaries. These residences are located in the southeastern quadrant of the facility. On-site residents of the facility are estimated to be no more than 24 (Chumney, 1989). There are no on-site gardens or agricultural use of the property.

Residents and neighbors of DDMT are potentially exposed via surface run-off flowing to drainage reservoirs (Lake Danielson) and storm canals. Dermal absorption during wading is the primary exposure route and is most likely to occur to children playing in the drainage canals. Dermal absorption surface water exposure intakes assume that wading frequency and duration is similar to average swimming frequency and duration (USEPA, 1988a).

Cane Creek, Nonconnah Creek and the Mississippi River (Lake McKellar) are classified for fishing and are all potentially impacted by DDMT. Cane Creek and Nonconnah Creek receive surface drainage from the facility. Some of the constituents present in on-site surface water and soils are associated with bioaccumulation in the food chain (i.e., 4-4'-DDT). Therefore, creek fisherman and recreational users of the Mississippi River are also potential receptors for DDMT.

As discussed in Section 3.1.6, some authors have presented the potential for recharge from the Fluvial aquifer to the Memphis Sand aquifer. Monitoring wells MW-36 and MW-37 are both screened in the Memphis Sand aquifer, but ground-water samples from these wells did not show evidence of the chlorinated hydrocarbons found in the Dunn Field Fluvial aquifer monitoring wells. Nonetheless, via potential penetration of contamination through the confining unit at Dunn Field, or through "windows" in the confining unit west of Dunn Field, leakage into the Memphis Sand aquifer has not been ruled out. With potential exposure to chlorinated hydrocarbons in their drinking water source, the residents of Memphis are considered potential receptors via 1) ingestion of drinking water, 2) dermal absorption during bathing and 3) inhalation of volatile compounds emitted by household use of drinking water (i.e., showering, dishwashing, etc.).

6.2.5 Calculation of Exposure Intakes

The following section shows the equations used to estimate human intakes via exposure to surface soils (onsite), surface water, and drinking water (offsite). Only the soil exposures consider a subchronic exposure scenario. Soil exposures are calculated only for adults, as DDMT has controlled access. All other potential exposure pathways consider chronic exposures for adults and children, and lifetime exposures to carcinogens. The format of the equations comes from the Risk Assessment Guidance For Superfund:

Human Health Evaluation Manual (USEPA, 1989b) with parameter inputs from the Superfund Exposure Assessment Manual and Exposure Factors Handbook (USEPA, 1988a and 1989b).

6.2.5.1 Current Onsite Employee Exposures - Current onsite employees could be exposed to soil contaminants by incidental ingestion of soil from hand to mouth contact, inhalation of fugitive dust and dermal absorption of contaminants present in the soil. Equations for the calculation of subchronic, chronic and lifetime exposures and their associated parameters are shown in Figures 6-3, 6-4 and 6-5. Construction workers were estimated to have higher inhalation rates than long-term employees as their work is more strenuous. Long term employees, were assumed to have daily soil exposure durations of eight hours, although they may only be outside for one or two hours per day. Because of the open nature of many site buildings and the steady traffic flow between areas, indoor and outdoor soil exposures were assumed to be essentially equivalent.

6.2.5.2 Current Offsite Fishing and Wading Exposures - Fishing onsite was ended in 1986. A fish survey by USAEHA found evidence of pesticides in Lake Danielson species. More recent sampling by Law illustrates the persistence of these compounds in the surface water and sediments. After estimating constituent dilution in Nonconnah Creek, potential intakes via ingestion of fish which may bioconcentrate site constituents were estimated using the equation and parameters in Figure 6-6.

Dermal absorption by fishermen wading and children playing in offsite creeks was estimated as shown in Figure 6-7. It was assumed that the receptors would have contact on half their total skin surface area and that these events would have the same frequency as swimming (USEPA, 1988a). The dermal permeability constant was assumed to equal that of water (0.0008 cm/hr).

FIGURE 6-3

INCIDENTAL INGESTION OF SOIL

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

Where:

CS = Chemical Concentration in Soil (mg/kg)
IR = Ingestion Rate (mg soil/day)
CF = Conversion Factor (10^{-6} kg/mg)
FI = Fraction Ingested from Contaminated source (unitless)
EF = Exposure Frequency (days/years)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time

Chronic Exposure to Onsite Employees:

CS: Mean Surface Soil Concentration
IR: 100 mg/day (adults)
CF: 10^{-6}kg/mg
FI: 8 hr/24 hr = 0.33
EF: 250 days/year
ED: 30 years
BW: 70 kg (average adult)
AT: Noncarcinogen: 10,950 days
Carcinogen: 25,550 days

Intake = CS x 3.2 x 10^{-7} days^{-1} (Noncarcinogen)
CS x 1.4 x 10^{-7} days^{-1} (Carcinogen)

Subchronic Incidental Ingestion of Soil:

CS: Maximum Surface Soil Concentration
IR: 100_6 mg/day
CF: 10^{-6} kg/mg
FI: 8 hr/24 hr = 0.33
EF: 125 days/year
ED: 1 year
BW: 70 kg (average adult)
AT: 183 days

Intake = CS x 3.2 x 10^{-7} days^{-1}

FIGURE 6-4

DAILY INHALATION INTAKE OF FUGITIVE DUST

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CS \times CF \times IR \times DC \times ET \times EF \times ED}{BW \times AT}$$

Where:

CS = Chemical Concentration in Soil (mg/kg)
CF = Correction Factor (10^{-6} kg/mg)
IR = Inhalation Rate (m^3/hr)
DC = Dust Content in Air (mg/m^3)
ET = Exposure Time (hrs/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
ABS = Absorption Rate in Lungs (unitless)
BW = Body Weight (kg)
AT = Averaging Time (days)

Chronic Exposure to Onsite Employees:

CF: 10^{-6} kg/mg
IR: 1.4 m^3/hour - light to moderate activity, average adult (EFH, 1989)
DC: 10 mg/m^3 (Small, 1984) x 0.45 (average % of particles ≤ 10 um (USEPA, 1988)
ET: 8 hrs/day
EF: 250 days/year
ED: 30 years
BW: 70 kg (average adult)
AT: 10,950 days (noncarcinogen)
25,550 days (carcinogen)

Intake = CS x 4.9 x 10^{-7} day^{-1} (Noncarcinogen)
CS x 2.1 x 10^{-7} (Carcinogen)

Subchronic Exposure of Construction Workers Onsite to Fugitive Dust:

Inhalation:

CF: 10^{-6} kg/mg
IR: 2.6 m^3/hour - moderate activity, average adult (SEAM 1988)
DC: 10 mg/m^3 (Small, 1984) x 0.45 (average % of particles ≤ 10 um (USEPA, 1988a)
ET: 8 hrs/day
EF: 125 days/year (six months)
ED: 1 year
BW: 70 kg (average adult)
AT: 183 days

Intake = CS x 9.1 x 10^{-7} day^{-1}

FIGURE 6-5

DERMAL CONTACT WITH CHEMICALS IN SOIL

Equation:

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CS \times CF \times SA \times AF \times ABS \times ET \times EF \times ED}{BW \times AT}$$

Where:

CS = Chemical Concentration in Soil (mg/kg)
CF = Conversion Factor (10^{-6} kg/mg)
SA = Skin Surface Area for contact (cm^2/event)
AF = Soil to Skin Adherence Factor (mg/cm^2)
ABS = Absorption Factor (unitless)
ET = Exposure Time (hr/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time

Chronic Dermal Absorption by Workers at the Site:

CS: Mean Surface Soil Concentration
CF: 10^{-6} kg/mg
SA: 3,280 cm^2/event (50% percentile, average adult SA for forearms, hands, and head; USEPA, 1989)
AF: 2.77 mg/cm^2 -- Kaolin clay (for hands; USEPA, 1988)
ABS: Absorption from food or soil = 30% (USEPA, 1989b)
ET: 8 hr/day (Site-specific estimate which includes exposure to indoor dust at site)
EF: 250 days/year
ED: 30 years
BW: 70 kg (average adult)
AT: Noncarcinogen: 10,950 days
Carcinogen: 25,550 days

Chronic Absorbed Dose = Mean CS x 2.13×10^{-4} day-1 (Noncarcinogen)
Mean CS x 9.14×10^{-5} day-1 (Carcinogen)

FIGURE 6-5 (CONT)

Subchronic Dermal Absorption by Construction Workers (Future):

CS: Maximum Surface Soil Concentration
CF: 10^{-6} kg/mg
SA: 3,280 cm^2/event (50% percentile, average adult SA for forearms, hands, and head; EFH, 1989)
AF: 2.77 mg/cm^2 -- Kaolin clay (for hands; SEAM, 1988)
ABS: Absorption from food or soil = 30% (USEPA, 1989b)
ET: 8 hr/day (Site-specific estimate which includes exposure to indoor dust at site)
EF: 125 days/year
ED: 1 year
BW: 70 kg
AT: 183 days

Subchronic Absorbed Dose = CS x 2.13 x 10^{-6} days-1

FIGURE 6-6

INGESTION OF CONTAMINATED FISH

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times BCF \times IR \times FI \times EF \times ED}{BW \times AT}$$

Where:

CW = Chemical Concentration in Surface Water (mg/l)
BCF = Bioconcentration Factor
IR = Ingestion Rate (g/day)
FI = Fraction Ingested from Contaminated Source (unitless)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time

Potential Intakes

IR: 6.5 g/day
FI: 0.25
EF: 365 days/year
ED: 30 years (adult); 12 years (children)
BW: 70 kg (average adult); 26 kg (child)
AT: 25,550 days (lifetime of adult); 10,950 days (working career); 4,380 days (child)

Intakes = $CW \times BCF \times 9.9 \times 10^{-3}\ \text{day}^{-1}$ (adult, carcinogenic)
$CW \times BCF \times 0.023\ \text{day}^{-1}$ (adult, chronic)
$CW \times BCF \times 0.0625\ \text{day}^{-1}$ (child)

FIGURE 6-7

DERMAL ABSORPTION OF CONTAMINANTS PRESENT IN SURFACE WATER

Equation:

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

Where:

CW = Chemical Concentration in Water (mg/liter)
SA = Skin Surface Area Available for Contact (cm^2)
PC = Chemical-specific Dermal Permeability Constant (cm/hr)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
CF = Volumetric Conversion Factor for Water (1 liter/1000 cm^3)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is avveraged days)

Variable Values; Chronic and Lifetime exposures during Wading:

	Adult, Chronic	Adult Lifetime	Child, Chronic
CW:	Mean Value	Mean Value	Mean Value
SA:	9,,075 cm^2	90,075 cm^2	4,700 cm^2
PC:	Permeability of water = 0.008 cm/hr (USEPA, 1988)		
ET:	2.6 hrs/day (same as swimming value; RAGES, 1989)		
EF:	7 days/yr	7 days/yr	7 days/yr
ED:	70 years	70 years	12 years
CF:	1 L/1000 cm^3	1 L/1000 cm^3	1 L/1000 cm^3
BW:	70 kg	70 kg	26 kg
AT:	25,550 days	25,550 days	4,380 days

Absorbed Dose = CW x 5.2 x 10^{-6} L/kg-day (adult,chronic and lifetime)

= CW x 7.2 x 10^{-6} L/kg-day (child, chronic)

6.2.5.3. Estimated Exposures to Residents of Memphis - Estimating exposure to residents of Memphis assumes that contaminants present in the Fluvial aquifer at DDMT have traveled laterally and vertically to the Memphis Sand aquifer at the Allen Well Field. There is currently no evidence that contaminants from the site have reached the well field. However, it is possible that constituents could be present at "below detection" limits. Also, Memphis Gas, Light and Water does not utilize a well with any detectable contaminants. Thus, this worst case scenario assumes that contaminants are present in the Allen Well Field at minimum analytical detection limits. Intakes are overestimated as a 70 year exposure duration, and the Allen Well Field is assumed to be the single source of drinking water. Equations to estimate ingestion, inhalation, and dermal absorption from potable water exposures are shown in Figures 6-8, 6-9 and 6-10.

6.2.6 Toxicity Assessment

A total of 103 constituents were identified in the four matrices sampled during Spring, 1989 and Winter, 1990. Twenty-eight constituents of concern have been selected from this total. Factors considered in selecting chemicals of concern include the following:

1) Measured concentrations and frequency of detection at the site;

2) Toxicity;

3) Physical and chemical characteristics related to environmental mobility and persistence;

4) Relative contribution of chemicals to overall health risks associated with the site.

FIGURE 6-8

INGESTION OF CHEMICALS IN DRINKING WATER

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

Where:

CW = Chemical Concentration in Water (mg/L)
IR = Ingestion Rate (L/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (days)

Potential Intakes:

CW: Assumes concentrations equal to lowest analytical detection method (i.e, GC methods); see text.
IR: 2 L/day adults; 1 L/day (children)
EF: 365 days/year
ED: 52 years (adult); 12 years (child)
BW: 70 kg (average adult); 26 kg (child 3-12 years)
AT: 25,550 days (lifetime); 4,380 days (child, chronic); 18,980 days (adult, chronic)

$$\begin{aligned} \text{Intake} = \; & CS \times 0.029 \text{ days}^{-1} \text{ (adult, chronic)} \\ & CS \times 0.021 \text{ days}^{-1} \text{ (adult, carcinogenic)} \\ & CS \times 0.038 \text{ days}^{-1} \text{ (child, chronic)} \end{aligned}$$

FIGURE 6-9

INHALATION OF CHEMICALS IN DRINKING WATER

Assumption:

Inhalation intakes to volatilized constituents will equal drinking water ingestion intakes (McKone, 1967)

Intake = CS x 0.029 days^{-1} (adult, chronic)
CS x 0.021 days^{-1} (adult, lifetime)
CS x 0.038 days^{-1} (child)

FIGURE 6-10

DERMAL CONTACT WITH CHEMICALS IN WATER

Equation:

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

Where:

CS = Chemical Concentration in Water (mg/L)
SA = Skin Surface Area for contact (cm^2)
PC = Dermal Permeability Constant (cm/hr)
ET = Exposure Time (hrs/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
CF = Volumetric Conversion Factor (1 Liter/1000 cm^3)
BW = Body Weight (kg)
AT = Averaging Time (days)

Potential Intakes

CW: Assumes concentration equal to lowest analytical method (i.e., GC methods); see text.
SA: 18,150 cm^2 (average adult)
9,400 cm^2 (average 3-12 year-old child) (SEAM, 1988)
PC: Permeability of Water = 0.0008 cm/hr (Blank et al., 1984, SEAM, 1988)
ET: 0.25 hr/day (shower time)
EF: 365 days/year
ED: 52 years (adult)
12 years (child)
CF: 1 Liter/1000 cm^3
BW: 70 kg (average adult)
26 kg (average child aged 3-12 years) (EAM, 1989)
AT: 25,550 days (lifetime of adult); 18,980 days (chronic exposure); 4,380 days (child)

Intakes = $CW \times 3.86 \times 10^{-5}\ day^{-1}$ (adult, chronic)
$CW \times 5.19 \times 10^{-5}\ day^{-1}$ (adult, lifetime)
$CW \times 7.23 \times 10^{-5}\ day^{-1}$ (child)

Methods discussed in "Risk Assessment Guidance for Superfund: Human Health Manual, Part A" (USEPA, 1989b) were used in ranking ground-water constituents. Constituents were also compared to available health standards and criteria. Chemicals selected as the primary constituents of concern at DDMT are listed in Table 6-3.

Tables 6-4, 6-5 and 6-6 show the frequency of detection of constituents present in soil, sediment and surface water samples. Constituents with near background concentrations or low mean concentrations (near quantitation limits) were eliminated. The selection of groundwater constituents was based on their estimated contribution to total health risk via ingestion (i.e., a toxicity screen). Any ground water constituent estimated to contribute one or more percent to the total health risks via ingestion were included.

The toxicity assessment is an integral part of the Baseline Risk Assessment process. In the toxicity assessment, quantitative reference values describing the toxicity of the chemicals of potential concern are evaluated. Toxicity values such as reference dose and carcinogen slope factor are based primarily on human and animal studies with supportive evidence from pharmacokinetic, mutagenicity and chemical structure studies. The following sections will describe toxicity values used to evaluate current and potential exposures associated with DDMT. Summaries of the toxic effects associated with the constituents of concern are given in Appendix I.

An additional consideration is a comparison of site concentrations to Applicable or Relevant and Appropriate Requirements (ARARs). Both Federal and State of Tennessee regulations, rules, guidelines and criteria are compared to site concentrations in ground water, surface water and surface soils.

TABLE 6-3
CONSTITUENTS OF CONCERN
Defense Depot Memphis Tennessee

	Groundwater	Soil	Surface Water and Sediment
VOLATILE ORGANICS:			
Acetone	X	X	X
Carbon Tetrachloride	X		
1,1-Dichloroethylene	X		
1,2-Dichloroethylene	X		
1,1,2,2-Tetrachlorethane	X		
Tetrachloroethylene	X		
Trichloroethylene	X	X	
Methylene chloride		X	
BASE/NEUTRAL/ACID EXTRACTABLES:			
Anthracene		X	
Benzo(a)anthracene		X	
Benzo(a)pyrene		X	
Benzo(b)fluoranthene		X	
Benzo(k)fluoranthene		X	
Chrysene		X	
Fluoranthene		X	
Indeno(1,2,3-cd)pyrene		X	
Phenanthrene		X	
Pyrene		X	
PESTICIDES & PCBS:			
4,4'-DDD		X	X
4,4'-DDE		X	X
4,4'-DDT		X	X
beta-BHC		X	X
Dieldrin	X	X	X
METALS:			
Arsenic	X	X	X
Barium	X		
Chromium	X	X	X
Lead	X	X	X
Mercury	X		

Table 6-4
Primary Constituents of Concern Detected in Surface Soils
Defense Depot Memphis Tennessee
(ug/kg)

Constituents of Concern (a)	Frequency of Detection	Range of Quantitation Limits	Arithmetic Mean (b)	Maximum Concentration
Acetone	90%	6-1400	23.4	1100
Trichloroethylene	14%	5-730	43.8	2100
Methylene Chloride	100%	3	154	7100
Anthracene	24%	340-21000	4917	130000
Benzo(a)anthracene	50%	340-21000	24741	970000
Benzo(a)pyrene	48%	340-21000	13715	450000
Benzo(b)fluoranthene	56%	340-21000	15882	540000
Benzo(k)fluoranthene	24%	340-21000	11136	450000
Chrysene	60%	340-21000	17936	620000
Fluoranthene	64%	340-21000	29454	860000
Indeno(1,2,3-cd)pyrene	36%	340-21000	8394	310000
Phenanthrene	60%	340-21000	21557	200000
Pyrene	74%	340-21000	26165	870000
4,4-DDT	58%	16-980	2130	59000
4,4-DDD	22%	16-980	202	3600
4,4-DDE	56%	16-980	1274	39000
beta-BHC	20%	8.1-490	161	2500
Dieldrin	38%	16-980	385	2900
Arsenic	78%	3000	16600	42000
Chromium	98%	1000	737000	16200000
Lead	100%	4000	903000	17500000

(a) Only constituents detected in 20% or greater of the samples are carried through the risk calculations unless the constituent is also important to other media.

(b) Means were calculated by adding 1/2 SQLs for samples at ND.

Table 6-5
Primary Constituents
Detected in Sediments
Defense Depot Memphis Tennessee
(ug/kg)

Constituents	Frequency of Detection (a)	Range of Detected Concentrations	Arithmetic Mean (b)	Maximum Concentration
Barium	10/10	76,000-104,000	98,000	10,400
Chromium	10/10	9,000-28,000	14,200	28,000
Lead	4/10	5,000-91,000	39,250	91,000
Mercury	8/10	40-60	47.5	60
4,4-DDD	6/10	45-3,000	724	3,000
4,4-DDE	5/10	36-460	158	460
4,4-DDT	2/10	620-2,900	1,760	2,900
Benzo(a)anthracene	3/10	230-1,100	670	1,100
Benzo(a)pyrene	3/10	500-1,300	677	1,300
Benzo(b)fluoranthene	3/10	380-1,800	957	1,800
Benzo(k)fluoranthene	3/10	290-1600	860	1,600
Chrysene	3/10	300-1,400	817	1,400
Fluoranthene	7/10	71-3,000	825	3,000
Phenanthrene	4/10	100-1,300	733	1,300
Pyrene	4/10	100-2,400	1,128	2,400

(a) Number of samples in which the chemical was positively detected over the number of samples available.
(b) Based on detected values

Table 6-6
Primary Constituents
in Surface Water
Defense Depot Memphis Tennessee
(ug/L)

Constituent	Frequency of Detection (a)	Range of Detected Concentrations	Arithmetic Mean (b)	Maximum Concentration
Arsenic	4/13	37-48	43	48
Barium	16/16	56-91	46	98
Chromium	3/13	10-20	17	20
Lead	4/13	40-295	121	295
Dieldrin	2/3	0.11-0.13	0.12	0.13
4,4-DDE	4/13	0.21-0.88	0.45	0.88
4,4-DDT	4/13	0.16-2.2	1.13	2.2
Acetone	11/13	1-110	14	110

(a) Number of samples in which the chemical was positively detected over the number of samples available.

(b) Calculated from detected samples

6.2.6.1 Toxicity Assessment for Noncarcinogenic Effects - Chemicals that give rise to toxic endpoints other than cancer and gene mutations are often referred to as "systemic toxicants" because of their effects on the function of various organ systems. Chemicals considered to be carcinogenic can also exhibit systemic toxicity effects. Systemic effects are often identified as having an exposure or dose threshold below which no health effect is noted. This characteristic distinguishes systemic toxicants from carcinogens and mutagens which are often treated as acting without a distinct threshold. In other words, there is no safe level of exposure for those compounds.

A chemical-specific reference dose, RfD, may be developed for varying exposure routes (oral and inhalation), lengths of exposure (chronic, subchronic or single event), and critical effects such as developmental toxicity. Chronic RfDs estimate the daily exposure level for the human population, including sensitive subpopulations, that is unlikely to produce an appreciable risk of deleterious effects during a lifetime. Subchronic RfDs are applied to exposures lasting more than a few weeks and up to seven years. Chronic RfDs are applied to exposures extending from at least seven years to a lifetime (70 years). Most exposures in the current assessment are assumed to be long-term. The oral and inhalation RfDs shown in Table 6-7 are derived primarily from the USEPA's Integrated Risk Information System (IRIS). When RfDs were not available from IRIS, values from the Health Effects Assessment Summary Tables (HEAST, 1989) were adopted.

6.2.6.2 Toxicity Assessment for Carcinogenic Effects - The USEPA has assigned a weight of evidence classification and a slope factor for many chemicals which have been classified as human and/or animal carcinogens. These indices can be derived for either oral or inhalation exposures. The weight of evidence classification indicates whether evidence is primarily from animal studies or is also based on epidemiological evidence. Chemicals with the

Table 6-7
Reference Dose and Cancer Slope Values

		Subchronic Reference Dose			Chronic Reference Dose			Cancer Slope Factors		
Constituents of Concern	Oral Absorption Efficiency	Ingestion (mg/kg-day)	Dermal Absorption (a) (mg/kg-day)	Inhalation (mg/kg-day)	Ingestion (mg/kg-day)	Dermal Absorption (a) (mg/kg-day)	Inhalation (mg/kg-day)	Ingestion (mg/kg-day)	Dermal Absorption (a) (mg/kg-day)	Inhalation (mg/kg-day)
Acetone	0.95	1.00E-01	9.50E-02	ND	1.00E-01	9.50E-02	ND	ND	ND	ND
Trichloroethene	0.95	ND	ND	ND	ND	ND	ND	1.10E-02	1.04E-02	1.70E-02
Methylene Chloride	0.60	6.20E-02	3.72E-02	ND	6.20E-02	3.72E-02	ND	7.50E-03	4.50E-03	ND
Anthracene	0.70	1.00E-01 (b)	7.00E-02	ND	1.00E-01 (b)	7.00E-02	ND	ND	ND	2.20E+00
Benzo(a)anthracene	0.70	1.00E-01 (b)	7.00E-02	ND	1.00E-01 (b)	7.00E-02	ND	ND	ND	2.20E+00
Benzo(a)pyrene	0.70	1.00E-01 (b)	7.00E-02	ND	1.00E-01 (b)	7.00E-02	ND	ND	ND	2.20E+00
Benzo(b)fluoranthene	0.70	1.00E-01 (b)	7.00E-02	ND	1.00E-01 (b)	7.00E-02	ND	ND	ND	2.20E+00
Benzo(k)fluoranthene	0.70	1.00E-01 (b)	7.00E-02	ND	1.00E-01 (b)	7.00E-02	ND	ND	ND	2.20E+00
Chrysene	0.70	1.00E-01 (b)	7.00E-02	ND	1.00E-01 (b)	7.00E-02	ND	ND	ND	2.20E+00
Fluoranthene	0.70	1.00E-01 (b)	7.00E-02	ND	1.00E-01 (b)	7.00E-02	ND	ND	ND	2.20E+00
Indeno(1,2,3-cd)pyrene	0.70	1.00E-01 (b)	7.00E-02	ND	1.00E-01 (b)	7.00E-02	ND	ND	ND	2.20E+00
Phenanthrene	0.70	1.00E-01 (b)	7.00E-02	ND	1.00E-01 (b)	7.00E-02	ND	ND	ND	2.20E+00
Pyrene	0.70	1.00E-01 (b)	7.00E-02	ND	1.00E-01 (b)	7.00E-02	ND	ND	ND	2.20E+00
4,4-DDT	0.80	5.00E-04	4.00E-04	ND	5.00E-04	4.00E-04	ND	3.40E-01	2.72E-01	3.40E-01
4,4-DDD	0.80	ND	ND	ND	ND	ND	ND	2.40E-01	1.92E-01	ND
4,4-DDE	0.80	ND	ND	ND	ND	ND	ND	3.40E-01	2.72E-01	ND
beta-BHC	0.91	3.00E-03	2.73E-03	ND	3.00E-04	2.73E-04	ND	1.80E+00	3.24E+00	1.80E+00
Dieldrin	0.10	5.00E-05	5.00E-06	ND	5.00E-05	5.00E-06	ND	1.60E+01	1.60E+00	1.60E+01
Arsenic	0.95	1.00E-03	9.50E-04	ND	1.00E-03	9.50E-04	ND	ND	ND	5.00E+01
Chromium	0.25	1.00E+01	2.50E+00	ND	1.00E+00	2.50E-01	ND	ND	ND	4.10E+01
Lead	0.50	ND	ND	ND	ND	ND	ND	ND	ND	ND

(a) Dermally Absorbed Reference Dose = Oral Reference Dose * Oral Absorption Efficiency of Compound

(b) Minimum Risk Level for PAH compounds (ATSDR, 1990)

ND = No data

strongest evidence of human carcinogenicity are denoted with Class A, B1, or B2, while chemicals with less supporting evidence are classified as C or D. The slope factor is usually the upper 95 percent confidence limit of the slope of the dose-response curve for the constituent and is expressed as (mg/kg-day)-1. Carcinogenic slope factors listed in Table 6-7 are primarily from USEPA (1990), with HEAST (1990) as a secondary source.

6.2.6.3 Toxicity Assessment of Dermal Exposures - No RfDs or slope factors have been derived for dermal absorption. Risks associated with dermal exposures may be evaluated with Oral Absorbed Dose RfDs or Oral Absorbed Slope Factors after dermal exposures are converted to their respective absorbed dose (USEPA, 1989b). Dermal exposures were adjusted to absorbed dose estimates by assuming that the contaminants permeate skin at a rate equal to the permeability of water (water-based contaminants only). Oral RfDs and SFs were also adjusted by oral absorption rates found or extrapolated from specific ATSDR Toxicological Profiles (ATSDR, 1987 to 1990) to give an Absorbed Dose Reference Dose or Absorbed Dose Slope Factor as shown in Table 6-7. The Dermal Absorbed Dose estimates can then be compared to Oral Absorbed criteria, as described in the Risk Assessment Guidance (USEPA, 1989b).

It is inappropriate to use oral slope factors to evaluate carcinogens which have direct action on the skin (i.e., skin cancer), but they can be applied to carcinogens which act in a systemic mode rather than local mode. Arsenic is one constituent which is associated with a dermally active mode of carcinogenicity.

6.2.6.4 Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria

6.2.6.4.1 Drinking Water Standards - In accordance with the Safe Drinking Water Act, the EPA has established Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) for a number of constituents. By definition, the MCLGs are non-enforceable goals while the MCLs are enforceable standards which must be set as close to the MCLGs as feasible. The MCLs combine health effects information on specific constituents with other inputs on exposure, methods for chemical analysis, methods of treatment, economics, etc. The total human exposure to specific contaminants is considered in developing the MCL, which attempts to set lifetime limits at the lowest practical level to minimize the amount of toxicant contributed by drinking water. A daily intake of two liters of water is assumed in developing these regulations (USEPA, 1989).

Relevant State Water rules include the State of Tennessee Public Water Supply Rules and the Tennessee Hazardous Waste Rules for the protection of ground water. Also to be considered are the Tennessee Superfund Hazardous Substance Guidelines. The first two are equal to Federal MCLs. The Superfund Guidelines are stricter for some constituents. The MCLs and State Guidelines for the constituents of concern are compared to Fluvial aquifer ground-water concentrations in Table 6-8.

6.2.6.4.2 <u>Ambient Water Quality Criteria</u> - Ambient water quality criteria (WQC) for constituents in surface waters are derived for the protection of aquatic life and for the protection of human health from the ingestion of contaminated water and/or organisms (USEPA, 1987a). Aquatic life WQC will be discussed in the environmental assessment section. The WQC for the protection of human health for the ingestion of contaminated water and organisms assumes a daily ingestion of two liters of water and 6.5 grams of fish. Ambient concentrations corresponding to several incremental lifetime cancer risk levels have been estimated for those constituents which exhibit carcinogenic and/or mutagenic effects in laboratory tests and are suspected of being potentially carcinogenic to humans. The ambient concentration which may result in one excess cancer case per one million persons (10^{-6}) are

TABLE 6-8
DRINKING WATER STANDARDS FOR CONSTITUENTS IN THE GROUNDWATER AT THE DDMT

CONSTITUENT	DDMT MAXIMUM GROUND-WATER CONCENTRATION (UG/L)	WELL LOCATION	SDWA MAXIMUM CONTAMINANT LEVEL (a) (UG/L)	TENNESSEE HAZARDOUS SUBSTANCE GUIDELINES(b) (UG/L)
ARSENIC	464	MW-17	50	50
BARIUM	3,740	MW-14	1,000	1,000
CHROMIUM	1,240	MW-7	50	50
LEAD	1,000	MW-10	50	50
MERCURY	6.8	MW-17	2	2
ACETONE	3,500	MW-37	--	--
CARBON TETRACHLORIDE	77	MW-6	5	5
1,1-DICHLOROETHYLENE	160	MW-10	7	7
1,2-DICHLOROETHYLENE	1,100	MW-31	100/70 (c)	350
1,1,2,2-TETRACHLOROETHANE	340	MW-12	--	0.17
TETRACHLOROETHYLENE	210	MW-5	5	0.8
TRICHLOROETHYLENE	1,700	MW-12	5	5
DIELDRIN	0.17	MW-9	--	0.000017

(a) Tennessee Maximum Contaminant Levels are equal to federal MCLs
Proposed MCLs included when final not available (FR 5/22/89)

(b) To Be Considered; These guidelines are not enforceable

(c) Trans isomer/Cis isomer

Additional sources: IRIS, 1990;

presented in this section as ambient Water Quality Criteria (WQC) for the potential carcinogenic constituents. The ambient WQC for the protection of human health are compared to maximum surface water concentrations at DDMT in Table 6-9.

6.2.7 Risk Characterization

The final component of the risk assessment process is risk characterization, whereby the potential for adverse public health or environmental effects for each of the exposure scenarios derived in the exposure assessment are estimated (USEPA, 1988a).

6.2.7.1 Potential Ground Water Risks - As the local quality of ground water within the Fluvial aquifer may have an adverse impact on the potable aquifer for Memphis (see discussion in Section 6.2.3.1), a comparison was made between drinking water intakes based on the minimum analytical detection limits for drinking water quality (proposed exposure point concentration for worst case scenario) and the chemical specific RfDs and SFs. Hazard Indices and Excess Cancer Risk was estimated for ingestion, inhalation and dermal absorption pathways. Adult exposures were for seventy years, while exposures for children had a duration of 12 years.

Tables 6-10 and 6-11 show the chronic hazard indices for children and adults, respectively, for exposure to constituents present in the Fluvial aquifer at Dunn Field. Assuming that these constituents have reached the Allen Well Field at near detection limit concentrations, cumulative hazard indices for ingestion, inhalation of volatilized constituents and dermal absorption during bathing are within an acceptable range (i.e., below one).

Table 6-11 also shows the lifetime excess cancer risk associated with consumption and use of potable water within near detection limit contamination. There would be a slight excess risk for the ingestion and dermal absorption routes (i.e. 2E-06, while a risk

TABLE 6-9
AMBIENT WATER QUALITY CRITERIA FOR CONSTITUENTS IN THE SURFACE WATER AT THE DDMT HUMAN HEALTH

CONSTITUENT	DDMT MAXIMUM SURFACE WATER CONCENTRATION (UG/L)	SAMPLE LOCATION	WATER QUALITY CRITERIA FOR THE PROTECTION OF: HUMAN HEALTH FROM THE INGESTION OF :	
			WATER & FISH (UG/L)	FISH ONLY (UG/L)
ARSENIC	48	SW-6	0.0022	0.018
BARIUM	98	SW-12	1000	--
CHROMIUM	20	SW-2;SW-12	50	--
LEAD	295	SW-9	50	--
DIELDRIN	0.13	SW-1	0.000071	0.000076
4,4'-DDE	0.88	SW-11	--	--
4,4'-DDT	2.2	SW-12	0.000024	0.000024

Table 6-10
Chronic Hazard Indices for Residents of Memphis, Child Drinking Water Exposures

Constituents in Dunn Field Plume	Minimum Analytical Detection Limits (a) (mg/L)	Child Chronic Exposure Intakes			Child Chronic Hazard Indices		
		Oral (mg/kg-day)	Dermal Absorption (mg/kg-day)	Inhalation (mg/kg-day)	Oral	Dermal Absorption	Inhalation
Arsenic	0.001	3.80E-05	7.23E-08	3.80E-05	3.80E-02	7.61E-05	ND
Barium	0.001	3.80E-05	7.23E-08	3.80E-05	7.60E-04	2.89E-06	3.80E-01
Chromium	0.0023	8.74E-05	1.66E-07	8.74E-05	8.74E-05	6.65E-07	ND
Lead	0.001	3.80E-05	7.23E-08	3.80E-05	ND	ND	ND
Carbon Tetrachloride	0.00012	4.56E-06	8.68E-09	4.56E-06	6.51E-03	1.30E-05	ND
1,1-Dichloroethylene	0.00013	4.94E-06	9.40E-09	4.94E-06	5.49E-04	1.10E-06	ND
1,2-Dichloroethylene	0.000002	7.60E-08	1.45E-10	7.60E-08	3.80E-06	7.61E-09	ND
1,1,2,2-Tetrachloroethane	0.00001	3.80E-07	7.23E-10	3.80E-07	ND	ND	ND
Tetrachloroethylene	0.00003	1.14E-06	2.17E-09	1.14E-06	1.14E-04	2.28E-07	ND
Trichloroethylene	0.00005	1.90E-06	3.62E-09	1.90E-06	ND	ND	ND
				Total	4.6E-02	9.4E-05	3.8E-01

(a) As described in the analytical methods section of ATSDR profiles

ND No Data; Reference Dose Values not available for these exposure routes

Table 6-11
Chronic Hazard Indices and Excess Cancer Risk
Residents of Memphis, Adult
Drinking Water Exposures

Constituents in Dunn Field Plume	Minimum Analytical Detection (mg/L)	Adult Chronic Exposure Intakes			Adult Chronic Hazard Indices			Excess Cancer Risk		
		Ingestion (mg/kg-day)	Dermal Absorption (mg/kg-day)	Inhalation (mg/kg-day)	Ingestion	Dermal Absorption	Inhalation	Oral	Dermal Absorption	Inhalation
Arsenic	0.001	2.90E-05	5.19E-08	2.90E-05	2.9E-02	5.5E-05	ND (a)	ND	ND	1E-03
Barium	0.001	2.90E-05	5.19E-08	2.90E-05	5.8E-04	2.1E-06	2.9E-01	ND	ND	ND
Chromium	0.0023	6.67E-05	1.19E-07	6.67E-05	6.7E-05	4.8E-07	ND	ND	ND	2E-03
Lead	0.001	2.90E-05	5.19E-08	2.90E-05	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	0.00012	3.48E-06	6.23E-09	3.48E-06	5.0E-03	9.4E-06	ND	3E-07	3E-07	3E-07
1,1-Dichloroethylene	0.00013	3.77E-06	6.75E-09	3.77E-06	4.2E-04	7.9E-07	ND	2E-06	1E-06	3E-06
1,2-Dichloroethylene	0.000002	5.80E-08	1.04E-10	5.80E-08	2.9E-06	5.5E-09	ND	2E-09	2E-09	ND
1,1,2,2-Tetrachloroethane	0.00001	2.90E-07	5.19E-10	2.90E-07	ND	ND	ND	4E-08	4E-08	4E-08
Tetrachloroethylene	0.00003	8.70E-07	1.56E-09	8.70E-07	8.7E-05	1.6E-07	ND	3E-08	3E-08	2E-09
Trichloroethylene	0.00005	1.45E-06	2.60E-09	1.45E-06	ND	ND	ND	1E-08	1E-08	2E-08
					3.5E-02	6.8E-05	2.9E-01	2E-06	2E-06	3E-03

ND No Data; Toxicity values not available for these exposure routes of 1E-06 is usually considered acceptable). The projected inhalation risk is approximately three magnitudes greater. Most of the inhalation risk is associated with metals, which have not yet been detected in any Allen Well Fields. In reality, no actual excess cancer risk is currently estimated for drinking water exposures, because the Allen Well Field does not serve as the sole drinking water source for any local population and no contaminants have actually been detected in Well 108, which is the closest Allen Well Field well to DDMT. Use of the Allen Well Field varies over time. It is currently used as a back-up source of potable water.

Actual onsite Fluvial ground-water concentrations were compared to federal MCLs and State water quality criteria. As shown in Table 6-8, the highest arsenic and mercury levels were present in MW-17 on the north central boundary of DDMT. The monitoring wells in Dunn Field had all other maximum concentrations of constituents of concern in ground water.

As shown in Table 6-8, the maximum lead concentration at DDMT (1,000 ug/l) exceeds all standards and criteria for drinking water. This maximum contamination value is 12 times the background level found in MW-16, which is an up-gradient well for the DDMT site. In general, the metals of concern, arsenic, barium, chromium, lead, and mercury, all exceed drinking water criteria and are several times greater than background levels present in MW-16. The chromium level detected in MW-7 is 25 times higher than the background level and the MCL for chromium.

While the main facility also had evidence of low concentrations of organic compounds, the seven organic compounds of concern are primarily localized in Dunn Field. The maximum concentrations of carbon tetrachloride, 1,1-dichloroethylene, 1,2-dichloroethylene, 1,1,2,2-tetrachloroethane, tetrachloroethylene and trichloroethylene are many times above drinking water standards and criteria. Acetone, detected once in the Memphis Sand Well MW-37, is equal to the RCRA RfD-based health criteria for water ingestion. Of additional concern is the fact that the chlorinated compounds have a tendency to leach through the soil, and the extent of contamination now extends beyond the installation boundaries. The horizontal and vertical extent of contamination in the Fluvial aquifer has not been completely defined.

A final concern is the finding of dieldrin in monitoring well MW-9 (Dunn Field in April 1989). The concentration detected is quite low, but most of the available health standards (i.e., WQC) are several fold lower. However, dieldrin was not detected in MW-9 or any other wells during the January 1990 sampling episode.

The high levels of ground-water constituents found at Dunn Field during the April 1989 ground-water sampling were confirmed by the data from the January 1990 ground-water sampling. Ground-water contamination extends beyond the northwest corner of Dunn Field (MW-31 and MW-32). While no chlorinated compounds were found in the deeper wells (MW-36 and MW-37), acetone was detected in MW-37 at a level potentially harmful to human health. Further sampling at Dunn Field would be advisable to confirm the presence of acetone and define the extent of contamination in the Fluvial aquifer.

On the main facility, metals contamination appears to be elevated at the northwestern corner. Also, low levels of chlorinated compounds were detected along the southwest corner, but at levels much lower than those seen at Dunn Field.

6.2.7.2 Surface Water Risks

6.2.7.2.1 - Off-site Exposures - Two potential offsite surface water exposures were quantitatively examined. Nonconnah Creek and Cane Creek receive some drainage flow from DDMT. These creeks are zoned for recreational use. The pathways examined were ingestion of fish which may have bioaccumulated site constituents and wading in water which contains contaminants. The diluted concentration of site constituents in offsite creeks was conservatively calculated to be 1.44% of the maximum onsite concentrations.

Table 6-12 illustrates that, even at these more dilute concentrations, the cumulative hazard indices for ingestion of fish for both adults and children exceed one (45 and 120, respectively). Excess cancer risk for fish ingestion was also quite high (1E-02). Most of the unacceptable risk associated with this pathway is attributable to the pesticides and arsenic. These constituents would tend to settle and bind to sediments, but are also fairly persistent in the environment.

As shown in Table 6-13, potential risks associated with wading exposures were not found to be unacceptable. The cumulative hazard indices for adults and children were 4.0E-4 and 8.1E-06, respectively. The excess cancer risk was estimated at 1E-8. It should also be observed that this risk calculation is for Nonconnah Creek and includes a 69:1 dilution factor. As dilution may not occur in the drainage channels immediately off-site, application of this factor may not be applicable. However, the deletion of this dilution factor would still result in an acceptable risk for waders in the drainage ditch system.

6.2.7.2.2 - Onsite Exposures - Lake Danielson and the golf course pond are not currently used for swimming or fishing. Surface water is not a drinking water source at the facility or in the surrounding city area. Therefore, ambient WQC for the protection of human health are not strictly relevant and appropriate for the lake or pond on the facility, but shall be considered in evaluating the quality of water leaving the facility via surface run-off.

As shown in Table 6-9, four metals and three pesticides from the indicator chemical list were detected in the ten surface water samples taken at DDMT. The maximum surface water concentrations of arsenic, lead, dieldrin and 4,4'-DDT exceed WQC for the ingestion of water and fish or fish alone. No criteria were available for 4,4'-DDE. Of the indicator chemicals, barium and chromium were present in the surface water at levels below criteria levels for the protection of human health.

Table 6-12
Potential Risks Associated with the Ingestion of Fish from Nonconnah Creek by Nearby Residents and their Families
Defense Depot Memphis Tennessee

Primary Constituents (a)	Mean (b) Concentration (mg/L)	Bioconcentration Factor	Adult Chronic and Lifetime Fish Ingestion Intake (mg/kg-day)	Child Fish Ingestion Intake (mg/kg-day)	Oral Reference Dose (mg/kg-day)	Oral Slope Factor (mg/kg-day)	Adult Chronic Oral Hazard Index	Child Oral Hazard Index	Lifetime Excess Cancer Risk
Arsenic	6.2E-04	44	6.27E-04	1.70E-03	0.001	ND	6.3E-01	1.7E+00	
Barium	6.6E-04	1	1.52E-05	4.14E-05	0.05	ND	3.0E-04	8.3E-04	
Chromium	2.4E-04	16	9.01E-05	2.45E-04	1	ND	9.0E-05	2.4E-04	
Copper	4.3E-04	200	1.99E-03	5.40E-03	ND	ND			
Lead	1.7E-03	49	1.96E-03	5.34E-03	ND	ND			
Zinc	1.3E-03	47	1.35E-03	3.68E-03	0.2	ND	6.8E-03	1.8E-02	
Dieldrin	1.7E-06	4760	1.89E-04	5.14E-04	0.00005	16	3.8E+00	1.0E+01	3E-03
4,4-DDE	6.5E-06	51000	7.60E-03	2.07E-02	ND	0.34			3E-03
4,4-DDT	1.6E-05	54000	2.02E-02	5.49E-02	0.0005	0.34	4.0E+01	1.1E+02	7E-03
Acetone	2.0E-04	1	4.64E-06	1.26E-05	0.1	ND	4.6E-05	1.3E-04	
						Total	4.5E+01	1.2E+02	1E-02

(a) Detected more than 15% of the time

(b) Calculation includes all surface water samples. Dieldrin concentrations were found only at Dunn Field.
Estimated Dilution Factor of 0.0144 based on flow from Lake Danielson Drainage Basin and flow in Nonconnah Creek (see text).

ND No Data; Toxicity values not available for these exposure routes

Table 6-13
Potential Off-site Risks Associated with Dermal Absorption During Wading by Nearby Residents and their Families
Defense Depot Memphis Tennessee

Primary Constituents (a)	Mean (b) Concentration (mg/L)	Adult Chronic and Lifetime Dermal Absorbed Dose (mg/kg-day)	Child Dermal Absorbed Dose (mg/kg-day)	Dermal Absorption Reference Dose (mg/kg-day)	Dermal Absorption Slope Factor (mg/kg-day)	Adult Chronic Oral Hazard Index	Child Oral Hazard Index	Lifetime Excess Cancer Risk
Arsenic	6.2E-04	2.24E-07	4.46E-09	0.00095	ND	2.4E-04	4.7E-06	
Barium	6.6E-04	2.39E-07	4.77E-09	0.0125	ND	1.9E-05	3.8E-07	
Chromium	2.4E-04	8.84E-08	1.76E-09	0.25	ND	3.5E-07	7.1E-09	
Copper	4.3E-04	1.56E-07	3.11E-09	ND	ND			
Lead	1.7E-03	6.29E-07	1.25E-08	ND	ND			
Zinc	1.3E-03	4.52E-07	9.02E-09	0.05	ND	9.0E-06	1.8E-07	
Dieldrin	1.7E-06	6.24E-10	1.24E-11	0.000005	16	1.2E-04	2.5E-06	1E-08
4,4-DDE	6.5E-06	2.34E-09	4.67E-11	ND	0.272			6E-10
4,4-DDT	1.6E-05	5.88E-09	1.17E-10	0.0004	0.272	1.5E-05	2.9E-07	2E-09
Acetone	2.0E-04	7.28E-08	1.45E-09	0.095	ND	7.7E-07	1.5E-08	
						4.0E-04	8.1E-06	1E-08

(a) Detected more than 15% of the time

(b) Calculation includes all surface water samples. Dieldrin concentrations were found only at Dunn Field.
Estimated Dilution Factor of 0.0144 based on flow from Lake Danielson Drainage Basin and flow in Nonconnah Creek (see text).

ND No Data; Toxicity value not available for these exposure routes

Pesticides were previously detected in the fish at Lake Danielson (USAEHA, 1986a). The continued presence of arsenic and DDT in Lake Danielson suggests that a source for these contaminants still exists. DDE and DDT were detected in the sediments of Lake Danielson. DDT, DDE, DDD and several polycyclic aromatic hydrocarbon compounds were present in the sediments from the golf course pond. Because of the toxicity and persistence in the environment of these compounds, it would be unadvisable to use Lake Danielson or the golf course lake for contact recreation.

Exposure to volatile compounds via vaporization from surface water is not considered a pathway at DDMT, as no volatiles were detected in the surface water discharged from the facility into the storm system. Lead, arsenic, DDT and DDE were present in SW-9, SW-10, SW-11 and SW-12, which are sample points on the southeastern boundaries of the facility. Dieldrin was present in a surface water discharge point for Dunn Field. All of these constituents tend to adsorb to sediments and are not highly volatile.

The results of the quantitative risk characterization of offsite concentrations (estimated) and the overstep of AWQC by onsite concentrations (actual) indicate that there are potential human health risks associated with the pesticides and metals found in site sediments and surface waters.

6.2.7.3 Surface Soil Risks - The surface soil investigations have discovered high concentrations of potentially carcinogenic and/or toxic constituents. While many of the areas examined have some grass cover, there are also many areas which are unpaved or have gravel cover. Traffic flow on the facility is steady, with activities occurring over a 40 year period. Therefore, assumptions were made concerning the distribution of constituents over the facility. It was assumed that chronically exposed individuals would have career exposures to the arithmetically averaged concentrations of the constituents of concern and that indoor dust concentrations would equal outdoor concentrations. For subchronic exposures, it was assumed that construction workers would be working in areas with maximum concentrations for all constituents of concern. In reality, maximum soil concentrations are spread over various locations at the facility.

The subchronic hazard indices for soil exposures via incidental ingestion of soils and absorption of soil constituents through the skin are shown in Table 6-14. There were no subchronic inhalation RfDs available for these soil constituents, so hazard indices for inhalation were not derived. Exposures via ingestion appear to be acceptable, while exposures via dermal absorption are unacceptably high (182.38 versus an acceptable value of 1). Most of the risk is associated with dieldrin, DDT, arsenic, and the PAH compounds.

Table 6-15 illustrates the chronic hazard indices for career employees exposed to site soils via incidental ingestion, dermal absorption and inhalation of fugitive dust. Once again, chronic inhalation RfDs were not available for these constituents, so inhalation hazard indices were not derived. Intakes for fugitive dust approximate those of incidental ingestion, so that risks for this route may be roughly the same as those associated with ingestion. The cumulative oral hazard indices are acceptable (i.e., below 1). The cumulative dermal absorption index is much higher (23). Dieldrin, arsenic and DDT contribute most of the risk via dermal absorption.

Table 6-16 demonstrates the excess risk of cancer associated with the potential carcinogens in surficial soils. The cumulative risk via ingestion is equal to the departure point of 1E-6. The dermal absorption and inhalation pathways exceed the departure point and have excess cancer risk values of 2E-4 and 7E-3, respectively. Most of the excess risk of cancer via inhalation is associated with arsenic and chromium. In this calculation, an assumption has been made that site chromium is hexavalent chromium, while the predominant species is probably trivalent chromium. The PAH compounds also contribute significantly to the excess risk via inhalation.

Table 6-14
Subchronic Exposure Intakes and Estimated Hazard Indices
for Construction Workers
Defense Depot Memphis Tennessee

		Subchronic Exposure Intakes			Subchronic Hazard Indices	
Constituents of Concern (a)	Maximum Surface Soil Concentration (mg/kg)	Incidental Ingestion (mg/kg-day)	Dermal Absorption (mg/kg-day)	Inhalation of Fugitive Dust (mg/kg-day)	Ingestion	Dermal Absorption
Acetone	1.1	3.5E-07	2.3E-04	1.0E-06	3.5E-06	0.0025
Trichloroethylene	2.1	6.7E-07	4.5E-04	1.9E-06	(c)	(c)
Methylene Chloride	7.1	2.3E-06	1.5E-03	6.5E-06	(c)	(c)
Anthracene	130	4.2E-05	2.8E-02	1.2E-04	4.2E-04 (b)	0.40
Benzo(a)anthracene	970	3.1E-04	2.1E-01	8.8E-04	3.1E-03	2.95
Benzo(a)pyrene	450	1.4E-04	9.6E-02	4.1E-04	1.4E-03	1.37
Benzo(b)fluoranthene	540	1.7E-04	1.2E-01	4.9E-04	1.7E-03	1.64
Benzo(k)fluoranthene	450	1.4E-04	9.6E-02	4.1E-04	1.4E-03	1.37
Chrysene	620	2.0E-04	1.3E-01	5.6E-04	2.0E-03	1.89
Fluoranthene	860	2.8E-04	1.8E-01	7.8E-04	2.8E-03	2.62
Indeno(1,2,3-cd)pyrene	310	9.9E-05	6.6E-02	2.8E-04	9.9E-04	0.94
Phenanthrene	200	6.4E-05	4.3E-02	1.8E-04	6.4E-04	0.61
Pyrene	870	2.8E-04	1.9E-01	7.9E-04	2.8E-03	2.65
4,4-DDT	59	1.9E-05	1.3E-02	5.4E-05	3.8E-02	31.42
4,4-DDD	3.6	1.2E-06	7.7E-04	3.3E-06	(c)	(c)
4,4-DDE	39	1.2E-05	8.3E-03	3.5E-05	(c)	(c)
beta-BHC	2.5	8.0E-07	5.3E-04	2.3E-06	2.7E-04	0.20
Dieldrin	2.9	9.3E-07	6.2E-04	2.6E-06	1.9E-02	123.54
Arsenic	42	1.3E-05	8.9E-03	3.8E-05	1.3E-02	9.42
Chromium	16200	5.2E-03	3.5E+00	1.5E-02	5.2E-04	1.38
Lead	17500	5.6E-03	3.7E+00	1.6E-02	(c)	(c)
				Total	8.7E-02	182.38

(a) Dermally Absorbed Reference Dose = Oral Reference Dose * Oral Absorption Efficiency of Compound

(b) Minimum Risk Level for PAH compounds (ATSDR, 1990) used for Reference Dose (1E-01)

(c) Subchronic Reference Dose Values not available for these compounds

Table 6-15
Potential Chronic Soil Exposure Risks for Employees
Defense Depot Memphis Tennessee

		Chronic Exposure Intakes			Chronic Hazard Indices (c)	
Constituents of Concern (a)	Arithmetic Mean (b) (mg/kg)	Incidental Ingestion (mg/kg-day)	Dermal Absorption (mg/kg-day)	Inhalation of Fugitive Dust (mg/kg-day)	Oral	Dermal Absorption
Acetone	0.02	7.5E-09	5.0E-06	1.1E-08	7.5E-08	5.2E-05
Trichloroethylene	0.04	1.4E-08	9.3E-06	2.1E-08	(d)	(d)
Methylene Chloride	0.15	4.9E-08	3.3E-05	7.5E-08	7.9E-07	8.8E-04
Anthracene (e)	4.9	1.6E-06	1.0E-03	2.4E-06	1.6E-05	1.5E-02
Benzo(a)anthracene	24.7	7.9E-06	5.3E-03	1.2E-05	7.9E-05	7.5E-02
Benzo(a)pyrene	13.7	4.4E-06	2.9E-03	6.7E-06	4.4E-05	4.2E-02
Benzo(b)fluoranthene	15.9	5.1E-06	3.4E-03	7.8E-06	5.1E-05	4.8E-02
Benzo(k)fluoranthene	11.1	3.6E-06	2.4E-03	5.5E-06	3.6E-05	3.4E-02
Chrysene	17.9	5.7E-06	3.8E-03	8.8E-06	5.7E-05	5.5E-02
Fluoranthene	29.5	9.4E-06	6.3E-03	1.4E-05	9.4E-05	9.0E-02
Indeno(1,2,3-cd)pyrene	8.4	2.7E-06	1.8E-03	4.1E-06	2.7E-05	2.6E-02
Phenanthrene	21.6	6.9E-06	4.6E-03	1.1E-05	6.9E-05	6.6E-02
Pyrene	26.2	8.4E-06	5.6E-03	1.3E-05	8.4E-05	8.0E-02
4,4-DDT	2.1	6.8E-07	4.5E-04	1.0E-06	1.4E-03	1.1E+00
4,4-DDD	0.2	6.5E-08	4.3E-05	9.9E-08	(d)	(d)
4,4-DDE	1.3	4.1E-07	2.7E-04	6.2E-07	(d)	(d)
beta-BHC	0.2	5.2E-08	3.4E-05	7.9E-08	1.7E-04	1.3E-01
Dieldrin	0.4	1.2E-07	8.2E-05	1.9E-07	2.5E-03	1.6E+01
Arsenic	16.6	5.3E-06	3.5E-03	8.1E-06	5.3E-03	3.7E+00
Chromium	737.0	2.4E-04	1.6E-01	3.6E-04	2.4E-04	6.3E-01
Lead	903.0	2.9E-04	1.9E-01	4.4E-04	(d)	(d)
				Total	1.0E-02	23

(a) Constituents detected in more than 10% of the samples

(b) Based on all surface soil samples

(c) Chronic Inhalation Reference Dose Values were not available.
Therefore, chronic hazard indices for inhalation could not be calculated.

(d) Chronic Reference Values are not available for these compounds.

(e) Minimum Risk Level for PAHs in food (ATSDR, 1990) used for Oral Reference Dose of PAH compounds.

Table 6-16
Estimated Excess Cancer Risks
Based on Soil Exposures to Career Employees
Defense Depot Memphis Tennessee

		Lifetime Exposure Intakes			Excess Cancer Risk		
Constituents of Concern	Arithmetic Mean (mg/kg)	Incidental Ingestion (mg/kg-day)	Dermal Absorption (mg/kg-day)	Inhalation of Fugitive Dust (mg/kg-day)	Ingestion	Dermal Absorption	Inhalation
Acetone	0.02	3.3E-09	2.1E-06	4.9E-09	ND	ND	ND
Trichloroethylene	0.04	6.1E-09	4.0E-06	9.2E-09	7E-11	4E-08	2E-10
Methylene Chloride	0.15	2.2E-08	1.4E-05	3.2E-08	2E-10	6E-08	ND
Anthracene	4.9	6.9E-07	4.5E-04	1.0E-06	ND	ND	2E-06
Benzo(a)anthracene	24.7	3.5E-06	2.3E-03	5.2E-06	ND	ND	1E-05
Benzo(a)pyrene	13.7	1.9E-06	1.3E-03	2.9E-06	ND	ND	6E-06
Benzo(b)fluoranthene	15.9	2.2E-06	1.5E-03	3.3E-06	ND	ND	7E-06
Benzo(k)fluoranthene	11.1	1.6E-06	1.0E-03	2.3E-06	ND	ND	5E-06
Chrysene	17.9	2.5E-06	1.6E-03	3.8E-06	ND	ND	8E-06
Fluoranthene	29.5	4.1E-06	2.7E-03	6.2E-06	ND	ND	1E-05
Indeno(1,2,3-cd)pyrene	8.4	1.2E-06	7.7E-04	1.8E-06	ND	ND	4E-06
Phenanthrene	21.6	3.0E-06	2.0E-03	4.5E-06	ND	ND	1E-05
Pyrene	26.2	3.7E-06	2.4E-03	5.5E-06	ND	ND	1E-05
4,4-DDT	2.1	3.0E-07	1.9E-04	4.5E-07	1E-07	5E-05	2E-07
4,4-DDD	0.2	2.8E-08	1.8E-05	4.2E-08	7E-09	4E-06	ND
4,4-DDE	1.3	1.8E-07	1.2E-04	2.7E-07	6E-08	3E-05	ND
beta-BHC	0.2	2.3E-08	1.5E-05	3.4E-08	4E-08	5E-05	6E-08
Dieldrin	0.4	5.4E-08	3.5E-05	8.1E-08	9E-07	6E-05	1E-06
Arsenic	16.6	2.3E-06	1.5E-03	3.5E-06	ND	ND	2E-04
Chromium	737.0	1.0E-04	6.7E-02	1.5E-04	ND	ND	6E-03
Lead	903.0	1.3E-04	8.3E-02	1.9E-04	ND	ND	ND
				Total	1E-06	2E-04	7E-03

ND = No data: Cancer Slope Factors not available

In Table 6-17, maximum soil concentrations are compared to the recommended soil concentration levels listed by the Tennessee Division of Superfund for hazardous substances in soils. These levels are guidelines for evaluating contamination at a site and are not considered enforceable.

Exposure parameters are expected to differ over the different use areas of the facility. Only two areas, Dunn Field and the golf course, have significant vegetation to limit the generation of fugitive dust during active site use. The rest of the facility is predominantly paved (55-60%), but some exposed areas do remain.

In summary, it is recognized that the risk characterization for surface soils may be conservative, particularly in the application of exposure parameters. However, the use of average values and the large deviation from acceptable values indicates that some risk is present from the surface soils. The risk characterization also points out that several constituents contribute most significantly to the risk and thus should be targeted during site remediation.

6.2.7.4 <u>Potential Sediment Risks</u> - As shown in Table 6-17, fairly high levels of PAHs as well as DDT, DDE and DDD were found in the golf course pond sediments (SD-5-SS) at levels which exceed Tennessee's recommended soil concentration values. Sediments do not pose a direct human health risk at DDMT, but do serve as a reservoir for contaminants in surface water which tend to bioaccumulate in the food chain.

6.2.7.5 <u>Potential Subsurface Soil Risks</u> - Subsurface soil contamination detected at the site was minimal and does not pose a public health risk. STB-6 did show evidence of contamination migrating from the Fluvial aquifer towards the Memphis Sand aquifer.

TABLE 6-17

TENNESSEE HEALTH-BASED CRITERIA FOR HAZARDOUS SUBSTANCES IN SOIL AND SEDIMENTS

CHEMICAL NAME	TENNESSEE DOSE, MG/KG SOIL (a)	CARCINOGEN CLASS (a)	DONT SOILS (MG/KG)		DONT SEDIMENTS (MG/KG)	
			Max.	Location	Max.	Location
VOLATILE ORGANICS:						
Acetone	0.59	NA	1.1	STB6-3	0.14	SD-4-9
1,2-Dichloroethylene	0.35	C	0.026	STB6-1	ND	
Methylene Chloride	8.6	B	7.1	SS-1	ND	
Tetrachloroethylene	0.1	C	0.031	SS-38 (c)	ND	
Trichloroethylene	0.07	B	2.100	SS-42	ND	
1,1,2,2-Tetrachlorethane	1.3	C	0.240	STB6-1	ND	
BASE/NEUTRAL/ACID EXTRACTABLES:						
Benzo(a)anthracene	0.0000028	B	970	SS-42	1.10	SD-5-SS (d)
Benzo(a)pyrene	0.0000028	B	450	SS-42	1.30	SD-5-SS
Dibenzo(a,h)anthracene	0.0000028	B	160	SS-42	0.33	SD-5-SS
PESTICIDES & PCBS:						
4,4'-DDD	0.00023	B	3.6	SS-11	3.000	SD-5-SS
4,4'-DDE	--	B	39.0	SS-11	0.460	SD-5-SS
4,4'-DDT	--	B	59.0	SS-11	2.900	SD-5-SS
beta-BHC	0.0024	B	2.5	SS-50	ND	
Dieldrin	0.0000048	B	4.5	SS-43	ND	
METALS:						
Arsenic	5	A	42	SS-37	ND	
Chromium IV (b)	5	A	16,200	SS-20	28.000	SD-5-SS
Lead	5	NA	1,120	SS-42	ND	

(a) Source: Integrated Risk Information System (USEPA, 1990); Tennessee Dept. of Superfund

(b) DONT values are for total chromium; species is not specified.

(c) SS: Surface Soil sample; STB: Soil Test Boring

(d) SD-5-SS: Sediment from site 5 (Golf Pond) at surface of pond sediment

ND Not Detected

6.2.7.6 Summary - In brief, an assessment of the DDMT facility revealed a large number of constituents present in ground water, surface water, surficial soils and sediments. Potential public health risk was associated with the following matrices:

1) The Fluvial aquifer contains chlorinated organic compounds which could negatively impact the Memphis Sand aquifer, the potable drinking source for 650,000 people. Information from hydrological models indicates that very low amounts of constituents could possibly have reached the receptor area at Allen Well Field. However, there is currently no monitoring evidence to show that contamination has reached the well field. Further investigation is needed to establish the extent of ground water contamination at and near Dunn Field. Additional information concerning the confining unit and the Memphis Sand aquifer quality beneath the facility and to the west would also be helpful.

2) Surficial soils contain potential human carcinogens at unacceptably high concentrations ($>10^{-6}$). Further investigation is necessary to establish the extent of contamination at facility "hot spots". Limits on human exposure (i.e., protective gear, limited access) are recommended for employees with high soil exposure until remediation of contaminated "hot spots" is accomplished.

3) Contamination of site surface waters and sediments have the potential for negative impacts off the facility. However, this risk appears to be primarily associated with the consumption of fish from Nonconnah Creek. This risk is probably overestimated due to the numerous conservative assumptions related to calculation of offsite risk due to fishing. Actual offsite monitoring of nearby creeks and fish bioassays from these creeks would be helpful in determining what offsite surface water impacts may occur. A continued ban

on fishing and swimming at Lake Danielson (and the golf course pond) is recommended. Incidental contact, such as from wading in the drainage channels immediately offsite, does not result in unacceptable risk.

6.3 ENVIRONMENTAL ASSESSMENT

6.3.1 Development and Use

The majority of the DDMT facility has been developed for urban use and does not support vegetative or animal life. Dunn Field, the golf course and the administrative area are the only areas which support notable vegetation.

6.3.2 Wildlife

Two areas, Dunn Field and the golf course, have evidence of typical urban wildlife such as squirrels, chipmunks, red foxes, opossums, quail, mourning doves, and turtles. Rats, mice and other pests are attracted to the subsistence stocks and are commonly found in the storage buildings (Phoenix Associates, Inc., 1984).

6.3.3 Aquatic Life

Lake Danielson was periodically stocked with bluegill and bass. Catfish have also been observed in the lake. Several fish kills have occurred in the lake (1976, 1980 and 1989). One incident in 1976 was associated with pesticide run-off into the lake. Lake Danielson receives a large amount of the surface drainage from the southeastern corner of the installation. Pesticide and herbicide contamination is also in evidence at the golf course pond and is probably associated with routine grounds care of the golf course (Harland, Bartholomew, 1988; Phoenix Associates, Inc., 1984).

6.3.4 Endangered Species

No threatened or endangered species are known to inhabit or utilize the DDMT facility or the area within one mile of the facility (Harland, Bartholomew and Associates, Inc. 1988).

6.3.5 Vegetation

Bermuda grass, black oaks and decorative shrubs and trees are the only vegetation present at the DDMT facility. Grass and trees are found predominantly at Dunn Field and the golf course. Most landscape shrubs are located around the family quarters, the golf course and around the administrative buildings in the southeastern corner (Harland, Bartholomew and Associates, 1988).

6.3.6 Potential Exposure Pathways

Aquatic life in Lake Danielson and the golf course pond are potentially exposed to soil contaminants carried by surface run-off. Offsite aquatic life in Cane Creek and Nonconnah Creek are potentially impacted by contact with surface drainage flowing into these creeks. Aquatic life in the Mississippi River is potentially impacted by contact with ground water discharged from the Fluvial aquifer. Plant and animal life are exposed via intake of potentially contaminated surface water and soil constituents.

6.3.7 Environmental Fate Processes

Some of the chemicals of concern have the ability to accumulate within the food chain (i.e, 4,4'-DDT, dieldrin). The volatile organic compounds volatilize quickly from water and surface soil. They do not tend to bioaccumulate and are persistent in the aqueous environment only under anaerobic conditions. The polycyclic aromatic hydrocarbons are readily absorbed by living aquatic species (ATSDR, 1988 and 1989). The PAHs have low vapor pressure and low water solubility, but a high propensity to adsorb to organic soils. Therefore, these compounds persist in surface soils for long periods of time. The half-life of dibenzo(a,h)anthracene is 750 days in soil. (ATSDR, 1988 and 1989).

Mercury is a potentially bioaccumulating compound in aquatic species, but was not detected in surface waters at DDMT. Lead and chromium are associated with some accumulation in vegetation and animals. In general, in aqueous environments, metals, polycyclic aromatic hydrocarbons, and pesticides tend to adsorb to sediments. The pesticides are eventually recycled to the aquatic environment, where they tend to bioaccumulate in fish tissue.

6.3.8 Proposed ARARs for Aquatic Life

Ambient WQC for the protection of aquatic life are compared to the maximum surface water concentrations in Table 6-18. Maximum surface water concentrations for chromium and lead exceed WQC. WQC for aquatic life are not available for arsenic and barium.

Of the volatile organic compounds, only acetone was detected in surface water. No WQC were available for acetone. The chronic ambient WQC for dieldrin and 4,4'-DDT are exceeded by the surface water samples from Dunn Field (SW-1) and the southeastern boundaries sample, SW-12.

6.3.9 Risk Characterization

There is no negative impact expected at DDMT on the environmental receptors coming into contact with Fluvial ground water. Dilution, after mixing, is also expected to reduce most of the contamination contributed by storm runoff to Nonconnah Creek and Cane Creek to acceptable levels. Nonetheless, estimated offsite levels of dieldrin and DDT almost equal or exceed chronic aquatic life protection levels. Lead levels also approach the chronic protection limit.

TABLE 6-18
AMBIENT WATER QUALITY CRITERIA FOR PROTECTION OF AQUATIC LIFE FOR CONSTITUENTS IN THE SURFACE WATER FOR DEFENSE DEPOT MEMPHIS TENNESSEE

CONSTITUENT	DDMT MAXIMUM SURFACE WATER CONCENTRATION (UG/L)	SAMPLE LOCATION	ESTIMATED OFFSITE SURFACE WATER CONCENTRATION (UG/L)	WATER QUALITY CRITERIA FOR THE PROTECTION OF: AQUATIC LIFE ACUTE	CHRONIC
ARSENIC	48	SW-6	0.62	--	--
BARIUM	98	SW-12	0.66	--	--
CHROMIUM	20	SW-2	0.24	16	11
LEAD	295	SW-9	1.7	82	3.2
ACETONE	110	SW-14	0.2	--	--
DIELDRIN	0.13	SW-1	0.0017	2.5	0.0019
4,4'-DDE	0.88	SW-11	0.0065	1,050	--
4,4'-DDT	2.2	SW-12	0.016	1.1	0.001

Sources: IRIS, 1990; Interim Final RFI Guidance, 1989.

The surface water quality in Lake Danielson and the golf course pond is inappropriate for the support of aquatic life because of the presence of DDT and related compounds in the surface water and sediments at these locations. One possible solution would be to redirect surface drainage away from Lake Danielson, though this proposal may not eliminate the problem. Continued monitoring may reveal that biodegradation and other environmental fate processes may reduce surface water contaminants to acceptable levels.

6.3.10 Summary

The presence of vegetation and animal life is limited at DDMT. Therefore, any negative impact on land flora and fauna is very low. Aquatic life in Lake Danielson and the golf course pond have suffered negative impacts from storm water runoff of pesticides at the facility. Traces of pesticides are still detected in surface water and sediments at the installation. Consequently, these bodies of water are unsuitable for the support of fish and are inappropriate locations for recreational activities such as fishing.

7.0 SUMMARY AND CONCLUSIONS

This chapter briefly summarizes the results and conclusions of this Remedial Investigation and provides recommendations for future work.

7.1 CONTAMINATION EXTENT AND SOURCE

7.1.1 Dunn Field Ground Water

The ground-water quality investigation at Dunn Field revealed elevated (above background and ARARs) levels of chlorinated volatile organic compounds and metals in the Fluvial aquifer both on the installation and beyond the installation boundaries. The investigation indicates that the plume of contaminated ground water has migrated in a generally west and northwest direction. The contamination source is probably associated with the waste material burial trenches in Dunn Field. The western extent of the plume is not defined. In other areas, the plume appears to be defined by wells with low or non-detected levels of organics and background levels of metals.

Soils analyzed from the soil test borings in Phase II at Dunn Field detected low levels of chlorinated volatile organics within the confining unit at STB-6 and in the Memphis Sand aquifer in STB-6 and STB-8. This contamination may have resulted from downward migration from the overlying Fluvial aquifer. However, the possibility also exists that the contamination may have been transported from the overlying aquifer during drilling operations.

Two monitoring wells were screened in the Memphis Sand aquifer. A fairly high level of acetone contamination was detected in MW-37. The source of acetone is unknown since this was not a significant contaminant in the Fluvial aquifer. No other significant contamination was detected in either Memphis Sand monitoring well.

7.1.2 Main Installation Ground Water

At the main installation, generally low levels of metals and chlorinated volatile organics were detected in two areas of the Fluvial aquifer. The first area is located near Lake Danielson (MW-25 and MW-26), and the second in the southwest corner of the installation (MW-21, MW-22 and MW-39). The source of this contamination has not been determined; however, analysis of surface soils showed the presence of tetrachloroethene and trichloroethene at Buildings 770, 757, 629 and T273 in the vicinity of these wells. Due to the high relative mobility of these compounds, the surface soil contamination could have contributed to the ground-water contamination.

The complex Fluvial aquifer flow regime suggests that a portion of Fluvial aquifer flow at the main installation is controlled by a sink or channel-like feature incised in the underlying confining unit. The two wells installed in the deepest known reach of the Fluvial aquifer (MW-34 and MW-38) were relatively free of the contaminants, suggesting that contamination is not currently accumulating in that area.

7.1.3 Surface Soils

The surface soil investigation focused on probable or known "hot spots" at ten separate areas at the main installation and Dunn Field. Surface soils were found to be contaminated by solvents, organic compounds, and/or metals at all sampling locations. Several of the samples were contaminated with pesticides and polycyclic aromatic hydrocarbons (PAHs). The six most contaminated areas were located at the main installation. Those areas are listed below, along with the suspected source of contamination:

	Site	Suspected Source of Contamination
1.	DRMR Yard	Leaking Drums
2.	Building 629	Spills swept or hosed out of doors at Building 629
3.	Building T-273 at golf course	Cleaning of pesticide application equipment
4.	Building 1088	General spillage from paint shop and/or cleaning operations
5.	Open Storage Area	Leakage from railroad tank cars on Tracks #3 and #4
6.	Building 770	General spillage from maintenance shop and waste oil storage drums

The extent of contamination was not fully defined in any area.

7.1.4 Surface Water and Sediment

The surface water investigations in Phase I and Phase II revealed low levels of organic compounds, metals and pesticides. The sediment investigation in Phase I showed appreciable levels of pesticides and herbicides in the golf course pond and in Lake Danielson.

7.2 FATE AND TRANSPORT

Potential routes of contaminant migration were described for the types of contaminants detected during the Remedial Investigation. Transport media include soil, surface water and ground water. The surface water and ground water contaminant migration pathways are capable of transporting pollutants from the installation into the adjacent receiving environment. The vertical migration from the Fluvial aquifer to the Memphis Sand aquifer appears possible.

The contaminants detected include the following: pesticides, herbicides, PCBs, chlorinated volatile organics, extractable organics, polycyclic aromatics (PAHs), and metals. Some of these contaminants are persistent in the environment.

Contaminant migration has been detected at DDMT and is expected, given the presence of contaminants and sufficient rainfall to both generate and mobilize pollutants. As metals were detected in all media samples, it is likely that this contaminant class is capable of migration. Chlorinated volatile organics were detected locally in ground water (especially in Dunn Field and west of Dunn Field), surface soils, subsurface soils (STB-6 and STB-8), and possibly in the Memphis Sand aquifer. This class of constituents is known to be very mobile in soil and tends to leach into ground water. Estimates of time for transport to the Memphis Sand aquifer range 25 to 150 years.

Pesticides and PCBs were detected in surface water and sediments. They are not very mobile in the environment and were detected at points relatively close to source areas. The low levels of pesticide contamination in the surface water samples, as compared to the appreciable contaminant levels in the sediments, suggest that pesticide contaminants are predominantly attached to the sediments with a lesser volume actually migrating off the Depot. The results of the quantitative risk characterization indicate that the installation's surface waters may be transporting low levels of pesticide contaminants through the surface drainage system to local fishing areas, and that human health could be potentially impacted by ingestion of fish from these areas.

PAHs were detected primarily in surface soils. This class of compounds is not very mobile. Therefore, it is suspected that they too were encountered at locations proximate to their original sources, for example, at spill sites in the former Property Disposal Yard (now DRMO storage area). Subchronic and chronic exposure to surface soil contamination may potentially pose a health risk to depot employees.

7.3 RISK ASSESSMENT

The Baseline Risk Assessment consisted of a Public Health Evaluation and an Environmental Assessment. The Public Health Evaluation concluded that although contamination of the Fluvial aquifer did not pose a direct threat to the health and safety of DDMT personnel or Memphis residents, it does constitute an indirect risk due to the potential Fluvial aquifer/Memphis Sand aquifer connection. The risk posed by contaminated surface soils is potentially unacceptable, but could be institutionally managed through site access restrictions and dust control management. Surface water and sediment contamination potentially serve as a continuing source of offsite risk, if actual offsite concentrations in recreational creeks are as great as estimated. The Environmental Assessment concluded that installation-related contamination posed little risk to study area terrestrial vegetation and animal life. The only identified threat was to aquatic life in Lake Danielson and the golf course pond.

7.4 RECOMMENDATION FOR FUTURE WORK

The following recommendations for the future are presented for consideration.

1) DDMT records show a general location for burial sites in the Dunn Field area. This set of records was proven to be inadequate and unreliable during the drilling portion of the RI. The ground-water contamination at Dunn Field probably has resulted from leakage out of these burial sites. Thus, remediation of these sites will be an important component of a permanent solution at Dunn Field. An accurate definition of the location and extent of the burial sites would allow the most economical design of a remediation system. We recommend that an indirect method, such as surface geophysical surveys, be performed to locate the contaminant burial trenches. This survey could include resistivity, magnetic, and electromagnetic methods.

2) The western extent of the contaminant plume within the Fluvial aquifer at Dunn Field will require further evaluation. We recommend that several additional off-base wells be installed in this area. The thickness of the Fluvial aquifer and the presence of the top of the confining unit should also be determined at each well location.

3) Monitoring well MW-37 should be resampled to confirm the presence of acetone.

4) Resample and analyze all monitoring wells for dissolved metals, in addition to total metals. This should provide less variable results, which can be more directly related to other existing data.

5) Additional Type III soil borings and/or monitoring wells should be installed within the plume at Dunn Field. Several important functions could be performed in conjunction with the soil borings: 1) additional analytical soil results could be obtained to confirm the penetration of contaminants into the confining unit; 2) undisturbed samples could be obtained and analyzed to evaluate the permeability of the confining unit; and 3) physico-chemical results (such as mineralogy and organic carbon content) which affect contaminant transport could be obtained. The soil boring(s) could be extended into the Memphis Sand to allow the installation of a Type III well. This would allow further confirmation of the acetone detected in monitoring well MW-37.

6) Install several additional wells at the main installation to confirm the low levels and extent of ground-water contamination. These wells would also allow local definition of the ground-water flow direction in the two areas where contamination was encountered (the southwest corner and Lake Danielson).

7) Remediation of the ground-water contamination at Dunn Field could involve a conventional pump-and-treat system, or a pumping system in conjunction with bioremediation or some other system. An economical design of an extraction well field would involve a more in-depth study of aquifer characteristics than is provided by the existing "slug-in/slug-out" test data. Transmissivity, storage coefficient and hydraulic conductivity could be evaluated in greater detail by the use of a pump test. A pump test well could be located in Dunn Field close enough to existing monitoring wells to permit their use as observation wells during the test. If properly designed, the pump test well could later be used as an extraction well. The ground water recovered during the test must be assumed to be contaminated; therefore, it should be retained on site for analysis, treatment and eventual release.

8) Surface soil contamination has been identified in several areas. While access restrictions could limit exposure in these areas, it may be desirable to selectively remediate areas for use. In those areas, additional sampling would define the extent of contamination. To define the horizontal extent, enough sampling should be performed to determine the periphery of the contaminated areas. Samples should also be taken at various depths to determine the vertical extent. Analysis could be done onsite using Thin Layer Chromatography (TLC). By using this method, the results for each sample could be obtained within minutes, and the extent of contamination could be determined during one sampling investigation at a greatly reduced cost.

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FINAL PAGE

ADMINISTRATIVE RECORD

FINAL PAGE

FINAL PAGE

ADMINISTRATIVE RECORD

FINAL PAGE