Final Report
Phase I RCRA Facility Investigation for Appendix I Sites

VOLUME VIII

SWMU-7, Fire Training Area 1
SWMU-11, Supernatant Pond
SWMU-12, Industrial Waste Pit No. 1
SWMU-13, Industrial Waste Pit No. 2
SWMU-23, Industrial Waste Treatment Plant, Abandoned Waste Tanks
SWMU-54, Stained Drainage Ditch and Drums (Near Bldg. 17)

Department of the Air Force
Oklahoma City Air Logistics Center
Tinker Air Force Base, Oklahoma

September 1994

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RFI REPORT

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Phase I RCRA Facility Investigation for Appendix I Sites

VOLUME VIII

SWMU-7, Fire Training Area 1

Department of the Air Force
Oklahoma City Air Logistics Center
Tinker Air Force Base, Oklahoma

September 1994

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List of Acronyms

AFB	Air Force Base
AOC	area of concern
CAL	Corrective Measures Study
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm/s	centimeters per second
CMS	Corrective Measures Study
DCE	dichloroethylene
DERP	Defense Environmental Restoration Program
DOD	U.S. Department of Defense
EID	Engineering Installation Division
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
FTA1	Fire Training Area 1
ft/ft	foot per foot
HSWA	Hazardous and Solid Waste Amendment
IRP	Installation Restoration Program
LSZ	lower saturated zone
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µmhos/cm	micromhos per centimeter
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
msl	mean sea level
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
PA/SI	preliminary assessment/site investigation
PCB	polychlorinated biphenyls
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation/feasibility study
RFI	RCRA Facility Investigation

List of Acronyms *(Continued)*

ROD	Record of Decision
RWDS	Radiological Waste Disposal Site
SARA	Superfund Amendments and Reauthorization Act
SP	Supernatant Pond
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TSD	treatment, storage, and disposal (facility)
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
USC	U.S. Code
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USZ	upper saturated zone
UWBZ	upper water bearing zone
VOC	volatile organic compounds
WQS	water quality standards

Executive Summary

This report provides a summary of the various investigations that have been conducted at solid waste management unit (SWMU)-7, Fire Training Area 1 (FTA1), Tinker Air Force Base (AFB), Oklahoma. The report has been prepared to determine and document whether sufficient investigations at FTA1 have been performed to meet regulatory requirements. Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. The Base encompasses approximately 5,000 acres.

Background. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints.

In 1984, Congress amended the Resource Conservation and Recovery Act (RCRA) with the Hazardous and Solid Waste Amendments (HSWA), which allow EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989, Tinker AFB submitted its Part B permit application for renewal of its operating RCRA Hazardous Waste Storage facility permit. The final RCRA HSWA permit issued on July 1, 1991, requires Tinker AFB to investigate all SWMUs and areas of concern (AOC) and to perform corrective action at those identified as posing a threat to human health of the environment. The permit specifies that a RCRA Facility Investigation (RFI) be conducted for 43 identified SWMUs and two AOCs on the Base. This document has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for FTA1.

Source Description. FTA1 was used from 1950 to 1962 as a fire control training area. Prior to exercises, the area was saturated with water to reduce infiltration of flammable liquids into the soil. Fire-fighting exercises consisted of either dousing an old aircraft with flammable liquids, setting carcass on fire, and then extinguishing the fire; or filling the area with flammable liquids, igniting the liquids, and then extinguishing the fire. No records or documents exist identifying the flammable liquids that were used.

Site Investigation. Previous IRP investigations included an initial records search report by Engineering Science (ES, 1982) and a confirmation/quantitation report performed by Radian Corporation (Radian, 1985 a,b). The records search report identified the site as a potential site for remediation and recommended that soil borings be obtained and analyzed to define the contaminants and to identify the limits of contamination. The confirmation/quantitation report mentioned the FTA1 site, but made no site-specific recommendations. No RIs were conducted at the site during either of the previous investigations.

In November 1985, the U. S. Army Corps of Engineers (USACE) initiated RIs at the site to define the extent of any possible contamination. From 1985 to 1989, 27 soil borings were drilled and three monitoring wells were installed. The soil borings were drilled at 24 on-site locations and 3 off-site locations. The off-site borings were drilled to establish background levels for contaminants detected in the soil. Two monitoring wells were installed in the upper saturated zone (USZ), one upgradient and one downgradient of FTA1. The third monitoring well was installed in the lower saturated zone (LSZ) as part of the RI for Landfills No. 1 and 4 (SWMUs 3 and 6) (USACE, 1993a). Soil and groundwater sampling was conducted throughout the investigation period. Two volatile organic compounds (VOC) (methylene chloride and acetone) were detected at significant levels. Bis(2-ethylhexyl)phthalate was the only significant semivolatile organic compound (SVOC) detected. Four metals (silver, cadmium, lead, and zinc) were detected above maximum background levels. Total organic carbon (TOC) was found at above background averages in more than half the samples.

In the USZ groundwater samples, three VOCs (vinyl chloride, trichloroethene, and benzene) were found at concentrations above primary drinking water standard maximum contaminant levels (MCL). Three VOCs (methylene chloride, tetrachloroethene, and trans-1,-2-dichloroethene) were found at concentrations above proposed MCLs.

Bis(2-ethylhexyl)phthalate was the only SVOC found at significant concentrations. All the compounds found were in the upgradient and downgradient monitoring wells and in the borings. Three metals (barium, chromium, and lead) were found above MCLs and background averages both upgradient and downgradient of the FTA1. TOC and conductivity were also found above background averages at the FTA1.

In 1993, two clusters (pairs) of monitoring wells were installed, one in the USZ and one in the LSZ for each pair, and one single monitoring well in the LSZ at FTA1. Currently, the site has one upgradient cluster (USZ and LSZ) and three downgradient clusters (USZ and LSZ). Sampling data from these wells are not available for inclusion into this report.

Baseline Risk Assessment. A baseline risk assessment (USACE, 1993b) was conducted to estimate the potential impact of the site on public health and the environment now and under future land use conditions.

All of the chemicals except vinyl chloride were eliminated from further assessment as carcinogenic agents. Three chemicals (1,2-dichloroethene, 1,1,2-trichloroethane, and 2-butanone) that could cause chronic noncarcinogenic effects were also retained through the screening process. Total carcinogenic risk to the population with the greatest potential (children swimming or wading in the creek) is 6×10^{-6}. This is well within the range of acceptable risks (1×10^{-4} to 1×10^{-6}) as defined by the U.S. Environmental Protection Agency (EPA) under the National Oil and Hazardous Substances Contingency Plan (NCP). The hazard from noncarcinogenic effects is also slight as shown by a hazard index of 0.06. Noncarcinogenic effects are generally deemed minimal if the hazard index is below 1.

Ecological risks were assessed for vegetation, earthworms, small mammals, and predatory birds from surface soil exposures. In addition, a future scenario of contaminated groundwater intersecting Crutcho Creek was also assessed for potential aquatic life effects. Bis(2-ethylhexyl)phthalate presented a potential risk to vegetation and zinc showed a small potential for effects on earthworms. The largest potential effect seen at the site was from small mammals exposed to lead. No increased risk was estimated for predatory birds or aquatic life.

Recommendations. The following activities should be conducted during a Phase II RFI for this site:

- Continue with annual monitoring of the groundwater beneath the site. Monitoring should include VOCs and metals.

- Collect additional soil samples to further complete the delineation and characterization of soil contamination.

- Collect site-specific soil background samples to be used in addition to USGS soil data to distinguish site-related from background concentrations in a statistically significant manner during the Phase II investigation.

- Prepare Phase II RFI work plan for submittal to EPA for approval before beginning field work.

- Include pertinent groundwater monitoring wells in the basewide groundwater investigation activity that will provide additional data for this site to determine the extent of contamination.

1.0 Introduction

1.1 Purpose and Scope

This document has been prepared in response to the U.S. Department of the Air Force, Tinker Air Force Base (AFB), Oklahoma request for a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Summary Report for solid waste management unit (SWMU)-7, Fire Training Area 1 (FTA1).

The objective of this RFI Summary Report is to provide Tinker AFB with one comprehensive report that summarizes the various investigations that have occurred at FTA1 since the first environmental investigation was initiated on Base in 1981. The purpose of this comprehensive summary document is to:

- Characterize the site (Environmental Setting).
- Define the source (Source Characterization).
- Define the degree and extent of contamination (Contamination Characterization).
- Identify actual or potential receptors.
- Identify all action levels for the protection of human health and the environment.

Additionally, this document briefly describes the procedures, methods, and results of all previous investigations that relate to FTA1 and contaminant releases, including information on the type and extent of contamination at the site, and actual or potential receptors. Where previous investigations, reports, or studies were not comprehensive and did not furnish the information required to determine the nature and extent of contamination, future work that can be conducted to complete the investigation has been recommended.

1.2 Preface

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the cleanup of hazardous waste disposal sites across the country. CERCLA gave the president authority to require responsible parties to remediate the sites or to undertake response actions through use of a fund (the Superfund). The president, through Executive Order 12580, delegated the U.S. Environmental Protection Agency (EPA) with the responsibility to investigate and remediate private party hazardous waste disposal sites that created a threat to human health and the environment. The president delegated responsibility for investigation and cleanup of federal facility disposal sites to the various federal agency heads. The Defense Environmental Restoration Program (DERP) was formally established by Congress in Title 10 U.S. Code (USC) 2701-2707 and 2810. DERP provides

centralized management for the cleanup of U.S. Department of Defense (DOD) hazardous waste sites consistent with the provisions of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300), and Executive Order 12580. To support the goals of DERP, the Installation Restoration Program (IRP) was developed to identify, investigate, and clean up contamination at installations.

Under the Air Force IRP, Tinker AFB began a Phase I study similar to a preliminary assessment/site investigation (PA/SI) in 1981 (Engineering Science [ES], 1982). This study helped locate 14 sites that needed further investigation. A Phase II study was performed in 1983 (Radian Corporation [Radian], 1985 a,b).

In 1986, Congress amended CERCLA through the SARA. SARA waived sovereign immunity for federal facilities. This act gave EPA authority to oversee the cleanup of federal facilities and to have the final authority for selecting the remedial action at federal facilities placed on the National Priorities List (NPL) if the EPA and the relevant federal agency cannot concur in the selection. Congress also codified DERP (SARA Section 211), establishing a fund for the DOD to remediate its sites because the Superfund is not available for the cleanup of federal facilities. DERP specifies the type of cleanup responses that the fund can be used to address.

In response to SARA, the DOD realigned its IRP to follow the investigation and cleanup stages of the EPA:

- PA/SI
- Remedial investigation/feasibility study (RI/FS)
- Record of Decision (ROD) for selection of a remedial action
- Remedial design/remedial action.

In 1984, Congress amended RCRA with the Hazardous and Solid Waste Amendments (HSWA) which allow the EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989 Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit.

EPA, in the Hazardous Waste Management Permit for Tinker AFB, dated July 1, 1991, identified 43 SWMUs and two areas of concern (AOC) on Tinker AFB that need to be addressed. This permit requires Tinker AFB to investigate all SWMUs and AOCs and to perform corrective action at those identified as posing a threat to human health or the environment. This RFI Summary Report has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for FTA1 and to document all determinations.

1.3 Facility Description

Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County (Figure 1-1) with its approximate geographic center located at 35^{o} 25' latitude and 97^{o} 24' longitude (U.S. Geological Survey [USGS], 1978). The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south (Figure 1-2). An additional area east of the main Base is used by the Engineering Installation Division (EID) and is known as Area D. The Base encompasses approximately 5,000 acres. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints. Wastes that are currently generated are managed at two permitted hazardous waste storage facilities. However, prior to enactment of RCRA, industrial wastes were discharged into unlined landfills and waste pits, streams, sewers, and ponds. Past releases from these landfills, pits, etc., as well as from underground tanks, have occurred. As a result, there are numerous sites of soil, groundwater, and surface water contamination on the Base.

The various reports generated as a result of investigative activities conducted at the FTA1 have been reviewed and evaluated in terms of the sites' status under RCRA regulations. A summary based on the review of these reports for FTA1 is presented in the following chapters and sections. In addition, recommendations for additional work is given at the end of the summary report.

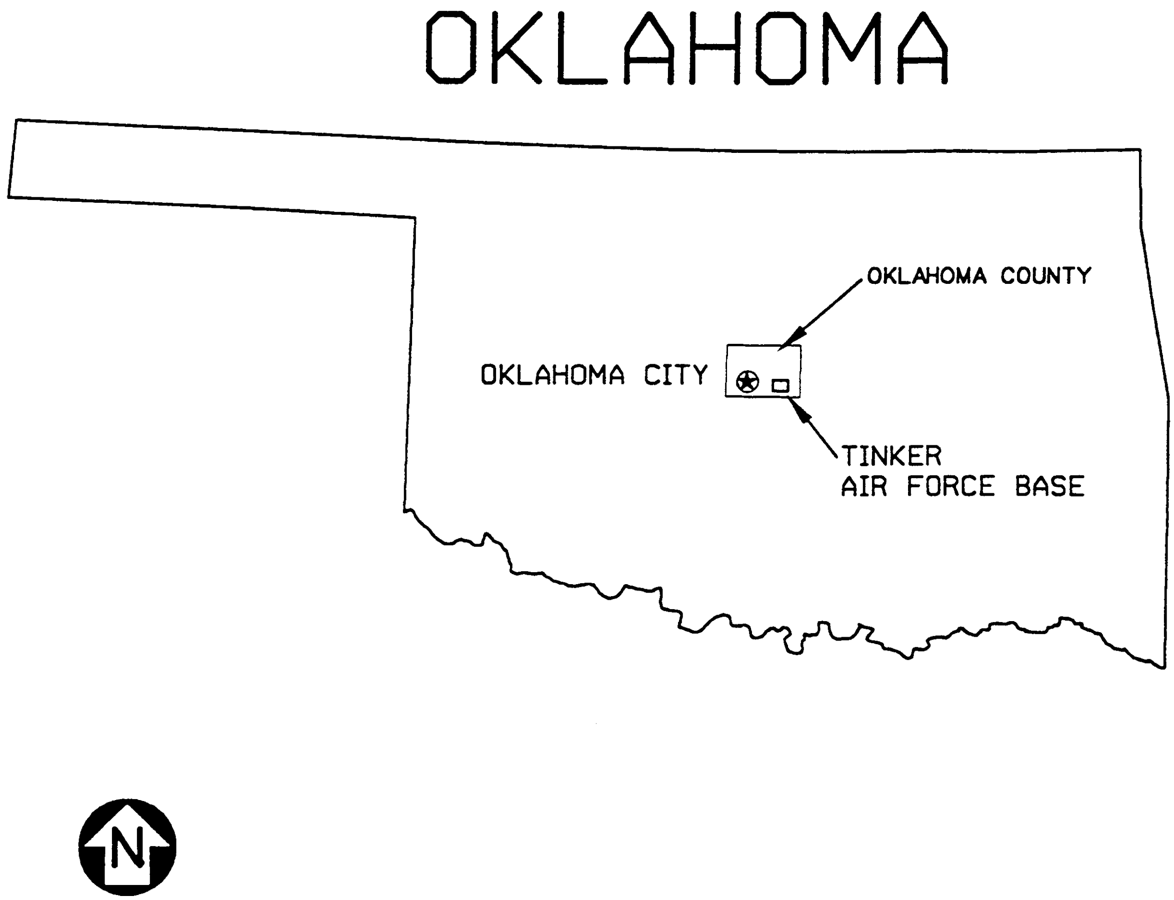

FIGURE 1-1
TINKER AIR FORCE BASE
OKLAHOMA
STATE INDEX MAP

PREPARED FOR
TINKER AFB
OKLAHOMA

STARTING DATE: 03/17/94 | DATE LAST REV.: | DRAFT. CHCK. BY:G. PACHECO | INITIATOR: C. WALLACE | DWG. NO.:
DRAWN BY:P.O. TERRY | DRAWN BY: | ENGR. CHCK. BY: C. WALLACE | PROJ. MGR.:J. TAYLOR | PROJ. NO.:

3/23/94 POT
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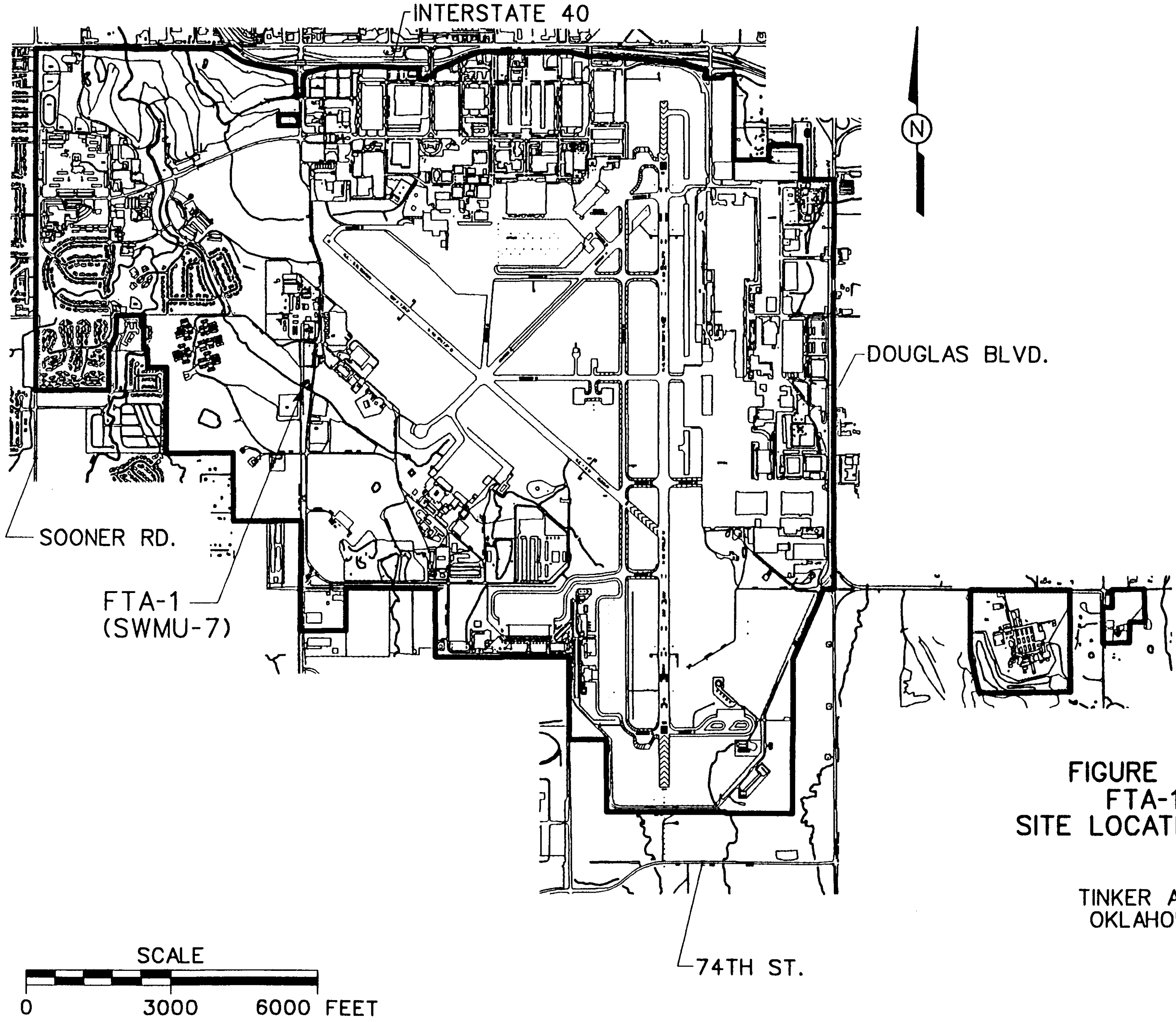


FIGURE 1-2
FTA-1
SITE LOCATION MAP

TINKER AFB
OKLAHOMA

STARTING DATE: 3/21/94	DATE LAST REV.:	DRAFT. CHCK. BY: G. PACHECO	INITIATOR: C. WALLACE	DWG. NO.:
DRAWN BY: P.O. TERRY	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J. TAYLOR	PROJ. NO.:

FILENAME: G:\TINKER\40983202.084

1.4 Site Description

FTA1 is located on the west side of Tinker AFB as shown on Figure 1-3. The site is bounded by Crutcho Creek to the south, Patrol Road to the east, the old municipal sewage treatment plant site to the north, and Air Depot Boulevard (which used to be the Tinker AFB boundary) to the west. As determined from aerial photographs, the active fire training/burning area was a circular-shaped area. The center of the site is located approximately 110 feet west of Patrol Road and 240 feet north of Crutcho Creek. The area was approximately 125 feet in diameter and was originally enclosed within an earthen dike. The area had a gravel bottom and was not lined (ES, 1982). The dike was apparently removed. The topography of FTA1 is flat and poorly drained. Water tends to collect in the area after rainfall. The site is sometimes covered with water when Crutcho Creek rises over its banks during heavy rainfall events.

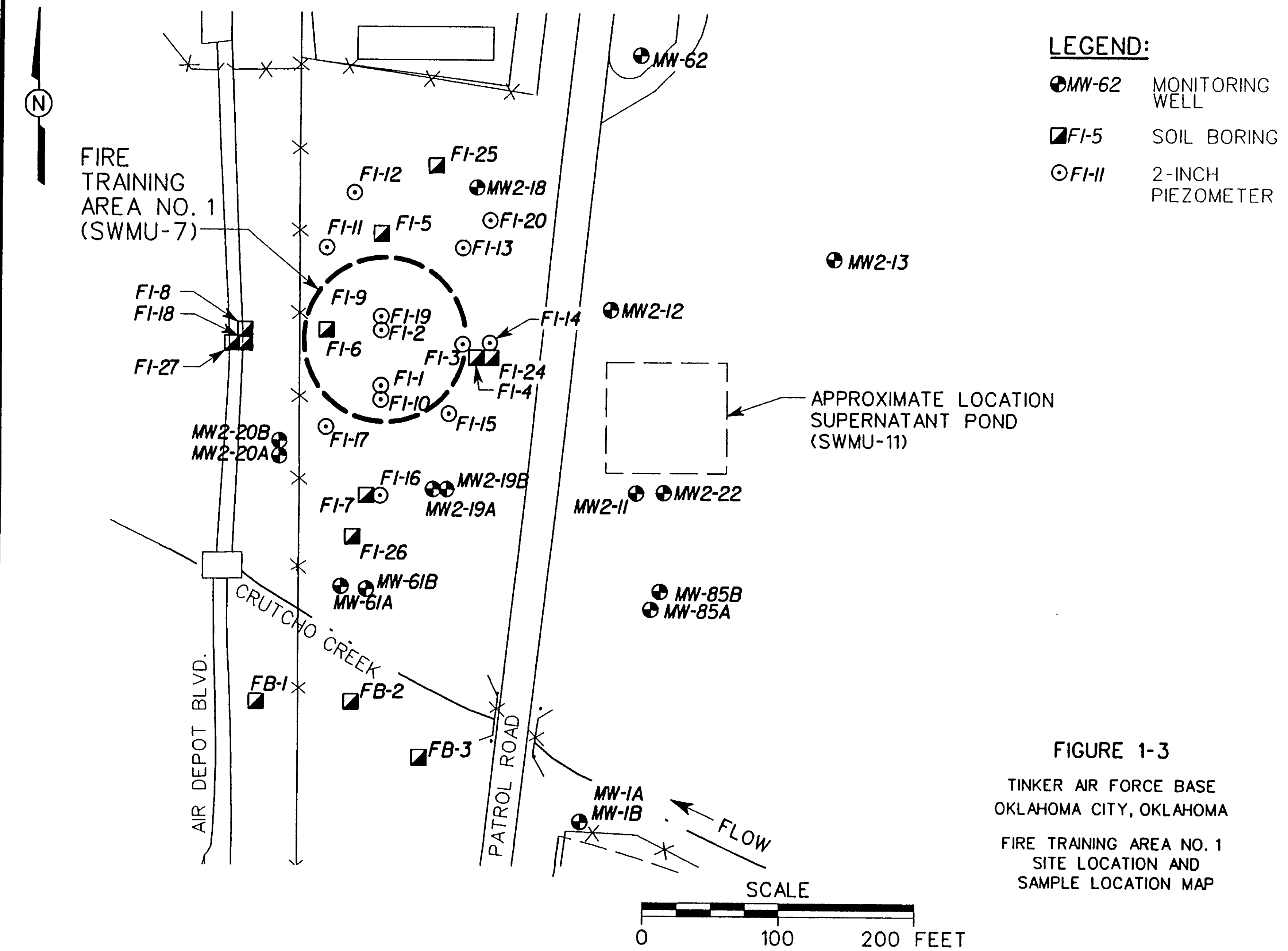


FIGURE 1-3

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

FIRE TRAINING AREA NO. 1
SITE LOCATION AND
SAMPLE LOCATION MAP

STARTING DATE: 01/15/94	DATE LAST REV.:09/08/94	DRAFT. CHCK. BY: G. PACHECO	INITIATOR: C. WALLACE	DWG. NO.: 40983202.014
DRAWN BY: LLS	DRAWN BY: P. TERRY	ENGR. CHCK. BY: C. WALLACE	PROJ. MGR.: J. TAYLOR	PROJ. NO.: 409832

8/24/96 POT
FILENAME:C:\TINKER\40983202.014

2.0 Background

2.1 Site Operations and History

Tinker AFB was originally known as the Midwest Air Depot and began operations in July 1941. The site was activated March 1942. During World War II, the depot was responsible for reconditioning, modifying, and modernizing aircraft, vehicles, and equipment.

FTA1 was used from 1950 to 1962 as a fire control training area for Tinker AFB fire fighters. Prior to exercises, the area was saturated with water to reduce infiltration of flammable liquids into the soil. Fire fighting exercises consisted of dousing an old aircraft carcass with flammable liquids, setting the carcass on fire, and then extinguishing the fire. Other exercises consisted of filling the area inside the dike with flammable liquids, igniting the liquids, and then extinguishing the fire. Water and/or a protein-based foam was used to extinguish the flame. After the exercises, the residual liquids were allowed to percolate into the soil. No records or documents exist identifying the flammable liquids that were used (ES, 1982).

2.2 Summary of Previous Investigations (USACE, 1992)

Engineering Science. FTA1 was identified as a potential remediation site in the IRP Phase I records search report prepared by ES in April 1982. The Phase I report recommended that soil borings in and around the site be obtained and analyzed to define the contaminants and to identify the limits of contamination.

Radian Corporation. FTA1 was briefly mentioned in the Phase II Confirmation/ Quantification Stage 1 report prepared by Radian in September 1985. In this report, the FTA1 site is included in an investigation zone along with Landfills No. 1 through 4 (SWMUs 3 through 6) and the Radiological Waste Disposal Site (RWDS) 1030W (SWMU-19). The Phase II report made no recommendations specific to FTA1.

U.S. Army Corps of Engineers. The U.S. Army Corps of Engineers (USACE) conducted RIs at FTA1 from 1985 to 1990 to characterize the site, to determine the nature, extent, and migration of any residual contamination of site soils or groundwater, and to define site geology and geohydrology. Twenty-four on-site and three off-site borings were drilled and three monitoring wells were installed. Seventeen of the on-site borings were used for the collection of water samples in the upper saturated zone (USZ) and for measurement of the potentiometric surface. Water and soil samples from the monitoring wells and borings were tested for total metals, total organic carbon (TOC), cyanide, polychlorinated biphenyls (PCB), pesticides, volatile organic compounds (VOC), semivolatile organic compounds (SVOC), pH, and conductivity, as applicable. A site and sample location map is presented in Figure 1-3.

In the soil samples, two VOCs (methylene chloride and acetone) were detected at significant levels. Bis(2-ethylhexyl)phthalate was the only significant SVOC detected. Five metals (arsenic, barium, cadmium, lead, and selenium) and TOC were detected at above background averages in more than half the samples.

In the USZ groundwater samples, three VOCs (vinyl chloride, trichloroethene, and benzene) were found at concentrations above primary drinking water standard maximum contaminant levels (MCL). Three VOCs (methylene chloride, tetrachloroethene, and trans-1,2-dichloroethene) were found at concentrations above proposed MCLs. Vinyl chloride, benzene, and tetrachloroethene, which were found in the groundwater, were not detected in any of the soil samples taken from the FTA1 site. Bis(2-ethylhexyl)phthalate was the only SVOC found at significant concentrations. All of these compounds were detected in the upgradient and downgradient piezometer wells. Three metals (barium, chromium, and lead) were found above MCLs and background averages both upgradient and downgradient of FTA1. TOC and conductivity were also found above background averages at the FTA1 site.

The lower saturated zone (LSZ) has not been fully investigated in vicinity of FTA1. One well in the LSZ (MW-61B) was sampled in 1988, 1989, and 1990 during the RI. In groundwater samples from this zone, trichloroethene was above the MCL, and methylene chloride was found above the proposed MCL. Bis(2-ethylhexyl)phthalate was found in 6 of 16 samples, with most of the detections above the MCL. No metals were found above the MCLs or background averages for this saturated zone. One sample had a pH value of 10.85, which is above the secondary MCL of 8.5.

Additional sampling of the USZ and LSZ was conducted in 1992 and 1993 from wells MW-61A (USZ), MW-61B (LSZ), and MW-62 (USZ). Several VOCs were detected at levels above the MCLs in both the USZ and LSZ.

In 1993, USACE installed additional monitoring wells in the vicinity of FTA1 and the Supernatant pond (SP) (SWMU-11); however, water level and water quality data are not available. The new wells include MW2-18 (LSZ) and two clusters, MW2-19A and B

(USZ/LSZ), and MW-20A and B (USZ/LSZ). New wells installed in the vicinity of the SP are MW2-12 (LSZ), MW2-13 (LSZ), and one cluster, MW2-11 (USZ) and MW2-22 (LSZ).

2.3 Current Regulatory Status

The IRP has been ongoing at Tinker AFB since the early 1980s. IRP studies on the Base were conducted according to IRP guidance, which is essentially the same as EPA's guidance for conducting RI/FS under CERCLA. All investigation and removal actions have been closely monitored and approved by the EPA.

Since receiving the Hazardous Waste Management Permit on July 1, 1991, many of the IRP sites have come under the jurisdiction of the RCRA permits branch of EPA. As such, they have been identified as SWMUs; however, a large amount of work has already been performed at most of these sites under the IRP. Additional investigation at the SWMUs will be performed under the IRP.

3.0 Environmental Setting

3.1 Topography and Drainage

3.1.1 Topography

Regional/Tinker AFB. The topography of Oklahoma City and surrounding area varies from generally level to gently rolling in appearance. Local relief is primarily the result of dissection by erosional activity or stream channel development. At Oklahoma City, surface elevations are typically in the range of 1,070 to 1,400 feet mean sea level (msl). At Tinker AFB, ground surface elevations vary from 1,190 feet msl near the northwest corner where Crutcho Creek intersects the Base boundary to approximately 1,320 feet msl at Area D (EID).

Site. FTA1 is located on the west side of Tinker AFB next to Patrol Road and Crutcho Creek. The land at the site is flat and poorly drained. The ground elevation is approximately 1,216 feet msl. The site is presently within an unutilized, open grassed area. The earthen dike that formerly enclosed the circular pit no longer exists.

3.1.2 Surface Drainage

Regional/Tinker AFB. Drainage of Tinker AFB land areas is accomplished by overland flow of runoff to diversion structures and then to area surface streams, which flow intermittently. The northeast portion of the Base is drained primarily by unnamed tributaries of Soldier Creek, which is itself a tributary of Crutcho Creek. The north and west sections of the Base, including the main instrument runway, drain to Crutcho Creek, a tributary of the North Canadian River. Two small unnamed intermittent streams crossing installation boundaries south of the main instrument runway generally do not receive significant quantities of Base runoff due to site grading designed to preclude such drainage. These streams, when flowing, extend to Stanley Draper Lake, approximately one-half mile south of the Base.

Site. The area in the vicinity of FTA1 is generally flat and poorly drained. Water tends to pond in the area after rainfall. Eventually, excess surface runoff may drain into Crutcho Creek, which is approximately 240 feet to the south. The site is sometimes covered with water when Crutcho Creek rises over its banks during heavy rainfall events.

3.2 Geology

3.2.1 Regional/Tinker AFB Geology

Tinker AFB is located within the Central Redbed Plain Section of the Central Lowland physiographic province, which is tectonically stable. No major fault or fracture zones have been mapped near Tinker AFB. The major lithologic units in the area of the Base are relatively flat-lying and have a regional westward dip of about 0.0076 foot per foot (ft/ft) (Bingham and Moore, 1975).

Geologic formations that underlie Tinker AFB include, from oldest to youngest, the Wellington Formation, Garber Sandstone, and the Hennessey Group; all are Permian in age.

All geologic units immediately underlying Tinker AFB are sedimentary in origin. The Garber Sandstone and Wellington Formation are commonly referred to as the Garber-Wellington Formation due to strong lithologic similarities. These formations are characterized by fine-grained, calcareously-cemented sandstones interbedded with shale. The Hennessey Group consists of the Fairmont Shale and the Kingman Siltstone. It overlies the Garber-Wellington Formation along the eastern portion of Cleveland and Oklahoma counties. Quaternary alluvium is found in many undisturbed streambeds and channels located within the area.

Stratigraphy. Tinker AFB lies atop a sedimentary rock column composed of strata that ranges in age from Cambrian to Permian above a Precambrian igneous basement. Quaternary alluvium and terrace deposits can be found overlying bedrock in and near present-day stream valleys. At Tinker AFB, Quaternary deposits consist of unconsolidated weathered bedrock, fill material, wind-blown sand, and interfingering lenses of sand, silt, clay, and gravel of fluvial origin. The terrace deposits are exposed where stream valleys have downcut through older strata and have left them topographically above present-day deposits. Alluvial sediments range in thickness from less than a foot to nearly 20 feet.

Subsurface (bedrock) geologic units which outcrop at Tinker AFB and are important to understanding groundwater and contaminant concerns at the Base consist of, in descending order, the Hennessey Group, the Garber Sandstone, and the Wellington Formation (Table 3-1). These bedrock units were deposited during the Permian Age (230 to 280 million years ago) and are typical of redbed deposits formed during that period. They are composed of a conformable sequence of sandstones, siltstones, and shales. Individual beds are lenticular and vary in thickness over short horizontal distances. Because lithologies are similar and because

Table 3-1

Major Geologic Units in the Vicinity of Tinker AFB (Modified from Wood and Burton, 1968)

(Page 1 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
QUATERNARY	PLEISTOCENE	Alluvium	0-70	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel in the flood plains and channels of stream	Moderately permeable. Yields small to moderate quantities of water in valleys of larger streams. Water is very hard, but suitable for most uses, unless contaminated by industrial wastes or oil field brines.
	AND RECENT	Terrace deposits	0-100	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the flood plains of the principal streams.	Moderately permeable. Locally above the water table and not saturated. Where deposits have sufficient saturated thickness, they are capable of yielding moderate quantities of water to wells. Water is moderately hard to very hard, but less mineralized than water in other aquifers. Suitable for most uses unless contaminated by oil field brines.

KN/1256/SWMU7/SWMU7.3-1/03-31-94/D2 10:35am

Table 3-1

(Page 2 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
PERMIAN	LOWER PERMIAN	Hennessey Group (includes Kingman Siltstone and Fairmont Shale)	700	Deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy or limey shale. Forms relatively flat to gently rolling grass-covered prairie.	Poorly permeable. Yields meager quantities or very hard, moderately to highly mineralized water to shallow domestic and stock wells. In places water contains large amounts of sulfate.
		Garber Sandstone	500±	Deep-red clay to reddish-orange, massive and cross-bedded fine-grained sandstone interbedded and interfingered with red shale and siltstone	Poorly to moderately permeable. Important source of groundwater in Cleveland and Oklahoma counties. Yields small to moderate quantities of water to deep wells; heavily pumped for industrial and municipal uses in the Norman and Midwest City areas. Water from shallow wells hard to very hard; water from deep wells moderately hard to soft. Lower part contains water too salty for domestic and most industrial uses.
		Wellington Formation	500±	Deep-red to reddish-orange massive and cross-bedded fine-grained sandstone interbedded with red, purple, maroon, and gray shale. Base of formation not exposed in the area.	

of a lack of fossils or key beds, the Garber Sandstone and the Wellington Formation are difficult to distinguish and are often informally lumped together as the Garber-Wellington Formation. Together, they are about 900 feet thick at Tinker AFB. The interconnected, lenticular nature of sandstones within the sequence forms complex pathways for groundwater movement.

The surficial geology of the north section of the Base is dominated by the Garber Sandstone, which outcrops across a board area of Oklahoma County. Generally, the Garber outcrop is covered by a veneer of soil and/or alluvium up to 20 feet thick. To the south, the Garber Sandstone is overlain by outcropping strata of the Hennessey Group, including the Kingman Siltstone and the Fairmont Shale (Bingham and Moore, 1975). Drilling information obtained as a result of geotechnical investigations and monitoring well installation confirms the presence of these units.

Depositional Environment. The Permian-age strata presently exposed at the surface in central Oklahoma were deposited along a low-lying north-south oriented coastline. Land features included meandering to braided sediment-loaded streams that flowed generally westward from highlands to the east (ancestral Ozarks). Sand dunes were common, as were cut-off stream segments that rapidly evaporated. The climate was arid and vegetation sparse. Off shore the sea was shallow and deepened gradually to the west. The shoreline's position varied over a wide range. Isolated evaporitic basins frequently formed as the shoreline shifted.

Across Oklahoma, this depositional environment resulted in an interfingering collage of fluviatile and wind-blown sands, clays, shallow marine shales, and evaporite deposits. The overloaded streams and evaporitic basins acted as sumps for heavy metals such as iron, chromium, lead, and barium. Oxidation of iron in the arid climate resulted in the reddish color of many of the sediments. Erosion and chemical breakdown of granitic rocks from the highlands resulted in extensive clay deposits. Evaporite minerals such as anhydrite ($CaSO_4$), barite ($BaSO_4$), and gypsum ($CaSO_4 \cdot 2H_2O$) are common.

Around Tinker AFB, the Hennessey Group represents deposition in a tidal flat environment cut by shallow, narrow channels. The Hennessey Group is comprised predominantly of red shales which contain thin beds of sandstone (less than 10 feet thick) and siltstone. In outcrop, "mudball" conglomerates, burrow surfaces, and dessication cracks are recognized. These units

outcrop over roughly the southern half of the Base, thickening to approximately 70 feet in the southwest from their erosional edge (zero thickness) across the central part of Tinker AFB.

In contrast, the Garber Sandstone and the Wellington Formation around Tinker AFB consist of an irregularly-interbedded system of lenticular sandstones, siltstones, and shales deposited either in meandering streams in the upper reaches of a delta or in a braided stream environment. Outcrop units north of Tinker AFB exhibit many small to medium channels with cut and fill geometries consistent with a stream setting. Sandstones are typically cross-bedded. Individual beds range in thickness from a few inches to approximately 50 feet and appear massive, but thicker units are often formed from a series of "stacked" thinner beds. Geophysical and lithologic well logs indicate that from 65 to 75 percent of the Garber Sandstone and the Wellington Formation are composed of sandstone at Tinker AFB. The percentage of sandstone in the section decreases to the north, south, and west of the Base. These sandstones are typically fine to very fine grained, friable, and poorly cemented. However, where sandstone is cemented by red muds or by secondary carbonate or iron cements, local thin "hard" intervals exist along disconformities at the base of sandstone beds. Shales are described as ranging from clayey to sandy, are generally discontinuous, and range in thickness from a few inches to approximately 40 feet.

Stratigraphic Correlation. Correlation of geologic units is difficult due to the discontinuous nature of the sandstone and shale beds. However, cross-sections (Figure 3-1) demonstrate that two stratigraphic intervals can be correlated over large sections of the Base in the conceptual model. These intervals are represented on geologic cross-sections A-A' and B-B' (Figures 3-2 and 3-3). Section A-A' is roughly a dip section and B-B' is approximately a strike section. The first correlatable interval is marked by the base of the Hennessey Group and the first sandstone at the top of the Garber Sandstone. This interval is mappable over the southern half of Tinker AFB. The second interval consists of a shale zone within the Garber Sandstone which, in places, is comprised of a single shale layer and, in other places, of multiple shale layers. This interval is more continuous than other shale intervals and in cross-sections appears mappable over a large part of the Base. It is extrapolated under the central portion of Tinker AFB where little well controls exists.

Structure. Tinker AFB lies within a tectonically stable area; no major near-surface faults or fracture zones have been mapped near the Base. Most of the consolidated rock units of the Oklahoma City area dip westward at a low angle. A regional dip of 0.0057 to 0.0076 ft/ft in

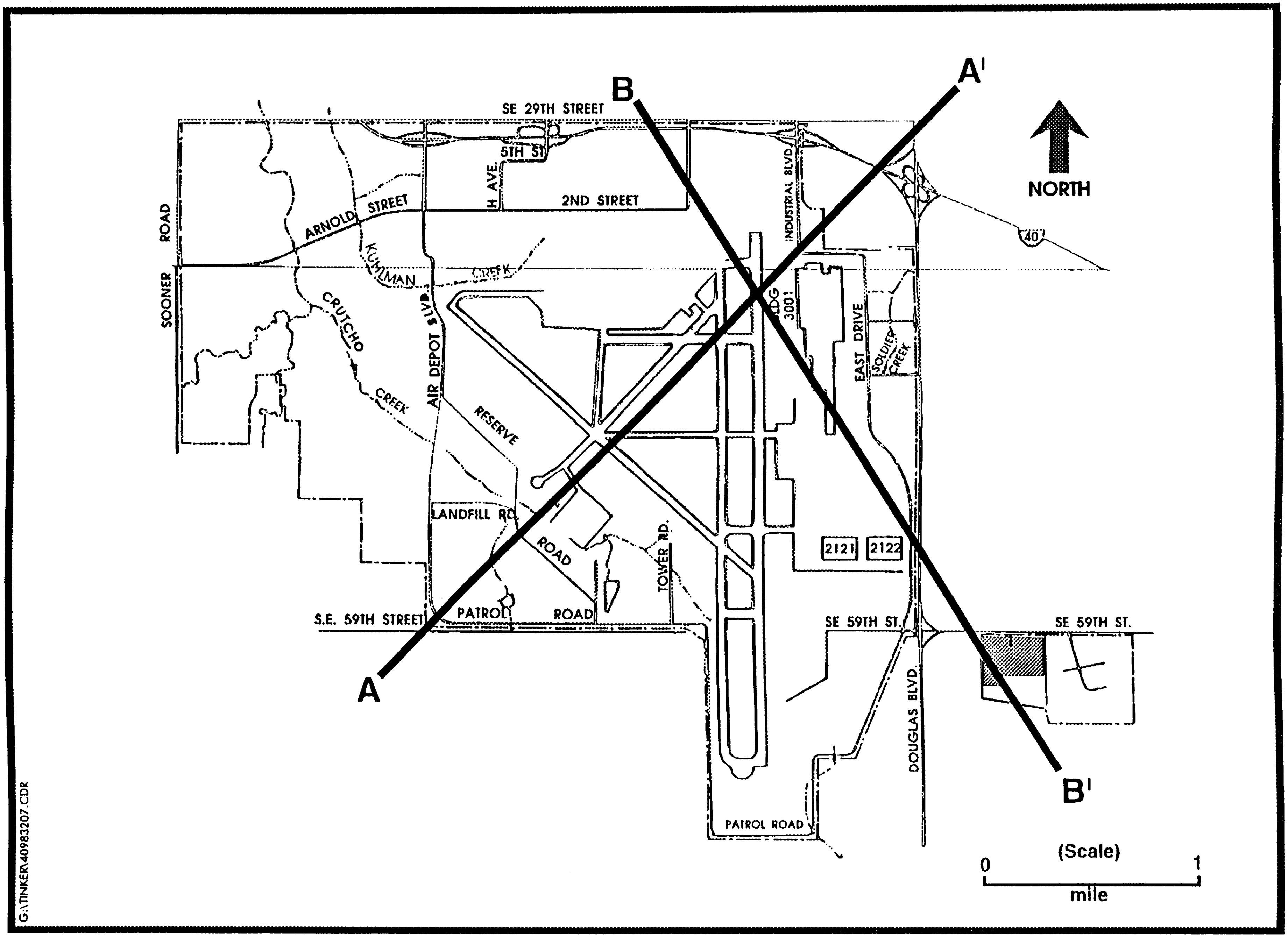


FIGURE 3-1 TINKER AFB GEOLOGIC CROSS SECTION LOCATION MAP

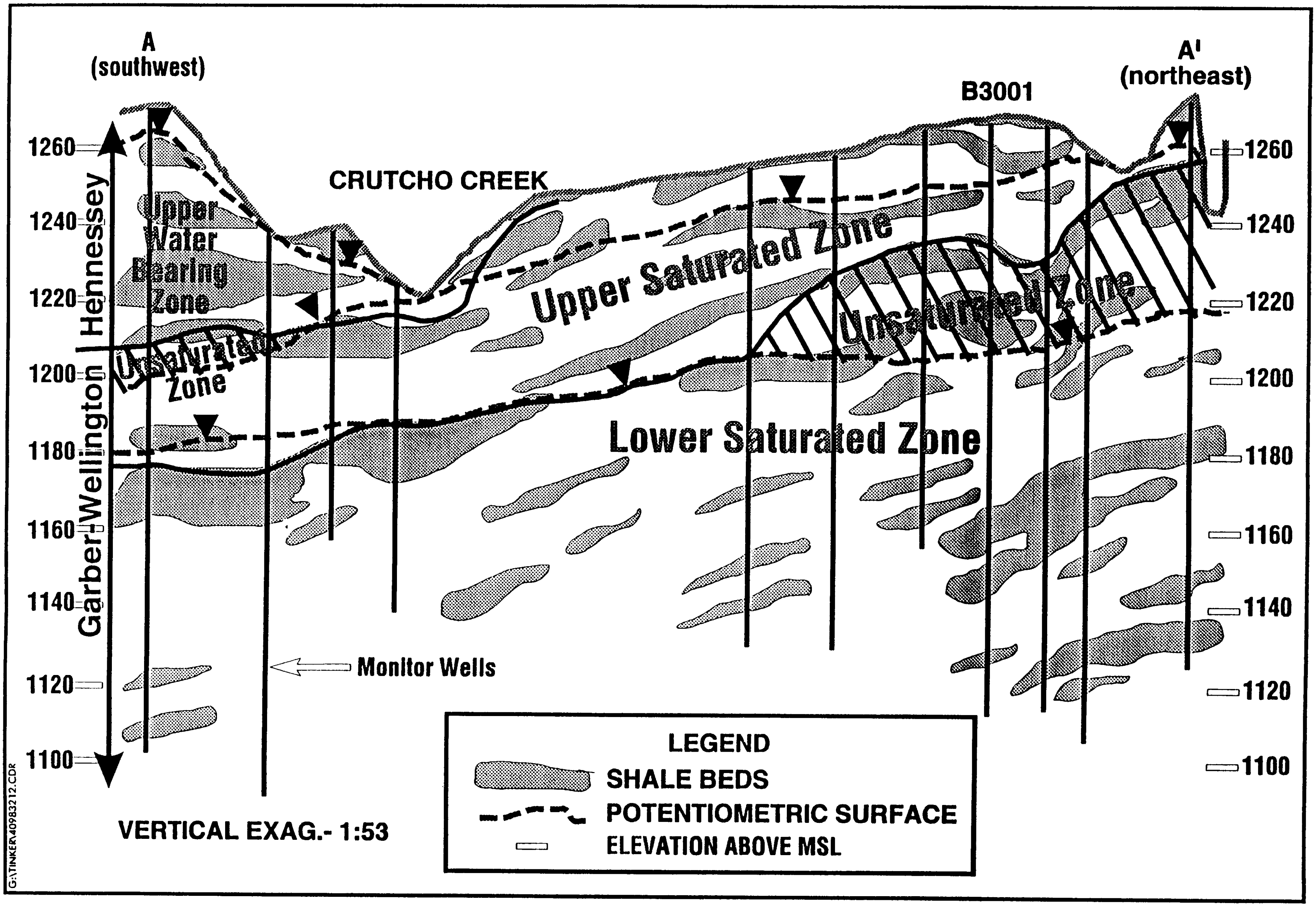


FIGURE 3-2 TINKER AFB GEOLOGIC CROSS SECTION A-A'

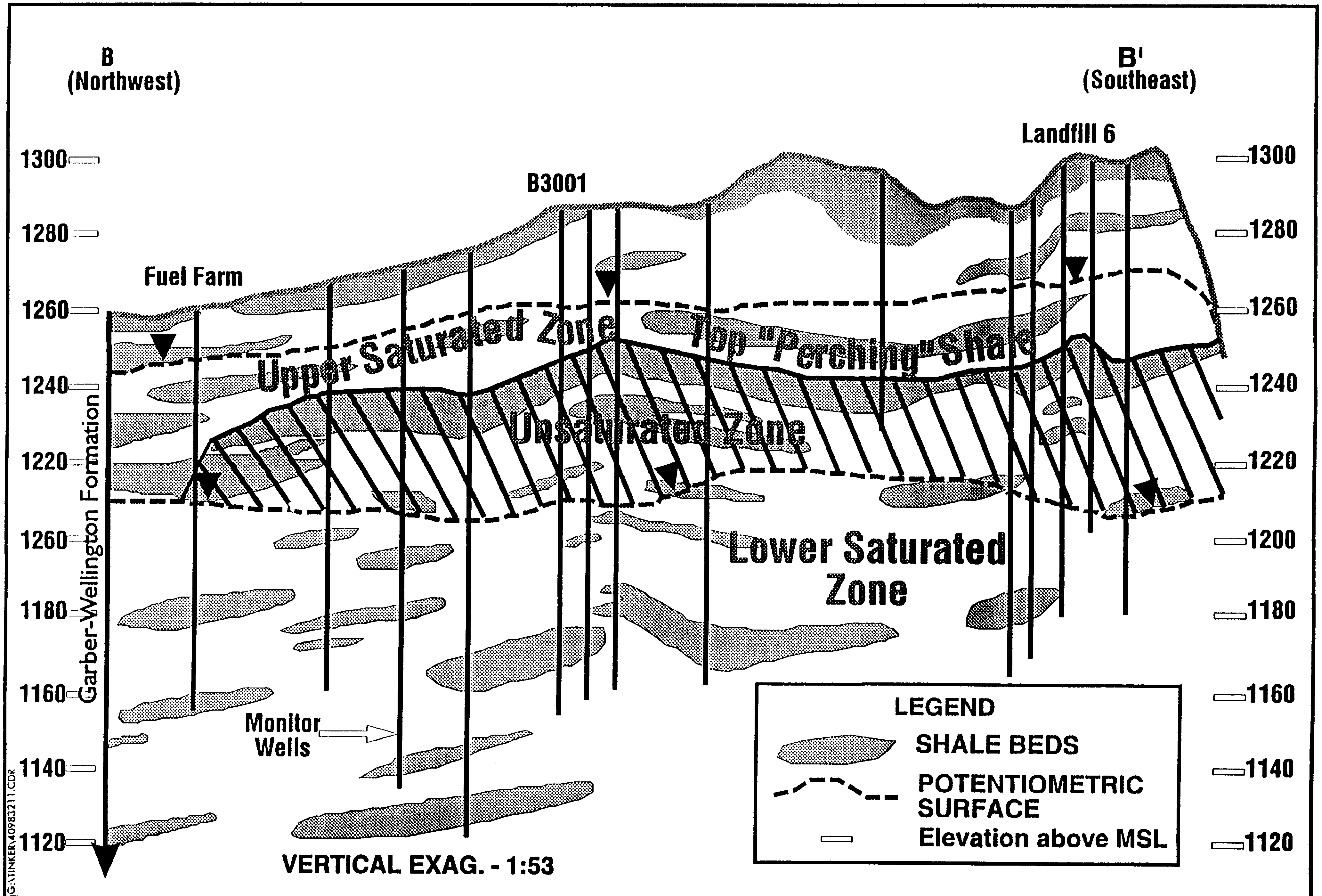


FIGURE 3-3 TINKER AFB GEOLOGIC CROSS SECTION B-B'

a generally westward direction is supported by stratigraphic correlation on geologic cross-sections at Tinker AFB. Bedrock units strike slightly west of north.

Although Tinker AFB lies in a tectonically stable area, regional dips are interrupted by buried structural features located west of the Base. A published east-to-west generalized geologic cross-section, which includes Tinker AFB, supports the existence of a northwest-trending structural trough or syncline located near the western margin of the base. The syncline is mapped adjacent to and just east of a faulted anticlinal structure located beneath the Oklahoma City Oil Field. The fault does not appear to offset Permian-age strata. There are indications that the syncline may act as a "sink" for some regional groundwater (southwest flow) at Tinker AFB before it continues to more distant discharge points.

3.2.2 Site Geology

Borings at FTA1 reveal that the overburden consists essentially of 5 to 8 feet of black to reddish-colored clay. The clay has low to medium plasticity with occasional pockets of organic material. Several borings indicated "black lenses with black nodules" which may be of organic origin. Beneath the shale is a highly-weathered red shale, about 6 feet in thickness, which in some borings has the appearance of a clay. Beneath the shale is a red sandstone, poorly cemented and approximately 20 feet thick. The clay and shale represent the lower part of the Hennessey Group (Fairmont Shale). The sandstone is the uppermost unit of the Garber Sandstone.

The deeper stratigraphy is characterized by alternating beds of shale and sandstone of variable thickness to a depth of greater than 70 feet, as seen in the boring logs from MW-61B and MW-85B. MW-85B is a monitoring well located approximately 200 feet east of MW-61B that is associated with the SP RI (USACE, 1991).

3.3 Hydrology

3.3.1 Regional/Tinker AFB Hydrology

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer system. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove, and Admire Groups. The Garber Sandstone and the Wellington Formation portion of the Central Oklahoma aquifer system is commonly referred to as the "Garber-Wellington aquifer" and is considered to be a single aquifer because these units were deposited under similar conditions and because many of the best producing wells are completed in this zone. On a regional scale, the aquifer is confined above by the less permeable Hennessey Group and below by the Late Pennsylvanian Vanoss Group.

Tinker AFB lies within the limits of the Garber-Wellington Groundwater Basin. Currently, Tinker derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest City and Del City derive water supplies from both surface sources and wells tapping the aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by a municipal distribution system also depend on the Garber-Wellington aquifer. Communities presently depending upon surface supplies (such as Oklahoma City) also maintain a well system drilled into the Garber-Wellington as a standby source of water in the event of drought.

Recharge of the Garber-Wellington aquifer is accomplished principally by percolation of surface waters crossing the area of outcrop and by rainfall infiltration in this same area. Because most of Tinker AFB is located in an aquifer outcrop area, the Base is considered to be situated in a recharge zone.

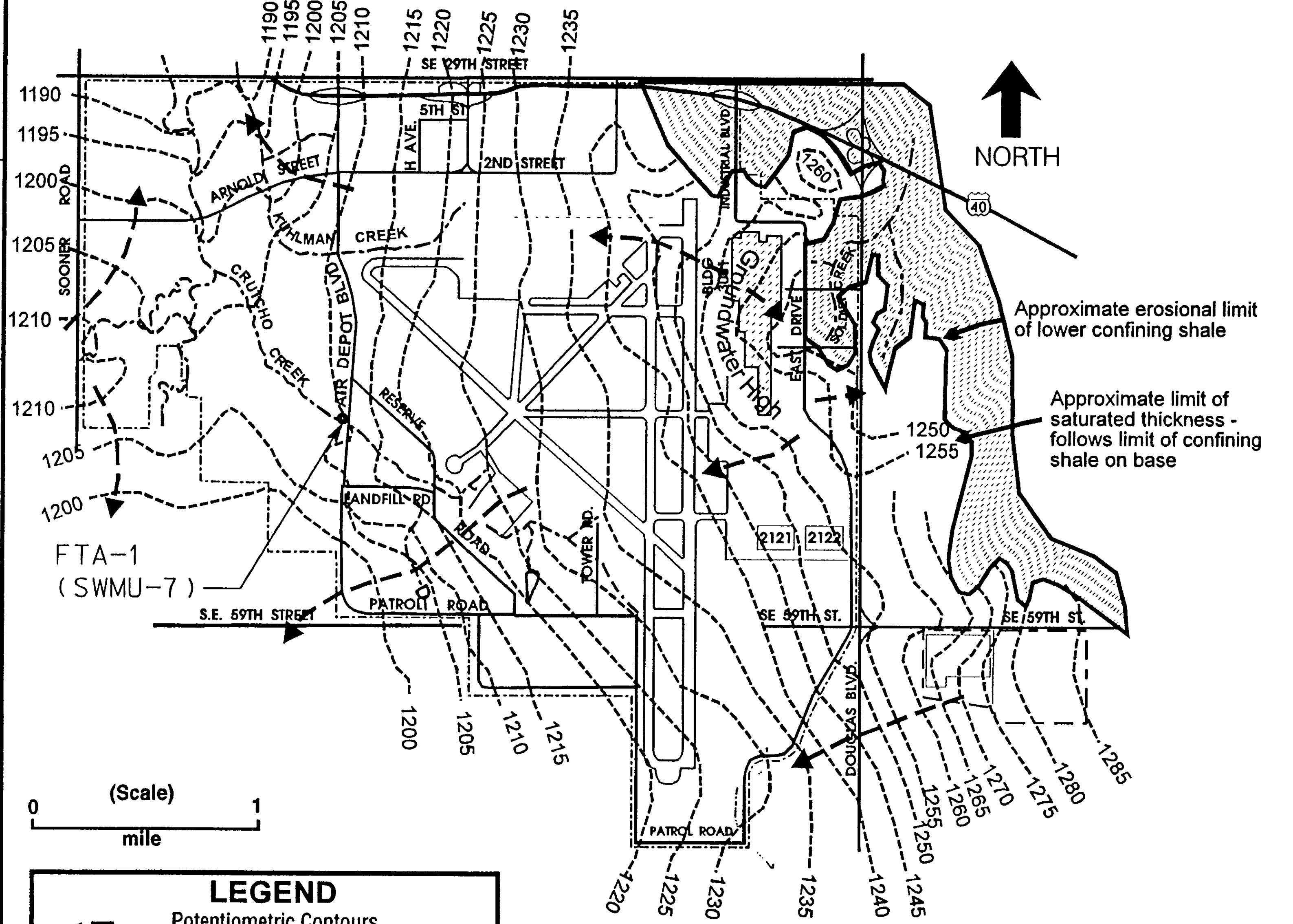
According to Wood and Burton (1968) and Wickersham (1979), the quality of groundwater derived from the Garber-Wellington aquifer is generally good, although wide variations in the concentrations of some constituents are known to occur. Wells drilled to excessive depths may encounter a saline zone, generally greater than 900 feet below ground surface. Wells drilled to such depths or those accidentally encountering the saline zone are either grouted over the lowest screens or may be abandoned.

Tinker AFB presently obtains its water supplies from a distribution system comprised of 29 water wells constructed along the east and west Base boundaries and by purchase from the Oklahoma City Water Department. All Base wells are finished into the Garber-Wellington aquifer. Base wells range from 700 to 900 feet in finished depth, with yields ranging from 205 to 250 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones with a combined thickness from 103 to 184 feet (Wickersham, 1979).

Although the variability in the geology and the recharge system at Tinker AFB makes it difficult to predict local flow paths, Central Oklahoma aquifer water table data show that regional groundwater flow under Tinker varies from west-northwest to southwest, depending on location. This theory is supported by contoured potentiometric data from base monitoring wells which show groundwater movement in the upper and lower aquifer zones to generally follow regional dip. Measured normal to potentiometric contours, groundwater flow gradients range from 0.0019 to 0.0057 ft/ft. However, because flow in the near-surface portions of the aquifer at Tinker AFB is strongly influenced by topography, local stream base-levels, complex subsurface geology, and location in a recharge area, both direction and magnitude of groundwater movement is highly variable. The interaction of these factors not only influences regional flow but gives rise to complicated local, often transient, flow patterns at individual sites.

As a result of ongoing environmental investigations and the approximately 450 groundwater monitoring wells installed on the Base during various investigations, a better understanding of the specific hydrological framework has emerged. The current conceptual model developed by Tinker AFB (Tinker, 1993), based on the increased understanding of the hydrological framework, has been revised from an earlier model adopted by the USACE. Previous studies reported that groundwater was divided into four water-bearing zones: the perched aquifer, the top of regional aquifer, the regional aquifer, and the producing zone. In the current model, two principal water table aquifer zones and a third less extensive zone have been identified. The third is limited to the southwest quadrant. The third aquifer zone consisted of saturated siltstone and thin sandstone beds in the Hennessey Shale and equates to the upper water bearing zone (UWBZ) described by the USACE (1993a) at Landfills No. 1 through 4 (SWMUs 3 through 6). In addition, numerous shallow, thin saturated beds of siltstone and sandstone exist throughout the Base. These are of limited areal extent and are often perched.

In the current conceptual hydrologic model, a USZ and an LSZ are recognized in the interval from ground surface to approximately 200 feet. Below this is found the producing zone from which the Base draws much of its water supply. Figure 3-4 shows the potentiometric surface for the USZ and Figure 3-5 shows the potentiometric surface for the LSZ. The USZ exists mainly under water table (unconfined) conditions, but may be partially confined locally. Conditions in the LSZ are difficult to determine due to screen placement and overly long sandpacks below the screen interval.



LEGEND

- Potentiometric Contours Elevation above MSL
- Approximate Direction of Groundwater Flow

Contours are extrapolated across center of base due to lack of data

FIGURE 3-4
TINKER AIR FORCE BASE
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C.WALLACE	DWG. NO.: 40983209C.
DRAWN BY: C.E.TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J.TAYLOR	PROJ. NO.: 409832

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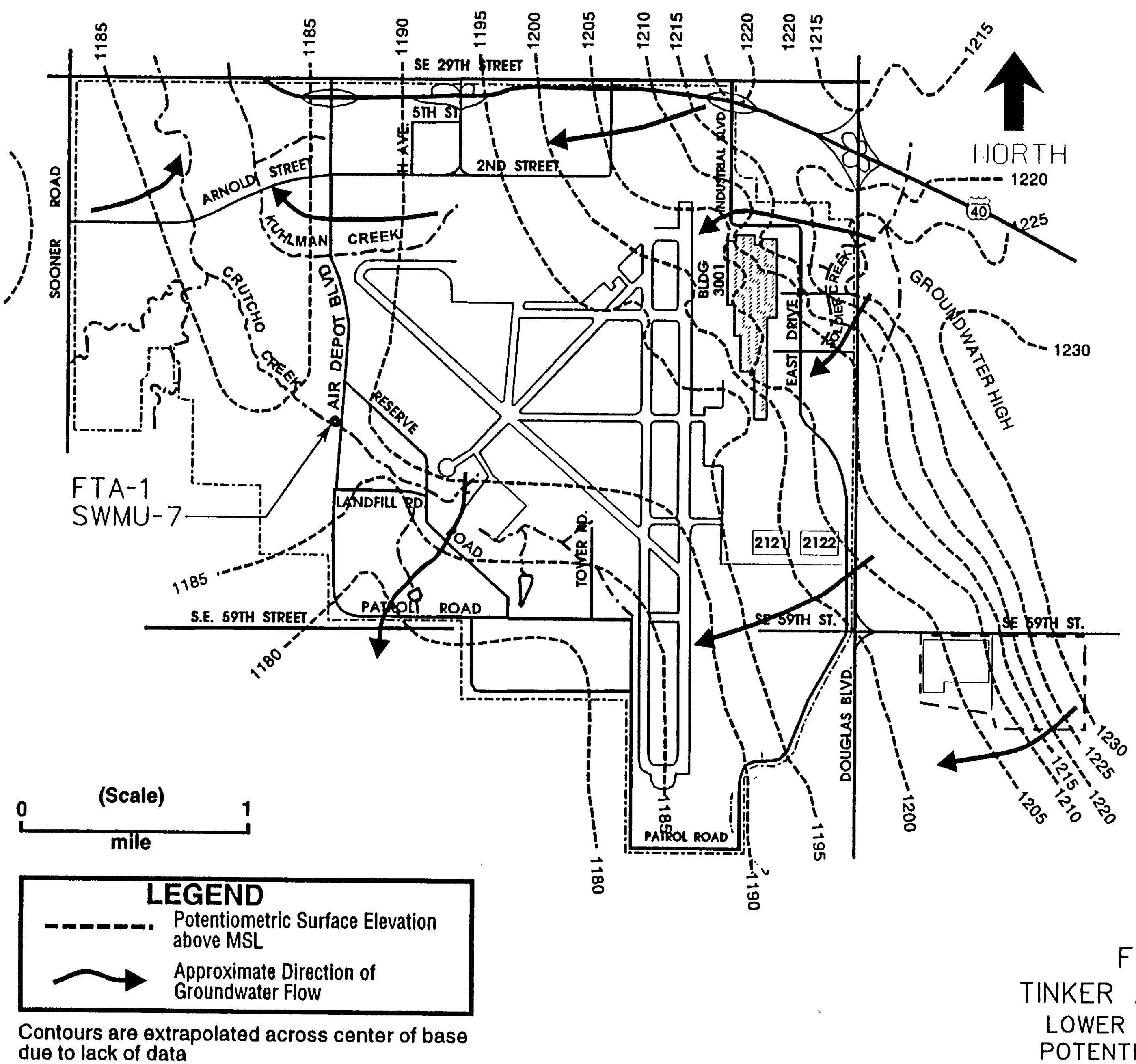

FIGURE 3-5
TINKER AIR FORCE BASE
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C. WALLACE	DWG. NO.: 409832O9C	
DRAWN BY: C.E.TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J. TAYLOR	PROJ. NO.: 409832	

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The USZ is found at a depth of 5 to 70 feet below ground surface and has a saturated thickness ranging from less than 1 foot at its eastern boundary to over 20 feet in places west of Building 3001. The USZ is erosionally truncated by Soldier Creek along the northeastern margin of Tinker AFB. This aquifer zone is considered to be a perched aquifer over the eastern one-third of Tinker AFB, where it is separated from the LSZ by an underlying confining shale layer and a vadose zone. The confining interval extends across the entire Base, but the vadose zone exists over the eastern one-third of this area. The available hydrogeologic data indicate that the vadose zone does not exist west of a north-south line located approximately 500 to 1,000 feet west of the main runway; consequently, the USZ is not perched west of this line. However, based on potentiometric head data from wells screened above and below the confining shale layer, the USZ remains a discrete aquifer zone distinct from the LSZ even over the western part of the Base. In areas where several shales interfinger to form the lower confining interval rather than a single shale bed, "gaps" may occur. In general, these "gaps" are not holes in the shale, but are places where multiple shales exist that are separated by slightly more permeable strata. Hydrologic data from monitoring wells indicate that these zones allow increased downward flow of groundwater above normal rates through the confining layer.

The LSZ is hydraulically interconnected and can be considered one aquifer zone down to approximately 200 feet. This area includes what was referred to by the USACE as the top of regional and regional zones. Hydrogeologic data from wells screened at different depths at the same location within this zone, however, provide evidence that locally a significant vertical (downward) component of groundwater flow exists in conjunction with lateral flow. The magnitude of the vertical component is highly variable over the Base. Preliminary evidence suggests that the LSZ is hydraulically discrete from the producing zone. Due to variations in topography, the top of the lower zone is found at depths ranging from 50 to 100 feet below ground surface under the eastern parts of the Base and as shallow as 30 feet to the west. Differences in potentiometric head values found at successive depths are due to a vertical (downward) component of groundwater flow in addition to lateral flow and the presence or absence of shale layers which locally confine the aquifer system. The LSZ extends east of the Base (east of Soldier Creek) beyond the limits of the USZ where it becomes the first groundwater zone encountered in off-Base wells. Because of the regional dip of bedding, groundwater gradient, and topography, the LSZ just east of the Base is generally encountered at depths less than 20 feet.

3.3.2 Site Hydrology

The groundwater at FTA1 that is encountered at 6 to 8 feet in the clay/shale of the Hennessey appears to be hydraulically connected to the groundwater found in the shallow sandstone unit beginning approximately 15 feet below ground surface. This aquifer zone is the USZ, which is considered to be the top of the Garber-Wellington aquifer.

The USZ groundwater gradient slopes to the southwest toward Crutcho Creek (Figure 3-6) with an average gradient of 0.0075 ft/ft. The USZ is mounded to the east underneath the SP (due to fill material at the pond) and flows toward the southern edge of FTA1 from that site. Current data, however, indicates the pond has been "cemented," in that the mound is disappearing. USZ elevations at the FTA1 site were measured in June 1989, July through September 1989, December 1989, and January 1990.

From groundwater contours of the USZ, it was determined that the USZ groundwater at FTA1 is flowing in a southwesterly direction with a hydraulic gradient of 0.0075 ft/ft. The average hydraulic conductivity of the USZ water-bearing zone materials at FTA1 is 3.64×10^{-5} centimeter per second (cm/s) (37.7 feet per year), which results in a groundwater velocity (Darcy's Law) of 1.23 feet per year (USACE, 1992). This value is based on an assumed effective porosity (n^e) of 0.23. The hydraulic conductivity is an average value from slug tests performed on four monitoring wells screened in the USZ.

There is apparently sufficient vertical permeability due to weathering to allow the USZ groundwater to communicate upwards into what would normally appear to be a confining layer. This movement is also aided by the presence of Crutcho Creek.

The LSZ is approximately 30 feet deep and groundwater flow in this zone in the vicinity of FTA1 and the SP is complicated by a local high that exists at monitoring well (MW)-1B (USACE, 1991). Further investigations are required to define the flow direction and contamination that exists in this aquifer. Available data indicate that groundwater flow in the LSZ at this site is to the southeast (Figure 3-7). However, the general flow direction in the LSZ across most of Tinker AFB is the the southwest (Figure 3-5).

3.4 Soils

Three major soil types have been mapped in the Tinker AFB area and are described in Table 3-2 (U.S. Department of Agriculture [USDA], 1969). The three soil types, the Darrell-Stephenville, Renfrow-Vernon-Bethany, and Dale-Canadian-Port, consist of sandy to fine

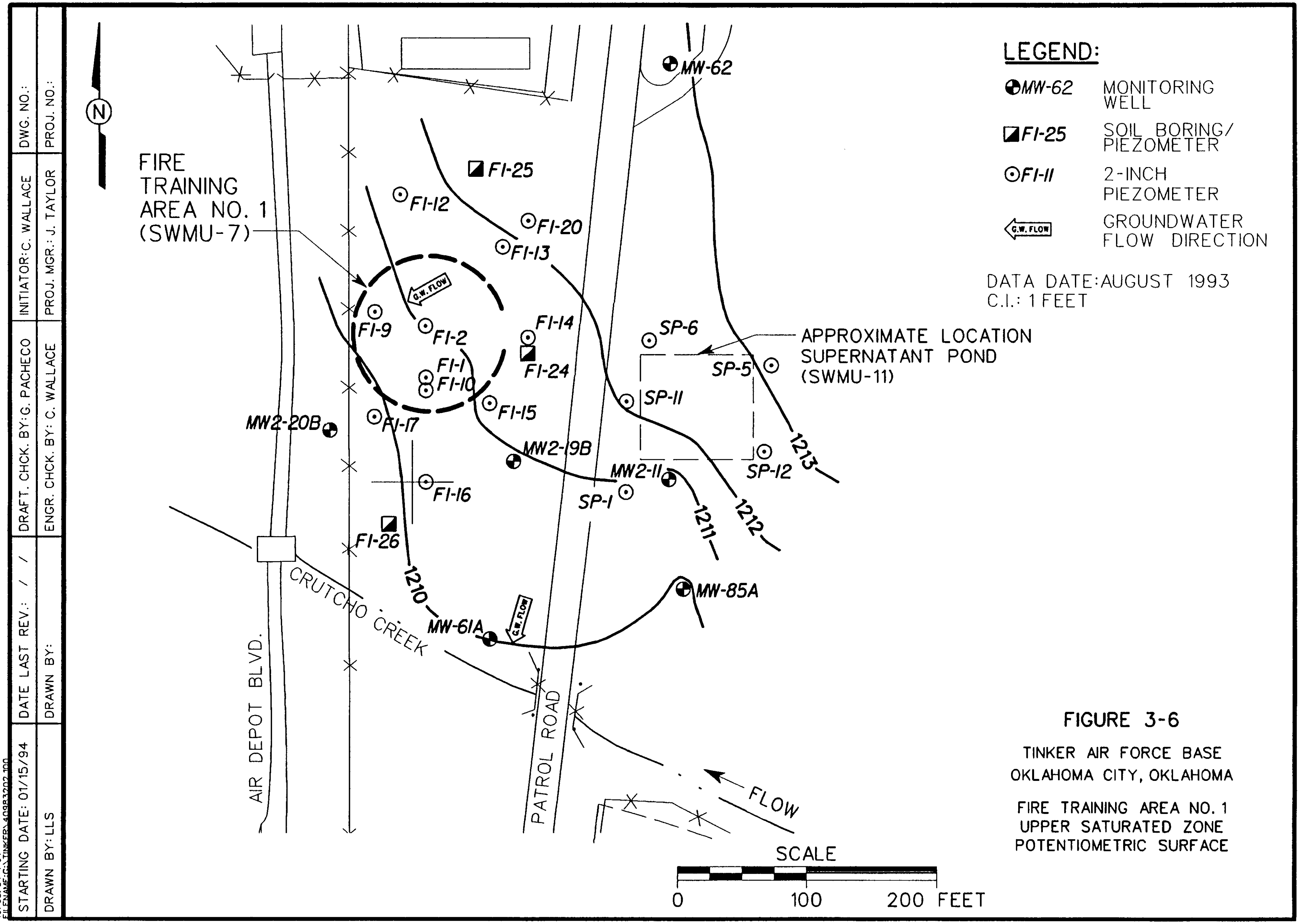

FIGURE 3-6

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

FIRE TRAINING AREA NO. 1
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE

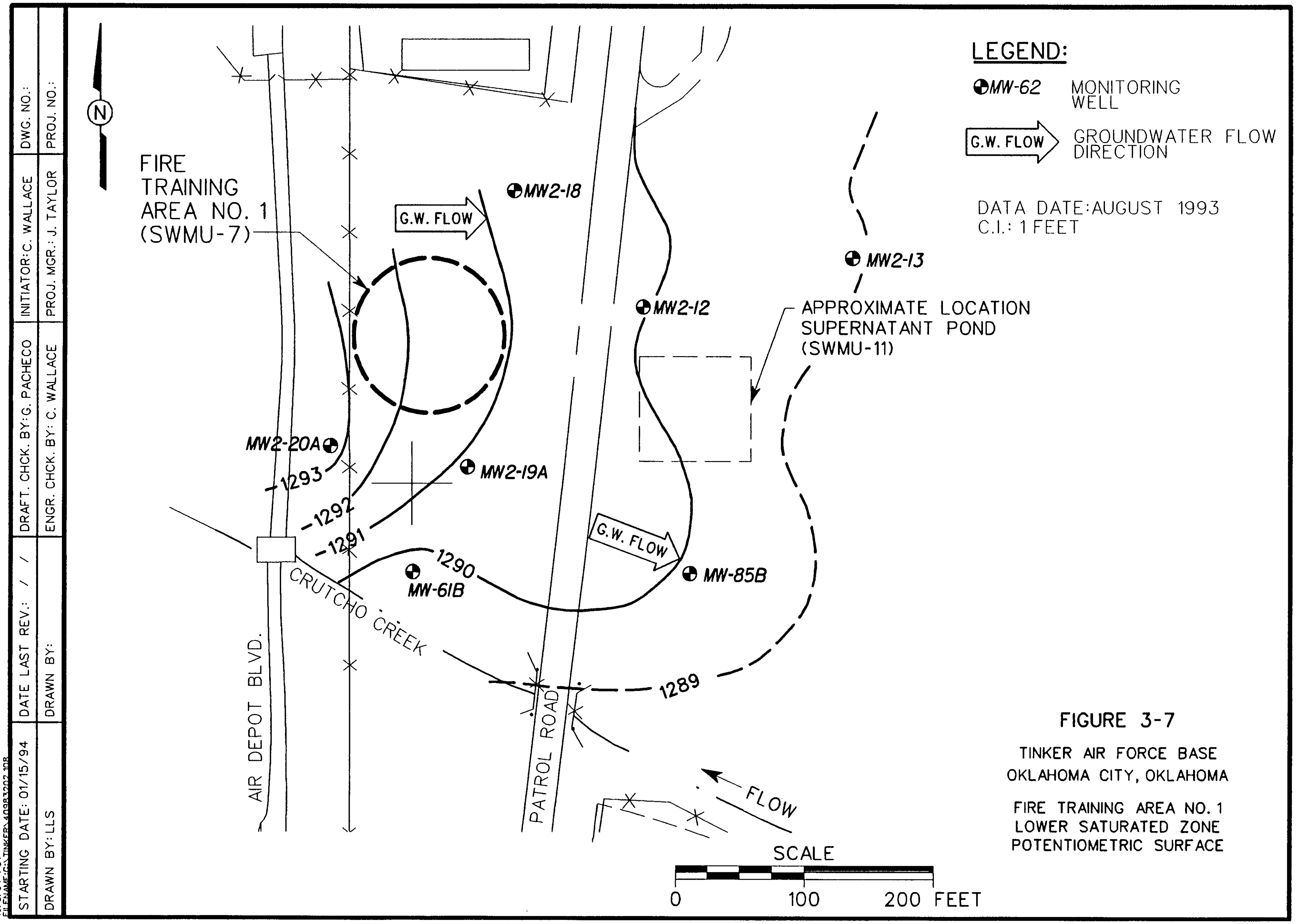

FIGURE 3-7

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

FIRE TRAINING AREA NO. 1
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE

Table 3-2

Tinker AFB Soil Associations (Source: USDA, 1969)

Association	Description	Thickness (in.)	Unified Classification[a]	Permeability (in./hr)
Darrell-Stephenville: loamy soils of wooded uplands	Sandy loam Sandy clay loam Soft sandstone (Garber Sandstone)	12-54	SM,ML,SC	2.0-6.30
Renfrow-Vernon-Bethany: loamy and clayey soils on prairie uplands	Silt loam - clay Clay loam Shale (Fairmont Shale)	12-60	ML,CL,MH,CH	<0.60-0.20
Dale-Canadian-Port: loamy soil on low benches near large streams	Fine sandy loam Silty clay loam Loam Clay loam	12-60	SM,ML,CL	0.05-6.30

[a]Unified classifications defined in U.S. Bureau of Reclamation, 5005-86.

sandy loam, silt loam, and clay loam, respectively. The Darrell-Stephenville and the Renfrow-Vernon-Bethany are primarily residual soils derived from the underlying shales of the Hennessey Group. The Dale-Canadian-Port association is predominantly a stream-deposited alluvial soil restricted to stream floodplains. The thickness of the soils ranges from 12 to 60 inches. FTA1 lies entirely within the Renfrow-Vernon-Bethany soil association.

4.0 Source Characterization

FTA1 is located on the west side of Tinker AFB. The active fire training/burning area was an unlined, diked circular-shaped area with a diameter of about 125 feet. The site was used between 1950 and 1962. Fire-fighting exercises consisted of dousing an old aircraft with flammable liquids, igniting a fire, and extinguishing the fire. Excess liquids were allowed to percolate into the soil.

Twenty-seven soil borings were drilled at the site during the course of the USACE investigations to a maximum depth of 28 feet below land surface. Two monitoring wells were installed in the USZ upgradient and downgradient of the site. Soil samples were collected from the borings for analysis. Groundwater samples were collected for analysis from the monitoring wells and piezometers were installed in soil boreholes.

The sampling results indicated that some contamination has occurred at this site. Soil contamination was found to be greatest in the upper 15 feet at the site. The primary organic compound detected in soil samples was bis(2-ethylhexyl)phthalate. This compound was reported to be present in samples from borings within the training area and in samples from borings located as far as 100 feet outside the designated training area. This compound is a commonly-used plasticizer and also a common laboratory contaminant artifact. At such elevated concentrations, the compound's presence was postulated in the report to be the result of burning aircraft.

Groundwater contamination in the USZ consisted of generally low concentrations of VOCs. The contaminant most frequently encountered and at the greatest concentrations was 1,2-dichloroethylene (DCE).

The nature and extent of soil and groundwater contamination is discussed in detail in Chapter 5.0, Contaminant Characterization.

5.0 Contaminant Characterization

5.1 Constituents of Potential Concern

Through several phases of investigation, selected soil and groundwater samples were analyzed for VOCs and SVOCs, pesticides, pH, and TOC. No pesticides were detected in any soil or groundwater samples tested.

Soils. A total of 24 on-site and 3 off-site borings were drilled during investigations of the FTA1 site. Soil samples taken from these borings have been used to characterize the contamination that exists at the FTA1 site. Soil samples were analyzed for metals, TOC, VOCs, SVOCs, pesticides, pH, and conductivity. Fifteen SVOCs, ten VOCs, metals, and TOC were detected with varying concentrations throughout FTA1.

Background for VOCs and SVOCs were obtained in investigations of FTA1. In June 1989, soils were obtained from three off-site borings drilled south of the FTA1 to obtain VOC and SVOC background concentrations. VOC and SVOC background values are given in Table 5-1. Sample locations are shown in Figure 1-3.

Background soil concentrations for trace metals were determined based on a study performed by the USGS (1991). The study area was confined to approximately four counties in central Oklahoma. Tinker AFB lies at the approximate center of this area. A total of 293 B-horizon soil samples were collected throughout this area. Soil samples were collected at the top of the B-horizon, which was usually 20 to 30 centimeters below the surface but ranged from 3 to 50 centimeters below the surface. For site-specific analytes for which the USGS offered no background value, the analyte was compared to an applicable action level. The background concentrations are presented in Table 5-2.

The use of B-horizon soil as selected by the USGS for metals background concentrations in soil is conservative in that the soil sampled does not reflect all possible anthropogenic influences. Most of the samples were obtained from hill crests and well drained areas in pasture and forested land, well away from roadways to minimize contamination from vehicular emissions (i.e., nearly "pristine" areas). Trace metal inputs to the study site soils on Base, however, will come from anthropogenic sources outside of the study area, in addition to those sources related to disposal activities or operations within the confines of the study site. Therefore, responsibility may be taken for more trace metal impacts than are actually attributable to a given site.

Table 5-1

Background Volatiles and Semivolatiles - Soil
SWMU-7, FTA1, Tinker AFB

Boring Number	FB-1	FB-2	FB-3	FB-4 TB	FB-5 QC	Average
SWD Sample Number	9-773	9-774	9-775	9-776	9-777	
Date Sampled	6-22-89	6-22-89	6-22-89	6-22-89	6-22-89	
Volatile Organics (μg/kg)						
Methylene chloride	11	11	20	13	16	14
Acetone	12J	19	<12	<10	<12	12
Chloroform	2BJ	2BJ	2BJ	2BJ	2BJ	2
Toluene	0.4J	<6	2J	3J	2J	1.8
Semivolatile Organics						
None Detected						
Indicators						
pH	8.25	8.10	7.90	8.50	7.90	8.08
Total Organic Carbon (mg/kg)	9200	2900	7200	600	5100	3100

TB = Travel Blank
QC = Quality Control
Average = Average of FB-1, FB-2, and FB-3. If compound was less than detection limit, half of detection limit was used.
J = Compound present below laboratory detection limits; therefore, value used is an estimated value.
B = Compound also found in blank.

Table 5-2

Background Concentrations of Trace Metals in Surface Soils[a] SWMU-7, FTA1, Tinker AFB

(Page 1 of 2)

Analyte	Lower Detection Limit	Background Concentration Range	
		Minimum Value	Maximum Value
Concentration in %			
Aluminum	0.005	0.38	8.9
Cadmium	0.005	0.01	9.4
Iron	0.005	0.18	5.8
Magnesium	0.005	0.02	5.3
Phosphorous	0.005	0.06	0.019
Potassium	0.05	0.1	2.4
Sodium	0.005	0.02	0.99
Titanium	0.005	0.04	0.42
Concentrations in ppm			
Arsenic	0.1	0.6	21
Barium	1	47	6400
Beryllium	1	<1	3
Bismuth	10	<DL[b]	<DL
Cadmium	2	<DL	<DL
Cerium	4	14	110
Chromium	1	5	110
Cobalt	1	<1	27
Copper	1	<1	59
Europium	2	---[c]	---
Gallium	4	<4	23
Gold	8	<DL	<DL
Holmium	4	<DL	<DL
Lanthanum	2	7	51
Lead	4	<4	27
Lithium	2	5	100

Table 5-2

(Page 2 of 2)

Analyte	Lower Detection Limit	Background Concentration Range	
		Minimum Value	Maximum Value
Manganese	10	24	3400
Molybdenum	2	<DL	<DL
Neodymium	4	6	47
Nickel	2	<2	61
Niobium	4	<4	16
Scandium	2	<2	15
Selenium	0.1	<0.1	1.2
Silver	2	<DL	<DL
Strontium	2	13	300
Tantalum	40	<DL	<DL
Thorium	1	<1.40	15.00
Tin	10	<DL	<DL
Uranium	0.1	0.650	6.400
Vanadium	2	5	220
Ytterbium	1	<1	3
Yttrium	2	3	43
Zinc	2	3	79

[a]All B-horizon soil samples (293) from USGS, 1991.
[b]All concentrations below the lower limits of determination.
[c]Insufficient or no data.

An additional level of conservatism was added in the manner in which the site-specific metals concentrations were compared to the background levels. Typically, the environmental concentrations of trace metals at study sites are represented by the arithmetic upper 95th confidence interval on the mean of a normal distribution. This upper 95th confidence interval value is then compared to the background values. The intent of this typical approach is to estimate a Reasonable Maximum Exposure case (i.e., well above the average case) that is still within the range of possible exposures.

To expedite this comparison and establish greater conservatism, the maximum concentration found at the site of concern, rather than the upper 95th confidence interval value, was compared to the USGS background values. If the environmental concentration of a particular analyte was below or within the minimum-maximum range of the USGS background concentrations, that analyte was considered to be naturally occurring and of no further concern to this investigation. Given the conservative approach of the comparisons, site-specific metals concentrations would have to significantly exceed the USGS background levels and be attributable to operations at the site before they would be considered a contaminant of concern.

The numerical comparison of site-specific metals concentrations to the USGS background concentrations is presented in Section 5.2.

Groundwater. During the RIs between 1985 to 1990, the USZ at the FTA1 was monitored by two monitoring wells (MW-61A and MW-62) and 17 polyvinyl chloride (PVC) piezometers installed in borings F1-1 to F1-3, F1-9 to F1-17, F1-20, and F1-24 to F1-27. All wells in the vicinity of FTA1 were installed as upgradient and/or downgradient wells for FTA1, the SP, and Landfills 1 through 6. During the RIs, no perimeter wells were available for use as background wells in the immediate vicinity of FTA1. Therefore, the background concentrations listed in Table 5-3 are taken from the USACE groundwater assessment report for the Base (USACE, 1987). Background wells were chosen to be representative of groundwater quality unaffected by man-made contamination. They are not necessarily upgradient. Analyses of groundwater included metals, VOCs, SVOCs, pH, TOC, and conductivity. Borings and well locations are shown in Figure 1-3.

Additional sampling of the USZ and LSZ was conducted in 1992 and 1993 from wells MW-61A (USZ), MW61-B (LSZ), and MW-62 (USZ). Additional wells were installed in 1993 in

Table 5-3

Background Concentrations
USZ and LSZ Groundwater
SWMU-7, FTA1, Tinker AFB

Compound	USZ	LSZ
Metals (µg/L)		
Arsenic	10	2
Barium	1,110	663
Cadmium	10	7.5
Chromium	46	10
Lead	57	48
Mercury	0.4	0.4
Selenium	2.1	0.5
Silver	10	10
Nickel	101	33
Zinc	110	120
Indicators		
pH (S.U.)	7.10	9.80
TOC (mg/L)	3.9	5.3
Conductivity (µmhos/cm)	684	718

Source: U.S. Army Corps of Engineers, Tulsa District, "Tinker Air Force Base, Oklahoma City, Oklahoma, Groundwater Assessment" September 1987.

both the USZ and LSZ, but sampling data are not available (see Section 2.2 for identification of these wells).

5.2 Soil Characterization

A total of 93 soil samples were taken from the 24 on-site borings. Ten of the 93 soil samples were only tested for SVOCs. These 10 samples were taken from borings F1-7 and F1-8. Thirty-eight of the 93 samples were tested only for pH, TOC, and conductivity. These 38 samples were taken from borings F1-9 to F1-20. The remaining 45 samples were tested for VOCs and SVOCs, pH, TOC, and conductivity. Only 10 of the 93 samples were tested for metals. These 10 samples were taken from borings F1-1, F1-2, and F1-3. Table 5-4 contains the concentrations of individual compounds from the soil sample analyses. Table 5-5 presents a summary of the detection frequencies, concentration ranges, and locations of maximum concentrations for the contaminants detected in the soil.

Ten VOCs were detected in the soil samples taken from FTA1. Five of these compounds (trans-1,2-dichloroethene, 1,1,1-trichloroethane, trichloroethene, 2-hexanone, and ethyl benzene) were detected in only 1 of the 45 samples analyzed for VOCs. Xylenes were detected in three of the samples and toluene was detected in five of the samples. The maximum concentration detected for both of these compounds was 6 micrograms per kilogram (µg/kg). All of the toluene and xylene detections were in the August 1989 sampling from borings F1-24, F1-26, and F1-27, which are located beyond the limits of contamination defined by the TOC analysis of borings F1-9 to F1-20. Chloroform was detected in 11 of the 45 samples at concentrations ranging from 2 to 5 µg/kg. All these detections were in the August 1989 samples taken from borings F1-24 to F1-27. Chloroform was not detected in any other soil samples, but was detected in the blanks; it is, therefore, probably a laboratory contaminant or a contaminant introduced during sampling. Acetone was detected in 30 samples at concentrations ranging from 21 to 610 µg/kg. The concentrations were above the background average of 12 µg/kg in 23 of the samples. Methylene chloride was the most frequently detected VOC. It was found in 43 of the 45 samples analyzed at concentrations ranging from 4 to 130 µg/kg. The concentrations of methylene chloride detected were at or above the background average of 14 µg/kg in 25 of the samples.

Fifteen SVOCs were detected in the soil samples taken from FTA1. Twelve of these compounds (n-nitrosodiphenylamine, anthracene, benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[a]pyrene, indeno[1,2,3-cd]pyrene, benzo[g,h,i]perylene, and butyl benzyl phthalate) were detected in only 1 of the 55 samples analyzed for SVOCs. Two SVOCs

Table 5-4

Summary of Detected Contaminants - Soil (USACE, 1992) SWMU-7, FTA1, Tinker AFB

(Page 1 of 16)

Boring Number	F1-1A	F1-1C	F1-1E	F1-2A	F1-2C	F1-2E	LLSBLK
SWD Sample Number	7-211	7-214	7-216	7-218	7-220	7-222	
Date Sampled	02-26-87	02-26-87	02-26-87	02-26-87	02-26-87	02-26-87	02-26-87
Depth	0-1'	4-7'	10-13'	0-1'	4-7'	10-13'	
Volatile Organics (µg/kg)							
Methylene chloride	19	16	16	11	14	20	<5
Acetone	<12	<12	<12	<13	<12	18	<10
Trans-1,2-dichloroethene	<6	<6	<6	<7	<6	<6	<5
Chloroform	<6	<6	<6	<7	<6	<6	<5
1,1,1-Trichloroethane	<6	<6	<6	<7	<6	<6	<5
Trichloroethene	<6	<6	<6	<7	<6	<6	<5
2-Hexanone	<12	<12	<12	<13	<12	<12	<10
Toluene	<6	<6	<6	<7	<6	<6	<5
Ethyl benzene	<6	<6	<6	<7	<6	<6	<5
Xylenes	<6	<6	<6	<7	<6	<6	<5
Metals (mg/kg)							
Silver	<0.5	<0.5	<0.5	1.6	2.7	<0.5	NT
Arsenic	1.3	<1.0	<1.0	<1.0	<1.0	1.9	NT
Barium	250	260	750	310	180	560	NT
Cadmium	0.88	0.5	1.1	17	0.89	0.53	NT
Chromium	11	9.9	7.5	36	8.3	5.9	NT
Mercury	0.14	<0.1	0.16	<0.1	<0.1	<0.1	NT
Nickel	8.6	11	11	20	8.3	11	NT
Lead	18	8.9	16	170	12	15	NT
Selenium	<0.1	<0.1	<0.1	<0.1	0.21	0.16	NT
Zinc	16	10	10	160	8.9	11	NT
Semivolatile Organics (µg/kg)							
n-Nitrosodipropylamine	<410	310 J	<400	<8100	<400	<410	<330
Fluoranthenebenzene	<410	<400	<400	<8100	<400	<410	<330
Pyrene	<410	<400	<400	<8100	<400	<410	<330

Table 5-4

Boring Number	F1-1A	F1-1C	F1-1E	F1-2A	F1-2C	F1-2E	LLSBLK
SWD Sample Number	7-211	7-214	7-216	7-218	7-220	7-222	
Date Sampled	02-26-87	02-26-87	02-26-87	02-26-87	02-26-87	02-26-87	02-26-87
Depth	0-1'	4-7'	10-13'	0-1'	4-7'	10-13'	
Semivolatile Organics (µg/kg) (Continued)							
Diethyl phthalate	<410	31 J	<400	<8100	<400	<410	<330
n-Nitrosodiphenylamine	<410	160 J	<400	<8100	<400	<410	<330
Phenanthrene	<410	10 J	<4001	<8100	<400	<410	<330
Anthracene	<410	9 J	<400	<8100	<400	<410	<330
Benzo(a)anthracene	<410	<400	<400	<8100	<400	<410	<330
Chrysene	<410	<400	<400	<8100	<400	<410	<330
Bis(2-ethylhexyl)phthalate	1900	610	410	<8100	1100	360 J	<330
Benzo(b)fluoranthene	<410	<400	<400	<8100	<400	<410	<330
Benzo(a)pyrene	<410	<400	<400	<8100	<400	<410	<330
Indeno(1,2,3-cd)pyrene	<410	<400	<400	<8100	<400	<410	<330
Benzo(g,h,i)perylene	<410	<400	<400	<8100	<400	<410	<330
Butyl benzyl phthalate	<410	<400	<400	<8100	<400	<410	<330
Indicators							
pH (S.U.)	7.28	6.54	7.37	7.36	6.88	7.73	NT
TOC (mg/kg)	2800	2500	500	26000	3800	1300	NT
Conductivity (µmhos/cm)	580	1100	570	240	390	530	NT

LLSBLK = Laboratory Soil Test
NT = Compound Not Tested For
J = Estimated Concentration

Table 5-4

(Page 3 of 16)

Boring Number	F1-3A	F1-3C	F1-3D	F1-3E	LLSBLK
SWD Sample Number	7-227	7-2280	7-229	7-230	
Date Sampled	03-09-87	03-09-87	03-09-87	03-09-87	03-09-87
Depth	0-1'	4-7'	10-13'	9-10'	
Volatile Organics (µg/kg)					
Methylene chloride	21	29	28	130	5 J
Acetone	13	28	10 J	<62	<10
Trans-1,2-dichloroethene	<6	<6	<6	<31	<5
Chloroform	<6	<6	<6	<31	<5
1,1,1-Trichloroethane	<6	<6	<6	<31	<5
Trichloroethene	<6	<6	<6	<31	<5
2-Hexanone	<12	<12	<12	<62	<10
Toluene	<6	<6	<6	<31	<5
Ethyl benzene	<6	<6	<6	<31	<5
Xylenes	<6	<6	<6	<31	<5
Metals (mg/kg)					
Silver	0.54	0.78	<0.5	<0.5	NT
Arsenic	<1.0	<1.0	1.6	1.2	NT
Barium	900	190	280	420	NT
Cadmium	1.4	0.52	0.59	0.54	NT
Chromium	7.3	8.8	8.9	8.9	NT
Mercury	<0.1	<0.1	<0.1	<0.1	NT
Nickel	7.9	7.3	9.5	9.7	NT
Lead	74	9.1	11	12	NT
Selenium	0.17	0.16	0.16	0.15	NT
Zinc	14	7.5	10	8.3	NT
Semivolatile Organics (µg/kg)					
n-Nitrosodipropylamine	<1600	<410	<410	<420	<400
Fluoranthenebenzene	<1600	<410	<410	<420	<400
Pyrene	<1600	<410	<410	<420	<400
Diethyl phthalate	<1600	<410	<410	<420	<400
n-Nitrosodiphenylamine	<1600	<410	<410	<420	<400
Phenanthrene	<1600	<410	<410	<420	<400

Table 5-4

(Page 4 of 16)

Boring Number	F1-3A	F1-3C	F1-3D	F1-3E	LLSBLK
SWD Sample Number	7-227	7-2280	7-229	7-230	
Date Sampled	03-09-87	03-09-87	03-09-87	03-09-87	03-09-87
Depth	0-1'	4-7'	10-13'	9-10'	
Semivolatile Organics (µg/kg) (Continued)					
Anthracene	<1600	<410	<410	<420	<400
Benzo(a)anthracene	<1600	<410	<410	<420	<400
Chrysene	<1600	<410	<410	<420	<400
Bis(2-ethylhexyl)phthalate	5200	5900	170 J	<420	1100
Benzo(b)fluoranthene	<1600	<400	<400	<420	<400
Benzo(a)pyrene	<1600	<400	<400	<420	<400
Indeno(1,2,3-cd)pyrene	<1600	<400	<400	<420	<400
Benzo(g,h,i)perylene	<1600	<400	<400	<420	<400
Butyl benzyl phthalate	<1600	<400	<400	<420	<400
Indicators					
pH (S.U.)	7.22	6.94	7.02	7.51	NT
TOC (mg/kg)	12000	4200	2700	1500	NT
Conductivity (µmhos/cm)	530	400	400	400	NT

J = Estimated Concentration
B = Analyte Found in Blank
NT = Compound Not Tested For

Table 5-4

Boring Number	F1-4	F1-4	F1-4	F1-4	F1-4
SWD Sample Number	7-374	7-375	7-376	7-377	7-378
Date Sampled	06-26-87	06-26-87	06-26-87	06-26-87	06-26-87
Depth	0-1'	1-4'	4-7'	7-10'	10-13'
Volatile Organics (µg/kg)					
Methylene chloride	7	5 J	9	5 J	15
Acetone	<12	11 J	35	12 J	190
Trans-1,2-dichloroethene	<6	<6	<6	<6	<6
Chloroform	<6	<6	<6	<6	<6
1,1,1-Trichloroethane	<6	<6	<6	<6	<6
Trichloroethene	<6	<6	<6	<6	<6
2-Hexanone	<12	7 J	<12	<12	<12
Toluene	<6	<6	<6	<6	<6
Ethyl benzene	<6	<6	<6	<6	<6
Xylenes	<6	<6	<6	<6	<6
Semovolatile Organics (µg/kg)					
n-Nitrosodipropylamine	<410	<410	<400	<400	<420
Fluoranthenebenzene	<410	<410	<400	<400	<420
Pyrene	<410	<410	<400	<400	<420
Diethyl phthalate	<410	<410	<400	<400	<420
n-Nitrosodiphenylamine	<410	<410	<400	<400	<420
Phenanthrene	<410	<410	<400	<400	<420
Anthracene	<410	<410	<400	<400	<420
Benzo(a)anthracene	<410	<410	<400	<400	<420
Chrysene	<410	<410	<400	<400	<420
Bis(2-ethylhxyl)phthalate	770	1700	2300	7300	250 J
Benzo(b)fluoranthene	<410	<410	<400	<400	<420
Benzo(a)pyrene	<410	<410	<400	<400	<420
Indeno(1,2,3-cd)pyrene	<410	<410	<400	<400	<420
Benzo(g,h,i)perylene	<410	<410	<400	<400	<420
Butyl benzyl phthalate	<410	<410	<400	<400	<420

LLSBLKB = Laboratory Soil Test
J = Compound Present Below Laboratory Detection Limits

Table 5-4

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Boring Number	F1-4	F1-4	F1-4	LLSBLK
SWD Sample Number	7-379	7-380	7-381	
Date Sampled	06-26-87	06-26-87	06-26-87	06-26-87
Depth	13-16'	16-22'	21.5-26.7'	
Volatile Organics (µg/kg)				
Methylene chloride	12	13	5 J	3 J
Acetone	46	94	<11	<10
Trans-1,2-dichloroethene	<6	<6	<6	<5
Chloroform	<6	<6	<6	<5
1,1,1-Trichloroethane	<6	<6	<6	<5
Trichloroethene	<6	<6	<6	<5
2-Hexanone	<12	<13	<11	<10
Toluene	<6	<6	<6	<5
Ethyl benzene	<6	<6	<6	<5
Xylenes	<6	<6	<6	<5
Semivolatile Organics (µg/kg)				
n-Nitrosodipropylamine	<400	<420	<380	<330
Fluoranthenebenzene	<400	<420	<380	<330
Pyrene	<400	<420	<380	<330
Diethyl phthalate	<400	<420	<380	<330
n-Nitrosodiphenylamine	<400	<420	<380	<330
Phenanthrene	<400	<420	<380	<330
Anthracene	<400	<420	<380	<330
Benzo(a)anthracene	<400	<420	<380	<330
Chrysene	<400	<420	<380	<330
Bis(2-ethylhexyl)phthalate	<400	560	230 J	<330
Benzo(b)fluoranthene	<400	<420	<380	<330
Benzo(a)pyrene	<400	<420	<380	<330
Indeno(1,2,3-cd)pyrene	<400	<420	<380	<330
Benzo(g,h,i)perylene	<400	<420	<380	<330
Butyl benzyl phthalate	<400	<420	<380	<330

J = Compound Present Below Laboratory Detection Limits

Table 5-4

Boring Number	F1-5	F1-5	F1-5	F1-5
SWD Sample Number	7-389	7-390	7-391	7-392
Date Sampled	06-30-87	06-30-87	06-30-87	06-30-87
Depth	0-1'	1-4'	4-7'	7-10'
Volatile Organics (µg/kg)				
Methylene chloride	7	11	5 J	7
Acetone	<12	18	<12	<13
Trans-1,2-dichloroethene	<6	<6	<6	<6
Chloroform	<6	<6	<6	<6
1,1,1-Trichloroethane	<6	<6	<6	3 J
Trichloroethene	<6	<6	<6	3 J
2-Hexanone	<12	<13	<12	<13
Toluene	<6	<6	<6	<6
Ethyl benzene	<6	<6	<6	<6
Xylenes	<6	<6	<6	<6
Semivolatile Organics (µg/kg)				
n-Nitrosodipropylamine	<400	<420	<410	<420
Fluoranthenebenzene	<400	<420	<410	<420
Pyrene	<400	<420	<410	<420
Diethyl phthalate	<400	<420	<410	<420
n-Nitrosodiphenylamine	<400	<420	<410	<420
Phenanthrene	<400	<420	<410	<420
Anthracene	<400	<420	<410	<420
Benzo(a)anthracene	<400	<420	<410	<420
Chrysene	<400	<420	<410	<420
Bis(2-ethylhexyl)phthalate	300 J	650	1800	250 J
Benzo(b)fluoranthene	<400	<420	<410	<420
Benzo(a)pyrene	<400	<420	<410	<420
Indeno(1,2,3-cd)pyrene	<400	<420	<410	<420
Benzo(g,h,i)perylene	<400	<420	<410	<420
Butyl benzyl phthalate	<400	<420	<410	<420

J = Compound Present Below Laboratory Detection Limits

Table 5-4

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Boring Number	F1-5	F1-5	F1-5	F1-5
SWD Sample Number	7-393	7-394	7-395	7-396
Date Sampled	06-30-87	06-30-87	06-30-87	06-30-87
Depth	10-13'	13-16'	16-22'	22-28'
Volatile Organics (µg/kg)				
Methylene chloride	8	23	4 J	<6
Acetone	<12	7 J	<12	3 J
Trans-1,2-dichloroethene	<6	<6	<6	<6
Chloroform	<6	<6	<6	<6
1,1,1-Trichloroethane	<6	<6	<6	<6
Trichloroethene	<6	<6	<6	<6
2-Hexanone	<12	<12	<12	<11
Toluene	<6	<6	<6	<6
Ethyl benzene	<6	<6	<6	<6
Xylenes	<6	<6	<6	<6
Semivolatile Organics (µg/kg)				
n-Nitrosodipropylamine	<410	<410	<400	<370
Fluoranthenebenzene	<410	<410	<400	<370
Pyrene	<410	<410	<400	<370
Diethyl phthalate	<410	<410	<400	<370
n-Nitrosodiphenylamine	<410	<410	<400	<370
Phenanthrene	<410	<410	<400	<370
Anthracene	<410	<410	<400	<370
Benzo(a)anthracene	<410	<410	<400	<370
Chrysene	<410	<410	<400	<370
Bis(2-ethylhexyl)phthalate	120 J	1000	1100	1000
Benzo(b)fluoranthene	<410	<410	<400	<370
Benzo(a)pyrene	<410	<410	<400	<370
Indeno(1,2,3-cd)pyrene	<410	<410	<400	<370
Benzo(g,h,i)perylene	<410	<410	<400	<370
Butyl benzyl phthalate	<410	<410	<400	<370

J = Compound Present Below Laboratory Detection Limits

Table 5-4

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Boring Number	F1-6	F1-6	F1-6	F1-6
SWD Sample Number	7-397	7-398	7-399	7-400
Date Sampled	06-30-87	06-30-87	06-30-87	06-30-87
Depth	0-1'	1-4'	4-7'	7-10'
Volatile Organics (µg/kg)				
Methylene chloride	6	8	7	20
Acetone	<12	4 J	<13	3 J
Trans-1,2-dichloroethene	<6	<7	<7	<6
Chloroform	<6	<7	<7	<6
1,1,1-Trichloroethane	<6	<7	<7	<6
Trichloroethene	<6	<7	<7	<6
2-Hexanone	<12	<13	<13	<13
Toluene	<6	<7	<7	<6
Ethyl benzene	<6	<7	<7	<6
Xylenes	<6	<7	<7	<6
Semivolatile Organics (µg/kg)				
n-Nitrosodipropylamine	<400	<440	<440	<420
Fluoranthenebenzene	<400	390 J	<440	<420
Pyrene	<400	330 J	<440	<420
Diethyl phthalate	<400	<440	<440	<420
n-Nitrosodiphenylamine	<400	<440	<440	<420
Phenanthrene	<400	170 J	<440	<420
Anthracene	<400	<440	<440	<420
Benzo(a)anthracene	<400	290 J	<440	<420
Chrysene	<400	170 J	<440	<420
Bis(2-ethylhexyl)phthalate	850	1100	1200	1200
Benzo(b)fluoranthene	<400	250 J	<440	<420
Benzo(a)pyrene	<400	180 J	<440	<420
Indeno(1,2,3-cd)pyrene	<400	200 J	<440	<420
Benzo(g,h,i)perylene	<400	180 J	<440	<420
Butyl benzyl phthalate	<400	<440	<440	<420

J = Compound Present Below Laboratory Detection Limits

Table 5-4

(Page 10 of 16)

Boring Number	F1-6	F1-6	F1-6	F1-6
SWD Sample Number	7-401	7-402	7-403	7-404
Date Sampled	06-30-87	06-30-87	06-30-87	06-30-87
Depth	10-13'	13-16'	16-22'	22-28'
Volatile Organics (µg/kg)				
Methylene chloride	17	91	20	18
Acetone	22	2 J	610	15
Trans-1,2-dichloroethene	<6	10	<6	<6
Chloroform	<6	<6	<6	<6
1,1,1-Trichloroethane	<6	<6	<6	<6
Trichloroethene	<6	<6	<6	<6
2-Hexanone	<12	<12	<12	<11
Toluene	<6	<6	<6	<6
Ethyl benzene	<6	<6	<6	<6
Xylenes	<6	<6	<6	<6
Semivolatile Organics (µg/kg)				
n-Nitrosodipropylamine	<410	<380	<390	<380
Fluoranthenebenzene	<410	<380	<390	<380
Pyrene	<410	<380	<390	<380
Diethyl phthalate	<410	<380	<390	<380
n-Nitrosodiphenylamine	<410	<380	<390	<380
Phenanthrene	<410	<380	<390	<380
Anthracene	<410	<380	<390	<380
Benzo(a)anthracene	<410	<380	<390	<380
Chrysene	<410	<380	<390	<380
Bis(2-ethylhexyl)phthalate	790	430	980	800
Benzo(b)fluoranthene	<410	<380	<390	<380
Benzo(a)pyrene	<410	<380	<390	<380
Indeno(1,2,3-cd)pyrene	<410	<380	<390	<380
Benzo(g,h,i)perylene	<410	<380	<390	<380
Butyl benzyl phthalate	<410	<380	<390	<380

J = Compound Present Below Laboratory Detection Limits

Table 5-4

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Boring Number	F1-7	F1-7	F1-7	F1-7	F1-7
SWD Sample Number	7-426	7-427	7-428	7-429	7-430
Date Sampled	07-09-87	07-09-87	07-09-87	07-09-87	07-09-87
Depth	0-1'	1-7'	7-13'	13-19'	19-25'
Semivolatile Organics (µg/kg)					
n-Nitrosodipropylamine	<410	<390	<400	<400	<400
Fluoranthenebenzene	<410	<390	<400	<400	<400
Pyrene	<410	<390	<400	<400	<400
Diethyl phthalate	<410	<390	<400	<400	<400
n-Nitrosodiphenylamine	<410	<390	<400	<400	<400
Phenanthrene	<410	<390	<400	<400	<400
Anthracene	<410	<390	<400	<400	<400
Benzo(a)anthracene	<410	<390	<400	<400	<400
Chrysene	<410	<390	<400	<400	<400
Bis(2-ethylhexyl)phthalate	2200	3600	440	280 J	1300
Benzo(b)fluoranthene	<410	<390	<400	<400	<400
Benzo(a)pyrene	<410	<390	<400	<400	<400
Indeno(1,2,3-cd)pyrene	<410	<390	<400	<400	<400
Benzo(g,h,i)perylene	<410	<390	<400	<400	<400
Butyl benzyl phthalate	<410	<390	<400	<400	<400

J = Compound Present Below Laboratory Detection Limits

Table 5-4

Boring Number	F1-8	F1-8	F1-8	F1-8	F1-8	LLSBLK
SWD Sample Number	7-431	7-432	7-433	7-434	7-435	
Date Sampled	07-19-87	07-19-87	07-09-87	07-09-87	07-09-87	07-09-87
Depth	0-1'	1-7'	7-13'	13-19'	19-25'	
Semivolatile Organics (µg/kg)						
n-Nitrosodipropylamine	<410	<400	<450	<420	<390	<330
Fluoranthenebenzene	<410	<400	<450	<420	<390	<330
Pyrene	<410	<400	<450	<420	<390	<330
Diethyl phthalate	<410	<400	69 J	<420	<390	<330
n-Nitrosodiphenylamine	<410	<400	<450	<420	<390	<330
Phenanthrene	<410	<400	<450	<420	<390	<330
Anthracene	<410	<400	<450	<420	<390	<330
Benzo(a)anthracene	<410	<400	<450	<420	<390	<330
Chrysene	<410	<400	<450	<420	<390	<330
Bis(2-ethylhexyl)phthalate	11000	1600	180 J	230 J	930	<330
Benzo(b)fluoranthene	<410	<390	<450	<420	<390	<330
Benzo(a)pyrene	<410	<400	<450	<420	<390	<330
Indeno(1,2,3-cd)pyrene	<410	<400	<450	<420	<390	<330
Benzo(g,h,i)perylene	<410	<400	<450	<420	<390	<330
Butyl benzyl phthalate	210 J	<400	<450	<420	<390	<330

J = Compound Present Below Laboratory Detection Limits

Table 5-4

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Boring Number	F1-9	F1-9	F1-9	F1-10	F1-10	F1-10
SWD Sample Number	9-795	9-796	9-797	9-798	9-799	9-800
Date Sampled	06-26-89	06-26-89	06-26-89	06-26-89	06-26-89	06-26-89
Depth	0-1'	4-7'	10-13'	0-5'	5-10'	10-15'
Indicators						
pH (S.U.)	NT	7.10	NT	7.00	6.90	NT
TOC (mg/kg)	26300	6200	6300	8100	4300	1500

Boring Number	F1-11	F1-11	F1-11	F1-12	F1-12	F1-12
SWD Sample Number	9-801	9-802	9-803	9-804	9-805	9-844
Date Sampled	06-26-89	06-26-89	06-26-89	06-26-89	06-26-89	06-26-89
Depth	2-5'	5-10'	10-15'	0-5'	5-10'	10-12'
Indicators						
pH (S.U.)	NT	6.80	NT	7.10	NT	7.40
TOC (mg/kg)	10000	5100	200	6800	1200	1200

Boring Number	F1-13	F1-13	F1-13	F1-13
SWD Sample Number	9-806	9-807	9-808	9-809
Date Sampled	06-27-89	06-27-89	06-27-89	06-27-89
Depth	0-5'	5-10'	7-10'	10-13'
Indicators				
pH (S.U.)	NT	7.40	NT	NT
TOC (mg/kg)	5000	1800	3700	400

Boring Number	F1-14	F1-14	F1-14	F1-14
SWD Sample Number	9-810	9-811	9-812	9-813
Date Sampled	06-27-89	06-27-89	06-27-89	06-27-89
Depth	0-4'	4-7'	7-10'	10-13'
Indicators				
TOC (mg/kg)	7800	3700	2200	500

Table 5-4

Boring Number	F1-15	F1-15	F1-15	F1-16	F1-16	F1-16
SWD Sample Number	9-814	9-815	9-816	9-817	9-818	9-819
Date Sampled	06-28-89	06-28-89	06-28-89	06-27-89	06-27-89	06-27-89
Depth	0-5'	5-10'	10-15'	0-5'	5-10'	10-15'
Indicators						
TOC (mg/kg)	6900	1800	16800	5200	1900	400

Boring Number	F1-17	F1-17	F1-18	F1-18	F1-18	F1-18
SWD Sample Number	9-820	9-821	9-822	9-823	9-824	9-825
Date Sampled	06-26-89	06-26-89	06-26-89	06-23-89	06-23-89	06-23-89
Depth	0-5'	5-10'	10-15'	0-5'	5-10'	10-10.5'
Indicators						
TOC (mg/kg)	6800	2700	7100	7300	3600	4200

Boring Number	F1-19	F1-19	F1-19	F1-20	F1-20	F1-20
SWD Sample Number	9-826	9-827	9-828	9-829	9-830	9-831
Date Sampled	06-26-89	06-26-89	06-26-89	06-27-89	06-27-89	06-27-89
Depth	0-5'	5-10'	10-15'	0-5'	5-10'	10-10.5'
Indicators						
pH (S.U.)	6.70	7.40	NT	NT	NT	NT
TOC (mg/kg)	9400	2600	1200	5900	1800	1000

Boring Number	EQ BLK
SWD Sample Number	9-840
Date Sampled	06-28-89
Depth	
Indicators	
pH (S.U.)	6.70
TOC (mg/kg)	13800

EQ BLK = Equipment Blank
NT = Compound Not Tested For

Table 5-4

(Page 15 of 16)

Boring Number	F1-24	F1-24	F1-24	F1-25	F1-25
SWD Sample Number	9-1143	9-1144	9-1145	9-1146	9-1147
Date Sampled	08-21-89	08-21-89	08-21-89	08-21-89	08-21-89
Depth	0-5'	5-7'	10-15'	0-5'	5-10'
Volatile Organics (µg/kg)					
Methylene chloride	29 B	33 B	23 B	16 B	37 B
Acetone	19	90	82	52 B	89
Trans-1,2-dichloroethene	NT	NT	NT	NT	NT
Chloroform	4 BJ	2 BJ	4 BJ	5 BJ	4 BJ
1,1,1-Trichloroethane	<6	<6	<6	<6	<6
Trichloroethene	<6	<6	<6	<6	<6
2-Hexanone	<12	<12	<12	<12	<12
Toluene	1 J	2 J	4 J	<6	<6
Ethyl benzene	<6	<6	<6	<6	<6
Xylenes	<6	1 J	4 J	<6	<6
Semivolatile Organics (µg/kg)					
n-Nitrosodipropylamine	<400	<400	<410	<380	<400
Fluoranthenebenzene	<400	<400	<410	<380	<400
Pyrene	<400	<400	<410	<380	<400
Diethyl phthalene	<400	<400	<410	<380	<400
n-Nitrosodiphenylamine	<400	<400	<410	<380	<400
Phenanthrene	<400	<400	<410	<380	<400
Anthracene	<400	<400	<410	<380	<400
Benzo(a)anthracene	<400	<400	<410	<380	<400
Chrysene	<400	<400	<410	<380	<400
Bis(2-ethylhexyl)phthalate	550	1100	<410	790	5700
Benzo(b)fluoranthene	<400	<400	<410	<380	<400
Benzo(a)pyrene	<400	<400	<410	<380	<400
Indeno(1,2,3-cd)pyrene	<400	<400	<410	<380	<400
Benzo(g,h,i)perylene	<400	<400	<410	<380	<400
Butyl benzyl phthalate	<400	<400	<410	<380	<400
Indicators					
TOC (mg/kg)	5800	2500	600	7000	1100

B = Compound Also Found in Blanks
NT = Compound Not Tested For
J = Compound Present Below Laboratory Detection Limits

Table 5-4

Boring Number	F1-26	F1-26	F1-26	F1-27	F1-27	F1-27
SWD Sample Number	9-1148	9-1149	9-1150	9-1151	9-1152	9-1153
Date Sampled	08-22-89	08-22-89	08-22-89	08-22-89	08-22-89	08-22-89
Depth	0-5'	5-10'	10-15'	0-5'	5-10'	10-15'
Volatile Organics (µg/kg)						
Methylene chloride	7 B	527	44 B	19 B	54 B	21 B
Acetone	60 B	230 B	140 B	30 B	140 B	70 B
Trans-1,2-dichloroethene	NT	NT	NT	NT	NT	NT
Chloroform	4 BJ	4 BJ	4 BJ	4 BJ	4 BJ	4 BJ
1,1,1-Trichloroethane	<6	<6	<6	<6	<6	<6
Trichloroethene	<6	<6	<6	<6	<6	<6
2-Hexanone	<12	<12	<12	<12	<12	<12
Toluene	2 J	<6	<6	<6	6 J	<6
Ethyl benzene	<6	<6	<6	<6	7	<6
Xylenes	<6	<6	<6	<6	6 J	<6
Semivolatile Organics (µg/kg)						
n-Nitrosodipropylamine	<390	<390	<390	<390	<400	<400
Fluoranthenebenzene	<390	<390	<390	<390	<400	<400
Pyrene	<390	<390	<390	<390	<400	<400
Diethyl phthalene	<390	<390	<390	<390	<400	<400
n-Nitrosodiphenylamine	<390	<390	<390	<390	<400	<400
Phenanthrene	<390	<390	<390	<390	<400	<400
Anthracene	<390	<390	<390	<390	<400	<400
Benzo(a)anthracene	<390	<390	<380	<390	<400	<400
Chrysene	<390	<390	<390	<390	<400	<400
Bis(2-ethylhexyl)phthalate	2500	2400	<390	<390	<400	<400
Benzo(b)fluoranthene	<390	<390	<390	<390	<400	<400
Benzo(a)pyrene	<390	<390	<390	<390	<400	<400
Indeno(1,2,3-cd)pyrene	<390	<390	<390	<390	<400	<400
Benzo(g,h,i)perylene	<390	<390	<390	<390	<400	<400
Butyl benzyl phthalate	<390	<390	<390	<390	<400	<400
Indicators						
TOC (mg/kg)	5700	3400	1300	8500	2900	8200

B = Compound Also Found in Blanks
NT = Compound Not Tested For
J = Compound Present Below Laboratory Detection Limits

Table 5-5

Detection Frequencies - Soil
(USACE, 1992)
SWMU-7, FTA1, Tinker AFB

(Page 1 of 2)

Compound	Detected Frequency	Concentration Range		Location of Maximum Concentration	
				Boring	Depth
Volatile Organics (µg/kg)					
Methylene chloride	44/45	4	130	F1-3E	9'-10'
Acetone	30/45	21	610	F1-6	16'-22'
Trans-1,2-dichloroethene	1/34	-	10	F1-6	13'-16'
Chloroform	11/45	2	5	F1-25	0'-5'
1,1,1-Trichloroethane	1/45	-	3	F1-5	7'-10'
Trichloroethene	1/45	-	3	F1-5	7'-10'
2-Hexanone	1/45	-	7	F1-4	1'-4'
Toluene	5/45	1.4	6	F1-27	5'-10'
Ethyl benzene	1/45	-	7	F1-27	5'-10'
Xylenes	3/45	1	6	F1-27	5'-10'
Metals (mg/kg)					
Silver	4/10	0.54	2.7	F1-2C	4'-7'
Arsenic	4/10	1.2	1.9	F1-2E	10'-13'
Barium	10/10	180	900	F1-3A	0'-1'
Cadmium	10/10	0.5	17	F1-2A	0'-1'
Chromium	10/10	5.9	36	F1-2A	0'-1'
Mercury	2/10	0.14	0.16	F1-1E	10'-13'
Nickel	10/10	7.3	20	F1-2A	0'-1'
Lead	10/10	8.9	170	F1-2A	0'-1'
Selenium	6/10	0.15	0.21	F1-2C	4'-7'
Zinc	10/10	7.5	160	F1-2A	0'-1'

Table 5-5

(Page 2 of 2)

Compound	Detected Frequency	Concentration Range		Location of Maximum Concentration	
				Boring	Depth
Semivolatile Organics (µg/kg)					
n-Nitrosodipropylamine	1/55	-	310	F1-1C	4'-7'
Fluoranthenebenzene	1/55	-	390	F1-6	1'-4'
Pyrene	1/55	-	330	F1-6	1'-4'
Diethyl phthalate	2/55	31	69	F1-8	7'-13'
n-Nitrosodiphenylamine	1/55	-	160	F1-1C	4'-7'
Phenanthrene	2/55	10	170	F1-6	1'-4'
Anthracene	1/55	-	9	F1-1C	4'-7'
Benzo(a)anthracene	1/55	-	290	F1-6	1'-4'
Chrysene	1/55	-	170	F1-6	1'-4'
Bis(2-ethylhexyl)phthalate	47/55	120	11000	F1-8	0'-1'
Benzo(b)fluoranthene	1/55	-	250	F1-6	1'-4'
Benzo(a)pyrene	1/55	-	180	F1-6	1'-4'
Indeno(1,2,3-cd)pyrene	1/55	-	200	F1-6	1'-4'
Benzo(g,h,i)perylene	1/55	-	180	F1-6	1'-4'
Butyl benzyl phthalate	1/55	-	210	F1-8	0'-1'
Indicators					
pH (S.U.)	19/19	6.54	7.73	F1-2E	10'-13'
TOC (mg/kg)	59/59	200	26300	F1-9	0'-1'
Conductivity (µmhos/cm)	10/10	240	1100	F1-1C	4'-7'

(diethyl phthalate and phenanthrene) were detected in 2 of the 55 samples analyzed. Most of these occurrences were in samples taken from F1-6. These 14 compounds were not considered significant due to the low detection frequencies and the low concentrations. The highest concentration of these 14 compounds was for fluoranthenebenzene at 390 µg/kg. The remaining SVOC, bis(2-ethylhexyl)phthalate, was detected in 47 of the 55 samples at concentrations ranging from 120 to 11,000 µg/kg. The maximum concentration occurred in boring F1-8 in the sample taken from 0 to 1 foot below the surface.

Ten samples were analyzed for ten metals. Barium, cadmium, chromium, nickel, lead, and zinc were detected in each of the ten samples analyzed for metals. Lead and zinc were detected above the maximum background levels in concentrations ranging from 8.9 to 170 milligrams per kilogram (mg/kg), and 7.5 to 160 mg/kg, respectively. Mercury was detected in two of the ten samples at concentrations of 0.14 and 0.16 mg/kg. There is no background level established for mercury.

5.3 Groundwater Characterization

5.3.1 Upper Saturated Zone, 1987-1990

During the RI between 1989 and 1990, a total of 26 water samples were collected from the 2 monitoring wells and the 17 PVC piezometers set in the borings that monitor the USZ groundwater at the FTA1 site (USACE, 1992). Twelve of the samples were analyzed for VOCs, SVOCs, pH, TOC, and conductivity. These 12 samples were taken from MW-61A, MW-62, F1-1, F1-2, and F1-3. Two of the samples were also analyzed for metals. Ten of the 26 samples were only analyzed for pH, TOC, and conductivity. These samples were taken from F1-9 to F1-17 and F1-20. The remaining four samples were analyzed for VOCs, SVOC, pH, TOC, and conductivity. These samples were taken from F1-24 to F1-27. Table 5-6 contains a summary of the individual compound analysis results for the groundwater samples. Table 5-7 presents a summary of detection frequencies, concentration ranges, and locations of maximum concentrations for contaminants found in the USZ borings.

VOCs were analyzed for in 16 USZ samples; 17 compounds were detected. Eight of these compounds were present at concentrations above MCLs or proposed MCLs. Vinyl chloride was detected in four samples at concentrations ranging from 3 to 71 micrograms per liter (µg/L). The MCL for vinyl chloride is 2 µg/L. Trichloroethene was detected in six samples at concentrations ranging from 8 to 32 µg/L. The MCL for trichloroethene is 5 µg/L.

Table 5-6

Summary of Detected Contaminants - USZ Groundwater (USACE, 1992) SWMU-7, FTA1, Tinker AFB

(Page 1 of 7)

Boring Number	61A	EQ BLK	61A	61A	62	62	62
SWD Sample Number	7-290	9-1436	9-1437	0-1322	7-289	9-1439	0-1324
Date Sampled	03-19-87	09-15-89	09-15-89	05-08-90	03-17-87	09-15-89	05-08-90
Volatile Organics (µg/L)							
Vinyl chloride	71	<10	<10	15	<10	<100	<50
Methylene chloride	<5	<5	<5	3 BJ	<5	30 BJ	7 J
Acetone	<10	<10	<10	<10	<10	<100	<50
1,2-Dichloroethene (total)	NT	<5	150	130	<5	<50	<25
Trans-1,2-dichloroethene	540	NT	NT	NT	<5	NT	NT
Chloroform	<5	<5	<5	<5	<5	37 BJ	<25
2-Butanone	<10	<10	<10	<10	<10	<100	<50
1,1,1-Trichloroethane	3 J	<5	<5	<5	<5	<50	<25
Trichloroethene	32	<5	20	21	17	<50	8 J
1,1,2-Trichloroethane	<5	<5	<5	<5	<5	<50	<25
Benzene	<5	<5	<5	<5	<5	<50	<25
4-Methyl-2-pentanone	<10	<10	<10	<10	<10	<100	<50
2-Hexanone	<10	<10	<10	<10	<10	<100	<50
Tetrachloroethene	<5	<5	<5	<5	4 J	<50	8 J
Chlorobenzene	<5	<5	<5	<5	<5	<50	<25
Ethyl benzene	<5	<5	<5	<5	<5	<50	<25
Xylenes	<5	<5	<5	<5	<5	<50	<25
Trichlorofluoromethane	NT	<10	45	<10	NT	690	<50
Metals (µg/L)							
Arsenic	2.3	NT	NT	NT	2.3	NT	NT
Barium	3200	NT	NT	NT	1100	NT	NT
Chromium	110	NT	NT	NT	58	NT	NT
Lead	98	NT	NT	NT	78	NT	NT
Nickel	53	NT	NT	NT	73	NT	NT
Zinc	<10	NT	NT	NT	88	NT	NT

Table 5-6

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Boring Number	61A	EQ BLK	61A	61A	62	62	62
SWD Sample Number	7-290	9-1436	9-1437	0-1322	7-289	9-1439	0-1324
Date Sampled	03-19-87	09-15-89	09-15-89	05-08-90	03-17-87	09-15-89	05-08-90
Semivolatile Organics (µg/L)							
1,2,4-Trichlorobenzene	<10	<10	4 J	22	<10	<10	<10
Fluoranthene	<10	<10	<10	<10	<10	<10	<10
Pyrene	<10	<10	<10	<10	<10	<10	<10
Di-n-butyl phthalate	<10	<10	<10	<10	<10	<10	<10
Bis(2-ethylhexyl)phthalate	<10	<10	4 J	69	<10	11	29
Di-n-octyl phthalate	<10	1 J	0.7 J	<10	<10	3 J	<10
Indicators							
pH (S.U.)	7.10	7.55	7.28	6.93	7.44	7.47	7.09
TOC (mg/L)	8.9	<0.10	1.85	1.68	20	1.31	0.626
Conductivity (µmhos/cm)	22.8	5	799	808	16.7	1121	1116

EQ BLK = Equipment Blank
NT = Compound Not Tested For
B = Analyte Found in Blank
J = Estimated Concentration

Table 5-6

(Page 3 of 7)

Boring Number	F1-1	F1-1	F1-2	F1-2	F1-3	F1-3
SWD Sample Number	7-368	9-1440	7-369	9-1441	7-370	9-1442
Date Sampled	06-04-87	09-15-89	06-04-87	09-15-89	06-04-87	09-15-89
Volatile Organics (µg/L)						
Vinyl chloride	3 J	<10	17	<10	<10	<10
Methylene chloride	<5	<5	<5	16B	<5	<5
Acetone	<10	<10	<10	<10	<10	<10
1,2-Dichloroethene (total)	NT	<5	NT	8	NT	NT
Trans-1,2-dichloroethene	15	NT	89	NT	<5	<5
Chloroform	<5	<5	<5	<5	<5	<10
2-Butanone	<10	<10	18	<10	6450	<5
1,1,1-Trichloroethane	<5	<5	<5	<5	<5	<5
Trichloroethene	<5	<5	17	<5	<5	<5
1,1,2-Trichloroethane	<5	<5	13	<5	<5	<5
Benzene	<5	<5	7	<5	9	<10
4-Methyl-2-pentanone	<10	<10	<10	<10	10 J	<10
2-Hexanone	<10	<10	<10	<10	210	<5
Tetrachloroethene	<5	<5	<5	<5	<5	<3 J
Chlorobenzene	<5	<5	<5	<5	21	<5
Ethyl benzene	<5	<5	<5	<5	<5	<2 J
Xylenes	<5	<5	<5	<5	<5	<10
Trichlorofluoromethane	NT	<10	NT	<10	NT	NT
Semivolatile Organics (µg/L)						
1,2,4-Trichlorobenzene	<10	<10	<10	<10	<10	<10
Fluoranthene	<10	<10	6 J	<10	<10	<10
Pyrene	<10	<10	10 J	<10	<10	<10
Di-n-butyl phthalate	<10	<10	<10	<10	<10	0.4 J
Bis(2-ethylhexyl)phthalate	<10	<10	<10	6 J	<10	3 BJ
Di-n-octylphthalate	<10	2 J	<10	2 J	<10	4 BJ
Indicators						
pH (S.U.)	6.40	7.10	6.60	7.38	6.60	6.76
TOC (mg/L)	15.6	5.87	12.3	5.08	12.4	5.29
Conductivity (µmhos/cm)	580	1200	780	549	770	736

J = Estimated Concentration
B = Analyte Found in Blank
NT = Compound Not Tested For

Table 5-6

(Page 4 of 7)

Boring Number	LLWBLK	LLWBLK
SWD Sample Number		
Date Sampled	03-21-87	06-06-87
Volatile Organics (µg/L)		
Vinyl chloride	<10	<10
Methylene chloride	2 J	<5
Acetone	<10	<10
1,1-Dichloroethane	<5	<5
1,2-Dichloroethene (Total)	<5	NT
Trans-1,2-dichloroethene	NT	<5
Chloroform	<5	<5
2-Butanone	<10	9 J
1,1,1-Trichloroethane	<5	<5
Trichloroethene	<5	<5
1,1,2-Trichloroethane	<5	<5
Benzene	1 J	<5
4-Methyl-2-Pentanone	<10	<10
2-Hexanone	<10	<10
Tetrachloroethene	<5	<5
Toluene	<5	<5
Chlorobenzene	<5	<5
Ethyl benzene	<5	<5
Xylenes	<5	<5
Trichlorofluoromethane	NT	NT
Semivolatile Organics (µg/L)		
Phenol	<10	<10
1,4-Dichlorobenzene	<10	<10
4-Methylphenol	<10	<10
Benzoic acid	<50	<50
1,2,4-Trichlorobenzene	<10	<10
Dimethyl phthalate	<10	<10
Fluoranthene	<10	<10

Table 5-6

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Boring Number	LLWBLK	LLWBLK
SWD Sample Number		
Date Sampled	03-21-87	06-06-87
Semivolatile Organics (µg/L) (Continued)		
Pyrene	<10	<10
Di-n-butyl phthalate	<10	<10
Bis-(2-ethylhexyl)phthalate	6 J	<10
Di-n-octyl phthalate	<10	<10

LLWBLK = Laboratory Water Test
J = Estimated Concentration
NT = Compound Not Tested For

Table 5-6

Boring Number	F1-9	F1-10	F1-11	F1-12	F1-13
SWD Sample Number	9-873	9-874	9-875	9-876	9-877
Date Sampled	07-20-87	07-20-87	07-20-87	07-20-87	07-20-87
Indicators					
pH (S.U.)	6.47	6.70	7.18	6.95	6.68
TOC (mg/L)	49.6	52.0	61.5	31.0	60.6
Conductivity (µmhos/cm)	632	800	1138	592	959

Boring Number	F1-14	F1-15	F1-16	F1-17	F1-20
SWD Sample Number	9-878	9-879	9-880	9-881	9-882
Date Sampled	07-20-87	07-20-87	07-20-87	07-20-87	07-20-87
Indicators					
pH (S.U.)	6.86	7.07	6.84	6.99	7.05
TOC (mg/L)	63.4	44.0	56.4	38.4	39.7
Conductivity (µmhos/cm)	1115	9330	1280	732	1050

Table 5-6

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Boring Number	F1-24	F1-25	F1-25D	F1-26	F1-26D	F1-27
SWD Sample Number	9-1328	9-1329	9-1330	9-1331	9-1332	9-1333
Date Sampled	09-14-89	09-14-89	09-14-89	09-14-89	09-14-89	09-14-89
Volatile Organics (µg/L)						
Vinyl chloride	<10	<10	<10	<10	<10	<10
Methylene chloride	7 B	2 BJ	<10	3 BJ	<10	<5
Acetone	<10	21	NT	140	NT	<10
1,2-Dichloroethene (Total)	<5	<5	NT	5	NT	5
Trans-1,2-dichloroethene	NT	NT	<5	NT	7.1	NT
Chloroform	<5	<5	<5	<5	<5	<5
2-Butanone	<10	<10	NT	<10	NT	<10
1,1,1-Trichloroethane	<5	<5	<5	<5	<5	<5
Trichloroethene	<5	<5	<5	<5	<5	<5
1,1,2-Trichloroethane	<5	<5	<5	<5	<5	<5
Benzene	<5	<5	<5	<5	<5	<5
4-Methyl-2-pentanone	<10	<10	NT	<10	NT	<10
2-Hexanone	<10	<10	NT	<10	NT	<10
Tetrachloroethene	<5	<5	<5	<5	<5	<5
Chlorobenzene	<5	<5	NT	<5	NT	<5
Ethyl benzene	<5	<5	<5	<5	<5	<5
Xylenes	<5	<5	NT	<5	NT	<5
Trichlorofluoromethane	10	<10	<10	<10	<10	<10
Semovolatile Organics (µg/L)						
1,2,4-Trichlorobenzene	<10	<10	<10	<10	<10	<10
Fluoranthene	<10	<10	<10	<10	<10	<10
Pyrene	<10	<10	<10	<10	<10	<10
Di-n-butyl phthalate	<10	<10	<10	<10	<10	<10
Bis(2-ethylhexyl)phthalate	<10	<10	<10	<10	24	<10
Di-n-octyl phthalate	<10	<10	NT	<10	NT	<10
Indicators						
pH (S.U.)	7.07	7.02	7.02	7.36	7.36	7.17
TOC (mg/L)	4.22	12.9	14	9.94	11	1.82
Conductivity (µmhos/cm)	1596	1000	1000	420	420	608

B = Analyte Found in Blank
J = Estimated Concentration
NT = Compound Not Tested For
D = Duplicate Sample (Quality Assurance/Quality Control)

Table 5-7

Detection Frequencies - USZ Groundwater (USACE, 1992) SWMU-7, FTA1, Tinker AFB

(Page 1 of 2)

Compound	Detected Frequency	Concentration Range		Location of Maximum Concentration
Volatile Organics (µg/L)				
Vinyl chloride	4/16	3	71	MW-61A
Methylene chloride	7/16	2	30	MW-62
Acetone	2/16	21	140	F1-26
1,2-Dichloroethene (total)	4/10	5	150	MW-61A
Trans-1,2-dichloroethene	3/6	5	540	MW-61A
Chloroform	1/16	-	37	MW-62
2-Butanone	2/16	18	6450	F1-3
1,1,1-Trichloroethane	1/16	-	3	MW-61A
Trichloroethene	6/16	8	32	MW-61A
1,1,2-Trichloroethane	1/16	-	13	F1-2
Benzene	2/16	7	9	F1-3
4-Methyl-2-pentanone	1/16	-	10	F1-3
2-Hexanone	1/16	-	210	F1-3
Tetrachloroethene	3/16	3	8	MW-62
Chlorobenzene	1/16	-	21	F1-3
Ethyl benzene	1/16	-	2	F1-3
Trichlorofluoromethane	3/10	10	690	MW-62
Metals (µg/L)				
Arsenic	2/2	2.3	2.3	MW-61A
Barium	2/2	1100	3200	MW-61A
Chromium	2/2	58	110	MW-61A
Lead	2/2	78	98	MW-61A
Nickel	2/2	53	73	MW-62
Zinc	1/2	-	88	MW-62

Table 5-7

Compound	Detected Frequency	Concentration Range		Location of Maximum Concentration
Semivolatile Organics (µg/L)				
1,2,4-Trichlorobenzene	2/16	4	22	MW-61A
Fluoranthenebenzene	1/16	-	6	F1-2
Pyrene	1/16	-	10	F1-2
Di-n-butyl phthalate	1/16	-	0.4	F1-3
Bis(2-ethylhexyl)phthalate	6/16	3	69	MW-61A
Di-n-octyl phthalate	5/16	0.7	4	F1-3
Indicators				
pH (S.U.)	26/26	6.40	7.47	MW-62
TOC (mg/kg)	26/26	1.31	63.4	F1-9
Conductivity (µmhos/cm)	26/26	16.7	9330	F1-15

Benzene was detected in two samples at concentrations of 7 to 9 µg/L. The MCL for benzene is 5 µg/L.

Methylene chloride was detected in seven samples at concentrations ranging from 2 to 30 µg/L; four of the concentrations were above the proposed MCL of 5 µg/L. Methylene chloride was also detected in the blanks and is a common laboratory contaminant. Tetrachloroethene was detected in three samples at concentrations ranging from 3 to 8 µg/L. Only one concentration was above the proposed MCL of 5 µg/L; 1,1,2-trichloroethane was detected in one sample at a concentration of 13 µg/L. There is currently no MCL or proposed MCL for this compound.

Six of the USZ samples were tested for trans-1,2-DCE, and the remaining ten samples were tested for 1,2-DCE (total). Total DCE is the sum of the cis and trans isomers. The proposed MCL for the trans isomer is 100 µg/L, and the proposed MCL for the cis isomer is 70 µg/L. There is no current or proposed MCL for the compound totals, so the values for the totals are compared to the more restrictive 70 µg/L proposed MCL for the cis isomer. The compound totals were found in four samples at concentrations ranging from 5 to 150 µg/L. Two of the samples were above the secondary MCL of 70 µg/L. The trans isomer was detected in three samples at concentrations ranging from 5 to 540 µg/L. Only one of the samples was above the secondary MCL of 100 µg/L.

Chloroform, 1,1,1-trichloroethane, chlorobenzene, and ethyl benzene were each detected in one sample at concentrations of 37, 3, 21, and 2 µg/L, respectively. All of these concentrations are below the MCLs or proposed MCLs of 100, 200, 100, and 700 µg/L, respectively.

Acetone and 2-butanone were detected in two samples each; acetone was found at concentrations of 21 and 140 µg/L, and 2-butanone at concentrations of 18 and 6,450 µg/L. 4-Methyl-2-pentanone and 2-hexanone were each detected in one sample at concentrations of 10 and 210 µg/L, respectively. Trichlorofluoromethane was tested for in ten samples and detected in three samples at concentrations ranging from 10 to 690 µg/L. There are no current or proposed MCLs for these five compounds.

SVOCs were analyzed for in 16 USZ samples. Six compounds were detected. There are no current or proposed MCLs for these six compounds. Fluoranthene, pyrene, and di-n-butyl phthalate were each detected in only 1 of the 16 samples at concentrations of 6, 10, and 0.4 µg/L, respectively. In two samples, 1,2,4-trichlorobenzene was detected at concentrations of

4 µg/L and 22 µg/L. Di-n-octyl phthalate was detected in five samples at concentrations ranging from 0.7 to 4 µg/L. The most frequently detected SVOC was bis(2-ethylhexyl) phthalate, which was found in six samples at concentrations ranging from 3 to 69 µg/L. Phthalates are common plasticizers and are often introduced into samples as laboratory contaminants. However, due to the high concentrations of bis(2-ethylhexyl)phthalate present in the soil, it is probable that the soil is the source of this contaminant in the groundwater.

Only two of the USZ water samples were analyzed for metals: the March 1987 samples from MW-61A and MW-62. Concentrations of barium, chromium, and lead were above the MCLs in both samples. Barium concentrations of 1,100 and 3,200 µg/L were above the MCL of 1,000 µg/L. The background average for barium in the perched aquifer is 1,110 µg/L. Chromium concentrations of 58 µg/L and 110 µg/L were above the MCL of 50 µg/L. Lead concentrations of 78 and 98 µg/L were above the MCL of 50 µg/L. The highest concentrations of all three of these metals were found in MW-61A, downgradient of FTA1. Arsenic was detected in both samples at 2.3 µg/L, well below the MCL of 50 µg/L. Nickel was detected in both samples at concentrations of 53 and 73 µg/L, below the secondary MCL of 100 µg/L. Zinc was only detected in MW-62 at a concentration of 88 µg/L, well below the secondary MCL of 5,000 µg/L. The maximum concentration of nickel and zinc were detected in MW-62, upgradient of FTA1.

All 26 USZ groundwater samples were analyzed for pH, TOC, and conductivity. The pH values ranged from 6.40 to 7.47. Two of the values (F1-1 at 6.40 and F1-9 at 6.47) were outside the secondary MCL range of 6.50 to 8.50. The background average for pH in the USZ is 7.10. The TOC concentrations ranged from 1.31 milligrams per liter (mg/L) to 63.4 mg/L. Twenty-one of these concentrations were above the background average of 3.9 mg/L. The conductivity readings ranged from 16.7 micromhos per centimeter (µmhos/cm) to 9,330 µmhos/cm. Eighteen of these values were above the background average of 684 µmhos/cm.

VOCs, SVOCs, and metal contamination in the USZ exist both upgradient and downgradient of the FTA1. Several of the significant VOCs detected in the USZ (vinyl chloride, benzene, and tetrachloroethene) were not detected in any of the soil borings drilled in the vicinity of FTA1. Therefore, it is unlikely that FTA1 is the source of all the contamination that exists in the USZ in this area. MW-62 is downgradient of the SP site, so it is possible that the SP is the source of the contamination in this well. Additional investigations are needed in the vicinity of FTA1 and the SP to determine if the SP is contributing to the contamination beneath FTA1.

USZ groundwater samples were taken from two monitoring wells (MW-61A and MW-62) and three PVC pipes (F1-1, F-2, and F1-3) in the 1987 and 1989. Analysis of the results indicate that several of the VOCs detected in 1987 sampling round were either not detected or were detected at significantly lower concentrations in the 1989 sampling round. In MW-61A, vinyl chloride was detected at 71 μg/L in 1987 and not detected in 1989. Trichloroethene dropped from 32 μg/L in 1987 to 20 μg/L in 1989. In MW-62, trichloroethene was found at 17 μg/L in 1987 and was not detected in 1989. In boring F1-2, vinyl chloride, 2-butanone, trichloroethene, and 1,1,2-trichloroethane were found at concentrations of 17, 18, 17, and 13 μg/L, respectively, in 1987, and were not detected in 1989. In boring F1-3, 2-butanone, 2-hexanone, and chlorobenzene were found at 6,450, 210, and 21 μg/L in 1987, and were not detected in 1989. This reduction in contaminant levels probably occurred because the PVC piezometers and monitoring wells introduced an oxygen source into the saturated zone and facilitated volatilization of the organics in the vicinity of the borings. It is not likely that this volatilization occurred throughout the entire contaminated section of the saturated zone. Additional investigations would be required to determine if the organics were volatilized in the sections of the aquifer between the existing borings. The additional investigations could consist of drilling borings between existing borings and sampling for VOCs.

5.3.2 Upper Saturated Zone, 1992-1993

Groundwater samples were collected from wells MW-61A and MW-62 in November 1992 and again from MW61-A in July 1993. The 1992 samples from MW-61A and MW-62 were analyzed for VOCs, SVOCs, metals, TDS, and TOC. The 1993 sample from MW-61A was analyzed for VOCs and SVOCs only. Table 5-8 presents a summary of the analytical results.

MW-61A represents a downgradient well in the USZ for FTA1. Trichloroethene was the only compound that exceeded the MCL (5 μg/L); the compound was detected at 10 μg/L in the 1992 event. All compounds detected during the 1993 event were below available MCLs, including trichloroethene, which was detected at 3 μg/L.

MW-62 represents an upgradient well in the USZ for FTA1. The November 1992 results revealed three VOCs that exceeded available MCLs. These VOCs were benzene, detected at 12 μg/L (MCL = 5 μg/L); tetrachloroethene, detected at 14 μg/L (MCL = 5 μg/L); and trichloroethene, detected at 78 μg/L (MCL = 5 μg/L).

Table 5-8

Summary of Detected Contaminants - USZ
SWMU-7, FTA1, Tinker AFB

(Page 1 of 2)

Well ID	MW-61A	MW-61A	MW-62
Date Sampled	11-23-92	7-18-93	11-23-92
Compound			
1,2-Dichlorobenzene (µg/L)	0.6	NT	3
Barium (µg/L)	492	NT	730
Benzene (µg/L)	4 B	4	12 B
Chlorobenzene (µg/L)	1	NT	3
Dimethylphthalate (µg/L)	7 J	NT	NT
Ethyl benzene (µg/L)	1	2	2
Isopropylbenzene (µg/L)	5	1	0.5
Methylene chloride (µg/L)	5 B	NT	3 B
Tetrachloroethene (µg/L)	3	NT	14
Toluene (µg/L)	0.6	20	2
Total dissolved solids (mg/L)	356	NT	534
Trichloroethene (µg/L)	10	3	78
Cis-1,2-dichloroethene (µg/L)	4	17	2
1,1-Dichloroethene (µg/L)	0.5	NT	NT
Naphthalene (µg/L)	2 B	NT	2 B
1,2,3-Trichlorobenzene (µg/L)	NT	3	NT
1,2,4-Trichlorobenzene (µg/L)	NT	15	NT
1,2,4-Trimethylbenzene (µg/L)	NT	2	NT
1,3,5-Trimethylbenzene (µg/L)	NT	0.6	NT
Vinyl chloride (µg/L)	NT	0.9	NT
Xylenes (total) (µg/L)	NT	1.7	3.2
n-Propylbenzene (µg/L)	NT	2	NT
p-Isopropyltoluene (µg/L)	NT	1.0	0.7
Sec-butylbenzene (µg/L)	NT	0.5	NT

Table 5-8

(Page 2 of 2)

Well ID	MW-61A	MW-61A	MW-62
Date Sampled	11-23-92	7-18-93	11-23-92
Compound (continued)			
1,1,1-Trichloroethane (µg/L)	NT	NT	NT
TOC (mg/L)	NT	NT	1.3
1,3-Dichlorobenzene (µg/L)	NT	NT	NT
1,4-Dichlorobenzene (µg/L)	NT	NT	NT

NT = Compound not tested for.
B = Analyte found in blank.
J = Estimated value.

5.4 Groundwater Characterization in the Lower Saturated Zone

5.4.1 Lower Saturated Zone, 1988-1990

At the time of the RI, MW-61B was the only monitoring well set in the LSZ close to FTA1. The well, located south and downgradient of the site, was installed as part of the RIs for Landfills 1 through 4. Available data for the LSZ are presented in this section. Table 5-9 presents a summary of the contaminants detected in MW-61B from three sampling rounds (September 1988, September 1989, and May 1990).

Four VOCs (methylene chloride, acetone, 1,2-dichloroethene [total], and trichloroethene) were detected in this well. Methylene chloride was detected in all three sampling rounds at concentrations of 22, 15, and 2 µg/L, respectively. The proposed MCL for methylene chloride is 5 µg/L. This compound was detected in the blanks from the 1989 and 1990 samples and is likely a laboratory contaminant. Acetone and 1,2-dichloroethene (total) were detected in the 1989 sample at concentrations of 50 and 9 µg/L, respectively. There is currently no MCL for acetone. As discussed in Section 5.3, concentrations for 1,2-dichloroethene (total) are being compared to the proposed MCL of 70 µg/L for cis-1,2-dichloroethene. The concentration present here is well below this proposed MCL. These compounds were not detected in the 1988 and 1990 samples. Trichloroethene was detected in the 1988 sample at a concentration of 14 µg/L, above the MCL of 5 µg/L, but was not detected in the 1989 or 1990 sample. The decrease in concentration may be attributable to the monitoring well installation introducing an oxygen source into the saturated zone and facilitating volatilization of organic compounds in the vicinity of the monitoring well.

Two SVOCs, bis(2-ethylhexyl)phthalate and di-n-octyl phthalate, were detected in MW-61B. Bis(2-ethylhexyl)phthalate was detected in all three samples at concentrations of 30, 6, and 37 µg/L. Di-n-octyl phthalate was detected in the 1989 sample at a concentration of 2 µg/L. It was not detected in either the 1988 or 1990 sample. Phthalates are common plasticizers and often show up as laboratory contaminants. At the low levels detected in these samples, the phthalates are likely laboratory contaminants.

Only the September 1988 sample from the MW-61B was analyzed for metals. Three metals (arsenic, barium, and chromium) were detected at concentrations above the background levels, but well below the MCLs. The concentrations found were 2.6 µg/L for arsenic, 730 µg/L for barium, and 13 µg/L for chromium. The background values for these metals are 2, 663, and 10 µg/L, respectively. The MCLs for these metals are 50, 1,000, and 50 µg/L, respectively.

Table 5-9

Summary of Detected Contaminants - LSZ, 1988-1990 (USACE, 1992) SWMU-7, FTA1, Tinker AFB

Boring Number	61B	61B	61B
SWD Sample Number	8-1496	9-1438	0-1323
Date Sampled	9-29-88	9-15-89	5-08-90
Volatile Organics (µg/L)			
Methylene chloride	22	15B	2BJ
Acetone	<10	50	<10
1,2-Dichloroethene (Total)	<5	9	<5
Trichloroethene	14	<5	<5
Semivolatile Organics (µg/L)			
Bis(2-ethylhexyl)phthalate	30	6J	37
Di-n-octyl phthalate	<10	2J	<10
Metals (µg/L)			
Arsenic	2.6	NT	NT
Barium	730	NT	NT
Chromium	13	NT	NT
Indicators			
pH (S.U.)	7.30	10.85	8.27
TOC (mg/L)	0.74	0.699	<.50
Conductivity (µmhos/cm)	689	460	531

B = Analyte found in blank.
J = Estimated value.
NT = Compound not tested for.

The pH values found in the samples were 7.30, 10.85, and 8.27, respectively. The 1989 value is above the secondary MCL of 8.5. The TOC concentrations of 0.74, 0.699, and less than 0.50 mg/L, all below the background average of 5.3 mg/L. The conductivity readings were 689, 460, and 531 µmhos/cm, all below the background average of 718 µmhos/cm.

5.4.2 Lower Saturated Zone, 1992

Groundwater from MW-61B was sampled in November 1992. The samples were analyzed for VOCs, SVOCs, TDS, and TOC. Table 5-10 presents a summary of the analytical results.

MW-61B represents a downgradient well in the LSZ for FTA1. Benzene (55 µg/L), trichloroethene (24 µg/L), and vinyl chloride (11 µg/L) were the only compounds that exceeded their espective MCLs of 5, 5, and 2 µg/L, respectively.

Table 5-10

Summary of Detected Contaminants - LSZ, 1992
SWMU-7, FTA1, Tinker AFB

(Page 1 of 2)

Well ID	MW-61B
Date Sampled	11-23-92
Compound	
1,2-Dichlorobenzene (µg/L)	NT
Barium (µg/L)	1390
Benzene (µg/L)	55
Chlorobenzene (µg/L)	1
Dimethyl phthalate (µg/L)	22
Ethyl benzene (µg/L)	3
Isopropylbenzene (µg/L)	0.8
Methylene chloride (µg/L)	5 B
Tetrachloroethene (µg/L)	4
Toluene (µg/L)	1
Total dissolved solids (mg/L)	788
Trichloroethene (µg/L)	24
Cis-1,2-dichloroethene (µg/L)	120
1,1-Dichloroethene (µg/L)	3
Naphthalene (µg/L)	2 B
1,2,3-Trichlorobenzene (µg/L)	2
1,2,4-Trichlorobenzene (µg/L)	9
1,2,4-Trimethylbenzene (µg/L)	NT
1,3,5-Trimethylbenzene (µg/L)	NT
Vinyl chloride (µg/L)	11
Xylenes (total) (µg/L)	1.2
n-Propylbenzene (µg/L)	NT
p-Isopropyltoluene (µg/L)	NT
Compound (continued)	
Sec-butylbenzene (µg/L)	NT

Table 5-10

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Well ID	MW-61B
Date Sampled	11-23-92
1,1,1-Trichloroethane (µg/L)	0.6
TOC (mg/L)	3.2
1,3-Dichlorobenzene (µg/L)	1.0
1,4-Dichlorobenzene (µg/L)	2

NT = Compound not tested for.
B = Analyte found in blank.
J = Estimated value.

6.0 Baseline Risk Assessment/Potential Receptors

A human health risk assessment and ecological assessment has been performed for FTA1 (USACE, 1993b). These assessments, which include evaluation of human and ecological receptors, are summarized in Sections 6.1 and 6.2, respectively.

6.1 Human Health Risk Assessment

Necessary elements of an exposure pathway are sources of contamination, transport media, routes of exposure, and human receptors at exposure points. Incomplete pathways indicate that exposure will not occur and no adverse impacts on local human health are anticipated.

The single release source at the site is soil contaminated with heavy metals and organic compounds. Contaminants in surface soil may move through volatilization (in the case of organic compounds) or be transported through association with particulate matter (in the case of inorganic compounds). These pathways were deemed incomplete because there are no receptors. The site is covered with vegetation to limit these pathways. In addition, no Base activities occur in this area, and the nearest Base housing structures are approximately 2,000 feet away and not in the path of prevailing winds. Daily traffic on a service road adjacent to the site would not be affected by these pathways.

Contaminated subsurface soil acts as a source of contamination for the USZ. Both organic and inorganic contaminants in the USZ would be expected to move towards the south and west at a relatively slow rate. In addition, a vertical component of USZ flow would allow contamination to migrate towards usable groundwater in the Garber-Wellington strata. The rate of contaminant movement in both the horizontal and vertical direction is not known and would be expected to vary radically by individual contaminant. However, geophysical evaluations at the site found no evidence of significant lateral or downward migration of the USZ (USACE, 1992). These same investigations revealed a clayey soil of low permeability which would be expected to limit movement of heavy metal contaminants by absorption.

It is virtually impossible for contaminants from the site to influence usable regional groundwater because of the great vertical and horizontal distance to the regional aquifer use points and impediments to contaminant movement in the area. Therefore, the potential exposure route involving ingestion of contaminated regional groundwater was deemed incomplete under current or future land use.

Contaminant transport via the USZ has the potential to result in a complete exposure pathway for individuals who swim or wade in Crutcho Creek. While contaminant transport to the creek has not been verified, observed contaminant levels in MW-61A (a monitoring well in the USZ located about 30 feet north of Crutcho Creek), and the verified hydraulic connection between the USZ and the creek indicate completion of this exposure pathway could occur over a 70-year exposure period. It was assumed water quality in the creek at the exposure point would be the same as groundwater quality.

Exposure routes associated with contaminated creek water might include inhalation of volatile organics, dermal exposure to contaminants in creek water or sediments, and incidental ingestion of water while wading or swimming. Inhalation of organic vapors from the creek was judged to be insignificant because of low chemical concentrations and the small surface area of the creek.

The potentially exposed population for the baseline risk assessment is limited to residents, including those living in Base facilities, who might come in contact with water in the upper reaches of Crutcho Creek. Activity patterns for the potentially exposed population, especially children, assumed the creek would be used for swimming and wading. It was also assumed that maximum contact with the water would be by a child for 2 hours 60 times a year and that ingestion of water would be incidental. This is a worse-case situation that might be applicable during the summer when the heat is extreme. Ingestion of fish was not considered a source of exposure because upper reaches of the creek provide only limited fish habitat and the fish are mostly minnows and small sunfish not large enough for consumption.

Three inorganic chemicals and six organic compounds that were chemicals of concern are capable of causing carcinogenic effects. Five inorganic chemicals and 11 organic compounds are capable of causing noncarcinogenic chronic and subchronic effects. Using various screening methods, all of the chemicals except vinyl chloride were eliminated from further assessment as a carcinogenic agent. Chemicals that could cause chronic and subchronic effects were screened down to three (1,2,3-DCE, 2-butanone, and 1,1,2-trichloroethane).

Total carcinogenic risk to the population with the greatest exposure potential (children swimming or wading in the creek) is 6×10^{-6}. This is well within the range of acceptable risks (1×10^{-4} to 1×10^{-6}) as defined by EPA under the NCP.

The hazard from noncarcinogenic effects is also slight as shown by a hazard index of 0.06. Noncarcinogenic effects are generally deemed minimal if the hazard index is below 1.0. Other populations, either on-Base or off-Base, have a much lower risk because pathways are incomplete.

6.2 Ecological Risks/Receptors

Ecological risks were evaluated for vegetation, earthworms, small mammals, and predatory birds directly and indirectly exposed to contaminants in surface soil. Also, a future scenario involving the intersection of contaminated groundwater with Crutcho Creek was evaluated for potential effects on aquatic life. Bis(2-ethylhexyl)phthalate represents a potential risk to site vegetation, and zinc represents a small potential risk to earthworms. The largest potential risk arises from the effects of lead, and to a smaller degree, the effects of cadmium, on small mammals. No increased risk was estimated for predatory birds. No increased risk to aquatic life was estimated from exposure to organic compounds. Chromium and lead represent a potential risk to aquatic organisms only if these contaminants reach the creek at the concentrations currently observed in the groundwater, which reflects a worst-case scenario. Limitations in the metals data, however, preclude drawing definite conclusions.

7.0 Action Levels

An "action level" is defined by EPA in proposed rule 40 CFR 264.521 (55 FR 30798; 7/27/90), "Corrective Action for Solid Waste Management Units (SWMU) at Hazardous Waste Management Facilities," as a health- and environment-based level, determined by EPA to be an indicator for protection of human health and the environment. In the preamble to this proposed rule, the focus of the RFI phase is defined as "characterizing the actual environmental problems at the facilities." As part of this characterization, a comparison of the contaminant concentrations to certain action levels should be made to determine if a significant release of hazardous constituents has occurred. This comparison is then used to determine if further action or corrective measures are required for a SWMU or an AOC. The preamble to the proposed rule states that the concept of action levels was introduced because of the need for "a trigger that will indicate the need for a Corrective Measures Study (CMS) and below which a CMS would not ordinarily be required" (55 FR 30798; 7/27/90). If constituent concentrations exceed certain action levels at a SWMU or an AOC, further action or a CMS may be warranted; if constituent concentrations are below action levels, a finding of no further action may be warranted. This chapter of the report presents the initial analytical data as compared to certain potential action levels.

Action levels are concentrations of contaminants at or below which exposure to humans or the environment should not produce acute or chronic effects.

The action level information is presented in this chapter so that a constituent concentration at a sample location can be compared with its potential action level. Only constituents identified in the analysis are listed in the SWMU-7, FTA1 table. Table 7-1 shows the action levels for soil, water, and air as published in federal or state regulations, policies, guidance documents, or proposed rules.

The action levels listed in Table 7-1 are:

- ***SWMU Corrective Action Levels (CAL)*** **-** The first set of action levels provided in the table are those taken from the proposed rule (40 CFR 264.521) and provided as Appendix A to the rule as "Examples of Concentrations Meeting Criteria for Action Levels." These levels are health-risk based and are provided

Table 7-1

Action Levels
SWMU-7, Fire Training Area 1, Tinker AFB

(Page 1 of 5)

Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	F1-1 0-13 ft	F1-2 0-13 ft	F1-3 0-13 ft	F1-4 0-26.7 ft	F1-5 0-28 ft
	Soil (mg/kg)	Water (mg/L)	Air (μg/m^3)	Water (mg/L)	Soil (mg/kg)	Air (μg/m^3)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)
Volatile Organics											
Acetone	8000	4.0						0.018	0.01-0.028	0.011-0.190	0.003-0.018
Methylene chloride	90	0.005	0.3	0.005			0.016-0.019	0.011-0.020	0.021-0.130	0.005-0.015	0.004-0.023
Semivolatile Organics											
Bis(2-ethylhexyl)phthalate	50	0.003		0.006			0.41-1.9	0.36-1.1	0.170-5.9	0.230-7.3	0.120-1.8
Metals											
Arsenic	80		7.0 x 10^{-5}	0.05	21		1.3	1.9	1.2-1.6		
Barium	4000		0.4	2	6400		250-750	180-560	190-900		
Cadmium	40		0.0006	0.005			0.5-1.1	0.53-17	0.52-1.4		
Chromium				0.1	110		7.5-11	5.9-36	7.3-8.9		
Lead				0.015[e]	27	1.5[f]	8.9-18	12-170	9.1-74		
Mercury	20			0.002			0.14-0.16				
Nickel	2000	0.7		0.1	61		8.6-11	8.3-20	7.3-9.7		
Selenium				0.05	1.2			0.16-0.21	0.15-0.17		
Zinc					79		10-16	8.9-160	7.5-14		

KN/1256/SWMU7/SWMU7.7-1/08-26-94/F1

Table 7-1

(Page 2 of 5)

Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	WQS[e]	F1-6 0-28 ft	F1-7 0-25 ft	F1-8 0-25 ft	F1-24 0-15 ft	F1-25 0-10 ft
	Soil (mg/kg)	Water (mg/L)	Air (µg/m³)	Water (mg/L)	Soil (mg/kg)	Air (µg/m³)	Water (mg/L)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)
Volatile Organics												
Acetone	8000	4.0						0.002-0.610			0.019-0.082	0.052-0.089
Methylene chloride	90	0.005	0.3	0.005				0.006-0.091			0.023-0.029	0.016-0.037
Trans-1,2-dichloroethene	8		0.04	0.1				0.010				
Semivolatile Organics												
Bis(2-ethylhexyl)phthalate	50	0.003		0.006				0.43-1.2	0.28-3.6	0.18-11.0	0.55-1.1	0.790-5.7

Table 7-1

(Page 3 of 5)

Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	F1-26 0-15 ft	F1-27 0-15 ft	MW-61A	MW-61B	MW-62
	Soil (mg/kg)	Water (mg/L)	Air (μg/m^3)	Water (mg/L)	Soil (mg/kg)	Air (μg/m^3)	Range (mg/kg)	Range (mg/kg)	(mg/L)	(mg/L)	(mg/L)
Organics											
1,1-Dichloroethene	10		0.03	0.007					NA	0.003	NA
1,1,1-Trichloroethane	7,000	3.0	1,000	0.2					NA	0.0006	NA
1,2-Dichlorobenzene				0.6					NA	NA	0.003
1,2-Dichloroethene (total)	8		0.04						0.130		
1,2,3-Trichlorobenzene									0.003	0.002	NA
1,2,4-Trichlorobenzene	2000	0.7	10	0.07					0.015	0.009	NA
1,2,4-Trimethylbenzene									0.002	NA	NA
1,3-Dichlorobenzene				0.6					NA	0.001	NA
1,3,5-Trimethylbenzene									0.0006	NA	NA
1,4-Dichlorobenzene				0.075					NA	0.002	NA
Acetone	8000	4.0					0.06-0.23	0.03-0.14			
Benzene				0.005					0.004	0.055	0.012
Bis(2-ethylhexyl)phthalate	50	0.003		0.006			2.4-2.5				
Chlorobenzene	2000	0.7	20	0.1					NA	0.001	0.003
Cis-1,2-dichloroethene	8		0.04	0.07					0.017	0.120	0.002
Dimethyl phthalate									NA	0.022	NA
Ethyl benzene	8000	4.0		0.7				0.007	0.002	0.003	0.002
Isopropylbenzene									0.001	0.0008	0.0005

KN/1256/SWMU7/SWMU7.7-1/08-26-94/F1

Table 7-1

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Parameters	SWMU CAL[a] Soil (mg/kg)	SWMU CAL[a] Water (mg/L)	SWMU CAL[a] Air (µg/m³)	MCL[b] Water (mg/L)	USGS[c] Background Soil (mg/kg)	NAAQS[d] Air (µg/m³)	F1-26 0-15 ft Range (mg/kg)	F1-27 0-15 ft Range (mg/kg)	MW-61A (mg/L)	MW-61B (mg/L)	MW-62 (mg/L)
Organics (Continued)											
Methylene chloride	90	0.005	0.3	0.005			0.007-0.527	0.019-0.054		0.005	0.003
n-Propylbenzene									0.002	NA	NA
Naphthalene									NA	0.002	0.002
p-isopropyltoluene									0.001	NA	0.0007
Sec-butylbenzene									0.0005	NA	NA
Tetrachloroethene	10	0.0007	1.0	0.005					NA	0.004	0.014
Toluene	20000	10	7,000	1.0					.020	0.001	0.002
Trichloroethene	60			0.005					0.003	0.024	0.078
Vinyl chloride				0.002					0.0009	0.011	NA
Xylenes	200,000	70	1,000	10					0.0017	0.0012	0.0032
Inorganics											
Barium	4000	0.4		2	6400				NA	1.39	0.73

Table 7-1

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Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	F1-2	F1-24	F1-25	F1-26	F1-27
	Soil (mg/kg)	Water (mg/L)	Air (µg/m³)	Water (mg/L)	Soil (mg/kg)	Air (µg/m³)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Volatile Organics											
1,2-Dichloroethene (total)	8		0.04				0.008			0.005	0.005
Acetone	8000	4.0							0.021	0.140	
Methylene chloride	90	0.005	0.3	0.005			0.016	0.007			
Trans-1,2-dichloroethene	8		0.04	0.1			NA	NA	NA	NA	NA
Trichlorofluoromethane	20,000	10	700					0.010			

[a]CAL - Corrective Action Levels
[b]MCL - Maximum Contaminant Levels
[c]USGS - United States Geological Survey
[d]NAAQS - National Ambient Air Quality Standards
[e]Action Level at the Tap
[f]3-Month Average

as specific examples of levels below which corrective action would not be required.

- ***Maximum Contaminant Levels (MCL) -*** These values are provided from 40 CFR Subpart G, Sections 141.60 through 0.63 as promulgated under the Safe Drinking Water Act. These levels are designated for water media only.

- ***USGS Background -*** These values are provided from the USGS report titled "Elemental Composition of Surficial Materials from Central Oklahoma" (USGS, 1991). These values represent the levels of metals which naturally occur in Central Oklahoma soils.

- ***Background -*** These levels are provided where background could be determined. Where available, background concentrations are listed for metals in soil samples taken on site, which were thought to be unaffected by releases from a unit.

- ***National Ambient Air Quality Standards (NAAQS) -*** These standards are published in 40 CFR Part 50 under the Clean Air Act and apply to point sources that emit a limited number of constituents to the air. The constituents regulated are nitrogen dioxide, sulphur dioxide, carbon monoxide, lead, ozone, and particulate matter. Currently, it is assumed that none of the SWMUs or AOCs emit these compounds in regulated quantities and no air samples have been taken which would allow for a valid comparison.

- ***Water Quality Standards (WQS) -*** The WQS are the standards for surface water quality as established by the State of Oklahoma. These standards apply to point source discharges to surface waters and have been listed for those units adjacent to surface water.

Table 7-1 also gives a brief comparative evaluation of the data collected and the related action levels. The data for each detected compound are compared with the appropriate action level in order to identify those constituents (compounds) with concentrations exceeding the action levels. This identification of the compounds above the action levels provides an indication of a potential environmental problem at a specific site. In addition, this information indicates whether there is a need for conducting a CMS so that a corrective action can be implemented/undertaken at the site.

For constituents that have a SWMU CAL and an MCL for water, the MCL will be used for the comparison. Also, constituents that do not have a USGS background value will be compared to the site background value if available.

The data included in Table 7-1 are representative of the data presented in Chapter 5.0. For each soil boring, a range was identified and used in the comparison to the action levels. For the groundwater samples, the results for the most recent sampling event were included in Table 7-1.

Evaluation of the soil data for FTA1 shows lead and zinc to be above the USGS background concentrations. Several organics were detected above MCLs in the groundwater. These constituents are benzene, trichloroethene, vinyl chloride, methylene chloride, and cis-1,2-dichloroethene. Bis(2-ethylhexyl)phthalate, a semivolatile, was also detected above the MCL.

8.0 Summary and Conclusions

Past practices at FTA1 have resulted in contamination in the upper 15 feet of the soil and groundwater in the USZ, and possibly in the LSZ. Remedial investigations have been conducted as a part of the U.S. Air Force IRP to define the nature and extent of contamination.

FTA1 was used from 1950 to 1962 as a fire control training area. Fire fighting exercises consisted of either dousing an old aircraft carcass with flammable liquids, setting the carcass on fire, and then extinguishing the fire; or filling the area with flammable liquids, igniting the liquids, and then identifying the flammable liquids that were used.

FTA1 is located on the west side of Tinker AFB and is bounded by Crutcho Creek to the south, Patrol Road to the east, an old municipal sewage treatment plant site to the north, and Air Depot Boulevard to the west. The active fire training/burning area was circular-shaped with a diameter of approximately 125 feet.

8.1 Remedial Investigations, 1985-1990

In November 1985, the USACE initiated RIs at the site to define the extent of any possible contamination. The initial investigation was conducted in February 1987 and consisted of drilling three soil borings and installing two monitoring wells. In June and July 1987, five additional soil borings were drilled. Follow-up investigations were conducted in June and August 1989. In June 1989, 3 off-site soil borings and 12 on-site soil borings were drilled, while in August 4 soil borings were drilled.

In all, 27 soil borings were drilled and three monitoring wells installed. The soil borings were drilled at 24 on-site locations and 3 off-site locations. The off-site borings were drilled to establish background levels for contaminants detected in the soil. In addition, PVC well screens were placed in the soil borings to monitor groundwater levels and to allow collection of groundwater samples. Two monitoring wells were installed in the USZ, one upgradient and one downgradient of FTA1. The third monitoring well was installed in the LSZ as part of the Landfills 1 through 4 RIs. Soil and groundwater sampling was conducted throughout the investigation period.

Soil samples were analyzed for VOCs, SVOCs, metals, pH, TOC, and conductivity. All samples were not analyzed for all the parameters. Two VOCs (methylene chloride and acetone) were detected at significant levels. Bis(2-ethylhexyl)phthalate was the only significant SVOC detected. Two metals (lead and zinc) were detected above maximum background levels. TOC was found at above the background average in more than half the samples.

USZ groundwater samples were analyzed for VOCs, SVOCs, metals, pH, TOC, and conductivity. All samples were not analyzed for all parameters. Three VOCs (vinyl chloride, trichloroethene, and benzene) were found at concentrations above primary drinking water standard MCLs. Three VOCs (methylene chloride, tetrachloroethene, and trans-1,2-dichloroethene) were found at concentrations above proposed MCLs. Vinyl chloride, benzene, and tetrachloroethene, which were found in the groundwater, were not detected in any of the soil samples taken from FTA1. Bis(2-ethylhexyl)phthalate was the only SVOC found at significant concentrations. All the detected compounds were found in the upgradient and downgradient monitoring wells and in the borings. Three metals (barium, chromium, and lead) were found above MCLs and background averages both upgradient and downgradient of FTA1. TOC and conductivity were also found above background averages at the site.

At the time of the RI, the LSZ was not fully investigated in the vicinity of FTA1. Groundwater samples from the LSZ were only taken from MW-61B near FTA1. Trichloroethene was found above the MCL, and methylene chloride was found above the proposed MCL. Bis(2-ethylhexyl)phthalate was found in the samples. No metals were found above the MCLs or background averages for the LSZ. One sample had a pH value of 10.85, which is above the secondary MCL of 8.5.

8.2 Groundwater Characterization, 1992-1993

Groundwater samples were collected from the USZ from wells MW-61A (downgradient) and MW-62 (upgradient) in 1992 and 1993. All compounds detected in the downgradient well during the 1993 event were below MCLs. In the upgradient well, three VOCs exceeded MCLs during the 1992 event.

In the LSZ, well MW-61B (downgradient) was sampled in 1992. Three VOCs were detected above MCLs.

8.3 Baseline Risk Assessment/Potential Receptors

A baseline risk assessment was performed to estimate the potential impact of the site on public health and the environment. All of the chemicals except vinyl chloride were eliminated from further assessment as a carcinogenic agent. Three chemicals were determined to potentially cause chronic effects (1,2-DCE, 2-butanone, and 1,1,2-trichloroethane).

Total carcinogenic risk to the population with the greatest potential (children swimming or wading in the creek) is 6×10^{-6}, which is well within the range of acceptable risks as defined by the EPA under the NCP. The hazard from noncarcinogenic effects is also slight as shown by a hazard index of 0.06. Noncarcinogenic effects are generally deemed minimal if the hazard index is below 1.0.

Ecological risks were assessed for vegetation, earthworms, small mammals, and predatory birds from surface soil exposures. Bis(2-ethylhexyl)phthalate presented a potential risk to vegetation and zinc showed a small potential for effects on earthworms. The largest potential effect seen at the site was from small mammals exposed to lead. No increased risk was estimated for predatory birds or aquatic life.

9.0 Recommendations

The groundwater in the vicinity of the FTA1 should be further investigated during a Phase II RFI as a part of the basewide groundwater investigation. Additional monitoring wells should be added to the USZ and LSZ during this investigation to delineate the horizontal distribution of groundwater contaminants across this portion of the Base. Based on the location of this site, it will be more appropriate to investigate it as part of a group comprising several waste units in close proximity: RWDS 1030W, RWDS 1022E, RWDS 62598, Landfills 1 through 4, and the SP. Details of specific sampling needs will be presented in the work plan/sampling plan for the Phase II RFI.

Site soil samples should be collected and analyzed to further define extent of contamination. Additional soil samples will be taken if needed.

Site-specific soil background samples were not collected, nor were the soil background values available for inclusion in this Phase I RFI report. Therefore, it is recommended that site-specific soil samples from uncontaminated areas be collected for analysis during the Phase II RFI field work. This additional information along with the USGS background values should be used in the Phase II report to distinguish site-related from background concentrations in a statistically significant manner. During the development of the Phase II RFI work plan, the number of background samples to be collected, the location of the soil borings, and the soil analysis to be preformed on the samples should be determined for EPA approval before beginning the field work.

10.0 References

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Final Report
Phase I RCRA Facility Investigation for Appendix I Sites

VOLUME VIII

SWMU-11, Supernatant Pond

Department of the Air Force
Oklahoma City Air Logistics Center
Tinker Air Force Base, Oklahoma

September 1994

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List of Acronyms

AFB	Air Force Base
AOC	area of concern
CAL	corrective action levels
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Procedure
cm/s	centimeters per second
CMS	Corrective Measures Study
DERP	Defense Environmental Restoration Program
DOD	U.S. Department of Defense
EID	Engineering Installation Division
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
ft^2	square feet
FTA1	Fire Training Area 1
ft/ft	foot per foot
HI	hazard index
HSWA	Hazardous and Solid Waste Amendments
HQ	hazard quotient
IRP	Installation Restoration Program
IT	IT Corporation
LSZ	lower saturated zone
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
msl	mean sea level
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
PA/SI	preliminary assessment/site investigation
PCB	polychlorinated biphenyls

PCE	tetrachloroethene
pCi/L	picocuries per liter
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation/feasibility study
RFI	RCRA Facility Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SP	Supernatant Pond
SS	solidification/stabilization
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TCA	trichloroethane
TCE	trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TRPH	total recoverable petroleum hydrocarbons
TSD	treatment, storage, and disposal (facility)
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
USC	U.S. Code
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USZ	upper saturated zone
UWBZ	upper water bearing zone
VOC	volatile organic compounds
WQS	water quality standards
yd^3	cubic yards

Executive Summary

This report provides a summary of the various investigations that have been conducted at solid waste management unit (SWMU)-11, the Supernatant Pond (SP), Tinker Air Force Base (AFB), Oklahoma. The report has been prepared to determine and document whether sufficient investigations at the SP have been performed to meet regulatory requirements. Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. The Base encompasses approximately 5,000 acres.

Background. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon^{TM}, jet fuels, and radium paints.

In 1984, Congress amended the Resource Conservation and Recovery Act (RCRA) with the Hazardous and Solid Waste Amendments (HSWA), which allow EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989, Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit. The final RCRA HSWA permit issued on July 1, 1991, requires Tinker AFB to investigate all SWMUs and areas of concern (AOC) and to perform corrective action at those identified as posing a threat to human health of the environment. The permit specifies that a RCRA Facility Investigation (RFI) be conducted for 43 identified SWMUs and two AOCs on the Base. This document has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for the SP.

Source Description. The SP was used as an impoundment for sewage effluent between 1954 and about 1970. As-built drawings show the SP was connected by a 10-inch diameter sanitary sewer pipe to the sludge drying beds at a sewage treatment plant located approximately 800 feet northwest of the site. Use of the sewage treatment plant was discontinued in 1970. Base personnel continued to use the SP as a disposal site for liquid wastes generated from base operations until 1980. Reportedly, these wastes included petroleum hydrocarbon sludge, solvents, and cyanide-contaminated liquids. Between 1980 and 1984, the SP was used for disposal of construction rubble and dirt (USACE, 1994).

Site Investigations. The Tinker AFB IRP initiated investigations to determine the nature and extent of contamination at various sites on the base in the early 1980s. A Phase I records search was conducted by Engineering Science in 1981, followed by a Phase II confirmation/quantification conducted by Radian Corporation in 1983. However, the SP site had not been identified as a potential remediation site at the time of those Phase I and Phase II IRP investigations. The site was identified in 1986 during the course of interviews conducted with former and present base employees by the USACE as part of investigations of other known potential remediation sites. Site investigations were conducted at the SP at two different times: during the RI and during actual remediation of the site.

The results of soil sampling conducted during the RI indicated low to moderate concentrations of cyanide, metals, acetone, chlorobenzene, 4-chloroaniline, and bis(2-ethylhexyl)phthalate. These contaminants were indicated at significant concentrations only within the former pond itself at a depth of 4 to 7 feet. Results of groundwater sampling indicated that radiometrics, arsenic, cadmium, and lead occurred at concentrations slightly above background concentrations and drinking water standards in the upper saturated zone (USZ) within and immediately adjacent to the SP. Acetone, chlorobenzene, and bis(2-ethylhexyl)phthalate were also detected at low concentrations. In a downgradient well (MW-85A), these analytes were either at or below drinking water standards and background concentrations or were not detected.

A total of ten additional composite samples were taken from the site during remediation activities, which were completed in November 1992. Soil samples were collected from ground level to a total depth of 8 feet. The upper 4 feet of soil was removed from the pond and sampled and analyzed for TCLP parameters. The results of the analysis determined that the soil from this zone was clean; therefore, the soil was used as backfill. Samples collected from the pond area between 4 and 8 feet below ground level showed no concentrations of volatile organic compounds (VOC), semivolatile organic compounds (SVOC), herbicides, or pesticides that exceeded Toxicity Characteristic Leaching Procedure (TCLP) hazardous characteristics. Only two metals (arsenic and barium) were detected in the samples.

Groundwater collected from three new monitoring wells installed during remediation of the SP were analyzed for metals, VOCs, and SVOCs. The only contaminant found that was not also detected in laboratory blanks was chromium. It was present at a maximum concentration equal to its maximum contaminant level (MCL).

Baseline Risk Assessment/Potential Receptors. A human health risk assessment and ecological assessment was performed for the SP site (USACE, 1994). The only exposure route that was judged to be a complete pathway was inhalation of organic vapors originating from soil gas at the SP.

The results of the human health risk assessment showed that the total cancer risk was well below the range of EPA acceptable risks. The hazard index for noncarcinogenic risk was well below the target value of one. Exposure pathways for ecological receptors were considered incomplete; therefore, ecological risks were not quantified.

Conclusions. Based on the findings of the site RI and the risk assessment, it was determined that the site did not pose an immediate threat to human health or the environment. However, due to the detection of soil contaminants above background levels, the SP site was selected for demonstrating the innovative soil solidification/stabilization (SS) technology. The solidification of the soil provided the additional benefit of guaranteeing protection of human health and the environment.

Demonstration of the SS technology began in June 1992. The entire former pond area was excavated to a depth of 8 feet. The construction rubble encountered in the excavated soil was tested and disposed at an approved industrial landfill. The excavated soil was solidified with cement and placed back into the site excavation. The solidified soil was then covered with an additional 4 feet of clean backfill.

The remediation of the SP site was completed in November 1992. Since the completion of the project, the permanent on-site monitoring wells have been sampled during the annual basewide monitoring program. With the exception of isopropylbenzene, all chemicals detected were present in higher concentrations at upgradient well MW-62 than at any of the downgradient wells. None of the constituents detected directly underneath or downgradient of the site exceeded their MCLs.

Recommendations. The following activities should be conducted during a Phase II RFI for this site:

- Continue with annual monitoring of the groundwater beneath the site. Monitoring should include VOCs and metals.

- Collect additional soil samples to further complete the delineation and characterization of soil contamination.

- Collect site-specific soil background samples to be used in addition to USGS soil data to distinguish site-related from background concentrations in a statistically significant manner during the Phase II investigation.

- Prepare Phase II RFI work plan for submittal to EPA for approval before beginning field work.

- Include pertinent groundwater monitoring wells in the basewide groundwater investigation activity that will provide additional data for this site to determine the extent of contamination.

1.0 Introduction

1.1 Purpose and Scope

This document has been prepared in response to the U.S. Department of the Air Force, Tinker Air Force Base (AFB), Oklahoma request for a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Summary Report for solid waste management unit (SWMU)-11, the Supernatant Pond (SP).

The objective of this RFI Summary Report is to provide Tinker AFB with one comprehensive report that summarizes the various investigations that have occurred at the SP since the first environmental investigation was initiated on Base in 1981. The purpose of this comprehensive summary document is to:

- Characterize the site (Environmental Setting).
- Define the source (Source Characterization).
- Define the degree and extent of contamination (Contamination Characterization).
- Identify actual or potential receptors.
- Identify all action levels for the protection of human health and the environment.

Additionally, this document briefly describes the procedures, methods, and results of all previous investigations that relate to the SP and contaminant releases, including information on the type and extent of contamination at the site, and actual or potential receptors. Where previous investigations, reports, or studies were not comprehensive and did not furnish the information required to determine the nature and extent of contamination, future work that can be conducted to complete the investigation has been recommended.

1.2 Preface

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the cleanup of hazardous waste disposal sites across the country. CERCLA gave the president authority to require responsible parties to remediate the sites or to undertake response actions through use of a fund (the Superfund). The president, through Executive Order 12580, delegated the U.S. Environmental Protection Agency (EPA) with the responsibility to investigate and remediate private party hazardous waste disposal sites that created a threat to human health and the environment. The president delegated responsibility for investigation and cleanup of federal facility disposal sites to the various federal agency heads. The Defense Environmental Restoration Program (DERP) was formally established by Congress in Title 10 U.S. Code (USC) 2701-2707 and 2810. DERP provides

centralized management for the cleanup of U.S. Department of Defense (DOD) hazardous waste sites consistent with the provisions of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300), and Executive Order 12580. To support the goals of DERP, the Installation Restoration Program (IRP) was developed to identify, investigate, and clean up contamination at installations.

Under the Air Force IRP, Tinker AFB began a Phase I study similar to a preliminary assessment/site investigation (PA/SI) in 1981 (Engineering Science [ES], 1982). This study helped locate 14 sites that needed further investigation. A Phase II study was performed in 1983 (Radian Corporation [Radian], 1985 a,b).

In 1986, Congress amended CERCLA through the SARA. SARA waived sovereign immunity for federal facilities. This act gave EPA authority to oversee the cleanup of federal facilities and to have the final authority for selecting the remedial action at federal facilities placed on the National Priorities List (NPL) if the EPA and the relevant federal agency cannot concur in the selection. Congress also codified DERP (SARA Section 211), establishing a fund for the DOD to remediate its sites because the Superfund is not available for the cleanup of federal facilities. DERP specifies the type of cleanup responses that the fund can be used to address.

In response to SARA, the DOD realigned its IRP to follow the investigation and cleanup stages of the EPA:

- PA/SI
- Remedial investigation/feasibility study (RI/FS)
- Record of Decision (ROD) for selection of a remedial action
- Remedial design/remedial action.

In 1984, Congress amended RCRA with the Hazardous and Solid Waste Amendments (HSWA), which allow the EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989 Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit.

EPA, in the Hazardous Waste Management Permit for Tinker AFB, dated July 1, 1991, identified 43 SWMUs and two areas of concern (AOC) on Tinker AFB that need to be addressed. This permit requires Tinker AFB to investigate all SWMUs and AOCs and to perform corrective action at those identified as posing a threat to human health or the environment. This RFI Summary Report has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for the SP and to document all determinations.

1.3 Facility Description

Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County (Figure 1-1) with its approximate geographic center located at 35° 25' latitude and 97° 24' longitude (U.S. Geological Survey [USGS], 1978). The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south (Figure 1-2). An additional area east of the main Base is used by the Engineering Installation Division (EID) and is known as Area D. The Base encompasses approximately 5,000 acres. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints. Wastes that are currently generated are managed at two permitted hazardous waste storage facilities. However, prior to enactment of RCRA, industrial wastes were discharged into unlined landfills and waste pits, streams, sewers, and ponds. Past releases from these landfills, pits, etc., as well as from underground tanks, have occurred. As a result, there are numerous sites of soil, groundwater, and surface water contamination on the Base.

The various reports generated as a result of investigative activities conducted at the SP have been reviewed and evaluated in terms of the sites' status under RCRA regulations. A summary based on the review of these reports for the SP is presented in the following chapters and sections. In addition, recommendations for additional work is given at the end of the summary report.

1.4 Site Description

The SP is located on the west side of Tinker AFB, east of and adjacent to Patrol Road and approximately 200 feet north of the northwest-flowing Crutcho Creek (Figure 1-3). The site

STARTING DATE: 03/17/94 | DATE LAST REV.: | DRAFT. CHCK. BY:G. PACHECO | INITIATOR: C. WALLACE | DWG. NO.:
DRAWN BY:P.O. TERRY | DRAWN BY: | ENGR. CHCK. BY: C. WALLACE | PROJ. MGR.:J. TAYLOR | PROJ. NO.:

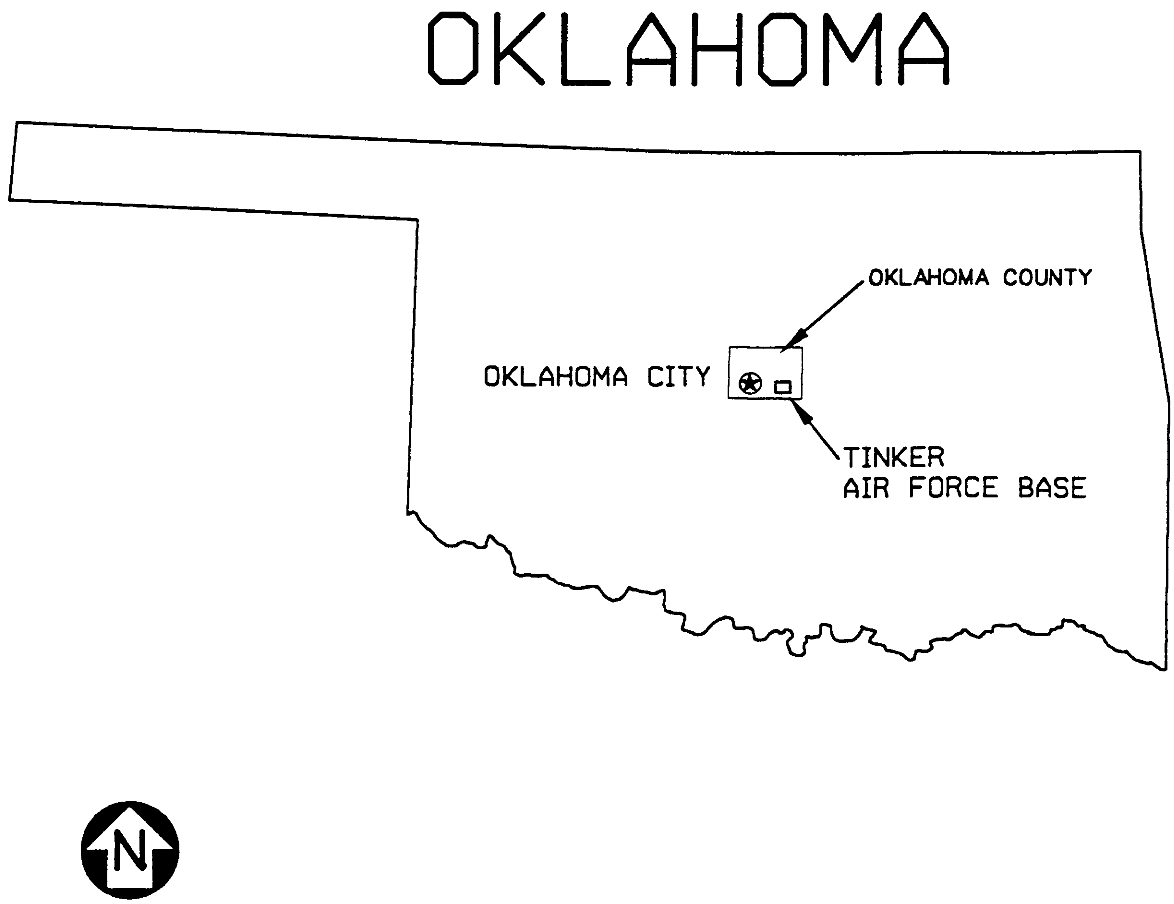

FIGURE 1-1
TINKER AIR FORCE BASE
OKLAHOMA
STATE INDEX MAP

PREPARED FOR
TINKER AFB
OKLAHOMA

3/23/94 POT
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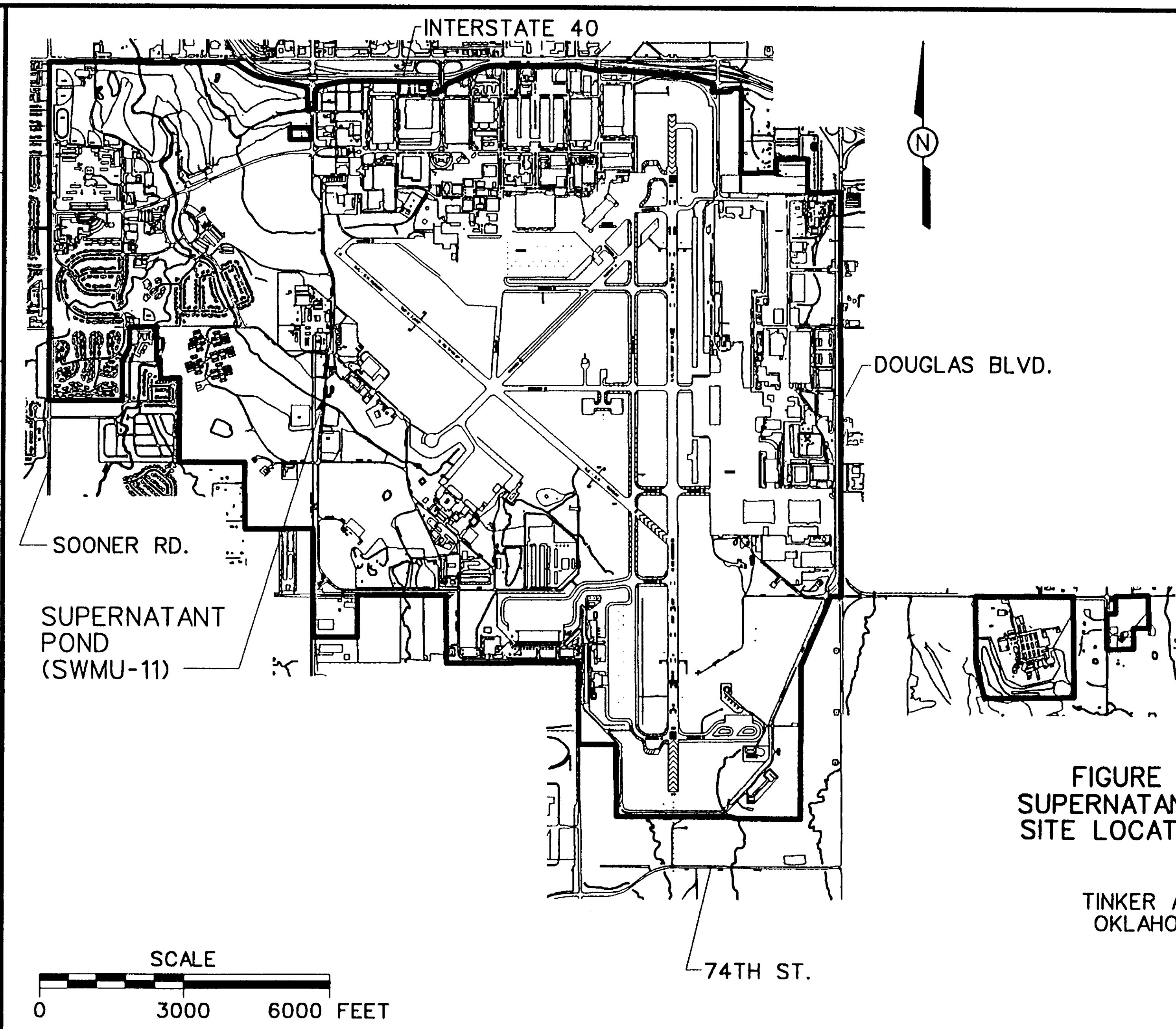
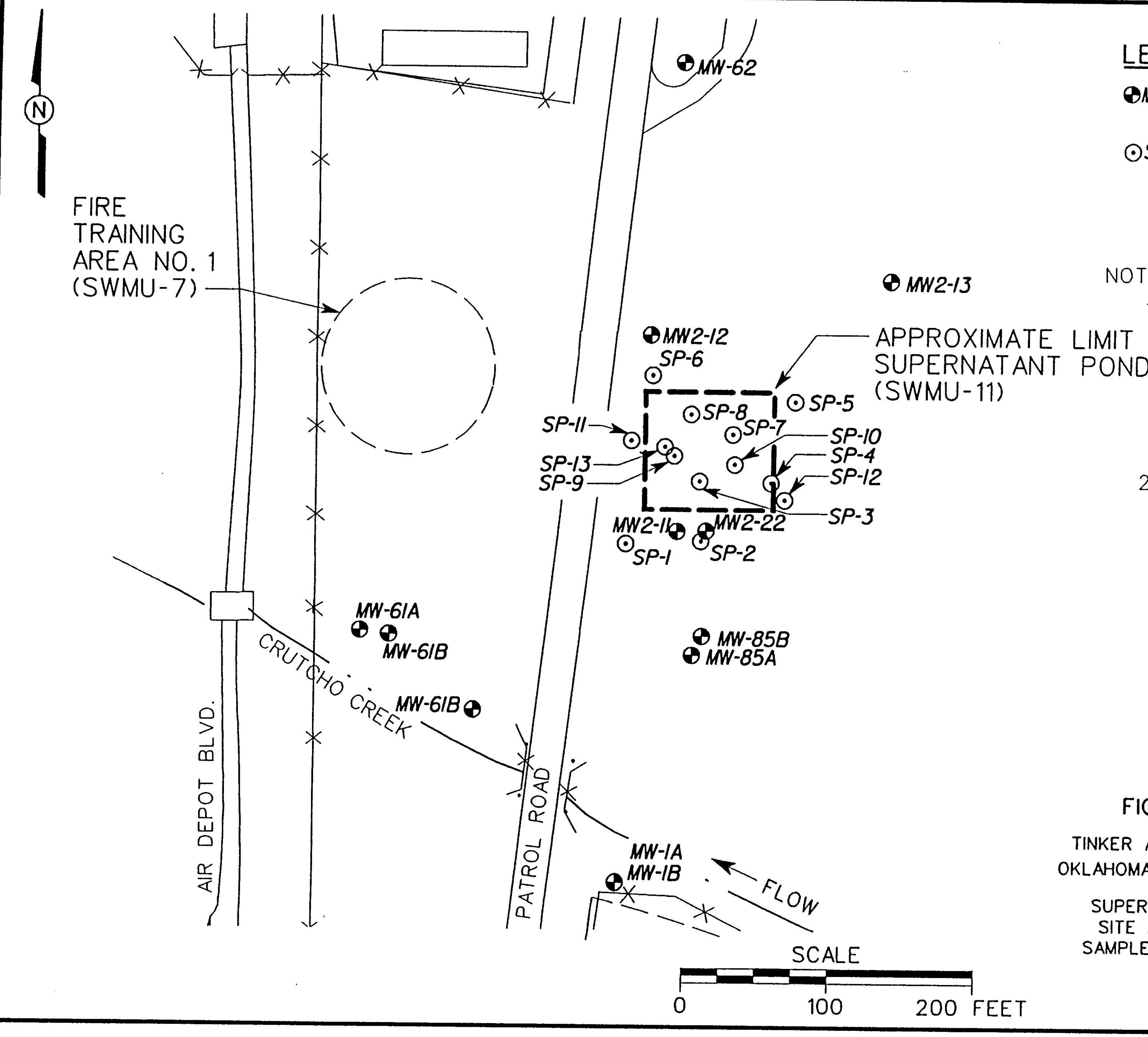


FIGURE 1-2
SUPERNATANT POND
SITE LOCATION MAP

TINKER AFB
OKLAHOMA

DRAWN BY: P.O. TERRY	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J. TAYLOR	PROJ. NO.:
STARTING DATE: 3/21/94	DATE LAST REV.:	DRAFT. CHCK. BY: G. PACHECO	INITIATOR: C. WALLACE	DWG. NO.:

FILENAME: G:\TINKER\40983202.085



LEGEND:

- MW-62 MONITORING WELL
- SP-6 SOIL BORING/ 2-INCH PIEZOMETER

NOTES:

1. BASE WATER SUPPLY WELL NO. 7 IS LOCATED APPROX. 500 FEET NORTH OF THE SUPERNATANT POND.
2. SEE RFI REPORT FOR FIRE TRAINING AREA NO. FTA-1 FOR LOCATIONS OF MONITORING WELLS NEAR FTA-1.

FIGURE 1-3

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

SUPERNATANT POND
SITE LOCATION AND
SAMPLE LOCATION MAP

STARTING DATE: 01/15/94	DATE LAST REV.:09/08/94	DRAFT. CHCK. BY:G. PACHECO	INITIATOR:C. WALLACE	DWG. NO.:40983202.015
DRAWN BY:P. TERRY	DRAWN BY:P. TERRY	ENGR. CHCK. BY: C. WALLACE	PROJ. MGR.: J. TAYLOR	PROJ. NO.:409832

08/25/94 POT
FILENAME:C:\TINKER\40983202.015

is directly east of Fire Training Area 1 (FTA1) (SWMU-7), which is also undergoing an RI. The SP site is an area of approximately 25,000 square feet (ft^2) (0.6 acres). The former pond covered an area of approximately 6,400 ft^2 (0.15 acres). A shallow ditch runs along the east side of the site and terminates in the creek south of the site. North of the site, this ditch parallels Patrol Road. The site supports growth of grass and is kept mowed. No evidence of previous activity is apparent on the surface (U.S. Army Corps of Engineers [USACE], 1991a).

2.0 Background

2.1 Site Operations and History

Tinker AFB was originally known as the Midwest Air Depot and began operations in July 1941. The site was activated March 1942. During World War II, the depot was responsible for reconditioning, modifying, and modernizing aircraft, vehicles, and equipment.

The SP is located on the west side of Tinker AFB, east of and adjacent to Patrol Road and approximately 200 feet north of the northwest-flowing Crutcho Creek. The SP appears on Tinker AFB maps as early as 1954. The former pond covered an area of approximately 6,400 ft^2 and is described by former and current Tinker AFB employees as "resembling a swimming pool." This structure was unlined (Tinker, 1992).

The SP was used as an impoundment for sewage effluent between 1954 and about 1970. As-built drawings show the SP was connected by a 10-inch diameter sanitary sewer pipe to the sludge drying beds at a sewage treatment plant located approximately 800 feet northwest of the site. Use of the sewage treatment plant was discontinued in 1970. Base personnel continued to use the SP as a disposal site for liquid wastes generated from base operations until 1980. Reportedly, these wastes included petroleum hydrocarbon sludge, solvents, and cyanide-contaminated liquids. Between 1980 and 1984, the SP was used for disposal of construction rubble and dirt (USACE, 1994).

During its period of operation, the SP was periodically subject to overflow during heavy rainfalls. The overflow entered a tributary just southeast of the site and flowed into Crutcho Creek (USACE, 1994).

When the pond ceased to be used as a disposal site in 1980, soil fill was placed in the depression. This fill was subject to significant settling and would not support growth of vegetation. Subsequently, construction rubble, consisting of asphalt, concrete, plastic pipe, etc., was placed in the pond followed by a layer of soil fill to maintain grass over the site. Approximately 300 cubic yards (yd^3) of construction material was used as backfill when the SP was removed from use (Tinker, 1992).

The SP was remediated in October 1992 using stabilization/solidification (SS) technology, which effectively locks contamination into a cement matrix. Because analysis of soil samples beneath the pond indicated no hazardous constituents, the project was more a demonstration of methodology than mitigation of environmental threat. Monitoring wells were also installed at the site and will be sampled on an annual basis (Tinker, 1992).

2.2 Summary of Previous Investigations

The Tinker AFB IRP initiated investigations to determine the nature and extent of contamination at various sites on the base in the early 1980s. A Phase I records search was conducted by ES in 1981, followed by a Phase II confirmation/quantification conducted by Radian in 1983. However, the SP had not yet been identified as a potential remediation site at the time of the Phase I and Phase II IRP investigations. The SP was identified in 1986 during the course of interviews conducted with former and present base employees by the USACE as part of investigations of other known potential remediation sites (USACE, 1991b). Site investigations were conducted at the SP at two different times, during the RI and during actual remediation of the site.

2.2.1 Remedial Investigation

An RI was conducted by the USACE at the SP from July 1989 to July 1990. The RI included a soil-gas survey with collection and analysis of 22 samples; drilling of 13 soil borings which were completed as shallow piezometers in the first water-bearing zone encountered; collection and analysis of seven soil samples; installation of two wells in the upper saturated zone (USZ) and lower saturated zone (LSZ); and sampling of the wells and piezometers in October/November 1989 and May 1990. The final RI report was published in October 1991 (USACE, 1991a).

The pond was found to overlie the Hennessey Formation (shale interbedded with siltstone and sandstone). Drilling showed that the former pond area was underlain by 5 to 7 feet of fill (clay, silt, sand, and construction debris), followed by clay and weathered shale to 15 feet, sandstone to 32 feet, shale between 32 and 55 feet, and sandstone below 55 feet. The upper sandstone and overlying weathered shale/clay fill are considered to comprise the USZ, formerly known as the perched aquifer. The lower sandstone comprises the uppermost portion of the LSZ, formerly designated as the top of regional aquifer.

The USZ water table was found to be mounded under the pond. Overall flow in the USZ was found to be to the south-southwest toward Crutcho Creek. The gradient in the LSZ was determined to be northward, based on three wells. However, based on a current data, the LSZ gradient is to the south-southeast.

Soil Gas. A soil gas survey was conducted to allow a preliminary screening of the site for the presence of volatile organic compounds (VOC) in the vadose zone. The soil gas survey indicated very low concentrations of 1,1,1-trichloroethane (TCA), tetrachloroethene (PCE), and total hydrocarbons at several of the 22 sample locations within and adjacent to the SP. The results are presented in Section 5.1. Subsequent soil and groundwater sampling and analysis did not detect the presence of TCA and PCE at the locations sampled during the soil gas survey. The RI concluded that the low levels of soil gas contaminants were not indicative of subsurface contamination.

Soils. Seven soil borings collected at the SP were analyzed for metals, pH, polychlorinated biphenyls (PCB), total recoverable petroleum hydrocarbons (TRPH), cyanide, VOCs, and semivolatile organic compounds (SVOC). The results are presented in Section 5.2. The RI concluded that contamination was present in the soil at a depth of 4 to 7 feet within the boundaries of the SP. Groundwater sampling from piezometers within and adjacent to the site indicated that leaching of contaminants was not significant. In addition, the RI concluded that the fill (including construction debris) that was present above the depth of 4 feet was not contaminated.

Groundwater. Three aquifer zones are identified at the SP. In the uppermost zone (USZ), the groundwater flows southwest toward the tributary of Crutcho Creek. The upper part of this shallow aquifer zone consists of a weathered clay, while the lower part is a sandstone. The second zone is the LSZ, which begins at a depth of about 55 feet below ground surface at the site and is thought to extend to approximately 250 feet. Water level data from wells representative of this zone indicate that the groundwater flows south-southeast in the LSZ. Below this is the third zone, known as the producing zone, which extends to a depth of at least 600 feet. This zone produces much of Tinker's water supply.

Groundwater from the USZ at the SP exhibited concentrations slightly above background levels of total organic carbon (TOC), radiometrics, and metals. Very low levels of VOCs and SVOCs were indicated in groundwater sampled from piezometers in and adjacent to the SP. Results of the groundwater sampling effort are presented in Section 5.3. Analyses of groundwater sampled from a downgradient well (MW-85A) did not indicate concentrations of TOC, radiometrics, or metals in excess of background levels or drinking water standards. VOCs and SVOCs were not indicated above detection limits in MW-85A. It was concluded that because MW-85A is downgradient from the SP, transport of groundwater contaminants in the USZ had either not occurred or had been very limited. Migration of contaminants was not anticipated to be significant in the future because only low levels of contaminants had been detected in groundwater in and adjacent to the SP.

Water quality in the LSZ was not fully assessed in the investigation because only one well near the site was screened in that zone. However, it should be noted that sampling of this well showed radionuclide and metals concentrations exceeding drinking water standards (Tinker, 1992).

Conclusions. The RI report concluded that the SP did not pose a hazard to health or the environment at that time. The report recommended that a risk assessment be conducted to determine if future risks may exist in the absence of remedial action. The report also recommended that a feasibility study be performed to evaluate remedial alternatives for the contaminated soil (Tinker, 1992).

2.2.2 Remediation

During the SP remediation, which was completed in November 1992, additional soil and groundwater samples were collected and analyzed. Findings of the results are presented in the following paragraphs. A summary of the remediation activities is presented in Section 2.3.

Soils. A total of ten composite samples were taken from the site during remediation. The samples were taken from ground level to a total depth of 8 feet. These ten composite samples were analyzed by the Toxicity Characteristic Leachate Procedure (TCLP) method to characterize the hazardous constituents that might have existed in the soil matrix. TCLP results indicated that there were no hazardous constituents in the soil.

Groundwater. Three new monitoring wells (one in the USZ and two in the LSZ) were installed at the SP during remediation (MW2-11, MW2-12, and MW2-13). Groundwater collected from the wells was analyzed for metals, VOCs, and SVOCs. Methylene chloride and bis(2-ethylhexyl)phthalate were detected in all the groundwater samples. Both methylene chloride and bis(2-ethylhexyl) phthalate were detected in the laboratory blanks and can be attributed to laboratory contamination. Chromium was found in the LSZ at the current maximum contaminant level (MCL) (Tinker, 1992).

Conclusions. During remediation of this site, no significant contamination was found; therefore, it was concluded that there was no threat to human health and the environment.

Field activities and detailed analyses confirmed that no contamination remained at the SP (Tinker, 1992).

2.3 Remediation Activities

Remediation and sampling activities at the SP took place in 1992 upon completion of the RI and is summarized in the following paragraphs (Tinker, 1993a).

Based on the findings of the site RI and the risk assessment (USACE, 1994), it was determined that the SP did not pose an immediate threat to human health or the environment. However, because soil contaminants were detected in excess of background and due to the limited size of the site and extent of contamination, this site was selected for demonstrating the innovative technology of soil SS. In addition, the solidification of the soil at the site guaranteed protection of human health and the environment, while demonstrating the effectiveness and applicability of this technology to similar sites.

Demonstration of the SS technology began in June 1992. The entire former pond area (70 by 90 feet) was excavated to a depth of 8 feet. Initially, the upper 4.0 feet was excavated and the construction rubble was removed. Then the lower 4.0 feet of soil was excavated and SS was employed to "lock" any potential contaminants into the cement matrix.

The upper 4 feet (940 yd^3) of soil and construction debris were removed using a backhoe and front-end loader. Approximately 260 yd^3 of construction debris was segregated from the soil using a shaker screen. Debris was than placed in roll-off boxes for disposal at an approved landfill. The remaining 680 yd^3 of soil was covered with visqueen to prevent contaminant migration. Five composite soil samples were collected and analyzed for full TCLP parameters. The results of the TCLP analysis of the soil were used to characterize the construction debris removed from the former pond for disposal. Based on the analyses, the construction debris was disposed at an approved industrial landfill.

The remaining 4.0 feet of soil, approximately 940 yd^3, was excavated and covered by visqueen to limit or eliminate any potential contamination from migration due to the percolation of rainwater. The excavated soils (lower than 4.0 feet) were then solidified with portland cement and fly ash using a Bovine rotary mixer, at a ratio of 250 pounds of portland cement and 40 pounds of fly ash per cubic yard of soil. Stockpiled soils were placed in 8- to 9-inch loose lifts, compacted to at least 92 percent Standard Proctor with a vibrating sheep's foot compactor. This procedure was continued until the fill level in the excavated pit had returned to the 4-foot mark. Following a 7-day curing period, approximately 1,700 yd^3 of backfill was placed in 12-inch loose lifts over the solidified material and packed with a bulldozer. The excavated soils were sampled prior to the solidification process. The five soil samples collected were analyzed for TCLP parameters; the results are discussed in Section 5.2.

2.3.1 Quality Assurance During Remediation Activities

The analytical laboratories were all required to possess Contract Laboratory Procedures (CLP) certification. During the SS process, a sample of the material to be compacted was collected and analyzed to assist in determining the necessary moisture content for optimum compaction. Two density tests were performed on the first compaction lift to ensure that no groundwater could infiltrate from the bottom of the pond. Nuclear density tests were performed following the compaction of every other lift. The average Standard Proctor compaction was 98.4 percent, approximately 6.4 percent higher than the specified 92 percent.

2.3.2 Operation and Maintenance

No operation and maintenance is required for the SP site. Long-term monitoring of the groundwater beneath the site will be continued until such time as the sampling indicates that there is no threat to human health or the environment. The groundwater will also be monitored for pH, calcium, and other chemical parameters that would indicate that the solidification of the soils was degrading. Should the concentrations of these parameters increase, the data and site specific conditions will be evaluated to determine what actions are required.

2.4 Current Regulatory Status

The IRP has been ongoing at Tinker AFB since the early 1980s. IRP studies on the Base were conducted according to IRP guidance, which is essentially the same as EPA's guidance for conducting RI/FS under CERCLA. All investigation and removal actions have been closely monitored and approved by the EPA.

Since receiving the Hazardous Waste Management Permit on July 1, 1991, many of the IRP sites have come under the jurisdiction of the RCRA permits branch of EPA. As such, they have been identified as SWMUs; however, a large amount of work has already been performed at most of these sites under the IRP. Additional investigation at the SWMUs will be performed under the IRP.

3.0 Environmental Setting

3.1 Topography and Drainage

3.1.1 Topography

Regional/Tinker AFB. The topography of Oklahoma City and surrounding area varies from generally level to gently rolling in appearance. Local relief is primarily the result of dissection by erosional activity or stream channel development. At Oklahoma City, surface elevations are typically in the range of 1,070 to 1,400 feet mean sea level (msl). At Tinker AFB, ground surface elevations vary from 1,190 feet msl near the northwest corner where Crutcho Creek intersects the Base boundary to approximately 1,320 feet msl at Area D (EID).

Site. The SP site is an area of approximately 25,000 ft^2. The site is located on the west side of Tinker AFB next to Patrol Road and Crutcho Creek. The land at the site is generally flat. The ground elevation of the site is approximately 1220 feet msl. The site supports growth of grass and is kept mowed. No evidence of previous activity is apparent on the surface (USACE, 1991a).

3.1.2 Surface Drainage

Regional/Tinker AFB. Drainage of Tinker AFB land areas is accomplished by overland flow of runoff to diversion structures and then to area surface streams, which flow intermittently. The northeast portion of the Base is drained primarily by unnamed tributaries of Soldier Creek, which is itself a tributary of Crutcho Creek. The north and west sections of the Base, including the main instrument runway, drain to Crutcho Creek, a tributary of the North Canadian River. Two small unnamed intermittent streams crossing installation boundaries south of the main instrument runway generally do not receive significant quantities of Base runoff due to site grading designed to preclude such drainage. These streams, when flowing, extend to Stanley Draper Lake, approximately one-half mile south of the Base.

Site. The SP site is approximately 200 feet north of the northwest-flowing Crutcho Creek. The area in the vicinity of the SP is generally flat. A shallow ditch runs along the east side of the site and terminates in the creek south of the site. North of the site, this ditch parallels Patrol road. Excess surface water from the site may drain into the ditch and/or Crutcho

Creek. During its period of operation, the pond would periodically overflow during heavy rainfalls; the overflow would then enter Crutcho Creek.

3.2 Geology

3.2.1 Regional/Tinker AFB Geology

Tinker AFB is located within the Central Redbed Plain Section of the Central Lowland physiographic province, which is tectonically stable. No major fault or fracture zones have been mapped near Tinker AFB. The major lithologic units in the area of the Base are relatively flat-lying and have a regional westward dip of about 0.0076 foot per foot (ft/ft) (Bingham and Moore, 1975).

Geologic formations that underlie Tinker AFB include, from oldest to youngest, the Wellington Formation, Garber Sandstone, and the Hennessey Group; all are Permian in age.

All geologic units immediately underlying Tinker AFB are sedimentary in origin. The Garber Sandstone and Wellington Formation are commonly referred to as the Garber-Wellington Formation due to strong lithologic similarities. These formations are characterized by fine-grained, calcareously-cemented sandstones interbedded with shale. The Hennessey Group consists of the Fairmont Shale and the Kingman Siltstone. It overlies the Garber-Wellington Formation along the eastern portion of Cleveland and Oklahoma counties. Quaternary alluvium is found in many undisturbed streambeds and channels located within the area.

Stratigraphy. Tinker AFB lies atop a sedimentary rock column composed of strata that ranges in age from Cambrian to Permian above a Precambrian igneous basement. Quaternary alluvium and terrace deposits can be found overlying bedrock in and near present-day stream valleys. At Tinker AFB, Quaternary deposits consist of unconsolidated weathered bedrock, fill material, wind-blown sand, and interfingering lenses of sand, silt, clay, and gravel of fluvial origin. The terrace deposits are exposed where stream valleys have downcut through older strata and have left them topographically above present-day deposits. Alluvial sediments range in thickness from less than a foot to nearly 20 feet.

Subsurface (bedrock) geologic units which outcrop at Tinker AFB and are important to understanding groundwater and contaminant concerns at the Base consist of, in descending order, the Hennessey Group, the Garber Sandstone, and the Wellington Formation (Table 3-1).

Table 3-1

Major Geologic Units in the Vicinity of Tinker AFB (Modified from Wood and Burton, 1968)

(Page 1 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
QUATERNARY	PLEISTOCENE AND RECENT	Alluvium	0-70	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel in the flood plains and channels of stream	Moderately permeable. Yields small to moderate quantities of water in valleys of larger streams. Water is very hard, but suitable for most uses, unless contaminated by industrial wastes or oil field brines.
		Terrace deposits	0-100	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the flood plains of the principal streams.	Moderately permeable. Locally above the water table and not saturated. Where deposits have sufficient saturated thickness, they are capable of yielding moderate quantities of water to wells. Water is moderately hard to very hard, but less mineralized than water in other aquifers. Suitable for most uses unless contaminated by oil field brines.

Table 3-1

(Page 2 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
PERMIAN	LOWER PERMIAN	Hennessey Group (includes Kingman Siltstone and Fairmont Shale)	700	Deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy or limey shale. Forms relatively flat to gently rolling grass-covered prairie.	Poorly permeable. Yields meager quantities or very hard, moderately to highly mineralized water to shallow domestic and stock wells. In places water contains large amounts of sulfate.
		Garber Sandstone	500±	Deep-red clay to reddish-orange, massive and cross-bedded fine-grained sandstone interbedded and interfingered with red shale and siltstone	Poorly to moderately permeable. Important source of groundwater in Cleveland and Oklahoma counties. Yields small to moderate quantities of water to deep wells; heavily pumped for industrial and municipal uses in the Norman and Midwest City areas. Water from shallow wells hard to very hard; water from deep wells moderately hard to soft. Lower part contains water too salty for domestic and most industrial uses.
		Wellington Formation	500±	Deep-red to reddish-orange massive and cross-bedded fine-grained sandstone interbedded with red, purple, maroon, and gray shale. Base of formation not exposed in the area.	

These bedrock units were deposited during the Permian Age (230 to 280 million years ago) and are typical of redbed deposits formed during that period. They are composed of a conformable sequence of sandstones, siltstones, and shales. Individual beds are lenticular and vary in thickness over short horizontal distances. Because lithologies are similar and because of a lack of fossils or key beds, the Garber Sandstone and the Wellington Formation are difficult to distinguish and are often informally lumped together as the Garber-Wellington Formation. Together, they are about 900 feet thick at Tinker AFB. The interconnected, lenticular nature of sandstones within the sequence forms complex pathways for groundwater movement.

The surficial geology of the north section of the Base is dominated by the Garber Sandstone, which outcrops across a board area of Oklahoma County. Generally, the Garber outcrop is covered by a veneer of soil and/or alluvium up to 20 feet thick. To the south, the Garber Sandstone is overlain by outcropping strata of the Hennessey Group, including the Kingman Siltstone and the Fairmont Shale (Bingham and Moore, 1975). Drilling information obtained as a result of geotechnical investigations and monitoring well installation confirms the presence of these units.

Depositional Environment. The Permian-age strata presently exposed at the surface in central Oklahoma were deposited along a low-lying north-south oriented coastline. Land features included meandering to braided sediment-loaded streams that flowed generally westward from highlands to the east (ancestral Ozarks). Sand dunes were common, as were cut-off stream segments that rapidly evaporated. The climate was arid and vegetation sparse. Off shore the sea was shallow and deepened gradually to the west. The shoreline's position varied over a wide range. Isolated evaporitic basins frequently formed as the shoreline shifted.

Across Oklahoma, this depositional environment resulted in an interfingering collage of fluviatile and wind-blown sands, clays, shallow marine shales, and evaporite deposits. The overloaded streams and evaporitic basins acted as sumps for heavy metals such as iron, chromium, lead, and barium. Oxidation of iron in the arid climate resulted in the reddish color of many of the sediments. Erosion and chemical breakdown of granitic rocks from the highlands resulted in extensive clay deposits. Evaporite minerals such as anhydrite ($CaSO_4$), barite ($BaSO_4$), and gypsum ($CaSO_4 \cdot 2H_2O$) are common.

Around Tinker AFB, the Hennessey Group represents deposition in a tidal flat environment cut by shallow, narrow channels. The Hennessey Group is comprised predominantly of red shales which contain thin beds of sandstone (less than 10 feet thick) and siltstone. In outcrop, "mudball" conglomerates, burrow surfaces, and dessication cracks are recognized. These units outcrop over roughly the southern half of the Base, thickening to approximately 70 feet in the southwest from their erosional edge (zero thickness) across the central part of Tinker AFB.

In contrast, the Garber Sandstone and the Wellington Formation around Tinker AFB consist of an irregularly-interbedded system of lenticular sandstones, siltstones, and shales deposited either in meandering streams in the upper reaches of a delta or in a braided stream environment. Outcrop units north of Tinker AFB exhibit many small to medium channels with cut and fill geometries consistent with a stream setting. Sandstones are typically cross-bedded. Individual beds range in thickness from a few inches to approximately 50 feet and appear massive, but thicker units are often formed from a series of "stacked" thinner beds. Geophysical and lithologic well logs indicate that from 65 to 75 percent of the Garber Sandstone and the Wellington Formation are composed of sandstone at Tinker AFB. The percentage of sandstone in the section decreases to the north, south, and west of the Base. These sandstones are typically fine to very fine grained, friable, and poorly cemented. However, where sandstone is cemented by red muds or by secondary carbonate or iron cements, local thin "hard" intervals exist along disconformities at the base of sandstone beds. Shales are described as ranging from clayey to sandy, are generally discontinuous, and range in thickness from a few inches to approximately 40 feet.

Stratigraphic Correlation. Correlation of geologic units is difficult due to the discontinuous nature of the sandstone and shale beds. However, cross-sections (Figure 3-1) demonstrate that two stratigraphic intervals can be correlated over large sections of the Base in the conceptual model. These intervals are represented on geologic cross-sections A-A' and B-B' (Figures 3-2 and 3-3). Section A-A' is roughly a dip section and B-B' is approximately a strike section. The first correlatable interval is marked by the base of the Hennessey Group and the first sandstone at the top of the Garber Sandstone. This interval is mappable over the southern half of Tinker AFB. The second interval consists of a shale zone within the Garber Sandstone which, in places, is comprised of a single shale layer and, in other places, of multiple shale layers. This interval is more continuous than other shale intervals and in cross-sections appears mappable over a large part of the Base. It is extrapolated under the central portion of Tinker AFB where little well controls exists.

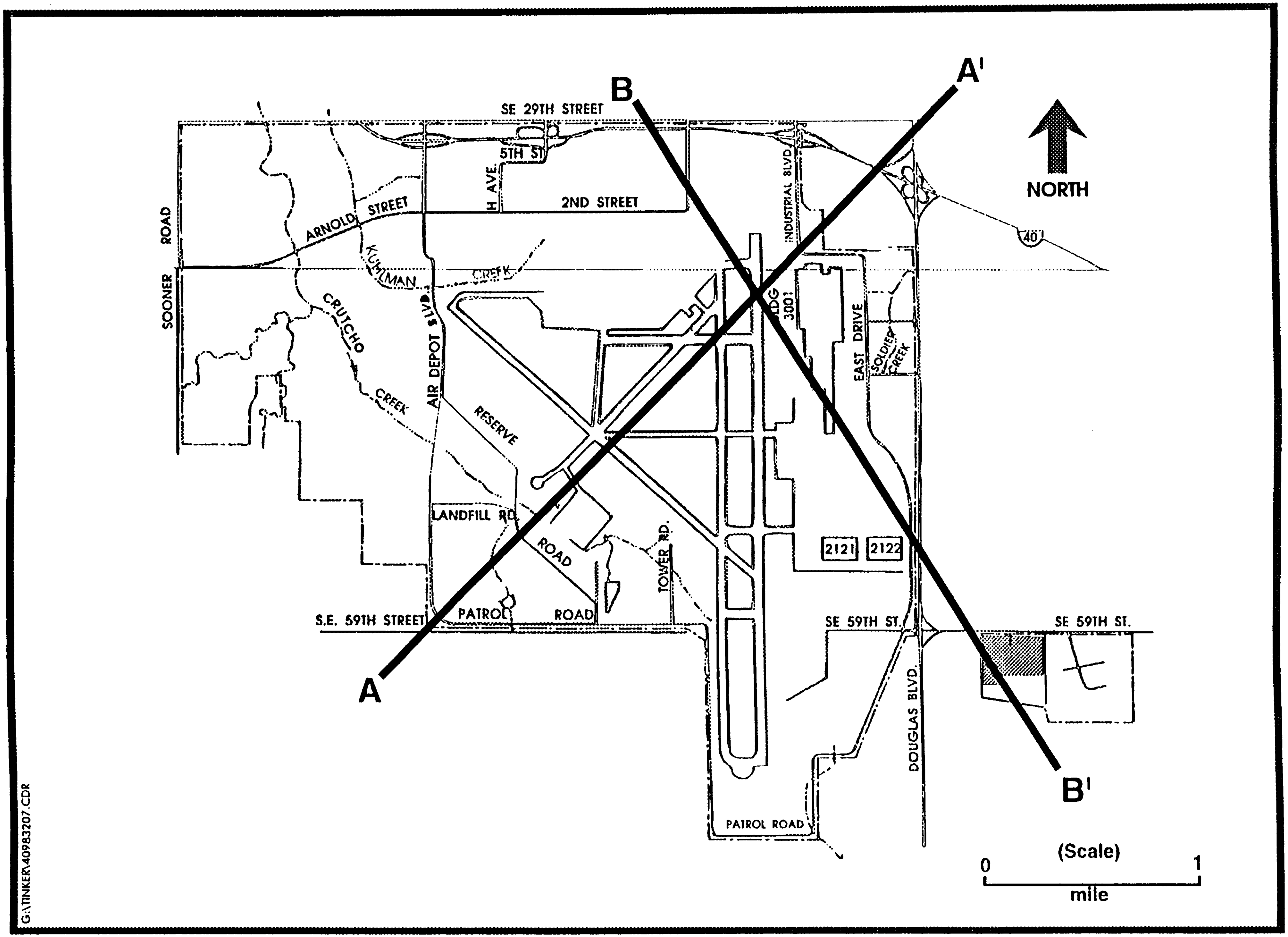


FIGURE 3-1 TINKER AFB GEOLOGIC CROSS SECTION LOCATION MAP

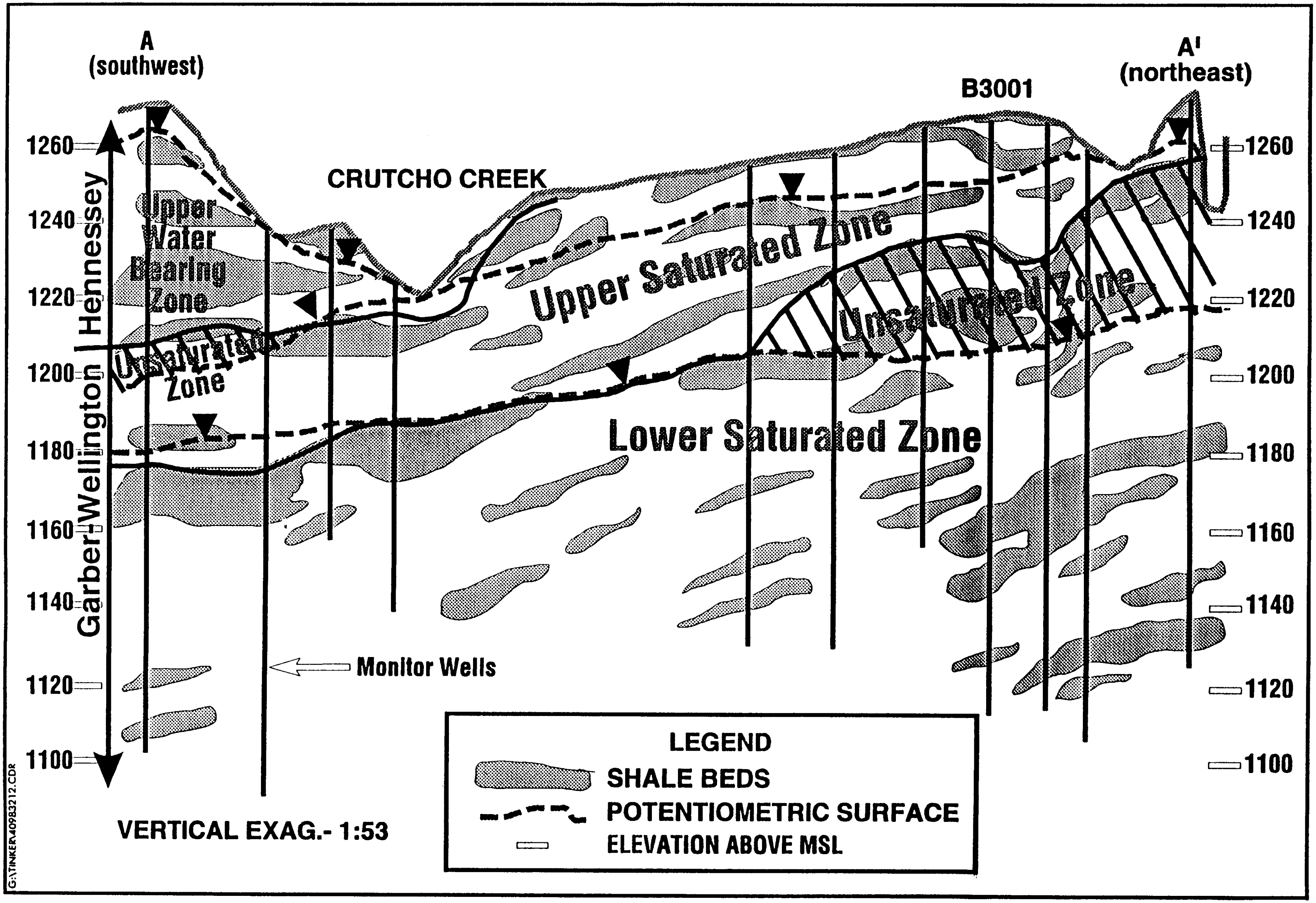


FIGURE 3-2 TINKER AFB GEOLOGIC CROSS SECTION A-A'

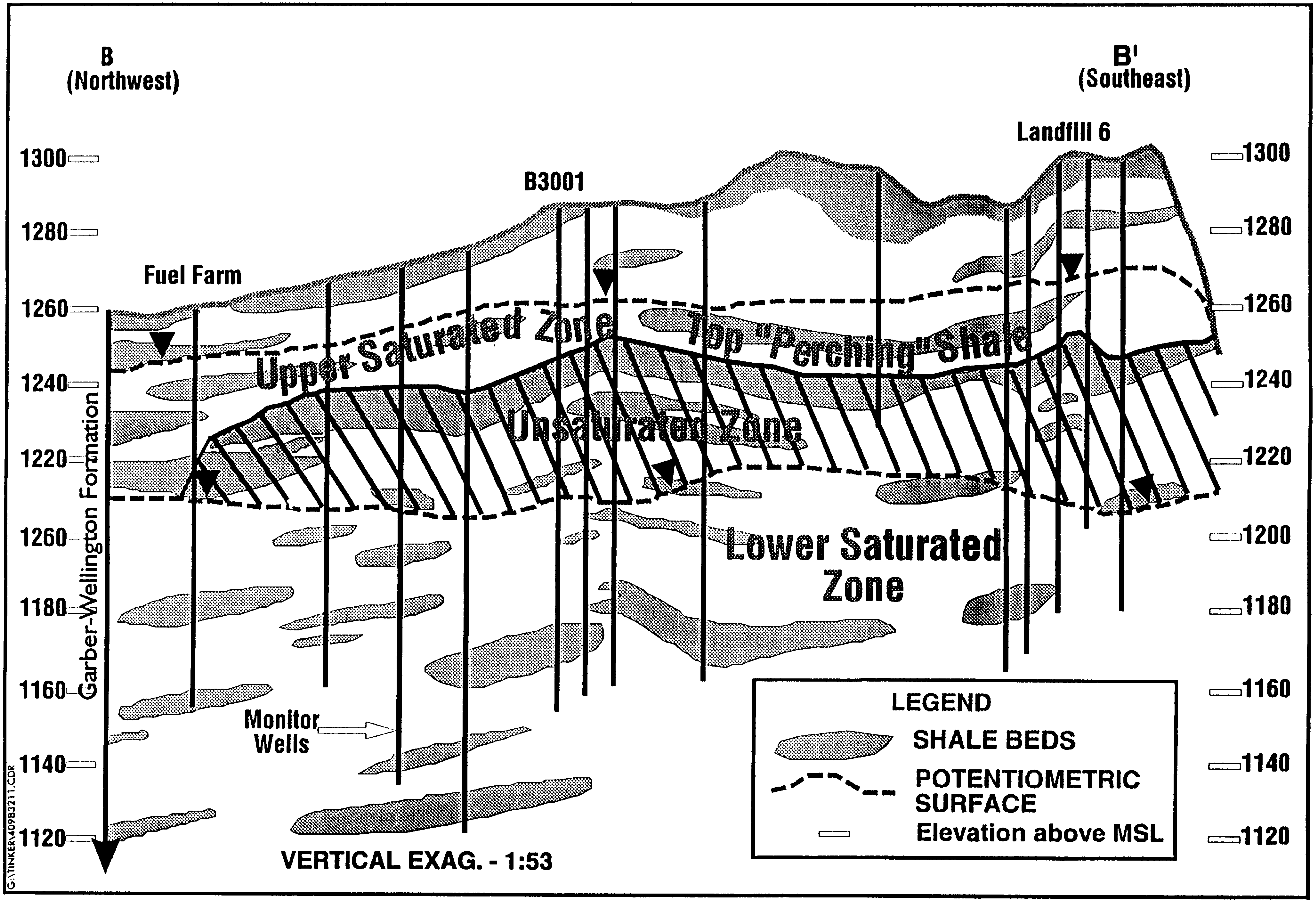


FIGURE 3-3 TINKER AFB GEOLOGIC CROSS SECTION B-B'

Structure. Tinker AFB lies within a tectonically stable area; no major near-surface faults or fracture zones have been mapped near the Base. Most of the consolidated rock units of the Oklahoma City area dip westward at a low angle. A regional dip of 0.0057 to 0.0076 ft/ft in a generally westward direction is supported by stratigraphic correlation on geologic cross-sections at Tinker AFB. Bedrock units strike slightly west of north.

Although Tinker AFB lies in a tectonically stable area, regional dips are interrupted by buried structural features located west of the Base. A published east-to-west generalized geologic cross-section, which includes Tinker AFB, supports the existence of a northwest-trending structural trough or syncline located near the western margin of the base. The syncline is mapped adjacent to and just east of a faulted anticlinal structure located beneath the Oklahoma City Oil Field. The fault does not appear to offset Permian-age strata. There are indications that the syncline may act as a "sink" for some regional groundwater (southwest flow) at Tinker AFB before it continues to more distant discharge points.

3.2.2 Site Geology

The Hennessey Group outcrops at the SP and consists of 14 to 15 feet of clay, silty clay, and weathered shale. This surficial clay and weathered shale is underlain by a sandstone unit of the Garber, which is approximately 18 feet thick and extends to a depth of approximately 32 to 33 feet. The unit is brown, fine-to very fine-grained, and moderately well sorted. Some interbedded shales up to several inches thick are present. This sandstone is underlain by a 23-feet-thick shale (32 to 55 feet in depth). The deepest unit penetrated by borings in the area of the site is a sandstone encountered at 55 feet. The thickness of this sandstone is unknown, but exceeds 10 feet (USACE, 1991a).

3.3 Hydrology

3.3.1 Regional/Tinker AFB Hydrology

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer system. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove, and Admire Groups. The Garber Sandstone and the Wellington Formation portion of the Central Oklahoma aquifer system is commonly referred to as the "Garber-Wellington aquifer" and is considered to be a single aquifer because these units were deposited under similar conditions and because many of the best producing wells are completed in this zone. On a regional scale, the aquifer is confined above by the less permeable Hennessey Group and below by the Late Pennsylvanian Vanoss Group.

Tinker AFB lies within the limits of the Garber-Wellington Groundwater Basin. Currently, Tinker derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest City and Del City derive water supplies from both surface sources and wells tapping the aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by a municipal distribution system also depend on the Garber-Wellington aquifer. Communities presently depending upon surface supplies (such as Oklahoma City) also maintain a well system drilled into the Garber-Wellington as a standby source of water in the event of drought.

Recharge of the Garber-Wellington aquifer is accomplished principally by percolation of surface waters crossing the area of outcrop and by rainfall infiltration in this same area. Because most of Tinker AFB is located in an aquifer outcrop area, the Base is considered to be situated in a recharge zone.

According to Wood and Burton (1968) and Wickersham (1979), the quality of groundwater derived from the Garber-Wellington aquifer is generally good, although wide variations in the concentrations of some constituents are known to occur. Wells drilled to excessive depths may encounter a saline zone, generally greater than 900 feet below ground surface. Wells drilled to such depths or those accidentally encountering the saline zone are either grouted over the lowest screens or may be abandoned.

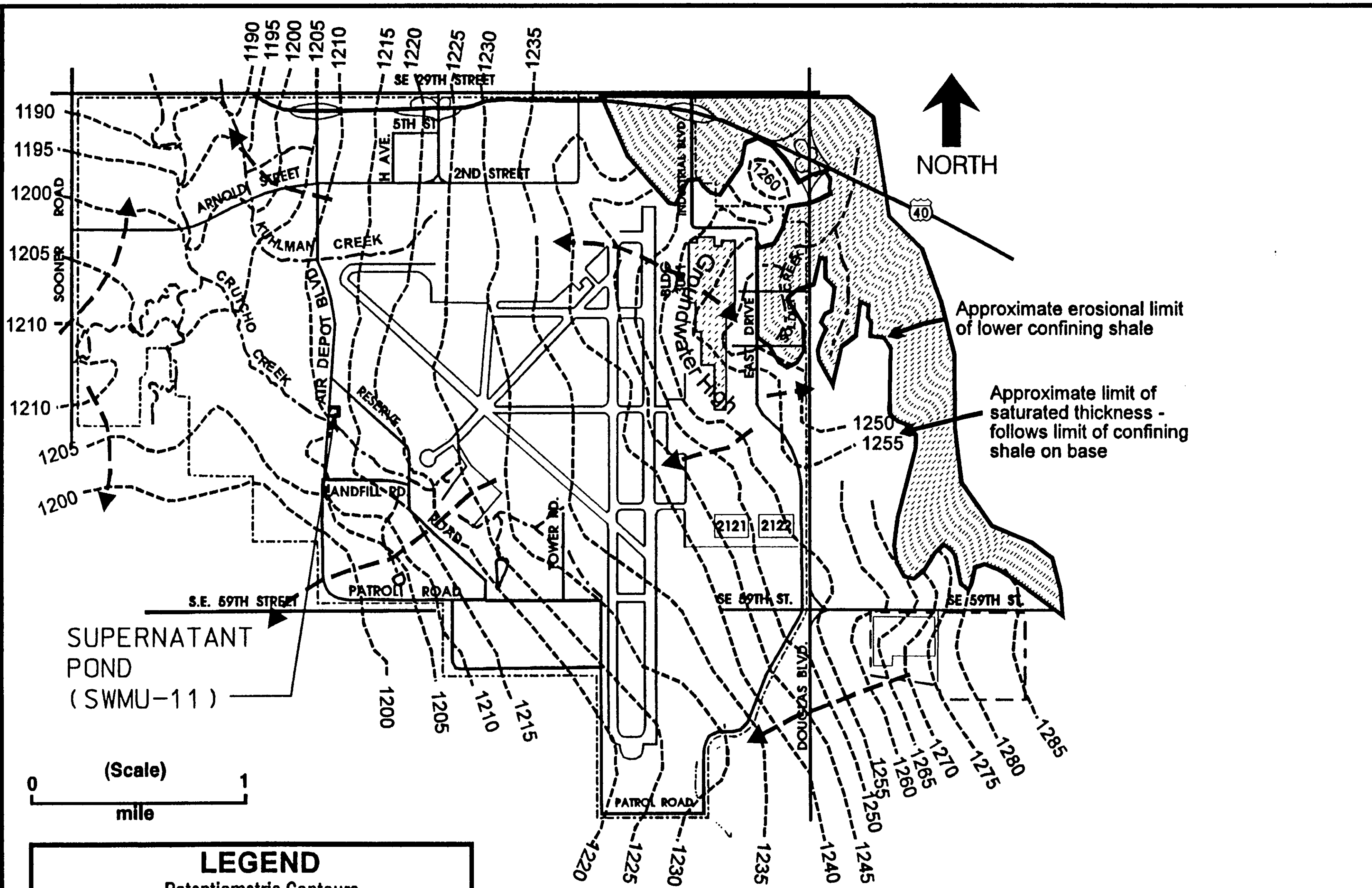
Tinker AFB presently obtains its water supplies from a distribution system comprised of 29 water wells constructed along the east and west Base boundaries and by purchase from the Oklahoma City Water Department. All Base wells are finished into the Garber-Wellington aquifer. Base wells range from 700 to 900 feet in finished depth, with yields ranging from 205 to 250 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones with a combined thickness from 103 to 184 feet (Wickersham, 1979).

Although the variability in the geology and the recharge system at Tinker AFB makes it difficult to predict local flow paths, Central Oklahoma aquifer water table data show that regional groundwater flow under Tinker varies from west-northwest to southwest, depending on location. This theory is supported by contoured potentiometric data from base monitoring wells which show groundwater movement in the upper and lower aquifer zones to generally follow regional dip. Measured normal to potentiometric contours, groundwater flow gradients range from 0.0019 to 0.0057 ft/ft. However, because flow in the near-surface portions of the aquifer at Tinker AFB is strongly influenced by topography, local stream base-levels, complex subsurface geology, and location in a recharge area, both direction and magnitude of groundwater movement is highly variable. The interaction of these factors not only influences regional flow but gives rise to complicated local, often transient, flow patterns at individual sites.

As a result of ongoing environmental investigations and the approximately 450 groundwater monitoring wells installed on the Base during various investigations, a better understanding of the specific hydrological framework has emerged. The current conceptual model developed by Tinker AFB (Tinker, 1993b), based on the increased understanding of the hydrological framework, has been revised from an earlier model adopted by the USACE. Previous studies reported that groundwater was divided into four water-bearing zones: the perched aquifer, the top of regional aquifer, the regional aquifer, and the producing zone. In the current model, two principal water table aquifer zones and a third less extensive zone have been identified. The third is limited to the southwest quadrant. The third aquifer zone consisted of saturated siltstone and thin sandstone beds in the Hennessey Shale and equates to the upper water bearing zone (UWBZ) described by the USACE (1993) at Landfills 1 through 4 (SWMUs 3 through 6). In addition, numerous shallow, thin saturated beds of siltstone and sandstone exist throughout the Base. These are of limited areal extent and are often perched.

In the current conceptual hydrologic model, a USZ and an LSZ are recognized in the interval from ground surface to approximately 200 feet. Below this is found the producing zone from which the Base draws much of its water supply. Figure 3-4 shows the potentiometric surface for the USZ and Figure 3-5 shows the potentiometric surface for the LSZ. The USZ exists mainly under water table (unconfined) conditions, but may be partially confined locally. Conditions in the LSZ are difficult to determine due to screen placement and overly long sandpacks below the screen interval.

The USZ is found at a depth of 5 to 70 feet below ground surface and has a saturated thickness ranging from less than 1 foot at its eastern boundary to over 20 feet in places west of Building 3001. The USZ is erosionally truncated by Soldier Creek along the northeastern margin of Tinker AFB. This aquifer zone is considered to be a perched aquifer over the



LEGEND

Potentiometric Contours Elevation above MSL

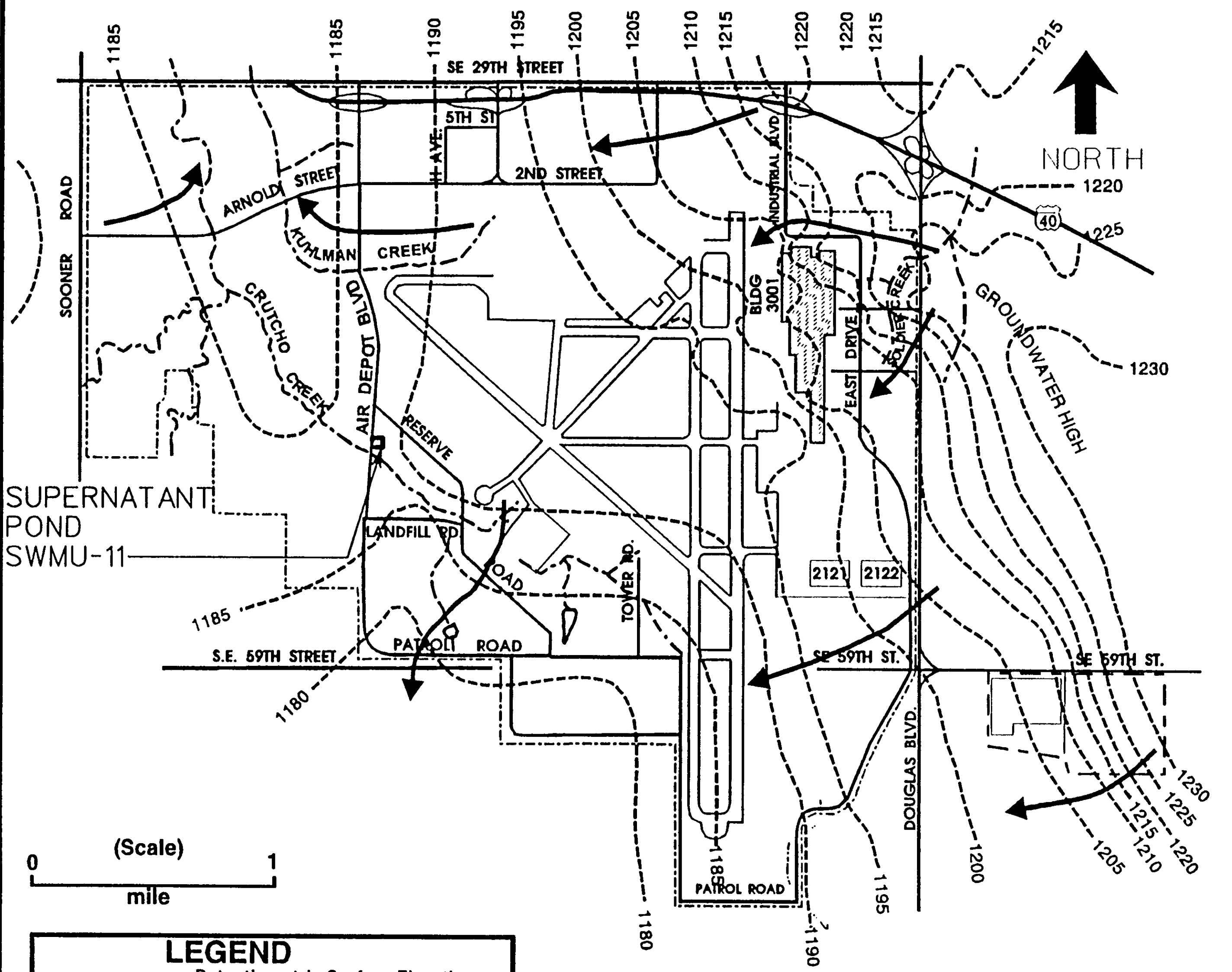
Approximate Direction of Groundwater Flow

Contours are extrapolated across center of base due to lack of data

FIGURE 3-4
TINKER AIR FORCE BASE
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C.WALLACE	DWG. NO.: 40983209C.
DRAWN BY: C.E.TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J.TAYLOR	PROJ. NO.: 409832

G:\TINKER\40983202C.517



LEGEND

- - - - - - Potentiometric Surface Elevation above MSL

⟶ Approximate Direction of Groundwater Flow

Contours are extrapolated across center of base due to lack of data

FIGURE 3-5
TINKER AIR FORCE BASE
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C.WALLACE	DWG. NO.: 409832O9C.
DRAWN BY: C.E.TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J.TAYLOR	PROJ. NO.: 409832

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eastern one-third of Tinker AFB, where it is separated from the LSZ by an underlying confining shale layer and a vadose zone. The confining interval extends across the entire Base, but the vadose zone exists over the eastern one-third of this area. The available hydrogeologic data indicate that the vadose zone does not exist west of a north-south line located approximately 500 to 1,000 feet west of the main runway; consequently, the USZ is not perched west of this line. However, based on potentiometric head data from wells screened above and below the confining shale layer, the USZ remains a discrete aquifer zone distinct from the LSZ even over the western part of the Base. In areas where several shales interfinger to form the lower confining interval rather than a single shale bed, "gaps" may occur. In general, these "gaps" are not holes in the shale, but are places where multiple shales exist that are separated by slightly more permeable strata. Hydrologic data from monitoring wells indicate that these zones allow increased downward flow of groundwater above normal rates through the confining layer.

The LSZ is hydraulically interconnected and can be considered one aquifer zone down to approximately 200 feet. This area includes what was referred to by the USACE as the top of regional and regional zones. Hydrogeologic data from wells screened at different depths at the same location within this zone, however, provide evidence that locally a significant vertical (downward) component of groundwater flow exists in conjunction with lateral flow. The magnitude of the vertical component is highly variable over the Base. Preliminary evidence suggests that the LSZ is hydraulically discrete from the producing zone. Due to variations in topography, the top of the lower zone is found at depths ranging from 50 to 100 feet below ground surface under the eastern parts of the Base and as shallow as 30 feet to the west. Differences in potentiometric head values found at successive depths are due to a vertical (downward) component of groundwater flow in addition to lateral flow and the presence or absence of shale layers which locally confine the aquifer system. The LSZ extends east of the Base (east of Soldier Creek) beyond the limits of the USZ where it becomes the first groundwater zone encountered in off-Base wells. Because of the regional dip of bedding, groundwater gradient, and topography, the LSZ just east of the Base is generally encountered at depths less than 20 feet.

3.3.2 Site Hydrology

There are two aquifer systems of interest at the SP: the USZ and the LSZ.

Upper Saturated Zone. The uppermost water bearing zone in the Garber-Wellington at Tinker AFB is commonly referred to as the USZ. At the SP, the USZ is primarily associated with the sandstone occurring at approximately 14 feet to 32 feet. The 13 piezometers at the SP are screened in this sandstone and in a water-producing surficial weathered shale and clay. It is probable that both stratigraphic units are connected hydraulically as a single unconfined aquifer in this area. The two units do exhibit different hydraulic properties; the hydraulic conductivity of the sandstone is higher than that of the soil and weathered shale overlying it. Based on bailer test data (SP-11), the soil/weathered shale exhibits a hydraulic conductivity of 2.6×10^{-6} centimeters per second (cm/s) while a slug test in the underlying sandstone (MW-61A) yielded a hydraulic conductivity of 5×10^{-3} cm/s. The monitoring wells and piezometers in place at FTA1 and the SP were designed to intercept the uppermost water bearing zone. The available well data does not allow a firm conclusion on the degree of hydraulic communication between the upper soil/weathered shale zone and the underlying sandstone. Based on water levels and geology, it is reasonable to treat them as a single hydrologic unit.

Based on available information, the following observations can be made at the SP:

- The overall gradient is to the south-southwest, indicating groundwater flow towards Crutcho Creek.
- A mounding is present in the immediate area of the SP which causes a local reversal of gradient with the possibility of radial groundwater flow from the SP area.
- The southern half of FTA1, MW-85A, MW-61A, and MW2-19B are all down-gradient of the SP. MW-62 is generally upgradient, but the water levels in piezometers at the center of the SP are higher.

The mounding observed at the SP is persistent at three different times of the year when water levels were measured. The higher water levels may be due to a local recharge effect attributable to hydraulic characteristics of the fill placed in the abandoned pond (USACE, 1991a).

Lower Saturated Zone. The top of this hydrologic unit corresponds with the top of the sandstone occurring at 55 feet. The unit is present in the entire Tinker AFB area and is a confined aquifer in the SP area. The wells in the site area which are screened in the unit are MW-61B, MW-85B, and MW2-19A. Based upon current data, the general LSZ gradient is to the south-southeast and monitoring wells MW2-19A, MW-61B, and MW-85B are down-gradient of the SP. Figures 3-6 and 3-7 show the potentiometric surfaces for the USZ and LSZ, respectively, extrapolated from surrounding data points at the SP.

3.4 Soils

Three major soil types have been mapped in the Tinker AFB area and are described in Table 3-2 (U.S. Department of Agriculture [USDA], 1969). The three soil types, the Darrell-Stephenville, Renfrow-Vernon-Bethany, and Dale-Canadian-Port, consist of sandy to fine sandy loam, silt loam, and clay loam, respectively. The Darrell-Stephenville and the Renfrow-Vernon-Bethany are primarily residual soils derived from the underlying shales of the Hennessey Group. The Dale-Canadian-Port association is predominantly a stream-deposited alluvial soil restricted to stream floodplains. The thickness of the soils ranges from 12 to 60 inches. The SP lies entirely within the Renfrow-Vernon-Bethany soil association.

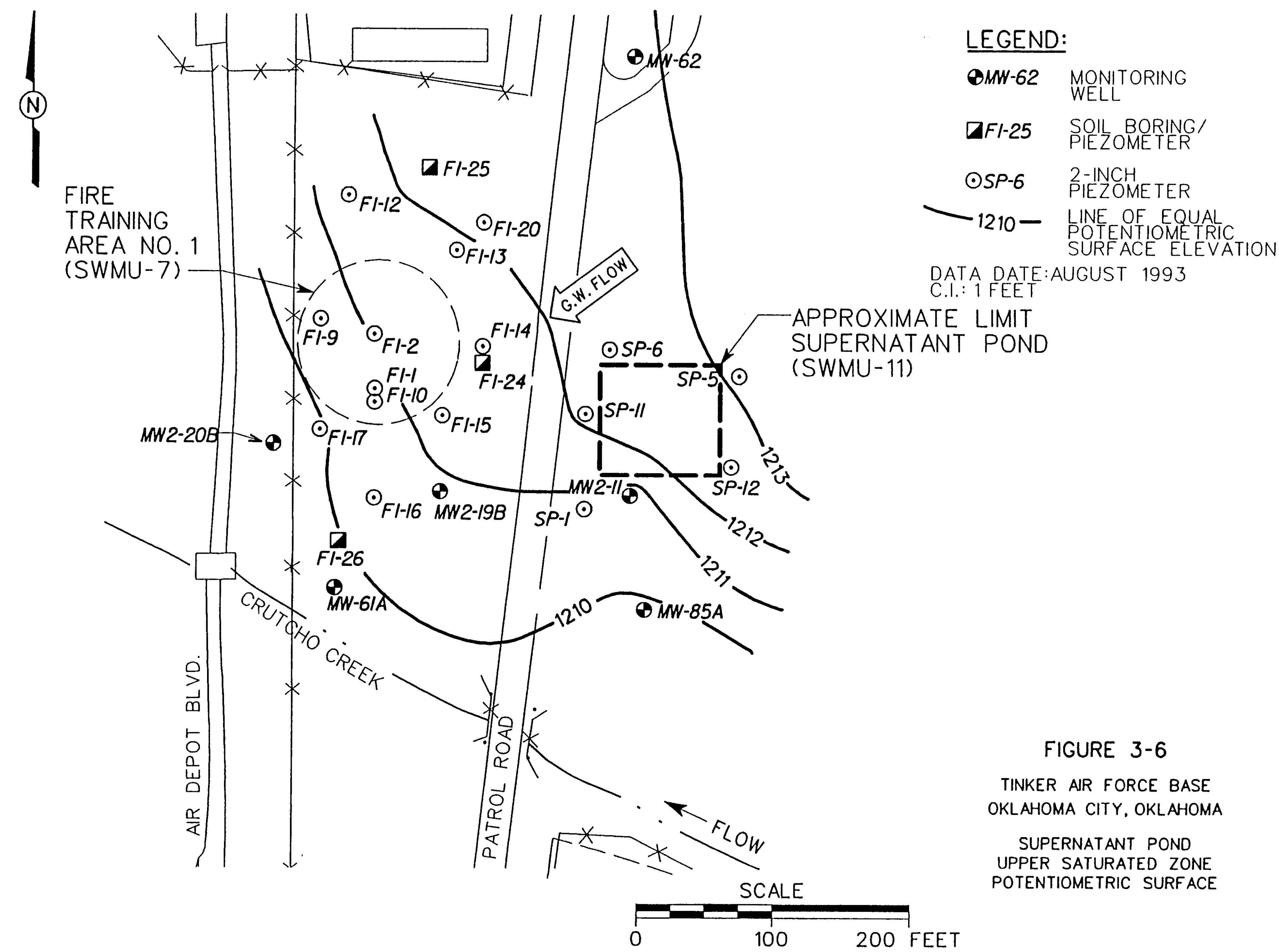

FIGURE 3-6

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

SUPERNATANT POND
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 01/15/94	DATE LAST REV.:09/07/94	DRAFT. CHCK. BY: G. PACHECO	INITIATOR: C. WALLACE	DWG. NO.: 40983202.101
DRAWN BY: P. TERRY	DRAWN BY: P. TERRY	ENGR. CHCK. BY: C. WALLACE	PROJ. MGR.: J. TAYLOR	PROJ. NO.: 409832

8/24/94 POT
FILENAME: G:\TINKER\40983202.101

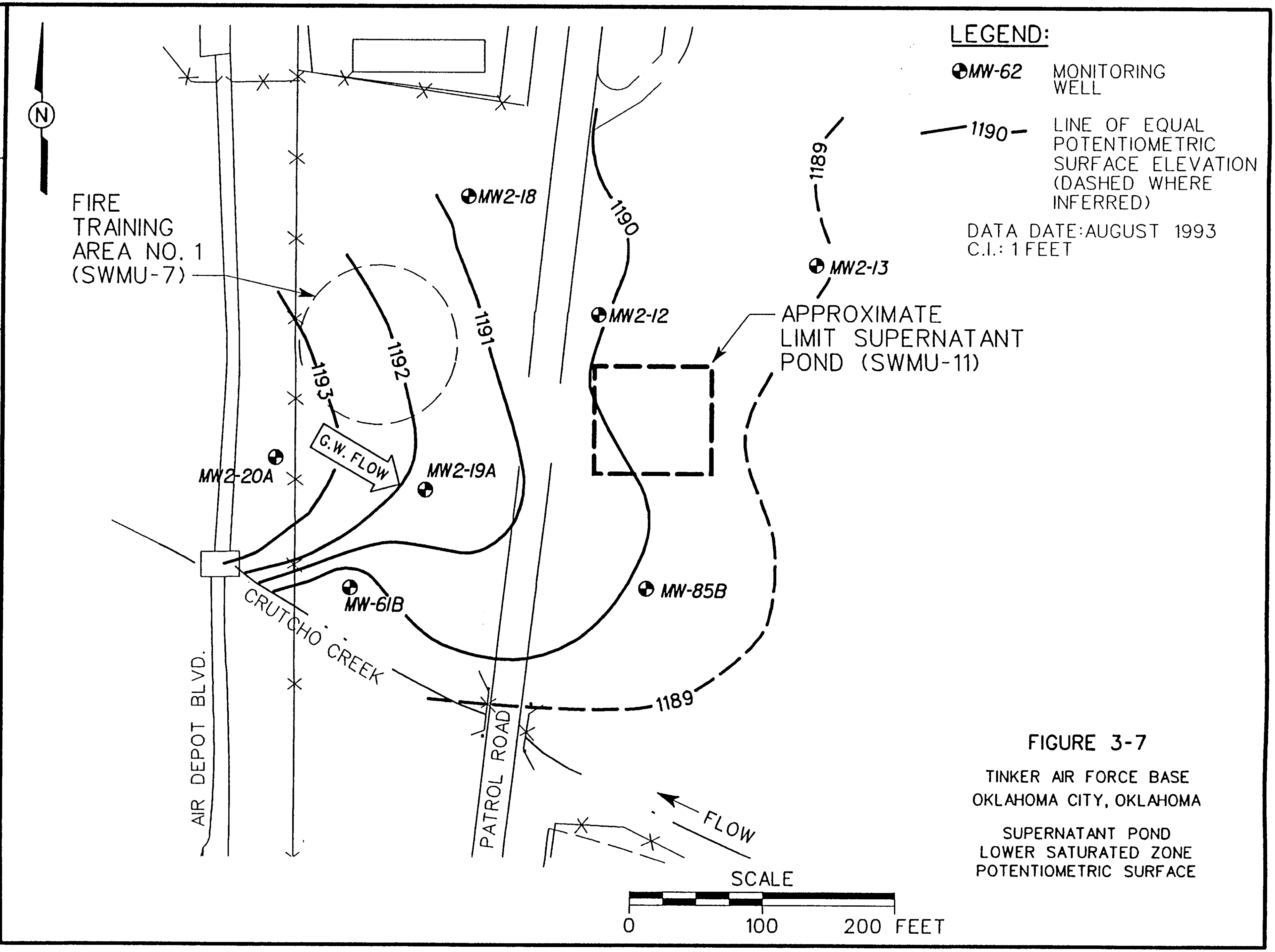
LEGEND:
MW-62 MONITORING WELL
1190 LINE OF EQUAL POTENTIOMETRIC SURFACE ELEVATION (DASHED WHERE INFERRED)
DATA DATE: AUGUST 1993
C.I.: 1 FEET
FIRE TRAINING AREA NO. 1 (SWMU-7)
APPROXIMATE LIMIT SUPERNATANT POND (SWMU-11)
MW2-18
MW2-13
MW2-12
MW2-19A
MW2-20A
MW-61B
MW-85B
1189
1190
1191
1192
1193
1189
G.W. FLOW
FLOW
AIR DEPOT BLVD.
CRUTCHO CREEK
PATROL ROAD
N
SCALE
0
100
200 FEET
FIGURE 3-7
TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA
SUPERNATANT POND
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE
STARTING DATE: 01/15/94
DRAWN BY: P. TERRY
DATE LAST REV.:08/24/96
DRAWN BY: P. TERRY
DRAFT. CHCK. BY: G. PACHECO
ENGR. CHCK. BY: C. WALLACE
INITIATOR: C. WALLACE
PROJ. MGR.: J. TAYLOR
DWG. NO.: 40983202.109
PROJ. NO.: 409832

Table 3-2

Tinker AFB Soil Associations
(Source: USDA, 1969)

Association	Description	Thickness (in.)	Unified Classification[a]	Permeability (in./hr)
Darrell-Stephenville: loamy soils of wooded uplands	Sandy loam Sandy clay loam Soft sandstone (Garber Sandstone)	12-54	SM,ML,SC	2.0-6.30
Renfrow-Vernon-Bethany: loamy and clayey soils on prairie uplands	Silt loam - clay Clay loam Shale (Fairmont Shale)	12-60	ML,CL,MH,CH	<0.60-0.20
Dale-Canadian-Port: loamy soil on low benches near large streams	Fine sandy loam Silty clay loam Loam Clay loam	12-60	SM,ML,CL	0.05-6.30

[a]Unified classifications defined in U.S. Bureau of Reclamation, 5005-86.

4.0 Source Characterization

The SP study area encompasses 25,000 ft^2. The former pond, which covered an area of approximately 6,400 ft^2, was used for impounding sewage effluent between 1954 and 1970 and for disposal of miscellaneous liquid wastes between 1970 and 1980. The miscellaneous liquid wastes included petroleum hydrocarbon sludges, solvents, and cyanide-contaminated liquids generated from base operations. The exact quantities and compositions of the liquid wastes disposed at the SP are not known. Disposal of liquid wastes in the pond ceased in 1980 and the pond was used for disposal of soil and construction debris.

5.0 Contaminant Characterization

Through two phases of investigation, soil gas, soils, and groundwater have been sampled for contaminants potentially introduced into the environment as a result of past waste disposal practices at the SP. In addition, postremediation groundwater samples were collected from MW-85A in 1992 and 1993. Analytical results of samples taken during the RI (USACE, 1991a) indicated that contamination was present in the soil at a depth of 4 to 7 feet within the boundaries of the SP. Results also indicated that the groundwater in the USZ below and adjacent to the SP contained concentrations above background levels of TOC, radiometrics, metals, VOCs, and SVOCs. During the remediation of the site, additional soil and groundwater sampling indicated that the soil was not contaminated, and groundwater in the LSZ was only slightly contaminated with chromium. The results of the postremediation groundwater sample analyses indicate that the groundwater in the USZ contains TOC concentrations slightly above background levels.

5.1 Soil Gas Characterization

Compounds analyzed in the soil gas survey included: TCA, trichloroethene (TCE), PCE, benzene, toluene, ethyl benzene, xylenes, and total hydrocarbons. The soil gas survey indicated detectable concentrations of 1,1,1-TCA, PCE, and total hydrocarbons at several of the 22 sample locations. The survey was performed during July 1989 when volatilization of any VOCs would be at or near maximum for the year. Only TCA, PCE, and total hydrocarbons were present at contourable levels. Maximum detected levels of TCA, PCE, and total hydrocarbons were 0.8, 0.004, and 17 micrograms per liter (µg/L), respectively, compared to their detection limits of 0.0002 µg/L, 0.005 µg/L, and 0.2 µg/L, respectively. Soil gas investigations of the SP site vary from 1.5 to 4.0 feet in depth. Subsequent groundwater and soil sampling and analysis, which were all taken at depths below 4.5 feet, failed to confirm the presence of TCA and PCE at the locations sampled during the soil gas survey. The levels of soil gas contaminants present are not considered indicative of subsurface contamination. Neither PCE nor TCA was detected in any of the soil samples taken from depths of 4.5 to 12.0 feet below the surface or in any perched groundwater samples taken from piezometers or monitoring wells at the site. The soil gas survey results are presented in Table 5-1 (USACE, 1991a).

Table 5-1

Remedial Investigation Soil Gas Survey Results (USACE, 1991a) SWMU-11, SP, Tinker AFB

(Page 1 of 2)

Sample	Depth	Date	TCA (µg/L)	TCE (µg/L)	PCE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethyl Benzene (µg/L)	Xylenes (µg/L)	Total Hydrocarbon (µg/L)
Air		07/26	0.0001	<0.0002	<0.00005	<0.02	<0.02	<0.02	<0.02	<0.1
SG-01	4'	07/26	<0.0002	<0.0005	0.0004	<0.05	<0.05	<0.05	<0.05	<0.2
SG-02	4'	07/26	<0.0002	<00005	<0.0001	<0.05	<0.05	<0.05	<0.05	<0.2
SG-03	3'	07/26	0.0006	<0.0005	0.0002	<0.05	<0.05	<0.05	<0.05	<0.2
SG-04	4'	07/26	0.0002	0.004	0.002	<0.05	<0.05	<0.05	<0.05	<0.2
SG-05	1.5'	07/26	0.0005	<0.0005	0.0002	<0.05	<0.05	<0.05	<0.05	<0.2
SG-06	3'	07/26	0.0005	<0.0005	0.0004	<0.05	<0.05	<0.05	<0.05	<0.2
Air		07/26	0.0001	<0.0002	<0.00005	<0.02	<0.02	<0.02	<0.02	<0.1
SG-07	2'	07/26	0.0002	<0.0005	0.001	<0.5	<0.5	<0.5	0.5	17
SG-08	4'	07/26	<0.0002	<0.0005	0.0002	<0.05	<0.05	<0.05	<0.05	<0.2
SG-09	3'	07/26	0.001	<0.0005	0.002	<0.05	<0.05	<0.05	<0.05	<0.2
SG-10	4'	07/26	0.8	<0.002	0.01	0.1	<0.05	<0.05	<0.05	<0.2
SG-11	3'	07/26	0.0004	<0.0005	0.0004	<0.05	<0.05	<0.05	<0.05	<0.2
SG-12	4'	07/26	0.2	<0.002	0.004	0.05	<0.05	<0.05	<0.05	<0.2
SG-13	3'	07/26	0.02	<0.0005	0.0002	<0.05	<0.05	<0.05	<0.05	0.2
SG-14	3'	07/26	0.02	<0.0005	0.006	<0.05	<0.05	5	<0.05	5
SG-15	3'	07/26	<0.0002	<0.0005	0.002	<0.05	<0.05	<0.05	<0.05	0.6

Table 5-1

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Sample	Depth	Date	TCA (µg/L)	TCE (µg/L)	PCE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethyl Benzene (µg/L)	Xylenes (µg/L)	Total Hydrocarbon (µg/L)
SG-16	3'	07/26	0.03	<0.0005	0.01	<0.05	<0.05	0.5	<0.05	0.5
Air		07/26	0.0001	<0.0002	<0.00005	<0.02	<0.02	<0.02	0.05	<0.1
Air		07/27	<0.0001	0.0005	<0.00006	<0.02	<0.02	0.1	0.04	0.5
SG-17	3'	07/27	<0.0003	<0.0006	<0.0008	<0.04	0.05	<0.04	<0.04	<0.2
SG-18	3'	07/27	<0.0003	<0.0006	0.0008	<0.04	<0.04	<0.04	<0.04	<0.2
SG-19	3'	07/27	0.001	<0.0006	0.001	<0.04	0.06	<0.04	<0.04	<0.2
SG-20	3'	07/27	0.0008	<0.0006	0.0003	<0.04	<0.04	<0.04	<0.04	<0.2
SG-21	2'	07/27	<0.0003	<0.0006	<0.0002	<0.04	<0.04	<0.04	<0.04	<0.2
SG-22	3'	07/27	<0.0003	<0.0006	0.002	<0.04	<0.04	<0.04	<0.04	<0.2
L2SG-2	6.5'	07/27	0.008	0.008	<0.0002	<0.4	<0.4	<0.04	<0.04	<0.2
L2SG-1	7'	07/27	0.004	0.001	<0.0002	<0.8	<0.8	<0.4	<0.4	<2
L2SG-5	2'	07/27	0.0003	<0.0006	<0.0002	<0.04	<0.04	<0.04	<0.04	<0.2
L2SG-3	2'	07/27	0.0006	<0.0006	<0.0002	<0.04	<0.04	<0.04	<0.04	<0.2
L2SG-4	5'	07/27	<0.0003	<0.0006	<0.0002	<0.04	<0.04	<0.04	<0.04	<0.2
L2SG-4	9'	07/27	<0.0003	0.01	<0.0002	12	68	0.5	<0.4	85
L2SG-6	9'	07/27	0.003	0.007	<0.0002	<0.4	4	<0.4	<0.4	16
L2SG-5	9'	07/27	0.0006	0.0006	<0.0002	<0.4	<0.4	<0.4	<0.4	<2
Air		07/27	0.001	<0.0006	<0.0002	<0.02	0.02	0.05	<0.02	<0.1

5.2 Soil Characterization

The results of chemical analyses of the soil samples from the seven borings are summarized in Table 5-2 (USACE, 1991a). Detection frequencies and maximum concentrations detected are presented in Table 5-3 (USACE, 1991a). The samples were analyzed for metals, pH, PCBs, TRPH, cyanide, VOCs, and SVOCs. Sample locations are shown on Figure 1-3.

Complete laboratory results are listed in Appendix F of the final RI report (USACE, 1991a). Six VOCs were detected in the soil samples: acetone, chlorobenzene, toluene, xylene, chloroform, and methylene chloride. Chloroform and methylene chloride were present in concentrations below the detection limit or also found in the laboratory blanks. It is probable that the presence of these compounds in the blanks was due to laboratory contamination. Acetone was indicated in all samples except SP-4. However, it was also detected in laboratory blanks in all samples except SP-7 and SP-9. In the latter samples, acetone may have been present as a contaminant. Chlorobenzene was indicated in one sample. Toluene and xylene were indicated at levels slightly above detection limits in SP-2.

Ten SVOCs were detected in samples SP-4, SP-7, and SP-9. Phenol was indicated in two samples at concentrations below and slightly above detection limits. Two samples indicated that 4-chloroaniline was present above detection limits. Bis(2-ethylhexyl)phthalate was indicated in all three samples at concentrations of 1300 to 2300 micrograms per kilogram (μg/kg). Compounds below detection limits included 1,4-dichlorobenzene, 4-methylphenol, phenanthrene, di-n-butyl phthalate, fluoranthene, pyrene, and chrysene. Fifteen to 20 tentatively-identified SVOCs were also present in each sample with maximum concentrations of 590J, 5400J, and 1100J in SP-4, SP-7, and SP-9, respectively.

PCBs were indicated in SP-7 and SP-9 at the detection limit. TRPH was indicated above the detection limit (10 milligrams per kilogram [mg/kg]) in SP-4 at a concentration of 68 mg/kg.

Inorganic analytes detected include cyanide and metals. Cyanide was indicated in SP-4 and SP-7 above the detection limit (0.05 mg/kg) at concentrations of 0.31 and 1.64 mg/kg, respectively.

A total of ten additional composite samples were taken from the site during remediation activities, which were completed in November 1992. The samples were taken from ground level to a total depth of 8 feet. Five of the samples came from the upper 4 feet of soil and construction debris, and five of the samples were taken from depths between 4 and 8 feet.

Table 5-2

Summary of Remedial Investigation Soil Sample Results (USACE, 1991a) SWMU-11, SP, Tinker AFB

(Page 1 of 2)

	Soil Samples						
USACE Sample No.	SP-2	SP-3	SP-4	SP-5	SP-6	SP-7	SP-9
Lab Sample No.	9-1178	9-1179	9-1180	9-1181	9-1182	9-1183	9-1184
Sample Depth (ft)	5.5-6.5	11.5-12.0	5.0-6.0	5.5-6.5	4.5-5.5	4.5,6.5-7	5.5-6.5
Collection Date	8-24-89	8-24-89	8-24-89	8-24-89	8-24-89	8-24-89	8-24-89
Location (In or Out of SP Fill Area)	out	in	in	out	out	in	in
Parameter							
pH	7.3	8.18	7.31	7.68	7.23	7.38	7.86
TRPH (mg/kg)	<10	<10	68	<10	<10	78	59
PCB (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1
Cyanide (mg/kg)	<0.05	<0.05	0.31	<0.05	<0.05	1.64	<0.05
Metals (mg/kg)							
Silver	<1	<1	33	<1	<1	<1	<1
Arsenic	1.3	<1	1.7	<1	1.4	4.8	4.3
Barium	290	600	390	180	320	1100	900
Cadmium	6.8	6.0	12	7.5	7.4	34	30
Chromium	18	17	37	25	22	120	130
Mercury	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Nickel	12	16	17	22	18	27	22
Lead	18	17	82	21	22	210	160
Selenium	<0.10	<0.10	0.20	<0.10	<0.10	2.0	<0.10
Zinc	24	23	170	34	25	690	740

Table 5-2

(Page 2 of 2)

	Soil Samples						
Volatiles (µg/kg)							
Acetone	B 14	B 39	<13	B 190	B 30	E 1700	80
Chlorobenzene	<6	<6	<6	<6	<6	130	<35
Toluene	6	<6	<6	<6	<6	<40	<35
Total xylene	10	<6	<6	<6	J 4	<40	<35
Chloroform	BJ 4	J 4	J 3	J 5	J 4	BJ 21	BJ 25
Methylene chloride	B 17	B 15	B 31	B 31	B 15	B 420	B 67
Semivolatiles (µg/kg)							
Phenol	<390	<400	<840	<390	<390	J 340	550
1,4-Dichlorobenzene	<12	<12	<13	<12	<12	J 220	88
4-Methylphenol	<390	<400	<840	<390	<390	<530	J 430
4-Chloroaniline	<390	<400	<840	<390	<390	1900	750
Phenanthrene	<390	<400	<840	<390	<390	J 140	J 81
Di-n-butyl phthalate	<390	<400	<840	<390	<390	<530	J 61
Fluoranthene	<390	<400	<840	<390	<390	J 230	J 140
Pyrene	<390	<400	J 280	<390	<390	J 330	J 200
Chrysene	<390	<400	<840	<390	<390	J 170	J 150
Bis(2-ethylhexyl)phthalate	<390	<400	1300	<390	<390	2300	2300

J = Estimated concentration below detection limit.
E = Concentration exceeded calibration range of instrument.
B = Analyte found in blank.

Table 5-3

Remedial Investigation Detection Frequencies and Soil Sample Maximum Concentrations (USACE, 1991a) SWMU-11, SP, Tinker AFB

	No. Detected	No. Tested	Maximum Concentration	Location of Maximum Concentration
Parameter				
pH	7	7	8.18	SP-3
TRPH (mg/kg)	3	7	78	SP-7
PCB (mg/kg)	2	7	0.1	SP-7, SP-9
Cyanide (mg/kg)	2	7	1.64	SP-7
Metals (mg/kg)				
Silver	1	7	33	SP-4
Arsenic	5	7	4.8	SP-7
Barium	7	7	1100	SP-7
Cadmium	7	7	34	SP-7
Chromium	7	7	130	SP-9
Mercury	0	7	<0.1	
Nickel	7	7	27	SP-7
Lead	7	7	210	SP-7
Selenium	2	7	2.0	SP-7
Zinc	7	7	740	SP-9
Volatiles (µg/kg)				
Acetone	6	7	1700E	SP-7
Chlorobenzene	1	7	130	SP-7
Toluene	1	7	6	SP-2
Total xylene	2	7	10	SP-2
Chloroform	7	7	25BJ	SP-9
Methylene chloride	7	7	420B	SP-7

Table 5-3

(Page 2 of 2)

	No. Detected	No. Tested	Maximum Concentration	Location of Maximum Concentration
Semivolatiles (μg/kg)				
Phenol	2	7	550	SP-9
1,4-Dichlorobenzene	2	7	220J	SP-7
4-Methylphenol	1	7	430J	SP-9
4-Chloroaniline	2	7	1900	SP-7
Phenanthrene	2	7	140J	SP-7
Di-n-butyl phthalate	1	7	61J	SP-9
Fluoranthene	2	7	230J	SP-7
Pyrene	3	7	330J	SP-7
Chrysene	2	7	170J	SP-7
Bis(2-ethylhexyl)phthalate	3	7	2300	SP-7, SP-9

E = Concentration exceeded calibration range of instrument.
B = Analyte found in blank.
J = Estimated concentration.

These ten composite samples were analyzed by TCLP method to characterize the hazardous constituents that potentially existed in the soil matrix.

Samples of the upper 4 feet of soil were used to characterize the construction debris removed from the former pond for disposal. Results of the five TCLPs indicated four metals were present at concentrations equal to or slightly above reporting limits. Barium and chromium were detected in all the samples with a maximum concentration of 4.4 and 0.14 milligrams per liter (mg/L), respectively. Cadmium was indicated in one sample with a concentration of 0.046 mg/L. Lead was indicated in two of the samples with a maximum concentration of 0.77 mg/L. No TCLP SVOCs, VOCs, or herbicides were detected in the five samples. Two pesticides were present in the samples above reporting limits. Heptachlor was detected twice at concentrations of 0.23 and 0.03 µg/L. Endrin was detected in one sample at a concentration of 0.28 µg/L. Both pesticides have a reporting limit of 0.1 µg/L. Based on these analyses, the construction debris was disposed at an approved industrial landfill (Tinker, 1993a).

The other five soil samples were collected from the lower 4 feet and analyzed for TCLP parameters. There were no SVOCs, VOCs, herbicides, or pesticides detected in the soils at concentrations that exceeded TCLP hazardous characteristics. There were two metals detected in all five of the soil samples analyzed. Arsenic and barium were detected with maximum concentrations of 2.65 µg/L and 1.3 mg/L, respectively (Tinker, 1993a).

5.2.1 Background Volatiles Analysis

In June 1989, as part of the SP RI, three borings (FB-1 through FB-3) were drilled off site, south of Crutcho Creek (Figure 1-3). Boring depths ranged from 7 to 10 feet. The purpose of these borings was to establish background values of TOC and organics in nearby unsaturated soils unaffected by the SP, but still within the floodplain of Crutcho Creek. Composite samples were obtained for analysis by taking soil from all auger flights from the ground surface to the bottom of the borings. Samples were analyzed for VOCs, SVOCs, TOC, and pH. Background TOC values ranged from 2,900 to 9,200 mg/kg with an average TOC value of 6,433 mg/kg. The background TOC average was generally lower than the TOC average from soil samples taken in the upper 5 feet of the SP, and generally higher than the TOC average in soil samples below 5 feet (USACE, 1991a).

5.2.2 Establishment of Surficial Soil Background Concentrations

Background soil concentrations for trace metals were determined based on a study performed by the USGS (1991). The study area was confined to approximately four counties in central Oklahoma. Tinker AFB lies at the approximate center of this area. A total of 293 B-horizon soil samples were collected throughout this area. Soil samples were collected at the top of the B-horizon, which was usually 20 to 30 centimeters below the surface but ranged from 3 to 50 centimeters below the surface. For site-specific analytes for which the USGS offered no background value, the analyte was compared to an applicable action level. The background concentrations are presented in Table 5-4.

The use of B-horizon soil as selected by the USGS for metals background concentrations in soil is conservative in that the soil sampled does not reflect all possible anthropogenic influences. Most of the samples were obtained from hill crests and well drained areas in pasture and forested land, well away from roadways to minimize contamination from vehicular emissions (i.e., nearly "pristine" areas). Trace metal inputs to the study site soils on Base, however, will come from anthropogenic sources outside of the study area, in addition to those sources related to disposal activities or operations within the confines of the study site. Therefore, responsibility may be taken for more trace metal impacts than are actually attributable to a given site.

An additional level of conservatism was added in the manner in which the site-specific metals concentrations were compared to the background levels. Typically, the environmental concentrations of trace metals at study sites are represented by the arithmetic upper 95th confidence interval on the mean of a normal distribution. This upper 95th confidence interval value is then compared to the background values. The intent of this typical approach is to estimate a Reasonable Maximum Exposure case (i.e., well above the average case) that is still within the range of possible exposures.

To expedite this comparison and establish greater conservatism, the maximum concentration found at the site of concern, rather than the upper 95th confidence interval value, was compared to the USGS background values. If the environmental concentration of a particular analyte was below or within the minimum-maximum range of the USGS background concentrations, that analyte was considered to be naturally occurring and of no further concern to this investigation. Given the conservative approach of the comparisons, site-

Table 5-4

Background Concentrations of Trace Metals in Surface Soils[a] SWMU-11, SP, Tinker AFB

(Page 1 of 2)

Analyte	Lower Detection Limit	Background Concentration Range	
		Minimum Value	Maximum Value
Concentration in %			
Aluminum	0.005	0.38	8.9
Cadmium	0.005	0.01	9.4
Iron	0.005	0.18	5.8
Magnesium	0.005	0.02	5.3
Phosphorous	0.005	0.06	0.019
Potassium	0.05	0.1	2.4
Sodium	0.005	0.02	0.99
Titanium	0.005	0.04	0.42
Concentrations in ppm			
Arsenic	0.1	0.6	21
Barium	1	47	6400
Beryllium	1	<1	3
Bismuth	10	<DL[b]	<DL
Cadmium	2	<DL	<DL
Cerium	4	14	110
Chromium	1	5	110
Cobalt	1	<1	27
Copper	1	<1	59
Europium	2	---[c]	---
Gallium	4	<4	23
Gold	8	<DL	<DL
Holmium	4	<DL	<DL
Lanthanum	2	7	51
Lead	4	<4	27
Lithium	2	5	100

specific metals concentrations would have to significantly exceed the USGS background levels and be attributable to operations at the site before they would be considered a contaminant of concern.

Metals detected above maximum background values include chromium, lead, selenium, and zinc. Samples from borings SP-7 and SP-9 (4.5 to 6.5 feet) generally contained the highest levels of metals.

5.3 Groundwater Characterization

5.3.1 Remedial Investigation Groundwater Sampling

Chemical analyses of 24 groundwater samples collected during the RI from 13 piezometers and 2 monitoring wells are summarized in Table 5-5. All wells in the vicinity of the SP were installed as upgradient and/or downgradient wells for the SP and FTA1, and Landfills 1 through 6. No perimeter wells were available for use as background wells in the immediate vicinity of the SP. Therefore, the background concentrations listed in Table 5-5 for groundwater are taken from the Base groundwater assessment document prepared by USACE (1987). Background wells were chosen to be representative of groundwater quality unaffected by man-made contamination. They are not necessarily upgradient. USZ background concentrations were computed by averaging concentrations detected in nine perimeter wells sampled from May to June 1986: MW-22B, MW-23B, MW-41B, MW-42B, MW-43B, MW-45B, MW-46B, MW-47B, and MW-48B. Top of regional (LSZ) background concentrations were computed by averaging concentrations detected in three perimeter wells (MW-22A, MW-23A, and MW-24A) sampled in March 1986. Partial samples were collected from the piezometers on four dates. Well numbers, sampling dates, laboratory numbers, and parameters analyzed are summarized in Table 5-6 (USACE, 1991a). The samples were analyzed for TOC, VOCs, SVOCs, PCBs, total petroleum hydrocarbon (TPH), gross alpha, gross beta, radium, cyanide, total dissolved solids (TDS), and metals. Some samples were not analyzed for all parameters because piezometers yielded insufficient water for collection and analysis of all analytes. Table 5-7 contains the detection limits and maximum concentrations for compounds found in the USZ. A complete list of chemical results can be found in Appendix F of the final RI report (USACE, 1991a). Sample locations are shown in Figure 1-3.

Upper Saturated Zone. Groundwater samples collected during the RI from the 13 piezometers and MW-85A are considered USZ samples. MW-61A and MW-62 were set in the USZ and sampled as part of the FTA1 RI. Due to the proximity of these wells to the SP

Table 5-5

Remedial Investigation Groundwater Sample Results (USACE, 1991a) SWMU-11, SP, Tinker AFB

(Page 1 of 3)

Well/Piezometer No.			Piezometers SP-1	SP-2	SP-3	SP-4	SP-5	SP-6	SP-7
Collection Date			10/89 11/89	11/89	10/89 11/89	10/89 11/89	11/89	11/89	10/89 11/89
Location in or out of SP Fill Area			Out	Out	In	In	Out	Out	In
Parameter	Drinking Water Standard or MCL	Background Concentration Perched Zone							
pH		7.10	6.51	6.88	7.70	7.23	7.44	6.98	8.66
Conductivity (μmhos/cm)		684	680	1010	1630	1280	1050	1090	860
TDS (mg/L)			570	NA	NA	NA	960	NA	600
PCB (μg/L)			<0.5	<0.5	<0.5	NA	NA	NA	NA
TOC (mg/L)		3.90	5.7	12.4	16.8	13.4	4.43	7.08	26.2
TPH (mg/L)			<0.5	NA	NA	NA	<0.5	NA	6.4
Cyanide (mg/L)		<0.2	<0.20	NA	NA	NA	0.20	NA	0.20
Radiometrics									
Gross alpha (pCi/L)	15	55.2	NA	95 ± 37	75 ± 30	NA	NA	NA	NA
Gross beta (pCi/L)	50	106.8	NA	215 ± 19	109 ± 15	NA	NA	NA	NA
Radium (pCi/L)	5		NA	29 ± 3	14 ± 2	NA	NA	NA	NA
Metals (μg/L)									
Arsenic	50	10	NA	9	12	NA	NA	NA	NA
Barium	1000	1110	NA	420	200	NA	NA	NA	NA
Cadmium	10	10	NA	6	<5	NA	NA	NA	NA
Chromium	50	46	NA	5.2	<5	NA	NA	NA	NA
Mercury	2	<0.4	NA	0.12	0.12	NA	NA	NA	NA
Lead	50	57	NA	61	13	NA	NA	NA	NA
Nickel		101	NA	36	19	NA	NA	NA	NA
Selenium	10	2.1	NA	<0.4	<0.4	NA	NA	NA	NA
Silver	50	10							
Zinc	5000	110							
Volatiles (μg/L)									
Acetone			<10	<10	<10	<10	<10	<10	49
Chlorobenzene			<5	<5	<5	<5	<5	<5	<5
Carbon disulfide			<5	<5	<5	<5	<5	<5	<5
Trichloroethene	5.0		<5	<5	<5	<5	<5	<5	<5
Methylene chloride			<5	<5	<5	12	<5	<5	<5
Semivolatiles (μg/L)									
Benzoic acid			J 4	NA	NA	<50	NA	<50	NA
Di-n-octyl phthalate			<10	NA	NA	<10	NA	J 2	NA
Bis(2-ethylhexyl)phthalate			BJ 3	NA	NA	J 5	NA	<10	NA
Bis(2-chloroisopropyl)ether			<10	NA	NA	<10	NA	<10	NA
4-Nitroaniline			<50	NA	NA	<50	NA	<50	NA
Di-n-butyl phthalate			<10	NA	NA	<10	NA	<10	NA
1,2,4-Trichlorobenzene			<10	NA	NA	<10	NA	<10	NA

Table 5-5

(Page 2 of 3)

Well/Piezometer No.	Piezometers SP-8	SP-9	SP-10	SP-11	SP-12	SP-13
Collection Date	10/89 11/89	11/89	11/89	11/89	11/89	11/89
Location in or out of SP Fill Area	In	In	In	Out	Out	In
Parameter	Drinking Water Standard or MCL	Background Concentration Perched Zone				
pH		7.10	7.80	7.18	7.12	6.77
Conductivity (µmhos/cm)		684	920	2830	1770	670
TDS (mg/L)			NA	1500	NA	710
PCB (µg/L)			NA	NA	<0.5	<0.5
TOC (mg/L)		3.90	12.3	13.4	17.8	12.6
TPH (mg/L)			NA	1.1	NA	<0.5
Cyanide (mg/L)		<0.2	NA	0.20	NA	0.20
Radiometrics						
Gross alpha (pCi/L)	15	55.2	NA	NA	13 ± 10	76 ± 34
Gross beta (pCi/L)	50	106.8	NA	NA	49 ± 13	312 ± 22
Radium (pCi/L)	5		NA	NA	4 ± 2	56 ± 4
Metals (µg/L)						
Arsenic	50	10	NA	NA	17	17
Barium	1000	1110	NA	NA	260	1100
Cadmium	10	10	NA	NA	<5	18
Chromium	50	46	NA	NA	<5	39
Mercury	2	<0.4	NA	NA	<0.1	<0.1
Lead	50	57	NA	NA	<10	100
Nickel		101	NA	NA	13	71
Selenium	10	2.1	NA	NA	<0.4	<0.4
Silver	50	10				
Zinc	5000	110				
Volatiles (µg/L)						
Acetone			<10	<10	<10	15
Chlorobenzene			<5	5	24	<5
Carbon disulfide			<5	<5	<5	<5
Trichloroethene	5.0		<5	<5	<5	<5
Methylene chloride			BJ 2	<5	<5	<5
Semivolatiles (µg/L)						
Benzoic acid			<50	<50	NA	<50
Di-n-octyl phthalate			J 2	<10	NA	<10
Bis(2-ethylhexyl)phthalate			14	<10	NA	<10
Bis(2-chloroisopropyl)ether			<10	J 5	NA	<10
4-Nitroaniline			<50	J 3	NA	<50
Di-n-butyl phthalate			<10	<10	NA	<10
1,2,4-Trichlorobenzene			<10	<10	NA	<10

Table 5-5

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Well/Piezometer No.				Monitoring Well MW-85A	MW-85A	MW-85B	MW-85B
Collection Date				11/89	5/8/90	11/21/89	5/8/90
Aquifer Zone				Perched	Perched	Top of Regional	Top of Regional
Parameter	Drinking Water Standard or MCL	Background Concentration Perched Zone	Background Concentration Top of Regional				
pH		7.10	9.80	6.94	6.85	7.53	7.41
Conductivity (µmhos/cm)		684	718	740	1041	510	763
TDS (mg/L)				600	NA	430	NA
PCB (µg/L)				<1.0	NA	<1.0	NA
TOC (mg/L)		3.90	5.30	2.85	4.02	2.43	0.836
TPH (mg/L)				<0.5	NA	<0.5	NA
Cyanide (mg/L)		<0.2	<0.20	0.20	<0.01	<0.20	<0.01
Radiometrics							
Gross alpha (pCi/L)	15	55.2	3.7	14 ± 8	NA	25 ± 15	NA
Gross beta (pCi/L)	50	106.8	9.3	8 ± 8	NA	42 ± 19	NA
Radium (pCi/L)	5			1.2 ± 0.7	NA	21 ± 3	NA
Metals (µg/L)							
Arsenic	50	10	2	1.7	<1.0	5.9	2.5
Barium	1000	1110	663	460	53.2	1200	112
Cadmium	10	10	<7.5	<5	16	<5	17.2
Chromium	50	46	<10	<5	<10	8	<10
Mercury	2	<0.4	<0.4	<0.1	<0.2	<0.1	<0.2
Lead	50	57	48	13	<20	14	<20
Nickel		101	33	10	<15	13	<15
Selenium	10	2.1	0.5	<0.4	<1.0	<0.4	<1.0
Silver	50	10	10		<10	NA	<10
Zinc	5000	110	120		10.5	NA	<10
Volatiles (µg/L)							
Acetone				<10	<10	<10	<10
Chlorobenzene				<5	<5	<5	<5
Carbon disulfide				J 1	<5	<5	<5
Trichloroethene	5.0			J 1	<5	<5	<5
Methylene chloride				<5	<5	J 1	<5
Semivolatiles (µg/L)							
Benzoic acid				>50	<50	<50	<50
Di-n-octyl phthalate				J 2	<10	12	<10
Bis(2-ethylhexyl)phthalate				<10	J 5	13	24
Bis(2-chloroisopropyl)ether				<10	<10	<10	<10
4-Nitroaniline				<50	<50	<50	<50
Di-n-butyl phthalate				J 0.7	<10	<10	<10
1,2,4-Trichlorobenzene				<10	<10	<10	<10

J = Estimated concentration below detection limit.
E = Concentration exceeded calibration range of instrument.
B = Analyte found in blank.
NA = Not analyzed.

Table 5-6

Groundwater Samples Collected During Remedial Investigation (USACE, 1991a) SWMU-11, SP, Tinker AFB

(Page 1 of 2)

Well/Piezometer Number	Date Sampled	Laboratory Number	Parameters
SP-1	10/24/89	9-1925	TOC, VOC, SVOC, PCB
SP-3	10/24/89	9-1926	TOC, VOC
SP-4	10/24/89	9-1927	TOC, VOC
SP-7	10/24/89	9-1928	TOC, VOC
SP-8	10/24/89	9-1929	TOC, VOC
SP-9	11/05/89	9-2009	TOC, VOC, SVOC
SP-10	11/05/89	9-2010	TOC, VOC, PCB
SP-11	11/05/89	9-2011	TOC, VOC, SVOC, PCB, Radiometrics, Cyanide, TDS, TPH, Metals
SP-13	11/05/89	9-2012	TOC, VOC, SVOC, PCB
SP-4	11/06/89	9-2013	SVOC
SP-5	11/06/89	9-2014	TOC, VOC, TDS, TPH, Cyanide
SP-6	11/06/89	9-2015	TOC, VOC, SVOC
SP-9	11/06/89	9-2016	TDS, TPH, Cyanide
SP-10	11/06/89	9-2017	Metals, Radiometrics
SP-1	11/07/89	9-2021	TDS, TPH, Cyanide
SP-2	11/07/89	9-2022	TOC, VOC, Radiometrics, PCB, Metals
SP-3	11/07/89	9-2023	Radiometrics, PCB, Metals
SP-7	11/07/89	9-2024	TDS, TPH, Cyanide
SP-8	11/07/89	9-2025	SVOC
SP-12	11/07/89	9-2026	TOC, VOC, Radiometrics, PCB
MW-85A	11/21/89	9-2041	TOC, VOC, SVOC, PCB, Radiometrics, Cyanide, TDS, TPH, Metals
MW-85B	11/21/89	9-2042	TOC, VOC, SVOC, PCB, Radiometrics, Cyanide, TDS, TPH, Metals
85A Equipment Blank	11/21/89	9-2043	TOC, VOC, SVOC, PCB, Radiometrics, Cyanide, TDS, TPH, Metals

Table 5-6

(Page 2 of 2)

Well/Piezometer Number	Date Sampled	Laboratory Number	Parameters
Travel Blank	11/21/89	9-2044	TOC, VOC, SVOC, PCB, Radiometrics, Cyanide, TDS, TPH, Metals
MW-85A	05/08/90	0-1318	TOC, VOC, SVOC, Cyanide, Chloride, Sulfate, Metals
MW-85B	05/08/90	0-1319	TOC, VOC, SVOC, Cyanide, Chloride, Sulfate, Metals
85B Equipment Blank	05/08/90	0-1320	TOC, VOC, SVOC, Cyanide, Chloride, Sulfate, Metals
Travel Blank	05/08/90	0-1321	TOC, VOC, SVOC, Cyanide, Chloride, Sulfate, Metals

TOC = Total organic carbon
VOC = Volatile organic compounds
SVOC = Semivolatile organic compounds
PCB = Polychlorinated biphenyls
TDS = Total dissolved solids
TPH = Total petroleum hydrocarbons

Table 5-7

Remedial Investigation Detection Frequencies and Groundwater Sample Maximum Concentrations, Upper Saturated Zone (USACE, 1991a) SWMU-11, SP, Tinker AFB

(Page 1 of 2)

	No. Detected		No. Tested	Maximum Concentration	Location of Maximum Concentration
Parameter					
pH	15		15	8.66	SP-7
Conductivity (μmhos/cm)	15		15	2830	SP-9
TDS (mg/L)	6		6	1500	SP-9
PCB (μg/L)	0		8	<1.0	
TOC (mg/L)	15		15	26.2	SP-7
TPH (mg/L)	2		6	6.4	SP-7
Cyanide (mg/L)	5		7	0.20	SP-5, SP-7, SP-9, SP-11, MW-85A
Radiometrics	>MCL	>BKG			
Gross alpha (pCi/L)	6	4	6	95 $\pm$ - 37	SP-2
Gross beta (pCi/L)	5	4	6	312 $\pm$ - 22	SP-11
Radium (pCi/L)	5	-	6	56 $\pm$ - 4	SP-11
Metals (μg/L)	>MCL	>BKG			
Arsenic	0	3	6	17	SP-10, SP-11
Barium	1	0	6	1100	SP-11
Cadmium	2	2	6	18	SP-11
Chromium	0	0	6	39	
Mercury	0	0	6	0.12	
Lead	2	2	6	100	SP-11
Nickel	-	0	6	71	
Selenium	0	0	6	<1.0	
Silver	0	0	1	<10	
Zinc	0	0	1	10.5	

Table 5-7

(Page 2 of 2)

	No. Detected	No. Tested	Maximum Concentration	Location of Maximum Concentration
Volatiles (μg/L)				
Acetone	3	15	49	SP-7
Chlorobenzene	3	15	24	SP-10
Carbon disulfide	1	15	1 J	MW-85A
Trichloroethene	1	15	1 J	MW-85A
Methylene chloride	3	15	12	SP-4
Semivolatiles (μg/L)				
Benzoic acid	1	9	4 J	SP-1
Di-n-octyl phthalate	3	9	2 J	SP-6, SP-8, MW-85A
Bis(2-ethylhexyl)phthalate	4	9	14	SP-8
Bis(2-chloroisopropyl)ether	1	9	5 J	SP-9
4-Nitroaniline	1	9	3 J	SP-9
Di-n-butyl phthalate	1	9	0.7 J	MW-85A
1,2,4-Trichlorobenzene	0	9	<10	

MCL = Maximum Concentration Level
BKG = Background
J = Estimated Concentration

site, the chemical summary data tables for those wells are presented in Appendix J of the SP report (USACE, 1991a). VOCs present above detection limits included acetone, chlorobenzene, and methylene chloride at respective maximum concentrations of 49, 24, and 12 µg/L. Acetone was present at a concentration slightly above the detection limit. Chlorobenzene was well below the MCL of 100 µg/L, and methylene chloride exceeded the 5 µg/L MCL. Since the indicated concentrations were relatively low and these compounds are common laboratory contaminants, the RI report concluded that the laboratory was probably the source of the contamination. Carbon disulfide and TCE were both indicated at a concentration of 1 µg/L in a sample from MW-85A collected on November 21, 1989. These compounds were not detected in a subsequent sample collected on May 8, 1990, and the earlier result was not a significant concentration. Carbon disulfide had no MCL at that time. The MCL for TCE is 5 µg/L, well above the concentration detected.

The only SVOC indicated at a concentration above detection limits was bis(2-ethylhexyl) phthalate in the sample from SP-8 (14 µg/L), and this compound only slightly exceeded its detection limit of 10 µg/L. Other SVOCs indicated at concentrations below detection limits include benzoic acid, di-n-octyl phthalate, bis(2-chloro-isopropyl)ether, 4-nitroaniline, and di-n-butyl phthalate.

PCBs and cyanide were not detected in any of the samples analyzed during the RI. The piezometers yielded insufficient water for collection and analysis of a full suite of analytes from each piezometer. Analyses for gross alpha and gross beta emissions and radium were performed on samples from five piezometers (SP-2, SP-3, SP-10, SP-11, and SP-12) and MW-85A. Indicated levels for these analytes were above background levels for samples from SP-2, SP-3, SP-11, and SP-12. The highest level of gross alpha detected was 95 plus or minus 37 picocuries per liter (pCi/L) in SP-2 compared to the MCL of 15 pCi/L. The maximum gross beta detected was 312 plus or minus 22 pCi/L in SP-11 compared to the MCL of 50 pCi/L. The maximum radium detected was 56 plus or minus 4 pCi/L compared to the MCL of 5 pCi/L. All radiometric parameters in the USZ were below the MCLs in the November 1989 sample taken from MW-85A.

Metals were not indicated at concentrations significantly above background concentrations and/or drinking water standards in USZ groundwater samples from the SP. Arsenic was indicated at concentrations slightly above background in samples from SP-3, SP-10, and SP-11 (12, 17, and 17 µg/L, respectively). Barium, cadmium, and lead were indicated at concentrations of 1100, 18, and 100 µg/L, respectively, in the sample from SP-11. These concentrations are slightly higher than background and/or drinking water standards.

Lower Saturated Zone. MW-85B is the well nearest the SP that was completed in the LSZ during the RI. This well was sampled twice as part of the SP RI. The results of these two samples are presented in Table 5-5. The detection frequency and maximum concentrations are found in Table 5-8. A complete list of chemical results can be found in Appendix F of the final RI report (USACE, 1991a). MW-61B was in the LSZ and was sampled as part of the Landfills 1 through 6 and FTA1 RIs. Due to the proximity of this well to the SP, chemical summary data may be of interest with respect to the SP. The data tables can be found in Appendix J of the SP report.

Only one VOC, methylene chloride, was detected in groundwater samples from MW-85B, at a concentration of 1 µg/L. This compound is a common laboratory contaminant and currently has no MCL.

SVOCs indicated include di-n-octyl phthalate and bis(2-ethylhexyl)phthalate at maximum concentrations of 12 and 24 µg/L, respectively. Di-n-octyl phthalate was indicated in only one analysis. Bis(2-ethylhexyl)phthalate was indicated in travel blanks for both sampling events and in the equipment blank for the second sample. Detection limits for these compounds are 10 µg/L. These compounds were either not actually present or occurred only at concentrations slightly above detection limits. Phthalates are common plasticizers frequently found in laboratory equipment. At the levels detected in these samples, the phthalates were probably laboratory contaminants. PCBs, TPH, and cyanide were not detected. TOC concentrations were below background levels.

In the November 1989 sample taken from MW-85B, gross alpha, gross beta, and radium were detected at 25 plus or minus 15, 42 plus or minus 19, and 21 plus or minus 3 pCi/L, respectively. These values exceeded background levels. Radium exceeded the drinking water standard of 5 pCi/L; both gross alpha and gross beta were present in concentrations less than drinking water standards of 15 and 50 pCi/L, respectively.

Arsenic was indicated at concentrations of 2.5 to 5.9 µg/L, which was slightly above the background concentration of 2 µg/L, but below the drinking water standard of 50 µg/L. Barium and cadmium concentrations varied from 112 to 1200 µg/L and from undetected to

Table 5-8

Remedial Investigation Detection Frequencies and Groundwater Sample Maximum Concentrations Lower Saturated Zone (USACE, 1991a) SWMU-11, SP, Tinker AFB

(Page 1 of 2)

	No. Detected		No. Tested	Maximum Concentration	Location of Maximum Concentration
Parameter					
pH	2		2	7.53	MW-85B
Conductivity (μmhos/cm)	2		2	763	MW-85B
TDS (mg/L)	1		1	430	MW-85B
PCB (μg/L)	0		1	<1.0	
TOC (mg/L)	2		2	2.43	MW-85B
TPH (mg/L)	0		1	<0.50	
Cyanide (mg/L)	0		2	<0.20	
Radiometrics	>MCL	>BKG			
Gross alpha (pCi/L)	1	0	1	25 ± 15	MW-85B
Gross beta (pCi/L)	1	0	1	42 ± 19	MW-85B
Radium (pCi/L)	1	-	1	21 ± 3	MW-85B
Metals (μg/L)	>MCL	>BKG			
Arsenic	0	2	2	5.9	MW-85B
Barium	1	1	2	1200	MW-85B
Cadmium	1	1	2	17.2	MW-85B
Chromium	0	0	2	8	MW-85B
Mercury	0	0	2	<0.2	
Lead	0	0	2	14	MW-85B
Nickel	-	0	2	13	MW-85B
Selenium	0	0	2	<1.0	
Silver	0	0	1	<10	
Zinc	0	0	1	<10.5	

Table 5-8

(Page 2 of 2)

	No. Detected	No. Tested	Maximum Concentration	Location of Maximum Concentration
Volatiles (μg/L)				
Acetone	0	2	<10	
Chlorobenzene	0	2	<5	
Carbon disulfide	0	2	<5	
Trichloroethene	0	2	<5	
Methylene chloride	1	2	1 J	MW-85B
Semivolatiles (μg/L)				
Benzoic acid	0	2	<50	
Di-n-octyl phthalate	1	2	12	MW-85B
Bis(2-ethylhexyl)phthalate	2	2	24	MW-85B
Bis(2-chloroisopropyl)ether	0	2	<10	
4-Nitroaniline	0	2	<50	
Di-n-butyl phthalate	0	2	<10	
1,2,4-Trichlorobenzene	0	2	<10	

MCL = Maximum Concentration Level
BKG = Background
J = Estimated Concentration

17.2 μg/L, respectively. The higher concentrations for both metals slightly exceeded background concentrations and drinking water standards.

5.3.2 Remediation Groundwater Sampling

During remediation of the SP, three new monitoring wells (one in the USZ and two in the LSZ) were installed. Groundwater collected from the wells was analyzed for metals, VOCs, and SVOCs. Methylene chloride and bis(2-ethylhexyl)phthalate were detected in all the groundwater samples; the maximum concentrations detected for these two compounds were 15 and 10 μg/L, respectively. Both methylene chloride and bis(2-ethylhexyl)phthalate were detected in the laboratory blanks and can be attributed to laboratory contamination. Chromium was found in the LSZ at a maximum concentration of 0.05 mg/L, which was equal to the MCL (Tinker, 1992).

5.3.3 Postremediation Groundwater Sampling

Remediation of the SP was completed in November 1992. Since the completion of the project, the permanent on-site monitoring wells have been sampled during the annual base-wide monitoring program. A summary of the postremediation groundwater monitoring results is presented in Table 5-9 (Tinker, 1993a).

No contamination was found in wells MW 2-12 and MW 2-13 located upgradient of the site in the LSZ. Fourteen VOCs were detected in well MW-62 upgradient of the site in the USZ. Two metals and five VOCs were detected in monitoring well MW 2-11 downgradient of the site in the USZ. Eight VOCs were present in MW-85A downgradient of the site in the USZ. With the exception of isopropylbenzene, all chemicals detected were higher in well MW-62 upgradient of the site in the USZ than in any of the downgradient wells. None of the constituents detected downgradient of the site exceeded their individual MCL. As previously noted, MCLs were used only as a comparison since none of the constituents detected directly underneath or downgradient of the site exceeded MCLs.

Table 5-9

Postremediation Summary of Groundwater Monitoring Results (Tinker, 1993a) SWMU-11, SP, Tinker AFB

			MW-85A	
Parameters	MW-62	MW 2-11	11/23/92	7/18/93
Arsenic (mg/L)	ND	0.0081	ND	ND
Barium (mg/L)	ND	3.7	174	ND
Cis-1,2-dichloroethene (µg/L)	2	0.9	2	ND
Trichloroethene (µg/L)	78	2	11	4
Chlorobenzene (µg/L)	3	9	2	ND
1,4-Dichlorobenzene (µg/L)	2	2	ND	ND
1,2-Dichlorobenzene (µg/L)	3	0.9	0.9	ND
Carbon tetrachloride (µg/L)	ND	ND	ND	ND
1,1-Dichloroethene (µg/L)	ND	ND	0.6	ND
Tetrachloroethene (µg/L)	14	ND	4	ND
Ethyl benzene (µg/L)	2	ND	2	2
Isopropylbenzene (µg/L)	0.5	ND	5	ND
Toluene (µg/L)	2	ND	0.7	19
p-Xylene (µg/L)	0.6	ND	ND	7
m-Xylene (µg/L)	0.6	ND	ND	7
o-Xylene (µg/L)	2	ND	0.5	4
n-Propylbenzene (µg/L)	0.7	ND	ND	ND
1,3-Dichlorobenzene (µg/L)	1	ND	ND	ND
Chloroform	-	-	ND	2
Benzene	-	-	B4	8
Dimethyl phthalate	-	-	14	ND
Methylene chloride	-	-	B6	1
Naphthalene	-	-	B2	ND
1,2,4-Trimethylbenzene	-	-	ND	2
TOC	-	-	5.4	-
TDS	-	-	556	-

B = Analyte found in blank.
ND = Not detected.

6.0 Baseline Risk Assessment/Potential Receptors

A human health risk assessment and ecological assessment (USACE, 1994) has been performed for the SP site. These assessments, which include evaluation of human and ecological receptors, are briefly summarized in Sections 6.1 and 6.2, respectively.

6.1 Human Receptors

The SP was an unlined formation originally covering approximately 6,400 ft^2 that was used from 1954 to 1970 to contain sewage effluent. The pond was used until 1980 as a disposal site for liquid wastes generated by base operations, including petroleum hydrocarbon sludges, solvents, and cyanide-containing liquids. After 1980, soil fill was placed in the depression left from disuse of the pond. The soil fill underwent significant settlement and was unable to support the growth of vegetation. Additional fill (construction rubble) was placed on the site and covered with a layer of soil. The site currently appears as a level, grass-covered area of approximately 25,000 ft^2. Subsurface soil and the USZ of groundwater are contaminated with organic compounds and heavy metals.

However, it is virtually impossible for contaminants from the site to influence the useable regional groundwater zone because of the great vertical and horizontal distance to regional aquifer zone use points, and impedements to contaminant movement in the area. The LSZ is overlain by approximately 50 feet of sandstone and shale.

The only complete exposure pathway was considered to be inhalation of VOCs from soil by on-site workers. The chemicals of concern that emerged from various EPA-approved screening processes were tetrachloroethene and 1,1,1-trichloroethane. Total cancer risk (attributed only to tetrachloroethene) was estimated to be 2×10^{-12}, well below the EPA acceptable range of 1×10^{-6} to 1×10^{-4}. The hazard index for noncarcinogenic risk was 7×10^{-7}, well below the target value of one.

6.2 Ecological Risks/Receptors

Exposure pathways for ecological receptors were considered to be incomplete, precluding contact of vegetation or wildlife with site-related contamination; therefore, ecological risks were not quantified.

7.0 Action Levels

An "action level" is defined by EPA in proposed rule 40 CFR 264.521 (55 FR 30798; 7/27/90), "Corrective Action for Solid Waste Management Units (SWMU) at Hazardous Waste Management Facilities," as a health- and environment-based level, determined by EPA to be an indicator for protection of human health and the environment. In the preamble to this proposed rule, the focus of the RFI phase is defined as "characterizing the actual environmental problems at the facilities." As part of this characterization, a comparison of the contaminant concentrations to certain action levels should be made to determine if a significant release of hazardous constituents has occurred. This comparison is then used to determine if further action or corrective measures are required for a SWMU or an AOC. The preamble to the proposed rule states that the concept of action levels was introduced because of the need for "a trigger that will indicate the need for a Corrective Measures Study (CMS) and below which a CMS would not ordinarily be required" (55 FR 30798; 7/27/90). If constituent concentrations exceed certain action levels at a SWMU or an AOC, further action or a CMS may be warranted; if constituent concentrations are below action levels, a finding of no further action may be warranted. This chapter of the report presents the initial analytical data as compared to certain potential action levels.

Action levels are concentrations of contaminants at or below which exposure to humans or the environment should not produce acute or chronic effects.

The action level information is presented in this chapter so that a constituent concentration at a sample location can be compared with its potential action level. Only constituents identified in the analysis are listed in the SWMU-11, SP table. Table 7-1 shows the action levels for soil, water, and air as published in federal or state regulations, policies, guidance documents, or proposed rules.

The action levels listed in Table 7-1 are:

- ***SWMU Corrective Action Levels (CAL) -*** The first set of action levels provided in the table are those taken from the proposed rule (40 CFR 264.521) and provided as Appendix A to the rule as "Examples of Concentrations Meeting Criteria for Action Levels." These levels are health-risk based and are provided

Table 7-1

Action Levels
SWMU-11, Supernatant Pond, Tinker AFB

(Page 1 of 6)

Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	WQS[e]	SP-2 5.5-6.5 ft	SP-3 11.5-12.0 ft	SP-4 5.0-6.0 ft	SP-5 5.5-6.5 ft	SP-6 4.5-5.5 ft
	Soil (mg/kg)	Water (mg/L)	Air (µg/m³)	Water (mg/L)	Soil (mg/kg)	Air (µg/m³)	Water (mg/L)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Organics												
Acetone	8000	4.0						0.014	0.039		0.190	0.030
Bis(2-ethylhexyl)phthalate	50	0.003		0.006						1.300		
Chlorobenzene	2000	0.7	20	0.1								0.130
Methylene chloride	90	0.005	0.3	0.005				0.017	0.015	0.031	0.031	0.015
Toluene	20,000	10	7000	1.0			301.9	0.006				
Xylene (total)	2.0×10^5	70	1000	10				0.010				
Metals												
Arsenic	80		7.00×10^{-5}	0.05	21		0.0014	1.3		1.7		1.4
Barium	4000		0.4	2	6400			290	600	390	180	320
Cadmium	40		0.0006	0.005			0.0841	6.8	6.0	12	7.5	7.4
Chromium				0.1	110		3.365	18	17	37	2.5	22
Lead				0.015[f]	27	1.5[g]	0.025	18	17	82	21	22
Nickel	2000	0.7		0.1	61		4.583	12	16	17	22	18
Selenium				0.05	1.2					0.20		
Silver	200						64.62			33		
Zinc					79			24	23	170	34	25

KN/1256/SWMU11/SWMU11.7-1/08-26-94/F1 11:25am

Table 7-1

(Page 2 of 6)

Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	WQS[e]	SP-7 4.5,6.5-7 ft	SP-9 5.5-6.5 ft	SP-2	SP-3	SP-4
	Soil (mg/kg)	Water (mg/L)	Air ($\mu g/m^3$)	Water (mg/L)	Soil (mg/kg)	Air ($\mu g/m^3$)	Water (mg/L)	(mg/kg)	(mg/kg)	(mg/L)	(mg/L)	(mg/L)
Organics												
1,4-Dichlorobenzene				0.075					0.088			
4-Chloroaniline								1.90	0.750			
Acetone	8000	4.0						1700	0.080			
Bis(2-ethylhexyl)phthalate	50	0.003		0.006				2.30	2.30	NA[h]	NA	
Chlorobenzene	2000	0.7	20	0.1				0.130				
Methylene chloride	90	0.005	0.3	0.005				0.420	0.067			0.012
Phenol	50000	20					4615		0.55	NA	NA	NA
Metals												
Arsenic	80		7.0×10^{-5}	0.05	21		0.0014	4.8	4.3	0.009	0.012	NA
Barium	4000		0.4	2	6400			1100	900	0.420	0.200	NA
Cadmium	40		0.0006	0.005			0.0841	34	30	0.006		NA
Chromium				0.1	110		3.365	120	130	0.0052		NA
Lead				0.015[f]	27	1.5[g]	0.025	210	160	0.061	0.013	NA
Mercury	20			0.002			0.0006			0.00012	0.00012	NA
Nickel	2000	0.7		0.1	61		4.583	27	22	0.036	0.019	NA
Selenium				0.05	1.2			2.0				NA
Zinc					79			690	740			NA

Table 7-1

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Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	WQS[e]	SP-7 4.5,6.5-7 ft	SP-9 5.5-6.5 ft	SP-2	SP-3	SP-4
	Soil (mg/kg)	Water (mg/L)	Air (µg/m^3)	Water (mg/L)	Soil (mg/kg)	Air (µg/m^3)	Water (mg/L)	(mg/kg)	(mg/kg)	(mg/L)	(mg/L)	(mg/L)
Radiometrics												
Gross Alpha				15 pCi/L						95 ± 37 pCi/L	75 ± 30 pCi/L	NA
Gross Beta										215 ± 19 pCi/L	109 ± 15 pCi/L	NA
Radium				20 pCi/L						29 ± 3 pCi/L	14 ± 2 pCi/L	NA

Table 7-1

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Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	WQS[e]	SP-7	SP-10	SP-11	SP-12	SP-13
	Soil (mg/kg)	Water (mg/L)	Air (µg/m³)	Water (mg/L)	Soil (mg/kg)	Air (µg/m³)	Water (mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Organics												
Acetone	8000	4.0						0.049				0.015
Bis(2-ethylhexyl)phthalate	50	0.003		0.006				NA	0.014		NA	
Chlorobenzene	2000	0.7	20	0.1						0.005	0.024	
Metals												
Arsenic	80		7.0×10^{-5}	0.05	21		0.0014	NA	NA	NA	0.017	0.017
Barium	4000		0.4	2	6400			NA	NA	NA	0.260	1.10
Cadmium	40		0.0006	0.005			0.0841	NA	NA	NA		0.018
Chromium				0.1	110		3.365	NA	NA	NA		0.039
Lead				0.015[f]	27	1.5[g]	0.025	NA	NA	NA		0.100
Nickel	2000	0.7		0.1	61		4.583	NA	NA	NA	0.013	0.071
Radiometrics												
Gross Alpha				15 pCi/L				NA	NA	NA	13 ± 10 pCi/L	76 ± 34 pCi/L
Gross Beta								NA	NA	NA	49 ± 13 pCi/L	312 ± 22 pCi/L
Radium				20 pCi/L				NA	NA	NA	4 ± 2 pCi/L	56 ± 4 pCi/L

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Table 7-1

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Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	WQS[e]	MW-85A	MW-85B	MW-62	MW2-11
	Soil (mg/kg)	Water (mg/L)	Air ($\mu g/m^3$)	Water (mg/L)	Soil (mg/kg)	Air ($\mu g/m^3$)	Water (mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Organics											
1,2-Dichlorobenzene				0.6						0.003	0.009
1,2,4-Trimethylbenzene								0.002		NA	NA
1,3-Dichlorobenzene				0.6						0.001	
1,4-Dichlorobenzene				0.075						0.002	0.002
Benzene				0.005			0.714	0.008		NA	NA
Bis(2-ethylhexyl)phthalate	50	0.003		0.006					0.024		
Chlorobenzene	2000	0.7	20	0.1						0.003	0.009
Chloroform	100	0.006	0.04	0.1			4.708	0.002		NA	NA
Cis-1,2-dichloroethene	8		0.04	0.07						0.002	0.0009
Ethyl benzene	8000	4.0		0.7			28.72	0.002		0.002	
Isopropylbenzene										0.005	
Methylene chloride	90	0.005	0.3	0.005				0.001		NA	
N-propylbenzene										0.0007	
Tetrachloroethene	10	0.0007	1.0	0.005						0.014	
Toluene	20,000	10	7000	1.0			301.9	0.019		0.002	
Trichloroethene	60			0.005				0.004		0.078	0.002
Xylene (total)	2.0×10^5	70	1000	10				0.018		0.0032	

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Table 7-1

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Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	WQS[e]	MW-85A	MW-85B	MW-62	MW2-11
	Soil (mg/kg)	Water (mg/L)	Air ($\mu g/m^3$)	Water (mg/L)	Soil (mg/kg)	Air ($\mu g/m^3$)	Water (mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Metals											
Arsenic	80		7.0×10^{-5}	0.05	21		0.0014		0.0025		0.0081
Barium	4000		0.4	2	6400				0.112		3.7
Cadmium	40		0.0006	0.005			0.0841		0.0172		

[a]CAL - Corrective Action Levels
[b]MCL - Maximum Contaminant Levels
[c]Background - Where available, background concentrations are listed
[d]NAAQS - National Ambient Air Quality Standards
[e]WQS - Water Quality Standards
[f]Action Level at the Tap
[g]3-Month Average
[h]NA - Not analyzed

as specific examples of levels below which corrective action would not be required.

- ***Maximum Contaminant Levels (MCL) -*** These values are provided from 40 CFR Subpart G, Sections 141.60 through 0.63 as promulgated under the Safe Drinking Water Act. These levels are designated for water media only.

- ***USGS Background -*** These values are provided from the USGS report titled "Elemental Composition of Surficial Materials from Central Oklahoma" (USGS, 1991). These values represent the levels of metals which naturally occur in Central Oklahoma soils.

- ***Background -*** These levels are provided where background could be determined. Where available, background concentrations are listed for metals in soil samples taken on site, which were thought to be unaffected by releases from a unit.

- ***National Ambient Air Quality Standards (NAAQS) -*** These standards are published in 40 CFR Part 50 under the Clean Air Act and apply to point sources that emit a limited number of constituents to the air. The constituents regulated are nitrogen dioxide, sulphur dioxide, carbon monoxide, lead, ozone, and particulate matter. Currently, it is assumed that none of the SWMUs or AOCs emit these compounds in regulated quantities and no air samples have been taken which would allow for a valid comparison.

- ***Water Quality Standards (WQS) -*** The WQS are the standards for surface water quality as established by the State of Oklahoma. These standards apply to point source discharges to surface waters and have been listed for those units adjacent to surface water.

Table 7-1 also gives a brief comparative evaluation of the data collected and the related action levels. The data for each detected compound are compared with the appropriate action level in order to identify those constituents (compounds) with concentrations exceeding the action levels. This identification of the compounds above the action levels provides an indication of a potential environmental problem at a specific site. In addition, this information indicates whether there is a need for conducting a CMS so that a corrective action can be implemented/undertaken at the site.

For constituents that have a SWMU CAL and an MCL for water, the MCL will be used for the comparison. Also, constituents that do not have a USGS background value will be compared to the site background value if available.

The data included in Table 7-1 are representative of the data presented in Chapter 5.0. For each soil boring, a range was identified and used in the comparison to the action levels. For the groundwater samples, the results for the most recent sampling event were included in Table 7-1.

Evaluation of the soil data for SP shows lead, chromium, selenium, and zinc above the existing background concentrations. These constituents do not have action levels. Organics benzene, trichloroethene, bis(2-ethylhexyl)phthalate, and tetrachloroethene were detected in the groundwater above MCLs. Inorganics, barium, cadmium, lead, and zinc were detected in groundwater above MCLs. Arsenic was detected above the WQS but below the MCL. Gross alpha and radium were also detected above MCLs in the groundwater.

8.0 Summary and Conclusions

The results of the RI at the SP demonstrated the presence of both inorganic and organic contaminants in the soil (Table 5-2). The chemicals detected above detection limits and known background concentrations included PCBs, cyanide, silver, arsenic, cadmium, chromium, lead, selenium, zinc, acetone, chlorobenzene, toluene, xylene, phenol, 4-chloroaniline, and bis(2-ethylhexyl)phthalate.

The fill material and undisturbed soils less than 4.5 feet deep were not sampled. These soils were not considered to be contaminated for the following reasons: (1) fill material was put in place after disposal activities had ceased; (2) undisturbed soils at depths of 4.5 to 6.5 feet immediately outside the former pond did not exhibit significant contamination; and, (3) the RI showed that the soil contamination was essentially limited to the bottom 4 to 7 feet of the former pond area (Tinker, 1993a).

Chemical analysis of groundwater sampled from the piezometers within the boundaries of the SP yielded low contaminant concentrations (Table 5-5). The piezometers were screened in the USZ which is in direct contact with the soils of the SP site. No significant levels of groundwater contamination were detected immediately below the site, which suggests that the soil contaminants are not readily leachable. The absence of downgradient contamination, the low hydraulic conductivity of the soil (2.6 x 10^{-6} cm/s), and the low concentration of contaminants in the USZ at the SP site indicate that the probability of significant groundwater transport of contaminants from the site is low. MCLs were used as a comparison for the constituents identified in the groundwater. None of the samples collected directly underneath or downgradient of the site exceeded the MCLs (Tinker, 1993a).

A human health risk assessment and ecological assessment (USACE, 1994) was performed for the SP site. The risk assessment was based on data, information, and conclusions presented in the SP RI report (USACE, 1991a). Inhalation of VOCs from soil by on-site workers was considered the only complete exposure pathway. Total cancer risk was estimated to be well below the EPA acceptable range of 1 x 10^{-6} to 1 x 10^{-4}. The HI for noncarcinogenic risk was 7 x 10^{-7}, well below the target value of one. Exposure pathways for ecological receptors were considered incomplete; therefore, ecological risks were not quantified.

The SP site was selected for demonstrating the innovative SS technology. The solidification of the soil would provide the additional benefit of guaranteeing protection of human health and the environment. Demonstration of the SS technology began in June 1992. The entire former pond area was excavated to a depth of 8 feet. The construction rubble encountered in the excavated soil was segregated and disposed at an approved industrial landfill. The soil that was excavated from 4 to 8 feet was solidified with cement and placed back into the site excavation. The solidified soil was then covered with an additional 4 feet of clean backfill.

The remediation of the SP was completed in November 1992. Since the completion of the project, the permanent on-site monitoring wells have been sampled during the annual base-wide monitoring program. With the exception of isopropylbenzene, all chemicals detected were present in higher concentrations at upgradient well MW-62 than at any of the downgradient wells. None of the constituents detected directly underneath or downgradient of the site exceeded their MCLs.

9.0 Recommendations

The groundwater in the vicinity of the SP should be further investigated during a Phase II RFI as a part of the basewide groundwater investigation. Additional monitoring wells should be added to the USZ and LSZ during this investigation to delineate the horizontal distribution of groundwater contaminants across this portion of the Base. Based on the location of this site, it will be more appropriate to investigate it as part of a group comprising several waste units in close proximity: RWDS 1030W, RWDS 1022E, RWDS 62598, Landfills 1 through 4, and FTA1. Details of specific sampling needs will be presented in the work plan/sampling plan for the Phase II RFI.

Site soil samples should be collected and analyzed to further define extent of contamination. Additional soil samples will be collected if needed.

Site-specific soil background samples were not collected, nor were the soil background values available for inclusion in this Phase I RFI report. Therefore, it is recommended that site-specific soil samples from uncontaminated areas be collected for analysis during the Phase II RFI field work. This additional information along with the USGS background values should be used in the Phase II report to distinguish site-related from background concentrations in a statistically significant manner. During the development of the Phase II RFI work plan, the number of background samples to be collected, the location of the soil borings, and the soil analysis to be preformed on the samples should be determined for EPA approval before beginning the field work.

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Final Report
Phase I RCRA Facility Investigation for Appendix I Sites
VOLUME VIII
SWMU-12, Industrial Waste Pit No. 1

Department of the Air Force
Oklahoma City Air Logistics Center
Tinker Air Force Base, Oklahoma

September 1994

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List of Acronyms

AFB	Air Force Base
AOC	area of concern
BTEX	benzene, toluene, ethyl benzene, xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DERP	Defense Environmental Restoration Program
DOD	U.S. Department of Defense
EID	Engineering Installation Division
EM	electromagnetic
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
ft/ft	foot per foot
HSWA	Hazardous and Solid Waste Amendments
IRP	Installation Restoration Program
IWP1	Industrial Waste Pit 1
IWTP	industrial wastewater treatment plant
LSZ	lower saturated zone
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
msl	mean sea level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan (NCP)
NPL	National Priorities List
PA/SI	preliminary assessment/site investigation
PCE	tetrachloroethene
RCRA	Resource Conservation and Recovery Act
ppb	parts per billion
RI/FS	remedial investigation/feasibility study
RFI	RCRA Facility Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SWMU	solid waste management unit
TCA	trichloroethane
TCE	trichloroethene
TPH	total petroleum hydrocarbon

TSD	treatment, storage, and disposal (facility)
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
USC	U.S. Code
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USZ	upper saturated zone
UWBZ	upper waste bearing zone

Executive Summary

This report provides a summary of the various investigations that have been conducted at solid waste management unit (SWMU)-12, Industrial Waste Pit No. 1 (IWP1), Tinker Air Force Base (AFB), Oklahoma. This report has been prepared to determine and document whether sufficient investigations have been performed at IWP1 to meet regulatory requirements. Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. The Base encompasses approximately 5,000 acres.

Background. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints.

In 1984, Congress amended the Resource Conservation and Recovery Act (RCRA) with the Hazardous and Solid Waste Amendments (HSWA), which allow EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or contaminants from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989, Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit. The final RCRA HSWA permit issued on July 1, 1991 requires Tinker AFB to investigate all SWMUs and areas of concern (AOC) and to perform corrective action at those identified as posing a threat to human health and the environment. The permit specifies that a RCRA Facility Investigation (RFI) be conducted for 43 identified SWMUs and two AOCs on the Base. This document has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for IWP1.

Source Description. IWP1 was in operation from 1947 to 1958 and was constructed without a liner. During its operational period, the pit received unspecified industrial waste streams originating from various aircraft plating and maintenance facilities on Tinker AFB. The pit is believed to contain large quantities of waste oils, contaminated fuels, chromates, phenols, cyanides, waste acids, and bases. The petroleum-based waste may have been periodically burned to reduce the volume of waste material in the pit (Radian Corporation, 1985a). IWP1 was filled in 1958 and the surface covered and graded, leaving no visible surface features to indicate its location.

Site Investigations. The initial phase of the investigations conducted at Tinker AFB was conducted by Engineering Science (ES, 1982). The purpose of this study was to conduct a literature search for the various potentially contaminated sites in order to determine from records what was actually disposed of at these sites. During the literature search, no information concerning the type of waste disposed of in IWP1 or the construction drawings were obtained.

The second phase involved investigations to confirm the presence of contamination and determine the nature and the extent of contamination at the different sites on the Base. In 1983 and 1984, Radian was retained to perform these investigations. One of the sites investigated was IWP1, which at the time was known as "zone 4." Various field activities at this site including electromagnetic (EM) survey, soil coring, and monitoring well installation were conducted to achieve the stated objective.

The results of the EM survey showed only one significant anomaly, with the rest of the area occupied with materials having near or slightly above background conductivity. The soil coring results showed the waste materials were thoroughly mixed with soil. Based on these data, no reliable estimate on the waste volume could be made because the pit boundaries were not well defined.

The analytical results show that IWP1 soils contain high levels of organics and heavy metals reflecting the origin of the waste. No well-defined distribution pattern of these parameters was observed. Both the soil coring and analytical results show broad variations in the appearance and chemical content of the material. Two monitoring wells, MW-4A and MW-4G, were sampled (MW-4F was dry) to investigate groundwater contamination around IWP1. The U.S. Army Corps of Engineers (USACE) renumbered these wells to MW-17, MW-18A, and MW-18B, respectively, consistent with the sitewide well numbering system. The results of analyses of groundwater showed little or no migration of waste constituents downward from the site. The shallow monitoring well (MW-18A) completed in the fill material showed the presence of total organic compound (TOC), lead, and phenol in significant concentrations. The deep monitoring well (MW-17) did not exhibit evidence of significant contamination of the groundwater on the site. Detected compounds in this well included trichloroethylene, diethyl phthalate, and 1,2-dichloroethane.

Roy F. Weston, Inc. (Weston) was contracted by Tinker AFB to perform a remedial investigation (RI) of IWP1 in 1990 and 1991 to supplement previous studies. The RI included a soil vapor survey, an EM survey, sampling and analysis of groundwater, water level measurements, geophysical logging of monitoring wells, soil coring, and permeability analysis (Weston, 1991a).

The soil gas survey resulted into a collection of 25 soil vapor samples which were analyzed for trichloroethane (TCA), trichloroethylene (TCE), perchloroethylene (PCE), methane, and benzene, toluene, ethyl benzene and xylenes (BTEX). Methane and TCE were detected in every sample; however, none of the detected constituents showed significant contamination. Low concentrations of PCE were detected in two samples. Low levels of benzene were detected in most of the samples, but only one sample also contained detectable amounts of toluene, ethyl benzene, and xylenes. The EM survey showed five potential anomalies which were interpreted as being associated with known cultural features. Thus, none of the anomalies were interpreted to be a result of hidden drums or waste sludges. These results closely agree with the findings of the Radian investigation.

Neutron and gamma ray geophysical borehole logging was performed on two monitoring wells and one soil boring. The geophysical logs indicate that the shallow subsurface soils are composed of moist interbedded clay and silt. Chemical analysis for one soil sample indicated the presence of low concentrations of metals. No organics were detected in the soil sample. Groundwater samples from monitoring wells MW-17 and MW-18A showed no or very low concentrations of contamination from organic constituents.

Characterization/Potential Receptors. No baseline risk assessment has been conducted for this site.

Conclusions. The Radian study concluded that the contaminants from the waste material are not currently migrating away from the site. In addition, the report concludes that a very limited possibility exists for the waste constituents to migrate away from the site due to the geologic containment provided by the impermeable shale bedrock.

The Weston study concluded that the IWP1 site does not exhibit contamination to warrant additional investigations. Therefore, the study recommended no further action be pursued at this site. However, preliminary evaluation of the existing data indicates a potential groundwater problem may exist at the site. Additional data requirements to support any conclusions or interpretations have been recommended.

Recommendations. Based on the documents reviewed, it appears that groundwater at this site has not been adequately investigated. Both the Radian and Weston studies failed to determine groundwater conditions at the site including: flow direction, and the characterization of the groundwater upgradient and downgradient of the waste pit. The reports assume groundwater flow to be in the southwest direction, but no groundwater wells were installed downgradient in order to establish whether there has been contaminant migration from the site. Also based on the comparison of existing data with action levels, there appears to be a potential groundwater problem that warrants further investigations of the site.

As this report is being prepared, efforts to obtain the additional data are underway. Groundwater monitoring wells are being planned for installation as a part of the RFI Phase II investigation of the site, which is a part of the basewide groundwater investigation. Three monitoring wells in the LSZ have been installed upgradient of the IWP1 as a result of studies at another site. Two downgradient monitoring wells in the USZ are planned for installation along the waste pit boundary. In addition, three well clusters for monitoring both the USZ and LSZ are planned to be installed downgradient of the site.

Therefore, in addition to the ongoing activities, the following is recommended.

- Continue groundwater monitoring for at least three sampling events for the new wells. Groundwater should be analyzed for VOCs, SVOCs, metals, and inorganic parameters.

- Determine groundwater flow direction and hydraulic parameters of the USZ by monitoring water levels and performing slug tests in the new monitoring wells.

- Collect site-specific soil background samples to be used in addition to USGS soil data to distinguish site-related from background concentrations in a statistically significant manner during the Phase II investigation.

- Develop a Phase II RFI work plan and submit it to EPA for approval before beginning field work.

- Determine number, location, and analysis required for soil background samples in addition to USGS soils data to distinguish site-related from background concentrations in a statistically significant manner.

- Determine number of additional soil samples required to delineate the contamination.

- Determine number of additional monitoring wells required to be installed under basewide groundwater investigation to provide data for this site.

1.0 Introduction

1.1 Purpose and Scope

This document has been prepared in response to the Department of Air Force, Tinker Air Force Base (AFB), Oklahoma request for a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Summary Report for solid waste management unit (SWMU)-12, Industrial Waste Pit No. 1 (IWP1)

The objective of this RFI Summary Report is to provide Tinker AFB with one comprehensive report that summarizes the various investigations that have occurred at IWP1 since the first environmental investigation was initiated on Base in 1981. The purpose of this comprehensive summary document is to:

- Characterize the site (Environmental Setting).
- Define the source (Source Characterization).
- Define the degree and extent of contamination (Contamination Characterization).
- Identify actual or potential receptors.
- Identify all action levels for the protection of human health and the environment.

Additionally, this document briefly describes the procedures, methods, and results of all previous investigations that relate to IWP1 and contaminant releases, including information on the type and extent of contamination at the site, and actual or potential receptors. Where previous investigations, reports, or studies were not comprehensive and did not furnish the information required to determine the nature and extent of contamination, future work that can be conducted to complete the investigation has been recommended.

1.2 Preface

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the cleanup of hazardous waste disposal sites across the country. CERCLA gave the president authority to require responsible parties to remediate the sites or to undertake response actions through use of a fund (the Superfund). The president, through Executive Order 12580, delegated the U.S. Environmental Protection Agency (EPA) with the responsibility to investigate and remediate private party hazardous waste disposal sites that created a threat to human health and the environment. The president delegated responsibility for investigation and cleanup of federal facility disposal sites to the various federal agency heads. The Defense Environmental Restoration Program (DERP) was formally established by Congress in Title 10 U.S. Code (USC) 2701-2707 and 2810. DERP provides

centralized management for the cleanup of U.S. Department of Defense (DOD) hazardous waste sites consistent with the provisions of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300), and Executive Order 12580. To support the goals of DERP, the Installation Restoration Program (IRP) was developed to identify, investigate, and clean up contamination at installations.

Under the Air Force IRP, Tinker AFB began a Phase I study similar to a preliminary assessment/site investigation (PA/SI) in 1981 (Engineering Science [ES], 1982). This study helped locate 14 sites that needed further investigation. A Phase II study was performed in 1983 (Radian Corporation [Radian], 1985 a,b).

In 1986, Congress amended CERCLA through SARA. SARA waived sovereign immunity for federal facilities. This act gave EPA authority to oversee the cleanup of federal facilities and to have the final authority for selecting the remedial action at federal facilities placed on the National Priorities List (NPL) if the EPA and the relevant federal agency cannot concur in the selection. Congress also codified DERP (SARA Section 211), establishing a fund for the DOD to remediate its sites because the Superfund is not available for the cleanup of federal facilities. DERP specifies the type of cleanup responses that the fund can be used to address.

In response to SARA, the DOD realigned its IRP to follow the investigation and cleanup stages of the EPA:

- PA/SI
- Remedial investigation/feasibility study (RI/FS)
- Record of Decision (ROD) for selection of a remedial action
- Remedial design/remedial action.

In 1984, Congress amended RCRA with the Hazardous and Solid Waste Amendments (HSWA), which allow the EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989 Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit.

EPA, in the Hazardous Waste Management Permit for Tinker AFB, dated July 1, 1991, identified 43 SWMUs and two areas of concern (AOC) on Tinker AFB that need to be addressed. This permit requires Tinker AFB to investigate all SWMUs and AOCs and to perform corrective action at those identified as posing a threat to human health or the environment. This RFI Summary Report has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for IWP1 and to document all determinations.

1.3 Facility Description

Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County (Figure 1-1) with its approximate geographic center located at 35° 25' latitude and 97° 24' longitude (U.S. Geological Survey [USGS], 1978). The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. An additional area east of the main Base is used by the Engineering Installation Division (EID) and is known as Area D. The Base encompasses approximately 5,000 acres. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints. Wastes that are currently generated are managed at two permitted hazardous waste storage facilities. However, prior to enactment of RCRA, industrial wastes were discharged into unlined landfills and waste pits, streams, sewers, and ponds. Past releases from these landfills, pits, etc., as well as from underground tanks, have occurred. As a result, there are numerous sites of soil, groundwater, and surface water contamination on the Base.

The various reports generated as a result of investigative activities conducted at the IWP1 have been reviewed and evaluated in terms of the sites' status under RCRA regulations. A summary based on the review of these reports for IWP1 is presented in the following chapters and sections. In addition, recommendations for additional work is given at the end of the summary report.

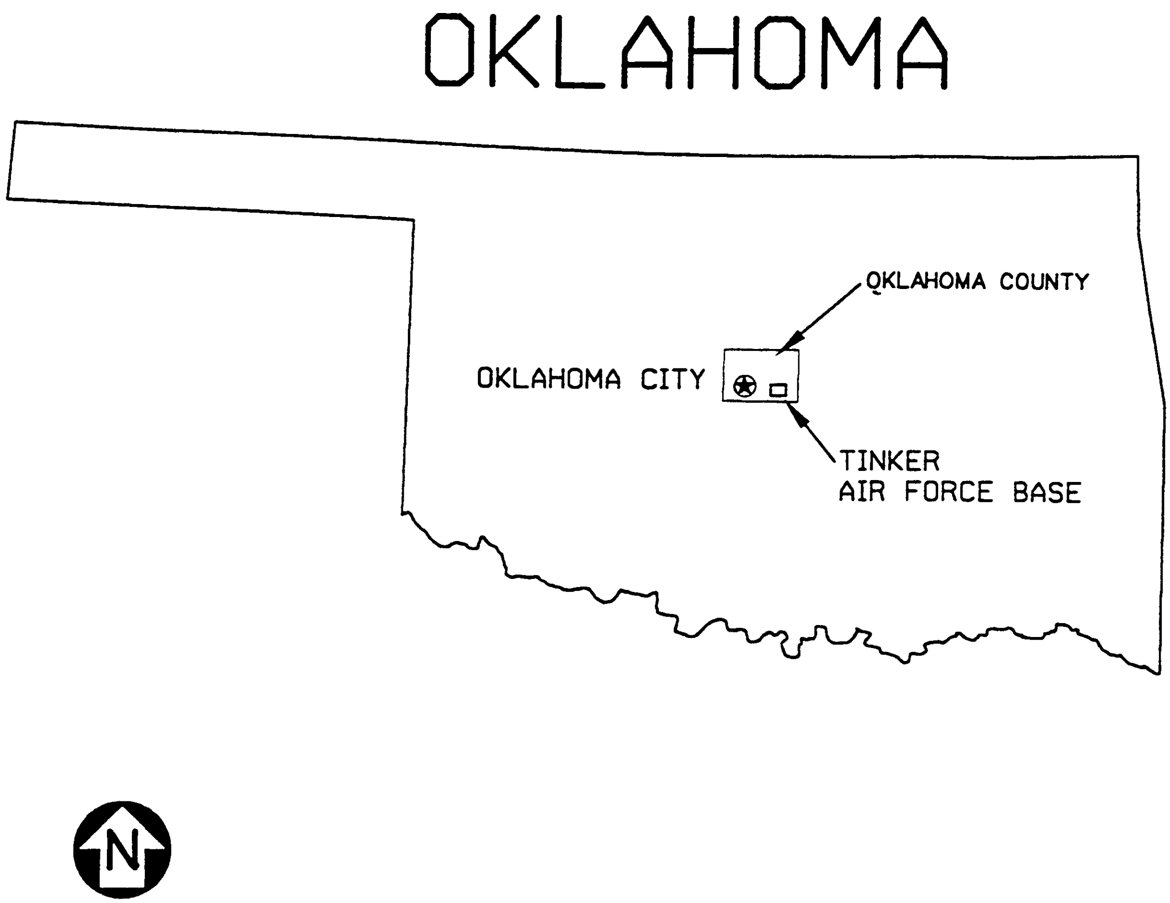

FIGURE 1-1
TINKER AIR FORCE BASE
OKLAHOMA
STATE INDEX MAP

PREPARED FOR
TINKER AFB
OKLAHOMA

STARTING DATE: 03/17/94 | DATE LAST REV.: | DRAFT. CHCK. BY:G. PACHECO | INITIATOR: C. WALLACE | DWG. NO.:
DRAWN BY:P.O. TERRY | DRAWN BY: | ENGR. CHCK. BY: C. WALLACE | PROJ. MGR.J. TAYLOR | PROJ. NO.:

3/23/94 POT
FILENAME: G:\TINKER\40983202.075

1.4 Site Description

IWP1 is located in the south-central part of Tinker AFB, approximately 500 yards southwest of Building 2121, approximately 400 yards west of Douglas Boulevard and southeast of Southeast 59th Street (Figure 1-2). The site is approximately 1.4 acres in size. IWP1 is no longer in use and has been covered with fill material, graded, and vegetated, leaving no visible surface features to indicate its location. The resulting topography after closure of the waste pit is a gentle slope toward Elm Creek, with minor depressions that occasionally allow the collection of water after precipitation.

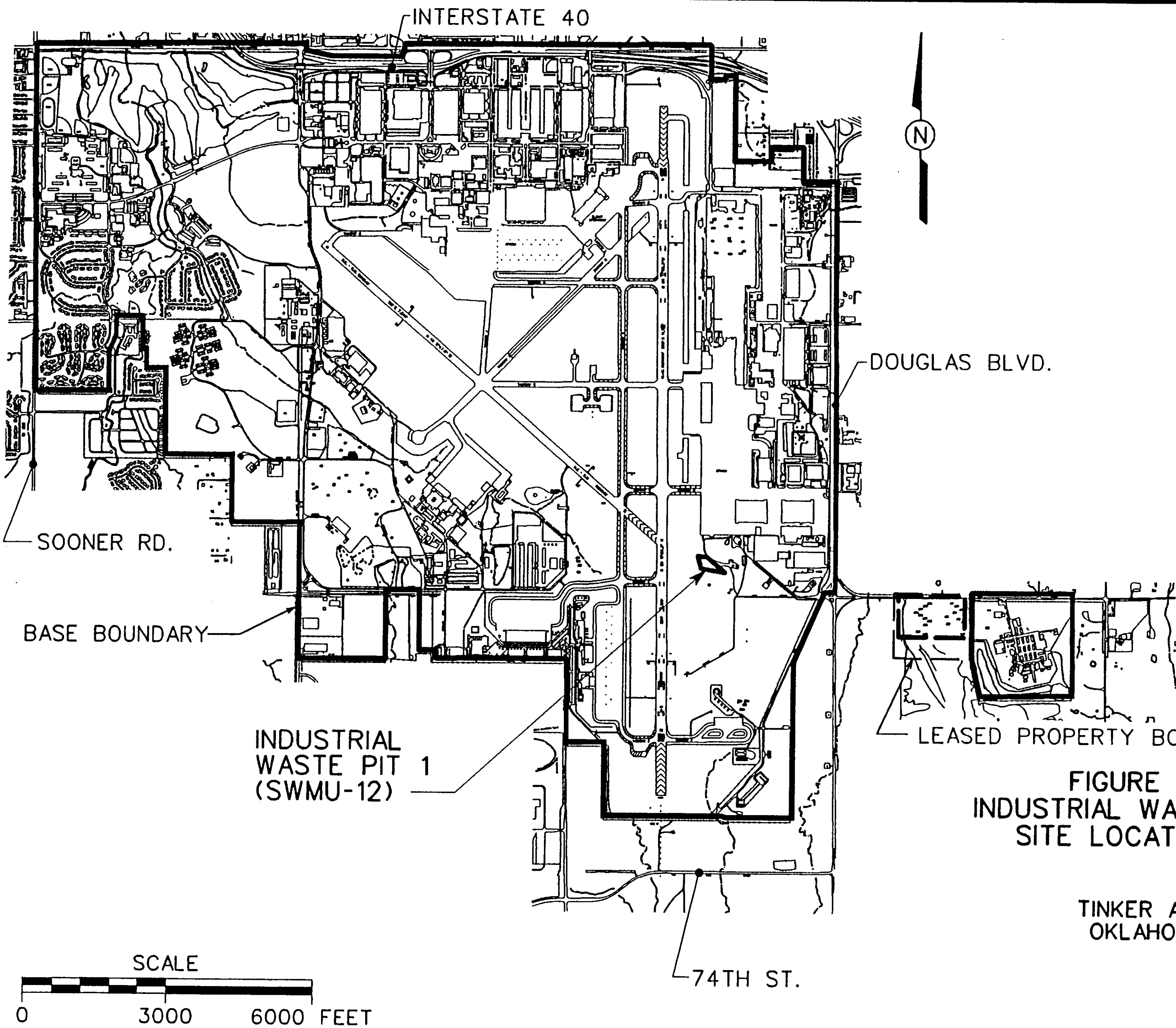

FIGURE 1-2
INDUSTRIAL WASTE PIT 1
SITE LOCATION MAP

TINKER AFB
OKLAHOMA

STARTING DATE: 3/18/94	DATE LAST REV.:8/25/94	DRAFT. CHCK. BY:G. PACHECO	INITIATOR:C. WALLACE	DWG. NO.:40983202.086
DRAWN BY: P.O. TERRY	DRAWN BY:P. TERRY	ENGR. CHCK. BY:	PROJ. MGR.:J. TAYLOR	PROJ. NO.:409832

FILENAME:G:\TINKER\40983202.086

2.0 Background

2.1 Site Operations and History

Tinker AFB was originally known as the Midwest Air Depot and began operations in July 1941. The site was activated March 1942. During World War II, the depot was responsible for reconditioning, modifying, and modernizing aircraft, vehicles, and equipment.

General refuse generated from Base operations has been disposed of in at least six landfills located on the Base property or leased land adjacent to the Base. However, the waste liquids and sludges generated from the various aircraft maintenance shops were not disposed of in the six landfills. Instead, they were disposed of in two large open pits which were specifically constructed to receive this type of waste. One of these waste pits, IWP1, is located in the south-central portion of the Base, approximately 500 yards southwest of Building 2121, on a hill between Patrol Road and the north-south runway.

IWP1 was in operation from 1947 to 1958 and was constructed without a liner. During its operational period the pit received unspecified industrial waste streams originating from various aircraft plating and maintenance facilities on Tinker AFB. The pit is believed to contain large quantities of waste oils, contaminated fuels, chromates, phenols, cyanides, waste acids and bases. The petroleum-based waste may have been periodically burned to reduce the volume of waste material in the pit (Radian, 1985a). The pit was filled in 1958 and the surface graded, leaving no visible surface features to indicate its location.

2.2 Summary of Previous Investigations

Engineering Science, Inc. Phase I studies under the IRP at Tinker AFB were conducted by ES and completed in April 1982. The purpose of these studies was to conduct a records search for the identification of past waste disposal activities which may have caused groundwater contamination on and off the Base. Among the sites identified as potentially contaminated was IWP1, which was designated as zone 4 in the ES study (ES, 1982).

Radian Corporation. During 1982 and 1983, Radian conducted investigations at this site. The investigations were designed to determine the nature and extent of the remains of IWP1. In addition, the overall purpose of the investigation included a determination of whether or not contamination has migrated off site; identification of environmental consequences of migrated contaminants; and recommendations for additional investigations to identify the magnitude, extent, and direction of movement of discovered contaminants (Radian, 1985a).

In order to achieve these objectives, several field activities were performed at the site. These activities included completion of shallow and deep groundwater monitoring wells, performance of electromagnetic (EM) surveys, and soil coring.

The results of the EM survey showed only one significant anomaly, with the rest of the area occupied with materials having near or slightly above background conductivity. The soil coring results showed the waste materials was thoroughly mixed with soil. Based on these data, a reliable estimate on the waste volume could not be made because the pit boundaries were not well defined.

The analytical results show that soils on site contain high levels of organics and heavy metals reflecting the origin of the waste. No well defined distribution pattern of these parameters was observed. Both the soil coring and analytical results show broad variations in the appearance and chemical content of the material. The results of analyses of groundwater showed little or no migration of waste constituents downward from the site. The shallow monitoring well (MW-18A) completed in the fill material showed the presence of total organic carbons (TOC), lead, and phenol in significant concentrations. The deeper monitoring well (MW-17) completed in the upper saturated zone (USZ) did not exhibit evidence of significant contamination of the groundwater on the site. Detected compounds in this well included: 100 parts per billion (ppb) of trichloroethylene, 8 ppb of dimethyl phthalate, and 3 ppb of 1,2-dichloroethane. Figure 2-1 shows the soil borings and monitoring well locations.

The Radian study concluded that the contaminants from the waste material are not currently migrating away from the site. In addition, the report concludes that there is a limited possibility for the waste constituents to migrate away from the site due to the underlying impermeable shale bedrock that provide a natural geologic containment system.

Roy F. Weston, Inc. Roy F. Weston, Inc. was contracted by Tinker AFB to perform a RI of IWP1. The RI was conducted in 1990 and 1991 to supplement previous studies. The RI included a soil vapor survey, an EM survey, sampling and analysis of groundwater, water level measurements, geophysical logging of monitoring wells, soil coring, and permeability analysis (Weston, 1991a, b).

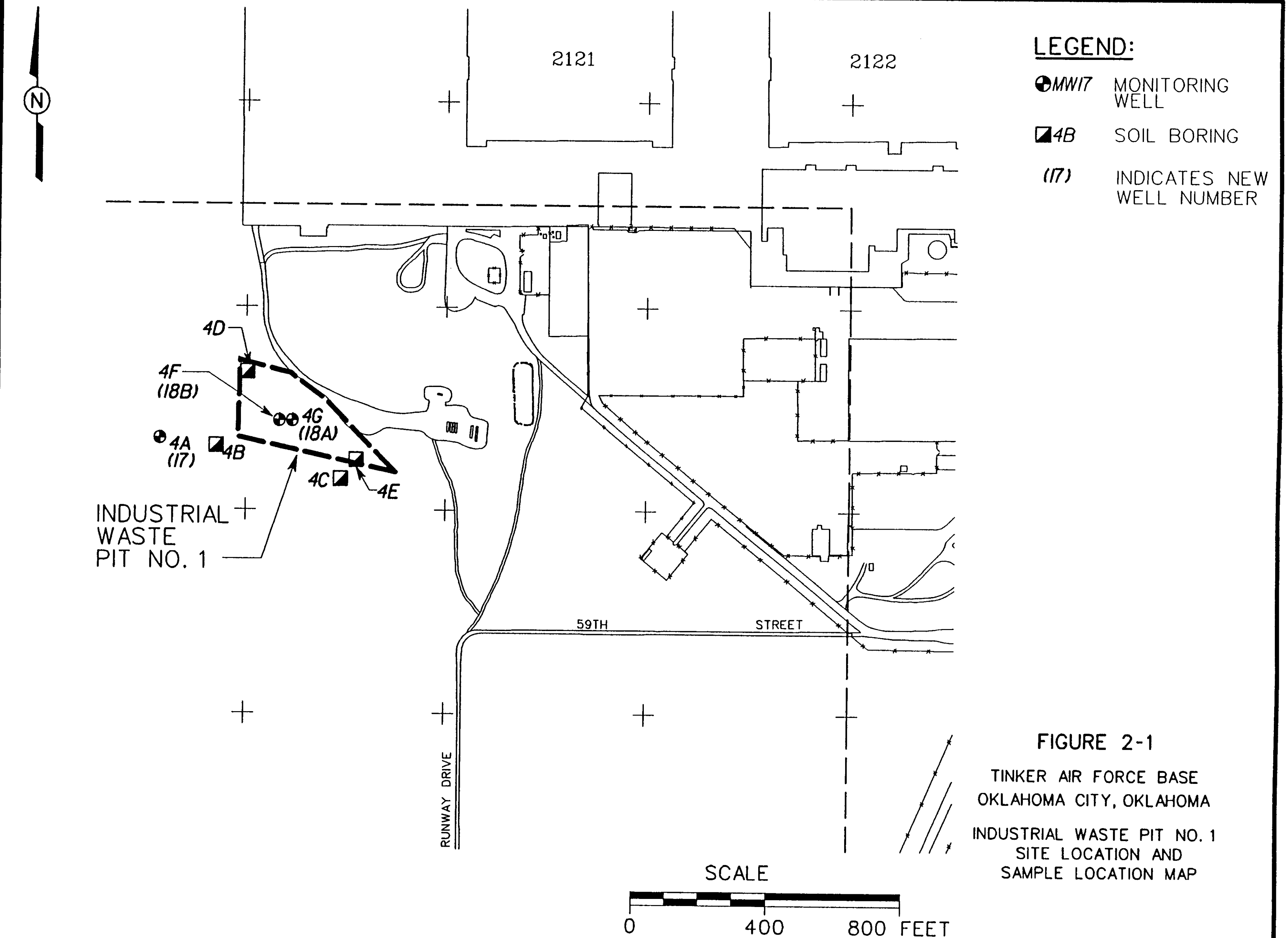

FIGURE 2-1

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

INDUSTRIAL WASTE PIT NO. 1
SITE LOCATION AND
SAMPLE LOCATION MAP

STARTING DATE: 01/14/94	DATE LAST REV.08/24/94	DRAFT. CHCK. BY: G. PACHECO	INITIATOR: C. WALLACE	DWG. NO.:40983202.002
DRAWN BY: P. TERRY	DRAWN BY: P. TERRY	ENGR. CHCK. BY: C. WALLACE	PROJ. MGR.: J. TAYLOR	PROJ. NO.:409832

The soil gas survey resulted into a collection of 25 soil vapor samples which were analyzed for trichloroethane (TCA), trichloroethylene (TCE), perchloroethylene (PCE), methane, and benzene, toluene, ethel benzene, and xylene (BTEX). Methane and TCE were detected in every sample; however, none of the detected contaminants showed significant concentrations. Low concentrations of PCE were detected in two samples. Low levels of benzene were detected in most of the samples, but only one sample also contained detectable levels of toluene, ethyl benzene, and xylenes. The EM survey showed five potential anomalies which were interpreted as being associated with known cultural features such as: the aboveground storage area/training area and an aboveground fuel storage tank battery (three anomalies); a sewer line (one anomaly); and the automobile used in the survey (one anomaly) (Weston, 1991a). Thus, none of the anomalies were interpreted to be a result of hidden drums or waste sludges. This interpretation is supported by the results of drilling operations (boring logs) in the IWP1 area which showed no hidden drums were encountered during drilling. These results closely agree with the findings of the Radian investigation.

Neutron and gamma ray geophysical borehole logging was performed on two monitoring wells and one soil boring. The geophysical logs indicate that the shallow subsurface soils are composed of interbedded clay and silt. Chemical analysis for one soil sample indicated the presence of low concentrations of metals. No organics were detected in the soil sample. Groundwater samples from wells MW-4A and MW-4G showed no or very low concentrations of contamination from organic constituents.

The Weston study concluded that the IWP1 site does not exhibit contamination to warrant additional investigations. Therefore, the study recommended no further action be pursued at this site. A summary of the results from both the Radian and Weston investigations is presented in Chapter 5.0.

2.3 Current Regulatory Status

The IRP has been ongoing at Tinker AFB since the early 1980s. IRP studies on the base were conducted according to IRP guidance, which is essentially the same as EPA's guidance for conducting RIs and FSs under CERCLA. All investigation and removal actions have been closely monitored and approved by the EPA.

Since receiving the Hazardous Waste Management Permit on July 1, 1991, many of the IRP sites have come under the jurisdiction of the RCRA permits branch of EPA. As such, they have been identified as SWMUs; however, a large amount of work has already been performed at most of these sites under the IRP. Additional investigation at the SWMUs will be performed under the IRP.

3.0 Environmental Setting

3.1 Topography and Drainage

3.1.1 Topography

Regional/Tinker AFB. The topography of Oklahoma City and surrounding area varies from generally level to gently rolling in appearance. Local relief is primarily the result of dissection by erosional activity or stream channel development. At Oklahoma City, surface elevations are typically in the range of 1,070 to 1,400 feet mean sea level (msl). At Tinker AFB, ground surface elevations vary from 1,190 feet msl near the northwest corner where Crutcho Creek intersects the Base boundary to approximately 1,320 feet msl at Area D (EID).

Site. IWP-1 is located on the southeast part of Tinker AFB at an elevation of approximately 1,278 feet msl.

3.1.2 Surface Drainage

Regional/Tinker AFB. Drainage of Tinker AFB land areas is accomplished by overland flow of runoff to diversion structures and then to area surface streams, which flow intermittently. The northeast portion of the Base is drained primarily by unnamed tributaries of Soldier Creek, which is itself a tributary of Crutcho Creek. The north and west sections of the Base, including the main instrument runway, drain to Crutcho Creek, a tributary of the North Canadian River. Two small unnamed intermittent streams crossing installation boundaries south of the main instrument runway generally do not receive significant quantities of Base runoff due to site grading designed to preclude such drainage. These streams, when flowing, extend to Stanley Draper Lake, approximately one-half mile south of the Base.

Site. Surface drainage in the vicinity of IWP1 is influenced by the graded and vegetated pit surface. The surface slope is very gentle, and occasionally precipitation results in standing water which may infiltrate into the waste pit. Eventually, the excess surface runoff may drain into Elm Creek, an intermittent stream.

3.2 Geology

3.2.1 Regional/Tinker AFB Geology

Tinker AFB is located within the Central Redbed Plain Section of the Central Lowland physiographic province, which is tectonically stable. No major fault or fracture zones have been mapped near Tinker AFB. The major lithologic units in the area of the Base are relatively flat-lying and have a regional westward dip of about 0.0076 foot per foot (ft/ft) (Bingham and Moore, 1975).

Geologic formations that underlie Tinker AFB include, from oldest to youngest, the Wellington Formation, Garber Sandstone, and the Hennessey Group; all are Permian in age.

All geologic units immediately underlying Tinker AFB are sedimentary in origin. The Garber Sandstone and Wellington Formation are commonly referred to as the Garber-Wellington Formation due to strong lithologic similarities. These formations are characterized by fine-grained, calcareously-cemented sandstones interbedded with shale. The Hennessey Group consists of the Fairmont Shale and the Kingman Siltstone. It overlies the Garber-Wellington Formation along the eastern portion of Cleveland and Oklahoma counties. Quaternary alluvium is found in many undisturbed streambeds and channels located within the area.

Stratigraphy. Tinker AFB lies atop a sedimentary rock column composed of strata that ranges in age from Cambrian to Permian above a Precambrian igneous basement. Quaternary alluvium and terrace deposits can be found overlying bedrock in and near present-day stream valleys. At Tinker AFB, Quaternary deposits consist of unconsolidated weathered bedrock, fill material, wind-blown sand, and interfingering lenses of sand, silt, clay, and gravel of fluvial origin. The terrace deposits are exposed where stream valleys have downcut through older strata and have left them topographically above present-day deposits. Alluvial sediments range in thickness from less than a foot to nearly 20 feet.

Subsurface (bedrock) geologic units which outcrop at Tinker AFB and are important to understanding groundwater and contaminant concerns at the Base consist of, in descending order, the Hennessey Group, the Garber Sandstone, and the Wellington Formation (Table 3-1). These bedrock units were deposited during the Permian Age (230 to 280 million years ago) and are typical of redbed deposits formed during that period. They are composed of a conformable sequence of sandstones, siltstones, and shales. Individual beds are lenticular and vary in thickness over short horizontal distances. Because lithologies are similar and because

Table 3-1

Major Geologic Units in the Vicinity of Tinker AFB (Modified from Wood and Burton, 1968)

(Page 1 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
QUATERNARY	PLEISTOCENE AND RECENT	Alluvium	0-70	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel in the flood plains and channels of stream	Moderately permeable. Yields small to moderate quantities of water in valleys of larger streams. Water is very hard, but suitable for most uses, unless contaminated by industrial wastes or oil field brines.
		Terrace deposits	0-100	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the flood plains of the principal streams.	Moderately permeable. Locally above the water table and not saturated. Where deposits have sufficient saturated thickness, they are capable of yielding moderate quantities of water to wells. Water is moderately hard to very hard, but less mineralized than water in other aquifers. Suitable for most uses unless contaminated by oil field brines.

Table 3-1

(Page 2 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
PERMIAN	LOWER PERMIAN	Hennessey Group (includes Kingman Siltstone and Fairmont Shale)	700	Deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy or limey shale. Forms relatively flat to gently rolling grass-covered prairie.	Poorly permeable. Yields meager quantities or very hard, moderately to highly mineralized water to shallow domestic and stock wells. In places water contains large amounts of sulfate.
		Garber Sandstone	500±	Deep-red clay to reddish-orange, massive and cross-bedded fine-grained sandstone interbedded and interfingered with red shale and siltstone	Poorly to moderately permeable. Important source of groundwater in Cleveland and Oklahoma counties. Yields small to moderate quantities of water to deep wells; heavily pumped for industrial and municipal uses in the Norman and Midwest City areas. Water from shallow wells hard to very hard; water from deep wells moderately hard to soft. Lower part contains water too salty for domestic and most industrial uses.
		Wellington Formation	500±	Deep-red to reddish-orange massive and cross-bedded fine-grained sandstone interbedded with red, purple, maroon, and gray shale. Base of formation not exposed in the area.	

of a lack of fossils or key beds, the Garber Sandstone and the Wellington Formation are difficult to distinguish and are often informally lumped together as the Garber-Wellington Formation. Together, they are about 900 feet thick at Tinker AFB. The interconnected, lenticular nature of sandstones within the sequence forms complex pathways for groundwater movement.

The surficial geology of the north section of the Base is dominated by the Garber Sandstone, which outcrops across a board area of Oklahoma County. Generally, the Garber outcrop is covered by a veneer of soil and/or alluvium up to 20 feet thick. To the south, the Garber Sandstone is overlain by outcropping strata of the Hennessey Group, including the Kingman Siltstone and the Fairmont Shale (Bingham and Moore, 1975). Drilling information obtained as a result of geotechnical investigations and monitoring well installation confirms the presence of these units.

Depositional Environment. The Permian-age strata presently exposed at the surface in central Oklahoma were deposited along a low-lying north-south oriented coastline. Land features included meandering to braided sediment-loaded streams that flowed generally westward from highlands to the east (ancestral Ozarks). Sand dunes were common, as were cut-off stream segments that rapidly evaporated. The climate was arid and vegetation sparse. Off shore the sea was shallow and deepened gradually to the west. The shoreline's position varied over a wide range. Isolated evaporitic basins frequently formed as the shoreline shifted.

Across Oklahoma, this depositional environment resulted in an interfingering collage of fluviatile and wind-blown sands, clays, shallow marine shales, and evaporite deposits. The overloaded streams and evaporitic basins acted as sumps for heavy metals such as iron, chromium, lead, and barium. Oxidation of iron in the arid climate resulted in the reddish color of many of the sediments. Erosion and chemical breakdown of granitic rocks from the highlands resulted in extensive clay deposits. Evaporite minerals such as anhydrite ($CaSO_4$), barite ($BaSO_4$), and gypsum ($CaSO_4 \bullet 2H_2O$) are common.

Around Tinker AFB, the Hennessey Group represents deposition in a tidal flat environment cut by shallow, narrow channels. The Hennessey Group is comprised predominantly of red shales which contain thin beds of sandstone (less than 10 feet thick) and siltstone. In outcrop, "mudball" conglomerates, burrow surfaces, and dessication cracks are recognized. These units

outcrop over roughly the southern half of the Base, thickening to approximately 70 feet in the southwest from their erosional edge (zero thickness) across the central part of Tinker AFB.

In contrast, the Garber Sandstone and the Wellington Formation around Tinker AFB consist of an irregularly-interbedded system of lenticular sandstones, siltstones, and shales deposited either in meandering streams in the upper reaches of a delta or in a braided stream environment. Outcrop units north of Tinker AFB exhibit many small to medium channels with cut and fill geometries consistent with a stream setting. Sandstones are typically cross-bedded. Individual beds range in thickness from a few inches to approximately 50 feet and appear massive, but thicker units are often formed from a series of "stacked" thinner beds. Geophysical and lithologic well logs indicate that from 65 to 75 percent of the Garber Sandstone and the Wellington Formation are composed of sandstone at Tinker AFB. The percentage of sandstone in the section decreases to the north, south, and west of the Base. These sandstones are typically fine to very fine grained, friable, and poorly cemented. However, where sandstone is cemented by red muds or by secondary carbonate or iron cements, local thin "hard" intervals exist along disconformities at the base of sandstone beds. Shales are described as ranging from clayey to sandy, are generally discontinuous, and range in thickness from a few inches to approximately 40 feet.

Stratigraphic Correlation. Correlation of geologic units is difficult due to the discontinuous nature of the sandstone and shale beds. However, cross-sections (Figure 3-1) demonstrate that two stratigraphic intervals can be correlated over large sections of the Base in the conceptual model. These intervals are represented on geologic cross-sections A-A' and B-B' (Figures 3-2 and 3-3). Section A-A' is roughly a dip section and B-B' is approximately a strike section. The first correlatable interval is marked by the base of the Hennessey Group and the first sandstone at the top of the Garber Sandstone. This interval is mappable over the southern half of Tinker AFB. The second interval consists of a shale zone within the Garber Sandstone which, in places, is comprised of a single shale layer and, in other places, of multiple shale layers. This interval is more continuous than other shale intervals and in cross-sections appears mappable over a large part of the Base. It is extrapolated under the central portion of Tinker AFB where little well controls exists.

Structure. Tinker AFB lies within a tectonically stable area; no major near-surface faults or fracture zones have been mapped near the Base. Most of the consolidated rock units of the Oklahoma City area dip westward at a low angle. A regional dip of 0.0057 to 0.0076 ft/ft in

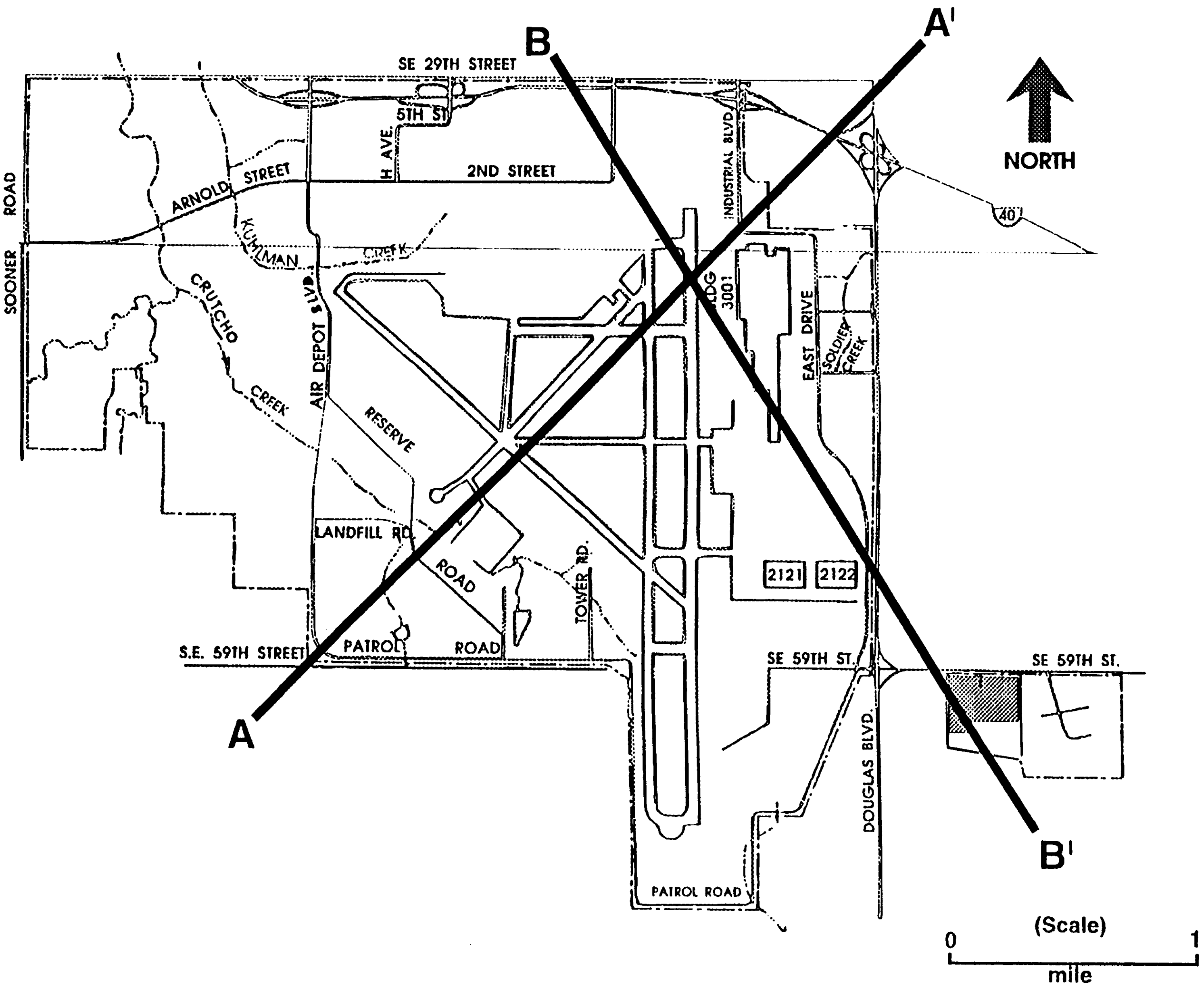

FIGURE 3-1 TINKER AFB GEOLOGIC CROSS SECTION LOCATION MAP

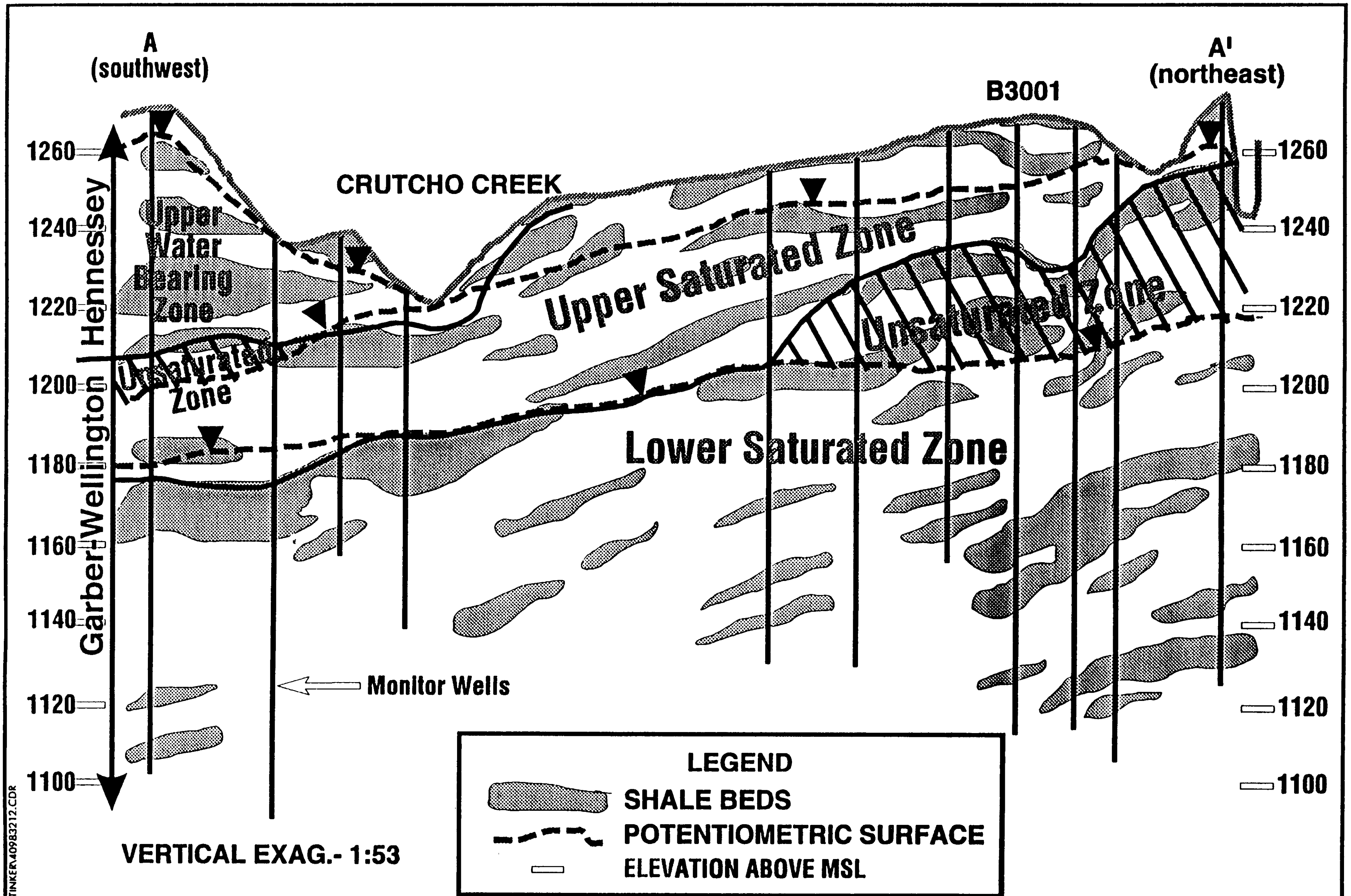

FIGURE 3-2 TINKER AFB GEOLOGIC CROSS SECTION A-A'

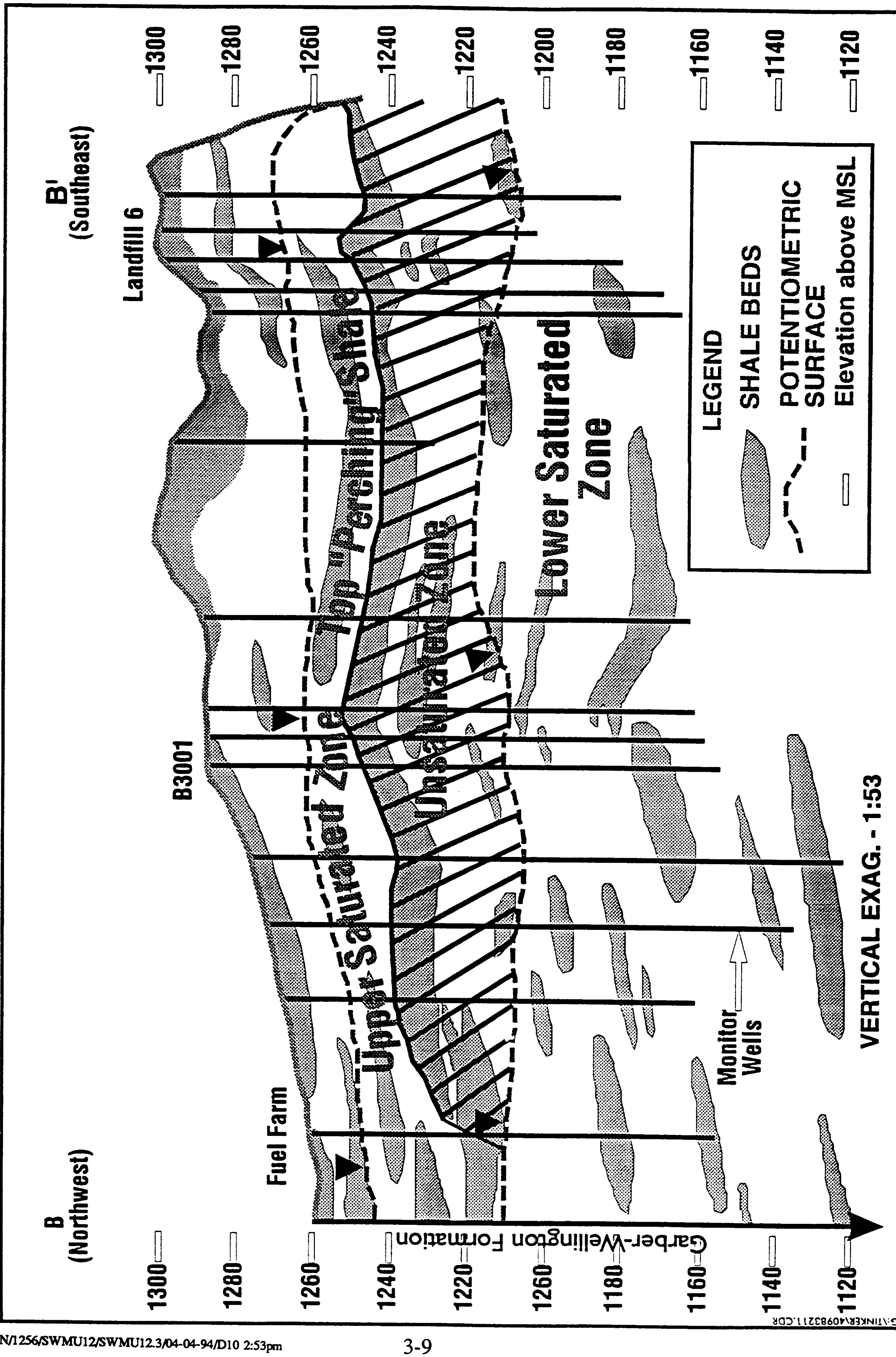

FIGURE 3-3 TINKER AFB GEOLOGIC CROSS SECTION B-B'

a generally westward direction is supported by stratigraphic correlation on geologic cross-sections at Tinker AFB. Bedrock units strike slightly west of north.

Although Tinker AFB lies in a tectonically stable area, regional dips are interrupted by buried structural features located west of the Base. A published east-to-west generalized geologic cross-section, which includes Tinker AFB, supports the existence of a northwest-trending structural trough or syncline located near the western margin of the base. The syncline is mapped adjacent to and just east of a faulted anticlinal structure located beneath the Oklahoma City Oil Field. The fault does not appear to offset Permian-age strata. There are indications that the syncline may act as a "sink" for some regional groundwater (southwest flow) at Tinker AFB before it continues to more distant discharge points.

3.2.2 Site Geology

The major geologic units around the IWP1 site are a thin soil cover, underlain by dry, yellowish red Fairmont Shale to a depth of approximately 20 feet. The Fairmont Shale is in turn underlain by sandstone of the Garber Sandstone (Radian, 1985a). The soil coring revealed considerable variations in geologic materials within the area of investigation. Generally, the subsurface consisted of soil and fill, underlain by weathered and unweathered shale bedrock (Radian, 1985). The soil and fill extend to approximately 5 feet while the base of the weathered shale is at approximately 10 feet.

3.3 Hydrology

3.3.1 Regional/Tinker AFB Hydrology

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer system. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove, and Admire Groups. The Garber Sandstone and the Wellington Formation portion of the Central Oklahoma aquifer system is commonly referred to as the "Garber-Wellington aquifer" and is considered to be a single aquifer because these units were deposited under similar conditions and because many of the best producing wells are completed in this zone. On a regional scale, the aquifer is confined above by the less permeable Hennessey Group and below by the Late Pennsylvanian Vanoss Group.

Tinker AFB lies within the limits of the Garber-Wellington Groundwater Basin. Currently, Tinker derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest City and Del City derive water supplies from both surface sources and wells tapping the aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by a municipal distribution system also depend on the Garber-Wellington aquifer. Communities presently depending upon surface supplies (such as Oklahoma City) also maintain a well system drilled into the Garber-Wellington as a standby source of water in the event of drought.

Recharge of the Garber-Wellington aquifer is accomplished principally by percolation of surface waters crossing the area of outcrop and by rainfall infiltration in this same area. Because most of Tinker AFB is located in an aquifer outcrop area, the Base is considered to be situated in a recharge zone.

According to Wood and Burton (1968) and Wickersham (1979), the quality of groundwater derived from the Garber-Wellington aquifer is generally good, although wide variations in the concentrations of some constituents are known to occur. Wells drilled to excessive depths may encounter a saline zone, generally greater than 900 feet below ground surface. Wells drilled to such depths or those accidentally encountering the saline zone are either grouted over the lowest screens or may be abandoned.

Tinker AFB presently obtains its water supplies from a distribution system comprised of 29 water wells constructed along the east and west Base boundaries and by purchase from the Oklahoma City Water Department. All Base wells are finished into the Garber-Wellington aquifer. Base wells range from 700 to 900 feet in finished depth, with yields ranging from 205 to 250 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones with a combined thickness from 103 to 184 feet (Wickersham, 1979).

Although the variability in the geology and the recharge system at Tinker AFB makes it difficult to predict local flow paths, Central Oklahoma aquifer water table data show that regional groundwater flow under Tinker varies from west-northwest to southwest, depending on location. This theory is supported by contoured potentiometric data from base monitoring wells which show groundwater movement in the upper and lower aquifer zones to generally follow regional dip. Measured normal to potentiometric contours, groundwater flow gradients range from 0.0019 to 0.0057 ft/ft. However, because flow in the near-surface portions of the aquifer at Tinker AFB is strongly influenced by topography, local stream base-levels, complex subsurface geology, and location in a recharge area, both direction and magnitude of ground-water movement is highly variable. The interaction of these factors not only influences regional flow but gives rise to complicated local, often transient, flow patterns at individual sites.

As a result of ongoing environmental investigations and the approximately 450 groundwater monitoring wells installed on the Base during various investigations, a better understanding of the specific hydrological framework has emerged. The current conceptual model developed by Tinker AFB (Tinker, 1993), based on the increased understanding of the hydrological framework, has been revised from an earlier model adopted by the U.S. Army Corp of Engineers (USACE). Previous studies reported that groundwater was divided into four water-bearing zones: the perched aquifer, the top of regional aquifer, the regional aquifer, and the producing zone. In the current model, two principal water table aquifer zones and a third less extensive zone have been identified. The third is limited to the southwest quadrant. The third aquifer zone consisted of saturated siltstone and thin sandstone beds in the Hennessey Shale and equates to the upper water bearing zone (UWBZ) described by the USACE (1993) at Landfills 1 through 4 (SWMUs 3 through 6). In addition, numerous shallow, thin saturated beds of siltstone and sandstone exist throughout the Base. These are of limited areal extent and are often perched.

In the current conceptual hydrologic model, a USZ and a lower saturated zone (LSZ) are recognized in the interval from ground surface to approximately 200 feet. Below this is found the producing zone from which the Base draws much of its water supply. Figure 3-4 shows the potentiometric surface for the USZ and Figure 3-5 shows the potentiometric surface for the LSZ. The USZ exists mainly under water table (unconfined) conditions, but may be partially confined locally. Conditions in the LSZ are difficult to determine due to screen placement and overly long sandpacks below the screen interval.

The USZ is found at a depth of 5 to 70 feet below ground surface and has a saturated thickness ranging from less than 1 foot at its eastern boundary to over 20 feet in places west of Building 3001. The USZ is erosionally truncated by Soldier Creek along the northeastern margin of Tinker AFB. This aquifer zone is considered to be a perched aquifer over the eastern one-third of Tinker AFB, where it is separated from the LSZ by an underlying confining shale layer and a vadose zone. The confining interval extends across the entire

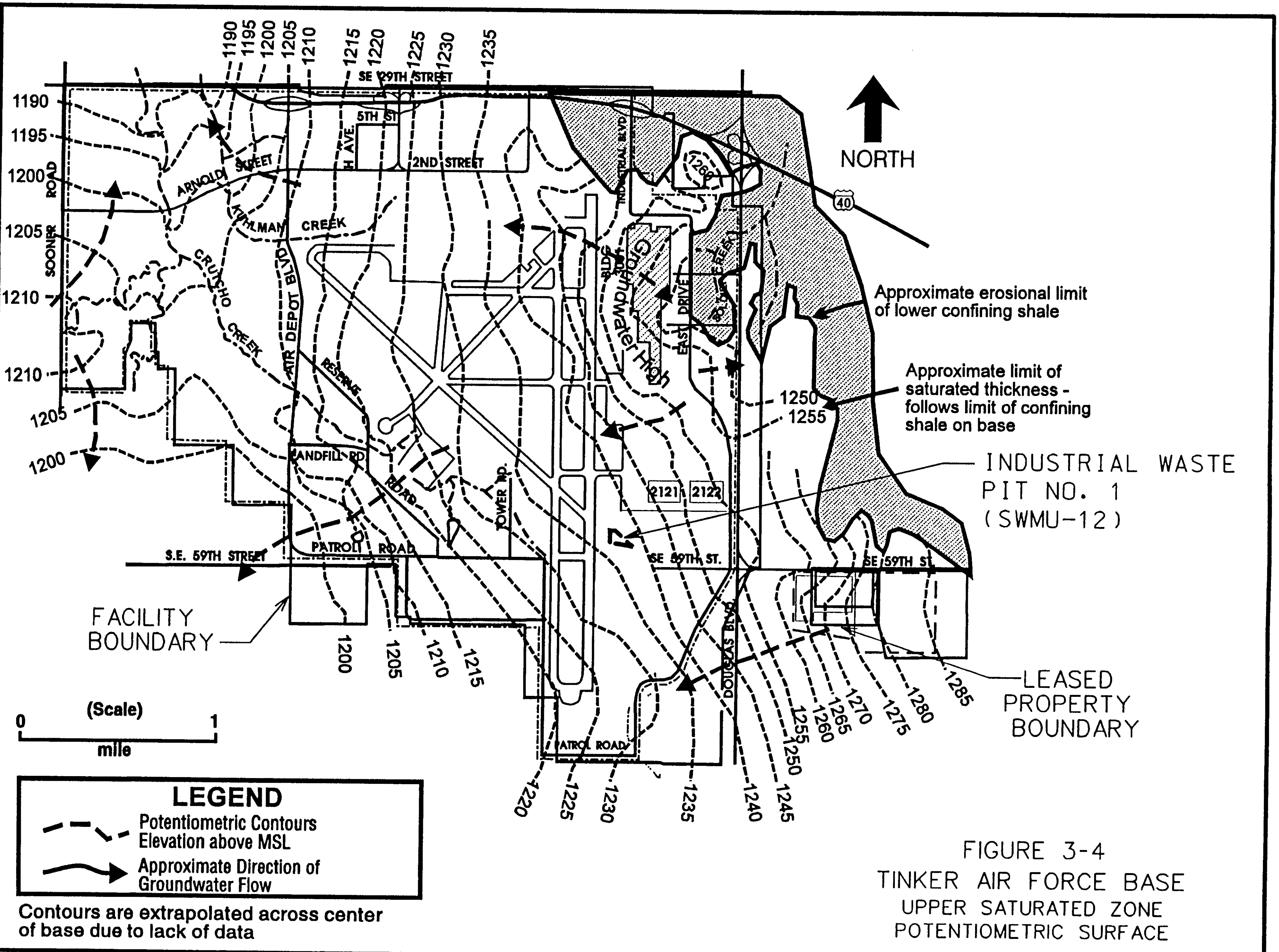

FIGURE 3-4
TINKER AIR FORCE BASE
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:4/25/94	DRAFT. CHCK. BY:	INITIATOR:C.WALLACE	DWG. NO.:40983209C.
DRAWN BY:C.E.TUMLIN	DRAWN BY:P. TERRY	ENGR. CHCK. BY:	PROJ. MGR.: J.TAYLOR	PROJ. NO.:409832

8/25/96 PG1
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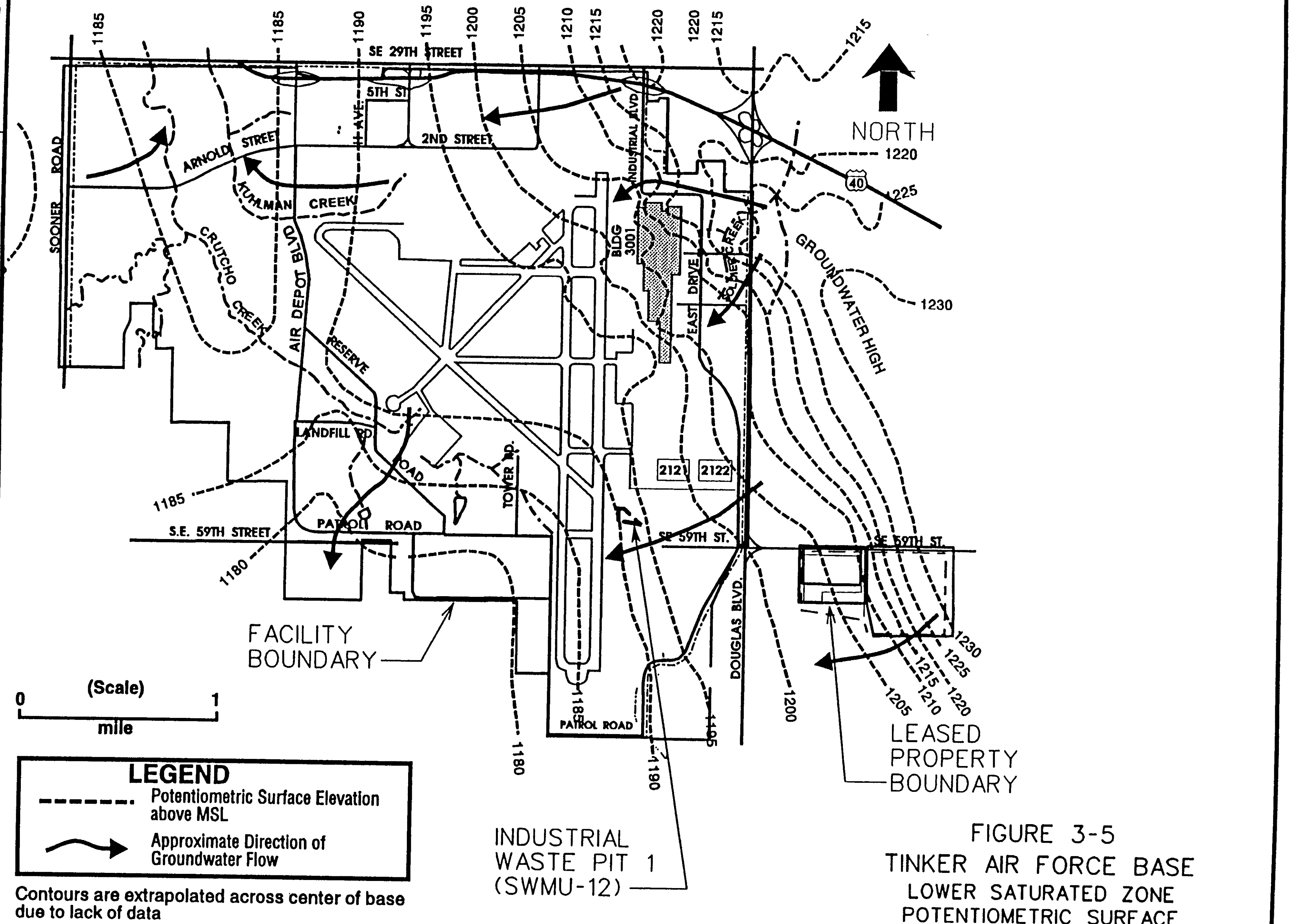

FIGURE 3-5
TINKER AIR FORCE BASE
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C.WALLACE	DWG. NO.:40983209C.
DRAWN BY: C.E.TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J.TAYLOR	PROJ. NO.:409832

G:\TINKER\40983202C.520

Base, but the vadose zone exists over the eastern one-third of this area. The available hydrogeologic data indicate that the vadose zone does not exist west of a north-south line located approximately 500 to 1,000 feet west of the main runway; consequently, the USZ is not perched west of this line. However, based on potentiometric head data from wells screened above and below the confining shale layer, the USZ remains a discrete aquifer zone distinct from the LSZ even over the western part of the Base. In areas where several shales interfinger to form the lower confining interval rather than a single shale bed, "gaps" may occur. In general, these "gaps" are not holes in the shale, but are places where multiple shales exist that are separated by slightly more permeable strata. Hydrologic data from monitoring wells indicate that these zones allow increased downward flow of groundwater above what normally leaks through the confining layer.

The LSZ is hydraulically interconnected and can be considered one aquifer zone down to approximately 200 feet. This area includes what was referred to by the USACE as the top of regional and regional zones. Hydrogeologic data from wells screened at different depths at the same location within this zone, however, provide evidence that locally a significant vertical (downward) component of groundwater flow exists in conjunction with lateral flow. The magnitude of the vertical component is highly variable over the Base. Preliminary evidence suggests that the LSZ is hydraulically discrete from the producing zone. Due to variations in topography, the top of the lower zone is found at depths ranging from 50 to 100 feet below ground surface under the eastern parts of the Base and as shallow as 30 feet to the west. Differences in potentiometric head values found at successive depths are due to a vertical (downward) component of groundwater flow in addition to lateral flow and the presence or absence of shale layers which locally confine the aquifer system. The LSZ extends east of the Base (east of Soldier Creek) beyond the limits of the USZ where it becomes the first groundwater zone encountered in off-Base wells. Because of the regional dip of bedding, groundwater gradient, and topography, the LSZ just east of the Base is generally encountered at depths less than 20 feet.

3.3.2 Site Hydrology

Groundwater at IWP1 was found to occur under two different conditions: in a shallow, saturated interval extending from just below the land surface to the top of the unweathered shale, and in the USZ. The shallow saturated interval corresponds to the soil zone and contains water that exists sporadically across the IWP1 site. This shallow water is most likely the accumulation of infiltrated rainwater that collects in surface depressions; it is discontinuous over the site and not connected with the USZ. The USZ was encountered at about 40 feet below the surface, approximately 20 feet below the Fairmont Shale-Garber Sandstone contact. Based on boring logs, an unsaturated sandstone unit approximately 10 to 15 feet thick is present below the Fairmont Shale-Garber Sandstone contact, but above the groundwater encountered at approximately 40 feet. This observation supports the assumption that shallow groundwater is separated from the USZ at IWP1. Groundwater flow in the USZ and LSZ at this site is assumed to be in the southwest direction (Figures 3-4 and 3-5).

3.4 Soils

Three major soil types have been mapped in the Tinker AFB area and are described in Table 3-2 (U.S. Department of Agriculture [USDA], 1969). The three soil types, the Darrell-Stephenville, Renfrow-Vernon-Bethany, and Dale-Canadian-Port, consist of sandy to fine sandy loam, silt loam, and clay loam, respectively. The Darrell-Stephenville and the Renfrow-Vernon-Bethany are primarily residual soils derived from the underlying shales of the Hennessey Group. The Dale-Canadian-Port association is predominantly a stream-deposited alluvial soil restricted to stream floodplains. The thickness of the soils ranges from 12 to 60 inches. IWP1 lies entirely within the Renfrow-Vernon-Bethany soil association.

Table 3-2

Tinker AFB Soil Associations
(Source: USDA, 1969)

Association	Description	Thickness (in.)	Unified Classification[a]	Permeability (in./hr)
Darrell-Stephenville: loamy soils of wooded uplands	Sandy loam Sandy clay loam Soft sandstone (Garber Sandstone)	12-54	SM,ML,SC	2.0-6.30
Renfrow-Vernon-Bethany: loamy and clayey soils on prairie uplands	Silt loam - clay Clay loam Shale (Fairmont Shale)	12-60	ML,CL,MH,CH	<0.60-0.20
Dale-Canadian-Port: loamy soil on low benches near large streams	Fine sandy loam Silty clay loam Loam Clay loam	12-60	SM,ML,CL	0.05-6.30

[a]Unified classifications defined in U.S. Bureau of Reclamation, 5005-86.

4.0 Source Characterization

Prior to the establishment of the industrial waste water collection and treatment facility, the industrial wastes were disposed of in large, open pits. One of these pits was IWP1. This pit was used for the disposal of liquid wastes and sludges generated from 1947 to 1958. These waste streams originated from the various aircraft maintenance shops at Tinker AFB. During the Base records search (ES, 1982), no written information was found that revealed the type of waste that was actually disposed of in this pit. However, based on general knowledge of chemical processes and routine activities in a maintenance shop, and on interviews with Base personnel, the waste material in IWP1 most likely contained the following: high levels of heavy metals; waste oils; contaminated fuels; chromates; phenols; cyanides; waste acids; and bases generated by plating and maintenance activities, including a variety of organic compounds such as solvents and degreasers (Radian, 1985a; Tinker, 1992).

No written information was found to indicate how the industrial waste pits were constructed. Reviewed documents (Radian, 1985a; Weston, 1991a; Tinker, 1992) indicate that the waste pits were not lined. Therefore, significant amounts of wastes may have migrated through the soil beneath and around the pit.

During the site investigations, soil cores through the waste were taken to determine the physical nature of the waste and also the extent of the waste pit. The soil cores showed the waste to be shallow and thoroughly mixed with the soil. Consequently, accurate and reliable boundaries for the pit and volume estimates of the waste could not be made.

5.0 Contaminant Characterization

Background soil concentrations for trace metals were determined based on a study performed by the USGS (1991). The study area was confined to approximately four counties in central Oklahoma. Tinker AFB lies at the approximate center of this area. A total of 293 B-horizon soil samples were collected throughout this area. Soil samples were collected at the top of the B-horizon, which was usually 20 to 30 centimeters below the surface but ranged from 3 to 50 centimeters below the surface. For site-specific analytes for which the USGS offered no background value, the analyte was compared to an applicable action level. The background concentrations are presented in Table 5-1.

The use of B-horizon soil as selected by the USGS for metals background concentrations in soil is conservative in that the soil sampled does not reflect all possible anthropogenic influences. Most of the samples were obtained from hill crests and well drained areas in pasture and forested land, well away from roadways to minimize contamination from vehicular emissions (i.e., nearly "pristine" areas). Trace metal inputs to the study site soils on Base, however, will come from anthropogenic sources outside of the study area, in addition to those sources related to disposal activities or operations within the confines of the study site. Therefore, responsibility may be taken for more trace metal impacts than are actually attributable to a given site.

An additional level of conservatism was added in the manner in which the site-specific metals concentrations were compared to the background levels. Typically, the environmental concentrations of trace metals at study sites are represented by the arithmetic upper 95th confidence interval on the mean of a normal distribution. This upper 95th confidence interval value is then compared to the background values. The intent of this typical approach is to estimate a Reasonable Maximum Exposure case (i.e., well above the average case) that is still within the range of possible exposures.

To expedite this comparison and establish greater conservatism, the maximum concentration found at the site of concern, rather than the upper 95th confidence interval value, was compared to the USGS background values. If the environmental concentration of a particular analyte was below or within the minimum-maximum range of the USGS background concentrations, that analyte was considered to be naturally occurring and of no further concern to this investigation. Given the conservative approach of the comparisons, site-specific metals concentrations would have to significantly exceed the USGS background

Table 5-1

Background Concentrations of Trace Metals in Surface Soils[a]
SWMU-12, IWP1, Tinker AFB

(Page 1 of 2)

Analyte	Lower Detection Limit	Background Concentration Range	
		Minimum Value	Maximum Value
Concentration in %			
Aluminum	0.005	0.38	8.9
Cadmium	0.005	0.01	9.4
Iron	0.005	0.18	5.8
Magnesium	0.005	0.02	5.3
Phosphorous	0.005	0.06	0.019
Potassium	0.05	0.1	2.4
Sodium	0.005	0.02	0.99
Titanium	0.005	0.04	0.42
Concentrations in ppm			
Arsenic	0.1	0.6	21
Barium	1	47	6400
Beryllium	1	<1	3
Bismuth	10	<DL[b]	<DL
Cadmium	2	<DL	<DL
Cerium	4	14	110
Chromium	1	5	110
Cobalt	1	<1	27
Copper	1	<1	59
Europium	2	---[c]	---
Gallium	4	<4	23
Gold	8	<DL	<DL
Holmium	4	<DL	<DL
Lanthanum	2	7	51
Lead	4	<4	27
Lithium	2	5	100

Table 5-1

(Page 2 of 2)

Analyte	Lower Detection Limit	Background Concentration Range	
		Minimum Value	Maximum Value
Manganese	10	24	3400
Molybdenum	2	<DL	<DL
Neodymium	4	6	47
Nickel	2	<2	61
Niobium	4	<4	16
Scandium	2	<2	15
Selenium	0.1	<0.1	1.2
Silver	2	<DL	<DL
Strontium	2	13	300
Tantalum	40	<DL	<DL
Thorium	1	<1.40	15.00
Tin	10	<DL	<DL
Uranium	0.1	0.650	6.400
Vanadium	2	5	220
Ytterbium	1	<1	3
Yttrium	2	3	43
Zinc	2	3	79

[a]All B-horizon soil samples (293) from USGS, 1991.
[b]All concentrations below the lower limits of determination.
[c]Insufficient or no data.

levels and be attributable to operations at the site before they would be considered a contaminant of concern.

The numerical comparison of site-specific metals concentrations to the USGS background concentrations is presented in the following section.

5.1 Constituents of Potential Concern

The analytical data for the different media sampled from IWP1 have not been evaluated in terms of identifying constituents of potential concern. The site investigations performed by Radian and Weston indicate the existence of minor contamination around the waste pit. However, significant contamination was observed in the soils within the waste pit boundaries. Based on data from previous studies, there appear to be no constituents of potential concern in groundwater media.

5.2 Soil Characterization

Ten soil samples were collected for a detailed analysis during the field investigations conducted by Radian (1985a). The analyses of the soil samples consisted of selected metals (cadmium, cyanide, chromium, copper, mercury, nickel, lead, and zinc), TOC, total organic halogen (TOX), oil and grease and phenols. Chromium, copper, nickel, lead, zinc, and oil and grease were detected in all the samples. Above background concentrations of heavy metals were detected in soil samples collected within the waste pit. The results of these analyses are provided in Table 5-2.

One additional soil sample was collected during the RI activities conducted by Weston (1991a). The sample was analyzed for metals (cyanide, cadmium, chromium, copper, lead, and zinc), total petroleum hydrocarbons (TPH), phenols, TOC, and TOX. No significant concentrations of the target analytes were detected in the sample. Results are shown in Table 5-2.

The soil gas survey conducted by Weston, resulted into a collection of 25 soil vapor samples which were analyzed for trichloroethane (TCA), trichloroethylene (TCE), perchloroethylene (PCE), methane, and BTEX. Methane and TCE were detected in every sample; however, none of the detected concentrations showed significant contamination. Low concentrations of PCE were detected in two samples. Low levels of benzene were detected in most of the samples, but only one sample contained detectable amounts of toluene, ethyl benzene, and xylenes. Complete results are contained in the RI report prepared by Weston (1991a).

Table 5-2

Analytical Results for Soils SWMU-12, IWP1, Tinker AFB

Parameter/Sample ID (µg/g, except as noted)	Radian Study[a]										Weston Study[b]
	4B.5	4B.6	4C.5	4D.2	4E.2	4E.3	4E.4	4E.5	4F.2	4F.3	MW-4H-8'
Cadmium	<.21	<.20	1.7	17	1.7	340	<.20	1.5	2.7	5.0	<0.48
Cyanide	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.59
Chromium	4.9	8.5	11	42	9.1	78	5.6	6.3	230	32	13.6
Copper	4.2	7.1	8.5	16	15	47	3.8	9.2	24	9.7	6.1
Mercury	10	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	-
Nickel	3.0	11	8.3	11	14	39	5.4	9.6	22	8.0	-
Oil & grease	780	410	290	206	1070	140	240	550	200	150	-
Lead	6.4	8.9	8.4	85	2.9	660	7.4	0.99	150	18	8.4
Phenol	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<3.7
Total organic carbon (%)	0.12	0.10	0.08	0.15	0.10	0.13	0.10	0.12	0.08	0.05	-
Total organic halogen	0.20	<.10	<.10	<.10	<.10	<.10	<.10	<.10	<.10	<.10	673
Zinc	5.3	9.4	7.4	57	14	1400	6.6	7.8	75	17	20.4
Acid/bases extractable, Organic priority pollutants (Modified EPA Method 625)	-	-	-	-	-	None Detected	-	-	-	-	-
Petroleum hydrocarbon	-	-	-	-	-	-	-	-	-	-	28.4

[a] Radian 1985
[b] Weston 1991a

5.3 Groundwater Characterization

Two groundwater samples, from wells MW-17 in the USZ and MW-18A in the shallow groundwater (MW-18B was dry during sampling), were collected and analyzed for selected constituents during the investigation activities conducted by Radian (1985). The target analytes included TOC, TOX, phenols, and selected metals (cadmium, cyanide, chromium, copper, mercury, nickel, lead, and zinc). Results of the analyses show very little or no contamination at all. Table 5-3 provides a summary of the results.

Two more groundwater samples were collected during the RI activities conducted by Weston (1991a). These samples were analyzed for the same parameters as those listed for the soil. Results are reported in Table 5-3.

Table 5-3

Analytical Results for Groundwater IWP1, SWMU-12, Tinker AFB

Parameter (mg/L)	Radian Study[a]			Weston Study[b]	
	MW-17	MW-18B	MW-18A	MW-17	MW-18A
Cadmium	<.002	(dry)	<.002	0.0083	0.053
Cyanide	<.01		<.01	<0.01	<0.01
Chromium	0.014		<.001	<0.02	<0.02
Copper	0.021		<.001	0.024	0.065
Mercury	0.0004		<.0002	-	-
Nickel	0.009		0.008	-	-
Oil & grease	<0.10		<0.10	-	-
Lead	0.006		0.022	0.2	0.058
Total organic carbon	<1		43	4.7	14.7
Total organic halogen	0.06		<.01	0.34	0.44
Zinc	1.2		1.4	2.6	4.2
Phenol	ND		0.001	0.068	<0.005
pH	-		-	7.4	7.2
Petroleum hydrocarbon	-		-	<0.23	<0.26
Specific conductance (µMhos/cm)	-		-	1870	1080

[a]Radian, 1985
[b]Weston, 1991a

6.0 Potential Receptors

A specific potential human and ecological receptor search has not been performed for IWP1. Data are available in the form of chemical analysis of soils and groundwater and can be used to initiate a potential receptors search. The following sections describe the data available to begin identification of potential receptors.

6.1 Human Receptors

Tinker AFB is situated on a relatively flat expanse of grassland. Prior to the development of the Base, the area was characterized by large tracts of agricultural land. The Base currently occupies approximately 5,000 acres of semi-improved and unimproved grounds that are used for the airfield, golf course, housing area, offices, shops, and other uses characteristic of military installations.

The Garber-Wellington aquifer, which underlies Tinker AFB, is the single most important source of potable groundwater in the Oklahoma City area. The recharge area for the Garber-Wellington aquifer covers the eastern half of Oklahoma County, including Tinker AFB. Approximately 75 percent of the Base's water supply is obtained from production wells pumping from this aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by municipal distribution systems also depend on the Garber-Wellington aquifer. Communities, such as Oklahoma City, presently depending upon surface water supplies also maintain a well system drilled into this aquifer as a standby source of water in the event of drought. Lake Stanley Draper, a local surface water supply reservoir with a small portion of its drainage basin within the boundaries of Tinker AFB, serves a significant recreational function as well.

In 1989, approximately 26,000 military and civilian personnel worked at Tinker AFB. Of these, approximately 2,722 personnel occupied on-Base housing, which consisted of 530 family housing units and seven dormitories. At that time, 1,262 of these residents were children. Military personnel and their families who reside on Base represent the nearest receptors to releases from Tinker AFB.

The current land use at and near the Base is not expected to change because the facilities have decades of useful life remaining and the Base has an important and continuing mission.

However, other future land use scenarios and any human receptors associated with those scenarios may need to be considered.

6.2 Ecological Receptors

Tinker AFB lies within a grassland ecosystem, which is typically composed of grasses, forbes, and riparian (i.e., trees, shrubs, and vines associated with water courses) vegetation. This ecosystem has generally experienced fragmentation and disturbances as result of urbanization and industrialization at and near the Base. While no threatened or endangered plant species occur on the Base, the Oklahoma penstemon (*Penstemon oklahomensis*), identified as a rare plant under the Oklahoma Natural Heritage Inventory Program, thrives in several locations on Base. Tinker AFB policy considers rare species as if they were threatened or endangered and provides the same level of protection for these species.

In general, wildlife on the Base is typically tolerant of human activities and urban environments. No federal threatened or endangered species have been reported at the Base. However, one specie found on the Base, the Texas horned lizard (*Phrynosoma cornutum*), is a Federal Category 2 candidate specie and under review for consideration to be listed as threatened or endangered. Air Force policy (AFR 126-1) considers candidate species as threatened or endangered and provides the same level of protection.

The Oklahoma Department of Wildlife Conservation also lists several species within the state as Species of Special Concern. Information on these species suggests declining populations but information is inadequate to support listing, and additional monitoring of populations is needed to determine the species status. These species also receive protection by Tinker AFB as threatened or endangered species. Of these species, the Swainson's hawk (*Buteo swainsoni*) and the burrowing owl (*Athene cunicularia*) have been sighted on Tinker AFB. The Swainson hawk, a summer visitor and prairie/meadow inhabitant, has been encountered Basewide. The burrowing owl has been known to inhabit the Air Field at the Base.

7.0 Action Levels

An "action level" is defined by EPA in proposed rule 40 CFR 264.521 (55 FR 30798; 7/27/90), "Corrective Action for Solid Waste Management Units (SWMU) at Hazardous Waste Management Facilities," as a health- and environment-based level, determined by EPA to be an indicator for protection of human health and the environment. In the preamble to this proposed rule, the focus of the RFI phase is defined as "characterizing the actual environmental problems at the facilities." As part of this characterization, a comparison of the contaminant concentrations to certain action levels should be made to determine if a significant release of hazardous constituents has occurred. This comparison is then used to determine if further action or corrective measures are required for a SWMU or an AOC. The preamble to the proposed rule states that the concept of action levels was introduced because of the need for "a trigger that will indicate the need for a Corrective Measures Study (CMS) and below which a CMS would not ordinarily be required" (55 FR 30798; 7/27/90). If constituent concentrations exceed certain action levels at a SWMU or an AOC, further action or a CMS may be warranted; if constituent concentrations are below action levels, a finding of no further action may be warranted. This chapter of the report presents the initial analytical data as compared to certain potential action levels.

Action levels are concentrations of contaminants at or below which exposure to humans or the environment should not produce acute or chronic effects.

The action level information is presented in this chapter so that identified constituents at the site can be compared with their respective potential action levels. Only those action levels relevant to IWP2 site are shown in Table 7-1 along with site-specific data. These action levels are for soil and water as published in federal or state regulations, policies, guidance documents, or proposed rules. A brief description and source of the published action levels in general is provided in the following paragraphs.

- ***SWMU Corrective Action Levels (CAL)*** - The first set of action levels provided in the table are those taken from the proposed rule (40 CFR 264.521) and provided as Appendix A to the rule as "Examples of Concentrations Meeting Criteria for Action Levels." These levels are health-risk based and are provided as specific examples of levels below which corrective action would not be required.

- ***Maximum Contaminant Levels (MCL)*** - These values are provided from 40 CFR Subpart G, Sections 141.60 through 0.63 as promulgated under the Safe

Table 7-1

Comparison of Soils and Groundwater Versus Action Levels IWP1, SWMU-12, Tinker AFB

Analyte	Reported[a] Conc. Range (Soil-mg/kg)	CAL[b] (mg/kg)	Maximum[c] Background (mg/kg)	Reported Conc. Range (Grdwtr-mg/L)	CAL (mg/L)	MCL[d] (mg/L)
Cadmium	1.5-340	40	ND	0.0083-0.053	NA[e]	0.005
Cyanide	0.59[f]	2000	NA	ND[g]	0.7	0.2
Chromium	4.9-230	NA	110	0.014[f]	NA	0.1
Copper	3.8-47	NA	59	0.021-0.065	NA	1.3
Mercury	10[f]	20	ND	0.0004[f]	NA	0.002
Nickel	3.0-39	2000	61	0.008-0.009	0.7	0.1
Oil & Grease	140-1070	NA	0	ND	NA	NA
Lead	0.99-660	NA	27	0.006-0.2	NA	0.015
Zinc	5.3-1400	NA	79	1.2-4.2	NA	NA
Phenol	ND	50,000	0	0.001-0.068	20	NA

[a] Reported range does not include nondetects.
[b] CAL - Corrective Action Level: Source.
[c] USGS background levels.
[d] MCL - Maximum Contaminant Level: Source.
[e] NA - Not available.
[f] Single detect.
[g] ND - Not detected.

Drinking Water Act. These levels are designated for water media only.

- ***USGS Background*** - These values are provided from the USGS report titled "Elemental Composition of Surficial Materials from Central Oklahoma" (USGS, 1991). These values represent the levels of metals which naturally occur in Central Oklahoma soils.

- ***Background*** - These levels are provided where background could be determined. Where available, background concentrations are listed for metals in soil samples taken on site, which were thought to be unaffected by releases from a unit.

- ***National Ambient Air Quality Standards (NAAQS)*** - These standards are published in 40 CFR Part 50 under the Clean Air Act and apply to point sources that emit a limited number of constituents to the air. The constituents regulated are nitrogen dioxide, sulphur dioxide, carbon monoxide, lead, ozone, and particulate matter. Currently, it is assumed that none of the SWMUs or AOCs emit these compounds in regulated quantities and no air samples have been taken which would allow for a valid comparison.

- ***Water Quality Standards (WQS)*** - The WQS are the standards for surface water quality as established by the State of Oklahoma. These standards apply to point source discharges to surface waters and have been listed for those units adjacent to surface water.

The data for each detected compound are compared with the appropriate action level in order to identify those constituents (compounds) with concentrations exceeding the action levels. This identification of the compounds above the action levels provides an indication of a potential environmental problem at a specific site. In addition, this information indicates whether there is a need for conducting a CMS so that a corrective action can be implemented/undertaken at the site.

For constituents that have a SWMU CAL and an MCL for water, the MCL will be used for the comparison. Also, constituents that do not have a USGS background value will be compared to the site background value if available.

Of the constituents detected in the soil samples, only cadmium exceed the action level for soil contamination. The above action level of concentration of cadmium was detected in a single soil sample out of 11 samples, consequently, it is considered to be not significant. Evaluation of the groundwater data shows cadmium and lead to be above their respective MCLs.

The presence of cadmium and lead above the action levels indicate a potential groundwater problem at the site. However, this evaluation is based on data from only one sampling event. Additional data is necessary to support this interpretation. Efforts to acquire the additional data are underway as discussed in Chapter 9.0.

8.0 Summary and Conclusions

Summary. IWP1 was in operation from 1947 to 1958 and was constructed without a liner. During its operational period, the pit received unspecified industrial waste streams originating from various aircraft plating and maintenance facilities on Tinker AFB. The pit is believed to contain waste oils, waste paint strippers, contaminated jet fuels, chromates, phenols, cyanides, waste acids and bases. The petroleum-based waste were periodically burned to reduce the volume of the waste material in the pit. The pit was filled in 1958 and the surface graded, leaving no visible surface features to indicate its location.

Previous investigations at the site have been conducted by Radian (1985a) and Weston (1991a, b). The Radian investigation found that the remains of the waste pit materials were very diffused and pit boundaries were not well defined. The soil coring showed the waste materials were thoroughly mixed with the soil. The EM survey data showed only one significant anomaly, with the rest of the area occupied with materials having near or slightly above background conductivity. The identified anomaly was interpreted to be a sewer line. The analytical data for the ten soil samples showed a significant presence of organics and metals, reflecting the origin of the waste itself. The results of analyses for the two groundwater samples showed little contamination and no migration of waste constituents downward from the site. The shallow well (MW-18A) completed in the fill material shows the presence of TOC, lead, and phenol in significant concentrations. The USZ monitoring well (MW-17) does not exhibit evidence of significant contamination of the groundwater on the site.

Results from the RI conducted by Weston (1991a) were in some ways similar to those reported by Radian (1985a). The EM survey showed five anomalies which were interpreted as being associated with known cultural features such as aboveground fuel storage tank battery, training area, sewer lines, etc. Thus, none of the anomalies were identified to be a result of hidden drums or waste sludges. Results of the soil gas survey did not show any significant contamination of the detected target analytes.

The geophysical logs indicate that the shallow subsurface soils are composed of moist interbedded clay and silt. Chemical analysis for one soil sample indicated the presence of low concentrations of metals. No organics were detected in the soil sample. Groundwater samples showed no or very low concentrations of contamination from organic constituents targeted.

Conclusion. The Radian study concluded that the contaminants from the waste material are not currently migrating away from IWP1. In addition, the report concludes that there is a very limited possibility of the waste constituents migrating away from the site due to the geologic containment provided by the impermeable shale bedrock.

The Weston study results were similar to the Radian study. Based on available data, the report concluded that IWP1 exhibits no significant contamination; therefore, no further action was recommended.

Both the Radian and Weston studies indicate no need for further action at the IWP1 site. However, based on the evaluations in Chapter 7.0, there appears to be a potential groundwater problem that may require further investigations. For example, cadmium and lead concentrations in groundwater exceeded the action levels indicating a potential groundwater problem. Additional data requirements to support any conclusions or interpretations are discussed in Chapter 9.0.

9.0 Recommendations

The investigations by Radian (1985a) and Weston (1991a, b) conducted at IWP1 were designed to determine the nature and extent of contamination and define the boundaries of the waste pit in order to reasonably estimate the volume of the waste in the pit. These objectives have been partially achieved. None of these previous studies adequately characterized the groundwater USZ within and around the waste pit.

Both the Radian and Weston studies indicated that contaminants were not migrating from the site. However, these studies failed to determine groundwater conditions at the site, including flow direction and, consequently, the characterization of the groundwater downgradient of the waste pit. The reports assume groundwater flow to be in the southwest direction, but no groundwater wells were installed downgradient in order to establish whether there has been contaminant migration from the site. Based on the comparison of existing data with action levels, there appears to be a potential groundwater problem that warrants further investigations of the site.

As this report is being prepared, efforts to obtain the additional data are underway. Groundwater monitoring wells are being planned for installation as a part of the RFI Phase II investigation of the site as a part of the basewide groundwater investigation. Three monitoring wells in the LSZ have been installed upgradient of the IWP1 as a result of studies at another site. Two USZ monitoring wells at the downgradient edge of the site are planned for installation. In addition, three well clusters for monitoring both the USZ and LSZ are planned to be installed downgradient of the site.

Site-specific soil background samples were not collected, nor were the soil background values available for inclusion in this Phase I RFI report. Therefore, it is recommended that site-specfic soil samples from uncontaminated areas be collected for analysis during the Phase II RFI field work. This additional involved along with the USGS background values should be used in the Phase II report to distinguish site-related from background concentrations in a statistically significant manner.

Therefore, in addition to the ongoing activities, the following are recommended:

- Continue groundwater monitoring for at least three sampling events for the new wells. Groundwater should be analyzed for VOCs, SVOCs, metals, and inorganic parameters.

- Determine groundwater flow direction and hydraulic parameters of the USZ by monitoring water levels and performing slug tests in the new monitoring wells.

- Develop a Phase II RFI work plan and submit it to EPA for approval. The Phase II work plan should include:

  - Number, location, and analysis for soil background samples
  - Additional soil samples required to delineate the contamination
  - Additional monitoring wells to be installed under the basewide groundwater investigation work plan that will provide data for this site.

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Final Report
Phase I RCRA Facility Investigation for Appendix I Sites

VOLUME VIII

SWMU-13, Industrial Waste Pit No. 2

Department of the Air Force
Oklahoma City Air Logistics Center
Tinker Air Force Base, Oklahoma

September 1994

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List of Acronyms

AFB	Air Force Base
AOC	area of concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMS	Corrective Measures Study
DERP	Defense Environmental Restoration Program
DOD	U.S. Department of Defense
E/B	exposure/benchmark (ratio)
EID	Engineering Installation Division
EM	electromagnetic
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
ft^2	square feet
ft^3	cubic feet
ft/ft	foot per foot
HSWA	Hazardous and Solid Waste Amendments
IRP	Installation Restoration Program
IWP2	Industrial Waste Pit 2
LSZ	lower saturated zone
msl	mean sea level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
PA/SI	preliminary assessment/site investigation
PCE	tetrachoroethane
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI/FS	remedial investigation/feasibility study
RFI	RCRA Facility Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SF	slope factor
SWMU	solid waste management unit
TCE	trichloroethene

TSD	treatment, storage, and disposal (facility)
TOC	total organic carbon or compounds
TOX	total organic halogen
USACE	U.S. Army Corps of Engineers
USC	U.S. Code
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USZ	upper saturated zone
UWBZ	upper waste bearing zone

Executive Summary

This report provides a summary of the various investigations that have been conducted at solid waste management unit (SWMU)-13, Industrial Waste Pit No. 2 (IWP2), Tinker Air Force Base (AFB), Oklahoma. The report has been prepared to determine and document whether sufficient investigations at IWP2 have been performed to meet regulatory requirements. Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. The Base encompasses approximately 5,000 acres.

Background. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints.

In 1984, Congress amended the Resource Conservation and Recovery Act (RCRA) with the Hazardous and Solid Waste Amendments (HSWA), which allow EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or contaminants from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989, Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit. The final RCRA HSWA permit issued on July 1, 1991, requires Tinker AFB to investigate all SWMUs and areas of concern (AOC) and to perform corrective action at those identified as a threat to human health or the environment. The permit specifies that a RCRA Facility Investigation (RFI) be conducted for 43 identified SWMUs and two AOCs on the Base. This document has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for IWP2.

Source Description. IWP2 was in operation from 1958 to 1965 and was constructed without a liner. During its operational period, the pit received unspecified industrial waste streams originating from various aircraft plating and maintenance facilities on Tinker AFB. The waste streams were thought to contain high levels of heavy metals and a variety of organic contaminants (degreasers, paint strippers, and other solvents and cleaners). Waste types known to have been disposed of in this pit include waste oils, cyanides, chromates, phenols, solvents, waste acids, and alkalies (Tinker, 1992). The materials in the pits were periodically burned to reduce the volume of waste material in the pit (Radian, 1985a). The pit was filled in 1965 and the surface covered, graded, and vegetated, leaving no visible surface features to indicate its location.

Site Investigations. The initial phase of the investigations conducted at Tinker AFB was conducted by Engineering Science (ES, 1982). The purpose of this study was to conduct a literature search for the various potentially contaminated sites in order to determine from records what was actually disposed of at these sites. During the literature search, no information concerning the type of waste disposed of in IWP2 or the construction drawings were obtained.

The second phase involved investigations to confirm the presence of contamination and determine the nature and the extent of contamination at the different sites. In 1983 and 1984, Radian Corporation (Radian) was retained to perform these investigations. Various field activities including electromagnetic (EM) survey, soil coring, and monitoring well installation were conducted to achieve the stated objective. Results of the EM survey were used to estimate the areal extent of the waste in IWP2. Based on the EM survey data interpretation, the areal extent of the buried waste was estimated to be approximately 38,000 square feet (ft^2). Visual observation of the soil cores indicated the waste material was shallow with an average depth of 5 feet. Based on this information, the volume of the waste material estimated to be in IWP2 is approximately 190,000 cubic feet (ft^3). During the Radian study, ten soil samples and three groundwater samples were collected and analyzed for selected chemical constituents. Chromium, copper, mercury, oil and grease, lead, and zinc were in significant concentrations in soil samples collected from within the waste pit. Overall, the results show the waste material to be high in organics and metals, reflecting the origin of the waste itself (Radian, 1985).

Groundwater samples were collected from all the three monitoring wells. Monitoring well 3G, completed in the waste material, revealed the presence of contamination similar to that detected in the soil. Constituents detected in significant concentrations in a water sample from this well include cadmium, chromium, nickel, lead, zinc, oil and grease, 1,2-dichlorobenzene, and phenol. The other two monitoring wells (3E and 3F) showed no contamination (Radian, 1985).

In January 1987, the USACE drilled eight borings along the edges of a proposed drainage ditch near IWP2. Visual examination of the soil cores indicated no waste materials were encountered. This observation was supported by the analytical results for the collected soil samples. In March 1989, the USACE installed three additional groundwater wells in order to characterize groundwater around IWP2. The newly installed wells, along with two existing wells, were sampled quarterly for 1 year from June 1989 to April 1990. Results from the different sampling rounds indicated a higher level of some metals and organics in the upper saturated zone (USZ) within the waste pit. These constituents include metals (cadmium, chromium, lead, nickel, zinc, and manganese) and organics (trichloroethene, chlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichlorobenzene, 2-methylphenol, vinyl chloride, 1,2-dichloroethane, trans-1,2-dichloroethene, 4-methylphenol, 2,4-dimethylphenol, and bis[ethylhexyl]phthalate). Wells installed outside the waste pit boundaries showed no significant contamination except for the presence of acetone, 2-butanone, dimethyl phthalate, trichloroethene, and bis(2-ethylhexyl)phthalate, which were detected in relatively significant concentrations (USACE, 1993a).

Characterizations/Baseline Risk Assessment. Evaluation of the potential impact of IWP2 on human health and the environment has been conducted. Data from the site were evaluated in terms of identifying chemicals of potential concern. Four inorganic chemicals in the soil media were found to be of potential concern: arsenic, barium, cadmium, and chromium. Similarly, groundwater data were screened to identify chemicals of concern; only one inorganic chemical and seven organic chemicals were retained as constituents of potential concern. The selected compounds include cadmium, vinyl chloride, trichloroethylene, 1,2-dichloroethene, chlorobenzene, 1,4-dichlorobenzene, 4-methylphenol, and bis(2-ethylhexyl)phthalate.

The baseline risk assessment indicates IWP2 poses no threat to human life and the environment (USACE, 1993b). Different pathways were evaluated in order to identify the potential receptors likely to be exposed to contaminants of IWP2. The primary potential exposure point for workers near the site was identified to be the Transient Munitions Facility, located approximately 320 feet west of IWP2. Therefore, the potentially exposed population identified in the baseline risk assessment were the industrial workers associated with the Transient Munitions Facility. The total carcinogenic risk to this population with the greatest exposure potential was 4×10^{-7}, well within the range of acceptable risks for Superfund sites of 1×10^{-4} to 1×10^{-6}. The hazard from noncarcinogenic effects was exhibited by a hazard index of 0.007, which is far below the minimum hazard index of 1 (USACE, 1993b).

Other ecological receptors identified in the site or its vicinity include the earthworms and bermuda grass. Earthworms are exposed by ingestion of contaminated soils and are subsequently consumed by higher trophic level consumer organisms. Bermuda grass is exposed through its root system and is subsequently consumed by herbivores. Consumer organism potentially exposed to chemicals of concern through the food chain are the gopher and the shrew. The gopher consumes grass and the shrew consumes earthworms and insects. The owl, a predator of each consumer organism, was selected as a receptor to represent a higher trophic level (USACE, 1993b).

However, no compounds at IWP2 are expected to cause ecological risks through the evaluated surface soil exposure pathway. Vegetation is expected to be relatively unaffected because barium, which exceeds the exposure/benchmark (E/B) ratio of 1 for vegetation, is not readily taken up by plants. Nickel and zinc are not expected to cause a risk to earthworms beyond the risk posed by background levels. Similarly, chromium and nickel pose little or no risk to small mammals. Predatory birds were shown to be at no risk from any of the chemicals present at the site. Mammals and birds would be deterred from inhabiting or hunting in the area by the close proximity of the runway to the site.

Conclusions. The Radian study concluded that the available hydrogeologic and chemical data are sufficient to describe current conditions and to evaluate the probable environmental effects of IWP2. The report also asserts that no changes in impacts are anticipated as long as existing land use and cover are maintained. Therefore, the report recommended no additional work for this area.

Based on available data, the USACE report (USACE, 1993a) concluded that IWP2 exhibits contamination that has migrated from the site into perched water, or the shallow Hennessey groundwater, and, to some extent, the top of USZ. Therefore, the report recommended continuation of monitoring of shallow groundwater and the USZ groundwater at this site.

Recommendations. Based on the evaluation of the existing data, there seems to be a potential groundwater problem at this site. A comparison of groundwater data with action levels revealed certain constituents were at concentration levels above the action levels. Significant contamination has migrated from IWP2 into the Hennessey groundwater and to some extent to the top of the USZ. However, most constituents were detected only once at concentrations above the action levels. Additional groundwater data is needed to support a determination of groundwater problem at this site. Therefore, the following is recommended:

- Continue groundwater monitoring and collect data for at least three sampling rounds in order to evaluate any trends in the data. In addition, these data will support evaluations for contaminant migration at the site.

- Additional monitoring wells should be installed in the Hennessey water bearing zone (HWBZ) during Phase II of the RFI program to determine the lateral extent of contamination.

- Collect site-specific soil background samples to be used in addition to USGS soil data to distinguish site-related from background concentrations in a statistically significant manner during the Phase II investigation.

1.0 Introduction

1.1 Purpose and Scope

This document has been prepared in response to the Department of Air Force, Tinker Air Force Base (AFB), Oklahoma request for a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Summary Report for solid waste management unit (SWMU)-13, Industrial Waste Pit No. 2 (IWP2).

The objective of this RFI Summary Report is to provide Tinker AFB with one comprehensive report that summarizes the various investigations that have occurred at IWP2 since the first environmental investigation was initiated on Base in 1981. The purpose of this comprehensive summary document is to:

- Characterize the site (Environmental Setting).
- Define the source (Source Characterization).
- Define the degree and extent of contamination (Contamination Characterization).
- Identify actual or potential receptors.
- Identify all action levels for the protection of human health and the environment.

Additionally, this document briefly describes the procedures, methods, and results of all previous investigations and baseline risk assessment that relate to IWP2 and contaminant releases, including information on the type and extent of contamination at the site, and actual or potential receptors. Where previous investigations, reports, or studies were not comprehensive and did not furnish the information required to determine the nature and extent of contamination, future work that can be conducted to complete the investigation has been recommended.

1.2 Preface

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the cleanup of hazardous waste disposal sites across the country. CERCLA gave the president authority to require responsible parties to remediate the sites or to undertake response actions through use of a fund (the Superfund). The president, through Executive Order 12580, delegated the U.S. Environmental Protection Agency (EPA) with the responsibility to investigate and remediate private party hazardous waste disposal sites that created a threat to human health and the environment. The president delegated responsibility for investigation and cleanup of federal facility disposal sites to the various federal agency heads. The Defense Environmental Restoration Program (DERP) was formally

established by Congress in Title 10 U.S. Code (USC) 2701-2707 and 2810. DERP provides centralized management for the cleanup of U.S. Department of Defense (DOD) hazardous waste sites consistent with the provisions of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300), and Executive Order 12580. To support the goals of DERP, the Installation Restoration Program (IRP) was developed to identify, investigate, and clean up contamination at installations.

Under the Air Force IRP, Tinker AFB began a Phase I study similar to a preliminary assessment/site investigation (PA/SI) in 1981 (Engineering Science [ES], 1982). This study helped locate 14 sites that needed further investigation. A Phase II study was performed in 1983 (Radian Corporation [Radian], 1985a,b).

In 1986, Congress amended CERCLA through the SARA. SARA waived sovereign immunity for federal facilities. This act gave EPA authority to oversee the cleanup of federal facilities and to have the final authority for selecting the remedial action at federal facilities placed on the National Priorities List (NPL) if the EPA and the relevant federal agency cannot concur in the selection. Congress also codified DERP (SARA Section 211), establishing a fund for the DOD to remediate its sites because the Superfund is not available for the cleanup of federal facilities. DERP specifies the type of cleanup responses that the fund can be used to address.

In response to SARA, the DOD realigned its IRP to follow the investigation and cleanup stages of the EPA:

- PA/SI
- Remedial investigation/feasibility study (RI/FS)
- Record of Decision (ROD) for selection of a remedial action
- Remedial design/remedial action.

In 1984, Congress amended RCRA with the Hazardous and Solid Waste Amendments (HSWA) which allow the EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989 Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit.

EPA, in the Hazardous Waste Management Permit for Tinker AFB, dated July 1, 1991, identified 43 SWMUs and two areas of concern (AOC) on Tinker AFB that need to be addressed. This permit requires Tinker AFB to investigate all SWMUs and AOCs and to perform corrective action at those identified as posing a threat to human health or the environment. This RFI Summary Report has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for IWP2 and to document all determinations.

1.3 Facility Description

Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County (Figure 1-1) with its approximate geographic center located at 35^{o} 25' latitude and 97^{o} 24' longitude (U.S. Geological Survey [USGS], 1978). The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. An additional area east of the main Base is used by the Engineering Installation Division (EID) and is known as Area D. The Base encompasses approximately 5,000 acres. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints. Wastes that are currently generated are managed at two permitted hazardous waste storage facilities. However, prior to enactment of RCRA, industrial wastes were discharged into unlined landfills and waste pits, streams, sewers, and ponds. Past releases from these landfills, pits, etc., as well as from underground tanks, have occurred. As a result, there are numerous sites of soil, groundwater, and surface water contamination on the Base.

The various reports generated as a result of investigative activities conducted at IWP2 have been reviewed and evaluated in terms of the sites' status under RCRA regulations. A summary based on the review of these reports for IWP2 is presented in the following chapters and sections. In addition, recommendations for additional work is given at the end of the summary report.

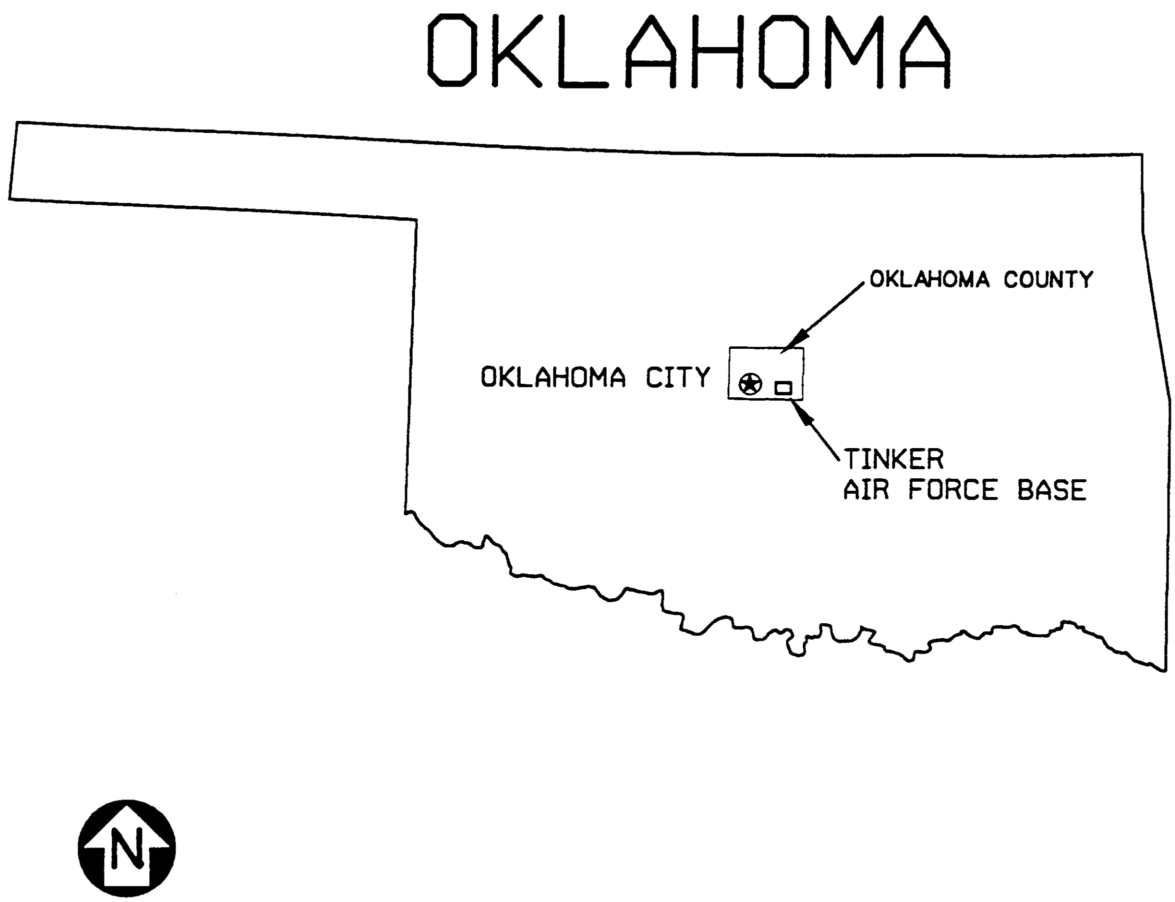


FIGURE 1-1
TINKER AIR FORCE BASE
OKLAHOMA
STATE INDEX MAP

PREPARED FOR
TINKER AFB
OKLAHOMA

STARTING DATE: 03/17/94 | DATE LAST REV.: | DRAFT. CHCK. BY:G. PACHECO | INITIATOR: C. WALLACE | DWG. NO.:
DRAWN BY:P.O. TERRY | DRAWN BY: | ENGR. CHCK. BY: C. WALLACE | PROJ. MGR.J. TAYLOR | PROJ. NO.:

3/23/94 POT
FILENAME: G:\TINKER\40983202.075

1.4 Site Description

IWP2 is located in the southeast corner of Tinker AFB, approximately 200 yards west of the Base boundary, west of Douglas Boulevard. The 2-acre, irregularly shaped elliptical area is located on a hill between Patrol Road and the north-south runway (Figure 1-2). IWP2 is in a restricted area next to the Transient Munitions Facility, which is located approximately 110 yards west of the waste pit. IWP2 is no longer in use and has been covered with fill material, graded, and vegetated, leaving no visible surface features to indicate its location.

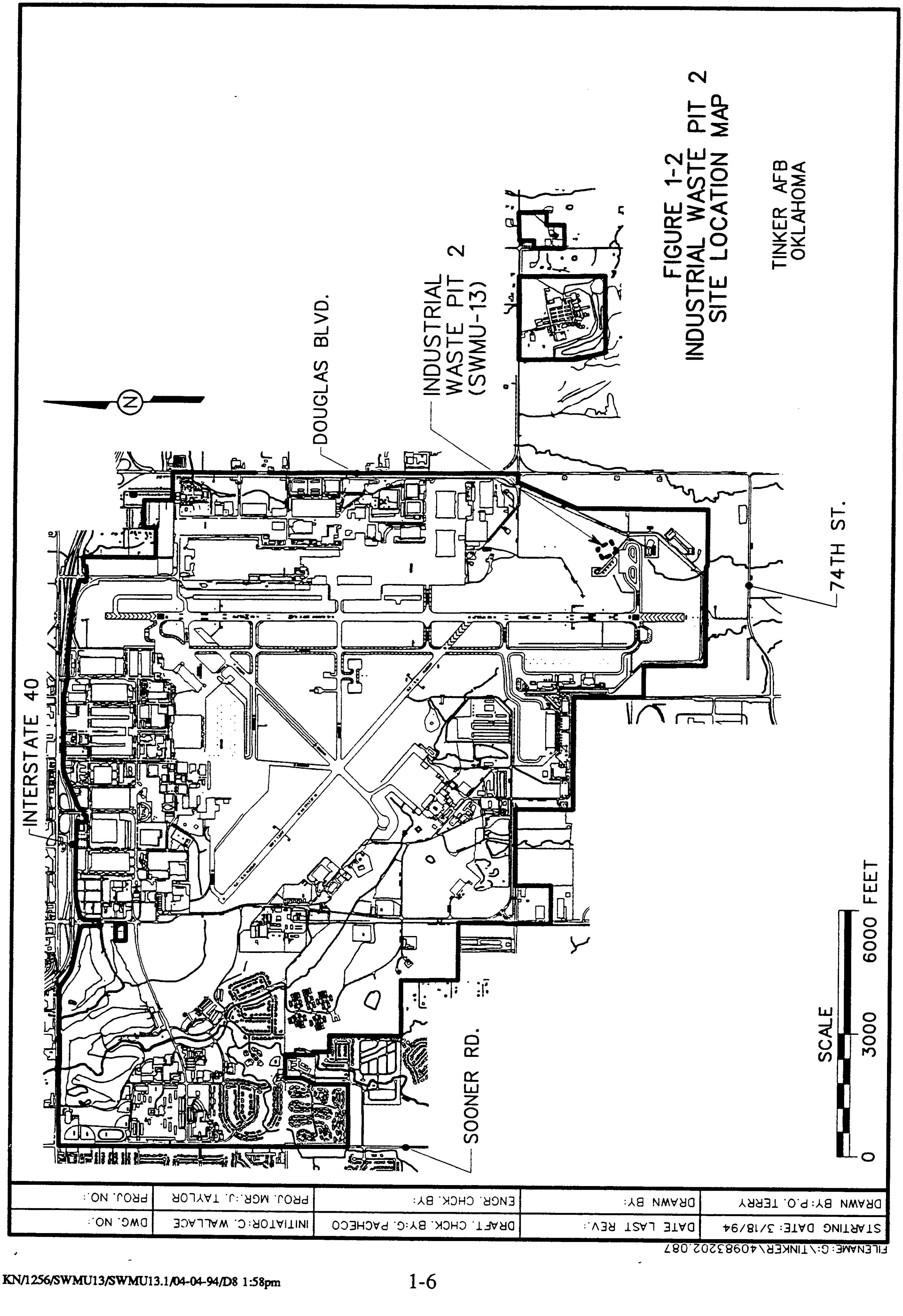


FIGURE 1-2
INDUSTRIAL WASTE PIT 2
SITE LOCATION MAP
TINKER AFB
OKLAHOMA
INDUSTRIAL
WASTE PIT 2
(SWMU-13)
DOUGLAS BLVD.
INTERSTATE 40
SOONER RD.
74TH ST.
N
SCALE
0
3000
6000 FEET
DRAWN BY: P.O. TERRY
STARTING DATE: 3/18/94
DRAWN BY:
DATE LAST REV.:
ENGR. CHCK. BY:
DRAFT. CHCK. BY: G. PACHECO
PROJ. MGR.: J. TAYLOR
INITIATOR: C. WALLACE
PROJ. NO.:
DWG. NO.:
FILENAME: G:\TINKER\40983202.087

2.0 Background

2.1 Site Operations and History

Tinker AFB was originally known as the Midwest Air Depot and began operations in July 1941. The site was activated March 1942. During World War II, the depot was responsible for reconditioning, modifying, and modernizing aircraft, vehicles, and equipment.

General refuse generated from Base operations has been disposed of in at least six landfills located on the Base property or leased land adjacent to the Base. However, the waste liquids and sludges generated from the various aircraft maintenance shops were not disposed of in the six landfills. Instead, they were disposed of in two large open pits which were specifically constructed to receive this type of waste. One of these waste pits, IWP2, is located in the southeast corner of the Base, on a hill between Patrol Road and the north-south runway

IWP2 was in operation from 1958 to 1965 and was constructed without a liner. During its operational period, the pit received unspecified industrial waste streams originating from various aircraft plating and maintenance facilities on Tinker AFB. The waste streams were thought to contain high levels of heavy metals, and a variety of organic compounds (degreasers, paint strippers and other solvents and cleaners). Waste types known to have been disposed of in this pit include: waste oils, cyanides, chromates, phenols, solvents, waste acids and alkalies (Tinker, 1992). The materials in the pits were periodically burned to reduce the volume of waste material in the pit (Radian, 1985a). The pit was filled in 1965 and the surface covered with clean fill, graded, and vegetated, leaving no visible surface features to indicate its location.

2.2 Summary of Previous Investigations

Engineering Science, Inc. Phase I studies under the IRP at Tinker AFB were conducted by ES and completed in April 1982. The purpose of these studies was to conduct a records search for the identification of past waste disposal activities which may have caused groundwater contamination on and off the Base. Among the sites identified as potentially contaminated was IWP2, which was designated as zone 3 in the ES study (ES, 1982).

Radian Corporation. During the period of 1983-84, Radian conducted Phase II investigations at the IWP2. The Phase II investigations were designed to confirm the presence of contamination and determine the magnitude and extent of environmental contamination that has occurred due to waste disposal practices at Tinker AFB. These investigations also included identifying environmental consequences of migrated contaminants and making recommendations for additional investigations in order to identify the magnitude, extent, and direction of movement of discovered contaminants (Radian, 1985a).

In order to achieve these objectives, several field activities were performed at IWP2, including completion of shallow and deep groundwater monitoring wells, performance of a geophysical survey (electromagnetic [EM] method), soil coring, and soil and groundwater sampling.

A geophysical survey was performed in order to define the waste pit, which is currently vacant land with no visible surface features to indicate its boundaries. The geophysical technique selected for the investigation was the EM survey using two devices: the Geonics EM31 and the EM34-3 ground conductivity sensors. The effective depth sampled by EM31 is approximately 20 feet; the depth sampled by EM34-3 depends on the coil separation and orientation, applied frequency, and, to some extent, on the conductivity profile of the subsurface. Details of operational procedures and the methodology employed to conduct the investigation are included in the Radian report (Radian, 1985a).

Results of the EM survey revealed two main areas with magnetic anomalies. One of the areas is within the estimated pit boundaries; this area is most likely the areal extent of the buried waste in the pit. The other area is located on the southwest side of the waste pit, and may be reflecting soil contamination.

Soil sampling was performed at the conclusion of the field geophysical survey. The results of the geophysical survey were used to determine the location of the soil borings to investigate the waste pit. Shallow soil samples were taken from five locations (3A, 3B, 3C/3G, 3D, and 3F); two of the locations (3F and 3G) were used for the installation of shallow groundwater monitoring wells. Deep soil was sampled from a location (3E) southwest of the waste pit. This borehole was converted into a deep groundwater monitoring well. A summary of the monitoring wells is provided in Table 2-1. The locations of the three groundwater monitoring wells were selected so that one monitoring well (3E) was downgradient of the waste pit, MW-3F was upgradient of the waste pit, and MW-3G was within the waste pit. Monitoring wells MW-3F and MW-3G were later renumbered by the U.S. Army Corps of Engineers (USACE)

Table 2-1

Monitoring Wells Summary
SWMU-13, IWP2, Tinker AFB

Well Number	Installation Date	Total Depth (ft)	Casing Diameter (in.)	Screen/Casing Type	Screen Interval (ft)	Slot Size (in.)	TOC[a] Elevation (ft)
MW-3E[b]	11/83	75.5	2	PVC Sch. 40	64.5 - 74.5	0.01	NA[c]
MW-15	11/83	30.4	2	PVC Sch. 40	15.4 - 30.4	0.01	1313.37
MW-16	2/84	8.0	2	PVC Sch. 40	3 - 8.0	0.01	1311.84
MW-80	3/89	75.0	4	PVC Sch. 40	45 - 65	0.01	1296.12
MW-81	3/89	91.6	4	PVC Sch. 40	67 - 87	0.01	1307.91
MW-82	3/89	106	4	PVC Sch. 40	70 - 90	0.01	1314.36

[a]Top of Casing.
[b]Monitoring well was plugged and abandoned.
[c]Not available.

to be MW-15 and MW-16, respectively, consistent with the sitewide well numbering system (Figure 2-1). These wells (MW-15 and MW-16) are completed in the Hennessey Shale above the groundwater in the Garber-Wellington formation. Monitoring well 3E was plugged and abandoned during the construction of the Transient Munitions Facility.

Evaluation of the soil coring data revealed that the waste material is very shallow, with an average thickness of less than 5 feet from the ground surface. The total area of the waste was estimated based on the results of the EM survey to be approximately 38,000 square feet (ft^2). Therefore, the total quantity of waste material present is approximately 190,000 cubic feet (ft^3).

Based on field screening, ten soil samples were selected for detailed chemical analysis. Analytical results are summarized in Section 5.1. The results show the waste material to be high in organics and metals, reflecting the origin of the waste itself. Groundwater samples were collected from all the three monitoring wells. The collected samples were subjected to chemical analysis and the results are summarized in Section 5.2. Monitoring well MW-16, completed in the waste material, revealed the presence of contamination similar to that detected in the soil. The other two wells, 3E and MW-15, showed no contamination.

The Radian study concluded that the available hydrogeologic and chemical data are sufficient to describe current conditions and to evaluate the probable environmental effects of the IWP2. The report also asserts that no changes in impacts are anticipated as long as existing land use and cover are maintained. Therefore, Radian recommended that no additional work was necessary for this area (Radian, 1985).

U.S. Army Corps of Engineers. In January 1987, the USACE drilled eight borings at the limits of a proposed drainage ditch to be located close to IWP2. The purpose of the boring was to determine if waste materials from IWP2 would be encountered during the excavation for the drainage ditch that was to be constructed as part of a construction plan for the Transient Munitions Facility. Based on visual examination of the soil samples from the borings, no waste materials were encountered. This observation was supported by the results from the chemical analysis of the soil samples. Metals were found to be within background range and no organics were detected, except methylene chloride, which was detected at very small concentrations. Results of the chemical analyses are summarized in Section 5.2 and presented in Appendix C of the IWP2 USACE RI report (USACE, 1993a).

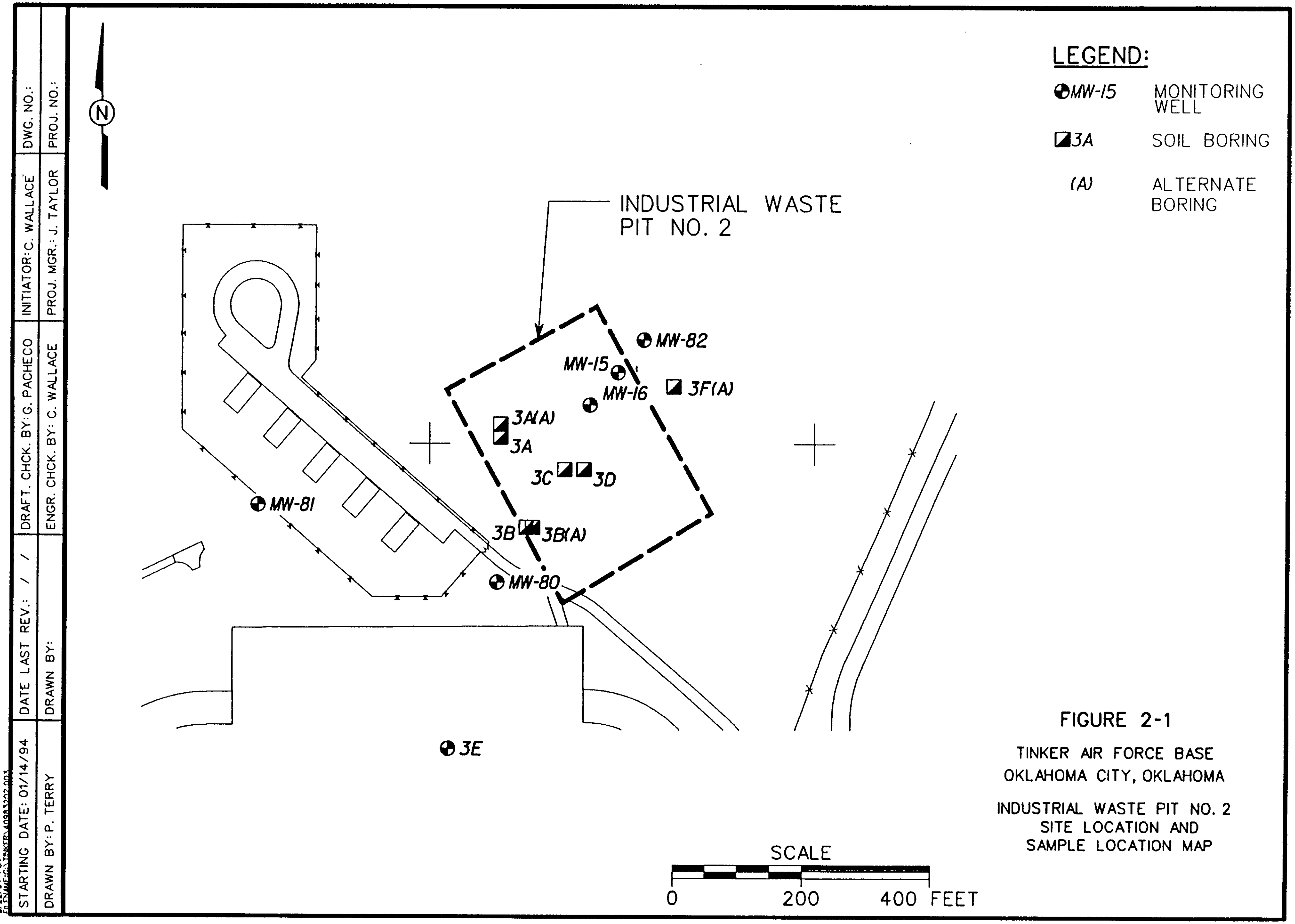


FIGURE 2-1

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

INDUSTRIAL WASTE PIT NO. 2
SITE LOCATION AND
SAMPLE LOCATION MAP

In March 1989, the USACE installed three additional monitoring wells (Table 2-1). One well (MW-82) was installed upgradient from the waste pit, and the other two wells (MW-80 and MW-81) were installed downgradient from the waste pit. These wells are installed in the upper saturated zone (USZ) at depths between 50 and 70 feet. The USZ is the portion of the aquifer referred to by the USACE as the perched aquifer. Although no data exists at the site to demonstrate that this saturated interval is perched there, the vadose zone below the USZ is projected under the site on the basis of regional hydrogeologic correlations. The new wells, along with the two existing wells, were sampled quarterly for one year. Results essentially confirmed previous findings that significant contamination (some organic and metals) exists in the shallow groundwater found in the Hennessey within the waste pit boundaries. However, the uppermost groundwater in the Garber-Wellington (USZ) upgradient and downgradient from the waste pit does not show any significant contamination. The summary results are provided in Section 5.2 and complete analytical results are contained in the USACE RI report for IWP2 (USACE, 1993a).

The USACE also conducted a baseline risk assessment on this site (USACE, 1993b). Details of this assessment are covered in Chapter 6.0.

2.3 Current Regulatory Status

The IRP has been ongoing at Tinker AFB since the early 1980s. IRP studies on the Base were conducted according to IRP guidance, which is essentially the same as EPA's guidance for conducting RI/FS under CERCLA. All investigation and removal actions have been closely monitored and approved by the EPA.

Since receiving the Hazardous Waste Management Permit on July 1, 1991, many of the IRP sites have come under the jurisdiction of the RCRA permits branch of EPA. As such, they have been identified as SWMUs; however, a large amount of work has already been performed at most of these sites under the IRP. Additional investigation at the SWMUs will be performed under the IRP.

3.0 Environmental Setting

3.1 Topography and Drainage

3.1.1 Topography

Regional/Tinker AFB. The topography of Oklahoma City and surrounding area varies from generally level to gently rolling in appearance. Local relief is primarily the result of dissection by erosional activity or stream channel development. At Oklahoma City, surface elevations are typically in the range of 1,070 to 1,400 feet mean sea level (msl). At Tinker AFB, ground surface elevations vary from 1,190 feet msl near the northwest corner where Crutcho Creek intersects the Base boundary to approximately 1,320 feet msl at Area D (EID).

Site. IWP2 is located on the southeast corner of Tinker AFB on land ranging in elevation from approximately 1,280 feet msl near Patrol Road to 1,310 feet msl. The disposal area was located at the crest of a low hill, with drainage away from the site in all directions. The area is now covered with grass and shows no signs of previous surface disturbance.

3.1.2 Surface Drainage

Regional/Tinker AFB. Drainage of Tinker AFB land areas is accomplished by overland flow of runoff to diversion structures and then to area surface streams, which flow intermittently. The northeast portion of the Base is drained primarily by unnamed tributaries of Soldier Creek, which is itself a tributary of Crutcho Creek. The north and west sections of the Base, including the main instrument runway, drain to Crutcho Creek, a tributary of the North Canadian River. Two small unnamed intermittent streams crossing installation boundaries south of the main instrument runway generally do not receive significant quantities of Base runoff due to site grading designed to preclude such drainage. These streams, when flowing, extend to Stanley Draper Lake, approximately one-half mile south of the Base.

Site. Surface drainage in the vicinity of IWP2 is influenced by the graded and vegetated pit surface. The surface slope is very gentle, and occasionally precipitation results in standing water which may infiltrate into the waste pit. Eventually, the excess surface runoff may drain into Elm Creek, an intermittent stream.

3.2 Geology

3.2.1 Regional/Tinker AFB Geology

Tinker AFB is located within the Central Redbed Plain Section of the Central Lowland physiographic province, which is tectonically stable. No major fault or fracture zones have been mapped near Tinker AFB. The major lithologic units in the area of the Base are relatively flat-lying and have a regional westward dip of about 0.0076 foot per foot (ft/ft) (Bingham and Moore, 1975).

Geologic formations that underlie Tinker AFB include, from oldest to youngest, the Wellington Formation, Garber Sandstone, and the Hennessey Group; all are Permian in age.

All geologic units immediately underlying Tinker AFB are sedimentary in origin. The Garber Sandstone and Wellington Formation are commonly referred to as the Garber-Wellington Formation due to strong lithologic similarities. These formations are characterized by fine-grained, calcareously-cemented sandstones interbedded with shale. The Hennessey Group consists of the Fairmont Shale and the Kingman Siltstone. It overlies the Garber-Wellington Formation along the eastern portion of Cleveland and Oklahoma counties. Quaternary alluvium is found in many undisturbed streambeds and channels located within the area.

Stratigraphy. Tinker AFB lies atop a sedimentary rock column composed of strata that ranges in age from Cambrian to Permian above a Precambrian igneous basement. Quaternary alluvium and terrace deposits can be found overlying bedrock in and near present-day stream valleys. At Tinker AFB, Quaternary deposits consist of unconsolidated weathered bedrock, fill material, wind-blown sand, and interfingering lenses of sand, silt, clay, and gravel of fluvial origin. The terrace deposits are exposed where stream valleys have downcut through older strata and have left them topographically above present-day deposits. Alluvial sediments range in thickness from less than a foot to nearly 20 feet.

Subsurface (bedrock) geologic units which outcrop at Tinker AFB and are important to understanding groundwater and contaminant concerns at the Base consist of, in descending order, the Hennessey Group, the Garber Sandstone, and the Wellington Formation (Table 3-1). These bedrock units were deposited during the Permian Age (230 to 280 million years ago) and are typical of redbed deposits formed during that period. They are composed of a conformable sequence of sandstones, siltstones, and shales. Individual beds are lenticular and vary in thickness over short horizontal distances. Because lithologies are similar and because

Table 3-1

Major Geologic Units in the Vicinity of Tinker AFB (Modified from Wood and Burton, 1968)

(Page 1 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
QUATERNARY	PLEISTOCENE AND RECENT	Alluvium	0-70	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel in the flood plains and channels of stream	Moderately permeable. Yields small to moderate quantities of water in valleys of larger streams. Water is very hard, but suitable for most uses, unless contaminated by industrial wastes or oil field brines.
		Terrace deposits	0-100	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the flood plains of the principal streams.	Moderately permeable. Locally above the water table and not saturated. Where deposits have sufficient saturated thickness, they are capable of yielding moderate quantities of water to wells. Water is moderately hard to very hard, but less mineralized than water in other aquifers. Suitable for most uses unless contaminated by oil field brines.

Table 3-1

(Page 2 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
PERMIAN	LOWER PERMIAN	Hennessey Group (includes Kingman Siltstone and Fairmont Shale)	700	Deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy or limey shale. Forms relatively flat to gently rolling grass-covered prairie.	Poorly permeable. Yields meager quantities or very hard, moderately to highly mineralized water to shallow domestic and stock wells. In places water contains large amounts of sulfate.
		Garber Sandstone	500±	Deep-red clay to reddish-orange, massive and cross-bedded fine-grained sandstone interbedded and interfingered with red shale and siltstone	Poorly to moderately permeable. Important source of groundwater in Cleveland and Oklahoma counties. Yields small to moderate quantities of water to deep wells; heavily pumped for industrial and municipal uses in the Norman and Midwest City areas. Water from shallow wells hard to very hard; water from deep wells moderately hard to soft. Lower part contains water too salty for domestic and most industrial uses.
		Wellington Formation	500±	Deep-red to reddish-orange massive and cross-bedded fine-grained sandstone interbedded with red, purple, maroon, and gray shale. Base of formation not exposed in the area.	

of a lack of fossils or key beds, the Garber Sandstone and the Wellington Formation are difficult to distinguish and are often informally lumped together as the Garber-Wellington Formation. Together, they are about 900 feet thick at Tinker AFB. The interconnected, lenticular nature of sandstones within the sequence forms complex pathways for groundwater movement.

The surficial geology of the north section of the Base is dominated by the Garber Sandstone, which outcrops across a board area of Oklahoma County. Generally, the Garber outcrop is covered by a veneer of soil and/or alluvium up to 20 feet thick. To the south, the Garber Sandstone is overlain by outcropping strata of the Hennessey Group, including the Kingman Siltstone and the Fairmont Shale (Bingham and Moore, 1975). Drilling information obtained as a result of geotechnical investigations and monitoring well installation confirms the presence of these units.

Depositional Environment. The Permian-age strata presently exposed at the surface in central Oklahoma were deposited along a low-lying north-south oriented coastline. Land features included meandering to braided sediment-loaded streams that flowed generally westward from highlands to the east (ancestral Ozarks). Sand dunes were common, as were cut-off stream segments that rapidly evaporated. The climate was arid and vegetation sparse. Off shore the sea was shallow and deepened gradually to the west. The shoreline's position varied over a wide range. Isolated evaporitic basins frequently formed as the shoreline shifted.

Across Oklahoma, this depositional environment resulted in an interfingering collage of fluviatile and wind-blown sands, clays, shallow marine shales, and evaporite deposits. The overloaded streams and evaporitic basins acted as sumps for heavy metals such as iron, chromium, lead, and barium. Oxidation of iron in the arid climate resulted in the reddish color of many of the sediments. Erosion and chemical breakdown of granitic rocks from the highlands resulted in extensive clay deposits. Evaporite minerals such as anhydrite ($CaSO_4$), barite ($BaSO_4$), and gypsum ($CaSO_4 \bullet 2H_2O$) are common.

Around Tinker AFB, the Hennessey Group represents deposition in a tidal flat environment cut by shallow, narrow channels. The Hennessey Group is comprised predominantly of red shales which contain thin beds of sandstone (less than 10 feet thick) and siltstone. In outcrop, "mudball" conglomerates, burrow surfaces, and dessication cracks are recognized. These units

outcrop over roughly the southern half of the Base, thickening to approximately 70 feet in the southwest from their erosional edge (zero thickness) across the central part of Tinker AFB.

In contrast, the Garber Sandstone and the Wellington Formation around Tinker AFB consist of an irregularly-interbedded system of lenticular sandstones, siltstones, and shales deposited either in meandering streams in the upper reaches of a delta or in a braided stream environment. Outcrop units north of Tinker AFB exhibit many small to medium channels with cut and fill geometries consistent with a stream setting. Sandstones are typically cross-bedded. Individual beds range in thickness from a few inches to approximately 50 feet and appear massive, but thicker units are often formed from a series of "stacked" thinner beds. Geophysical and lithologic well logs indicate that from 65 to 75 percent of the Garber Sandstone and the Wellington Formation are composed of sandstone at Tinker AFB. The percentage of sandstone in the section decreases to the north, south, and west of the Base. These sandstones are typically fine to very fine grained, friable, and poorly cemented. However, where sandstone is cemented by red muds or by secondary carbonate or iron cements, local thin "hard" intervals exist along disconformities at the base of sandstone beds. Shales are described as ranging from clayey to sandy, are generally discontinuous, and range in thickness from a few inches to approximately 40 feet.

Stratigraphic Correlation. Correlation of geologic units is difficult due to the discontinuous nature of the sandstone and shale beds. However, cross-sections (Figure 3-1) demonstrate that two stratigraphic intervals can be correlated over large sections of the Base in the conceptual model. These intervals are represented on geologic cross-sections A-A' and B-B' (Figures 3-2 and 3-3). Section A-A' is roughly a dip section and B-B' is approximately a strike section. The first correlatable interval is marked by the base of the Hennessey Group and the first sandstone at the top of the Garber Sandstone. This interval is mappable over the southern half of Tinker AFB. The second interval consists of a shale zone within the Garber Sandstone which, in places, is comprised of a single shale layer and, in other places, of multiple shale layers. This interval is more continuous than other shale intervals and in cross-sections appears mappable over a large part of the Base. It is extrapolated under the central portion of Tinker AFB where little well controls exists.

Structure. Tinker AFB lies within a tectonically stable area; no major near-surface faults or fracture zones have been mapped near the Base. Most of the consolidated rock units of the Oklahoma City area dip westward at a low angle. A regional dip of 0.0057 to 0.0076 ft/ft in

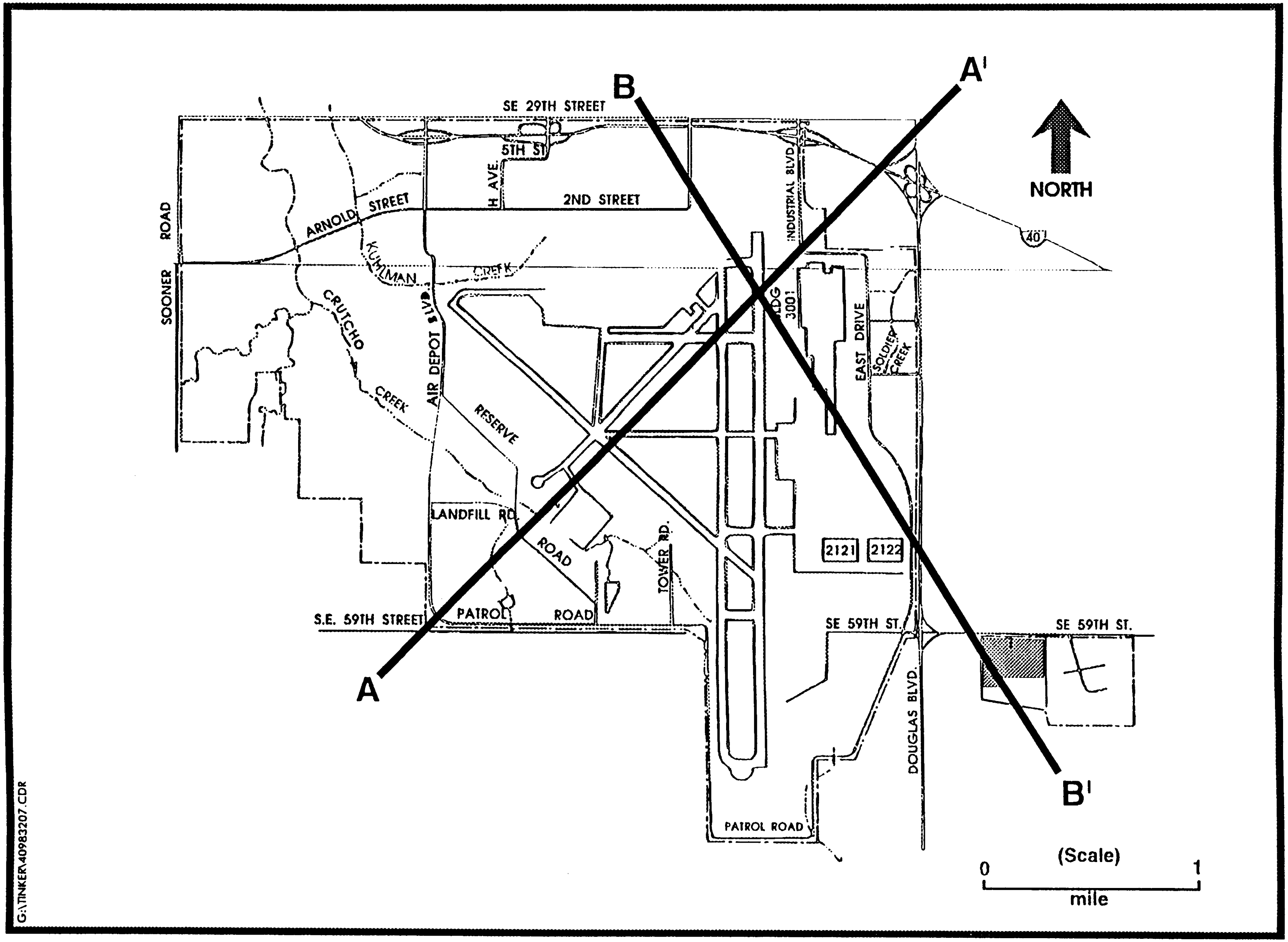


FIGURE 3-1 TINKER AFB GEOLOGIC CROSS SECTION LOCATION MAP

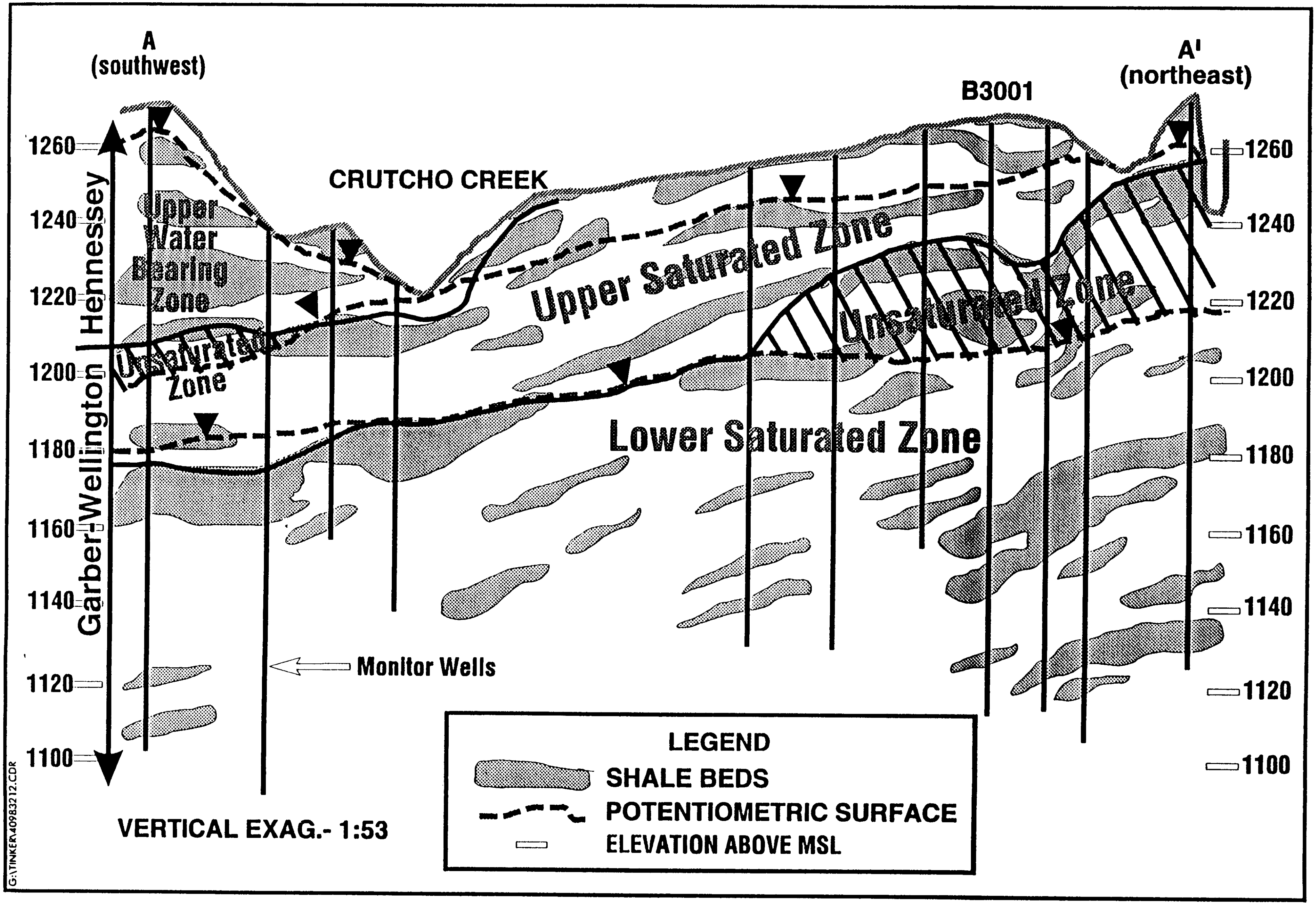


FIGURE 3-2 TINKER AFB GEOLOGIC CROSS SECTION A-A'

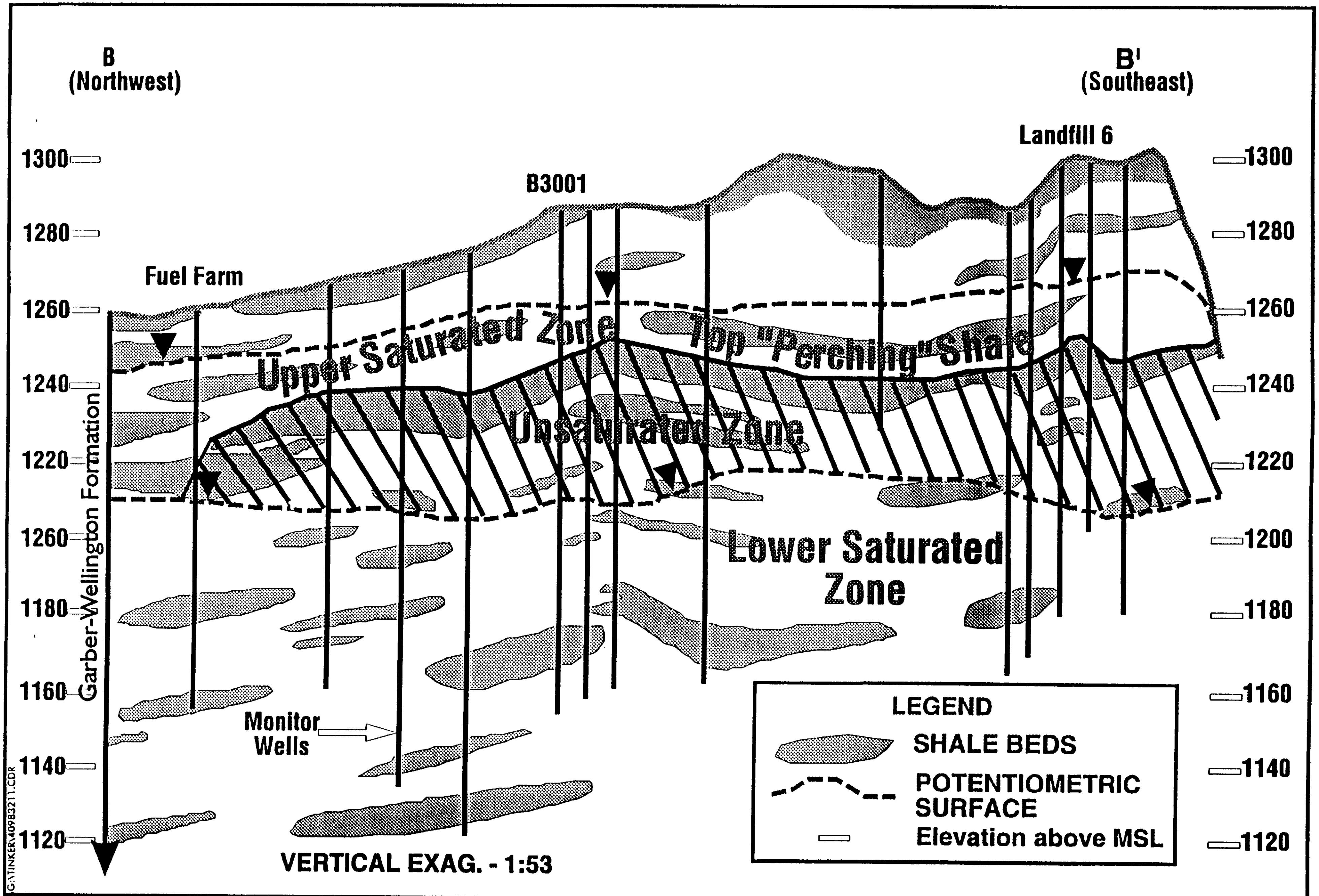


FIGURE 3-3 TINKER AFB GEOLOGIC CROSS SECTION B-B'

a generally westward direction is supported by stratigraphic correlation on geologic cross-sections at Tinker AFB. Bedrock units strike slightly west of north.

Although Tinker AFB lies in a tectonically stable area, regional dips are interrupted by buried structural features located west of the Base. A published east-to-west generalized geologic cross-section, which includes Tinker AFB, supports the existence of a northwest-trending structural trough or syncline located near the western margin of the base. The syncline is mapped adjacent to and just east of a faulted anticlinal structure located beneath the Oklahoma City Oil Field. The fault does not appear to offset Permian-age strata. There are indications that the syncline may act as a "sink" for some regional groundwater (southwest flow) at Tinker AFB before it continues to more distant discharge points.

3.2.2 Site Geology

The major geologic units around the IWP2 are a thin soil cover, underlain by dry, yellowish-red Fairmont Shale. The Fairmont Shale is in turn underlain by sandstone of the Garber Sandstone (Radian, 1985a). The surficial soil, which is mostly impervious in the IWP2 area, is predominantly fine-grained and consist of residual and allevial soil. The surficial geology consists of Kingman siltstone and Fairmont shale which make up the Hennessey Group. The Hennessey ranges in thickness from 40 to 60 feet at the site. The IWP2 area is basically composed of the Hennessey Group. Sandstone lenses occur within the shale. IWP2 is located above the shale layer (USACE, 1993a). The soil coring revealed considerable variations in geologic materials within the area of investigation. Generally, the subsurface consisted of soil and fill, underlain by weathered and unweathered shale and sandstone.

3.3 Hydrology

3.3.1 Regional/Tinker AFB Hydrology

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer system. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove, and Admire Groups. The Garber Sandstone and the Wellington Formation portion of the Central Oklahoma aquifer system is commonly referred to as the "Garber-Wellington aquifer" and is considered to be a single aquifer because these units were deposited under similar conditions and because many of the best producing wells are completed in this zone. On a regional scale, the aquifer is confined above by the less permeable Hennessey Group and below by the Late Pennsylvanian Vanoss Group.

Tinker AFB lies within the limits of the Garber-Wellington Groundwater Basin. Currently, Tinker derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest City and Del City derive water supplies from both surface sources and wells tapping the aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by a municipal distribution system also depend on the Garber-Wellington aquifer. Communities presently depending upon surface supplies (such as Oklahoma City) also maintain a well system drilled into the Garber-Wellington as a standby source of water in the event of drought.

Recharge of the Garber-Wellington aquifer is accomplished principally by percolation of surface waters crossing the area of outcrop and by rainfall infiltration in this same area. Because most of Tinker AFB is located in an aquifer outcrop area, the Base is considered to be situated in a recharge zone (Havens, 1981).

According to Wood and Burton (1968) and Wickersham (1979), the quality of groundwater derived from the Garber-Wellington aquifer is generally good, although wide variations in the concentrations of some constituents are known to occur. Wells drilled to excessive depths may encounter a saline zone, generally greater than 900 feet below ground surface. Wells drilled to such depths or those accidentally encountering the saline zone are either grouted over the lowest screens or may be abandoned.

Tinker AFB presently obtains its water supplies from a distribution system comprised of 29 water wells constructed along the east and west Base boundaries and by purchase from the Oklahoma City Water Department. All Base wells are finished into the Garber-Wellington Aquifer. Base wells range from 700 to 900 feet in finished depth, with yields ranging from 205 to 250 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones with a combined thickness from 103 to 184 feet (Wickersham, 1979).

Although the variability in the geology and the recharge system at Tinker AFB makes it difficult to predict local flow paths, Central Oklahoma aquifer water table data show that regional groundwater flow under Tinker varies from west-northwest to southwest, depending on location. This theory is supported by contoured potentiometric data from base monitoring wells which show groundwater movement in the upper and lower aquifer zones to generally follow regional dip. Measured normal to potentiometric contours, groundwater flow gradients range from 0.0019 to 0.0057 ft/ft. However, because flow in the near-surface portions of the aquifer at Tinker AFB is strongly influenced by topography, local stream base-levels, complex subsurface geology, and location in a recharge area, both direction and magnitude of groundwater movement is highly variable. The interaction of these factors not only influences regional flow but gives rise to complicated local, often transient, flow patterns at individual sites.

As a result of ongoing environmental investigations and the approximately 450 groundwater monitoring wells installed on the Base during various investigations, a better understanding of the specific hydrological framework has emerged. The current conceptual model developed by Tinker AFB (Tinker, 1993), based on the increased understanding of the hydrological framework, has been revised from an earlier model adopted by the USACE. Previous studies reported that groundwater was divided into four water-bearing zones: the perched aquifer, the top of regional aquifer, the regional aquifer, and the producing zone. In the current model, two principal water table aquifer zones and a third less extensive zone have been identified. The third is limited to the southwest quadrant. The third aquifer zone consisted of saturated siltstone and thin sandstone beds in the Hennessey Shale and equates to the upper water bearing zone (UWBZ) described by the USACE (1993c) at Landfills No. 1 through 4 (SWMUs 3 through 6). In addition, numerous shallow, thin saturated beds of siltstone and sandstone exist throughout the Base. These are of limited areal extent and are often perched.

In the current conceptual hydrologic model, an USZ and a lower saturated zone (LSZ) are recognized in the interval from ground surface to approximately 200 feet. Below this is found the producing zone from which the Base draws much of its water supply. Figure 3-4 shows the potentiometric surface for the USZ and Figure 3-5 shows the potentiometric surface for the LSZ. The USZ exists mainly under water table (unconfined) conditions, but may be partially confined locally. Conditions in the LSZ are difficult to determine due to screen placement and overly long sandpacks below the screen interval.

The USZ is found at a depth of 5 to 70 feet below ground surface and has a saturated thickness ranging from less than 1 foot at its eastern boundary to over 20 feet in places west of Building 3001. The USZ is erosionally truncated by Soldier Creek along the northeastern margin of Tinker AFB. This aquifer zone is considered to be a perched aquifer over the

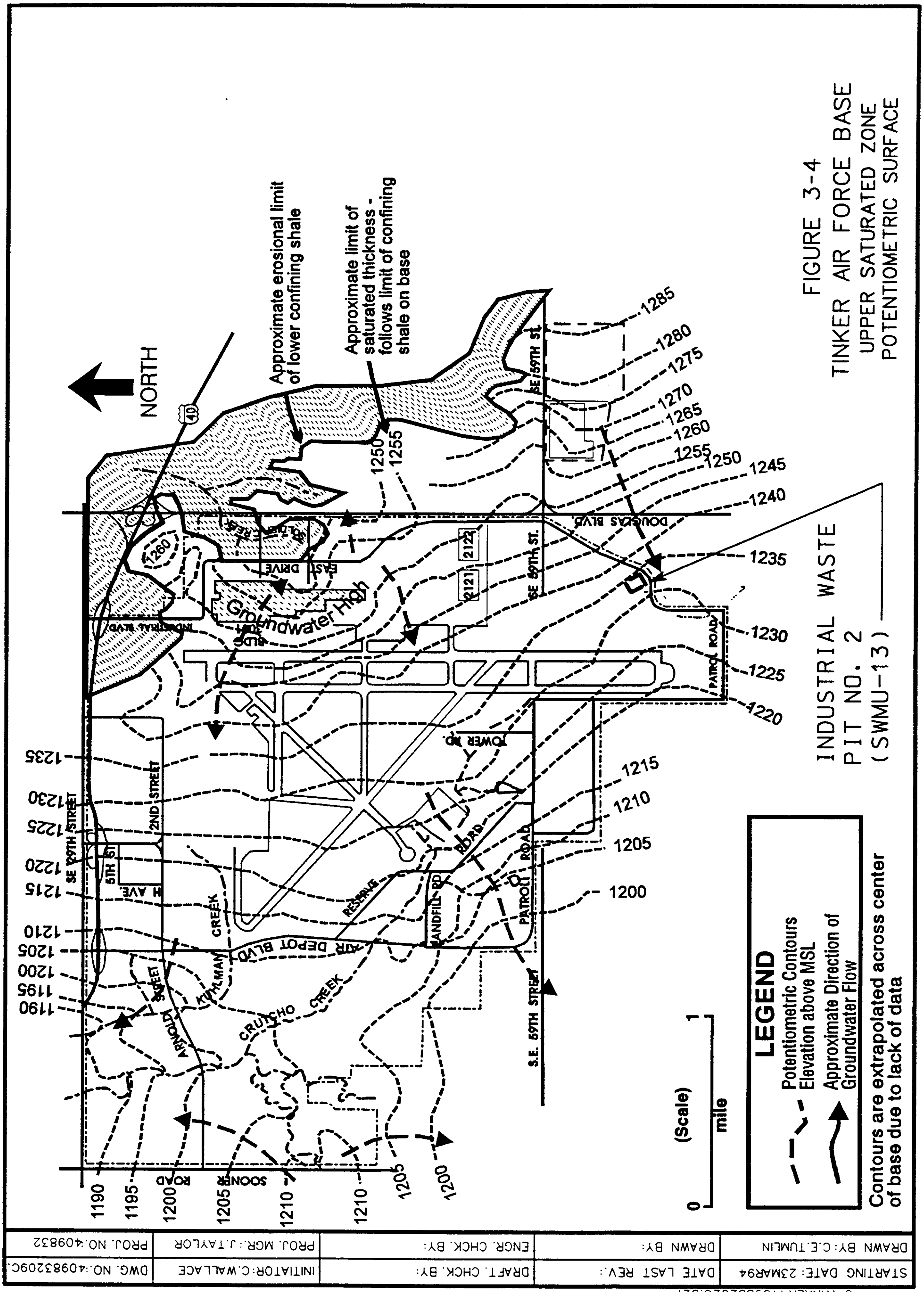
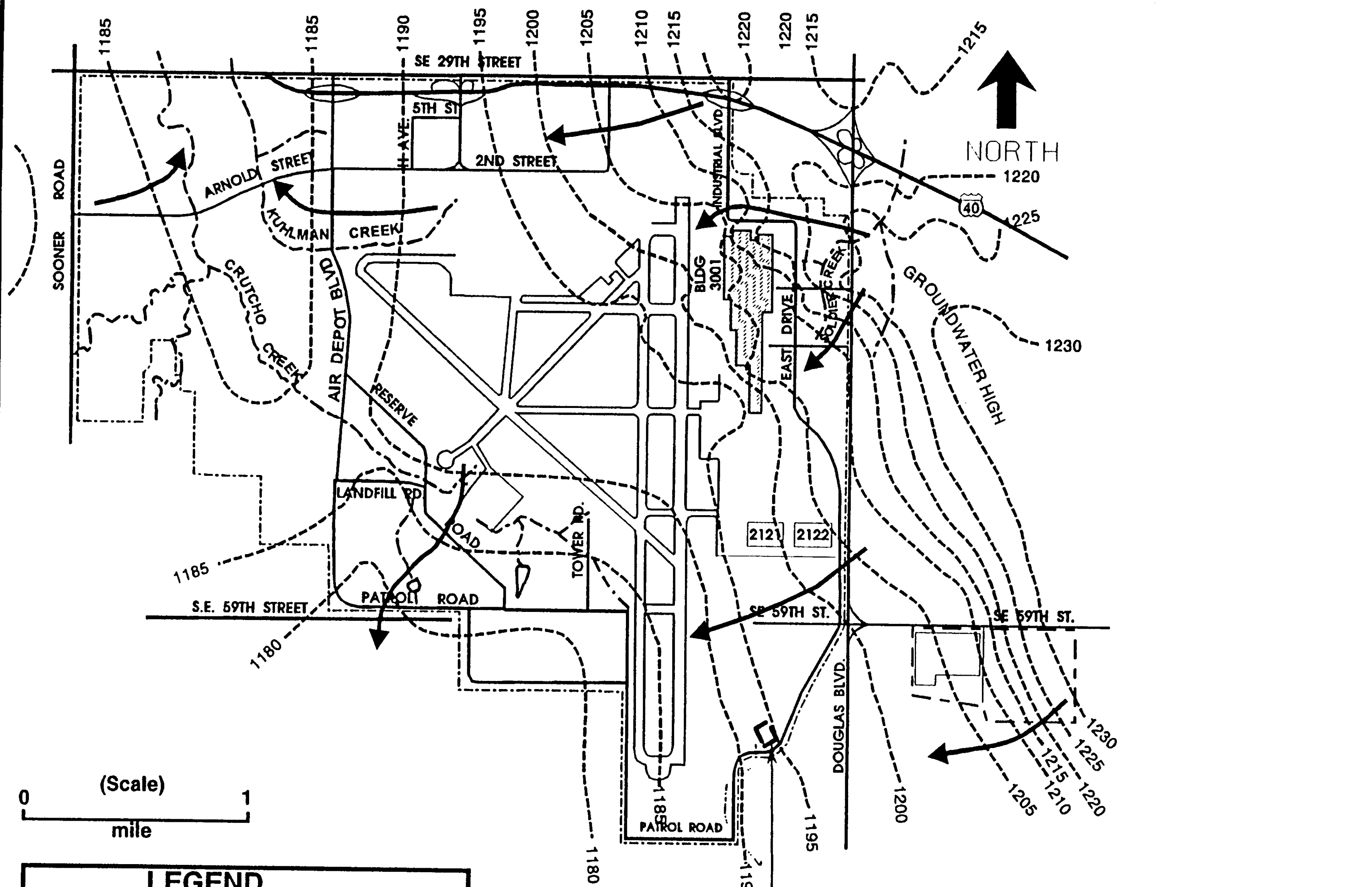


FIGURE 3-4
TINKER AIR FORCE BASE
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE
INDUSTRIAL WASTE
PIT NO. 2
(SWMU-13)
NORTH
Approximate erosional limit of lower confining shale
Approximate limit of saturated thickness - follows limit of confining shale on base
Groundwater High
LEGEND
Potentiometric Contours Elevation above MSL
Approximate Direction of Groundwater Flow
Contours are extrapolated across center of base due to lack of data
(Scale)
0
1
mile
DOUGLAS BLVD
AIR DEPOT BLVD
PATROL ROAD
TOWER RD.
SOONER ROAD
S.E. 59TH STREET
CRUTCHO CREEK
KUHLMAN CREEK
ARNOLD STREET
STARTING DATE: 23MAR94
DRAWN BY: C.E.TUMLIN
DATE LAST REV.:
DRAWN BY:
DRAFT. CHCK. BY:
ENGR. CHCK. BY:
INITIATOR: C.WALLACE
PROJ. MGR.: J.TAYLOR
DWG. NO.: 40983209C
PROJ. NO.: 409832



(Scale)
0 — 1 mile

LEGEND

- - - - - Potentiometric Surface Elevation above MSL

→ Approximate Direction of Groundwater Flow

Contours are extrapolated across center of base due to lack of data

INDUSTRIAL WASTE PIT 2 SWMU-13

FIGURE 3-5
TINKER AIR FORCE BASE
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C. WALLACE	DWG. NO.: 40983209C
DRAWN BY: C.E. TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J. TAYLOR	PROJ. NO.: 409832

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eastern one-third of Tinker AFB, where it is separated from the LSZ by an underlying confining shale layer and a vadose zone. The confining interval extends across the entire Base, but the vadose zone exists over the eastern one-third of this area. The available hydrogeologic data indicate that the vadose zone does not exist west of a north-south line located approximately 500 to 1,000 feet west of the main runway; consequently, the USZ is not perched west of this line. However, based on potentiometric head data from wells screened above and below the confining shale layer, the USZ remains a discrete aquifer zone distinct from the LSZ even over the western part of the Base. In areas where several shales interfinger to form the lower confining interval rather than a single shale bed, "gaps" may occur. In general, these "gaps" are not holes in the shale, but are places where multiple shales exist that are separated by slightly more permeable strata. Hydrologic data from monitoring wells indicate that these zones allow increased downward flow of groundwater above what normally leaks through the confining layer.

The LSZ is hydraulically interconnected and can be considered one aquifer zone down to approximately 200 feet. This area includes what was referred to by the USACE as the top of regional and regional zones. Hydrogeologic data from wells screened at different depths at the same location within this zone, however, provide evidence that locally a significant vertical (downward) component of groundwater flow exists in conjunction with lateral flow. The magnitude of the vertical component is highly variable over the Base. Preliminary evidence suggests that the LSZ is hydraulically discrete from the producing zone. Due to variations in topography, the top of the lower zone is found at depths ranging from 50 to 100 feet below ground surface under the eastern parts of the Base and as shallow as 30 feet to the west. Differences in potentiometric head values found at successive depths are due to a vertical (downward) component of groundwater flow in addition to lateral flow and the presence or absence of shale layers which locally confine the aquifer system. The LSZ extends east of the Base (east of Soldier Creek) beyond the limits of the USZ where it becomes the first groundwater zone encountered in off-Base wells. Because of the regional dip of bedding, groundwater gradient, and topography, the LSZ just east of the Base is generally encountered at depths less than 20 feet.

3.3.2 Site Hydrology

Groundwater at IWP2 was found to occur under three different conditions: in a shallow saturated interval extending from just below the land surface to the top of the unweathered shale (the Hennessey water bearing zone [HWBZ]); in a sandstone body isolated in a dominantly shale section directly below the waste site (also the HWBZ); and in the regional water table aquifer (USZ). The shallow saturated zone corresponds to the soil zone and contains water that exists sporadically across the IWP2 site. Figure 3-6 shows the potentiometric surface for the USZ at IWP2. Groundwater flow in the USZ at IWP2 site is in the southwest direction (Figure 3-5). Directly underneath the waste, the shallow groundwater in the Hennessey Formation was encountered at 16 feet below land surface. The USZ was encountered at about 63 feet below the surface, approximately 30 feet below the Fairmont Shale-Garber Sandstone contact.

3.4 Soils

Three major soil types have been mapped in the Tinker AFB area and are described in Table 3-2 (U.S. Department of Agriculture [USDA], 1969). The three soil types, the Darrell-Stephenville, Renfrow-Vernon-Bethany, and Dale-Canadian-Port, consist of sandy to fine sandy loam, silt loam, and clay loam, respectively. The Darrell-Stephenville and the Renfrow-Vernon-Bethany are primarily residual soils derived from the underlying shales of the Hennessey Group. The Dale-Canadian-Port association is predominantly a stream-deposited alluvial soil restricted to stream floodplains. The thickness of the soils ranges from 12 to 60 inches. IWP2 lies entirely within the Renfrow-Vernon-Bethany soil association.

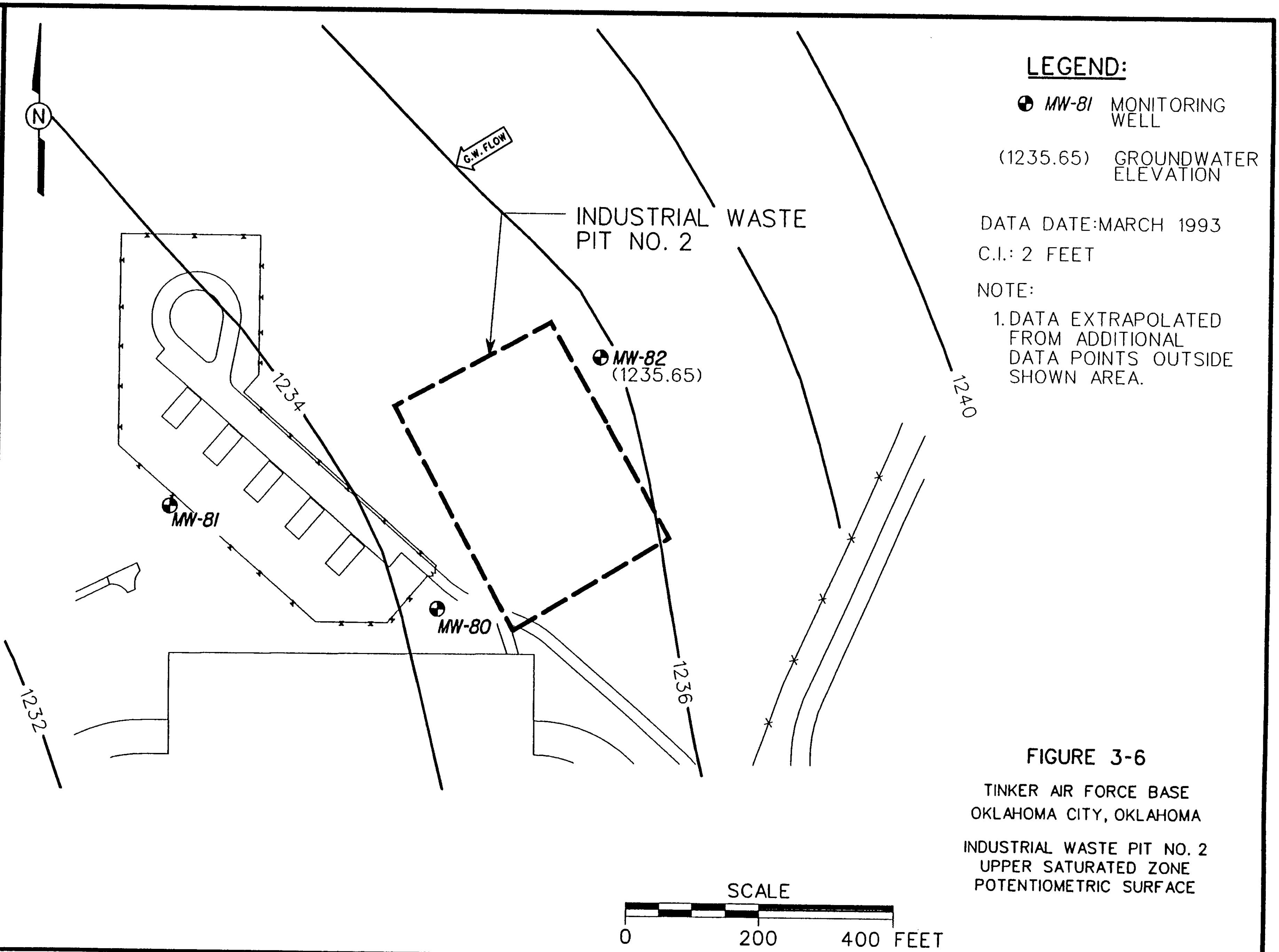

FIGURE 3-6

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

INDUSTRIAL WASTE PIT NO. 2
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 01/14/94	DATE LAST REV.: / /	DRAFT. CHCK. BY: G. PACHECO	INITIATOR: C. WALLACE	DWG. NO.:
DRAWN BY: P. TERRY	DRAWN BY:	ENGR. CHCK. BY: C. WALLACE	PROJ. MGR.: J. TAYLOR	PROJ. NO.:

09/22/94 POT
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Table 3-2

Tinker AFB Soil Associations (Source: USDA, 1969)

Association	Description	Thickness (in.)	Unified Classification[a]	Permeability (in./hr)
Darrell-Stephenville: loamy soils of wooded uplands	Sandy loam Sandy clay loam Soft sandstone (Garber Sandstone)	12-54	SM,ML,SC	2.0-6.30
Renfrow-Vernon-Bethany: loamy and clayey soils on prairie uplands	Silt loam - clay Clay loam Shale (Fairmont Shale)	12-60	ML,CL,MH,CH	<0.60-0.20
Dale-Canadian-Port: loamy soil on low benches near large streams	Fine sandy loam Silty clay loam Loam Clay loam	12-60	SM,ML,CL	0.05-6.30

[a]Unified classifications defined in U.S. Bureau of Reclamation, 5005-86.

4.0 Source Characterization

Prior to the establishment of the industrial waste water collection and treatment facility, the industrial wastes were disposed of in large, open pits. One of these pits was IWP2. This pit was used for the disposal of liquid wastes and sludges generated from 1958 to 1965. These waste streams originated from the various aircraft maintenance shops at Tinker AFB. During the Base records search (ES, 1982), no written information was found that revealed the type of waste actually disposed of in this pit. However, based on general knowledge of chemical processes and routine activities in a maintenance shop, and on interviews with Base personnel, the waste material in IWP2 most likely contained the following: high levels of heavy metals, large quantities of waste oils, contaminated fuels, chromates, phenols, cyanides, waste acids, and bases generated by plating and maintenance activities, including a variety of organic compounds such as solvents and degreasers (Radian, 1985a; USACE, 1992).

Similarly, no written information was found to indicate how the industrial waste pits were constructed. Reviewed documents (Radian, 1985a; USACE, 1992; USACE, 1993a,b) indicate that the waste pits were not lined. Consequently, it is likely that significant amounts of waste constituents have migrated through the soils beneath and around the waste pit because the majority of the waste was either sludge or liquids.

During the site investigations by Radian, an EM survey was conducted and soil cores through the waste material were taken to determine the physical nature of the waste and to estimate the extent or the boundaries of the waste pit. Visual observation of the soil cores showed the waste to be very shallow, with an average thickness of approximately 5 feet. The EM survey results provided data to estimate the areal extent of the buried waste. Evaluation of the EM data plots indicated the areal extent of the waste material to be approximately 38,000 ft^2. Based on this information, the volume of the waste material in IWP2 was estimated to be approximately 190,000 ft^3 (Radian, 1985a).

5.0 Contaminant Characterization

5.1 Soil Characterization

Background soil concentrations for trace metals were determined based on a study performed by the USGS (1991). The study area was confined to approximately four counties in central Oklahoma. Tinker AFB lies at the approximate center of this area. A total of 293 B-horizon soil samples were collected throughout this area. Soil samples were collected at the top of the B-horizon, which was usually 20 to 30 centimeters below the surface but ranged from 3 to 50 centimeters below the surface. For site-specific analytes for which the USGS offered no background value, the analyte was compared to an applicable action level. The background concentrations are presented in Table 5-1.

The use of B-horizon soil as selected by the USGS for metals background concentrations in soil is conservative in that the soil sampled does not reflect all possible anthropogenic influences. Most of the samples were obtained from hill crests and well drained areas in pasture and forested land, well away from roadways to minimize contamination from vehicular emissions (i.e., nearly "pristine" areas). Trace metal inputs to the study site soils on Base, however, will come from anthropogenic sources outside of the study area, in addition to those sources related to disposal activities or operations within the confines of the study site. Responsibility may thus be taken for more trace metal impacts than are actually attributable to a given site.

An additional level of conservatism was added in the manner in which the site-specific metals concentrations were compared to the background levels. Typically, the environmental concentrations of trace metals at study sites are represented by the arithmetic upper 95th confidence interval on the mean of a normal distribution. This upper 95th confidence interval value is then compared to the background values. The intent of this typical approach is to estimate a Reasonable Maximum Exposure (RME) case (i.e., well above the average case) that is still within the range of possible exposures.

To expedite this comparison and establish greater conservatism, the maximum concentration found at the site of concern, rather than the upper 95th confidence interval value, was compared to the USGS background values. If the environmental concentration of a particular analyte was below or within the minimum-maximum range of the USGS background concentrations, that analyte was considered to be naturally occurring and of no further concern to this investigation. Given the conservative approach of the comparisons, site-specific metals

Table 5-1

Background Concentrations of Trace Metals in Surface Soils[a] SWMU-13, IWP2, Tinker AFB

(Page 1 of 2)

Analyte	Lower Detection Limit	Background Concentration Range	
		Minimum Value	Maximum Value
Concentration in %			
Aluminum	0.005	0.38	8.9
Cadmium	0.005	0.01	9.4
Iron	0.005	0.18	5.8
Magnesium	0.005	0.02	5.3
Phosphorous	0.005	0.06	0.019
Potassium	0.05	0.1	2.4
Sodium	0.005	0.02	0.99
Titanium	0.005	0.04	0.42
Concentrations in ppm			
Arsenic	0.1	0.6	21
Barium	1	47	6400
Beryllium	1	<1	3
Bismuth	10	<DL[b]	<DL
Cadmium	2	<DL	<DL
Cerium	4	14	110
Chromium	1	5	110
Cobalt	1	<1	27
Copper	1	<1	59
Europium	2	---[c]	---
Gallium	4	<4	23
Gold	8	<DL	<DL
Holmium	4	<DL	<DL
Lanthanum	2	7	51
Lead	4	<4	27
Lithium	2	5	100

Table 5-1

(Page 2 of 2)

Analyte	Lower Detection Limit	Background Concentration Range	
		Minimum Value	Maximum Value
Manganese	10	24	3400
Molybdenum	2	<DL	<DL
Neodymium	4	6	47
Nickel	2	<2	61
Niobium	4	<4	16
Scandium	2	<2	15
Selenium	0.1	<0.1	1.2
Silver	2	<DL	<DL
Strontium	2	13	300
Tantalum	40	<DL	<DL
Thorium	1	<1.40	15.00
Tin	10	<DL	<DL
Uranium	0.1	0.650	6.400
Vanadium	2	5	220
Ytterbium	1	<1	3
Yttrium	2	3	43
Zinc	2	3	79

[a]All B-horizon soil samples (293) from USGS, 1991.
[b]All concentrations below the lower limits of determination.
[c]Insufficient or no data.

concentrations would have to significantly exceed the USGS background levels and be attributable to operations at the site before they would be considered a contaminant of concern.

The numerical comparison of site-specific metals concentrations to the USGS background concentrations is presented in the following section.

Radian Study. During the Radian Study (1985a), ten soil samples were selected for detailed chemical analysis. The analysis included selected metals (cadmium, cyanide, chromium, copper, mercury, nickel, lead and zinc) and organics (oil and grease, total organic carbon [TOC], total organic halogen [TOX], and phenols). The samples were retained for analysis based on field screening. The results are summarized in Table 5-2. Cadmium, chromium, copper, and lead were detected at concentrations above background. Chromium, copper, and lead were above background levels in only one sample out of ten samples. Oil and grease were detected at relatively higher concentration levels in all the samples. Complete results are contained in the Radian report (Radian, 1985a).

USACE Study. Sixteen soil samples were collected by the USACE (1993a) as part of a plan to relocate a drainage ditch near IWP2 due to the construction of the Transient Munitions Facility. The collected samples were tested for the presence of selected metals (arsenic, barium, cadmium, chromium, lead, mercury, nickel, selenium, silver, and zinc) and organic volatile compounds. The results are summarized in Table 5-3. The IWP2 area analytical results show no significant contamination above background levels.

5.2 Groundwater Characterization

Radian Study. During the Radian study (1985a), three groundwater monitoring wells were installed in order to determine the nature and extent of groundwater contamination around IWP2. Two wells were installed to monitor the shallow groundwater in the Hennessey at the site; one of the wells was placed within the waste pit and the other well was placed upgradient of the waste pit to monitor the shallow water extending underneath the waste material. The third well was placed downgradient of the waste pit to monitor the USZ. The groundwater encountered in the waste pit corresponds to the soil zone and contains water that exists sporadically across the site. The shallow groundwater was also encountered in 3F (MW-15) at a depth of 16 feet below the ground surface. No groundwater was encountered during the drilling of 3G (MW-16); however, after several hours, water collected into the well. Monitor-

Table 5-2

Analytical Results for Soil SWMU-13, IWP2, Tinker AFB

Parameter (µg/g, except as noted)	USGS Maximum Background	Soil Sample ID Number									
		3Aa[a]	3Aa (alt)	3Ab	3Bb	3Bd	3Be	3Ca	3Cb	3Fb	3Fc
Cadmium	ND[b]	3.2	2.0	0.49	0.25	0.20	<.15	23	1.2	0.25	<.02
Cyanide	NA[c]	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Chromium	110	8.9	6.2	4.5	3.8	2.9	4.0	750	5.7	15	4.0
Copper	59	7.1	4.1	11	5.6	5.6	5.7	130	13	5.1	2.3
Mercury	ND	4.0	4.5	4.1	3.5	3.4	4.0	3.5	3.5	3.8	3.8
Nickel	61	38	13	13	7.2	5.4	6.0	40	11	7.9	5.7
Oil & grease	NA	2,000	5,000	2,000	500	1,500	500	6,000	1,000	1,500	1,000
Lead	27	5.2	2.5	2.9	2.5	1.8	1.9	41	3.3	9.2	1.6
Phenol	NA	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Total organic carbon (%)	NA	0.11	0.32	0.02	0.02	0.02	0.04	0.52	0.03	0.19	0.02
Total organic halogen	NA	<1	12	<1	<1	<1	<1	14	<1	<1	<1
Zinc	79	9.2	3.0	12	5.9	5.0	8.2	36	7.6	16	5.7
Modified EPA Method 625 Analysis for Soil Sample 3Ca											
1,2-Dichlorobenzene	NA	44									
1,3-Dichlorobenzene	NA	1.5									
1,4-Dichlorobenzene	NA	6.6									
Di-n-butyl phthalate	NA	3.0									

[a]3Aa - "3A" is boring number/location, "a" is sample number.
[b]ND - Nondetect.
[c]NA - Not analyzed.

KN/1256/SWMU13/SWMU13.5-2/08-26-94/F1

Table 5-3

Chemical Analyses of Soil Samples
Transient Munitions Facility
SWMU-13, IWP2, Tinker AFB

Boring Number	Depth (ft)	Silver	Arsenic	Barium	Cadmium	Chromium	Mercury	Nickel	Lead	Selenium	Zinc	Methylene Chloride
		Constituents										
1048	0- 3	<0.5	<1.0	250	1.9	14	<0.1	13	8.0	<0.1	14	
1048	6-7.5	1.1	<1.0	260	0.64	8.2	<0.1	21	8.4	<0.1	19	
1049	0- 3	<0.5	<1.0	360	<0.5	16	<0.1	16	7.3	<0.1	14	
1049	3- 6	0.66	<1.0	270	<0.5	9.2	<0.1	21	8.2	<0.1	16	
1051	0- 3	1.2	13	530	0.92	14	<0.1	20	15	<0.1	17	
1051	6- 7	<0.5	<1.0	89	0.59	5.0	<0.1	7.1	6.5	<0.1	5.0	
1052	0- 3	0.81	8.4	720	1.0	12	<0.1	25	12	<0.1	20	
1052	3- 6	0.63	<1.0	64	0.63	10	<0.1	17	5.7	<0.1	14	
1053	0- 3	<0.5	<1.0	200	<0.5	23	<0.1	17	5.3	<0.1	17	
1053	3- 4	0.67	<1.0	75	0.67	7.0	<0.1	12	5.4	<0.1	11	
1050	0- 3	.72	.54	591	.48	32.3	<0.1	19.8	11.5	<0.1	18.1	.043
1050	3- 6	.83	.32	287	.62	7.8	<0.1	14.3	10.1	<0.1	11.2	.023
1054	0- 3	.42	.89	260	.64	32.9	<0.1	11.9	8.9	<0.1	9.4	.033
1054	3- 6	1.04	1.14	375	1.0	19.8	<0.1	21.0	8.3	<0.1	9.2	.052
1055	0- 3	1.0	<1	730	1.3	11.0	<0.1	15.0	14.6	<0.1	13.0	.240
1055	3- 6	.83	<1	320	.83	7.7	<0.1	12.0	9.9	<0.1	11.0	1.60
USGS Maximum Background		ND	21	6400	ND	110	ND	61	21	1.2	79	0.0

All results are reported in milligrams/kilogram (mg/kg) or parts per million (ppm).

Source: USACE, 1993a.

ing well 3E was completed at 80 feet below grade, and groundwater was observed during drilling at 63 feet below the surface. This groundwater represents the USZ. (Monitoring well 3E was later plugged during construction of the Transient Munitions Facility.) During the Radian study, groundwater was only assumed to be flowing in the southwest direction. No groundwater contour map was developed.

During this study, three groundwater samples were collected (one sample from each well) and analyzed for selected constituents (metals: cadmium, cyanide, chromium, copper, mercury, nickel, lead and zinc; and organics: oil and grease, TOC, TOX, total phenol, and acid/neutral extractable organic priority pollutants). The water sample collected from the well within the waste pit showed significant contamination of metals and organics. The constituents detected in fairly high concentrations include: cadmium, chromium, nickel, lead, zinc, oil and grease, 1,2-dichlorobenzene, and phenol (Table 5-4). The water samples from the other two wells did not show any significant contamination. Complete results are contained in the Radian report (1985a).

USACE Study. In March 1989, three additional monitoring wells (MW-80, MW-81, MW-82) were installed to monitor groundwater at IWP2. The existing two wells and the three newly installed wells were sampled quarterly for 1 year by USACE to determine the nature and extent of contamination around IWP2. Two of the wells (MW-15 and MW-16) monitor the shallow Hennessey groundwater within the waste pit boundaries and directly beneath the waste pit. The remaining three wells (MW-80, MW-81, and MW-82) were installed to monitor the USZ upgradient and downgradient of the waste pit. These five monitoring wells were sampled quarterly from June 1989 until April 1990.

The collected water samples were analyzed for general chemistry, metals, and organic constituents. The samples collected from monitoring well MW-16 exhibited significant contamination of both metallic and organic constituents. Cadmium, chromium, lead, nickel, zinc, and manganese were detected at relatively higher concentrations (Table 5-5). Trichloroethene (TCE), chlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichlorobenzene, and 2-methylphenol, vinyl chloride, 1,2-dichloroethane, trans- 1,2-dichloroethene, 4-methylphenol, 2,4-dimethylphenol, and bis(ethylhexyl)phthalate were among the detected organic compounds in relatively high concentrations (Table 5-5). This monitoring well (MW-16) is located within the waste pit boundary. Consequently, it shows more contamination than the other monitoring well (MW-15), which monitors the shallow Hennessey groundwater

Table 5-4

Analytical Results for Groundwater
SWMU-13, IWP2, Tinker AFB

Parameter (mg/L, except as noted)	Well 3E[a]	Well MW-15	Well MW-16
Cadmium	<.002	<.002	2.2
Cyanide	<.01	<.01	<.01
Chromium	<.001	<.001	12
Copper	<.001	<.001	0.15
Mercury	0.0004	0.0006	<.0005
Nickel	<.003	<.003	82
Oil & grease	<0.10	<0.10	70
Lead	<.002	<.002	3.3
Phenol	<.005	<.005	80[b]
Total organic carbon	<1	3	4000
Total organic halogen	<.01	<.01	3.4
Zinc	0.016	0.024	29
Acid/Neutral Extractable Organic Priority Pollutants (Modified EPA Method 625)			
1,2-Dichlorobenzene	ND	ND	20
Phenol	ND	ND	220

[a]Well 3E was plugged during the construction of the Transient Munitions Facility.
[b]Probable low bias due to interferences with colorimetric procedure, large dilution required for analysis.

Source: Radian, 1985a

Table 5-5

Summary of Analytical Results for Groundwater
Hennessey Water Bearing Zone
SWMU-13, IWP2, Tinker AFB

	MW-15 6/1989	MW-15 9/1989	MW-15 1/1990	MW-15 4/1990	MW-15 11/1992	MW-15 12/1993	MW-16 9/1989	MW-16 1/1990
General Chemistry (mg/L)								
Chloride	44	44	80	50	NA	NA	210	190
Conductivity (µMhos/cm)	514	590	803	1,080	NA	NA	1,330	2,830
Cyanide	<0.2	<0.2	<0.2	NA	NA	NA	<0.2	<0.2
Nitrate, dissolved	0.25	0.53	NA	NA	NA	NA	<0.2	NA
pH (standard unit)	7.6	7.6	7.5	7.8	NA	NA	7.8	7.8
Sulfate	82.4	18	23	45.1	NA	NA	5.7	67
Total organic carbon	3.7	0.48	0.94	0.78	1.9	NA	3.23	17.7
Metals (µg/L)								
Arsenic	7.5	1.6	2.5	2.9	2.6	13.5	3.2	<1
Barium	340	200	160	125	50.4	397	640	230
Cadmium	<5	<5	<5	<5	<5	<5	150	150
Chromium	7	12	8	<10	<7	90.4	740	590
Lead	56	48	50	27.5	<42	32.4	1020	790
Magnesium	35,000	28,000	25,000	33,000	NA	NA	36,000	52,000
Manganese	960	1200	690	592	NA	NA	1400	730
Nickel	12	14	10	16.2	<15	89.9	1800	2400
Selenium	<0.4	0.8	1.1	2.1	<10	<30	<0.4	0.6
Sodium	85,000	NA	40,000	100,000	NA	NA	NA	33,000
Zinc	150	97	50	31.2	NA	NA	19200	7700
Organics (µg/L)								
Vinyl chloride	NA	<2	<2	<2	<0.5	<10	1J	7J
Methylene chloride	NA	<1	<1	1B	<0.6	<5	2BJ	0.6J
Chloroform	NA	<1	<1	0.1J	<0.5	<5	2BJ	<1
1,2-Dichloroethane	NA	<1	<1	<1	<0.5	<5	<5	10
Trans-1,2-dichloroethene	NA	<1	<1	<1	<0.5	<5	4J	35
Trichloroethene	NA	<1	2	2.0	2.0	<5	<5	43
Benzoic acid	NA	<50	<50	<50	NA	NA	3J	<50
Chlorobenzene	NA	<1	<1	<1	<0.5	<5	200	9
1,3-Dichlorobenzene	NA	<10	<10	<10	<10	<5	110	10
1,4-Dichlorobenzene	NA	<10	<10	<10	<10	<5	370E	5J

Table 5-5

(Page 2 of 2)

	MW-15 6/1989	MW-15 9/1989	MW-15 1/1990	MW-15 4/1990	MW-15 11/1992	MW-15 12/1993	MW-16 9/1989	MW-16 1/1990
1,2-Dichlorobenzene	NA	<10	<10	<10	<10	<5	300E	<10
2-Chlorophenol	NA	<10	<10	<10	<10	<10	17	<10
2-Methylphenol	NA	<10	<10	<10	NA	<10	82	11
4-Methylphenol	NA	<10	<10	<10	NA	<10	72	4J
Phenanthrene	NA	<10	<10	<10	<10	<10	0.4J	<10
Naphthalene	NA	<10	<10	<10	3B	<10	4J	<10
2-Methylnapthalene	NA	<10	<10	<10	NA	<10	3J	<10
2,4-Dimethylphenol	NA	<10	<10	<10	<10	<10	72	12
Bis(2-ethylhexyl)phthalate	NA	3BJ	7J	<10	<10	9J	2BJ	<10
Di-n-butyl phthalate	NA	<10	<10	<10	<10	<10	0.5BJ	<10
Di-n-octyl phthalate	NA	3J	<10	<10	<10	3J	1J	<10
Tetrachloroethene	NA	<1	<1	<1	<0.5	<5	<5	0.5J
1,2,4-Trichlorobenzene	NA	<10	<10	<10	<10	<5	<10	0.8J

NA - Not Analyzed.
B - Analyte was also found in sample blank.
E - Concentration exceeds instrument calibration range for that specific analysis.
J - Concentration is an estimated value.

extending underneath the waste pit. Complete results are included in the RI draft final report for IWP2 (USACE, 1993a).

The USZ is monitored by monitoring wells MW-80, MW-81, and MW-82. Groundwater samples collected from these wells does not show any significant contamination (Table 5-6), except for the presence of acetone, 2-butanone, dimethyl phthalate, TCE, and bis(2-ethylhexyl)phthalate, which were detected in relatively significant concentrations.

Table 5-6

**Summary of Analytical Results for Groundwater
Upper Saturated Zone
SWMU-13, IWP2, Tinker AFB**

(Page 1 of 2)

	MW-80 6/1989	MW-80 9/1989	MW-80 1/1990	MW-80 4/1990	MW-80 11/1992	MW-80 12/1993	MW-81 6/1989	MW-81 9/1989	MW-81 1/1990	MW-81 4/1990	MW-81 11/1992	MW-81 12/1993	MW-82 6/1989	MW-82 9/1989	MW-82 1/1990	MW-82 4/1990	MW-82 7/1992	MW-82 11/1992	MW-82 12/1993
General Chemistry (mg/L)																			
Chloride	13	16	30	21	NA	NA	20	24	10	23	NA	NA	35	40	20	34	NA	NA	NA
Conductivity (µmhos/cm)	389	420	566	722	NA	NA	347	380	519	641	NA	NA	527	550	735	941	NA	NA	NA
Cyanide	<0.2	<0.2	<0.2	NA	NA	NA	<0.2	<0.2	<0.2	NA	NA	NA	<0.2	<0.2	<0.2	NA	NA	NA	NA
Nitrate, dissolved	0.97	1	NA	NA	NA	NA	1.14	1.2	NA	NA	NA	NA	1.28	1.5	NA	NA	NA	NA	NA
pH (standard units)	7.3	7.5	7.6	7.5	NA	NA	7.3	7.5	7.7	7.5	NA	NA	7.3	7.4	7.4	7.5	NA	NA	NA
Sulfate	15.8	18	23	40.3	NA	NA	14	27	12	38.9	NA	NA	27.6	25	28	44.7	NA	NA	NA
Total organic carbon	4.97	1.1	2.26	<0.5	NA	NA	3.92	0.45	1.38	<0.5	NA	NA	3.98	0.70	1.53	<0.5	NA	NA	NA
Metals (µg/L)																			
Arsenic	3.9	<1	<1	2.5	3.1	12.5	4.9	1.5	3.4	3.8	5.5	7.2	4.9	1.5	3.1	3.1	NA	3.4	11.7
Barium	300	200	160	242	109	388	580	390	210	287	212	348	350	320	300	219	NA	180	355
Chromium	<5	<5	<5	<10	<7	42.4	<5	<5	<5	<10	<7	<20	7.5	<5	5	<10	NA	<7	23.6
Lead	<10	<10	<10	<20	<42	20.6	<10	<10	<10	<20	<42	<3	17	<10	<10	<20	NA	<42	10
Magnesium	34,000	27,000	27,000	30,000	NA	NA	16,000	25,000	23,000	26,400	NA	NA	36,000	34,000	35,000	35,900	NA	NA	NA
Manganese	190	64	90	110	NA	NA	240	120	27	69.2	NA	NA	710	340	220	106	NA	NA	NA
Nickel	<5	37	10	<15	<15	48.5	<5	22	14	<15	<15	<40	6.8	9.8	6.5	<15	NA	<15	<40
Selenium	<0.4	<0.4	0.7	<1	2.0	<30	<0.4	<0.4	0.6	<1	<2	<3	0.4	2.7	0.5	<1	NA	<2	<15
Sodium	16	NA	15	14.3	NA	NA	16	NA	14	13.9	NA	NA	41	NA	37	35.4	NA	NA	NA
Zinc	<5	72	14	18.5	NA	NA	10	42	30	<10	NA	NA	67	24	30	<10	NA	NA	NA

KN/1256/SWMU13/SWMU13.5-6/09-08-94/F21

Table 5-6

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	MW-80 6/1989	MW-80 9/1989	MW-80 1/1990	MW-80 4/1990	MW-80 11/1992	MW-80 12/1993	MW-81 6/1989	MW-81 9/1989	MW-81 1/1990	MW-81 4/1990	MW-81 11/1992	MW-81 12/1993	MW-82 6/1989	MW-82 9/1989	MW-82 1/1990	MW-82 4/1990	MW-82 7/1992	MW-82 11/1992	MW-82 12/1993
Organics (µg/L)																			
1,2,4-Trimethylbenzene	NA	NA	NA	NA	<0.5	<5	NA	NA	NA	NA	<0.5	<5	NA	NA	NA	NA	2.0	<0.5	<5
1,3,5-Trimethylbenzene	NA	NA	NA	NA	<0.5	<5	NA	NA	NA	NA	<0.5	<5	NA	NA	NA	NA	<1.0	<0.5	<5
2-Butanone	<2	<2	<2	<2	NA	<10	<2	<2	17	<2	NA	<10	<2	<2	<2	<2	NA	NA	<10
Acenaphthalene	<10	<10	<10	<10	<12	<10	<10	<10	<10	<10	<10	<10	<10	<10	1J	<10	NA	<11	<10
Acetone	<2	<2	10	<2	NA	<10	<2	<2	<2	<2	NA	<10	<2	<1	<2	<2	NA	NA	<10
Bis(2-ethylhexyl)phthalate	<10	9BJ	<10	16	<12	<10	<10	2BJ	<10	17	<10	<10	<10	2BJ	<10	3J	NA	<11	<10
Chlorobenzene	<1	<1	<1	<1	0.8	<5	<1	<1	<1	<1	<0.5	<5	<1	<1	<1	<1	<0.5	<0.5	<5
Di-n-octyl phthalate	<10	2J	<10	<10	<12	<10	<10	1J	<10	<10	<10	<10	<10	0.8J	<10	<10	NA	<11	<10
Dimethyl phthalate	1J	4J	3J	<10	4J	<10	2J	<10	8J	<10	13	<10	3J	3J	<10	<10	NA	27	<10
Methylene chloride	<1	<1	1	2B	0.8B	<5	<1	<1	0.5J	<1	0.7B	<5	0.4J	0.7J	<1	<1	NA	1B	<5
Naphthalene	<10	<10	<10	<10	2.0B	<10	<10	<10	<10	<10	2B	<10	<10	<10	<10	<10	<0.5	2B	<10
p-Chloro-m-cresol	<10	<10	<10	<10	NA	NA	<10	<10	<10	<10	NA	NA	<10	<10	2J	<10	NA	NA	NA
Pyrene	<10	<10	<10	<10	<12.0	<10	<10	<10	<10	<10	<10	<10	<10	<10	2J	<10	NA	<11	<10
Tetrachlorethene	<1	<1	<1	<1	0.6	<5	<1	<1	<1	<1	<0.5	<5	<1	<1	<1	<1	<0.5	<0.5	<5
Toluene	<1	<1	<1	<1	<0.5	<5	<1	<1	<1	<1	<0.5	<5	<1	<1	<1	<1	1.0	0.6	<5
Trichloroethene	<1	<1	0.8J	<1	21.0	<5	<1	<1	0.3J	<1	17	<5	<1	<1	<1	<1	8.0	2	<5
Xylenes total	<1	<1	<1	<1	<0.5	<5	<1	<1	<1	<1	<0.5	<5	<1	<1	<1	<1	1.2	<0.5	<5

NA - Not analyzed.
B - Analyte was also found in sample blank.
J - Concentration is an estimated value.

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6.0 Baseline Risk Assessment/Potential Receptors

A human health risk assessment and ecological assessment (USACE, 1993b) has been performed for IWP2. These assessments, which include evaluations of human and ecological receptors, are summarized in Sections 6.1 and 6.2, respectively.

6.1 Human Health Risk Assessment

IWP2 is an unlined excavated pit used from 1958 through 1965 for the disposal of industrial wastes, after which it was covered with a layer of relatively uncontaminated soil. The soil currently supports a mixture of cool- and warm-season grasses and some small trees. The industrial wastes include lubricating oils, solvents, acidic and alkaline compounds, and materials containing cyanide, chromates, and phenols. Based on the Radian study (Radian, 1985a) the total quantity of the waste material was estimated to be approximately 190,000 cubic feet of nonhomogeneous wastes covered by a layer of soils that are slightly contaminated with organic and inorganic chemicals from the waste.

Contamination appears to have migrated to the soil and groundwater below the waste. The chemicals of concern for groundwater are 1,2-dichloroethane, 1,4-dichlorobenzene, 4-methylphenol, bis(2-ethylhexyl)phthalate, cadmium, chlorobenzene, TCE, and vinyl chloride. Some of the contaminants have entered the USZ of groundwater beneath and near the site, and one organic compound has reached the top of the deep regional aquifer. There is evidence of intermittent discharge of water from the pit to an adjacent creek, but the presence of contaminants in the surface water or sediment has not yet been confirmed, and the creek is not considered within the boundary of the site.

Inhalation of particulates from resuspended dust by Tinker AFB workers adjacent to the site was judged to be the only complete exposure pathway. Other potential receptors were considered and rejected because military housing on the Base is limited and is not in the vicinity of IWP2, access to the Base is limited, and the use of the Base is not expected to change in the foreseeable future. In addition, USZ is not used as a source of drinking water. Although it is conceivable that vertical flow could result in contamination of the deep regional aquifer, geophysical investigations have found no evidence of this. Most Tinker AFB water supply wells are located upgradient of the site and draw from depths of 250 to 700 feet, reducing the likelihood that IWP2 contaminants could impact the water supply.

EPA-approved screening techniques were used to limit the chemicals of concern in surface soil to arsenic, barium, and chromium. The total cancer risk was estimated at 4.0×10^{-7}, below the EPA target range of 10^{-6} to 10^{-4}. The total hazard index for noncancer risk was 7.0×10^{-3}, below the value (one) at which concern for adverse effects increase.

6.2 Ecological Risks/Receptors

Ecological receptors identified to exist in the site or its vicinity include earthworms, small mammals, predatory birds, and bermuda grass. Earthworms are exposed by ingestion of contaminated soils and subsequently consumed by the higher trophic level consumer organisms. Bermuda grass is exposed through its root system and is subsequently consumed by herbivores. Consumer organism potentially exposed to chemicals of concern through the food chain are the gopher and the shrew. The gopher consumes grass and the shrew consumes earthworms and insects. The owl, a predator of each consumer organism, was selected as a receptor to represent a higher trophic level (USACE, 1993b).

However, no compounds at the IWP2 site are expected to cause ecological risks through the surface soil exposure pathway evaluated. Vegetation is expected to be relatively unaffected because the one compound (barium) that exceeds the exposure/benchmark (E/B) ratio of 1 for vegetation is not readily taken up by plants. Compounds that might be expected to cause a risk to earthworms (nickel and zinc) did not present any risk beyond that contributed by background nickel and zinc concentrations. Chromium and nickel presented little or no incremental risk to small mammals. Arsenic, which had E/B ratios above 1, is not expected to acutely or chronically affect small mammals at the site. Predatory birds were shown to be at no risk from any of the chemicals present at the site. Mammals and birds would be deterred from inhabiting or hunting in the area by the close proximity of the runway to the IWP2 site.

7.0 Action Levels

An "action level" is defined by EPA in proposed rule 40 CFR 264.521 (55 FR 30798; 7/27/90), "Corrective Action for Solid Waste Management Units (SWMU) at Hazardous Waste Management Facilities," as a health- and environment-based level, determined by EPA to be an indicator for protection of human health and the environment. In the preamble to this proposed rule, the focus of the RFI phase is defined as "characterizing the actual environmental problems at the facilities." As part of this characterization, a comparison of the contaminant concentrations to certain action levels should be made to determine if a significant release of hazardous constituents has occurred. This comparison is then used to determine if further action or corrective measures are required for a SWMU or an AOC. The preamble to the proposed rule states that the concept of action levels was introduced because of the need for "a trigger that will indicate the need for a Corrective Measures Study (CMS) and below which a CMS would not ordinarily be required" (55 FR 30798; 7/27/90). If constituent concentrations exceed certain action levels at a SWMU or an AOC, further action or a CMS may be warranted; if constituent concentrations are below action levels, a finding of no further action may be warranted. This chapter of the report presents the initial analytical data as compared to certain potential action levels.

Action levels are concentrations of contaminants at or below which exposure to humans or the environment should not produce acute or chronic effects.

The action level information is presented in this chapter so that identified constituents at the site can be compared with their respective potential action levels. Only those action levels relevant to IWP2 site are shown in Table 7-1 along with site specific data. These action levels are for soil and water as published in federal or state regulations, policies, guidance documents, or proposed rules. A brief description and source of the published action levels in general is provided in the following paragraphs.

- ***SWMU Corrective Action Levels (CAL) -*** These action levels are taken from the proposed rule (40 CFR 264.521) and provided as Appendix A to the rule as "Examples of Concentrations Meeting Criteria for Action Levels." These levels are health-risk based and are provided as specific examples of levels below which corrective action would not be required.

- ***Maximum Contaminant Levels (MCL) -*** These values are provided from 40 CFR Subpart G, Sections 141.60 through 0.63 as promulgated under the Safe Drinking Water Act. These levels are designated for water media only.

Table 7-1

Comparison of Action Levels Versus Soil and Groundwater Data
SWMU-13, IWP2, Tinker AFB

Analyte	Reported[a] Concentration Range (Soil - mg/kg)	CAL[b] (mg/kg)	Average Background[c]	Reported Concentration Range (Groundwater - mg/L)	CAL (mg/L)	MCL[d] (mg/L)
Barium	64 - 730	4000	218	0.05 - 0.6	None	2.0
Cadmium	0.20 - 23	40	0.72	0.15 - 2.2	None	0.005
Chromium	2.9 - 750	None	23	0.005 - 12	None	0.1
Mercury	0.1 - 4.5	20	<0.1	0.0004 - 0.0006	None	0.002
Nickel	5.4 - 40	2000	21	0.00065 - 82	0.7	0.1
Lead	1.6 - 41	None	15	0.017 - 3.3	None	0.015
Zinc	3 - 36	None	25	0.010 - 29	None	None
1,2-Dichlorobenzene	44[e]	None	0	0.3 - 20	None	0.6
1,4-Dichlorobenzene	6.6[e]	None	0[f]	0.005 - 0.370	None	0.075
1,2-Dichloroethane	NA[g]	8	0	0.010[e]	None	0.005
Bis(2-ethylhexyl)phthalate	NA	50	0	0.002 - 0.017	0.003	0.006
Chlorobenzene	NA	2000	0	0.0008 - 0.20	0.7	0.1
Methylene Chloride	NA	90	0	0.0004-0.002	0.005	0.005
Tetrachloroethene	NA	10	0	0.0005 - 0.0006	0.0007	0.005
Phenol	ND	5000	0	220[e]	20	None
Trichloroethene	NA	60	0	0.0003 - 0.043	None	0.005
Trans 1,2-Dichloroethene	NA	8	0	0.004 - 0.035	None	0.1
Vinyl Chloride	NA	None	0	0.001 - 0.007	None	0.002

[a]Reported range does not include nondetects.
[b]CAL - Corrective Action level
[c]USGS - United States Geologic Service background concentrations
[d]MCL - Maximum Contaminant Level
[e]Single detect
[f]Background assumed to be 0
[g]NA - Not Analyzed

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- ***USGS Background -*** These values are provided from the USGS report titled "Elemental Composition of Surficial Materials from Central Oklahoma" (USGS, 1991). These values represent the levels of metals which naturally occur in Central Oklahoma soils.

- ***Background -*** These levels are provided where background could be determined. Where available, background concentrations are listed for metals in soil samples taken on site, which were thought to be unaffected by releases from a unit.

- ***National Ambient Air Quality Standards (NAAQS) -*** These standards are published in 40 CFR Part 50 under the Clean Air Act and apply to point sources that emit a limited number of constituents to the air. The constituents regulated are nitrogen dioxide, sulphur dioxide, carbon monoxide, lead, ozone, and particulate matter. Currently, it is assumed that none of the SWMUs or AOCs emit these compounds in regulated quantities and no air samples have been taken which would allow for a valid comparison.

- ***Water Quality Standards (WQS) -*** The WQS are the standards for surface water quality as established by the State of Oklahoma. These standards apply to point source discharges to surface waters and have been listed for those units adjacent to surface water.

The listing of the action levels along with site specific data (Table 7-1) allows a comparative evaluation of the data to be made. The data for each detected compound are compared with the appropriate action level in order to identify those constituents (compounds) with concentrations exceeding the action levels. The identification of the compounds above the action levels provides an indication of a potential environmental problem at a specific site. In addition, this information indicates whether there is a need for conducting a CMS so that a corrective action can be implemented/undertaken at the site.

For constituents that have a SWMU CAL and an MCL for water, the MCL will be used for the comparison. Also, constituents that do not have a USGS background value will be compared to the site background value if available.

Evaluation of the soils data (Table 7-1) shows none of the detected compounds exhibit concentrations above the action levels. However, some of the detected constituents (cadmium, chromium, mercury, and lead) show concentrations that exceed the background concentrations.

Of the metallic constituents detected in groundwater, cadmium, chromium, nickel, and lead exceed the action levels for groundwater. Above MCL concentrations for each of these metals were detected in monitoring well MW-16. This is a shallow well located within the waste pit, consequently all the constituents with concentrations above the MCLs were detected in this well. Lead was also occasionally detected at concentrations exceeding the MCL in monitoring wells MW-15, MW-80, and MW-82 (Tables 5-3, 5-4, 5-5, and 7-1).

Several organic compounds (1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichloroethane, trichloroethene, and phenol) were detected at concentrations above the MCLs. 1,2-Dichlorobenzene, 1,4-dichlorobenzene, and 1,2-dichloroethane were only detected once in MW-16 at levels above the MCLs. Phenol was also detected once in MW-16 at levels above the SWMU-CAL. Trichloroethene was detected at concentrations above MCL only once in monitoring wells MW-16, MW-80, MW-81, and MW-82 (Tables 5-3, 5-4, 5-5, and 7-1). The concentrations of these constituents in the shallow groundwater indicate a potential groundwater problem at this site.

8.0 Summary and Conclusions

8.1 Summary

IWP2 was in operation from 1958 to 1965 and was constructed without a liner. During its operational period, the pit received unspecified industrial waste streams originating from various aircraft plating and maintenance facilities on Tinker AFB. The waste pit is believed to contain large quantities of waste oils, waste paint strippers, contaminated jet fuels, chromates, phenols, cyanides, waste acids, and bases. The petroleum-based wastes were periodically burned to reduce the volume of the waste material in the pit. The pit was filled in 1965, covered, and the surface graded, leaving no visible surface features to indicate its location (Radian, 1985a).

The investigations conducted at IWP2 by Radian and the USACE were designed to determine the nature and extent of contamination, to define the boundaries of the waste pit, and to reasonably estimate the volume of the waste in the pit. Both investigations have partially achieved these objectives. Data collected under the Radian study is not fully evaluated in order to determine the extent of contamination. Soil data collected under both studies is not fully addressed as the groundwater data. In addition, the nature and extent of contamination of the USZ is not well defined.

Radian Study. The geophysical survey results revealed a magnetic anomaly which was interpreted to be an area underlain by significant quantities of waste. The total area depicting this anomaly was estimated to be approximately 38,000 ft^2. The soil coring results indicated the waste body to be very shallow, with an average depth of 5 feet. Therefore, the total quantity of material estimated to be present in the waste pit is approximately 190,000 ft^3.

The analytical results for soils show the waste material contains relatively high concentrations of heavy metals and organics, reflecting the origin of the waste itself. Cadmium, chromium, nickel, lead, oil and grease, and zinc were detected in relatively high concentrations.

Among the three groundwater samples from three monitoring wells (one well was subsequently destroyed) collected and analyzed by Radian, only one sample showed significant concentrations. This sample was collected from the monitoring well installed within the waste pit boundaries (MW-3G or MW-16). Detected constituents from this sample included: cadmium, chromium, nickel, lead, zinc, oil and grease, 1,2-dichlorobenzene, and phenol. The majority of the detected constituents are similar to those detected in soil samples collected from the waste pit material, indicating that the contaminants in the soil have leached into the shallow groundwater in the Hennessey.

USACE Study. In March 1989, three additional monitoring wells were installed to monitor the groundwater in the vicinity of IWP2. One well was installed upgradient and the other two were installed downgradient of the waste pit area. The two existing wells installed by Radian and the three newly installed wells were monitored quarterly for 1 year. Contaminated groundwater was present mainly in samples from monitoring well MW-16, which was completed within the waste pit boundaries. Groundwater samples exhibited the presence of metals (cadmium, chromium, lead, nickel, zinc, and manganese) and organics (trichloroethene, chlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichlorobenzene, 2-methyl-phenol, vinyl chloride, 1,2-dichloroethane, trans-1,2-dichloroethene, 4-methylphenol, 2,4-dimethylphenol, and bis[ethylhexyl]phthalate) at significantly high concentrations. The results of the groundwater samples from the remaining four monitoring wells did not show any significant contamination except for the presence of acetone, 2-butanone, dimethyl phthalate, trichloroethene, and bis(2-ethylhexyl)phthalate.

Baseline Risk Assessment. The baseline risk assessment indicates that IWP2 poses no threat to human life and the environment (USACE, 1993b). Different pathways were evaluated in order to identify the potential receptors likely to be exposed to contaminants of IWP2. The primary potential exposure point for workers near the site was identified to be the Transient Munitions Facility, located approximately 320 feet west of the IWP2 site. Therefore, the potentially exposed population identified in the baseline risk assessment were the industrial workers associated with the Transient Munitions Facility. The total carcinogenic risk to this population with the greatest exposure potential was 4×10^{-7}, well within the range of acceptable risks for Superfund sites of 1×10^{-4} to 1×10^{-6}. The hazard from noncarcinogenic effects was exhibited by a hazard index of 0.007, which is below the minimum hazard index of 1 (USACE, 1993b).

Ecological receptors identified in the site or its vicinity include the earthworms and bermuda grass. Earthworms are exposed by ingestion of contaminated soils and are subsequently consumed by higher trophic level consumer organisms. Bermuda grass is exposed through its root system and is subsequently consumed by herbivores. Consumer organism potentially exposed to chemicals of concern through the food chain are the gopher and the shrew. The gopher consumes grass and the shrew consumes earthworms and insects. The owl, a predator of each consumer organism, was selected as a receptor to represent a higher trophic level (USACE, 1993b).

However, no compounds at the IWP2 site are expected to cause ecological risks through the surface soil exposure pathway evaluated. Vegetation is expected to be relatively unaffected because barium, which exceeds the E/B ratio of 1 for vegetation, is not readily taken up by plants. Nickel and zinc are not expected to cause a risk to earthworms beyond the risk posed by background levels. Similarly, chromium and nickel pose little or no risk to small mammals. Predatory birds were shown to be at no risk from any of the chemicals present at the site. Mammals and birds would be deferred from inhabiting on hunting in the area by the close proximity of the runway to the site.

8.2 Conclusions

Investigations conducted at IWP2 have concluded that the site appears to pose no threat to human health or the environment, as long as the landfill cover is maintained and current land use does not change (Radian, 1985a; USACE, 1993b). Reviewed documents (Radian, 1985a; USACE, 1992; USACE, 1993a, b) indicate that contaminants from the waste material are not currently migrating away from the site. In addition, the presence of an impermeable shale bedrock provides natural containment and limits the potential migration of contaminants. The site has been covered with clean fill material, graded, and vegetated to control surface water runoff and infiltration into the waste material. The groundwater surrounding the site shows no significant contamination.

The Radian study concluded that the contaminants from the waste material are not currently migrating away from the site. In addition, the Radian report states that as long as the waste pit cover is not disturbed or the surface drainage is not disrupted, it is unlikely that significant contaminant migration will occur. Therefore, Radian recommended that no additional work was necessary for this area (Radian, 1985a).

The USACE study groundwater results were similar to the Radian study. Based on available data, the report concluded that IWP2 exhibits significant contamination that has migrated from the site into the shallow Hennessey groundwater and to some extent to the top of the USZ. Therefore, the USACE study recommended further monitoring of both the shallow groundwater and the top of the USZ (USACE, 1993a).

Based on the evaluations in Section 7.0, the soils appear to pose no environmental problem. However, the concentrations of certain heavy metals (cadmium, chromium, lead, and nickel) and organics (1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichloroethane, phenol, and TCE) (Table 7-1) in the shallow Hennessey groundwater (as indicated by data from MW-16), indicates a potential groundwater problem at this site. The concentration levels of these parameters exceed their respective MCLs. TCE was detected above the MCL only once in the wells (MW-80 and MW-82) monitoring the USZ. This one-time occurrence is questionable. Additional groundwater monitoring is needed to support this conclusion.

These conclusions have been based on insufficient data and are subject to change as more data become available. Recommendations for additional data are discussed in Chapter 9.0.

9.0 Recommendations

This RFI Summary Report has been prepared to determine and document whether sufficient investigations at IWP2 have been performed to meet the permit requirements. Based on the evaluation of the existing data, there seems to be a potential groundwater problem at this site. As discussed in Sections 5.2 and 8.2, available data from the two wells, MW-15 and MW-16, show significant contamination has migrated from IWP2 into the Hennessey groundwater (HWBZ) and to some extent to the top of the USZ as indicated by MW-80, -81, and -82.

Additional monitoring wells are needed to define the extent of contamination in the Hennessey groundwater. A comparison of groundwater data with action levels revealed certain constituents were at concentration levels above the action levels. However, in the USZ most of them were detected only once at concentrations above the action levels. A one-time detection above the action levels is questionable. Additional groundwater data is needed to support a determination of potential groundwater problems at this site. Therefore, the following additional work is recommended:

- Continue groundwater monitoring and collect data for at least three sampling rounds in order to evaluate any trends in the data. In addition, these data will support evaluations for contaminant migration at the site.

- Additional monitoring wells should be installed in the HWBZ during Phase II of the RFI program to determine the lateral extent of contamination.

In addition, to fully evaluate the extent of soil contamination at this site it is recommended that site-specific soil background samples be collected during the Phase II RFI. This additional information along with the USGS background values should be used in the Phase II report to distinguish site-related from background concentrations in a statistically significant manner. During the development of the Phase II RFI work plan, the number of background samples to be collected, the location of the soil borings, and the soil analysis to be performed on the samples should be determined for EPA approval.

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Final Report
Phase I RCRA Facility Investigation for Appendix I Sites

VOLUME VIII

SWMU-23, Industrial Waste Treatment Plant, Abandoned Waste Tanks

Department of the Air Force
Oklahoma City Air Logistics Center
Tinker Air Force Base, Oklahoma

September 1994

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List of Acronyms

AFB	Air Force Base
AOC	area of concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CAL	Corrective Action Limits
CFR	Code of Federal Regulations
CMS	Corrective Measure Study
DERP	Defense Environmental Restoration Program
DOD	U.S. Department of Defense
EID	Engineering Installation Division
EP	extraction procedure
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
ft/mi	feet per mile
HSWA	Hazardous and Solid Waste Amendments
ICP-AES	inductively coupled plasma - atomic emission spectrometric (techniques)
IRP	Installation Restoration Program
IWTP	industrial wastewater treatment plant
LDR	Land Disposal Restriction
LSZ	lower saturated zone
g/kg	micrograms per kilogram
µg/L	micrograms per liter
MCL	maximum concentration level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
msl	mean sea level
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
PA/SI	preliminary assessment/site investigation
PCB	polychlorinated biphenyl
ppm	parts per million
PRC	PRC Environmental Management, Inc.
RCRA	Resource Conservation and Recovery Act

RI/FS	remedial investigation/feasibility study
RFI	RCRA Facility Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SVOC	semivolatile organic compound
SWMU	solid waste management unit
SWTP	Sanitary Waste Treatment Plant
TCLP	Toxicity Characteristic Leaching Procedure
TSD	treatment, storage, and disposal (facility)
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.W. Geological Survey
UWBZ	upper water bearing zone
USZ	upper saturated zone
VOC	volatile organic compounds
yd^3	cubic yards

Executive Summary

This report provides a summary of the various investigations that have been conducted at solid waste management unit (SWMU)-23, Industrial Waste Treatment Plant (IWTP) Abandoned Waste Tanks, Tinker Air Force Base (AFB), Oklahoma. The report has been prepared to determine and document whether sufficient investigations at the Abandoned Waste Tanks have been performed to meet regulatory requirements. Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. The Base encompasses approximately 5,000 acres.

Background. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of large quantities of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints.

In 1984, Congress amended the Resource Conservation and Recovery Act (RCRA) with the Hazardous and Solid Waste Amendments (HSWA), which allow the U.S. Environmental Protection Agency (EPA) to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989, Tinker AFB submitted its Part B permit application for renewal of its operating RCRA Hazardous Waste Storage facility permit. The final RCRA HSWA permit, issued on July 1, 1991, requires Tinker AFB to investigate all SWMUs and areas of concern (AOC) and to perform corrective actions at those identified as posing a threat to human health and the environment. The permit specifies that a RCRA Facility Investigation (RFI) be conducted for 43 identified SWMUs and AOC on the Base. This document has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for the Abandoned Waste Tanks site.

Source Description. The Abandoned Waste Tanks consisted of 11 open-top concrete batch processing tanks which were located on the west side of the IWTP. The tanks included two cyanide tanks, two chromium tanks, four "strong dump" tanks, one acid tank, one alkali tank, and one phenol tank. The batch processing tanks were constructed in 1963 and were utilized for routine wastewater treatment until 1975. From 1975 to 1985, the batch processing tanks were utilized intermittently for waste treatment. In 1985, the tanks were removed from active use. During the unit's operational period, waste stored in the tanks included cyanide, chromium, acids, alkali, and phenol. All 11 tanks were removed from the site in 1992. The tanks were demolished in place and excavated along with associated contaminated soils; all soil and debris was disposed of in a permitted hazardous waste treatment and disposal facility.

Site Investigations. Installation Restoration Program (IRP) investigations for the Abandoned Waste Tanks were conducted by the U.S. Army Corps of Engineers (USACE) in 1987 in support of removing the 11 abandoned storage tanks. Soil investigations were conducted around each storage tank. The investigations included installation of 13 soil borings in the area. Soil samples around the cyanide tanks, the chromium tanks, and the "strong dumps" tanks were found to be free of any contamination. Soils beneath the phenol tanks and the acid and alkali tanks contained phenol, organic compounds, and cyanide. USACE recommended the removal of all tanks and excavation and disposal of soils.

Roy F. Weston, Inc. conducted an interim remedial action for the removal of the Abandoned Waste Tanks in 1992. Remedial activities included the demolition, removal, and disposal of all 11 tanks and associated piping, and excavation and disposal of the soils around the tanks.

Groundwater at the site occurs in two principal zones: an intermittent perched water table which exists over much of the site, and the zone of saturation. A total of 23 monitoring wells have been installed at the site in order to evaluate groundwater contamination in the IWTP area, which includes the Abandoned Waste Tanks. Groundwater sampling has been conducted annually at the site since 1988 and it has been determined that groundwater contamination exists in the form of metals, volatile organic compounds (VOC), and semivolatile organic compounds (SVOC). It is suspected that multiple sources, including the Abandoned Waste Tanks, are responsible for groundwater contamination beneath the IWTP.

Removal of the 11 waste processing tanks and associated piping and excavation and disposal of contaminated soils around the tanks eliminated the source of contamination at the Abandoned Waste Tanks site. Although groundwater analytical data indicated the presence of constituents of potential concern, groundwater in the vicinity of the IWTP is an operable unit to the National Priorities List (NPL). All future groundwater assessment and evaluation will be conducted under the Comprehensive Environmental Response, Compensation, and Liability

Act (CERCLA) authority. Consequently, no further action is recommended for the Abandoned Waste Tanks site.

1.0 Introduction

1.1 Purpose and Scope

This document has been prepared in response to the Department of Air Force, Tinker Air Force Base (AFB), Oklahoma request for a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Summary Report for solid waste management unit (SWMU)-23, Industrial Waste Treatment Plant (IWTP) Abandoned Waste Tanks.

The objective of this RFI Summary Report is to provide Tinker AFB with one comprehensive report that summarizes the various investigations that have occurred at the Abandoned Waste Tanks site since the first environmental investigation was conducted on Base in 1981. The purpose of this comprehensive summary document is to:

- Characterize the site (Environmental Setting).
- Define the source (Source Characterization), if any.
- Define the degree and extent of contamination (Contamination Characterization).
- Identify actual or potential receptors.
- Identify all action levels for the protection of human health and the environment.

Additionally, this document briefly describes the procedures, methods, and results of all previous investigations and remedial actions that relate to the Abandoned Waste Tanks and contaminant releases, if any, including information on the type and extent of contamination at the site, sources and migration pathways, and actual or potential receptors. Where previous investigations, reports, or studies were not comprehensive and did not furnish the information required to determine the nature and extent of contamination, future work that can be conducted to complete the investigation has been recommended.

1.2 Preface

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the cleanup of hazardous waste disposal sites across the country. CERCLA gave the president authority to require responsible parties to remediate the sites or to undertake response actions through use of a fund (the Superfund). The president, through Executive Order 12580, delegated the U.S. Environmental Protection Agency (EPA) with the responsibility to investigate and remediate private party hazardous waste disposal sites that created a threat to human health and the environment. The president delegated responsibility for investigation and cleanup of federal facility disposal sites to the various federal agency heads. The Defense Environmental Restoration Program (DERP) was formally

established by Congress in Title 10 U.S. Code 2701-2707 and 2810. DERP provides centralized management for the cleanup of U.S. Department of Defense (DOD) hazardous waste sites consistent with the provisions of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300), and Executive Order 12580. To support the goals of the DERP, the Installation Restoration Program (IRP) was developed to identify, investigate, and clean up contamination at installation.

Under the Air Force IRP, Tinker AFB began a Phase I study similar to a preliminary assessment/site investigation (PA/SI) in 1981 (Engineering Science [ES], 1982). This study helped locate 14 sites that needed further investigation. A Phase II study was performed in 1983 (Radian Corporation [Radian], 1985a,b).

In 1986, Congress amended CERCLA through SARA. SARA waived sovereign immunity for federal facilities. This act gave the EPA authority to oversee the cleanup of federal facilities and to have the final authority for selecting the remedial action at federal facilities placed on the National Priorities List (NPL) if the EPA and the relevant federal agency cannot concur in the selection. Congress also codified DERP (SARA Section 211), establishing a fund for the DOD to remediate its sites because the Superfund is not available for the cleanup of federal facilities. DERP specifies the type of cleanup responses that the fund can be used to address.

In response to SARA, the DOD realigned its IRP to follow the investigation and cleanup stages of the EPA:

- PA/SI
- Remedial investigation/feasibility study (RI/FS)
- Record of Decision (ROD) for selection of a remedial action
- Remedial design/remedial action.

In 1984, Congress amended RCRA with the Hazardous and Solid Waste Amendments (HSWA), which allow the EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989, Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit.

EPA, in the Hazardous Waste Management Permit for Tinker AFB, dated July 1, 1991, identified 43 SWMUs and two areas of concern (AOC) on Tinker AFB that need to be addressed. The permit requires Tinker AFB to investigate all SWMUs and AOCs and to perform corrective action at those identified as posing a threat to human health or the environment. This RFI Summary Report has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for the Abandoned Waste Tanks and to document all determinations.

1.3 Facility Description

Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County (Figure 1-1) with its approximate geographic center located at 35° 25' latitude and 97° 24' longitude (U.S. Geological Survey [USGS], 1978). The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. An additional area east of the main Base is used by the Engineering Installation Division (EID) and is known as Area D. The Base encompasses approximately 5,000 acres. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints. Wastes that are currently generated are managed at two permitted hazardous waste storage facilities or treated at the IWTP. However, prior to enactment of RCRA, industrial wastes were discharged into unlined landfills and waste pits, streams, sewers, and ponds. Past releases from these landfills, pits, etc., as well as from underground tanks, have occurred. As a result, there are numerous sites of soil, groundwater, and surface water contamination on the Base.

The various reports generated as a result of investigative activities conducted at the Abandoned Waste Tanks have been reviewed and evaluated in terms of the sites' status under RCRA regulations. A summary based on the review of these reports for this site is presented in the following chapters and sections. In addition, recommendations for additional work is given at the end of the summary report.

1.4 Site Description

The IWTP is located in the northeast portion of Tinker AFB, east of Douglas Boulevard and adjacent to the tributary of Soldier Creek. The abandoned waste processing tanks identified

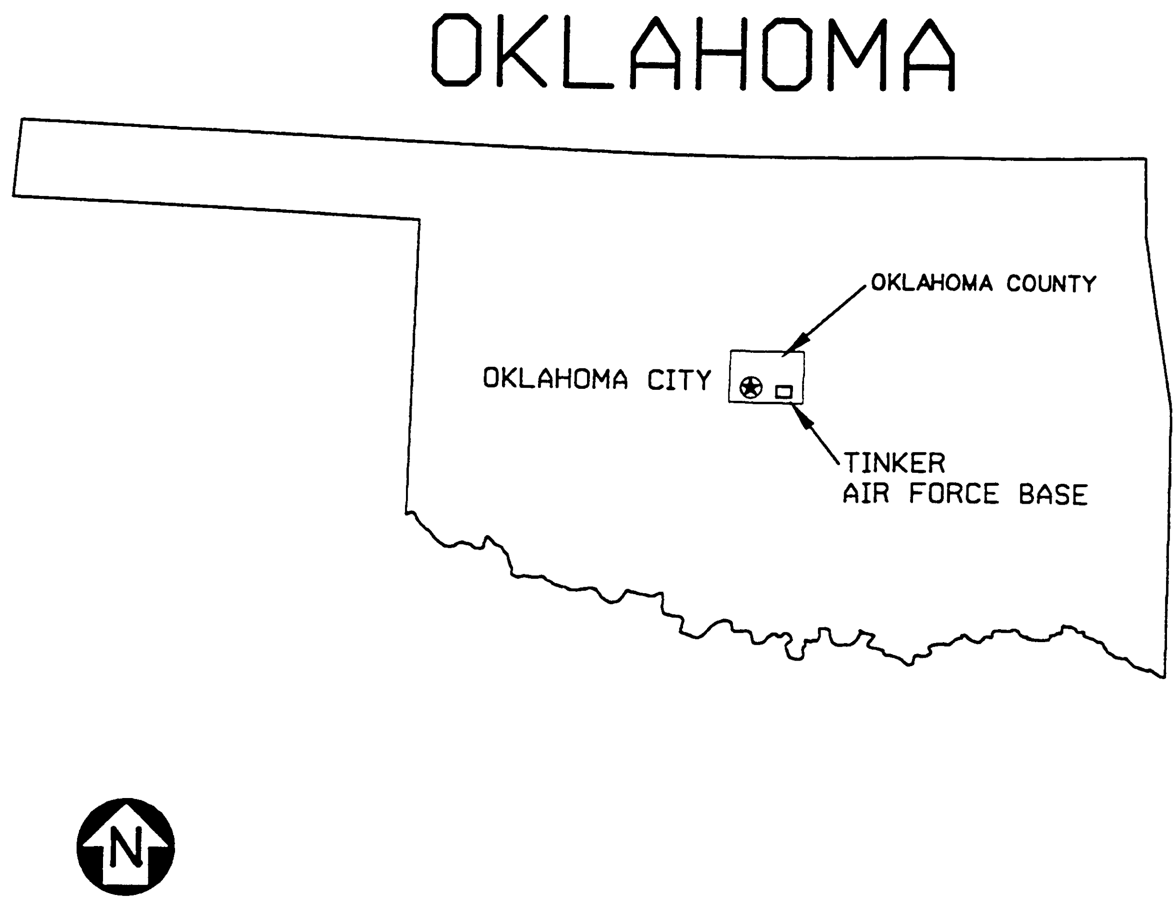


FIGURE 1-1
TINKER AIR FORCE BASE
OKLAHOMA
STATE INDEX MAP

PREPARED FOR
TINKER AFB
OKLAHOMA

STARTING DATE: 03/17/94 | DATE LAST REV.: | DRAFT. CHCK. BY: G. PACHECO | INITIATOR: C. WALLACE | DWG. NO.:
DRAWN BY: P.O. TERRY | DRAWN BY: | ENGR. CHCK. BY: C. WALLACE | PROJ. MGR.: J. TAYLOR | PROJ. NO.:

3/23/94 POT
FILENAME: G:\TINKER\40983202.075

as Abandoned Waste Tanks were located in the west and southwest portion of the IWTP. The tanks consisted of 11 concrete batch processing tanks arranged in six groups: two chromium waste processing tanks with an underground pump transfer dry pit; two cyanide waste processing tanks with an underground pump transfer pit; two groups of strong dump tanks with a transfer pit for each group; a single phenol processing tank; and an acid and alkali tank separated by a pump transfer pit. Although these tanks were originally designated to receive only certain wastes, it is likely that all tanks received a variety of wastes during their period of operation.

Figure 1-2 shows the location of the IWTP and the Abandoned Waste Tanks relative to Tinker AFB.

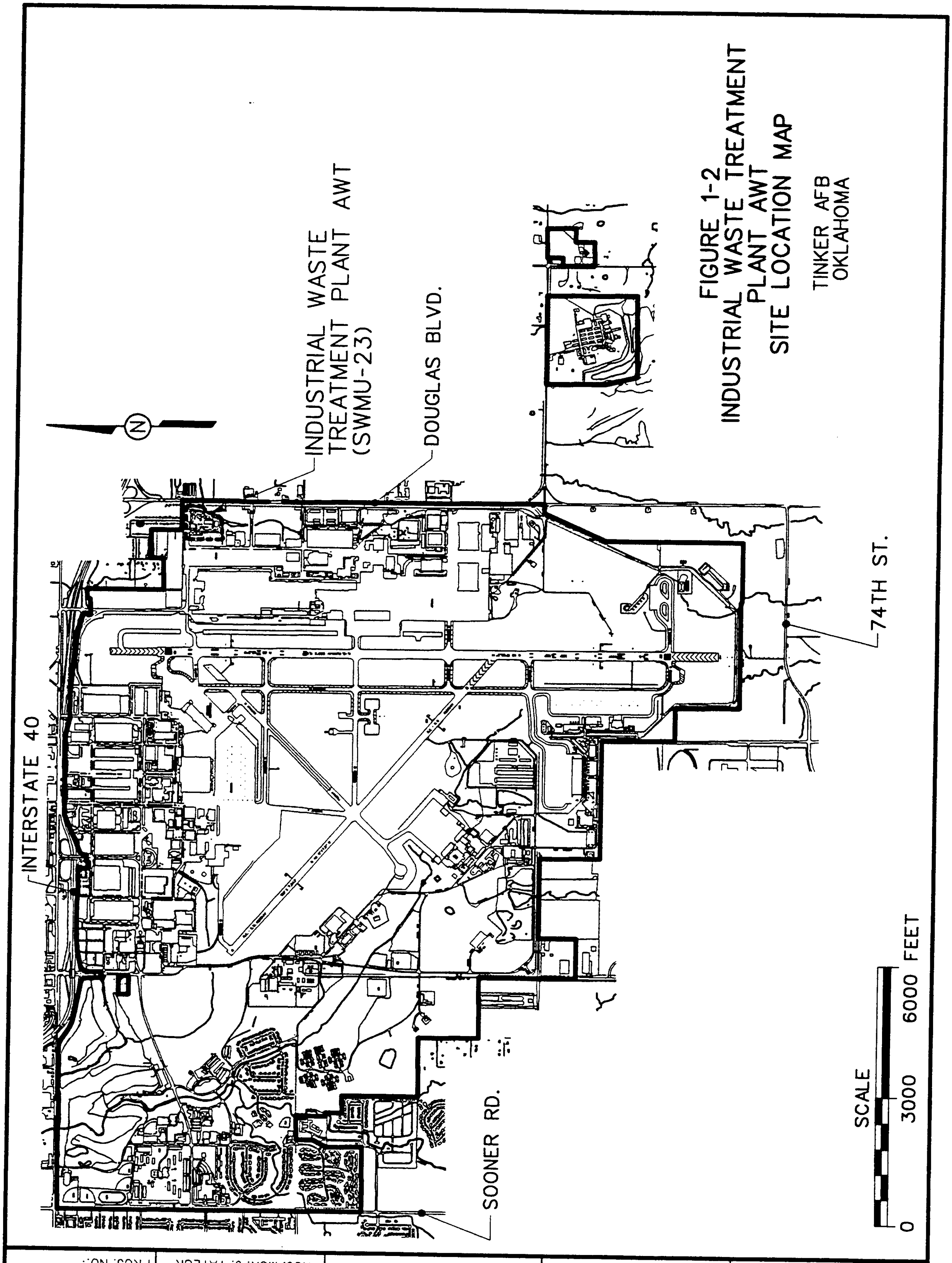


FIGURE 1-2
INDUSTRIAL WASTE TREATMENT PLANT AWT
SITE LOCATION MAP

TINKER AFB
OKLAHOMA

2.0 Background

2.1 Site Operations and History

Tinker AFB was originally known as the Midwest Air Depot and began operations in July 1941. The site was activated March 1942. During World War II the depot was responsible for reconditioning, modifying, and modernizing aircraft, vehicles, and equipment.

The IWTP is a process treatment plant for all the industrial wastewater generated at Tinker AFB. The IWTP facility is located in the northeast corner of Tinker AFB and contains two separate outfalls which discharge treated effluent to East Soldier Creek. One outfall is for treated industrial waste effluent discharging from the IWTP and the other outfall is for treated domestic waste effluent which discharges from the Sanitary Waste Treatment Plant (SWTP) (SWMU-32). Both plants are located in the same area and operate under National Pollutant Discharge Elimination Systems (NPDES) permits. The unit identified as Abandoned Waste Tanks was located on the southwest part of the IWTP and consisted of 11 open-top concrete storage tanks. The tanks were approximately 10-foot square with approximately 3 feet of their walls aboveground, and were approximately 10 feet deep. The tanks consisted of two cyanide tanks; two chromium tanks; four "strong dump" tanks in two separate groups; one acid and one alkali tank; and a phenol holding tank. Figure 2-1 shows the locations of the tanks at the Abandoned Waste Tanks site.

The batch processing tanks were operating from the 1940s to 1985. Waste stored in the tanks included phenolic paint stripping wastes, chrome plating wastes, alkaline cyanide wastes, and mixed waste acids.

During the visual site inspection in 1989 by PRC Environmental Management, Inc. (PRC, 1989), staining was observed on the insides of tank walls and on the surrounding ground, indicating that some tanks may have overflowed. The storage tanks were removed from the Abandoned Waste Tanks site in 1992 (USACE, 1992). Soils around the tanks were excavated and disposed of in a permitted waste landfill. The tank areas were restored by asphalt replacement and bermuda sod placement.

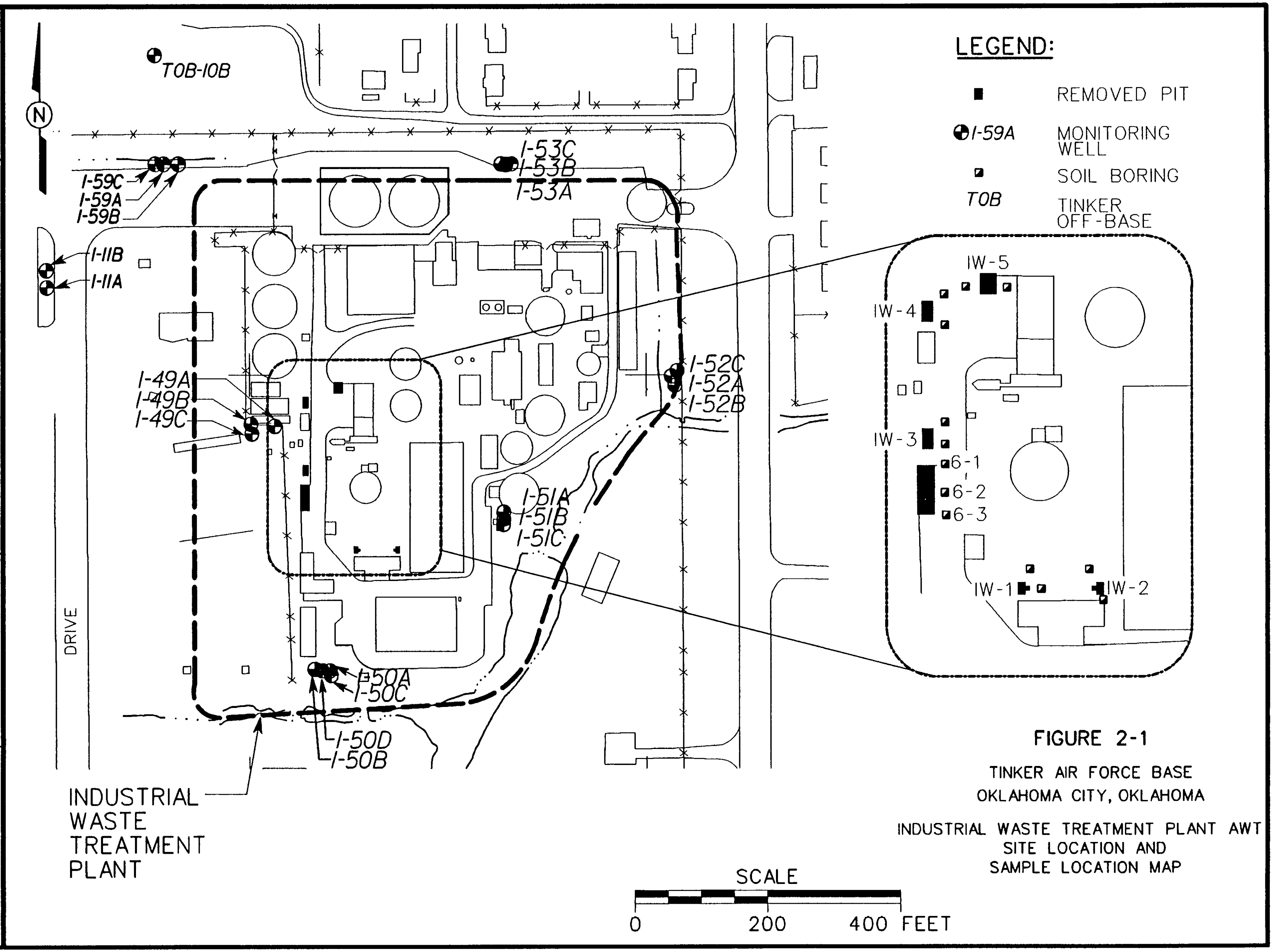


FIGURE 2-1

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

INDUSTRIAL WASTE TREATMENT PLANT AWT
SITE LOCATION AND
SAMPLE LOCATION MAP

STARTING DATE: 01/14/94	DATE LAST REV.: / /	DRAFT. CHCK. BY: G. PACHECO	INITIATOR: C. WALLACE	DWG. NO.:
DRAWN BY: P. TERRY	DRAWN BY:	ENGR. CHCK. BY: C. WALLACE	PROJ. MGR.: J. TAYLOR	PROJ. NO.:

2.2 Summary of Previous Investigations

U.S. Army Corps of Engineers. IRP investigations for the Abandoned Waste Tanks were conducted by the U.S. Army Corps of Engineers (USACE) in July 1987 (USACE, 1989). The investigations were conducted in support of removing the 11 abandoned, aboveground, concrete storage tanks.

Soil investigations were conducted around the tanks to determine if any contamination existed. Thirteen soil borings were drilled and sampled to a depth of 6 feet below the bottom of each tank. Soils around the cyanide tank, the chromium tank, and the "strong-dump" tanks were found free of any contamination. However, soils under the phenol tank and the acid and alkali tanks were found to be contaminated by phenol and organic compounds and cyanide.

The IRP investigations recommended the removal of all tanks, and excavation and disposal of soils. Specifically, it was recommended that cyanide tanks, chromium tanks, and "strong dump" tanks be removed and backfilled with no special treatment of the underlying soils. It was recommended that the top foot of soil from beneath the phenol tank be removed and disposed in a RCRA-permitted landfill. Finally, it was recommended that the soil beneath and around the acid/alkali tanks be excavated to a depth of 15 feet and disposed in a permitted hazardous waste landfill.

Roy F. Weston, Inc. Remediation activities for the Abandoned Waste Tanks were conducted by Roy F. Weston, Inc. from July 1992 through October 1992 (Weston, 1993). The remedial actions included the demolition and removal of the 11 waste processing tanks. The tank removal process consisted of sheet pile installation, tank purging and cleaning, tank demolition and removal, and sampling and analysis for characterization disposal procurement. Additionally, impacted soil was removed and soil samples collected and analyzed for confirmation cleanup levels. Finally, the site was restored by sod placement and asphalt replacement.

2.3 Current Regulatory Status

The IRP has been ongoing at Tinker AFB since the early 1980s. IRP studies on the Base were conducted according to IRP guidance, which is essentially the same as EPA's guidance for conducting RI/FS under CERCLA. All investigation and removal actions have been closely monitored and approved by the EPA.

Since receiving the Hazardous Waste Management Permit on July 1, 1991, many of the IRP sites have come under the jurisdiction of the RCRA permits branch of the EPA. As such, these sites have been identified as SWMUs; however, a large amount of work has already been performed at most of these sites under the IRP. Additional investigation at the SWMUs will be performed under the IRP.

3.0 Environmental Setting

3.1 Topography and Drainage

3.1.1 Topography

Regional/Tinker AFB. The topography of Oklahoma City and surrounding area varies from generally level to gently rolling in appearance. Local relief is primarily the result of dissection by erosional activity or stream channel development. At Oklahoma City, surface elevations are typically in the range of 1,070 to 1,400 feet mean sea level (msl). At Tinker AFB, ground surface elevations vary from 1,190 feet msl near the northwest corner where Crutcho Creek intersects the Base boundary to approximately 1,320 feet msl at Area D (EID).

Site. Site-specific topography information was not available from previous investigations for the Abandoned Waste Tanks area.

3.1.2 Surface Drainage

Regional/Tinker AFB. Drainage of Tinker AFB land areas is accomplished by overland flow of runoff to diversion structures and then to area surface streams, which flow intermittently. The northeast portion of the Base is drained primarily by unnamed tributaries of Soldier Creek, which is itself a tributary of Crutcho Creek. The north and west sections of the Base, including the main instrument runway, drain to Crutcho Creek, a tributary of the North Canadian River. Two small unnamed intermittent streams crossing installation boundaries south of the main instrument runway generally do not receive significant quantities of Base runoff due to site grading designed to preclude such drainage. These streams, when flowing, extend to Stanley Draper Lake, approximately one-half mile south of the Base.

Site. Site-specific drainage information was not available from previous investigations for the Abandoned Waste Tanks area.

3.2 Geology

3.2.1 Regional/Tinker AFB Geology

Tinker AFB is located within the Central Redbed Plain Section of the Central Lowland physiographic province, which is tectonically stable. No major fault or fracture zones have been mapped near Tinker AFB. The major lithologic units in the area of the Base are relatively flat-lying and have a regional westward dip of about 0.0076 foot per foot (ft/ft) (Bingham and Moore, 1975).

Geologic formations that underlie Tinker AFB include, from oldest to youngest, the Wellington Formation, Garber Sandstone, and the Hennessey Group; all are Permian in age.

All geologic units immediately underlying Tinker AFB are sedimentary in origin. The Garber Sandstone and Wellington Formation are commonly referred to as the Garber-Wellington Formation due to strong lithologic similarities. These formations are characterized by fine-grained, primarily calcareously-cemented sandstones interbedded with shale. Several sections of the sandstone units, however, are characterized by baritic cementing. The Hennessey Group consists of the Fairmont Shale and the Kingman Siltstone. It overlies the Garber-Wellington Formation along the eastern portion of Cleveland and Oklahoma counties. Quaternary alluvium is found in many undisturbed streambeds and channels located within the area.

Stratigraphy. Tinker AFB lies atop a sedimentary rock column composed of strata that ranges in age from Cambrian to Permian above a Precambrian igneous basement. Quaternary alluvium and terrace deposits can be found overlying bedrock in and near present-day stream valleys. At Tinker AFB, Quaternary deposits consist of unconsolidated weathered bedrock, fill material, wind-blown sand, and interfingering lenses of sand, silt, clay, and gravel of fluvial origin. The terrace deposits are exposed where stream valleys have downcut through older strata and have left them topographically above present-day deposits. Alluvial sediments range in thickness from less than a foot to nearly 20 feet.

Subsurface (bedrock) geologic units which outcrop at Tinker AFB and are important to understanding groundwater and contaminant concerns at the Base consist of, in descending order, the Hennessey Group, the Garber Sandstone, and the Wellington Formation (Table 3-1). These bedrock units were deposited during the Permian Age (230 to 280 million years ago) and are typical of redbed deposits formed during that period. They are composed of a

Table 3-1

Major Geologic Units in the Vicinity of Tinker AFB (Modified from Wood and Burton, 1968)

(Page 1 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
QUATERNARY	PLEISTOCENE	Alluvium	0-70	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel in the flood plains and channels of stream	Moderately permeable. Yields small to moderate quantities of water in valleys of larger streams. Water is very hard, but suitable for most uses, unless contaminated by industrial wastes or oil field brines.
	AND RECENT	Terrace deposits	0-100	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the flood plains of the principal streams.	Moderately permeable. Locally above the water table and not saturated. Where deposits have sufficient saturated thickness, they are capable of yielding moderate quantities of water to wells. Water is moderately hard to very hard, but less mineralized than water in other aquifers. Suitable for most uses unless contaminated by oil field brines.

Table 3-1

(Page 2 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
PERMIAN	LOWER PERMIAN	Hennessey Group (includes Kingman Siltstone and Fairmont Shale)	700	Deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy or limey shale. Forms relatively flat to gently rolling grass-covered prairie.	Poorly permeable. Yields meager quantities or very hard, moderately to highly mineralized water to shallow domestic and stock wells. In places water contains large amounts of sulfate.
		Garber Sandstone	500±	Deep-red clay to reddish-orange, massive and cross-bedded fine-grained sandstone interbedded and interfingered with red shale and siltstone	Poorly to moderately permeable. Important source of groundwater in Cleveland and Oklahoma counties. Yields small to moderate quantities of water to deep wells; heavily pumped for industrial and municipal uses in the Norman and Midwest City areas. Water from shallow wells hard to very hard; water from deep wells moderately hard to soft. Lower part contains water too salty for domestic and most industrial uses.
		Wellington Formation	500±	Deep-red to reddish-orange massive and cross-bedded fine-grained sandstone interbedded with red, purple, maroon, and gray shale. Base of formation not exposed in the area.	

conformable sequence of sandstones, siltstones, and shales. Individual beds are lenticular and vary in thickness over short horizontal distances. Because lithologies are similar and because of a lack of fossils or key beds, the Garber Sandstone and the Wellington Formation are difficult to distinguish and are often informally lumped together as the Garber-Wellington Formation. Together, they are about 900 feet thick at Tinker AFB. The interconnected, lenticular nature of sandstones within the sequence forms complex pathways for groundwater movement.

The surficial geology of the north section of the Base is dominated by the Garber Sandstone, which outcrops across a board area of Oklahoma County. Generally, the Garber outcrop is covered by a veneer of soil and/or alluvium up to 20 feet thick. To the south, the Garber Sandstone is overlain by outcropping strata of the Hennessey Group, including the Kingman Siltstone and the Fairmont Shale (Bingham and Moore, 1975). Drilling information obtained as a result of geotechnical investigations and monitoring well installation confirms the presence of these units.

Depositional Environment. The Permian-age strata presently exposed at the surface in central Oklahoma were deposited along a low-lying north-south oriented coastline. Land features included meandering to braided sediment-loaded streams that flowed generally westward from highlands to the east (ancestral Ozarks). Sand dunes were common, as were cut-off stream segments that rapidly evaporated. The climate was arid and vegetation sparse. Off shore the sea was shallow and deepened gradually to the west. The shoreline's position varied over a wide range. Isolated evaporitic basins frequently formed as the shoreline shifted.

Across Oklahoma, this depositional environment resulted in an interfingering collage of fluviatile and wind-blown sands, clays, shallow marine shales, and evaporite deposits. The overloaded streams and evaporitic basins acted as sumps for heavy metals such as iron, chromium, lead, and barium. Oxidation of iron in the arid climate resulted in the reddish color of many of the sediments. Erosion and chemical breakdown of granitic rocks from the highlands resulted in extensive clay deposits. Evaporite minerals such as anhydrite ($CaSO_4$), barite ($BaSO_4$), and gypsum ($CaSO_4 \cdot 2H_2O$) are common.

Around Tinker AFB, the Hennessey Group represents deposition in a tidal flat environment cut by shallow, narrow channels. The Hennessey Group is comprised predominantly of red shales which contain thin beds of sandstone (less than 10 feet thick) and siltstone. In outcrop, "mudball" conglomerates, burrow surfaces, and dessication cracks are recognized. These units outcrop over roughly the southern half of the Base, thickening to approximately 70 feet in the southwest from their erosional edge (zero thickness) across the central part of Tinker AFB.

In contrast, the Garber Sandstone and the Wellington Formation around Tinker AFB consist of an irregularly-interbedded system of lenticular sandstones, siltstones, and shales deposited either in meandering streams in the upper reaches of a delta or in a braided stream environment. Outcrop units north of Tinker AFB exhibit many small to medium channels with cut and fill geometries consistent with a stream setting. Sandstones are typically cross-bedded. Individual beds range in thickness from a few inches to approximately 50 feet and appear massive, but thicker units are often formed from a series of "stacked" thinner beds. Geophysical and lithologic well logs indicate that from 65 to 75 percent of the Garber Sandstone and the Wellington Formation are composed of sandstone at Tinker AFB. The percentage of sandstone in the section decreases to the north, south, and west of the Base. These sandstones are typically fine to very fine grained, friable, and poorly cemented. However, where sandstone is cemented by red muds or by secondary carbonate or iron cements, local thin "hard" intervals exist along disconformities at the base of sandstone beds. Shales are described as ranging from clayey to sandy, are generally discontinuous, and range in thickness from a few inches to approximately 40 feet.

Stratigraphic Correlation. Correlation of geologic units is difficult due to the discontinuous nature of the sandstone and shale beds. However, cross-sections (Figure 3-1) demonstrate that two stratigraphic intervals can be correlated over large sections of the Base in the conceptual model. These intervals are represented on geologic cross-sections A-A' and B-B' (Figures 3-2 and 3-3). Section A-A' is roughly a dip section and B-B' is approximately a strike section. The first correlatable interval is marked by the base of the Hennessey Group and the first sandstone at the top of the Garber Sandstone. This interval is mappable over the southern half of Tinker AFB. The second interval consists of a shale zone within the Garber Sandstone which, in places, is comprised of a single shale layer and, in other places, of multiple shale layers. This interval is more continuous than other shale intervals and in cross-sections appears mappable over a large part of the Base. It is extrapolated under the central portion of Tinker AFB where little well controls exists.

Structure. Tinker AFB lies within a tectonically stable area; no major near-surface faults or fracture zones have been mapped near the Base. Most of the consolidated rock units of the Oklahoma City area dip westward at a low angle. A regional dip of 0.0057 to 0.0076 ft/ft in

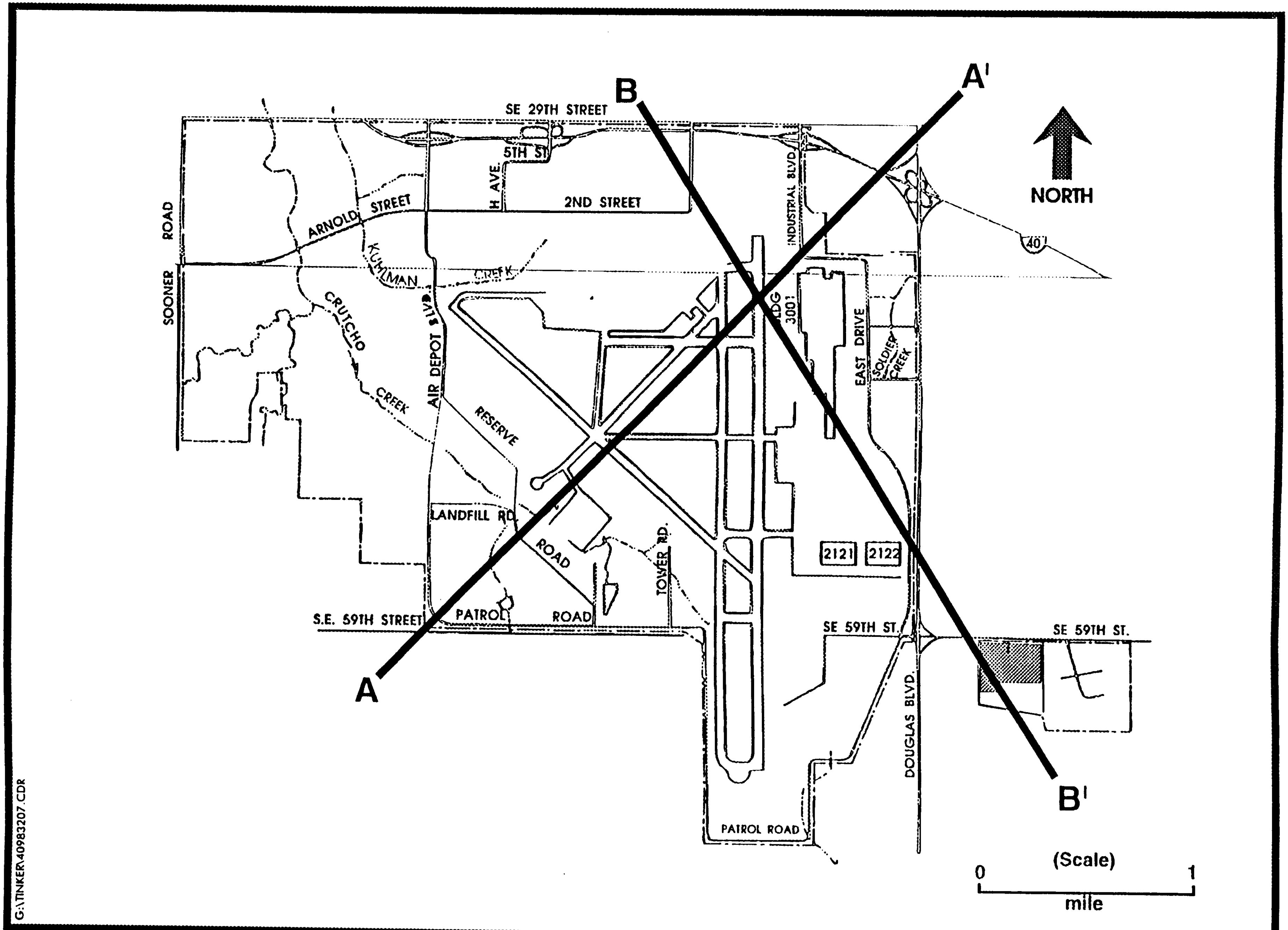


FIGURE 3-1 TINKER AFB GEOLOGIC CROSS SECTION LOCATION MAP

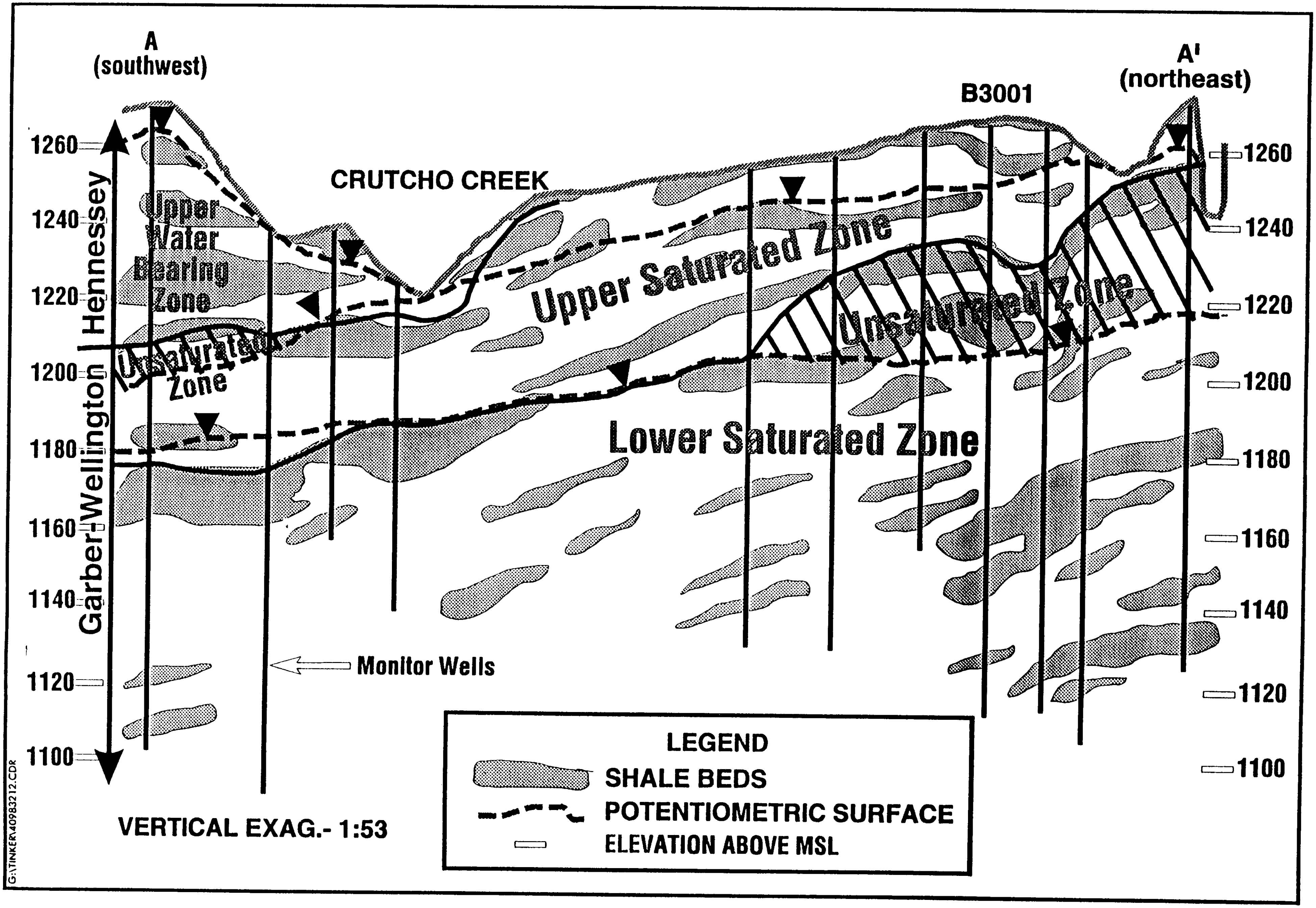


FIGURE 3-2 TINKER AFB GEOLOGIC CROSS SECTION A-A'

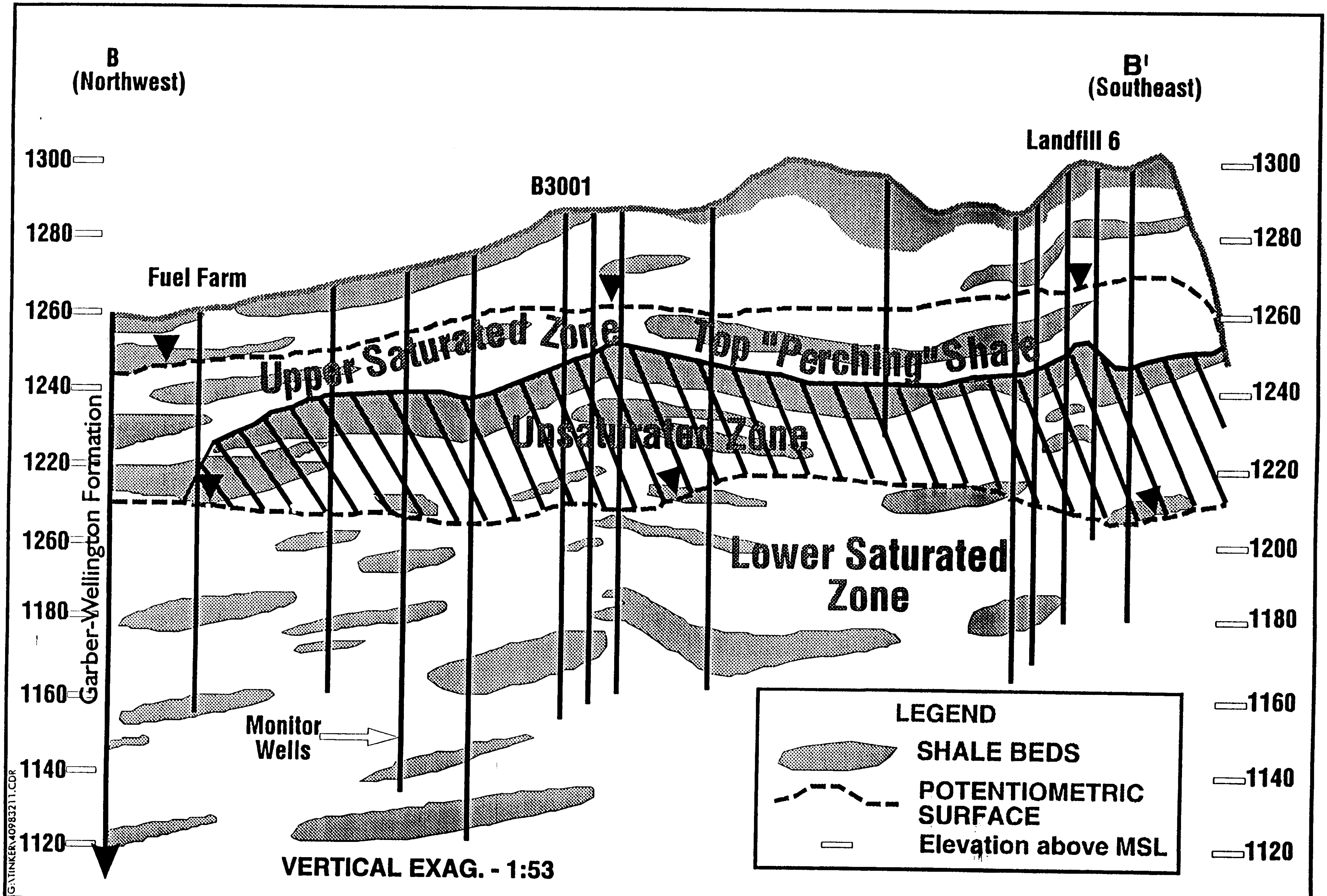


FIGURE 3-3 TINKER AFB GEOLOGIC CROSS SECTION B-B'

a generally westward direction is supported by stratigraphic correlation on geologic cross-sections at Tinker AFB. Bedrock units strike slightly west of north.

Although Tinker AFB lies in a tectonically stable area, regional dips are interrupted by buried structural features located west of the Base. A published east-to-west generalized geologic cross-section, which includes Tinker AFB, supports the existence of a northwest-trending structural trough or syncline located near the western margin of the base. The syncline is mapped adjacent to and just east of a faulted anticlinal structure located beneath the Oklahoma City Oil Field. The fault does not appear to offset Permian-age strata. There are indications that the syncline may act as a "sink" for some regional groundwater (southwest flow) at Tinker AFB before it continues to more distant discharge points.

3.2.2 Site Geology

No site-specific geologic information has been gathered for the Abandoned Waste Tanks area.

3.3 Hydrology

3.3.1 Regional/Tinker AFB Hydrology

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer system. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove, and Admire Groups. The Garber Sandstone and the Wellington Formation portion of the Central Oklahoma aquifer system is commonly referred to as the "Garber-Wellington aquifer" and is considered to be a single aquifer because these units were deposited under similar conditions and because many of the best producing wells are completed in this zone. On a regional scale, the aquifer is confined above by the less permeable Hennessey Group and below by the Late Pennsylvanian Vanoss Group.

Tinker AFB lies within the limits of the Garber-Wellington Groundwater Basin. Currently, Tinker derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest City and Del City derive water supplies from both surface sources and wells tapping the aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by a municipal distribution system also depend on the Garber-Wellington aquifer. Communities presently depending upon surface supplies (such as Oklahoma City) also maintain a well system drilled into the Garber-Wellington as a standby source of water in the event of drought.

Recharge of the Garber-Wellington aquifer is accomplished principally by percolation of surface waters crossing the area of outcrop and by rainfall infiltration in this same area. Because most of Tinker AFB is located in an aquifer outcrop area, the Base is considered to be situated in a recharge zone.

According to Wood and Burton (1968) and Wickersham (1979), the quality of groundwater derived from the Garber-Wellington aquifer is generally good, although wide variations in the concentrations of some constituents are known to occur. Wells drilled to excessive depths may encounter a saline zone, generally greater than 900 feet below ground surface. Wells drilled to such depths or those accidentally encountering the saline zone are either grouted over the lowest screens or may be abandoned.

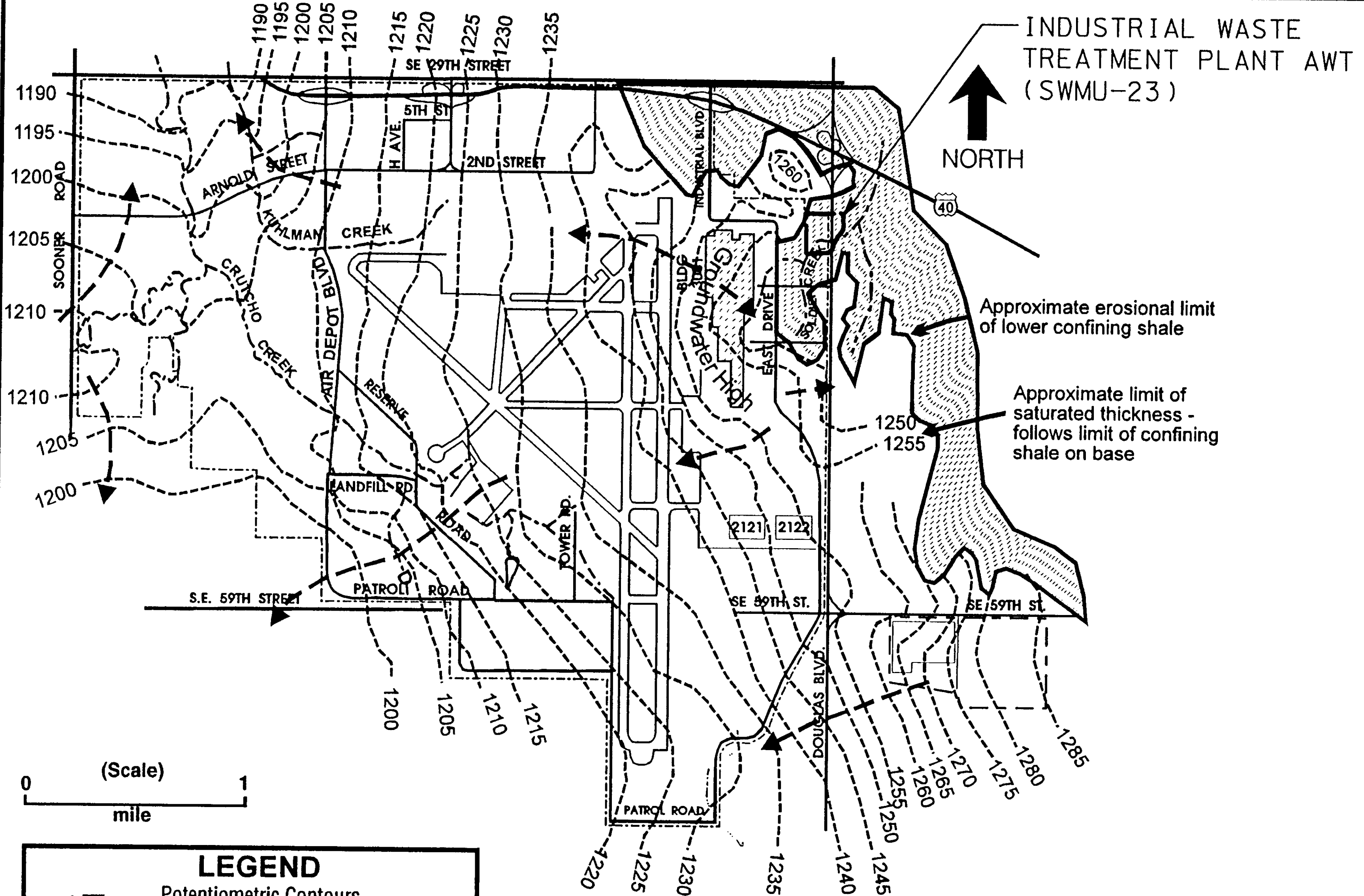
Tinker AFB presently obtains its water supplies from a distribution system comprised of 29 water wells constructed along the east and west Base boundaries and by purchase from the Oklahoma City Water Department. All Base wells are finished into the Garber-Wellington aquifer. Base wells range from 700 to 900 feet in finished depth, with yields ranging from 205 to 250 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones with a combined thickness from 103 to 184 feet (Wickersham, 1979).

Although the variability in the geology and the recharge system at Tinker AFB makes it difficult to predict local flow paths, Central Oklahoma aquifer water table data show that regional groundwater flow under Tinker varies from west-northwest to southwest, depending on location. This theory is supported by contoured potentiometric data from base monitoring wells which show groundwater movement in the upper and lower aquifer zones to generally follow regional dip. Measured normal to potentiometric contours, groundwater flow gradients range from 0.0019 to 0.0057 ft/ft. However, because flow in the near-surface portions of the aquifer at Tinker AFB is strongly influenced by topography, local stream base-levels, complex subsurface geology, and location in a recharge area, both direction and magnitude of ground-water movement is highly variable. The interaction of these factors not only influences regional flow but gives rise to complicated local, often transient, flow patterns at individual sites.

As a result of ongoing environmental investigations and the approximately 450 groundwater monitoring wells installed on the Base during various investigations, a better understanding of the specific hydrological framework has emerged. The current conceptual model developed by Tinker AFB (Tinker, 1993), based on the increased understanding of the hydrological framework, has been revised from an earlier model adopted by the USACE. Previous studies reported that groundwater was divided into four water-bearing zones: the perched aquifer, the top of regional aquifer, the regional aquifer, and the producing zone. In the current model, two principal water table aquifer zones and a third less extensive zone have been identified. The third is limited to the southwest quadrant. The third aquifer zone consisted of saturated siltstone and thin sandstone beds in the Hennessey Shale and equates to the upper water bearing zone (UWBZ) described by the USACE (1993) at Landfills No. 1 through 4 (SWMUs 3 through 6). In addition, numerous shallow, thin saturated beds of siltstone and sandstone exist throughout the Base. These are of limited areal extent and are often perched.

In the current conceptual hydrologic model, an upper saturated zone (USZ) and a lower saturated zone (LSZ) are recognized in the interval from ground surface to approximately 200 feet. Below this is found the producing zone from which the Base draws much of its water supply. Figure 3-4 shows the potentiometric surface for the USZ and Figure 3-5 shows the potentiometric surface for the LSZ. The USZ exists mainly under water table (unconfined) conditions, but may be partially confined locally. Conditions in the LSZ are difficult to determine due to screen placement and overly long sandpacks below the screen interval.

The USZ is found at a depth of 5 to 70 feet below ground surface and has a saturated thickness ranging from less than 1 foot at its eastern boundary to over 20 feet in places west of Building 3001. The USZ is erosionally truncated by Soldier Creek along the northeastern margin of Tinker AFB. This aquifer zone is considered to be a perched aquifer over the eastern one-third of Tinker AFB, where it is separated from the LSZ by an underlying confining shale layer and a vadose zone. The confining interval extends across the entire Base, but the vadose zone exists over the eastern one-third of this area. The available hydrogeologic data indicate that the vadose zone does not exist west of a north-south line located approximately 500 to 1,000 feet west of the main runway; consequently, the USZ is not perched west of this line. However, based on potentiometric head data from wells screened above and below the confining shale layer, the USZ remains a discrete aquifer zone distinct from the LSZ even over the western part of the Base. In areas where several shales interfinger to form the lower confining interval rather than a single shale bed, "gaps" may occur. In general, these "gaps" are not holes in the shale, but are places where multiple



LEGEND

- Potentiometric Contours Elevation above MSL
- Approximate Direction of Groundwater Flow

Contours are extrapolated across center of base due to lack of data

FIGURE 3-4
TINKER AIR FORCE BASE
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C.WALLACE	DWG. NO.:409832O9C.
DRAWN BY: C.E.TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J.TAYLOR	PROJ. NO.:409832

G:\TINKER\409832O2C.531

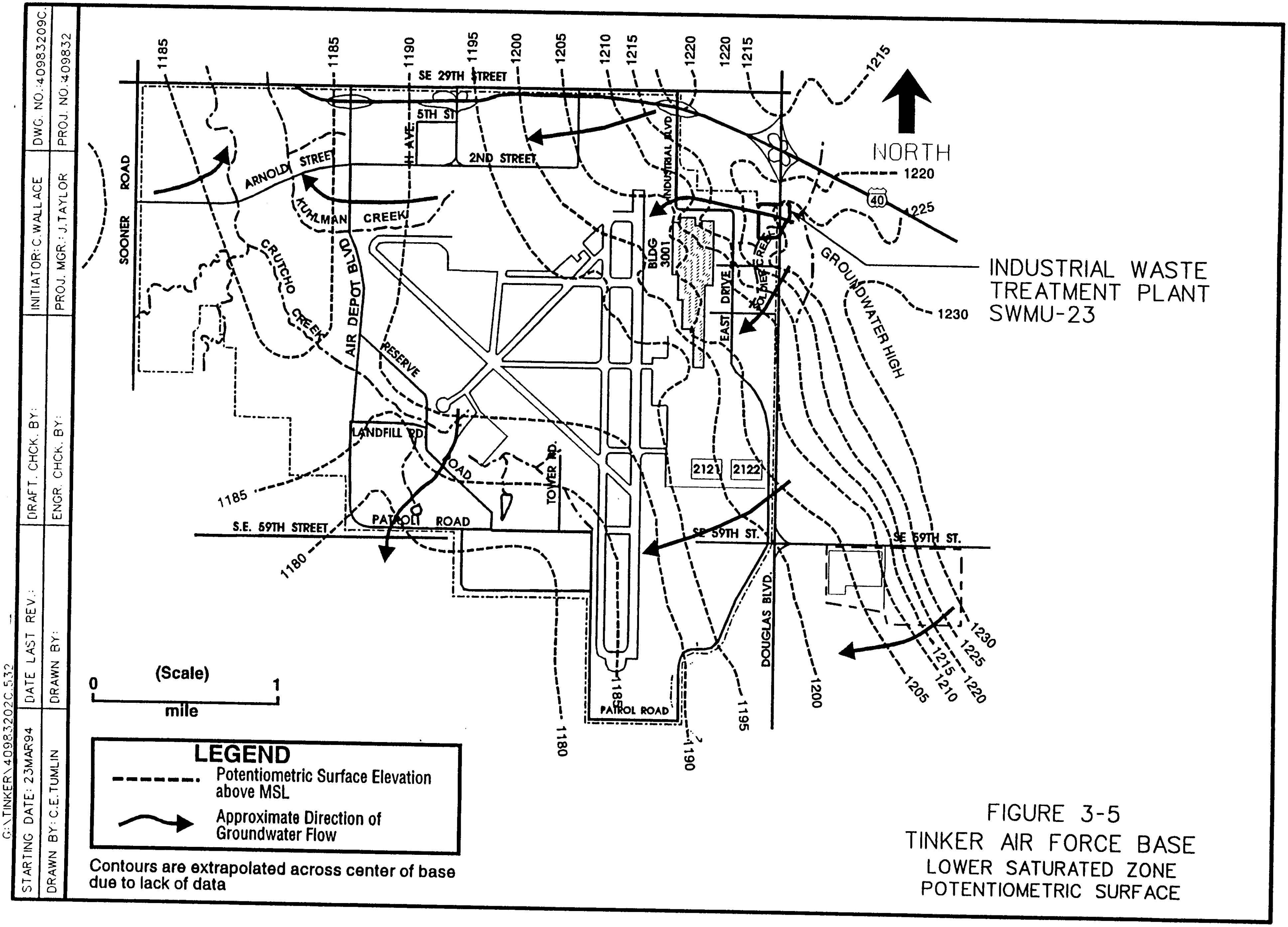


FIGURE 3-5
TINKER AIR FORCE BASE
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE

shales exist that are separated by slightly more permeable strata. Hydrologic data from monitoring wells indicate that these zones allow increased downward flow of groundwater above what normally leaks through the confining layer.

The LSZ is hydraulically interconnected and can be considered one aquifer zone down to approximately 200 feet. This area includes what was referred to by the USACE as the top of regional and regional zones. Hydrogeologic data from wells screened at different depths at the same location within this zone, however, provide evidence that locally a significant vertical (downward) component of groundwater flow exists in conjunction with lateral flow. The magnitude of the vertical component is highly variable over the Base. Preliminary evidence suggests that the LSZ is hydraulically discrete from the producing zone. Due to variations in topography, the top of the lower zone is found at depths ranging from 50 to 100 feet below ground surface under the eastern parts of the Base and as shallow as 30 feet to the west. Differences in potentiometric head values found at successive depths are due to a vertical (downward) component of groundwater flow in addition to lateral flow and the presence or absence of shale layers which locally confine the aquifer system. The LSZ extends east of the Base (east of Soldier Creek) beyond the limits of the USZ where it becomes the first groundwater zone encountered in off-Base wells. Because of the regional dip of bedding, groundwater gradient, and topography, the LSZ just east of the Base is generally encountered at depths less than 20 feet.

3.3.2 Site Hydrology

Site-specific hydrological data gathered at the Abandoned Waste Tanks site and surrounding area have allowed for the development of potentiometric surface maps for the USZ and LSZ. The USZ beneath this area flows to west-southwest as shown in Figure 3-6. Figure 3-7 shows that the LSZ at this site flows to the west; however, all LSZ wells at this site may not be screened at the same level within the LSZ. Because of this possible variation and because there is a known vertical flow component it is difficult to define the single potentiometric surface. These concerns are being addressed as part of groundwater investigations conducted under CERCLA authority for Building 3001/IWTP groundwater operable units.

3.4 Soils

Three major soil types have been mapped in the Tinker AFB area and are described in Table 3-2 (U.S. Department of Agriculture [USDA], 1969). The three soil types, the Darrell-Stephenville, Renfrow-Vernon-Bethany, and Dale-Canadian-Port, consist of sandy to fine sandy loam, silt loam, and clay loam, respectively. The Darrell-Stephenville and the

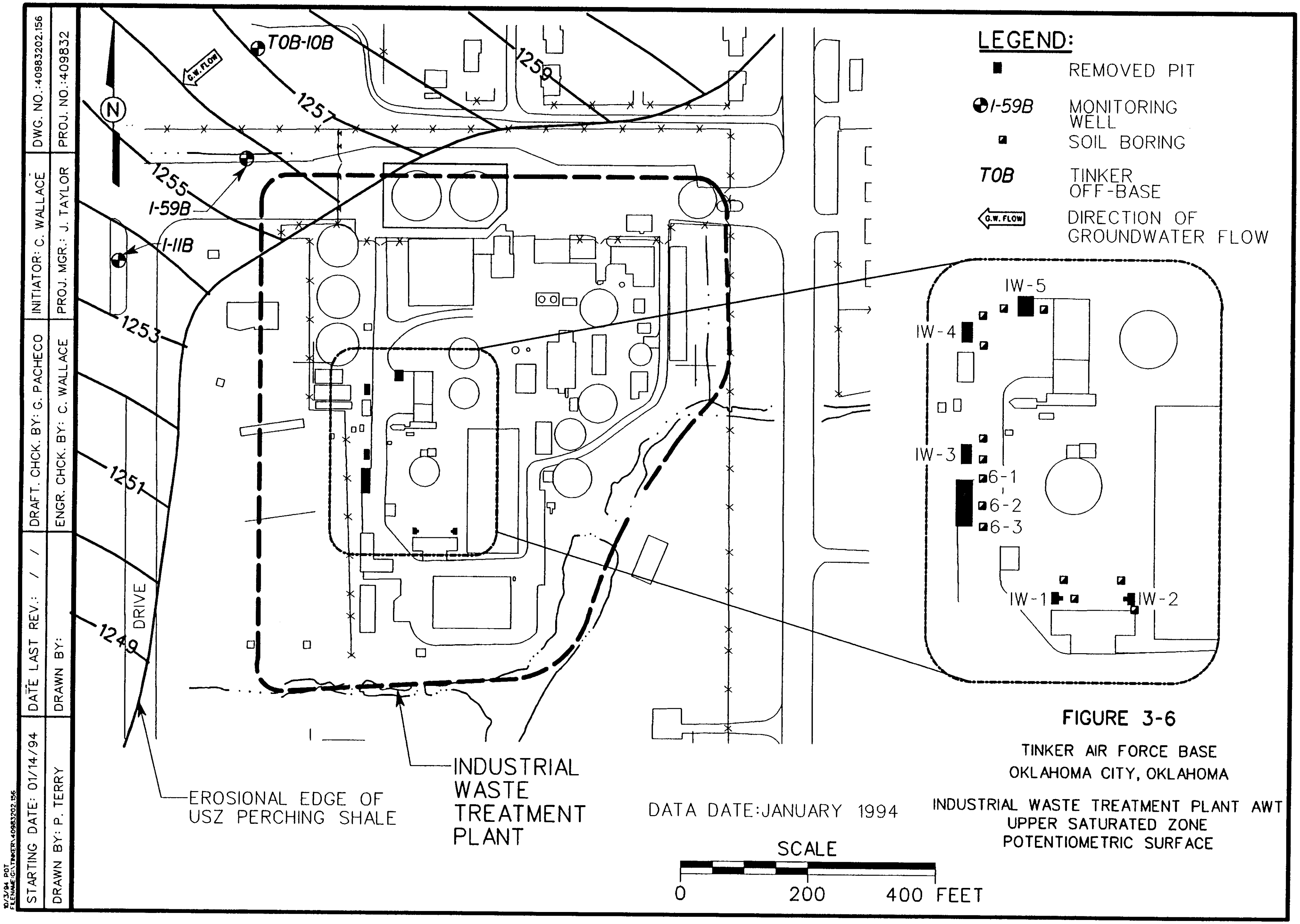
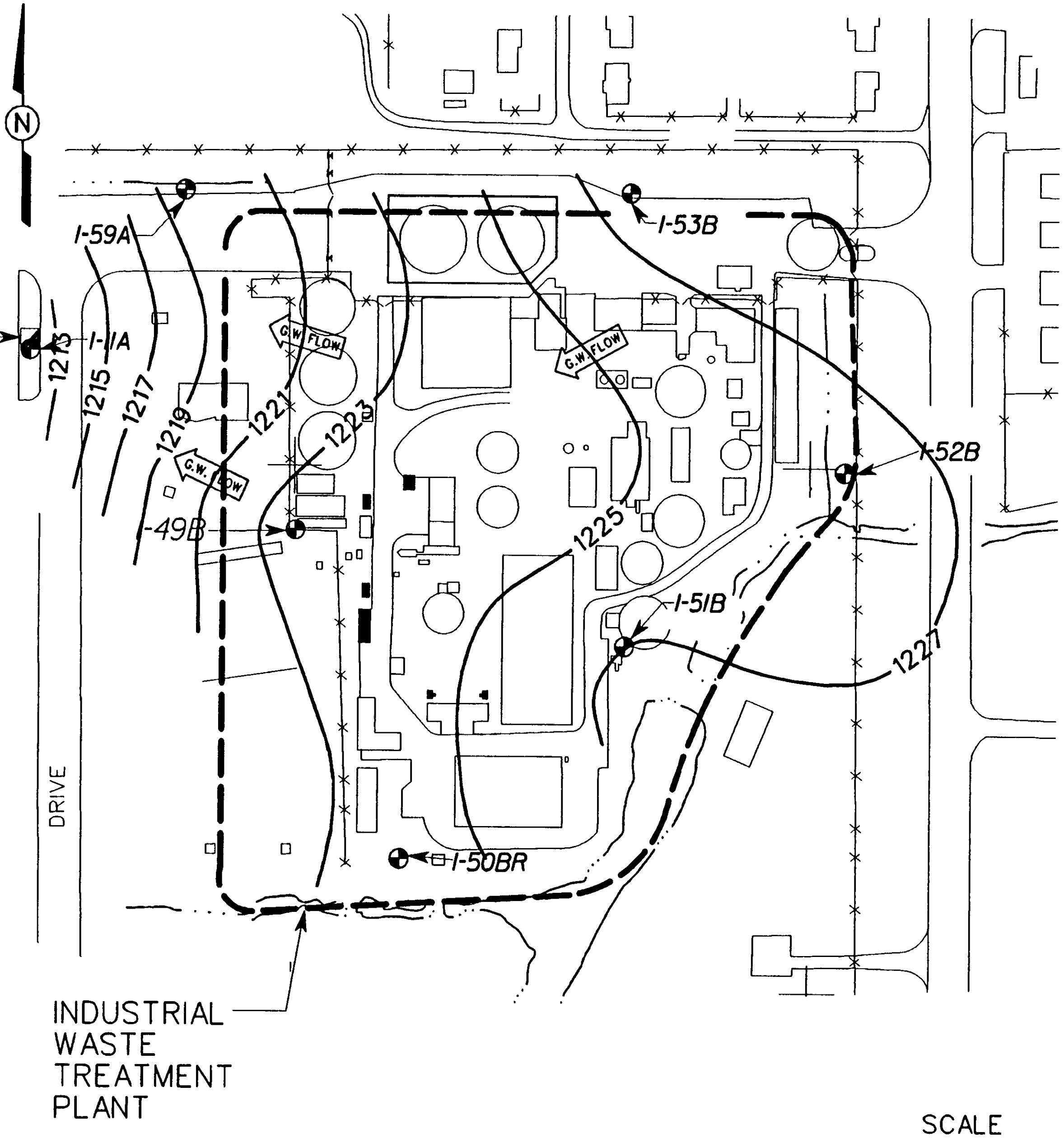


FIGURE 3-6

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

INDUSTRIAL WASTE TREATMENT PLANT AWT
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE



LEGEND:

■ REMOVED PIT

I-49A MONITORING WELL

G.W. FLOW GROUNDWATER FLOW DIRECTION

DATA DATE: MARCH 1993
C.I.: 2 FEET

NOTE:
1. DATA EXTRAPOLATED FROM ADDITIONAL DATA POINTS OUTSIDE SHOWN AREA.

SCALE
0 200 400 FEET

FIGURE 3-7

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

INDUSTRIAL WASTE TREATMENT PLANT AWT
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 01/14/94	DATE LAST REV.: / /	DRAFT. CHCK. BY: G. PACHECO	INITIATOR: C. WALLACE	DWG. NO.:
DRAWN BY: P. TERRY	DRAWN BY:	ENGR. CHCK. BY: C. WALLACE	PROJ. MGR.: J. TAYLOR	PROJ. NO.:

10/3/94 POT

Table 3-2

Tinker AFB Soil Associations
(Source: USDA, 1969)

Association	Description	Thickness (in.)	Unified Classification[a]	Permeability (in./hr)
Darrell-Stephenville: loamy soils of wooded uplands	Sandy loam Sandy clay loam Soft sandstone (Garber Sandstone)	12-54	SM,ML,SC	2.0-6.30
Renfrow-Vernon-Bethany: loamy and clayey soils on prairie uplands	Silt loam - clay Clay loam Shale (Fairmont Shale)	12-60	ML,CL,MH,CH	<0.60-0.20
Dale-Canadian-Port: loamy soil on low benches near large streams	Fine sandy loam Silty clay loam Loam Clay loam	12-60	SM,ML,CL	0.05-6.30

[a]Unified classifications defined in U.S. Bureau of Reclamation, 5005-86.

Renfrow-Vernon-Bethany are primarily residual soils derived from the underlying shales of the Hennessey Group. The Dale-Canadian-Port association is predominantly a stream-deposited alluvial soil restricted to stream floodplains. The thickness of the soils ranges from 12 to 60 inches. The Abandoned Waste Tanks site area lies entirely within the Darrell-Stephenville soil association.

4.0 Source Characterization

The Abandoned Waste Tanks consisted of 11 concrete batch processing tanks, which included two cyanide tanks, two chromium tanks, four "strong dump" tanks, an acid tank, an alkali tank, and a phenol holding tank. The batch processing tanks were constructed in 1963 and were utilized for routine wastewater treatment until 1975 (CDM Federal Programs Corporation [CDM], 1992). From 1975 to 1985, the tanks were utilized intermittently for waste treatment. Although the tanks were originally designated to receive only certain wastes, communications with plant personnel indicated that these tanks received a variety of waste during their operation period. Waste managed at the tanks included cyanide, chromium, acids, alkali, and phenol.

During IRP investigations, 13 soil borings were drilled around the Abandoned Waste Tanks area. Soil samples were collected from 0 to 1 foot, 2 to 3 feet, and 5 to 6 feet below the bottom of each tank. The samples were composited from each elevation within each group except the acid/alkali tanks. The soil samples were analyzed for metals, organics, pesticides and polychlorinated biphenyl (PCB), pH, oil and grease, and cyanide. Soil around the cyanide, chromium, and "strong dump" tanks were found to contain no contamination. Soils around the phenol tank had 2 parts per million (ppm) phenols in the sample. The acid/alkali tanks were contaminated with several organics and cyanide.

As an interim corrective measure, all of the 11 tanks were removed, together with the affected piping and contaminated soils surrounding the tanks. All piping, motors, and lining material removed from the processing tanks was triple-washed with detergent using a high-pressure washer. The rinse waters were sampled using Toxicity Characteristic Leaching Procedure (TCLP) to determine that no hazardous constituents remained. Several sections of various liners were also analyzed by TCLP prior to disposal of piping, motors, and liners. Six of the ten liners were determined to be nonhazardous and were disposed of along with the piping and motors at an industrial waste landfill. The remaining four liners were found hazardous below Land Disposal Restrictions (LDR) and were transported along with approximately 1,800 cubic yards (yd^3) of soil and debris to a permitted hazardous waste disposal facility with certification below LDRs. The remaining 2,200 yd^3 of soil and debris were above LDRs and, therefore, required treatment prior to disposal at a permitted hazardous waste treatment and disposal facility.

5.0 Contaminant Characterization

Soils and groundwater have been sampled for contaminants potentially introduced into the environment as a result of past waste disposal practices at the Abandoned Waste Tanks. Analytical results of the samples taken in and around the Abandoned Waste Tanks site indicate some metals concentrations appear to be slightly elevated. However, the soils in the Hennessey and Garber-Wellington Formations are known for their high metals concentrations due to the depositional environment from which the geologic formations were formed.

Background soil concentrations for trace metals were determined based on a study performed by the USGS (1991). The study area was confined to approximately four counties in central Oklahoma. Tinker AFB lies at the approximate center of this area. A total of 293 B-horizon soil samples were collected throughout this area. Soil samples were collected at the top of the B-horizon, which was usually 20 to 30 centimeters below the surface but ranged from 3 to 50 centimeters below the surface. For site-specific analytes for which the USGS offered no background value, the analyte was compared to an applicable action level. The background concentrations are presented in Table 5-1.

The use of B-horizon soil as selected by the USGS for metals background concentrations in soil is conservative in that the soil sampled does not reflect all possible anthropogenic influences. Most of the samples were obtained from hill crests and well drained areas in pasture and forested land, well away from roadways to minimize contamination from vehicular emissions (i.e., nearly "pristine" areas). Trace metal inputs to the study site soils on Base, however, will come from anthropogenic sources outside of the study area, in addition to those sources related to disposal activities or operations within the confines of the study site. Responsibility may thus be taken for more trace metal impacts than are actually attributable to a given site.

An additional level of conservatism was added in the manner in which the site-specific metals concentrations were compared to the background levels. Typically, the environmental concentrations of trace metals at study sites are represented by the arithmetic upper 95th confidence interval on the mean of a normal distribution. This upper 95th confidence interval value is then compared to the background values. The intent of this typical approach is to estimate a Reasonable Maximum Exposure (RME) case (i.e., well above the average case) that is still within the range of possible exposures.

Table 5-1

Background Concentrations of Trace Metals in Surface Soils[a]
SWMU-23, Abandoned Waste Tanks, Tinker AFB

(Page 1 of 2)

Analyte	Lower Detection Limit	Background Concentration Range	
		Minimum Value	Maximum Value
Concentration in %			
Aluminum	0.005	0.38	8.9
Cadmium	0.005	0.01	9.4
Iron	0.005	0.18	5.8
Magnesium	0.005	0.02	5.3
Phosphorous	0.005	0.06	0.019
Potassium	0.05	0.1	2.4
Sodium	0.005	0.02	0.99
Titanium	0.005	0.04	0.42
Concentrations in ppm			
Arsenic	0.1	0.6	21
Barium	1	47	6400
Beryllium	1	<1	3
Bismuth	10	<DL[b]	<DL
Cadmium	2	<DL	<DL
Cerium	4	14	110
Chromium	1	5	110
Cobalt	1	<1	27
Copper	1	<1	59
Europium	2	---[c]	---
Gallium	4	<4	23
Gold	8	<DL	<DL
Holmium	4	<DL	<DL
Lanthanum	2	7	51
Lead	4	<4	27
Lithium	2	5	100

Table 5-1

(Page 2 of 2)

Analyte	Lower Detection Limit	Background Concentration Range	
		Minimum Value	Maximum Value
Manganese	10	24	3400
Molybdenum	2	<DL	<DL
Neodymium	4	6	47
Nickel	2	<2	61
Niobium	4	<4	16
Scandium	2	<2	15
Selenium	0.1	<0.1	1.2
Silver	2	<DL	<DL
Strontium	2	13	300
Tantalum	40	<DL	<DL
Thorium	1	<1.40	15.00
Tin	10	<DL	<DL
Uranium	0.1	0.650	6.400
Vanadium	2	5	220
Ytterbium	1	<1	3
Yttrium	2	3	43
Zinc	2	3	79

[a]All B-horizon soil samples (293) from USGS, 1991.
[b]All concentrations below the lower limits of determination.
[c]Insufficient or no data.

To expedite this comparison and establish greater conservatism, the maximum concentration found at the site of concern, rather than the upper 95th confidence interval value, was compared to the USGS background values. If the environmental concentration of a particular analyte was below or within the minimum-maximum range of the USGS background concentrations, that analyte was considered to be naturally occurring and of no further concern to this investigation. Given the conservative approach of the comparisons, site-specific metals concentrations would have to significantly exceed the USGS background levels and be attributable to operations at the site before they would be considered a contaminant of concern.

The numerical comparison of site-specific metals concentrations to the USGS background concentrations is presented in the following section.

These metal concentrations in Table 5-1 were compared to both the USGS and Soil Conservation Services metal concentrations established for the Oklahoma aquifer. The metal concentrations in the soils at Tinker AFB were well within the limit for the area.

During IRP investigations (USACE, 1989), 13 borings were drilled around the Abandoned Waste Tanks site. Soil samples were collected from the soils underlying the tanks and composited from several depth intervals in each tank group. Table 5-2 presents the soil samples compositing scheme. The soil samples were analyzed for metals, volatile organic compounds (VOC), semivolatile organic compounds (SVOC), pesticides/PCBs, pH, oil and grease, and cyanide. Metals, VOCs, SVOCs, and cyanide were detected. Table 5-3 presents a summary of the soil data.

Groundwater. Groundwater at the Abandoned Waste Tanks site has been investigated through the installation of 23 groundwater monitoring wells. Groundwater at the site occurs in two zones: the USZ and the LSZ. Eight of the monitoring wells were installed into the USZ and 15 wells were installed into the LSZ. Table 5-4 summarizes monitoring well data at this site.

Groundwater samples were collected from all 22 existing wells at the site in 1991 (CDM, 1993); in 1992 water samples were collected from 17 wells (Weston, 1993b). Groundwater

Table 5-2

Soil Samples Compositing Scheme
SWMU-23, Abandoned Waste Tanks, Tinker AFB

Tank Group	Sample ID	Number Borings/ per Sample ID	Composite from each elevation?	Total Analyzed/ per Sample ID
Cyanide	IW-1	2	yes	3
Chromium	IW-2	2	yes	3
Strong Dump A	IW-3	2	yes	3
Strong Dump B	IW-4	2	yes	3
Phenol	IW-5	2	yes	3
Acid/Alkali	IW6-1	1	no	3
Acid/Alkali	IW6-2	1	no	3
Acid/Alkali	IW6-3	1	no	3
				24

Table 5-3

Detected Compounds in IWTP Soil Samples
(Concentrations in mg/kg)
SWMU-23, Abandoned Waste Tanks, Tinker AFB

(Page 1 of 6)

Boring Number:	IW-1	IW-2	IW-3	IW-4
Analyte	(9 to 10 feet)			
Organics				
Acetone	0	0	0	0.021
Methylene chloride	0.018	0.011	0	0
Tetrahydrofuran	0.009	0.008	0.004	0
Metals				
Arsenic	0	1.0	0	0
Barium	110	93	140	55
Cadmium	0.8	0.7	0	0.7
Chromium	890	8.5	12	16
EP Toxicity (chromium)	0.1	0	0	0
Lead	4.2	7.1	10	6.4
Silver	0	0	0	0.7
General Chemistry				
Oil and grease	0	0	20	0
pH	7.16	7.94	8.43	8.54

Table 5-3

(Page 2 of 6)

Boring Number:	IW-1	IW-2	IW-3	IW-4
Analyte	(11 to 12 feet)			
Organics				
Acetone	0.019	0	0	0.033
Methylene chloride	0.04	0.012	0	0
Tetrahydrofuran	0.008	0.009	0.004	0
Metals				
Arsenic	1.6	0	0	0
Barium	97	150	38	63
Cadmium	0.6	0.5	0	2.0
Chromium	420	7.3	0	30
Lead	2.6	5.5	3.9	6.4
Mercury	0	0	0	0
Selenium	0	0	0	0
Silver	0	0	0	2.7
General Chemistry				
Oil and grease	0	0	30	0
pH	8.07	7.08	8.51	9.01

KN/1256/SWMU23/SWMU23.5-3/03-30-94/D3 3:01pm

Table 5-3

(Page 3 of 6)

Boring Number:	IW-1	IW-2	IW-3	IW-4
Analyte	(14 to 15 feet)			
Organics				
Methylene chloride	0.021	0	0	0.01
Tetrahydrofuran	0.008	0.007	0.004	0
Metals				
Arsenic	1.6	0	0	0
Barium	73	110	40	23
Cadmium	0.8	0	0	0.7
Chromium	46	8.0	7.3	11
Lead	4.4	5.9	4.6	6.7
General Chemistry				
Oil and grease	20	0	30	0
pH	8.15	7.00	7.80	8.66
Silver	0	0	0	0

Table 5-3

(Page 4 of 6)

Boring Number:	IW-5	IW-6-1	IW-6-2	IW-6-3
Analyte	(12 to 13 feet)			
Organics				
Acetone	0	0	0	0.042
Chlorobenzene	0	0.009	0	0
Ethyl benzene	0	0.013	0	0
Methylene chloride	0.011	0	0	0.012
Tetrachloroethylene	0	0.56	0	0
Toluene	0	0.019	0	0
Total xylenes	0	0.05	0	0
Trichloroethylene	0	0.28	0	0
Phenols	2.0	0	0	0
Metals				
Arsenic	1.2	1.0	0	2.1
Barium	460	140	110	340
Cadmium	0.5	0	1.4	7.0
Chromium	11	26	24	1,900
EP toxicity (chromium)	0	0	0	0.12
EP toxicity (silver)	0	0	0	0.00
Lead	5.9	8.1	3.9	11.0
Silver	0	0.7	0	47
General Chemistry				
Cyanide	0	0	0	3
Oil and grease	80	720	0	0
pH	8.77	8.60	7.82	6.75

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Table 5-3

(Page 5 of 6)

Boring Number:	IW-5	IW-6-1	IW-6-2	IW-6-3
Analyte	(14 to 15 feet)			
Organics				
Acetone	0	0	0	0.053
Chlorobenzene	0	0.007	0	0
Methylene chloride	0.009	0	0	0.007
Trichloroethylene	0	0.048	0	0
Tetrachloroethylene	0	0.062	0	0
Tetrahydrofuran	0	0	0.004	0
Metals				
Arsenic	0	1.3	0	1.0
Barium	23	50	47	54
Cadmium	0.7	0	2.2	0
Chromium	0	7.1	130	6.4
Lead	5.2	3.5	1.6	6.0
Mercury	0	0	0	0
Selenium	0	0	0	0
Silver	0	0	4.1	0
General Chemistry				
Cyanide	0	0	8	0
Oil and grease	70	240	70	50
pH	8.79	8.70	8.66	7.06

KN/1256/SWMU23/SWMU23.5-3/03-30-94/D3 3:01pm

Table 5-3

(Page 6 of 6)

Boring Number:	IW-5	IW-6-1	IW-6-2	IW-6-3
Analyte	(17 to 18 feet)			
Organics				
Acetone	0	0	0	0.026
Methylene chloride	0.009	0	0	0.01
Tetrahydrofuran	0	0	0.003	0
Metals				
Arsenic	1.3	0	1.4	1.2
Barium	51	27	81	150
Cadmium	0.5	0	2.3	4.1
Chromium	7.8	0	59	120
Lead	6.2	2.6	3.8	6.3
Silver	0	0	1.9	3.1
General Chemistry				
Oil and grease	30	84	20	90
pH	8.77	8.85	8.53	9.16

Table 5-4

Groundwater Monitoring Well Data
SWMU-23, Abandoned Waste Tanks, Tinker AFB

Monitoring Well	Total Depth (ft)	Screened Interval (ft)	Top of Casing Elevation (ft)	Zone Monitored
1-49A	57	47-57	1254.7	LSZ[a]
1-49B	37	27-37	1257.8	USZ[b]
1-49C	117	107-117	1257.5	LSZ
1-50A	64.7	54.7-64.7	1247.5	LSZ
1-50B	41.5	31.5-41.5	1248.0	USZ
1-50C	107	97-107	1249.0	LSZ
1-50D	247	237-247	NA[c]	LSZ
1-51A	61.2	51.2-61.2	1243.3	LSZ
1-51B	23.4	13.4-23.4	1242.6	USZ
1-51C	89	79-89	1243.1	LSZ
1-52A	59.9	49.9-59.9	1236.4	LSZ
1-52B	18.4	8.4-18.4	1237.0	USZ
1-52C	107	97-107	1237.0	LSZ
1-53A	59.5	49.5-59.5	1250.2	LSZ
1-53B	28	18-28	1251.5	USZ
1-53C	107	97-107	NA	LSZ
72	15.1	5.1-15.1	NA	USZ

[a]LSZ - Lower saturated zone
[b]USZ - Upper saturated zone
[c]NA - Data not available

samples were analyzed for metals, VOCs, and SVOCs. Tables 5-5 and 5-6 summarize the groundwater analytical results for the USZ and the LSZ, respectively.

5.1 Soil Characterization

Metals, organic compounds, and cyanide were detected in the soils at the Abandoned Waste Tanks site. Soils beneath the cyanide, chromium, and strong dump tank groups did not contain any contamination. However, soils underlying the acid/alkali tanks contained several organic compounds and cyanide. Low levels of phenol were detected in soils underlying the phenol tank. Table 5-3 presents a summary of the soil analytical results for each tank group. The following section contains a detailed discussion of each tank group.

Cyanide Tanks, IW-1. Metals and organic compounds were detected at IW-1. Metals were all within the USGS background values for the area except for chromium. Chromium was detected above background for the samples taken from 0 to 1 foot, at 890 milligrams per kilogram (mg/kg), and 2 to 3 feet at 420 mg/kg below the bottom of the tanks. The 0- to 1-foot sample was tested for EP toxicity and yielded 0.1 milligrams per liter (mg/L) for chromium. This value is well below the 5 mg/L necessary to classify the soil as a hazardous waste due to chromium. Methylene chloride, acetone, and tetrahydrofuran were the organic compounds detected in low concentrations (maximum concentration of 40 micrograms per kilogram [μg/kg]) in the samples. Tetrahydrofuran was detected in the laboratory blank, and methylene chloride and acetone are common laboratory contaminants. Their presence in the samples could be due to inadvertent contamination in the field or laboratory, and/or actual contamination of site soils. An investigation was conducted to determine the source of these contaminants, which have been found at several IRP sites. Results of the investigation concluded that the organic compounds were most likely the result of laboratory and/or field contamination; in addition, toxicity data indicated that these compounds were harmless at the concentrations found in the samples. The pH and oil and grease levels were not indicative of any significant spills of hydrocarbons or acid/alkali.

Chromium Tanks, IW-2. All metal concentrations were less than background limits. The organics, methylene chloride and tetrahydrofuran, were found at low, insignificant concentrations (less than 15 micrograms per kilogram [μg/kg]. The pH values were not indicative of any acid/alkali spills, and oil and grease were not detected.

Table 5-5

Summary of Groundwater Analytical Results
Upper Saturated Zone, Selected IWTP Wells
(Concentrations in μg/L)
SWMU-23, Abandoned Waste Tanks, Tinker AFB

(Page 1 of 3)

Sample Location: Date Sampled:	MW1-11B 1991	MW1-49B 1991	MW1-49B 1992	MW1-50B 1991	MW1-50B 1992	MW1-51B 1991	MW1-51B 1992	MW1-52B 1991	MW1-52B 1992	MW1-53B 1991	MW1-53B 1992	MW1-59B 1991	MW1-60B 1991
Inorganic analysis													
Aluminum	ND	656	ND	26.9B	ND	392	ND	23.5B	ND	790	ND	14300	ND
Antimony	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	2.0B	ND	ND	ND	ND	ND	ND	ND	ND	2.5B	ND	2.5B	ND
Barium	206	66.7B	102	1130	2020	155B	108	133B	143	526	404	731	163B
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.7B	ND
Calcium	59400	124000	ND	87700	ND	54200	ND	61200	ND	70300	ND	13600	64700
Chromium	ND	73.7	14.6	ND	ND	ND	7.9	ND	ND	299	ND	23.8	ND
Cobalt	ND	7.0B	ND	3.7B	ND	ND	ND	4.2B	ND	13.1B	ND	5.6B	ND
Copper	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.0B	ND	24.9B	ND
Iron	ND	478	ND	21.4B	ND	300	ND	30.1B	ND	5090	ND	11800	7.5B
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.6	ND	18.5	ND
Magnesium	27400	56400	ND	40400	ND	30200	ND	32700	ND	34200	ND	8150	25900
Manganese	80.0	158	ND	17	ND	187	ND	2720	ND	184	ND	721	ND
Nickel	ND	185	208	53.9	61.7	ND	ND	13.6B	ND	315	17.2	25.8B	ND
Potassium	ND	2130UJ	ND	1540UJ	ND	1600UJ	ND	1120B	ND	1740UJ	ND	2290B	708B
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.0	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

KN/1256/SWMU23/SWMU23US.5-5/04-04-94/D2 12:28pm

Table 5-5

(Page 2 of 3)

Sample Location: Date Sampled:	MW1-11B 1991	MW1-49B 1991	MW1-49B 1992	MW1-50B 1991	MW1-50B 1992	MW1-51B 1991	MW1-51B 1992	MW1-52B 1991	MW1-52B 1992	MW1-53B 1991	MW1-53B 1992	MW1-59B 1991	MW1-60B 1991
Sodium	146000	133000	ND	19000	ND	26600	ND	95500	ND	36600	ND	431000	13400
Vanadium	3.6B	9.2B	ND	8.1B	ND	3.6B	ND	ND	ND	16.1B	ND	23.8B	ND
Zinc	ND	19.1UJ	ND	36.9	ND	10.0UJ	ND	ND	ND	27.3UJ	ND	58.5	ND
Organic Analyses													
Benzene	ND	ND	0.200J	7	7	ND	ND	ND	0.6	ND	ND	ND	ND
Tetrachloroethene	ND	210J	57E	30	43	ND	ND	ND	ND	ND	0.4J	ND	ND
Toluene	ND	ND	0.100J	ND	0.6	ND	ND	ND	2	ND	ND	ND	ND
Chlorobenzene	ND	ND	0.800	580D	530	ND	ND	ND	ND	ND	ND	ND	ND
Isopropylbenzene	ND	ND	ND	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND
1,3-Dichlorobenzene	ND	ND	0.300J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	0.200J	18	12	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene	ND	ND	0.5	18	23	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dimethylphthalate	ND	ND	ND	ND	46	ND	ND	ND	ND	ND	ND	ND	ND
Xylenes (total)	ND	ND	ND	ND	0.25	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	46	29	24	29	ND	ND	ND	0.5	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	0.4J	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-dichloroethene	ND	ND	21	ND	520	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	18	13	ND	6	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl chloride	ND	ND	0.2J	160D	150	ND	ND	ND	ND	ND	ND	ND	ND
Methylene chloride	11B	6UJ	1B	9UJ	0.4J	6UJ	0.4JB	8JB	2B	ND	4B	5B	5JB
Trans-1,2-dichloroethene	ND	ND	0.1J	ND	2	ND	ND	ND	ND	ND	ND	ND	ND

Table 5-5

(Page 3 of 3)

Sample Location: Date Sampled:	MW1-11B 1991	MW1-49B 1991	MW1-49B 1992	MW1-50B 1991	MW1-50B 1992	MW1-51B 1991	MW1-51B 1992	MW1-52B 1991	MW1-52B 1992	MW1-53B 1991	MW1-53B 1992	MW1-59B 1991	MW1-60B 1991
1,1,1-Trichloroethane	ND	5	3	ND	2	ND	ND	ND	ND	ND	0.2J	ND	ND
1,1-Dichloroethane	ND	ND	3	9	11	ND	ND	4J	ND	ND	ND	ND	ND
Chloroform	ND	6	3	ND	ND	ND	ND	ND	2	ND	ND	ND	ND
2-Chloronaphthalene	ND	ND	ND	9J	6J	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-butyl phthalate	ND	ND	ND	ND	ND	ND	4JB	ND	ND	ND	4JB	ND	ND
1,2,3-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	ND	13	NAF	210D	NAF	ND	NAF	ND	NAF	ND	NAF	ND	ND
Naphthalene	ND	ND	1B	ND	ND	ND	0.9B	ND	ND	ND	1B	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	0.4J	ND	ND	ND	ND	ND	ND	ND	ND
Ethyl benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorodifluoromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND
o-Xylene	ND	ND	ND	ND	0.2J	ND	ND	ND	ND	ND	ND	ND	ND
Sec-butylbenzene	ND	ND	ND	ND	0.1J	ND	ND	ND	ND	ND	ND	ND	ND
1,3,5-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis(2-ethylhexyl)phthalte	ND	ND	ND	ND	ND	ND	1J	ND	ND	ND	1J	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = Not detected.
NAF = The compound was Not Analyzed For.

Table 5-6

Summary of Groundwater Analytical Results, Lower Saturated Zone, Selected IWTP Wells (Concentrations in µg/L) SWMU-23, Abandoned Waste Tanks, Tinker AFB

(Page 1 of 2)

Sample Location: Date Sampled:	MW11-1A 1991	MW1-49A 1991	MW1-49A 1992	MW1-49C 1991	MW1-49C 1992	MW1-50A 1991	MW1-50A 1992	MW1-50C 1991	MW1-50C 1992	MW1-50D 1992	MW1-51A 1991	MW1-51A 1992
Inorganic Analysis												
Aluminum	341	24.9B	NAF	209	NAF	59.2B	NAF	47.6B	NAF	NAF	ND	NAF
Antimony	21.1B	ND	NAF	ND	NAF	ND	NAF	ND	NAF	NAF	ND	NAF
Arsenic	2.1B	ND	ND	7.8B	11.4	ND	ND	ND	ND	ND	ND	ND
Barium	145B	783	838	250	483	1280	1350	2300	1010	810	1320	1340
Beryllium	ND	ND	NAF	ND	NAF	ND	NAF	ND	NAF	NAF	ND	NAF
Calcium	110000	72000	NAF	20200	NAF	94500	NAF	51500	NAF	NAF	100000	NAF
Chromium	101	7.8B	ND	5.3	40.2	ND	ND	ND	ND	ND	ND	ND
Cobalt	8.9B	31.2B	NAF	ND	NAF	13.8B	NAF	3.7B	NAF	NAF	17.2B	NAF
Copper	ND	ND	NAF	ND	NAF	ND	NAF	ND	NAF	NAF	ND	NAF
Iron	200	26.8B	NAF	88.3B	NAF	37.7B	NAF	71.1B	NAF	NAF	71.1B	NAF
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Magnesium	57000	33300	NAF	9310	NAF	45300	NAF	24400	NAF	NAF	48500	NAF
Manganese	14.0B	8.1B	NAF	8.4B	NAF	8.2B	NAF	5860	NAF	NAF	30.5	NAF
Nickel	485	768	590	ND	ND	150	167	54.0	46.1	ND	240	226
Potassium	740B	2330UJ	NAF	93100	NAF	2080UJ	NAF	2810UJ	NAF	NAF	2080UJ	NAF
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	15.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sodium	62900	68100	NAF	28700	NAF	33100	NAF	37600	NAF	NAF	49700	NAF
Vanadium	4.3B	3.2B	NAF	70.8	NAF	4.0B	NAF	ND	NAF	NAF	3.1B	NAF
Zinc	ND	12.4UJ	NAF	8.9UJ	NAF	14.7UJ	NAF	17.5UJ	NAF	NAF	26.1UJ	NAF
Organic Analyses												
Benzene	4J	7	9	ND	2	10	14	6J	5	ND	9	6
Bromodichloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	600D	300D	390	37	14	120	42	92J	26	3	89	31
Toluene	ND	ND	2	ND	0.4J	ND	4	ND	1	ND	ND	3
Chlorobenzene	470D	980D	1200	40	4.0	590D	460	430D	220	8	650D	55
Isopropylbenzene	ND	ND	1	ND	ND	ND	1	ND	ND	ND	ND	0.9
1,3-Dichlorobenzene	ND	ND	8	ND	ND	6J	17	ND	4	ND	ND	11
1,4-Dichlorobenzene	43	100	150	2J	0.7	71	69	1B	21	1	71	62
1,2-Dichlorobenzene	82	260	360	10	2	210	210	84	70	4	170	150
1,2,4-Trichlorobenzene	ND	ND	0.700	ND	ND	ND	1	ND	ND	ND	ND	1

Sample Location: Date Sampled:	MW1-51C 1991	MW1-51C 1992	MW1-52A 1991	MW1-52A 1992	MW1-52C 1991	MW1-52C 1992	MW1-53A 1991	MW1-53A 1992	MW1-53C 1992	MW1-59A 1991	MW1-59C 1991	MW1-60A 1991	MW1-60C 1991	MW-7 199
Inorganic Analysis														
Aluminum	1590	NAF	ND	NAF	24800	NAF	49.9B	NAF	NAF	30.3B	ND	897	ND	NAF
Antimony	ND	NAF	ND	NAF	22.2B	NAF	ND	NAF	NAF	ND	21.8B	ND	24.7B	NAF
Arsenic	2.2B	ND	ND	ND	4.3B	ND	ND	ND	5.1	ND	ND	2.3B	20B	19.5
Barium	1510	1460	139B	754	2020	138	1090	1210	1030	61.9B	784	389	420	575
Beryllium	ND	NAF	ND	NAF	1.5B	NAF	ND	NAF	NAF	ND	ND	ND	ND	NAF
Calcium	94500	NAF	71000	NAF	81000	NAF	76000	NAF	NAF	128000	78600	94700	85900	NAF
Chromium	ND	ND	ND	ND	27.2	ND	ND	ND	ND	277	106	40.5	54.8	ND
Cobalt	12.8B	NAF	6.6B	NAF	15.5B	NAF	ND	NAF	NAF	ND	ND	14.4B	ND	NAF
Copper	ND	NAF	ND	NAF	17.5B	NAF	ND	NAF	NAF	ND	ND	ND	ND	NAF
Iron	811	NAF	66.6B	NAF	13500	NAF	27.4B	NAF	NAF	40.7B	12B	556	10.3B	NAF
Lead	ND	ND	ND	ND	8.9	ND	ND	ND	ND	ND	1.2B	ND	ND	ND
Magnesium	47200	NAF	37000	NAF	55300	NAF	38300	NAF	NAF	70600	39100	44000	43400	NAF
Manganese	29.7	NAF	1590	NAF	1040	NAF	13.6B	NAF	NAF	ND	ND	25.5	ND	NAF
Nickel	64.7	66.2	35.4B	16.9	58.8	44.9	14.4B	ND	ND	93.9	14.8B	320	ND	ND
Potassium	2130UJ	NAF	2160B	NAF	4940B	NAF	1930UJ	NAF	NAF	771B	1590B	1260B	997B	NAF
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sodium	26100	NAF	68200	NAF	24100	NAF	11400	NAF	NAF	50100	12000	35500	23100	NAF
Vanadium	15.2B	NAF	ND	NAF	71.3	NAF	7.0B	NAF	NAF	ND	5.8B	4.2B	4.3B	NAF
Zinc	18.6UJ	NAF	ND	NAF	63.2	NAF	23.4UJ	NAF	NAF	ND	ND	ND	ND	NAF
Organic Analyses														
Benzene	ND	1	ND	0.6	ND	0.6	ND	ND	ND	ND	ND	ND	ND	0.7
Bromodichloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	6	ND	ND	ND	ND	ND	ND	0.9	ND	26	9	140J	ND	ND
Toluene	ND	ND	ND	2	ND	2	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	150	230	ND	ND	ND	10	ND	ND	ND	ND	ND	ND	ND	11
Isopropylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-Dichlorobenzene	ND	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.8
1,4-Dichlorobenzene	15	18	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	2
1,2-Dichlorobenzene	16	19	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	2
1,2,4-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5

Table 5-6

(Page 2 of 2)

Sample Location: Date Sampled:	MW11-1A 1991	MW1-49A 1991	MW1-49A 1992	MW1-49C 1991	MW1-49C 1992	MW1-50A 1991	MW1-50A 1992	MW1-50C 1991	MW1-50C 1992	MW1-50D 1992	MW1-51A 1991	MW1-51A 1992	MW1-51C 1991	MW1-51C 1992	MW1-52A 1991	MW1-52A 1992	MW1-52C 1991	MW1-52C 1992	MW1-53A 1991	MW1-53A 1992	MW1-53C 1992	MW1-59A 1991	MW1-59C 1991	MW1-60A 1991	MW1-60C 1991	MW-7 1992
Dimethylphthalate	ND	ND	ND	ND	ND	ND	20	ND	ND	32	ND	100	ND	98	ND	64	ND	39	ND	26	15	ND	ND	ND	ND	ND
Xylenes (total)	ND	ND	1	ND	ND	ND	2	ND	0.9	ND	ND	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	460D	490D	700	75	41	440D	150	210D	180	29	530D	330	21	7	ND	8	ND	0.5	ND	3	10	23	20	110J	18	ND
1,2-Dichloropropane	14	6	6	ND	ND	28	24	8J	8	ND	44	23	7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cis-1,2-dichloroethene	ND	ND	620	ND	39	ND	530	ND	300	41	ND	1,200.0	ND	16	ND	8	ND	ND	ND	2	10	ND	ND	ND	ND	ND
1,1-Dichloroethane	21	23	26	ND	1	64	44	32J	21	1	110	100	28	3	ND	0.8	ND	2	ND	ND	ND	ND	4J	5J	ND	0.7
Vinyl chloride	88	220D	180	23	2	290D	40	190D	52	4	890D	780	110	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene chloride	15B	16UJ	9	9UJ	1B	13UJ	4B	7UJ	1	1B	20UJ	7B	20UJ	0.7B	6BJ	0.9B	11B	1B	9UJ	1B	0.9B	13B	7B	6BJ	13B	1B
Trans-1,2-dichloroethene	ND	ND	15	ND	3	ND	20	ND	7	1	ND	15	ND	0.9	ND	0.9	ND	ND	ND	ND	0.7	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	8	13	14	ND	0.4J	7	6	15J	2	ND	6	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3J	ND	ND
1,1-Dichloroethene	32	16	25	ND	1	30	39	15J	10	0.6	28	17	7	ND	ND	0.7	ND	ND	ND	ND	ND	8	6	10J	ND	0.6
Chloroform	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	2	ND	ND	ND	21	ND	12J	ND	ND
2-Chloronaphthalene	ND	4J	4J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-butylphthalate	ND	ND	2JB	ND	1J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	28	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	180	270D	NAF	43	NAF	390D	NAF	280D	NAF	NAF	840D	NAF	79	NAF	ND	NAF	ND	NAF	ND	NAF	NAF	16	18	26J	7	NAF
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND
Ethyl benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorodifluoromethane	ND	ND	ND	ND	ND	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND	ND	2	ND	0.8	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
o-Xylene	ND	ND	1	ND	ND	ND	ND	ND	0.9	ND	ND	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sec-butylbenzene	ND	ND	0.8	ND	ND	ND	ND	ND	0.1J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3,5-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	0.1J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	0.2J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis(2-ethylhexyl)phthalate	ND	ND	ND	ND	ND	ND	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3J	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND

\+ = Prometon herbicide detected in trace amounts (<20 ppb) in samples MW1-59A and MW1-60A.
J = Presence of analyte is reliable; value shown is estimated quantity.
B = Analyte found in associated blank as well as in sample.
ND = Analyte not detected.
UJ = The material was analyzed for but was not detected. The sample quantitation limit is an estimated quantity.
NAF = The material was Not Analyzed for.

Table 5-6
Supplement

Summary of Groundwater Analytical Results
Lower Saturated Zone, Selected IWTP Wells
(Concentrations in μg/L)
SWMU-23, Abandoned Waste Tanks, Tinker AFB

(Page 1 of 2)

The 1992 round of water samples were analyzed for the following compounds, although none were detected:

1,1,1,2-Tetrachloroethane	1,1,2,2-Tetrachloroethane
1,1-Dichloropropene	1,2,3-Trichloropropane
1,2-Dibromo-3-chloropropane	1,2-Diphenylhydrazine
1,2-Dichlorobenzene-d4	1,2-Dibromoethane
1,3-Dichloropropane	1,2-Dichloroethane
2,2-Dichloropropane	1,4-Dichlorobenzene
2,4,6-Tribromophenol	2,4,5-Trichlorophenol
2,4-Dichlorophenol	2,4,6-Trichlorophenol
2,4-Dinitrophenol	2,4-Dimethylphenol
2,6-Dinitrotoluene	2,4-Dinitrotoluene
2-Flourobiphenyl	2-Chlorotoluene
2-Methylnaphthalene	2-Flourophenol
2-Nitroaniline	2-Methylphenol
3,3'-Dichlrobenzidine	2-Nitrophenol
4,6-Dinitro-2-methylphenol	3-Nitroaniline
4-Chloro-3-methylphenol	4-Bromophenyl-phenylether
4-Chlorophenyl-phenylether	4-Chloroaniline
4-Methylphenol	4-Chlorotoluene
Acenaphthene	4-Nitrophenol
Anthracene	Acenaphthylene
Benzo(A)Anthracene	Benzidine
Benzo(B)Fluoranthene	Benzo(A)Pyrene
Benzo(K)Fluoranthene	Benzo(G,H,I)Perylene
Benzyl alcohol	Benzioc acid

Table 5-6
Supplement

(Page 2 of 2)

Bis(2-chloroethyl)ether	Bis(2-chloroethoxy)methane
Bis(2-ethylhexyl)phthalate	Bis(2-chloroisopropyl)ether
Bromobenzene	Butylbenzyl phthalate
Bromomethane	Bromochloromethane
Carbon tetrachloride	Bromoform
Di-n-octyl phthalate	Chrysene
Dibenzofuran	Chloromethane
Dibromochloromethane	Dibenzo(A,H)Anthracene
Fluoranthene	Diethyl phthalate
Hexachlorobenzene	Dibromomethane
Hexachlorocyclopentadiene	Fluorene
Hexachlorobutadiene	Hexachlorobutadiene
Isophorone	Hexachloroethane
n-Nitroso-dimethlylamine	Indeno(1,2,3-CD)pyrene
Nitrobenzene	n-Nitroso-di-n-propylamine
Pentachlorophenol	n-Nitrosodiphenylamine
Phenol	Nitrobenzene-D5
Pyrene	Phenanthrene
Terphenyl-D14	Phenol-D5
n-Propylbenzene	Styrene
p-Isopropyltoluene	Trichlorofluoromethane
Tert-butylbenzene	Cis-1,3-dichloropropene
	n-Butylbenzene
	p-Bromofluorobenzene
	Trans-1,3-dichloropropene

Strong Dump A Tanks, IW-3. All metal concentrations were less than background limits. The only organic, tetrahydrofuran, was found at a low concentration (4 μg/kg) and was attributed to laboratory contamination due to its presence in the laboratory blank. The pH and oil and grease levels were not indicative of any significant spills of hydrocarbons or acid/alkali.

Strong Dump B Tanks, 1W-4. All metal concentrations were less than background levels. Methylene chloride was the only organic compound detected, at concentrations of 10 μg/kg. The pH and oil and grease levels were not indicative of any significant spills of hydrocarbon or acid/alkali.

Phenol Tank, IW-5. All metal concentrations were less than background levels. The only organic, methylene chloride, was found at a low, toxicologically insignificant concentration (less than 12 μg/kg). The pH and oil and grease values were not indicative of any significant spills of hydrocarbons or acid/alkali. Phenols were detected at 2 mg/kg in the sample 0 to 1 foot below the tank bottom, enough to technically classify any excavated material as hazardous waste.

Acid/Alkali Tanks; IW6-1, IW6-2, and IW6-3. Concentrations of chromium above background levels were detected in the 2- to 3-foot sample from boring IW6-2 and the 0- to 1-foot and 5- to 6-foot samples from boring IW6-3. These samples were tested for EP toxicity, and yielded a maximum value of 0.10 mg/L for chromium. These values were well below the 5 mg/L necessary to classify the soils as a hazardous waste due to EP toxicity for chromium. Several organics were detected in the 0- to 1-foot and 2- to 3-foot samples taken from boring IW6-1. Detected were trichloroethylene (280 and 48 μg/kg), tetrachloroethylene (560 and 62 μg/kg), toluene (19 and 0 μg/kg), chlorobenzene (9 and 7 μg/kg), ethyl benzene (13 and 0 μg/kg), and total xylenes (50 and 0 μg/kg). This data shows that the number and concentration of listed organics decreases with depth, reaching zero below 15 feet. Cyanide at concentrations of 8 mg/kg and 3 mg/kg was detected in the 2- to 3-foot samples from boring IW6-2, and the 0- to 1-foot sample from boring IW6-3, respectively. The presence of listed organics and cyanide in the soils detected in the 2- to 3-foot sample of boring IW6-2 and in the 0- to 1-foot sample from surrounding the three tanks was sufficient to classify the excavated material from acid/alkali tank area as hazardous waste. The pH and oil and grease levels were not indicative of any significant spills of hydrocarbons or acid/alkali.

5.2 Groundwater Characterization

Upper Saturated Zone. The chemical quality of the USZ was determined by the sampling of eight monitoring wells. Wells MW1-50B, MW1-51B, MW1-52B, and MW1-49B were located hydraulically upgradient and wells MW1-11B, MW1-60B, MW1-59B, and MW1-53B were located downgradient of the site. The general groundwater flow is to the west-northwest based on the Basewide current hydrologic conceptual model (Tinker, 1993). The concentration of the contaminants detected in the USZ groundwater during the two sampling events (1991 and 1992) are shown in Table 5-5 for each well.

Chromium and nickel were found in MW1-53B in 1991 at concentrations of 299 and 315 micrograms per liter (µg/L), respectively. Both metals were below detection limits in the well (MW1-53B) in 1992. Nickel was detected in the MW1-49B at a concentration of 208 µg/L in 1992. Barium was detected in MW1-50B at 2,020 µg/L in 1992. All other metals were found at low levels in 1992 in the USZ.

Sixteen VOCs were found above the detection limits in the USZ. The detected VOCs included benzene, toluene, tetrachloroethene, chlorobenzene, trichloroethane, 1-2, dichloropropane, cis-1,2-dichloroethene, 1,1-dichloroethane, vinyl chloride, methylene chloride, trans-1,2-dichloroethene, 1,1,1-trichloroethane, 1,1-dichloroethene, chloroform, 1,2-dichloroethane, and ethyl benzene. Seven of the 16 volatile organics were detected at slightly elevated levels. Benzene, tetrachloroethene, chlorobenzene, trichloroethene, cis-1,2-dichloroethene, 1,1-dichloroethene, and vinyl chloride were detected at elevated concentrations in monitoring wells MW1-51B and MW1-49B. Other VOCs were detected at lower concentrations in the USZ at the site.

Ten SVOCs including bis(2-ethylhexyl)phthalate, 2-chloronaphthalene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, dimethylphthalate, di-n-butylphthalate, 1,2,3-trichlorobenzene, and naphthalene were detected in the USZ. None of the SVOCs were detected at levels of concern in the USZ.

Lower Saturated Zone. Samples from 15 monitoring wells have been analyzed to determine the chemical quality of LSZ. Table 5-6 summarizes the groundwater analytical results for the LSZ. Chromium, antimony, barium, and nickel were detected at slightly elevated concentrations in the LSZ. Maximum concentration of nickel were found in well MW1-49A at 768 and 590 µg/L in 1991 and 1992, respectively. Antimony was detected in four wells at concentrations ranging from 21.1 to 24.7 μg/L. Barium was found in 1991 in well MW1-50C at a concentration of 2300 μg/L. Concentrations of chromium of up to a maximum value of 299 μg/L were found in MW1-59A in 1991.

VOCs and SVOCs were sporadically detected throughout the site. Tetrachloroethene, trichloroethene, vinyl chloride, and benzene were the primary VOCs in the LSZ. The primary SVOCs detected in the LSZ were 1,4-dichlorobenzene and 1,2-dichlorobenzene. These compounds were considered primary because of the frequency and concentrations throughout the site.

Benzene was detected at concentrations ranging from 1 to 9 μg/L. Tetrachloroethene was detected in 14 wells at a maximum concentration of 390 μg/L in 1992 in MW1-49A. Concentrations of vinyl chloride of up to 180 μg/L were found in the LSZ. In 1991, trichloroethene was detected at elevated levels in six wells at concentrations ranging from 24 to 490 μg/L. In 1992, trichloroethene was detected in nine wells with a maximum concentration of 700 μg/L in well MW1-49A.

Ten SVOCs were found in the LSZ: bis(2-ethylhexyl)phthalate, 2-chloronaphthalene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, dimethylphthalate, di-n-butylphthalate, 1,2,3-trichlorobenzene, and naphthalene. The only SVOC detected at elevated levels was 1,4-dichlorobenzene. Concentrations of 1,4-dichlorobenzene at 100 μg/L and 150 μg/L were detected in well MW1-49A in 1991 and 1992, respectively.

In addition, three wells (MW1-11A, MW1-59A, and MW1-60) in the northwest portions of the site contained trace amounts (less than 10 μg/L) of prometon, a nonselective pre- and post emergent herbicide used on noncrop land. There is currently no MCL established for prometon.

6.0 Potential Receptors

A specific potential human and ecological receptor search has not been performed for the Abandoned Waste Tanks. Data are available in the form of chemical analysis of soils and groundwater necessary to initiate a potential receptors search. The following sections describe the data available to begin identification of potential receptors.

6.1 Human Receptors

Tinker AFB is situated on a relatively flat expanse of grassland. Prior to the development of the Base, the area was characterized by large tracts of agricultural land. The Base currently occupies approximately 5,000 acres of semi-improved and unimproved grounds that are used for the airfield, golf course, housing area, offices, shops, and other uses characteristic of military installations.

The Garber-Wellington aquifer, which underlies Tinker AFB, is the single most important source of potable groundwater in the Oklahoma City area. The recharge area for the Garber-Wellington aquifer covers the eastern half of Oklahoma County, including Tinker AFB. Approximately 75 percent of the Base's water supply is obtained from production wells pumping from this aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by municipal distribution systems also depend on the Garber-Wellington aquifer. Communities, such as Oklahoma City, presently depending upon surface water supplies also maintain a well system drilled into this aquifer as a standby source of water in the event of drought. Lake Stanley Draper, a local surface water supply reservoir with a small portion of its drainage basin within the boundaries of Tinker AFB, serves a significant recreational function as well.

In 1989, approximately 26,000 military and civilian personnel worked at Tinker AFB. Of these, approximately 2,722 personnel occupied on-Base housing, which consisted of 530 family housing units and seven dormitories. At that time, 1,262 of these residents were children. Military personnel and their families who reside on Base represent the nearest receptors to releases from Tinker AFB.

The current land use at and near the Base is not expected to change because the facilities have decades of useful life remaining and the Base has an important and continuing mission.

However, other future land use scenarios and any human receptors associated with those scenarios may need to be considered.

6.2 Ecological Receptors

Tinker AFB lies within a grassland ecosystem, which is typically composed of grasses, forbes, and riparian (i.e., trees, shrubs, and vines associated with water courses) vegetation. This ecosystem has generally experienced fragmentation and disturbances as result of urbanization and industrialization at and near the Base. While no threatened or endangered plant species occur on the Base, the Oklahoma penstemon (*Penstemon oklahomensis*), identified as a rare plant under the Oklahoma Natural Heritage Inventory Program, thrives in several locations on Base. Tinker AFB policy considers rare species as if they were threatened or endangered and provides the same level of protection for these species.

In general, wildlife on the Base is typically tolerant of human activities and urban environments. No federal threatened or endangered species have been reported at the Base. However, one specie found on the Base, the Texas horned lizard (*Phrynosoma cornutum*), is a Federal Category 2 candidate specie and under review for consideration to be listed as threatened or endangered. Air Force policy (AFR 126-1) considers candidate species as threatened or endangered and provides the same level of protection.

The Oklahoma Department of Wildlife Conservation also lists several species within the state as Species of Special Concern. Information on these species suggests declining populations but information is inadequate to support listing, and additional monitoring of populations is needed to determine the species status. These species also receive protection by Tinker AFB as threatened or endangered species. Of these species, the Swainson's hawk (*Buteo swainsoni*) and the burrowing owl (*Athene cunicularia*) have been sighted on Tinker AFB. The Swainson hawk, a summer visitor and prairie/meadow inhabitant, has been encountered Basewide. The burrowing owl has been known to inhabit the Air Field at the Base.

7.0 Action Levels

An "action level" is defined by EPA in proposed rule 40 CFR 264.521 (55 FR 30798; 7/27/90), "Corrective Action for Solid Waste Management Units (SWMU) at Hazardous Waste Management Facilities," as a health- and environment-based level, determined by EPA to be an indicator for protection of human health and the environment. In the preamble to this proposed rule, the focus of the RFI phase is defined as "characterizing the actual environmental problems at the facilities." As part of this characterization, a comparison of the contaminant concentrations to certain action levels should be made to determine if a significant release of hazardous constituents has occurred. This comparison is then used to determine if further action or corrective measures are required for a SWMU or an AOC. The preamble to the proposed rule states that the concept of action levels was introduced because of the need for "a trigger that will indicate the need for a Corrective Measures Study (CMS) and below which a CMS would not ordinarily be required" (55 FR 30798; 7/27/90). If constituent concentrations exceed certain action levels at a SWMU or an AOC, further action or a CMS may be warranted; if constituent concentrations are below action levels, a finding of no further action may be warranted. This chapter of the report presents the initial analytical data as compared to certain potential action levels.

Action levels are concentrations of contaminants at or below which exposure to humans or the environment should not produce acute or chronic effects.

The action level information is presented in this chapter so that a constituent concentration at a sample location can be compared with its potential action level. Only constituents identified in the analysis are listed in the SWMU-23, Abandoned Waste Tanks table. Table 7-1 shows the action levels for soil, water, and air as published in federal or state regulations, policies, guidance documents, or proposed rules.

The action levels listed in Table 7-1 are:

- ***SWMU Corrective Action Levels (CAL)*** **-** The first set of action levels provided in the table are those taken from the proposed rule (40 CFR 264.521) and provided as Appendix A to the rule as "Examples of Concentrations Meeting Criteria for Action Levels." These levels are health-risk based and are provided

Table 7-1

Action Levels
SWMU-23, Abandoned Waste Tanks, Tinker AFB

(Page 1 of 2)

Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	WQS[e]	IW-1 9-15 ft	IW-2 9-15 ft	IW-3 9-15 ft	IW-4 9-15 ft	IW-5 12-18 ft	IW-6-1 12-18 ft	IW-6-2 12-18 ft	IW-6-3 12-18 ft
	Soil (mg/kg)	Water (mg/L)	Air (μg/m³)	Water (mg/L)	Soil (mg/kg)	Air (μg/m³)	Water (mg/L)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)
Organics															
1,3-Dichlorobenzene				0.6											
1,4-Dichlorobenzene				0.075											
Acetone	8000	4.0						0.019			0.021-0.033				0.026-0.053
Chlorobenzene	2000	0.7	20	0.1									0.007-0.009		
Ethyl benzene	8000	4.0		0.7			28.72						0.013		
Isopropylbenzene															
Methylene Chloride	90	0.005	0.3	0.005				0.018-0.04	0.011-0.012		0.01	0.009-0.011			0.007-0.012
Phenols	50,000	20					4615								
Tetrachloroethylene	10	0.0007	1.0	0.005									0.0056-0.062		
Tetrahydrofuran								0.008-0.009	0.007-0.009	0.004				0.003-0.004	
Toluene	20,000	10	7000	1.0			301.9						0.019		
Trichloroethylene	60			0.005									0.048-0.28		
Xylenes (total)	2.0×10^5	70	1000	10									0.05		
Inorganics															
Arsenic	80		7.0×10^{-5}	0.05	21		0.0014	1.6	1.0			1.2-1.3	1.0-1.3		1.0-2.1
Barium	4000		0.4	2	6400			73-110	93-150	38-140	23-63	23-460	27-140	47-110	54-340
Cadmium	40		0.0006	0.005			0.0841	0.6-0.8	0.5-0.7		0.7-2.0	0.5-0.7		1.4-2.3	4.1-7.0

KN/1256/SWMU23/SWMU23.7-1/04-04-94/D3

Table 7-1

(Page 2 of 2)

Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	WQS[e]	IW-1 9-15 ft	IW-2 9-15 ft	IW-3 9-15 ft	IW-4 9-15 ft	IW-5 12-18 ft	IW-6-1 12-18 ft	IW-6-2 12-18 ft	IW-6-3 12-18 ft
	Soil (mg/kg)	Water (mg/L)	Air (μg/m³)	Water (mg/L)	Soil (mg/kg)	Air (μg/m³)	Water (mg/L)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)	Range (mg/kg)
Inorganics (Continued)															
Chromium				0.1	110		3.365	46-890	7.3-8.5	7.3-12.0	11-30	7.8-11.0	7.1-26	24-130	6.4-1900
Chromium VI	400		9.0×10^{-5}												
Lead				0.015[f]	27	1.5[g]	0.025	2.6-4.4	5.5-7.1	3.9-10.0	6.4-6.7	5.2-6.2	2.6-8.1	1.6-3.9	6.0-11.0
Silver	200						64.62				0.7-2.7		0.7	1.9-4.1	63.1-47

[a]CAL - Corrective Action Levels
[b]MCL - Maximum Contaminant Levels
[c]USGS - United States Geological Survey
[d]NAAQS - National Ambient Air Quality Standards
[e]WQS - Water Quality Standards
[f]Action Level at the Tap
[g]3 Month Average

as specific examples of levels below which corrective action would not be required.

- ***Maximum Contaminant Levels (MCL) -*** These values are provided from 40 CFR Subpart G, Sections 141.60 through 0.63 as promulgated under the Safe Drinking Water Act. These levels are designated for water media only.

- ***USGS Background -*** These values are provided from the USGS report titled "Elemental Composition of Surficial Materials from Central Oklahoma" (USGS, 1991). These values represent the levels of metals which naturally occur in Central Oklahoma soils.

- ***Background -*** These levels are provided where background could be determined. Where available, background concentrations are listed for metals in soil samples taken on site, which were thought to be unaffected by releases from a unit.

- ***National Ambient Air Quality Standards (NAAQS) -*** These standards are published in 40 CFR Part 50 under the Clean Air Act and apply to point sources that emit a limited number of constituents to the air. The constituents regulated are nitrogen dioxide, sulphur dioxide, carbon monoxide, lead, ozone, and particulate matter. Currently, it is assumed that none of the SWMUs or AOCs emit these compounds in regulated quantities and no air samples have been taken which would allow for a valid comparison.

- ***Water Quality Standards (WQS) -*** The WQS are the standards for surface water quality as established by the State of Oklahoma. These standards apply to point source discharges to surface waters and have been listed for those units adjacent to surface water.

Table 7-1 also gives a brief comparative evaluation of the data collected and the related action levels. The data for each detected compound are compared with the appropriate action level in order to identify those constituents (compounds) with concentrations exceeding the action levels. This identification of the compounds above the action levels provides an indication of a potential environmental problem at a specific site. In addition, this information indicates whether there is a need for conducting a CMS so that a corrective action can be implemented/undertaken at the site.

For constituents that have a SWMU CAL and an MCL for water, the MCL will be used for the comparison. Also, constituents that do not have a USGS background value will be compared to the site background value if available.

The data included in Table 7-1 are representative of the data presented in Chapter 5.0. For each soil boring, a range was identified and used in the comparison to the action levels.

Evaluation of the soil data for the Abandoned Waste Tanks shows chromium in soil sample IW-6-3 to be above the USGS background. As groundwater beneath the Abandoned Waste Tanks site is to be addressed under the ongoing CERCLA program, no evaluation of groundwater data was performed.

8.0 Summary and Conclusions

The IWTP is located in the northeast portion of Tinker AFB, east of Douglas Boulevard and adjacent to the tributary of Soldier Creek. The Abandoned Waste Tanks were located in the southwest corner of the IWTP. The tanks consisted of 11 concrete batch processing tanks arranged in 6 groups. The tanks included two cyanide tanks, two chromium tanks, four "strong dump" tanks, one acid tank, one alkali tank, and a phenol holding tank. The tanks received a variety of wastes during their period of operation. Wastes stored in the tanks included cyanide, chromium, acids, alkali, and phenol. The batch processing tanks were constructed in 1963 and were utilized for routine wastewater treatment until 1975. From 1975 to 1985, the tanks were utilized intermittently for waste treatment.

During IRP investigations, 13 soil borings were drilled around the Abandoned Waste Tanks site. Soil samples were collected and analyzed beneath each tank group. Soil samples taken from cyanide, chromium, and "strong dump" tanks were found to contain no contamination. Soils underlying the phenol tank contained low levels of phenol. The acid/alkali tanks were contaminated with several organic compounds and cyanide.

All 11 storage tanks and associated piping were removed from the site in 1992. Soils around the tanks were excavated and disposed of in permitted waste landfills. The tanks area was restored by asphalt placement and sod replacement.

Groundwater at the Abandoned Waste Tanks site occurs in two zones: the USZ and the LSZ. A total of 23 monitoring wells were installed at the site to monitor both the USZ and the LSZ. Groundwater sampling analyses indicated contaminants found at the Abandoned Waste Tanks site included heavy metals, VOCs, and SVOCs. Contaminants in the USZ were similar to those found in the LSZ. Contaminant concentrations were approximately the same levels in the USZ as in the LSZ.

The current conditions report by USACE (1992) concluded that the removal of the 11 tanks eliminated a source of contamination to the soil and groundwater and reduced the risk associated with the site. Consequently, no further action was recommended for the Abandoned Waste Tanks site.

9.0 Recommendations

Removal of the 11 waste processing tanks and associated piping and the excavation and disposal of contaminated soils around the tanks eliminated the source of contamination at the site. Although groundwater analytical data indicated the presence of constituents of potential concern, groundwater in the vicinity of the IWTP is an operable unit to the NPL. All future groundwater assessment and evaluation will be conducted under CERCLA authority. Consequently, no further action is recommended for the Abandoned Waste Tanks site.

10.0 References

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Final Report
Phase I RCRA Facility Investigation for Appendix I Sites

VOLUME VIII

SWMU-54, Stained Drainage Ditch and Drums (Near Bldg. 17)

Department of the Air Force
Oklahoma City Air Logistics Center
Tinker Air Force Base, Oklahoma

September 1994

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List of Acronyms

AFB	Air Force Base
AOC	area of concern
BTEX	benzene, toluene, ethyl benzene, and xylene
CDM	CDM Federal Programs
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DERP	Defense Environmental Restoration Program
DOD	U.S. Department of Defense
EID	Engineering Installation Division
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
ft/ft	foot per foot
HSWA	Hazardous and Solid Waste Amendments
IRP	Installation Restoration Program
LSZ	lower saturated zone
msl	mean sea level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
PA/SI	preliminary assessment/site investigation
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation/feasibility study
RFI	RCRA Facility Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SWMU	solid waste management unit
TCLP	Toxicity Characteristic Leading Procedure
TPH	total petroleum hydrocarbons
TSD	treatment, storage, and disposal (facility)
USACE	U.S. Army Corps of Engineers
USC	U.S. Code
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USZ	upper saturated zone
UWBZ	upper water bearing zone

Executive Summary

This report provides a summary of the various investigations that have been conducted for solid waste management unit (SWMU)-54, Stained Drainage Ditch and Drums near Building 17 (BLDG 17), Tinker Air Force Base (AFB), Oklahoma. The report has been prepared to determine and document whether sufficient investigations at BLDG 17 have been performed to meet regulatory requirements. Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. The Base encompasses 5,000 acres.

Background. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints.

In 1984, Congress amended the Resource Conservation and Recovery Act (RCRA) with the Hazardous and Solid Waste Amendments (HSWA), which allow EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989, Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit. The final RCRA HSWA permit issued on July 1, 1991, requires Tinker AFB to investigate all SWMUs and areas of concern (AOC) and to perform corrective action at those identified as posing a threat to human health and the environment. The permit specifies that a RCRA Facility Investigation (RFI) be conducted for 43 identified SWMUs and two AOCs on the Base. This document has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for SWMU-54.

Source Description. Building 17, located in the north-central section of Tinker AFB, was constructed in the 1950s as a paint shop and continues to serve the base in that capacity. Throughout the years, various chemicals associated with painting activities were stored outside in a fenced, paved area adjacent to Building 17. A concrete drainage culvert extended from the paved storage area towards a storm sewer drain. The Stained Drainage Ditch and Drums are identified as BLDG 17. The material stored at BLDG 17 included paint materials, cans, thinners, acetone, methyl ethyl ketone, toluene, tape brushes, rags, and clothing filters. The exact quantities of hazardous materials that might have been kept at this site are not known.

Site Investigations. The BLDG 17 site was discovered by the U.S. Army Corps of Engineers (USACE) during the Basewide RCRA facility assessment in May 1989 (Tinker, 1992a). A paved concrete area (approximately 50 by 60 feet) southwest of Building 17 had been used for storage of chemicals generated from painting activities. The area had visible and extensive discoloration, indicating that spills may have occurred throughout the years. In addition, interviews with base personnel revealed that an on-site drainage culvert had been used to dispose of unknown chemicals in the past. No previous quantitative or qualitative studies had been performed at Building 17.

A total of 20 boreholes were drilled through the concrete pad to a depth of 7.5 feet below ground level. Composite samples were taken of the concrete and from each borehole. The composite soil samples taken were analyzed for total petroleum hydrocarbons (TPH), benzene, toluene, ethyl benzene, and xylene (BTEX), and total lead. No contaminants were detected. The concrete was removed and the underlying upper 1 foot of soil was excavated and composite samples were obtained to identify any contamination that had possibly leached through the concrete pad. The concrete pad and excavated soils were loaded into roll-off containers. One soil sample was taken from each roll-off container and analyzed for Toxicity Characteristic Leaching Procedure (TCLP) parameters. The design of this removal was completed in July 1992 and excavation and construction was completed in September 1992. Analyses performed on the samples collected during the removal confirmed that no contamination was present at this site.

Although sampling analysis indicated no contamination at Building 17, visual indications of contamination led to a selection and implementation of a remedial action for the site. Remediation of the site included excavation and disposal of the concrete pad and the underlying upper 1 foot of soil.

The removed material was disposed of as a nonhazardous waste. Clean backfill was brought on site to replace the 1 foot of soil removed and a new concrete pad was poured. Currently, the site is used for the storage of construction material and there is no plan to store chemicals at this location in the future.

Conclusions/Recommendations. Based on data evaluations, no contamination was found at this site. However, because the analyses performed on the soil samples collected were partial (because they were for BTEX, TPH, and TCLP only) it is recommended that additional soil samples be collected during the Phase II RFI. The collected sample should be analyzed for VOCs and SVOCs.

To fully evaluate the extent of soil contamination at this site it is recommended that site-specific soil background samples be collected during the Phase II RFI. This additional information along with the USGS background values should be used in the Phase II report to distinguish site-related from background concentrations in a statistically significant manner. During the development of the Phase II RFI work plan, the number of background samples to be collected, the location of the soil borings, and the soil analysis to be performed on the samples should be determined for EPA approval.

1.0 Introduction

1.1 Purpose and Scope

This document has been prepared in response to the U.S. Department of the Air Force, Tinker Air Force Base (AFB), Oklahoma request for a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Summary Report for solid waste management unit (SWMU)-54, Stained Drainage Ditch and Drums near Building 17 (BLDG 17).

The objective of this RFI Summary Report is to provide Tinker AFB with one comprehensive report that summarizes the various investigations that have occurred at BLDG 17 since the first environmental investigation was initiated on Base in 1981. The purpose of this comprehensive summary document is to:

- Characterize the site (Environmental Setting).
- Define the source (Source Characterization).
- Define the degree and extent of contamination (Contamination Characterization).
- Identify actual or potential receptors.
- Identify all action levels for the protection of human health and the environment.

Additionally, this document briefly describes the procedures, methods, and results of all previous investigations and remedial actions that relate to BLDG 17 and contaminant releases, including information on the type and extent of contamination at the site, and actual or potential receptors. Where previous investigations, reports, or studies were not comprehensive and did not furnish the information required to determine the nature and extent of contamination, future work that can be conducted to complete the investigation has been recommended.

1.2 Preface

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the cleanup of hazardous waste disposal sites across the country. CERCLA gave the president authority to require responsible parties to remediate the sites or to undertake response actions through use of a fund (the Superfund). The president, through Executive Order 12580, delegated the U.S. Environmental Protection Agency (EPA) with the responsibility to investigate and remediate private party hazardous waste disposal sites that created a threat to human health and the environment. The president delegated responsibility for investigation and cleanup of federal facility disposal sites to the various federal agency heads. The Defense Environmental Restoration Program (DERP) was formally

established by Congress in Title 10 U.S. Code (USC) 2701-2707 and 2810. DERP provides centralized management for the cleanup of U.S. Department of Defense (DOD) hazardous waste sites consistent with the provisions of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300), and Executive Order 12580. To support the goals of DERP, the Installation Restoration Program (IRP) was developed to identify, investigate, and clean up contamination at installations.

Under the Air Force IRP, Tinker AFB began a Phase I study similar to a preliminary assessment/site investigation (PA/SI) in 1981 (Engineering Science [ES], 1982). This study helped locate 14 sites that needed further investigation. A Phase II study was performed in 1983 (Radian Corporation [Radian], 1985a,b).

In 1986, Congress amended CERCLA through the SARA. SARA waived sovereign immunity for federal facilities. This act gave EPA authority to oversee the cleanup of federal facilities and to have the final authority for selecting the remedial action at federal facilities placed on the National Priorities List (NPL) if the EPA and the relevant federal agency cannot concur in the selection. Congress also codified DERP (SARA Section 211), establishing a fund for the DOD to remediate its sites because the Superfund is not available for the cleanup of federal facilities. DERP specifies the type of cleanup responses that the fund can be used to address.

In response to SARA, the DOD realigned its IRP to follow the investigation and cleanup stages of the EPA:

- PA/SI
- Remedial investigation/feasibility study (RI/FS)
- Record of Decision (ROD) for selection of a remedial action
- Remedial design/remedial action.

In 1984, Congress amended RCRA with the Hazardous and Solid Waste Amendments (HSWA) which allow the EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989 Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit.

EPA, in the Hazardous Waste Management Permit for Tinker AFB, dated July 1, 1991, identified 43 SWMUs and two areas of concern (AOC) on Tinker AFB that need to be addressed. This permit requires Tinker AFB to investigate all SWMUs and AOCs and to perform corrective action at those identified as posing a threat to human health or the environment. This RFI Summary Report has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for BLDG 17 and to document all determinations.

1.3 Facility Description

Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County (Figure 1-1) with its approximate geographic center located at 35^{o} 25' latitude and 97^{o} 24' longitude (U.S. Geological Survey [USGS], 1978). The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. An additional area east of the main Base is used by the Engineering Installation Division (EID) and is known as Area D. The Base encompasses approximately 5,000 acres. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints. Wastes that are currently generated are managed at two permitted hazardous waste storage facilities. However, prior to enactment of RCRA, industrial wastes were discharged into unlined landfills and waste pits, streams, sewers, and ponds. Past releases from these landfills, pits, etc., as well as from underground tanks, have occurred. As a result, there are numerous sites of soil, groundwater, and surface water contamination on the Base.

The various reports generated as a result of investigative activities conducted at BLDG 17 have been reviewed and evaluated in terms of the sites' status under RCRA regulations. A summary based on the review of these reports for BLDG 17 is presented in the following chapters and sections. In addition, recommendations for additional work is given at the end of the summary report.

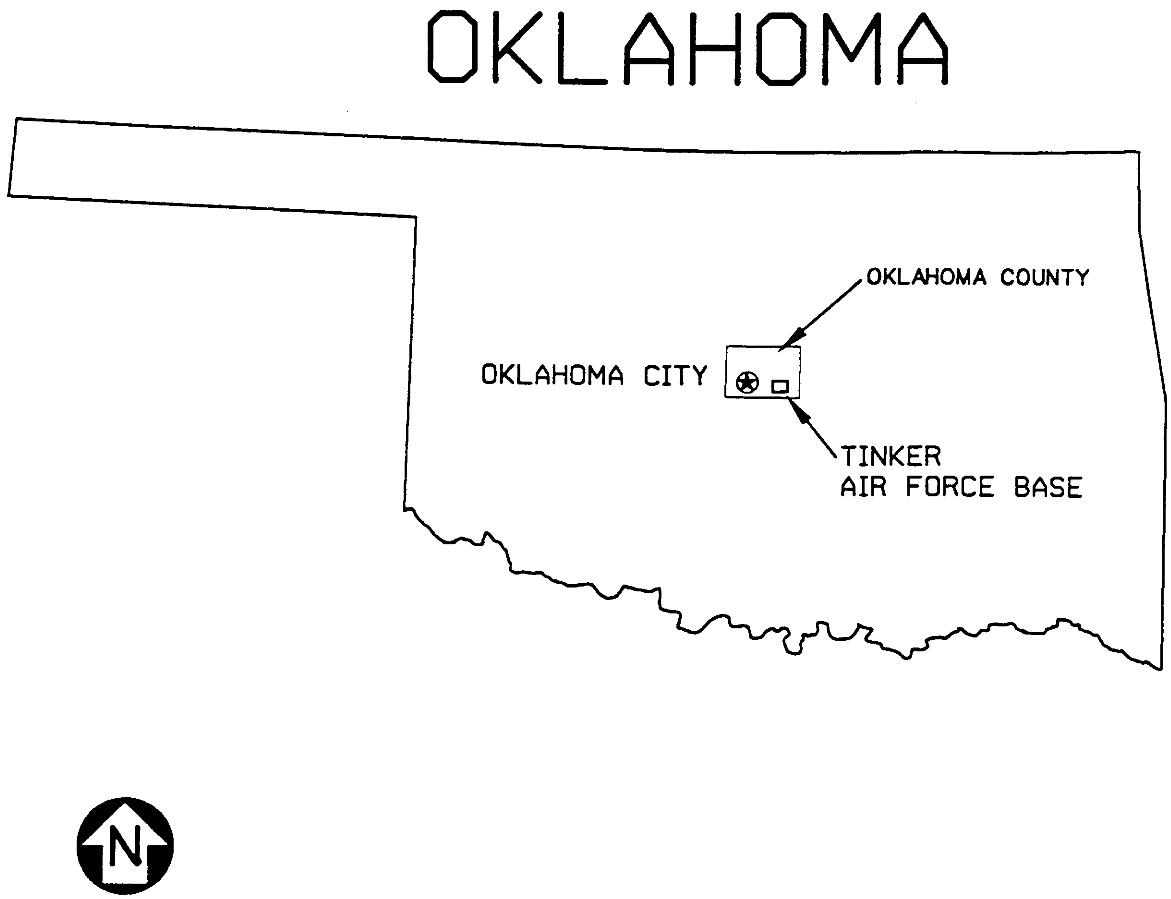


FIGURE 1-1
TINKER AIR FORCE BASE
OKLAHOMA
STATE INDEX MAP

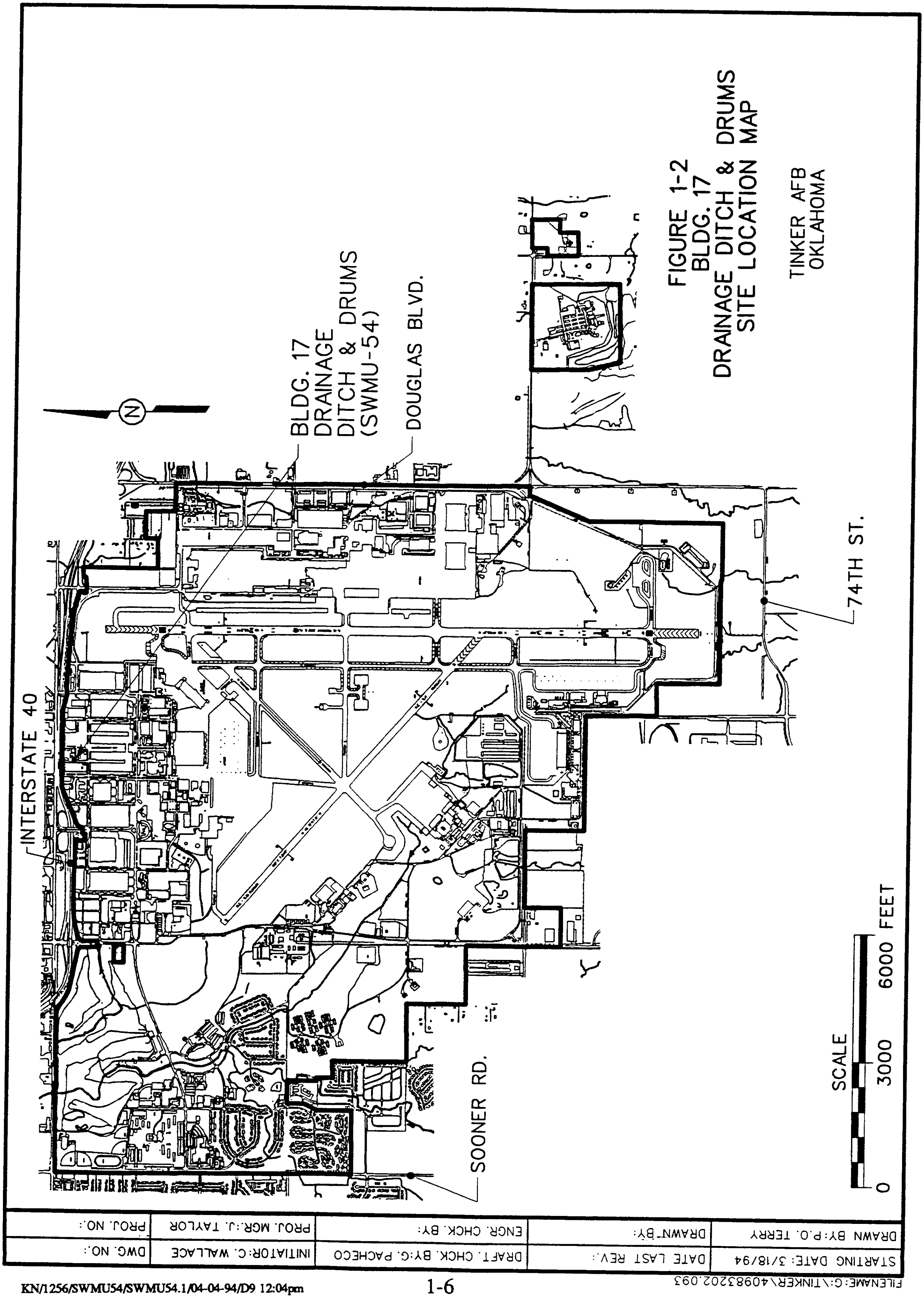
PREPARED FOR
TINKER AFB
OKLAHOMA

STARTING DATE: 03/17/94 | DATE LAST REV.: | DRAFT. CHCK. BY: G. PACHECO | INITIATOR: C. WALLACE | DWG. NO.:
DRAWN BY: P.O. TERRY | DRAWN BY: | ENGR. CHCK. BY: C. WALLACE | PROJ. MGR.: J. TAYLOR | PROJ. NO.:

3/23/94 POT
FILENAME: G:\TINKER\40983202.075

1.4 Site Description

Building 17 is located in the north-central section of Tinker AFB approximately 300 feet south of the Base boundary and Interstate 40. BLDG 17 consists of a paved storage area and a drainage ditch, located to the southwest of Building 17. Figure 1-2 shows the location of the site in relationship to Tinker AFB.



INTERSTATE 40
BLDG. 17 DRAINAGE DITCH & DRUMS (SWMU-54)
DOUGLAS BLVD.
74TH ST.
SOONER RD.
N
SCALE
0
3000
6000 FEET
FIGURE 1-2
BLDG. 17
DRAINAGE DITCH & DRUMS
SITE LOCATION MAP
TINKER AFB
OKLAHOMA
DRAWN BY: P.O. TERRY
DRAWN BY:
ENGR. CHCK. BY:
PROJ. MGR.: J. TAYLOR
PROJ. NO.:
STARTING DATE: 3/18/94
DATE LAST REV.:
DRAFT. CHCK. BY: G. PACHECO
INITIATOR: C. WALLACE
DWG. NO.:
FILENAME: G:\TINKER\40983202.093

2.0 Background

2.1 Site Operations and History

Tinker AFB was originally known as the Midwest Air Depot and began operations in July 1941. The site was activated March 1942. During World War II, the depot was responsible for reconditioning, modifying, and modernizing aircraft, vehicles, and equipment.

Building 17, located in the north-central section of Tinker AFB, was constructed in the 1950s primarily for the staging of paint-related material for Basewide usage (Tinker, 1992a). Throughout the years, various chemicals associated with painting activities were stored outside in a fenced, paved area adjacent to Building 17. An on-site drainage culvert extended from the storage area to a storm sewer drain in the vicinity of Building 17. The storage area and the drainage culvert are identified as BLDG 17. The materials stored at BLDG 17 included paint materials, cans, thinners, acetone, methyl ethyl ketone, toluene, tape brushes, rags, and clothing filters. The exact quantities of hazardous materials that might have been kept at the BLDG 17 site are not known.

2.2 Summary of Previous Investigations

BLDG 17 Site was discovered by the U.S. Army Corps of Engineers (USACE) during the Basewide RCRA facility assessment in May 1989 (Tinker, 1992b). A paved concrete area (approximately 50 by 60 feet) southwest of Building 17 had been used for storage of chemicals generated from painting activities. The area had visible and extensive discoloration, indicating that spills may have occurred throughout the years. In addition, interviews with Base personnel revealed that an on-site drainage culvert had been used to dispose of unknown chemicals in the past. No previous quantitative or qualitative studies had been performed at BLDG 17.

A total of 20 boreholes were drilled through the concrete pad to a depth of 7.5 feet below ground level. Soil samples were taken from each borehole. The soil samples were composited every foot, beginning at 2.5 feet below ground surface, and in every borehole for a total of 100 soil samples. The 100 soil samples were analyzed for total petroleum hydrocarbons (TPH), benzene, toluene, ethyl benzene, and xylene (BTEX) and total lead. The concrete pad was broken and the broken concrete was removed and loaded into roll-off containers. The next 1 foot of soil underlying the concrete pad was removed and loaded into roll-off containers. One soil sample was taken from each of the roll-off containers containing soil; that sample analyzed for Toxicity Characteristic Leaching Procedure (TCLP) parameters. The design of this removal was completed in July 1992, and the excavation and construction was completed in September 1992. The results of the TCLP analysis were used for disposal purposes. The results of all analyses performed on the samples collected during the removal revealed that no contamination was present at this site. Figure 2-1 shows the soil boring locations of BLDG 17.

2.3 Current Regulatory Status

The IRP has been ongoing at Tinker AFB since the early 1980s. IRP studies on the Base were conducted according to IRP guidance, which is essentially the same as EPA's guidance for conducting RI/FS under CERCLA. All investigation and removal actions have been closely monitored and approved by the EPA.

Since receiving the Hazardous Waste Management Permit on July 1, 1991, many of the IRP sites have come under the jurisdiction of the RCRA permits branch of EPA. As such, they have been identified as SWMUs; however, a large amount of work has already been performed at most of these sites under the IRP. Additional investigation at the SWMUs will be performed under the IRP.

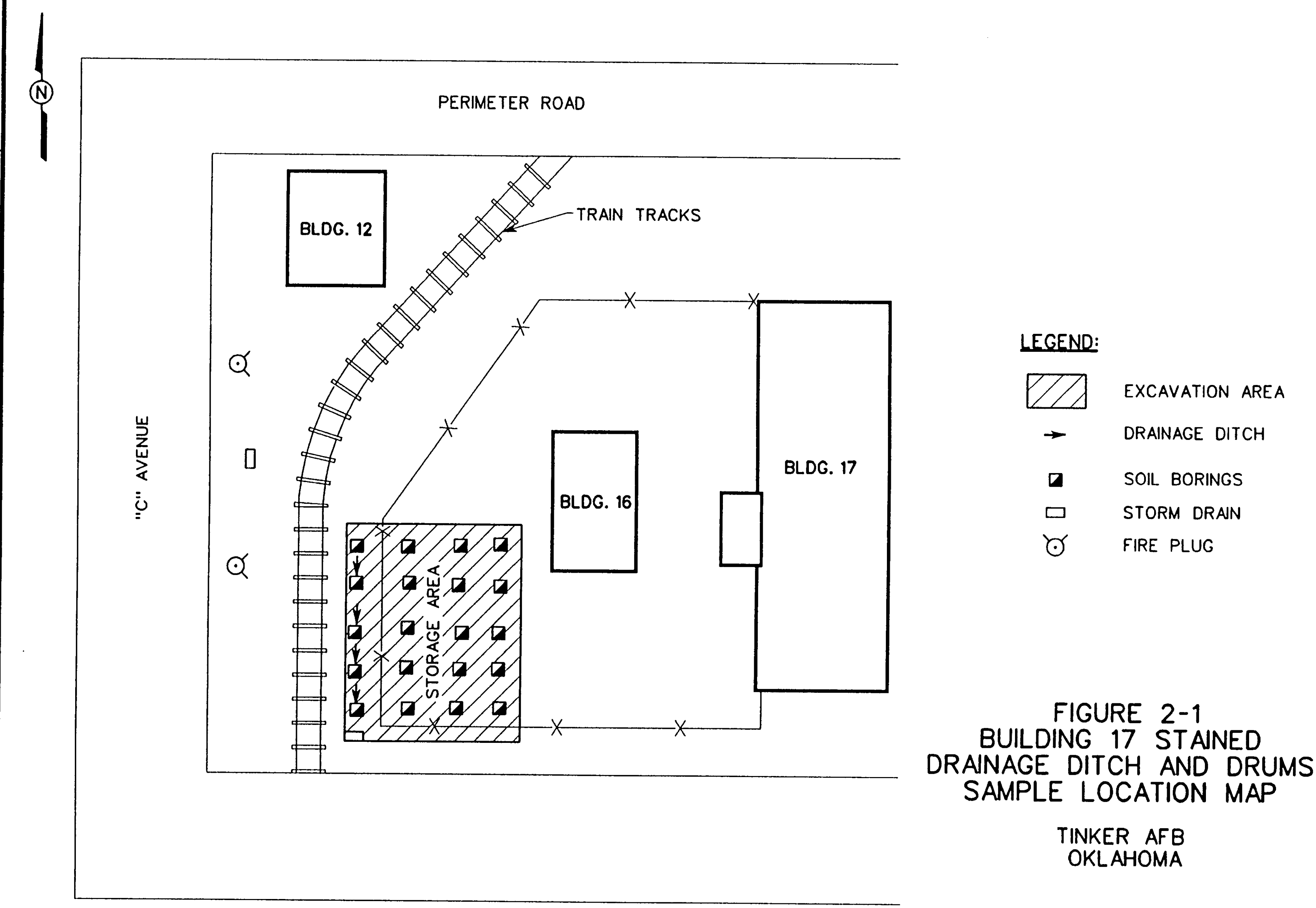


FIGURE 2-1
BUILDING 17 STAINED
DRAINAGE DITCH AND DRUMS
SAMPLE LOCATION MAP

TINKER AFB
OKLAHOMA

STARTING DATE: 03/28/94	DATE LAST REV.:	DRAFT. CHCK. BY: G. PACHECO	INITIATOR: C. WALLACE	DWG. NO.:
DRAWN BY: L. STOUT	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J. TAYLOR	PROJ. NO.:

FILENAME: G:\TINKER\40983202.096

3.0 Environmental Setting

3.1 Topography and Drainage

3.1.1 Topography

Regional/Tinker AFB. The topography of Oklahoma City and surrounding area varies from generally level to gently rolling in appearance. Local relief is primarily the result of dissection by erosional activity or stream channel development. At Oklahoma City, surface elevations are typically in the range of 1,070 to 1,400 feet mean sea level (msl). At Tinker AFB, ground surface elevations vary from 1,190 feet msl near the northwest corner where Crutcho Creek intersects the Base boundary to approximately 1,320 feet msl at Area D (EID).

Site. No site-specific topographic information was available on BLDG 17.

3.1.2 Surface Drainage

Regional/Tinker AFB. Drainage of Tinker AFB land areas is accomplished by overland flow of runoff to diversion structures and then to area surface streams, which flow intermittently. The northeast portion of the Base is drained primarily by unnamed tributaries of Soldier Creek, which is itself a tributary of Crutcho Creek. The north and west sections of the Base, including the main instrument runway, drain to Crutcho Creek, a tributary of the North Canadian River. Two small unnamed intermittent streams crossing installation boundaries south of the main instrument runway generally do not receive significant quantities of Base runoff due to site grading designed to preclude such drainage. These streams, when flowing, extend to Stanley Draper Lake, approximately one-half mile south of the Base.

Site. At the BLDG 17 site, the storm water culvert located on the southwest corner of Building 17 ultimately drains into Kuhlman Creek.

3.2 Geology

3.2.1 Regional/Tinker AFB Geology

Tinker AFB is located within the Central Redbed Plain Section of the Central Lowland physiographic province, which is tectonically stable. No major fault or fracture zones have been mapped near Tinker AFB. The major lithologic units in the area of the Base are relatively flat-lying and have a regional westward dip of about 0.0076 foot per foot (ft/ft) (Bingham and Moore, 1975).

Geologic formations that underlie Tinker AFB include, from oldest to youngest, the Wellington Formation, Garber Sandstone, and the Hennessey Group; all are Permian in age.

All geologic units immediately underlying Tinker AFB are sedimentary in origin. The Garber Sandstone and Wellington Formation are commonly referred to as the Garber-Wellington Formation due to strong lithologic similarities. These formations are characterized by fine-grained, calcareously-cemented sandstones interbedded with shale. The Hennessey Group consists of the Fairmont Shale and the Kingman Siltstone. It overlies the Garber-Wellington Formation along the eastern portion of Cleveland and Oklahoma counties. Quaternary alluvium is found in many undisturbed streambeds and channels located within the area.

Stratigraphy. Tinker AFB lies atop a sedimentary rock column composed of strata that ranges in age from Cambrian to Permian above a Precambrian igneous basement. Quaternary alluvium and terrace deposits can be found overlying bedrock in and near present-day stream valleys. At Tinker AFB, Quaternary deposits consist of unconsolidated weathered bedrock, fill material, wind-blown sand, and interfingering lenses of sand, silt, clay, and gravel of fluvial origin. The terrace deposits are exposed where stream valleys have downcut through older strata and have left them topographically above present-day deposits. Alluvial sediments range in thickness from less than a foot to nearly 20 feet.

Subsurface (bedrock) geologic units which outcrop at Tinker AFB and are important to understanding groundwater and contaminant concerns at the Base consist of, in descending order, the Hennessey Group, the Garber Sandstone, and the Wellington Formation (Table 3-1). These bedrock units were deposited during the Permian Age (230 to 280 million years ago) and are typical of redbed deposits formed during that period. They are composed of a conformable sequence of sandstones, siltstones, and shales. Individual beds are lenticular and vary in thickness over short horizontal distances. Because lithologies are similar and because of a lack of fossils or key beds, the Garber Sandstone and the Wellington Formation are difficult to distinguish and are often informally lumped together as the Garber-Wellington Formation. Together, they are about 900 feet thick at Tinker AFB. The interconnected, lenticular nature of sandstones within the sequence forms complex pathways for groundwater movement.

Table 3-1

Major Geologic Units in the Vicinity of Tinker AFB
(Modified from Wood and Burton, 1968)

(Page 1 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
QUATERNARY	PLEISTOCENE	Alluvium	0-70	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel in the flood plains and channels of stream	Moderately permeable. Yields small to moderate quantities of water in valleys of larger streams. Water is very hard, but suitable for most uses, unless contaminated by industrial wastes or oil field brines.
	AND RECENT	Terrace deposits	0-100	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the flood plains of the principal streams.	Moderately permeable. Locally above the water table and not saturated. Where deposits have sufficient saturated thickness, they are capable of yielding moderate quantities of water to wells. Water is moderately hard to very hard, but less mineralized than water in other aquifers. Suitable for most uses unless contaminated by oil field brines.

Table 3-1

(Page 2 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
PERMIAN	LOWER PERMIAN	Hennessey Group (includes Kingman Siltstone and Fairmont Shale)	700	Deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy or limey shale. Forms relatively flat to gently rolling grass-covered prairie.	Poorly permeable. Yields meager quantities or very hard, moderately to highly mineralized water to shallow domestic and stock wells. In places water contains large amounts of sulfate.
		Garber Sandstone	500±	Deep-red clay to reddish-orange, massive and cross-bedded fine-grained sandstone interbedded and interfingered with red shale and siltstone	Poorly to moderately permeable. Important source of groundwater in Cleveland and Oklahoma counties. Yields small to moderate quantities of water to deep wells; heavily pumped for industrial and municipal uses in the Norman and Midwest City areas. Water from shallow wells hard to very hard; water from deep wells moderately hard to soft. Lower part contains water too salty for domestic and most industrial uses.
		Wellington Formation	500±	Deep-red to reddish-orange massive and cross-bedded fine-grained sandstone interbedded with red, purple, maroon, and gray shale. Base of formation not exposed in the area.	

The surficial geology of the north section of the Base is dominated by the Garber Sandstone, which outcrops across a board area of Oklahoma County. Generally, the Garber outcrop is covered by a veneer of soil and/or alluvium up to 20 feet thick. To the south, the Garber Sandstone is overlain by outcropping strata of the Hennessey Group, including the Kingman Siltstone and the Fairmont Shale (Bingham and Moore, 1975). Drilling information obtained as a result of geotechnical investigations and monitoring well installation confirms the presence of these units.

Depositional Environment. The Permian-age strata presently exposed at the surface in central Oklahoma were deposited along a low-lying north-south oriented coastline. Land features included meandering to braided sediment-loaded streams that flowed generally westward from highlands to the east (ancestral Ozarks). Sand dunes were common, as were cut-off stream segments that rapidly evaporated. The climate was arid and vegetation sparse. Off shore the sea was shallow and deepened gradually to the west. The shoreline's position varied over a wide range. Isolated evaporitic basins frequently formed as the shoreline shifted.

Across Oklahoma, this depositional environment resulted in an interfingering collage of fluviatile and wind-blown sands, clays, shallow marine shales, and evaporite deposits. The overloaded streams and evaporitic basins acted as sumps for heavy metals such as iron, chromium, lead, and barium. Oxidation of iron in the arid climate resulted in the reddish color of many of the sediments. Erosion and chemical breakdown of granitic rocks from the highlands resulted in extensive clay deposits. Evaporite minerals such as anhydrite ($CaSO_4$), barite ($BaSO_4$), and gypsum ($CaSO_4 \bullet 2H_2O$) are common.

Around Tinker AFB, the Hennessey Group represents deposition in a tidal flat environment cut by shallow, narrow channels. The Hennessey Group is comprised predominantly of red shales which contain thin beds of sandstone (less than 10 feet thick) and siltstone. In outcrop, "mudball" conglomerates, burrow surfaces, and dessication cracks are recognized. These units outcrop over roughly the southern half of the Base, thickening to approximately 70 feet in the southwest from their erosional edge (zero thickness) across the central part of Tinker AFB.

In contrast, the Garber Sandstone and the Wellington Formation around Tinker AFB consist of an irregularly-interbedded system of lenticular sandstones, siltstones, and shales deposited either in meandering streams in the upper reaches of a delta or in a braided stream environment. Outcrop units north of Tinker AFB exhibit many small to medium channels with cut and fill geometries consistent with a stream setting. Sandstones are typically cross-bedded. Individual beds range in thickness from a few inches to approximately 50 feet and appear massive, but thicker units are often formed from a series of "stacked" thinner beds. Geophysical and lithologic well logs indicate that from 65 to 75 percent of the Garber Sandstone and the Wellington Formation are composed of sandstone at Tinker AFB. The percentage of sandstone in the section decreases to the north, south, and west of the Base. These sandstones are typically fine to very fine grained, friable, and poorly cemented. However, where sandstone is cemented by red muds or by secondary carbonate or iron cements, local thin "hard" intervals exist along disconformities at the base of sandstone beds. Shales are described as ranging from clayey to sandy, are generally discontinuous, and range in thickness from a few inches to approximately 40 feet.

Stratigraphic Correlation. Correlation of geologic units is difficult due to the discontinuous nature of the sandstone and shale beds. However, cross-sections (Figure 3-1) demonstrate that two stratigraphic intervals can be correlated over large sections of the Base in the conceptual model. These intervals are represented on geologic cross-sections A-A' and B-B' (Figures 3-2 and 3-3). Section A-A' is roughly a dip section and B-B' is approximately a strike section. The first correlatable interval is marked by the base of the Hennessey Group and the first sandstone at the top of the Garber Sandstone. This interval is mappable over the southern half of Tinker AFB. The second interval consists of a shale zone within the Garber Sandstone which, in places, is comprised of a single shale layer and, in other places, of multiple shale layers. This interval is more continuous than other shale intervals and in cross-sections appears mappable over a large part of the Base. It is extrapolated under the central portion of Tinker AFB where little well controls exists.

Structure. Tinker AFB lies within a tectonically stable area; no major near-surface faults or fracture zones have been mapped near the Base. Most of the consolidated rock units of the Oklahoma City area dip westward at a low angle. A regional dip of 0.0057 to 0.0076 ft/ft in a generally westward direction is supported by stratigraphic correlation on geologic cross-sections at Tinker AFB. Bedrock units strike slightly west of north.

Although Tinker AFB lies in a tectonically stable area, regional dips are interrupted by buried structural features located west of the Base. A published east-to-west generalized geologic cross-section, which includes Tinker AFB, supports the existence of a northwest-trending structural trough or syncline located near the western margin of the base. The syncline is

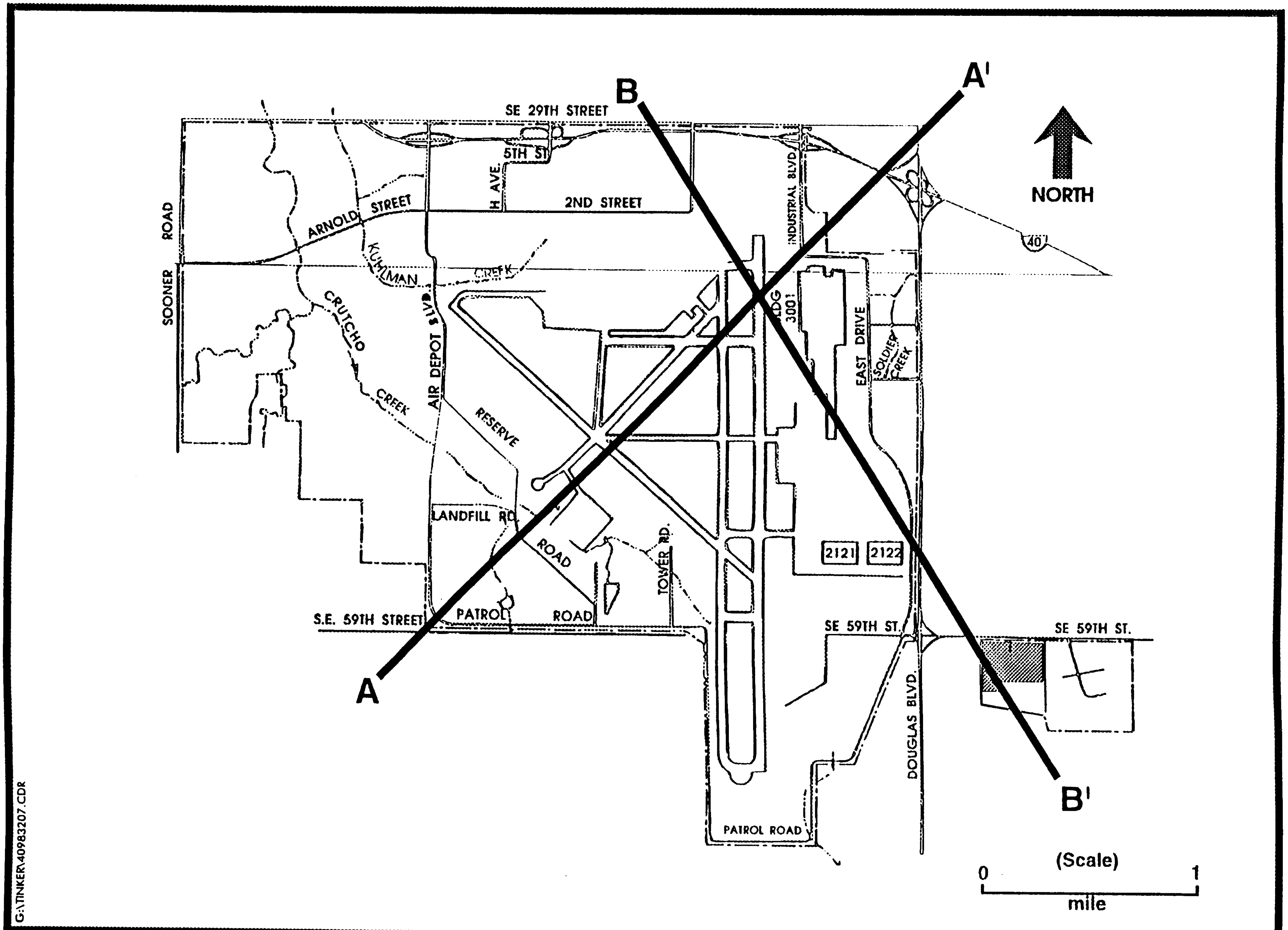


FIGURE 3-1 TINKER AFB GEOLOGIC CROSS SECTION LOCATION MAP

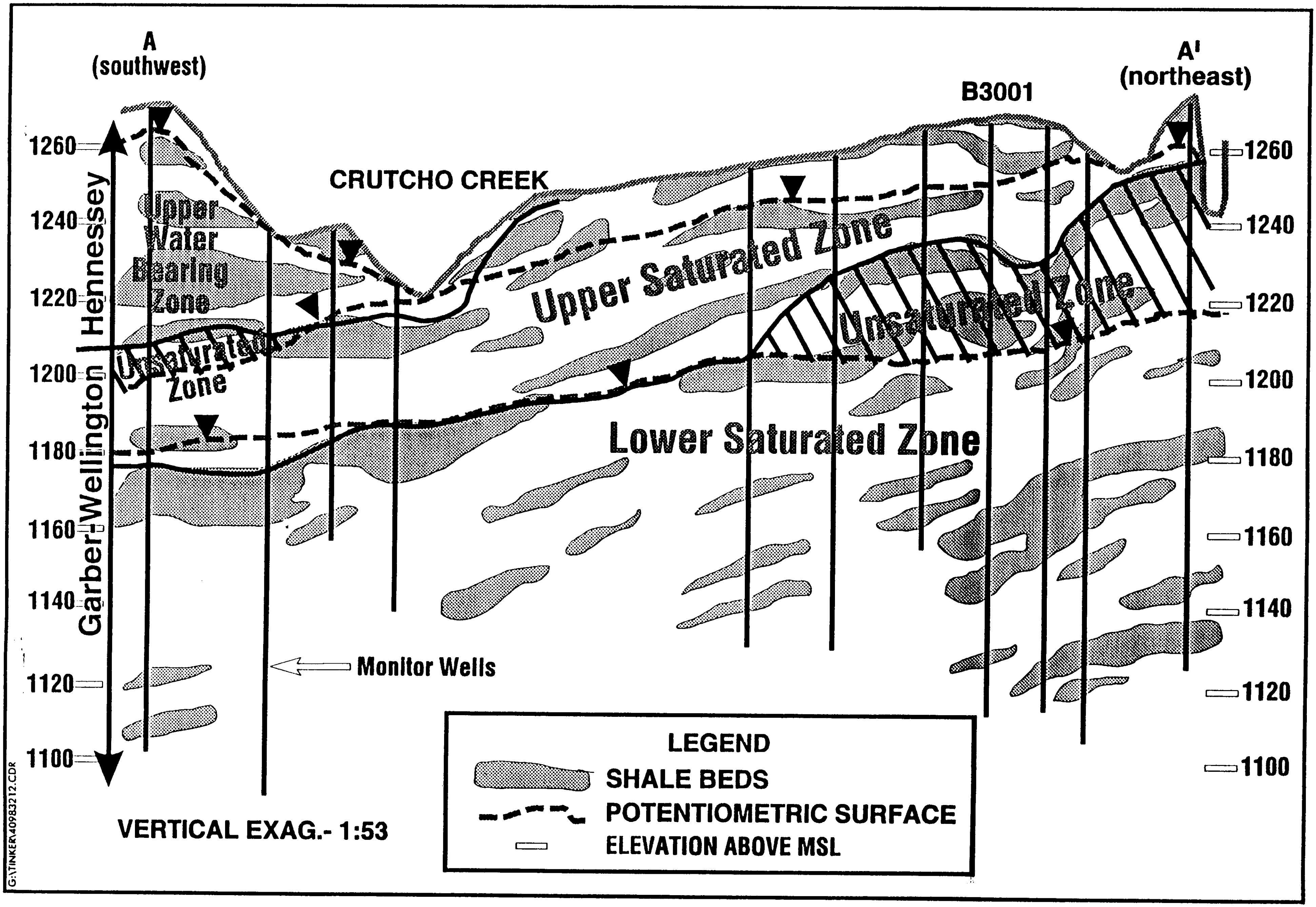


FIGURE 3-2 TINKER AFB GEOLOGIC CROSS SECTION A-A'

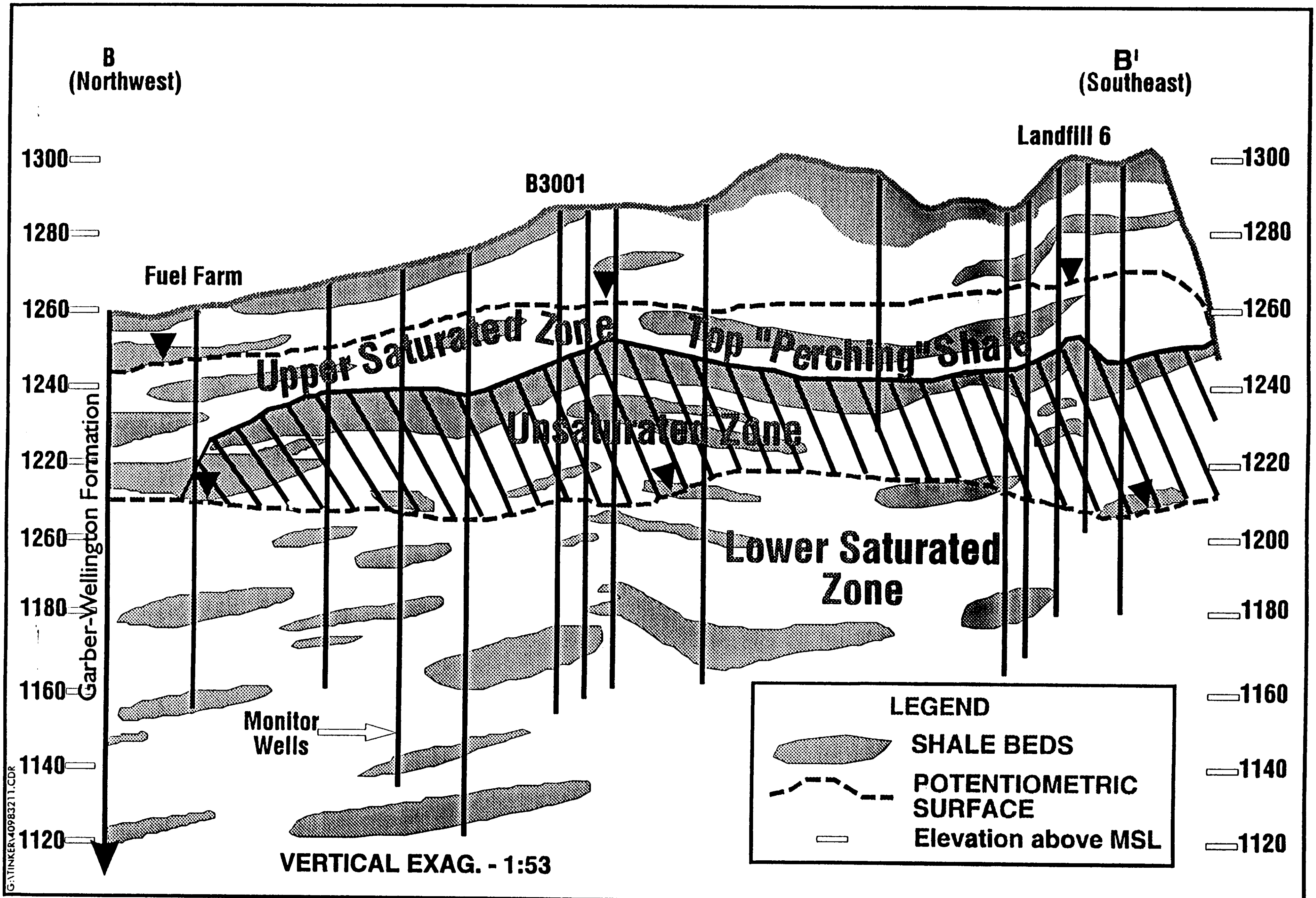


FIGURE 3-3 TINKER AFB GEOLOGIC CROSS SECTION B-B'

mapped adjacent to and just east of a faulted anticlinal structure located beneath the Oklahoma City Oil Field. The fault does not appear to offset Permian-age strata. There are indications that the syncline may act as a "sink" for some regional groundwater (southwest flow) at Tinker AFB before it continues to more distant discharge points.

3.2.2 Site Geology

BLDG 17 is located in the Interior Lowlands physiographic province on gently westward dipping Permian redbeds. Bedrock units encountered at Tinker AFB include the Garber-Wellington Formation and the overlying Hennessey Formation.

The Garber Sandstone and Wellington Formations are hydrologically interconnected units which are not easily distinguished from other rock types. Sediments of the Garber-Wellington are deltaic in origin and the stream-deposited sandstones interfinger with marine shales. Because of shifting channels and changing currents during deposition, detailed correlation of lithologic units is possible only over short distances.

BLDG 17 is located in an area where the Garber-Wellington geological formation exists singularly and begins at the ground surface.

3.3 Hydrology

3.3.1 Regional/Tinker AFB Hydrology

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer system. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove, and Admire Groups. The Garber Sandstone and the Wellington Formation portion of the Central Oklahoma aquifer system is commonly referred to as the "Garber-Wellington aquifer" and is considered to be a single aquifer because these units were deposited under similar conditions and because many of the best producing wells are completed in this zone. On a regional scale, the aquifer is confined above by the less permeable Hennessey Group and below by the Late Pennsylvanian Vanoss Group.

Tinker AFB lies within the limits of the Garber-Wellington Groundwater Basin. Currently, Tinker derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest

City and Del City derive water supplies from both surface sources and wells tapping the aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by a municipal distribution system also depend on the Garber-Wellington aquifer. Communities presently depending upon surface supplies (such as Oklahoma City) also maintain a well system drilled into the Garber-Wellington as a standby source of water in the event of drought.

Recharge of the Garber-Wellington aquifer is accomplished principally by percolation of surface waters crossing the area of outcrop and by rainfall infiltration in this same area. Because most of Tinker AFB is located in an aquifer outcrop area, the Base is considered to be situated in a recharge zone.

According to Wood and Burton (1968) and Wickersham (1979), the quality of groundwater derived from the Garber-Wellington aquifer is generally good, although wide variations in the concentrations of some constituents are known to occur. Wells drilled to excessive depths may encounter a saline zone, generally greater than 900 feet below ground surface. Wells drilled to such depths or those accidentally encountering the saline zone are either grouted over the lowest screens or may be abandoned.

Tinker AFB presently obtains its water supplies from a distribution system comprised of 29 water wells constructed along the east and west Base boundaries and by purchase from the Oklahoma City Water Department. All Base wells are finished into the Garber-Wellington aquifer. Base wells range from 700 to 900 feet in finished depth, with yields ranging from 205 to 250 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones with a combined thickness from 103 to 184 feet (Wickersham, 1979).

Although the variability in the geology and the recharge system at Tinker AFB makes it difficult to predict local flow paths, Central Oklahoma aquifer water table data show that regional groundwater flow under Tinker varies from west-northwest to southwest, depending on location. This theory is supported by contoured potentiometric data from base monitoring wells which show groundwater movement in the upper and lower aquifer zones to generally follow regional dip. Measured normal to potentiometric contours, groundwater flow gradients range from 0.0019 to 0.0057 ft/ft. However, because flow in the near-surface portions of the aquifer at Tinker AFB is strongly influenced by topography, local stream base-levels, complex subsurface geology, and location in a recharge area, both direction and magnitude of groundwater movement is highly variable. The interaction of these factors not only influences regional flow but gives rise to complicated local, often transient, flow patterns at individual sites.

As a result of ongoing environmental investigations and the approximately 450 groundwater monitoring wells installed on the Base during various investigations, a better understanding of the specific hydrological framework has emerged. The current conceptual model developed by Tinker AFB (Tinker, 1993), based on the increased understanding of the hydrological framework, has been revised from an earlier model adopted by the USACE. Previous studies reported that groundwater was divided into four water-bearing zones: the perched aquifer, the top of regional aquifer, the regional aquifer, and the producing zone. In the current model, two principal water table aquifer zones and a third less extensive zone have been identified. The third is limited to the southwest quadrant. The third aquifer zone consisted of saturated siltstone and thin sandstone beds in the Hennessey Shale and equates to the upper water bearing zone (UWBZ) described by the USACE (USACE, 1993) at Landfills No. 1 through 4 (SWMUs 3 through 6). In addition, numerous shallow, thin saturated beds of siltstone and sandstone exist throughout the Base. These are of limited areal extent and are often perched.

In the current conceptual hydrologic model, an upper saturated zone (USZ) and a lower saturated zone (LSZ) are recognized in the interval from ground surface to approximately 200 feet. Below this is found the producing zone from which the Base draws much of its water supply. Figure 3-4 shows the potentiometric surface for the USZ and Figure 3-5 shows the potentiometric surface for the LSZ. The USZ exists mainly under water table (unconfined) conditions, but may be partially confined locally. Conditions in the LSZ are difficult to determine due to screen placement and overly long sandpacks below the screen interval.

The USZ is found at a depth of 5 to 70 feet below ground surface and has a saturated thickness ranging from less than 1 foot at its eastern boundary to over 20 feet in places west of Building 3001. The USZ is erosionally truncated by Soldier Creek along the northeastern margin of Tinker AFB. This aquifer zone is considered to be a perched aquifer over the eastern one-third of Tinker AFB, where it is separated from the LSZ by an underlying confining shale layer and a vadose zone. The confining interval extends across the entire Base, but the vadose zone exists over the eastern one-third of this area. The available hydrogeologic data indicate that the vadose zone does not exist west of a north-south line located approximately 500 to 1,000 feet west of the main runway; consequently, the USZ is not perched west of this line. However, based on potentiometric head data from wells

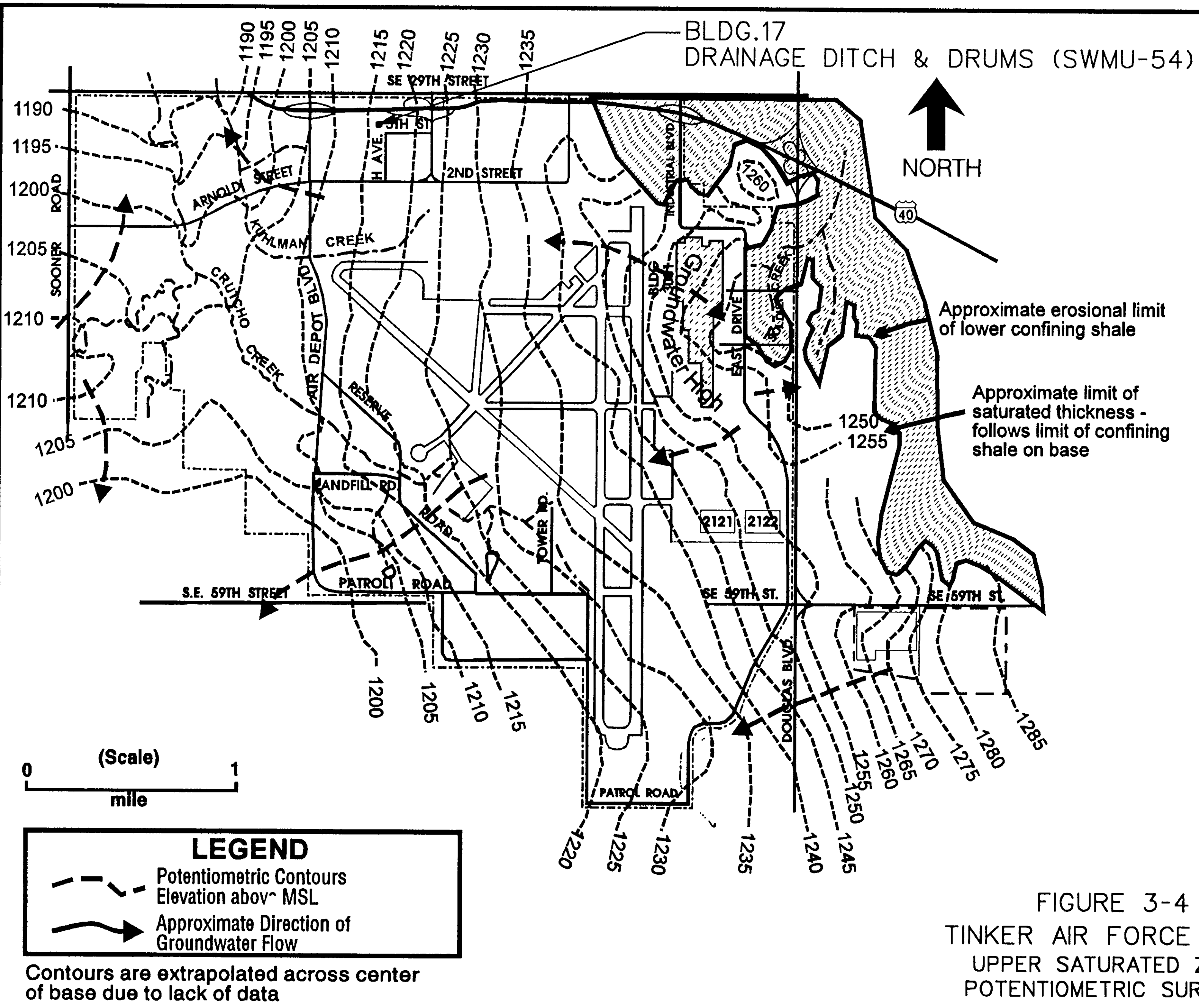


FIGURE 3-4
TINKER AIR FORCE BASE
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C.WALLACE	DWG. NO.:40983209C.
DRAWN BY: C.E.TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J.TAYLOR	PROJ. NO.:409832

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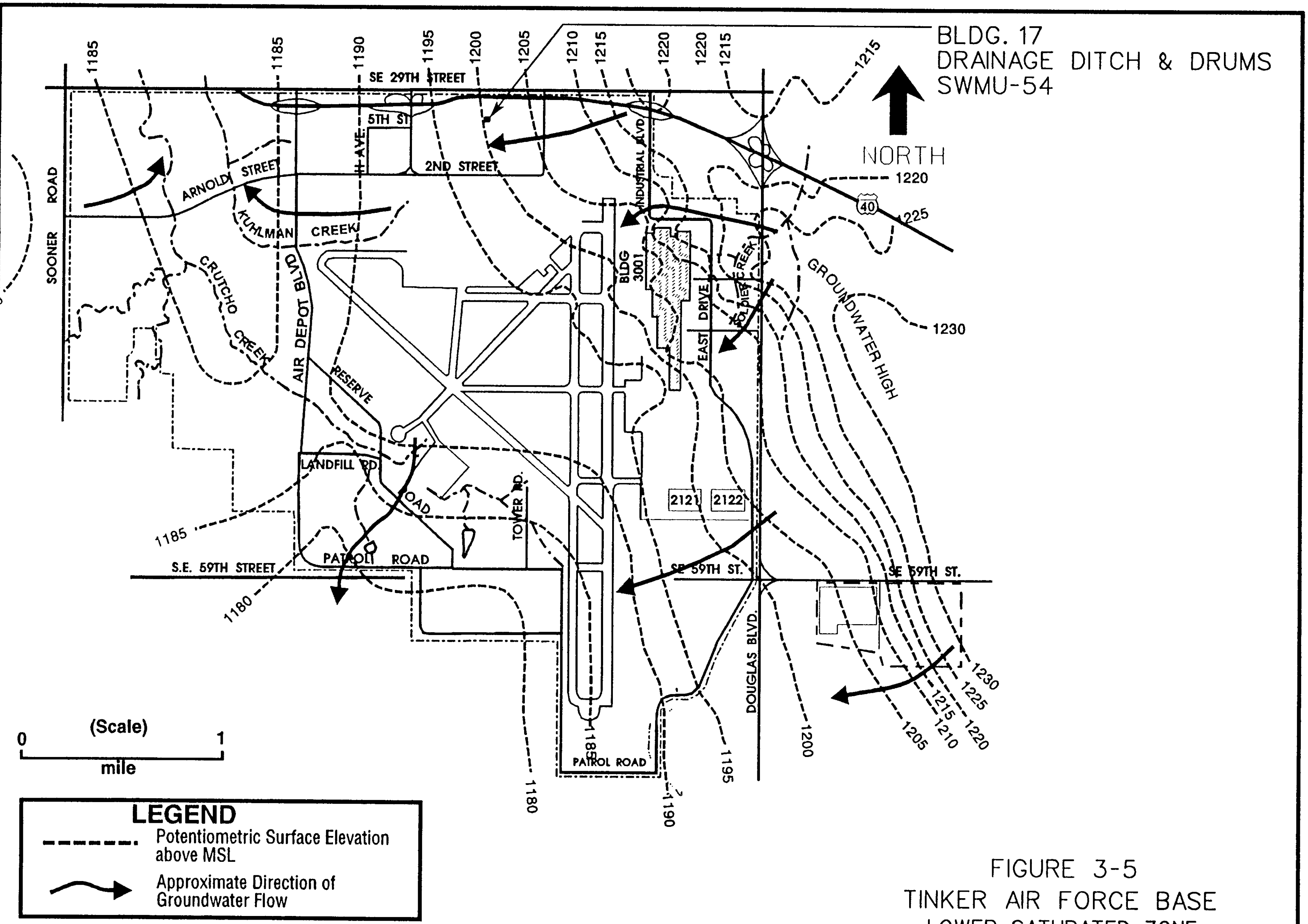

FIGURE 3-5
TINKER AIR FORCE BASE
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C.WALLACE	DWG. NO.: 40983209C.
DRAWN BY: C.E.TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J.TAYLOR	PROJ. NO.: 409832

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screened above and below the confining shale layer, the USZ remains a discrete aquifer zone distinct from the LSZ even over the western part of the Base. In areas where several shales interfinger to form the lower confining interval rather than a single shale bed, "gaps" may occur. In general, these "gaps" are not holes in the shale, but are places where multiple shales exist that are separated by slightly more permeable strata. Hydrologic data from monitoring wells indicate that these zones allow increased downward flow of groundwater above what normally leaks through the confining layer.

The LSZ is hydraulically interconnected and can be considered one aquifer zone down to approximately 200 feet. This area includes what was referred to by the USACE as the top of regional and regional zones. Hydrogeologic data from wells screened at different depths at the same location within this zone, however, provide evidence that locally a significant vertical (downward) component of groundwater flow exists in conjunction with lateral flow. The magnitude of the vertical component is highly variable over the Base. Preliminary evidence suggests that the LSZ is hydraulically discrete from the producing zone. Due to variations in topography, the top of the lower zone is found at depths ranging from 50 to 100 feet below ground surface under the eastern parts of the Base and as shallow as 30 feet to the west. Differences in potentiometric head values found at successive depths are due to a vertical (downward) component of groundwater flow in addition to lateral flow and the presence or absence of shale layers which locally confine the aquifer system. The LSZ extends east of the Base (east of Soldier Creek) beyond the limits of the USZ where it becomes the first groundwater zone encountered in off-Base wells. Because of the regional dip of bedding, groundwater gradient, and topography, the LSZ just east of the Base is generally encountered at depths less than 20 feet.

3.3.2 Site Hydrology

The direction of groundwater flow in the vicinity of BLDG 17 is to the west for the USZ (Figure 3-4) and southwest for the LSZ (Figure 3-5). No groundwater was encountered during drilling activities at the site (deepest depth of drilling was 7.5 feet). Generally in this area, the USZ is located at a depth of 20 feet and the top of the LSZ is 50 to 100 feet below ground surface.

3.4 Soils

Three major soil types have been mapped in the Tinker AFB area and are described in Table 3-2 (U.S. Department of Agriculture [USDA], 1969). The three soil types, the Darrell-Stephenville, Renfrow-Vernon-Bethany, and Dale-Canadian-Port, consist of sandy to fine

Table 3-2

Tinker AFB Soil Associations
(Source: USDA, 1969)

Association	Description	Thickness (in.)	Unified Classification[a]	Permeability (in./hr)
Darrell-Stephenville: loamy soils of wooded uplands	Sandy loam Sandy clay loam Soft sandstone (Garber Sandstone)	12-54	SM,ML,SC	2.0-6.30
Renfrow-Vernon-Bethany: loamy and clayey soils on prairie uplands	Silt loam - clay Clay loam Shale (Fairmont Shale)	12-60	ML,CL,MH,CH	<0.60-0.20
Dale-Canadian-Port: loamy soil on low benches near large streams	Fine sandy loam Silty clay loam Loam Clay loam	12-60	SM,ML,CL	0.05-6.30

[a]Unified classifications defined in U.S. Bureau of Reclamation, 5005-86.

sandy loam, silt loam, and clay loam, respectively. The Darrell-Stephenville and the Renfrow-Vernon-Bethany are primarily residual soils derived from the underlying shales of the Hennessey Group. The Dale-Canadian-Port association is predominantly a stream-deposited alluvial soil restricted to stream floodplains. The thickness of the soils ranges from 12 to 60 inches. In the vicinity of BLDG 17, soils that were investigated included the 1-foot top cover soil immediately beneath the storage concrete pad.

4.0 Source Characterization

Building 17 was constructed in the 1950s as a paint shop; throughout the years, various chemicals associated with painting activities (e.g., paint and solvents) were stored outside in a fenced, paved area adjacent to Building 17. The storage area was approximately 50 by 60 feet. In addition, an on-site drainage culvert was used to dispose of unknown chemicals.

A total of 20 evenly spaced boreholes were drilled to a depth of 7.5 feet below ground surface within the storage area. Samples for detailed analysis were then collected from three different zones: the concrete pavement, the soil in the boreholes, and 1 foot of soil immediately below the concrete pavement. Soil samples were analyzed for TPH, BTEX, and total lead. The pulverized concrete from the 20 boreholes was removed and formed into two composite samples which were analyzed for TCLP parameters. No contaminants were detected.

Additionally, 100 soil samples were taken in 1-foot intervals from the 20 boreholes. No contaminants were found in any of the soil samples.

The concrete was then removed and the underlying upper 1 foot of soil was excavated and 15 composite samples were obtained to identify any contaminants that had possibly leached through the concrete pad. No visible signs of contamination were noted during the excavation. The sampling results confirmed that no contamination was present.

The removed material was disposed of as a nonhazardous waste. Clean backfill was brought on site to replace the 1 foot of soil removed and a new concrete pad was poured. The design of this removal was completed in July 1992 and the excavation and construction was completed in September 1992.

During drilling activities at the site, groundwater was not encountered at the deepest depth of drilling, 7.5 feet. Generally in this area, groundwater occurs at a depth of 20 feet below ground surface and deeper.

5.0 Contaminant Characterization

Soil investigations were conducted at the paved area southwest of Building 17 to determine if any environmental contamination occurred as a result of past storage practices at the site. Analytical results of the soil indicated concentrations of BLDG 17 site metals above detection limits, but well below background levels for Tinker AFB.

Background soil concentrations for trace metals were determined based on a study performed by the USGS (1991). The study area was confined to approximately four counties in central Oklahoma. Tinker AFB lies at the approximate center of this area. A total of 293 B-horizon soil samples were collected throughout this area. Soil samples were collected at the top of the B-horizon, which was usually 20 to 30 centimeters below the surface but ranged from 3 to 50 centimeters below the surface. For site-specific analytes for which the USGS offered no background value, the analyte was compared to an applicable action level. The background concentrations are presented in Table 5-1.

The use of B-horizon soil as selected by the USGS for metals background concentrations in soil is conservative in that the soil sampled does not reflect all possible anthropogenic influences. Most of the samples were obtained from hill crests and well drained areas in pasture and forested land, well away from roadways to minimize contamination from vehicular emissions (i.e., nearly "pristine" areas). Trace metal inputs to the study site soils on Base, however, will come from anthropogenic sources outside of the study area, in addition to those sources related to disposal activities or operations within the confines of the study site. Therefore, responsibility may be taken for more trace metal impacts than are actually attributable to a given site.

An additional level of conservatism was added in the manner in which the site-specific metals concentrations were compared to the background levels. Typically, the environmental concentrations of trace metals at study sites are represented by the arithmetic upper 95^{th} confidence interval on the mean of a normal distribution. This upper 95^{th} confidence interval value is then compared to the background values. The intent of this typical approach is to estimate a Reasonable Maximum Exposure case (i.e., well above the average case) that is still within the range of possible exposures.

To expedite this comparison and establish greater conservatism, the maximum concentration found at the site of concern, rather than the upper 95^{th} confidence interval value, was

Table 5-1

Background Concentrations of Trace Metals in Surface Soils[a]
SWMU-54, BLDG 17, Tinker AFB

(Page 1 of 2)

Analyte	Lower Detection Limit	Background Concentration Range	
		Minimum Value	Maximum Value
Concentration in %			
Aluminum	0.005	0.38	8.9
Cadmium	0.005	0.01	9.4
Iron	0.005	0.18	5.8
Magnesium	0.005	0.02	5.3
Phosphorous	0.005	0.06	0.019
Potassium	0.05	0.1	2.4
Sodium	0.005	0.02	0.99
Titanium	0.005	0.04	0.42
Concentrations in ppm			
Arsenic	0.1	0.6	21
Barium	1	47	6400
Beryllium	1	<1	3
Bismuth	10	<DL[b]	<DL
Cadmium	2	<DL	<DL
Cerium	4	14	110
Chromium	1	5	110
Cobalt	1	<1	27
Copper	1	<1	59
Europium	2	---[c]	---
Gallium	4	<4	23
Gold	8	<DL	<DL
Holmium	4	<DL	<DL
Lanthanum	2	7	51
Lead	4	<4	27
Lithium	2	5	100

Table 5-1

(Page 2 of 2)

Analyte	Lower Detection Limit	Background Concentration Range	
		Minimum Value	Maximum Value
Manganese	10	24	3400
Molybdenum	2	<DL	<DL
Neodymium	4	6	47
Nickel	2	<2	61
Niobium	4	<4	16
Scandium	2	<2	15
Selenium	0.1	<0.1	1.2
Silver	2	<DL	<DL
Strontium	2	13	300
Tantalum	40	<DL	<DL
Thorium	1	<1.40	15.00
Tin	10	<DL	<DL
Uranium	0.1	0.650	6.400
Vanadium	2	5	220
Ytterbium	1	<1	3
Yttrium	2	3	43
Zinc	2	3	79

[a]All B-horizon soil samples (293) from USGS, 1991.
[b]All concentrations below the lower limits of determination.
[c]Insufficient or no data.

compared to the USGS background values. If the environmental concentration of a particular analyte was below or within the minimum-maximum range of the USGS background concentrations, that analyte was considered to be naturally occurring and of no further concern to this investigation. Given the conservative approach of the comparisons, site-specific metals concentrations would have to significantly exceed the USGS background levels and be attributable to operations at the site before they would be considered a contaminant of concern.

5.1 Soil Characterization

Samples for detailed analysis were collected from three different zones at the storage area southwest of Building 17: the concrete pavement, the soil in the 20 boreholes, and the 1 foot of soil immediately below the concrete pavement. Soil samples were analyzed for TPH, BTEX, and total lead. The pulverized concrete samples were analyzed for TCLP parameters. The analytical results are presented in Tables 5-2 through 5-4.

Barium, cadmium, chromium, lead, and silver were found above detection limits in the concrete samples and the 1 foot of soil immediately below the concrete pavement. However, metal concentrations from the BLDG 17 site were below the USGS background levels. VOCs and SVOCs were below detection limits in all composited samples collected for disposal purposes.

5.2 Sediment Characterization

No samples were collected from the on-site drainage culvert at BLDG 17. Any chemicals entering the culvert would eventually flow into Kuhlman Creek. A detailed investigation of Kuhlman Creek has been conducted and any potential impact due to the discharge of chemicals from the BLDG 17 site should be addressed in the study. However, at the time this report went into printing, the Kuhlman Creek study report was not available for review.

Table 5-2

Results for Composite Samples of Concrete TCLP Analysis (Concentrations in mg/L) SWMU-54, BLDG 17, Tinker AFB

(Page 1 of 2)

Parameters	Cement Sample Building 17A	Cement Sample Building 17B
Arsenic	<0.001	<0.001
Barium	0.87	1.1
Benzene	<0.01	<0.01
Cadmium	0.05	0.05
Carbon tetrachloride	<0.01	<0.01
Chlordane	<0.005	<0.005
Chlorobenzene	<0.01	<0.01
Chloroform	<0.01	<0.01
Chromium	0.05	0.09
o-Cresol	<0.01	<0.01
m-Cresol	<0.01	<0.01
p-Cresol	<0.01	<0.01
2,4-D	<0.01	<0.01
1,4-Dichlorobenzene	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01
1,1-Dichloroethylane	<0.01	<0.01
2,4-Dinitrotoluene	<0.01	<0.01
Endrin	<0.005	<0.005
Heptachlor	<0.005	<0.005
Hexachlorobenzene	<0.01	<0.01
Hexachlorobutadiene	<0.01	<0.01
Hexachloroethane	<0.01	<0.01
Lead	0.05	<0.05
Lindane	<0.005	<0.005
Mercury	<0.001	<0.001

Table 5-2

(Page 2 of 2)

Parameters	Cement Sample Building 17A	Cement Sample Building 17B
Methoxychlor	<0.01	<0.01
Methyl ethyl ketone	<0.01	<0.01
Nitrobenzene	<0.01	<0.01
Pentachlorophenol	<0.01	<0.01
Pyridine	<0.01	<0.01
Selenium	<0.001	<0.001
Silver	0.03	0.03
Tetracholoethylene	<0.01	<0.01
Toxaphene	<0.005	<0.005
Trichloroethylene	<0.01	<0.01
2,4,5-Trichlorophenol	0.01	<0.01
2,4,6-Trichlorophenol	<0.01	<0.01
2,4,5-TP Silvex	<0.05	<0.05
Vinyl chloride	<0.01	<0.01
Ignitability	<140	<140
Corrosivity (pH)	12.59	12.55
Releasable cyanide (mg/kg)	<0.125	<0.125
Releasable Sulfide (mg/kg)	<1.0	<1.0

Table 5-3

Results for Soil Samples Taken from 2.5 Feet to 7.5 Feet
BTEX, TPH, Total Lead
SWMU-54, BLDG 17, Tinker AFB

Parameters (mg/kg)	Maximum Concentration	Minimum Concentration
Benzene	<0.01	<0.01
Toluene	<0.01	<0.01
Ethyl benzene	<0.01	<0.01
m&p-Xylene	<0.01	<0.01
o-Xylene	<0.01	<0.01
TPH (DRO)	<1.0	<1.0
Lead	13	<0.50

Table 5-4

Results for Composite Soil Samples Ground Level to 1 Foot TCLP Analysis (Concentrations in mg/L) SWMU-54, BLDG 17, Tinker AFB

(Page 1 of 2)

Parameters	Maximum Concentration	Minimum Concentration
Arsenic	<0.001	<0.001
Barium	3.0	1.4
Benzene	<0.01	<0.01
Cadmium	0.05	0.05
Carbon tetrachloride	<0.01	<0.01
Chlordane	<0.005	<0.005
Chlorobenzene	<0.01	<0.01
Chloroform	<0.01	<0.01
Chromium	0.05	0.09
o-Cresol	<0.01	<0.01
m-Cresol	<0.01	<0.01
p-Cresol	<0.01	<0.01
2,4-D	<0.01	<0.01
1,4-Dichlorobenzene	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01
1,1-Dichloroethylane	<0.01	<0.01
2,4-Dinitrotoluene	<0.01	<0.01
Endrin	<0.005	<0.005
Heptachlor	<0.005	<0.005
Hexachlorobenzene	<0.01	<0.01
Hexachlorobutadiene	<0.01	<0.01
Hexachloroethane	<0.01	<0.01
Lead	0.05	<0.05
Lindane	<0.005	<0.005
Mercury	<0.001	<0.001

Table 5-4

(Page 2 of 2)

Parameters	Maximum Concentration	Minimum Concentration
Methoxychlor	<0.01	<0.01
Methyl ethyl ketone	<0.01	<0.01
Nitrobenzene	<0.01	<0.01
Pentachlorophenol	<0.01	<0.01
Pyridine	<0.01	<0.01
Selenium	<0.001	<0.001
Silver	0.03	0.03
Tetracholoethylene	<0.01	<0.01
Toxaphene	<0.005	<0.005
Trichloroethylene	<0.01	<0.01
2,4,5-Trichlorophenol	<0.01	<0.01
2,4,6-Trichlorophenol	<0.01	<0.01
2,4,5-TP Silvex	<0.05	<0.05
Vinyl chloride	<0.01	<0.01
Ignitability (^{o}F)	<140	<140
Corrosivity (pH)	10.37	8.35
Releasable cyanide (mg/kg)	<0.20	<0.20
Releasable sulfide (mg/kg)	<0.10	<0.10

6.0 Potential Receptors

A specific potential human and ecological receptor search has not been performed for BLDG 17. The following sections describe the data available to begin identification of potential receptors.

6.1 Human Receptors

Tinker AFB is situated on a relatively flat expanse of grassland. Prior to the development of the Base, the area was characterized by large tracts of agricultural land. The Base currently occupies approximately 5,000 acres of semi-improved and unimproved grounds that are used for the airfield, golf course, housing area, offices, shops, and other uses characteristic of military installations.

The Garber-Wellington aquifer, which underlies Tinker AFB, is the single most important source of potable groundwater in the Oklahoma City area. The recharge area for the Garber-Wellington aquifer covers the eastern half of Oklahoma County, including Tinker AFB. Approximately 75 percent of the Base's water supply is obtained from production wells pumping from this aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by municipal distribution systems also depend on the Garber-Wellington aquifer. Communities, such as Oklahoma City, presently depending upon surface water supplies also maintain a well system drilled into this aquifer as a standby source of water in the event of drought. Lake Stanley Draper, a local surface water supply reservoir with a small portion of its drainage basin within the boundaries of Tinker AFB, serves a significant recreational function as well.

In 1989, approximately 26,000 military and civilian personnel worked at Tinker AFB. Of these, approximately 2,722 personnel occupied on-Base housing, which consisted of 530 family housing units and seven dormitories. At that time, 1,262 of these residents were children. Military personnel and their families who reside on Base represent the nearest receptors to releases from Tinker AFB.

The current land use at and near the Base is not expected to change because the facilities have decades of useful life remaining and the Base has an important and continuing mission. However, other future land use scenarios and any human receptors associated with those scenarios may need to be considered.

6.2 Ecological Receptors

Tinker AFB lies within a grassland ecosystem, which is typically composed of grasses, forbes, and riparian (i.e., trees, shrubs, and vines associated with water courses) vegetation. This ecosystem has generally experienced fragmentation and disturbances as result of urbanization and industrialization at and near the Base. While no threatened or endangered plant species occur on the Base, the Oklahoma penstemon (*Penstemon oklahomensis*), identified as a rare plant under the Oklahoma Natural Heritage Inventory Program, thrives in several locations on Base. Tinker AFB policy considers rare species as if they were threatened or endangered and provides the same level of protection for these species.

In general, wildlife on the Base is typically tolerant of human activities and urban environments. No federal threatened or endangered species have been reported at the Base. However, one specie found on the Base, the Texas horned lizard (*Phrynosoma cornutum*), is a Federal Category 2 candidate specie and under review for consideration to be listed as threatened or endangered. Air Force policy (AFR 126-1) considers candidate species as threatened or endangered and provides the same level of protection.

The Oklahoma Department of Wildlife Conservation also lists several species within the state as Species of Special Concern. Information on these species suggests declining populations but information is inadequate to support listing, and additional monitoring of populations is needed to determine the species status. These species also receive protection by Tinker AFB as threatened or endangered species. Of these species, the Swainson's hawk (*Buteo swainsoni*) and the burrowing owl (*Athene cunicularia*) have been sighted on Tinker AFB. The Swainson hawk, a summer visitor and prairie/meadow inhabitant, has been encountered Basewide. The burrowing owl has been known to inhabit the Air Field at the Base.

7.0 Action Levels

An "action level" is defined by EPA in proposed rule 40 CFR 264.521 (55 FR 30798; 7/27/90), "Corrective Action for Solid Waste Management Units (SWMU) at Hazardous Waste Management Facilities," as a health- and environment-based level, determined by EPA to be an indicator for protection of human health and the environment. In the preamble to this proposed rule, the focus of the RFI phase is defined as "characterizing the actual environmental problems at the facilities." As part of this characterization, a comparison of the contaminant concentrations to certain action levels should be made to determine if a significant release of hazardous constituents has occurred. This comparison is then used to determine if further action or corrective measures are required for a SWMU or an AOC. The preamble to the proposed rule states that the concept of action levels was introduced because of the need for "a trigger that will indicate the need for a Corrective Measures Study (CMS) and below which a CMS would not ordinarily be required" (55 FR 30798; 7/27/90). If constituent concentrations exceed certain action levels at a SWMU or an AOC, further action or a CMS may be warranted; if constituent concentrations are below action levels, a finding of no further action may be warranted. This chapter of the report presents the initial analytical data as compared to certain potential action levels.

Action levels are concentrations of contaminants at or below which exposure to humans or the environment should not produce acute or chronic effects.

The action level information is presented in this chapter so that a constituent concentration at a sample location can be compared with its potential action level. Only constituents identified in the analysis are listed in the SWMU-54, BLDG 17 table. Table 7-1 shows the action levels for soil, water, and air as published in federal or state regulations, policies, guidance documents, or proposed rules.

The action levels listed in Table 7-1 are:

- ***SWMU Corrective Action Levels (CAL) -*** The first set of action levels provided in the table are those taken from the proposed rule (40 CFR 264.521) and provided as Appendix A to the rule as "Examples of Concentrations Meeting Criteria for Action Levels." These levels are health-risk based and are provided

Table 7-1

Action Levels
SWMU-54, BLDG 17, Tinker AFB

Parameters	SWMU CAL[a]			MCL[b]	USGS[c] Background	NAAQS[d]	Composite Sample 2.5 - 7.5 ft
	Soil (mg/kg)	Water (mg/L)	Air (μg/m^3)	Water (mg/L)	Soil (mg/kg)	Air (μg/m^3)	Range (mg/kg)
Inorganics							
Lead				0.015[e]	27	1.5[f]	13

[a]CAL - Corrective Action Levels
[b]MCL - Maximum Contaminant Levels
[c]USGS - United States Geological Survey
[d]NAAQS - National Ambient Air Quality Standards
[e]Action Level at the Tap
[f]3 Month Average

as specific examples of levels below which corrective action would not be required.

- ***Maximum Contaminant Levels (MCL) -*** These values are provided from 40 CFR Subpart G, Sections 141.60 through 0.63 as promulgated under the Safe Drinking Water Act. These levels are designated for water media only.

- ***USGS Background -*** These values are provided from the USGS report titled "Elemental Composition of Surficial Materials from Central Oklahoma" (USGS, 1991). These values represent the levels of metals which naturally occur in Central Oklahoma soils.

- ***Background -*** These levels are provided where background could be determined. Where available, background concentrations are listed for metals in soil samples taken on site, which were thought to be unaffected by releases from a unit.

- ***National Ambient Air Quality Standards (NAAQS) -*** These standards are published in 40 CFR Part 50 under the Clean Air Act and apply to point sources that emit a limited number of constituents to the air. The constituents regulated are nitrogen dioxide, sulphur dioxide, carbon monoxide, lead, ozone, and particulate matter. Currently, it is assumed that none of the SWMUs or AOCs emit these compounds in regulated quantities and no air samples have been taken which would allow for a valid comparison.

- ***Water Quality Standards (WQS) -*** The WQS are the standards for surface water quality as established by the State of Oklahoma. These standards apply to point source discharges to surface waters and have been listed for those units adjacent to surface water.

Table 7-1 also gives a brief comparative evaluation of the data collected and the related action levels. The data for each detected compound are compared with the appropriate action level in order to identify those constituents (compounds) with concentrations exceeding the action levels. This identification of the compounds above the action levels provides an indication of a potential environmental problem at a specific site. In addition, this information indicates whether there is a need for conducting a CMS so that a corrective action can be implemented/undertaken at the site.

For constituents that have a SWMU CAL and an MCL for water, the MCL will be used for the comparison. Also, constituents that do not have a USGS background value will be compared to the site background value if available.

The data included in Table 7-1 are representative of the data presented in Chapter 5.0. For each soil boring, a range was identified and used in the comparison to the action levels.

Evaluation of the soil data for BLDG 17 shows a detection of lead in the composite soil sample. This detection is below the USGS background concentration. No groundwater samples were taken at the BLDG 17 site.

8.0 Summary and Conclusions

Building 17 site is located in the north-central section of Tinker AFB, approximately 300 feet south of the Base boundary and Interstate 40. Building 17 was constructed in the 1950s as a paint shop. Various chemicals associated with painting activities were stored outside in a fenced, paved area southwest of Building 17. The paved area drains to a storm water culvert located on the southwest corner of the site. The storm water culvert ultimately drains into Kuhlman Creek. The storage area and the drainage culvert are identified as BLDG 17.

BLDG 17 was discovered during the Basewide RCRA facility assessment in May 1989 (Tinker, 1992b). The enclosed concrete area (approximately 50 by 60 feet) that had been used for chemical storage had visible and extensive discoloration, indicating that spills may have occurred throughout the years. In addition, interviews with Base personnel revealed that the on-site drainage culvert had been used to dispose of unknown chemicals in the past.

A total of 20 evenly spaced boreholes were drilled to a depth of 7.5 feet below the ground surface within the storage area. Five of the boreholes were drilled in the low end (i.e., west edge) of the paved area serving the on-site drainage culvert.

Soil sampling analyses indicated that contamination did not exist at the site. However, based on visual indications of contamination, a remedial action was selected and implemented for the site. Remediation of the site included excavation and disposal of the concrete pad and the underlying upper 1 foot of soil. Clean backfill material was used to replace the 1 foot of soil removed. A new concrete pad was poured. Remediation efforts were completed on September 4, 1992. Currently, the site is used for the storage of construction material; there is no plan to store chemicals at this location in the future.

No groundwater was encountered at the deepest depth of drilling, 7.5 feet. In this area, the USZ is generally located at a depth of 20 feet and the LSZ is 50 to 100 feet below ground surface.

9.0 Recommendations

Soil removal from the BLDG 17 site eliminated a potential source for a threat to human health or environment. Based on evaluations of available data, no contamination was found at this site. The soil samples taken during the soil removal action were only analyzed for select VOCs (BTEX), TPH, and TCLP parameters. The analyses performed do not provide sufficient information to support any conclusions made. It is therefore recommended that during the Phase II RFI soil samples be taken and analyzed for VOCs and SVOCs to confirm the absence of contamination at the site.

In addition, to fully evaluate the extent of soil contamination at this site it is recommended that site-specific soil background samples be collected during the Phase II RFI. This additional information along with the USGS background values should be used in the Phase II report to distinguish site-related from background concentrations in a statistically significant manner. During the development of the Phase II RFI work plan, the number of background samples to be collected, the location of the soil borings, and the soil analysis to be performed on the samples should be determined for EPA approval.

If no contamination is found at the site, a recommendation of no further action will be made for this site.

10.0 References

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