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INSTALLATION RESTORATION PROGRAM
PHASE II - CONFIRMATION/QUANTIFICATION
STAGE 2

VOLUME I

LUKE AIR FORCE BASE, ARIZONA

Roy F. Weston, Inc.
West Chester, Pennsylvania 19380

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JUNE 1988

FINAL REPORT FOR PERIOD SEPTEMBER 1986 TO JUNE 1988

Approved for Public Release; Distribution is Unlimited

PREPARED FOR:

HEADQUARTERS TACTICAL AIR COMMAND
COMMAND SURGEON'S OFFICE (HQ TAC/SGPB)
LANGLEY AIR FORCE BASE, VIRGINIA

UNITED STATES AIR FORCE
OCCUPATIONAL & ENVIRONMENTAL HEALTH LABORATORY (USAFOEHL)
TECHNICAL SERVICES DIVISION (TS)
BROOKS AIR FORCE BASE, TEXAS 78235-5501

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INSTALLATION RESTORATION PROGRAM

PHASE II - CONFIRMATION/QUANTIFICATION

STAGE 2

FINAL REPORT

A-1

Prepared For:

Luke Air Force Base, Arizona
Headquarters Tactical Air Command
Command Surgeon's Office (HQ TAC/SGPB)
Langley Air Force Base, Virginia

June 1988

Prepared By:

Roy F. Weston, Inc.
West Chester, Pennsylvania 19380

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TECHNICAL SERVICES DIVISION (TS)
BROOKS AIR FORCE BASE, TEXAS 78235-5501

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Abstract

An Installation Restoration Program (IRP) Phase II Stage 2 study was performed at Luke AFB, AZ, between September 1986 and April 1988. Five sites (plus the base production wells) were investigated: a canal that receives runoff which has bypassed an oil/water separator (the O/W Separator Canal); a petroleum, oil and lubricants disposal area ~~(the POL Area)~~; a former fire training area ~~(the South Fire Training Area, or SFTA)~~; a site that contains both current and former fire training areas (the Current and North Fire Training Area, or NFTA); and a series of lagoons that receive effluent from the base Sewage Treatment Plant (located two miles east of the base and termed the STP Effluent Canal site). The scope of the investigation included soil-gas surveys at three sites, a geophysical survey at the POL Area, soil borings and subsurface soil sampling at all sites, monitor well installation and groundwater sampling ~~(three rounds)~~ at all sites including the base production wells, and surface water and sediment sampling at two sites. Analytes included volatile organic compounds, base/neutral-acid extractable compounds, pesticides, PCBs, heavy metals, and other indicator and site-specific parameters.

The four sites located on the base share a similar hydrogeologic setting. They are underlain by a stratigraphic sequence that is characterized by sandy silts and silty sands interbedded with coarse-grained beds of sand or sand and gravel. The water table at these sites is located between 350 and 360 feet below land surface. The STP Effluent Canal site is underlain by coarser materials, and the water table is located approximately 140 feet below land surface.

Generally compounds that were detected above background in the various sampled media fall into one of three categories: (1) probable sampling artifacts (i.e., compounds inadvertently introduced to samples during sampling, handling, or laboratory analysis); (2) scattered occurrences of compounds that are found infrequently, at low concentrations, and that do not appear in any identifiable pattern or distribution; and (3) occurrences of compounds that are found in an identifiable pattern or distribution. The majority of compounds detected at Luke AFB fall into one of the first two categories. Occurrences of compounds that fall into the third category include various target compounds in soil-gas at three sites, oil and grease in soil at the NFTA, nitrate/nitrite in groundwater at the STP Effluent Canal site, petroleum hydrocarbons in the sediment at the O/W Separator Canal, and lead in the soil and sediment at the STP Effluent Canal. None of these occurrences were considered to be significant in terms of threat to human health or to the environment.

No further IRP actions were recommended for any of the sites, however, non-IRP recommendations were made for two sites. At the STP Effluent Canal site, quarterly monitoring of the effluent for nitrogen compounds is recommended. At the NFTA, the closure of the current unlined fire training area is recommended to avoid potential future environmental impacts caused by migration of petroleum products through the subsurface soils.

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PREFACE

This report documents the methodologies, findings, and recommendations associated with the performance of the Phase II Stage 2 study of the U.S. Air Force Installation Restoration Program at Luke Air Force Base, Glendale, Arizona. This work was conducted by Roy F. Weston, Inc. (WESTON) under Contract No. F33615-84-D-4400, Delivery Order No. 0015.

Mr. Peter J. Marks was Program Manager for this contract. Ms. Katherine A. Sheedy, P.G. was Project Director. The Task Manager was Mr. J. Gregory Hill, P.E. The Senior Project Scientist and Field Team Leader was Ms. Deborah L. Jones.

Laboratory analyses were accomplished at WESTON's laboratory under the supervision of Mr. Earl M. Hansen, Ph.D., Analytical Laboratory Manager.

WESTON wishes to acknowledge Major Jesse Humberd, Luke AFB Bioenvironmental Engineer, for his kind assistance in conducting this project.

This project was accomplished during the period September 1986 to June 1988. Lt. Jerald E. Styles, Technical Services Division, USAF Occupational and Environmental Health Laboratory (USAFOEHL) was the Technical Monitor.

Approved:

Peter J. Marks
Program Manager

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EXECUTIVE SUMMARY

ES.1 INTRODUCTION

Roy F. Weston, Inc. (WESTON) was retained by the U.S. Air Force Occupational and Environmental Health Laboratory (USAFOEHL) under Contract No. F33615-84-D-4400 to provide general engineering, hydrogeological, and analytical services. Those services were applied to the Installation Restoration Program (IRP) Phase II Stage 2 effort at Luke Air Force Base (Luke AFB) under Task Order 0015 of that contract.

Luke AFB, which is assigned to the Tactical Air Command (TAC), occupies 4,198 acres of land in Maricopa County, Arizona, 13 miles west of downtown Phoenix. Since the start of operations in 1941 as a World War II fighter pilot training facility, activities at Luke AFB in support of operational missions have resulted in the occurrence on the installation of several sites of potential environmental concern.

The field investigation conducted under Task Order 0015 included five sites (plus the base production wells) as listed below:

- Oil/Water (O/W) Separator Canal - A canal receiving runoff that bypasses an oil/water separator.
- POL Trenches and Lagoon (POL Area) - A POL (petroleum, oil, and lubricant) disposal area.
- South Fire Training Area (SFTA) - An area with four former fire training pits.
- Current and North Fire Training Areas (NFTA) - An area with three former fire training pits and two current fire training pits.
- Sewage Treatment Plant (STP) Effluent Canal - A series of lagoons that receive effluent from the STP.
- Base Production Wells - Six operational water supply wells.

The locations of these sites are shown in Figure ES-1.

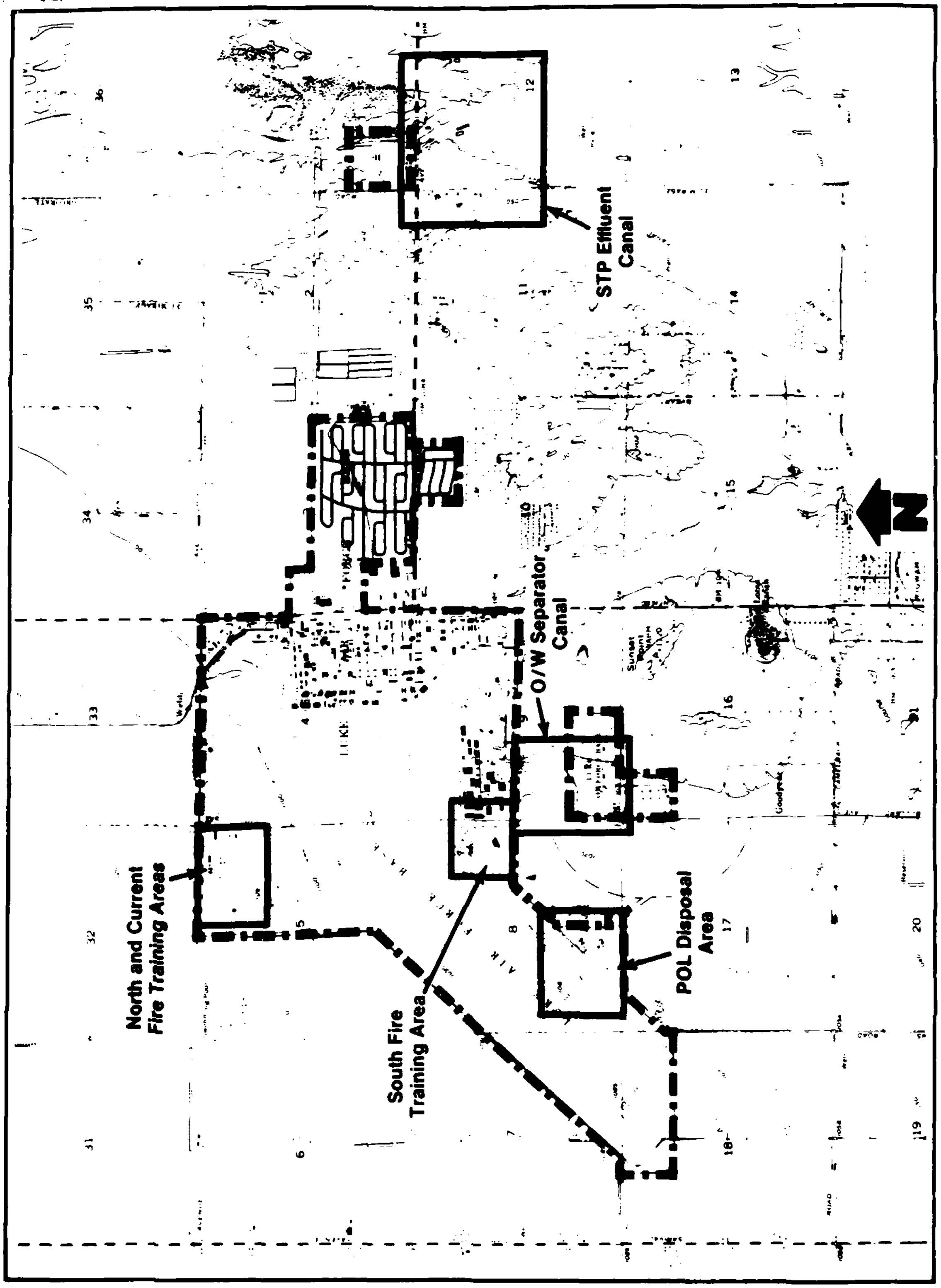

FIGURE ES-1 LOCATIONS OF PHASE II STAGE 2 INVESTIGATION SITES, LUKE AFB, AZ

ES.2 SCOPE OF WORK

The scope of the investigation included:

- Soil-gas surveys at the O/W Separator Canal, at the POL Area, and at the STP Effluent Canal.
- Geophysical surveys at the POL Area.
- Soil borings and subsurface soil sampling at all sites.
- Monitor well installation and groundwater sampling at all sites.
- Surface water sampling at the O/W Separator Canal, effluent sampling at the STP Effluent Canal, and sediment sampling at the O/W Separator Canal and at the STP Effluent Canal.

Table ES-1 contains a summary of field activities undertaken at each site. Analyses performed are summarized in Table ES-2.

ES.3 MAJOR FINDINGS

ES.3.1 Hydrogeologic Conditions

The four sites located on the base (the O/W Separator Canal, the POL Area, the SFTA, and the NFTA) share a similar hydrogeologic setting. All sites are underlain by a stratigraphic sequence that is characterized by sandy silts and silty sands interbedded with coarser-grained beds of sand or sand and gravel. The water table at these sites is located between 350 and 360 feet below land surface.

The STP Effluent Canal site, located approximately 2 miles east of the base, contains lagoons that receive the effluent from the STP. These lagoons are located in the bed of the Agua Fria River. The hydrogeologic setting at that site is distinctly different from the four sites located on the base. The STP Effluent Canal site is underlain by cobbles and sand and gravel associated with the river with finer-grained materials found at greater depths. The water table is located much closer to the ground surface here, approximately 140 feet below land surface, than at the base sites. The water table is continually recharged by infiltrating effluent from the lagoons, resulting in a water table "mound" beneath the site.

Table ES-1

Summary of Specific Actions
Phase II Stage 2 Sites
Luke AFB, Arizona

Sites	Soil Borings	Monitor Wells	Soil-Gas	Soil Samples	Groundwater Samples	Effluent Samples	Surface Water Samples	Geophysical Survey
Oil/Water Separator Canal	6	2	23 probes	68*	6	---	2	---
POL Trenches and Lagoon	9	3	37 probes	90	9	---	---	GPR and EM
South Fire Training Area	2	2	---	40	6	---	---	---
Current and North Fire Training Areas	4	3	---	80	9	---	---	---
Sewage Treatment Plant Effluent Canal	6	1	20 probes	46**	3	9	---	---
Base Production Wells	---	---	---	---	27	---	---	---

*Includes 20 sediment samples.
**Includes 10 sediment samples.
---Not analyzed at this site.

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Table ES-2

Summary of Analytical Protocol
Luke AFB, Arizona

Site	Potential Contaminant	Sample Medium	Analytes
Oil/Water Separator Canal	Petroleum products Spent solvents Pesticides	Groundwater/ Surface Water	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil/ Sediment	VOCs Petroleum hydrocarbons
POL Trenches and Lagoon	Petroleum products Leaded petroleum sludge Spent solvents Pesticides	Groundwater	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil	VOCs Metals

Key

VOCs = Volatile organic compounds including xylenes
MEK = Methyl ethyl ketone
BNAs = Base/neutral-acid extractables
O&G = Oil and grease
TOC = Total organic carbon
TKN = Total Kjeldahl nitrogen
Metals = Priority pollutant metals
Pesticides/PCBs = Priority pollutant pesticides and polychlorinated biphenyls
DBCP = Dibromochloropropane
Radiological = Gross alpha, beta, gamma, and radium-226

Table ES-2
(continued)

Site	Potential Contaminant	Sample Medium	Analytes
South Fire Training Area	Petroleum products Spent solvents Pesticides	Groundwater	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil	VOCs MEK O&G Metals
Current and North Fire Training Areas	Petroleum products Spent solvents	Groundwater	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil	VOCs MEK O&G Metals

Key

VOCs = Volatile organic compounds including xylenes
MEK = Methyl ethyl ketone
BNAs = Base/neutral-acid extractables
O&G = Oil and grease
TOC = Total organic carbon
TKN = Total Kjeldahl nitrogen
Metals = Priority pollutant metals
Pesticides/PCBs = Priority pollutant pesticides and polychlorinated biphenyls
DBCP = Dibromochloropropane
Radiological = Gross alpha, beta, gamma, and radium-226

Table ES-2
(continued)

Site	Potential Contaminant	Sample Medium	Analytes
Sewage Treatment Plant Effluent Canal	Spent solvents Pesticides	Groundwater/ Effluent	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs Nitrate/ Nitrite TKN
		Soil/ Sediment	VOCs Metals
Base Production Wells	Pesticides Radioisotopes Petroleum products Spent solvents	Groundwater	VOCs MEK BNAs O&G Metals Pesticides/ PCBs Radiological DBCP

Key

VOCs = Volatile organic compounds including xylenes
MEK = Methyl ethyl ketone
BNAs = Base/neutral-acid extractables
O&G = Oil and grease
TOC = Total organic carbon
TKN = Total Kjeldahl nitrogen
Metals = Priority pollutant metals
Pesticides/PCBs = Priority pollutant pesticides and polychlorinated biphenyls
DBCP = Dibromochloropropane
Radiological = Gross alpha, beta, gamma, and radium-226

ES.3.2 Summary of Analytical Results and Significance of Findings

Generally, compounds that were detected above background levels in the various sampled media at Luke AFB fall into one of three categories: (1) probable laboratory or sampling artifacts (i.e., compounds inadvertently introduced to samples during sampling, handling, or laboratory analysis); (2) scattered occurrences of compounds that are found infrequently and at low concentrations and that do not appear in any identifiable pattern or distribution; and (3) occurrences of compounds that are found in an identifiable pattern or distribution.

The majority of compounds detected at Luke AFB fall into one of the first two categories. Occurrences of compounds that fall into the third category include:

- Various target compounds in the soil-gas at the O/W Separator Canal, at the POL Area, and at the STP Effluent Canal.
- Oil and grease in the soil at the NFTA.
- Nitrate/nitrite in the groundwater at the STP Effluent Canal.
- Petroleum hydrocarbons in the sediment at the O/W Separator Canal.
- Lead in the soil and the sediment at the STP Effluent Canal.

These occurrences are discussed below:

- Various target compounds in the soil-gas at the O/W Separator Canal, at the POL Area, and at the STP Effluent Canal. At all three sites surveyed, elevated concentrations of various target compounds were detected in the soil-gas. These concentrations appeared in identifiable patterns, indicating the existence of a probable relationship between the particular source areas and the distributions of compounds found in the soil-gas. However, neither soil nor groundwater contamination was associated with these soil-gas concentrations.
- Oil and grease (O&G) in the soil at the NFTA. Relatively high O&G concentrations (greater than 1,000 mg/kg) were detected at three locations, all at 10 feet in depth or shallower. At greater depths, O&G concentrations above background levels (up to 329 mg/kg) were

detected consistently in one boring (06-04)* located at the Current Fire Training Area. These concentrations are not considered to be significant in terms of oil and grease migration.

- Nitrate/nitrite in groundwater at the STP Effluent Canal. Nitrate/nitrite was detected at concentrations of 6.73, 7.40, and 6.76 mg/L in MW-101 at the STP Effluent Canal during three sample rounds. The concentrations are below the MCL for nitrate (10 mg/L). The probable source of these concentrations is the STP effluent that infiltrates to the water table from lagoons at the site. Concentrations of total Kjeldahl nitrogen (TKN) in the effluent ranged from 24.9 to 27.9 mg/L in the nine samples collected. Subsequent oxidation of nitrogen compounds (those analyzed as TKN) probably resulted in the formation of nitrate/nitrite.

- Petroleum hydrocarbons in sediment at the O/W Separator Canal. Concentrations of petroleum hydrocarbons were detected, as expected based on visible sediment staining. Significant reduction of petroleum hydrocarbons with depth was noted in the top 12 inches of sediment. These concentrations are not considered to be significant in terms of petroleum hydrocarbons migration at the site.

- Lead in the soil and the sediment at the STP Effluent Canal. Concentrations of lead were detected in all soil samples, ranging from 20 to 72 ppb, and in three of ten sediment samples, ranging from 22 to 57 ppb. Although the STP effluent cannot be ruled out as a source, it is likely that these concentrations are naturally occurring.

ES.4 RECOMMENDATIONS

ES.4.1 Site Categorization

Based on the results of this investigation, five sites at Luke AFB will be classified into one of three possible alternative categories:

- Category I: No further action required.

---

*During discussions in this report the initial zeroes of the three-digit soil boring sample numbers were dropped for consistency with handwritten field logs.

- Category II: Further investigation required.
- Category III: Remedial action or continued monitoring required.

There were no sites at Luke AFB where a significant environmental impact was identified. Therefore, it is recommended that all Luke AFB sites be classified as Category I sites requiring no further IRP action. However, non-IRP recommended actions are presented below for two sites: the North Fire Training Area (Current Fire Training Area only) and the STP Effluent Canal Area.

ES.4.2 Non-IRP Recommended Actions at the Current Fire Training Area

It is recommended that the current fire training facility be closed and that a replacement facility be constructed at the same or a new location. In spite of the minimal potential for contaminant migration that currently exists, continued use of the facility will result in the continued introduction of petroleum products to the subsurface. The potential for contaminant migration may increase with time, resulting in an eventual threat to the groundwater. It is recommended that the new facility be lined (so that all fluids will be contained) and be equipped with an oil/water separator. Separated oil would be collected for reuse or proper disposal, and water would be piped to the Sewage Treatment Plant.

ES.4.3 Non-IRP Recommended Actions at the STP Effluent Canal Area

It is recommended that the Sewage Treatment Plant effluent be monitored quarterly for Total Kjeldahl Nitrogen. This recommendation is based on the occurrence of nitrate/nitrite in MW-101 at the STP Effluent Canal site.

The nitrate/nitrite concentrations were consistently below the MCL for nitrate, and the concentrations of nitrate/nitrite will decrease with increasing distance from the site. However, if a significant increase in nitrogen loading to the STP effluent lagoons were to occur, the nitrate/nitrite concentrations in the groundwater would be expected to increase.

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SECTION 1

INTRODUCTION

1.1 INSTALLATION RESTORATION PROGRAM

In 1976, the Department of Defense (DOD) devised a comprehensive Installation Restoration Program (IRP) for its facilities. The purpose of the IRP is to assess and to control the migration and potential migration of hazardous environmental contamination that may have resulted from past operations and disposal practices at DOD facilities. In response to the Resource Conservation and Recovery Act of 1976 (RCRA) and in anticipation of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund), the DOD issued a Defense Environmental Quality Program Policy Memorandum dated June 1980 (DEQPPM 80-6) requiring the identification of past hazardous waste disposal sites at DOD installations. The U.S. Air Force implemented DEQPPM 80-6 by message in December 1980. The program was revised by DEQPPM 81-5 (11 December 1981) which reissued and amplified all previous directives and memoranda on the IRP. The Air Force implemented DEQPPM 81-5 by message on 21 January 1982.

The IRP has been developed as a four-phase program as follows:

- Phase I - Problem Identification/Records Search
- Phase II - Problem Confirmation/Quantification
- Phase III - Technology Base Development
- Phase IV - Corrective Action

1.2 PROGRAM HISTORY AT LUKE AIR FORCE BASE

Roy F. Weston, Inc. (WESTON) has been retained by the United States Air Force Occupational and Environmental Health Laboratory (USAFOEHL) under Contract Number F33615-84-D-4400 to provide general engineering, hydrogeological, and analytical services. The Phase I Problem Identification/Records Search for Luke Air Force Base (Luke AFB) was completed by CH2M Hill during late 1981 and early 1982; the Final Report was dated February 1982. In response to the findings contained in the Phase I Final Report, USAFOEHL issued Task Order 0012 to WESTON directing that a presurvey site inspection be conducted at Luke AFB. The purpose of that presurvey was to obtain sufficient information to develop a work scope and a cost estimate for the conduct of Phase II Problem Confirmation/Quantification (Stage 1), at Luke AFB. The Presurvey Report was submitted in December 1982.

Task Order 0024 was issued on 12 September 1983 ordering the Phase II Stage 1 study for four sites, the base production wells, and the sewage treatment plant at Luke AFB. WESTON's Final Report for the Phase II Stage 1 investigation was submitted in August 1984. The purpose of that investigation was to confirm and quantify possible contamination using a series of soil borings, soil samples, active production well samples, and effluent samples in and around Luke AFB.

Findings from the Stage 1 study indicated that contamination levels were generally low. Soil and groundwater chemical analyses from the Stage 1 study are summarized in Section 4 and are incorporated into the discussion on the significance of findings. The major soil contaminants were oil and grease (O&G) at the fire training areas and at the Petroleum, Oil, and Lubricants (POL) Trenches and Lagoon site. Lead and chloroform were also found in the soil at the POL site. Oil and grease and 1,1-dichloroethane were the most common contaminants found in soil samples from the Perimeter Road Waste POL Application Area and the North Fire Training Area. Base production wells were sampled, and water quality was found to be generally good. Two volatile organic compounds (VOCs) were detected in production wells PW-4 and PW-10: 1,2-dichloroethane, which ranged from 1.4 to 10.8 ug/L, and trans-1,2-dichloroethene at 100 ug/L in production well PW-10. Also, dibromochloropropane (DBCP) was detected in PW-10 at the limit of detection (0.1 micrograms per liter (ug/L)), and low gross beta and low gamma levels were detected in PW-4.

Based on the results of the Phase II Stage 1 investigation, three sites (POL Trenches and Lagoon, the North Fire Training Area, and the South Fire Training Area) and the base production wells were identified as requiring further investigation. In addition, the Sewage Treatment Plant (STP) Effluent Canal and the Oil/Water (O/W) Separator Canal were listed as IRP sites requiring investigation. As a result, USAFOEHL issued Task Order 0015 in September 1986 ordering a Phase II Stage 2 study for five sites plus the base production wells at Luke AFB. The sites are listed in Table 1-1 along with a summary of field sampling activities undertaken as part of the Phase II Stage 2 study. A copy of the formal Task Order and the Statement of Work are presented in Appendix B.

In February 1986, WESTON completed an investigation at the site of Facility 993, a former underground tank fuel storage facility. Three underground storage tanks were removed in 1983, and the site was partially paved over, leaving a dirt "triangle" over the former facility. The field investigations, conducted from October 1985 to February 1986, included drilling five soil borings for the recovery of subsurface soil samples and installing three monitor wells. Sampling and analyses indicated that the soil was contaminated to a maximum depth of 60 feet

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Table 1-1

Summary of Specific Actions, Phase II Stage 2 Sites, Luke AFB, Arizona

Site	Soil Borings	Monitor Wells	Soil-Gas	Soil Samples	Groundwater Samples	Effluent Samples	Surface Water Samples	Geophysical Survey
Oil/Water Separator Canal	6	2	23 probes	68*	6	---	2	---
POL Trenches and Lagoon	9	3	37 probes	90	9	---	---	GPR and EM
South Fire Training Area	2	2	---	40	6	---	---	---
Current and North Fire Training Areas	4	3	---	80	9	---	---	---
Sewage Treatment Plant Effluent Canal	6	1	20 probes	46**	3	9	---	---
Base Production Wells	---	---	---	---	27	---	---	---

*Includes 20 sediment samples.
**Includes 10 sediment samples.
---Not performed at this site.
GPR - Ground penetrating radar.
EM - Electromagnetic terrain conductivity.

(beneath the site) with O&G and associated VOCs. The groundwater sampled from the monitor wells was not found to be contaminated. Based on the results of that study, it was concluded that groundwater occurs 350 feet below ground surface and is separated from the zone of contaminated soil by 290 feet of dense, dry, low-permeability soils. The probability of future impact on the groundwater quality at that site is considered to be low. Recommendations for closure included capping the site to prevent surface infiltration and periodically monitoring the groundwater quality according to RCRA requirements.

On 22 September 1986, WESTON personnel met with representatives of Luke AFB, the Arizona Department of Environmental Quality* (ADEQ), and the Arizona Department of Water Resources (ADWR) to review the goals of the Phase II Stage 2 investigation, to contact Luke AFB security staff responsible for site access and safety, and to discuss drilling procedures, locations, and schedules. The surface geophysical surveys commenced on 22 September 1986, and the remainder of the field program was initiated on 7 October 1986. All field work was completed by 12 February 1987. This report documents the procedures of and the findings of the Phase II Stage 2 investigation.

1.3 BASE PROFILE

Luke AFB is assigned to the Tactical Air Command (TAC) and occupies 4,198 acres of land in Maricopa County, Arizona, 13 miles west of downtown Phoenix. The base is located east of the White Tank Mountains, southwest of Sun City, and north of Litchfield Park as shown in Figure 1-1. In addition, Luke AFB supports the following off-site facilities:

- Gila Bend Air Force Auxiliary Field
- Luke Air Force Range
- Auxiliary Field No. 1
- Holbrook Radar Bomb Scoring Range
- Fort Tuthill Recreation Annex
- Sanitary Landfill Annex (now closed)
- Waste Treatment Annex
- Humbolt Mountain Radar Site

Construction at Luke AFB began in March 1941, after the land had been acquired from the City of Phoenix. Occupation of the base took place in June 1941 with the primary intent of providing advanced flight training to fighter pilots. In November 1946, the base was deactivated after having trained 17,000 pilots over a 5-year period. The Gila Bend Gunnery Range, a

*Formerly the Arizona Department of Health Services (ADHS).

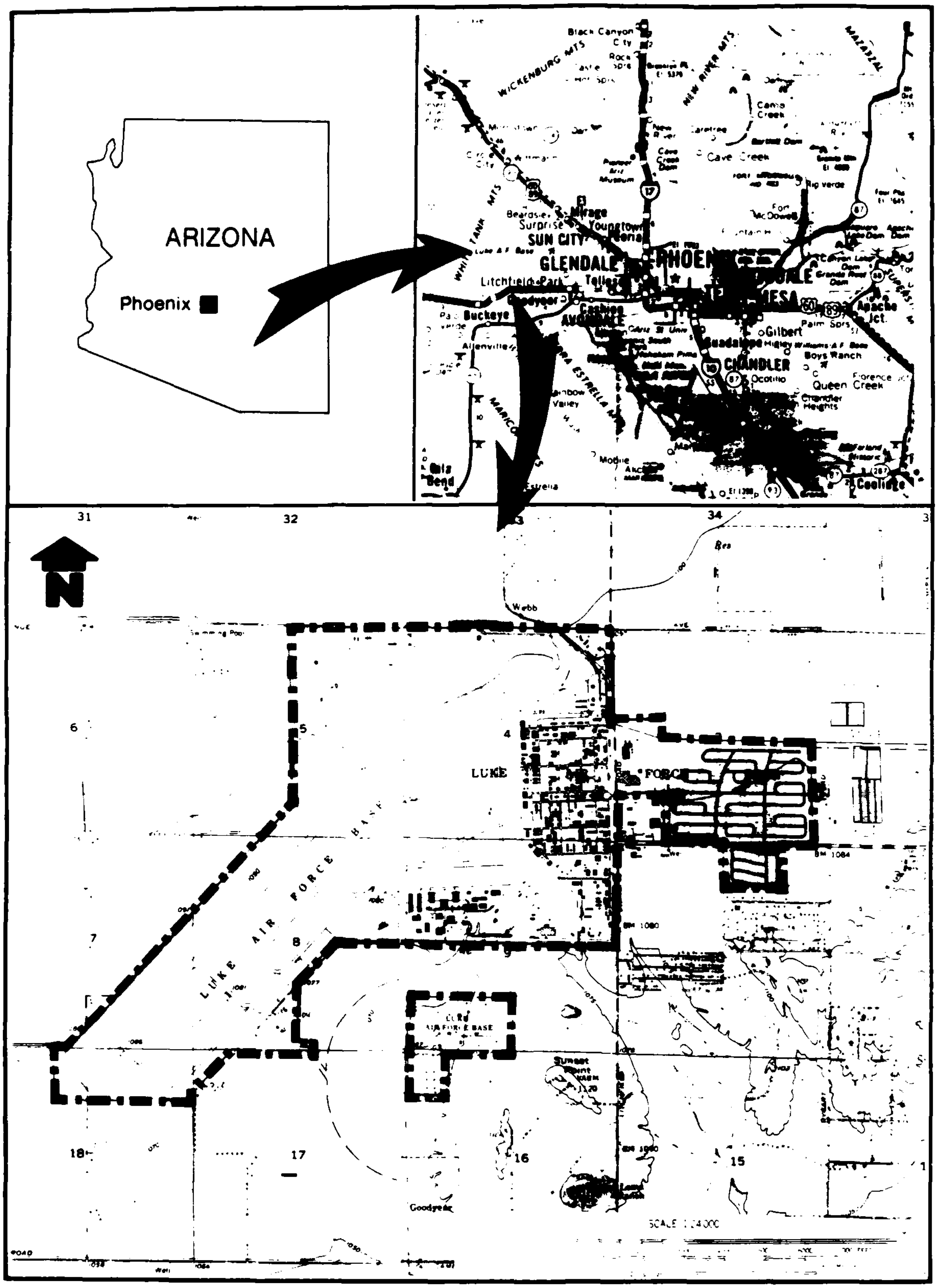

FIGURE 1-1 INDEX MAP SHOWING LOCATION OF LUKE AFB, AZ

major part of the training operation, remained open but was operated by Williams AFB which is located near Chandler, Arizona. Luke AFB reopened with the onset of the Korean War in February 1951 in order to provide advanced flight training. The base was transferred from the Air Training Command (ATC) to the Tactical Air Command in July 1958. In December 1980, the 832nd Air Division replaced Tactical Training Luke (TTL) to become the current host of Luke AFB. The primary purpose of the unit today is to provide command supervision of both the F-16 training program of the 58th Tactical Training Wing and the F-15 and F-5 programs of the 405th Tactical Training Wing.

1.4 CONTAMINATION PROFILE

To date, no large-scale industrial operations generating large quantities of hazardous waste have been conducted at Luke AFB. The generation of waste oils and solvents from cleaning and painting operations has been small relative to other bases that have significant industrial aircraft maintenance or overhaul missions. Personnel interviewed at the base indicated that up to 100,000 gallons per year of POL waste (mostly JP-4) were disposed at the POL trenches between 1970 and 1972. Smaller quantities of combustible wastes were burned during fire training exercises conducted at the fire training areas. It is suspected that pesticides have been introduced into the soils through extensive agricultural operations from farms adjacent to the northern, western and southern base boundaries. Based on the Phase I Records Search Report (CH2M Hill, 1982), the chemical parameters related to the most potentially hazardous materials at Luke AFB would be O&G, pesticides, and VOCs.

To determine whether or not past operation and disposal practices have adversely affected the environment, soils and groundwater in and around the five sites and groundwater from base production wells were sampled and were analyzed for the parameters listed in Table 1-2. Each of the six sites is described below, and their locations are shown in Figure 1-2. The details of the field investigation are reported in Section 3 of this report, and the results of the sample analyses are reported in Section 4.

1.4.1 Oil/Water (O/W) Separator Canal

The Oil/Water (O/W) Separator Canal is located on the southern side of the base as shown in Figure 1-3. The canal bed is approximately 12 to 15 feet below ground surface and is 6 to 10 feet wide. The oil/water separator (located approximately 100 feet north of the east-west road - "N" Street) collects runoff from runways, aircraft washings, and maintenance areas. Under normal conditions, the flow is retained in the separator, the oil is collected for proper disposal, and the wastewater is pumped to the Sewage Treatment Plant for treatment.

Table 1-2

Summary of Analytical Protocol,
Luke AFB, Arizona

Site	Potential Contaminant	Sample Medium	Analytes
Oil/Water Separator Canal	Petroleum products Spent solvents Pesticides	Groundwater/ Surface water	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil/ Sediment	VOCs Petroleum hydrocarbons
POL Trenches and Lagoon	Petroleum products Leaded petroleum sludge Spent solvents Pesticides	Groundwater	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil	VOCs Metals

Key

VOCs = Volatile organic compounds including xylenes
MEK = Methyl ethyl ketone
BNAs = Base/neutral-acid extractable compounds
O&G = Oil and grease
TOC = Total organic carbon
TKN = Total Kjeldahl nitrogen
Metals = Priority pollutant metals
Pesticides/PCBs = Priority pollutant pesticides and poly-chlorinated biphenyls
DBCP = Dibromochloropropane
Radiological = Gross alpha, gross beta, gamma, and radium-226

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Table 1-2
(continued)

Site	Potential Contaminant	Sample Medium	Analytes
South Fire Training Area	Petroleum products Spent solvents Pesticides	Groundwater	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil	VOCs MEK O&G Metals
Current and North Fire Training Areas	Petroleum products Spent solvents	Groundwater	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil	VOCs MEK O&G Metals

Key

VOCs = Volatile organic compounds including xylenes
MEK = Methyl ethyl ketone
BNAs = Base/neutral-acid extractable compounds
O&G = Oil and grease
TOC = Total organic carbon
TKN = Total Kjeldahl nitrogen
Metals = Priority pollutant metals
Pesticides/PCBs = Priority pollutant pesticides and polychlorinated biphenyls
DBCP = Dibromochloropropane
Radiological = Gross alpha, gross beta, gamma, and radium-226

Table 1-2
(continued)

Site	Potential Contaminant	Sample Medium	Analytes
Sewage Treatment Plant Effluent Canal	Spent solvents Pesticides	Groundwater/ Effluent	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs Nitrate/ Nitrite TKN
		Soil/ Sediment	VOCs Metals
Base Production Wells	Pesticides Radioisotopes Petroleum products Spent solvents	Groundwater	VOCs MEK BNAs O&G Metals Pesticides/ PCBs DBCP Radiological

Key

VOCs = Volatile organic compounds including xylenes
MEK = Methyl ethyl ketone
BNAs = Base/neutral-acid extractable compounds
O&G = Oil and grease
TOC = Total organic carbon
TKN = Total Kjeldahl nitrogen
Metals = Priority pollutant metals
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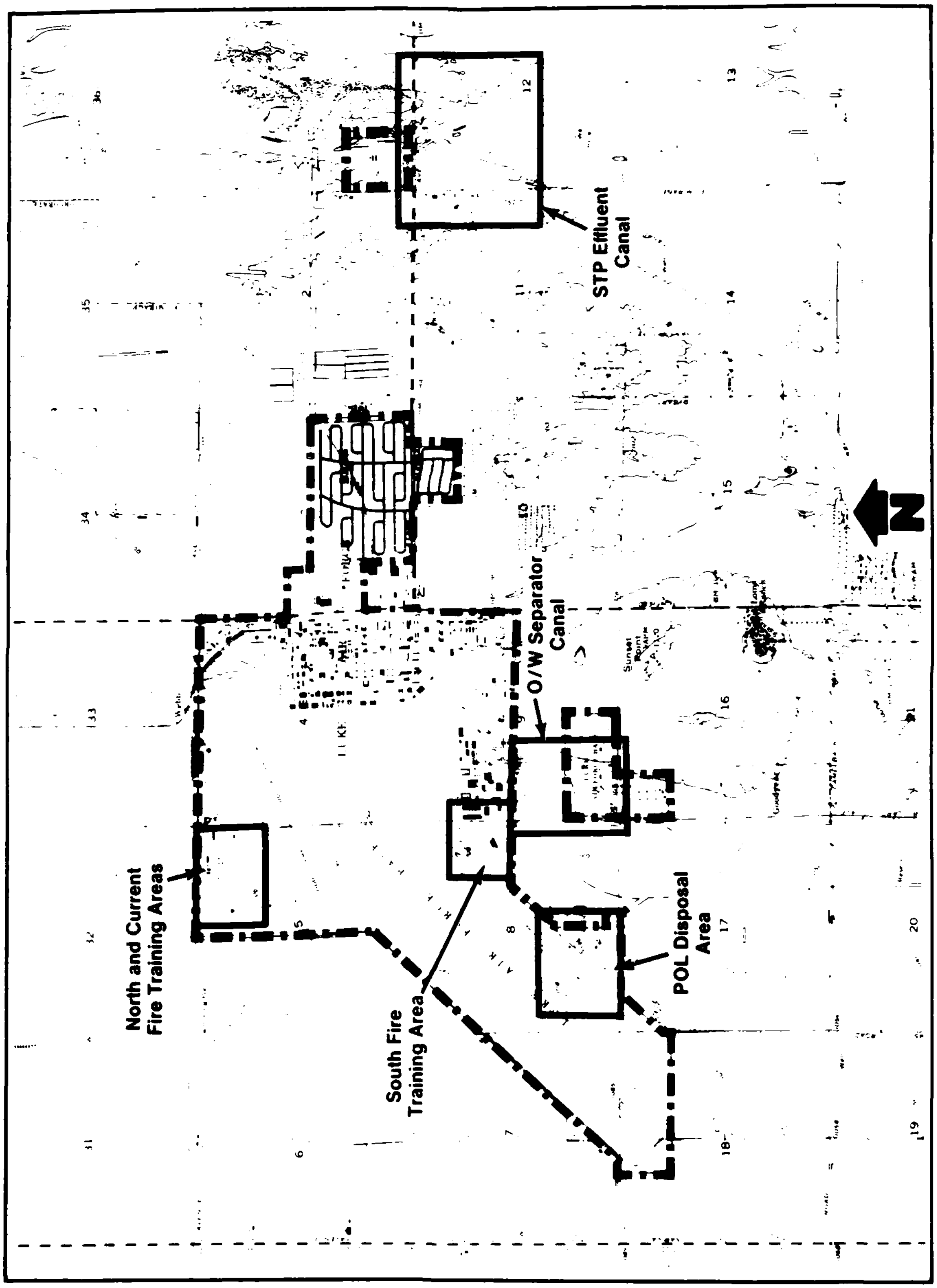

FIGURE 1-2 LOCATIONS OF PHASE II STAGE 2 INVESTIGATION SITES, LUKE AFB, AZ

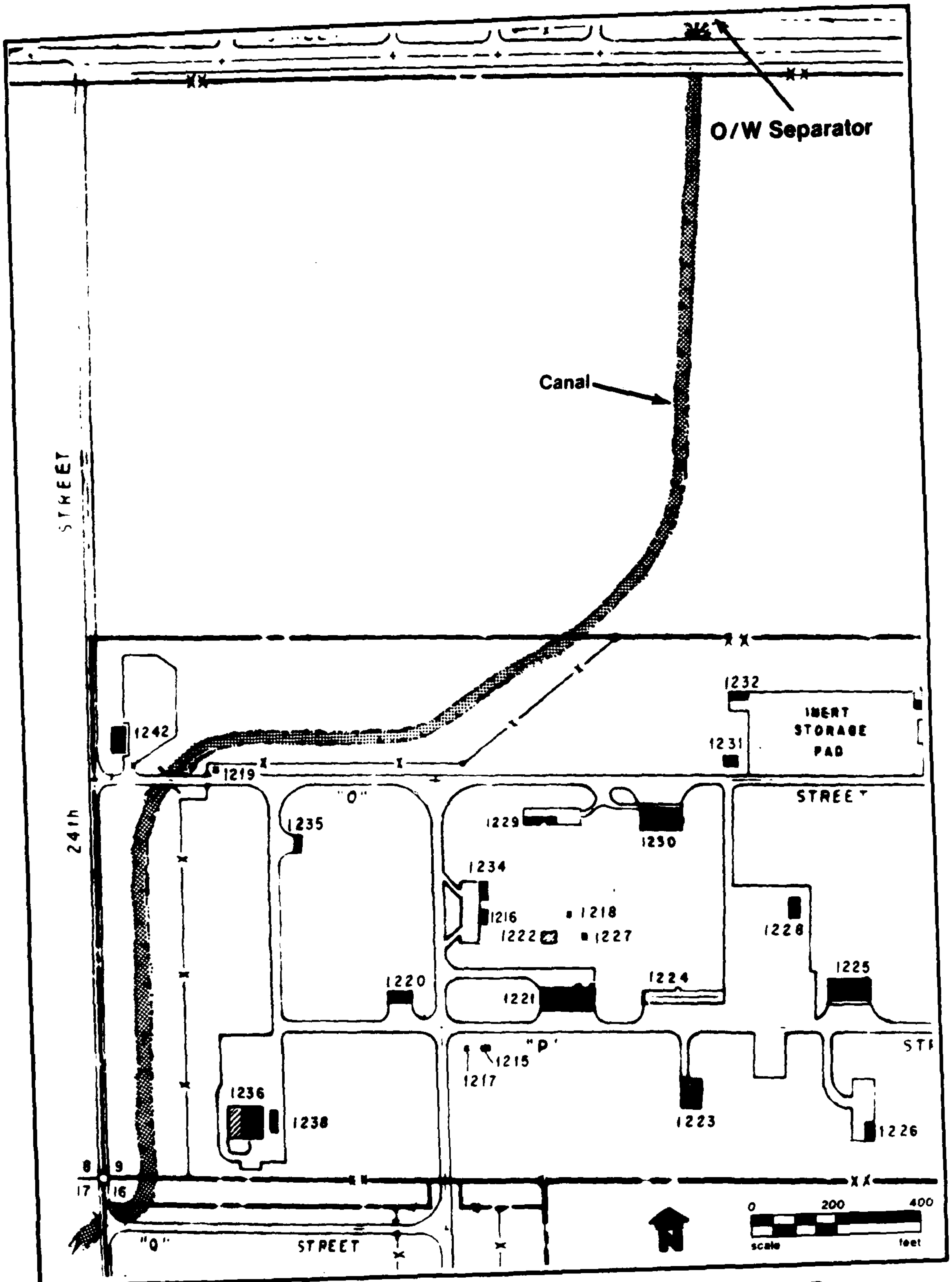

FIGURE 1-3 O/W SEPARATOR CANAL SITE MAP, LUKE AFB, AZ

During periods of heavy rainfall, the separator is bypassed, and flow is diverted to the canal through a series of pipes and culverts. The water flows south through the canal that begins immediately south of "N" Street, running approximately 3,600 feet before crossing the base boundary. After flow has stopped, ponded water remains in several sections of the canal. This water generally disappears within 24 to 48 hours due to evaporation and infiltration into the canal bed.

1.4.2 POL Trenches and Lagoon (POL Area)

The POL Trenches and Lagoon (POL Area) are located south of base production well PW-11 and southeast of the power check pad as shown in Figure 1-4. The site was used for the disposal of base-generated POL wastes from 1970 through 1972. Many shallow trenches, covering an estimated area of 5 to 10 acres, were excavated at this site. There was also a shallow lagoon located at the northeastern corner of the site. The liquid waste was distributed over the site in shallow trenches ranging from 1 to 1.5 feet deep. The waste was left to weather for 4 to 6 weeks after which the trenches were backfilled and the residual products were covered. An estimated volume of 100,000 gallons per year, mostly waste JP-4, may have been disposed at this site. Surface drainage flows overland in a southwesterly direction. This area is now used for storage of asphalt rubble from the demolition of an aircraft taxiway in 1979. Some asphalt has been removed for recycling by the City of Glendale, but many piles still remain.

1.4.3 South Fire Training Area (SFTA)

This site was the original fire training area and is located in the south-central portion of the base between Facility 999 and "N" Street (see Figure 1-5). The site was used from 1941 until 1946 and from 1951 until about 1963. Training exercise fires were fueled by a mixture of flammable liquids, including waste POL products, generated by the base. The waste was poured onto old aircraft or simulated aircraft in a cleared area and was then ignited. Surface drainage from the site flows in a southerly direction. The area is now completely paved, and an Air Force Reserve facility (Building 998) has been constructed over the former pits.

1.4.4 Current and North Fire Training Areas (NFTA)

These sites are located in the northern portion of the base (see Figure 1-6). The Current Fire Training Area is located approximately 1,000 feet east of the former North Fire Training Area (NFTA). The NFTA was used from about 1963 until 1973. Operations at the Current Fire Training Area commenced following

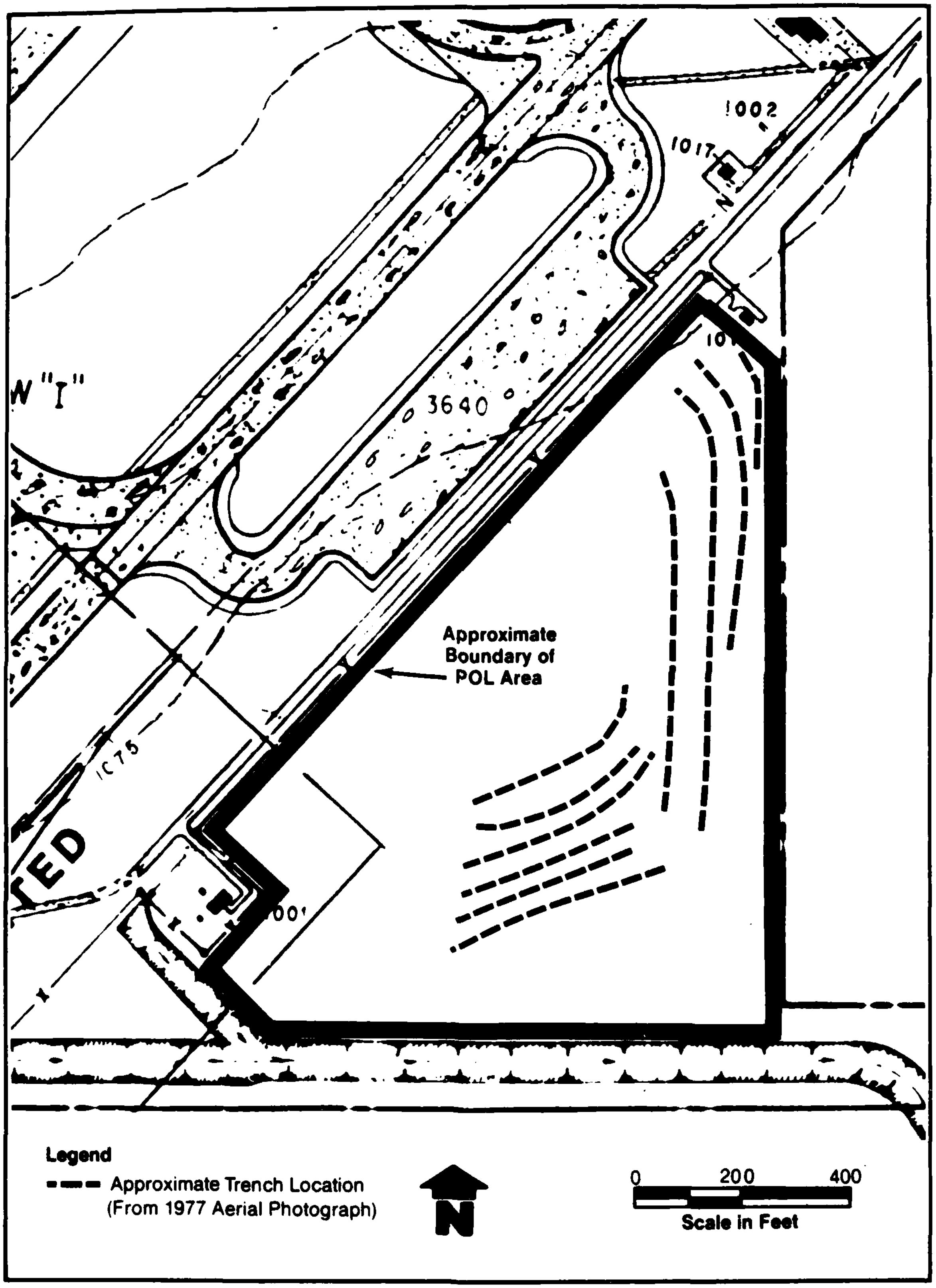

FIGURE 1-4 POL AREA SITE MAP, LUKE AFB, AZ

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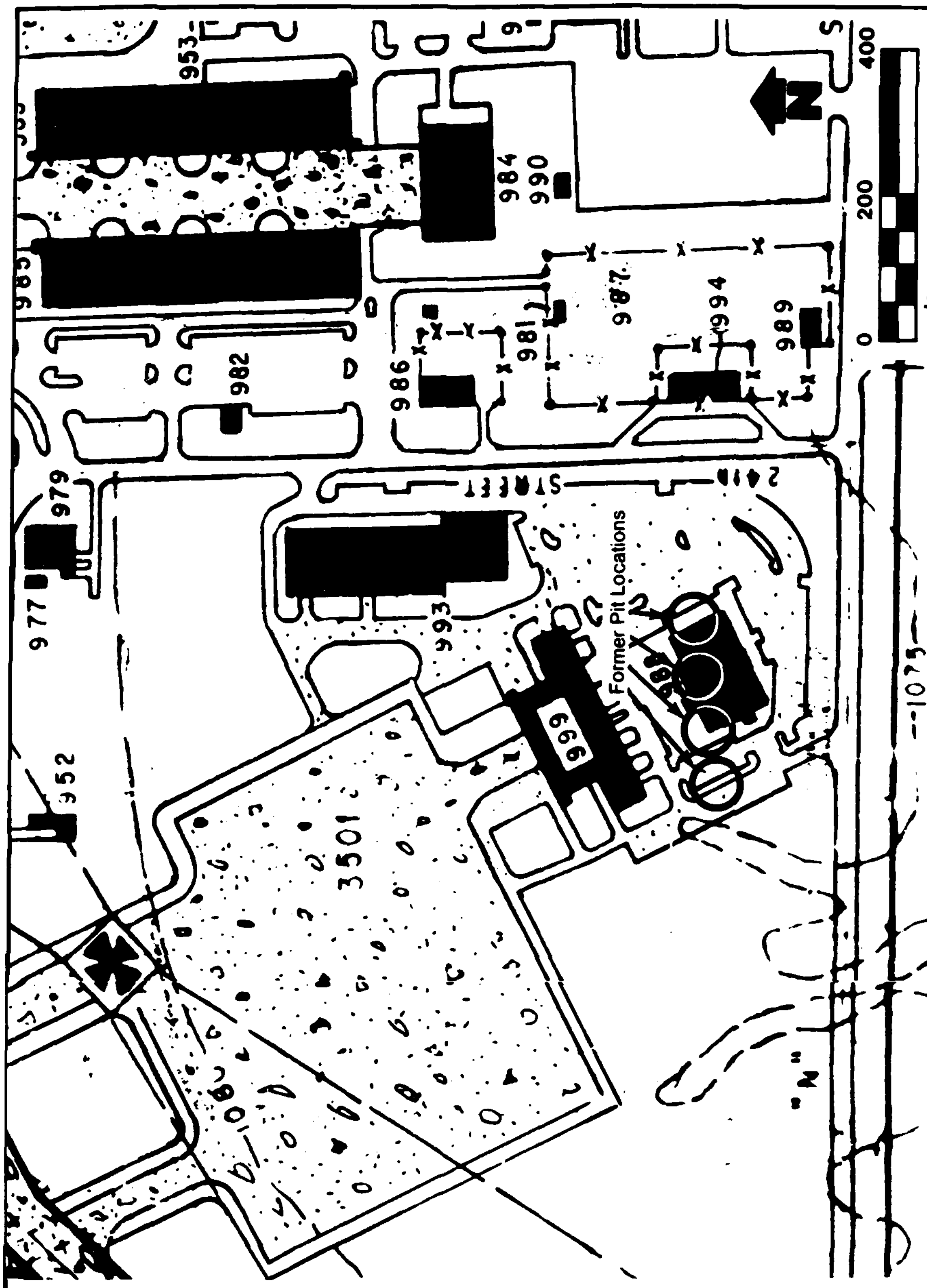

FIGURE 1-5 SOUTH FIRE TRAINING AREA SITE MAP, LUKE AFB, AZ

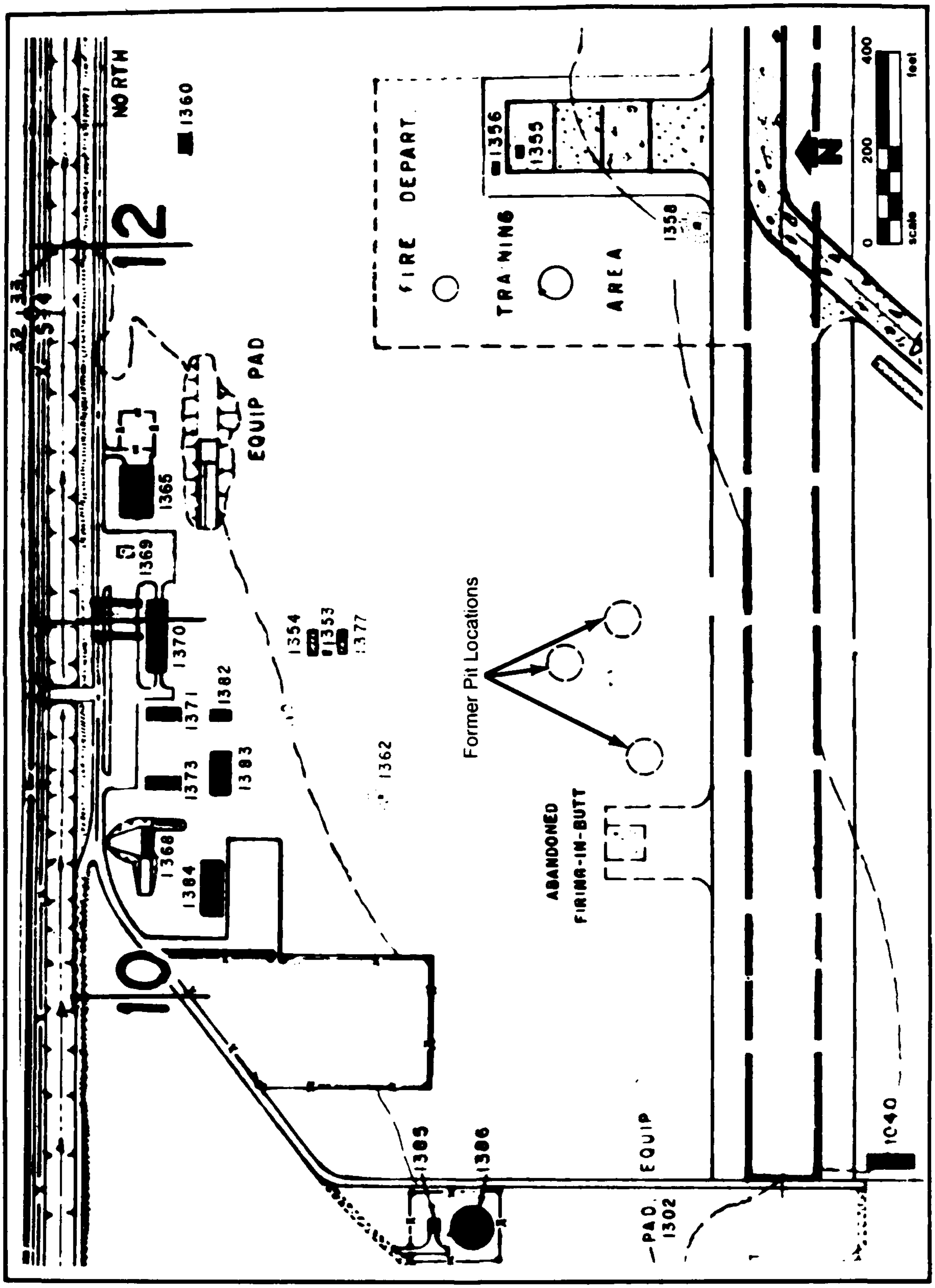

FIGURE 1-6 NORTH AND CURRENT FIRE TRAINING AREAS
SITE MAP, LUKE AFB, AZ

closure of the NFTA. Training exercises are conducted in a fashion similar to those discussed in Subsection 1.4.3 with the exception that a berm was added to prevent overflow of fuel and other potential contaminants to the surrounding area. Also, current practice involves the application of water to the bermed area prior to applying fuels. This process lessens the direct infiltration of petroleum products. Surficial evidence indicates past fuel spillage in the general area. Both the Current and North Fire Training Areas exhibit little or no topographic relief.

1.4.5 Sewage Treatment Plant (STP) Effluent Canal

Wastewater from Luke AFB is treated at the Base Sewage Treatment Plant, built during the early 1940's. The STP is located on Glendale Avenue, approximately 2 miles east of the Main Base, and adjacent to the Agua Fria River as shown in Figure 1-7. The STP includes a comminutor, two sedimentation units, two trickling filters, a secondary clarifier, and a chlorine contact chamber. Two anaerobic digestors are used to digest the sludge which is then dewatered on sludge drying beds. The design capacity of the STP is 0.94 million gallons per day (mgd) with a peak flow of 3.15 mgd. At present, the STP is operating at 0.6 to 0.7 mgd. The majority of this flow consists of domestic sewage. Industrial wastewater, which is commingled with and treated with domestic wastewater, is estimated to comprise less than 5 percent of the total average daily flow.

The effluent from the STP is discharged into a canal that flows into lagoons in the dry Agua Fria River bed. The treated effluent is routinely monitored by personnel at the STP for conventional parameters, including biological oxygen demand (BOD), pH, chemical oxygen demand (COD), and O&G, in accordance with U.S. Environmental Protection Agency (U.S. EPA) regulations. Sample results are reported to U.S. EPA, ADEQ, and TAC Headquarters. The information is available through the Civil Engineering Water Department at Luke AFB.

1.4.6 Base Production Wells

Locations of the base production wells are presented in Figure 1-8. Those wells now in use were installed between 1941 and 1985 with depths ranging from 475 to 1,200 feet below ground surface. Production wells PW-2, PW-3, PW-5, PW-6, and PW-8 have been abandoned. No written records exist to document the well abandonment. However, according to information obtained from Bill Moloche, Civil Engineering Water Department, wells PW-2 and PW-3 have been cement capped and well PW-8 has some type of metal obstruction approximately 50 feet below surface. Well PW-8 also has a metal surface cap that is not cemented or

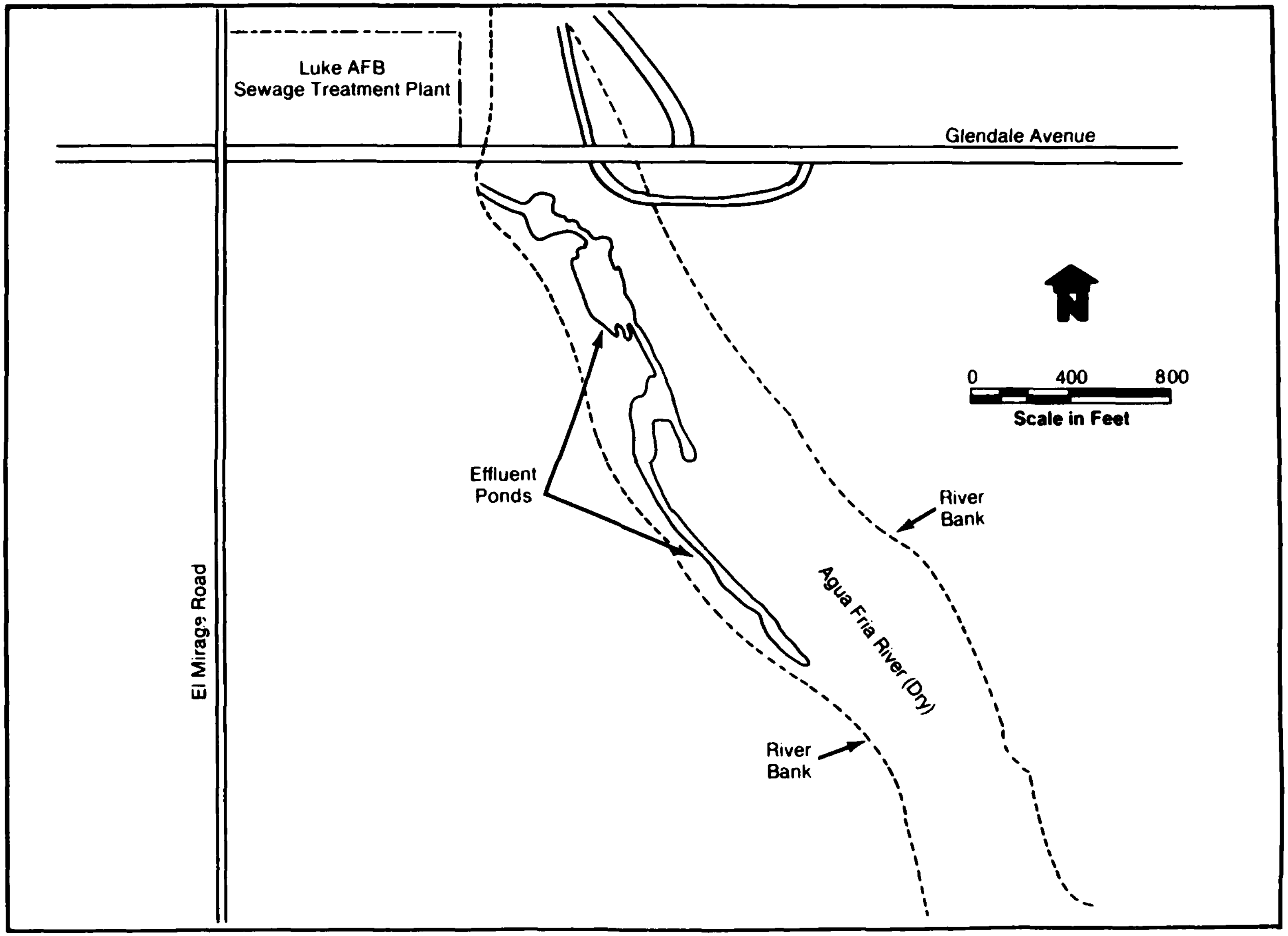

FIGURE 1-7 STP EFFLUENT CANAL SITE MAP, LUKE AFB, AZ

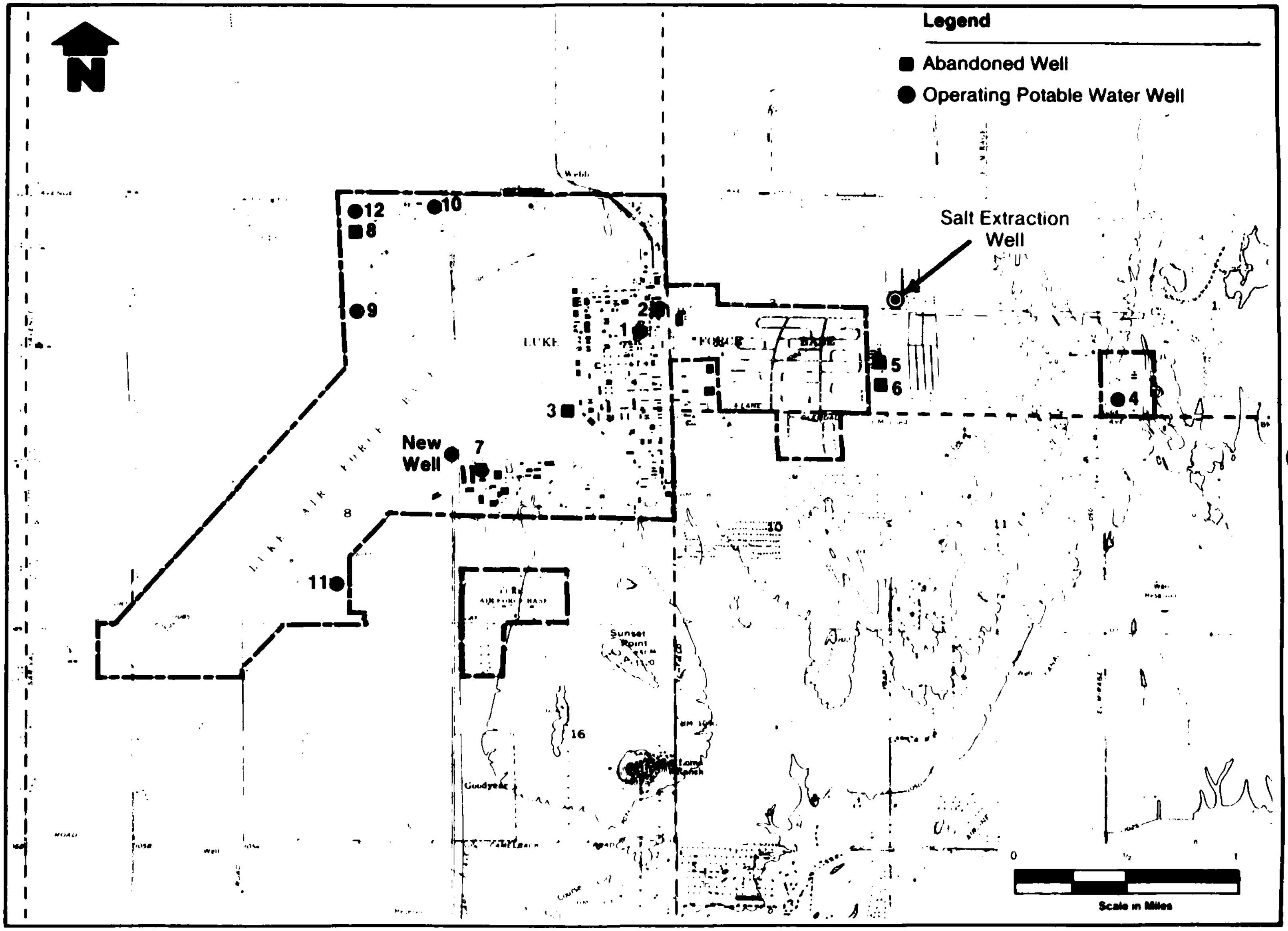

FIGURE 1-8 LOCATIONS OF PRODUCTION WELLS, LUKE AFB, AZ

welded in place. There is no information available on wells PW-5 and PW-6. In addition, production well PW-12 was being serviced and was not in operation during the sampling period. Therefore, sampling activities occurred at six production wells: PW-1, PW-4, PW-7, PW-9, PW-10, and PW-11. Two new wells have been installed on the base, one near the Fire Station and one near the control tower on the southern side of the base. Pumps have not been installed in either well, and neither well was sampled.

1.5 FACTOR OF CONCERN

The following factor of concern should be kept in mind in reading this report:

- Luke AFB overlies an extensively developed and over-pumped aquifer (upper alluvial unit). Major water use in the area is for agricultural irrigation. At present, groundwater is the sole source of potable water at Luke AFB. Surface water from the Central Arizona Project (CAP) is available to the base, but at a significantly higher cost than that of groundwater. Any contamination introduced into the aquifer by either on-base or off-base activities could have far-reaching impacts on the available supplies of potable water that currently support the base mission at Luke AFB.

1.6 PROJECT TEAM

The Phase II Stage 2 Study at Luke AFB was conducted by WESTON staff and was managed through WESTON's corporate headquarters in West Chester, Pennsylvania.

1.6.1 WESTON Staff

The following personnel served lead functions in this project:

- Peter J. Marks, Program Manager - Corporate Vice President, M.S. in Environmental Science, 20 years experience in laboratory analysis and applied environmental science.

- Katherine A. Sheedy, P.G., Project Director - M.S. in Geology, Registered Professional Geologist, 13 years experience in hydrogeology and environmental geology.

- J. Gregory Hill, P.E., Senior Hydrogeologist and Task Manager - M. S. in Geology, 11 years experience in environmental engineering and hydrogeology.

- <u>Deborah L. Jones, Project Scientist and Field Team Leader</u> - M.S. in Environmental Pollution Control, 3 years experience in investigation of soil and groundwater contamination.

- <u>Earl M. Hansen, Ph.D., Analytical Laboratory Manager</u> - Ph.D. in Chemistry, 16 years experience in environmental sampling and analysis including 3 years as Laboratory Quality Assurance Manager.

- <u>Alison Dunn, P.G., QA/QC Officer</u> - M.S. in Hydrology, 5 years experience in hydrology and evaluation of subsurface contamination.

Professional profiles of these key personnel, as well as those of other project personnel, are included in Appendix K.

1.6.2 Subcontractors

The monitor well drilling tasks of the Phase II Stage 2 study at Luke AFB were performed by Beylik Drilling, Inc. of La Habra, California. The soil borings were performed by Western Technologies, Inc. of Phoenix, Arizona. Additional soil borings at the STP Effluent Canal were drilled by Layne Environmental Services of Tempe, Arizona. All monitor well drilling and soil boring operations were performed under the direct supervision of a WESTON field scientist. Soil-gas surveys were conducted by Tracer Research Corporation of Tucson, Arizona, under subcontract to WESTON. Soil-gas surveys were guided by and were coordinated by WESTON's Field Team Leader. Geophysical logging of monitor well boreholes was performed by Welenco of Tempe, Arizona, and was supervised by a WESTON field scientist.

SECTION 2

ENVIRONMENTAL SETTING

2.1 REGIONAL GEOLOGY

Luke Air Force Base (Luke AFB) is located within the Sonoran Desert section of the Basin and Range physiographic province. In general, the province is characterized by north to northwest trending isolated mountain ranges separated by desert plains. The Sonoran Desert section consists primarily of desert plain with low narrow ranges comprising less than one-fourth of the area of this section. Luke AFB rests on a broad alluvium-filled valley within the western portion of the Phoenix Basin and is surrounded on the north, south, and west by highland bedrock mountain ranges. The White Tank Mountains lie approximately 8 miles west of Luke AFB, the Sierra Estrella lie 12 miles to the south, and the Hieroglyphic Mountains lie about 15 miles to the north. The rocks forming the mountains are predominantly Precambrian granites, gneisses, and schists overlain locally by volcanic and sedimentary rocks of Tertiary Age.

The history of mountain building and sedimentation in the area of Luke AFB is complex, and much of it is of little relevance to an environmental investigation of the shallow subsurface. By the beginning of the Tertiary Age, approximately 67 million years ago, the mountains were in a state of uplift, and eroded sediments were deposited into the subsiding basin, producing the thick valley-fill sequence found in the subsurface of Luke AFB today. The coarse-grained sediments were deposited primarily in stream channels crossing the subsiding basin. In areas outside of the channels with restricted circulation, fine-grained sediments, including shallow-water lacustrine deposits, were deposited. Locally, evaporites are interbedded with these fine-grained sediments. Studies of the valley-fill material indicate that in most areas of the Sonoran Desert there is little horizontal continuity to the beds of fine- and coarse-grained sediments (Stulik and Twenter, 1964).

The thickness of the valley-fill sequence varies from a few feet at the periphery of the basin adjacent to the mountains to an estimated maximum of 10,000 feet at Litchfield Park just south of Luke AFB. These unconsolidated sediments are deposited on top of basement rock that is probably of the same composition as the nearby mountain ranges.

No wells have penetrated the entire thickness of the alluvium to bedrock except at the periphery of the basin. The deepest well in the Luke AFB vicinity is a 3,500-foot deep salt extraction well that is located at the Morton salt processing operation approximately one mile east of the base (see Figure 1-8, p. 1-18). This is the only mineral extraction operation in the vicinity of the base. There is a sand and gravel operation east of the STP in the vicinity of the Agua Fria River bed.

2.2 CLIMATE

Luke AFB is characterized by desert climatic conditions. Average annual precipitation is 7 inches. Most of the precipitation occurs in the form of rainfall from July through September with the heaviest rainfall occurring in August. The remaining part of the year is generally dry. Average monthly temperatures at the Phoenix Airport range from 49.7°F in January to 83.6°F in June (Climates of the United States, Volume II, 1974).

The average yearly lake evaporation rate for the Phoenix area is 72 inches per year. Therefore, the potential loss of water to evapotranspiration for the area exceeds precipitation by 65 inches per year.

2.3 TOPOGRAPHY

Within a few miles of Luke AFB, topographic relief of the western Phoenix Basin ranges from about 1,000 feet above mean sea level (MSL) on the desert plain to over 4,500 feet above MSL in the White Tank mountains with the land surface varying from very steep to virtually flat. Elevations at Luke AFB, located on the desert plain, range from 1,110 feet above MSL at the northwestern corner to 1,075 feet above MSL at the southeastern corner of the base. The ground surface generally slopes uniformly from northwest to southeast at 25 feet per mile.

2.4 DRAINAGE

Runoff from the extremely sparse and irregular rainfall at Luke AFB is channeled into a network of surface ditches and storm drains. Due to the extreme aridity and the resulting excess evapotranspiration potential, much of this surface runoff never reaches discharge points to natural surface streams. Instead it infiltrates or evaporates. Drainage from the northern portion of the base discharges to the east toward the nearest natural surface water feature, the Agua Fria River. Drainage from the central and southern portions of the base discharges to the south toward the Salt and Gila Rivers.

Figure 2-1 shows rivers in the vicinity of the base, the Agua Fria, the Salt, and the Gila. The rivers near Luke AFB are dry most of the year and flow only during and immediately following storms, fed primarily by runoff from nearby mountains and small amounts of runoff from the valley floor. The Agua Fria, flowing north to south, lies approximately 2 miles east of the main portion of Luke AFB. The Sewage Treatment Plant is located adjacent to and discharges into the Agua Fria River. The Agua Fria discharges into the Salt River, which flows from east to west and lies approximately 6.5 miles south of the base. The Salt River discharges into the Gila River, which flows east to west, discharging to the Colorado River. The Gila River is located approximately 7 miles south of Luke AFB. In previous years, these rivers experienced erratic natural flows that sometimes resulted in flooding. These natural flows represented virtually the only local recharge to groundwater resources in the Luke AFB area. Dams and reservoirs were constructed in the mountains around Luke AFB in order to assist in water resource management and to prevent periodic damaging floods caused by these rivers.

2.5 SOILS

The soils of Luke AFB are generally well-drained with low to moderate permeability. These soils were formed on valley plains deposits derived from the weathering of igneous and metamorphic rocks that form the adjacent highlands. In many areas some calcium carbonate cemented ("caliche") layers occur below the surface. Slopes range from 0 to 3 percent. The major soil associations at Luke AFB, as mapped by the USDA Soil Conservation Service (USDA, 1977), consist of:

- Gilman-Estrella-Avondale Association

  These are nearly level to gently sloping soils, formed in recent alluvium on broad valley plains and low stream terraces, consisting of well-drained clay loams with moderate permeability.

  Gilman soils are the most predominant at Luke AFB and consist of 60 inches or more of loam or very fine sandy loam that is thinly stratified with finer to coarser textured material in the lower part.

- Mohall-Laveen Association

  These soils are nearly level loams and clay loams formed on old alluvial fans and valley plains and are well-drained with low to moderate permeability.

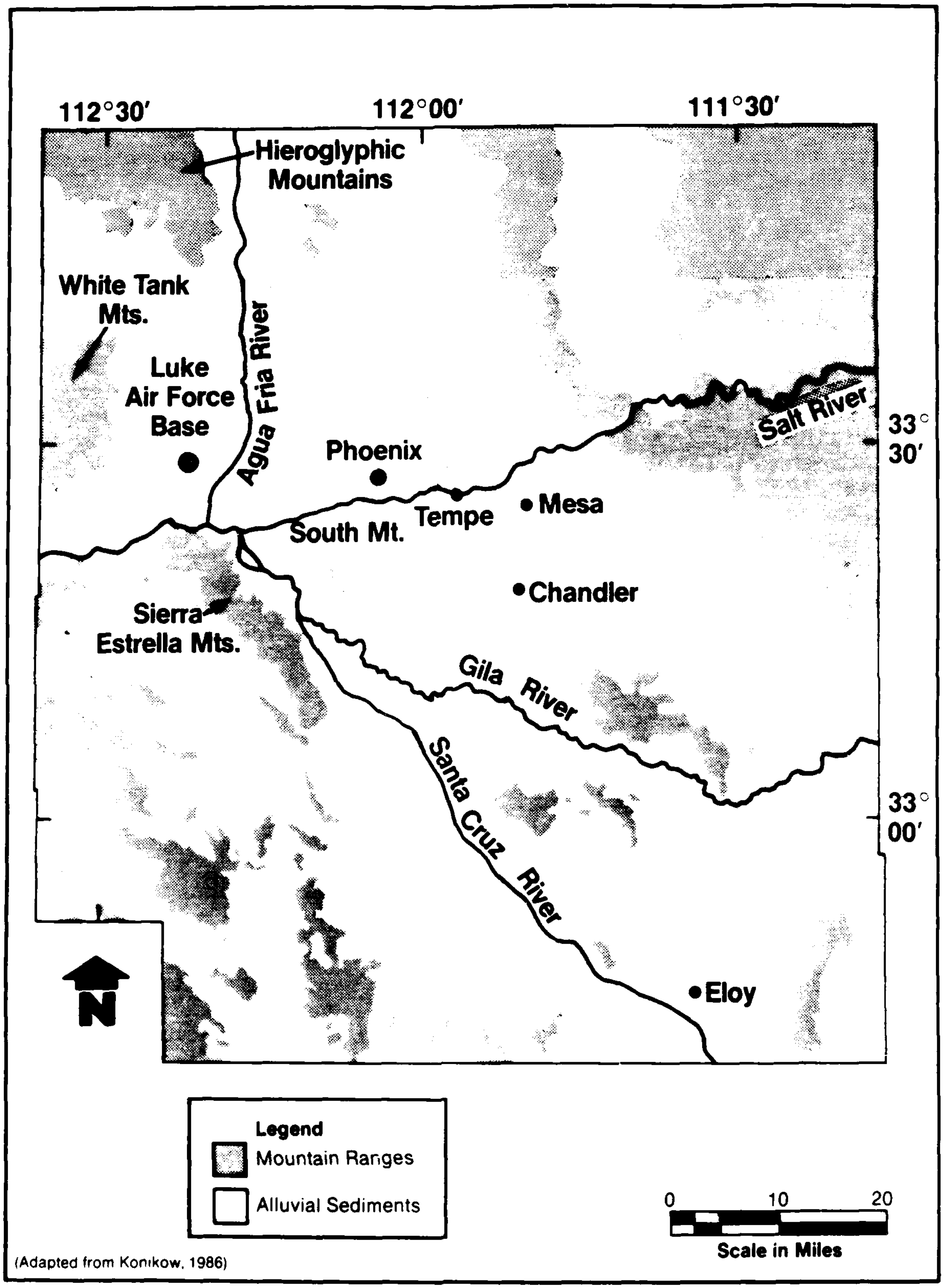

FIGURE 2-1 PHYSIOGRAPHIC FEATURES IN THE LUKE AFB AREA, AZ

The majority of on-base soils either have been paved over or have been disturbed by excavation or other base activities.

2.6 HYDROGEOLOGY

2.6.1 Groundwater Occurrence

Groundwater occurs primarily within the unconsolidated alluvial valley-fill deposits of the Phoenix Basin. The saturated thickness of these sediments is extremely variable, ranging from 20 to 10,000 feet, with the thicker deposits in the center of the basin. In the vicinity of Luke AFB, near the center of the basin, the unconsolidated sediments are thought to be as much as 10,000 feet thick. In general, the unconsolidated alluvium can be divided into three hydrogeologic units referred to as the upper alluvial unit, the middle fine-grained unit, and the lower conglomerate unit.

The upper alluvial unit is the major source of groundwater in the Luke AFB vicinity and is the unit into which the base production wells and monitor wells are completed. The base wells are completed at depths of 475 to 1,200 feet, and the monitor wells are completed between depths of 220 to 455 feet below the surface. Locations of base production wells are shown in Figure 1-8 (p. 1-18). The deposits within this hydrologic unit are unconsolidated to partially consolidated, and groundwater occurs under unconfined or water table conditions. There are areas where the occurrence of locally extensive clay and/or silt layers results in a perched or confined groundwater condition. However, under the influence of long-term groundwater withdrawals, aquifer response is predominantly unconfined over the unit as a whole. The upper alluvial unit ranges in thickness from a few feet at the periphery of the Phoenix Basin to over 1,200 feet near the base. Well yields within this unit are high, ranging from 500 to 3,000 gallons per minute (gpm), with variations resulting from differences in well construction, well depth, and local hydrogeologic conditions.

The middle fine-grained unit occurs immediately below the upper unit and consists of sedimentary deposits of low permeability, primarily clay and silt in the upper section and gypsum and salt in the lower section. The gypsum and salt deposits tend to impede the downward flow of groundwater. Some groundwater does occur in the lower section of the middle unit within limited sand and gravel deposits. Where it does occur, it is under artesian or confined conditions. This unit ranges in thickness from a few feet at the edge of the Phoenix Basin to over 1,500 feet in the vicinity of Luke AFB. The occurrence of evaporite minerals, gypsum (calcium sulfate), and halite (sodium chloride) in this unit has a significant effect on local groundwater quality. The Luke Salt Body, which is estimated to be over 6,500 feet thick, is located south and east of the base and occurs within this unit.

As mentioned in Subsection 2.1 (p. 2-1), a salt extraction well is located approximately 1 mile east of the base. This well is used to extract salt from the Luke Salt Body. Hydrogeologic impacts of the use of this well on the upper alluvial aquifer are expected to be minimal because water is injected into the salt body and is then recovered, and the brine is allowed to settle in on-site lagoons. Therefore, the system is a closed loop with the volume of water injected equalling the volume of water removed. The sand and gravel operation is not known to have any effect on the regional groundwater regime.

The lower conglomerate unit consists of a heterogeneous mixture of sand, gravel, and some clay. The low permeability of the overlying middle unit causes groundwater in the lower unit to be artesian. The exception is in those areas at the periphery of the Phoenix Basin where the middle unit is absent and the upper alluvial unit rests directly on top of the lower conglomerate unit. In those areas, the two units are hydrologically the same, and the upper unit recharges the lower unit directly. The lower conglomerate unit ranges in thickness from a few feet near the edge of the Phoenix Basin to greater than 3,000 feet in the vicinity of Luke AFB. Wells penetrating this unit are generally located along the Phoenix Basin edge and withdraw water from both the upper and lower units with well yields that are generally greater than 1,000 gpm.

2.6.2 Regional Water Table Configuration and Groundwater Flow Patterns

Within the upper unit, groundwater historically flowed southwesterly from recharge areas at the base of the mountains, following the channels of the Agua Fria and the Gila Rivers, both of which contributed recharge to the aquifer. Flow out of the groundwater basin occurred under the Gila River bed south of the White Tank Mountains.

However, groundwater withdrawals in the vicinity of Luke AFB have increased regularly during the past 50 years. More than 90 percent of the groundwater withdrawn is used for agricultural irrigation. The increased use of groundwater in the Luke AFB area has caused a number of significant changes in the hydrogeologic/geologic regime. During the period from 1923 to 1977, the average groundwater levels declined over 300 feet, averaging a decline of over 5 feet per year.

Today, as a result of large-scale off-base agricultural withdrawals, a large cone of depression has formed west of Luke AFB (shown in Figure 2-2). As a result, the groundwater no longer flows southwesterly, but instead flows toward this depression from all directions. Very little, if any, groundwater leaves the Phoenix Basin as underflow. Recharge in the Luke AFB area now occurs almost entirely as excess irrigation water in the agricultural fields surrounding the base.

Figure 2-3 shows changes in water table elevations during the 7-year period from 1976 to 1983. Basin-wide, the water table has roughly stabilized during this period as a result of water conservation measures. However, locally, there were significant water table variations during this period. Northwest of Luke AFB, water table declines of 24 to 29 feet have occurred. A water table rise is shown southeast and southwest of the base where water table elevations have increased as much as 62 feet for the same 7-year period.

2.7 RECORDS SEARCH

Records of existing wells within a 3-mile radius of the Luke AFB Main Base area and the Sewage Treatment Plant area were investigated at the offices of the Arizona Department of Water Resources (ADWR). Those records indicate that approximately 760 wells fall within this 3-mile radius, the vast majority of which are irrigation wells. Data related to well construction were available for all wells, and driller logs were available for roughly half of the wells. Water level measurement data were available for approximately 320 of the wells. The water level measurement data, the driller logs, and the construction data of 28 representative wells are provided in Appendix D.

The well construction data include: location, date completed, use of water, casing diameter, depth of well, depth to first screen, elevation of land surface, and a water level measurement with date of measurement. These are summarized below:

- Date Completed - Very few wells predate 1920; most were drilled during the 1940's through the 1970's.

- Use of Water - Mostly for irrigation; many wells are labeled "unknown"; it is assumed that most of these are also for irrigation.

- Casing Diameter - Ranges from 8 to 34 inches; 20 inches is most common.

- Depth of Well - Ranges from less than 200 feet (only for older wells) to 3,425 feet; most range from 400 to 1,200 feet.

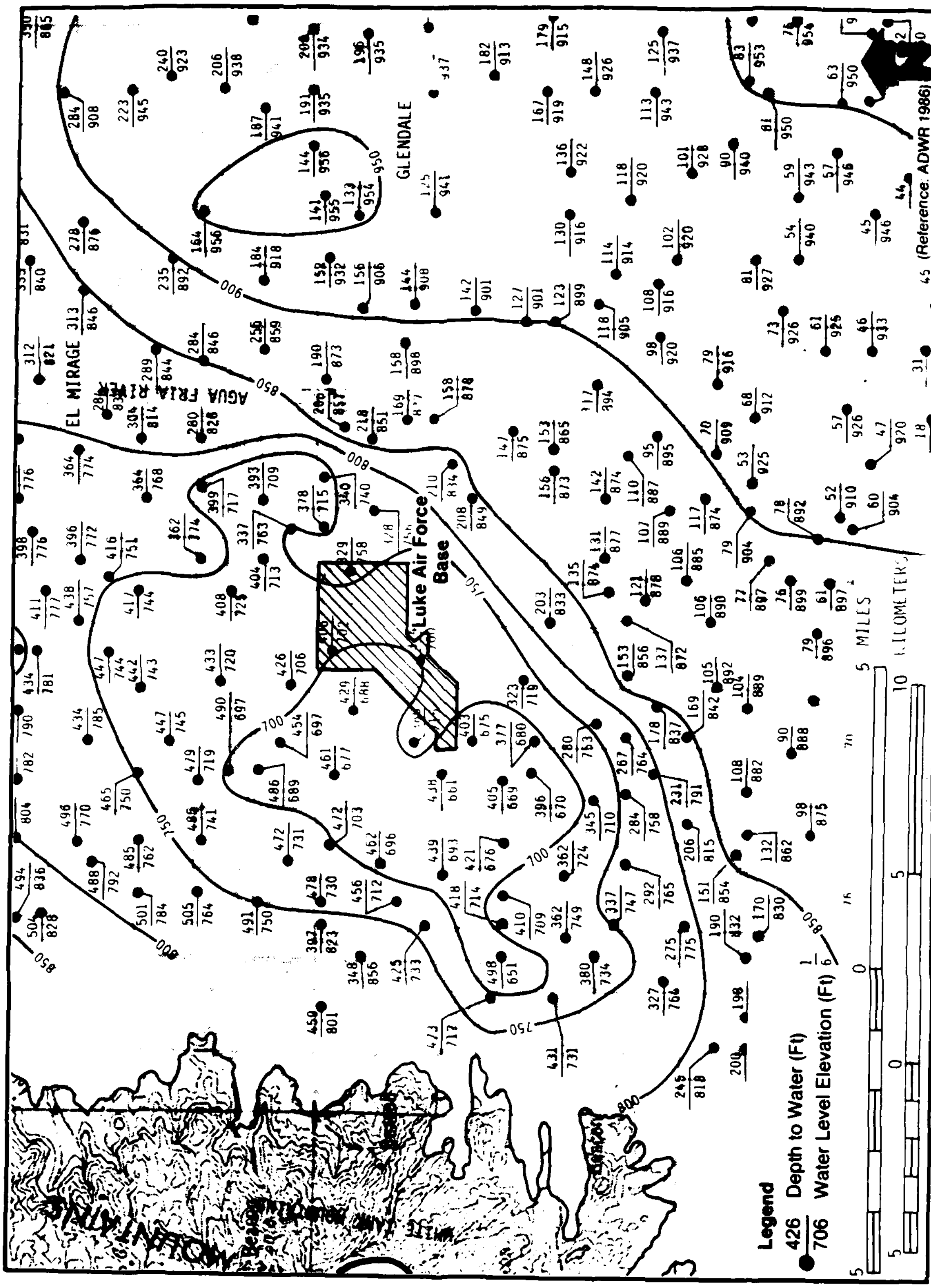

FIGURE 2-2 REGIONAL WATER TABLE MAP, 1983 - LUKE AFB, AZ

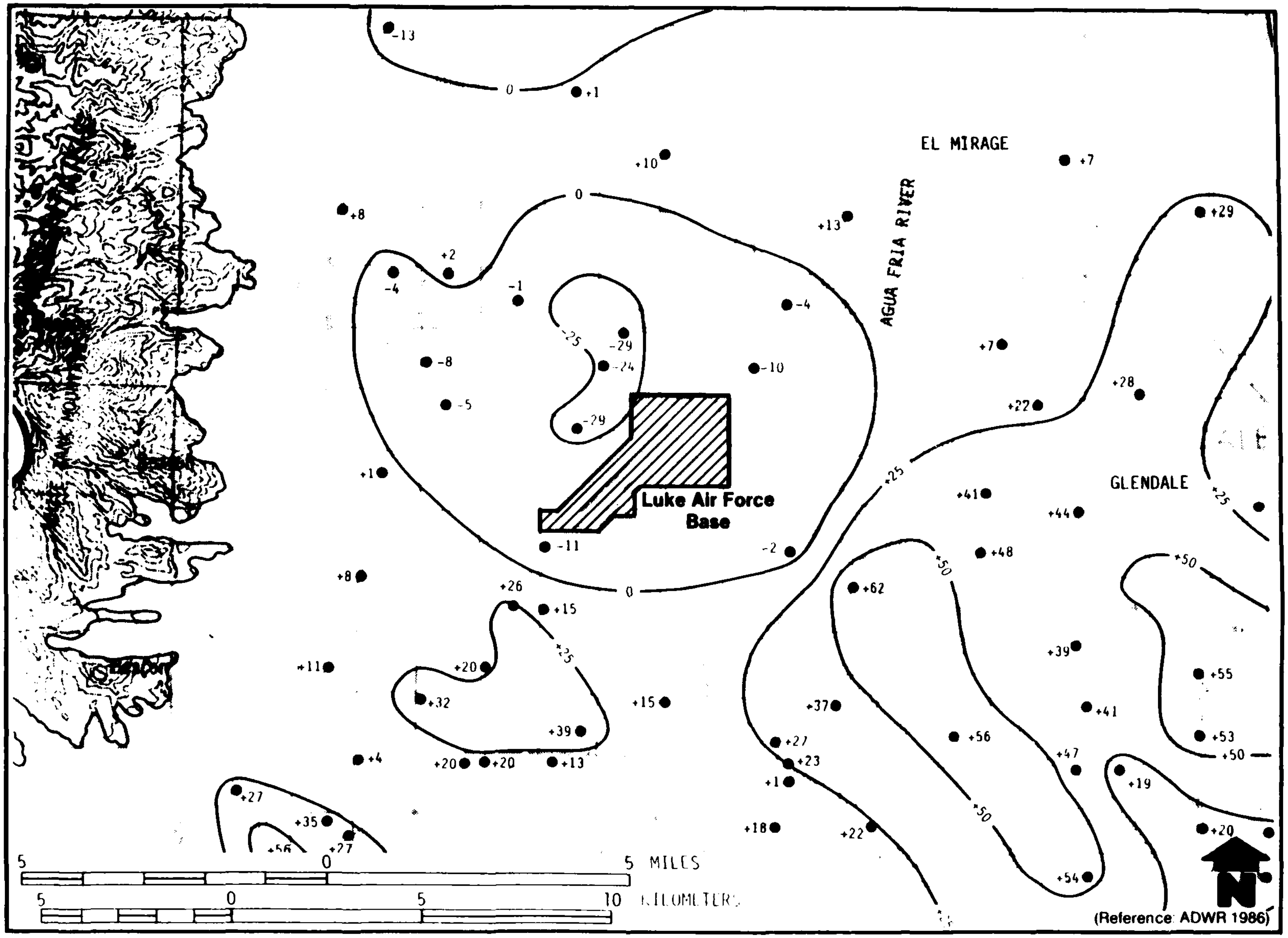

FIGURE 2-3 CHANGES IN WATER TABLE ELEVATION (FT) - 1976-1983, LUKE AFB, AZ

- Depth to First Screen - Extremely variable; typically is approximately half of the well depth.

- Elevation of Land Surface - Nearly all between 1,000 and 1,300 feet above mean sea level.

- Groundwater Level - Ranges from less than 100 feet below ground surface (older measurements only) to over 500 feet below ground surface.

Periodic water level measurement data were collected by ADWR for approximately 370 wells within the 3-mile radius. For those wells with a long record of water level measurements, the decline in water levels discussed earlier is clearly shown.

Driller logs were available for roughly half of the 760 wells. The logs were examined, and 28 were chosen for inclusion in this report as being representative of the area. The locations of those wells are shown in Figure 2-4. Well numbers are cross-referenced in Appendix D.

The quality of driller logs varies greatly, and the terminology used to describe subsurface stratigraphy is inconsistent from driller to driller. The logs are often prepared, at least partially, by the "feel" of the rig as it is drilling rather than by a detailed description of cuttings returned to the surface. However, the logs can be broadly correlated in that they describe a predominance of fine-grained materials (termed "clay" or "caliche") with interbeds of sands or gravels.

A records search was also performed to determine the types of land use north of the base and whether there were any potential off-base sources of contamination. The records search and the visual observations of this area indicate that the land has been used for agricultural purposes for as long as the base has been in existence. According to information obtained from Agricultural Stabilization and Conservation Service personnel in Phoenix, Arizona, the crops most commonly grown in this area include cotton and vegetables. Prior to 1974, chlorinated hydrocarbon pesticides and herbicides, such as chlordane and heptachlor, which have low toxicity, but whose residues remain in the soil for long periods of time, were used. Routine analyses by the Food and Drug Administration revealed trace amounts of DDT residues in some crops. The use of chlorinated hydrocarbon pesticides and herbicides was banned in 1974. Between 1974 and 1984, toxaphene was commonly used, and its use was banned in 1984. Currently used pesticides and herbicides are organophosphate compounds which may have high toxicity, but are very short-lived. The high temperatures and arid climate in the Phoenix area cause most of the residues to be eliminated within 3 days of application.

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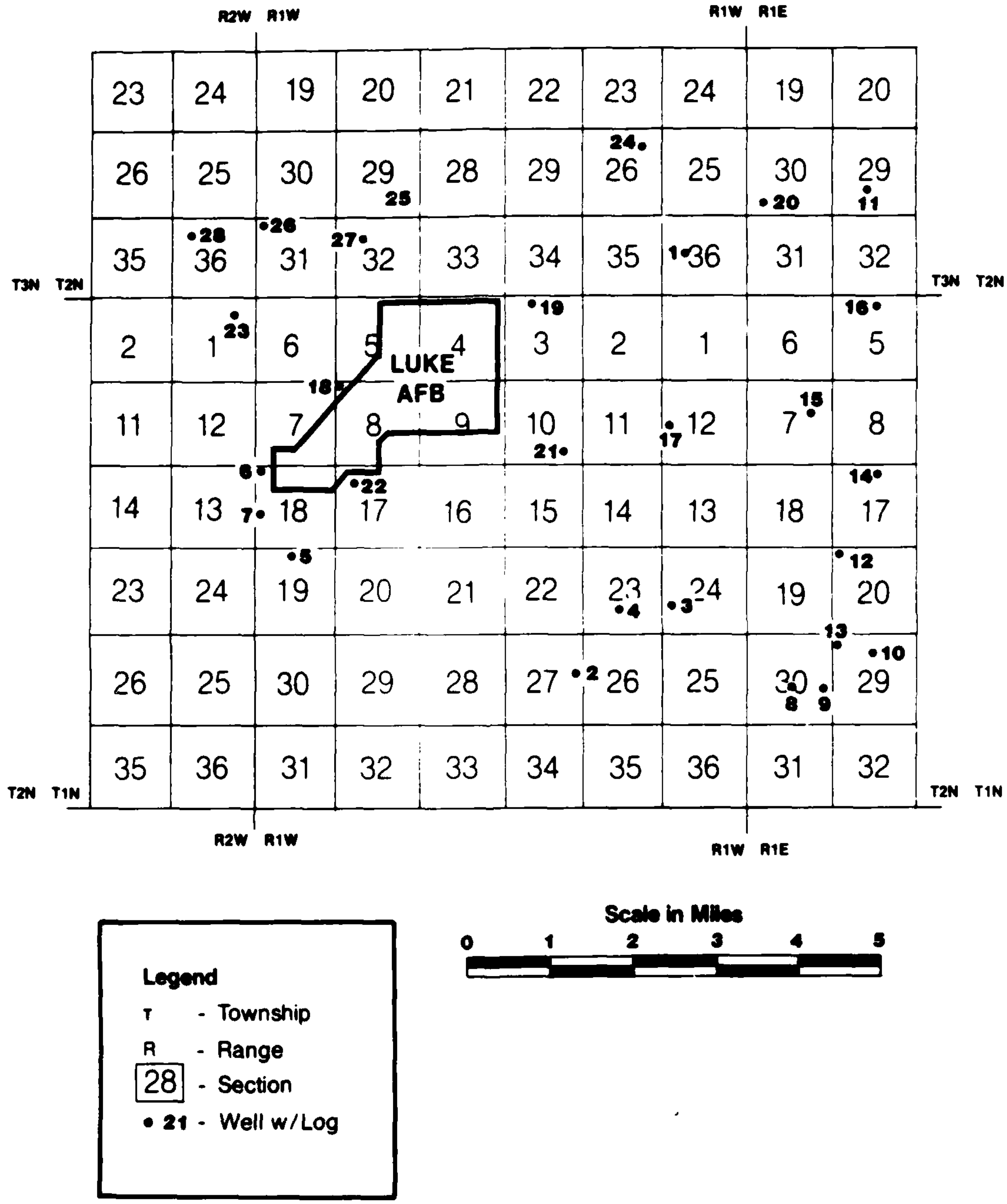

FIGURE 2-4 WELL LOCATION MAP FOR SELECTED OFF-BASE WELL LOGS LUKE AFB, AZ

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SECTION 3

FIELD PROGRAM

3.1 PROGRAM DEVELOPMENT

The Phase I Records Search Report for Luke AFB was prepared in 1982. Five sites were identified in the Phase I Report as potential contamination sources: the POL Area, the South Fire Training Area (SFTA), the North Fire Training Area (NFTA), the Perimeter Road Waste POL Application Area, and the Waste Treatment Annex. All five were investigated during the Phase II Stage 1 study. Based on the results of the Stage 1 study, three sites (the POL Area, the SFTA, and the NFTA) and the base production wells were identified as requiring further investigation. In addition, the Sewage Treatment Plant (STP) Effluent Canal and the Oil/Water (O/W) Separator Canal were listed as IRP sites requiring investigation. As a result, USAFOEHL issued Task Order 0015 in September 1986 ordering a Phase II Stage 2 study for five sites and the base production wells (see Table 1-1, p. 1-3).

The following subsections review the general approach of the study, the selection of analytical protocols for the investigation, and the field activities as they were carried out.

3.1.1 General Considerations

The primary purpose of a Phase II confirmation stage investigation is to establish the presence or absence of contamination at a site. This Stage 2 investigation was conducted to provide further information on Stage 1 sites of concern and to investigate sites that were not evaluated during the Stage 1 study, but that have been identified as potential contaminant sources since that time. The Stage 2 field program consisted of the use of ground penetrating radar (GPR), electromagnetic terrain conductivity (EM), drilling of soil borings and monitor wells, groundwater and surface water sampling, and sediment and effluent sampling.

3.1.2 Analytical Protocol

Based on the Phase I and the Phase II Stage 1 Reports, the key chemical parameters of potential concern at Luke AFB were found to be: the priority pollutant volatile organic compound (VOCs), methyl ethyl ketone (MEK), oil and grease (O&G), base/neutral-acid extractable compounds (BNAs), petroleum hydrocarbons (TPH), and the priority pollutant pesticides and polychlorinated biphenyls (PCBs). In addition, the priority pollutant metals (including antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc) were considered to be of concern at specific sites. Total organic carbon (TOC) is considered to be a good general indicator parameter for organic contamination and was included, therefore, as a screening parameter in the analytical protocol for each site. The analytical protocol developed for the Phase II Stage 2 study described in this report is summarized in Table 3-1. A list of U.S. EPA priority pollutant VOCs, BNAs, and pesticides/PCBs is provided in Table 3-2.

Monitor well MW-101 was analyzed for total Kjeldahl nitrogen (TKN) and nitrate/nitrite in the area potentially affected by the STP effluent discharge. Base production wells were sampled for radiological parameters, including gross alpha, gross beta, gamma, and radium-226, and for dibromochloropropane (DBCP).

3.2 FIELD INVESTIGATION

WESTON conducted a Phase II Stage 2 field investigation from September 1986 through February 1987 to characterize contamination at five sites at Luke AFB. The field activities included soil-gas investigation, soil borings and sampling, installing monitor wells, surface geophysical surveys, sediment and surface water sampling, groundwater sampling, and elevation surveys. The field work is summarized on a site-by-site basis in Table 1-1 (p. 1-3). Data obtained from those programs were used to determine the magnitude and the extent of contamination, if present, and also the potential for migration of those contaminants.

3.2.1 Schedule of Activity

The field investigation at Luke AFB was initiated on 22 September 1986 and was completed on 12 February 1987. A chronology of WESTON's field activities is summarized in Table 3-3.

3.2.2 Methodology

The procedures used during the field investigation are detailed in the following subsections. All field procedures were detailed in the Technical Operations Plan (TOP) (see Appendix M) that was prepared prior to the initiation of field work. Any deviations from those procedures are discussed in the following subsections.

3.2.2.1 Soil-Gas Analysis

The soil-gas sampling was conducted by Tracer Research Corporation (TRC) of Tucson, Arizona, under subcontract to WESTON. This method was developed by TRC to investigate subsurface contamination from volatile organic chemicals, such as solvents

Table 3-1

Summary of Analytical Protocol,
Luke AFB, Arizona

Site	Potential Contaminant	Sample Medium	Analytes
Oil/Water Separator Canal	Petroleum products Spent solvents Pesticides	Groundwater/ Surface water	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil/ Sediment	VOCs Petroleum hydrocarbons
POL Trenches and Lagoon	Petroleum products Leaded petroleum sludge Spent solvents Pesticides	Groundwater	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil	VOCs Metals

Key

VOCs = Volatile organic compounds including xylenes
MEK = Methyl ethyl ketone
BNAs = Base/neutral-acid extractable compounds
O&G = Oil and grease
TOC = Total organic carbon
TKN = Total Kjeldahl nitrogen
Metals = Priority pollutant metals
Pesticides/PCBs = Priority pollutant pesticides and polychlorinated biphenyls
DBCP = Dibromochloropropane
Radiological = Gross alpha, gross beta, gamma, and radium-226

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Table 3-1
(continued)

Site	Potential Contaminant	Sample Medium	Analytes
South Fire Training Area	Petroleum products Spent solvents Pesticides	Groundwater	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil	VOCs MEK O&G Metals
Current and North Fire Training Areas	Petroleum products Spent solvents	Groundwater	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs
		Soil	VOCs MEK O&G Metals

Key

VOCs = Volatile organic compounds including xylenes
MEK = Methyl ethyl ketone
BNAs = Base/neutral-acid extractable compounds
O&G = Oil and grease
TOC = Total organic carbon
TKN = Total Kjeldahl nitrogen
Metals = Priority pollutant metals
Pesticides/PCBs = Priority pollutant pesticides and polychlorinated biphenyls
DBCP = Dibromochloropropane
Radiological = Gross alpha, gross beta, gamma, and radium-226

WESTON

Table 3-1
(continued)

Site	Potential Contaminant	Sample Medium	Analytes
Sewage Treatment Plant Effluent Canal	Spent solvents Pesticides	Groundwater/ Effluent	VOCs MEK BNAs O&G TOC Metals Pesticides/ PCBs Nitrate/ Nitrite TKN
		Soil/ Sediment	VOCs Metals
Base Production Wells	Pesticides Radioisotopes Petroleum products Spent solvents	Groundwater	VOCs MEK BNAs O&G Metals Pesticides/ PCBs DBCP Radiological

Key

VOCs = Volatile organic compounds including xylenes
MEK = Methyl ethyl ketone
BNAs = Base/neutral-acid extractable compounds
O&G = Oil and grease
TOC = Total organic carbon
TKN = Total Kjeldahl nitrogen
Metals = Priority pollutant metals
Pesticides/PCBs = Priority pollutant pesticides and polychlorinated biphenyls
DBCP = Dibromochloropropane
Radiological = Gross alpha, gross beta, gamma, and radium-226

Table 3-2

Parameter List of VOCs, BNAs, Pesticides/PCBs Analyzed, Luke AFB, Arizona

VOC Analytes	BNA Analytes	Pesticides/PCBs Analytes
Chloromethane	2,4,6-Trichlorophenol	Alpha-BHC
Bromomethane	2,4,5-Trichlorophenol	Beta-BHC
Vinyl chloride	2-Chloronaphthalene	Delta-BHC
Chloroethane	2-Nitroaniline	Gamma-BHC (Lindane)
Methylene chloride	Dimethyl phthalate	Heptachlor
Acetone	Acenaphthylene	Aldrin
Carbon disulfide	3-Nitroaniline	Heptachlor epoxide
1,1-Dichloroethene	Acenaphthene	Endosulfan I
1,1-Dichloroethane	2,4-Dinitrophenol	Dieldrin
trans-1,2-Dichloroethene	4-Nitrophenol	4,4'-DDE
Chloroform	Dibenzofuran	Endrin
1,2-Dichloroethane	2,3-Dinitrotoluene	Endosulfan II
2-Butanone (MEK)	2,6-Dinitrotoluene	4,4'-DDD
1,1,1-Trichloroethane	Diethyl phthalate	Endrin aldehyde
Carbon tetrachloride	4-Chlorophenyl phenyl ether	Endosulfan sulfate
Bromodichloromethane	Fluorene	4,4'-DDT
1,2-Dichloropropane	4-Nitroaniline	Methoxychlor
trans-1,3-Dichloropropene	4,6-Dinitro-2-methylphenol	Endrin ketone
Trichloroethene	N-Nitrosodiphenylamine	Chlordane
Dibromochloromethane	4-Bromophenyl phenyl ether	Toxaphene
1,1,2-Trichloroethane	Hexachlorobenzene	Aroclor 1016
Benzene	Pentachlorophenol	Aroclor 1221
cis-1,3-Dichloropropene	Phenanthrene	Aroclor 1232
2-Chloroethyl vinyl ether	Anthracene	Aroclor 1242
Bromoform	Di-n-butyl phthalate	Aroclor 1248
4-Methyl-2-pentanone(MIBK)	Fluoranthene	Aroclor 1254
Tetrachloroethene	Pyrene	Aroclor 1260
1,1,2,2-Tetrachloroethane	Butyl benzyl phthalate	
Toluene	3,3'-Dichlorobenzidine	
Chlorobenzene	Benzo(a)anthracene	
Ethylbenzene	Bis(2-ethylhexyl) phthalate	
Styrene	Chrysene	
Total Xylenes	Di-n-octyl phthalate	
1,2-Dichlorobenzene	Benzo(b)fluoranthene	

Table 3-2
(continued)

VOC Analytes	BNA Analytes	Pesticides/PCBs Analytes
1,3-Dichlorobenzene	Benzo(k)fluoranthene	
1,4-Dichlorobenzene	Benzo(a)pyrene	
Trichlorofluoromethane	Indeno(1,2,3-c,d)pyrene	
Dichlorodifluoromethane	Dibenz(a,h)anthracene	
	Benzo(g,h,i)perylene	
	Phenol	
	Bis(2-chloroethyl) ether	
	2-Chlorophenol	
	Benzyl alcohol	
	2-Methylphenol	
	Bis(2-chloroisopropyl) ether	
	4-Methylphenol	
	N-Nitroso-di-n-propylamine	
	Hexachloroethane	
	Nitrobenzene	
	Isophorone	
	2-Nitrophenol	
	2,4-Dimethylphenol	
	Benzoic acid	
	Bis(2-chloroethoxy) methane	
	2,4-Dichlorophenol	
	1,2,4-Trichlorobenzene	
	Naphthalene	
	4-Chloroaniline	
	Hexachlorobutadiene	
	4-Chloro-3-methylphenol	
	2-Methylnaphthalene	
	Hexachlorocyclopentadiene	

Table 3-3

Field Activity Schedule,
Luke AFB, Arizona

Date	Activity
22 September 1986	Met with base personnel, discussed work scope, marked locations of soil borings and monitor wells, obtained clearances.
22 to 25 September 1986	Completed ground penetrating radar and electromagnetic conductivity surveys.
7 to 23 October 1986	Completed 21 soil borings with auger rig.
22 October 1986	Met with ADWR, ADHS, and base personnel to discuss specific monitor well drilling procedures.
22 October to 5 December 1986	Completed installation of 11 monitor wells.
13 December 1986	Completed well development.
15 to 22 December 1986	First round of water sampling including monitor wells, production wells, and effluent. Completed sediment sampling.
5 to 7 January 1987	Sampled surface water, MW-102, and MW-103 with development rig, first round.
19 to 23 January 1987	Second round of water sampling including monitor wells, production wells, and surface water.
19 January to 24 January 1987	Completed six soil borings at the Sewage Treatment Plant Effluent Canal.
9 February to 13 February 1987	Third round of water sampling including monitor wells and production wells.

and petroleum products, by measuring their concentration in the shallow soil soil-gas. The presence of contaminants in the soil-gas indicates that there may be contamination from the observed compounds in the soil near the measuring point. Soil-gas samples were collected at the O/W Separator Canal, the POL Area, and the STP Effluent Canal.

The method of operation consisted of selecting points of interest at the various investigation sites, driving a hollow steel probe into the ground, and evacuating a small amount (5 to 10 liters) of air. The sample was collected in a syringe during the evacuation step by inserting a needle through the evacuation line and drawing a sample from the gas stream (see Figure 3-1). The probes were typically driven into the ground to depths of 2 to 5 feet by a hydraulic mechanism consisting of two cylinders and a set of clamps mounted on the rear of a van. This mechanism allows the weight of the van to be applied to the probes. The probes consisted of 7-foot lengths of 0.75-inch diameter steel pipe that were fitted with detachable drive points. A hydraulic hammer was used to assist in driving probes past cobbles and through very hard, compact soil.

Ten milliliters of gas were collected at each measuring point for immediate analysis in the TRC analytical field van. A gas chromatograph equipped with an electron capture detector was used to detect trichloroethene (TCE), trichloroethane (TCA), and tetrachloroethene (PCE), and a flame ionization detector was used for analysis of benzene, toluene, xylenes, and total hydrocarbons. It should be noted that total hydrocarbons include C1-C8 aliphatic, aromatic, and alicyclic compounds. Duplicate samples were taken at each location to provide quality control. Ambient air samples were also collected at regular intervals during the soil-gas sampling in order to determine background concentrations. Ambient air samples were obtained by collecting a syringe-full of air outside of and far enough away from the van to exclude its exhausts. The results are shown in Appendix O-1. Contaminant concentrations were calculated for each location, were compiled by the TRC chemist, and were checked by the TRC hydrogeologist. Soil-gas samples were labeled according to the numbering scheme described in Subsection 3.2.2.12.

3.2.2.2 Health and Safety Program

A Health and Safety Plan was prepared and was approved by the WESTON Health and Safety Officer prior to commencing field operations. During drilling, the air was monitored using an HNu Model PI-101 photoionizer and a Century organic vapor analyzer (OVA)/flame ionization detector. The OVA was used in those areas where compounds that might not be detected by the HNu (e.g., chloroform) were suspected. When levels of organic vapors exceeded 25 ppm in the breathing zone, as stated in the

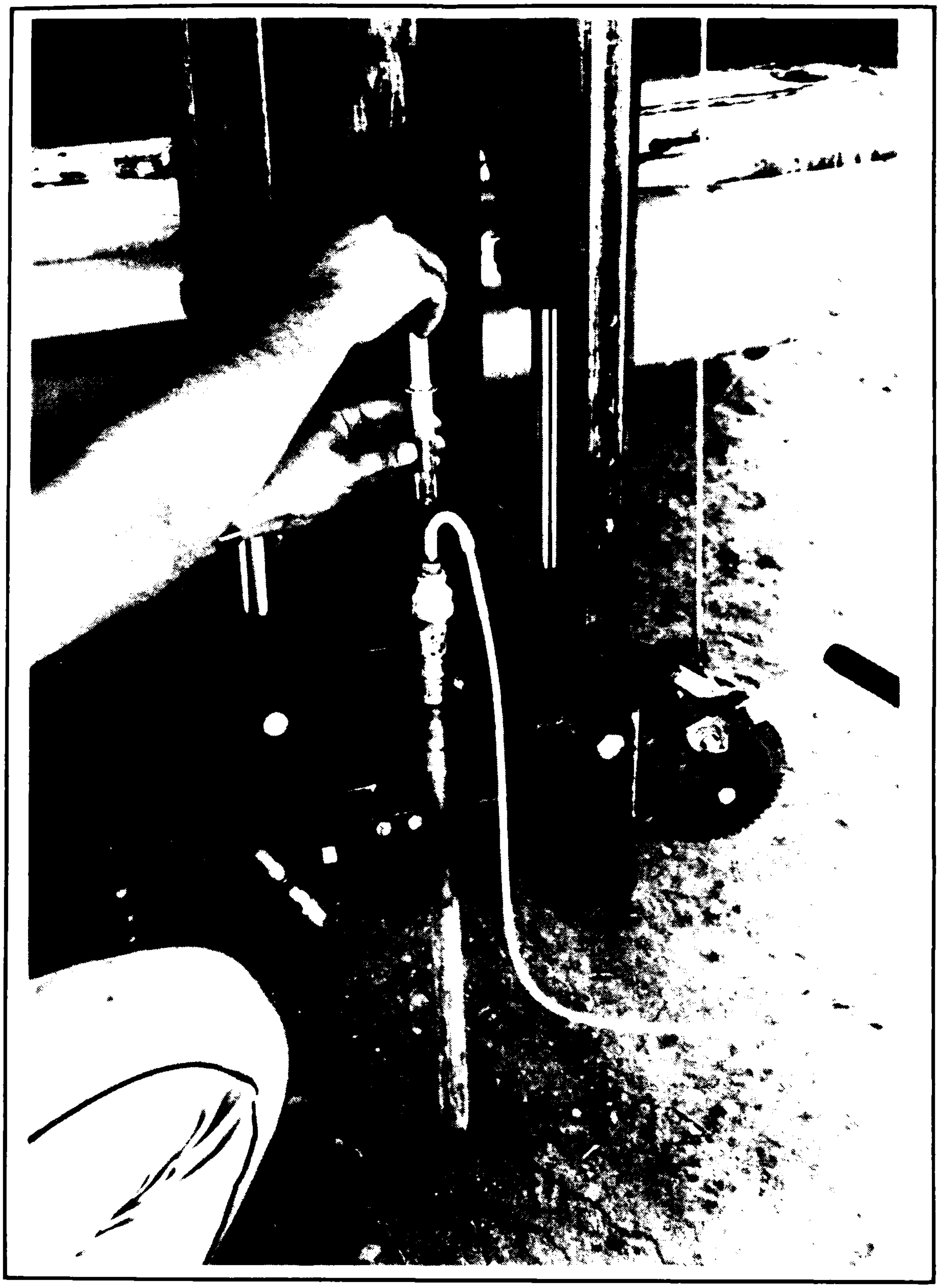


FIGURE 3-1 SOIL-GAS SAMPLING TECHNIQUE, LUKE AFB, AZ

Health and Safety Plan, Level C respiratory protection was used. Although elevated levels of organics were detected in the auger at many sites, the concentrations measured in the breathing zone were generally below 25 ppm. Level C protection was used only during drilling for soil boring 04-03 at the POL Area. A copy of the Health and Safety Plan is provided in Appendix M.

3.2.2.3 Soil Borings and Sampling

The soil boring program was initiated 7 October 1986, and a total of 27 soil borings were completed at the five sites. The drilling was conducted in two stages. The first stage was conducted by Western Technologies, Inc. (WTI) of Phoenix, Arizona, under subcontract to WESTON from 7 to 23 October 1986. WTI completed 21 soil borings using a hollow-stem auger rig at all sites except the STP Effluent Canal. WTI attempted to use the auger rig to drill four soil borings along the canal. The maximum depth penetrated was 20 feet before auger refusal. When it was discovered that the auger rig could not penetrate the large cobbles found at the site, Layne Environmental Services (Layne) of Tempe, Arizona, was subcontracted to drill those soil borings with an air-hammer rig. The remaining six borings were drilled by Layne during the second stage conducted from 19 to 24 January 1987. Soil boring locations were determined during a predrilling site inspection and after interviews with base personnel, a review of geophysical and soil-gas data, and a review of historical reports, maps, and aerial photographs. The soil borings were staked, and base clearances were obtained prior to drilling. All soil borings were drilled and were sampled under the supervision of a WESTON geoscientist.

The soil borings drilled by WTI were located at the O/W Separator Canal, the POL Area, the South Fire Training Area, and the Current and North Fire Training Areas. Each soil boring was advanced from the ground surface with a CME 75 drill rig using conventional 3.25-inch ID hollow-stem augers. The soil was sampled at 5-foot intervals throughout the depth of the soil boring. Samples were recovered using a 2-inch diameter, 18-inch long split-spoon sampler according to standard penetration test techniques (ASTM D1586-84). The split-spoon sampler was driven into undisturbed soil ahead of the auger and penetrated a maximum of 1.5 feet per sample.

Full recovery was not always obtained when the sediments were very loose or highly cemented. Actual recovery was noted on the soil boring logs provided in Appendix D.

The sampler was fitted with four California ring samplers, which are 4-inch long, 2-inch diameter brass tubes with one 2-inch long spacer, that collect soil samples for VOCs analysis with a minimum of disturbance and exposure to the atmosphere.

Immediately after the split-spoon was opened, one brass tube was removed for VOCs analysis using a stainless steel sampling utensil. This tube was capped on both ends with Teflon sheeting and tightly fitted plastic caps and was sealed with tape on both ends. The other tubes were used for analysis of the remaining parameters (as listed in Table 3-1, p. 3-3). The soil was extruded from those tubes into the appropriate containers. All tubes and containers were labeled with the sample identification number, date, installation name, and analyte and were placed on ice in an insulated cooler immediately after collection. The on-site WESTON project scientist described each soil sample using the Unified Soil Classification System (USCS), noting texture, consistency, color, moisture content, and any visible staining or odor. Blow counts also were noted.

Three split-spoon samplers were used in a rotating fashion to expedite sample recovery. Each sampler was decontaminated using an Alconox and water solution followed by a rinse with distilled water and a methanol rinse. The methanol was allowed to evaporate completely before reusing the equipment.

During drilling operations, the air was monitored for organic vapors in the open auger and in the breathing zone. Headspace measurements also were taken in the jarred soil samples. Results of the air monitoring are recorded on the soil boring logs in Appendix D.

The number of soil samples to be taken for chemical analysis from each soil boring was predetermined and was stated in the Scope of Work (see Appendix B). Although a split-spoon sample was taken for stratigraphic descriptions at each 5-foot interval, only selected samples were submitted for chemical analysis. Samples for analysis were taken at depths where soil discoloration or odor was noticed, where air monitoring equipment indicated elevated levels of contaminants, or where heavier textured soils, such as clays, were encountered. In the absence of any of the above indicators, samples were selected from pre-determined depths that gave the best coverage of the soil boring with the available number of samples.

Additional soil samples were collected for the purpose of validating field and analytical techniques. Because of the heterogeneous nature of soils, duplicate samples were taken as splits of a single sample, whenever possible, rather than as separate samples. A separate brass tube was taken for duplicate VOCs analysis; for other parameters, the soil sample was extruded from the tube into two separate containers as evenly as possible. Duplicate samples were numbered such that laboratory personnel were not able to identify the sample as a duplicate.

Samples of the soil cuttings were taken at three locations for analysis of EP toxicity, ignitability, O&G, and total organic halogens (TOX). Two samples were taken at the NFTA and one at the POL Area. The cuttings samples were taken as they came up the auger using a clean stainless steel trowel and were placed into a 250-ml glass jar. The indicated depth for the cuttings is an estimate, and the samples may actually be a composite sample from an interval of several feet. The samples were delivered to the WESTON laboratory for analysis.

The soil borings at the STP Effluent Canal were drilled by Layne using a truck-mounted Becker hammer rig. (The Becker hammer consists of a dual-walled drill pipe (6.625-inch OD, 4-inch ID) with a fixed non-rotating bit that drives the pipe into the ground while removing the cuttings with compressed air. The compressed air passes down through the 1-inch annulus and returns up through the center of the drill pipe.) The cuttings were brought up by air and were discharged through a cyclone at the side of the rig where they were examined and classified. A continuous stratigraphic log was kept by the WESTON geoscientist. Split-spoon samples were attempted at each 10-foot interval to collect samples for classification and at certain depths for chemical analysis. Several of the split-spoons met refusal while others yielded limited recovery due to the rocky nature of the material to be sampled. A description of the soil was recorded as completely as possible in the field notebook. As before, descriptive information included texture, consistency, color, moisture content, and any visible staining. With the Becker hammer, split-spoons were driven using the weight of the rig rather than a 140-lb hammer (ASTM D1586-84), which enabled the split-spoon sampler to be pushed between the cobbles so that a soil sample could be collected.

Samples for chemical analysis were collected at depths where soil staining was noticed or where finer textured soils, such as silts and clays, were encountered. Air monitoring was performed during the initial drilling attempt with the auger rig, and no concentrations of organic vapors were measured.

Upon completion, all boreholes were grouted by pumping a cement grout from bottom to top to prevent the borehole from acting as a conduit for contaminants, and all were marked with a wooden stake. Drill cuttings were spread out near each site, except the cuttings from the SFTA soil borings, which were removed to a site adjacent to the POL Area.

Fifteen soil samples for analysis of physical characteristics were taken from the soil borings at selected depths. The list of physical characteristics included plasticity index, percent organic matter, particle size (including hydrometer), cation exchange capacity, percent moisture, degree of saturation, calcium/magnesium ratio, and pH. Samples were taken when different lithologic horizons were encountered, particularly those of a clayey texture, as interpreted by the on-site WESTON geoscientist. The samples were collected by removing a brass tube from the split-spoon sampler with as little disturbance as possible, capping both ends, and sealing with tape. The tube was labeled and was submitted to the WTI laboratory in Phoenix, Arizona, for analysis. The laboratory results, including grain size distribution curves, are included in Appendix N.

3.2.2.4 Monitor Well Installation

Eleven monitor wells were installed by Beylik Drilling, Inc. (Beylik) of LaHabra, California, under subcontract to WESTON. All wells were installed with a rotary drilling rig under the supervision of an on-site WESTON geoscientist. The necessary permits for well installation were obtained by Beylik prior to the start of drilling activities. Total depths of the eleven monitor wells ranged from 220 to 455 feet below ground surface with the lower 60 feet of the well being screened.

The purpose of the monitor wells is to monitor the water table. However, with mud-rotary drilling, evidence of the water table is often masked by the volume of fluid used for drilling in the hole. Therefore, depths to water and the respective screened intervals were initially estimated based on 1985 water level information obtained by the Arizona Department of Water Resources (ADWR) and previous water level measurements taken from base wells. After the initial well at a site was developed and the water level was measured, that information was used to determine screened intervals for subsequent wells at the same site.

A 14.75-inch roller bit was used to drill to approximately 18.5 feet below ground surface using air circulation. Small amounts of water were added intermittently to control dust. The hole was cased with a 20-foot section of 10-inch ID steel casing and was grouted in place with 1.5 feet of stickup above ground surface. The grout was allowed to set for approximately 6 hours. The grout mixture consisted of quick-set cement and bentonite at a ratio of 20:1. Five to six gallons of water were used to mix one 94-pound bag of cement with 5 pounds of bentonite.

After the surface casing had firmly set in place, the drilling fluid was switched to mud and/or foam, and a 9.875-inch bit was advanced to a depth of 10 feet above the estimated water table. At this depth, mud was circulated through the hole to clean out any remaining cuttings, to develop a mud cake on the borehole wall to prevent caving of loose material, and to prepare for open hole wireline logging which requires a mud medium. The drill string was then removed, and the hole was logged for spontaneous potential (SP), natural gamma, point source resistivity, 6-foot spacing resistivity, and caliper by Welenco Inc. of Tempe, Arizona, a local wireline logging company.

Upon completion of logging, the hole was cased from the surface to within 1 foot of the bottom with 6.625-inch ID steel casing. This intermediate casing was grouted in place with a 20:1 cement:bentonite grout mixture. A volume of grout equal to the volume of the annulus between the 6-inch intermediate casing and the borehole was pumped into the intermediate casing. A cylindrical rubber plug, measuring 6 inches in diameter by 1 foot in length, was forced down the intermediate casing atop the grout with pressurized water. Upon reaching the bottom of the hole, the rubber plug blocked circulation and caused an increase on the pump pressure gauge on the drilling rig. This indicated that all of the grout was now in the annulus. The hole was left in this pressurized state for approximately 6 hours until the grout had set. A small sample of the grout mixture was taken at each well so the WESTON geologist could verify that the grout had set before continuing drilling.

A 6-inch bit was used to drill the final portion of the hole to a depth of approximately 70 feet below the bottom of the intermediate casing. In general, each hole was over-drilled by 10 to 20 feet to allow for some collapse of formation material and for settling of cuttings during well construction. Mud was again circulated to prepare the hole for wireline logging. Then, following removal of the drill string, the same suite of geophysical logs was run. After logging, the hole was screened at the bottom with 60 feet of 4-inch ID stainless steel wire-wound screen welded to 4-inch ID double-wall black iron riser pipe. Fine gravel was poured down the annulus to form a filter pack in the screened interval. The riser pipe was cut off at approximately 2 feet above ground surface and was fitted with a locking steel cap. A typical monitor well is shown in Figure 3-2. The well cuttings were inspected and were described at 5-foot intervals by the on-site WESTON geologist.

All drill cuttings were contained in a pit or in a portable mud tank on-site. Following completion of the wells drilled utilizing portable mud tanks, the cuttings were pumped out and were transported to an area near the POL Area used by the base for dumping rubble and construction debris. For those wells drilled utilizing earthen mud pits, the pits were backfilled and were regraded. No field evidence of contamination (based on visual observation, odor, or organic vapor measurements) was found in the drill cuttings and, therefore, no testing was indicated.

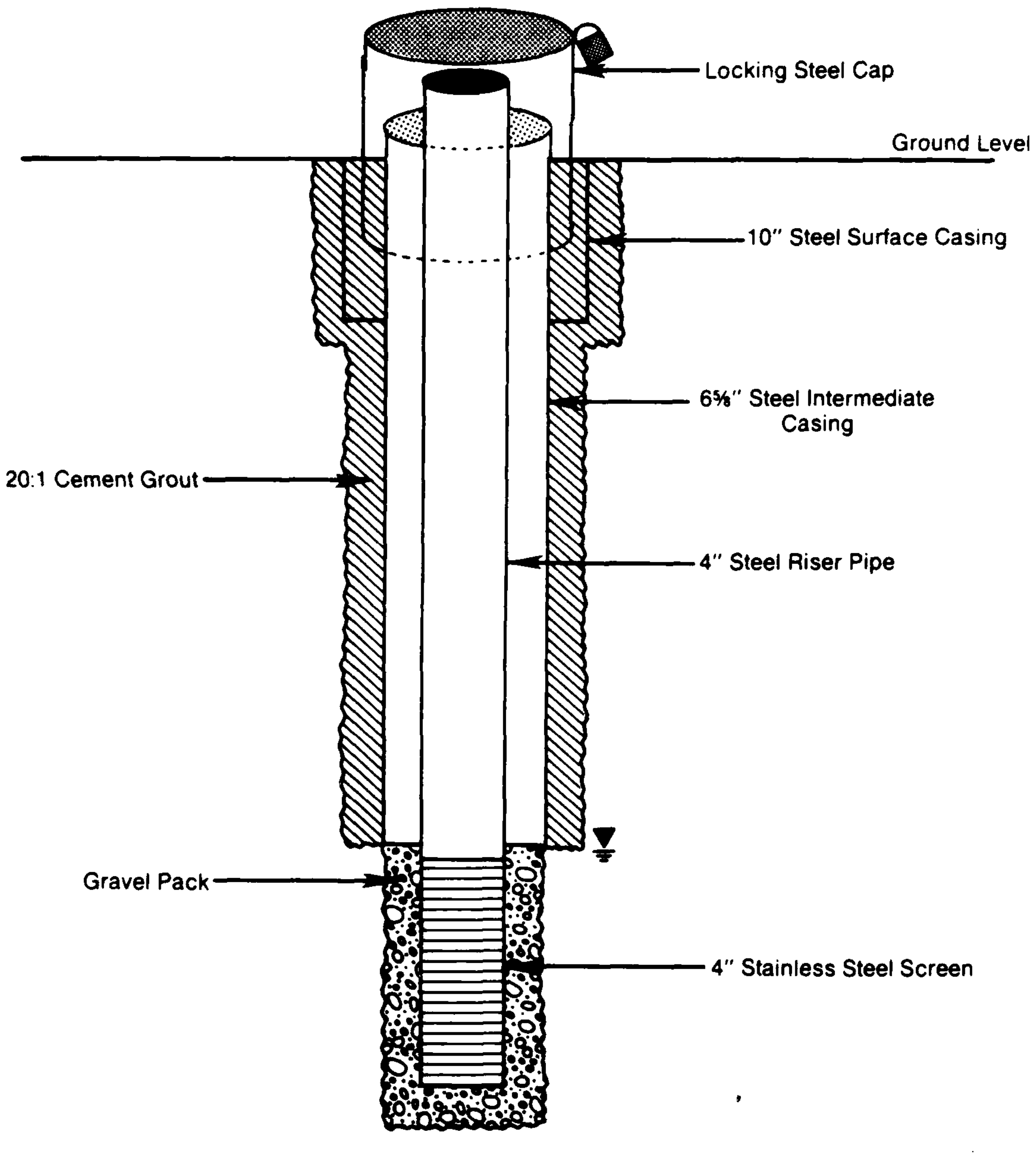


FIGURE 3-2 TYPICAL MONITOR WELL CONSTRUCTION, LUKE AFB, AZ

All monitor wells were developed after installation was complete in order to loosen and remove the mud cake from the formation. Well development included a combination of swabbing, pumping, and bailing techniques. The swab, which consisted of a 2-inch diameter pipe fitted with a 3-inch diameter rubber ring, was moved up and down through the screened interval to ensure that all portions of the screen were clean and were free of clogged sediment. The sediment-laden water was then bailed from the well with a 6-foot long steel bottom-loading bailer. This bailing action reduced the viscosity and allowed the water to be pumped by a submersible pump. The pump was then set at the bottom of the screen and was raised up through the screened interval while pumping. This ensured that pumped water was drawn through all portions of the screen. Pumping continued for several hours until the discharged water was as clear of suspended solids as possible.

3.2.2.5 Borehole Geophysical Logging

Borehole geophysical logging was undertaken during the drilling of all monitor wells as discussed in Subsection 3.2.2.4. The logging technique involves lowering various sensing devices on a cable to the bottom of the borehole and recording varying response signals as the tool is raised through the hole. The log response curves enable the user to characterize subsurface stratigraphy. The logging methods used at Luke AFB included spontaneous potential, resistivity, gamma ray, and caliper. Descriptions of each log follow.

Spontaneous Potential

The spontaneous potential (SP) logging tool is a three-pad instrument that contacts the walls of the uncased borehole as it is pulled up the hole. It measures the difference in electrokinetic potential between an electrode fixed at the surface and a downhole electrode contacting the formation. Electrokinetic potential is the charge related to the ionic activities of solutions in the formation. Positively charged sodium (Na^+) ions diffuse through clays while negatively charged chloride (Cl^-) ions are adsorbed, thus causing the clay in the formation to act as a cationic membrane. The flow of the Na^+ ions from the more concentrated formation water through the clay into the less concentrated borehole mud sets up a positive charge (potential) opposite the clays in the borehole. This is the clay membrane potential set up by the selective cation permeability of the clay and is the "zero" baseline on the far right side of an SP graph. Deviations from the clay baseline to more porous/permeable formations result in negative responses.

Used in conjunction with other logs, SP data analysis is used to detect permeable beds, to locate bed boundaries, and to give quantitative indications of the amount of clay in a formation as part of an "electric log suite." A discussion of the interpretation of the SP log and all other electrical logs used at Luke AFB is provided in Appendix L.

Resistivity

Resistivity tools, including the 16- and 64-inch "normal resistivity," are contact-pad instruments passing a current of constant intensity between the surface generator and the electrodes down the hole. A second set of electrodes, spaced either 16 or 64 inches apart, responds to the resistance of the formation against the constant current over the 16- or 64-inch spacing. The electrodes are spaced so that the instrument responses represent the weighted average of resistivities from the formation. The resistivity response average concentrates on the same depth being measured by the SP tool. The resistivity tool responses give accurate readings on bed boundaries, resistivities of fluids within the formation, and the resistivity of the formation. In addition, the movement of drilling fluids into the formation, which is an indication of porous and permeable beds, is noted on resistivity logs.

Resistivity logs can be used to define natural additives to the formation water that would result in varying resistance to current flow, such as salts. The resistivity log is also part of the normal suite of electric logs and is run simultaneously with the spontaneous potential tool.

Gamma Ray

The gamma ray log is a measurement of the natural radioactivity of downhole formations. In sedimentary or unconsolidated formations, the gamma ray log normally reflects the shale or clay content of the formations. This is because the radioactive elements tend to concentrate in clays and shales. Clean sands or gravels usually have a very low level of radioactivity, unless radioactive contaminants such as volcanic ash or granite wash are present, as in the valley where Luke AFB is located. High levels of radioactivity can also be found when formation waters contain dissolved potassium salts.

A gamma ray log can be recorded in cased wells as well as in uncased wells. One is frequently used as a substitute for SP in cased wells where SP is unobtainable or in open holes where the SP is unsatisfactory. This was the case with MW-108 at the SFTA where the proximity to power lines caused interference and made acquisition of an SP log impossible. The gamma ray log must be run in conjunction with the caliper log as materials interposed between the tool and the formations (e.g., drilling fluids) absorb gamma rays. Thus, a washout filled with drilling fluid would give erroneous readings. This type of log is useful for locating fine-grained formations, clays, silts, or shales, as well as for defining gradations from coarse to fine strata.

Caliper

The caliper is simply a pad tool that measures the size of the hole. The three spring-loaded pads extend out against the walls of the hole and measure the minimum size of the hole drilled. Washouts, over-sized holes, and swelling clays can be determined from the caliper log and are critical in an analysis of the gamma ray log that is run simultaneously with the caliper log.

3.2.2.6 Pumping Test

After completion and development of each well, a short-duration pumping test was conducted. Short duration pumping tests were deemed appropriate for the low-capacity pumps that were installed in the monitor wells. The tests were to be run a maximum of 4 hours or until the water level had stabilized, as described in the Technical Operations Plan (TOP). The tests were attempted on all wells that had submersible pumps installed in them, which excluded MW-102 and MW-103 at the O/W Separator Canal. The pumping tests were proposed to take place concurrently with the first round of groundwater sampling. Some pumping tests were not able to be completed until the second round of sampling. The procedure followed for the pumping tests was as follows:

- Measure static water level prior to starting the pumps.
- Start the pump, and begin recording time and drawdown measurements.
- Record drawdown measurements in increments of 0.5 minutes for the first 10 minutes, then every 1 minute for the next 20 minutes, then every 10 minutes for the remainder of the test.
- Check the flow rate periodically by timing the discharge into a 5-gallon pail.
- Continue the pumping test as long as hydraulically significant data are being obtained. As a general rule, the tests were terminated when the difference between successive drawdown measurements represented less than 1 percent of the total drawdown. Two of the

tests (MW-101 and MW-104) were conducted over a longer duration to verify water level stabilization over a longer pumping period.

- Shut off pump, and begin recording recovery measurements.

- Record recovery measurements every 0.5 minutes for the first 10 minutes, then every 1 minute for the next 20 minutes.

- If recovery measurements have not stabilized within 30 minutes, continue to record recovery measurements at 5-minute intervals for another 30 minutes. At the end of this time, the pumping test will be completed.

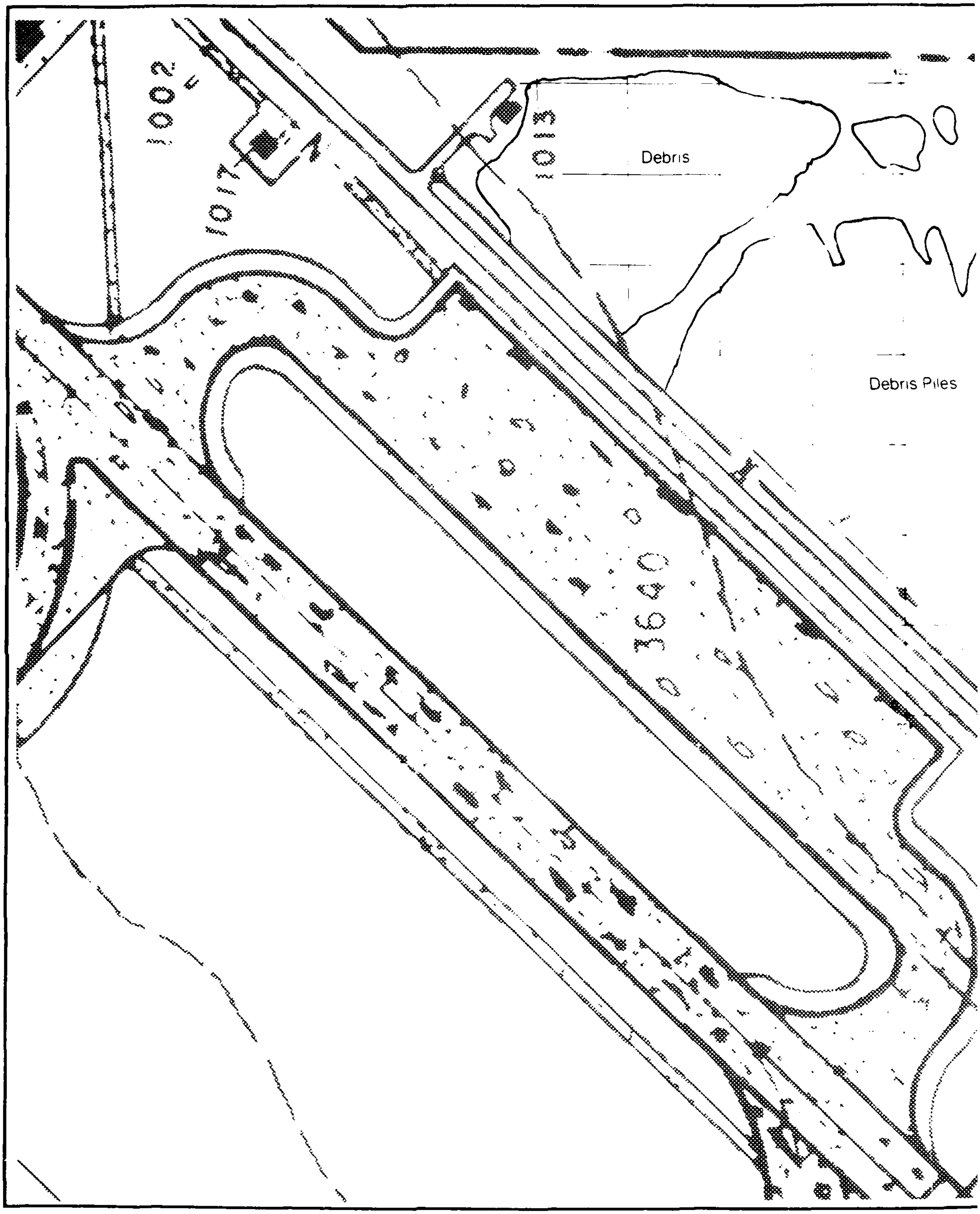
An analysis of the pumping test results is provided in Subsection 4.2.4.

3.2.2.7 Surface Geophysical Survey - POL Area

At the POL Area, a surface geophysical survey was conducted in an effort to delineate the trenches and a shallow lagoon, which were reportedly located in the area south of PW-11. The surface geophysical survey also was used to aid in the selection of soil boring and monitor well locations in the POL Area. That survey was conducted between 22 and 25 September 1986 and employed two complementary geophysical techniques: electromagnetic terrain conductivity (EM) and ground penetrating radar (GPR). The surveys were conducted on a grid covering as much of the former waste disposal trenches and lagoon area as possible (see Figure 3-3). Many areas were inaccessible to the crew due to construction debris piles. Where practical, base personnel used a bulldozer to clear traverses through the debris piles. Details of the EM and GPR techniques are discussed in the following paragraphs.

Electromagnetic Terrain Conductivity (EM)

A Geonics EM-31 electromagnetic terrain conductivity meter was used to conduct the EM survey. The EM-31 utilizes induced magnetism in the soils to measure soil matrix conductivity. Following Ampere's Law, an alternating electrical current in the transmitter coil of the instrument produces a primary alternating magnetic field that is detected in the receiver coil. Based on Faraday's Law, this primary magnetic field induces small electrical currents in the earth. The currents, in turn, generate secondary magnetic fields proportional to the conductivity of the soil. These secondary magnetic fields are also detected by the receiver coil and, through comparison with the primary magnetic field, are translated into terrain conductivity



1002
1017
1013
Debris
Debris Piles
3640

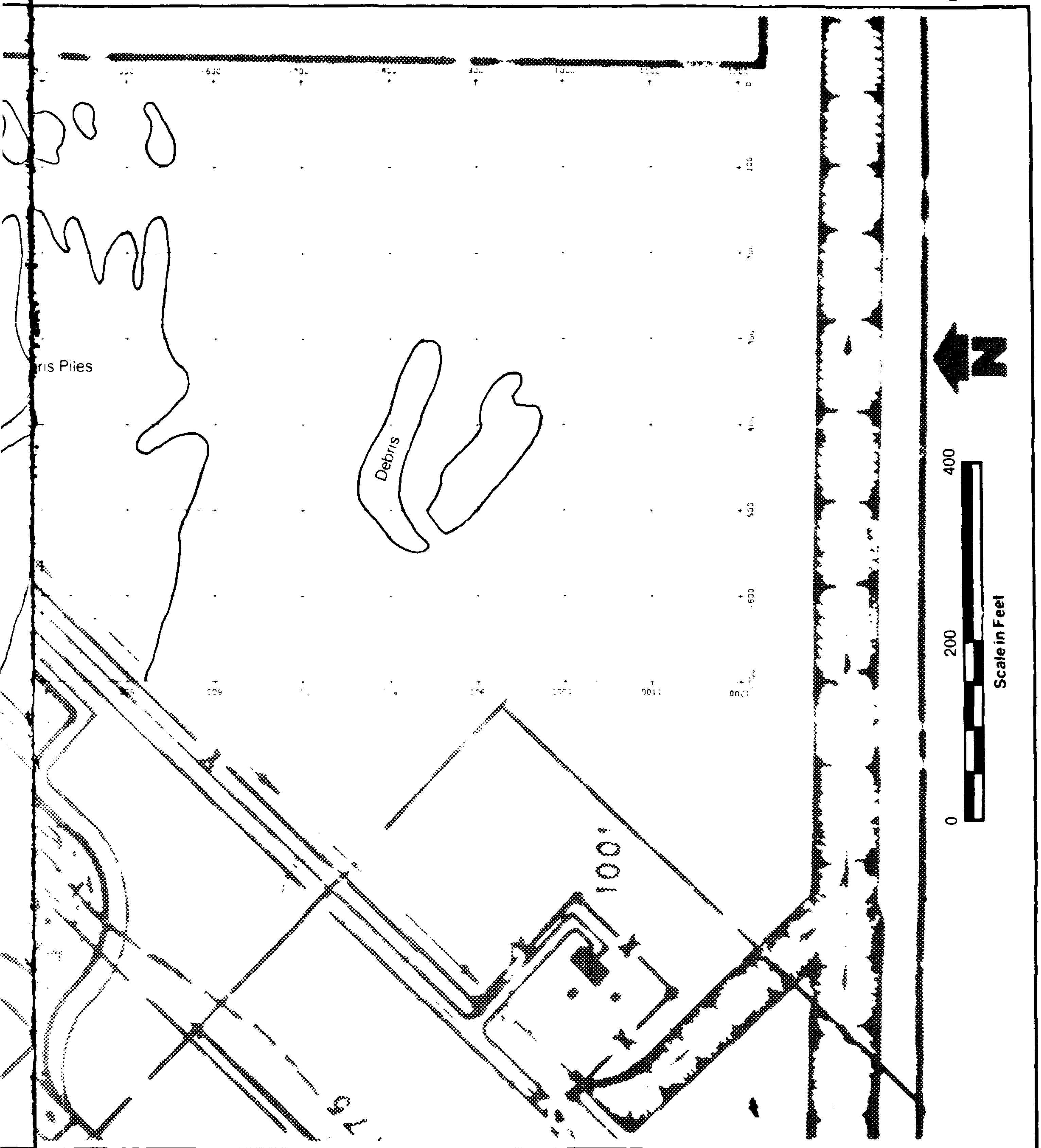


FIGURE 3-3 GEOPHYSICAL SURVEY GRID, POL AREA
LUKE AFB, AZ

in millimhos per meter (mmhos/m). In the POL trenches and lagoon, any soil saturated with POL waste product would, in theory, exhibit a lower conductivity relative to surrounding soils.

Readings were taken at 50-foot intervals along the north-south grid lines and at 25-foot intervals along the east-west grid lines (see Figure 3-3) with an EM-31 meter in the vertical dipole mode. A base station was established at grid point 60° South by 0° West where measurements were taken every 4 hours, or six times over the 1.5-day survey period, as a quality control procedure.

Ground Penetrating Radar (GPR)

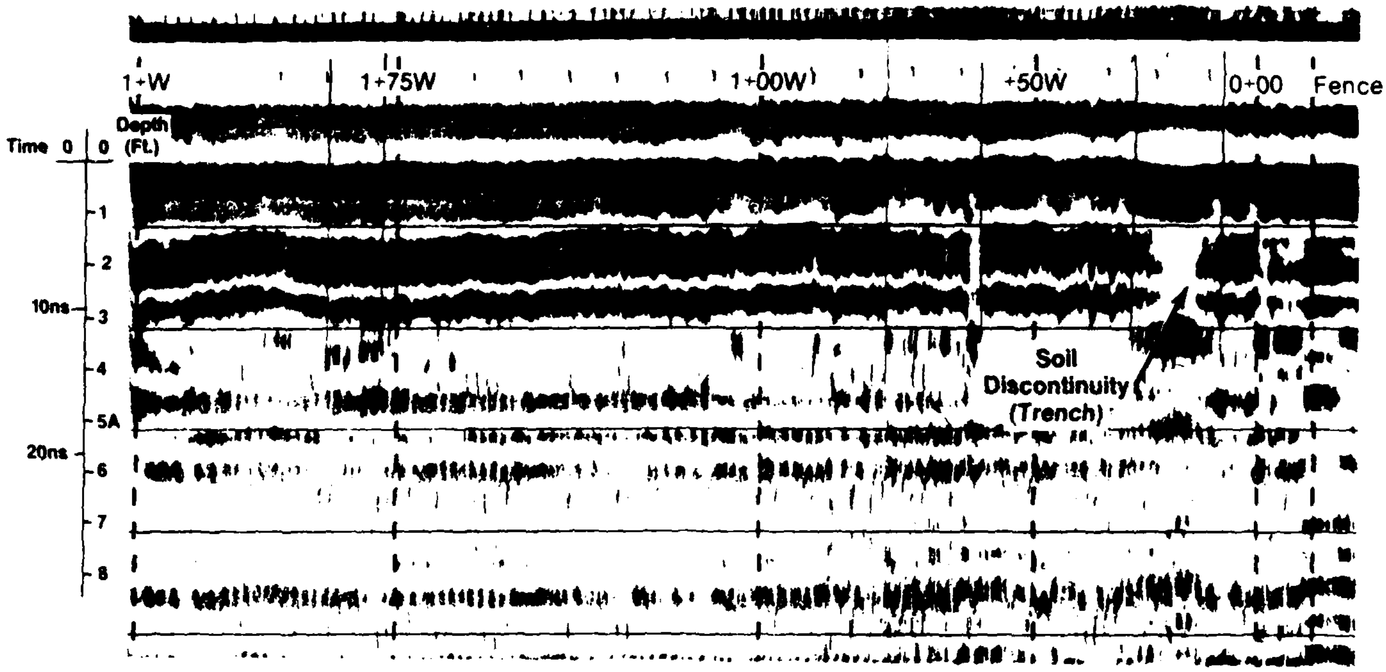
Ground penetrating radar (GPR) was conducted at the site using a Geophysical Survey Systems Incorporated Model 4800 radar system coupled to a Model 3105 AP (300 MHz) transceiver. GPR utilizes high-frequency radio waves to acquire subsurface information. Electromagnetic waves are transmitted from a moving transceiver into the ground subsurface where they are reflected by subsurface interfaces of differing dielectric properties. These reflected waves travel back to the surface and are recorded via the transceiver as a function of amplitude versus time. Amplitude variations indicating variations in the electrical properties of subsurface materials are continuously recorded on an electrosensitive strip-chart recorder. A continuous cross-sectional horizontal profile of shallow subsurface conditions is thus produced.

Prior to conducting the survey, the instrument was depth-calibrated to a drainage culvert at a known depth of 3 feet. A dielectric value of 3.00 was then calculated for the site soils. The trenches were originally reported to WESTON as being between 3 and 5 feet deep; therefore, the effective penetration depth of the GPR was set to approximately 7 feet. That allowed a detailed profile covering the maximum depth of interest at this site to be produced.

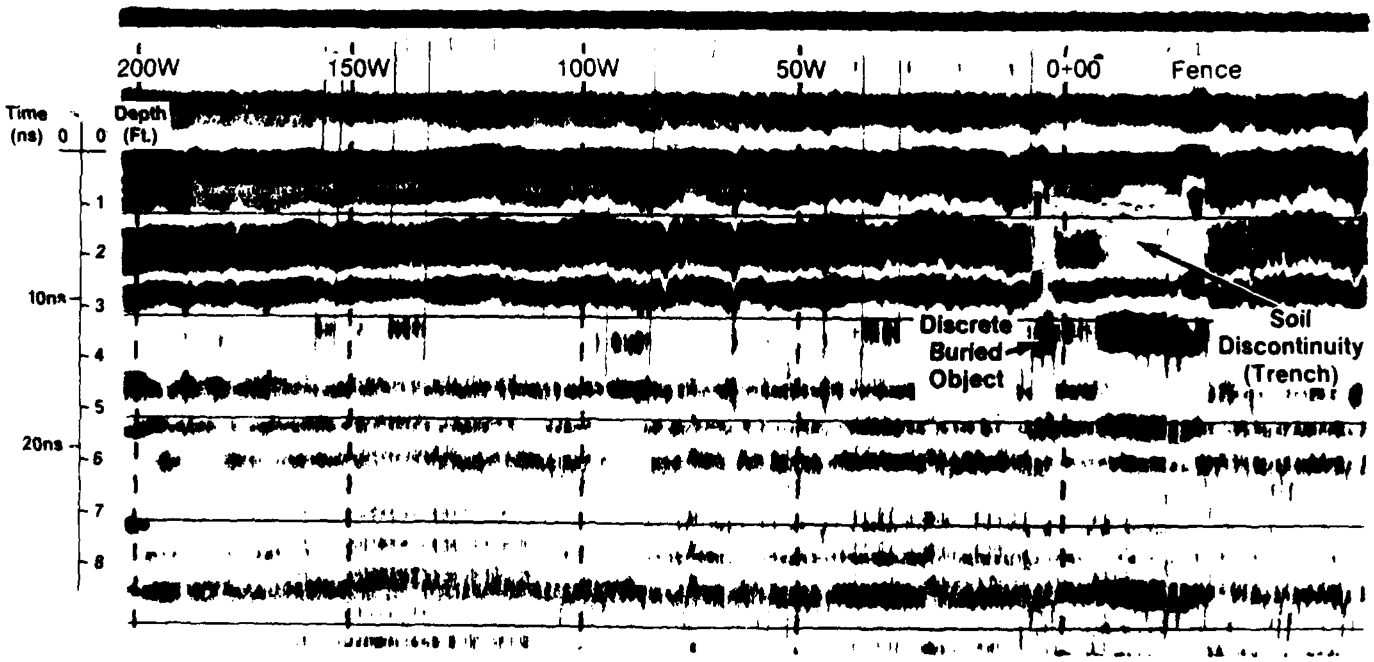
GPR traverses were conducted along the same system of grid lines as the EM survey. An example of the expression of a trench on the GPR printout is shown in Figure 3-4.

3.2.2.8 Sediment and Surface Water Sampling

Sediment samples were collected from two sites, the STP Effluent Canal and the O/W Separator Canal, in order to characterize the sediments in those potential contaminant source areas. Sample analytes for the sediment samples collected from both sites are shown in Table 3-1 (p. 3-3).



Traverse 300S



Traverse 400S

FIGURE 3-4 TYPICAL GPR PROFILES, POL AREA LUKE AFB, AZ

At the STP Effluent Canal, samples were taken with a bucket auger. The auger was driven approximately 10 inches below the soil surface at the designated locations. A subsample was taken from each location and was placed in laboratory-prepared sample bottles for analysis of VOCs and priority pollutant metals. The VOCs samples were transferred first to 40-ml vials using a stainless steel spatula. Every attempt was made to exclude rocks, twigs, and vegetation from the sample. Sample locations were marked on an aerial photograph of the site, and locations were also logged in the field notebook. The auger was decontaminated between sample locations with an Alconox and water solution, then a distilled water rinse, followed by a methanol rinse. The methanol was allowed to evaporate from the auger prior to reuse.

At the O/W Separator Canal, sediment samples were taken with a combination of auger and hand trowel techniques. At ten evenly spaced intervals along the length of the canal, which was dry at the time of sampling, a sample was collected from the surface of the canal bed and was composited. A hand trowel and stainless steel spatulas were used to collect the VOCs and petroleum hydrocarbons samples.

Ten other samples were taken at five additional locations in the canal that appeared to have accumulated concentrations of oil or fuel products. At those locations, the hand auger was driven into the sediments approximately 12 inches. Decontamination procedures were followed between sampling points. From each hand auger sample, the top 6 inches were composited and were placed into sample jars, and the bottom 6 inches were composited and were placed into another set of sample jars. The sample locations and depths were cross-referenced in the field notebook.

STP effluent samples were collected immediately downstream of the final chlorination tank. The samples were collected three times daily for a consecutive 3-day period during the first sampling round in January 1987. The samples were collected from the effluent stream with a Teflon and glass sampler and were poured directly into sample containers.

Two surface water samples were collected from the O/W Separator Canal. Water is present in the canal only immediately following precipitation events when the separator is bypassed, allowing the increased flow to reach the canal. The samples were collected as close to the origin of the canal as possible, which is approximately 20 feet south of the culvert that carries the flow from the separator to the canal. The sample bottles were gently immersed in the water to avoid aeration or turbulence. The samples were collected at the same locations during the two sampling rounds.

3.2.2.9 Groundwater Sampling

Monitor Wells

Groundwater sampling took place in three 1-week rounds during December 1986 and January and February 1987. All groundwater sampling of the 11 monitor wells was done after the wells had been properly developed as discussed in Subsection 3.2.2.4 (p. 3-14). At least 7 days passed between the time well development was completed and monitor well sampling began. Nine of the 11 monitor wells had permanent pumps installed (stainless steel Grundfos Model SP 2-34) that were used to sample the wells. A generator to power the pumps was supplied by the base. The following procedure was used during the sampling process:

- The depth from the top of the casing to the top of the static water in the well was measured and was recorded.
- The depth to water was subtracted from the depth to the bottom of the casing to determine the height of and the volume of standing water in the casing (1 foot of water in 4-inch ID casing is equivalent to 0.65 gallons).
- The pump was started, and a quantity of water approximately equal to three times the calculated volume of water in the well casing was removed.
- Samples for chemical analyses were obtained from the discharge port immediately after purging was completed. For collecting VOCs and TOC samples, the discharge flow rate was set as low as possible to avoid aeration. Samples were placed in laboratory-prepared bottles, were filled to the top, and were capped securely.
- Samples were placed on ice in an insulated cooler immediately after collection. Samples were packed with vermiculite at the end of the day and were delivered to the express mail service for overnight delivery to the WESTON laboratory.

Samples for metals analyses were filtered only during the third round for wells MW-102, MW-103, and MW-105. The samples collected from those wells during the first and second rounds were very silty, and it was known that the suspended sediment could greatly increase the metals concentrations in the samples. The samples were filtered through a 0.45-micron glass fiber filter using a vacuum pump and were preserved with nitric acid in a sample container.

The last samples collected from each well were the samples for analyses of pH, temperature, and specific conductance. After initially calibrating the instruments with the appropriate buffers and standard solutions, measurements were taken by immersing the probes into the grab samples. The instrument probes were flushed with distilled water between sample measurements. All data were recorded in the field notebook. The field-tested water quality parameters and water level measurements for all three sampling rounds are included in Subsection 4.5.

Pumps were not installed in MW-102 and MW-103 because they each had a very low volume of water in the casing and did not have high enough recovery rates to sustain pumping. Approximate well yields ranging from 0.4 to 0.6 gpm were measured during well development, which was accomplished with a bailer on those two wells. To collect the samples from MW-102 and MW-103, a development rig from Layne was utilized. A bottom-loading steel bailer capable of holding approximately 2.5 gallons was lowered into the well on an automatic winch. The bailer was retrieved after being filled with water and was emptied into a 5-gallon bucket to measure the approximate purge rate. Bailing continued at a rate of 0.5 to 0.6 gpm until three well volumes had been removed. A Teflon bailer with a ball-check valve was then lowered on a cable into the wells and was filled with water. Samples were collected in the appropriate containers and were sent to the WESTON laboratory for analysis.

Production Well Sampling

In addition to the monitor wells, groundwater samples were collected from all operating base production wells. Sampling of the production wells was accomplished using their permanent pumps. There are six wells in the Luke AFB production system (PW-1, PW-7, PW-9, PW-10, PW-11, and PW-12) plus well PW-4 which serves the Waste Treatment Annex area. At the time of sampling, PW-12 was out of service and could not be sampled. Wells that were on-line at the time of sampling were sampled after allowing water to flow through the sampling discharge port for 3 to 5 minutes, thus purging the sampling line. Wells not operating at the time of sampling were restarted by a base escort and were allowed to run for approximately 15 minutes prior to opening the sampling port. After the wells were purged, each sample container was filled, taking care to avoid aeration and turbulence in the sample. The sample analytes are shown in Table 3-1 (p. 3-3). Samples were also collected from the base wells for pH, temperature, and specific conductance and were immediately analyzed on-site.

All data were recorded in the field notebook. Samples for chemical analyses were placed on ice in an insulated cooler, and at the end of each day, were shipped by overnight carrier to the WESTON laboratory.

Quality Control/Quality Assurance Sampling

In order to validate field and analytical techniques, field blanks and field duplicates were collected that amounted to approximately 15 percent of the total samples collected. Two field blanks were collected for each sampling round. One blank was collected by pouring base-supplied deionized water through the Teflon bailer used to sample MW-102 and MW-103, and the other blank was collected by pouring the deionized water through the pipe assembly used for sampling all other monitor wells. The bailer and pipe assembly were thoroughly decontaminated with deionized water from the base supply before the field blanks were collected. Field blanks were analyzed for the same parameters as the monitor well and base production well samples.

Field duplicates were collected at selected locations including seven monitor wells and one production well. Field duplicates were collected at well locations presumed most likely to be contaminated in order to verify whether concentrations of contaminants, if any, were present. Duplicates were collected as separate samples, not as splits of a single sample.

Ten percent of the water samples were collected in duplicate to be sent to the USAFOEHL laboratory for analysis. The duplicate samples to be collected were selected prior to the sampling by the Luke AFB Bioenvironmental Engineer. A total of six water samples were collected for this purpose, two during each sampling round.

Trip blanks were also submitted to the laboratory for analysis of VOCs to ensure that no contamination was introduced into the samples from the laboratory or during shipment. Trip blanks were prepared at the WESTON laboratory using laboratory deionized water to fill two 40-ml glass vials per trip blank. They were sent to Luke AFB in coolers with the empty sample bottles and were kept in the coolers during water sampling. One trip blank per day was returned to the laboratory with the water samples that had been collected during the day. The trip blanks remained tightly sealed during the entire process.

3.2.2.10 Well Elevation Survey

All monitor wells and soil borings were horizontally located on a map of the base to an accuracy of 1 foot. Monitor well top-of-casing elevations were also surveyed with respect to base and U.S. Geological Survey (USGS) benchmarks to an accuracy of 0.01 foot. The surveying services were supplied by West Valley Engineering of Litchfield Park, Arizona. Monitor well MW-101, south of the STP, was surveyed with respect to a Maricopa County benchmark on Glendale Avenue. All other monitor wells were tied into an on-base USGS benchmark south of the runway. This information was used in combination with the depth-to-water measurements to establish the gradient and the direction of groundwater flow.

3.2.2.11 Sample Custody and Documentation

A record of all soil and water samples collected was kept in the field notebook. Information included time and date of sampling, the sample identification number (in accordance with the TOP sample numbering system), and for soil samples, the depth at which the sample was collected and a physical description of the soil sample. A table summarizing the soil boring information, which included the soil boring number, the date completed, and a brief description of the soil boring location, was compiled in the field notebook. A table with monitor well information, including well identification number, total depth, screened interval, and a summary of materials used, was also compiled. Field sampling sheets were used to document water sampling. The sheets were used to record the time and date of sampling, well number, equipment used to collect the sample, depth to water in the well, and field measurements of pH, temperature, and specific conductance. All field sampling sheets are included in Appendix E.

Chain-of-Custody Records and Shipping

To maintain a record of sample transfer between sampling personnel, of shipment, and of receipt by the laboratory, a chain-of-custody record was completed for each sample submitted to the laboratory. Each time the samples were transferred, the signatures of the persons relinquishing and receiving the samples, as well as date and time, were recorded.

The ice chests were secured with custody seals and were dated and signed by the sampler before transferring them to the express delivery service. All samples shipped to USAFOEHL were accompanied by completed AF 2752A and AF 2752B forms. Sample numbers for those forms were obtained from the Luke AFB Bioenvironmental Engineering office. All ice chests were shipped for overnight delivery to ensure that the samples remained cool. Chain-of-custody forms for all samples are included in Appendix G.

3.2.2.12 Sample Numbering System

The sample numbering system described below was developed to identify each and every sample taken during the water and soil sampling programs. The sample numbering system provides a tracking procedure to allow retrieval of information concerning a particular sample. This system has been standardized for use on all USAF projects and conforms with the Information Management System numbering scheme.

Each sample number consists of three components: site, location, and sample identifiers.

<u>Site Identifier</u> - a two-digit designation that identifies the site from which the sample was collected. It comprises the first two digits of the sample code. The following numbers were used for the six locations investigated during the Stage 2 investigation at Luke AFB:

- 01 - Base Production Wells
- 02 - STP Effluent Canal
- 03 - O/W Separator Canal
- 04 - POL Area
- 05 - SFTA
- 06 - NFTA

<u>Location Identifier</u>* - a three-digit designation that identifies the sample location within each site. It follows the site identifier. The designation includes the number of the monitor well (101), the soil boring (001), or the sediment sample (002).

<u>Sample Identifier</u> - a four-character alphanumeric designation that identifies the sample according to sample type. The first character is always a letter, as follows:

- B - Soil borings
- D - Sediment
- E - Effluent
- G - Soil-gas
- M - Monitor wells (Groundwater)
- P - Production wells (Groundwater)
- W - Surface water

The remaining three characters are digits and are used to provide additional information about the sample. For a groundwater or surface water sample, the three digits indicate from which sampling round the sample came (e.g., 001, 002, etc). For a soil boring sample, the three digits indicate the depth from which the sample was obtained (e.g., 05 feet, 10 feet, 15 feet, etc.). For a sediment sample, the three digits represent the depth sequence from which the sample was collected (e.g., 001 - top 6 inches, 002 - 6 to 12 inches) and are cross-referenced in the field notebook. For an effluent sample, the three digits indicate the sequence in which the sample was taken (e.g., 001, the first sample of the day).

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* During discussions in this report, the initial zeroes of the three-digit soil boring sample numbers were dropped for consistency with handwritten field logs.

An example of each type of sample number for samples collected at Luke AFB during Phase II Stage 2 follows:

Soil sample from Site 03 (O/W Separator Canal) from soil boring 02 at 95 feet.	03-002-B095
Sediment sample from surface of Site 02 (STP Effluent Canal), third location.	02-003-D001
Effluent sample collected from Site 02 (STP Effluent Canal) on the third day, first sample of the day.	02-003-E001
Soil-gas sample collected at Site 05 (POL Area), fourth location, from a depth of 5 feet.	05-004-G005
Groundwater sample collected at Site 05 (SFTA), from monitor well MW-107, first round.	05-107-M001
Groundwater sample collected from base production well PW-10, second round.	01-010-P002
Surface water sample collected from Site 03 (O/W Separator Canal) at location 1, first round.	03-001-W001

Blanks and Duplicate Sample Numbering - The last four characters of the numbering system are used to denote that a sample was a field duplicate or a field blank. The site and location identifier will not change.

Field Duplicate - The second character of the sample identifier is a number 1, which indicates that the sample is a duplicate of the sample denoted in the location identifier.

Example: 05-107-M101

Field duplicate of the groundwater sample collected from Site 05 (SFTA), monitor well MW-107, sampling round 1.

Example: 03-002-B195

Duplicate soil sample taken at Site 03 (O/W Separator Canal) from soil boring 02 at 95 feet.

Field Blank - The first character of the sample identifier denotes the sample type. The second character of the sample identifier is always a number 2 to denote a field blank. The next two digits indicate during which sampling round the sample was collected. The site and location identifiers for field blank are the numbers of the location and corresponding site that was sampled immediately prior to collecting the field blank with the same piece of sampling equipment.

Example: 06-109-M202

Field blank collected at Site 06 (NFTA) immediately after sampling monitor well MW-109 during round 2.

All sample numbers were documented by the WESTON Field Team Leader, and the date of sample collection was documented in the field notebook and on the chain-of-custody forms.

3.2.3 Site-Specific Details

This subsection includes a review of the field investigation on a site-by-site basis including field locations and basic data for wells and soil borings. Additional general information on drilling and sampling methods, materials, and equipment used has been provided in Subsection 3.2.2 (p. 3-2). Field activities for each site are summarized in Table 1-1 (p. 1-3).

3.2.3.1 Oil/Water (O/W) Separator Canal

Twenty-three soil-gas locations were sampled along the canal as shown in Figure 3-5. Eleven locations were spaced at regular (320-ft) intervals along the ditch from its origin to the point where the canal crosses the base boundary. Wherever possible, the soil-gas samples were taken in the canal bed. Where water or steep banks prohibited access for the TRC van, the sample was taken from the top of the canal bank. Eleven samples were taken along two perpendicular transects of the canal (at locations 1 and 5) to investigate the pattern of contaminant concentrations with distance from the canal. One soil-gas sample (location 21) was taken in an open field about 440 feet east of the canal to obtain a representative "background" sample.

Six 100-foot soil borings were drilled and were sampled at this site at locations shown in Figure 3-6. The locations were distributed to obtain a representative characterization of the soil along the canal. Soil samples were collected as described in Subsection 3.2.2.3 (p. 3-11) and were submitted to the laboratory for analysis of VOCs and petroleum hydrocarbons. Air was monitored with an HNu meter for organic vapors in the auger and in the breathing zone. No elevated levels of vapors were detected during the entire drilling operations at the canal. There were no odors or visual evidence of contamination in the subsurface soils.

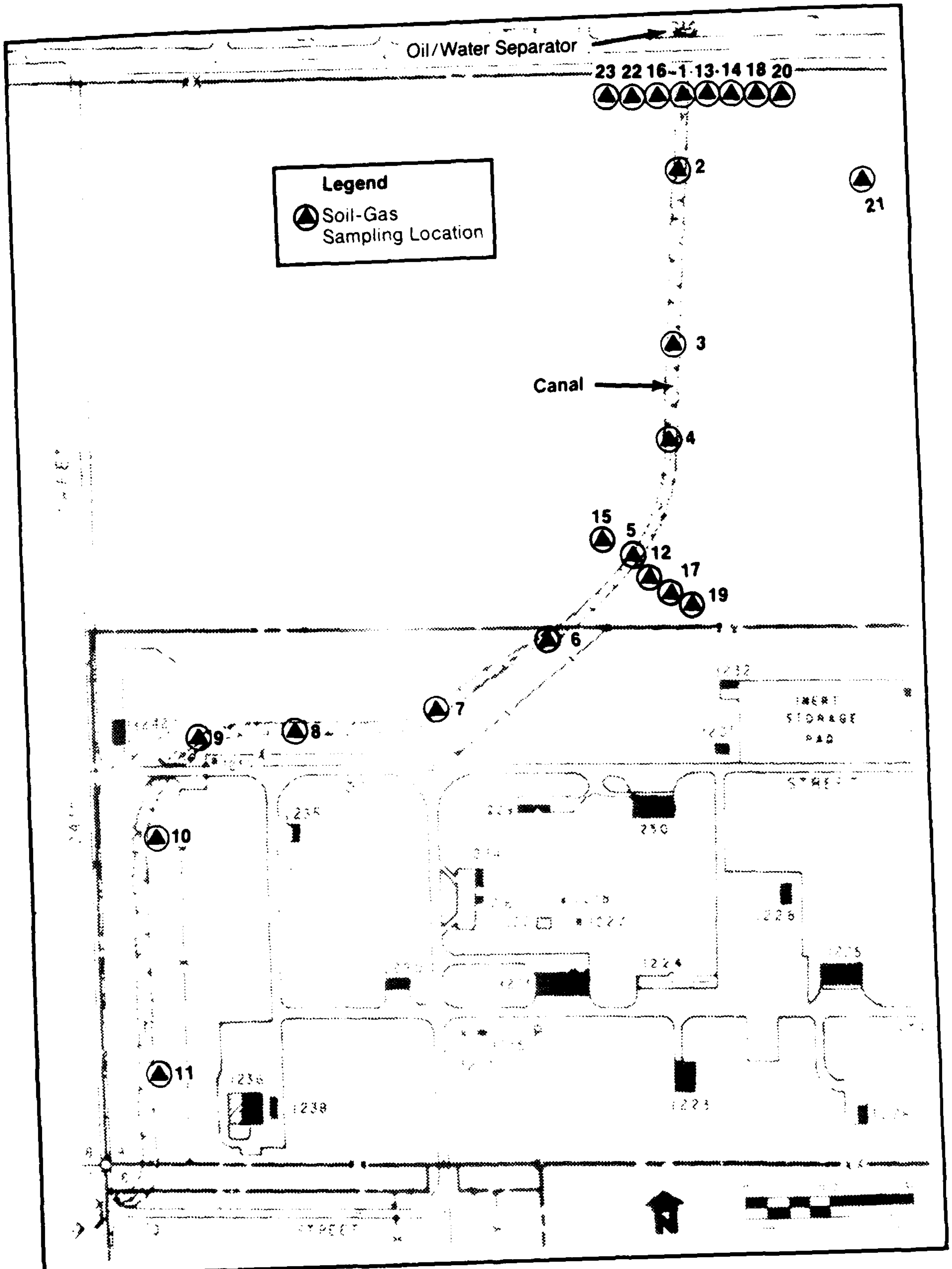


FIGURE 3-5 SOIL-GAS SAMPLING LOCATIONS,
O/W SEPARATOR CANAL, LUKE AFB, AZ

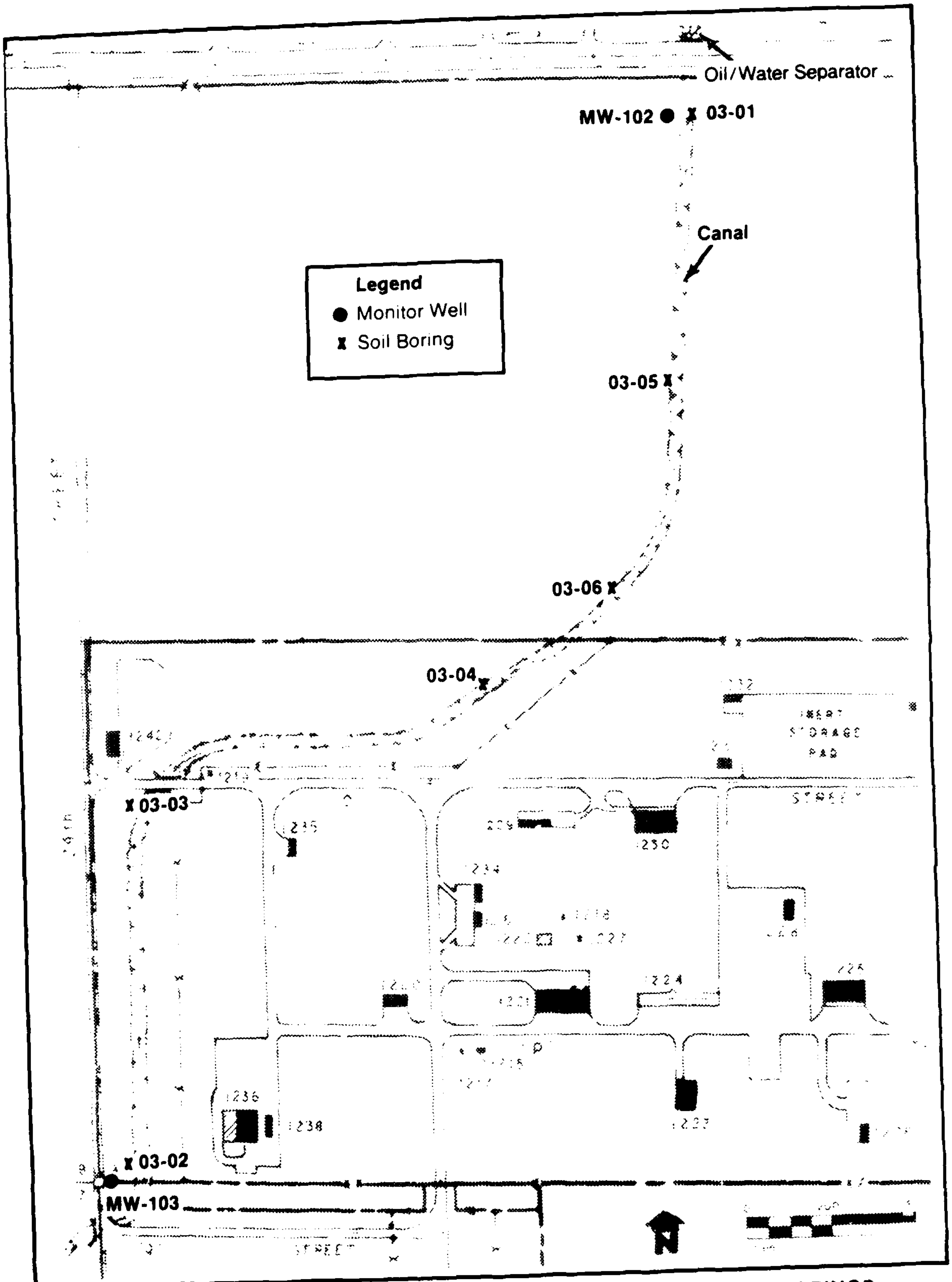


FIGURE 3-6 LOCATIONS OF MONITOR WELLS AND SOIL BORINGS OIL/WATER SEPARATOR CANAL, LUKE AFB, AZ

Two monitor wells (MW-102 and MW-103) were installed at the O/W Separator Canal at locations shown in Figure 3-6. The monitor wells were drilled to an average depth of 410 feet and were constructed with 60 feet of screen each. Well completion details are shown in Table 3-4.

Estimated groundwater level depths in this area were 350 feet based on water level measurements taken in the Facility 993 monitor wells located approximately 0.5 miles northwest of MW-102. After the monitor wells were developed, water levels were measured and were found to be much lower than originally predicted (380 to 392 feet below surface), which indicated there was only 18 to 30 feet of water in the bottom of those two monitor wells. As mentioned previously, no pumps were installed in those wells. A complete discussion of these findings is included in Subsection 4.2. Three rounds of water samples were collected from those wells, and laboratory chemical analysis results are included in Subsection 4.6.

Other field activities at the O/W Separator Canal included surface water and sediment sampling. Sediment sampling locations are shown in Figure 3-7. Details of these procedures are discussed in Subsection 3.2.2.5 (p. 3-17).

3.2.3.2 POL Area

Two types of surface geophysical surveys, GPR and EM, were run at this site and are described in Subsection 3.2.2.7 (p. 3-20).

Thirty-seven soil-gas samples were collected at the locations shown in Figure 3-8. Sampling locations were based on the results of the geophysical surveys and on analysis of aerial photographs of the site. Approximate trench locations were identified from the EM survey and the aerial photographs, and an attempt was made to penetrate the buried trenches with the soil-gas probes. Additional areas of subsurface abnormalities were identified by the GPR survey and were pinpointed with the soil-gas probes. Soil-gas sampling results are provided in Appendix O.

Nine soil borings were drilled adjacent to the identified trenches at the locations shown in Figure 3-9 and were sampled. Locations were selected based on areas of elevated concentrations found during the soil-gas sampling as well as areas identified as former disposal trenches by analysis of the aerial photographs and surface geophysical surveys. Soil samples were collected using the procedure described in Subsection 3.2.2.3 (p. 3-11) and were submitted to the laboratory for analysis of VOCs and U.S. EPA priority pollutant metals. A sample was taken from the drill cuttings at approximately 85 feet and was submitted to the WESTON laboratory for analysis of EP toxicity, ignitability, O&G, and TOX.

Table 3-4

Monitor Well Construction Summary,
Luke AFB, Arizona

Well Number	Total Depth (ft)	Screened Interval (ft)	Length of Intermediate Casing (ft)	Approximate Water Level* (ft)
101	220	160-220	160	140
102	410	350-410	340	390
103	413	353-413	336	378
104	420	360-420	370	357
105	414	354-414	368	357
106	430	370-430	370	359
107	410	350-410	340	350
108	410	350-410	350	349
109	455	395-455	380	362
110	420	360-420	350	360
111	420	360-420	348	363

*Approximate water level is the average depth below ground surface of three measurements during December 1986 and during January and February 1987.

WESTON

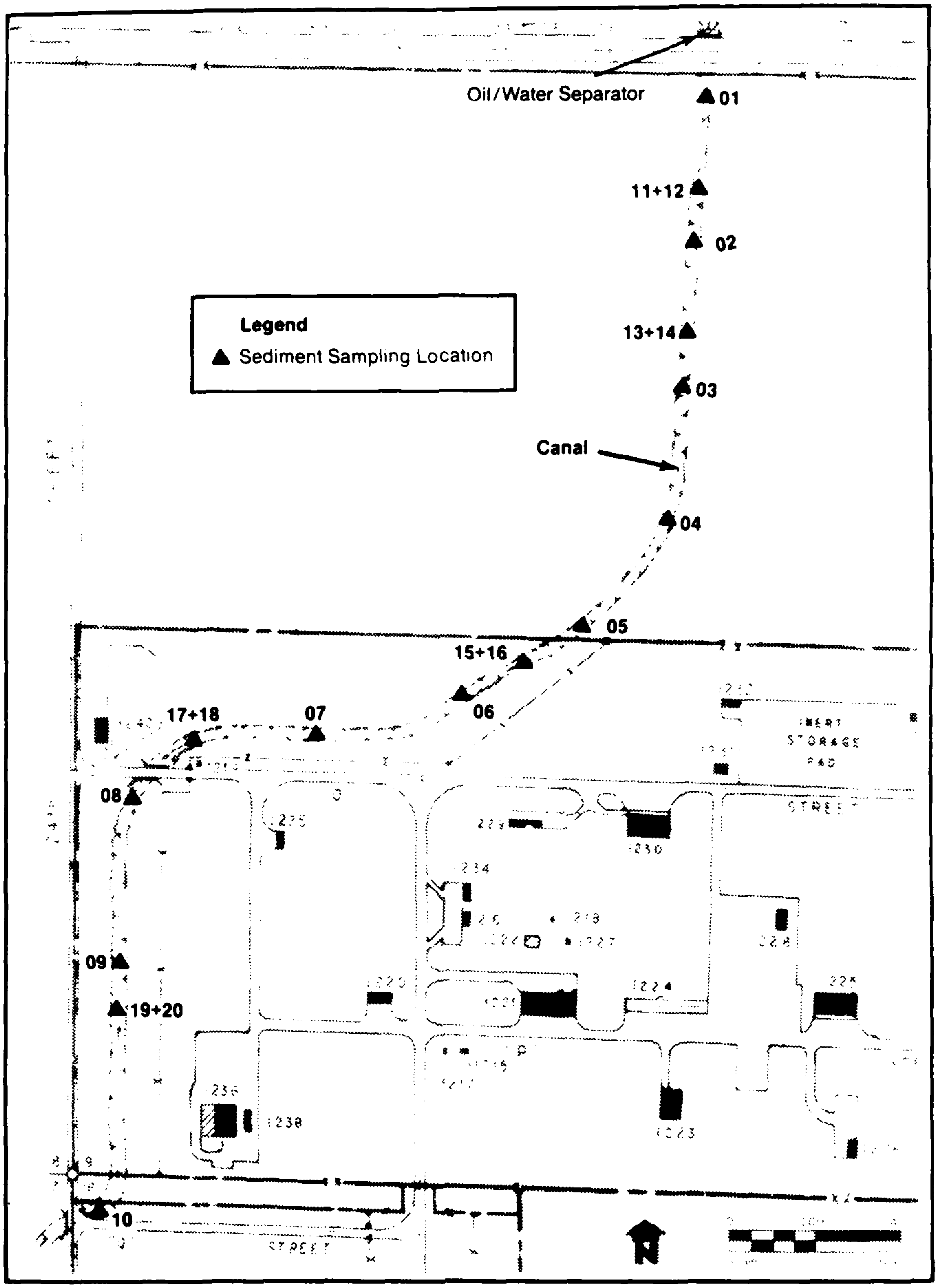


FIGURE 3-7 SEDIMENT SAMPLING LOCATIONS, OIL/WATER SEPARATOR CANAL, LUKE AFB, AZ

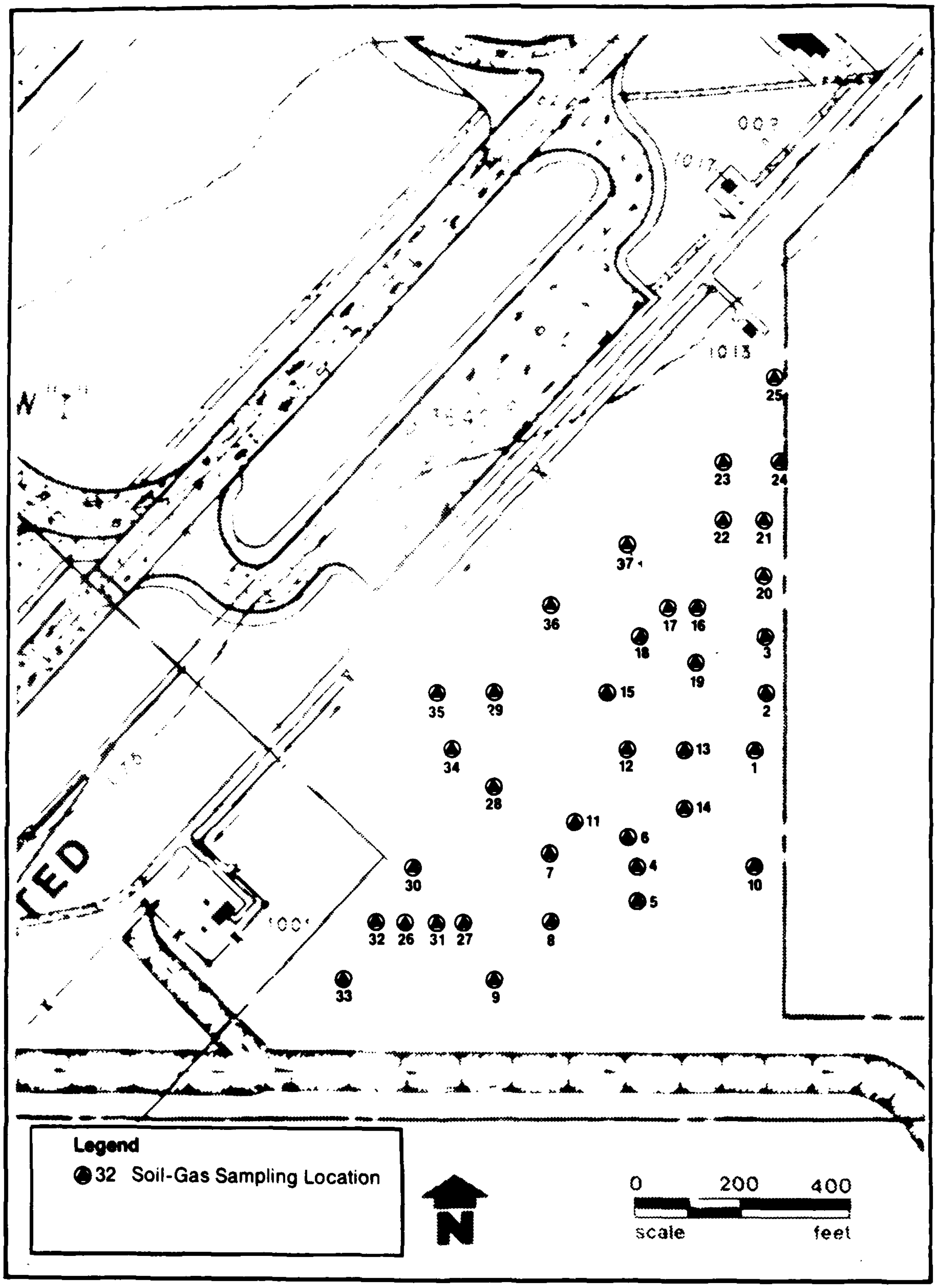


FIGURE 3-8 SOIL-GAS SAMPLING LOCATIONS, POL AREA, LUKE AFB, AZ

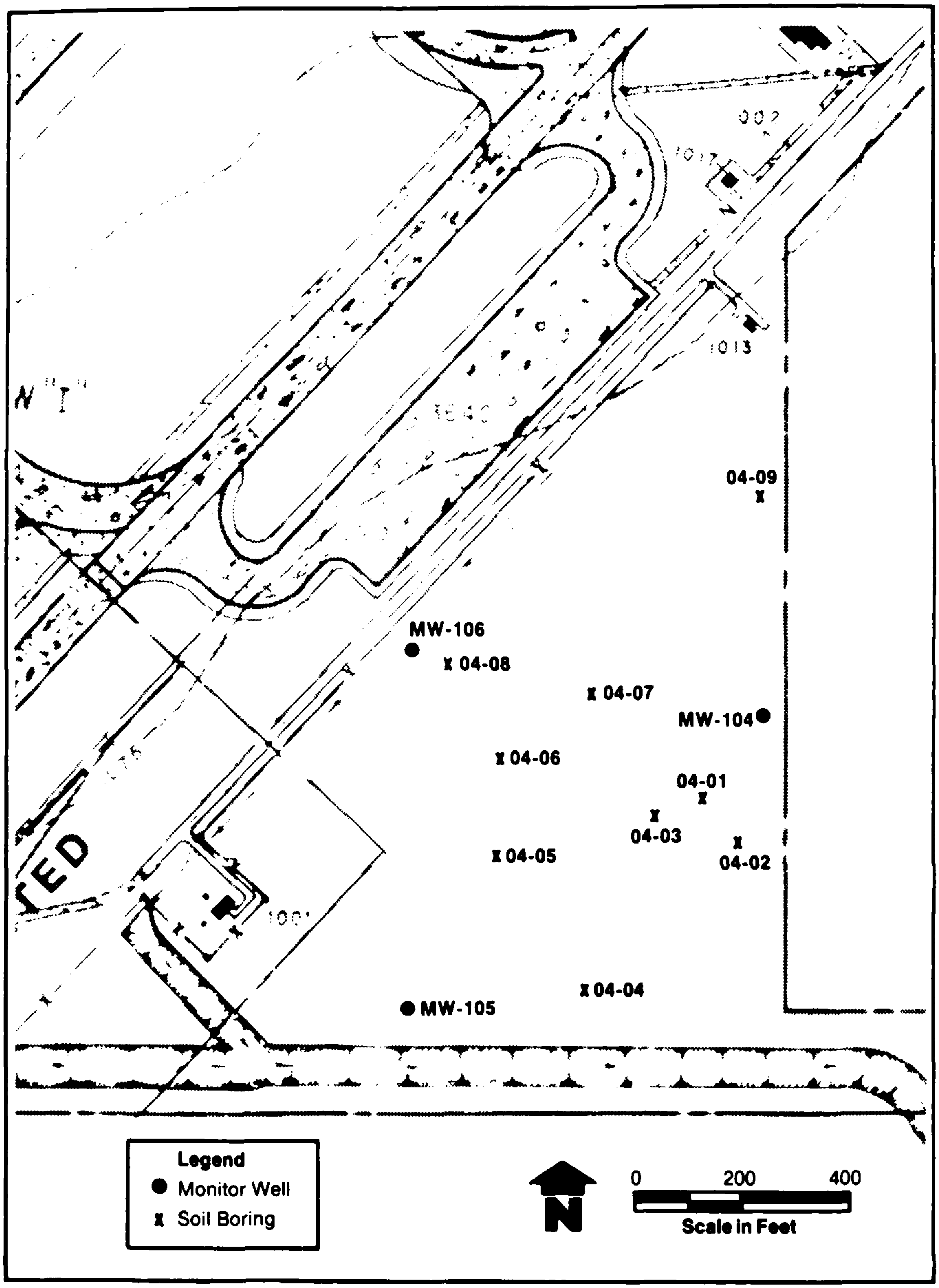


FIGURE 3-9 LOCATIONS OF MONITOR WELLS AND SOIL BORINGS POL AREA, LUKE AFB, AZ

Three monitor wells (MW-104, MW-105, and MW-106) were installed at this site at locations shown in Figure 3-9. The locations were chosen to encircle the entire site as completely as possible. The monitor wells were drilled to an average depth of 420 feet and were constructed with 60 feet of screen each. Well completion details are shown in Table 3-4. Prior to drilling, groundwater levels were estimated to be approximately 380 feet below ground surface in this area based on information obtained from the 1983 ADWR regional water table map (see Figure 2-2, p. 2-8). After the monitor wells were developed, the groundwater levels were measured at approximately 360 feet.

Three rounds of water samples were collected from these wells following procedures discussed in Subsection 3.2.2.9 (p. 3-25). Laboratory analytical results are included in Subsection 4.6.

3.2.3.3 South Fire Training Area

Two monitor wells and two soil borings were drilled at this site at locations shown in Figure 3-10. A series of aerial photographs of the site (which were included in the 1984 Phase II Stage 1 IRP report) were examined to determine the locations of the former fire training pits. A new building has been constructed in this area; therefore, three of the four pits were not accessible. However, soil borings were located as close to the former pits as possible. Monitor well locations were chosen so that MW-107 was located between the former pits and MW-108 was in the presumed downgradient direction.

Soil samples were collected from the soil borings and were analyzed for VOCs, MEK, priority pollutant metals, and O&G. Analytical results are summarized in Subsection 4.5.

The monitor wells were drilled to a depth of 410 feet and were screened from 350 to 410 feet. Water levels in these wells were measured at 350 feet below ground surface. Due to the interference from overhead power lines, electric logs could not be run on MW-108.

Elevated levels of organic vapors were detected in the auger during drilling in the top 10 feet of the soil borings and during installation of the surface casing for MW-107. Results are included in the soil boring logs in Appendix D. This area has been a paved parking lot for many years so the asphalt may have acted as a cap, trapping vapors beneath it. When the asphalt was penetrated with the auger, accumulated vapors were released into the air. The hole was allowed to aerate before continuing drilling, and vapor readings decreased rapidly. Vapors were not detectable after the auger had reached 20 feet.

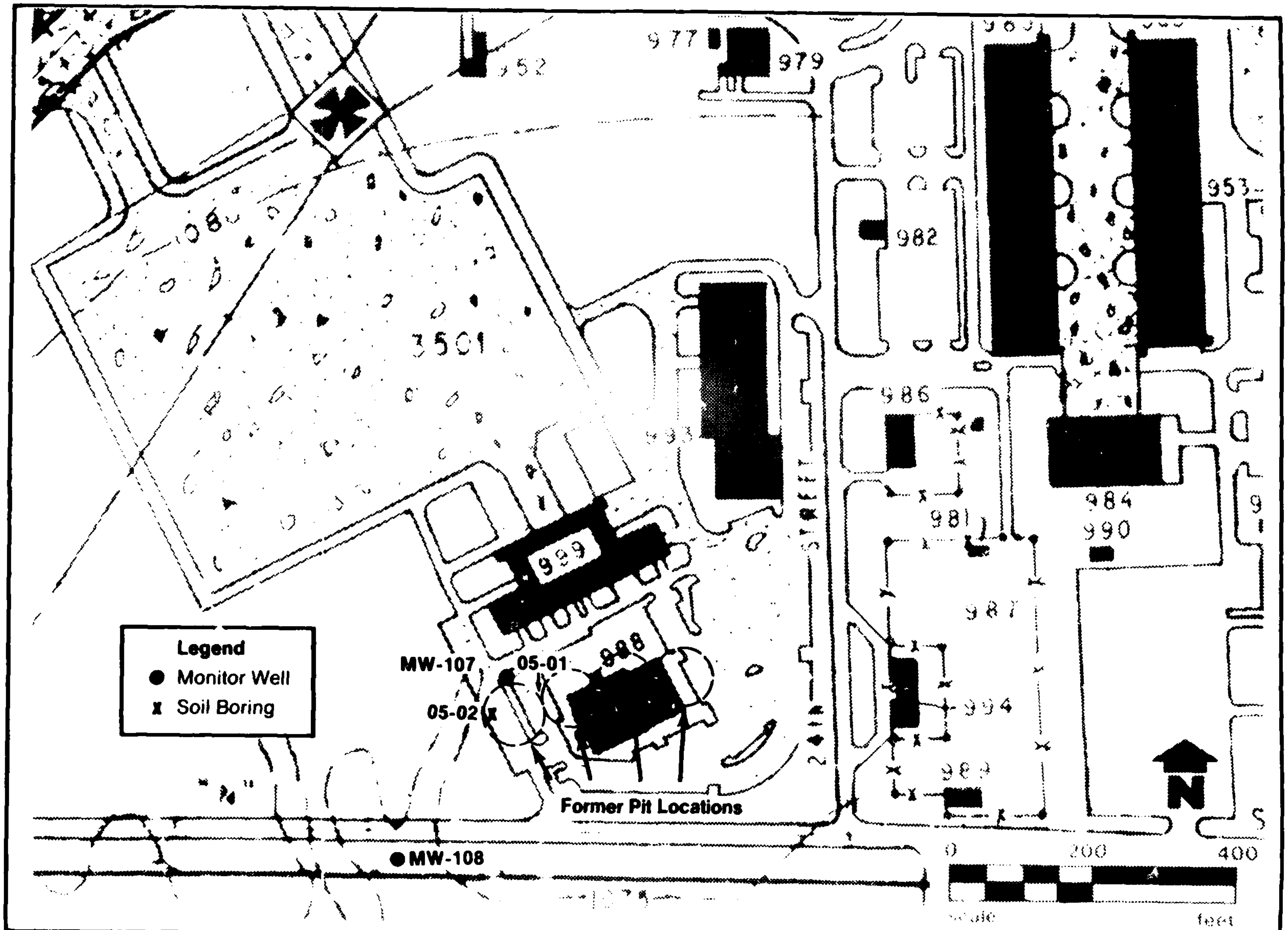


FIGURE 3-10 LOCATIONS OF MONITOR WELLS AND SOIL BORINGS
SOUTH FIRE TRAINING AREA, LUKE AFB, AZ

Three rounds of groundwater samples were collected from MW-107 and MW-108 following procedures described in Subsection 3.2.2.9 (p. 3-25). Laboratory analytical results are included in Subsection 4.6.

3.2.3.4 Current and North Fire Training Areas

Three monitor wells and four soil borings were drilled at this site at locations shown in Figure 3-11. The monitor well locations were chosen such that MW-111 was in the presumed upgradient direction and MW-109 and MW-110 were in the presumed downgradient direction. MW-111 was located on the perimeter of the base in order to monitor any off-base contamination. The former North Fire Training Area was identified by examining aerial photographs from 1969 and 1976 that distinctly show the blackened pits. There is also some surficial evidence remaining of the pits so they were readily located in the field. Two soil borings, 06-01 and 06-02, were drilled in the former pits, and two soil borings, 06-03 and 06-04, were drilled in the current fire training pits.

The soil borings were drilled through 20 feet of fine sand and silt that is underlain by a 5- to 10-foot layer of sand and gravel. Below that lie sand and silt interbedded with discontinuous lenses of caliche to the total soil boring depth of 100 feet.

Continual air monitoring was conducted throughout the soil boring program. Elevated levels of organic vapors were detected in the auger, in the headspace in the sample from the upper 25 feet in soil boring 06-01, and for the first 5 feet in soil boring 06-02. Variable readings were obtained throughout soil boring 06-04, ranging from non-detectable to 600 ppm, but not decreasing consistently with depth throughout the soil boring. Readings decreased to non-detectable levels at 55 feet, then began to increase to a maximum of 600 ppm at 85 feet. No detectable organic vapors were observed in soil boring 06-03. A possible explanation for the differences in vapor readings among the soil borings is that 06-01 and 06-02 were located directly in the center of the former fire training pits, and 06-03 and 06-04 were located within the blackened pit area, but off to the side. Soil borings 06-03 and 06-04 could not be located in the center of the active pits because of fire training exercise obstructions, ponded water, and waste fuel.

Soil samples were collected at 5-foot intervals as described in Subsection 3.2.2.3 (p. 3-11). A total of 80 samples were analyzed for VOCs, MEK, U.S. EPA priority pollutant metals, and O&G. Analytical results are included in Subsection 4.5.

WESTON

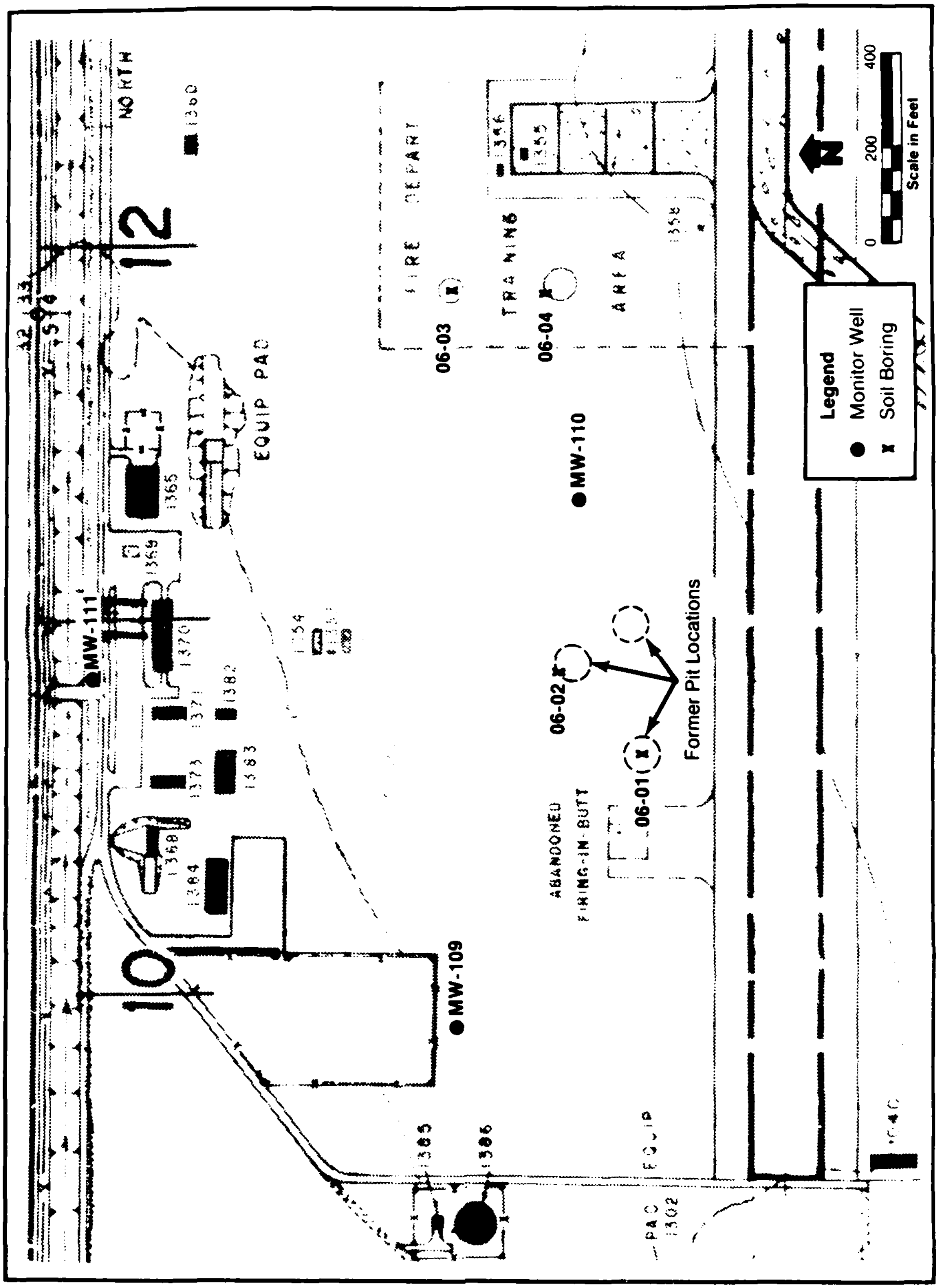


FIGURE 3-11 LOCATIONS OF MONITOR WELLS AND SOIL BORINGS NORTH FIRE TRAINING AREA, LUKE AFB, AZ

Groundwater levels in this area were estimated to be 395 to 400 feet deep based on the 1983 ADWR regional water table (see Figure 2-2, p. 2-8). The first well drilled at this site, MW-109, was screened from 395 to 455 feet based on that information. Before drilling the next well at this site, MW-109 was completely developed, and the water level was measured several times and was found to be 360 feet deep. Therefore, MW-110 and MW-111 were screened from 360 to 420 feet, and water levels in each well were measured at approximately 360 feet. Three rounds of water samples were collected from the three monitor wells following procedures described in Subsection 3.2.2.9 (p. 3-25). Laboratory analytical results are presented in Subsection 4.6.

3.2.3.5 Sewage Treatment Plant (STP) Effluent Canal

Twenty soil-gas samples were taken at this site at locations shown in Figure 3-12. The locations were spaced along the canal, as close as possible to the ponds and the former canal bed, where maximum infiltration would be occurring. Thick vegetation prohibited access to the desired locations near the origin of the canal in some cases. All probes at this site were driven 2 to 4 feet below ground surface, and the soil-gas sample was then collected. Probe 19 was located to determine the lateral extent of potential contaminant migration in the vicinity of probe 7, and probe 20 was located northeast of probe 1 for the same reason. Probe 15 was located the farthest south from the origin of the canal to be used as a background data point. Soil-gas sampling results are included in Appendix O.

A total of ten soil borings and one monitor well were drilled at this site at locations shown in Figure 3-13. Four soil borings were attempted with a hollow-stem auger and were not able to be advanced more than 20 feet because of the presence of coarse gravel and cobbles. One of the four soil borings reached only 5 feet in depth, for a total footage with the auger of 65 feet. A Becker hammer rig was used to complete six soil borings, numbered 02-05 through 02-10, to a depth of 100 feet. Soil samples were collected where sufficient recovery was obtained in split-spoons and were submitted to the WESTON laboratory for analysis of VOCs and metals. No elevated levels of organic vapors were detected in the breathing zone or augers during the drilling program at this site. Also, there was no visual evidence of contamination in the subsurface soils.

MW-101 was drilled on the western side of the canal to a depth of 220 feet and was screened from 160 to 220 feet. Water levels measured in three surrounding irrigation wells (shown in Figure 3-13) averaged 175 feet below ground surface. The water level at the monitor well location was estimated at 160 feet, assuming

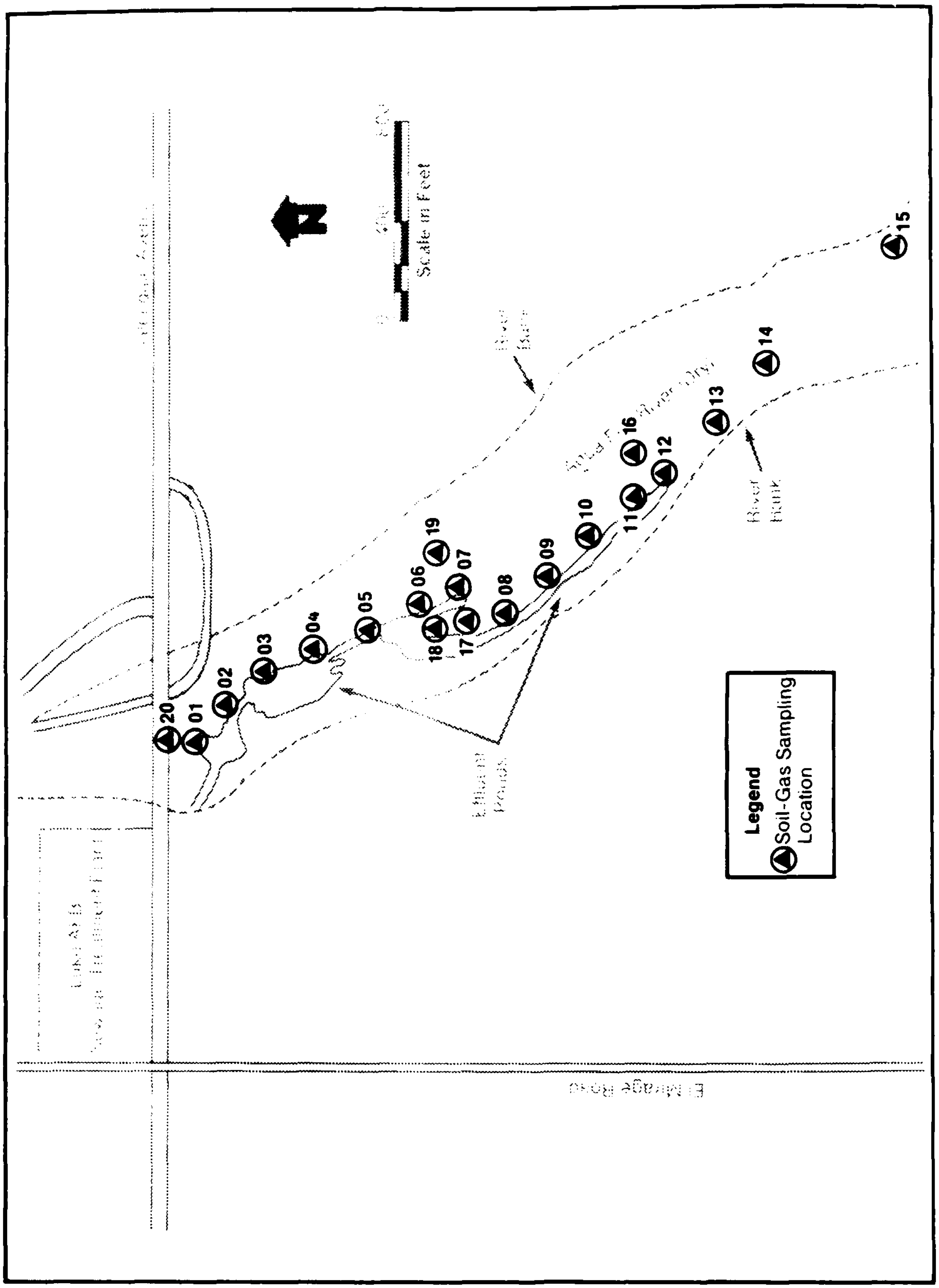


FIGURE 3-12 SOIL-GAS SAMPLING LOCATIONS, STP EFFLUENT CANAL, LUKE AFB, AZ

WESTON

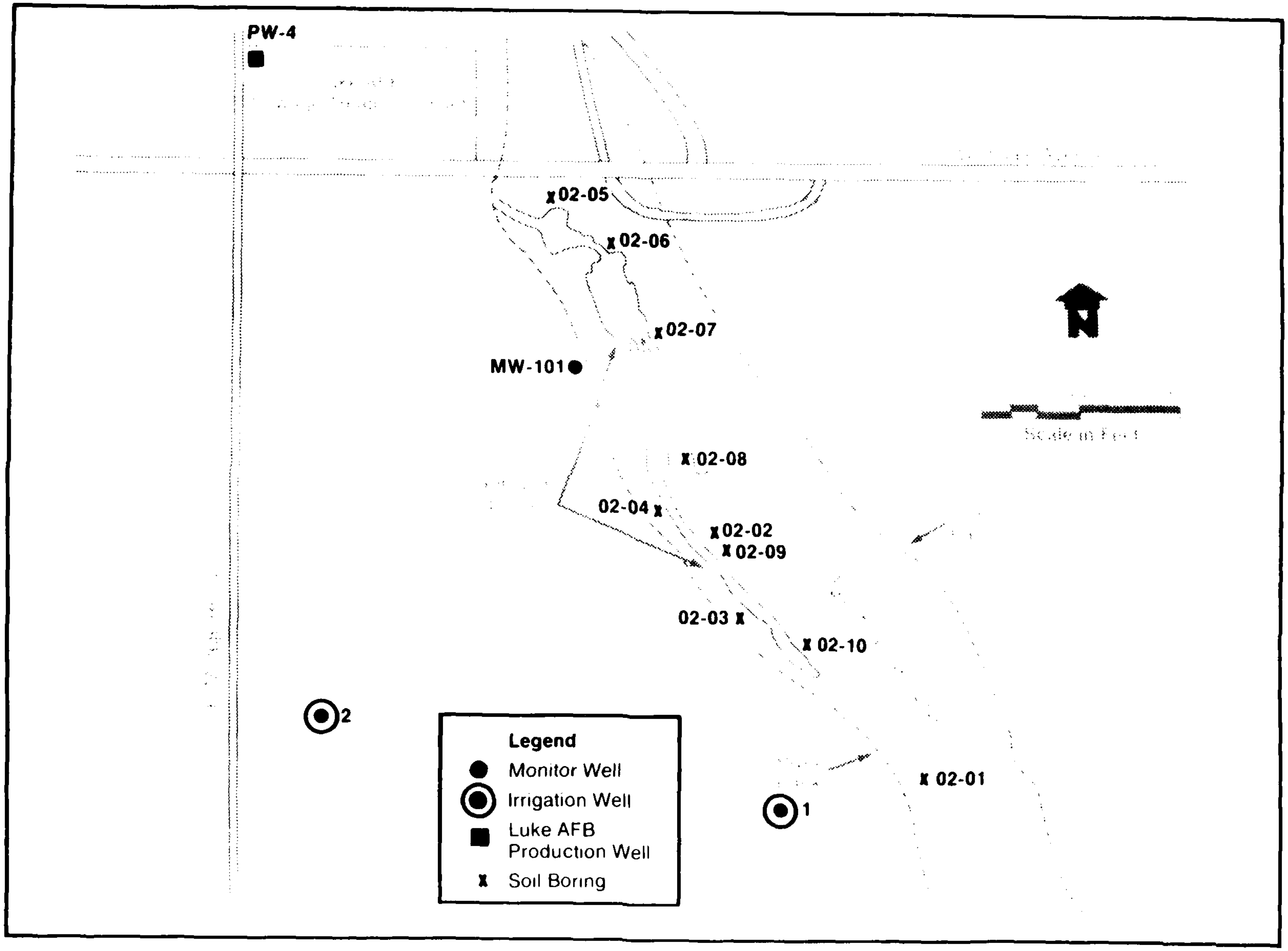


FIGURE 3-13 LOCATIONS OF SOIL BORINGS, MONITOR WELLS AND IRRIGATION WELLS - STP EFFLUENT CANAL, LUKE AFB, AZ

there was some mounding of the water table due to constant infiltration from the STP Effluent Canal. After the monitor well was developed, the water level was measured at about 140 feet below ground surface. Three rounds of water samples were collected from the monitor well following procedures outlined in Subsection 3.2.2.9 (p. 3-25). Laboratory analytical results are presented in Subsection 4.5. Other activities at this site included sediment and effluent sampling. Sediment sampling locations are shown in Figure 3-14. Details of these sampling procedures are provided in Subsection 3.2.2.5 (p. 3-17).

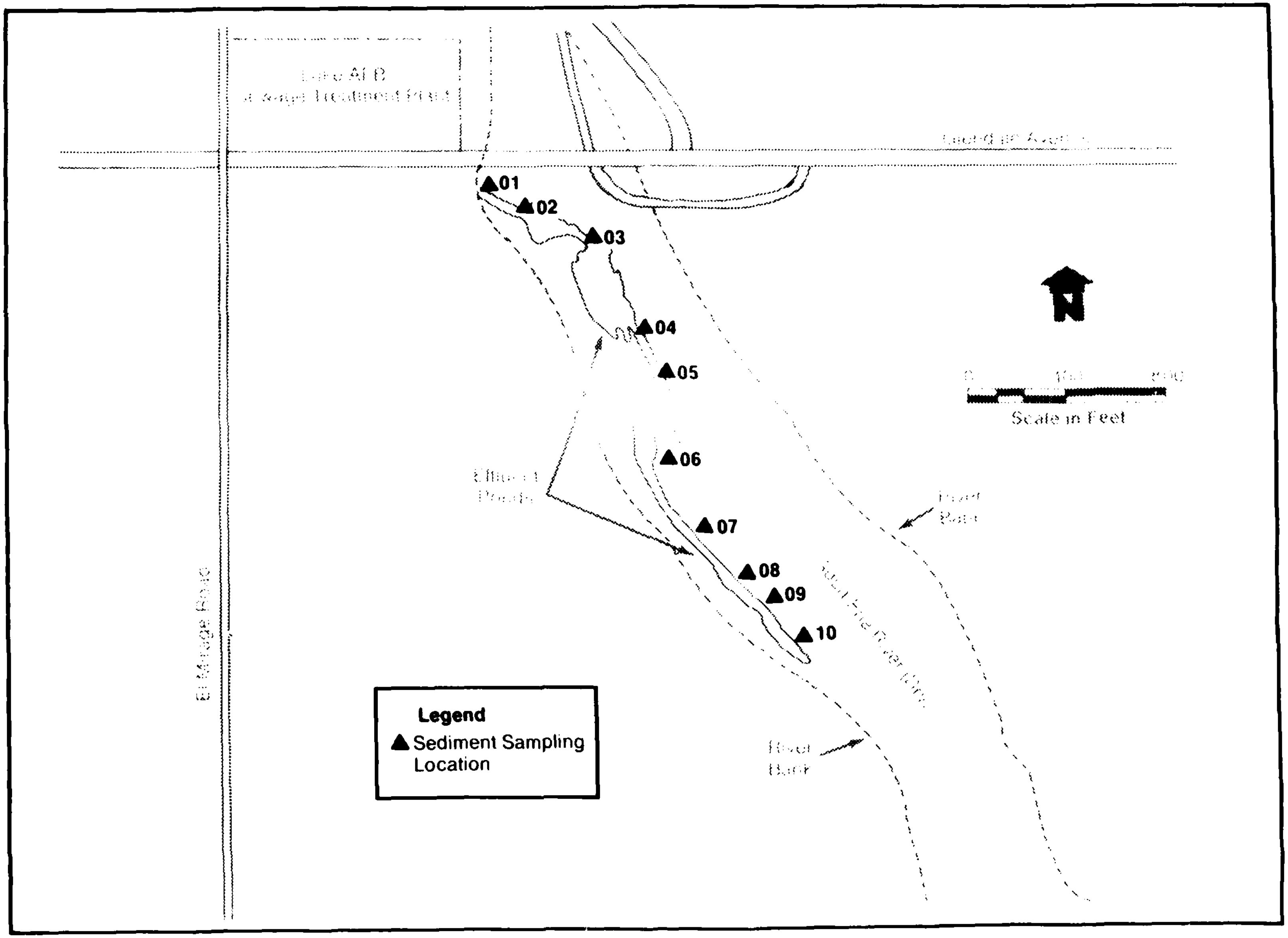


FIGURE 3-14 SEDIMENT SAMPLING LOCATIONS,
STP EFFLUENT CANAL, LUKE AFB, AZ

SECTION 4

DISCUSSION OF RESULTS AND SIGNIFICANCE OF FINDINGS

The regional geologic setting in the vicinity of Luke AFB, based upon existing data, was described in Section 2. In this section, site-specific detail is provided based on the Phase II Stage 2 field investigation.

4.1 SITE INTERPRETIVE GEOLOGY

Subsurface geologic conditions were assessed utilizing data derived from the soil boring and monitor well drilling programs. Geologic logs were prepared for each soil boring (see Appendix D) based on split-spoon sampling and cuttings returned at the surface. Geologic logs were prepared for each monitor well (see Appendix D) based on well cuttings correlated with information gained from the borehole geophysical logs.

Because of the proximity of several of the sites on the southern portion of the base, (the POL Trenches and Lagoon, the South Fire Training Area, and the Oil/Water Separator Canal), similar geologic features were encountered. Therefore, the discussion of the geology of these sites was combined. Separate discussions are included for the North Fire Training Area and the STP Effluent Canal sites.

4.1.1 South Base

The subsurface geology of the South Base area is characterized by interbedded silts, sands, sandy silts, sands and gravels, silty clays, and caliche. This type of interbedding is typical of intermontane valley-fill deposits of the Basin and Range province.

Cross-sections showing the vertical distributions of subsurface materials from ground surface to 100 feet below ground surface were developed based on the soil boring logs. The locations of these cross-sections are shown in Figures 4-1 through 4-3. The cross-sections are shown in Figures 4-4 through 4-7. As can be seen in the cross-sections, the dominant lithology is silty sand interbedded with coarse-grained beds of sand or sand and gravel. Correlations of various geologic units were made between soil borings. The coarse sands and gravels are interpreted to have been deposited during infrequent periods of heavy rains; fine sands and silts are interpreted to have been deposited outside of major runoff channels, possibly as a product of dry, wind-blown deposition.

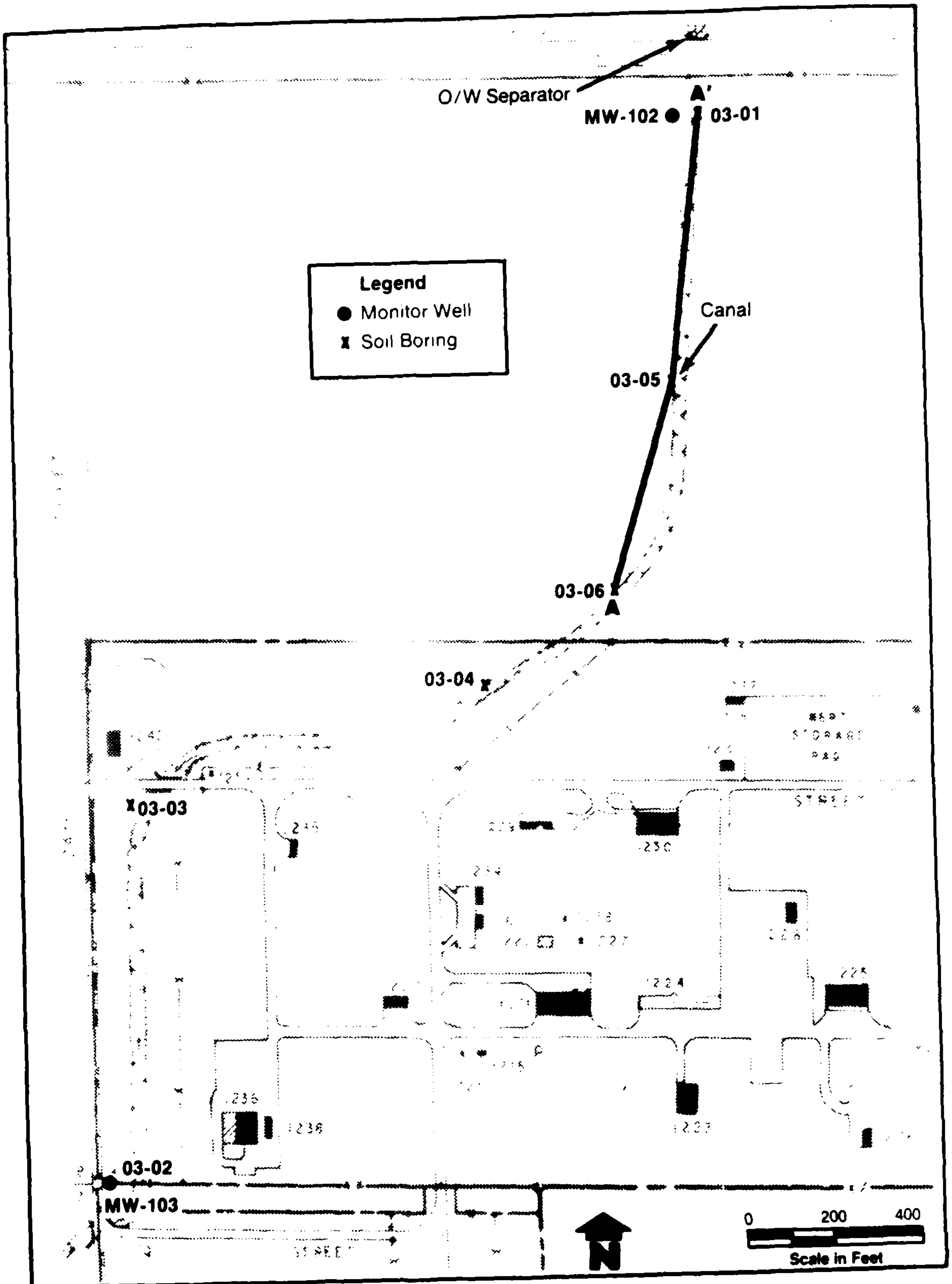


FIGURE 4-1 LOCATION OF GEOLOGIC CROSS-SECTION A-A', O/W SEPARATOR CANAL, LUKE AFB, AZ

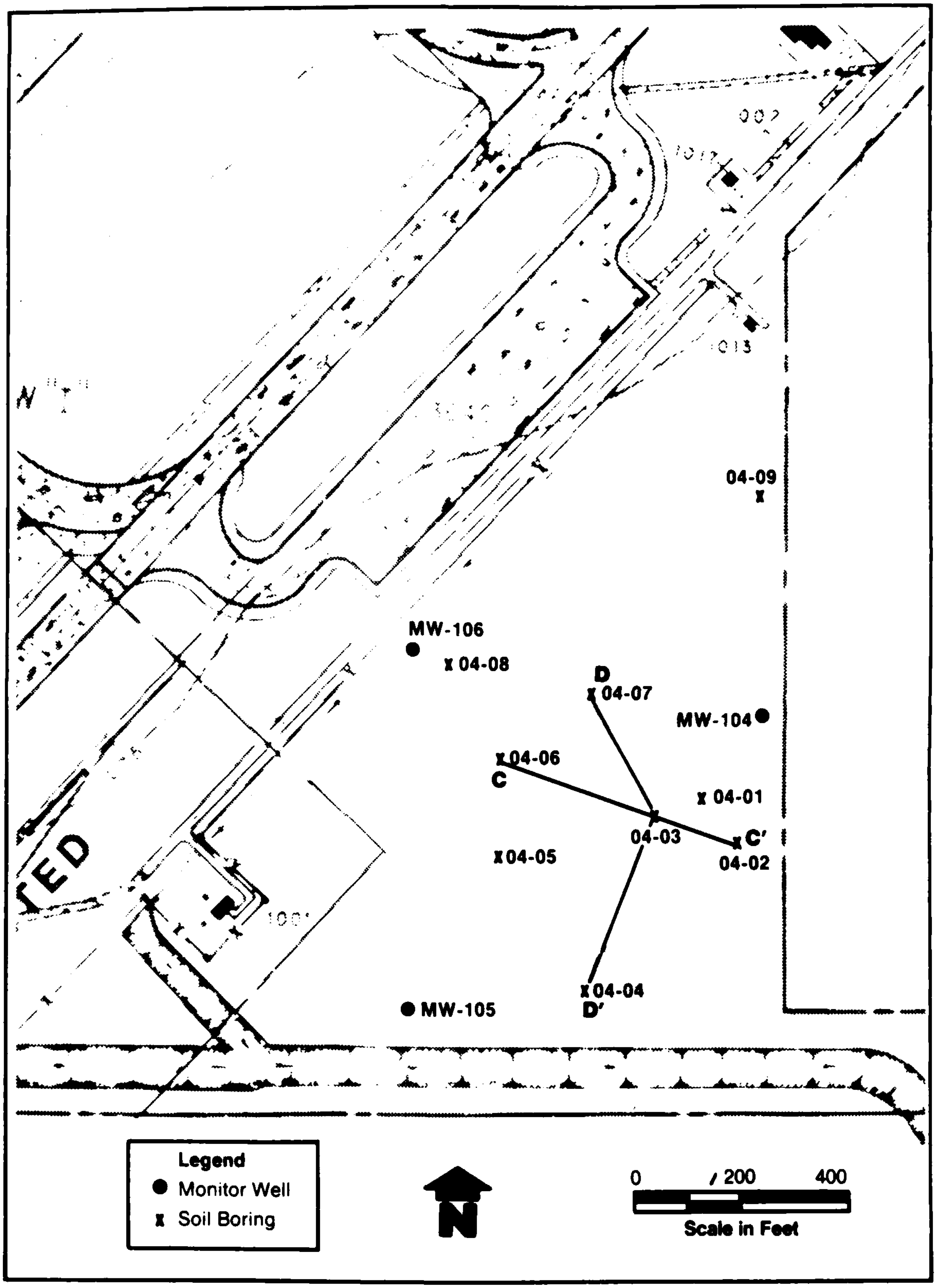


FIGURE 4-2 LOCATIONS OF CROSS-SECTIONS C-C' AND D-D', POL AREA, LUKE AFB, AZ

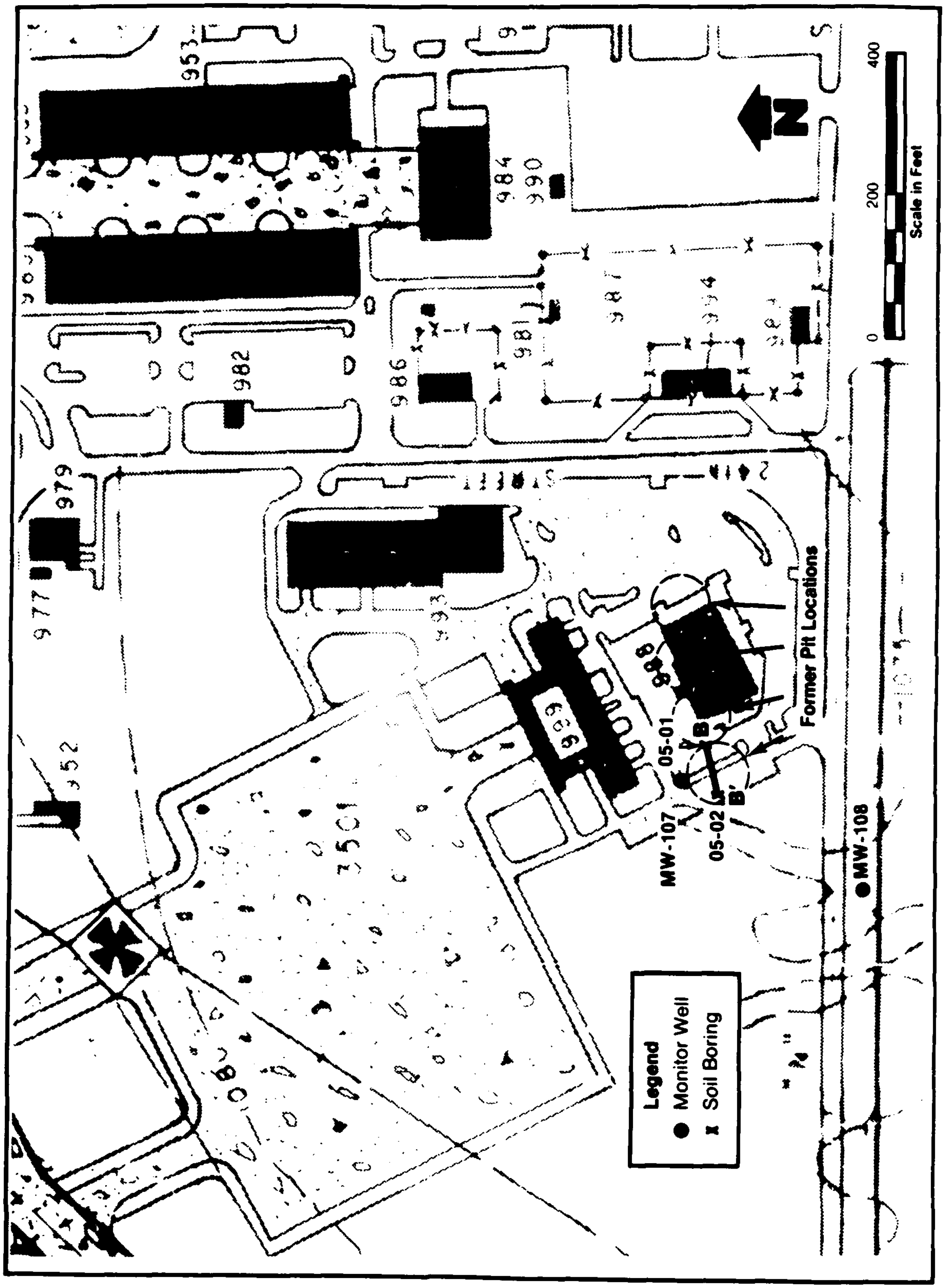


FIGURE 4-3 LOCATION OF GEOLOGIC CROSS-SECTION B-B', SOUTH FIRE TRAINING AREA, LUKE AFB, AZ

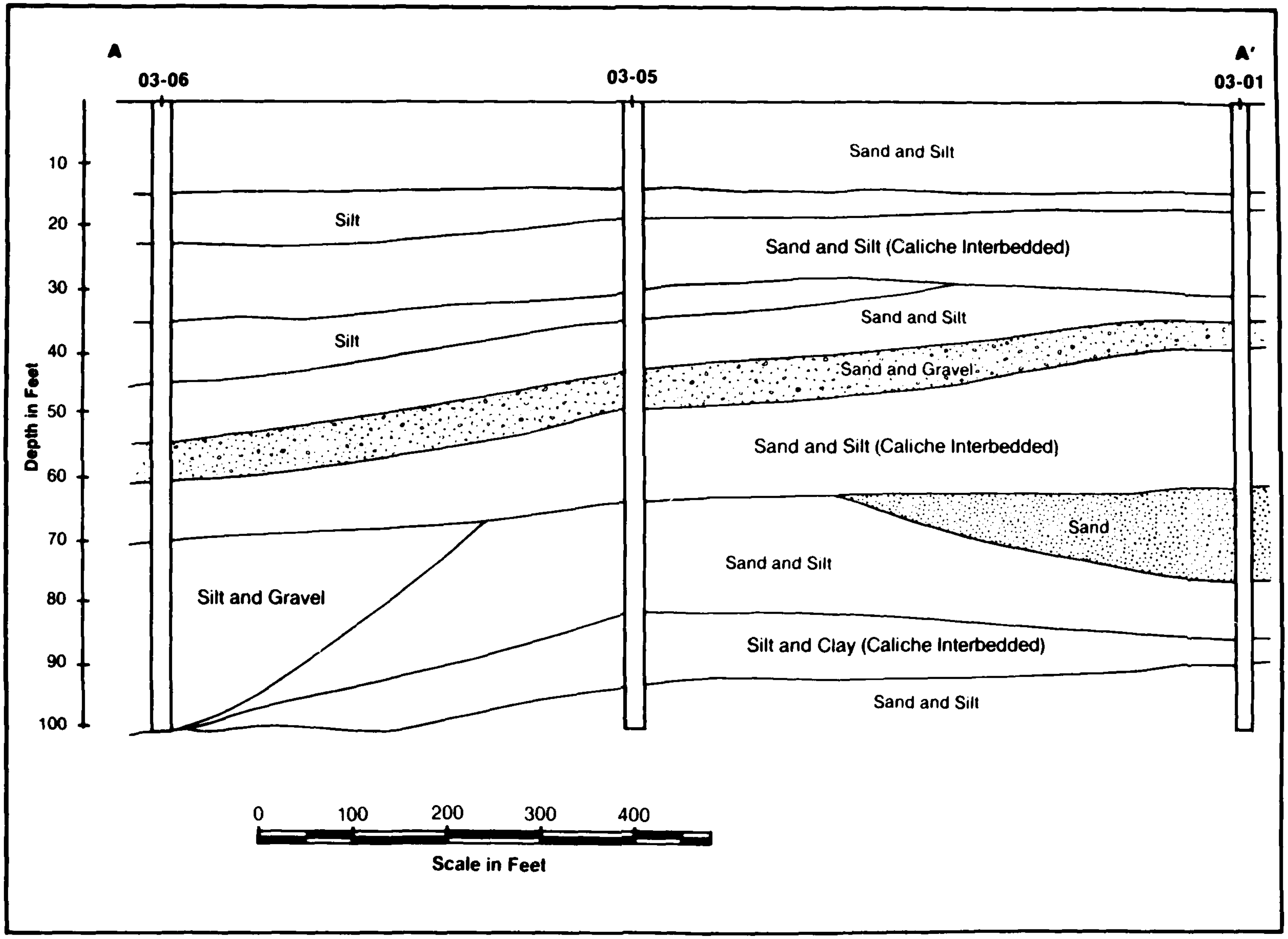


FIGURE 4-4 GEOLOGIC CROSS-SECTION A-A′, O/W SEPARATOR CANAL, LUKE AFB, AZ

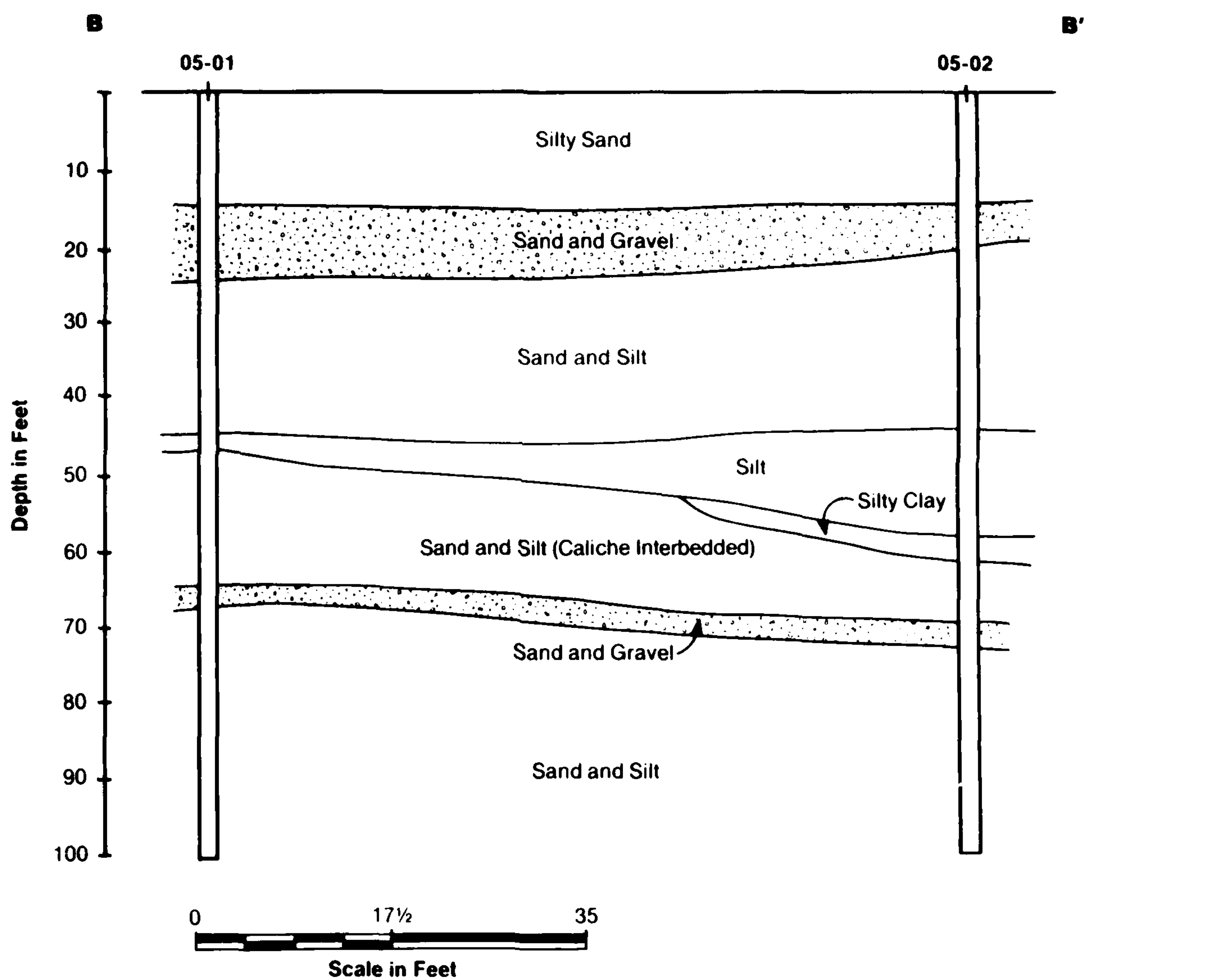


FIGURE 4-5 GEOLOGIC CROSS-SECTION B-B′, SOUTH FIRE TRAINING AREA, LUKE AFB, AZ

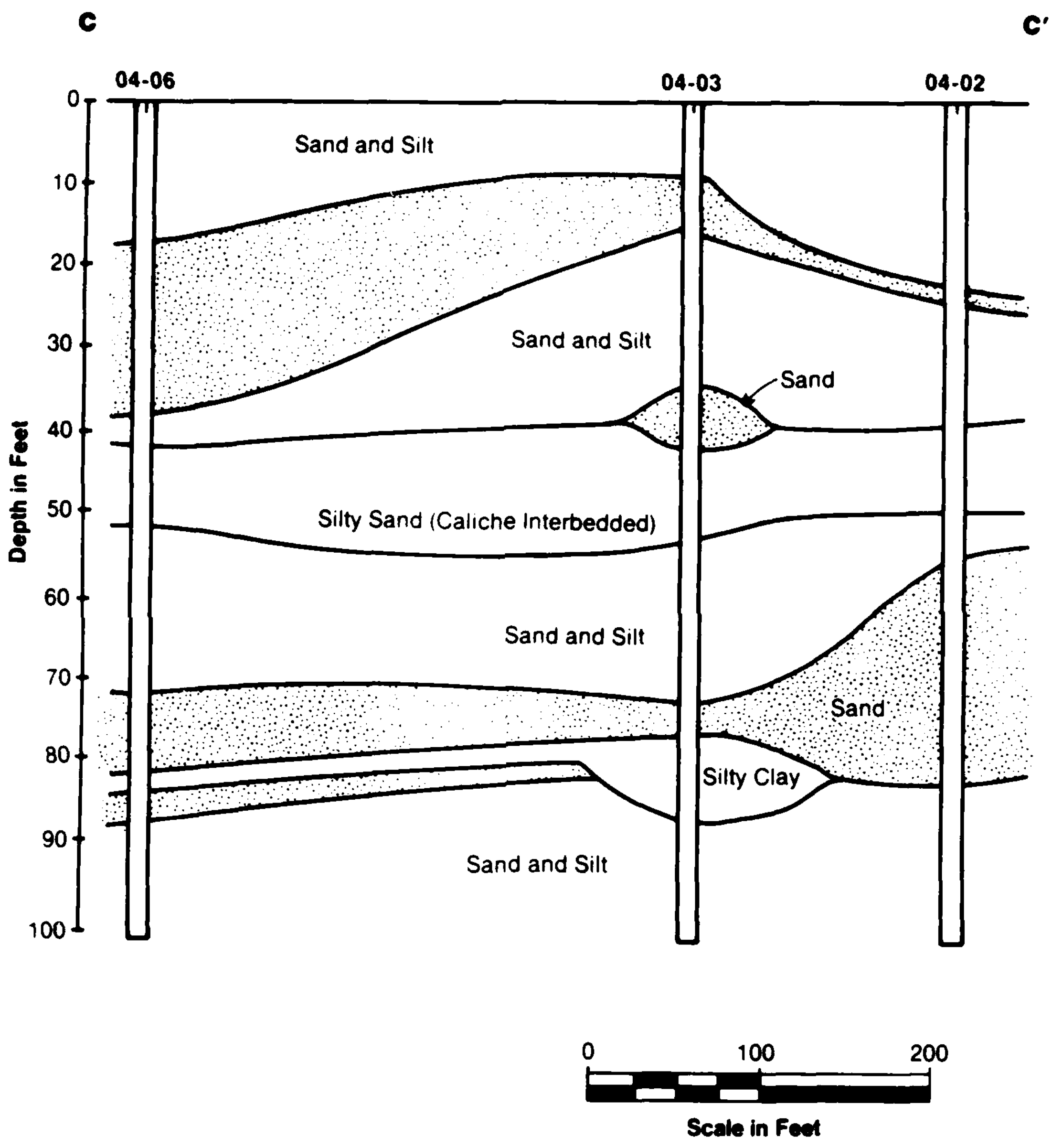


FIGURE 4-6 GEOLOGIC CROSS-SECTION C-C', POL AREA, LUKE AFB, AZ

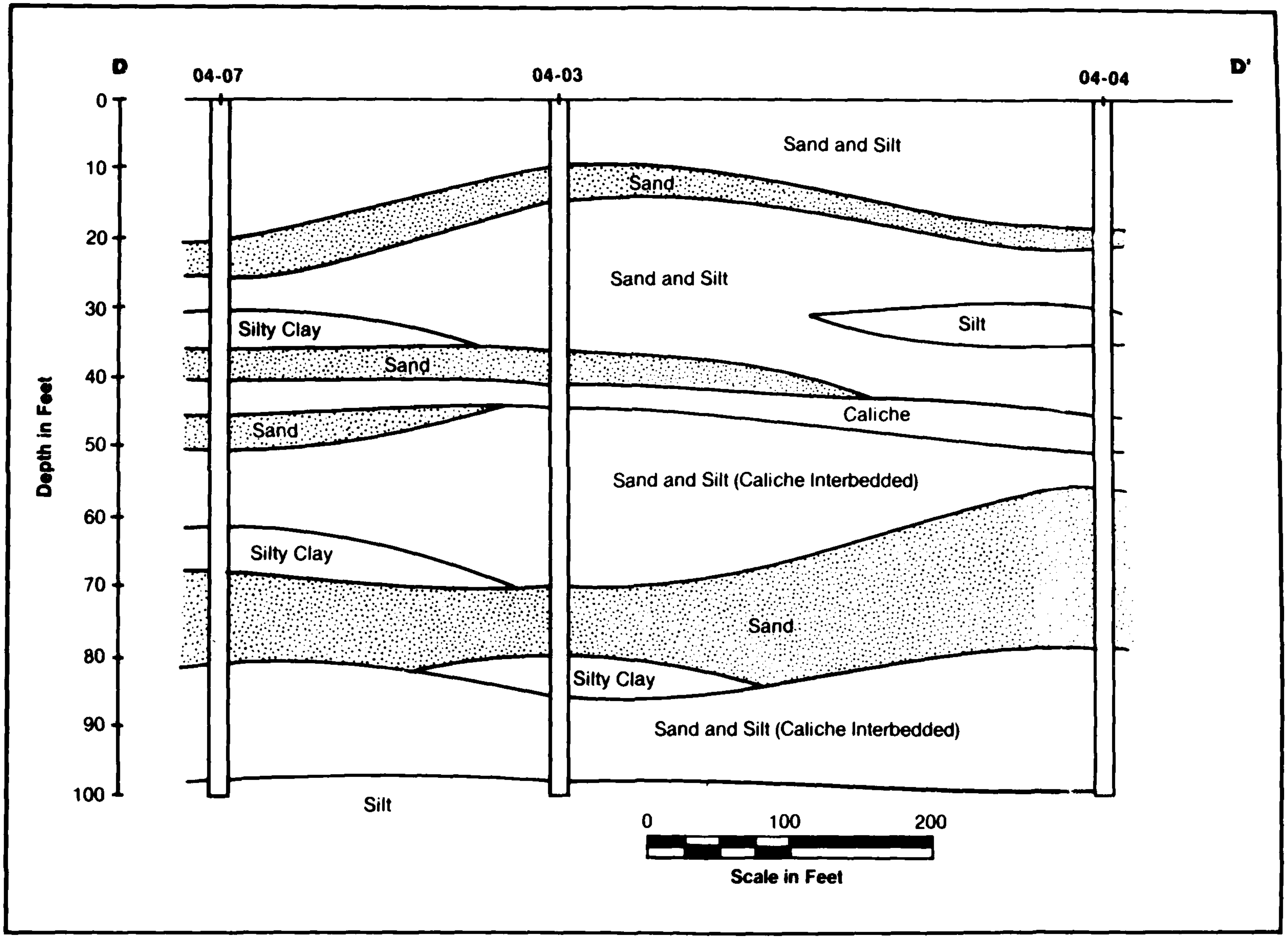


FIGURE 4-7 GEOLOGIC CROSS-SECTION D-D', POL AREA, LUKE AFB, AZ

Present, but not as abundant, are beds of caliche and silty clay. The caliche is a hard, cemented, silty calcium carbonate layer deposited near the ground surface by evaporating water. The clay-rich beds could have been formed by muds deposited in small temporary ponds or lakes formed during wetter periods.

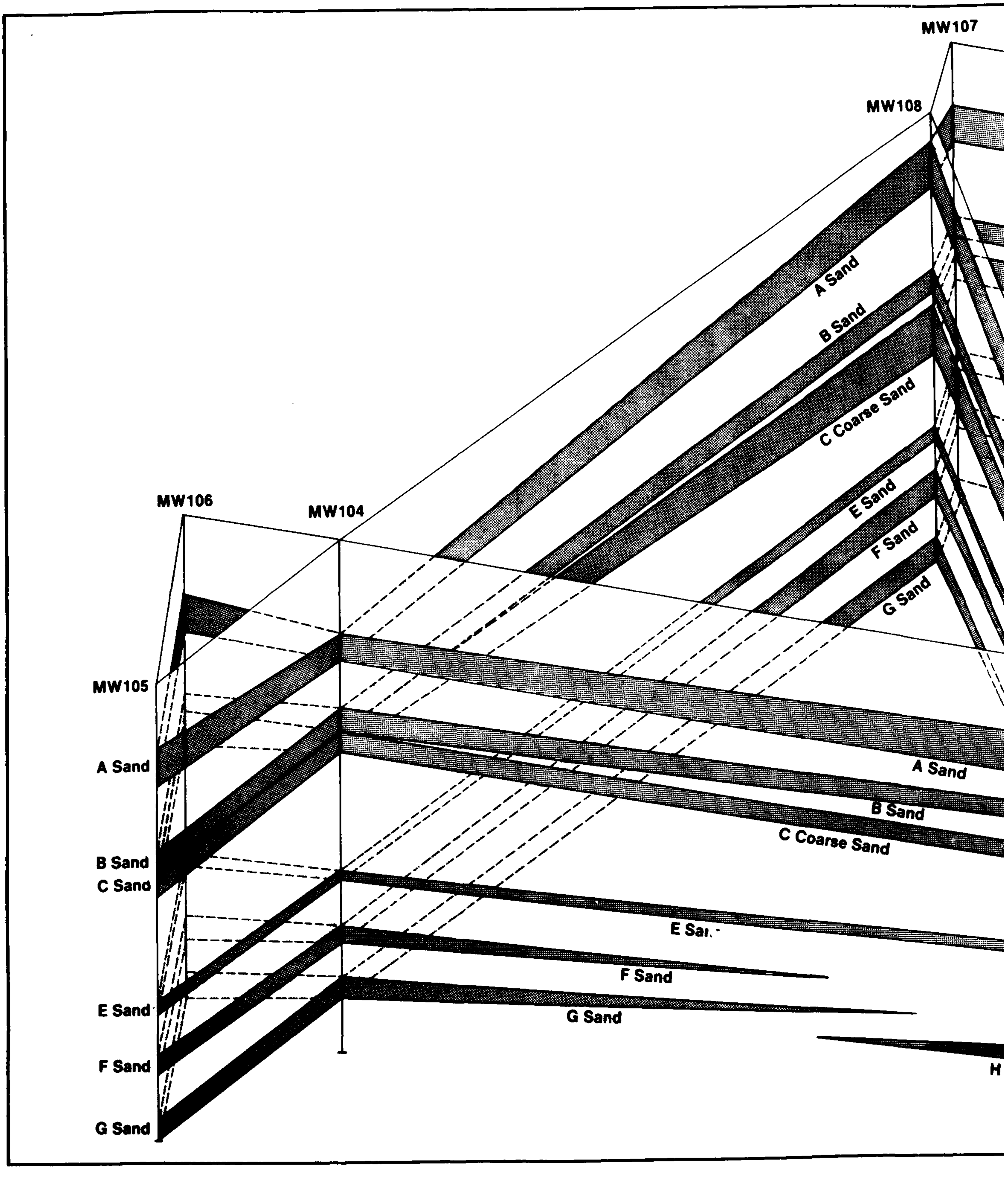
A fence diagram was constructed to illustrate the deeper subsurface geology of the South Base area. The fence diagram (Figure 4-8, with well locations shown in Figure 4-9) was based on the monitor well geologic logs correlated with the borehole geophysical logs. Although it has less detail than the cross-sections based on the soil boring logs, it shows broad relationships (similar to those described above for soil borings) between thicker fine-grained beds (primarily silty sands) interbedded with coarse-grained sand or sand and gravel beds. The sand units were arbitrarily labeled A, B, C, etc., and were correlated based on continuity of borehole geophysical resistivity response, spontaneous potential, and gamma ray response (see Figures 4-10 through 4-12). Sands A, B, C, and E are reasonably correlative with minor differences in thickness and elevations. Sand F, however, appears only at the base of MW-102 and is nonexistent in MW-103, as is Sand G. A separate and distinct Sand H is found at the base of MW-103 and does not appear to be correlative with any other sand unit. It is assumed that Sand H is a lens not connected with any other sand seen in the other monitor wells. Sand G was not encountered in MW-102 and is assumed to be deeper than the well. Sand F is shown not to be continuous between MW-102 and MW-103 based on hydrogeologic considerations presented in Subsection 4.2.1.

4.1.2 The North Fire Training Area (NFTA)

Although the NFTA is separated from the South Base sites by approximately 1.25 miles, the subsurface geology in both areas is similar and appears to be broadly correlative. A cross-section based on soil borings and a fence diagram based on monitor wells were developed (see Figure 4-13 for locations, Figure 4-14 for the cross-section, Figure 4-15 for the fence diagram, and Figure 4-16 for the geophysical log response diagram). As in the South Base area, the geology is characterized by sandy silt units interbedded with sand or sand and gravel units. The six labeled sands in the South Base area (Sands A through G) are identified in all three well logs at the NFTA and are correlative to the South Base sands. Relatively minor differences in layer thicknesses and elevation below ground surface exist between the Souch Base and the NFTA.

4.1.3 The STP Effluent Canal Area

The subsurface conditions (particularly at shallower depths) at the STP Effluent Canal area are dictated by the presence of the


MW107
MW108
A Sand
B Sand
C Coarse Sand
E Sand
F Sand
G Sand
MW106
MW104
MW105
A Sand
B Sand
C Sand
E Sand
F Sand
G Sand
A Sand
B Sand
C Coarse Sand
F Sand
G Sand
H

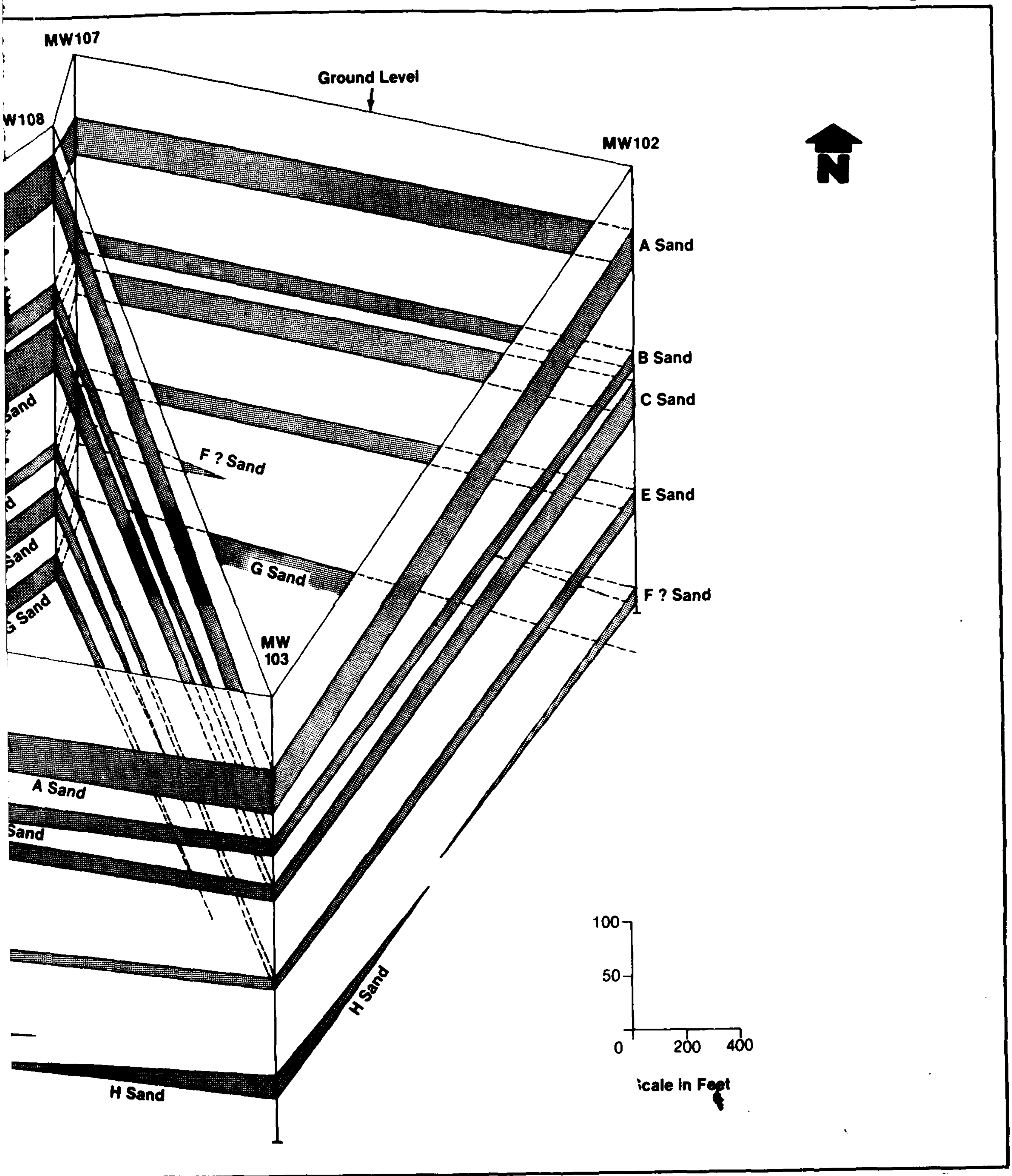


FIGURE 4-8 STRATIGRAPHIC FENCE DIAGRAM - SOUTH BASE AREA, LUKE AFB, AZ

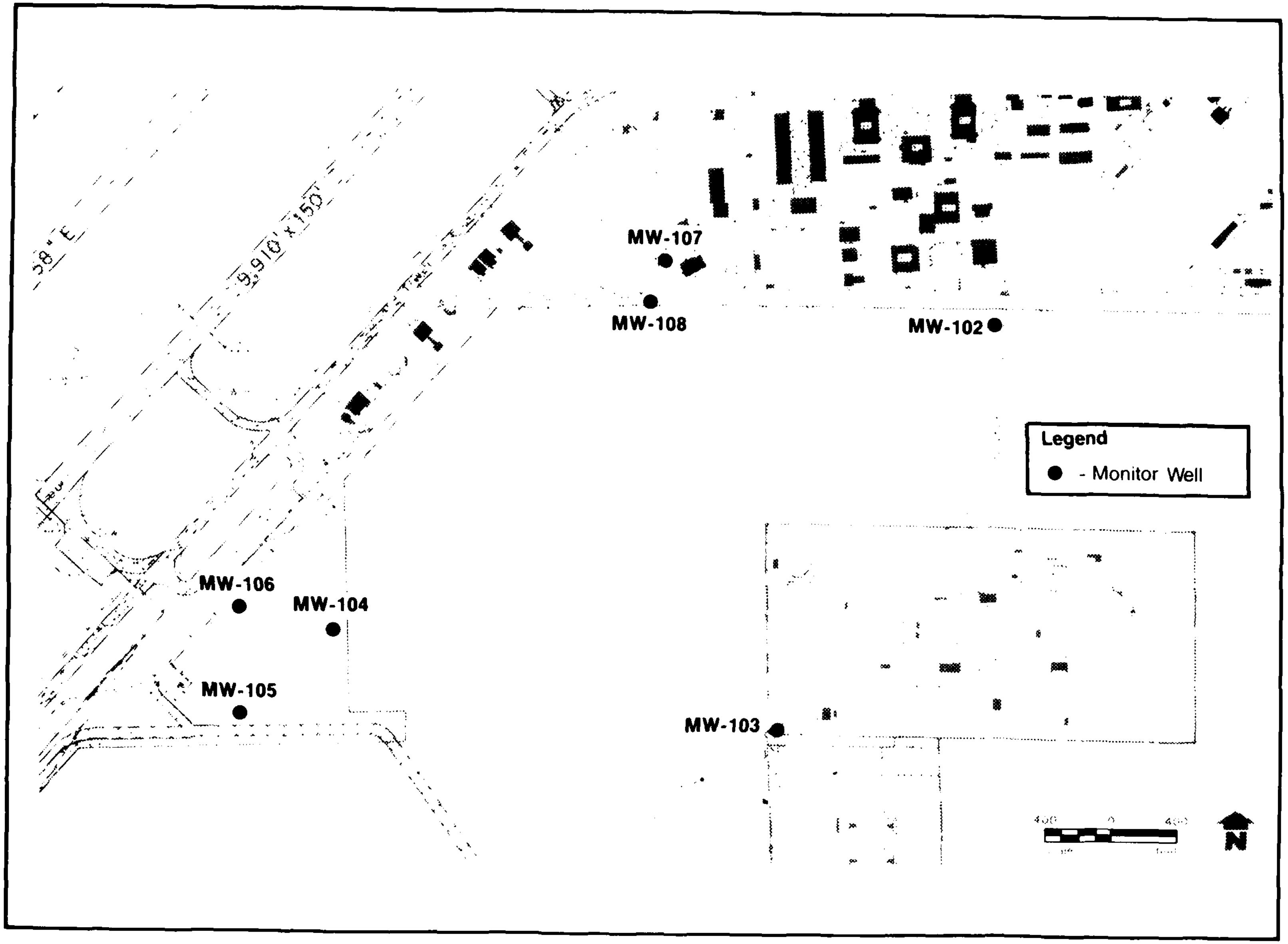
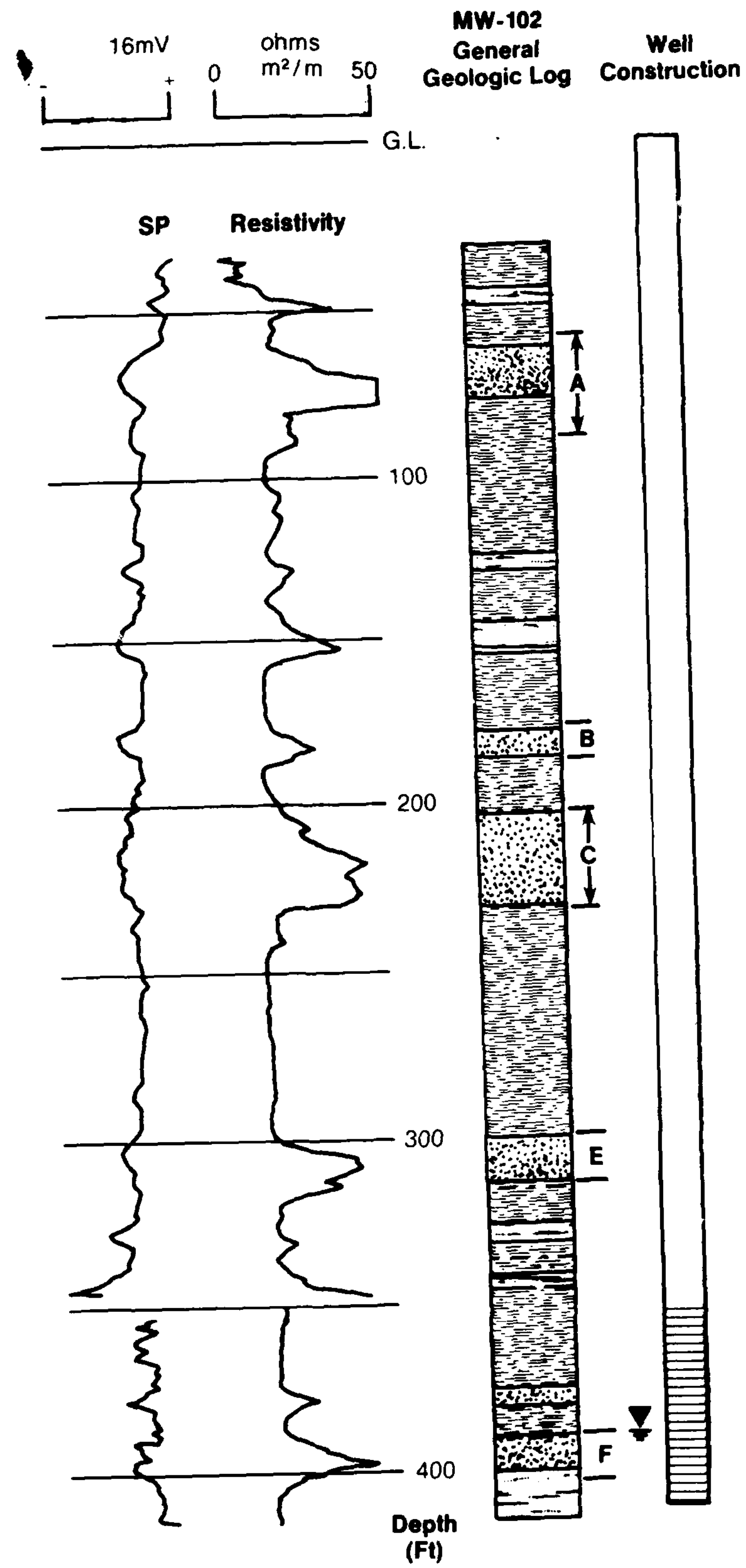


FIGURE 4-9 LOCATIONS OF MONITOR WELLS, SOUTH BASE, POL AREA, LUKE AFB, AZ


16mV
ohms
0 m²/m 50
MW-102
General
Geologic Log
Well
Construction
G.L.
SP
Resistivity
100
200
300
400
Depth
(Ft)
A
B
C
E
F

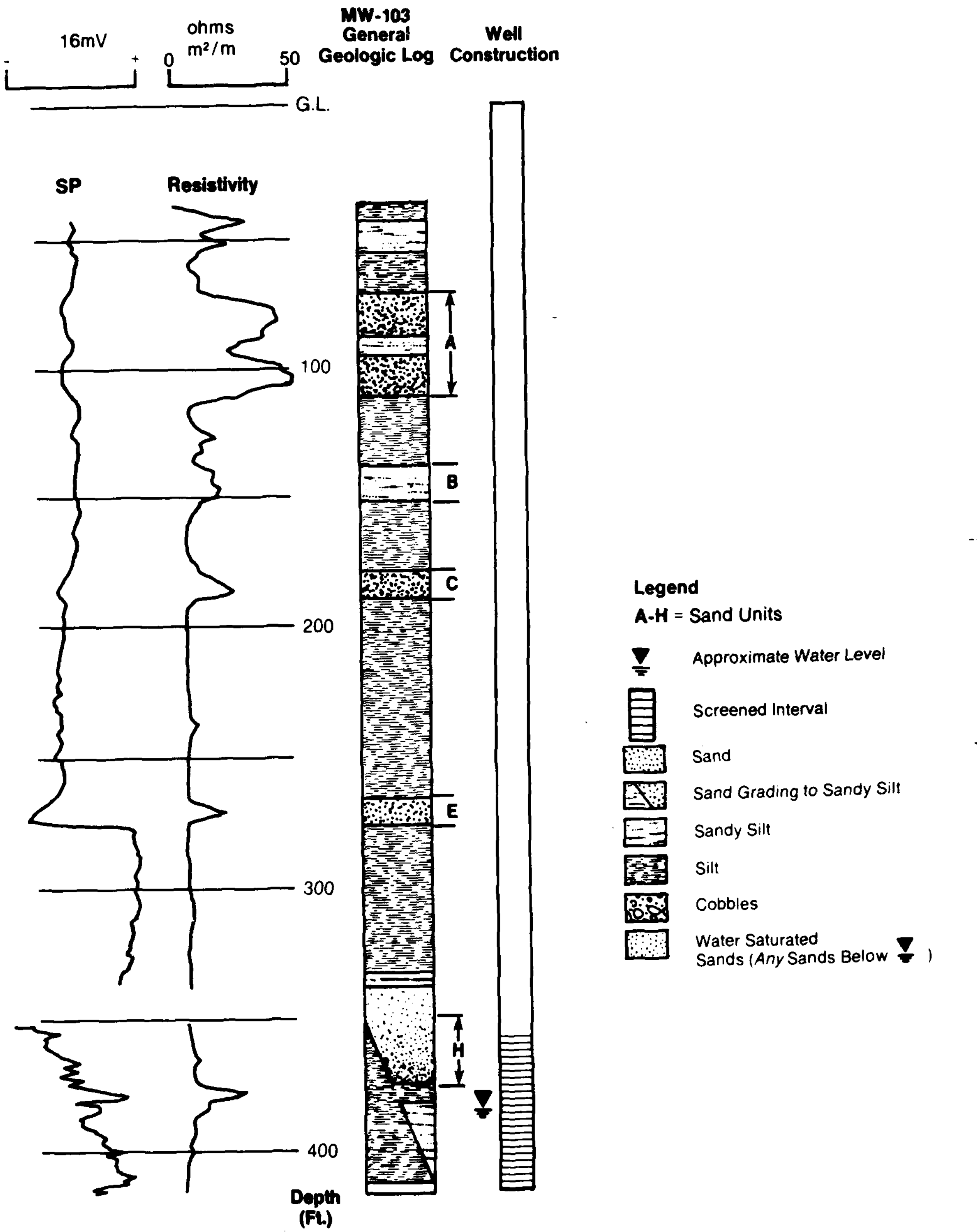
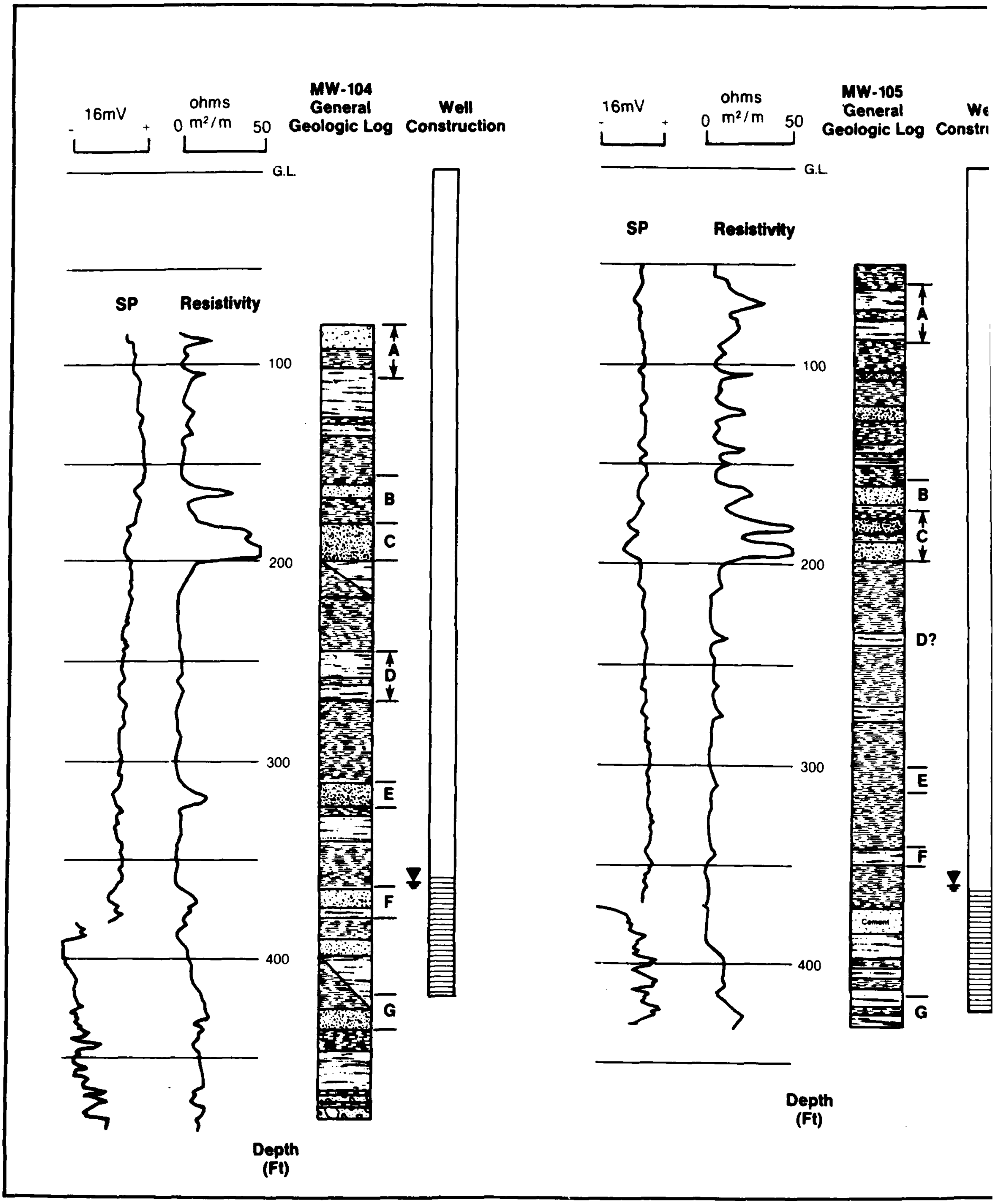


FIGURE 4-10 COMPARISON OF GEOPHYSICAL AND GEOLOGIC LOGS, OIL/WATER SEPARATOR CANAL, LUKE AFB, AZ


16mV
- +
ohms
0 m²/m 50
MW-104
General
Geologic Log
Well
Construction
G.L.
SP
Resistivity
100
200
300
400
A
B
C
D
E
F
G
Depth
(Ft)
16mV
- +
ohms
0 m²/m 50
MW-105
General
Geologic Log
G.L.
SP
Resistivity
100
200
300
400
A
B
C
D?
E
F
G
Cement
Depth
(Ft)

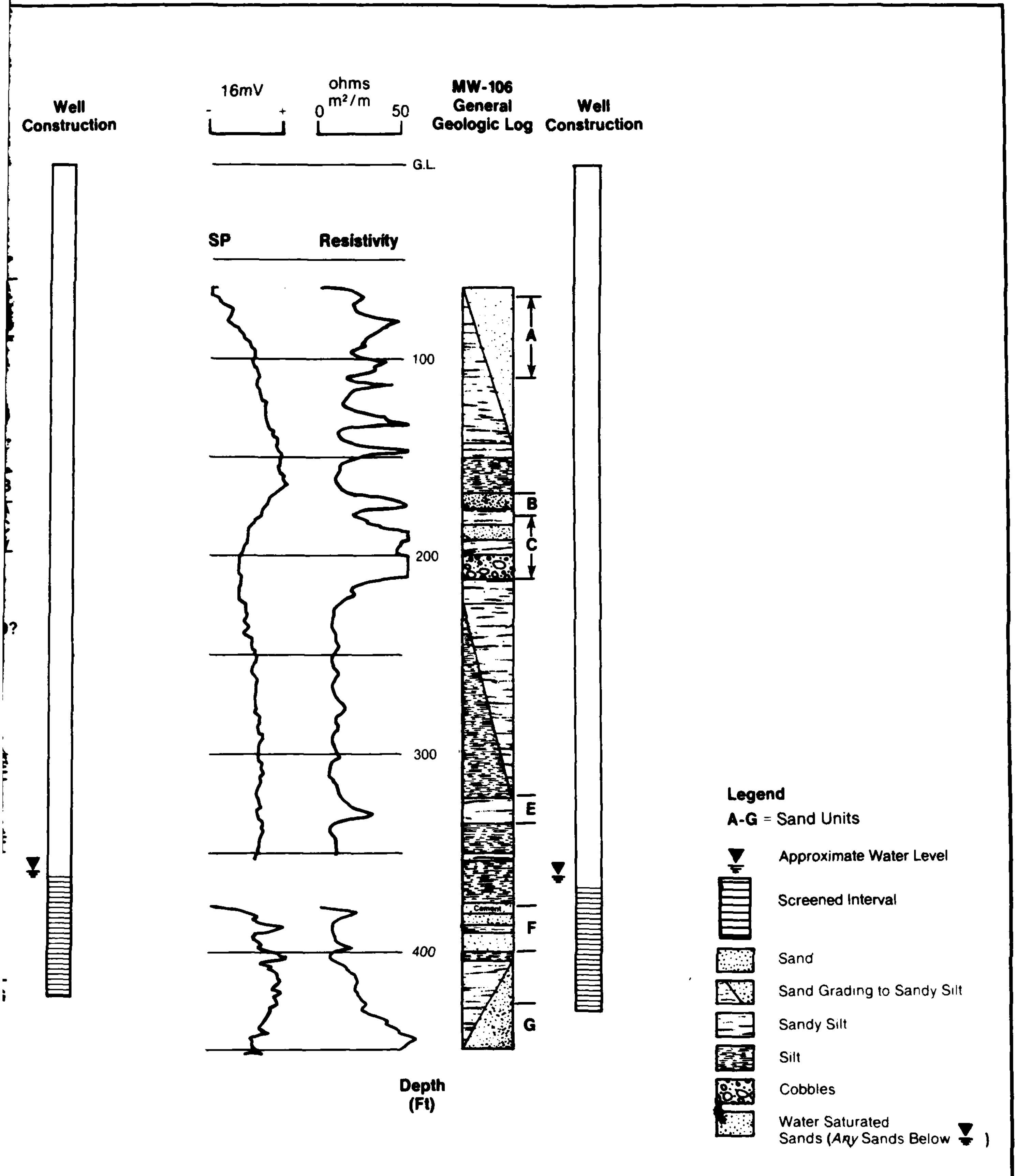
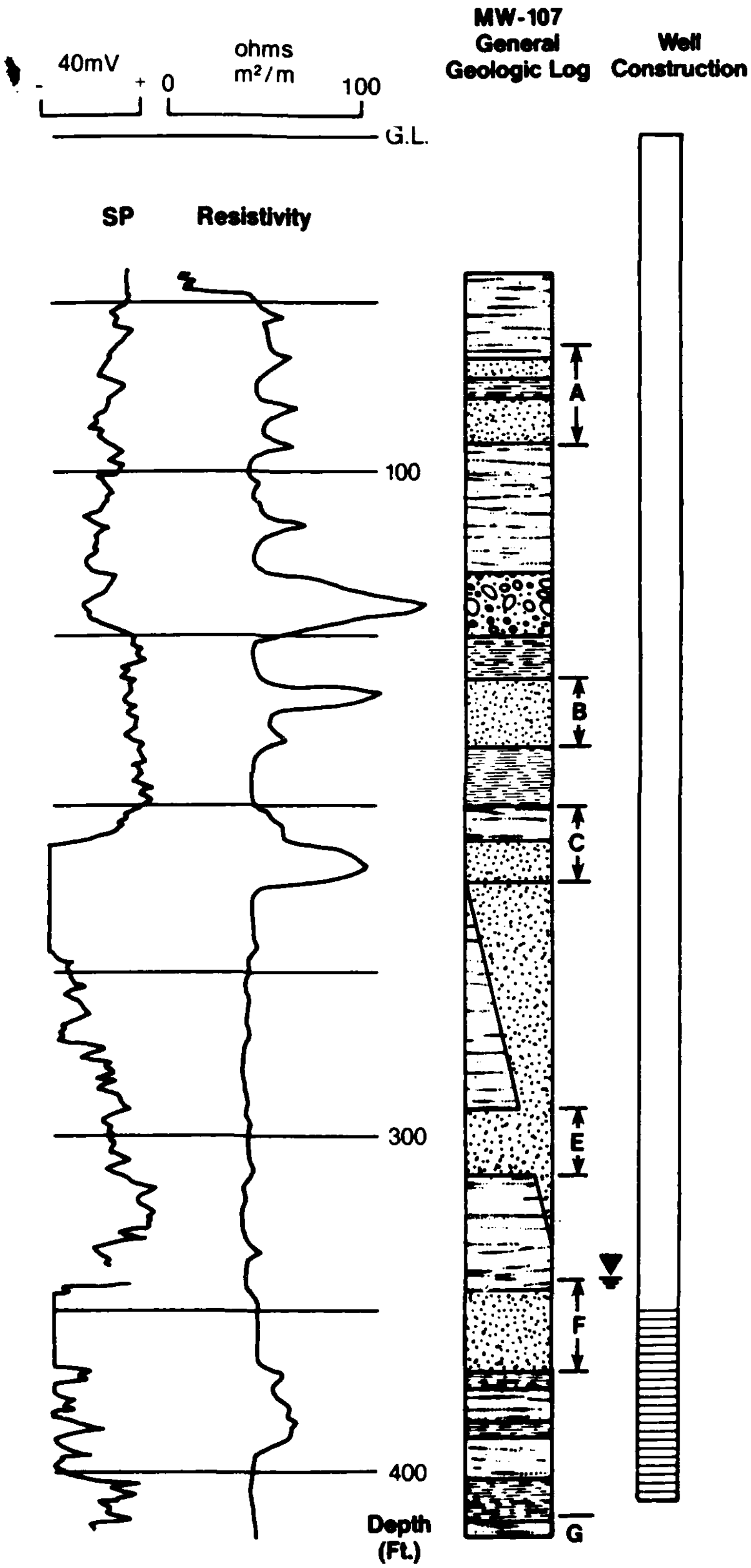


FIGURE 4-11 COMPARISON OF GEOPHYSICAL AND GEOLOGIC LOGS, POL AREA, LUKE AFB, AZ



MW-107
General
Geologic Log
Well
Construction
40mV
-
+
0
ohms
m²/m
100
G.L.
SP
Resistivity
100
300
400
Depth
(Ft.)
A
B
C
E
F
G

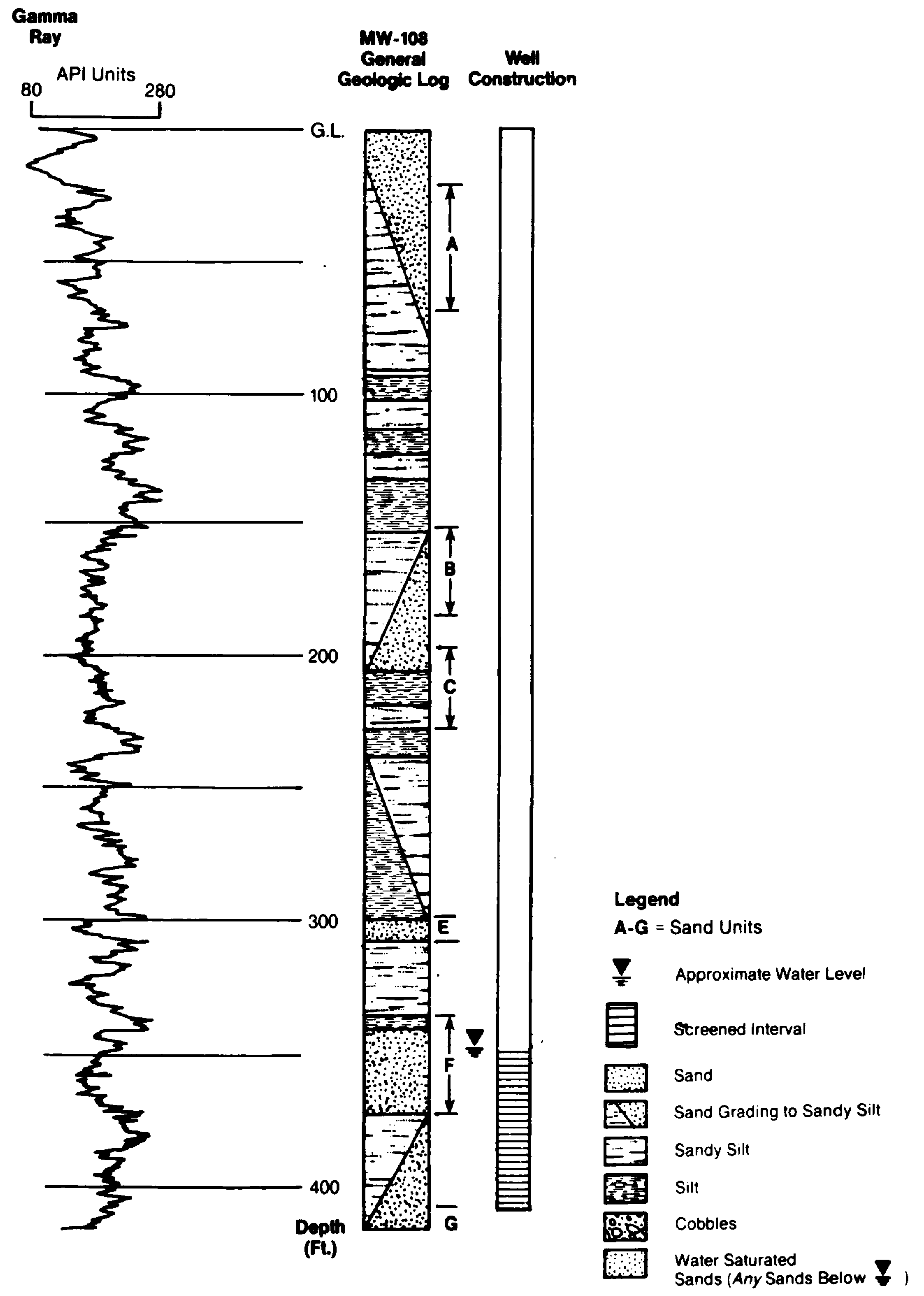


FIGURE 4-12 COMPARISON OF GEOPHYSICAL AND GEOLOGIC LOGS, SOUTH FIRE TRAINING, LUKE AFB, AZ

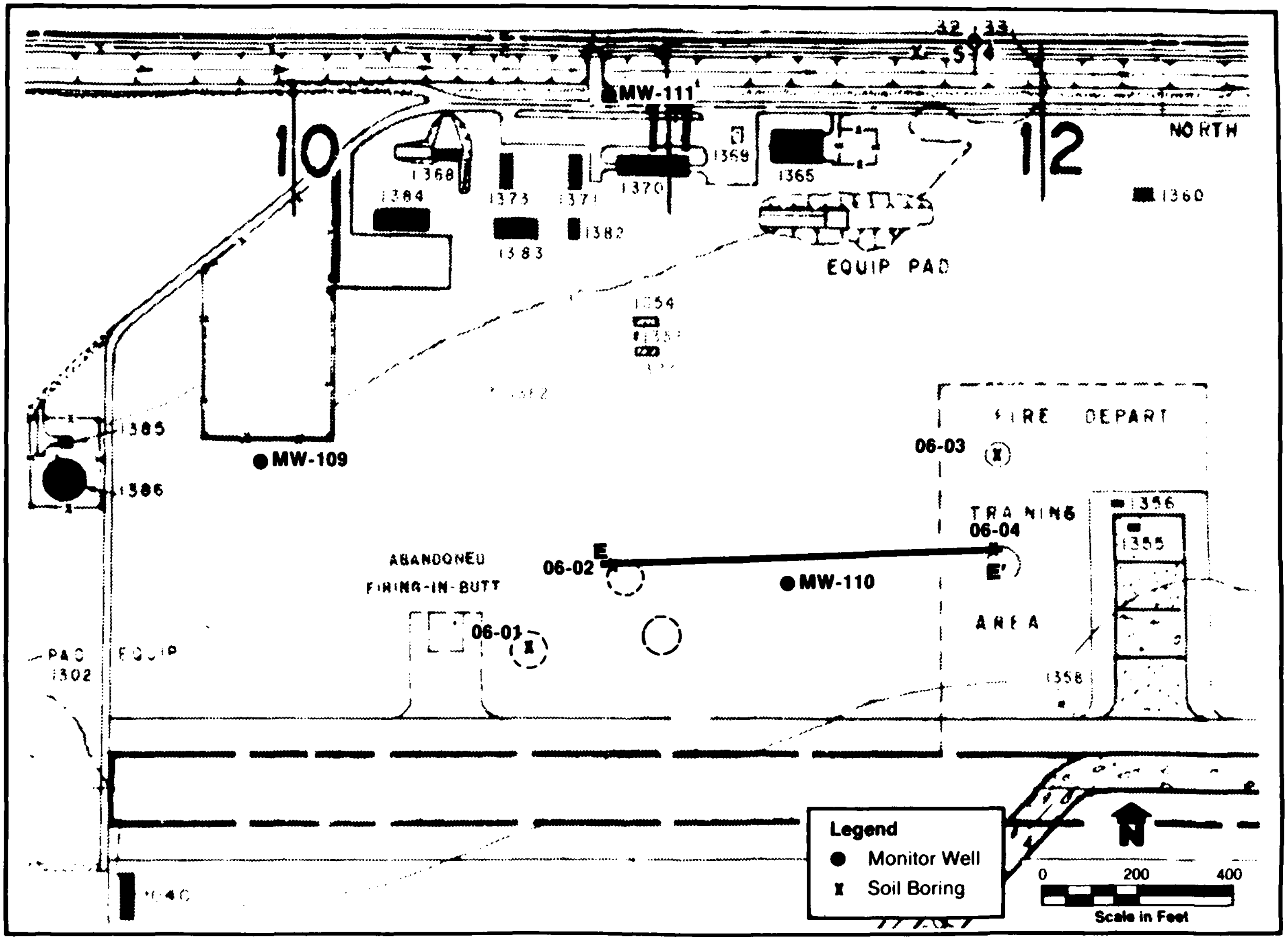


FIGURE 4-13 LOCATION OF CROSS-SECTION E-E', NORTH FIRE TRAINING AREA, LUKE AFB, AZ

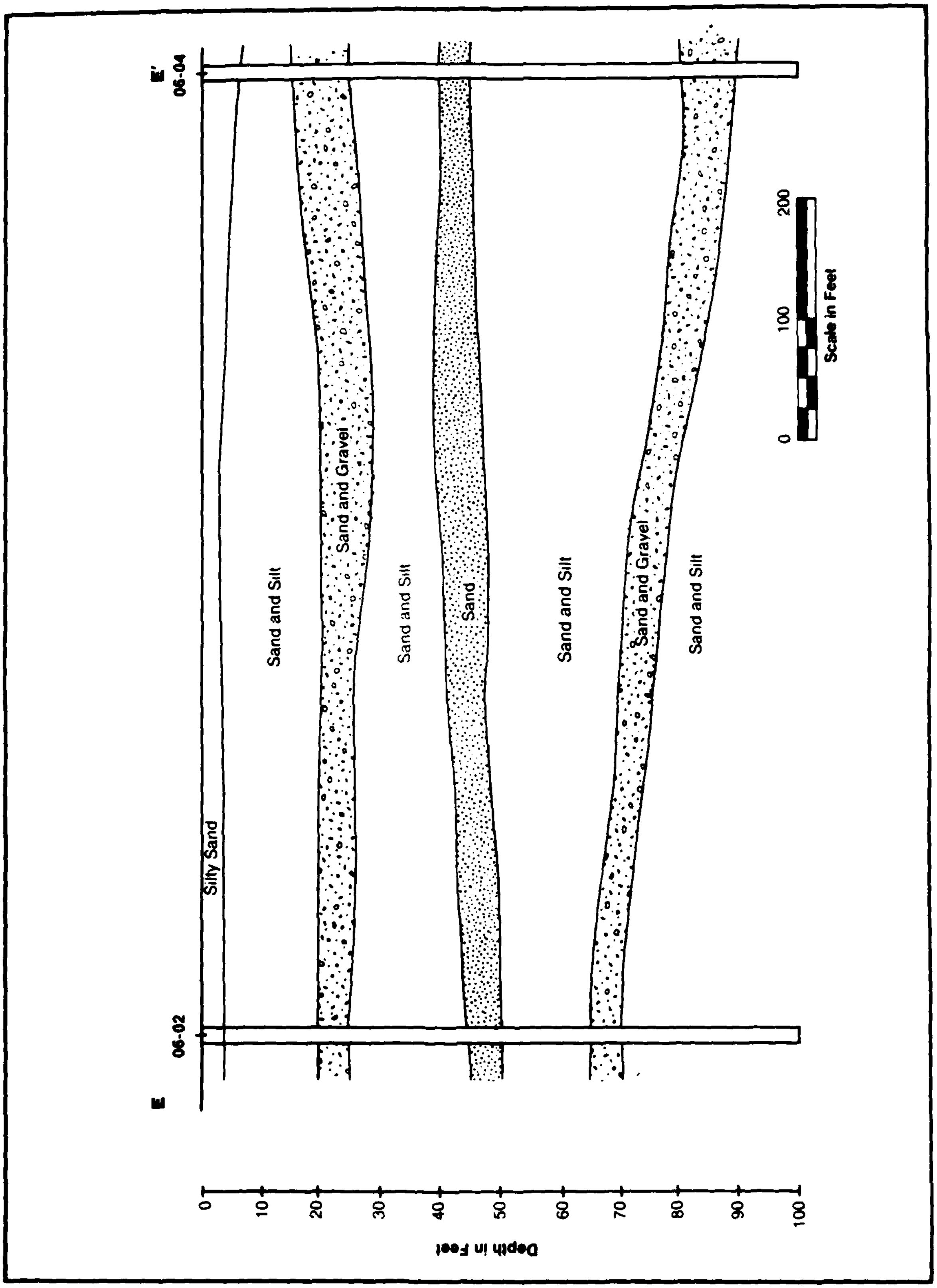


FIGURE 4-14 GEOLOGIC CROSS-SECTION E-E', NORTH FIRE TRAINING AREA, LUKE AFB, AZ

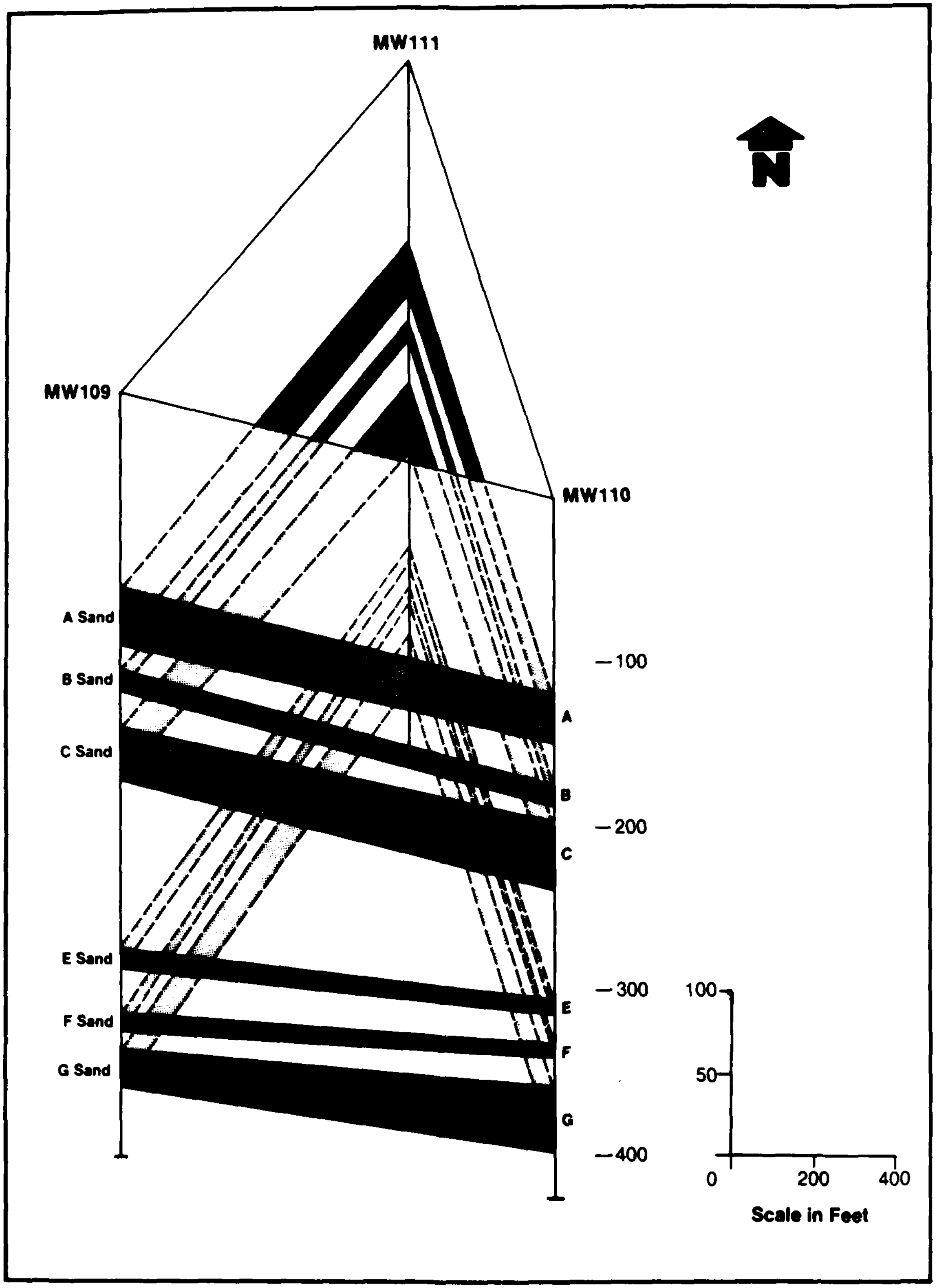
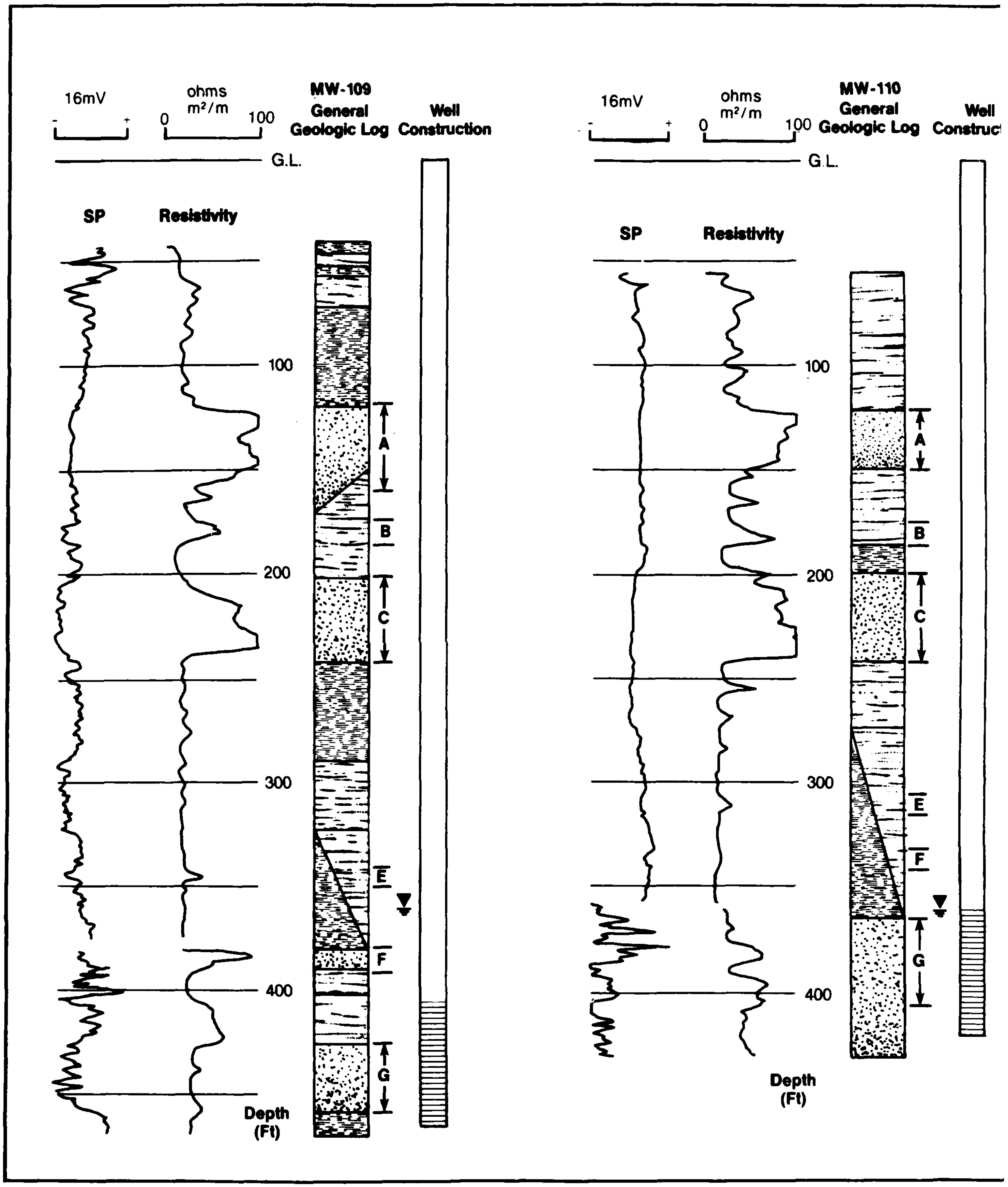


FIGURE 4-15 STRATIGRAPHIC FENCE DIAGRAM — NORTH FIRE TRAINING AREA, LUKE AFB, AZ



16mV
ohms
m²/m
0
100
MW-109
General
Geologic Log
Well
Construction
G.L.
SP
Resistivity
100
200
300
400
Depth
(Ft)
A
B
C
E
F
G
16mV
ohms
m²/m
0
100
MW-110
General
Geologic Log
Well
Construct
G.L.
SP
Resistivity
100
200
300
400
Depth
(Ft)
A
B
C
E
F
G

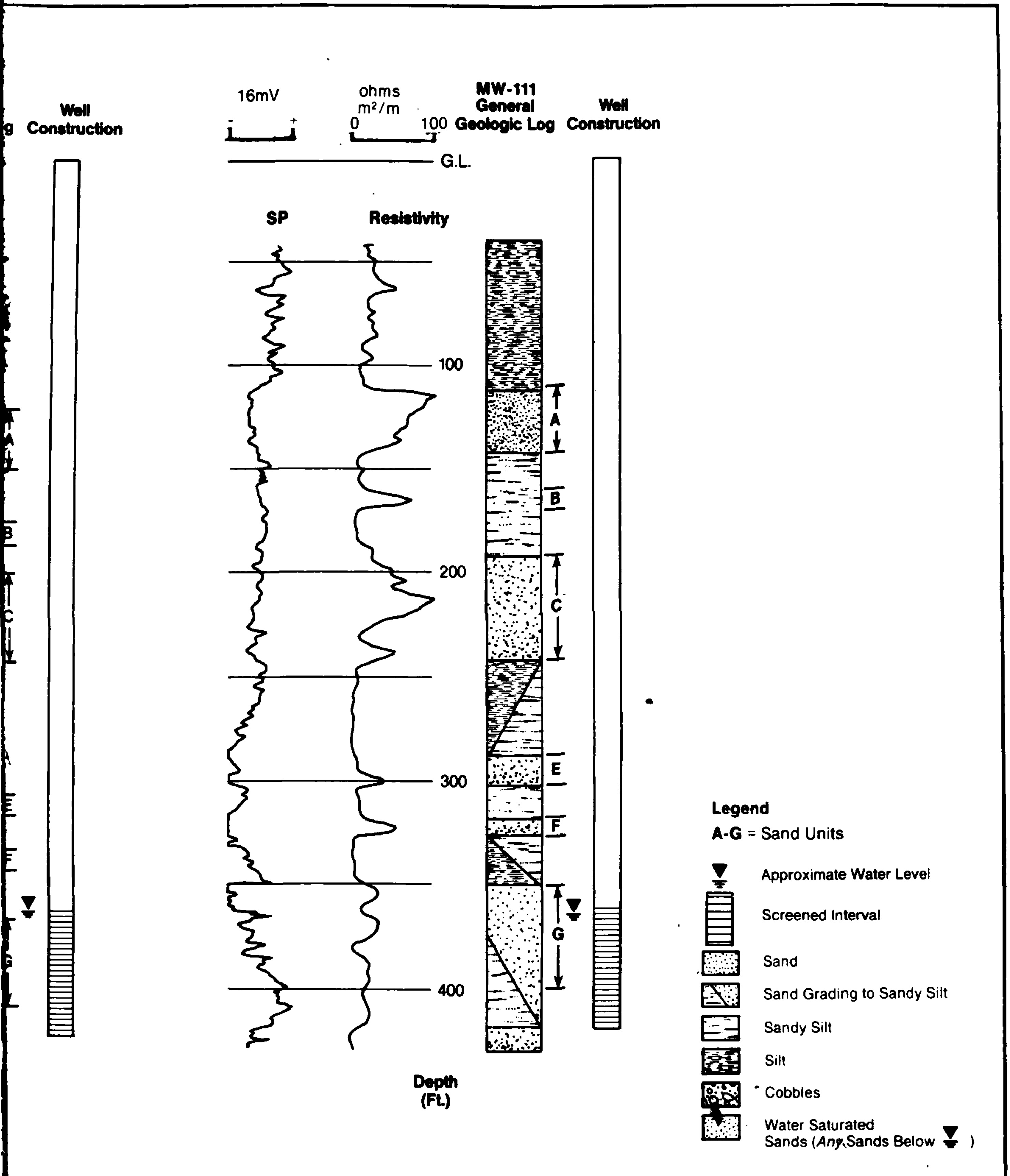


FIGURE 4-16 COMPARISON OF GEOPHYSICAL AND GEOLOGIC LOGS, NORTH FIRE TRAINING AREA, LUKE AFB, AZ

Agua Fria River and by periodic episodes of large flows of water into the river. The deposits found in each of the six soil borings (see Figure 4-17, with locations shown in Figure 3-14, p. 3-47) are layers of cobbles, coarse sand, and some silt. High-volume, rapid, turbulent-flow river deposition is indicated by the presence of cobbles. Large quantities of water from heavy rains move silts and sands rapidly down the river; however, the cobbles are moved at a slower pace and are deposited where the flow energy becomes insufficient to move them any farther. Silts and clays may also have been wind-blown into the river channel. The lack of correlation shown in Figure 4-17 is a result of the somewhat haphazard depositional environment associated with an intermittent river such as the Agua Fria. The river channel itself is composed of cobbles, gravels, and sands with only a few zones of silts or clay.

The subsurface geology was determined to a depth of 230 feet below the STP Effluent Canal based on logs of MW-101. The borehole geophysical logs (see Figure 4-18) and the geologic drilling log indicate that the major lithology encountered to a depth of 44 feet was cobbles with interbedded sands and gravels. Between 44 and 120 feet, silt and sand layers (each typically between 10 and 20 feet thick) are interbedded. Between 120 and 154 feet, there are sandy silts with fine interbeds of silty sands. A coarser sand layer is present between 154 and 164 feet and below that to 172 feet are silts and/or clays. An 8-foot sand interval is between 172 and 180 feet with a 2-foot clay "stringer" to 182 feet. Below 182 feet is a sequence with decreasing grain size where the amount of silt increases to the bottom of the hole.

4.1.4 Physical Soil Properties Testing Results

Laboratory physical property tests were performed on selected split-spoon soil samples obtained from soil borings as described in Subsection 3.2.2.3 (p. 3-11). The results of these tests are presented in Appendix N and are summarized in Table 4-1. The Unified Soil Classification System (USCS) symbol determined from the results of the grain size and the Atterberg limit test data are also presented in that table.

Of the 15 samples tested, 10 are classified as fine-grained soils. According to the USCS, these soils classify as low- (ML) and high-plasticity (MH) silty soils and low- (CL) and high-plasticity (CH) clayey soils. Nine of the 10 fine-grained soils are predominantly silt with percentages of silt ranging from 40 to 78 percent. One fine-grained sample (03-05-B035) was predominantly clay. These results verify the geologist's logs, which identify silt as the predominant fine-grained material encountered in the soils at Luke AFB.

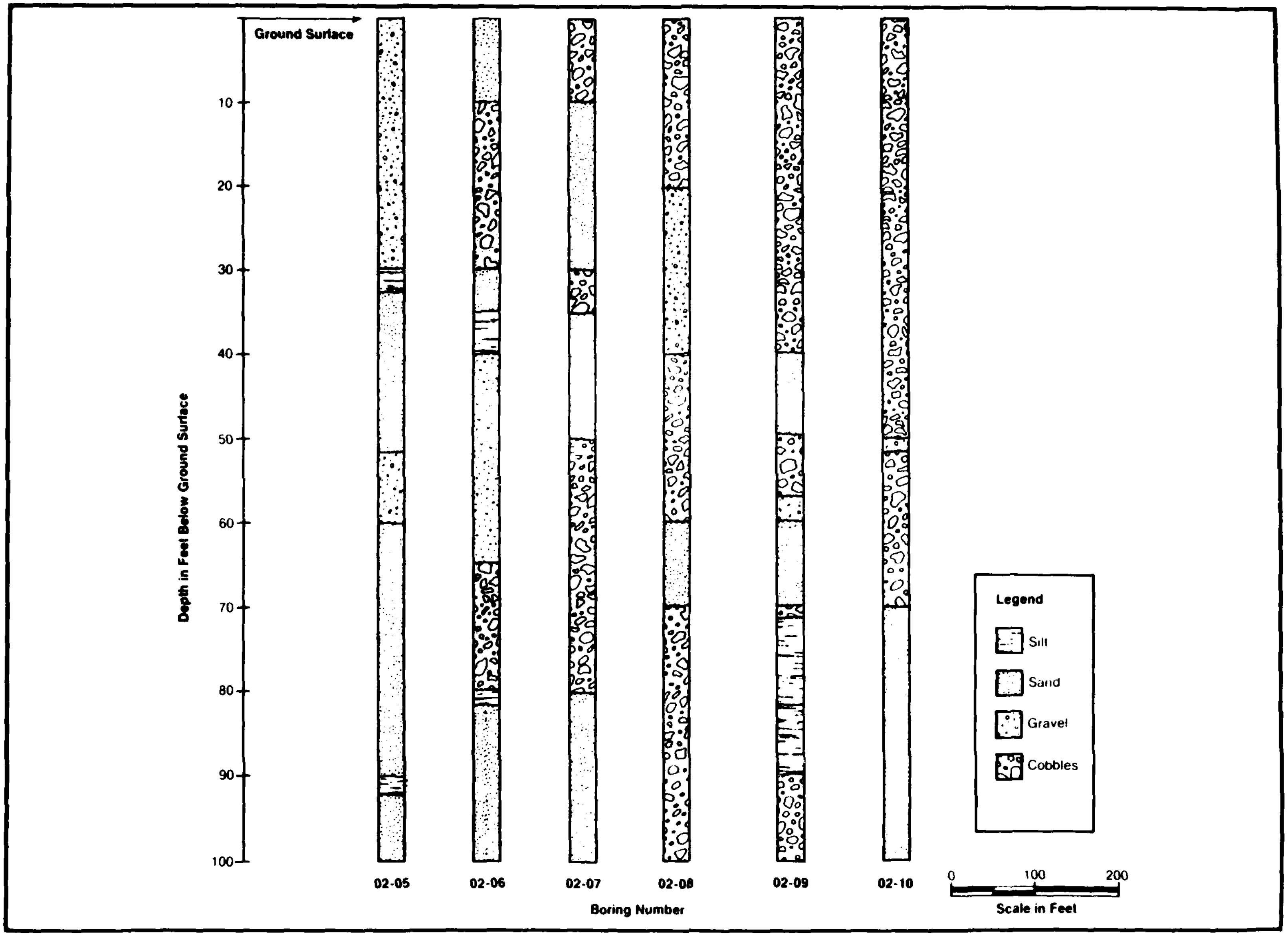


FIGURE 4-17 GEOLOGIC LOGS FROM SOIL BORINGS, STP EFFLUENT CANAL, LUKE AFB, AZ

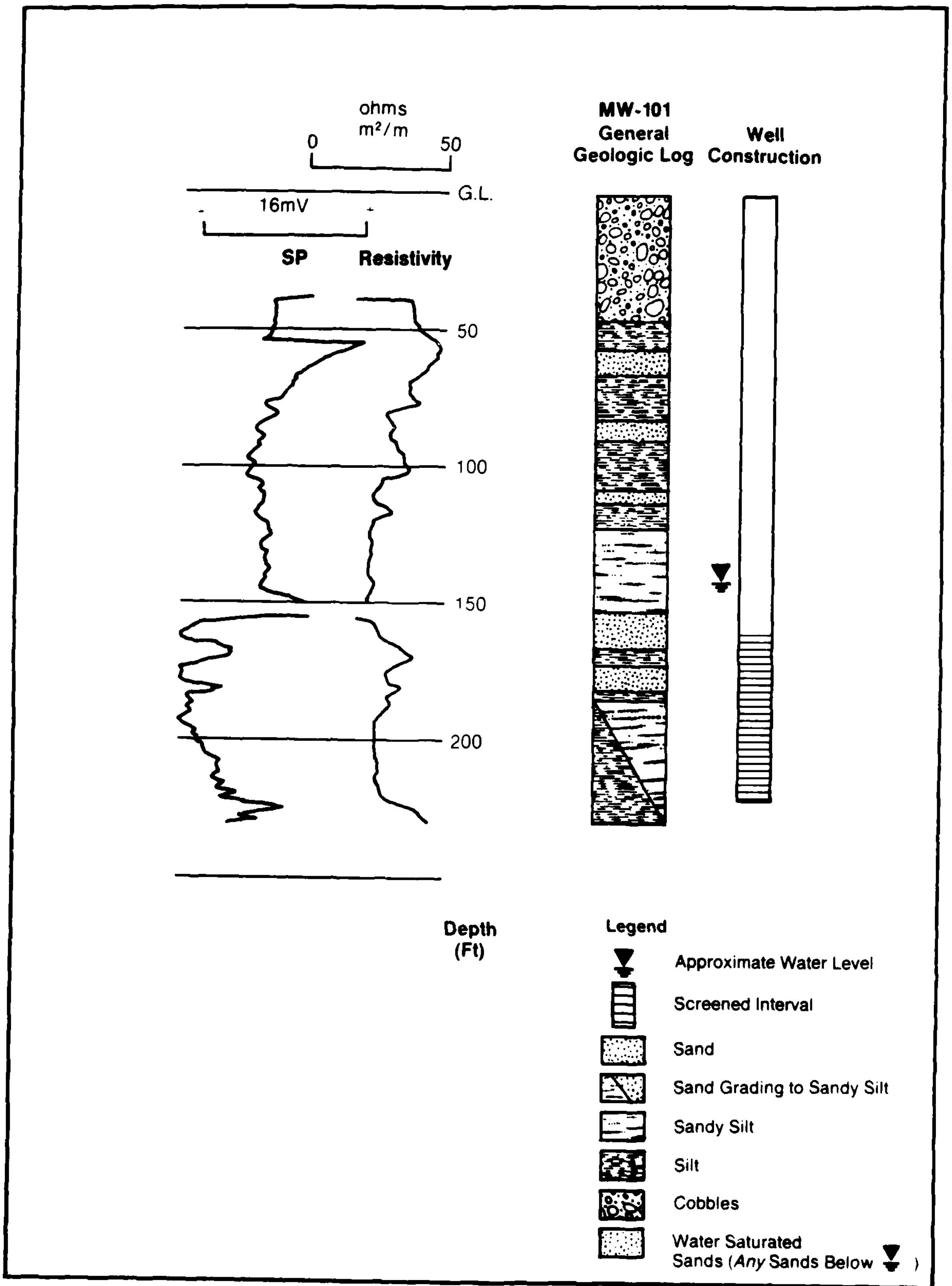


FIGURE 4-18 COMPARISON OF GEOPHYSICAL AND GEOLOGIC LOGS, STP EFFLUENT CANAL, LUKE AFB, AZ

Table 4-1

Grain Size Distribution of Selected Soil Samples
Luke AFB, Arizona

Sample ID	Site	Depth (ft)	Grain Size (%) Gravel	Sand	Silt	Clay	USCS Class	Atterberg Limits LL	PL	In Situ Conditions Dry Density (pcf)	Moisture Content (%)	Assumed Specific Gravity	Degree of Saturation (%)	pH	Cation Exchange Capacity (meq/100 g)	Organic Matter (%)
03-04-B025	O/W Canal	25	0	14	78	7	ML	36	8	92.1	12.5	2.68	41.1	9.7	20	0.34
03-04-B060	O/W Canal	60	0	39	45	16	CL	36	16	81.6	21.6	2.68	55.1	8.6	15	0.34
03-05-B035	O/W Canal	35	0	22	40	37	CH	56	32	94.8	27.7	2.68	97.2	9.1	30	0.19
03-05-B085	O/W Canal	85	3	20	32	45	MH	52	22	92.6	29.0	2.68	96.5	8.2	51	0.30
04-05-B090	POL Area	90	2	11	48	39	CL	44	18	96.0	26.2	2.68	94.5	8.1	30	0.28
04-06-B025	POL Area	25	0	82	9	9	SM	---	NP	103.7	16.1	2.70	69.6	8.2	9.1	0.19
04-06-B050	POL Area	50	0	15	56	29	CL	44	18	88.7	24.2	2.68	73.2	8.3	23	0.28
04-06-B075	POL Area	75	0	54	37	9	SM	---	NP	92.3	8.9	2.70	29.1	8.2	11	0.10
04-06-B098	POL Area	98	42	15	28	14	GC	34	11	113.2	14.1	2.68	79.3	8.4	12	0.34
06-01-B010	NFTA	10	0	28	41	31	CL	36	16	102.3	14.1	2.68	59.5	8.2	16	0.34
06-01-B100	NFTA	100	11	28	48	13	ML	---	NP	111.5	10.2	2.68	54.7	8.4	24	0.37
06-03-B025	NFTA	25	8	82	7	3	SP-SM	---	NP	102.9	4.3	2.70	18.2	9.6	25	0.13
06-03-B035	NFTA	35	0	44	53	2	ML	---	NP	Disturbed	7.8	2.70	---	9.0	23	0.52
06-03-B075	NFTA	75	10	48	18	24	SC	63	34	95.0	17.0	2.68	59.9	8.7	17	0.19
06-03-B085	NFTA	85	0	16	69	15	ML	---	NP	98.2	13.7	2.68	52.3	9.2	10	0.13

meq/100 g - milliequivalents per 100 grams
LL - Liquid Limit
PL - Plastic Limit
NP - Not Plastic
pcf - Pounds per cubic foot
--- - Test not performed

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Fifteen samples were tested; four from the O/W Separator Canal, five from the POL Area, and six from the NFTA.

Of the 15 samples tested, 5 are classified as coarse-grained soils. These soils classify as non-plastic silty sand (SM), as sandy clayey gravel (GC), a poorly graded sand with non-plastic silty fines (SP-SM), and a clayey sand (SC). Of these five soils, two (04-06-B025 and 06-03-B025) are "clean" sands with greater than 80 percent sand and minor amounts of silt and clay. The other three coarse-grained soils contain significantly higher percentages of fine-grained materials ranging from 42 to 46 percent silt and clay.

Moisture content (the ratio of the weight of water to the dry weight of soil) ranged from 4.3 to 29.0 percent, and the degree of saturation (the ratio of the volume of water to the total soil void volume) ranged from 18.2 to 97.2 percent.

The values of moisture content above 15 percent and the values of degree of saturation above 60 percent are considered high for the Phoenix area according to the laboratory personnel from Western Technologies, Inc. (WTI) in Phoenix who performed the analyses. The higher values associated with the O/W Separator Canal are probably the result of infiltrating water from the canal. Other high values may be indicative of anomalously high moisture retention characteristics of particular soils sampled.

The pH of the soils ranged from 8.1 to 9.7. These data are typical of the alkaline conditions in the Phoenix Basin and are consistent with the high pH values found in the groundwater (see Subsection 4.5.4).

Cation exchange capacity (CEC) is a measure of the ability of a soil to hold and exchange cations. In general, it is a function of the amount and type of clay-sized particles present in a given soil sample. At Luke AFB, CEC varied from 9.1 milliequivalents per 100 grams (meq/100 g) of dry soil to 51 meq/100 g. As expected, the higher CEC values are associated with the fine-grained soils.

Organic matter was found in the soil samples at levels ranging from 0.10 to 0.52 percent. These relatively low values are consistent with what would be expected for arid soils at depth. Generally, the higher organic matter levels are associated with those soils that contain higher percentages of fine-grained materials.

The calcium and magnesium concentrations in the soil (Appendix N) are a measure of the buffering capacity of the soil. The values determined (ranging from 2,100 to 6,200 parts per million (ppm) for calcium and ranging from 470 to 1,140 ppm for magnesium) were termed "very high" by the laboratory, typical for the Phoenix area alkaline soils.

4.2 HYDROGEOLOGY

As discussed in Subsection 2.6 (p. 2-5), groundwater at Luke AFB generally occurs in an unconfined or water table condition. As such, the water levels measured in the monitor wells are generally representative of the regional water table (with the exception of MW-102 and MW-103 as discussed below). Table 4-2 summarizes water level elevation measurements for the three sampling rounds for the monitor wells (including monitor wells associated with the Facility 993 study that were used to develop the South Base water table contour map). The water levels show little variation from round to round. Water table maps presented in this section are based on water levels measured during the second sampling round.

4.2.1 South Base Area

Because of the proximity of the POL Area, the SFTA, the neighboring Facility 993 study area, and the O/W Separator Canal, these areas have been grouped for purposes of evaluating groundwater occurrence and flow.

Figure 4-19 is a water table map of the South Base area. Note that, in principle, groundwater will flow perpendicular to the contour lines, from higher to lower water table elevations. The data indicate that for this portion of the base, groundwater is flowing nearly due west. This is generally consistent with Figure 2-1 (p. 2-4), which shows the regional water table configuration as mapped by the Arizona Department of Water Resources (ADWR) in 1983. Therefore, groundwater pumping centers to the west of Luke AFB are apparently continuing to strongly influence regional groundwater flow. The impact of Luke AFB production wells on the regional as well as on the local flow system appears to be minimal (although gradients are probably impacted in the immediate vicinity of the production wells).

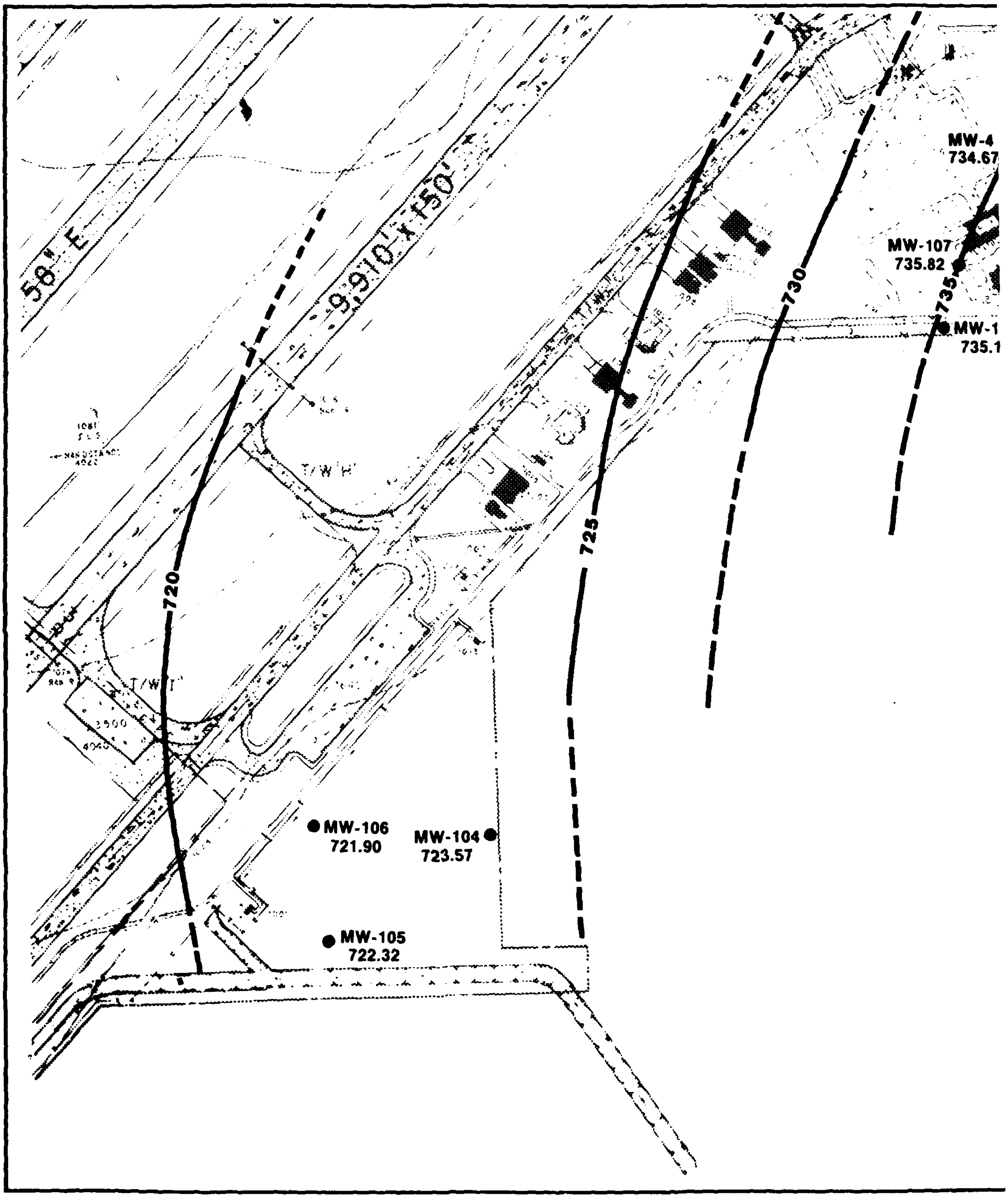
A significant exception to the above discussion of water table configuration occurs at MW-102 and MW-103 located at the northern and southern ends, respectively, of the O/W Separator Canal. As shown in Figure 4-19, the water levels associated with those wells were not used in preparation of the South Base water table map. This exclusion was based on the observation that water levels in MW-102 and MW-103 are not representative of the regional water table (they are much lower) and, in fact, more likely represent a localized groundwater hydraulic regime. This localized system is probably a result of the fact that neither MW-102 nor MW-103 is screened in regionally continuous

Table 4-2

Water Table Elevations Measured in Monitor Wells, Luke AFB, Arizona

Well No.	Elevation[a] (ft)	Round 1		Round 2		Round 3	
		SWL[b] (ft) (15-22	Elevation[c] (ft) December 1986)	SWL[b] (ft) (19-23	Elevation[c] (ft) January 1987)	SWL[b] (ft) (9-12	Elevation[c] (ft) February 1987)
101	1050.86	140.18	910.68	141.63	909.23	138.78	912.08
102	1089.34	392.45	696.89	390.32	699.02	386.65	702.69
103	1082.30	380.16	702.14	378.60	703.70	376.50	705.80
104	1081.44	358.15	723.29	357.87	723.57	356.47	724.97
105	1080.12	359.28	720.84	357.80	722.32	356.70	723.42
106	1081.63	---	---	359.73	721.90	358.19	723.44
107	1087.14	---	---	351.32	735.82	349.98	737.16
108	1084.23	350.12	734.11	349.04	735.19	348.00	736.23
109	1110.40	363.82	746.58	362.19	748.21	362.10	748.30
110	1109.13	361.08	748.05	360.37	748.76	359.53	749.60
111	1110.01	364.06	745.95	363.39	746.62	362.68	747.33
3*	1086.46	349.69	736.77	348.71	737.75	347.87	738.59
4*	1088.28	351.57	736.71	353.61	734.67	350.33	737.95
5*	1086.46	349.50	736.96	350.66	735.80	347.98	738.48

[a]Elevation of top of casing.
[b]SWL = Static water level, measured from top of casing.
[c]Water table elevation = (a-b).
--Not measured due to blocked measuring tube.
*Facility 993 wells used in developing water table contour map.


58 E
9,910' x 150'
T/W 'H'
T/W 'I'
720
725
730
735
MW-4
734.67
MW-107
735.82
MW-1
735.1
MW-106
721.90
MW-104
723.57
MW-105
722.32

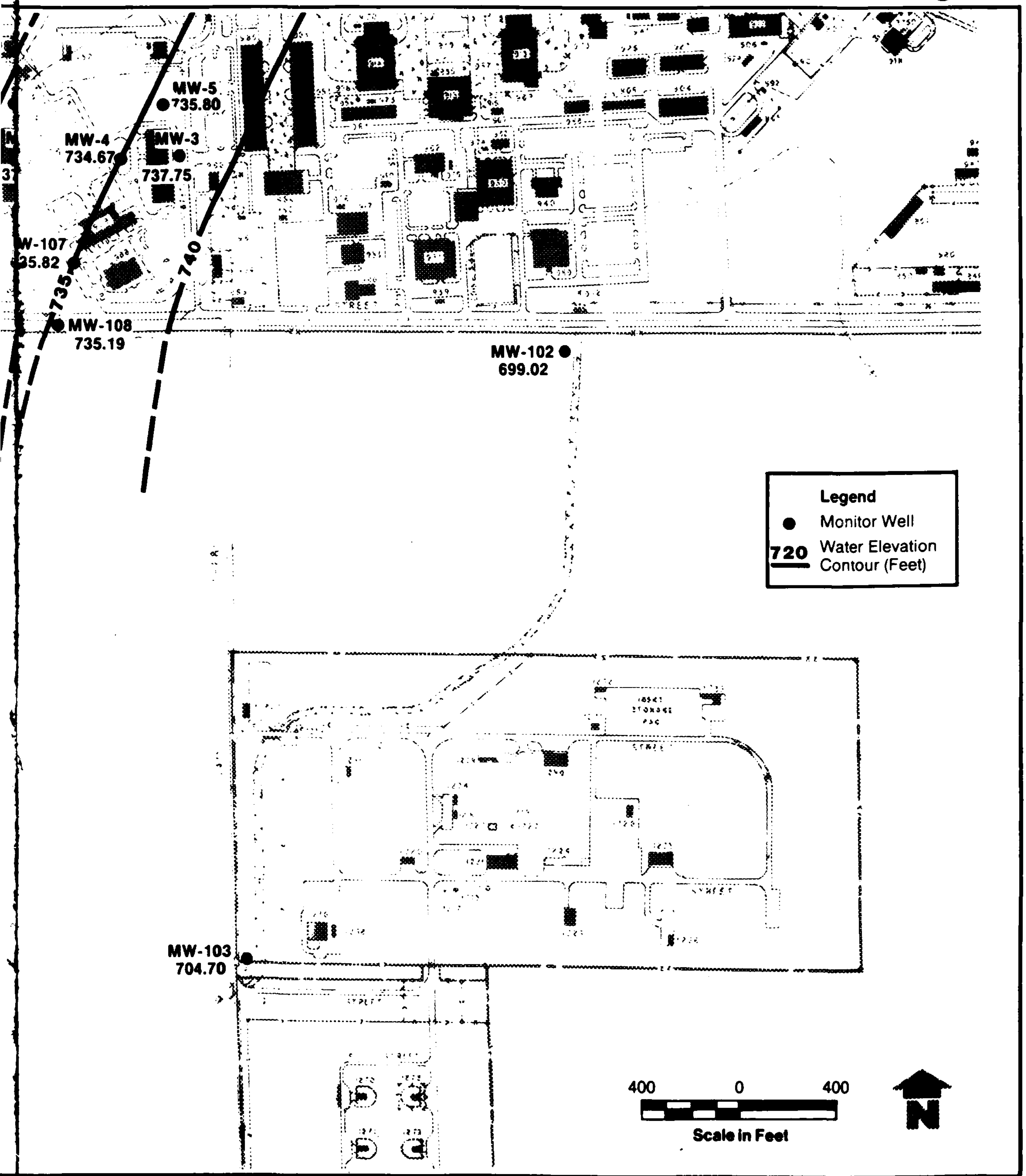


FIGURE 4-19 WATER TABLE ELEVATION MAP, JANUARY 1987, SOUTH BASE, LUKE AFB, AZ

sand units. Therefore, groundwater intercepted by the screens of those wells is hydraulically isolated from the regional water table aquifer. This conclusion is supported by the following factors relative to MW-102 and MW-103:

- Inconsistency with other South Base and regional water table data.
- Low yield and poor development characteristics of those wells.
- Geologic/stratigraphic interpretations.

Each factor is discussed in detail below.

Inconsistency with other South Base and regional water table data. The water table map shown in Figure 4-19 was constructed with data from eight wells and shows a consistent water table gradient sloping from east to west across the area. The data from MW-102 and MW-103 are inconsistent with this trend. If an attempt is made to contour these data including MW-102 and MW-103, an extremely sharp gradient reversal must be present with the water table sloping steeply eastward from the SFTA. Such a water table configuration could be caused by either a major groundwater recharge area located between the SFTA and the O/W Separator Canal or by a major pumping center located east of the canal. There is no evidence that either case exists. The data from MW-102 and MW-103 are also entirely inconsistent with the regional east to west water table gradient shown in the 1983 ADWR regional water table map (see Figure 2-1, p. 2-4).

Low yield and poor development characteristics of MW-102 and MW-103. Among all of the monitor wells installed as part of this investigation, MW-102 and MW-103 were unique in terms of low yield and the inability to be developed free of silt and clay. These two factors indicate that those wells were screened in predominantly fine-grained materials, and that the saturated zones intercepted are not significant water-bearing zones.

Geologic/stratigraphic interpretation. The well logs for MW-102 and MW-103, as presented in Figure 4-10 (p. 4-12), show that predominately fine-grained materials are present in the screened interval of both those monitor wells. Also, and more significantly, based on the interpretation presented in Figure 4-8 (p. 4-10), it can be seen that the sand layers intercepted by the screen in MW-103 are not connected to or are poorly connected to sand layers in other parts of the South Base area. For MW-102, the lowermost sand unit (Sand unit F) does appear to correlate to other South Base wells. However, if this sand unit were fully continuous with a more regional water-bearing sand, then regionally consistent water levels would have been found in MW-102, which is not the case. Therefore, the correlation between MW-102 and MW-107 is questioned, as shown in Figure 4-8 (p. 4-10). It can be concluded, therefore, that any sand layers intercepted by the screens in those two wells pinch out, and water associated with them is not hydraulically connected to groundwater in the regional water table aquifer.

It should be pointed out that both MW-102 and MW-103 are screened at the water table. The purpose of the monitor wells (stated in Subsection 3.2.2.4, p. 3-14) is to monitor the water table, and these wells are, therefore, suitable for the purposes of this study.

4.2.2 North Fire Training Area (NFTA)

The NFTA is located approximately 1.25 miles north of the South Base area Since there are no monitor wells located between these two areas, water level control data are insufficient for groundwater flow patterns between the two areas to be interpreted. Figure 4-20 is a simplified water table map based upon water levels from three wells: MW-109, MW-110, and MW-111. The water table gradient shown was constructed based on the premise that three points define a planar surface. Although these data indicate that northerly flow occurs in the NFTA, it should not be interpreted that this flow pattern is consistent over a large area. It should be pointed out that a west-southwest gradient is indicated for this portion of the base based on the 1983 Arizona Department of Water Resources regional water table map (see Figure 2-1, p. 2-4), and it is concluded that the northerly gradient indicated by the water level data represents a localized condition. Irrigation wells located to the north of the base probably account for the currently observed northward gradient in the NFTA.

4.2.3 STP Effluent Canal Area

Only one monitor well (MW-101) was installed at the STP Effluent Canal area, and, therefore, no conclusions can be drawn concerning groundwater flow patterns. However, the following conclusions can be drawn based on the 1983 ADWR regional water table map and upon comparison of water level measurements taken in two nearby irrigation wells, production well PW-4, and monitor well MW-101:

- The regional water table slopes to the west in the vicinity of the STP Effluent Canal area.
- Water table mounding is present beneath the site in the vicinity of MW-101 with the local water table approximately 40 feet above the regional water table surface.

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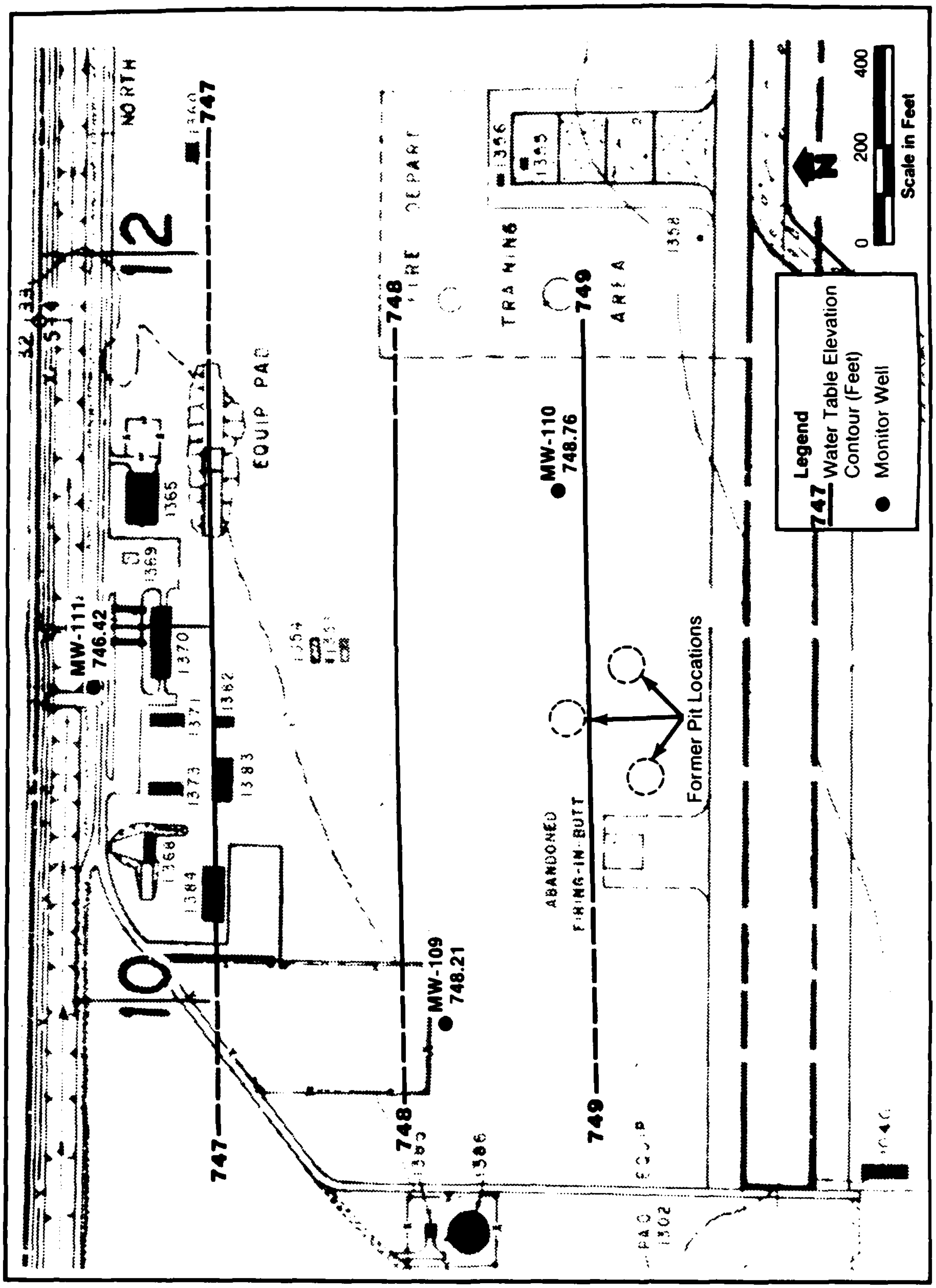

FIGURE 4-20 WATER TABLE ELEVATION MAP, JANUARY 1987, NORTH FIRE TRAINING AREA, LUKE AFB, AZ

In order to estimate the water table elevation at MW-101 prior to drilling, water level measurements were taken in October 1986 at two nearby irrigation wells (measurements were taken by ADWR personnel who visited the site with WESTON and U.S. Air Force personnel). In addition, U.S. Air Force personnel at the Sewage Treatment Plant provided the static water level in production well PW-4 as measured 2 weeks previously. The water level data are presented below:

Well	Ground Surface Elevation (approx. feet above MSL)	Depth to Water (ft)	Water Table Elevation (approx. feet above MSL)
Irrigation Well 1	1,045	166	879
Irrigation Well 2	1,055	204	851
Production Well 4	1,065	210	855

Based on these measurements (plus the first round water table elevation from MW-101, see Table 4-2, p. 4-25), a water table map was prepared (see Figure 4-21). As can be seen, the overall westward gradient is apparent, as is the localized water table mounding caused by the infiltration of the effluent from the Sewage Treatment Plant. It should be noted that this map is highly generalized and is based on approximate water levels. Sufficient data are not available to confirm the precise configuration of the water table in the vicinity of the STP Effluent Canal area, particularly east of the Agua Fria River.

4.2.4 Pumping Test Results

As described in Subsection 3.2.2.6 (p. 3-19), pumping tests were performed on all monitor wells except MW-102 and MW-103 (which do not contain pumps) and MW-105. A pumping test was not performed on MW-105 due to insuffient well yield. An attempt was made to perform the test at a reduced flow rate, but the water level fell rapidly with the pump intake, and the test was not completed. Of the eight sets of pumping test data, six were sufficient to estimate aquifer properties. The two tests that did not provide usable data were performed at MW-107 and MW-109.

At both MW-107 and MW-109, the groundwater flow in the aquifer exceeded the pump's capacity to remove water so no usable data were obtained. For MW-107, total drawdown was less than 1 foot.

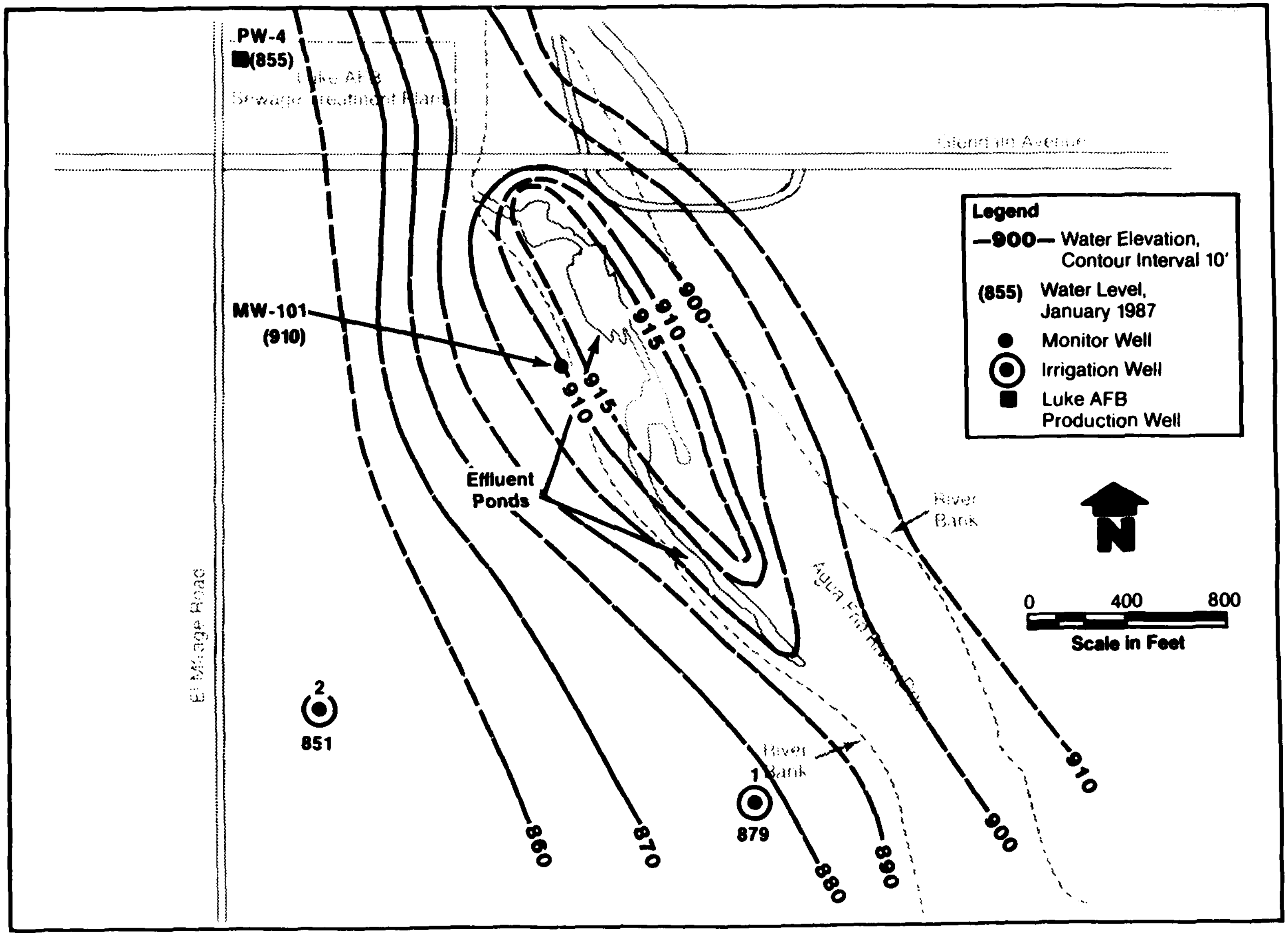

FIGURE 4-21 WATER TABLE ELEVATION MAP, JANUARY 1987, STP EFFLUENT CANAL, LUKE AFB, AZ

For MW-109, a 3.6-foot drawdown occurred during the first 30 seconds, but the water level dropped only an additional 0.3 feet during the succeeding 70 minutes of the test.

Estimates of transmissivity and storativity (or specific yield as it is referred to in unconfined aquifers) were obtained for the remaining pumping tests. For monitor wells MW-104, MW-106, MW-108, and MW-111, non-steady-state water table type curves (Prickett, 1965) best fit the data and were used to estimate transmissivity and specific yield. For MW-110, a Jacob straight line semilog solution was utilized (Fetter, 1980). That method proved to be the most suitable because of a pumping rate change during the test. For MW-101, type curves for a leaky aquifer (Cooper, 1963, in Lohman, 1972) best fit the data and were used to determine the aquifer properties. The results of the pumping test analyses are shown in Table 4-3. Data plots and calculations are presented in Appendix C. Hydraulic conductivities (equal to transmissivity divided by permeable bed thickness) calculated from these tests, representing a bulk average for the screened interval in each well, ranged from 0.49 to 12 feet/day.

Considering the hydraulic conductivities for typical silts and fine sands and the average bed thicknesses of the most permeable zones within the screened intervals, the transmissivity values are within the range expected for the materials present.

The transmissivity calculated for MW-101 at the STP Effluent Canal area is greater than for the other wells by approximately an order of magnitude. This is primarily due to higher hydraulic conductivity values associated with the coarse-grained subsurface materials encountered at that site.

4.2.5 Groundwater Velocity

Darcy's equation of groundwater flow was used to estimate groundwater flow rates:

$$V = K\, i/n$$

where:
- V = groundwater velocity (ft/day)
- K = hydraulic conductivity (permeability) (ft/day)
- i = hydraulic gradient (ft/ft)
- n = effective porosity (dimensionless)

Based on average hydraulic conductivity values calculated from the pumping tests, a typical effective porosity value of 0.25, and gradients as shown on the water table maps (Figures 4-19, 4-20, and 4-21), groundwater velocities were estimated as shown in Table 4-4.

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Table 4-3

Summary of Pumping Test Results, Luke AFB, Arizona

Monitor Well	Trans-missivity (ft^2/day)	Specific Yield (Dimension-less)	Permeable Bed Thickness (ft)	Hydraulic Conductivity (ft/day)
MW-101	613	0.01	52	12
MW-104	31	0.15	38	0.82
MW-106	79	0.02	46	1.7
MW-108	57	0.02	31	1.8
MW-110	25+	---*	51	0.49
MW-111	47	0.12	35	1.3

+ Based on the method utilized for evaluating this test, this estimate is considered a minimum value.

* Calculation of a specific yield value was not possible for this test.

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Table 4-4

Groundwater Flow Velocities, Luke AFB, Arizona

Area	Average Hydraulic Conductivity[1] (ft/day)	Groundwater Flow (ft/day)	Velocity (ft/year)
O/W Separator Canal	---	---	---
POL Area	1.4	0.016	6.0
SFTA	1.8	0.090	33
NFTA	1.3	0.011	4.0
STP Effluent Canal	12	0.60 - 3.7	220 - 1,350

1 Hydraulic conductivities for the South Base sites were obtained by averaging values from MW-104, MW-106, and MW-108. For the NFTA, the hydraulic conductivity for MW-111 was used since the value for MW-110 represents a minimum.

---Not determined

4.3 GEOPHYSICAL SURVEY DATA ANALYSIS - POL AREA

Geophysical surveys were performed only at the POL Area, as described in Subsection 3.2.2.7 (p. 3-20). An electromagnetic terrain conductivity (EM) survey using an EM-31 and a ground penetrating radar (GPR) survey were performed. The EM data were stored in the field on a datalogger (Omni Data Polycorder). In the office, the data were uploaded to a UNISYS 1100/72 computer. A contour plot of the EM-31 Quadrature data was produced on a flat-bed plotter using a contour plotting system software package. Prior to constructing the contour plot, a surface or posting of all the field data was created. The postings were checked against the field data for quality assurance. A contour plot was then constructed based on the computer posting of the EM field data. The plot was reviewed in detail to ensure that each contour interval honored its respective data points. The data were contoured at 10-mmho/m intervals.

Analysis of GPR survey data involved the interpretation of each profile individually and then comparing the results collectively. The interpretation process had two objectives:

- Application of specific knowledge of signature densities and geometric configurations to the identification of trenches, soil structures, discontinuities, and subsurface disturbances.

- Identification of trends and conditions by comparing standard profiles. Through this process, soil interfaces and continuous stratigraphic features were identified.

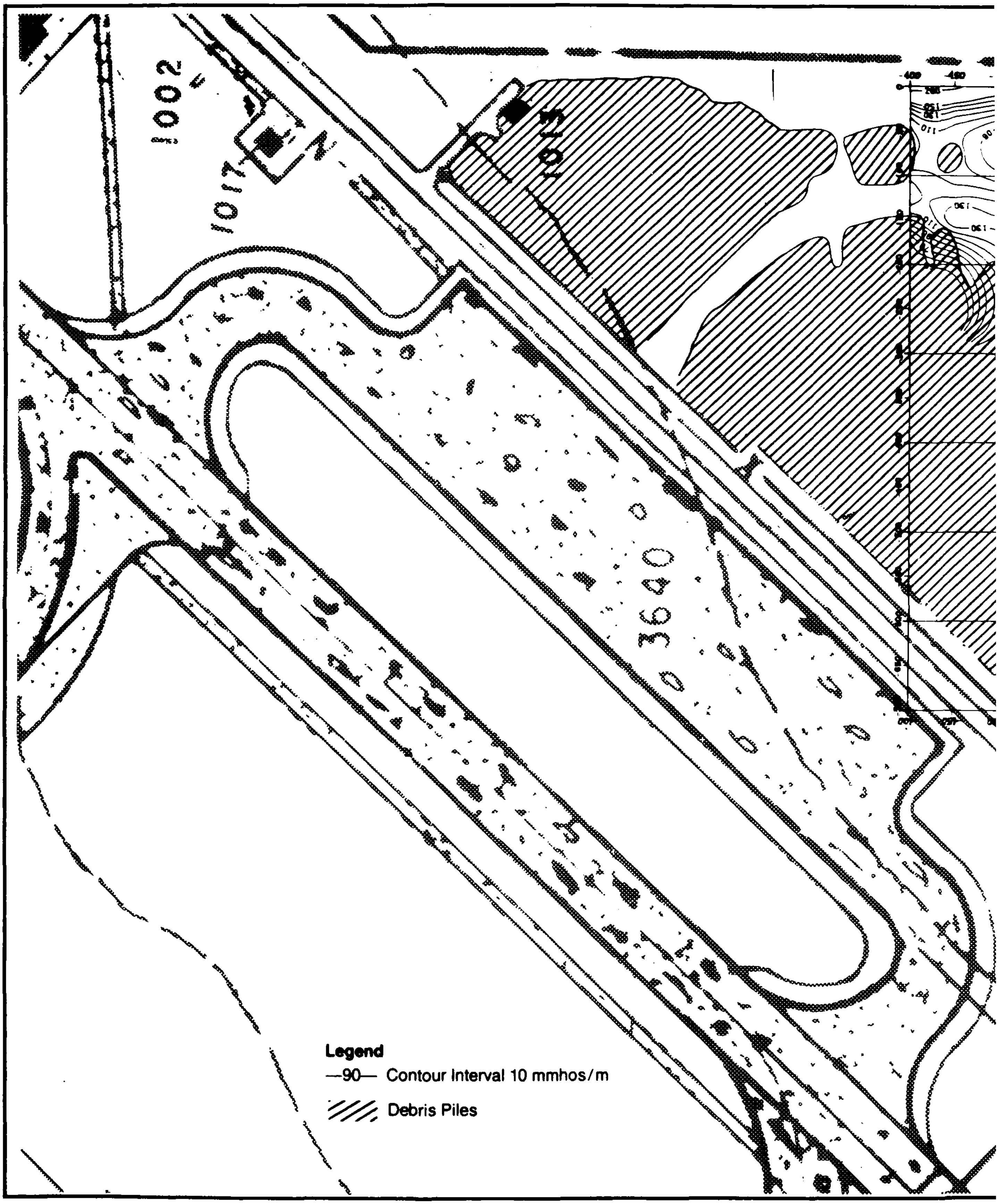
The GPR profiles produced by the survey at the POL Area exhibited good resolution that clearly defined disturbed subsoils and highlighted characteristic signatures of discrete objects beneath the site.

4.3.1 Electromagnetic Terrain Conductivity Survey

Figure 4-22, is a contour plot of the soil conductivities at the POL Area.

Terrain conductivity values ranged from 50 to 240 mmhos/m. Widely variable background conductivities were encountered across the site, most likely reflecting lithologic or depositional changes.

This is supported by physical log descriptions from several soil borings indicating variations in the nature, depth, or thickness of various unconsolidated sediments.



1002
1017
1015
3640
Legend
—90— Contour Interval 10 mmhos/m
Debris Piles

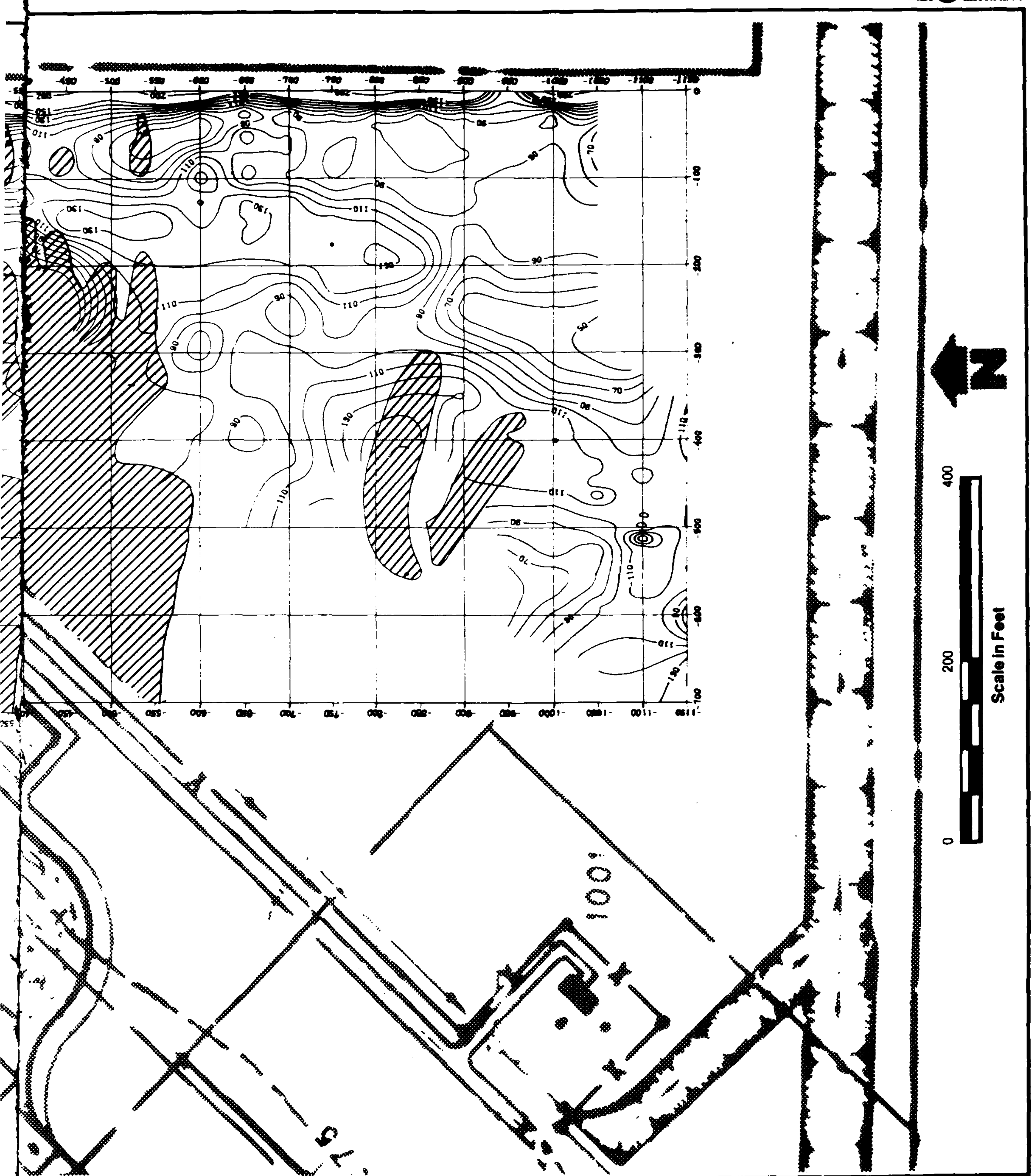


FIGURE 4-22 | CONTOUR PLOT OF EM CONDUCTIVITY DATA, POL AREA, LUKE AFB, AZ

Readings in excess of 200 mmhos/m were recorded at 10 of the 12 stations monitored along the 0+00 W traverse adjacent to a wire fence. It is likely that these anomalous fluxes are conducted by the fence. The conductivities decreased by a factor of from two to three approximately 20 feet from the fence.

The general trend of the contour plot exhibits broad areas of contrasting conductivities. These areas correspond to the groups of trenches (as identified in a 1977 aerial photograph, see Figure 1-4, p. 1-13) rather than the individual trenches and lagoon. There are several explanations for this, as follows:

- Terrain conductivity is more a function of the fluid filling the voids between individual soil particles than of the particles themselves. In wet environments, the conductivity of an oil-saturated soil would be much less than that of a water-saturated or partially water-saturated soil. In extremely arid environments, such as the Luke AFB area, the primary interstitial medium in near-surface soils is air. Both oil and air have extremely low conductivities, which may account for the lack of a pronounced contrast in the EM data over former disposal trenches.

- The POL waste products from adjacent trenches may have migrated and may have merged over the 15 years since disposal ceased in this area.

- Contaminants may not be present at a level high enough to produce a marked and unambiguous conductivity contrast over the site background noise.

- Large quantities of construction debris on the ground surface rendered many of the data stations in the suspected lagoon area inaccessible or directly affected by conductive surface sources. Consequently, an insufficient density of data over the lagoon and the surrounding background area limited the conclusions that could be drawn.

As seen in Figure 4-22, several small localized anomalies were detected randomly throughout the site. Such anomalous signatures are typically associated with iron alloy conductors (e.g., metallic scrap, steel reinforcement in concrete, etc.). In view of the surrounding data, some of these anomalies appear to be the direct result of independent subsurface sources, while others represent broader subsurface sources. The most obvious example of an individual anomaly (145 mmhos/m) is located within a shallow trench at grid node 500W by 1100S.

4.3.2 Ground Penetrating Radar Survey

Figure 4-23 depicts an interpretive subsurface plot of the POL Area based on the analysis of the GPR findings. Several small discontinuities or "breaks" were detected randomly across the site. These discontinuities are shallow (within the upper 3 to 5 feet of soil). They most likely represent the remains of the individual waste disposal trenches and other small, localized areas of cultural disturbances, e.g., shallow excavations.

When viewed collectively, the profiles depict obvious linear features varying in length from approximately 200 to 600 feet. These features are plotted on Figure 4-23 and correspond to three of the original ten trenches revealed in the 1977 aerial photograph.

As seen in the radar profile in Figure 3-4 (p. 3-23), these discontinuities appear as abrupt breaks in the stratigraphy, shown by a marked decrease in amplitude in the return radar signal. Also seen in that figure are a few high-amplitude hyperbolic signatures indicative of discrete buried objects. The locations of those objects are plotted in Figure 4-23.

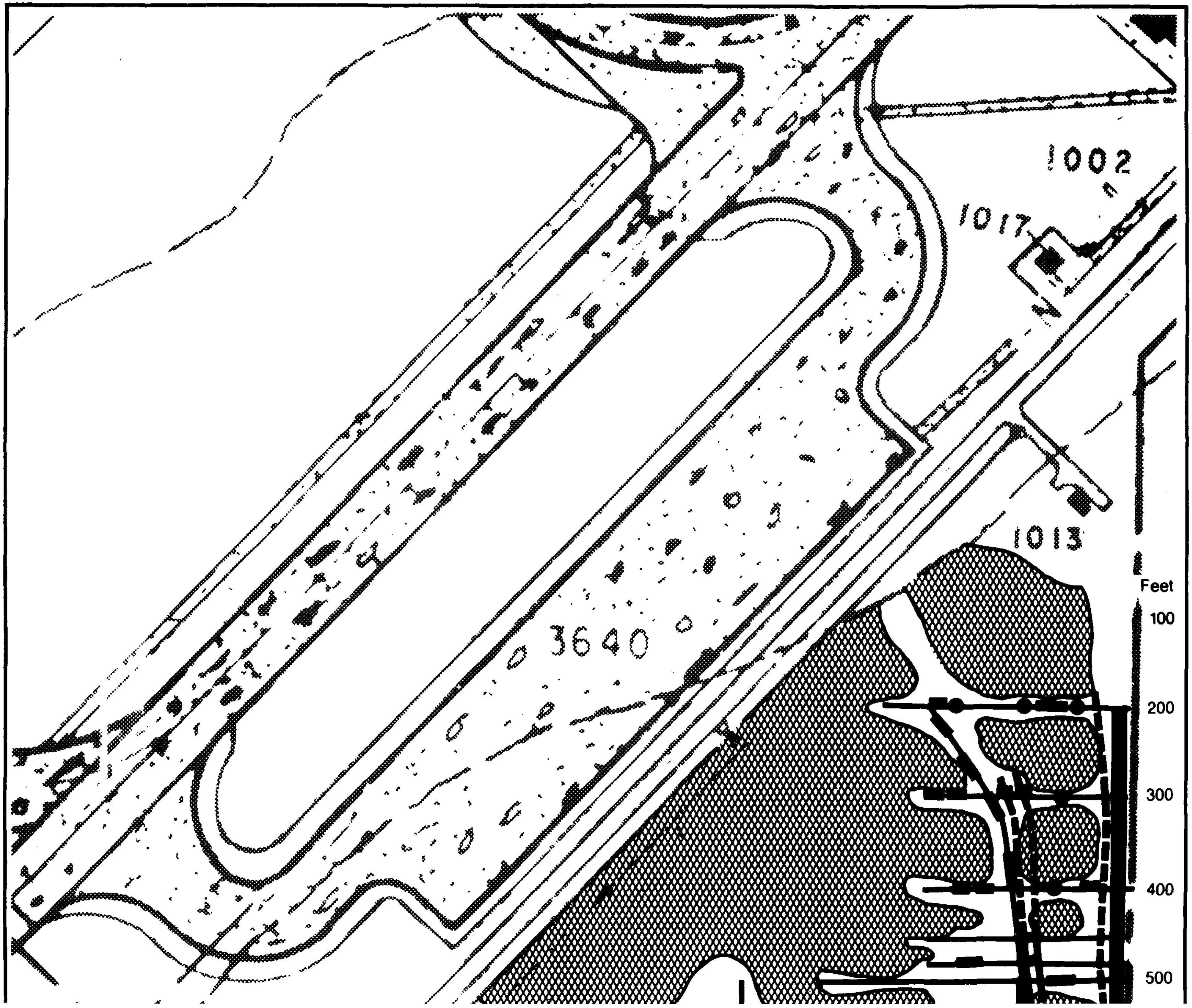
4.3.3 Geophysical Survey Conclusions

The disposal trenches and lagoon locations were not clearly defined by the EM and GPR surveys; however, several subsurface anomalies were identified. It was unclear in some cases whether an anomaly represented a former trench, a particular buried object, or a change in stratigraphy. Some of those locations were identified, and soil-gas samples were collected there. Also, some soil borings were drilled at locations identified by the geophysical surveys. Further discussion of the correlation between the surface geophysical surveys and the soil-gas sample results is included in Subsection 4.6.2.1.

4.4 BASIS FOR INTERPRETATION OF ANALYTICAL RESULTS

Interpretation of the analytical data developed from the Phase II Stage 2 field program must take into consideration the following major factors:

- Quality Assurance/Quality Control (QA/QC) data.
- Background parameter levels in the matrices sampled, i.e., soil, sediment, surface water, and groundwater.
- Limitations inherent in the analytical methods used for specific parameters.
- Relevant Federal and State water quality standards and guidance criteria.



1002
1017
1013
3640
Feet
100
200
300
400
500

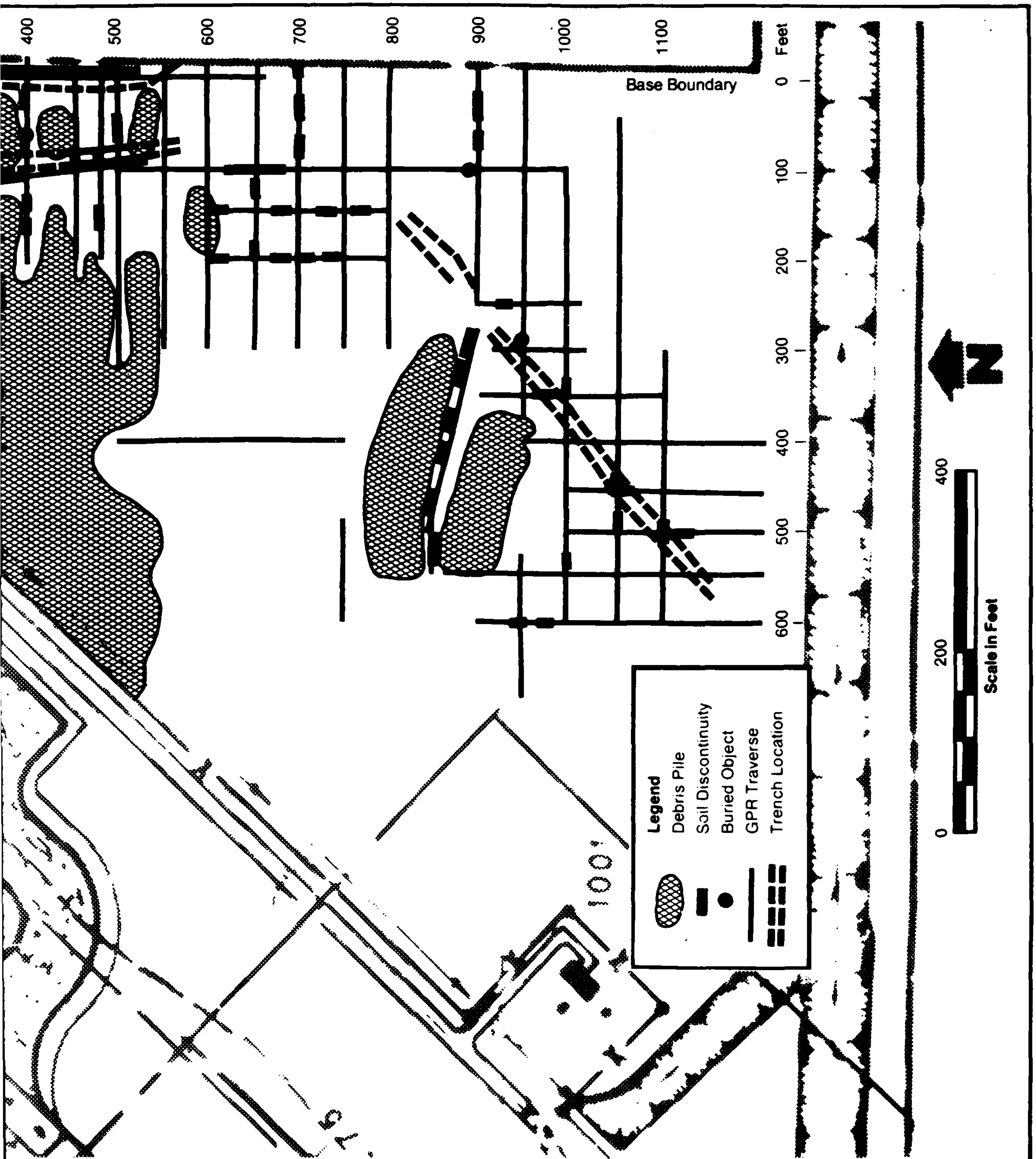


FIGURE 4-23 INTERPRETATION OF GPR RESULTS POL AREA, LUKE AFB, AZ

Evaluation of these factors establishes the frame of reference for the assessment of the significance of analytical results on a site-by-site basis. A consistent frame of reference, in turn, allows evaluation of the relative environmental conditions between various sites and the subsequent determination of the need and priorities for remedial actions - the objective of Phase II of the IRP. The subsections that follow discuss these factors in greater detail for each analytical parameter or groups of parameters.

4.4.1 Quality Assurance/Quality Control

Quality assurance/quality control (QA/QC) sample types analyzed as part of this study included trip blanks, field blanks, lab blanks, blank spikes, matrix spikes, lab duplicates, and field duplicates. In addition, detection of any VOCs in a sample triggered analysis of the sample on a second column to confirm identity. A laboratory QC summary is presented in Appendix F, which discusses laboratory-generated QA/QC samples (i.e., lab blanks, blank spikes, matrix spikes, and lab duplicates.) These data were all within appropriate control limits as discussed in the QA/QC Plan with the following exceptions:

- Metals spike recoveries were outside control limits for antimony and silver for the majority of cases, and in some cases for arsenic and selenium. These excursions are specifically addressed in the laboratory QC summary presented in Appendix F.

- TOC spike recoveries were outside control limits in some cases. These excursions are also addressed in Appendix F.

Note that even the data associated with the metals and TOC data discussed above are usable, based on discussions in Appendix F.

Laboratory blanks are specifically discussed in Appendix F. Only one blank showed a detection for the organic fraction, and it was not detected in any actual samples. Several metals were detected in blanks, as discussed in Appendix F. In no instances do these blank detections significantly impact data usability or the conclusions drawn.

Generally speaking, laboratory duplicates showed good correlation, adding confidence to the analytical data.

Trips blank and field blank results are summarized in Table 4-5.

The trip blank detections were compared to the analytical data associated with the same laboratory batch of data. Most of the trip blank detections did not have corresponding detections in

Table 4-5

Concentrations of VOCs, BNAs, and Metals in Trip Blanks and Field Blanks Luke AFB, Arizona (all units ug/L unless otherwise specified)

Water/Effluent Trip Blanks	Round 1							Round 2		Round 4	
Batch #:	8612-387	8612-374	8612-402	8612-402	8612-433	8612-396	8612-402	8701-554	8701-561	8703-880	8703-898
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	38
Methylene chloride	180	160	230	230	650	220	160	ND	ND	ND	ND
Toluene	ND	ND	ND	7.8	ND	ND	ND	ND	2.3	ND	ND
Tetrachloroethene	7	2.5	ND	ND	ND	ND	ND	ND	ND	ND	ND

Sediment Trip Blank Batch #:	8612-433
Methylene chloride	650

Water/Effluent Field Blanks	Round 1		Round 2		Round 3	
(Metals) Batch #:	8701-484[a]	8612-387[b]	8701-578[b]	8701-578[a]	8702-724[b]	8702-724[a]
ID #:	03-103-M201	06-109-M201	04-105-M202	02-101-M202	02-101-M203	03-102-M203
As	ND	ND	ND	ND	2.0	NA
Cu	ND	62	39	22	31	ND
Cr	ND	ND	ND	ND	ND	ND
Ni	ND	ND	20	ND	ND	ND
Pb	ND	68	10	6.7	9.8	7.8
Tl	ND	ND	5.7	ND	ND	ND
Zn	70	33	35	79	87	18
Acetone	220	ND	ND	ND	33	28
TOC (mg/L)	1.32	0.50	4.80	NA	0.651	0.946
TKN (mg/L)	NA	NA	0.14	NA	0.13	NA

NA - Not analyzed
ND - Not detected

[a] - Bailer blank.
[b] - Pipe assembly blank.

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the same batch, and had, therefore, no impact on data interpretation. The exceptions are the 38 ug/L of acetone from the fourth round (as discussed in Subsection 4.6.5.4), the 650 ug/L of methylene chloride in the sediment trip blank (as discussed in Subsection 4.6.1.3), and the tetrachloroethene detected during the first round (as discussed in Subsection 4.4.2).

The field blanks were collected as described in Subsection 3.2.2.9 (p. 3-25) (i.e., two field blanks per sampling round, one by pouring base-supplied deionized water through the Teflon bailer used to sample MW-102 and MW-103, and one by pouring the deionized water through the pipe assembly used for sampling all other monitor wells). Based on three considerations, there is reason to suspect that at least some of the field blank data are from contaminated deionized water: 1) WESTON field personnel used no acetone in any field operations, 2) the metals concentrations are much higher than would normally be expected in a field blank (even the piping assembly blanks), and 3) the bailer blanks have metals concentrations that would not be expected since no metals are involved with a bailer blank. It should be pointed out that it is possible that the compounds found in these blanks were introduced during field preparation of the blanks and that the blanks are, therefore, legitimate.

However, because there is doubt about the field blank detections, it will be assumed that these data were caused by contaminated deionized water. This is a conservative assumption, because if the blank data are considered legitimate, they would be used to question detections found in actual sample data. By disregarding the field blank data, those compounds detected in the field blanks were not questioned when they occurred in actual groundwater samples.

4.4.2 Volatile Organic Compounds (VOCs)

In general, VOCs (see Table 3-2, p. 3-6) are man-made and are associated with human activities. They are not found in areas unaffected by man; natural background levels are expected to be zero in soils, surface waters, and groundwaters. At Luke AFB, no consistent distribution of VOCs was found in either soil or water. Some of the compounds that were detected are suspected to be laboratory artifacts.

Some matrix spike recoveries are low (50 to 70 percent) for some VOCs. Matrix spike recoveries are not controlled by the QA/QC Plan, but are provided for data usability guidance. These low matrix spike recoveries do not impact any of the conclusions drawn concerning VOCs because of their low concentrations and scattered occurrence. (Note that generally speaking, 50 percent matrix spike recovery indicates that a VOC detected may be present at approximately twice the reported concentration.)

Note concerning tetrachloroethene results: Tetrachloroethene (PCE) was detected in several water samples collected during the first sampling round. However, PCE was also inexplicably detected in several trip blanks. The source of PCE in the trip blanks could not be determined. All sample locations where PCE was detected were, therefore, resampled (including those locations where it was detected by the first column but not confirmed by the second column). No PCE was detected (first or second column) in any samples taken during this resampling effort. It was concluded, therefore, that it is unlikely that any PCE actually was present in the water being sampled. For a more complete discussion of the PCE data and its detection in first round samples see Appendix P.

4.4.3 Base/Neutral-Acid Extractable Compounds (BNAs)

This grouping of compounds (see Table 3-2, p. 3-6) represents a wide range of organic chemicals generally referred to as semi-volatiles. They are generally associated with human activities, and natural background levels are expected to be zero in soils, surface waters, and groundwaters. The only BNAs detected at Luke AFB were bis(2-ethylhexyl) phthalate and di-n-octyl phthalate. Phthalates are components of most plastics.

4.4.4 Pesticides

Pesticides (see Table 3-2, p. 3-6) are man-made compounds that are not expected to be found in areas unaffected by human activities. The background levels of these materials are expected, therefore, to be zero. No pesticide compounds were detected in any samples from Luke AFB.

4.4.5 Polychlorinated Biphenyls (PCBs)

PCBs (listed as Aroclors in Table 3-2, p. 3-6) are man-made compounds most commonly used in electrical equipment such as transformers, capacitors, and switching equipment. Therefore, they are found only in areas affected by human activities, and natural background levels are expected to be zero in soils, surface waters, and groundwaters. The specificity of the analytical procedures for PCBs is relatively high, and interferences from other compounds generally do not pose a problem in identifying and quantifying PCBs. No PCBs were detected in any samples from Luke AFB.

4.4.6 Oil and Grease (O&G) and Petroleum Hydrocarbons (TPH)

The methods used for analysis of O&G and TPH differ from the other more specific analytical techniques discussed earlier in that they do not measure an absolute quantity of a specific substance, but rather they measure a group of substances with similar physical characteristics. In effect, these parameters are defined by the analytical method used for their determination on the basis of their common solubility in Freon. The O&G method will measure sulfur compounds, chlorophyll, certain organic dyes, biological lipids, and mineral hydrocarbons, including petroleum distillates, as well as other extractable organic compounds. The petroleum hydrocarbons method is also based on a Freon extraction, but utilizes silica gel to selectively remove some non-petroleum O&G prior to quantitative analysis.

Despite analytical interferences from non-petroleum substances, these methods are useful as a general indicator of oil and grease contamination. Interferences from non-petroleum substances are generally expected to be of greater concern in soils because of the broad range of organic compounds commonly present in that matrix.

Background levels (caused by interference from naturally occurring compounds) determined by the O&G method in uncontaminated soils are considered to be 50 mg/kg or less. This is based primarily on the experience gained by USAFOEHL in sampling O&G at many bases nationwide. For petroleum hydrocarbons, these background interference levels generally occur at less than 20 mg/kg.

Groundwater is expected to show little impact from interfering compounds. Generally accepted background levels of O&G in water samples are 1 mg/L or less. Surface waters are likely to have detectable levels of these compounds resulting from solubilization when runoff contacts soils. Petroleum hydrocarbons were not analyzed in any water samples.

4.4.7 Total Organic Carbon (TOC)

TOC analyses were performed on all water samples at Luke AFB, but not on any soil samples. Generally, background groundwater TOC concentrations can range up to 20 mg/L, but at Luke AFB, sample results showed background concentrations to be typically less than 5.0 mg/L. This lower background is probably due to low concentrations of organic matter in the arid environment.

4.4.8 Metals

Metals samples were analyzed for 12 specific metals (see Subsection 3.1.2, p. 3-1) by atomic absorption spectrophotometry. This method may be subject to interferences from the sample matrix, although such interference is more common in complex matrices such as soils and sediments. In addition, heavy metals are present in soils at natural levels characteristic of a given region and its geology. Natural background levels for soils in North America are summarized in Table 4-6 and must be considered in the evaluation of results for soil samples. (Note that local soils background data were not available.) These numbers have been compiled from several sources and represent the typical range of naturally occurring metals concentrations in soils across North America.

For water samples, water quality criteria have been established by regulatory agencies for the various metals and provide one important context for evaluating metals results.

Background groundwater quality was not specifically established by any of the wells in this study, but data are available from the City of Phoenix. Metals data for six wells located west of Phoenix in the general vicinity of Luke AFB are shown in Table 4-7. As can be seen, chromium is the one element that appears to be present in potentially significant concentration.

4.4.9 TKN and Nitrate/Nitrite

Total Kjeldahl nitrogen (TKN) and nitrate/nitrite analyses were performed on all water samples (effluent and groundwater) associated with the STP Effluent Canal. Background levels of TKN and nitrate/nitrite are not an issue since there are no background levels associated with effluent, and the groundwater monitored in MW-101 is derived solely from the effluent lagoons.

4.4.10 Water Quality Standards

Federal and state environmental regulatory efforts have included the establishment of standards governing water quality, with particular emphasis on drinking water supplies and water use. Similar standards have not been developed with regard to soils and sediments because the relationship of soil contamination to potential or actual contamination of water is frequently unclear, and the probability of direct ingestion of contaminants by man is low. The subsections that follow discuss applicable Federal and Arizona standards considered in the evaluation of water quality conditions at Luke AFB.

4.4.10.1 Federal Drinking Water Standards (MCLs)

In 1975, the U.S. EPA originally promulgated a set of interim primary drinking water standards based on human health criteria to which was added a set of recommended secondary drinking water standards based on aesthetic properties including color, turbidity, taste, and odor. In 1980, the U.S. EPA adopted the term "maximum contaminant level" (MCL) to describe all current drinking water standards. It should be noted that MCLs regulate the quality of water as delivered to the end user and not at the source water. Secondary drinking water standards are now

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Table 4-6

Ranges of Metals Concentrations in Natural Soils in North America

Metal	Concentration Range (ppm)
Arsenic	1-50
Barium	100-5,000
Cadmium	0.01-7.0
Chromium	5-1,000
Copper	2-100
Iron	14,000-42,000
Lead	2-200
Mercury	0.02-0.20
Nickel	5-500
Selenium	0.1-2.0
Silver	0.1-1.0
Zinc	2-30

Reference: Pressant (1971)
Allaway (1968)

Table 4-7

Metals Concentrations in Groundwater From Wells in the Salt River Basin, Arizona

Well No.	Well Location Total Depth (ft) Depth to Water (ft)	Date Sampled	Ag (ug/L)	As (ug/L)	Ba (mg/L)	Cd (ug/L)	Cr (ug/L)	Cu (mg/L)	Hg (ug/L)	Pb (ug/L)	Se (ug/L)	Zn (mg/L)
Sunny Boy Water Co. Well No. 2	A-3-1-31-ABB TD = 837 DTW = 134	7-30-86	<5	<20	<0.5	<1.0	<10	<0.01	0.6	<20	<5	<0.05
Goodyear Municipal Well No. 6	B-1-1-3-BAC TD = 467 DTW = 101	7-30-86	<5	<20	<0.5	<1.0	11	<0.01	<0.5	>20	<5	<0.05
Litchfield Park Well No. 2	B-2-1-27-DAA TD = 650 DTW = 159	7-30-86	<5	<20	<0.5	<1	24	<0.01	<0.5	<20	<5	0.05
City of Peoria 89th Ave. and Union Hills	A-4-1-34-BBA TD = 1,255 DTW = 366	--	<5	<20	<0.5	<1	<10	<0.01	<0.5	<20	<5	<0.05
AZ Water Co. White Tanks No. 7	B-1-2-3-BBB TD = 604 DTW = 83.6	9-10-86	<5	<20	<0.5	<1	28	<0.01	<0.5	<20	<5	<0.05
AZ Water Co. White Tanks No. 4	B-2-2-33-CBD2 DTW = 322	9-10-86	<5	<20	<0.5	<1	31	<0.01	<0.5	<20	<5	<0.05

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described as "secondary maximum contaminant levels" (SMCLs) and are not enforceable standards but are guidelines. A summary list of the contaminants regulated by these standards and that were detected at Luke AFB is shown in Table 4-8.

4.4.10.2 Water Quality Criteria

On 28 November 1980, the U.S. EPA issued criteria for 64 toxic pollutant categories in water systems. The criteria established recommended maximum concentrations for acute and chronic exposure to those pollutants for both human life and for marine and freshwater aquatic life. The derivation of those criteria was based on cancer risk, toxic properties, and organoleptic properties. The criteria represent water quality guidelines and are not enforceable. They were intended to present scientific data and guidance on the environmental effects of pollutants to be used in the derivation of regulatory requirements. The contaminants included in the water quality criteria and which were included in the analytical protocols at Luke AFB are listed in Table 4-8. The specific values presented in Table 4-8 are those for ingestion of water and of organisms.

4.4.10.3 Suggested No Adverse Response Levels (SNARLs)

The U.S. EPA Office of Drinking Water provides, on request, advice on the health effects of unregulated contaminants found in drinking water supplies. This information suggests contaminant levels in drinking water that are believed to pose no risk of adverse health effects, with a margin of safety. These concentrations are identified by the acronym SNARL (Suggested No Adverse Response Level) and are normally provided for 1-day, 10-day, and long-term exposures, as available data permit.

SNARLs are not enforceable standards under Federal regulations, but have, in some cases, been adopted by state regulatory authorities as legal limits. They may or may not lead to the establishment of a national standard or MCL. Since MCLs must consider occurrence and relative source contribution of a contaminant, it is quite possible that an eventual MCL might differ from the corresponding SNARL. In addition, SNARLs are subject to continuing revision as available data change. SNARLs for compounds included in the analytical protocols at Luke AFB are summarized in Table 4-8.

4.4.10.4 Maximum Contaminant Level Goals (MCLGs)

Known as recommended MCLs (RMCLs) until the 1986 Amendments to the Safe Drinking Water Act, these non-enforceable health goals are based exclusively on human health and toxicological data. According to Congressional guidance, these standards are to be

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Table 4-8

Water Quality Standards for Compounds Detected, Luke AFB, Arizona

Parameter	MCL	SMCL	MCLG	ADEQ* Action Level	SNARL	Ambient Water Quality Criteria[c]
O&G (mg/L)	---	0.0	---	---	---	---
Nitrate (mg/L)	10	---	---	10	---	---
Metals (ug/L)						
Antimony	---	---	---	---	---	146
Arsenic	50	---	50	50	---	---
Beryllium	---	---	---	---	---	---
Cadmium	10	---	5	10	5[b]	10
Chromium	50	---	120	50	---	50
Copper	---	---	1,300	---	---	---
Lead	50	---	20	50	---	50
Mercury	2	---	3	2	---	0.144
Nickel	---	---	---	---	---	13.4
Selenium	10	---	45	10	---	10
Silver	50	---	---	50	---	50
Thallium	---	---	---	---	---	13
Zinc	---	5,000	---	---	---	---

*Arizona Department of Environmental Quality.
[a]Acute; 24-hr exposure.
[b]Chronic.
[c]For ingestion of water and organisms.
MCL - Maximum Contaminant Level.
SMCL - Secondary Maximum Contaminant Level.
MCLG - Maximum Contaminant Level Goal.
SNARL - Suggested No Adverse Response Level.
--- Not applicable.

Table 4-8
(continued)

Parameter	MCL	SMCL	MCLG	ADEQ* Action Level	SNARL	Ambient Water Quality Criteria[c]
Radiological Parameters (pCi/L)						
Gross alpha	15	---	---	15	---	---
Gross beta	50	---	---	50	---	---
Radium-226	5	---	---	5	---	---
Organics (ug/L)						
Acetone	---	---	---	---	---	---
Chloroform	100	---	---	100	22,000[a]	---
Bromodichloro-methane	100	---	---	100	---	---
Tetrachloro-ethene	---	---	0.0	3.0	172,000[a]	---
Toluene	---	---	2,000	340	340[b]	14,300
Di-n-octyl phthalate	---	---	---	---	---	---
Bis(2-ethyl-hexyl)phthalate	---	---	---	---	4,200[b]	15,000
Dibromochloro-methane	100	---	---	100	---	---

*Arizona Department of Environmental Quality.
[a]Acute; 24-hr exposure.
[b]Chronic.
[c]For ingestion of water and organisms.
MCL - Maximum Contaminant Level.
SMCL - Secondary Maximum Contaminant Level.
MCLG - Maximum Contaminant Level Goal.
SNARL - Suggested No Adverse Response Level.
--- Not applicable.

set so as "to prevent the occurrence of any known or anticipated adverse health effect," including an adequate margin of safety. In cases where no safe threshold for a contaminant has been established, the MCLG "should be set at zero level."

MCLs are set as close to MCLGs as is "feasible." Feasible, in this case, means "using the best technology, treatment techniques, and other means available, taking costs into consideration." Some MCLs have been set very close to or equal to the corresponding MCLG; in other cases, economic or other considerations have dictated that the MCL be set at a higher level. Only MCLs must be met by public water systems.

4.4.10.5 Arizona Water Quality Standards For Drinking Water

The Arizona Department of Environmental Quality (ADEQ) has primacy for implementation of the Federal Safe Drinking Water Act. All Federal MCLs are adopted and enforced by the State. If there is an MCLG for a particular parameter, the ADEQ adopts it as an action level. An action level is used as a recommended reference for "no adverse health impact." If the State finds drinking water contamination above the action level, they notify the water users that health impacts are possible. The MCLGs are not enforceable standards. Applicable action levels are presented in Table 4-8. Water quality criteria have been established by ADEQ for those VOCs known to be or suspected to be carcinogenic, and the applicable criteria appear in Table 4-8.

4.5 ANALYTICAL RESULTS SUMMARY

This subsection contains a generalized summary of the analytical results obtained from the sampling program described in Section 3 on a matrix-by-matrix and parameter-by-parameter basis. The data are presented in this manner so that pertinent conclusions and observations relevant to more than one site can be made. Subsection 4.6 contains a site-by-site discussion of results and the significance of those results. Subsection 4.6 includes, where appropriate, more detail than is presented here and also contains a discussion of applicable Phase II Stage 1 results.

The environmental media discussed in this subsection include:

Medium	Sites
Subsurface soil	All sites
Soil-gas	O/W Separator Canal POL Area STP Effluent Canal

Medium	Sites
Organic vapor (HNu results)	All sites
Groundwater	All sites

The environmental media discussed in Subsection 4.6 under site-specific results include:

Medium	Sites
Surface sediment	O/W Separator Canal STP Effluent Canal
Surface water	O/W Separator Canal
STP effluent	STP Effluent Canal

4.5.1 Soil Results

Chemical data for soil at the five sites were obtained as follows: VOCs and priority pollutant metals at all sites; MEK and O&G at fire training areas only; and petroleum hydrocarbons at the O/W Separator Canal only.

Soil VOCs data for all sites are summarized in Table 4-9. There were very few compounds detected, and, for the most part, they were detected at concentrations of less than 0.01 mg/kg. There were also no clear patterns of VOCs distribution at the Luke AFB sites, nor did any particular contaminant occur on a consistent basis. Based on the low concentrations and number of samples with detected VOCs, the VOCs results are not considered to be significant.

O&G data (NFTA and SFTA only) are summarized in Tables 4-10 and 4-11. Oil and grease concentrations are variable with relatively high concentrations (greater than 1,000 mg/kg) found in several of the samples taken from shallow depths and significantly lower concentrations (most less than 30 mg/kg) found at greater depths. As discussed in Subsection 4.4.6 (p. 4-43), background levels of O&G are often considered to be 50 mg/kg or less. Most of the O&G concentrations listed in Tables 4-10 and 4-11 are less than 50 mg/kg and can, therefore, be considered background levels. At the SFTA, there were no concentrations of O&G above background levels below a depth of 5 feet. At the NFTA, there were only three values detected above background levels below a depth of 10 feet in soil borings 06-01, 06-02, and 06-03. Soil boring 06-04 yielded several samples with detected concentrations greater than 100 mg/kg at depth, including the three deepest (at 90, 95, and 100 feet). Soil borings 06-04 and 06-03 were drilled in the Current Fire

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Table 4-9

Analytical Results for VOCs in Soils, Luke AFB, Arizona (mg/kg)

Location and Boring No.	Chloro-form	MEK[a]	Total Xylenes	Toluene	1,2-Dichloro-ethane	TCE[b]
O/W Separator Canal						
03-01						
98 feet	0.002	NA	ND	ND	0.006	ND
03-02						
10 feet	0.002	NA	ND	ND	ND	ND
15 feet	0.001	NA	ND	ND	ND	ND
20 feet	0.001	NA	ND	ND	ND	ND
POL Area						
04-03						
5 feet	ND	NA	120	0.142	ND	ND
10 feet	ND	NA	0.05	0.003	ND	ND
60 feet	ND	NA	ND	0.006	ND	ND
04-06						
98 feet	0.003	NA	ND	0.008	ND	0.003
SFTA						
05-01						
100 feet	ND	ND	ND	ND	ND	0.005
05-02						
98 feet	ND	ND	ND	0.007	ND	0.007

[a]MEK = Methyl ethyl ketone.
[b]TCE = Trichloroethene.
[c]No VOCs detected at the Sewage Treatment Plant.
NA - Not Analyzed.
ND - Not Detected.
( )- Field duplicate.

Note: VOCs listed in Table 3-2 (p. 3-6) but not reported here were not detected.

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Table 4-9
(continued)

Location and Boring No.	Chloro-form	MEK[a]	Total Xylenes	Toluene	1,2-Dichloro-ethane	TCE[b]
NFTA						
06-01						
5 feet	ND	ND	68 (93)	ND	ND	ND
10 feet	ND	ND	36	ND	ND	ND
06-02						
5 feet	ND	14	ND	ND	ND	ND
STP[c] Effluent Canal	ND	NA	ND	ND	ND	ND

[a]MEK = Methyl ethyl ketone.
[b]TCE = Trichloroethene.
[c]No VOCs detected at the Sewage Treatment Plant.
NA - Not Analyzed.
ND - Not Detected.
( )- Field duplicate.

Note: VOCs listed in Table 3-2 (p. 3-6) but not reported here were not detected.

Table 4-10

Soil Analytical Results - Oil and Grease, North Fire Training Area, Luke AFB, Arizona (mg/kg)

Depth (ft)	Boring Number 06-01	06-02	06-03	06-04
5	5,660 (3,960)	2,060	ND	1.8
10	10,400	18.3	1.7	ND
15	2.5	5.7	13.9 (-)	2.9
20	6.3	NA	ND	13.6
25	18.5	ND	10.6	61.2
30	NA	1.2 (6.6)	ND	15.7 (12.1)
35	2.6	278	1.5	22.3
40	13.8	1.4	9.3	163
45	5.9	1.4	ND	92.3
50	14.8	2.0	9.2	1.9
55	22.1	7.0	16.1	124.0
60	3.7	1.6	3.6	9.9
65	2.4	NA	13.2	8.4
70	8.6	ND	8.5	78.2 (2.64)
75	25.1	1.2 (2.1)	11.9	276
80	211	3.0	7.2	3.5
85	2.0	4.8	12.9	92.3
90	28.6	1.9	92.8	124
95	5.5	1.6	117	329
100	ND	2.1	18.5*	201

*Sample collected from 98 feet.
ND - Not detected.
NA - Not analyzed.
( ) - Field duplicate.
(-) - Field duplicate not detected.

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Table 4-11

Soil Analytical Results - Oil and Grease, South Fire Training Area, Luke AFB, Arizona (mg/kg)

Depth (ft)	Boring Number 05-01	05-02
5	3,660	ND
10	ND	ND
15	ND	ND
20	7.4	ND
25	9.8	ND (27.9)
30	11.3 (32.3)	ND
35	11.0	ND
40	13.8	7.0
45	ND	16.6
50	ND	36.3
55	ND	ND
60	NA	ND
65	12.7	ND (-)
70	ND	7.8
75	27.4	ND
80	ND (-)	21.8
85	ND	28.0
90	ND	36.7
95	ND	15.4
100	NA	23.2*

*Sample collected from 98 feet.
NA - Not analyzed.
ND - Not detected.
( ) - Field duplicate.
(-) - Field duplicate not detected.

Training Area; soil borings 06-01 and 06-02 were drilled in the former fire training area of the NFTA.

Petroleum hydrocarbons were consistently found in most of the subsurface soil samples at the O/W Separator Canal (see Table 4-12). The only sample with a concentration above 20 mg/kg was at 5 feet in soil boring 03-04 with a concentration of 72.3 mg/kg. As discussed in Subsection 4.4.6 (p. 4-43), concentrations below 20 mg/kg are generally considered to be associated with background interference; therefore, no significant petroleum hydrocarbons concentrations were found below 10 feet.

Metals data for all sites are summarized in Table 4-13. The data presented in that table represent ranges of concentrations found at the various sites. Note that the ranges are consistent from site to site (with the exception of lead and possibly nickel at the STP Effluent Canal area, discussed in Subsection 4.6.5.2). Examination of the full data set (see Appendix H) reveals no obvious trends related to depth of sample within a soil boring or between soil borings. Comparison of these data with Table 4-6 (p. 4-46), which shows naturally occurring metals concentrations typically found in soils, indicates that these values are indicative of background occurrences of these metals and are not related to environmental contamination of any of the sites investigated.

4.5.2 Soil-Gas Results

Soil-gas surveys were performed at the O/W Separator Canal, the POL Area, and the STP Effluent Canal as described in Subsection 3.2.2.1 (p. 3-). At the O/W Separator Canal, the soil-gas contained elevated (above ambient air) concentrations of trichloroethene (TCE) and 1,1,1-trichloroethane (TCA). At the POL Area, elevated concentrations of tetrachloroethene (PCE), benzene, toluene, total xylenes, and total hydrocarbons were found. At the STP Effluent Canal, elevated concentrations of PCE were found. At all three sites, identifiable patterns of soil-gas contamination were found indicating the existence of a probable relationship between the particular source area and the distribution of contaminants found in soil-gas.

It can be concluded that the compounds identified by the soil-gas surveys were introduced to the subsurface at the three sites surveyed. However, it is important to note that these compounds were not detected by the soil analyses; i.e., the soil-gas concentrations are not associated with any currently detectable soil contamination. Therefore, volatile compounds that enter the subsurface must be volatilizing to the soil-gas rather than adsorbing onto the soil particles or remaining solubilized in soil water. The volatilization of a compound to

Table 4-12

Soil Analytical Results - Petroleum Hydrocarbons, Oil/Water Separator Canal, Luke AFB, Arizona (mg/kg)

Boring No.	Depth (ft)	Petroleum hydrocarbons	Boring No.	Depth (ft)	Petroleum hydrocarbons
03-01	5	2.4	03-04	5	72.3
	10	8.7		10	18.1
	15	6.4		15	15.6
	25	4.9		20	13.9
	40	2.6		35	ND
	60	1.4		50	ND
	98	2.9		70	5.2
				95	ND
03-02	5	3.1	03-05	5	ND
	10	4.2		10	ND
	15	5.2		15	ND
	20	2.7		20	ND
	35	2.8 (3.0)		35	ND
	55	2.7		50	ND
	75	2.3		75	16.6 (ND)
	98	3.4		95	ND
03-03	5	7.6	03-06	5	ND
	10	4.0		10	ND
	15	4.0 (268)		15	15.2
	25	2.0		20	5.6
	40	2.7		40	7.7
	60	2.6		45	ND (12.8)
	80	8.6		65	17.5
	98	2.0		80	8.8
				100	19.2

ND - Not detected.
( ) - Field duplicate.

Table 4-13

Priority Pollutant Metals Analytical Summary for Soils and Sediment Luke AFB, Arizona (mg/kg)

Site Name	Ag	As	Be	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Se	Tl	Zn
						Soils							
POL Area	ND-4.6	ND-24	ND-1.0	ND-9.4	5.5-49	4.9-50	ND	ND-40	ND	ND	ND	ND	8.9-231
SFTA	ND	ND-14	ND-0.7	1.2-4.8	6.9-47	8.3-36	ND-1.8	6.6-33	ND	ND	ND	ND	13-62
NFTA	ND	0.6-5.7	ND-0.9	ND-11	3.6-39	7.4-75	ND-1.3	2.9-39	ND	ND	ND	ND	3.1-75
STP Effluent Canal	ND-3.7	1.7-11	ND-0.99	1.6-9.0	9-58	9.5-75	ND-0.46	6.9-171	20-72	ND	ND	ND	15-81
						Sediment							
STP Effluent Canal	ND-3.7	1.8-5.4	ND-0.9	1.2-6.4	6.3-50	11-53	ND-0.7	11-42	ND-57	ND	ND	ND	20-101

ND - Not detected.

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the gaseous phase is a function, in part, of the temperature and the moisture content of the gas in contact with the volatile compound. Therefore, the volatilization of these compounds in soils is enhanced in the hot, dry climate of south-central Arizona where soil temperatures are high and moisture contents are low.

It should be noted that based on the experience of both WESTON and Tracer Research Corporation (who performed the soil-gas surveys), concentrations of TCE, TCA, and PCE up to 1,000 ug/L in soil-gas may not be detectable in the soil.

4.5.3 HNu Results

HNu organic vapor measurements were taken during the soil boring program, both at the top of the borehole and in soil sample headspace, as described in Subsection 3.2.2.3 (p. 3-11). HNu measurements are provided in the soil boring logs in Appendix D and are summarized below.

Oil/Water Separator Canal: No significant HNu readings.

POL Area: Generally speaking, no significant HNu readings were detected in the top 70 feet of the soil borings (exception: at soil boring 04-03, concentrations were detected in the top 25 feet of the boring). Significant borehole HNu readings were found below 70 feet in all soil borings except 04-05 and 04-08. These readings were as high as 250 parts per million (ppm), with many above 100 ppm.

SFTA: HNu readings in the two SFTA soil borings (05-01 and 05-02) were significant (as high as 100 ppm) in the top 40 feet of the boreholes. No HNu levels were found in the lower half of either borehole.

NFTA: The most significant HNu reading in the four soil borings at the NFTA occurred in the top of 50 feet of the soil borings (as high as 100 ppm). In one borehole, 06-04, readings as high as 600 ppm were obtained between 80 and 90 feet.

STP Effluent Canal: No significant readings.

The HNu results associated with the SFTA and those occurring in the shallow portion of the NFTA can be explained in much the same way as the soil-gas results. Although not compound-specific, the organic vapors detected by the HNu may be indicative of the presence of VOCs in the soil-gas at those sites. These compounds are most likely associated with the fuels that have been applied to the fire training areas; however, no VOC contamination remains or is detectable in the soil.

In general, the same conclusion has been reached regarding the presence of dissociated high HNu readings at depth as shown at the POL Area and in one soil boring at the NFTA. Although no clear explanation is apparent, the readings are apparently associated with soil-gas contamination only. No soil contamination that can be correlated with these HNu readings has been found at depth at any of these sites.

4.5.4 Groundwater Results

All groundwater samples from the monitor and production wells were analyzed for VOCs, MEK, BNAs, pesticides/PCBs, O&G, TOC, and metals. Production well samples also were analyzed for dibromochloropropane (DBCP) and radiological parameters. Discussion of those results is provided in Subsection 4.6.6. No pesticides/PCBs were detected in any water samples.

VOC results for groundwater are summarized in Table 4-14. In all of the VOC results for groundwater samples, only eight positive findings of VOCs were detected. Of these, two were PCE and have been discounted as previously discussed. Four of the remaining six involve acetone. Because there are no water quality standards for acetone and because it occurred inconsistently from sampling round to sampling round, its occurrence is not considered to be significant. Also, although not indicated by laboratory QA/QC results, acetone may be a laboratory artifact. The remaining two positive findings are bromodichloromethane and dibromochloromethane. They were detected during only one of three sampling rounds at production well PW-4 and may be related to chlorination at the well (see further discussion in Subsection 4.6.6). In general, it is concluded that there is no significant detectable contamination of groundwater by VOCs at Luke AFB.

BNA results for groundwater also are summarized in Table 4-14. The only compounds detected were bis(2-ethylhexyl) phthalate (BEHP) in eleven water samples at concentrations less than 130 ug/L and di-n-octyl phthalate (DNOP) in one sample at 13 ug/L. These compounds are components of most plastics and are easily introduced randomly to the samples while sampling. This is the most likely explanation for their presence in the groundwater samples. Note that all concentrations are well below water quality standards (for BEHP, the SNARL is 4,200 ug/L and the Ambient Water Quality Criteria is 15,000 ug/L; for DNOP, no water quality standards have been established (see Table 4-8, p. 4-49)).

Oil and grease results for groundwater are summarized in Tables 4-15 and 4-16. In the monitor wells, O&G was found during two of three rounds at MW-102 and during all three rounds at MW-103 (at the O/W Separator Canal site) at concentrations ranging

Table 4-14

Analytical Results for VOCs, BNAs, and Pesticides/PCBs, Monitor Wells and Production Wells, Luke AFB, Arizona (ug/L)

Monitor Well No.	Acetone	Bromodi-chloro-methane	Dibromo-chloro-methane	Tetra-chloro-ethene	Di-n-octyl phthalate	Bis(2-ethylhexyl) phthalate	Pesti-cides/PCBs
MW-101	ND	ND	ND	13	ND	ND (-)	ND
	ND	ND	ND	ND	ND (-)	33 (-)	ND (-)
	ND	ND	ND	ND	ND	ND	ND
MW-102	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
MW-103	ND (-)	ND (-)	ND (-)	ND (-)	ND (-)	ND (-)	ND
	ND	ND	ND	ND	ND	19	ND
	64	ND	ND	ND	13	130	ND
MW-104	ND	ND	ND	ND	ND	ND	ND
	ND (-)	ND (-)	ND (-)	ND (-)	ND (-)	18 (-)	ND
	ND	ND	ND	ND	ND	ND	ND
MW-105	62	ND	ND	ND	ND	ND	ND
	40	ND	ND	ND	ND (-)	ND	ND
	ND (-)	ND (-)	ND (-)	ND (-)	ND (-)	ND (-)	ND (-)
MW-106	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	25	ND
MW-107	ND (-)	ND (-)	ND (-)	ND (-)	ND (-)	ND (-)	ND
	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
MW-108	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	12	ND

ND - Not detected.
( ) - Field duplicate.
(-) - Field duplicate not detected.

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Table 4-14
(continued)

Monitor Well No.	Acetone	Bromodi-chloro-methane	Dibromo-chloro-methane	Tetra-chloro-ethene	Di-n-octyl phthalate	Bis(2-ethylhexyl) phthalate	Pesti-cides/ PCBs
MMW-109	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	10	ND
	ND (-)	ND (-)	ND (-)	ND (-)	ND (-)	ND (-)	ND (-)
MW-110	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
MW-111	ND (-)	ND (-)	ND (-)	1.0 (-)	ND (-)	ND (-)	ND
	42	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
PW-1	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
PW-4	ND	2.4	6.3	ND	ND	ND	ND
	ND	ND	ND	ND	ND	15	ND
	ND	ND	ND	ND	ND	ND	ND
PW-7	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	10	ND
	ND	ND	ND	ND	ND	ND	ND
PW-9	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
PW-10	ND	ND	ND	ND	ND	16 (36)	ND
	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND
PW-11	ND	ND	ND	ND	ND	11	ND
	ND	ND	ND	ND	ND	ND	ND
	ND	ND	ND	ND	ND	ND	ND

ND - Not detected.
( ) - Field duplicate.
(-) - Field duplicate not detected.

Table 4-15

Groundwater Analytical Results
Total Organic Carbon and Oil and Grease - Monitor Wells
Luke AFB, Arizona

	MW-101	MW-102	MW-103	MW-104	MW-105	MW-106	MW-107	MW-108	MW-109	MW-110	MW-111
Total Organic Carbon (mg/L)											
Round 1	0.978	2.63	3.01 (3.19)	0.702	1.87	0.604	3.88 (0.792)	1.5	0.90	1.00	0.50 (0.90)
Round 2	0.70 (0.70)	1.10	3.10	0.923 (0.923)	1.80	ND	0.540	0.50	0.50	0.80	2.90
Round 3	0.553	2.91	1.76	0.791	0.695 (0.791)	0.984	0.749	0.946	1.00 (0.50)	0.791	0.50
Oil and Grease (mg/L)											
Round 1	ND	ND	4.1 (1.9)	ND	ND	ND	ND (ND)	ND	ND	ND	ND
Round 2	ND (-)	0.70	1.00	1.00 (-)	ND	ND	ND	ND	ND	ND	ND
Round 3	ND	1.30	2.70	ND	ND (-)	ND	ND	ND	ND (-)	ND	ND

ND - Not detected.
( ) - Field duplicate.
(-) - Field duplicate not detected.

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Table 4-16

Groundwater Analytical Results,
Total Organic Carbon and
Oil and Grease - Production Wells,
Luke AFB, Arizona

	PW-1	PW-4	PW-7	PW-9	PW-10	PW-11
Total Organic Carbon (mg/L)						
Round 1	0.802	ND	ND	ND	0.643 (0.643)	ND
Round 2	0.923	0.80	0.70	0.60	ND	ND
Round 3	0.888	ND	0.791	ND	ND	0.598
Oil and Grease (mg/L)						
Round 1	ND	ND	0.50	ND	ND (-)	0.60
Round 2	ND	ND	ND	ND	ND	ND
Round 3	ND	2.00	0.40	0.20	ND	0.20

ND - Not detected.
() - Duplicate.
(-) - Duplicate not detected.

from 0.7 to 4.1 mg/L. A complete discussion of this occurrence is found in Subsection 4.6.1.5.

In the production wells, O&G concentrations ranging from 0.20 to 2.00 mg/L were found in six samples with no apparent consistent distribution. The oil and grease in the production wells is likely caused by leakage of oil and grease from the oil-lubricated vertical turbine pumps with which the wells are equipped. This argument is further supported by the lack of potential sources near any of the production wells and the absence of O&G in groundwater near clearly identified potential sources such as the POL Area and the fire training areas.

TOC results for groundwater also are presented in Tables 4-15 and 4-16. TOC occurs somewhat consistently in both monitor wells and production wells at concentrations between 0.5 and 3.88 mg/L. Based on the discussion in Subsection 4.4.7 (p. 4-44), it has been concluded that the general presence of TOC at levels below 5 mg/L is probably associated with a background occurrence caused by the presence of naturally occurring organic matter.

Metals data are summarized in Tables 4-17 and 4-18. (Note that all samples were unfiltered for the first two sampling rounds, although third round samples from MW-102, MW-103, and MW-105, as explained below, were filtered.) When comparing the metals data from the unfiltered monitor well samples, no particular pattern emerges except that MW-102, MW-103, and MW-105 contain somewhat higher metal concentrations than the other monitor wells, and metal concentrations in the monitor wells are higher than in the production wells. These results are consistent with the following observations:

- Water from MW-102, MW-103, and MW-105 was the cloudiest (contained the most suspended sediment) of the monitor wells.

- Because of the extensive pumping associated with the production wells, they would be expected to contain less suspended sediment than the monitor wells.

- With unfiltered samples, any metals found in association with suspended sediment in the well would be analyzed as part of the water sample.

For each monitor well and production well (and for each sampling round), field determinations were made of groundwater pH, temperature, and specific conductance. These data are presented in Table 4-19. Values for pH ranged from 7.0 to 10.7, indicating generally alkaline groundwater conditions. Values for pH are higher for the monitor wells than for the production wells, indicating that the pH may be influenced by the existence of higher levels of suspended sediment in monitor wells.

Table 4-17

Groundwater Analytical Results, Priority Pollutant Metals - Monitor Wells, Luke AFB, Arizona

Analyte (ug/L)	Round	MW-101	MW-102*	MW-103*	MW-104	MW-105*	MW-106	MW-107	MW-108	MW-109	MW-110	MW-111
		Monitor Well Number										
Silver (Ag)	1	ND	ND	ND (-)	ND	ND	ND	ND (-)	ND	ND	ND	ND (-)
	2	ND (-)	ND	ND	ND (-)	ND	ND	ND	ND	ND	ND	ND
	3	24	ND	ND	ND	ND (-)	ND	ND	ND	ND (-)	ND	ND
Arsenic (As)	1	ND	11	23 (23)	ND	13	ND	ND (42)	13	ND	ND	ND (-)
	2	3.9 (4.4)	16	20	2.6 (3.0)	16	3.3	2.5	ND	3.7	2.5	2.2
	3	3.6	8.2	29	3.0	4.6 (4.9)	8.7	3.4	2.6	7.3 (6.5)	5.4	2.8
Beryllium (Be)	1	ND	ND	ND (-)	ND	ND	ND	ND (-)	ND	ND	ND (-)	ND (-)
	2	ND (-)	ND	ND	ND (-)	ND	ND	ND	ND	ND	ND	ND
	3	ND	ND	ND	ND	ND (-)	ND	ND	ND	ND (-)	ND	ND
Cadmium (Cd)	1	ND	8	10 (9)	ND	11	ND	ND (-)	ND	ND	ND	ND (-)
	2	9.0 (7.0)	11	18	ND (-)	25	ND	ND	8.0	ND	ND	ND
	3	8.0	ND	ND	ND	ND (-)	ND	ND	13	ND (-)	ND	ND
Chromium (Cr)	1	14	83	88 (96)	16	46	47	16 (14)	ND	10	24	16 (16)
	2	15 (19)	62	54	ND (-)	148	26	10	15	ND	22	13
	3	23	12	ND	ND	ND (-)	86	12	24	ND (-)	28	ND

ND - Not detected.
( ) - Field duplicate.
(-) - Field duplicate not detected.
* - Filtered, third round only.

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Table 4-17
(continued)

Analyte (ug/L)	Round	MW-101	MW-102*	MW-103*	MW-104	MW-105*	MW-106	MW-107	MW-108	MW-109	MW-110	MW-111
		Monitor Well Number										
Copper (Cu)	1	ND	73	75 (85)	ND	26	ND	ND (-)	ND	ND	25	ND (-1)
	2	ND (-)	81	148	ND (-)	203	23	ND	ND	ND	ND	ND
	3	35	ND	ND	ND	ND (-)	33	21	23	ND (-)	ND	ND
Mercury (Hg)	1	ND	.21	.21 (-)	ND	ND	ND	ND (-)	ND	ND	ND	ND
	2	ND (-)	ND	ND	ND (-)	ND	.31	ND	2.4	ND	ND	ND
	3	ND	.21	ND	ND	ND (-)	ND	ND	ND	ND	ND	ND
Nickel (Ni)	1	ND	55	56 (64)	ND	ND	ND	ND (-)	ND	ND	ND	ND (47)
	2	31 (35)	35	33	ND (-)	92	29	ND	33	ND	ND	ND
	3	38	ND	ND	ND	ND (-)	22	ND	49	ND (-)	ND	ND
Lead (Pb)	1	8.2	30	42 (44)	11	44	11	ND (6.1)	14	7.0	28	16 (12)
	2	ND (5.5)	25	46	8.2 (7.5)	86	11	5.5 (6.1)	7.9	18	10	6.9
	3	5.8	5.9	9.2	6.0	5.2 (-)	18	17	6.8	8.4 (8.1)	10	7.1
Antimony (Sb)	1	ND	ND	ND (-)	ND	ND	ND	ND (-)	ND	ND	ND	ND (-)
	2	ND (-)	ND	ND	ND (-)	ND	ND	ND	ND	ND	ND	ND
	3	ND	ND	ND	ND	ND (-)	ND	60	ND	ND (-)	ND	ND

ND - Not detected.
( ) - Field duplicate.
(-) - Field duplicate *not detected*.
* - Filtered, third round only.

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Table 4-17
(continued)

Analyte (ug/L)	Round	Monitor Well Number MW-101	MW-102*	MW-103*	MW-104	MW-105*	MW-106	MW-107	MW-108	MW-109	MW-110	MW-111
Selenium (Se)	1	ND	3	ND (-)	ND	ND	ND	ND (-)	ND	ND	ND	ND (-)
	2	ND (-)	2.0	ND	2.0 (-)	ND	ND	5.0	2.0	ND	ND	ND
	3	ND	ND	ND	ND	ND (-)	6.1	4.0	2.1	ND (-)	ND	2.7
Thallium (Tl)	1	ND	ND	ND (-)	ND	ND	ND	ND (-)	ND	ND	ND	ND (-)
	2	ND (-)	ND	ND	ND (-)	ND	ND	ND	ND	5.2	8.7	ND
	3	ND	ND	ND	ND	ND (-)	6.5	ND	ND	ND (-)	8.3	ND
Zinc (Zn)	1	170	158	241 (297)	1,480	46,800	1,240	1,000 (1,050)	620	170	590	500 (470)
	2	640 (578)	456	2,940	2,930 (2,760)	34,900	796	1,470	1,110	649	904	1,380
	3	420	40	ND	1,780	70 (48)	2,970	1,400	1,050	290 (309)	2,910	889

ND - Not detected.
( ) - Field duplicate.
(-) - Field duplicate not detected.
* - Filtered, third round only.

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Table 4-18

Groundwater Analytical Results,
Priority Pollutant Metals - Production Wells,
Luke AFB, Arizona

Analyte (ug/L)	Round	PW-1	PW-4	PW-7	PW-9	PW-10	PW-11
		Production Well Number					
Silver (Ag)	1	ND	ND	ND	ND	ND (-)	ND
	2	ND	ND	ND	ND	ND	ND
	3	ND	ND	ND	ND	ND	ND
Arsenic (As)	1	ND	10.8	16	18	19 (19)	ND
	2	4.7	9.5	15	20	17	5.3
	3	6.8	14	12	19	20	7.2
Beryllium (Be)	1	ND	ND	ND	ND	ND (-)	ND
	2	ND	ND	ND	ND	ND	ND
	3	ND	ND	ND	ND	ND	ND
Cadmium (Cd)	1	ND	ND	ND	ND	ND (-)	ND
	2	7.0	8.0	11	6.0	11	ND
	3	ND	ND	ND	ND	ND	ND
Chromium (Cr)	1	ND	24	ND	15	11 (13)	ND
	2	22	30	35	54	41	ND
	3	ND	27	ND	50	20	ND
Copper (Cu)	1	200	ND	ND	ND	ND (-)	ND
	2	25	ND	24	ND	21	ND
	3	622	ND	ND	31	ND	ND
Mercury (Hg)	1	ND	ND	ND	ND	ND (-)	ND
	2	ND	ND	ND	ND	ND	ND
	3	ND	ND	ND	0.21	ND	ND
Nickel (Ni)	1	ND	ND	ND	ND	ND (-)	ND
	2	ND	48	56	27	65	ND
	3	ND	30	ND	ND	ND	ND

ND - Not detected.
( ) - Field duplicate.
(-) - Field duplicate not detected.

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Table 4-18
(continued)

Analyte (ug/L)	Round	PW-1	PW-4	PW-7	PW-9	PW-10	PW-11
		Production Well Number					
Lead (Pb)	1	8.2	ND	ND	ND	ND (-)	ND
	2	ND	6.6	6.5	6.8	9.0	ND
	3	20	ND	6.3	10	5.9	5.2
Antimony (Sb)	1	ND	ND	ND	ND	ND (-)	ND
	2	ND	ND	ND	ND	ND	ND
	3	ND	ND	ND	ND	ND	ND
Selenium (Se)	1	ND	ND	ND	ND	ND (-)	ND
	2	9.0	ND	ND	ND	ND	2.0
	3	ND	ND	ND	ND	ND	ND
Thallium (Tl)	1	ND	ND	ND	ND	ND (-)	ND
	2	ND	ND	ND	8.0	ND	ND
	3	7.5	ND	7.1	ND	ND	ND
Zinc (Zn)	1	55	ND	ND	ND	ND (-)	21
	2	55	29	40	33	20	17
	3	96	ND	16	46	16	21

ND - Not detected.
( ) - Field duplicate.
(-) - Field duplicate not detected.

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Table 4-19

Summary of Field-Tested Parameters, Monitor Wells and Production Wells, Luke AFB, Arizona

Well No.	Round	Date Sampled	pH	Temperature (°C)	Specific Conductance (micro-mhos/m)
MW-101	1	12-17-86	8.1	23.8	750
	2	01-22-87	7.2	20.5	700
	3	02-12-87	7.7	24.0	490
MW-102	1	01-06-87	8.6	24.0	409
	2	01-21-87	9.0	21.0	530
	3	02-10-87	8.6	26.0	440
MW-103	1	01-06-87	10.3	24.0	1,230
	2	01-21-87	10.1	22.0	1,190
	3	02-10-87	9.5	26.0	1,100
MW-104	1	12-15-86	8.1	25.0	450
	2	01-20-87	7.4	21.5	750
	3	02-10-87	7.8	25.0	610
MW-105	1	12-15-86	10.7	25.0	790
	2	01-21-87	9.6	22.5	440
	3	02-11-87	9.1	24.0	340
MW-106	1	12-15-86	7.8	26.0	1,000
	2	01-21-87	7.4	24.0	550
	3	02-10-87	7.8	----	425
MW-107	1	12-22-86	7.4	24.0	1,200
	2	01-20-87	7.4	23.0	1,600
	3	02-11-87	7.9	24.0	1,600
MW-108	1	12-18-86	8.1	22.5	2,200
	2	01-21-87	7.3	20.0	1,200
	3	02-11-87	6.8	23.0	1,650
MW-109	1	12-16-86	8.9	27.0	1,200
	2	01-22-87	7.0	24.5	700
	3	02-07-87	7.6	28.0	670
MW-110	1	12-16-86	9.3	27.0	1,100
	2	01-22-87	7.5	23.0	1,100
	3	02-09-87	7.9	27.0	700
MW-111	1	12-16-86	7.8	25.0	1,420
	2	01-21-87	7.5	24.0	850
	3	02-07-87	7.5	24.0	650

--- Data not obtained.

Table 4-19
(continued)

Well No.	Round	Date Sampled	pH	Temperature (°C)	Specific Conductance (micro-mhos/m)
PW-1	1	12-18-86	7.2	21.0	2,900
	2	01-20-87	7.0	19.0	2,180
	3	02-10-87	7.3	24.0	2,400
PW-4	1	12-17-86	7.8	17.7	700
	2	01-22-87	7.2	23.5	750
	3	02-12-87	7.4	25.0	600
PW-7	1	12-18-86	7.5	23.0	700
	2	01-22-87	7.6	25.0	600
	3	02-10-87	8.1	25.0	330
PW-9	1	12-18-86	8.3	30.0	650
	2	01-22-87	7.65	24.0	460
	3	02-10-87	8.3	28.0	465
PW-10	1	12-18-86	8.3	29.5	595
	2	01-22-87	7.8	24.5	410
	3	02-10-87	8.2	26.0	390
PW-11	1	12-18-86	7.3	21.5	1,200
	2	01-20-87	7.9	22.0	600
	3	02-10-87	7.8	27.0	470

--- Data not obtained.

Temperatures (ranging from 19.1 to 30°C) and specific conductance (ranging from 330 to 2,900 micro-mhos) show no particular pattern and reflect localized variability.

Because of the high metals concentrations found during the first and second sampling rounds in MW-102, MW-103, and MW-105 and because these wells also contained the highest amount of suspended sediment of all wells sampled, they were filtered as part of the third round sampling effort. Third round results for those three wells are, therefore, for dissolved metals only. As can be seen, a significant reduction occurred in the metals concentration for those wells during the third round. This phenomenon is most clearly seen in the analytical results for cadmium, chromium, copper, lead, nickel, and zinc. Sample results from MW-102, MW-103, and MW-105 that exceeded water quality standards for the first and/or second sampling rounds were for chromium (MCL is 50 ug/L), cadmium (MCL is 10 ug/L), mercury (MCL is 2.0 ug/L), nickel (Ambient Water Quality Criterion is 13.4 ug/L) and zinc (SMCL is 5,000 ug/L). Without fail, concentrations for these three wells were well within drinking water standards for the third round.

For the monitor wells other than MW-102, MW-103, and MW-105, MCLs were exceeded in three specific samples: cadmium during round 3, MW-108; chromium during round 3, MW-106; and mercury during round 2, MW-108. In addition, the Ambient Water Quality Criterion for nickel was exceeded in all wells except MW-104, MW-107, MW-109, and MW-110.

Based on the filtered versus unfiltered results from MW-102, MW-103, and MW-105, it is probable that these concentrations would not have occurred in a filtered sample.

In the production wells, there were four instances where individual samples exceeded MCLs and five instances where the Ambient Water Quality Criterion for nickel was exceeded:

Compound	Well	Sampling Round	Concentration (ppb)	MCL (ppb)	Ambient Water Quality Criterion (ppb)
Cadmium	PW-7	2	11	10	NA
Cadmium	PW-10	2	11	10	NA
Chromium	PW-9	2	54	50	NA
Chromium	PW-9	3	50	50	NA

NA - Not applicable

Compound	Well	Sampling Round	Concen-tration (ppb)	MCL (ppb)	Ambient Water Quality Criterion (ppb)
Nickel	PW-4	2	48	NA	13.4
Nickel	PW-4	3	30	NA	13.4
Nickel	PW-7	2	56	NA	13.4
Nickel	PW-9	2	27	NA	13.4
Nickel	PW-10	2	65	NA	13.4

NA - Not applicable

It is likely that the chromium results reflect naturally occurring levels of chromium in the groundwater. This conclusion is based on the following factors:

- As discussed in Subsection 4.4.8 (p. 4-44), chromium concentrations (up to 31 ppb) have been found in Phoenix municipal water supply wells located west of Phoenix. In addition, naturally occurring chromium concentrations were documented in Paradise Valley, located in the Phoenix Basin, immediately east of Phoenix (about 20 miles east of Luke AFB). (Robertson, 1975). There, naturally occurring chromium concentrations as high as 200 mg/L were found.

- Chromium appeared rather consistently in both monitor wells and production wells.

- No anomalously high chromium levels were found in the monitor wells (keeping in mind the above discussion of filtering). If environmental sources of chromium were to be found at Luke AFB, it is expected that they would be found in monitor wells rather than production wells.

The cadmium and nickel results do not appear to be indicative of background based upon the water quality of the Phoenix municipal wells.

Although there is no clear explanation for the occurrence of nickel and cadmium in the production wells, it is unlikely that they represent environmental contamination of groundwater based on the following factors:

- Cadmium and nickel appear somewhat consistently in monitor wells, indicating that they may be present in the groundwater at background levels.

- The levels of cadmium and nickel are not significantly higher in monitor wells than in production wells. If environmental sources of cadmium and nickel were to be found at Luke AFB, it is expected that they would be found in higher concentrations in monitor wells rather than production wells. Since monitor wells are screened at the water table where higher concentrations of surface-source contaminants would be more likely to be found.

- The concentrations of nickel and cadmium in the production wells are not consistent from sampling round to sampling round. Note that most positive values are from the second round, and that nickel and cadmium were not detected (with one exception) during the first and third rounds. There is no apparent reason for this inconsistency, as laboratory QA/QC shows no reason to question the data, and a review of the sampling procedures used shows no variation from round to round. The cause of the nickel and cadmium results in the production wells more likely is sediment in the samples than environmental contamination from surface sources. While it is possible that the amount of sediment in a sample could vary from round to round, there is no reason that nickel and cadmium, as environmental contaminants, would show variation. (Note that for monitor wells, where it is clear that sediment in unfiltered samples has influenced metals results, there is great variability in concentrations from round to round.) This argument is supported by the fact that the wells that showed the nickel and cadmium results (PW-4, PW-7, PW-9, and PW-10) are not frequently used and had to be turned on prior to sampling. It is possible that sediment entered the well because of turbulence associated with pump startup.

It is concluded that the metals found in the groundwater are associated with naturally occurring metals concentrations supplemented by metals associated with the sediment suspended in groundwater in the monitor wells.

4.6 SITE-SPECIFIC RESULTS

This subsection contains discussions of the analytical results at each site in greater detail. In addition, data obtained during the Phase II Stage 1 investigation are presented and are reviewed to supplement the site-by-site discussions.

4.6.1 Oil/Water (O/W) Separator Canal

At the O/W Separator Canal, analytical results were obtained for subsurface soils, soil-gas, groundwater, sediment, and surface water as described in Section 3.

4.6.1.1 Soil-Gas Results

Twenty-three soil-gas samples were taken at the O/W Separator Canal area (see Appendix O). Samples were collected along the length of the canal and along two perpendicular transects (see Figure 4-24). TCE and TCA concentrations determined during the soil-gas testing at the O/W Separator Canal are presented in Table 4-20. A distinct pattern of elevated concentrations for TCE and TCA emerged from these data.

Along the canal, soil-gas concentrations of TCA were elevated, with concentrations generally decreasing to the south (downstream from the oil/water separator). Along the transects perpendicular to the canal, the TCA concentrations varied as might be expected; i.e., they decreased with increasing distance from the canal. However, the TCE concentrations showed a distinctly different pattern, best illustrated by the data along transect 1 at the northern end of the canal.

In the canal, TCE concentrations were significantly lower than TCA concentrations. Moving away from the canal in either direction, concentrations at first increase and then decrease. This pattern was also present along transect 2, although insufficient sampling was performed west of the canal to verify the trend in that direction.

This pattern of soil-gas concentrations may be associated with historical solvent use patterns at Luke AFB. Currently, TCA is typically more commonly used than TCE, but historically the reverse may have been true. Therefore, TCE may have been introduced earlier to the subsurface and since that time may have migrated away from the canal. TCA, being currently in use, would then predominate in the canal bed.

Neither PCE nor total hydrocarbons concentrations in soil-gas below the O/W Separator Canal were found to be significantly above ambient air readings. Because of the presence of oil staining on the soil, it was expected that the hydrocarbons soil-gas concentrations would be much higher. However, the lighter hydrocarbons fraction associated with the oil apparently volatilizes or biodegrades at or near the surface, and only the non-volatile fraction enters the subsurface. This conclusion is supported by two observations: 1) the lack of HNu readings at the site; and 2) the presence of petroleum hydrocarbons in sediments and shallow subsurface soils.

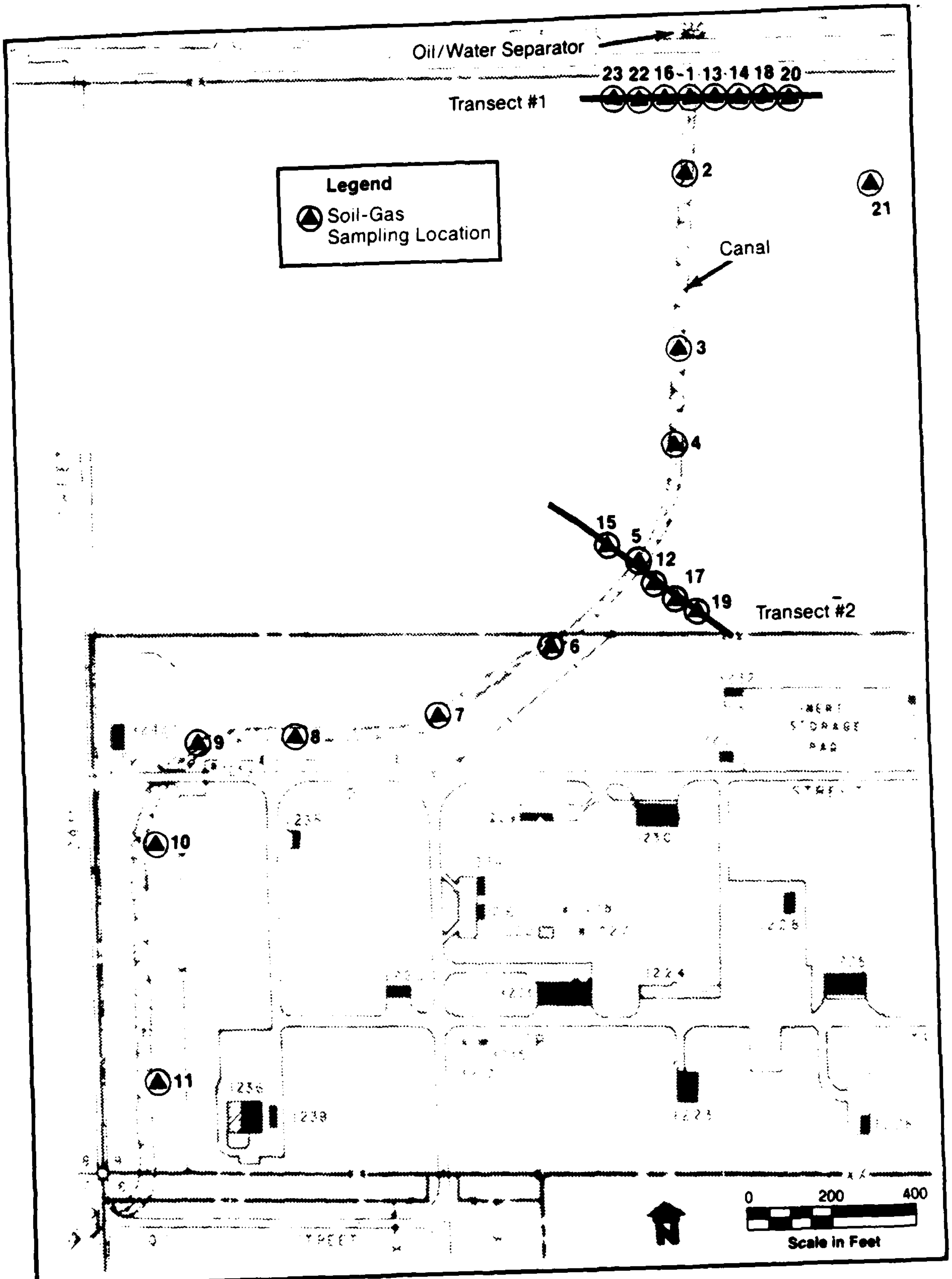

FIGURE 4-24 SOIL-GAS SAMPLING TRANSECTS, O/W SEPARATOR CANAL, LUKE AFB, AZ

Table 4-20

TCE and TCA Soil-Gas Concentrations[1]
Oil/Water Separator Canal,
Luke AFB, Arizona

Samples Along Canal from N to S	TCA (ug/L)	TCE (ug/L)
1	0.2	<0.00009
2	0.008	0.001
3	0.2	<0.00009
4	0.03	0.002
5	0.01	<0.00009
6	0.02	0.001
7	0.008	0.001
8	0.003	0.0005
9	0.02	<0.00009
10	0.002	0.002
11	0.004	0.004
Samples Along Transect No. 1 from W to E	**TCA (ug/L)**	**TCE (ug/L)**
23	0.0008	0.002
22	0.0006	0.006
16	0.001	0.004
1 (in canal)	0.2	<0.00009
13	0.0007	0.002
14	0.0006	0.01
18	0.0006	0.03
20	0.0006	0.008
Samples Along Transect No. 2 from W to E	**TCA (ug/L)**	**TCE (ug/L)**
15	0.0005	0.002
5 (in canal)	0.01	<0.00009
12	0.01	0.0008
17	0.0006	0.006
19	0.0004	0.0008

[1]All concentrations are in ug/L of air.

4.6.1.2 Soil Results

Six 100-foot soil borings were drilled at the O/W Separator Canal, and a total of 36 subsurface soil samples were collected. Samples were analyzed for VOCs and petroleum hydrocarbons. VOCs were detected in soil borings 03-01 and 03-02 (see Table 4-9, p. 4-53) and are shown in Figure 4-25. In boring 03-01, chloroform and 1,2-dichloroethane were detected at low levels at 98 feet only. In boring 03-02, chloroform was detected at low levels from 10 to 20 feet. Below 20 feet no VOCs were detected. As discussed in Subsection 4.5.1 (p. 4-52), these results are not considered to be significant based upon low concentrations and the low number of samples with detected VOCs.

Petroleum hydrocarbons were consistently detected in most of the subsurface soil samples at the O/W Separator Canal (see Table 4-12, p. 4-58). The petroleum hydrocarbons results are shown graphically in Figure 4-25 at the locations and depths they were found. In most cases the concentrations are below 10 mg/kg. There are no consistent trends between concentration and depth. As discussed in Subsection 4.5.1 (p. 4-52), these concenrations are within background ranges and are, therefore, not considered to be significant.

4.6.1.3 Sediment Samples

Twenty sediment samples were collected and were analyzed for VOCs and petroleum hydrocarbons. Sample results are summarized in Tables 4-21 and 4-22, and petroleum hydrocarbons results are shown in Figure 4-25. The only VOC detected was methylene chloride at concentrations ranging from 0.005 to 0.009 mg/kg in samples 1 through 10. No VOCs were detected in samples 11 through 20. Samples 1 through 10 were collected on one day, and samples 11 through 20 were collected the following day. A trip blank that accompanied samples 1 through 10 contained 650 ug/L of methylene chloride. It is clear, therefore, that the methylene chloride was introduced to the samples and that it is not actually present in the sediment.

The distribution of petroleum hydrocarbons is related to the sampling locations. As described in Subsection 3.2.2.8 (p. 3-22), samples 1 through 10 were collected from the canal bed, regularly spaced along the canal; samples 11 to 20 were collected at five areas with obvious oil staining. At each of five locations, one sample was taken from the top 6 inches of sediment, and one sample was taken from 6 to 12 inches. (Example: sample 11 is from 0 to 6 inches; sample 12 is from 6 to 12 inches.)

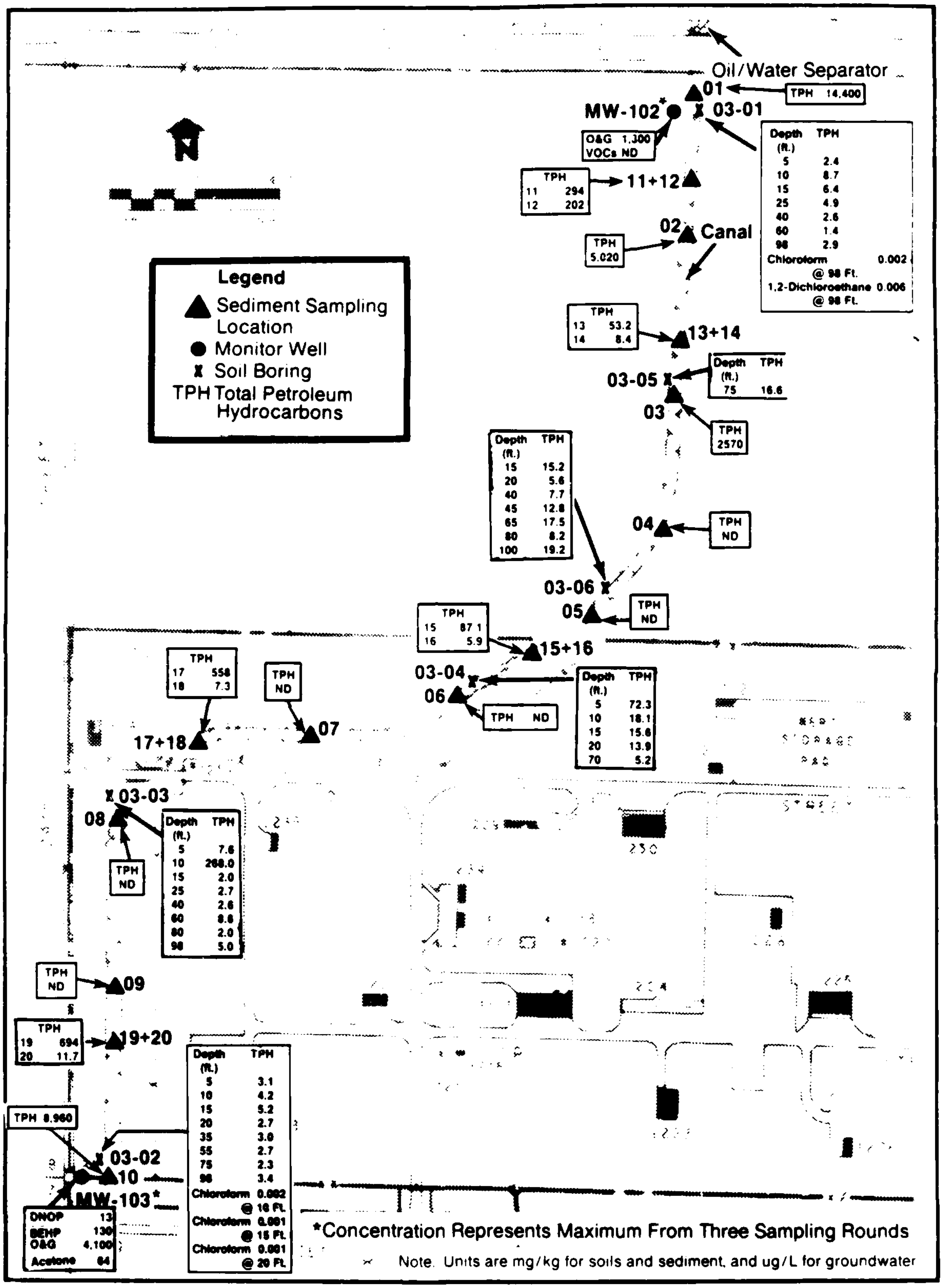

FIGURE 4-25 SUMMARY OF COMPOUND CONCENTRATIONS DETECTED IN SOILS, SEDIMENT, AND GROUNDWATER AT OIL /WATER SEPARATOR CANAL, LUKE AFB, AZ

Table 4-21

Analytical Results for VOCs in Sediment,
Luke AFB, Arizona

Location	Methylene chloride (mg/kg)
O/W Separator Canal	
OW-1	0.008
OW-3	0.008
OW-5	0.009
OW-6	0.006
OW-7	0.006
OW-8	0.007
OW-9	0.007
OW-10	0.005

Note: VOCs listed in Table 3-2 (p. 3-6) but not reported here were not detected.

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Table 4-22

Analytical Summary for Petroleum Hydrocarbons in Sediment, O/W Separator Canal, Luke AFB, Arizona

Sample No.	Total Petroleum Hydrocarbons (mg/kg)
1	14,400
2	5,020
3	2,570
4	ND
5	ND
6	ND
7	ND
8	ND
9	ND
10	8,960
11	294
12	202
13	53.2
14	8.40
15	87.1
16	5.90
17	558
18	7.30
19	694 (390)
20	11.7

ND - Not Detected.

Petroleum hydrocarbons were found in relatively high concentrations in samples 1, 2, and 3 (14,400, 5,020, and 2,570 mg/kg, respectively), which are located at the northern end of the canal near the oil/water separator. These three locations are in an area where standing water remains after a rainfall and concentrations of petroleum hydrocarbons would be expected. The lack of petroleum hydrocarbons in samples 4 through 9 does not indicate a complete absence of petroleum hydrocarbons for that portion of the canal, only that these samples were taken in localized areas where pools of standing water do not accumulate. Sample 10, with a concentration of 8,960 mg/kg, represents a localized area of petroleum hydrocarbons concentration.

Samples 11 through 20 show an expected pattern of petroleum hydrocarbons distribution, with the sample taken from the top 6 inches (odd numbered locations) containing significantly higher concentrations than the samples taken from 6 to 12 inches (even-numbered locations). The magnitude of the decrease in concentration with depth indicates that petroleum hydrocarbons do not readily migrate through the subsurface soils.

4.6.1.4 Surface Water Results

Two surface water samples were taken from the O/W Separator Canal on two separate occasions. A single sample was taken from standing water at the upstream end of the canal during each of the first two sampling rounds. Note that an oil sheen was present during both sampling rounds. Samples were analyzed for VOCs, BNAs, pesticides/PCBs, O&G, metals, and TOC. Results are shown in Table 4-23. There were no pesticides/PCBs detected.

The only VOC detected was PCE at 12 ug/L during the first sampling round only. PCE was not found in any associated blanks and is, therefore, considered to be present in the sample. This concentration of PCE is above drinking water standards (the MCLG and ADEQ action levels). However, drinking water standards do not apply to surface water in the O/W Separator Canal. PCE did not appear during the second sampling round or in the groundwater in MW-102 or MW-103 (see Subsection 4.6.1.5). Also, although not supported by laboratory QA/QC data, it is possible that this occurrence of PCE is related to the spurious PCE results found in other first round samples. Therefore, considering its low concentration and the above factors, this occurrence of PCE is not considered to be significant. Levels of bis(2-ethylhexyl) phthalate (BEHP) were found in each sample (at 13 and 10 ug/L), and di-n-octyl phthalate (DNOP) was found in one sample at 16 ug/L. These concentrations may represent a sampling artifact, but in any case are well below the SNARL of 4,200 ug/L for BEHP. Low levels of O&G (3.1 and 1.0 mg/L) and TOC (17.3 and 8.5 mg/L) were found, most likely related to the presence of an oil sheen during sampling. Concentrations of several metals also were found.

Table 4-23

Analytical Results for Surface Water, Oil/Water Separator Canal, Luke AFB, Arizona

Analyte	Sample ID Number 03-001-W001 (Round 1)	03-001-W002 (Round 2)
Total Organic Carbon (mg/L)	17.3	8.5
Oil and Grease (mg/L)	3.1	1.0
Pesticides/PCBs (ug/L)	ND	ND
BNAs (ug/L)		
Bis(2-ethylhexyl) phthalate	13	10
Di-n-octyl phthalate	16	ND
VOCs (ug/L)		
Tetrachloroethene	12	ND
Metals (ug/L)		
Ag (silver)	ND	ND
As (arsenic)	3.1	2.9
Be (beryllium)	ND	ND
Cd (cadmium)	ND	ND
Cr (chromium)	10	ND
Cu (copper)	ND	ND
Hg (mercury)	0.34	ND
Ni (nickel)	ND	ND
Pb (lead)	7.5	22
Sb (antimony)	ND	ND
Se (selenium)	3.0	ND
Tl (thallium)	ND	ND
Zn (zinc)	65	85

ND - Not detected.
Note: VOCs and BNAs listed in Table 3-2 (p. 3-6) but not reported here were not detected.

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4.6.1.5 Groundwater Results

Three rounds of groundwater samples were collected from MW-102 and MW-103 located at the O/W Separator Canal area. As discussed in Subsection 4.2.1 (p. 4-24), MW-102 and MW-103 are hydrogeologically anomalous when compared to other South Base monitor wells and published regional water table data. However, MW-102 and MW-103 do monitor the water table in the vicinity of the O/W Separator Canal, and are, therefore, appropriate for monitoring groundwater quality in terms of any potential impact from the O/W Separator Canal.

Samples were analyzed for VOCs, MEK, BNAs, pesticides/PCBs, O&G, TOC, and metals. As discussed in Subsection 4.4.7 (p. 4-44), metals concentrations detected fall within the range of natural background levels. No pesticides/PCBs or MEK were detected. The only VOC detected (see Table 4-14, p. 4-62) was acetone at 64 ug/L at MW-103 during one round. There are no drinking water standards for acetone; therefore, this result is not considered to be significant.

Oil and grease was found during two of three sampling rounds at MW-102 and during all three rounds at MW-103 at concentrations ranging from 0.7 to 4.1 mg/L (see Table 4-15, p. 4-64). There are three possible explanations for the presence of O&G in these monitor wells: 1) it was introduced during sampling; 2) it is associated with high levels of suspended solids (mostly clays) in the samples analyzed; or 3) it was transported via percolating water from the O/W Separator Canal. Of these explanations, one of the first two (or a combination) is considered more likely than the third due to the hydrogeologic setting at the screened interval of these wells (see Subsection 4.2.1, p. 4-24).

MW-102 and MW-103 were purged before sampling using a pump rig and a large metal bailer as discussed in Subsection 3.2.2.9 (p. 3-25). All other wells were purged using dedicated sampling pumps. It is possible that in spite of the decontamination procedures utilized, small amounts of oil and/or grease from the bailer or steel cable were introduced to the well during purging. It is also possible that the high levels of suspended sediment in MW-102 and MW-103 contributed sufficient organic matter to the sample to cause background interferences with the analytical method. These interferences could be manifested in the reported levels of O&G in these wells.

It is unlikely that the O&G in MW-102 and MW-103 was introduced to the water table via percolating water from the O/W Separator Canal considering the following factors:

- Petroleum hydrocarbons levels in the soil above the water table are at background levels below 10 feet in depth.

- Petroleum hydrocarbons results from the sediment sampling (in the canal) show a significant decrease in concentrations over a 12-inch interval.

- There were no significant levels of VOCs detected in the soils.

BNAs were detected as follows: DNOP at 13 ug/L in MW-103, round 3; and BEHP at 19 and 130 ug/L in MW-103, round 2 and 3, respectively. These concentrations are probably sampling artifacts associated with O&G as discussed above. In any case, these concentrations are well below any applicable water quality standards.

TOC and metals concentrations in groundwater at the O/W Separator Canal are considered to be representative of background levels as discussed in Subsections 4.5.4 (p. 4-61).

4.6.1.6 Site Contamination Profile - O/W Separator Canal

The following is a summary of findings at the O/W Separator Canal:

- Soil-gas - Elevated concentrations of TCE and TCA were found in a symmetrical pattern indicating the canal as the source. These results are not associated with detectable soil contamination.

- Soil - No significant VOC contamination is present, and petroleum hydrocarbons concentrations are representative of background levels.

- Canal Bottom Sediment - No VOCs (other than probable laboratory artifacts) were detected. Concentrations of petroleum hydrocarbons were found as expected based on visible sediment staining and areas of standing water. Significant reduction of petroleum hydrocarbons with depth was noted in the top 12 inches of sediment.

- Surface Water - No significant contamination detected.

- Groundwater - No significant contamination detected.

4.6.2 POL Area Results

At the POL Area, analytical results were obtained from a soil-gas survey, subsurface soil sampling, and groundwater sampling. In addition, results from the Phase II Stage 1 Report are discussed below.

4.6.2.1 Soil-Gas Results

Thirty-six soil-gas samples were taken at the POL Area (see Appendix O). These samples indicated the presence of elevated concentrations of TCE, TCA, PCE, benzene, toluene, xylenes, and total hydrocarbons. Isoconcentration maps showing the distributions of soil-gas concentrations of TCE, TCA, PCE, and total hydrocarbons are shown in Figures 4-26 through 4-29.

The distributions of TCE, TCA, and PCE are similar, with the highest zone of soil-gas concentrations located in the south-central portion of the site. Maximum concentrations of these constituents are 8 ug/L for TCE, 0.8 ug/L for TCA, and 0.8 ug/L for PCE. Note that, based on the experience of both WESTON and Tracer Research Corporation, who performed the survey, concentrations of TCE, TCA, and PCE up to 1,000 ug/L in soil-gas may not be detectable in the soil.

The distribution of total hydrocarbons is generally similar, with the highest soil-gas concentrations also occurring in the south-central portion of the site. Soil-gas total hydrocarbons concentrations are significantly higher than soil-gas concentrations of individual hydrocarbon compounds since many volatile hydrocarbon compounds are included in this analysis. As is true with individual compounds, there is no correlation between soil-gas concentrations for total hydrocarbons and hydrocarbon compounds found in the soils. This lack of correlation can be attributed, at least in part, to the presence in the soil of hydrocarbon compounds that were not specifically analyzed for as part of the soil VOCs analyses. In addition, factors discussed in Subsection 4.5.2 (p. 4-57) would also contribute to this lack of correlation. Note that benzene, toluene, and xylenes (BTX) are components of total hydrocarbons, and that areas of elevated concentrations of these compounds in soil-gas generally coincided with the total hydrocarbons data. However, the distribution of BTX was less regular and has, therefore, not been plotted here.

A comparison of soil-gas results with the geophysics results can be made by examination of soil-gas isoconcentration maps, the EM terrain conductivity map (see Figure 4-22, p. 4-36), and the GPR featuresmap (see Figure 4-23, p. 4-39). It is apparent that the northeast-southwest trending trench shown on the GPR figure corresponds to the location and trend of soil-gas concentrations. The EM results are less correlative, but an area of low terrain conductivity in the south-central portion of the site may correspond to the soil-gas concentrations. Evidently, the northeast-southwest trending trench was more significant than other trenches in terms of introducing volatile compounds to the subsurface.

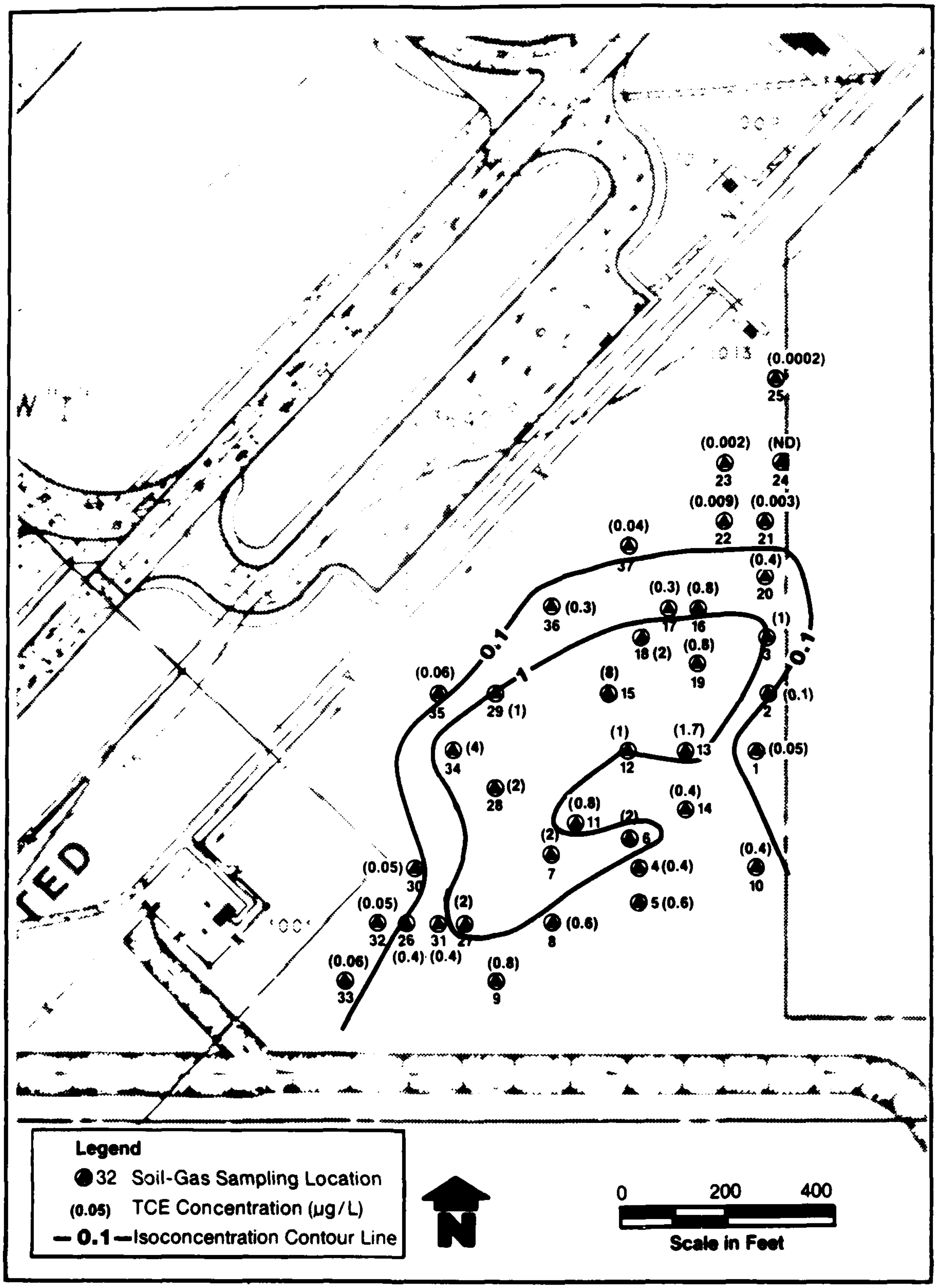

FIGURE 4-26 ISOCONCENTRATION MAP FOR TRICHLOROETHENE (TCE) IN SOIL-GAS, POL AREA, LUKE AFB, AZ

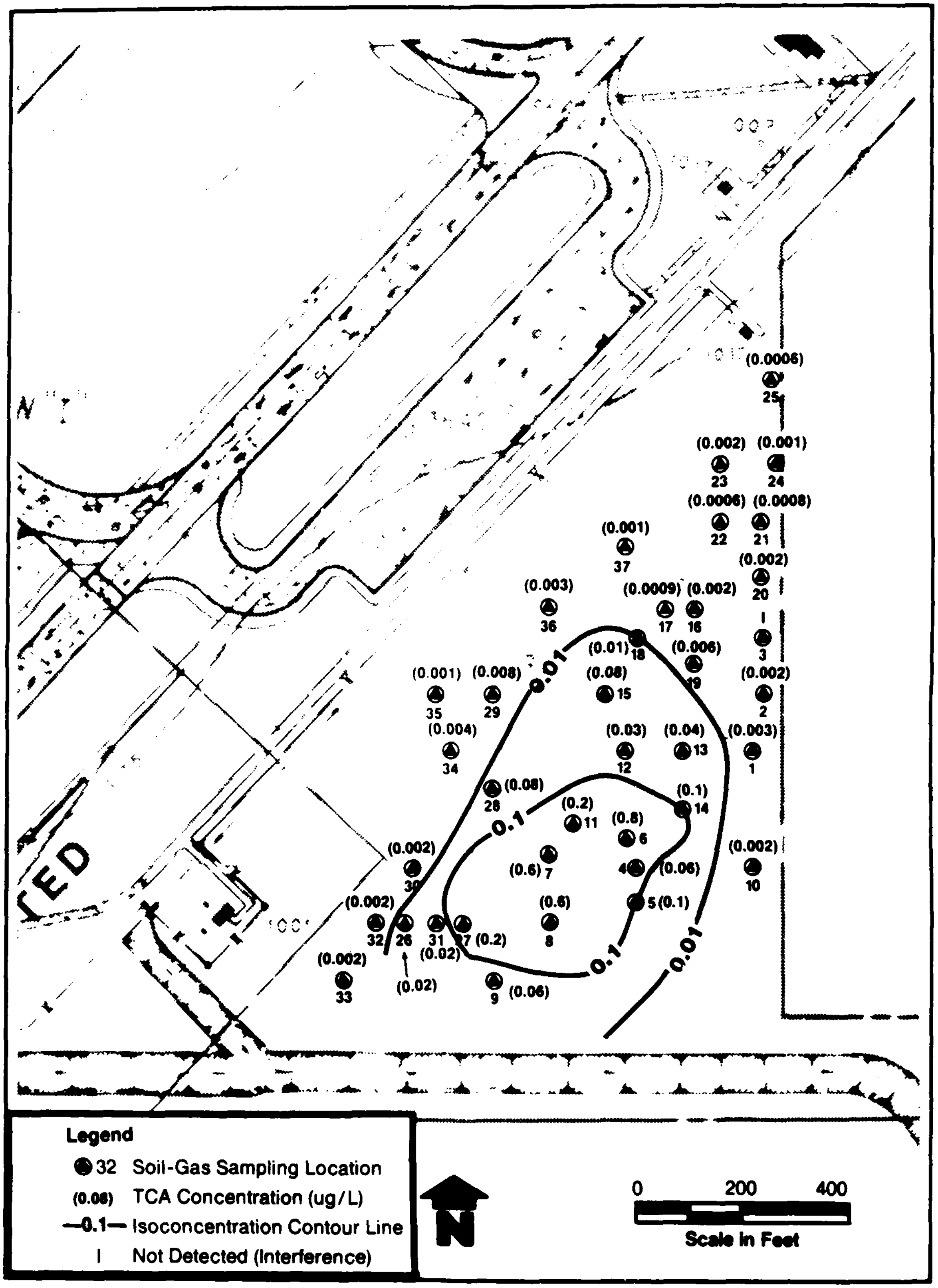

FIGURE 4-27 ISOCONCENTRATION MAP OF 1,1,1-TRICHLOROETHANE (TCA) IN SOIL-GAS, POL AREA, LUKE AFB, AZ

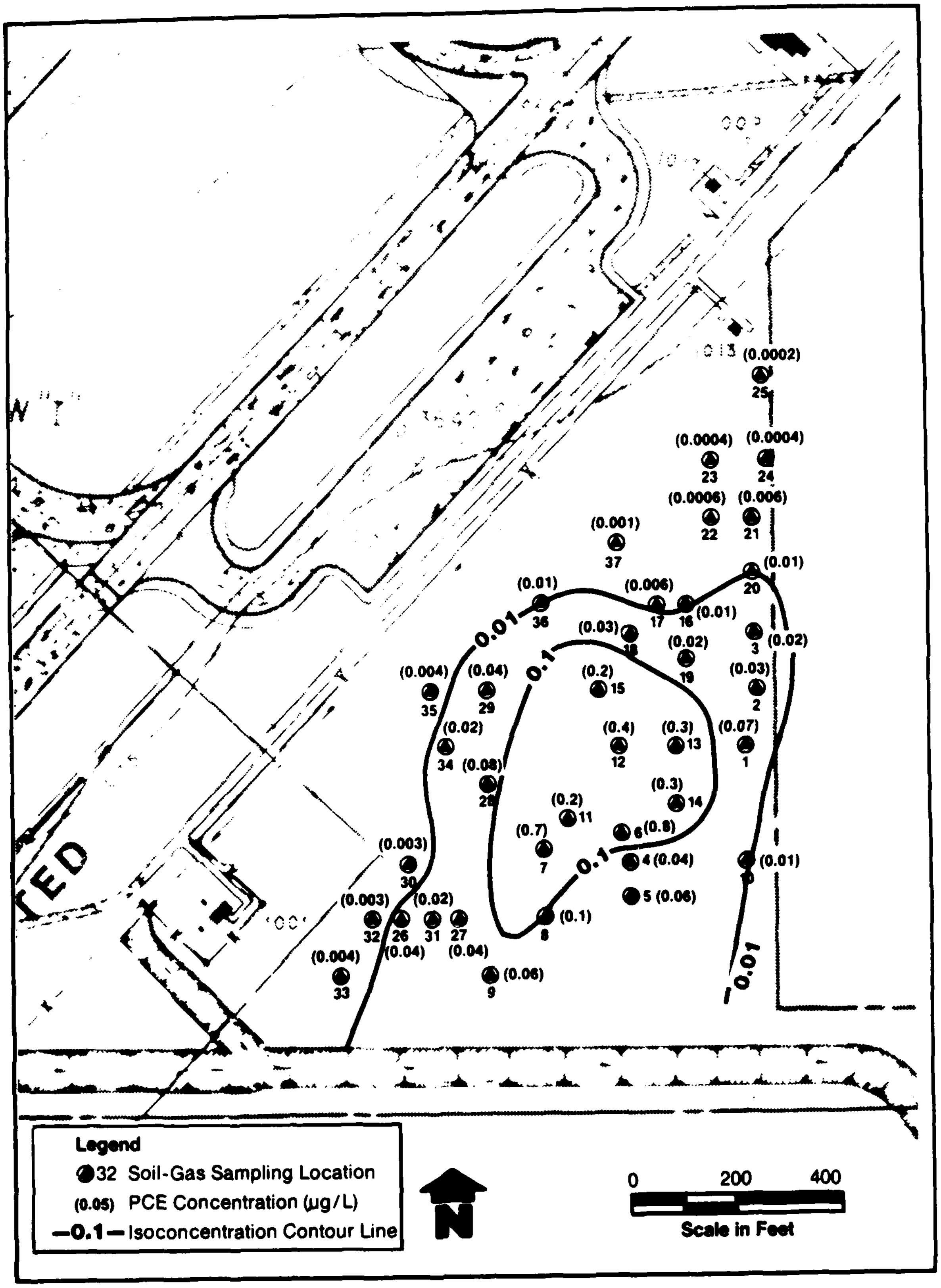

FIGURE 4-28 ISOCONCENTRATION MAP FOR TETRACHLOROETHENE (PCE) IN SOIL-GAS, POL AREA, LUKE AFB, AZ

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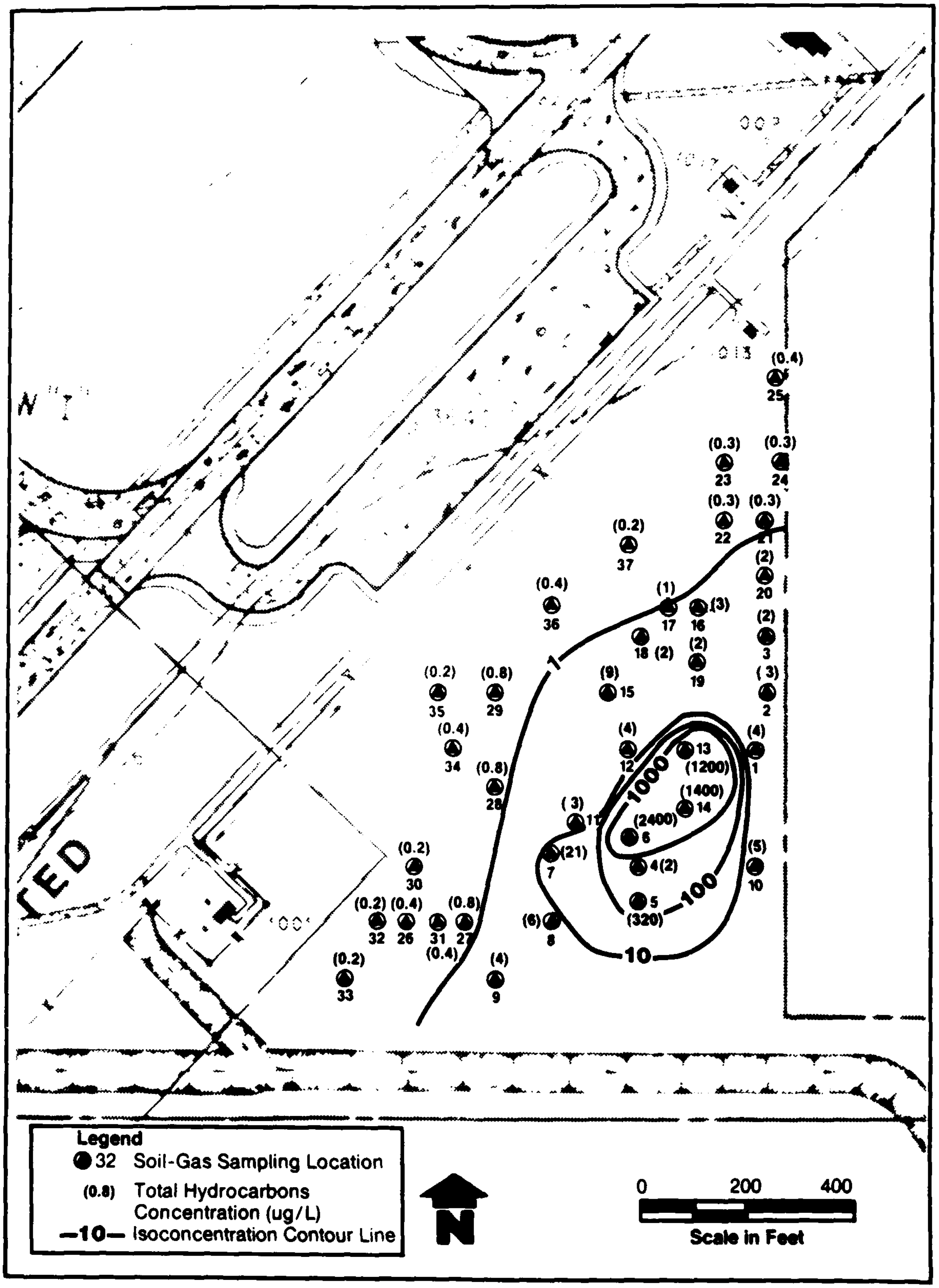

FIGURE 4-29 ISOCONCENTRATION MAP FOR TOTAL HYDROCARBONS IN SOIL-GAS, POL AREA, LUKE AFB, AZ

4.6.2.2 Soil Results

Nine 100-foot soil borings were drilled at the POL Area, and a total of 90 subsurface samples were taken. Soil samples were analyzed for VOCs and metals. See Subsection 4.5.1 (p. 4-52) for a presentation of and discussion of the metals results.

VOCs were detected only in soil borings 04-03 and 04-06 as shown in Table 4-9 (p. 4-53) and are summarized in Figure 4-30 at the appropriate locations. In soil boring 04-03, VOCs were present primarily in the 5-foot sample, which contains elevated concentrations of toluene and total xylenes. Levels of these contaminants were much lower in the 10-foot sample from the same soil boring and were not detected in lower samples with the exception of a trace of toluene found in the 60-foot sample. In soil boring 04-06, trace levels (less than 10 ug/L) of chloroform, toluene, and TCE were found in the 98-foot sample only. As discussed in Subsection 4.5.1 (p. 4-52), these results are not considered to be significant based upon low concentrations and the low number of samples with detected VOCs.

4.6.2.3 Groundwater Results

Three rounds of groundwater samples were collected from MW-104, MW-105, and MW-106. Samples were analyzed for VOCs, MEK, BNAs, pesticides/PCBs, O&G, TOC, and metals (see Tables 4-14, 4-15, and 4-17, pp. 4-62, 4-64, and 4-65, respectively). The only BNA compound detected was BEHP in MW-106 during round 3 and in MW-104 during round 2 at concentrations below applicable standards. As discussed in Subsection 4.5.4 (p. 4-61), these results may represent sampling artifacts. No pesticides/PCBs or MEK were detected. The only VOC detected was acetone during rounds 1 and 2 in MW-105. Because there are no drinking water standards for acetone, these results are not considered to be significant.

The results mentioned above and the O&G results are summarized in Figure 4-30 at the associated sampling locations. Oil and grease was detected at 1.0 mg/L in MW-104. This result is not considered to be significant because of the low concentration and the fact that O&G was not found in a field duplicate of the same sample, nor during other rounds in MW-104, nor in other POL Area monitor wells. TOC and metals concentrations are considered to be background levels (or, in the case of metals, the result of sediment in unfiltered samples) as discussed in Subsections 4.4.7 (p. 4-44) and 4.5.4 (p. 4-61).

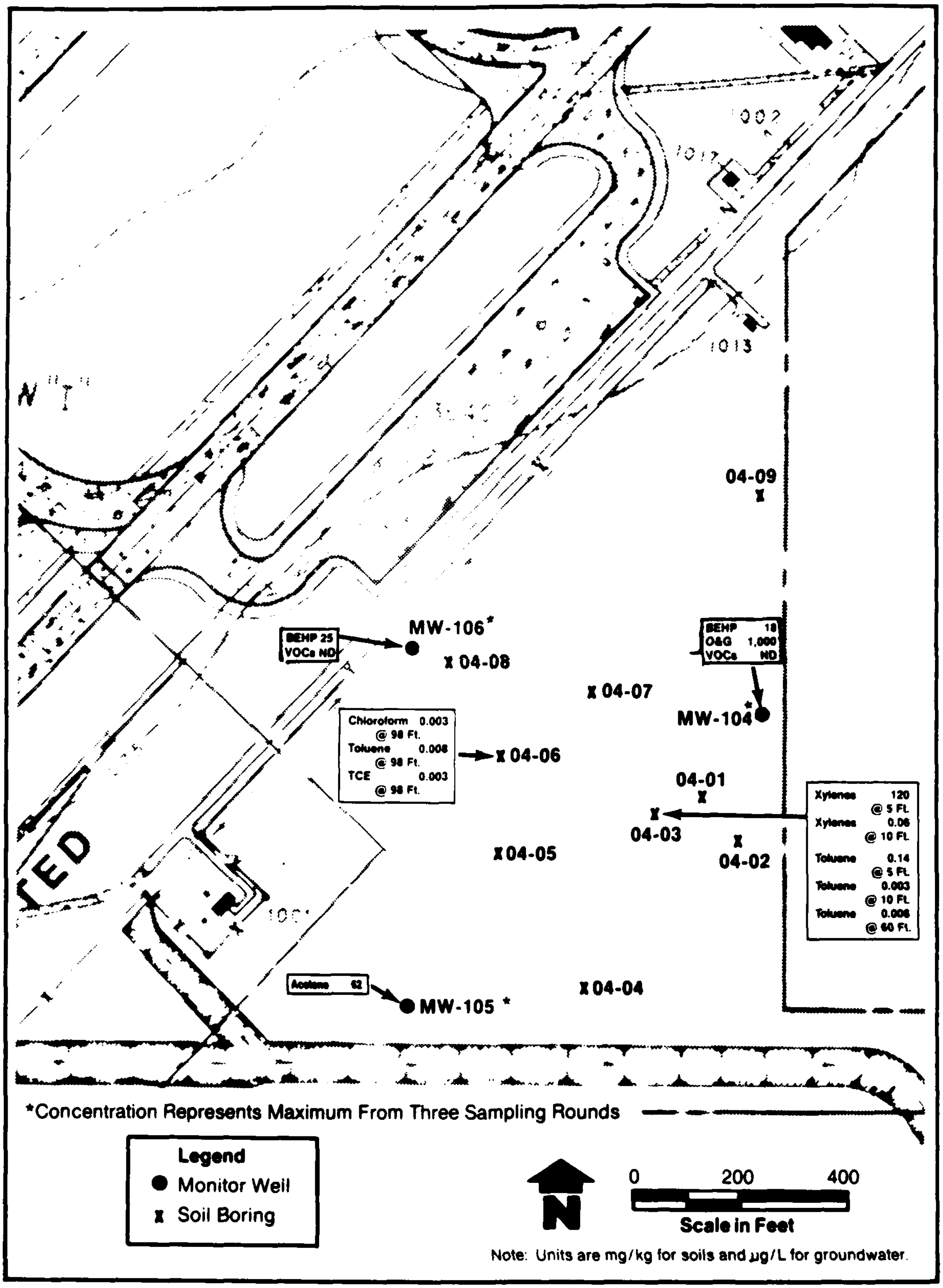

FIGURE 4-30 SUMMARY OF COMPOUND CONCENTRATIONS DETECTED IN SOILS AND GROUNDWATER AT THE POL AREA, LUKE AFB, AZ

4.6.2.4 Phase II Stage 1 Results - POL Area

As part of the Phase II Stage 1 study, subsurface soils were collected from 20-foot soil borings at the POL Area. Locations of those samples are shown in Figure 4-31, and the sample results are summarized in Table 4-24.

The Stage 1 VOC results are generally consistent with data obtained during the Stage 2 study, with widely scattered levels of VOCs detected. Of note is the presence of dichloroethene and dichloroethane compounds in soil boring SB-3 and the presence of chloroform in soil borings SB-5, SB-6, SB-7, and SB-8. These results probably represent isolated occurrences that were not encountered during the Stage 2 study.

Oil and grease was present at the POL Area in many of the soil samples collected during Stage 1. However, except for one shallow sample, it was detected at concentrations of 75 mg/kg or less. These concentrations are not significantly above background levels as discussed in Subsection 4.4.6 (p. 4-43). Oil and grease was not analyzed for in soils at this site during Stage 2.

4.6.2.5 Site Contamination Profile - POL Area

The following is a summary of findings at the POL Area:

- Soil-gas - Elevated concentrations of TCE, TCA, PCE, benzene, toluene, total xylenes, and total hydrocarbons were found generally centered in the south-central portion of the site. These soil-gas concentrations were not manifested as detectable soil contamination.

- Soil - No consistent significant contamination was detected, although scattered low levels of VOC contamination were found.

- Groundwater - No significant contamination detected.

4.6.3 South Fire Training Area Results

Analytical results at the SFTA were obtained for soils and groundwater. Results from the Stage 1 study are discussed below.

4.6.3.1 Soil Results

Two 100-foot soil borings were drilled at the SFTA, and a total of 40 subsurface soil samples were taken. Soil samples were analyzed for the following constituents: VOCs, metals, and O&G. Metals results, as discussed in Subsection 4.5.1 (p. 4-52), were found to fall within natural background ranges.

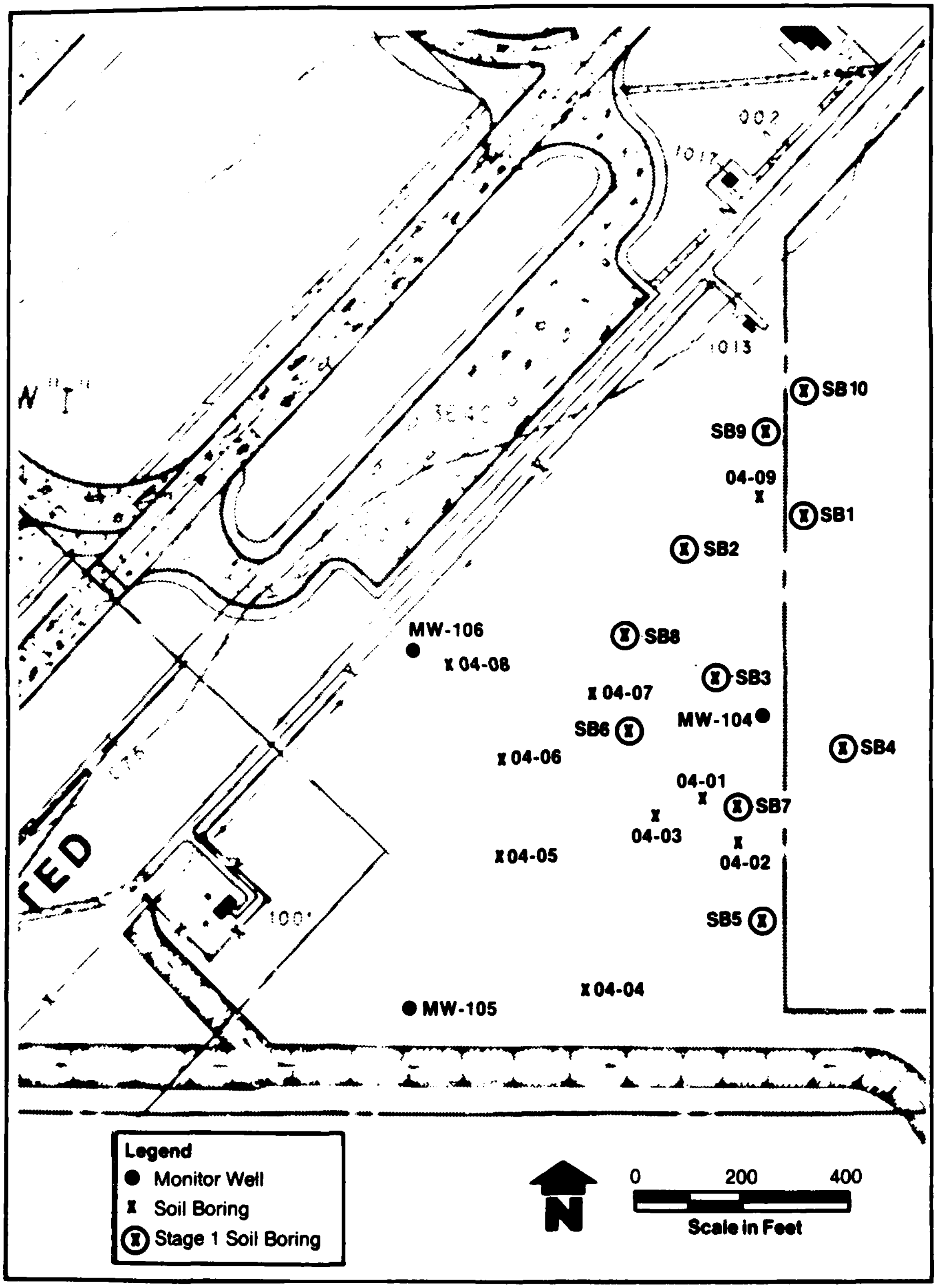

FIGURE 4-31 LOCATIONS OF SOIL BORINGS (STAGES 1 AND 2) AND MONITOR WELLS, POL AREA, LUKE AFB, AZ

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Table 4-24

Soil Analytical Summary - Stage 1, POL Trenches and Lagoon (POL Area), Luke AFB, Arizona

Soil Boring Sample No.	Sample Depth (ft)	Oil and Grease (mg/kg)	VOCs (mg/kg) 1,2-Dichloro-ethane	1,1-Dichloro-ethane	1,1-Dichloro-ethene	trans-1,2-Dichloro-ethene	Chloro-form
SB1-4	4.5-6.0	209	ND	ND	ND	ND	ND
SB1-14	19.5-21.0	16	ND	ND	ND	ND	ND
SB2-4	4.5-6.0	26	ND	ND	ND	ND	ND
SB2-15	19.5-21.0	75	ND	ND	ND	ND	ND
SB3-6	7.5-9.0	ND	0.003	ND	ND	ND	0.008
SB3-14	19.5-21.0	ND	0.012	0.014	0.010	0.011	ND
SB5-5	4.0-5.0	18	ND	ND	ND	ND	0.120
SB6-15	14.0-15.0	38	ND	ND	ND	ND	0.200
SB7-20	19.0-20.0	43	ND	ND	ND	ND	0.160
SB8-6	5.0-6.0	63	ND	ND	0.012	ND	0.035

ND - Not detected.
Note: VOCs listed in Table 3-2 (p. 3-6) but not reported here were not detected.

As shown in Table 4-9 (p. 4-53) and as summarized in Figure 4-32 at the associated sampling locations, VOCs were detected in only two samples: in soil boring 05-01, 0.005 mg/kg of TCE was found at 100 feet, and in 05-02, 0.007 mg/kg of toluene and 0.007 mg/kg of TCE were found at 98 feet. As discussed in Subsection 4.5.1 (p. 4-52), based on the low concentrations of these compounds and the lack of any vertical trends, these data are not considered to be significant.

Oil and grease results for soil borings 05-01 and 05-02 are presented in Table 4-11 (p. 4-56) and are summarized in Figure 4-32. In general, these results show O&G occurring with an irregular distribution. In soil boring 05-01, after a relatively high reading of 3,660 mg/kg at a depth of 5 feet, concentrations of O&G ranged between not detected and 32.3 mg/kg to a depth of 75 feet. Oil and grease was not detected below 75 feet. In soil boring 05-02, O&G was not detected in the top 20 feet, then occurred at concentrations ranging from not detected to 36.7 mg/kg. From 80 feet to 98 feet O&G was consistently found at concentrations ranging from [illegible] to 36.7 mg/kg. With the exception of the 3,660 mg/kg of O&G found at 5 feet in 05-01, all the other values of O&G are within generally accepted background levels as discussed in Subsection 4.4.6 (p. 4-43). The high value in soil boring 05-01 is not considered to be environmentally significant since it is an isolated occurrence. It is not associated with any high O&G concentration at depth, and the area is predominantly capped with a building and parking lots. Therefore, there is no substantive vertical migration of O&G at this site.

4.6.3.2 Groundwater Results

Three rounds of groundwater samples were collected for MW-107 and MW-108 located at the SFTA. Samples were analyzed for VOCs, MEK, BNAs, pesticides/PCBs, O&G, TOC, and metals. No VOCS, pesticides/PCBs, O&G, or MEK were detected. The only BNA compound detected was BEHP in MW-108 at 12 ug/L as shown in Figure 4-32. Since it appeared during only one round at much less than the drinking water standards, this result is not considered to be significant.

As discussed in Subsections 4.4.7 (p. 4-44) and 4.5.4 (p. 4-61), the levels of TOC and most metals detected are considered to fall within background ranges for these parameters. The exceptions are cadmium and mercury, which occurred slightly above MCLs in MW-108 for single samples. Those concentrations are attributed to sediment in unfiltered samples.

4.6.3.3 Phase II Stage 1 Results - SFTA

As part of the Phase II Stage 1 study, near-surface soil samples were collected from excavation sites while construction

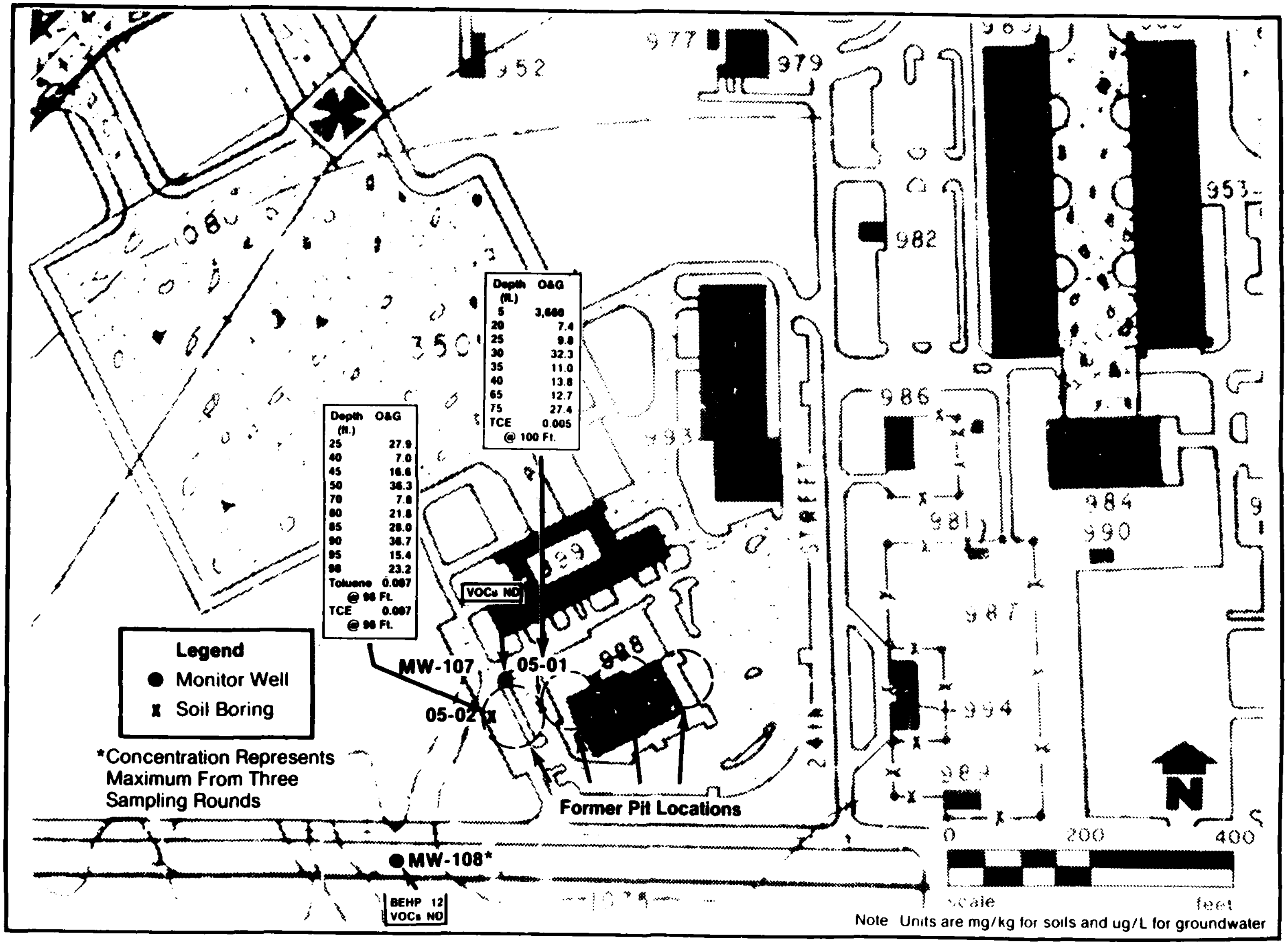

FIGURE 4-32 SUMMARY OF COMPOUND CONCENTRATIONS DETECTED IN SOILS AND GROUNDWATER AT THE SOUTH FIRE TRAINING AREA, LUKE AFB, AZ

of Building 988 was ongoing. The locations of these sampling points are shown in Figure 4-33, and the sample results are summarized in Table 4-25. The high levels of O&G at locations S1 and S2 and the concentrations of VOCs detected are considered indicative of the fact that the samples were collected from areas of oil staining within the excavation sites and probably represent localized worst-case occurrences of contamination in the near-surface soils.

4.6.3.4 Site Contamination Profile - SFTA

The following is a summary of findings at the South Fire Training Area:

- Soil - No significant soil contamination was detected at depth, although some localized areas of soil contamination were detected at Building 988. These areas of local contamination have been essentially capped with a building and parking lots.

- Groundwater - No significant contamination detected.

4.6.4 North Fire Training Area Results

At the North Fire Training Area, analytical results were obtained for subsurface soil borings and groundwater. In addition, a discussion of previous Stage 1 results is presented.

4.6.4.1 Soil Results

Four 100-foot soil borings were drilled at the NFTA: two at the Current Fire Training Area and two at the former fire training area. Soil borings 06-01 and 06-02 are associated with the former fire training area and soil borings 06-03 and 06-04 with the Current Fire Training Area (see Figure 4-34). A total of 80 subsurface samples were taken and were analyzed for VOCs, O&G, and metals. Metals results, as discussed in Subsection 4.5.1 (p. 4-52), were found to fall within natural background ranges.

VOCs were not detected in soil borings 06-03 or 06-04 (see Table 4-9, p. 4-53). In soil boring 06-01, total xylenes were found at concentrations of 68 (93) and 36 mg/kg at depths of 5 feet and 10 feet, respectively. In soil boring 06-02, MEK was detected at 14 mg/kg at 5 feet below ground surface. The results are summarized in Figure 4-35. As discussed in Subsection 4.5.1 (p. 4-52), these VOCs results are not considered to be significant due to the low concentrations and the lack of a consistent distribution pattern.

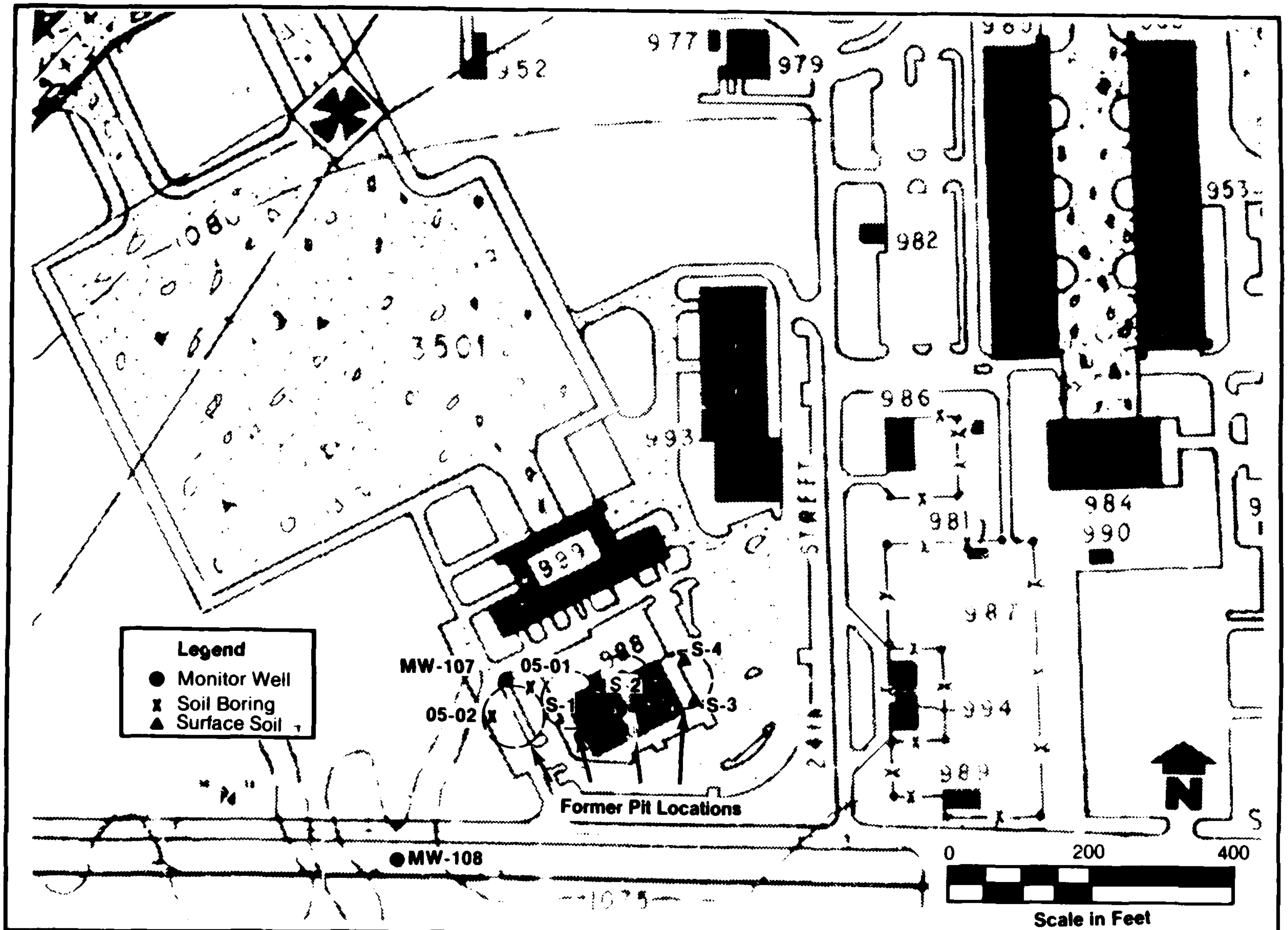

FIGURE 4-33 LOCATIONS OF SURFACE SOIL SAMPLE LOCATIONS (STAGE 1)
AND SOIL BORINGS AND MONITOR WELLS (STAGE 2),
SOUTH FIRE TRAINING AREA, LUKE AFB, AZ

Table 4-25

Soil Analytical Summary - Stage 1,
South Fire Training Area,
Luke AFB, Arizona

Sample	Approximate Depth (feet)	Oil and Grease (mg/kg)	VOCs (mg/kg) 1,1,1-Trichloroethane	Chloroform	Trichloroethene	Bromodichloromethane
S-1	1	14,600	0.004	0.162	0.022	0.003
S-2	2	36,500	ND	0.023	ND	ND
S-3	2	1,250	ND	ND	ND	ND
S-4	1	197	0.002	0.057	0.016	0.001

Note: VOCs listed in Table 3-2 (p. 3-6) but not reported here were not detected.

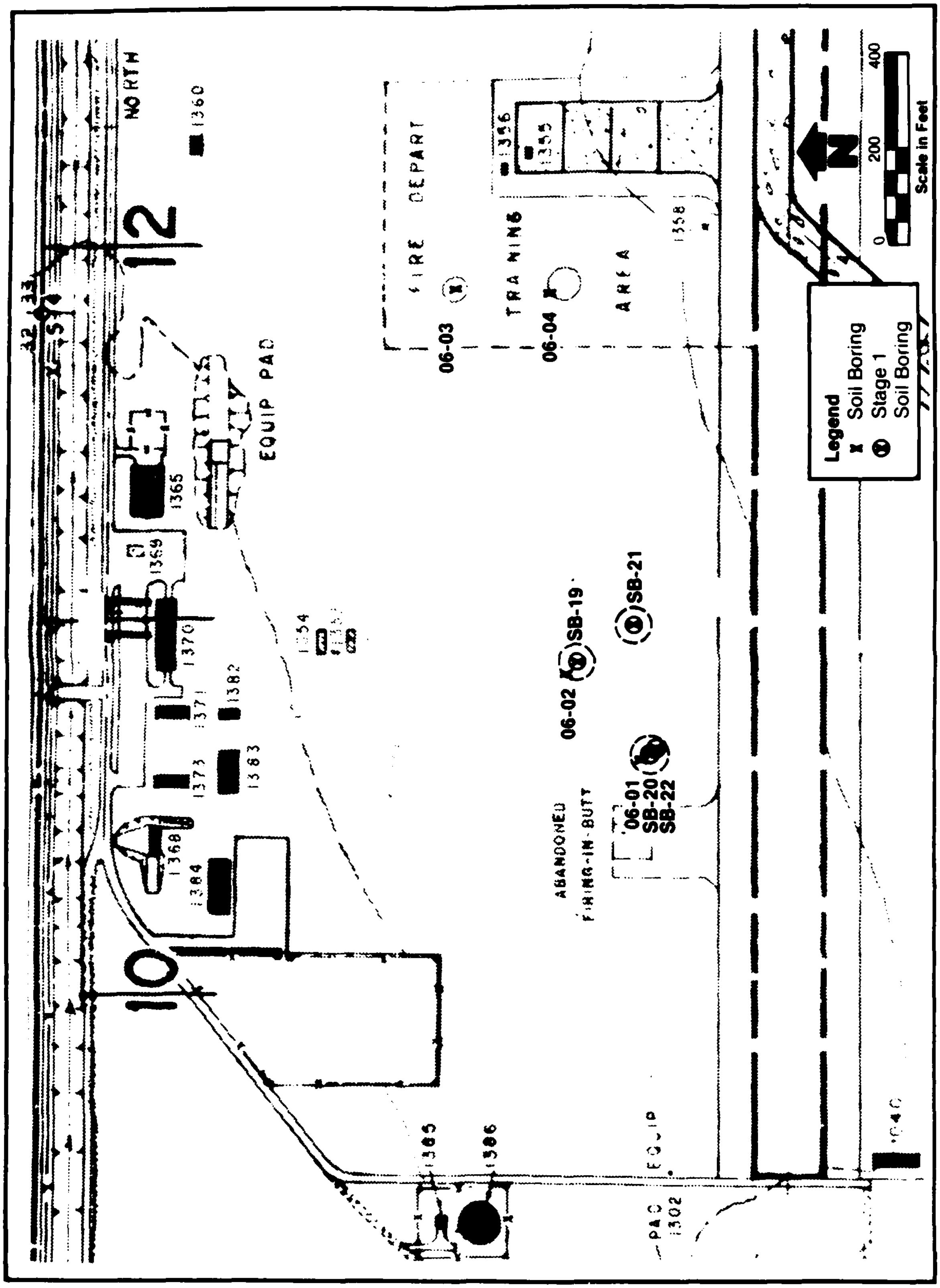

FIGURE 4-34 LOCATIONS OF SOIL BORINGS (STAGES 1 AND 2), NORTH FIRE TRAINING AREA, LUKE AFB, AZ

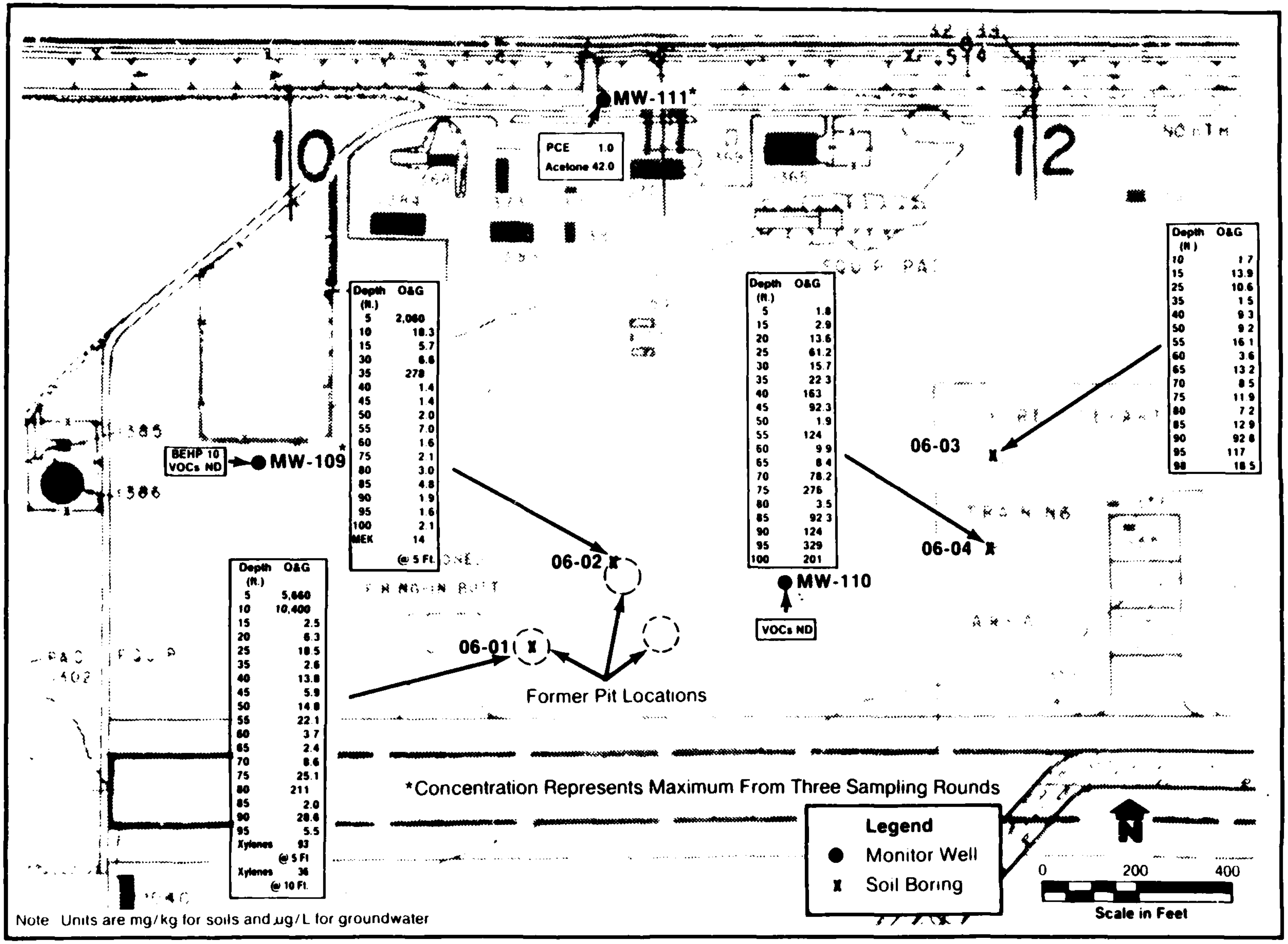

FIGURE 4-35 SUMMARY OF COMPOUND CONCENTRATIONS DETECTED IN SOILS AND GROUNDWATER AT THE NORTH FIRE TRAINING AREA, LUKE AFB, AZ

Oil and grease was detected in all four soil borings (see Table 4-10, p. 4-55). In soil boring 06-01, relatively high concentrations were detected at 5 feet and 10 feet (5,660 and 10,400 mg/kg, respectively), and in soil boring 06-02, a relatively high concentration (2,060 mg/kg) was detected at a depth of 5 feet. For these two soil borings, both located at the former fire training area, low readings indicative of background levels were generally present at depths below 10 feet. (Note that anomalously high readings over 200 mg/kg were found at one location in each soil boring.) These concentrations could represent isolated zones of O&G accumulation or localized soil zones with a higher natural organic matter content.

In soil boring 06-03 located at the Current Fire Training Area, O&G levels above background are absent until depths of 90 and 95 feet where concentrations of 92.8 and 117 mg/kg were detected. As in soil borings 06-01 and 06-02, these concentrations could represent an isolated zone of O&G accumulation or a localized zone with a higher natural organic matter content.

At depths greater than 35 feet, the highest concentrations of O&G were detected in soil boring 06-04, also located at the Current Fire Training Area. Although relatively low concentrations are present above 35 feet (only one reading above 22.3 mg/kg), concentrations above 100 mg/kg were detected at 6 of 13 samples below 35 feet. Note that at the former fire training area (borings 06-01 and 06-02), O&G concentrations are higher in shallow soils than in the Current Fire Training Area (borings 06-03 and 06-04). This could be the result of differing practices at the two fire training areas. At the former fire training area, petroleum products were in direct contact with the ground prior to ignition. At the Current Fire Training Area, water is applied to the bermed area prior to the application of fuels. This practice would tend to reduce direct infiltration of petroleum products into the ground.

The O&G detected at the NFTA is not considered to be significant in terms of environmental concern. For soil borings 06-01, 06-02, and 06-03, there has been no significant vertical migration of O&G based on the predominance of background concentrations of O&G found in samples taken at depths below 10 feet. In soil boring 06-04, O&G concentrations above background levels were found at depths mostly below 35 feet. These data may be indicative of the vertical migration of O&G. However, this is also not considered to be environmentally significant considering the following factors:

- Although concentrations of O&G are above background levels in soil boring 06-04, they are relatively low (i.e., an order of magnitude less than the highest near-surface levels found at the NFTA).

- Only the heavier, less mobile hydrocarbons fraction is represented by the O&G results. The lighter, more mobile fraction (represented by VOCs) is not present in any significant concentrations at the NFTA.

- The water table is located at a depth of approximately 360 feet at the NFTA, and the geologic materials located above the water table are predominantly low-permeability, fine-grained materials (silts and silty sands). In the absence of consistent hydraulic loading at the site, downward migration of relatively immobile hydrocarbon compounds through those fine-grained materials to the water table is not expected.

4.6.4.2 Groundwater Results

Three rounds of groundwater samples were collected from MW-109, MW-110, and MW-111 located at the NFTA. Samples were analyzed for VOCs, MEK, BNAs, pesticides/PCBs, O&G, TOC, and metals. No pesticides/PCBs or O&G were detected. Metals concentrations were found to fall within the natural ranges listed in Table 4-6 (p. 4-46). The only VOCs encountered were in MW-111 including PCE at 1.0 ug/L during round 1 and acetone at 42 ug/L during round 2 as shown in Table 4-14 (p. 4-62) and as summarized in Figure 4-35. As discussed in Subsection 4.5.4 (p. 4-61), these results are not considered to be significant.

The only BNA found was BEHP at 10 ug/L during the second round in MW-109. As discussed in Subsection 4.5.4 (p. 4-61), its presence probably represents a laboratory artifact.

4.6.4.3. Previous Phase II Stage 1 Sample Results - NFTA

As part of the Phase II Stage 1 study, subsurface soil samples were collected from 20-foot deep soil borings at the NFTA. The locations of those soil borings are shown in Figure 4-34 (p. 4-103), and the sample results are summarized in Table 4-26. The Stage 1 O&G concentrations are comparable to the Stage 2 data, especially when comparing sample depths and locations (i.e., the high readings in soil boring 06-01 are from the same location and depth as the high readings from SB-20 and SB-22).

The VOCs data for Stage 1 indicated the presence of numerous compounds in the upper 20 feet of soil, none of which were detected during the Stage 2 sampling. Of the compounds detected during Stage 1, several may be considered relatively insignificant. Those compounds detected at only one location (bromomethane, 1,2-dichloropropane, trichloroethene, and vinyl chloride) probably represent isolated occurrences. However, the following compounds were detected at several locations:

Table 4-26

Soil Analytical Summary - Stage 1, North Fire Training Area, Luke AFB, Arizona

Soil Boring Sample No.	Sample Depth (ft)	Oil & Grease (mg/kg)	VOCs (mg/kg) 1,2-Dichloroethane	1,1-Dichloroethane	1,1-Dichloroethylene	Bromomethane	1,1,1-Trichloro-ethane	Chloroform	Bromodichloro-methane	1,2-Dichloropropane	Trichloroethylene	Vinyl chloride
SB 19-12	11-12	ND	ND	ND	ND	ND	0.002	0.540	0.101	ND	ND	ND
SB 19-17	16-17	300	0.004	0.002	0.021	0.013	ND	ND	ND	ND	ND	ND
SB 20-3	2-3	24,700	0.007	0.009	0.035	ND	ND	ND	ND	ND	ND	ND
SB 20-5	4-5	17,500	0.190	ND	0.015	ND	0.022	0.390	0.019	0.001	0.002	0.090
SB 20-13	12-13	350	0.001	ND	0.003	ND	ND	ND	ND	ND	ND	ND
SB 20-19	18-19	1,400	0.016	0.005	0.013	ND	ND	ND	ND	ND	ND	ND
SB 21-6	5-6	4,500	ND	ND	0.002	ND	ND	ND	ND	ND	ND	ND
SB 21-20	19-20	350	0.004	0.004	0.023	ND	ND	ND	ND	ND	ND	ND
SB 22-4	3-4	18,900	0.031	0.003	0.006	ND	ND	ND	ND	ND	ND	ND
SB 22-6	5-6	11,250	ND	ND	0.006	ND	ND	ND	ND	ND	ND	ND
SB 22-10	9-10	150	ND	ND	ND	ND	0.011	0.32	0.013	ND	ND	ND
SB 22-20	19-20	300	ND	ND	ND	ND	0.011	0.8	0.016	ND	ND	ND

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Compound	Number of Samples Where Detected During Stage 1	Concentration Range (mg/kg)
1,2-Dichloroethane	7	0.001-0.190
1,1-Dichloroethane	5	0.002-0.009
1,1-Dichloroethene	9	0.002-0.035
1,1,1-Trichloroethane	4	0.002-0.022
Bromodichloromethane	4	0.010-0.019
Chloroform	4	0.320-0.800

It should be noted that Stage 1 soil boring locations 20 and 22 are in the same pit as Stage 2 soil boring 06-01. Stage 1 soil boring 19 is in the same pit as Stage 2 soil boring 06-02. Stage 1 soil boring 21 and Stage 2 soil borings 06-02, 06-03, and 06-04 are in independent locations in or around the fire training pits.

Based on a comparison of Stage 1 and Stage 2 VOC results in the upper 20 feet of the soil profile at the former fire training area, it appears as though VOC concentrations have decreased to non-detectable levels over the 3 years between the Stage 1 and Stage 2 sampling efforts. This decrease in concentrations to levels below detection limits is thought to be due to the arid climate causing a high degree of volatilization of compounds. This decrease in VOC contamination is consistent with observations at the POL Area and the O/W Separator Canal concerning the volatilization of VOCs from soils to the soil-gas.

Based on the Stage 1 data, there was probably solvent disposal at the former fire training area, and high concentrations of VOCs would have been present in the soil in 1973 when use of those pits was discontinued. In the 10 years between 1973 and 1983, VOC concentrations would have steadily decreased, reaching the level shown during the Stage 1 study by 1984.

4.6.4.4 Site Contamination Profile - NFTA

The following is a summary of findings at the NFTA:

Former Fire Training Area:

- Soil - No significant contamination detected.
- Groundwater - No significant contamination detected.

Current Fire Training Area:

- Soil - No significant VOC contamination was detected. Below 15 feet, O&G concentrations were generally at background levels, with the exception of soil boring 06-04 where concentrations over 100 mg/kg were detected intermittently to a depth of 100 feet. These concentrations are not considered to be environmentally significant.

- Groundwater - No significant contamination detected.

4.6.5. STP Effluent Canal Results

Analytical results from the STP Effluent Canal area were obtained for soil-gas, sediments, sewage treatment effluent, and groundwater. A discussion of previous Stage 1 results is also presented.

4.6.5.1 Soil-Gas Results

Twenty soil-gas samples were taken at the STP Effluent Canal (see Appendix O for data). TCA, benzene, toluene, xylenes, and total hydrocarbons were not significantly above background levels for any samples. PCE concentrations were significantly above background levels in the northern part of the site (see Figure 4-36), with two areas of particularly elevated concentratrations: at the northern area of the lagoon and in the vicinity of locations 06, 07, 17, and 18. These locations are at the southern end of the northern group of lagoons in an area where active infiltration of water to the subsurface was apparent. A separate area of elevated PCE concentration was also found at the far southern end of the lagoon system at location 12.

TCE concentrations were, for the most part, not significantly above background levels, with the exception of two sample locations, 07 and 18. These sample locations coincide with the area of highest PCE concentrations as discussed above.

4.6.5.2 Soil Results

Four soil borings were attempted at the STP Effluent Canal using a hollow-stem auger, although these borings had to be terminated at a shallow depth (20 to 25 feet) due to auger refusal. A total of 11 subsurface soil samples were collected from these borings. In addition, six 100-foot soil borings were drilled using a Becker hammer rig, and a total of 25 soil samples were collected during this effort. Samples were analyzed for VOCs and metals. No VOCs were detected.

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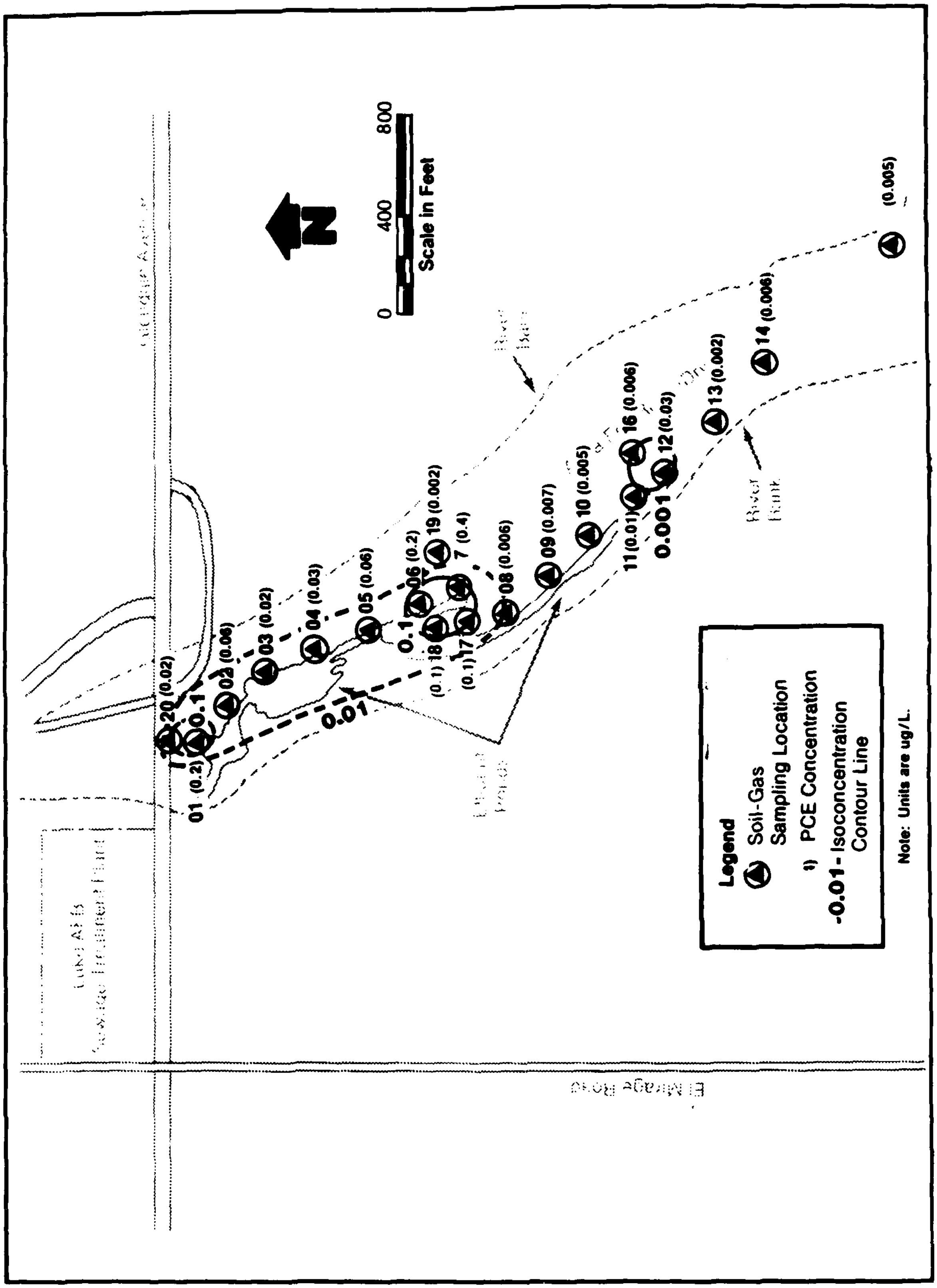

FIGURE 4-36 ISOCONCENTRATION MAP OF TETRACHLORETHENE (PCE) IN SOIL-GAS, STP EFFLUENT CANAL, LUKE AFB, AZ

Metals results (see Table 4-13, p. 4-59) are generally consistent with what was found at the other four Luke AFB sites. The exception, however, is lead, which was not detected at the other sites, but which was consistently detected in subsurface soil samples. The distribution of lead in the soils and sediment at the STP Effluent Canal is shown in Figure 4-37.

There are two explanations for this occurrence. Either the lead is naturally occurring in the soils or the lead is a result of loading to the soil from the STP effluent. Of these two explanations, it is more likely that the lead is naturally occurring based on the following factors:

- The concentrations detected are within the ranges of naturally occurring lead concentrations (see Table 4-6, p. 4-46), and the geologic environment at the STP Effluent Canal is significantly different from the other Luke AFB sites where lead was not found (see Subsection 4.1, p. 4-1).

- There is no pattern to the lead distribution in the soil borings. A pattern of decreasing lead concentrations with depth would occur if the source of lead were the STP effluent.

- Concentrations of lead in the STP effluent are low, ranging from not detected to 13 ug/L.

- In the three sediment samples containing lead, concentrations were comparable to the soil results. If the STP effluent were the source, lead would be expected at higher frequency and concentration.

Note that lead concentrations in groundwater at the STP Effluent Canal (in MW-101) are low, ranging from not detected to 8.2 ug/L (see Table 4-17, p. 4-67). These concentrations are comparable (even somewhat lower) than lead concentrations detected in the monitor wells located on the base and, therefore, probably represent background levels (see Subsection 4.5.4, p. 4-61). Therefore, even if the STP effluent is contributing to the lead concentrations in soils, there appears to be no impact on groundwater quality.

Note also that nickel occurs at somewhat higher concentrations at the STP Effluent Canal when compared with other Luke AFB sites. However, it did not occur in the effluent; this is probably related to differences in the geologic environment.

The results for all other metals also represent naturally occurring background levels consistent with the other Luke AFB sites.

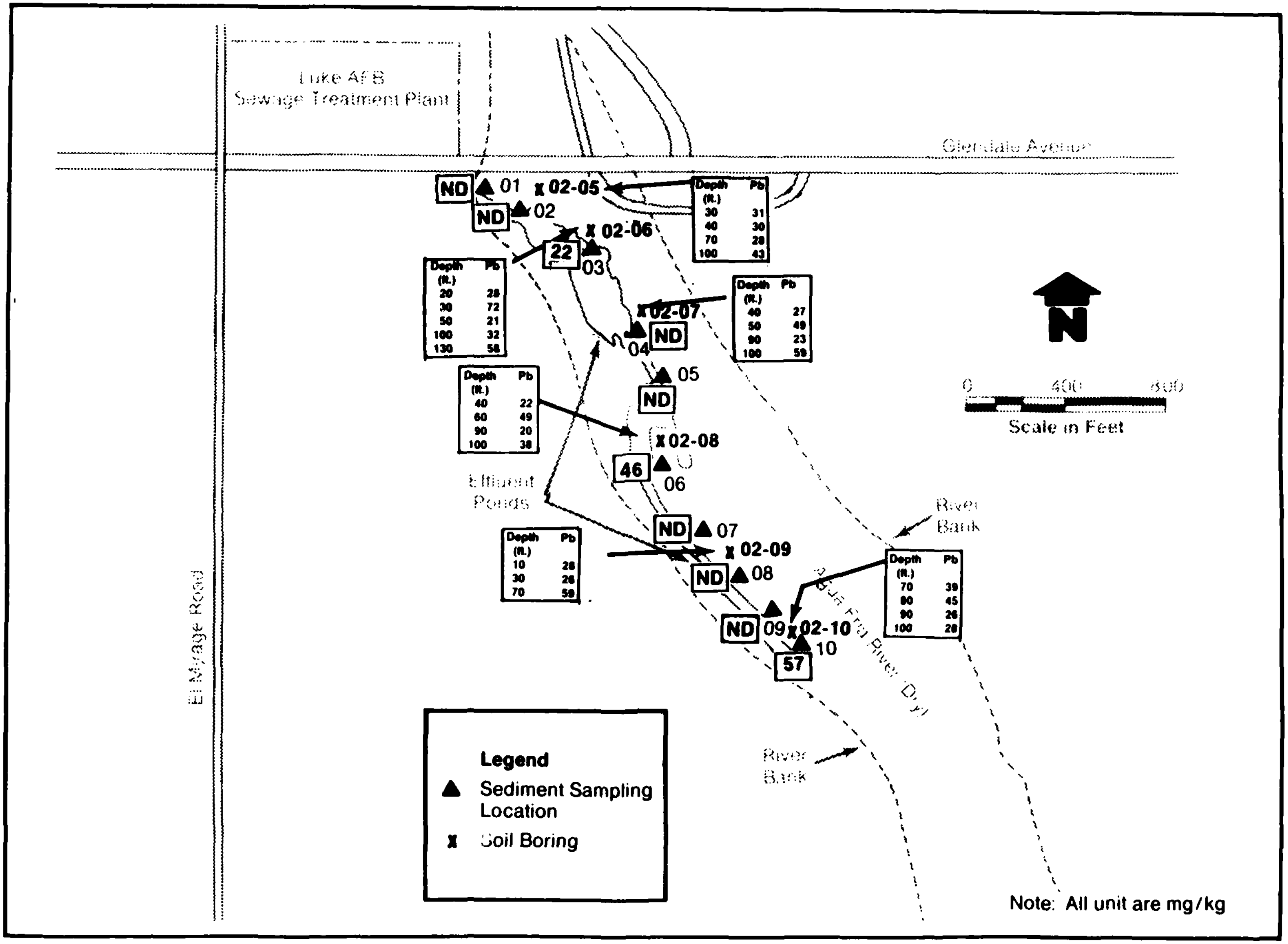

FIGURE 4-37 LEAD CONCENTRATIONS IN SOIL AND SEDIMENT, STP EFFLUENT CANAL, LUKE AFB, AZ

4.6.5.3 Sediment Results

Ten sediment samples were collected at the STP Effluent Canal and were analyzed for VOCs and metals. There were no VOCs detected.

As with the metals results in soil at the STP Effluent Canal, sediment metals results also show lead concentrations not found in soil or sediment samples at other Luke AFB sites. Based on arguments presented above relative to soils results, it is likely that the lead found in the sediment at the STP Effluent Canal is naturally occurring.

The results for all other metals also represent naturally occurring background levels consistent with soil and sediment results from the other Luke AFB sites (see Table 4-13, p. 4-59).

4.6.5.4 Sewage Treatment Plant Effluent Results

Nine effluent samples from the Sewage Treatment Plant were taken during the first round of water sampling: three per day on three consecutive days as described in Subsection 3.2.2.8 (p. 3-22). These samples were analyzed for VOCs, MEK, BNAs, pesticides/PCBs, O&G, nitrate/nitrite, TOC, total Kjeldahl nitrogen (TKN), and metals. No pesticides/PCBs were found. Note that four additional samples were taken, two on 5 March 1987 and two on 6 March 1987, and were analyzed for VOCs only. These additional samples were taken in response to positive PCE results in some of the first round samples as discussed previously in Subsection 4.4.2 (p. 4-42).

The most consistent VOC detected (see Table 4-27) was acetone, with concentrations of 23 to 150 ug/L in 10 of 13 samples, although four of the ten detections are considered suspect because acetone was detected in an associated trip blank. Trace (less than 10 ug/L) amounts of chloroform, toluene, and total xylenes were found, while one sample contained 43 ug/L of MEK. PCE was detected during the initial sampling but was not found in any of the resampled effluent. Considering that neither the effluent nor the lagoons are potential drinking water sources, these concentrations are not considered to be significant, nor are they significant as a source or potential source of groundwater contamination (see groundwater discussion below).

Of the nine original samples, seven contained BEHP, the only BNA detected (see Table 4-27). As discussed previously, this compound is a component in most plastics and is commonly found as a sampling artifact. However, given the consistency with which it was found in the effluent samples and the fact that it did not occur in lab or field blanks associated with the effluent samples, it is probably present in the effluent. As

Table 4-27

Analytical Results for VOCs and BNAs, STP Effluent Samples, Luke AFB, Arizona

Analyte	Sample Number*												
	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3	4-1	4-2	4-3	4-4
<u>VOCs</u> (ug/L)													
Acetone	100	52	65	42	ND	ND	45	23	ND	150+	120+	60+	36+
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.3	ND	ND	ND
Methyl ethyl ketone	ND	ND	ND	ND	ND	ND	ND	ND	ND	43	ND	ND	ND
Tetrachloro-ethylene	3.0	ND	ND	6.0	ND	ND	1.2	ND	1.3	ND	ND	ND	ND
Toluene	ND	1.6	ND	ND	ND	ND	ND	ND	ND	2.7	2.8	ND	ND
Total Xylenes	ND	ND	1	ND	ND	ND	ND	ND	ND	5.6	5.1	ND	ND
<u>BNAs</u> (ug/L)													
Bis(2-ethyl-hexyl) phthalate	ND	12	14	13	18	57	ND	16	12	NA	NA	NA	NA

*Sample numbers are coded such that 3-2, for example, is the second effluent sample collected on the third day, etc. Corresponding sample numbers as submitted to the laboratory are reported below:
+Acetone was detected in trip blanks associated with these samples, and these data are, therefore, considered to be suspect.

1-1	02-001-E001	2-1	02-002-E001	3-1	02-003-E001	4-1	02-004-E001
1-2	02-001-E002	2-2	02-002-E002	3-2	02-003-E002	4-2	02-004-E002
1-3	02-001-E003	2-3	02-002-E003	3-3	02-003-E003	4-3	02-004-E003
						4-4	02-004-E004

NA - Not analyzed.
ND - Not detected.

Note: VOCs and BNAs listed in Table 3-2 (p. 3-6) but not reported here were not detected.

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with VOCs, these levels of BEHP are not considered to be significant in terms of environmental impact, especially when compared to the Ambient Water Quality Criteria of 4,200 ug/L.

The results for TOC (15 to 23 mg/L), O&G (2.6 to 11.2 mg/L), and nitrate/nitrite (0.31 to 0.66 mg/L) (see Table 4-28) are within the normal range for a secondary waste treatment facility such as the Luke AFB Sewage Treatment Plant. TKN results are not normally reported for treatment plants, and normal ranges were not available. TKN concentrations in the effluent ranged from 24.9 to 27.9 mg/L.

Metals results (see Table 4-29) show minor amounts of arsenic, chromium, lead, mercury, and zinc. The NPDES permit for the STP does not regulate metals so there is no direct basis for evaluation of these results. However, for purposes of comparison, it can be noted that all metals concentrations reported are less than drinking water standards (see Table 4-8, p. 4-49).

4.6.5.5 Groundwater Results

MW-101 monitors the groundwater beneath the STP Effluent Canal. Three rounds of samples were collected and were analyzed for VOCs, MEK, BNAs, pesticides/PCBs, O&G, nitrate/nitrite, TOC, TKN, and metals. No pesticides/PCBs or O&G were detected in MW-101.

The only VOC detected was PCE at 13 ug/L during the first round (see Table 4-14, p. 4-62). As discussed in Subsection 4.5.4 (p. 4-61), this result most probably represents a laboratory artifact.

The only BNA detected was BEHP at 33 ug/L during the second round. As discussed in Subsection 4.5.4 (p. 4-61), this result is not considered to be significant. Both PCE and BEHP are summarized in Figure 4-38.

Concentrations of TOC and metals were consistent with background levels as discussed in Subsections 4.4.7 (p. 4-44) and 4.5.4 (p. 4-61).

Nitrate/nitrite and TKN results for MW-101 are presented in Table 4-28. As can be seen, TKN was detected during only one sampling round at a concentration of 0.10 mg/L. This compound is not regulated for drinking water, and the concentration detected is not considered to be significant.

Nitrate/nitrite concentrations are 6.73, 7.40, and 6.76 mg/L for the three sampling rounds. These concentrations are significantly higher than those found in the effluent, which ranged from 0.31 to 0.66 mg/L. The source of the nitrate and nitrite in the

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Table 4-28

Analytical Results for TOC, O&G, Nitrate/Nitrite, and TKN, STP Effluent Canal and MW-101, Luke AFB, Arizona

Sample Number*		Total Organic Carbon (mg/L)	Oil and Grease (mg/L)	Nitrate/ Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)
1-1		20.7	8.6	0.56	27.7
1-2		17.7	11.2	0.59	27.8
1-3		21.2	9.7	0.55	24.9
2-1		19.4	7.5	0.34	26.7
2-2		22.0	4.2	0.44	27.3
2-3		22.6	5.6	0.47	26.4
3-1		15.8	3.6	0.66	26.1
3-2		16.3	2.6	0.47	27.9
3-3		15.0	4.1	0.31	26.5
MW-101	Round 1	0.978	ND	6.73	ND
	Round 2	0.700 (0.7)	ND	7.40 (6)	0.1
	Round 3	0.553	ND	6.76	ND**

*See Table 4-27 (p. 4-114) for explanation of STP effluent sample numbers.
**Nitrate interference.

ND - Not detected.
( ) - Duplicate sample.

Table 4-29

Analytical Results For Priority Pollutant Metals, STP Effluent Samples, Luke AFB, Arizona

Analyte (ug/L)	Sample Number* 1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3
Silver (Ag)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic (As)	ND	13.3	11.8	12	13	12	ND	ND	ND
Beryllium (Be)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium (Cd)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium (Cr)	22	25	32	ND	13	13	12	ND	ND
Copper (Cu)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury (Hg)	0.35	ND	ND	ND	ND	ND	ND	ND	ND
Nickel (Ni)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lead (Pb)	13	9.1	8.6	8.6	7.2	5.4	ND	ND	ND
Antimony (Sb)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium (Se)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium (Tl)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc (Zn)	52	47	45	79	56	52	ND	30	28

*See Table 4-27 (p. 4-114) for explanation of STP effluent sample numbers.
ND - Not detected.

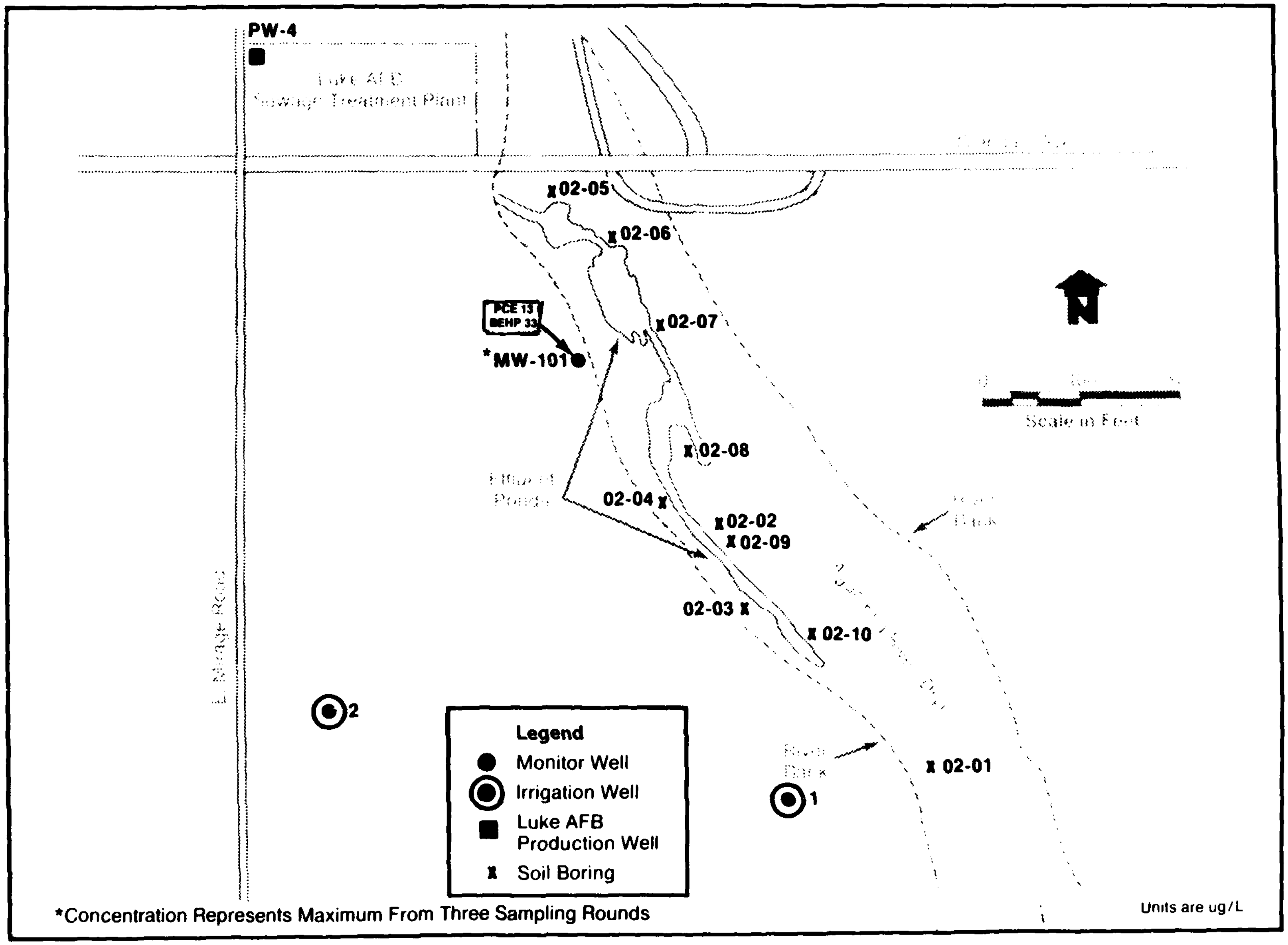

FIGURE 4-38 SUMMARY OF COMPOUND CONCENTRATIONS DETECTED IN GROUNDWATER AT THE STP EFFLUENT CANAL, LUKE AFB, AZ

groundwater may be from oxidation of nitrogen compounds (those analyzed as TKN) in the effluent. Any other source is unlikely because localized groundwater mounding at the STP Effluent Canal results in a radial flow pattern, with groundwater flowing away from the site in all directions. Although the nitrate/nitrite will migrate with the groundwater flow, concentrations of nitrate/nitrite will decrease with increased distance from the source (the STP Effluent Canal lagoon system). This decrease will occur because of dispersion, and consequent dilution and may be augmented by biodegradation.

The MCL for nitrate is 10 mg/L. Since nitrate is combined with nitrite in the analyses, a direct comparison between the nitrate/nitrite results and the MCL cannot be made. However, nitrate levels in the effluent are equal to or less than the nitrate/nitrite results, and a comparison between the MCL and the effluent nitrate/nitrite results is, therefore, conservative.

4.6.5.6 Previous Phase II Stage 1 Results

As part of the Phase II Stage 1 study, one effluent sample was collected from the STP for analysis of VOCs and phenol. Sample results are summarized in Table 4-30. The Stage 1 results are not readily comparable to the Stage 2 results and probably reflect variable influent chemistry at the STP.

4.6.5.7 Site Contamination Profile - STP Effluent Canal Area

The following is a summary of findings at the STP Effluent Canal Area:

- Soil-gas - Elevated levels of PCE and, to a much less extent, TCE were detected. The soil-gas concentrations are not associated with any soil contamination.
- Soil - No significant contamination detected.
- Sediment - No significant contamination detected.
- Effluent - May act as a source of nitrate/nitrite in groundwater.
- Groundwater - Nitrate/nitrite detected at concentrations below MCL for nitrate (10 mg/L).

4.6.6 Base Production Well Sampling Results

4.6.6.1 Discussion of Results

Three rounds of samples were collected from the operational Luke AFB production wells (PW-1, PW-4, PW-7, PW-9, PW-10, and

Table 4-30

Summary of Water Quality Data - Stage 1, Sewage Treatment Plant Effluent, Luke AFB, Arizona

Analyte	Effluent (ug/L)
Phenol	5.0
1,2-Dichloroethane	2.9
Chloroform	2.0
Bromodichloromethane	0.15
Trichloroethene	0.63

PW-11). These samples were analyzed for VOCs, MEK, BNAs, pesticides/PCBs, O&G, TOC, metals, radiological parameters, and dibromochloropropane (DBCP). No pesticides/PCBs, MEK, or DBCP were detected. TOC and metals were found at levels characteristic of background levels (see Subsections 4.4.7 (p. 4-44) and 4.5.4 (p. 4-61)).

The only VOCs detected were bromodichloromethane at 2.4 ug/L and dibromochloromethane at 6.8 ug/L in PW-4 during the first sampling round only (see Table 4-14, p. 4-62). These compounds are commonly formed during the chlorination of drinking water supplies, which typically have naturally occurring concentrations of bromine. The sampling location for PW-4 was adjacent to the point where chlorine was added; therefore, it is likely that the presence of chlorine in the sample from PW-4 accounts for the presence of these compounds. In any case, concentrations detected are well below the MCL for these compounds (100 ug/L).

The only BNA detected (see Table 4-14, p. 4-62) was BEHP, which was found in 4 of 18 samples at concentrations between 10 and 36 ug/L. These concentrations are well below drinking water standards and are not considered to be significant. The radiological results are summarized in Table 4-31. The gamma emitters (Mn-54, Co-60, Cs-134, and Cs-137) were below detectable limits in all wells during all three sampling rounds. Gross alpha concentrations ranged from not detected to 3.8 ± 2.4 picoCuries per liter (pCi/L); gross beta ranged from not detected to 6.8 ± 4.5 pCi/L, and radium-226 ranged from not detected to 0.19 ± 0.06 pCi/L. All values found are well below the MCLs for these parameters (gross alpha at 15 pCi/L, gross beta at 50 pCi/L, and radium-226 at 5 pCi/L).

4.6.6.2 Previous Phase II Stage 1 Results

As part of the Phase II Stage 1 study, one round of groundwater samples was collected from base production wells PW-1, PW-4, PW-7, PW-10, PW-11, and PW-12. Sample results are summarized in Table 4-32.

The VOCs detected during Stage 1 were DBCP and trans-1,2-dichloroethene found only in PW-10 near the NFTA, and 1,2-dichloroethane found in PW-4 at the STP and in PW-10. DBCP was detected at 0.1 ug/L, the detection limit, during Stage 1. Its occurrence during Stage 1 was probably not related to base activities since it is associated with agricultural application of pesticides, and PW-10 is located adjacent to off-base agricultural land. Trans-1,2-dichloroethene and 1,2-dichloroethane, also detected in PW-10 during Stage 1, were not detected in soils or monitor wells associated with the NFTA.

Table 4-31

Analytical Data Summary for Radiological Parameters, Production Wells, Luke AFB, Arizona (pCi/L)

	PW-1	PW-4	PW-7	PW-9	PW-10	PW-11
Gross Alpha						
Round 1	ND	ND	1.4±1.2	1.5±1.3	1.4±1.2 (ND)	1.3±1.2
Round 2	3.8±2.4	ND	ND	ND	2.3±1.3	ND
Round 3	ND	ND	3.6±1.6	ND	ND	ND
Gross Beta						
Round 1	1.7±1.1	2.0±1.1	1.4±1.1	1.6±1.1	1.8±1.1 (2.1±1.1)	2.2±1.1
Round 2	ND	ND	6.4±1.4	1.7±1.1	1.7±1.1	2.9±1.2
Round 3	6.8±4.5	1.4±1.1	2.8±1.2	ND	2.2±1.1	2.3±1.2
Radium-226						
Round 1	ND	0.07±0.04	0.13±0.10	ND	0.19±0.05 (0.09±0.05)	0.12±0.06
Round 2	0.14±0.05	0.19±0.06	0.08±0.04	ND	ND	ND
Round 3	ND	ND	ND	ND	ND	0.17±0.04

All gamma emitters (Mn-54, Co-60, Cs-134, and Cs-137) were not detected.)

ND = Not detected (indicates level is less than the detection limit). All detection limits for radiological parameters are shown in Appendix H.

( ) = Field duplicate.

The error given is the probable counting error at 95 percent confidence level.

Table 4-32

Summary of Water Quality Data - Stage 1, Base Production Wells, Luke AFB, Arizona (ug/L)

Production Well	DBCP	Lead	Oil and Grease	Gross Beta[1]	Gamma[1]	VOCs 1,2-Dichloroethane	VOCs trans-1,2-Dichloroethene
PW-1	ND	NA	NA	NA	NA	NA	NA
PW-4	ND	NA	ND	34±4	38±4	1.4	ND
PW-7	ND	NA	NA	NA	NA	NA	NA
PW-10	0.1	NA	ND	NA	NA	10.8	100.0
PW-11	ND	50	ND	NA	NA	ND	ND
PW-12	ND	NA	NA	NA	NA	NA	NA

[1]picoCuries per liter.
NA - Not analyzed.
ND - Not detected.

Note: VOCs listed in Table 3-2 (p. 3-6) but not reported here were not detected.

During Stage 2, none of these compounds were detected in any production well during any sampling round.

Radiologic parameters were detected in PW-4 during Stage 1 with gross beta emissions at 34 ± 4 pCi/L and gamma emissions at 38 ± 4 pCi/L. During Stage 2, gamma emissions were not detected, and the highest gross beta concentrations for the three rounds of samples was 2.0 ± 1.1 pCi/L.

Lead was detected at 50 ug/L in PW-11 during Stage 1. During Stage 2, lead was not detected during the first two sampling rounds, but was detected at 5.2 ug/L during the third.

In summary, those parameters detected during the Stage 1 study are currently not at significant levels based on the Stage 2 analytical results.

4.7 SUMMARY OF ANALYTICAL RESULTS AND SIGNIFICANCE OF FINDINGS

Generally, compounds that were detected above background levels in the various sampled media at Luke AFB fall into one of three categories: (1) probable laboratory or sampling artifacts (i.e., compounds inadvertently introduced to samples during sampling, handling, or laboratory analysis); (2) scattered occurrences of compounds that are found infrequently and at low concentrations and which do not appear in any identifiable pattern or distribution; and (3) occurrences of compounds that are found in an identifiable pattern or distribution.

The majority of compounds detected at Luke AFB fall into one of the first two categories. Occurrences of compounds that fall into the third category include:

- Various target compounds in the soil-gas at the O/W Separator Canal, at the POL Area, and at the STP Effluent Canal.

- Oil and grease in the soil at the NFTA.

- Nitrate/nitrite in the groundwater at the STP Effluent Canal.

- Petroleum hydrocarbons in the sediment at the O/W Separator Canal.

- Lead in the soil and the sediment at the STP Effluent Canal.

These occurrences are discussed below:

- <u>Various target compounds in the soil-gas at the O/W Separator Canal, at the POL Area, and at the STP Effluent Canal</u>. At all three sites surveyed, elevated concentrations of various compounds were detected in the soil-gas. These concentrations appeared in identifiable patterns, indicating the existence of a probable relationship between the particular source area and the distribution of compounds found in the soil-gas. However, neither soil nor groundwater contamination was associated with these soil-gas concentrations. VOCs that enter the subsurface volatilize to the soil-gas rather than remaining dissolved in soil moisture or adsorbed onto soil particles.

- Oil and grease in soil at the NFTA. Relatively high O&G concentrations (greater than 1,000 mg/kg) were detected at three locations, all at 10 feet in depth or shallower. At greater depths, O&G concentrations above background levels (up to 329 mg/kg) were detected consistently in one soil boring (06-04) located at the Current Fire Training Area. These concentrations are not considered to be significant in terms of oil and grease migration.

- Nitrate/nitrite in groundwater at the STP Effluent Canal. Nitrate/nitrite was detected at concentrations of 6.73, 7.40, and 6.76 mg/L in MW-101 at the STP Effluent Canal during three sampling rounds. The concentrations are below the MCL for nitrate (10 mg/L). The probable source of these concentrations is the STP effluent, which infiltrates to the water table from lagoons at the site. Concentrations of total Kjeldahl nitrogen (TKN) in the effluent ranged from 24.9 to 27.9 mg/L in the nine samples collected. Subsequent oxidation of nitrogen compounds (those analyzed as TKN) probably resulted in the formation of nitrate/nitrite.

- Petroleum hydrocarbons in sediment at the O/W Separator Canal. Concentrations of petroleum hydrocarbons were detected as expected based on visible sediment staining. Significant reduction of petroleum hydrocarbons with depth was noted in the top 12 inches of sediment. These concentrations are not considered to be significant in terms of petroleum hydrocarbons migration at the site.

- Lead in the soil and the sediment at the STP Effluent Canal. Concentrations of lead were detected in all soil samples, ranging from 20 to 72 ppb, and in three of ten sediment samples, ranging from 22 to 57 ppb. Although the STP effluent cannot be ruled out as a source, it is likely that these concentrations are naturally occurring.

SECTION 5

ALTERNATIVE MEASURES

5.1 INTRODUCTION

Based on the results of this investigation, all five sites at Luke AFB have been classified into one of three possible alternative IRP categories:

- Category I: No further action required.
- Category II: Further investigation required.
- Category III: Remedial action required.

This section contains a review of pertinent site information relevant to the discussion of these alternatives for each site as well as a discussion of appropriate alternative actions where applicable. Table 5-1 summarizes the conditions of applicability and the rationale for recommendations relative to each category.

5.2 SITE-SPECIFIC ALTERNATIVES SUMMARY

Table 5-2 summarizes the applicability of Categories I, II, and III with regard to each site. As can be seen, Category I (no further action required) is most appropriate for all Luke AFB sites.

Table 5-1

Site Classification Applicability and Rationale

Category	Conditions of Applicability	Rationale for Recommendation
I	No environmental or human health threat present; no potential for contaminant migration.	Further action not necessary.
II	Contamination present; extent and/or migration pathways are insufficiently defined to determine need for remediation.	Insufficient data available to make final site decision.
III	Contamination present; extent and/or migration pathways defined sufficiently to confirm need for site remediation; or immediate action necessary to address immediate environmental or human health threat.	Sufficient data available to confirm need for remediation.

Table 5-2

Summary of Site-Specific Applicability of Categories I, II, and III, Luke AFB, Arizona

Site	Discussion (with supporting subsection)
O/W Separator Canal	
Category I	Appropriate for application to site; no significant contamination of soil (4.6.1.2, p. 4-80), sediment (4.6.1.3, p. 4-80), surface water (4.6.1.4, p. 4-84), or groundwater (4.6.1.5, p. 4-86) detected.
Category II	Inappropriate for application to site; sufficient data exist to determine that site remediation is not necessary.
Category III	Inappropriate for application to site; data indicate no significant threat to human health or to the environment exists.
POL Area	
Category I	Appropriate for application to site; no significant contamination of soil (4.6.2.2, p. 4-93) or groundwater (4.6.2.3, p. 4-93) detected.
Category II	Inappropriate for application to site; sufficient data exist to determine that site remediation is not necessary.
Category III	Inappropriate for application to site; data indicate no significant threat to human health or to the environment exists.

Table 5-2
(continued)

Site	Discussion (with supporting subsection)
SFTA	
Category I	Appropriate for application to site; no significant contamination of soil (4.6.3.1, p. 4-95) or groundwater (4.6.3.2, p. 4-98) detected
Category II	Inappropriate for application to site; sufficient data exist to determine that site remediation is not necessary.
Category III	Inappropriate for application to site; data indicate no significant threat to human health or to the environment exists.
NFTA	
Category I	Appropriate for application to site; no significant contamination of soil (4.6.4.1, p. 4-100) or groundwater (4.6.4.2, p. 4-106) detected.
Category II	Inappropriate for application to site; sufficient data exist to determine that site remediation is not necessary.
Category III	Inappropriate for application to site; data indicate no significant threat to human health or to the environment exists.

Table 5-2
(continued)

Site	Discussion (with supporting subsection)
STP Effluent Canal Area	
Category I	Appropriate for application to site; no significant contamination of soil (4.6.5.2, p. 4-109), sediment (4.6.5.3, p. 4-113), effluent (4.6.5.4, p. 4-113), or groundwater (4.6.5.5, p. 4-115) detected.
Category II	Inappropriate for application to site; sufficient data exist to determine that site remediation is not necessary.
Category III	Inappropriate for application to site; data indicate no significant threat to human health or to the environment exists.

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SECTION 6

RECOMMENDATIONS

6.1 GENERAL RECOMMENDATIONS

Based upon the results of the IRP Phase II Stage 2 investigation at Luke AFB and as presented in Section 5, the following recommendations are made relative to site classification:

Site	Category
Oil/Water Separator Canal	I
POL Area	I
South Fire Training Area	I
North Fire Training Area	I
STP Effluent Canal	I

No further IRP action is recommended at any Luke AFB site. However, non-IRP recommended actions are presented below for two sites: the North Fire Training Area (Current Fire Training Area only) and the STP Effluent Canal Area.

6.2 NON-IRP RECOMMENDED ACTIONS AT THE CURRENT FIRE TRAINING AREA

It is recommended that the current fire training facility be modified to eliminate potential adverse environmental effects. In spite of the minimal potential for contaminant migration that currently exists (as discussed in Subsection 4.6.4, p. 4-100), continued use of the facility will result in the continued introduction of petroleum products to the subsurface. The potential for contaminant migration may increase with time, resulting in an eventual threat to the groundwater. Potential modifications could include lining the facility (so that all fluids will be contained) and installing an oil/water separator. Separated oil would be collected for reuse or proper disposal, and the separated water would be pumped to the Sewage Treatment Plant.

6.3 NON-IRP RECOMMENDED ACTIONS AT THE STP EFFLUENT CANAL AREA

It is recommended that the Sewage Treatment Plant effluent be monitored quarterly for total Kjeldahl nitrogen (TKN). This recommendation is based on the detection of nitrate/nitrite in MW-101 at the STP Effluent Canal Area.

The nitrate/nitrite concentrations were consistently below the MCL for nitrate, and as discussed in Subsection 4.6.5 (p. 4-109), the concentration of nitrate/nitrite will decrease with increasing distance from the site. However, if a significant increase in nitrogen loading to the STP effluent lagoons were to occur, the nitrate/nitrite concentrations in the groundwater would be expected to increase.

6.4 RECOMMENDED MONITOR WELL ABANDONMENT PROCEDURE

Should the monitor wells be abandoned (with State concurrence) at some future date, the procedure will be in accordance with Arizona Department of Water Resources regulations.

Arizona's regulations on well construction and licensing (Title 12, Chapter 15, Article 8) define well abandonment as filling or sealing the well so as to prevent the well from being a channel allowing vertical movement of water. The regulations require a well penetrating a single aquifer system, such as the monitor wells at Luke AFB, be filled with cement grout, concrete, or cuttings from the well to the land surface. The annular space outside the casing should be filled with cement from the land surface to a minimum of 20 feet below the land surface. Materials contaminated with toxic compounds are not to be used in well abandonment.

The owner of the well is required to notify the Department of Water Resources in writing at least 30 days after abandonment has been completed. The notification should include the well owner's name, the location of the well, and the method of abandonment.

Current regulations should be consulted at the time that well abandonment would be necessary to ensure that up-to-date regulations are being met.