INSTALLATION RESTORATION PROGRAM

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SOUTH DAKOTA AIR NATIONAL GUARD
JOE FOSS FIELD, SIOUX FALLS, SD

REMEDIAL INVESTIGATION

REPORT
FINAL

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AIR NATIONAL GUARD
INSTALLATION RESTORATION PROGRAM
REMEDIAL INVESTIGATION
114 TACTICAL FIGHTER GROUP
SOUTH DAKOTA AIR NATIONAL GUARD
JOSS FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

REPORT
FINAL

Prepared for:

Air National Guard Support Center
Andrews Air Force Base, Maryland

Prepared by:

Science Applications International Corporation

Submitted by:

Hazardous Waste Remedial Actions Program
Martin Marietta Energy Systems, Inc.

For the

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TABLE OF CONTENTS

Section **Page**

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

EXECUTIVE SUMMARY

This Remedial Investigation (RI) report describes field activities, presents and evaluates data, and provides recommendations for two sites at 114 Tactical Fighter Group, South Dakota Air National Guard (SDANG), Joe Foss Field, Sioux Falls, South Dakota. A Preliminary Assessment (Phase I Records Search) identified two sites as potential hazardous waste sites. Therefore, preliminary site studies were conducted during a Site Inspection (SI) program for the U.S. National Guard Bureau's Installation Restoration Program.

The two sites under investigation are Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area. The RI field program at the Base, which was performed during October and November 1988 and from April through July 1989, consisted of the following data collection activities:

- Groundwater probe/soil gas surveys
- Shallow seismic reflection geophysical survey (Site 1 – Underground Fuel Storage Area only)
- Drilling, soil sampling, and abandonment of soil borings, including background soil borings
- Drilling, soil sampling, installation, and groundwater sampling of monitoring wells
- Aquifer testing (Site 1 – Underground Fuel Storage Area only)
- Static groundwater measurement.

The following paragraphs describe and discuss briefly the results and conclusions of the activities conducted at each of the two sites studied during the RI at SDANG.

Site 1 – Underground Fuel Storage Area

Site 1 – Underground Fuel Storage Area includes 12, 25,000-gallon underground fuel storage tanks, all of which have been abandoned. The southern portion of the site also includes four underground lube oil storage tanks, which also have been abandoned. Results from the Preliminary Assessment (HMTC 1986) and a U.S. Environmental Protection Agency (EPA) sampling event at Site 1 – Underground Fuel Storage Area indicated the potential for contamination in the vicinity of the underground fuel storage tanks.

Results from the SI field program conducted at Site 1 – Underground Fuel Storage Area confirmed groundwater and soils contamination. Contamination was detected in the vicinity of the 12 underground fuel storage tanks and was characterized as fuel products, including petroleum hydrocarbons, benzene, ethylbenzene, toluene, and xylene isomers. The source of contamination appeared to be located in the southeastern portion of the fuel tank facility. No groundwater or soil contamination was found in the vicinity of the four underground lube oil storage tanks.

Receptors at risk at Site 1 – Underground Fuel Storage Area were identified as consumers of water from the nearby municipal water supply wells. Because of the low hydraulic gradient that exists at the site and the apparent attenuation of contamination to the soils, no immediate threat to the municipal water supply was identified based upon the current supply well pumping rates.

As a result of the SI program, volatile organic compounds (VOCs) were detected in the groundwater at Site 1 – Underground Fuel Storage Area at concentrations such that remediation was deemed necessary. Therefore, other activities were conducted at Site 1-Underground Fuel Storage Area concurrent with the RI program. A focused feasibility study (FFS) and treatability tests were conducted for the groundwater at the site which determined that air stripping was the most cost-effective method for remediation of the VOCs in the groundwater. Discharge of the treated groundwater to the Diversion Channel of the Big Sioux River was selected as the discharge method. Draft engineering design plans and specifications were prepared for the groundwater extraction and treatment system. In addition, underground storage tank (UST) removal plans and specifications are currently being prepared to remove the source of contamination at the site.

Results from the RI program confirmed the southern area of groundwater and soil contamination located in the vicinity of the underground storage tanks and also identified an additional area of contamination north of the tanks. The southern area measures approximately 280 by 160 feet at its furthest boundaries, encompassing a contaminated area of approximately 24,000 square feet. The northern area of contamination is associated with the railroad ditches and measures approximately 320 by 60 feet at its furthest boundaries, encompassing a contaminated area of approximately 17,000 square feet. Contamination in both areas of Site 1 – Underground Fuel Storage Area is found in the subsurface groundwater and soils and is characterized as both VOCs and semivolatile organic compounds (SVOCs). Elevated concentrations of inorganic compounds (i.e., lead and arsenic) were detected in the soil and groundwater; however, their presence is not thought to be site-related.

Results of the public health risk assessment for Site 1 – Underground Fuel Storage Area showed no immediate endangerment to human health from the presence of contamination at the site. No adverse noncarcinogenic effects are expected from exposure to either groundwater or soil contamination. Because of the presence of benzene and polynuclear aromatic hydrocarbons present in the groundwater, however, the excess lifetime cancer risk of hypothetical ingestion exposure to chemicals in the groundwater exceeded the acceptable range established by EPA.

Remedial actions are recommended at Site 1 – Underground Fuel Storage Area. The design plans for treatment of the groundwater at the site should be finalized so that groundwater remediation of the VOCs can begin as soon as possible. Monitoring should be conducted for the presence of SVOCs in the groundwater and in the VOC treatment system effluent. Threshold concentrations should be established for the SVOCs in the VOC treatment system effluent to determine if an add-on unit should be provided for SVOC treatment. Although there are no adverse effects expected from soil contamination at the site, removal of the contaminated soils is recommended. In addition, the UST removal plans should also be finalized and the tanks removed. Although the municipal water supply wells are not currently threatened by the contamination at Site 1 – Underground Fuel Storage Area, quarterly groundwater monitoring of existing wells MW-1-1, MW1-3, MW-1-10, MW-1-11, MW1-12, and MW1-14 is recommended until remediation has been completed so as to monitor any contamination movement and to ensure that there is no significant migration toward the municipal wells. Analytes of concern during monitoring should include VOCs, specifically benzene, toluene, ethylbenzene, and xylenes, and semivolatile organics.

Site 3 – Base Fire Training Area

Site 3 – Base Fire Training Area is a 7,800 square foot, circular area where approximately 500 gallons of off-specification fuel and oil were burned on a monthly basis from the early 1970s to mid-1987. Data collected at Site 3 – Base Fire Training Area from the SI program indicated that contaminants analyzed were not present in the groundwater and soils at the water table. Soil gas survey results did indicate localized areas of contamination in the shallow soils of the burn pit and near the drum holding area of the site. The shallow soil contamination was characterized as petroleum hydrocarbons, xylene isomers, and benzene within the burn pit and petroleum hydrocarbons, benzene, toluene, and xylene isomers adjacent to the drum holding area. The source of contamination was attributed to activities or waste handling practices at the burn pit and drum holding area.

The SI program identified receptors at risk at Site 3 – Base Fire Training Area as populations in the vicinity of the site that may be exposed to contaminants present in the surficial soils. No immediate risk of exposure through consumption of drinking water was identified at that time.

Evaluation of the data collected during the RI confirmed that localized areas of contamination exist in the surficial soils at Site 3 – Base Fire Training Area. The maximum extent of soil contamination was approximately 10 feet below land surface (BLS), within the confines of the burn pit. Results indicate that contamination has penetrated the surficial clay layer present at the burn pit. The soil contamination was characterized as VOCs and SVOCs. In addition, contamination of the surficial soils was confirmed in the vicinity of the drum holding area to depths of approximately 2.5 feet BLS. Contaminants in the soils are primarily SVOCs. No site-related groundwater contamination was detected at Site 3 – Base Fire Training Area, and no site-related inorganic compounds were detected.

The public health risk assessment results for Site 3 – Base Fire Training Area indicate that there is no immediate endangerment to human health from soil contamination. There are no adverse noncarcinogenic effects related to the soil contamination as long as the soil remains undisturbed. The excess lifetime cancer risk from exposure to soils at the site is within the acceptable range established by EPA.

Although there is no immediate threat to the groundwater at Site 3 – Base Fire Training Area, contaminants have migrated to the base of the surficial clay layer present at the site. Therefore, removal of the contaminated soil within the burn pit and drum holding areas is recommended to ensure that future contamination of groundwater does not occur.

REFERENCE

Hazardous Materials Technical Center. 1986. *Installation Restoration Program, Phase I Records Search*. South Dakota Air National Guard Base, Joe Foss Field, Sioux Falls, South Dakota. Prepared for Air National Guard Support Center, Andrews Air Force Base, Maryland. June 1986.

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1. INTRODUCTION

This report documents the Remedial Investigation (RI) performed by Science Applications International Corporation (SAIC) at the South Dakota Air National Guard (SDANG), Joe Foss Field, Sioux Falls, South Dakota, under the U.S. Department of Defense (DOD) Installation Restoration Program (IRP). The following subsections provide an overview of the IRP, discuss the findings of previous studies at SDANG, and outline the objectives of the RI performed at SDANG from November 1988 to July 1989. The RI activities were performed in accordance with the Remedial Investigation/Feasibility Study (RI/FS) Work Plan, which was approved in July 1988.

1.1 INSTALLATION RESTORATION PROGRAM OVERVIEW

Enactment of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980 required disposers of toxic and hazardous wastes to identify the location and contents of waste disposal sites and to implement actions to eliminate any hazards to the public health or the environment. The U.S. Department of Defense (DOD) recognized that defense installations have long been conducting operations involving the use and handling of toxic and hazardous materials. In response to CERCLA requirements, DOD initiated the IRP.

The objectives of the IRP are to identify, quantify, and evaluate the development of feasible remedies for environmental problems and resolve these problems and related public health hazards caused by hazardous materials use or disposal on DOD installations. The IRP consists of the following phases:

- **Preliminary Assessment** – To identify and evaluate the type and location of suspected problems associated with past hazardous waste handling procedures, disposal sites, and spill sites. This is accomplished through interviews with past and present Base employees, historical records searches, and visual site inspections. In addition, detailed geologic, hydrologic, meteorologic, land use, and environmental data for the area of study are gathered. A detailed analysis of all information obtained will identify sites of concern.
- **Site Inspection** – To acquire the necessary data to either confirm or deny the existence of suspected environmental contamination at each identified site of concern and to preliminarily assess the potential risks to human health, welfare, and the environment. The Site Inspection (SI) includes identification of specific chemical contaminants and their concentrations in soils and groundwater and determines the potential for contaminant migration through site-specific hydrogeologic determinations.
- **Remedial Investigation** – To acquire the necessary data to define the extent of confirmed environmental contamination and to continue to assess the associated potential risks to human health, welfare, and the environment. The RI quantifies the magnitude and extent of contamination at the sites and identifies the specific chemical contaminants present and their concentrations in the soils and groundwater. A determination also is

made as to the potential for contaminant migration by assessing site-specific hydrogeologic and contaminant characteristics.

- **Feasibility Study** – To select and describe a remedial action that addresses the applicable or relevant and appropriate requirements for mitigating confirmed environmental contamination at each site. The Feasibility Study (FS) considers risk assessments and cost benefit analyses, in providing the necessary data, direction, and documented supportive rationale to acquire regulatory concurrence (Federal, State, and local) with the recommended remedial alternative(s). The FS evaluates, develops, and provides recommendations for remedial actions at each site where remediation is required.
- **Remedial Design** – To provide engineering design drawings and construction specifications required to implement the recommended remedial actions contained in the FS. The implementation of the remediation plan requires appropriate regulatory acceptance.

1.2 SITE BACKGROUND INFORMATION

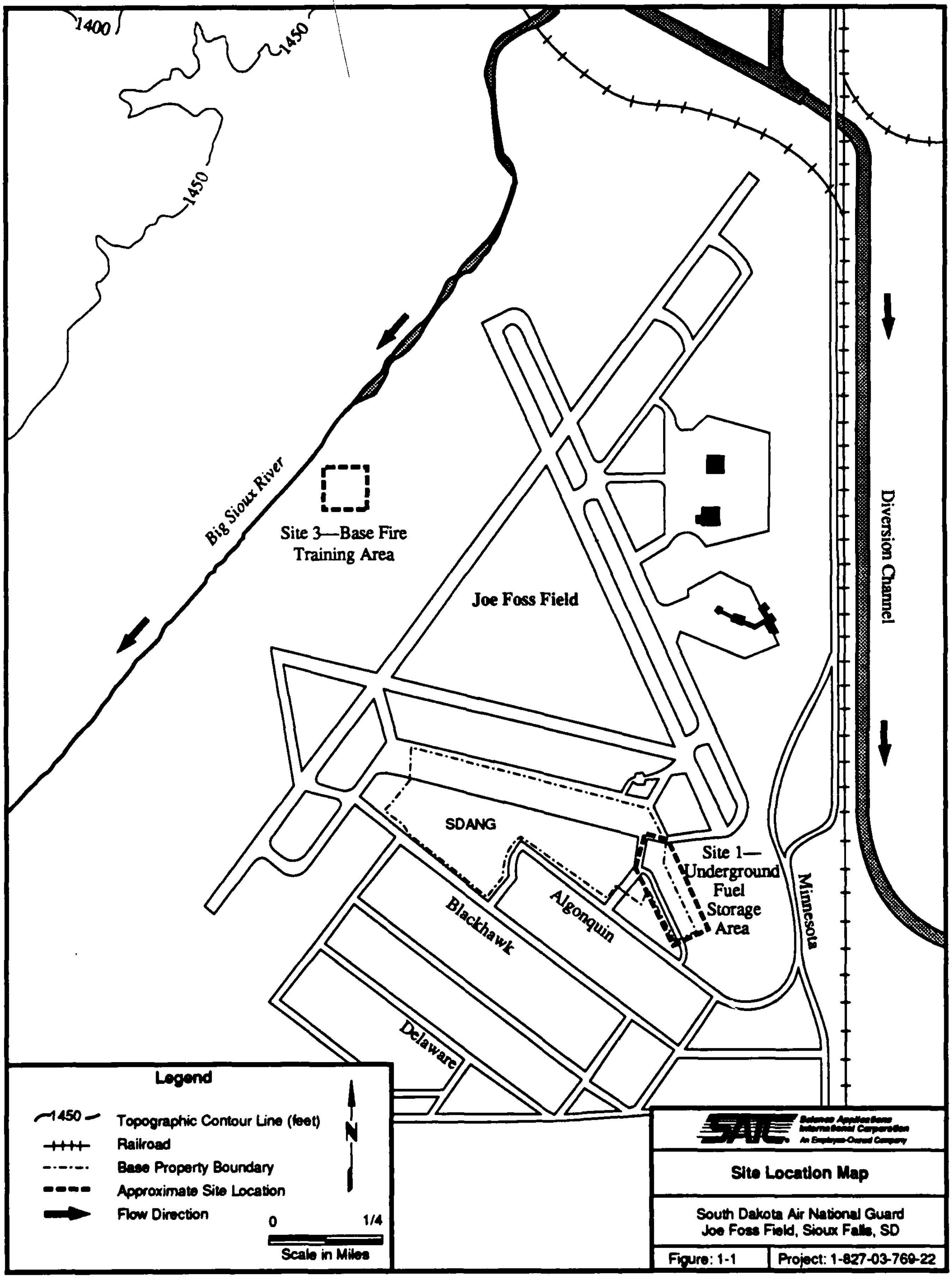
1.2.1 Preliminary Assessment

The purpose of the Preliminary Assessment was to identify the type and location of past waste disposal, handling, and spill sites at SDANG and to assess the potential for contaminant presence and migration. This phase consisted primarily of personnel interviews, a records search, and a site visit. The initial investigation, conducted by the Hazardous Materials Technical Center (HMTC 1986), established the possibility of six sites of concern. Four of these sites were eliminated from further study based on the type and small amounts of material spilled, the length of time since a spill had occurred, and the lack of visual environmental stress. Decision Documents will be prepared for the four sites which did not require further investigation. Two of the sites, however, were deemed to warrant further study: Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area (see Figure 1-1).

1.2.1.1 Site 1 – Underground Fuel Storage Area

Site 1 – Underground Fuel Storage Area is located on the east end of the Base (see Figure 1-2). The area includes 12, 25,000-gallon underground fuel storage tanks, which were used in the past to store jet fuel (JP-4), No. 2 fuel oil, and aviation gasoline. Each fuel storage tank is 8 feet in diameter and under approximately 5 feet of cover. Four underground lube oil storage tanks are located southeast of the site. These tanks were constructed during World War II, abandoned after the war, and are now empty.

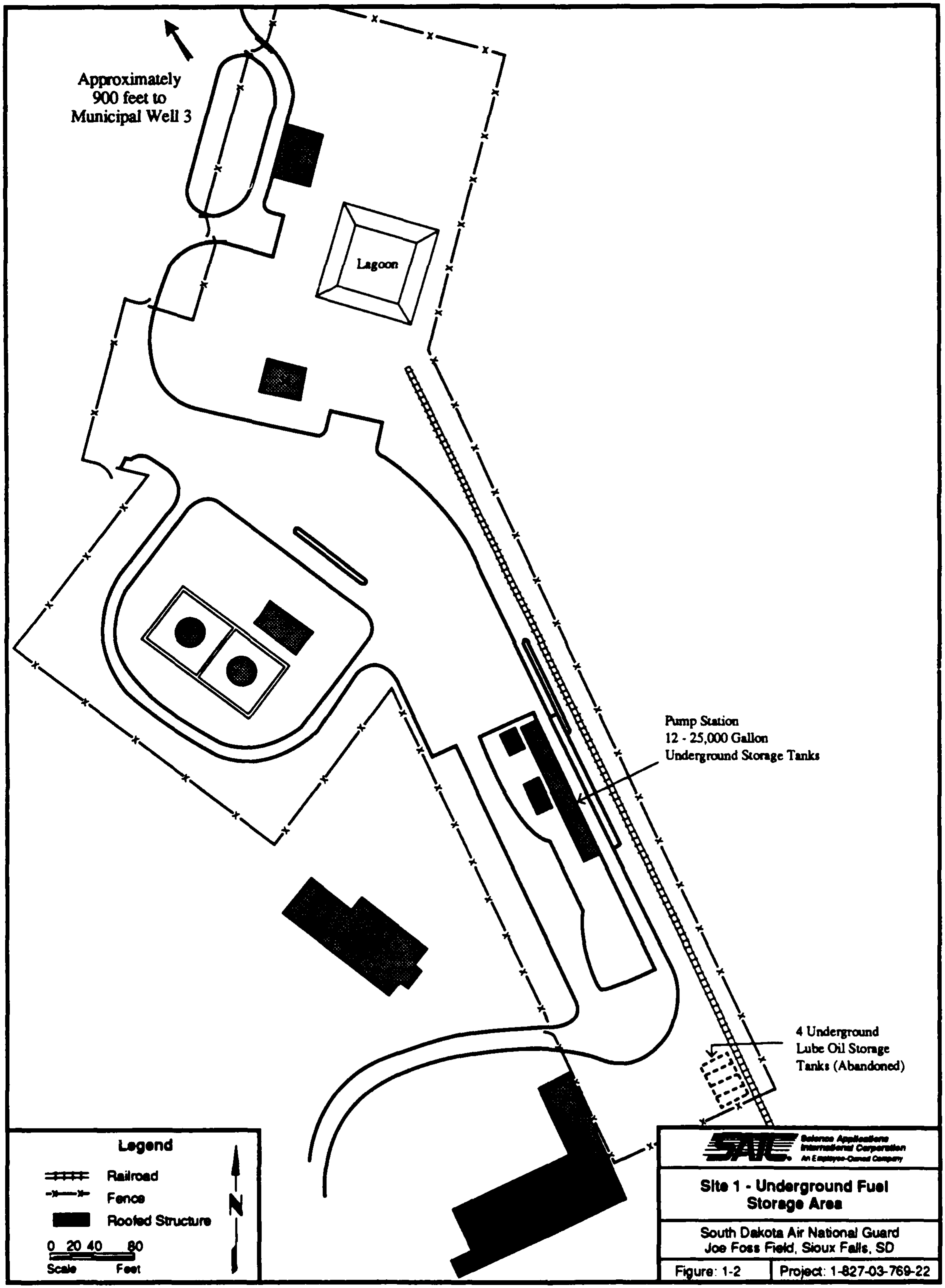
In 1983, an integrity pressure test was performed on 7 of the 12 fuel storage tanks, which were inactive at that time. Pinhole-sized leaks were detected in three of the tanks. These tanks were not in use at the time of the test but had previously contained No. 2 fuel oil and aviation gasoline. At the time of the leak detection tests, soil samples were collected from four auger



Site Location Map

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 1-1 | Project: 1-827-03-769-22



Site 1 - Underground Fuel Storage Area

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 1-2 Project: 1-827-03-769-22

borings near the inactive tanks. According to personnel performing the borings, strong petroleum odors were noticed approximately 11 feet below land surface (BLS) and 1 to 2 feet into saturated materials in three of the four borings.

The U.S. Environmental Protection Agency sampled both soil and groundwater in the area of the underground fuel storage tanks in February 1985. The results of the analysis, dated May 30, 1986, were inconclusive as to contamination with JP-4, diesel, and/or No. 2 fuel oil. The analysis also indicated the presence of arsenic, yet no source was identified.

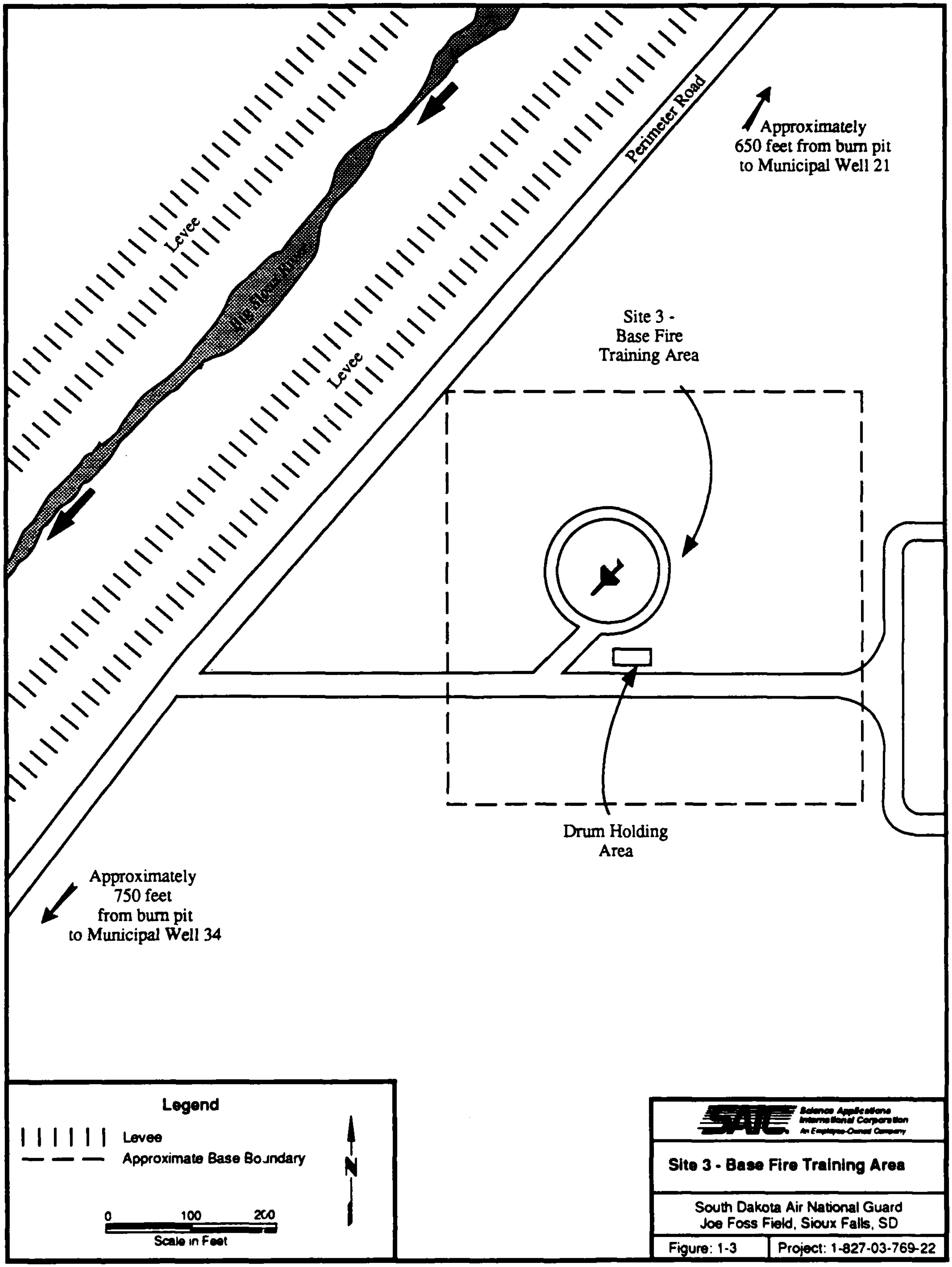
1.2.1.2 Site 3 – Base Fire Training Area

Site 3 – Base Fire Training Area is located near the base ordnance area, northwest of the main Base (see Figure 1-3). The site is approximately 7,800 square feet, roughly circular, and reportedly has an underlying liner. The integrity of the liner, however, is questionable. The soil below the Fire Training Area is a low permeability clay. Site 3 – Base Fire Training Area was used mainly by Base personnel with occasional use by city and State personnel. Approximately 500 gallons of JP-4 and waste oil were burned at the site on a monthly basis from the early 1970s until mid-1987. Fuel was transferred to the site in drums, some of which were temporarily stored before training exercises in an area adjacent to the site. Some of these drums previously contained photographic chemicals, naphtha, lube oils, and cleaning solvents before they were used to hold fire training fuels.

1.2.2 Site Inspection

The SI was initiated at the Base during October 1987. The purpose of the SI was to acquire data to determine if contamination of the groundwater and soils at the water table was present. Additional objectives of the SI program were to identify the sources and nature of contamination and to provide a preliminary assessment of the extent, magnitude, and movement of contamination at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area, if contamination was confirmed. Identification of possible receptors of potential contamination also was included in the scope of the SI. Complete details of the SI program, methods employed, results, and conclusions are provided in the Site Inspection Report (SAIC 1988). A summary of the results and recommendations of the program is presented in the following discussion.

The SI field program at SDANG consisted of groundwater probe and/or soil gas surveys, monitoring well installation, collection and analyses of soil and groundwater samples, and aquifer testing at the two sites of concern. Results from the field program confirmed that the groundwater and soils at Site 1 – Underground Fuel Storage Area are contaminated in the vicinity of the 12



Site 3 - Base Fire Training Area

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 1-3
Project: 1-827-03-769-22

underground fuel storage tanks. No contamination was found in the vicinity of the four lube oil tanks. The contamination in the area of the underground fuel storage tanks was characterized as fuel products (i.e., gasoline, JP-4), including benzene, ethylbenzene, toluene, and xylene isomers. In addition, high concentrations of petroleum hydrocarbons were confirmed. Concentrations of total hydrocarbons were as high as 8,500 micrograms per liter (µg/L) in the soil gas at Site 1 – Underground Fuel Storage Area, while concentrations of benzene, toluene, and xylene isomers, all constituents of gasoline and JP-4, were detected from the groundwater probe/soil gas survey at concentrations as high as 370 µg/L, 1,800 µg/L, and 4,900 µg/L, respectively. Groundwater data and data collected from soils at the water table correlated closely with the groundwater probe/soil gas survey results. In soils, contaminant concentrations for petroleum hydrocarbons were 99 milligrams per kilogram, ethylbenzene was 2,300 micrograms per kilogram (µg/kg), and xylene isomers was 6,300 µg/kg. Groundwater samples contained as much as 4,800 µg/L of petroleum hydrocarbons, 220 µg/L of ethylbenzene, 3,300 µg/L of xylene isomers, and 120 µg/L of benzene. No free-floating petroleum product was found at the site.

The contaminant plume was determined to extend in a north/south direction at Site 1 – Underground Fuel Storage Area, coinciding with the groundwater flow direction. Based on the groundwater probe data, the contaminant plume covers approximately 48,000 square feet. Since the SI study was limited to Base property, however, the extent of contamination to the northeast of the site was not completely defined. A sharp decline in the levels of contamination observed in this direction indicated that the contamination may not extend far beyond the Base boundary. The full extent of contamination, including any potential off-Base contamination, was investigated during the RI program. Potential receptors at risk were identified as the consumers of the water from the 33 nearby Sioux Falls water supply wells.

Additional field investigation activities were recommended for Site 1 – Underground Fuel Storage Area at the conclusion of the SI program to obtain data necessary to further define the vertical and horizontal extent of contamination at the site and beyond the installation property boundaries. Additional data collection pertaining to the influence of the nearby municipal water supply wells on contaminant migration also was recommended. A public health evaluation was recommended to determine the risk of exposure to contamination at Site 1 – Underground Fuel Storage Area.

Results of the SI program conducted at Site 3 – Base Fire Training Area indicated that localized areas of contamination exist in the shallow soils at depths of approximately 8 to 13 feet BLS. Contamination of the groundwater or the soils at the water table was not indicated by the analytical data collected. Total hydrocarbons were detected at concentrations from 760 to 2,400 µg/L in the soil gas in areas within the burn pit and the drum holding area. Contamination was characterized further (in the soil gas) as xylene isomers (72 to 150 µg/L) and benzene (120 µ/L) within the burn pit and benzene (520 µg/L), xylene isomers (80 µg/L), and toluene (120 µg/L) adjacent to the drum holding area. Trichloroethylene also was detected at Site 3 – Base Fire Training Area at very low levels ranging from 0.001 to 0.1 µg/L in the soil gas. Soil gas results indicated that the contamination, primarily constituents of fuel, was present at depths of approximately 8 to 13 feet BLS. Surficial soils were not analyzed to determine the presence or magnitude of contamination. Potential receptors at risk at Site 3 – Base Fire Training Area were identified as populations that may be exposed to contaminants present in the soils (i.e., Base personnel and the general public that have access to or are in the vicinity of Site 3 – Base Fire Training Area).

Studies to further define the horizontal and vertical extent of contamination were recommended for Site 3 – Base Fire Training Area to obtain the data necessary to determine if remedial actions are necessary, and if they are, to evaluate and select the most cost-effective remedial action alternative for Site 3 – Base Fire Training Area. Analysis of additional groundwater samples was recommended to confirm that groundwater contamination has not occurred at Site 3 – Base Fire Training Area. In addition, an evaluation of the risks to public health associated with exposure to contaminants in the surficial soils was recommended.

1.3 REMEDIAL INVESTIGATION

The objective of the RI at SDANG was to collect the data necessary for site and contaminant characterization to determine if remedial actions were required at the sites of concern. The SI provided initial data that were used to determine the presence of contamination and furnished recommendations for additional work required to complete the characterization of the sites of concern. The RI focused on two sites: Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area. Based on SI recommendations, contained in Subsection 1.2.2, specific objectives of the RI were to:

- Determine the horizontal and vertical extent and magnitude of groundwater and soils contamination at Site 1 – Underground Fuel Storage Area
- Determine the horizontal and vertical extent of soils contamination at Site 3 – Base Fire Training Area
- Validate existing data that indicate that groundwater contamination is not present at Site 3 – Base Fire Training Area

- Provide data to determine the potential for future contaminant migration to the groundwater at Site 3 – Base Fire Training Area
- Assess the public health risks associated with existing contamination at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area
- Define geologic and physical properties at the sites to evaluate potential remedial actions.

SAIC conducted various field activities to obtain the data necessary to accomplish these goals, which are summarized in Table 1-1.

1.4 ADDITIONAL IRP ACTIVITIES

Following the conclusion of the SI program and concurrent with the RI activities, additional IRP activities were conducted at Site 1 – Underground Fuel Storage Area. Although additional RI data collection activities were planned, it was determined that remediation would be necessary for treatment of the volatile organic compounds (VOCs) present in the groundwater at Site 1 – Underground Fuel Storage Area. The objective of the additional activities was to achieve early remediation of the VOCs present in the groundwater at Site 1 – Underground Fuel Storage Area, in order to reduce the potential for volatile organic contaminant migration in the direction of the City of Sioux Falls municipal water supply wells. The activities which were conducted were based on the results of the SI available at that time.

Various groundwater treatment technologies and surface water discharge locations were evaluated in order to select a remedial action alternative. The evaluation was documented in the Focused Feasibility Study (FFS) for groundwater at Site 1 – Underground Fuel Storage Area (SAIC 1989). Air stripping and discharge of the treated groundwater to the Diversion Channel downstream of the city surface water intake structures was recommended as the remedial action alternative. The FFS was submitted to the appropriate regulatory agencies for review in March 1989 and distributed for public comment in September 1989. The recommended alternative (air stripping and discharge to the Diversion Channel) was selected as the remedial action alternative for the VOCs in the groundwater at Site 1 – Underground Fuel Storage Area following completion of the FFS public comment period in October 1989.

Treatability tests were conducted in January 1989 in order to obtain data for the design of a full scale air stripper treatment unit. Details of the treatability tests are provided in the Treatability Testing Work Plan (SAIC 1989). Results from the treatability tests indicated that air stripping could be effectively used to remove the VOCs present in the groundwater at Site 1 – Underground Fuel Storage Area. The treatability tests also provided design criteria necessary for the design

TABLE 1-1. SUMMARY OF SAIC REMEDIAL INVVESTIGATION FIELD ACTIVITIES FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Site	Investigation Activity	Purpose of Activity
Site 1- Underground Fuel Storage Area	• Groundwater Probe Survey (35 sampling points)	• Define the horizontal extent and magnitude of groundwater contamination northeast (off-base) of the site.
	• Shallow Seismic Reflection Survey	• Define bedrock depth, configuration and properties, clay continuity and thickness, and location of buried high permeability channels (if they exist).
	• Shallow Soil Borings (2 borings, 55' in depth; 18 soil samples collected including 2/boring for laboratory analysis, 1 for geotechnical analysis)	• Define the vertical extent and magnitude of contamination in the vicinity of the monitoring wells installed during the SI. • Define aquifer and bedrock (>25') composition and properties.
	• Monitoring Well Drilling, Installation, and Soil Sampling (10 wells, 25' in depth; 55 soil samples collected including 2/well for laboratory analysis, 3 for geotechnical analysis)	• Define composition, magnitude, and vertical and horizontal extent of soil and groundwater contamination. • Allow verification of and correlation with groundwater probe data. • Provide data to assess the risk of the soil contamination to human health. • Define the surficial geology. • Provide a hydrologic data monitoring point (i.e., slug tests, static water levels). • Establish future monitoring points to assess the effectiveness of any remedial actions taken.

TABLE 1-1. SUMMARY OF SAIC REMEDIAL INVVESTIGATION FIELD ACTIVITIES FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Site	Investigation Activity	Purpose of Activity
Site 1 - Underground Fuel Storage Area (continued)	• Groundwater sampling - 1/89, 5/89, 7/89, (112 samples collected, 28 sampling points, 4 samples/point)	• Define and quantify groundwater contamination. • Provide data for contaminant presence/ concentration comparison over 3 sampling episodes. • Provide data for groundwater remedial actions. • Provide data to assess risk of groundwater contamination to human health. • Verify and correlate groundwater probe data.
	• Vertical and Horizontal Surveying of all New and Previously Installed Monitoring Wells in the Vicinty of Site 1	• Provide a static water level measuring point that will be used to determine groundwater flow directions before and after remediation begins.
	• 36-Hour Pumping Test	• Define values of various aquifer hydrologic parameters (e.g., transmissivity, storativity).
Site 3 - Base Fire Training Area	• Shallow Soil Borings (5 borings, 12.5' in depth; 31 soil samples collected including 2/boring for laboratory analysis, 5 for geotechnical analysis)	• Determine the magnitude and extent of soil contamination. • Provide data to determine the potential of the soil contamination to affect the future groundwater quality. • Provide data to assess the risk of the soil contamination to human health.

TABLE 1-1. SUMMARY OF SAIC REMEDIAL INVVESTIGATION FIELD ACTIVITIES FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Site	Investigation Activity	Purpose of Activity
Site 3 - Base Fire Training Area (continued)	• Monitoring Well Drilling, Installation, and Soil Sampling (1 well, 25' depth; 5 samples collected for lithologic description)	• New well to ensure that site is not affecting groundwater quality within Municipal Well #34 radius of influence. • Ensure the validity of analytical results and recommendations of the SI. • Resolve background data inconsistencies found during the SI.
	• Groundwater sampling - 5/89 (20 samples, 5 sampling points, 4 samples/point)	• Define and quantify groundwater contamination. • Provide data to assess risk of groundwater contamination to human health.
Other Activities	• Screening of All Soil Samples, *First Round* of Groundwater Samples, Field Blank Water, Decontamination Water, and Pump Test Water with Onsite Gas Chromatograph (150 samples)	• Allow selection of most appropriate soil samples to be sent to offsite laboratory. • Determine levels of contaminants in all environmental samples. • QA/QC of field measures and decontamination procedures. • Determine the total depth of soil borings from results.
	• Background Soil Boring (2 borings, 25' depth; 8 soil samples collected including 3/boring for laboratory analysis)	• Determine background levels of analytes (contaminants) not tested for during the SI. • Resolve background data inconsistencies found during the SI.
	• Surface water sampling (12 samples, 3 sampling stations, 4 samples/station)	• Determine background levels of contaminants for obtaining an NPDES discharge permit relative to the remedial actions for groundwater treatment at Site 1. Analytical results of these samples are shown in Appendix E (pages E-113 - E-115).

of a full-scale air stripper and a groundwater recovery well system. The results and design criteria are documented in the Preliminary Design Criteria Report (PDCR) (SAIC 1989).

Surface water samples were collected in July 1989 from three locations in the Diversion Channel of the Big Sioux River and analyzed for metals, total petroleum hydrocarbons, VOCs, and semivolatile organic compounds. The data were collected to determine background (in-stream) concentrations of contaminants for obtaining a National Pollutant Discharge Elimination System (NPDES) permit relative to the remedial actions for groundwater treatment at Site 1 - Underground Fuel Storage Area. The surface water sample results are provided in Appendix E. Further discussion of the surface water sample results are not provided in this report because they are not relevant to the characterization of contamination at the two sites of concern.

Draft engineering design plans and specifications were then prepared for the air stripper, groundwater recovery well system, and surface water discharge piping (SAIC 1989). After a NPDES permit for discharge is issued, remedial actions will be implemented at Site 1 - Underground Fuel Storage Area. The plans and specifications will be finalized as bid documents, a construction contractor will be selected, and remediation of the groundwater will begin.

Underground storage tank (UST) removal plans and specifications are currently being prepared so that the 12 tanks at Site 1 – Underground Fuel Storage Area can be removed (SAIC 1990).

1.5 REPORT ORGANIZATION

The remainder of this RI report contains the following sections:

- Field Program Investigation, discusses various field activities and associated procedures conducted during the investigation
- Study Area Characterization, presents an overview of the environmental setting at SDANG
- Results and Significance of Findings, presents hydrogeologic and field sampling data evaluations
- Public Health Risk Evaluation, discusses the baseline risk assessment of exposure to chemicals present at or released from SDANG
- Conclusion and Recommendations, presents the conclusions of the study's findings and recommendations for any future IRP activities.

In addition, a reference list and a list of abbreviations and acronyms are included. A separate volume of appendices detailing monitoring well completion, shallow seismic surveys, soil gas/groundwater probe surveys, laboratory methods and results, aquifer test methods, risk assessment methods and biographies of key personnel are provided.

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2. FIELD PROGRAM

This section briefly describes the Remedial Investigation (RI) field program methods that were implemented by Science Applications International Corporation (SAIC) at the South Dakota Air National Guard (SDANG) Base, Joe Foss Field, Sioux Falls, South Dakota. The methods were determined based on the results of the Site Inspection (SI) and the specific objectives of the RI, as summarized in Sections 1.2 and 1.3, respectively. A summary of the RI field program is presented in Table 2-1 indicating modifications to the activities initially planned in SAIC's Remedial Investigation/Feasibility Study (RI/FS) Work Plan (SAIC 1988), and reasons for the modifications.

2.1 GROUNDWATER PROBE/SOIL GAS SURVEY PROCEDURES

A groundwater probe survey was conducted in April 1989 at Site 1 – Underground Fuel Storage Area by Tracer Research Corporation (TRC) of Tucson, Arizona, under the direction of SAIC personnel. The purpose of the groundwater probe survey was to define the horizontal extent and magnitude of groundwater contamination northeast (off-Base) of Site 1 – Underground Fuel Storage Area that was not investigated during the SI program. The strategy was to sample groundwater on a regular pattern (approximate 50-foot centers), beginning near the area of known contamination (northeastern Base boundary in the vicinity of Site 1) and progress in the general directions of contaminant detection, toward points of no contaminant detection. Based upon contamination trends that were identified during the SI, it was assumed that a total of 25 probes would be necessary. Another area of contamination north of the storage area was discovered that warranted the use of 10 additional probes (35 total). The location of the groundwater probe samples collected at Site 1 – Underground Fuel Storage Area are shown in Figure 2-1.

A soil gas survey was conducted at Site 3 – Base Fire Training Area. The purpose of the survey was to define the horizontal extent of soil contamination in and around the burn pit and drum storage area where data from the SI were incomplete. A total of 10 soil gas samples were collected from these areas. The locations of the soil gas sampling points are shown in Figure 2-2.

Samples from both the groundwater probe and soil gas surveys were collected and processed identically with the following exceptions. Groundwater probe survey samples were collected by drilling with hollow-stem augers to the water table, approximately 12 feet below land surface. The sample was then collected by lowering tubing within the probe, evacuating groundwater with a peristaltic pump, and depositing the sample into a 40-milliliter volatile organic analysis vial. Soil gas samples were collected by hydraulically pushing the hollow steel probe 4 feet into the ground

TABLE 2-1. SUMMARY OF PROPOSED AND IMPLEMENTED REMEDIAL INVESTIGATION FIELD ACTIVITIES FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

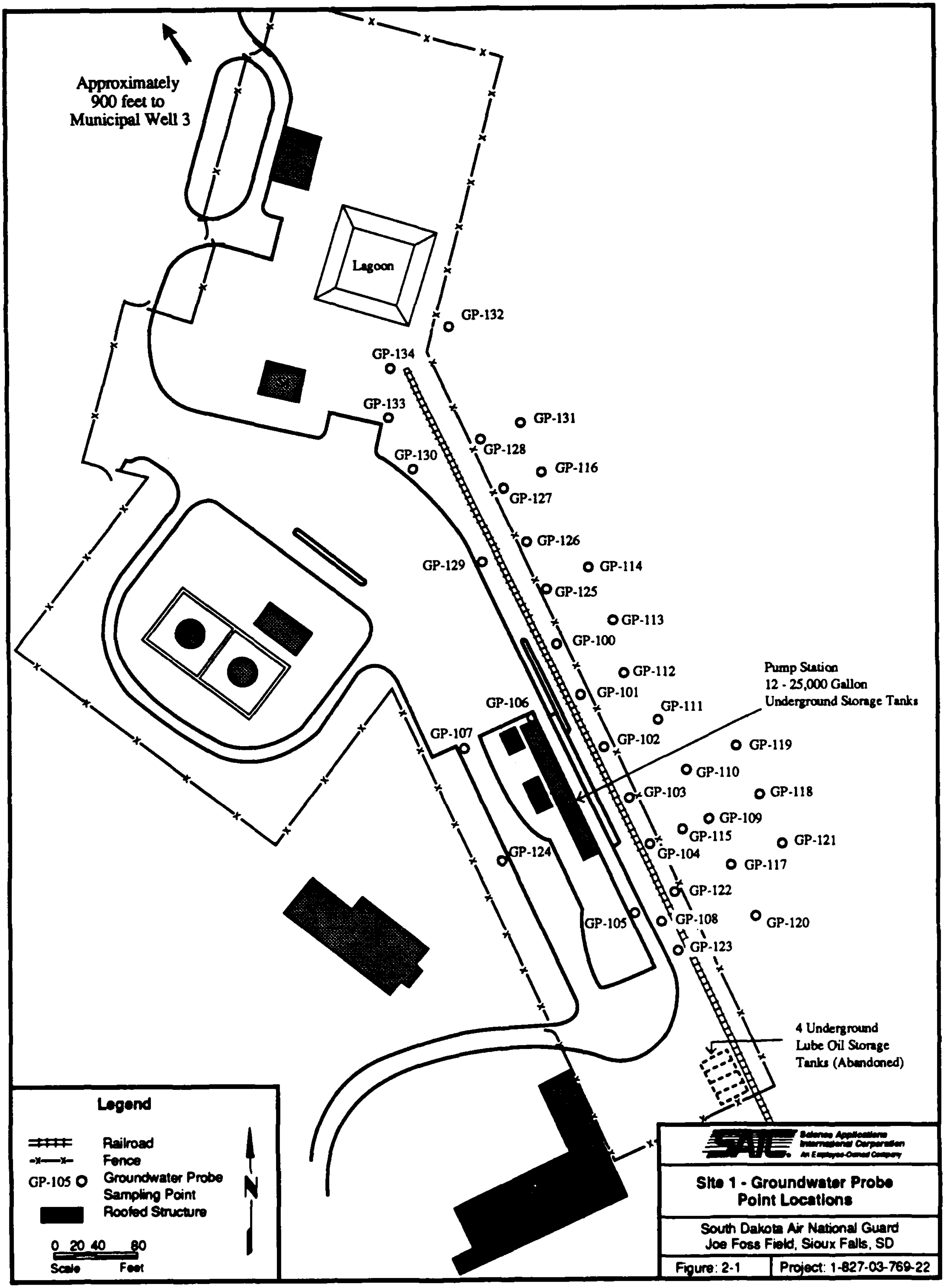
Site	Work Plan Proposed Investigation Activity	Implemented Investigation Activity	Reason for Modification
Site 1- Underground Fuel Storage Area	• Groundwater Probe Survey (15 sampling points)	• Groundwater Probe Survey (35 sampling points)	• Contamination extended off-base requiring additional sampling points to completely define the horizontal extent of contamination.
	• Shallow Seismic Reflection Survey	• Implemented as proposed	
	• Shallow Soil Borings (2 borings, 55′ in depth; 18 soil samples collected including 2/boring for laboratory analysis, 1 for geotechnical analysis)	• Implemented as proposed	
	• Monitoring Well Drilling Installation and Soil Sampling (6 wells with an option for 4 additional wells; 2 soil samples/well for laboratory analysis)	• Monitoring Well Drilling, Installation, and Soil Sampling (10 wells, 25′ in depth; 55 soil samples collected including 2/well for laboratory analysis, 3 for geotechnical analysis)	• Necessary to exercise option to install 4 additional wells due to unforseen extent of contamination.
	• Groundwater Sampling: 2 rounds for 6 new wells plus 3 wells installed by SAIC during the SI plus any optional wells	• Groundwater Sampling: 2 rounds (4/89, 7/89) for 10 new wells plus 3 wells installed by SAIC during the SI	• 4 additional wells were installed and sampled at Site 1 to help define the full extent of contamination.
	• A third round of optional groundwater sampling for volatile organic compounds for all new RI wells and the 3 wells installed during the SI.	• Option not implemented	• Sufficient data were obtained from the 2 initial rounds of groundwater sampling.

TABLE 2-1. SUMMARY OF PROPOSED AND IMPLEMENTED REMEDIAL INVESTIGATION FIELD ACTIVITIES FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Site	Work Plan Proposed Investigation Activity	Implemented Investigation Activity	Reason for Modification
Site 1- Underground Fuel Storage Area (continued)	• Optional groundwater sampling	• Groundwater sampling of SI well MW1-1, MW1-3, and MW1-4 (1/89)	• To obtain necessary groundwater data for the Feasibility Study.
	• Vertical and Horizontal Surveying of all New and Previously Installed Monitoring Wells in the Vicinty of Site 1	• Implemented as proposed	
	• 72-Hour Pumping Test and Installation of one Aquifer Test Well (~30' in depth)	• 36-Hour Pumping Test	• Aquifer test well sealed off from aquifer during installation; necessary to use existing upgradient monitoring wells to perform test. Adequate, reliable data were achieved in 36-hours.
Site 3 - Base Fire Training Area	• Shallow Soil Borings (5 borings, 12.5' in depth; 31 soil samples collected including 2/boring for laboratory analysis, 5 for geotechnical analysis)	• Implemented as proposed	
	• Monitoring Well Drilling, Installation, and Soil Sampling (1 well, 25' depth; 2 samples collected for laboratory analysis)	• Monitoring Well Drilling, Installation, and Soil Sampling (1 well, 25' depth; 5 samples collected for lithologic description)	• Laboratory analysis was unnecessary due to the lack of contamination discovered in this upgradient direction during the soil gas survey.
	• Groundwater sampling - 5/89 (20 samples, 5 sampling points, 4 samples/point)	• Implemented as proposed	

TABLE 2-1. SUMMARY OF PROPOSED AND IMPLEMENTED REMEDIAL INVESTIGATION FIELD ACTIVITIES FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

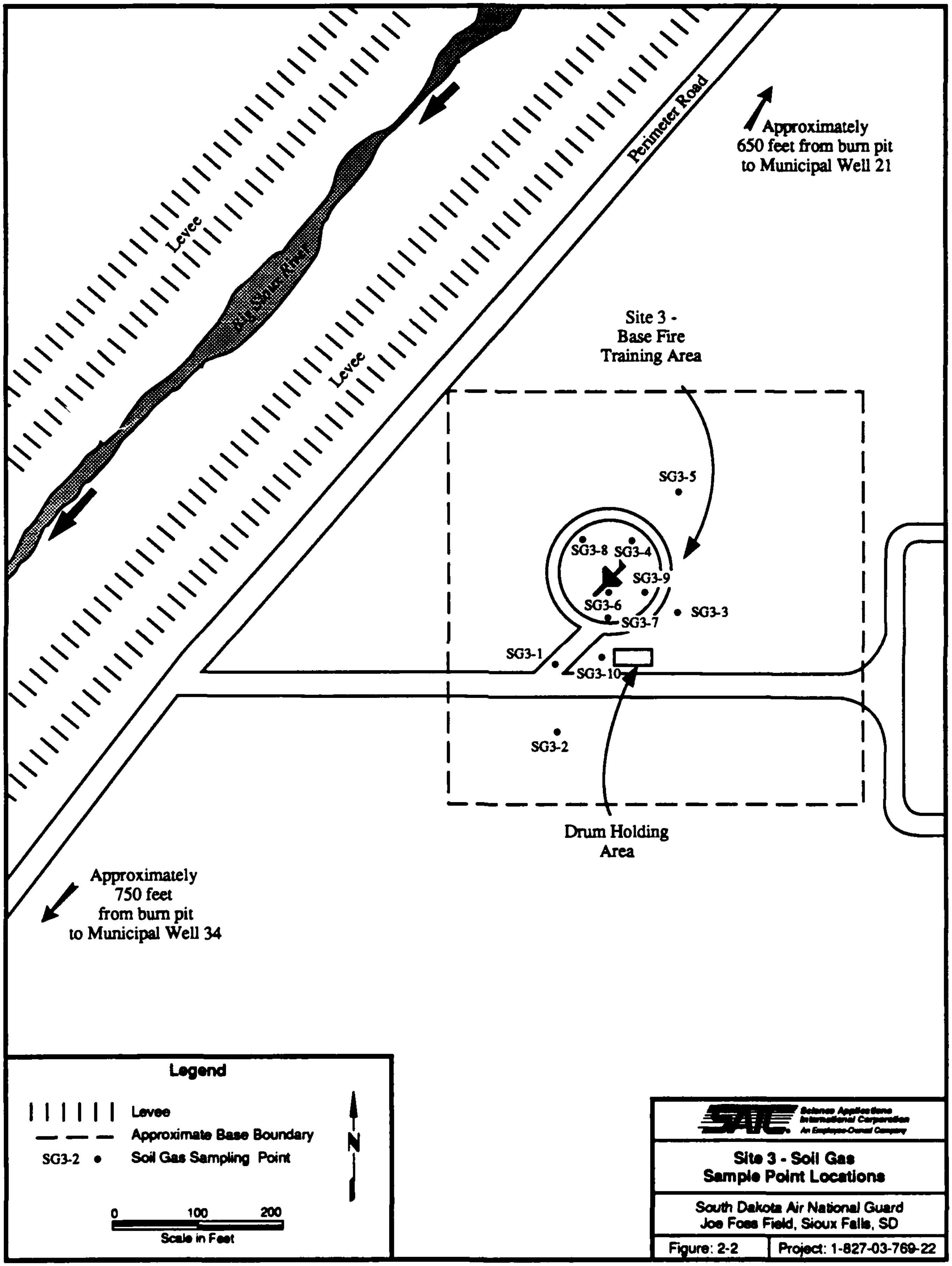
Site	Work Plan Proposed Investigation Activity	Implemented Investigation Activity	Reason for Modification
Other Activities	• Screening of All Soil Samples, First Round of Groundwater Samples, Field Blank Water, Decontamination Water, and Pump Test Water with Onsite Gas Chromatograph (150 samples)	• Implemented as proposed	
	• Background Soil Boring (2 borings, 25' depth; 8 soil samples collected including 3/boring for laboratory analysis)	• Implemented as proposed	
	• Additional groundwater sampling	• Surface water sampling (12 samples, 3 sampling stations, 4 samples/station)	• Samples taken coincidental to RI field program to determine background levels of contaminants for obtaining an NPDES discharge permit relative to the remedial actions for groundwater treatment at Site 1 - Underground Fuel Storage Area



Site 1 - Groundwater Probe Point Locations

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 2-1 | Project: 1-827-03-769-22



Site 3 - Soil Gas Sample Point Locations

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 2-2 | Project: 1-827-03-769-22

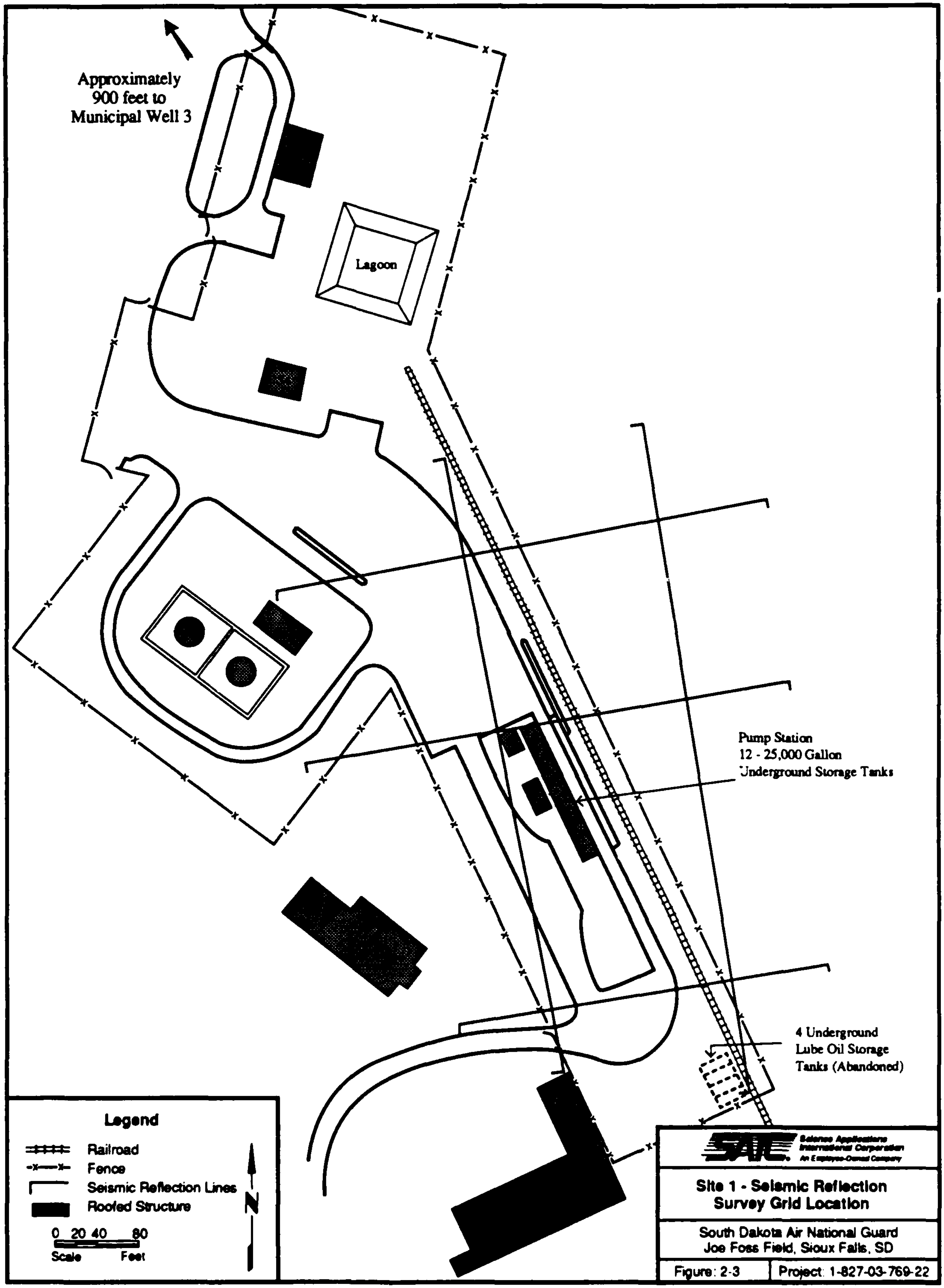
and evacuating 5 to 10 liters of gas with a vacuum pump. During this evacuation, soil gas samples were collected with a syringe by inserting the syringe needle through a silicone evacuation line and down into the steel probe. Following the collection of the sample (either soil gas or water), the probes and hollow-stem augers were extracted from the ground and the hole was backfilled with cement/bentonite grout.

Gas chromatography (GC) can detect virtually all light, volatile organic compounds (VOCs). However, only the following petroleum compounds related to fire fighting were quantified: total petroleum hydrocarbons, total xylenes, benzene, toluene, tetrachloroethylene (PCE), trichloroethylene (TCE), carbon tetrachloride, bromochloromethanes, and 1,1,1-trichloroethane (TCA). Additional discussion of the GC analysis techniques is presented in Appendix C.

2.2 SHALLOW SEISMIC REFLECTION GEOPHYSICAL SURVEY PROCEDURES

A shallow seismic reflection survey was conducted in November 1988 in and around the area of contamination at Site 1 – Underground Fuel Storage Area. The location of the survey grid is shown in Figure 2-3. The survey was performed by Minnesota Geophysical Associates of Andover, Minnesota, under the direction of SAIC field personnel. The objective of the survey was to define the aquifer boundaries, bedrock depth, configuration and properties, clay continuity and thickness, and location of buried high-permeability channels, if they exist. This information is used to determine potential contaminant migration pathways and to evaluate potential remedial action alternatives.

The method of seismic reflection consists of measuring the travel times of compressional waves generated from a surface energy source as they are reflected at the interfaces of different geologic media (e.g., quartzite bedrock, saturated gravels). The energy source varied depending on shot location and consisted of either a sledgehammer, self-contained seisgun or a hydraulic hammer, listed in order of increasing energy output. The reflected energy waves were detected by a line of geophones spaced on 50-foot centers. The geophone data were fed through a multichannel recording system (Bison Instruments Inc. "Geo-Pro" Model 8024-12) to a processor that produces magnetic and hard copy output for computer and visual analysis. Two 500-foot lines of geophones were run in approximately a north-south direction, and three 300-foot lines of geophones were run in an east-west direction. These north-south and east-west lines created a 300- by 500- foot grid over the contaminated area. A more detailed description of the data collection and analysis methods is presented in Appendix B.



Site 1 - Seismic Reflection Survey Grid Location

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 2-3 Project: 1-827-03-769-22

2.3 ONSITE GAS CHROMATOGRAPHY PROCEDURES

The onsite, laboratory-grade GC, used during the groundwater probe and soil gas surveys, was also used throughout the field program (April through July 1989) to screen all environmental samples (approximately 150), including all soil samples, the first sampling round of all groundwater monitoring wells, decontamination water, quality assurance/quality control (QA/QC) samples, and discharge water produced during the aquifer testing activities. The onsite GC was operated by TRC; sampling and overall direction were conducted by SAIC field personnel. Screening by onsite GC was used to select soil samples to be sent to the offsite laboratory for analysis to determine the total depth of soil borings and monitoring well boreholes and to provide a cost-effective and timely method of analyzing environmental samples and a variety of QA/QC samples.

Samples were analyzed using a Varian 3300 GC and a Spectra-Physics SP270 computing integrator. The GC can detect virtually all light, volatile organic compounds. However, only the following petroleum compounds and those related to fire fighting were quantified based upon SI results: total petroleum hydrocarbons, total xylenes, benzene, toluene, PCE, TCE, carbon tetrachloride, bromochloromethanes, and 1,1,1-TCA. Additional discussion of the GC analysis techniques can be found in Appendix C.

2.4 DRILLING AND WELL INSTALLATION PROCEDURES

The drilling and well installation program at the Base consisted of three different activities that included 1) monitoring well drilling and installation, 2) soil boring and abandonment, and 3) aquifer test well drilling and installation. Drilling was performed by Layne-Western Company of Omaha, Nebraska, under the direction of SAIC field personnel during April 1989. Table 2-2 summarizes the general drilling, soil sampling, and well installation specifications for the drilling and well installation program. The drilling and well installation program provides geologic, hydrologic, and chemical data that are used to characterize the nature, magnitude, extent, transport, and fate of the contamination present at the sites.

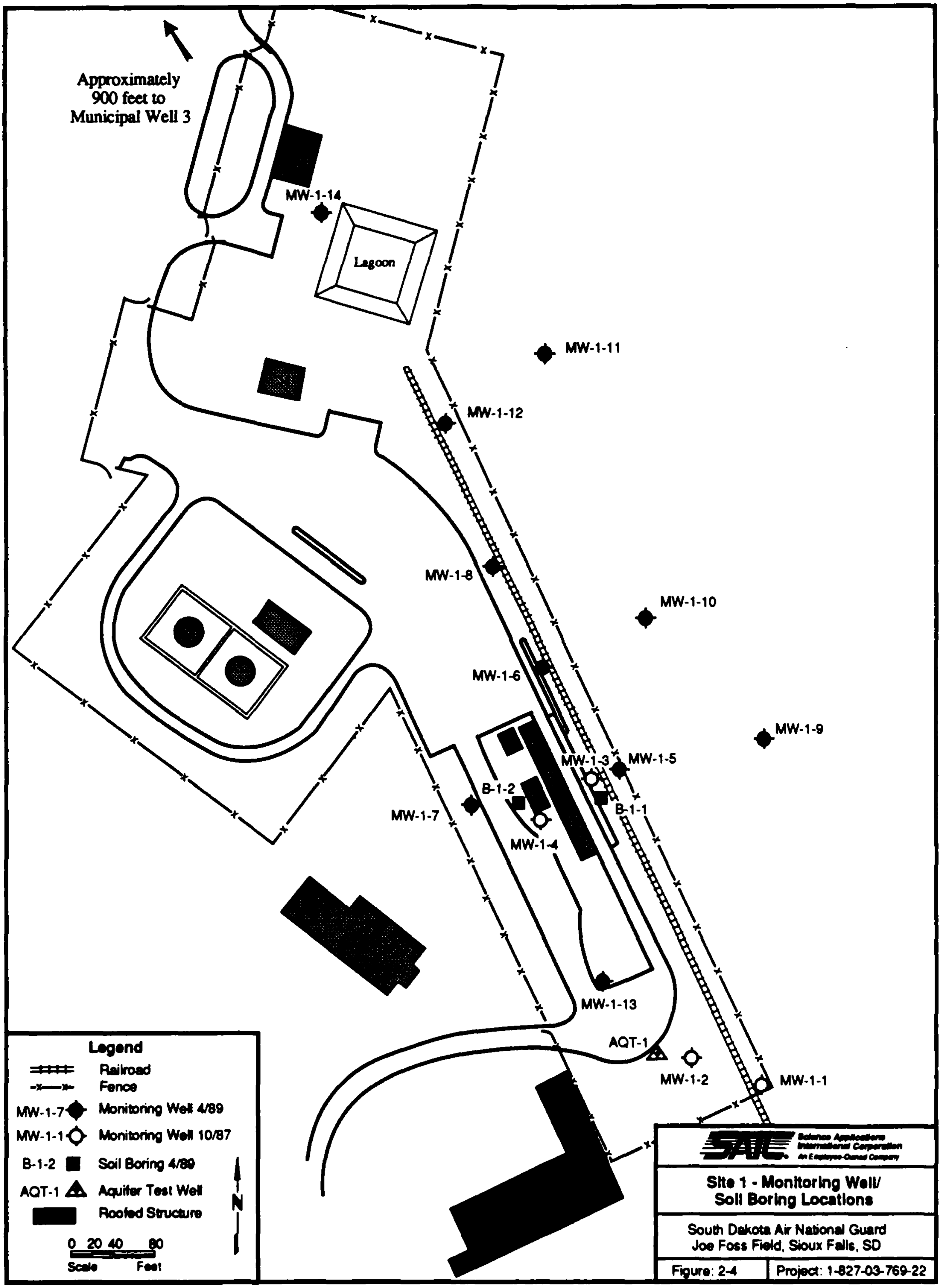
2.4.1 Monitoring Well Installation

Ten monitoring wells (i.e., MW-1-5 through MW-1-14) were drilled at Site 1 – Base Underground Fuel Storage Area, and one monitoring well (MW-3-5) was drilled at Site 3 – Former Base Fire Training Area. The locations of the monitoring wells installed at Site 1 – Underground Fuel Storage Area are illustrated in Figure 2-4. Monitoring wells MW-1-1 through MW-1-4 were installed at Site 1 – Underground Fuel Storage Area during the SI program. Figure 2-5 shows the location of the monitoring well installed at Site 3 – Base Fire Training Area.

TABLE 2-2. GENERAL DRILLING AND WELL INSTALLATION SPECIFICATIONS FOR THE REMEDIAL INVESTIGATION FIELD PROGRAM FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Site/Boring Type	Soil Boring/Well Drilling Specifications				Well Installation Specifications (If Applicable)		
	Number of Borings/Well	Location	Soil Sample Interval	Total Depth	Well Inside Diameter	Screen Length	Bottom of Screen Depth (Below Water Table)
SITE 1 - UNDERGROUND FUEL STORAGE AREA							
Soil Borings	2	In immediate vicinity of previously installed SI monitoring wells.	5 feet	Depth of bedrock (55'BLS).	---	---	---
Monitoring Wells	10	3 monitoring wells along the perimeter of detected contamination. 3 monitoring wells downgradient of the site and the municipal supply wells. 4 monitoring wells around the recently found area of contamination north of the USTs.	5 feet	Depth where two consecutive soil samples show no contamination based on onsite GC results or 10 feet below the water table (20'BLS), whichever is deeper.	4 inches (d)	(b)	(c)
SITE 3 - BASE FIRE TRAINING AREA							
Soil Borings	5	In localized areas of soil contamination found during the SI, 3 in burn pit, 2 adjacent to drum holding area.	2.5 feet	Depth where two consecutive soil samples show no contamination based upon onsite GC results or the bottom of the surficial clay layer, whichever is deeper.	---	---	---
Monitoring Wells	1	Between the site and Municipal Well #34.	5 feet	Depth where two consecutive soil samples show no contamination based upon onsite GC results or 10 feet below the water table (20'BLS), whichever is deeper.	4 inches (d)	(b)	(c)
BASE VICINITY							
Background Soil Borings	2	Relatively remote upgradient location, showing no signs of past waste handling practices. in vicinity of SDANG.	5 feet(a)	Depth of deepest environmental soil sample sent to offsite lab.	---	---	---

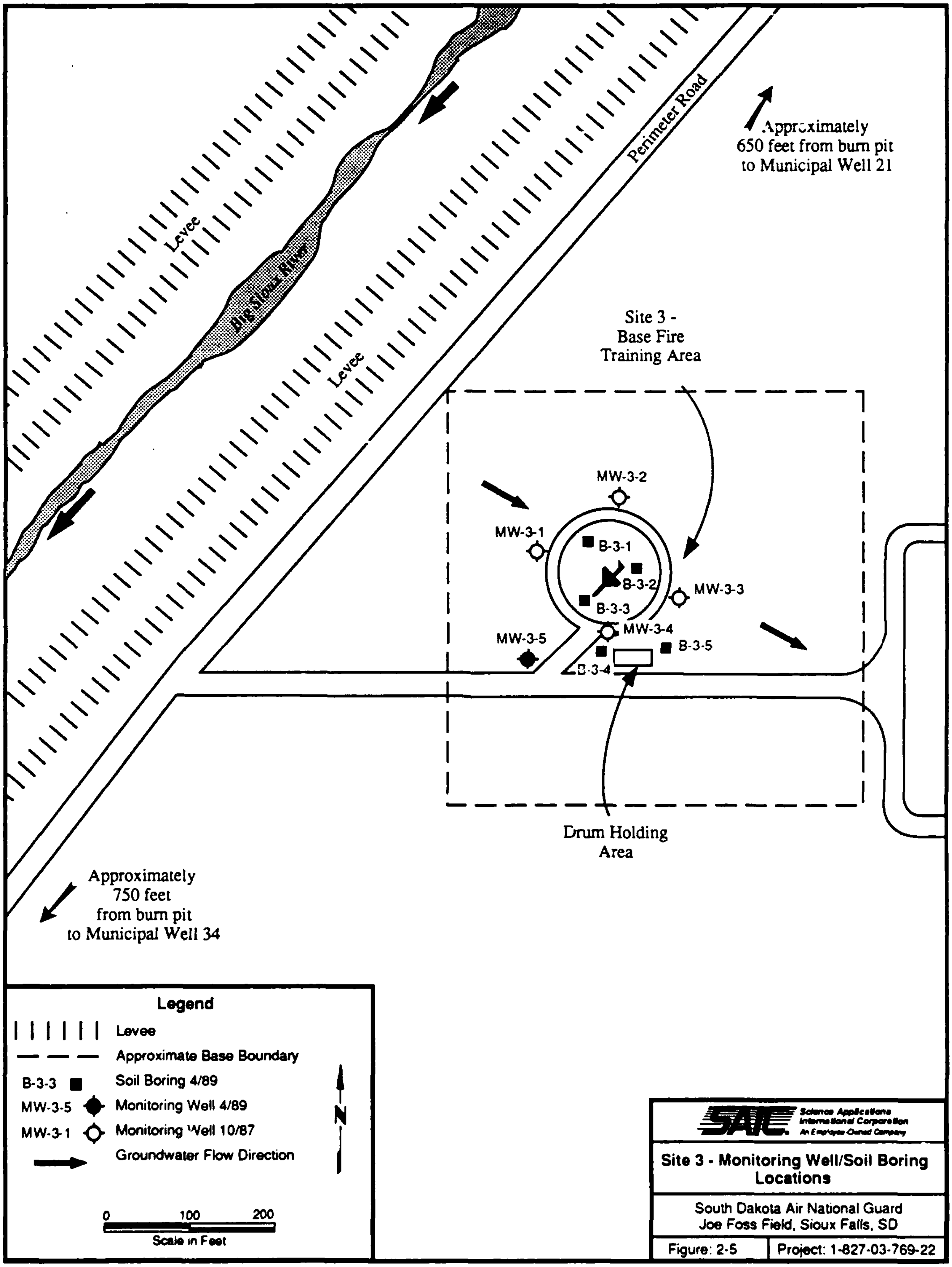
(a) In similar soil horizons as other environmental samples.
(b) 3 feet above water table to the bottom of detected contamination based upon onsite GC results (10 feet minimum).
(c) Bottom of detected contamination based upon onsite GC results.
(d) 4-inches used because of ease of installation, development, purging, and sampling.



Site 1 - Monitoring Well/ Soil Boring Locations

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 2-4 Project: 1-827-03-769-22



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Site 3 - Monitoring Well/Soil Boring Locations

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 2-5 | Project: 1-827-03-769-22

Monitoring well MW-3-5 was installed at Site 3 – Base Fire Training Area at the request of the city to monitor potential horizontal contaminant migration from the site in the direction of Municipal Well 34, located southwest of the site. Monitoring wells MW-3-1 through MW-3-4 were installed at Site 3 – Base Fire Training Area during the SI program. Appendix A contains the as-built diagrams for each of these monitoring wells. All monitoring wells were drilled and installed with hollow-stem auger drilling methods using the following procedures:

1. Once the borehole was drilled to completion depth, the auger plug was removed and sand pack was added to fill the borehole from the completion depth to the depth of the bottom of the well screen (2 feet minimum). An appropriate length (10 foot minimum) of threaded flush-joint PVC well screen and riser were installed (4-inch inside diameter (ID), 0.040 inch slot, PVC Schedule 40). The well screen and casing were steam cleaned prior to installation in the borehole. The screen slots were sized so as to retain a minimum of 90 percent of the sandpack material. The screen interval (10 feet minimum) extended 3 feet above and a minimum of 7 feet below the water table to allow for annual fluctuation in the groundwater table elevation to allow any free-floating petroleum, oils, and lubricants to enter the well during sampling. The total depth and therefore the length of the screen was the bottom of detected contamination based upon onsite soil sample GC results. The top of the PVC casing was completed flush to the ground so as not to interfere with normal activities around the Base.
2. The augers were raised in 2-foot increments, and silica sand pack was added. The sand pack was pulverized Sioux Quartzite with percent retained sizes for 9.5, 4.8, 2.0, and 1.2 mm of 0, 75, 81, and 96 percent, respectively. The incremental lifting of the augers and emplacement of sand pack continued until the sand pack extended at least 3 feet above the top of the screen. Periodic sounding during this process ensured a continuous sand pack.
3. After the sand pack had been tremied in place and measurements had been taken to ensure its proper location, at least 1 foot of bentonite pellet seal was placed on top of the sand pack.
4. After the bentonite seal was in place and allowed to hydrate for 30 minutes and measurements taken to ensure its proper location, a cement/bentonite grout was tremied in place from the top of the seal to approximately 1 foot below the land surface. The grout mixture consisted of potable water, bentonite, and Type I or II Portland cement with 94 pounds of cement and 5 pounds of bentonite per 6.5 gallons of water.
5. A protective man-hole cover capable of being locked to prevent unauthorized entry was installed within 24 hours of well installation. A concrete pad was then built around the cover. The pad was provided with a rubber gasket to prevent surface water seepage. All wells were fitted with keyed-alike locks.
6. As soon as possible following each well installation, each well was developed by surging and/or pumping until well water was relatively turbidity free and acceptable in clarity and specific conductivity to the Supervisory Geologist (i.e., where clarity and conductivity stabilized and showed no further improvement or reduction with continued development). The total volume of water that was removed was estimated and recorded.

2.4.2 Soil Boring and Abandonment Procedures

Two soil borings (i.e., B-1-1 and B-1-2) were drilled to the bottom of the aquifer at Site 1 – Underground Fuel Storage Area, and five shallow borings (i.e., B-3-1 through B-3-5) were drilled at Site 3 – Base Fire Training Area. Borings were drilled and sampled with the same methods as monitoring well boreholes, but upon reaching completion depth, all soil borings not completed as wells were abandoned by backfilling with cement/bentonite grout tremied into place. The soil boring locations for Site 1 – Underground Fuel Storage Area are shown in Figure 2-4. Figure 2-5 shows the locations of the soil borings at Site 3 – Base Fire Training Area.

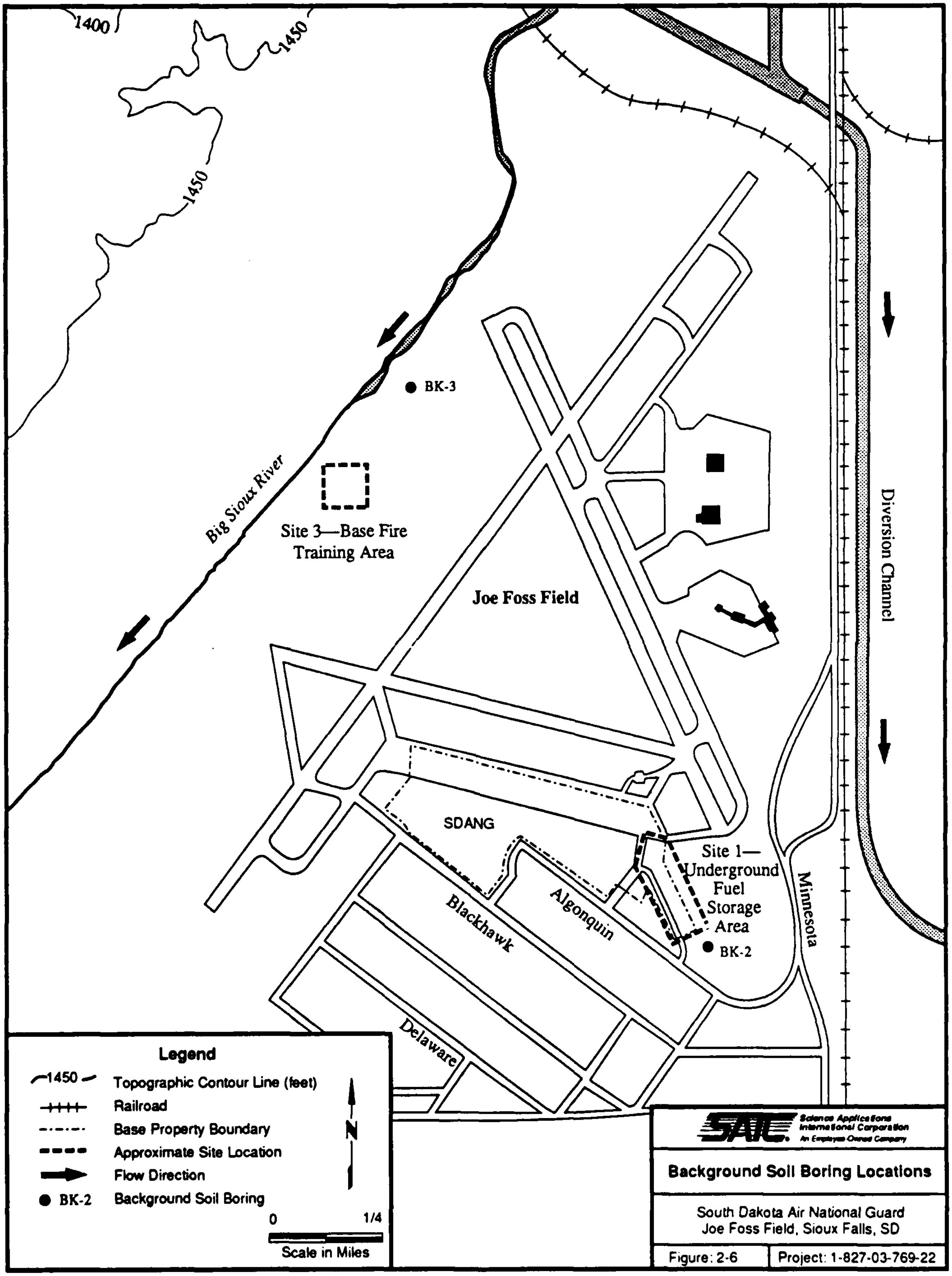
2.5 SAMPLING PROCEDURES

To help meet the RI objectives, the following standard procedures were followed for subsurface soils sampling, monitoring well sampling, and QA/QC.

2.5.1 Subsurface Soils Sampling Procedures

Subsurface soil sampling refers to samples collected during soil boring and monitoring well drilling activities at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area. In addition, background soil samples were collected from a soil boring at two locations where soil contamination was determined to be minimal. The background soil boring locations (i.e., BK-2 and BK-3) are shown in Figure 2-6. Split-spoon samplers were used to collect samples at specified intervals (5 feet at Site 1 – Underground Fuel Storage Area, Site 3 – Base Fire Training Area monitoring well, and background borings; 2.5 feet at Site 3 – Base Fire Training Area soil borings) and at changes in geology throughout the depth of the boring. A Shelby tube sampler was used to collect relatively undisturbed soil samples, which underwent geotechnical and physical characteristics testing. Split-spoon samples were examined for a variety of characteristics, and the results of this examination are presented in log form in Appendix A.

Two soil samples were sent to the chemical laboratory from each soil boring or monitoring well borehole based on the onsite GC results and proximity to the water table. At Site 1 – Underground Fuel Storage Area, the most contaminated soil samples were sent to the laboratory for chemical characterization. If all samples showed similar or no contamination based on the onsite GC monitoring, the first two soil samples below the water table were sent to the laboratory for chemical characterization. At Site 3 – Base Fire Training Area, the surficial soil sample and the most contaminated soil sample from the remaining samples were sent to the laboratory for analysis. If all of the remaining samples showed similar or no contamination based upon the onsite GC monitoring, a randomly selected sample was sent to the laboratory for chemical characterization. The laboratory analyses were conducted to quantify and characterize any contamination detected



Background Soil Boring Locations

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 2-6 Project: 1-827-03-769-22

during the onsite GC monitoring. Laboratory chemical and physical parameters were selected for each site based on the SI results and are presented in Table 2-3. The chemical analytical methods, containers, preservation methods, and holding times are listed in Table 2-4. Methods for the soil physical characterization tests are provided in Table 2-5.

2.5.2 Monitoring of Well Sampling

2.5.2.1 Purging

Prior to purging and sample collection, static water level measurements were taken in each well using an electric water level indicator. A water table sample was taken with a clear Teflon® bailer to detect any free-floating petroleum product. The depth to groundwater was used to calculate the casing volume of each monitoring well, and a minimum of five casing volumes of water was purged from each well using a submersible pump. Field measurements for temperature, pH, and specific conductance were monitored during purging to ensure that these parameters had stabilized. Purging ensured that a representative sample of the aquifer (i.e., not stagnant well water) was collected.

2.5.2.2 Groundwater Sampling

Groundwater samples were collected within 0.5 hours of purging each monitoring well. The chemical parameters and analytical methods are listed in Tables 2-3 and 2-4, respectively. Groundwater samples were retrieved with a point-source, Teflon® bailer and dispensed directly into an appropriate pre-labeled sample bottle containing the required preservative (if any was required) for the analyte to be tested. Additionally, some of the individual analyte samples from each monitoring well were field filtered to minimize the effect of sediment within the water sample and to analyze for dissolved metals rather than total metals. Field measurements for temperature, pH, and specific conductance were taken at each monitoring well at the time of sampling.

2.5.3 Quality Assurance/Quality Control

The following QA/QC samples were collected during environmental sampling:

- One field blank was collected per sampling team per day prior to the start of sampling. The blanks were prepared by pouring ASTM Type II water into sample containers at the site to be sampled that day and were maintained with other media samples collected in the field. Field blanks were used to evaluate the field sampling procedures.

TABLE 2-3. SUMMARY OF CHEMICAL AND PHYSICAL PARAMETERS FOR GROUNDWATER AND SOIL SAMPLING PLAN FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Parameters	Site 1	Site 3	Background Soil	Soil Gas	Groundwater Probe	Surface Water
GROUNDWATER CHARACTERIZATION						
Contaminant Characteristics:						
Total Petroleum Hydrocarbons	X	X				X
Purgeable Organic Compounds	X	X				X
Full Metals Scan*		X				
Lead, Arsenic Only	X					X
Semi-Volatiles (BNA)**	X	X				X
Total Volatile Hydrocarbons					X	
Chlorinated Hydrocarbons					X	
Aromatic Hydrocarbons					X	
Water Quality Parameters:						
Iron	X					
Manganese	X					
Sulfate	X					
Chloride	X					
pH	X					
Sodium	X					
Magnesium as CaCO3	X					
Calcium as CaCO3	X					
Total Dissolved Solids	X					
Total Suspended Solids	X					
Nitrate	X					
Total Alkalinity	X					
SOIL CHARACTERIZATION						
Contaminant Characteristics:						
Total Petroleum Hydrocarbons	X	X	X			
Purgeable Organic Compounds	X	X	X			
Full Metals Scan*		X	X			
Lead, Arsenic Only	X					
EP Toxicity (Metals)**	X	X	X			
Semi-Volatiles (BNA)**	X	X	X			
Total Organic Carbon	X	X	X			
Total Volatile Hydrocarbons				X		
Chlorinated Hydrocarbons				X		
Aromatic Hydrocarbons				X		
Physical Characteristics:						
Soil Engineering Classification	X	X				
Grain Size	X	X				
Atterberg Limits	X	X				
Organic Matter Content	X	X	X			
Cation Exchange Capacity	X	X	X			
Bulk Density	X	X				
% Moisture	X	X	X			

* Full metals scan includes antimony, arsenic, beryllium, cadmium, chromium, chromium VI, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc.

**Indicates EPA Region VIII recommended analytes.

TABLE 2-4. SUMMARY OF SAMPLE PRESERVATION, ANALYTICAL METHODS, AND STORAGE PROCEDURES FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Media	Parameter	Method (1)	Containers	Preservative	Holding Time
Water	Petroleum Hydrocarbons	E418.1	2, 1.0 L glass bottles with Teflon® septa	H2SO4 to pH <2 and Cool to 4° C	28 days
	Purgeable Organic Compounds (Hazardous Substance List)	SW8240	4, 40 mL glass vials with Teflon® septa	Cool to 4° C	14 days
	Metal Scan:				
	Antimony	LXWM1B/SW7041	500 mL plastic	HNO3 to pH <2	6 months
	Arsenic	LXWM3A/SW7061	500 mL plastic	HNO3 to pH <2	6 months
	Beryllium	LXWM1B/SW6010	500 mL plastic	HNO3 to pH <2	6 months
	Cadmium	LXWM1B/SW6010	500 mL plastic	HNO3 to pH <2	6 months
	Chromium	LXWM1B/SW6010	500 mL plastic	HNO3 to pH <2	6 months
	Copper	LXWM1B/SW6010	500 mL plastic	HNO3 to pH <2	6 months
	Lead	LXWM2/SW7421	500 mL plastic	HNO3 to pH <2	6 months
	Mercury	LXWM4/SW7470	500 mL plastic	HNO3 to pH <2	30 days
	Nickel	LXWM1B/SW6010	500 mL plastic	HNO3 to pH <2	6 months
	Selenium	LXWM3B/SW7741	500 mL plastic	HNO3 to pH <2	6 months
	Silver	LXWM1B/SW6010	500 mL plastic	HNO3 to pH <2	6 months
	Thallium	LXWM2/SW7841	500 mL plastic	HNO3 to pH <2	6 months
	Zinc	LXWM1B/SW6010	500 mL plastic	HNO3 to pH <2	6 months
	Semi-Volatiles (Acid/Base/ Neutral Compounds) (Hazardous Substance List)	SW3510/SW8270	3, 1.0 L glass bottles with Teflon® septa	Cool to 4° C	Extraction 7 days Analyzed 40 days after Extraction
	Water Quality Parameters				
	Iron	LXWM1B/SW6010	500 mL plastic	HNO3 to pH <2	6 months
	Manganese	LXWM1B/SW6010	500 mL plastic	HNO3 to pH <2	6 months
	Sulfate	E300.0	1.0 L plastic	H2SO4 to pH <2 and Cool to 4° C	28 days
	Chloride	E300.0	1.0 L plastic	H2SO4 to pH <2 and Cool to 4° C	28 days
	pH	SW9040	500 mL plastic	Cool to 4° C	6 hours
	Sodium	SW7770	500 mL plastic	HNO3 to pH <2	6 months
	Magnesium (as CaCO3)	SW7450	500 mL plastic	HNO3 to pH <2	6 months
	Calcium (as CaCO3)	SW7140	500 mL plastic	HNO3 to pH <2	6 months
	Total Dissolved Solids	E160.1	1.0 L plastic	Cool to 4° C	7 days
	Total Suspended Solids	E160.2	1.0 L plastic	Cool to 4° C	7 days
	Nitrate as N	E300.0	1.0 L plastic	H2SO4 to pH <2 and Cool to 4° C	24 hours
	Total Alkalinity as CaCO3	E310.1	500 mL plastic	Cool to 4° C	14 days

TABLE 2-4. SUMMARY OF SAMPLE PRESERVATION, ANALYTICAL METHODS, AND STORAGE PROCEDURES FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Media	Parameter	Method (1)	Containers	Preservative	Holding Time
Soils	Petroleum Hydrocarbons	SW3550/E418.1	8 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	14 days
	Purgeable Organic Compounds (Hazardous Substance List)	SW8240	8 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	14 days
	Metals Scan:				
	Antimony	LXSM1/SW7041	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months
	Arsenic	LXSM3A/SW7061	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months
	Beryllium	LXSM1/SW6010	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months
	Cadmium	LXSM1/SW6010	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months
	Chromium	LXSM1/SW6010	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months
	Copper	LXSM1/SW6010	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months
	Lead	LXSM2/SW7421	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months
	Mercury	LXSM4/SW7471	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	30 days
	Nickel	LXSM1/SW6010	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months
	Selenium	LXSM3B/SW7741	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months
	Silver	LXSM1/SW6010	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months
	Thallium	LXSM2/SW7841	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months
	Zinc	LXSM1/SW6010	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	6 months

TABLE 2-4. SUMMARY OF SAMPLE PRESERVATION, ANALYTICAL METHODS, AND STORAGE PROCEDURES FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Media	Parameter	Method (1)	Containers	Preservative	Holding Time
Soils (cont'd)	EP Toxicicty Metals	SW1310	32 oz. widemouth glass jar with Teflon® liner	None Required	6 months
	Semi-Volatiles (Acid/Base/ Neutral Compounds) (Hazardous Substance List)	SW3550/SW8270	16 oz. widemouth glass jar with Teflon® liner	Cool to 4° C	Extraction 14 days Analyzed 40 days after Extraction
	Total Organic Carbon	LXSB9/LXSB9	1.0 L plastic	H2SO4 to pH <2	28 days

(1) E600-series methods referenced from Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater, U.S. EPA, Federal Register, Vol. 49, No. 209, October 26, 1984.

Additional E-series methods referenced from Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, March 1979.

SW-series methods referenced from Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, Third Edition, November 1986.

ICP metals analyses referenced from Inductively Coupled Plasma - Atomic Emission Spectrometric Method for Trace Element Analyses of Water and Wastes Method 20, U.S. EPA, Federal Register, Vol. 49, No. 209, October 26, 1984.

A-series methods referenced from Standard Methods for the Examination of Water and Wastewater, 16th edition. APHA, AWWA, WPCF, 1985.

LX-series methods refer to Laucks in-house methods, see Appendix F.

TABLE 2-5. SUMMARY OF SOIL PHYSICAL AND GEOTECHNICAL CHARACTERIZATION PARAMETERS AND METHODS FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Parameter	Method (1)
Soil Engineering Classification	ASTM D2487
Grain Size	ASTM D422
Atterberg Limits	ASTM D4318
Organic Matter Content	ASTM D2974
Cation Exchange Capacity	USEPA SW9080/9081
Bulk Density	ASTM D1587
Percent Moisture	ASTM D2216

(1) SW-methods referenced from Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, Third Edition, November 1986.

ASTM methods referenced from American Society for Testing and Materials. 1984 Annual Book of ASTM Standards. Section 4: Construction.

- One trip blank was collected per volatile organic compound (VOC) sample shipment container. Trip blanks were prepared by pouring ASTM Type II water into VOC sample containers at the offsite laboratory prior to the commencement of field activities. The blanks were then sent to the Base in the containers holding the empty sampling bottles and were maintained with other media samples collected in the field. Trip blanks were used to determine if any contamination in the environmental samples was attributable to sample or bottle transport conditions.
- One bailer wash was collected for every 10 groundwater samples sent to the laboratory for analysis for each site. Bailer washes consisted of pouring ASTM Type II water through the bailer and into sample containers immediately after the bailer had been decontaminated.

  One equipment blank was collected per day when soil sampling was conducted. Equipment blanks consisted of pouring ASTM Type II water through the split-spoon samplers and into the sample containers immediately after decontamination of the split-spoon. These samples were then handled as other field groundwater samples. Bailer washes and equipment blanks were used to verify the effectiveness of the field decontamination procedures.
- Field replicates were collected at pre-selected monitoring points for a total equal to 10 percent of the environmental samples sent to the laboratory for analysis for each site. Field replicates were environmental samples collected at the same time and in the same manner as the normal laboratory samples. Field replicates were not the same as laboratory replicates but were used to assess the reproducibility of field sampling techniques.

Details of the QA/QC program are provided in Section 4.1

2.6 AQUIFER TESTING

A 72-hour constant pumping rate aquifer test was planned in the aquifer test well (AQT-1) in the vicinity of Site 1 – Underground Fuel Storage Area. Mud rotary drilling, the accepted method of installing large diameter wells (i.e., 12-inches), was used to install the well. This technique, however, apparently sealed the well from the aquifer; hence, the well was incapable of producing the flow needed for testing. The test well was not abandoned during the field program; yet, it cannot be sampled barring further attempts to develop the well.

As an alternative to the aquifer test well, several existing 4-inch monitoring wells at Site 1 – Underground Fuel Storage Area were considered for the constant pumping rate aquifer test. Several short-term pump tests, approximately 1 hour in duration, were conducted to determine the specific capacity of existing upgradient monitoring wells at Site 1 – Underground Fuel Storage Area. Monitoring well MW-1-1, the furthest upgradient, was selected based on these tests and its location.

A 36-hour constant pumping rate aquifer test was conducted by SAIC personnel in July 1989 within monitoring well MW-1-1 at Site 1 – Underground Fuel Storage Area. The purpose of the aquifer test was to define values of various aquifer hydrologic parameters (i.e., transmissivity, storativity). This information is used to determine contaminant migration rates and to evaluate potential remedial action alternatives. Aquifer testing consists of pumping a well at a constant rate and measuring the resultant drawdown within the test well and nearby observation wells at specified time intervals after the commencement of and immediately following the test. The wells selected for the test, MW-1-1, MW-1-2, and MW-1-13, each had its well screen located in the same sandy aquifer material and the same distance above and below the water table (within ± 2 vertical feet). These factors contributed to the reliable aquifer hydrologic data obtained from the 36-hour pump test.

A pumping rate of 80 gallons/minute (gpm) was determined through the preliminary short-term aquifer test and values generated by response calculations performed prior to the actual aquifer test. During the test, the discharge rate was constantly monitored to ensure that a constant rate (+/- 50 percent) was maintained. Water levels were monitored within the test well (MW-1-1) and observation wells (MW-1-2 and MW-1-13) throughout testing, as well as during a 24-hour period prior to testing to determine any antecedent water level fluctuation trends. Water level data were recorded by a "Hermit" data logger (In-Situ, Inc.), which uses pressure transducers to accurately detect water level changes. All groundwater was discharged into the Base storm sewer system.

As a precautionary measure, aquifer test water was screened using the onsite GC at 2-hour intervals to ensure that all discharged water was below harmful contaminant concentration levels. At no time during the testing did any contaminants detected in the discharge water exceed the drinking water maximum contaminant levels or maximum contaminant level goals. Further discussion of the procedures used for aquifer testing are presented in Appendix G.

2.7 SURVEYING OF MONITORING WELLS

After the monitoring wells were completed at the Base, they were surveyed to provide accurate static groundwater level measurements, thereby determining the groundwater flow direction. The survey was performed by Schmitz-Kalda Associates of Sioux Falls, South Dakota, during May 1989. Eight previously installed monitoring wells in the vicinity of Site 1 - Underground Fuel Storage Area (Twin Cities Testing, summer 1987) were also tied to this survey. The survey was completed to a vertical accuracy of 0.01 feet and a horizontal accuracy of 1 foot and was tied to the National Geodetic Survey Vertical Datum and the South Dakota State Coordinate System.

REFERENCES

Science Applications International Corporation. 1988. *Installation Restoration Program Remedial Investigation/Feasibility Study Work Plan*. South Dakota Air National Guard, Joe Foss Field, Sioux Falls, South Dakota. Prepared for Air National Guard Support Center, Andrews Air Force Base, Maryland. July 1988.

3. STUDY AREA CHARACTERIZATION

3.1 INTRODUCTION

An awareness of the environmental setting of the South Dakota Air National Guard (SDANG) Base at Joe Foss Field in Sioux Falls, Minnehaha County, South Dakota, is important in 1) evaluating previous Installation Restoration activities completed on the Base, 2) scoping and completing an effective Remedial Investigation (RI) program to quantify the extent and magnitude of environmental contamination at the sites in question, and 3) subsequently interpreting the results of the RI work as the basis for the Feasibility Study. This section summarizes the geographical setting, regional and site hydrogeology, regional background levels, climate and air quality, natural resources, and human environmental information for SDANG.

3.2 GEOGRAPHICAL SETTING

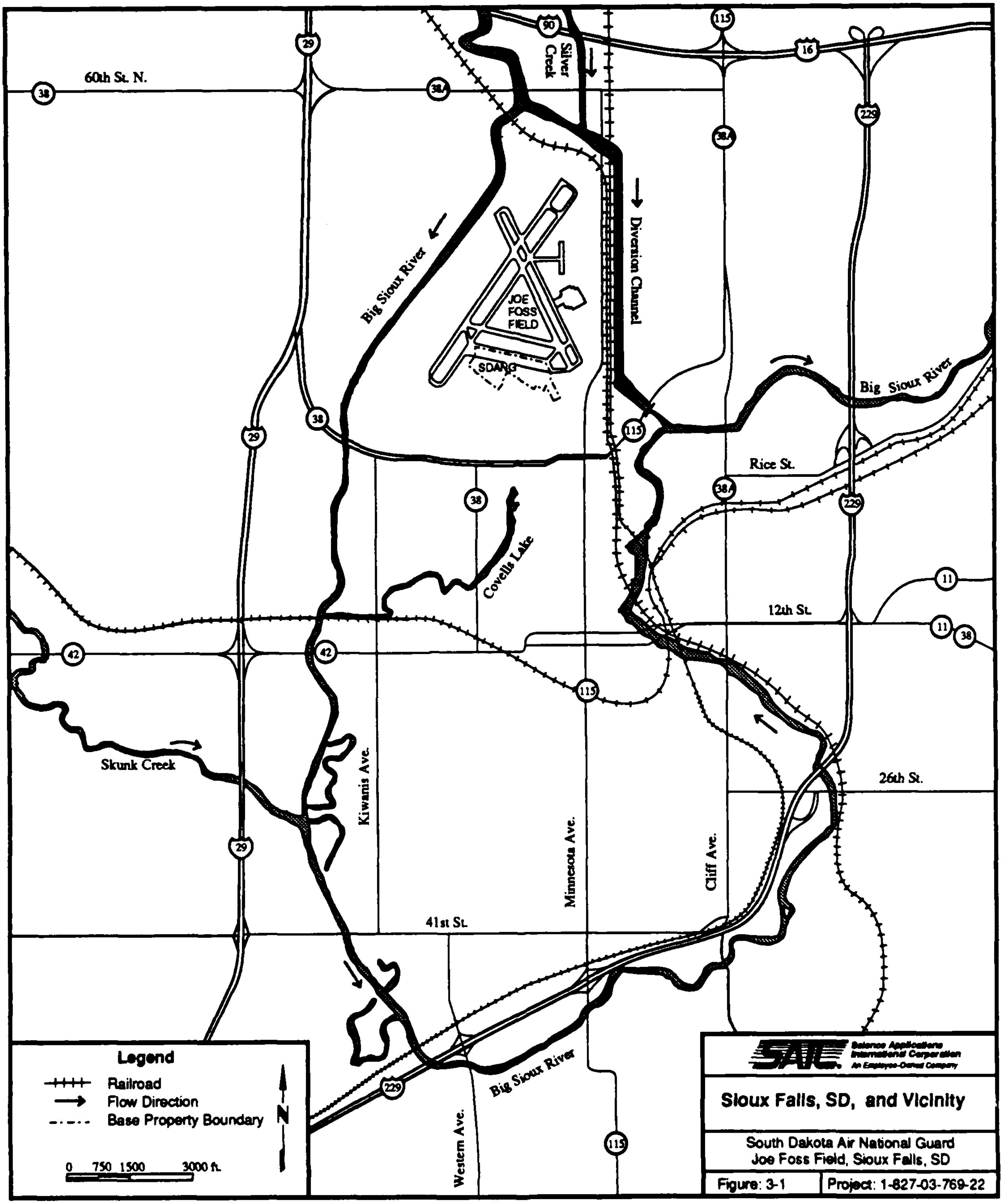
3.2.1 Physiography

Joe Foss Field is the Sioux Falls, South Dakota, municipal airport. The 114th Tactical Fighter Group of the South Dakota Air National Guard shares the airfield with civilian aviation. The airfield is located within the city limits of Sioux Falls, South Dakota, 2 miles north of the downtown area. The site location map is shown in Figure 3-1. Sioux Falls, Minnehaha County, South Dakota, is located in the Big Sioux River Valley in the southeastern portion of South Dakota. The surrounding terrain is composed of gently rolling hills, typical of the post-glacial Midwestern United States.

The SDANG Base lies at the extreme southern edge of the Coteau des Prairies (Prairie Hills), which is a highland plateau of the Central Lowland Province in the western part of the United States between the Minnesota River lowland to the east and the James River lowland to the west. The Big Sioux River, which runs adjacent to the Base, is the only large stream that drains the Coteau des Prairies (Koch 1982).

3.2.2 Topography

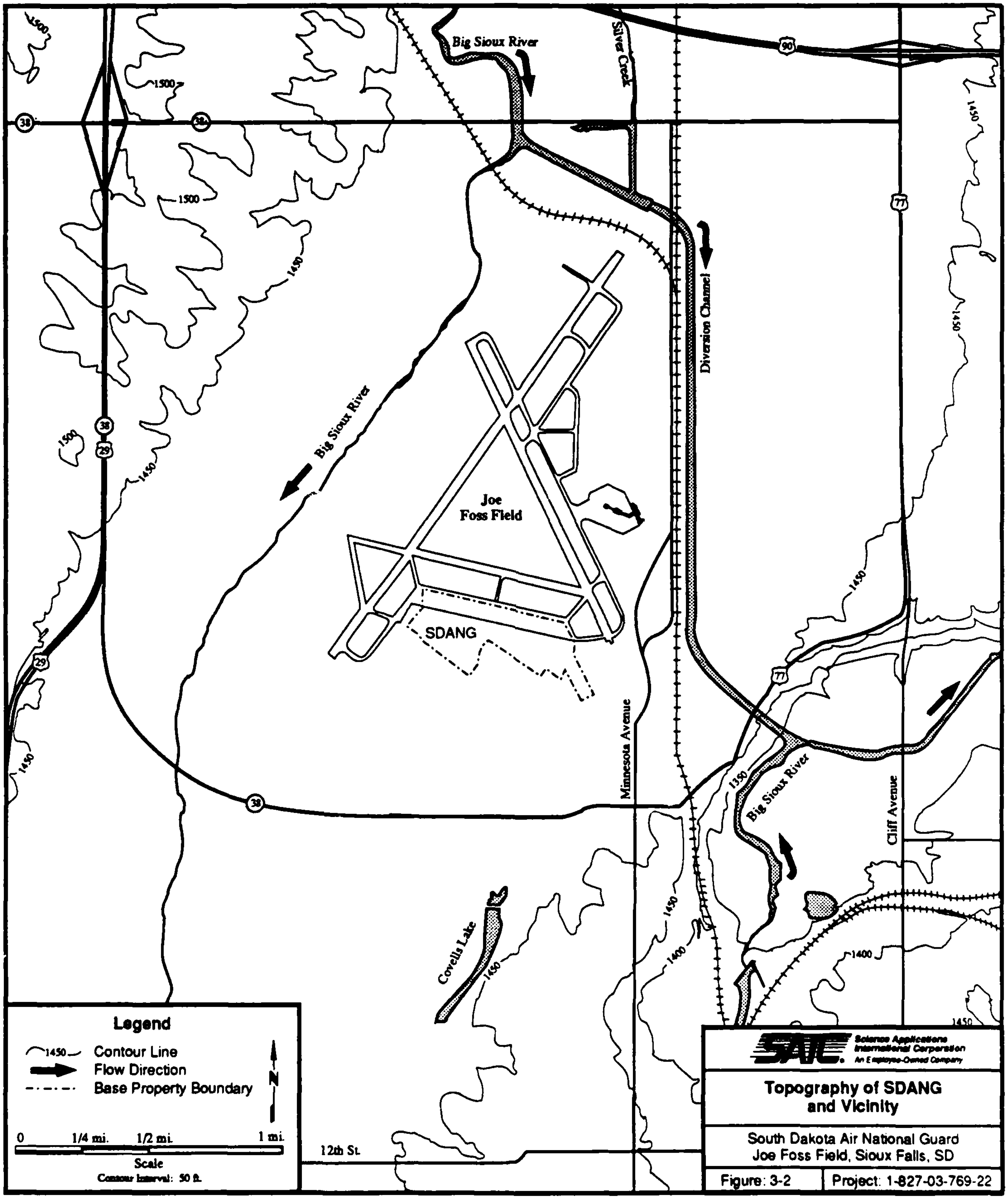
The Base lies entirely within the flood plain of the Big Sioux River which has an above bankfull stage flooding recurrence interval of 2.3 years (Jorgensen and Ackroyd 1973). Consequently, the associated topography of the Sioux Falls area has little or no relief (Figure 3-2). The flood plain lowland is approximately 3 miles wide at the airfield, and the airfield is nearly centered upon it. There is no significant relief within 1 mile of either of the two sites of concern (Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area). The Big Sioux River and the Diversion Channel are of low gradient near the airfield.



Sioux Falls, SD, and Vicinity

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-1 | Project: 1-827-03-769-22



Topography of SDANG and Vicinity

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-2 | Project: 1-827-03-769-22

3.3 REGIONAL HYDROGEOLOGY

3.3.1 Regional Geology

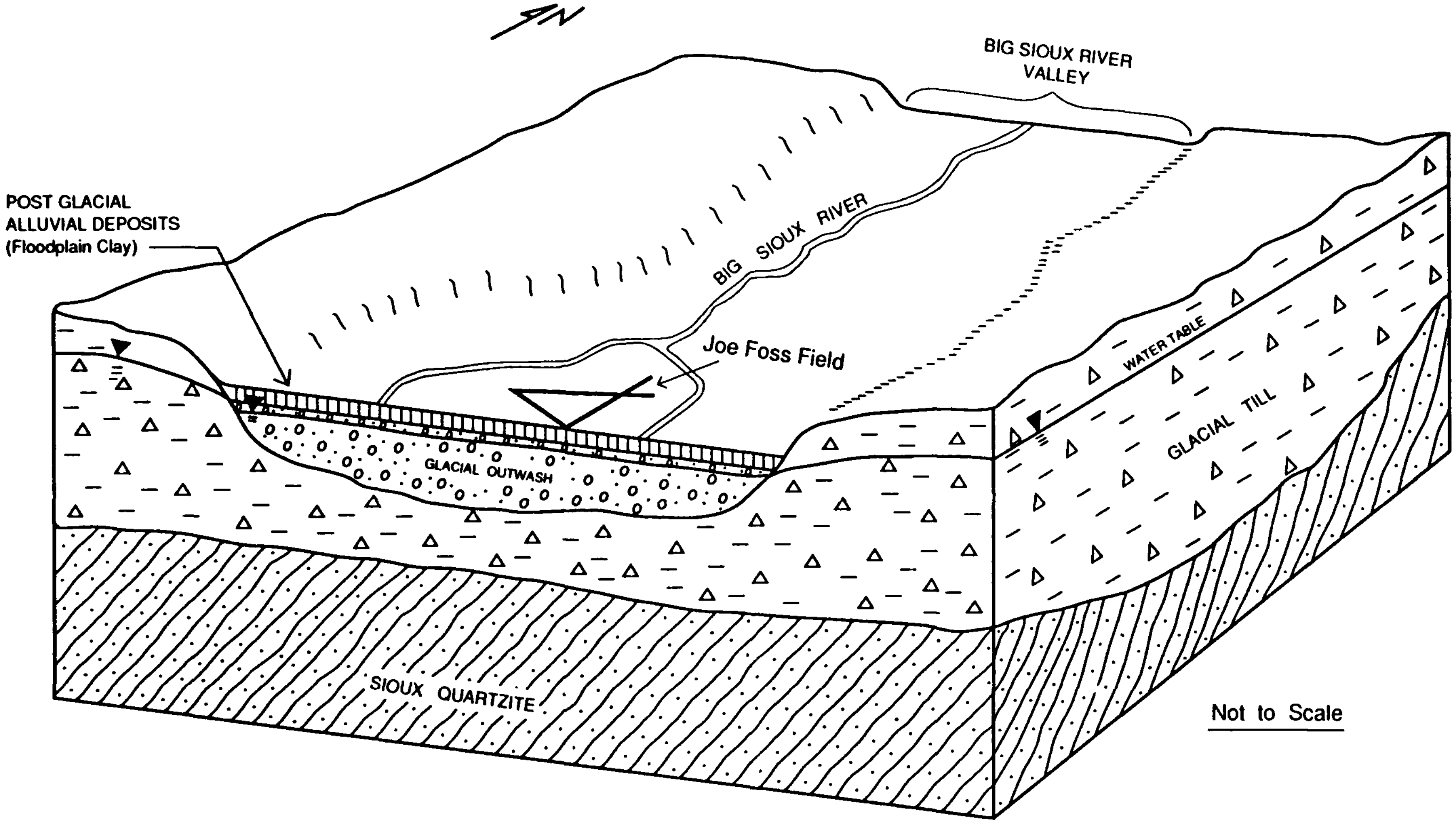
The geology of the Sioux Falls area is dominated by the effects of continental glaciations during the ice ages. As mentioned earlier, the study area is within the Coteau des Prairies, a highland plateau. Figure 3-3 shows a generalized conceptual representation of the geology of this area. This high plateau is a reflection of a bedrock high that occurs within the area. The bedrock high served to deflect the southward advancing ice sheets to the east and the west and protected the highland area from glacial erosion. The Coteau des Prairies is flanked to the east and west by the moraines of these deflected ice sheets. The meltwater from these surrounding ice sheets was directed onto the Coteau des Prairies and into the Big Sioux River, which was a much larger braided river at the time.

The rocks that exist within the region consist of the crystalline bedrock, overlain by as much as 200 feet of glacial erosional deposits collectively termed glacial drift. Also, within the Big Sioux River valley, there is a thin (generally less than 15 feet), discontinuous mantle of alluvial sediments overlying the drift.

In the Coteau des Prairies, the bedrock is the extremely hard, fractured Sioux Quartzite of Precambrian Age thought to be more than 4,000 feet thick. The Quartzite forms bedrock highs both in the Sioux Falls area and to the north near the town of Dell Rapids, forming rapids and waterfalls in these areas. Quartzite is an ancient quartz sandstone that has been metamorphosed into lithified rock. In outcrop sections, the formation is fine-grained, shows relict bedding features, is extremely hard and fractured, and possesses a characteristic pink color.

At least 200 feet of glacial drift mantles the quartzite over most of the region with the exception of areas near bedrock highs of the Sioux Quartzite where sediments overlying the bedrock gradually thin and "pinch out." The drift consists primarily of glacial till and glacial outwash.

The glacial till is characterized by an unstratified layer of particles of all grain sizes ranging from clay to large boulders and is formed by the direct deposition of sediments contained within melting ice. This till layer is more than 200 feet thick in some parts of the Coteau des Prairies but is generally thinner within the Big Sioux River valley where it has been eroded by the scouring of the river. The till is very thin or nonexistent in the localized bedrock high areas in the Sioux Falls area.



Not to Scale

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Generalized Hydrogeologic Conceptual Model of the Coteau des Prairies

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-3	Project: 1-827-03-769-22

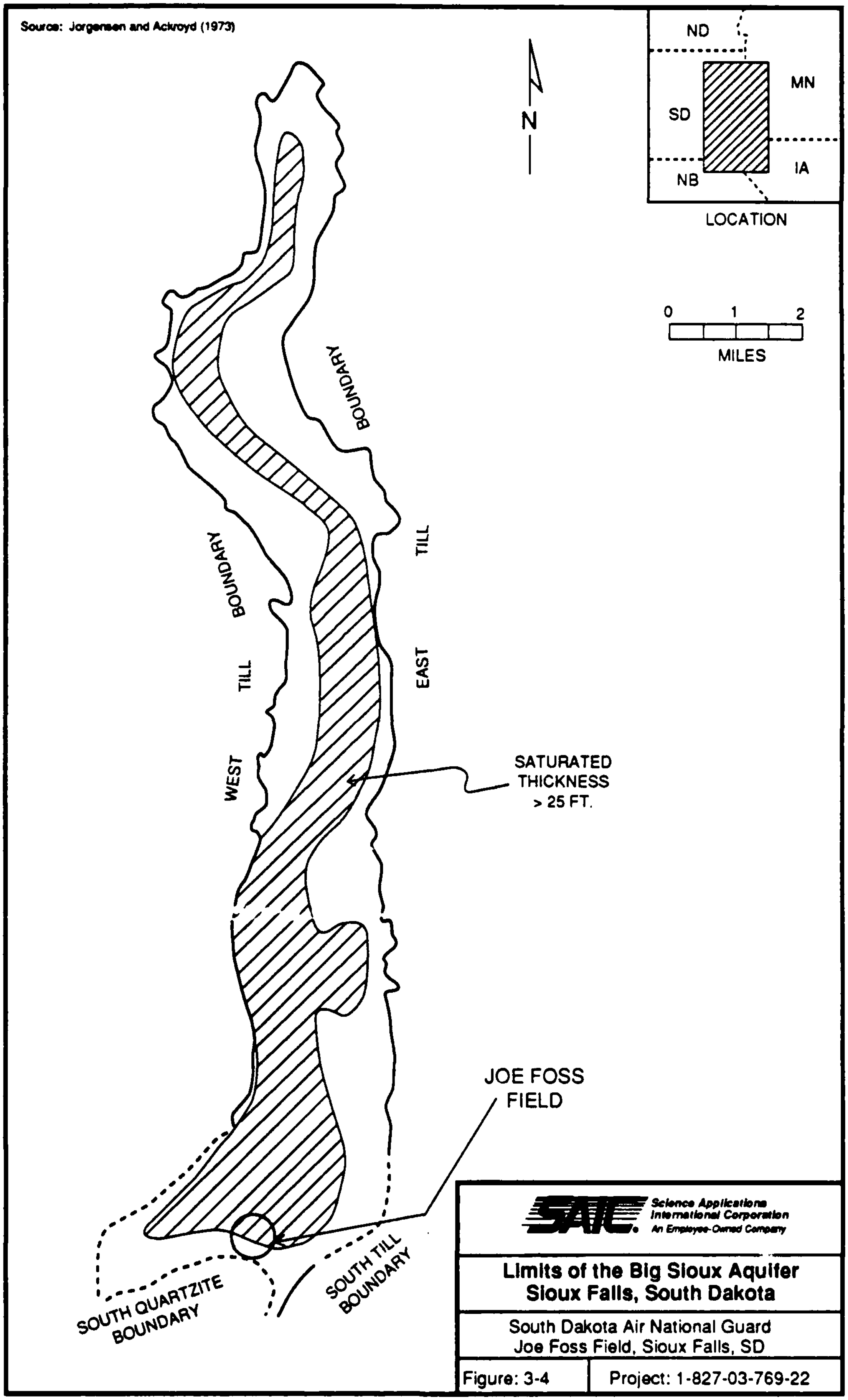
Restricted laterally to the river valley and to the north and south by Quartzite outcrops, there is at least 50 feet of coarse-grained glacial drift deposited upon the till. This drift, known as glacial outwash, consists of coarse sand and gravel along with trace amounts of silt and clay. Outwash was formed by the reworking and deposition of glacially derived sediments by the glacial meltwater-fed Big Sioux River.

An inconsistent (0 to 20 feet thick) mantle of post-glacial alluvial deposits overlies the drift within the river valley. The deposits principally consist of very fine-grained flood deposits with some slightly coarser grained river channel deposits. Because of its thinness and surficial location, this flood plain clay has been disturbed by construction activities throughout the valley. The presence or absence and composition of this deposit dictate the soil composition within the river valley.

3.3.2 Regional Subsurface Hydrology

The primary aquifer located within the Sioux Falls area, The Big Sioux Aquifer, comprises approximate 36 square miles within the saturated portions of the gravelly sand, glacial outwash deposits, as shown in Figure 3-3. Figure 3-4 illustrates the approximate boundaries of the aquifer. The water-table aquifer is generally bounded underneath and to the east and west by glacial till and to the north and south by the bedrock highs of the Sioux Quartzite. These rocks form relatively low permeability boundaries to the aquifer. The aquifer ranges in thickness from 0 feet, where the sediments pinch out along the valley flanks and Quartzite outcrops, to as much as 50 feet within the south-central portions of the valley.

Recharge of the aquifer is primarily by precipitation infiltration and seepage from the Big Sioux River. Of the precipitation that fell within the drainage area of the Big Sioux River between 1970 and 1979, an estimated 90.5 percent is returned to the atmosphere through evapotranspiration, 1.5 percent is contributed to the surface water runoff, and 8 percent is added to aquifer storage (Koch 1982). Recharge by river seepage occurs primarily in the southern one-third of the aquifer where seepage is induced by the pumping of the city of Sioux Falls municipal well field. During periods of low streamflow, as much as 95 percent of the streamflow may infiltrate into the aquifer in this area (Koch 1982). Streambed infiltration rates have been measured ranging from 4 to 7.4 gallons per day per foot (gal/day/ft) and vary due to scouring of the streambed, the presence of dams, dredging activities, and stream levels (Jorgensen and Ackroyd 1973).



Source: Jorgensen and Ackroyd (1973)

Limits of the Big Sioux Aquifer
Sioux Falls, South Dakota

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-4

Project: 1-827-03-769-22

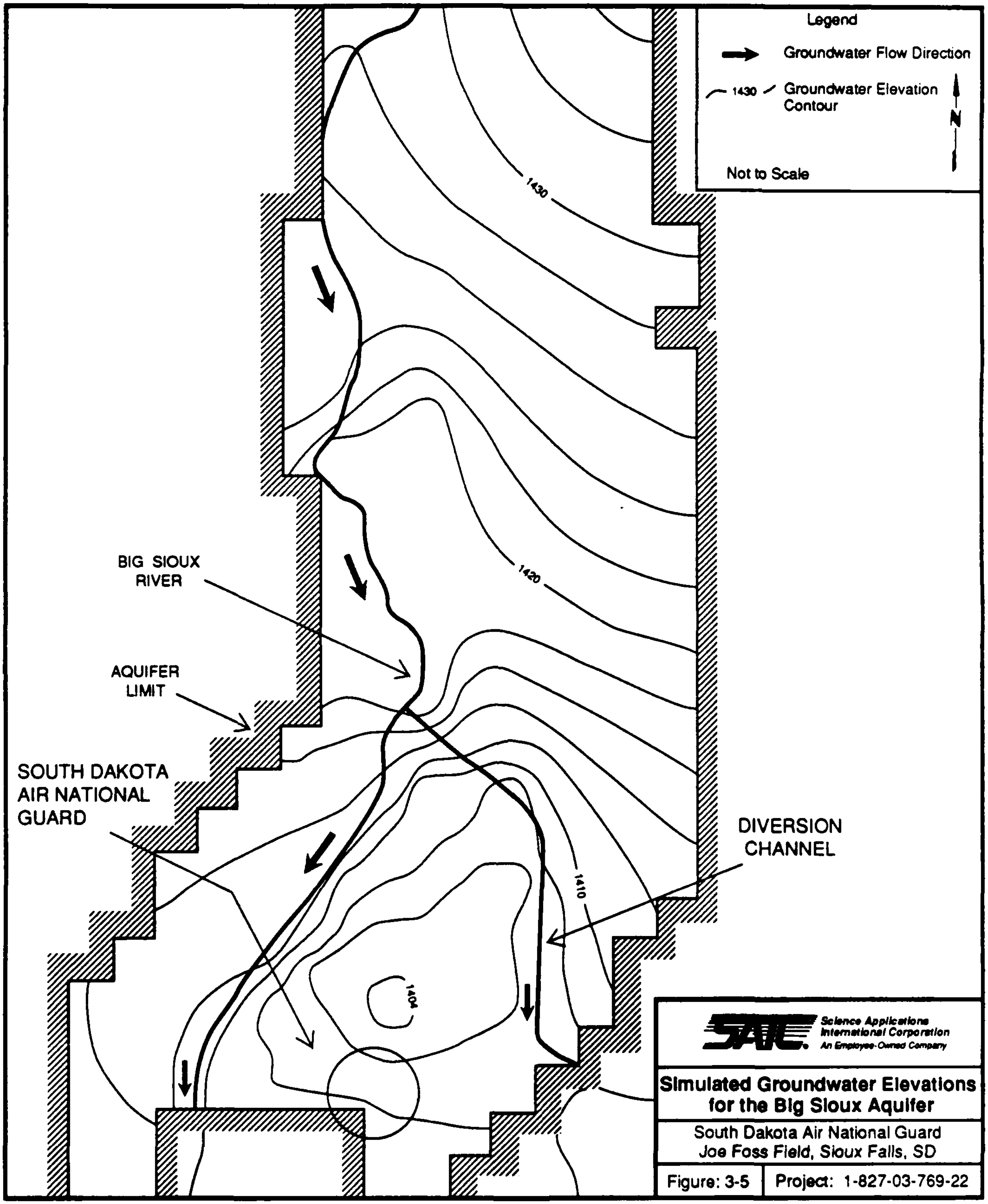
Discharge of the aquifer occurs through evapotranspiration and seepage into the Big Sioux River and by groundwater pumpage. Seepage into the river occurs primarily in the northern two-thirds of the aquifer. Groundwater pumpage occurs primarily in the southern one-third of the aquifer by the city of Sioux Falls municipal well field. Approximately 2.3 billion gallons were extracted from the aquifer in 1986, an amount that has been increasing in recent years as Sioux Falls' population increases.

It should be noted that the following information represents average trends and that the hydrologic system is dynamic, fluctuating seasonally and yearly depending on the relative strengths of the components of aquifer recharge and discharge.

Groundwater table depths vary from 0 to 20 feet below land surface. Water table elevations range from 1,400 to 1,470 feet above mean sea level in the southern and northern portions of the aquifer, respectively. Yearly groundwater level fluctuation averages 4.2 feet depending on pumping and precipitation amounts (Koch 1982). Groundwater levels tend to rise in the spring and early summer when precipitation (snowmelt and rainfall) infiltration is highest. Levels are lowered from mid-summer to late fall when precipitation is low and groundwater pumpage is at a maximum.

Figure 3-5 shows the simulated groundwater elevations for the Big Sioux Aquifer under normal conditions. In the northern two-thirds of the aquifer, groundwater flow is generally north to south with a component of flow toward the river where groundwater discharges. In the southern one-third of the aquifer, groundwater flow directions are dominated by the pumping of the municipal well field. Generally, flow is directed radially inward toward the central portion of the valley (beneath the Joe Foss Field runways), which is the approximate geographic center of the municipal well field.

Storativity (S) is the unitless measure of the fraction of volume that gravity will drain from a unit volume of the unconfined aquifer material. Typical values of sand and gravel range from 0.15 to 0.25 (Johnson Division 1986). Storativity of the Big Sioux Aquifer has been estimated to be 0.20, based upon grain size analyses of aquifer material (Koch 1982). Using this as an average value, the Big Sioux Aquifer has a storage capacity of approximately 32.5 billion gallons (1.23×10^8 meters^3 [m^3]).



Simulated Groundwater Elevations for the Big Sioux Aquifer

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-5 Project: 1-827-03-769-22

Source: Koch (1982)

Hydraulic conductivity (K) values range from 1,500 to 6,500 gallons per day per $foot^2$ ($gal/day/ft^2$) (10^{-2} to 10^{-1} cm/sec)(Koch 1982)(Ranney Water Supply Systems 1954). These values are within values for medium sand to fine gravel (Freeze and Cherry 1979).

Transmissivity (T) is a measure of an entire aquifer's ability to transmit water. For example, T values of 1,000; 10,000; and 100,000 gal/day/ft roughly correlate to aquifers that can be developed for domestic, industrial, and municipal water supplies, respectively. T values of the Big Sioux Aquifer range from 0 to 250,000 gal/day/ft (0.03 m^2/s). This value is relatively high and allows the production of volumes in excess of 1,000 gal/min from some wells.

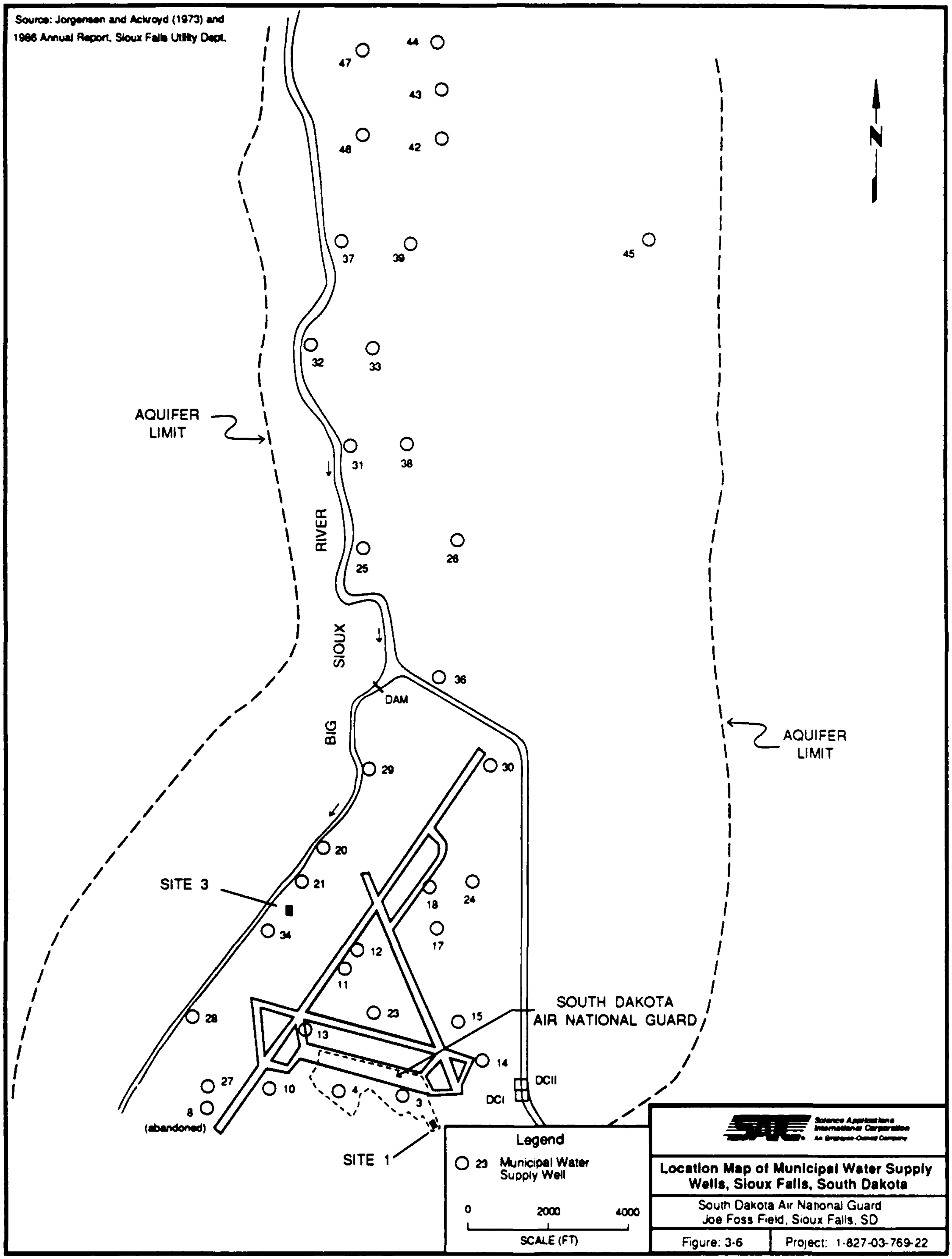
The primary use of groundwater in the southern one-third of the Big Sioux Aquifer in the vicinity of Sioux Falls is for municipal water supply for the city of Sioux Falls. The wells for this supply are located in a well field that covers the southern one-third of the aquifer. The majority of these wells are located adjacent to the Big Sioux River to take advantage of induced recharge effects and to reduce the groundwater residence time thereby reducing the dissolved solids content. Figure 3-6 and Table 3-1 show the locations of the municipal wells and 1986 pumpage for the municipal water supply, respectively. In 1986, total pumpage from these groundwater wells exceeded 2.1 billion gallons. The well field is augmented by two surface water intakes within the Diversion Channel, which supplied 2.0 billion gallons in 1986. Relatively small amounts of groundwater also are used for water supply in small communities to the north and for irrigation purposes throughout the valley. Although not fully utilized, over 8.5 million gallons per day of irrigation water rights have been granted for aquifer water.

3.4 SITE HYDROGEOLOGY

3.4.1 Site Geology

The soil sampling associated with drilling operations conducted during this RI provided information helpful in representing subsurface geology at the Base. The locations and depiction of geologic profiles at Site 1 – Underground Fuel Storage Area are shown in Figures 3-7 through 3-9. The location and depiction of the geologic profile at Site 3 – Base Fire Training Area are shown in Figures 3-10 and 3-11, respectively. Sediments encountered included post-glacial alluvial deposits (flood plain clay), glacial outwash, and glacial till.

A surficial layer of post-glacial alluvial deposits was encountered in all soil borings and monitoring well boreholes at the Base. The layer was found to be laterally continuous within the site areas with the exception of Site 1 – Underground Fuel Storage Area, where past construction activities have disturbed or eliminated this layer around the tank area. The 10 to 15 feet thick



Source: Jorgensen and Ackroyd (1973) and 1986 Annual Report, Sioux Falls Utility Dept.

Location Map of Municipal Water Supply Wells, Sioux Falls, South Dakota

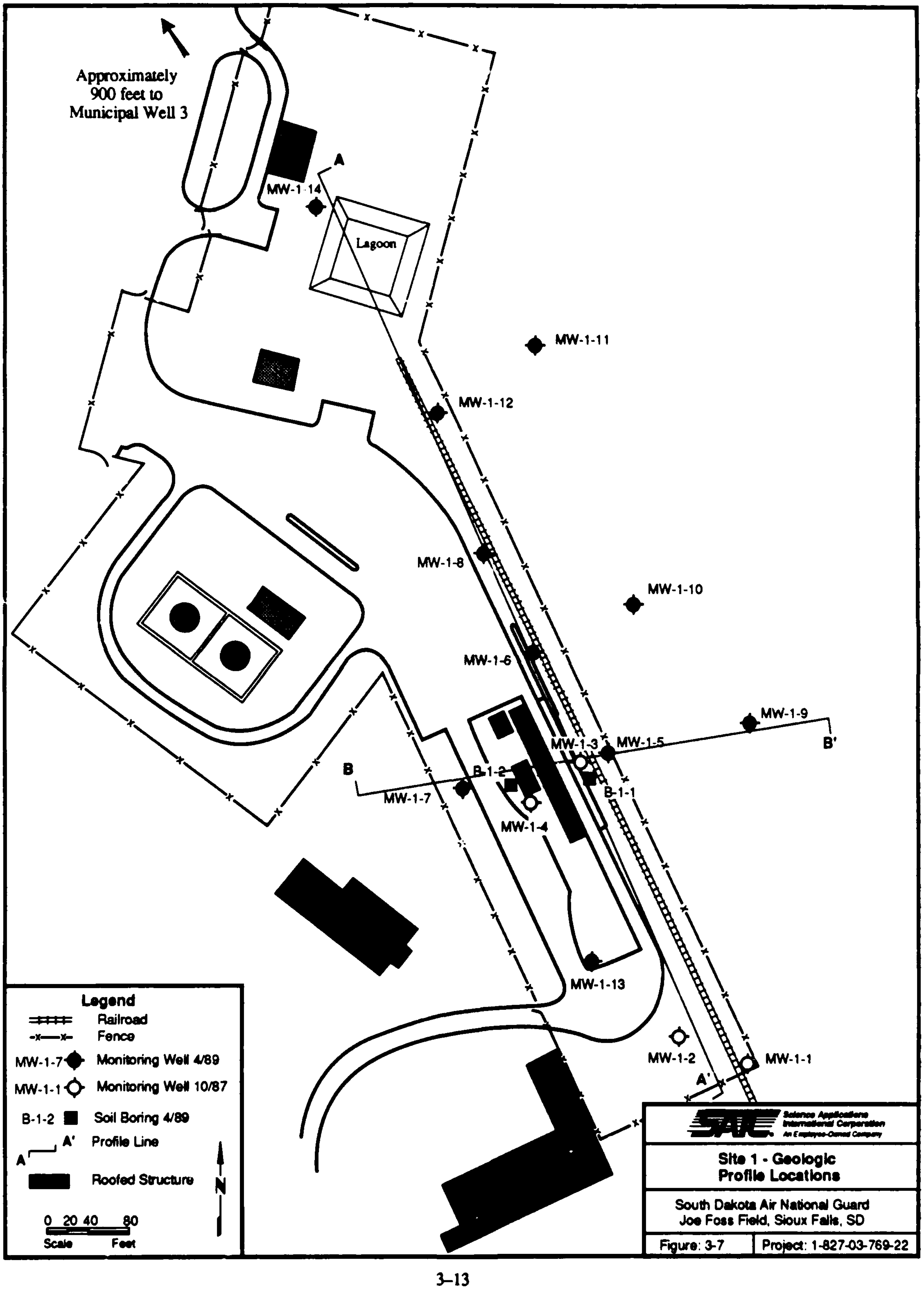
South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-6 Project: 1-827-03-769-22

TABLE 3-1. SUMMARY OF SIOUX FALLS, SOUTH DAKOTA MUNICIPAL WATER SUPPLY WELL DATA

WELL I.D. *	TYPE	YEAR CONSTRUCTED	DEPTH (Ft.)	DIAMETER (Ft.)	GALLONS PUMPED (1986)	HOURS PUMPED (1986)	AVG. DAILY WITHDRAWAL (MILLION GAL)	PUMPING RATE (GPM)	PERCENT OF TOTAL
3	Wolfe	1911	32	50	38,775,100	2348	0.40	278	0.63
4	Ranney (Converted)	1931-1956	34	50	164,427,700	3159	1.25	868	2.66
10	Early Bragstad	1934	37	18	33,365,000	2242	0.36	250	0.54
11	Early Bragstad	1934	37	18	60,911,000	3167	0.46	319	0.99
12	Early Bragstad	1941	36	18	72,158,000	2913	0.59	410	1.17
13	Bragstad	1941	35	40	110,692,800	3908	0.68	472	1.79
14	Bragstad	1942	30	40	21,774,000	1700	0.31	215	0.35
15	Bragstad	1943	44	40	109,203,600	2811	0.93	646	1.77
17	Bragstad	1943	36	40	72,437,000	3035	0.57	396	1.18
18	Bragstad	1943	39	40	65,783,000	2262	0.70	486	1.07
20	Bragstad	1944	37	40	253,228,000	4528	1.34	931	4.10
21	Bragstad	1945	35	40	70,325,000	3601	0.47	326	1.14
23	Bragstad	1950	34	40	86,958,000	3442	0.61	424	1.14
24	Bragstad	1950	38	40	61,436,000	2512	0.59	410	1.00
25	Bragstad	1951	35	40	119,726,300	5094	0.56	389	1.94
26	Bragstad	1951	34	40	171,697,700	5935	0.65	451	2.78
27	Bragstad	1954	39	40	134,657,400	3706	0.87	604	2.21
28	Bragstad	1956	40	40	251,679,600	4908	1.23	854	4.07
29	Ranney	1956	41	13	326,283,000	3809	2.06	1431	5.28
30	Ranney	1956	50	13	181,578,000	2921	1.49	1035	2.94
31	Ranney	1957	48	13	436,981,000	3935	1.77	1229	7.08
32	Ranney	1957	41	13	453,019,000	1575	1.44	1000	7.35
33	Ranney	1957	38	13	328,762,000	4141	1.91	1326	5.32
36	Ranney	1974	40	16	423,159,000	5074	2.00	1389	6.85
37	Ranney	1975	33	16	288,287,000	4858	1.42	986	4.67
38	Ranney	1977	36	16	230,559,000	3439	1.61	1118	3.74
39	Ranney	1977	34	16	190,612,000	3168	1.44	1000	3.08
42	42" Gravel Pack	1978	41	2.6	160,681,700	6117	0.63	438	2.60
43	42" Gravel Pack	1973	40	2.6	161,755,000	6470	0.60	417	2.62
44	42" Gravel Pack	1978	38	2.6	142,237,700	6434	0.53	368	2.31
45	42" Gravel Pack	1978	39	2.6	56,560,500	5140	0.26	181	0.91
46	Ranney	1980	46	16	538,525,000	6154	2.10	1458	8.73
47	Ranney	1980	41	16	266,149,700	6215	1.03	715	4.31
DC1	Diversion Channel	1964			12,479,000	146	2.05	1424	0.20
DC2	Diversion Channel	1968			74,814,000	487	3.69	2563	1.21

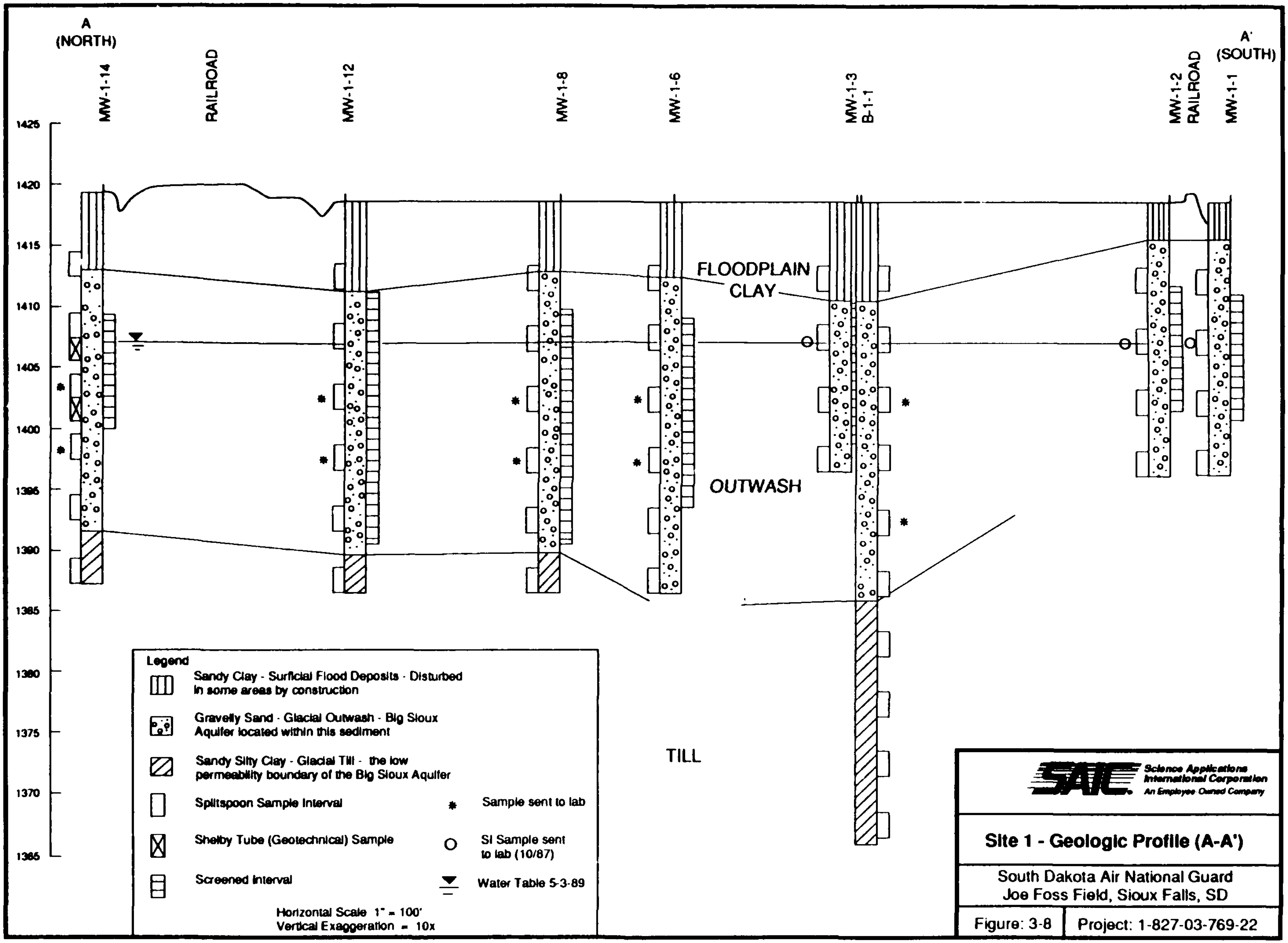
* Wells 8 and 34 have been abandoned.



Site 1 - Geologic Profile Locations

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-7 Project: 1-827-03-769-22



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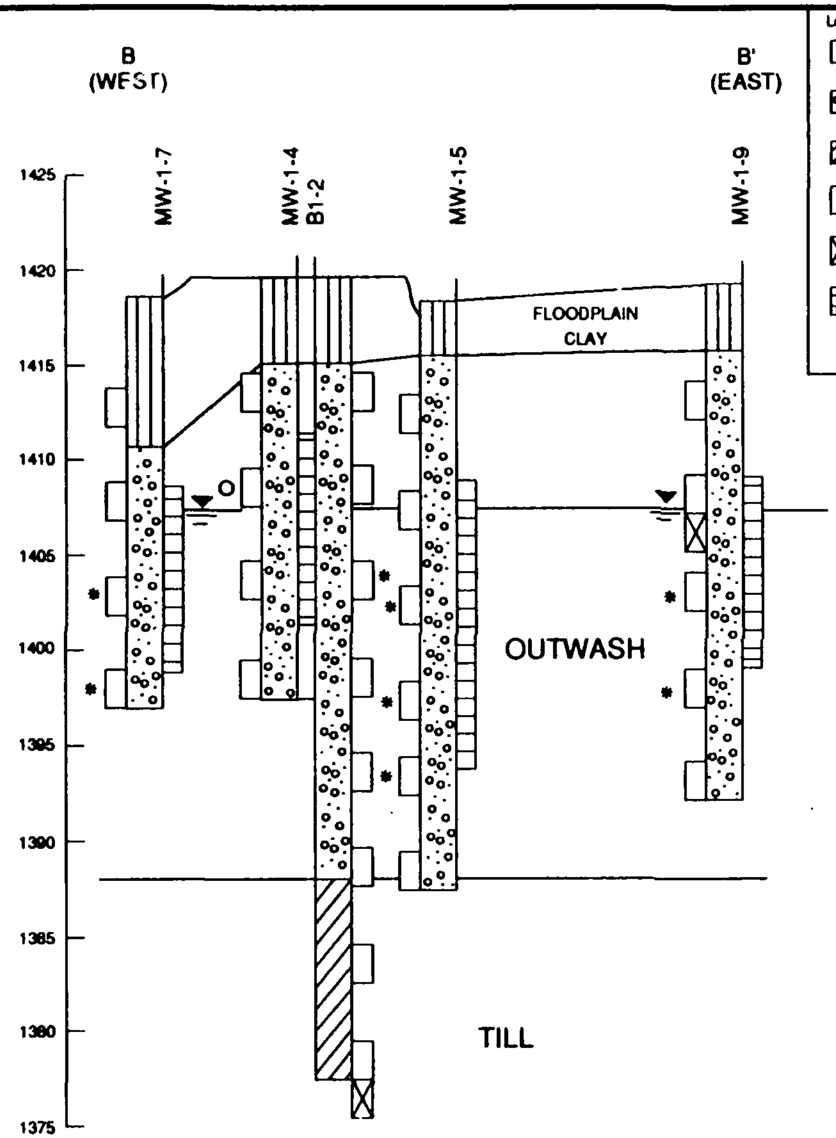
Site 1 - Geologic Profile (A-A')

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-8 Project: 1-827-03-769-22



Legend

- ▥ Sandy Clay - Surficial Flood Deposits - Disturbed in some areas by construction
- ▩ Gravelly Sand - Glacial Outwash - Big Sioux Aquifer located within this sediment
- ▨ Sandy Silty Clay - Glacial Till - the low permeability boundary of the Big Sioux Aquifer
- ▯ Splitspoon Sample Interval
- ☒ Shelby Tube (Geotechnical) Sample
- ⊟ Screened Interval
- * Sample sent to lab
- ○ SI Sample sent to lab (10/87)
- ▼ Water Table 5-3-89

Horizontal Scale 1" = 100'
Vertical Exaggeration = 10x

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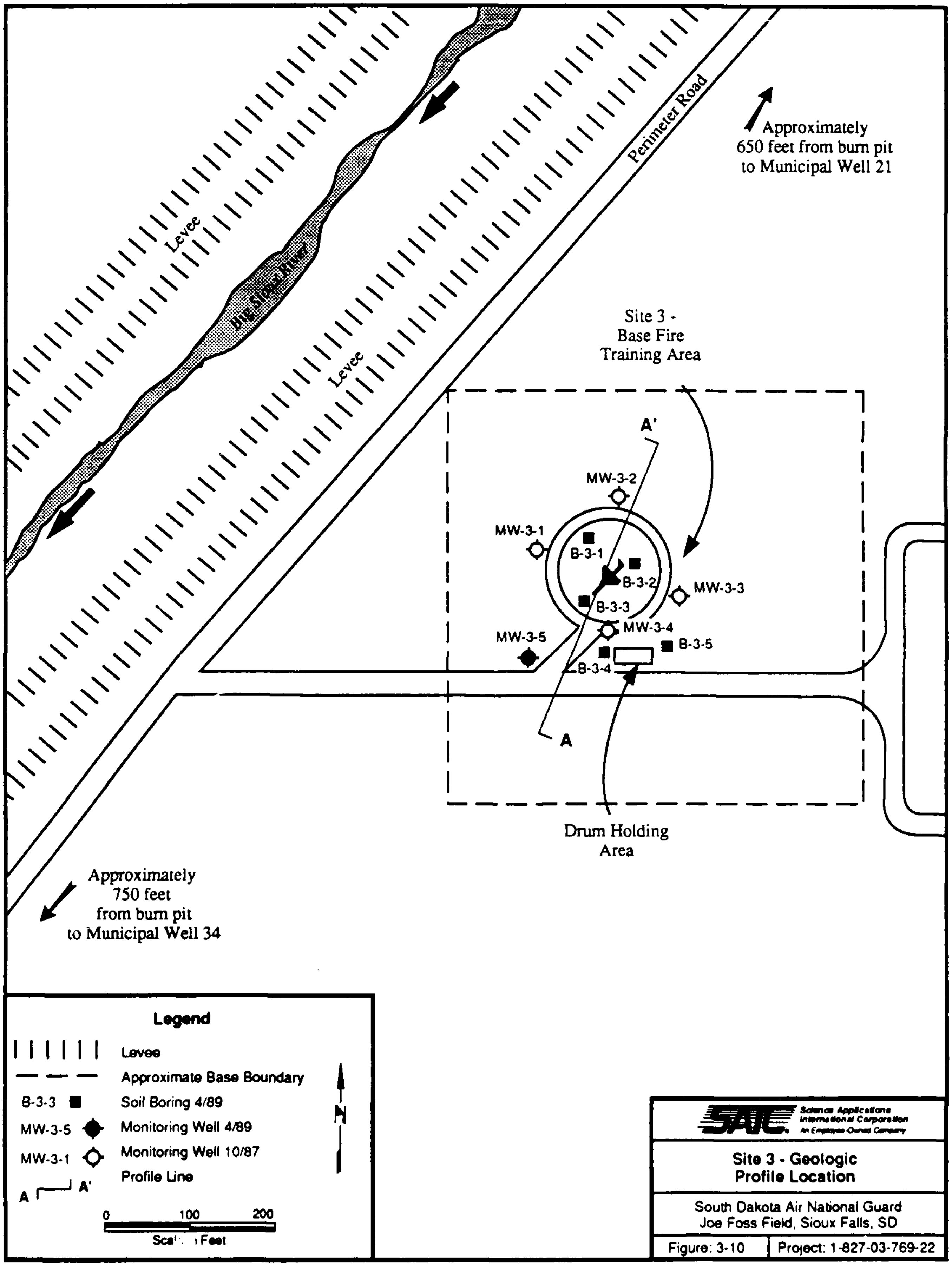
Site 1 - Geologic Profile (B-B')

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

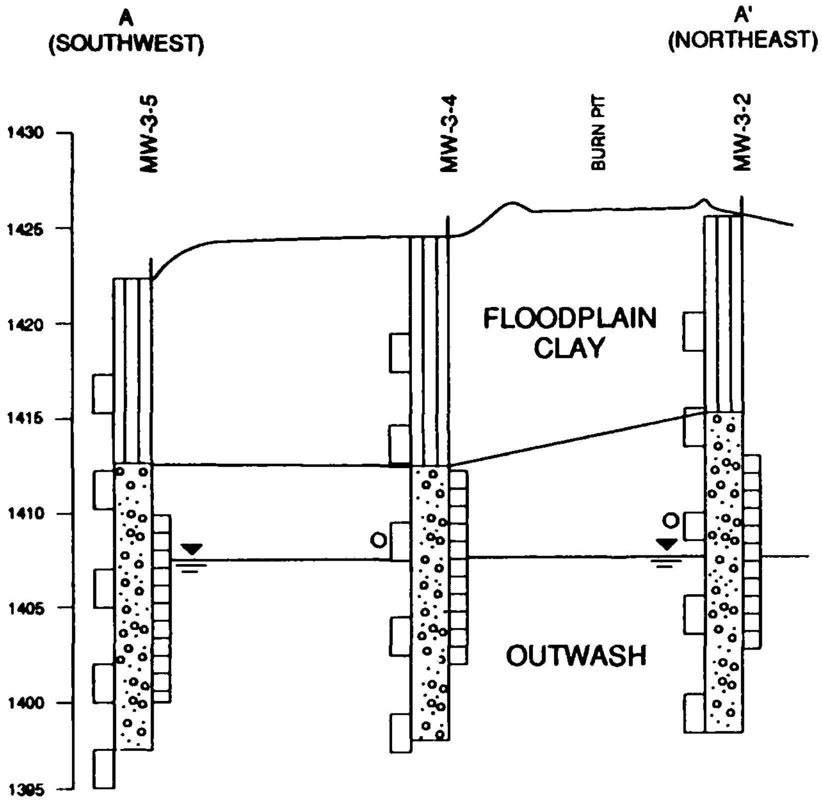
Figure: 3-9 | Project: 1-827-03-769-22



Site 3 - Geologic Profile Location

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-10 Project: 1-827-03-769-22



Legend

- ▥ Sandy Clay - Surficial Flood Deposits - Disturbed in some areas by construction
- ▨ Gravelly Sand - Glacial Outwash - Big Sioux Aquifer located within this sediment
- ☐ Splitspoon Sample Interval
- ☒ Shelby Tube (Geotechnical) Sample
- ⊟ Screened Interval
- ✱ Sample sent to lab
- ○ SI Sample sent to lab (10/87)
- ▼ Water Table 5-3-89

Horizontal Scale 1" = 100'
Vertical Exaggeration = 10x

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Site 3 - Geologic Profile (A-A')

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-11 Project: 1-827-03-769-22

deposit consisted of a dark gray, clayey silt with traces of fine sand. Figure 3-12 shows the sieve analysis results of two samples (B-3-1-(2') and B-3-5-(2')) of this flood plain clay layer.

The character of the post-glacial alluvial deposits determines the soil types found at the sites. Figure 3-13 shows the soil types present in the immediate Base area that are of the Luton-Dimmick association. These soils consist of fine-textured to moderately fine-textured flood plain soils. The soil type underlying both sites is the Luton, which is the finest grained of the association. There are also Rauville and Dimmick type soils close to each site, which are slightly coarser grained and are associated with river channel deposits.

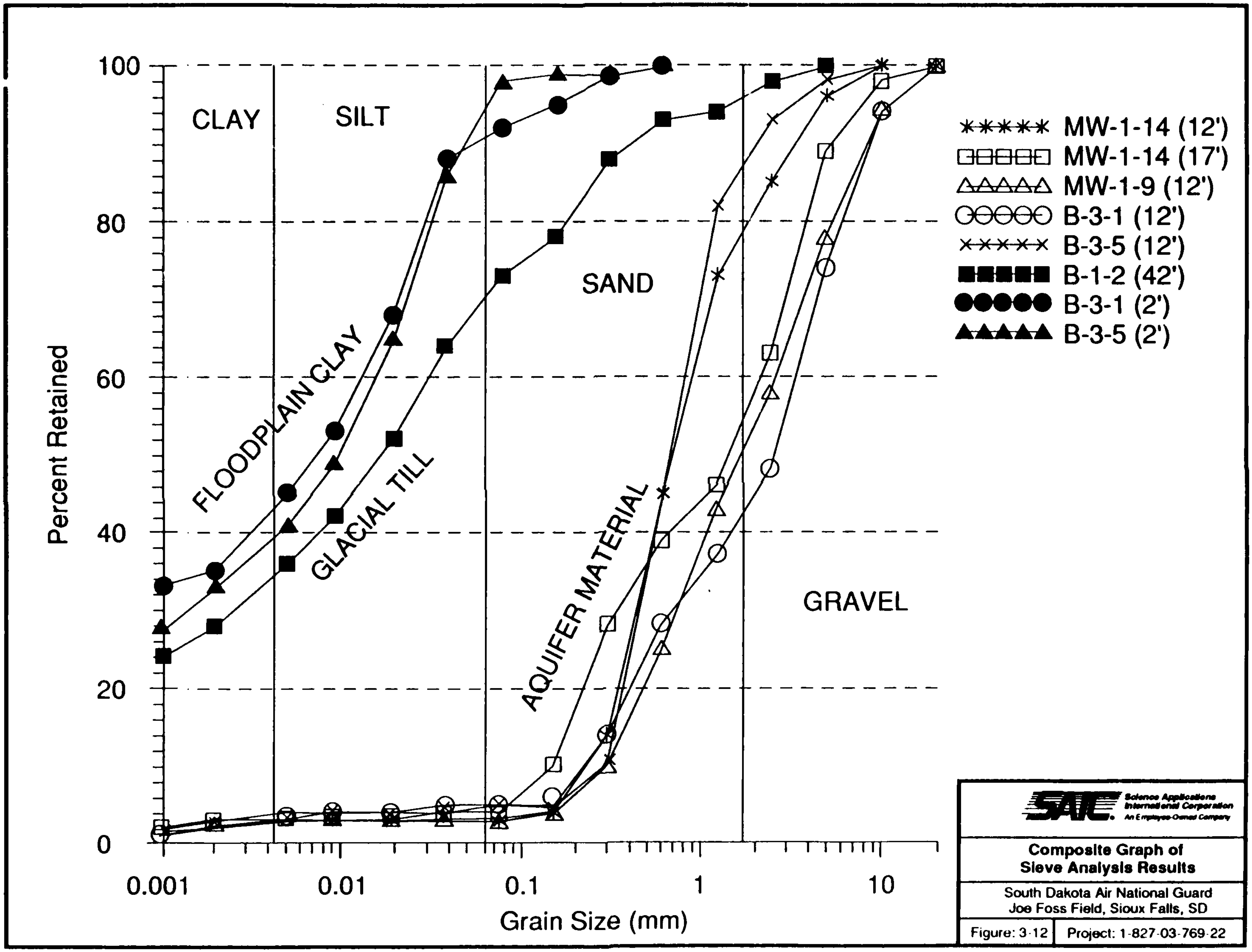
The glacial outwash was encountered underlying the surficial alluvial deposits. The outwash was laterally continuous at both sites. The deposit ranges from 20 to approximately 25 feet thick at Site 1 – Underground Fuel Storage Area. The bottom of the outwash was not encountered at Site 3 – Base Fire Training Area, but well log information for the area indicates that it is approximately 35 feet thick (Koch 1982). Samples were generally composed of gray, sandy gravels with traces of silt and clay. Sieve analyses results of five outwash samples (aquifer material) are shown in Figure 3-12.

The glacial till was found beneath the outwash (Site 1 – Underground Fuel Storage Area only). The outwash/till contact, encountered by drilling, was located at a depth of approximately 30 to 35 feet. The thickness of the unit is unknown, but the geophysical data indicate a thickness of approximately 100 to 130 feet in the vicinity of Site 1 – Underground Fuel Storage Area where the till probably contacts the Sioux Quartzite. As shown in Figure 3-12, till samples were composed of an extremely poorly sorted mixture of dark gray, clay, silt, and sand with traces of gravel.

3.4.2 Site Hydrogeology

The saturated outwash deposits compose the Big Sioux Aquifer in the study area. Characteristics of this aquifer are summarized in Table 3-2. The aquifer is under water table (unconfined) conditions at both sites.

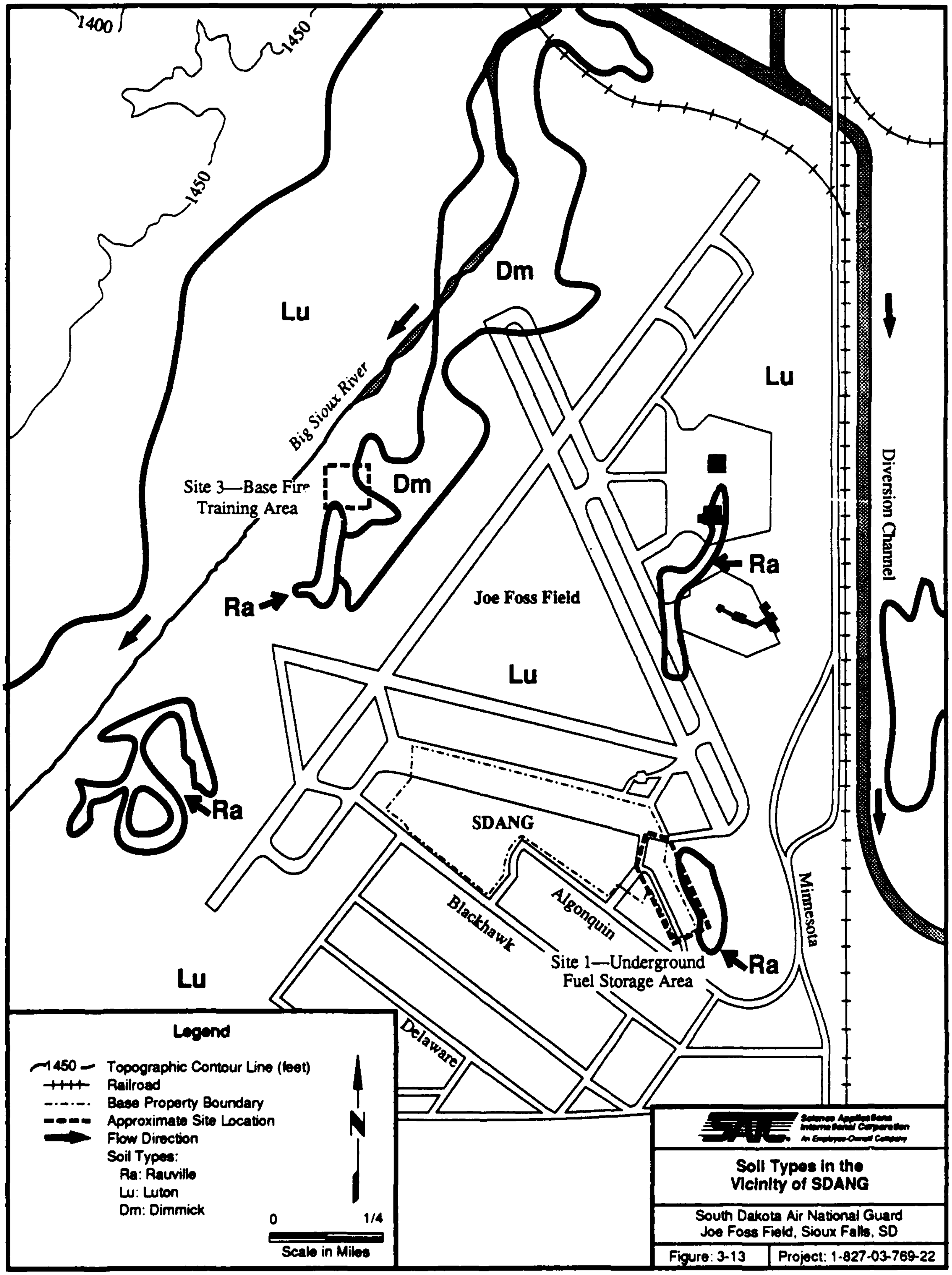
Figure 3-14 shows a hydrograph of the water levels measured in monitoring wells at Site 1 – Underground Fuel Storage Area. Because measurements have been sporadic, it is difficult to make definitive statements regarding water level fluctuations. Based upon this incomplete data, however, static water levels have fluctuated more than 1.5 feet throughout the past 2 years. These



Composite Graph of Sieve Analysis Results

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-12 | Project: 1-827-03-769-22



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Soil Types in the Vicinity of SDANG

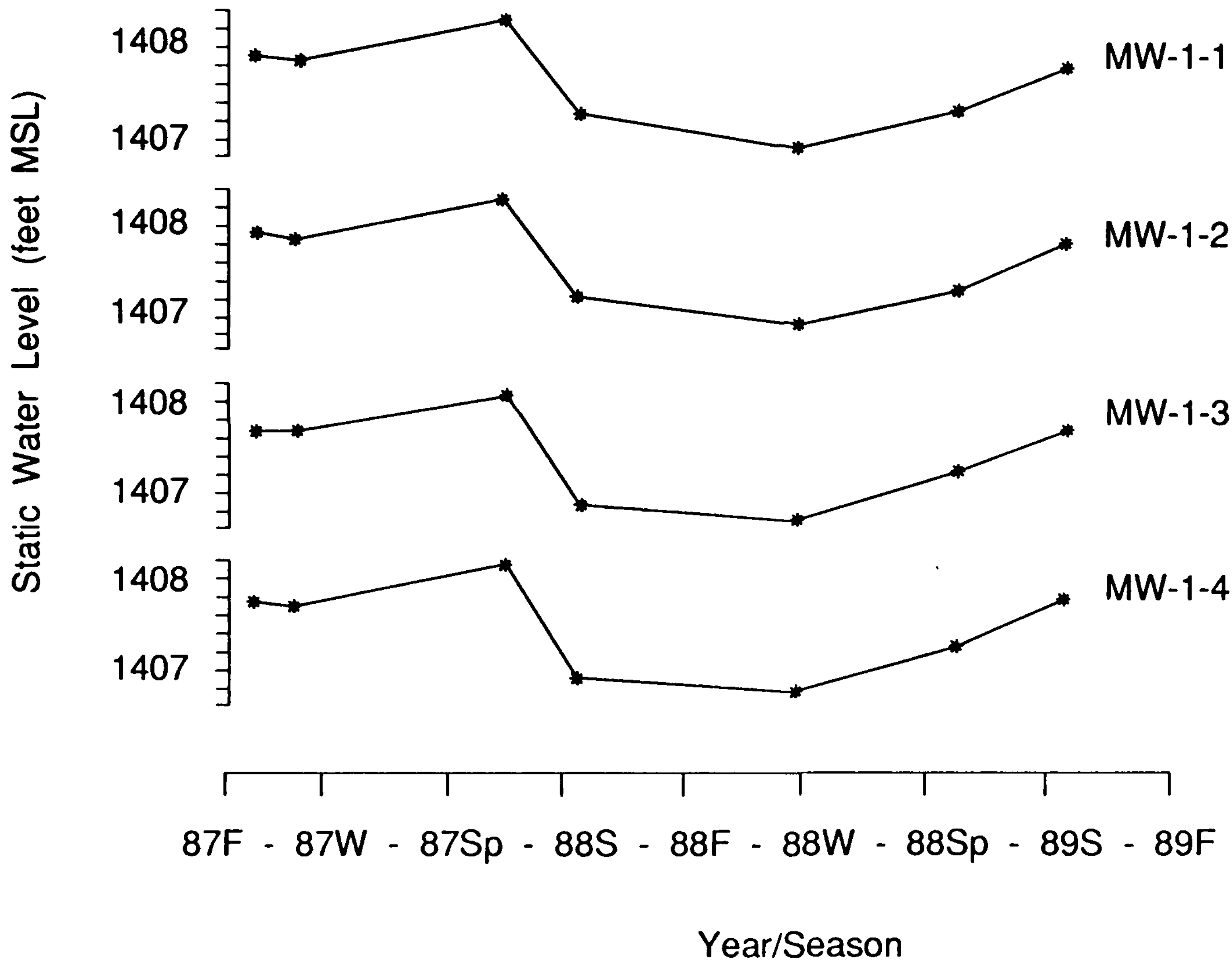
South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-13 | Project: 1-827-03-769-22

TABLE 3-2. CHARACTERISTICS OF THE BIG SIOUX AQUIFER IN THE VICINITY OF SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Parameter	Site 1 - Underground Fuel Storage Area	Site 3 - Base Fire Training Area
Aquifer Material	Glacial Outwash - Sandy gravel with traces of silt and clay. Average grain size approx. 0.006 inches (1.5 mm).	Glacial Outwash - Sandy gravel with traces of silt and clay. Average grain size approx. 0.006 inches (1.5 mm).
Aquifer Thickness	15 to 20 feet (4.6 to 6.1 m)	25 to 30 feet (7.6 to 9.1 m)
Static Groundwater Depth (Elevation)*	11 to 13 feet BLS (1406 to 1408 ft MSL)	11 to 14 feet BLS (1409 to 1411 ft MSL)
Groundwater Flow Direction	North +/- 20 degrees (see Figure 3-5)	Southeast +/- 20 degrees (see Figure 3-5)
Groundwater Gradients*	0.0003 to 0.0013	0.0025 to 0.0019
Hydraulic Conductivity (K)		
From SI Slug Testing	2750 gal/day/ft^2 (0.13 cm/sec)	2550 gal/day/ft^2 (0.12 cm/sec)
From Grain Size Analysis	4500 gal/day/ft^2 (0.21 cm/sec)	5350 gal/day/ft^2 (0.25 cm/sec)
Transmissivity*		
From K and Thickness	67,500 to 90,000 gpd/ft	133,750 to 160,500 gpd/ft
From Aquifer Testing	86,500 gpd/ft	Not Tested
Storativity		
From Aquifer Testing	0.19	Not Tested
Groundwater Flow Rate*	328 to 1476 ft/yr 100 to 450 m/yr	2460 to 3280 ft/yr 750 to 1000 m/yr

* Parameters strongly effected by climatic conditions and municipal well pumpage. Values should be regarded as estimates.



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Hydrograph of Selected Wells

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-14 Project: 1-827-03-769-22

fluctuations agree with the aquifer-wide seasonal variations of higher levels in the spring and early summer and dropping levels during the late summer and fall.

Figures 3-15 and 3-16 are water table contour maps for the two sites on July 5, 1989. Flow directions agree with the trend of radially inward groundwater flow toward the municipal well field. These directions have not deviated more than 20 degrees during the periods of water level monitoring (2 years). Water table gradients have differed by as much as 400 percent at the sites. This large difference reflects the effect of variation in groundwater pumpage upon the aquifer.

Storativity (S) values for the aquifer material at the site were obtained through the RI aquifer testing. There was no aquifer testing performed at Site 3 – Base Fire Training Area; however, the value is expected to be similar because of the similarities between the sediments.

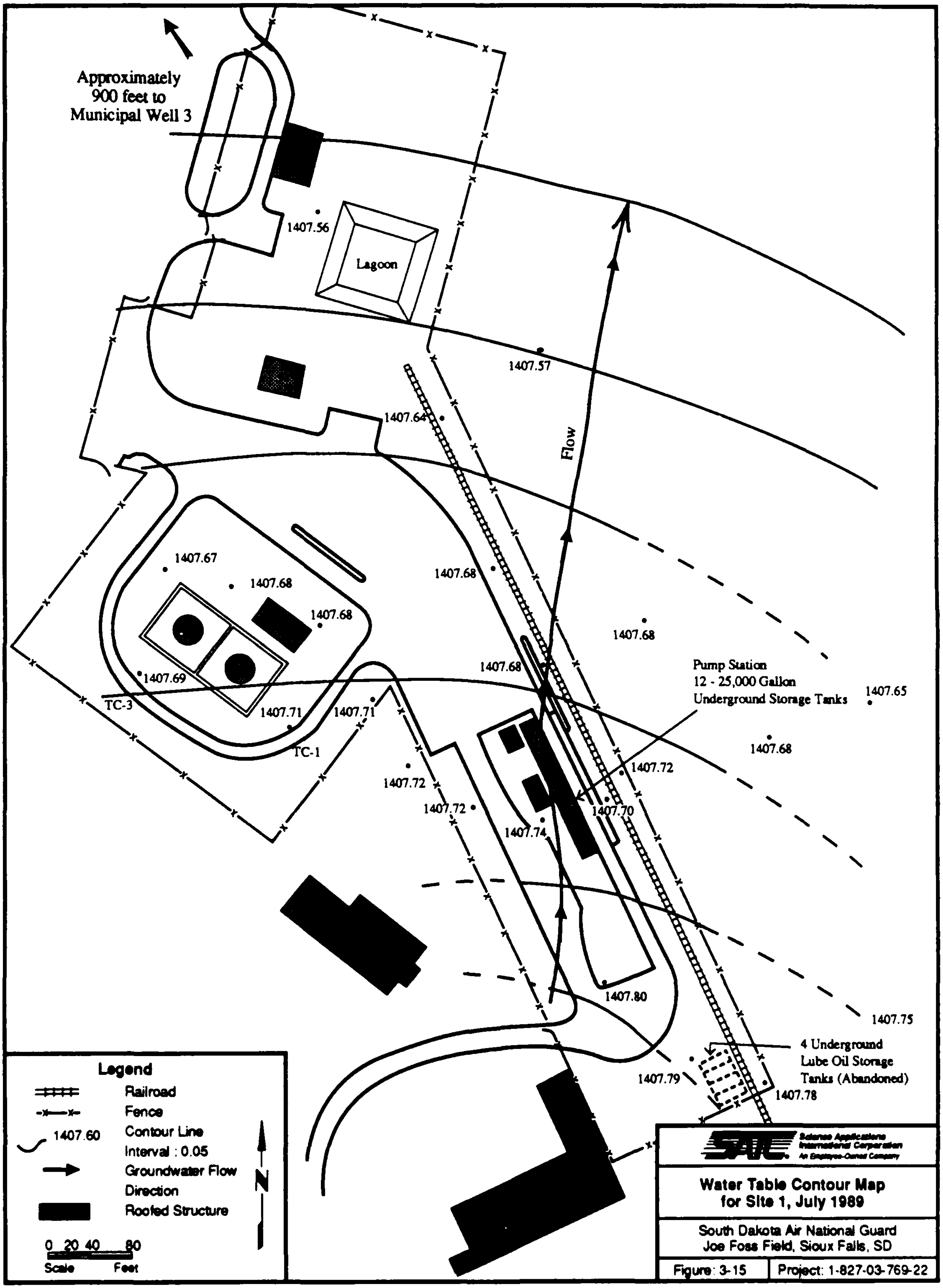
Hydraulic conductivity (K) values were obtained from Site Inspection slug test results (average) and by calculations based upon average grain size. The slug test values appear to be low when compared to published values for sandy gravel (Freeze and Cherry 1979). This difference may be a result of the analysis method used (i.e., Hvorslev) and/or of well inefficiency effects due to the extremely rapid injection of water (during testing) of the exceptionally high permeability sediments within the aquifer. The K values determined from average grain size values agree closely with published values. These values were determined from the following calculation (Shepherd 1989):

$$K = 3500d^{1.65} \tag{1}$$

where:

3,500 = Constant for river channel deposit
d = Average grain size diameter in millimeters
and
1.65 = Constant for river channel deposit.

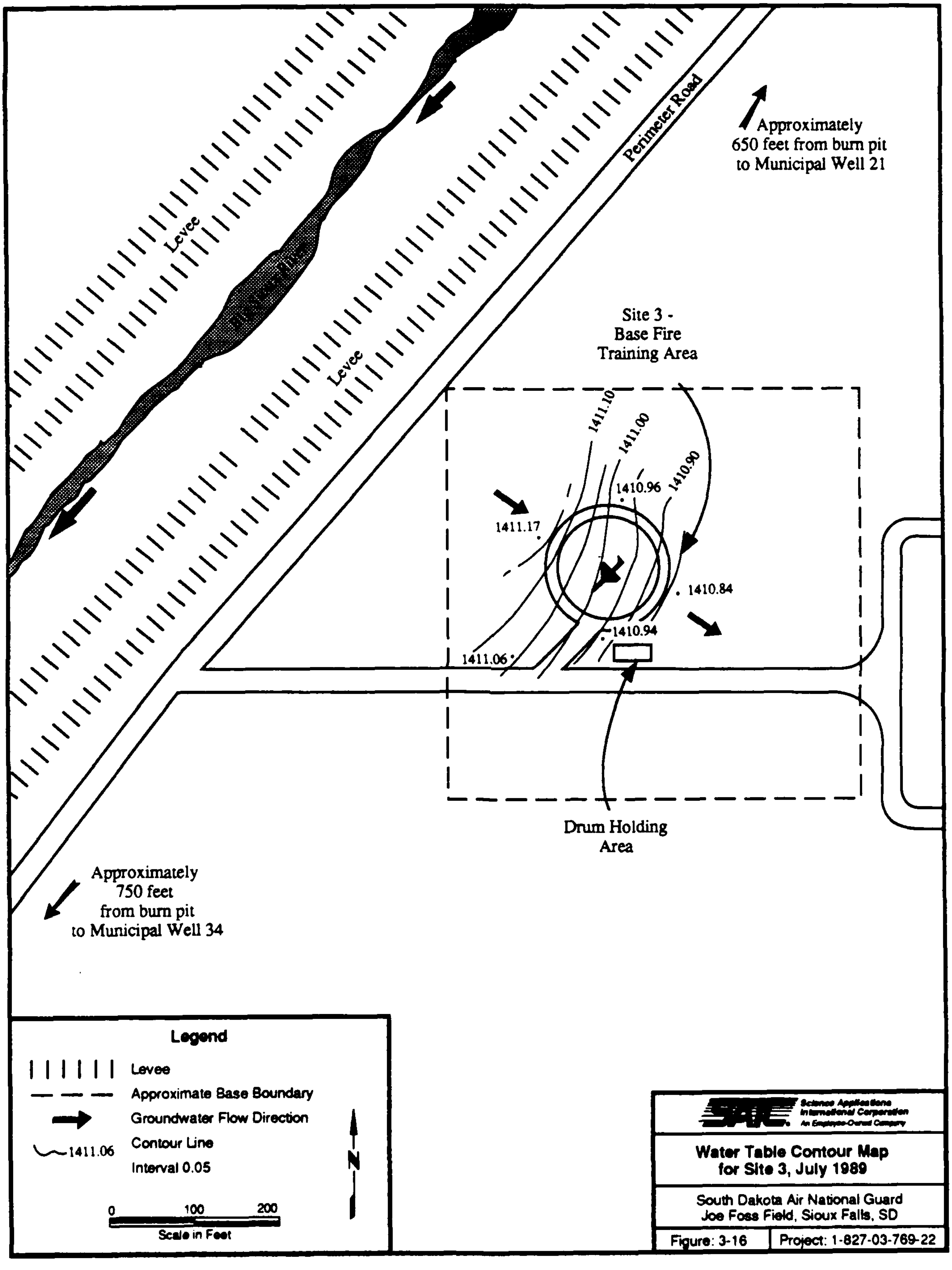
Transmissivity (T) values were obtained from RI aquifer testing (Site 1 – Underground Fuel Storage Area only) and by calculations based upon K values and aquifer thickness. T values obtained from these methods agree within 10 percent and also agree with the value determined during the testing of a nearby municipal well (Ranney Method Water Supplies 1956). The aquifer test was conducted at Site 1 – Underground Fuel Storage Area in July 1989 at a pumping rate of 80 gpm for a duration of 36 hours. These testing parameters were the maximum possible using the wells in place at the site and were adequate to obtain T and S values. See Appendix H for



Water Table Contour Map for Site 1, July 1989

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-15 Project: 1-827-03-769-22



Water Table Contour Map for Site 3, July 1989

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-16 Project: 1-827-03-769-22

additional data on the testing and analysis procedures. T was also determined from the following calculation:

$$T = Kb \qquad (2)$$

where:

K = Hydraulic conductivity from grain size calculations
and
b = Saturated outwash thickness.

Because of the thinness and large K of the aquifer sediments, a small change in aquifer thickness results in a very large change in T. For example, an increase in aquifer thickness of 5 feet in the vicinity of Site 1 – Underground Fuel Storage Area would increase T by 22,000 to 30,000 gpd/ft.

Groundwater flow rates (V) can be estimated using the following equation:

$$V = Ki/n \qquad (3)$$

where:

K = Hydraulic conductivity from grain size calculations
i = Hydraulic gradient (both high and low values)
and
n = Effective porosity of outwash.

Changes in stratigraphy and especially municipal well pumping rates would have a major effect on these rates.

3.5 SURFACE WATER HYDROLOGY

3.5.1 Occurrence and Drainage Patterns

SDANG is located within the boundaries of the flood plain associated with 500-year frequency floods (Federal Emergency Management Agency 1982). The Big Sioux River and the flood Diversion Channel, which form the north, west, and east boundaries of the Base, are levied in the vicinity of the airport. The levels of both the river and the Diversion Channel are controlled by a dam on the river and a weir on the Diversion Channel, immediately downstream of the divergence of the two channels.

Surface drainage is poorly developed in the immediate vicinity of the airport. Surface waters from the airport eventually find their way into the Big Sioux River to the west of the airport and also empty into the Diversion Channel to the east, via small runs and branches located near the airport boundaries and also via a storm sewer system. The Diversion Channel, which joins the Big

Sioux River north of the airport, is used to supplement Sioux Falls' drinking water when the wells are overused (HMTC 1986), as well as to divert flood waters from central parts of the city.

Surface water flow directions are shown in Figure 3-17. The Big Sioux River, west of the Base, flows south. Water in the Diversion Channel flows south along the eastern border of the airport. Surface flow directions within the airport grounds are not ascertainable from area maps.

The Big Sioux River has a total drainage area of more than 5,000 miles^2 (mi^2) upstream of Dell Rapids; however, about 2,000 mi^2 of the drainage area is usually noncontributing. The river originates in northeastern South Dakota and drains glacial till and outwash plains as it runs southward to its confluence with the Missouri River at Sioux City, Iowa. The stream has a low and nearly uniform gradient except near Dell Rapids and Sioux Falls, where it flows over outcrops of erosion-resistant Sioux Quartzite. The streambed material consists of permeable silt and sand except in the backwater area behind the Diversion Channel dam and the weir where it consists predominantly of relatively impermeable clay and silt (Jorgensen and Ackroyd 1973).

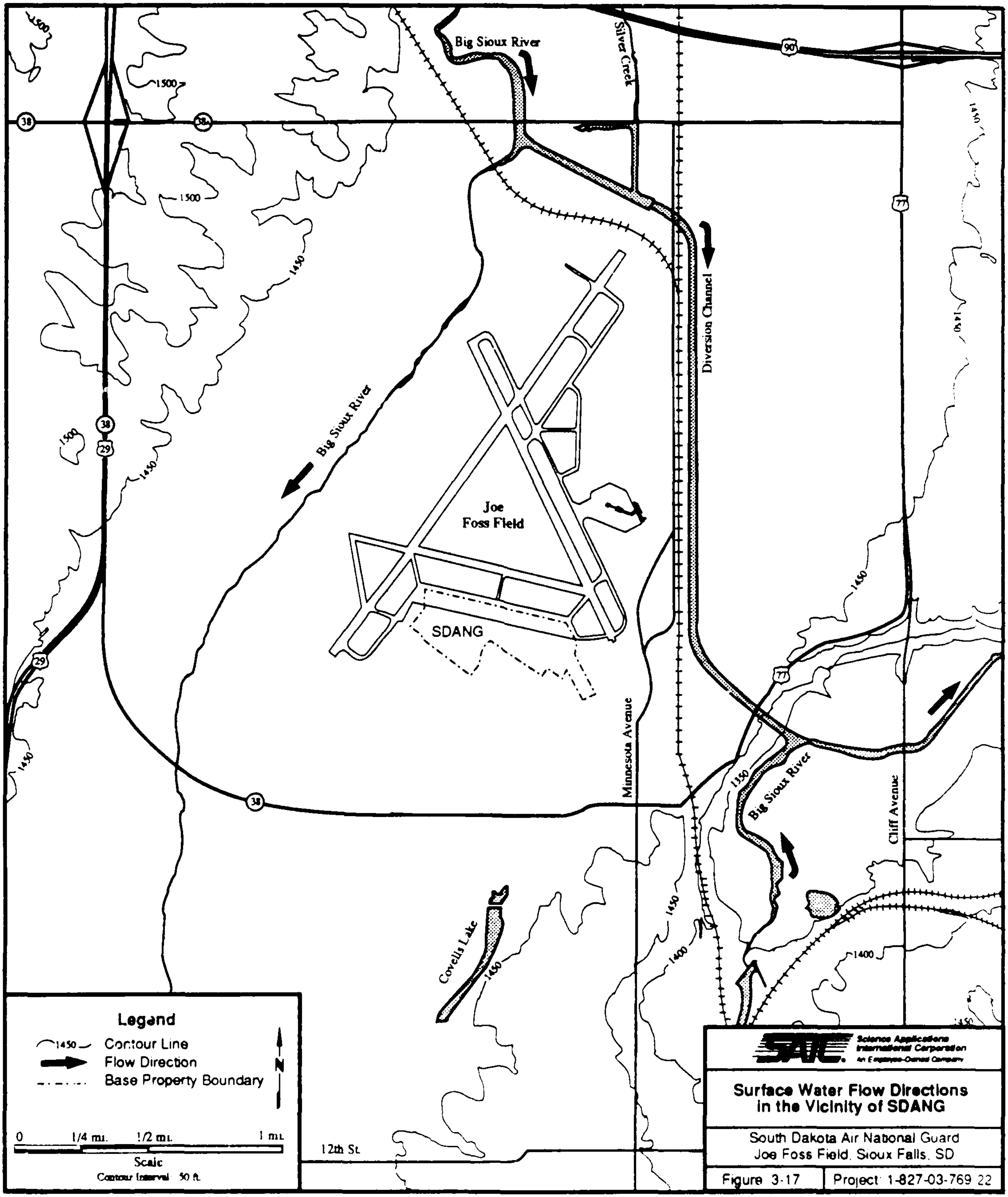
In general, the Big Sioux River between Dell Rapids and Renner receives more water from the aquifer than is discharged to the aquifer. Conversely, the river, on average, discharges water to the aquifer between Renner and the State Highway 38 bridge (Jorgensen and Ackroyd 1973). The Sioux Falls well field is located in the latter area. The well field has lowered the water table so that water presently infiltrates from the stream to the aquifer (Koch 1982).

The average annual base flow into the Big Sioux River between Dell Rapids and Cliff Avenue in Sioux Falls is 19 feet^3 per second (ft^3/s [13,700 acre-ft]) based on streamflow records from 1970 to 1979. Of that volume, 14.1 ft^3/s is treated municipal waste water from the city of Sioux Falls, which flows into the river, and 4.9 ft^3/s (3,500 acre-ft) is streamflow gain from groundwater and surface runoff (Koch, 1982).

3.5.2 Surface Water Quality

Surface water quality in the Big Sioux River is monitored at two water quality monitoring stations within 2 miles of the Base, which are operated by the South Dakota Department of Water and Natural Resources. The two stations, shown in Figure 3-18, are numbered and described as:

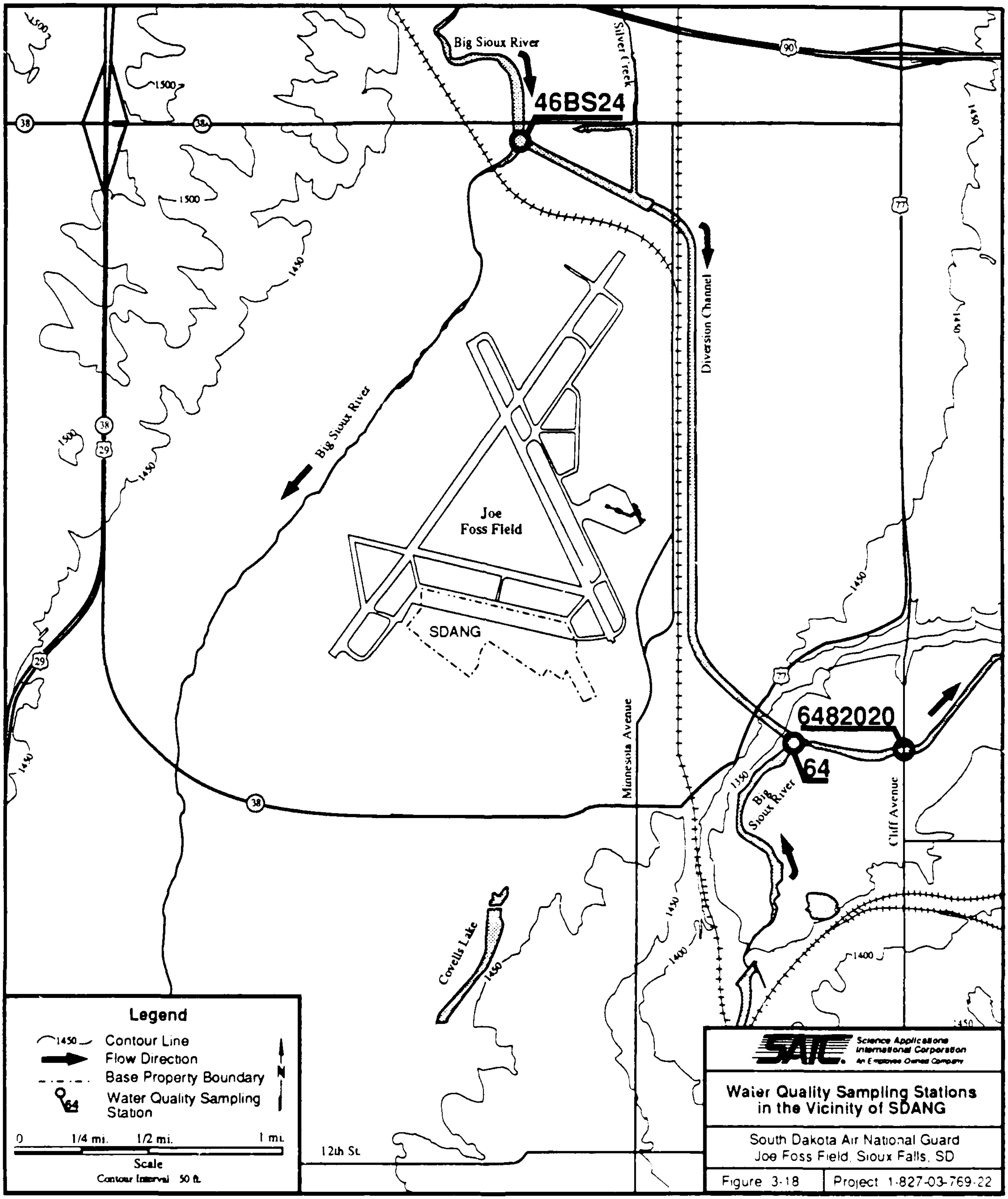
- Station 46BS24, which is upstream of the Diversion Channel and the airport, along the northern edge of the property at State Route 38A (60th Street North)
- Station 64, which is located at Falls Park, about 1 mile southeast of the airport property.



Surface Water Flow Directions in the Vicinity of SDANG

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure 3-17 | Project 1-827-03-769 22



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Water Quality Sampling Stations in the Vicinity of SDANG

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure 3-18

Project 1-827-03-769-22

Water samples are collected from these locations on a monthly basis and analyzed for conventional, inorganic, and bacteriological pollutants (fecal coliform; ammonia; ortho- and total phosphates; conductivity; suspended solids; alkalinity; hardness; total solids; and, in May through August only, sodium, calcium, and magnesium). Testing data for 1983 through 1989 are available for each of the sites.

The U.S. Geological Survey maintains a gauging station (6482020) on the Big Sioux River at North Cliff Avenue, about 1 mile east of the northern property line of the airport. The location of the station is shown in Figure 3-18. Only streamflow and water temperature are collected on a regular basis at this monitoring station. Water quality data were collected at this site for 1980 and 1981, however.

For purposes of water quality standards, the Big Sioux River in the vicinity of the Base, is classified by the South Dakota Department of Water and Natural Resources for the following uses:

- Domestic water supply
- Warm water semipermanent fish life propagation
- Immersion recreation
- Limited contact recreation
- Wildlife propagation and stock watering
- Irrigation.

Table 3-3 lists the applicable surface water quality standards for various water quality parameters and the measured concentrations of each of those parameters when available. When standards for more than one use are different for a given parameter, the Department of Water and Natural Resources mandates that the more restrictive of the two standards will apply.

Based on the available data, water quality is generally good for the parameters measured. Data were collected at three stations along the Big Sioux River during the period 1983 through 1989. The total dissolved oxygen exceeds the State standard of 5.0 milligrams per liter (mg/L) with an average value of 10.71 mg/L, a minimum of 5.5 mg/L, and a maximum of 15.5 mg/L. The average measured pH value of 8.1 is within the range set by the standards (pH 6.5 to 8.3 for immersion recreation). pH values varied between 8.7 and 6.4 during the period of data collection.

TABLE 3-3. SURFACE WATER QUALITY STANDARDS FOR THE GREATER SIOUX FALLS, SOUTH DAKOTA AREA

PARAMETERS	Units	Domestic Water Supply	Warm Water Fish	Immersion Recreation	Limited Contact Recreation	Wildlife Propagation	Irrigation	Total Standards
GENERAL								
Dissolved Oxygen	mg/L	---	5	5	5	---	---	5
Dissolved Solids	mg/L	1000	---	---	---	2500	---	1000
Suspended Solids	mg/L	---	90	---	---	---	---	90
Temperature (max)	°F	---	90	---	---	---	---	90
Conductivity	umhos/c	---	---	---	---	4000	2500	2500
Alkalinity	mg/L	---	---	---	---	750	---	750
pH		6.5-9.0	6.5-9.0	6.5-8.3	6.0-9.0	6.0-9.5	---	6.5-8.3
Fecal Coliforms	per 100	5000	---	200	1000	---	---	200
METALS								
Arsenic	mg/L	0.05	---	---	---	---	---	0.05
Barium	mg/L	1	---	---	---	---	---	1
Cadmium	mg/L	0.01	---	---	---	---	---	0.01
Chromium	mg/L	0.05	---	---	---	---	---	0.05
Chloride	mg/L	250	---	---	---	---	---	250
Cyanide (free)	mg/L	---	0.005	---	---	---	---	0.005
Cyanide (total)	mg/L	---	0.02	---	---	---	---	0.02
Lead	mg/L	0.05	---	---	---	---	---	0.05
Mercury	mg/L	0.002	---	---	---	---	---	0.002
Selenium	mg/L	0.01	---	---	---	---	---	0.01
Silver	mg/L	0.05	---	---	---	---	---	0.05
MISCELLANEOUS INORGANICS								
Fluoride	mg/L	4	---	---	--	---	---	4
Nitrates	mg/L	---	---	---	--	50	---	50
Sulfate	mg/L	500	---	---	--	---	---	500
Un-ionized NH3-N	mg/L	---	0.04	---	--	---	---	0.04
Chlorine	mg/L	---	0.02	---	--	---	---	0.02
Hydrogen Sulfide	mg/L	---	0.002	---	--	---	---	0.002
Polychlorinated Biphenyls	mg/L	---	1E-06	---	--	---	---	1E-06
Sodium Absorption	%	---	---	---	--	---	10	10

South Dakota Department of Water and Natural Resources (1984).

Standards were exceeded in samples from 1980 and 1982 for cadmium, arsenic, and silver in the Big Sioux River at North Cliff Avenue just below the water treatment plant, approximately 1 mile east of the Base. Chlorinated organic pollutants were not monitored.

3.5.3 Surface Water Uses

While both the Big Sioux River and the Diversion Channel are classified for use as domestic water supply, only the Diversion Channel is utilized extensively by the city of Sioux Falls for this purpose.

The Big Sioux River in the vicinity of the Base is utilized for several recreational purposes. Sport fishing is common in the river immediately upstream of the Diversion Channel weir, both from shore and boat. The Big Sioux River west of the Base is fished minimally. Both canoeing and fishing are common along the river between the confluence with Skunk Creek and the falls. The area below the falls is also heavily fished. Swimming along the Big Sioux River is not encouraged by the city parks department and is prohibited near the falls. Covells Lake, approximately 1 mile south of Site 1 – Underground Fuel Storage Area is utilized for recreational boating and swimming. This lake is directly fed by the Big Sioux Aquifer. There is no known recreational use of the Diversion Channel (Weires 1989).

3.6 REGIONAL BACKGROUND CONCENTRATIONS FOR SDANG

3.6.1 Groundwater Background Concentrations

An adequate data base is not available in order to establish regional groundwater quality. Select parameters were analyzed in water samples collected from several Sioux Falls municipal wells. However, the municipal wells which were sampled are located near a commercial industrial district which could contribute to higher concentrations of compounds in the groundwater than would normally exist at background levels. Therefore, the data may not be reflective of actual background conditions. The groundwater quality data and the South Dakota water quality standards for several parameters are compared in Table 3-4.

Suitable background comparison concentrations for the specific sites of concern are provided from the analytical results of groundwater collected from the site-specific upgradient wells: MW-1-1 and MW-3-5. These results indicate concentrations of contaminants below South Dakota water quality standards (see Table 3-4). South Dakota maximum water quality standard concentrations exist for lead (20 μg/L), selenium (10 μg/L), chromium (50 μg/L), and arsenic (50 μg/L). These concentrations are higher than the average background concentrations found at SDANG (see Table 3-5): lead (11 μg/L), selenium (7 μg/L), chromium (7 μg/L), and arsenic (6 μg/L). Copper,

TABLE 3-4. SOUTH DAKOTA WATER QUALITY STANDARDS vs. GROUNDWATER QUALITY IN THE VICINITY OF SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Parameter	Average Observed Concentration (1)	Water Quality Standard Concentration
Sulfates	329 mg/L	500 mg/L
Chloride	47 mg/L	250 mg/L
Lead	1.4 µg/L	20 µg/L
Selenium	< 0.2 µg/L	10 µg/L
Chromium	< 20 µg/L	50 µg/L
Arsenic	1.65 µg/L	50 µg/L
Nitrates	0.28 mg/L	10 mg/L
Fluoride	0.24 mg/L	2.4 mg/L
TDS	896 mg/L	1000 mg/L
pH	NA	6.5 - 8.5

South Dakota Department of Water and Natural Resources

TDS - Total Dissolved Solids
NA - Not Available
(1) - Data were obtained from Sioux Falls, South Dakota Muncipal Wells.

TABLE 3-5. BACKGROUND GROUNDWATER DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

	1989 DATA(5)					1987 DATA					1989 & 1987 DATA(5)			
Parameter	LLD (1)	Mean (1-4)	(Min-Max) Range (3,4)	No. Samples (3,4)	No. Positives (3,4)	LLD (1)	Mean (1-4)	(Min-Max) Range (3,4)	No. Samples (3,4)	No. Positives (3,4)	Grand Mean (1-4)	(Min-Max) Range (3,4)	No. Samples (3,4)	No. Positives (3,4)
PETROLEUM HYDROCARBONS	0.5	ND	(ND)	2	0									
INORGANICS														
Dissolved Arsenic	5	6.00	(ND-6)	2	1									
Dissolved Cadmium	1	ND	(ND)	1	0									
Dissolved Chromium	1	7.00	(7)	1	1									
Dissolved Copper	1	13.00	(13)	1	1									
Dissolved Lead	1	11.00	(ND-11)	2	1									
Dissolved Nickel	2	25.00	(25)	1	1									
Dissolved Selenium	5	7.00	(7)	1	1									
Dissolved Zinc	1	42.00	(42)	1	1									
VOLATILE ORGANICS														
Acetone	5	ND	(ND)	2	0									
Benzene	1	ND	(ND)	2	0									
Ethylbenzene	1	ND	(ND)	2	0									
Methylene Chloride	1	ND	(ND)	2	0									
Toluene	1	ND	(ND)	2	0									
Total Xylenes	1	ND	(ND)	2	0									
SEMIVOLATILE ORGANICS														
Acenaphthene	2	ND	(ND)	2	0									
Anthracene	2	ND	(ND)	2	0									
Benzo(a)anthracene	2	ND	(ND)	2	0									
Benzo(a)pyrene	4	ND	(ND)	2	0									
Benzo(b)fluoranthene	4	ND	(ND)	2	0									
Benzo(k)fluoranthene	4	ND	(ND)	2	0									
Bis(2-ethylhexyl)phthalate	2	8.25	(2.5-14)	2	2									
Chrysene	2	ND	(ND)	2	0									
Dibenzofuran	2	ND	(ND)	2	0									
Diethyl phthalate	2	ND	(ND)	2	0									
2,4-Dimethylphenol	2	ND	(ND)	2	0									
Di-n-butyl phthalate	2	ND	(ND)	2	0									
Di-n-octyl phthalate	2	ND	(ND)	2	0									
Fluoranthene	2	ND	(ND)	2	0									
Fluorene	2	ND	(ND)	2	0									
Indeno(1,2,3-c,d)pyrene	4	ND	(ND)	2	0									
2-Methylnaphthalene	2	ND	(ND)	2	0									
Naphthalene	4	ND	(ND)	2	0									
Phenanthrene	2	ND	(ND)	2	0									
Pyrene	2	ND	(ND)	2	0									

(1)LLD is the Lowest Level of Detection given in units of mg/L for Petroleum Hydrocarbons, and µg/L for Inorganics, Volatile Organics, and Semi-Volatile Organics.

(2)Means were calculated by taking the means of re-extractions,duplicates, and different sampling dates and means of all the above where appropriate. ND's were not factored in to the calculations of the means.

(3)If the analyte concentration were greater than 10 times the method blank concentration, the data were included; otherwise, the data were excluded.

(4)ND's were considered a sample but not considered in the calculation of the means.

(5)Reflects data from upgradient wells MW1-1 and MW3-5.

ND-Not Detected; inorganics were filtered on the site during the January 1989 sampling round.

nickel, and zinc were also detected at low levels in MW-1-1 and MW-3-5 (average concentrations of 13 µg/L, 25 µg/L, and 42 µg/L, respectively). Their presence in the samples taken from MW-1-1 and MW-3-5 is likely due to the potable water rinses of sampling equipment, typifying the water quality of the region. Organic contamination was found only in the form of bis(2-ethylhexyl)phthalate (average concentration 8.25 µg/L), which is a common contaminant found in water that has been containerized in plastic. The source of this contaminant is likely to be the plastic containers, which housed the ASTM Type II water used for equipment decontamination rinses. This contaminant was also detected at low levels (2 µg/L) in associated equipment blanks (EB-10 and EB-11).

3.6.2 Surface Water and Soil Background Concentrations

Background concentrations in surface water are assumed to be represented by the water quality data taken from the monitoring station upstream of the Diversion Channel on the Big Sioux River. (This information is provided in Table 3-6.) Between 1983 and 1989, samples were collected monthly and tested for standard bacteriological and inorganic pollutants. No data on organic contaminants were available.

A set of soil background samples were taken during the Site Inspection in 1987 at a location 400 feet northeast of Site 3 – Base Fire Training Area (SAIC 1988). A second set of six soil background samples were taken during the Remedial Investigation. Maximum background concentrations were determined from these 10 samples, and are presented in Tables 3-7 and 3-8. Of the listed metals, the soil samples had detectable quantities of arsenic, beryllium, chromium, cadmium, copper, lead, nickel, selenium, and zinc. Of the listed volatile organics, acetone, and xylenes were present in detectable amounts.

The background soil borings indicate a clay-silty clay near the surface and a sandy material near the aquifer. Results of the analysis of the clay material, shown in Table 3-7, indicate that the dominant contaminants are metals: arsenic (4.55 mg/kg), chromium (11 mg/kg), copper (9.5 mg/kg), lead (6.10 mg/kg), nickel (14.50 mg/kg), and zinc (33.25 mg/kg). Beryllium, cadmium, and selenium were all detected at levels below 1 mg/kg. Acetone (28.5 µg/kg), xylenes (2.5 µg/kg), and bis (2-ethylhexyl)phthalate (19.00 µg/kg) also were detected in the clay material of the background soil borings. Acetone is commonly introduced in laboratory practices. Bis (2-ethylhexyl)phthalate is commonly found at similar concentrations in water containerized in plastic. Total organic carbon (TOC) concentrations and total petroleum hydrocarbon concentrations reflect concentrations similar to those of tentatively identified compounds (TICs) totals. TICs are

TABLE 3-6. MONITORING STATION WATER QUALITY FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

PARAMETERS	Units	Total Standards	Big Sioux River Average	Sample Location		
				468S24(1)	64(2)	6482020(3)
GENERAL						
Dissolved Oxygen	mg/L	5	10.71	10.73	10.89	9.86
Dissolved Solids	mg/L	1000	925.3	NA	NA	925.3
Suspended Solids	mg/L	90	NA	NA	NA	NA
Temperature (max)	°F	90	92	92	90	86
Conductivity	umhos/cm	2500	998	870.4	975.7	1100.2
Alkalinity	mg/L	750	217.8	216.6	219.2	212.5
pH		6.5-8.3	8.1	8.12	8.17	7.54
Fecal Coliforms	per 100mL	200	NA	NA	NA	NA
METALS						
Arsenic	mg/L	0.05	NA	NA	NA	NA
Barium	mg/L	1	NA	NA	NA	NA
Cadmium	mg/L	0.01	13	NA	NA	13
Chromium	mg/L	0.05	NA	NA	NA	NA
Chloride	mg/L	250	221.4	NA	NA	221.4
Cyanide (free)	mg/L	0.005	NA	NA	NA	NA
Cyanide (total)	mg/L	0.02	0.244	NA	NA	0.244
Lead	mg/L	0.05	NA	NA	NA	NA
Mercury	mg/L	0.002	NA	NA	NA	NA
Selenium	mg/L	0.01	NA	NA	NA	NA
Silver	mg/L	0.05	0.381	NA	NA	0.381
MISCELLANEOUS INORGANICS						
Fluoride	mg/L	4	NA	NA	NA	NA
Nitrates	mg/L	50	50.45	1.3	1.5	50.45
Sulfate	mg/L	500	NA	NA	NA	NA
Un-ionized NH3-N	mg/L	0.04	0.01	0.0034	0.0045	0.1132
Chlorine	mg/L	0.02	NA	NA	NA	NA
Hydrogen Sulfide	mg/L	0.002	NA	NA	NA	NA
Polychlorinated Biphenyls	mg/L	1E-06	NA	NA	NA	NA
Sodium Absorption	%	10	3.51	NA	NA	3.51

South Dakota Department of Water and Natural Resources Water Quality Gauging Stations
(1) Station 468S24 Upstream Of The Diversion Channel
(2) Station 64 Located At Falls Park
U.S. Geological Survey Gauging Station
(3) Station 6482020 On The Big Sioux River At North Cliff Ave.
NA - Not Available

TABLE 3-7. CLAY LEVEL BACKGROUND DATA AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

	1989 DATA (5)					1987 DATA (5)					1989 & 1987 DATA (5)			
Parameters	LLD (1)	Mean (1-4)	Range (Min-Max) (3,4)	No. Samples (3,4)	No. Positives (3,4)	LLD (1)	Mean (1-4)	Range (Min-Max) (3,4)	No. Samples (3,4)	No. Positives (3,4)	Grand Mean (1-4)	Range (Min-Max) (3,4)	No. Samples (3,4)	No. Positives (3,4)
PETROLEUM HYDROCARBONS	20	86.00	(ND-86)	2	1	20	ND	(ND)	1	0	86.00	(ND-86)	3	1
TOTAL ORGANIC CARBON	0.1	1.60	(0.9-2.3)	2	2	0.1	ND	(ND)	1	0	1.60	(ND-2.3)	3	2
INORGANICS														
Arsenic	0.5	5.90	(5.4-6.4)	2	2	0.5	3.20	(3.2)	1	1	4.55	(3.2-6.4)	3	3
Beryllium	0.1	0.45	(0.3-0.6)	2	2	0.1	ND	(ND)	1	0	0.45	(ND-0.6)	3	2
Cadmium	0.5	0.50	(ND-0.5)	2	1	0.5	ND	(ND)	1	0	0.50	(ND-0.5)	3	1
Chromium	1	16.00	(10-22)	2	2	1	6.00	(6)	1	1	11.00	(6-22)	3	3
Copper	1	9.50	(6-13)	2	2	1	ND	(ND)	1	0	9.50	(ND-13)	3	2
Lead	0.5	9.10	(7.2-11)	2	2	0.5	3.10	(3.1)	1	1	6.10	(3.1-11)	3	3
Nickel	2	19.00	(18-20)	2	2	2	10.00	(10)	1	1	14.50	(10-20)	3	3
Selenium	0.5	0.60	(ND-0.6)	2	1	0.5	ND	(ND)	1	0	0.60	(ND-0.6)	3	1
Zinc	1	49.50	(35-64)	2	2	1	17.00	(17)	1	1	33.25	(17-64)	3	3
VOLATILE ORGANICS														
Acetone	8	37.00	(ND-37)	2	1	8	20.00	(20)	1	1	28.50	(ND-37)	3	2
Ethylbenzene	2	ND	(ND)	2	0	2	ND	(ND)	1	0	ND	(ND)	3	0
Methylene Chloride	2	ND	(ND)	2	0	2	ND	(ND)	1	0	ND	(ND)	3	0
Toluene	2	ND	(ND)	2	0	2	ND	(ND)	1	0	ND	(ND)	3	0
Total Xylenes	2	2.50	(2-3)	2	2	2	ND	(ND)	1	0	2.50	(ND-3)	3	2
SEMIVOLATILE ORGANICS														
Acenaphthene	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Anthracene	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Benzo(a)anthracene	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Benzo(a)pyrene	76	ND	(ND)	2	0	76	NT	(NT)	0	0	ND	(ND)	2	0
Benzo(b)fluoranthene	76	ND	(ND)	2	0	76	NT	(NT)	0	0	ND	(ND)	2	0
Benzo(g,h,i)perylene	76	ND	(ND)	2	0	76	NT	(NT)	0	0	ND	(ND)	2	0
Benzo(k)fluoranthene	76	ND	(ND)	2	0	76	NT	(NT)	0	0	ND	(ND)	2	0
Bis(2-ethylhexyl)phthalate	38	19.00	(17-21)	2	2	38	NT	(NT)	0	0	19.00	(17-21)	2	2
Chrysene	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Dibenzofuran	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Dibenzo(a,h)anthracene	76	ND	(ND)	2	0	76	NT	(NT)	0	0	ND	(ND)	2	0
Diethylphthalate	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Dimethylphthalate	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Di-n-butylphthalate	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Di-n-octylphthalate	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Fluoranthene	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Fluorene	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Indeno(1,2,3-c,d)pyrene	76	ND	(ND)	2	0	76	NT	(NT)	0	0	ND	(ND)	2	0
2-Methylnaphthalene	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
4-Methylphenol	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Naphthalene	76	ND	(ND)	2	0	76	NT	(NT)	0	0	ND	(ND)	2	0
Phenanthrene	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Phenol	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0
Pyrene	38	ND	(ND)	2	0	38	NT	(NT)	0	0	ND	(ND)	2	0

(1)Units: PETROLEUM HYDROCARBONS,INORGANICS-mg/kg DB, INORGANICS-mg/Kg DB; TOTAL ORGANIC CARBON-%DB; VOLATILE ORGANICS, SEMIVOLATILE ORGANICS-µg/Kg
(2)Means were calculated using means of re-extractions with first extractions, of duplicates with original samples, and of both where applicable.
(3)If the analyte concentration was greater than 10 times the method blank concentration, the data were included; otherwise, the data were excluded.
(4)ND's were considered a sample but they were not considered in the calculation of the means.
(5)Data were obtained from background soil borings BK-1 (1987), BK-2 and BK-3 (1989).
ND-Not Detected; NT-Not Tested

TABLE 3-8. AQUIFER LEVEL BACKGROUND DATA AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

	1989 DATA (5)					1987 DATA (5)					1989 & 1987 DATA (5)			
Parameters	LLD (1)	Mean (1-4)	Range (Min-Max) (3,4)	No. Samples (3,4)	No. Positives (3,4)	LLD (1)	Mean (1-4)	Range (Min-Max) (3,4)	No. Samples (3,4)	No. Positives (3,4)	Grand Mean (1-4)	Range (Min-Max) (3,4)	No. Samples (3,4)	No. Positives (3,4)
PETROLEUM HYDROCARBONS	20	500.50	(ND-970)	4	2	20	ND	(ND)	2	0	500.50	(ND-970)	6	2
TOTAL ORGANIC CARBON	0.1	1.15	(0.9-1.4)	4	4	0.1	ND	(ND)	2	0	1.15	(ND-1.4)	6	4
INORGANICS														
Arsenic	0.5	2.28	(1.8-3.3)	4	4	0.5	1.00	(0.8-1.2)	2	2	1.64	(0.8-3.1)	6	6
Beryllium	0.1	ND	(ND)	4	0	0.1	ND	(ND)	2	0	ND	(ND)	6	0
Cadmium	0.5	ND	(ND)	4	0	0.5	ND	(ND)	2	0	ND	(ND)	6	0
Chromium	1	8.50	(6-11)	4	4	1	5.50	(4-7)	2	2	7.00	(4-11)	6	6
Copper	1	3.50	(2-5)	4	4	1	ND	(ND)	2	0	3.50	(ND-5)	6	4
Lead	0.5	2.70	(2.4-3.1)	4	4	0.5	3.50	(2.4-4.6)	2	2	3.10	(2.4-4.6)	6	6
Nickel	2	15.75	(12-22)	4	4	2	13.00	(12-14)	2	2	14.38	(12-22)	6	6
Selenium	0.5	ND	(ND)	4	0	0.5	0.50	(ND-0.5)	2	1	0.50	(ND-0.5)	6	1
Zinc	1	20.00	(17-25)	4	4	1	15.00	(12-18)	2	2	17.50	(12-25)	6	6
VOLATILE ORGANICS														
Acetone	8	51.75	(41-62)	4	4	8	32.00	(22-42)	2	2	41.88	(22-62)	6	6
Ethylbenzene	2	ND	(ND)	4	0	2	ND	(ND)	2	0	ND	(ND)	6	0
Methylene Chloride	2	3.00	(ND-3)	4	1	2	ND	(ND)	2	0	3.00	(ND-3)	6	1
Toluene	2	ND	(ND)	4	0	2	ND	(ND)	2	0	ND	(ND)	6	0
Total Xylenes	2	ND	(ND)	4	0	2	ND	(ND)	2	0	ND	(ND)	6	0
SEMIVOLATILE ORGANICS														
Acenaphthene	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Anthracene	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Benzo(a)anthracene	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Benzo(a)pyrene	76	ND	(ND)	4	0	76	NT	(NT)	0	0	ND	(ND)	4	0
Benzo(b)fluoranthene	76	ND	(ND)	4	0	76	NT	(NT)	0	0	ND	(ND)	4	0
Benzo(g,h,i)perylene	76	ND	(ND)	4	0	76	NT	(NT)	0	0	ND	(ND)	4	0
Benzo(k)fluoranthene	76	ND	(ND)	4	0	76	NT	(NT)	0	0	ND	(ND)	4	0
Bis(2-ethylhexyl)phthalate	38	52.00	(ND-52)	4	1	38	NT	(NT)	0	0	52.00	(ND-52)	4	1
Chrysene	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Dibenzofuran	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Dibenzo(a,h)anthracene	76	ND	(ND)	4	0	76	NT	(NT)	0	0	ND	(ND)	4	0
Diethylphthalate	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Dimethylphthalate	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Di-n-butylphthalate	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Di-n-octyltphthalate	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Fluoranthene	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Fluorene	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Indeno(1,2,3-c,d)pyrene	76	ND	(ND)	4	0	76	NT	(NT)	0	0	ND	(ND)	4	0
2-Methylnaphthalene	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
4-Methylphenol	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Naphthalene	76	ND	(ND)	4	0	76	NT	(NT)	0	0	ND	(ND)	4	0
Phenanthrene	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Phenol	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0
Pyrene	38	ND	(ND)	4	0	38	NT	(NT)	0	0	ND	(ND)	4	0

(1)Units: PETROLEUM HYDROCARBONS,INORGANICS-mg/kg DB, INORGANICS-mg/Kg DB; TOTAL ORGANIC CARBON-%DB; VOLATILE ORGANICS, SEMIVOLATILE ORGANICS-µg/Kg
(2)Means were calculated using means of re-extractions with first extractions, of duplicates with original samples, and of both where applicable.
(3)If the analyte concentration was greater than 10 times the method blank concentration, the data were included; otherwise, the data were excluded.
(4)ND's were considered a sample but they were not considered in the calculation of the means.
(5)Data were obtained from background soil borings BK-1 (1987), BK-2 and BK-3 (1989).
ND-Not Detected; NT-Not Tested

compounds that are not positively identifiable using current analysis instrumentation and U.S. Environmental Protection Agency (EPA) methods and, as a result, have not been extensively regulated or studied.

Analysis results of sandy (aquifer) materials, presented in Table 3-8, indicate that it is mainly composed of inorganic materials: arsenic (1.64 mg/kg), chromium (7.00 mg/kg), copper (3.50 mg/kg), lead (3.10 mg/kg), nickel (14.38 mg/kg), and zinc (17.50 mg/kg). Selenium was detected below 1 mg/kg. Lead was detected in the associated equipment blanks, EB-10 (2.5 µg/L) and EB-11 (1.2 µg/L). Zinc was detected in equipment blank EB-11 (6 µg/L). The concentrations of lead and zinc detected in the associated equipment blanks are low, relative to the concentrations detected in the aquifer material. Therefore, the concentrations of lead and zinc will be considered background levels. Acetone (41.88 µg/kg), methylene chloride (3.00 µg/kg), and bis (2-ethylhexyl)phthalate (52.00 µg/kg) are the organic compounds found in the sandy material. These organics are commonly introduced by laboratory methods.

3.7 CLIMATE AND AIR QUALITY

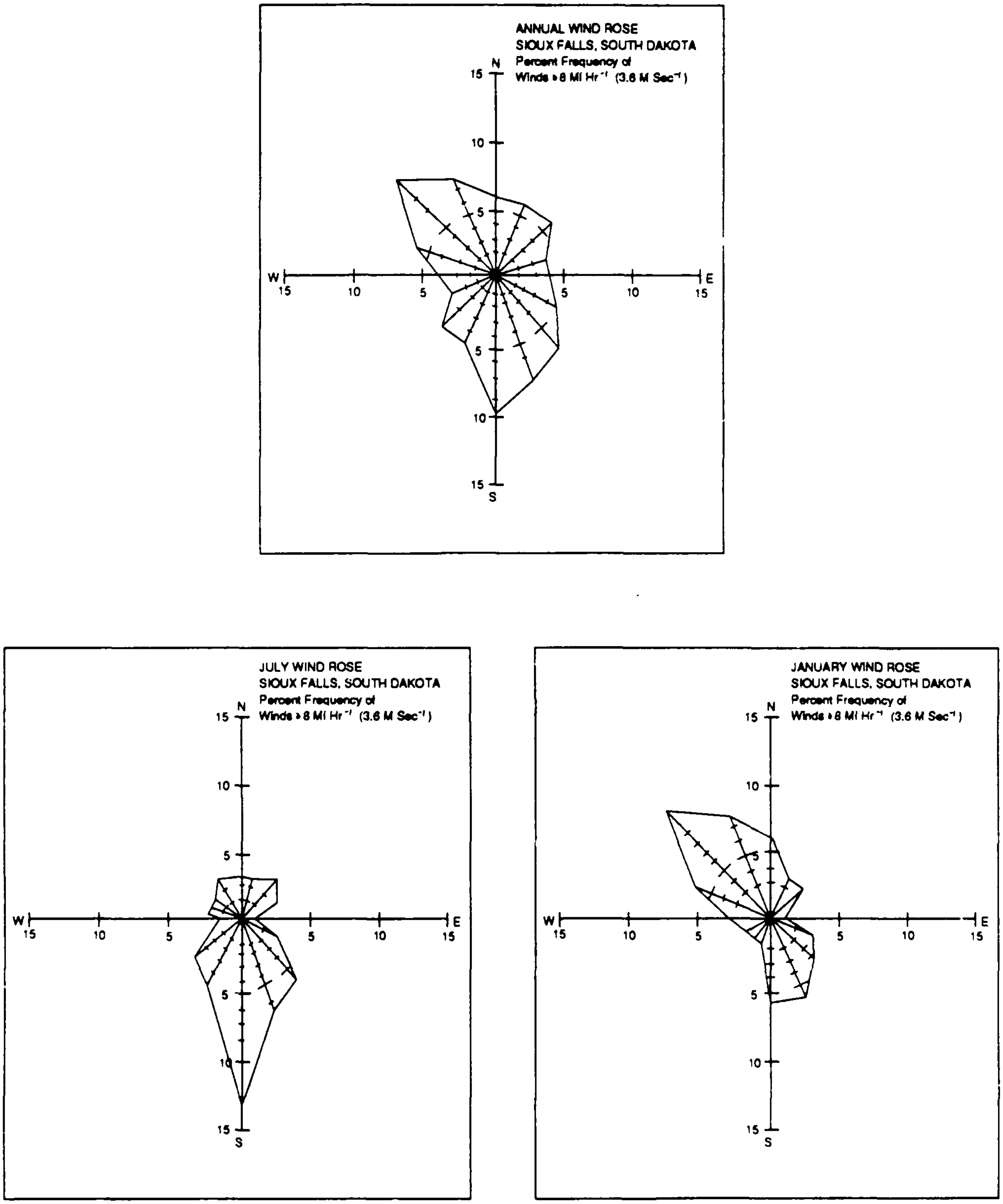
3.7.1 Climate

Climatic data for Sioux Falls, South Dakota, are based on National Oceanic and Atmospheric Administration records from 1958 to 1987. The mean annual temperature in Sioux Falls is 46.1°F. Precipitation averages 25.18 inches annually. The wettest month is June, with average precipitation of 4.14 inches. January is the driest month, with an average precipitation 0.60 inches. Annual snowfall averages 39.7 inches. Net precipitation for the area is negative 9.63 inches per year, when calculated according to the method given in the Federal Register (HMTC 1986). Rainfall intensity based on a 1-year, 24-hour rainfall is 4.59 inches (HMTC 1986).

The mean wind speed is 11.1 miles per hour (mph) (NOAA 1987). Seasonal wind roses for Sioux Falls, South Dakota, based on winds with speeds of 8 mile/hour and greater, are shown in Figure 3-19. The annual average prevailing wind direction is south with a secondary northwesterly trend. Mean wind direction varies seasonally (see Figure 3-19) with a mean January wind direction of northwest and a mean July direction of south-southeast (NOAA 1987).

3.7.2 Air Quality

Air quality information is collected by the South Dakota, Department of Water and Natural Resources at three locations within the city of Sioux Falls. The three locations are the airport, Sioux Falls City Hall (approximately 2 miles south of the airport), and Augustana College (approximately 4 miles south of the airport). Total suspended particulate data are collected at all



Science Applications International Corporation
An Employee-Owned Company

Wind Roses for Sioux Falls, South Dakota

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-19	Project: 1-827-03-769-22

three monitoring stations. Sulfur and nitrogen dioxides are measured at City Hall. Inhalable particulate data are collected at Augustana College.

Data from the three sites from the years 1982 through 1988 indicate that air quality is good in the Sioux Falls area. Measured mean particulate concentrations at the airport lie within national and State standards (60 micrograms per meter^3 [$\mu g/m^3$]) with a high measured mean concentration of 50.1 $\mu g/m^3$. Sulfur dioxide concentrations also fall within the State and national standards of 80 $\mu g/m^3$, with a maximum measured mean value at City Hall of less than 5.0 $\mu g/m^3$. Nitrogen dioxide concentrations at the same site also fall below the 100 $\mu g/m^3$ standard, with a maximum measured mean concentration of 25.6 $\mu g/m^3$.

3.8 NATURAL RESOURCES

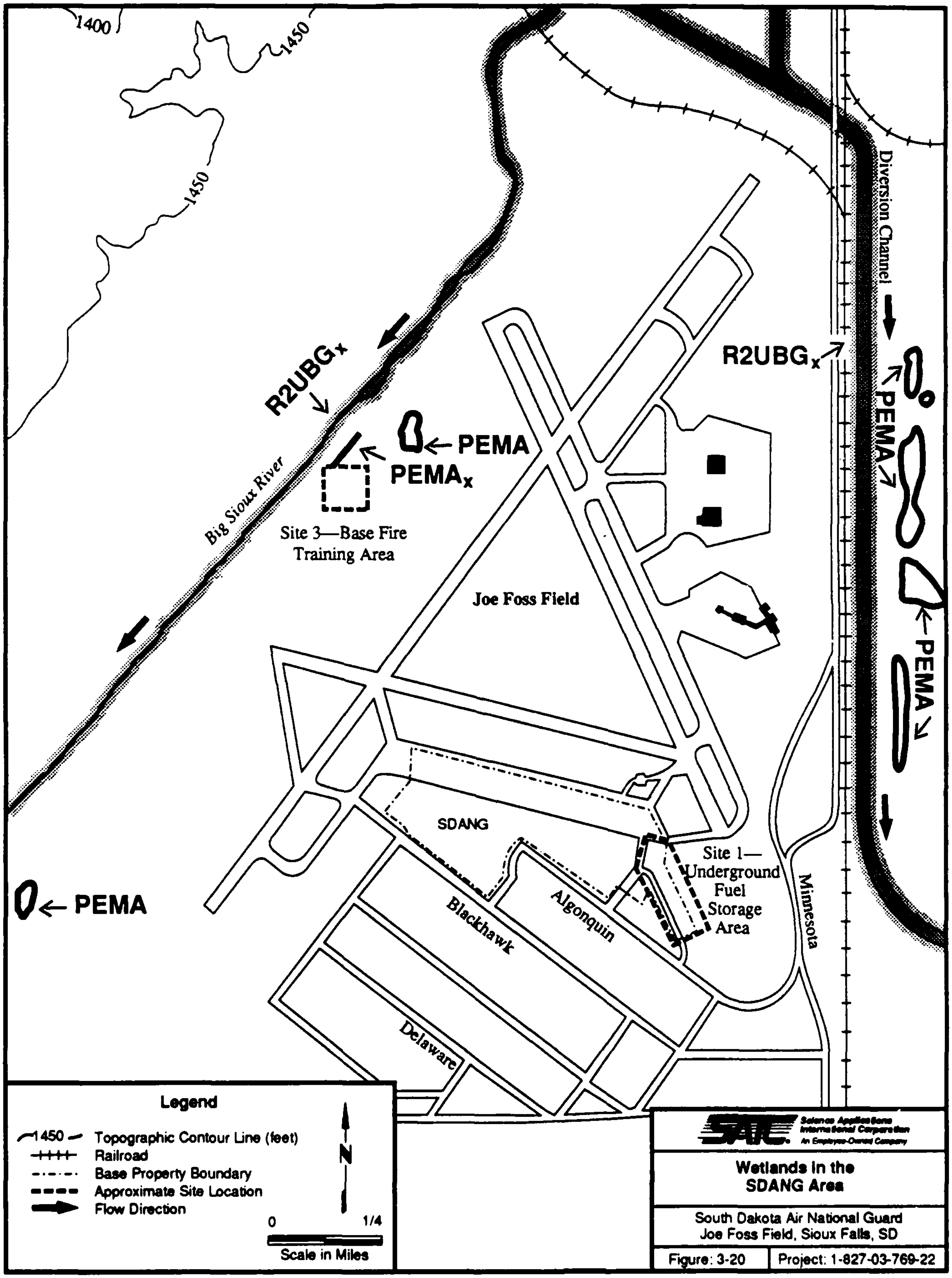
3.8.1 Wetlands

The U.S. Fish and Wildlife Service recognizes wetlands as vital resources for migratory waterfowl and therefore are considered under the Service's "no net loss of wetlands" policy (U.S. Department of the Interior 1989). As part of the Federal Government's program to preserve and enhance the nation's wetlands, the National Wetlands Inventory (NWI) project has developed maps of wetland types.

The NWI map of designated wetlands in the area of the Base is presented in Figure 3-20. Table 3-9 provides descriptions of the abbreviations used in the figure. Most of the wetlands near the Base are temporary. Several of these small wetland areas are located near Site 3 – Base Fire Training Area; however, no wetland areas have been identified in close vicinity to Site 1 – Underground Fuel Storage Area .

3.8.2 Endangered and Threatened Species

Information on rare and threatened species that may be found within or near the project area was obtained from the U.S. Department of the Interior and the South Dakota Department of Game, Fish, and Parks. Table 3-10 lists these species and their environment of probable occurrence. The species consist of two prairie plant types, an amphibian, and several species of migratory birds. There is no reason to expect that any of these species of migratory birds would be attracted to the site area since no critical habitats exist for these species in the vicinity of the site. Indicating these species as being endangered in South Dakota is due to statewide recorded sitings and creates a public awareness of their presence in South Dakota (South Dakota Department of Game, Fish and Parks, 1990).



Wetlands in the SDANG Area

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-20 | Project: 1-827-03-769-22

TABLE 3-9. DESCRIPTIONS OF WETLAND DESIGNATIONS FOR SIOUX FALLS, SOUTH DAKOTA AREA

Designation	Description
PEMA	Palustrine, emergent, temporarily flooded
PEMAx	Palustrine, emergent, temporarily flooded, artificially excavated
R2UBGx	Lower perennial riverine, unconsolidated bottom, intermittently exposed, excavated

U.S. Department of the Interior, Fish and Wildlife Service, South Dakota State Office (1989)

TABLE 3-10. ENDANGERED SPECIES SUMMARY FOR THE GREATER SIOUX FALLS, SOUTH DAKOTA AREA

Rare and Unique Species	Expected Occurence
Bush Clover Lespedeza Capitata	Rare in S. Dakota; occurs in native, tallgrass prairies
Compass Plant Silphium Laciniatum	Rare in S. Dakota; occurs in native, tallgrass prairies
Blanding's Turtle Emydoidea Blandingii	State threatened species; prefers calm, shallow waters, rich, aquatic vegetation and sandy uplands for nesting
FEDERALLY ENDANGERED SPECIES	
Bald Eagle Haliaeetus Leucocephalus	Winters along the Missouri River
Peregrine Falcon Falco Peregrinus	Regarded as a migrant; usually associated with wetlands and open areas
Eskimo Curlew Numenius Borealis	A species associated with native praries

U.S. Department of the Interior Fish and Wildlife Services, South Dakota State Office (1989)
South Dakota Department of Game Fish and Parks (1989)

3.9 DEMOGRAPHICS

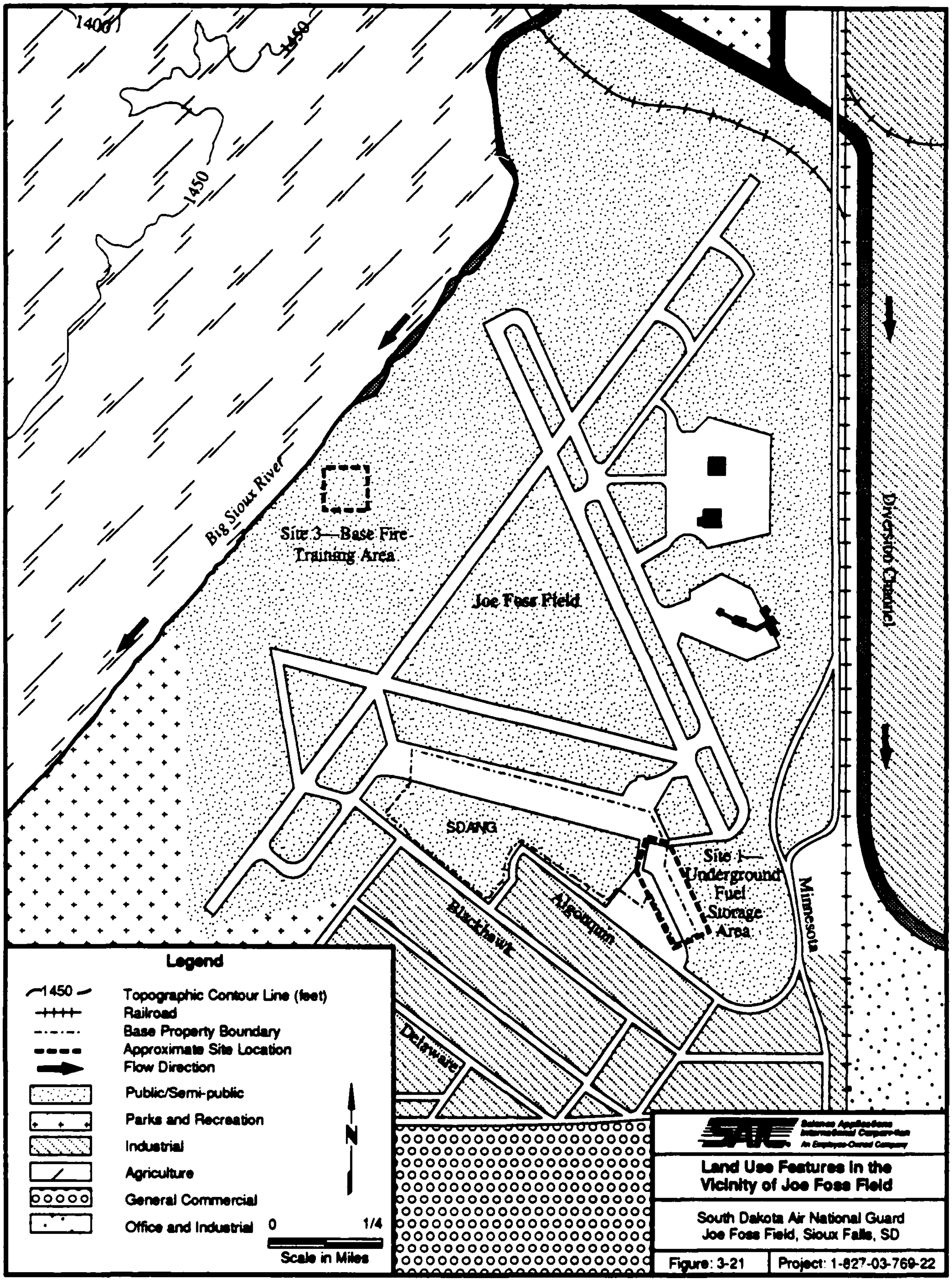
3.9.1 Land Uses

The area surrounding both Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area is devoted to a variety of land uses as designated by the Sioux Falls Planning and Services Department (Figure 3-21). Both sites are located near the airfield boundaries. Site 1 – Underground Fuel Storage Area lies near the southeast corner of the airfield, which is immediately surrounded on its southern and eastern boundaries by office and industrial areas. Beyond, are regions devoted to low to medium density residential and park and recreational areas. Site 3 – Base Fire Training Area lies nearest the Big Sioux River, which is bounded on its western shore by public and semi-public lands with park and recreational areas and agricultural lands adjacent to these. The southeast corner of the airfield is bounded by park area. The area immediately opposite the Diversion Channel from the airport is devoted to the State prison farm. Schools located within 1 mile of the Base include Jane Addams elementary school (250 students), and Axtell Park Junior High School (675 students) which are both south of the Base.

3.9.2 Population and Age Distribution

Current population and age data for the city of Sioux Falls, as well as projections for growth through the year 2015, have been published by the Sioux Falls Planning and Services Department (1986). In 1985, the total population was 93,700. This figure is expected to exceed 115,000 by the year 2015.

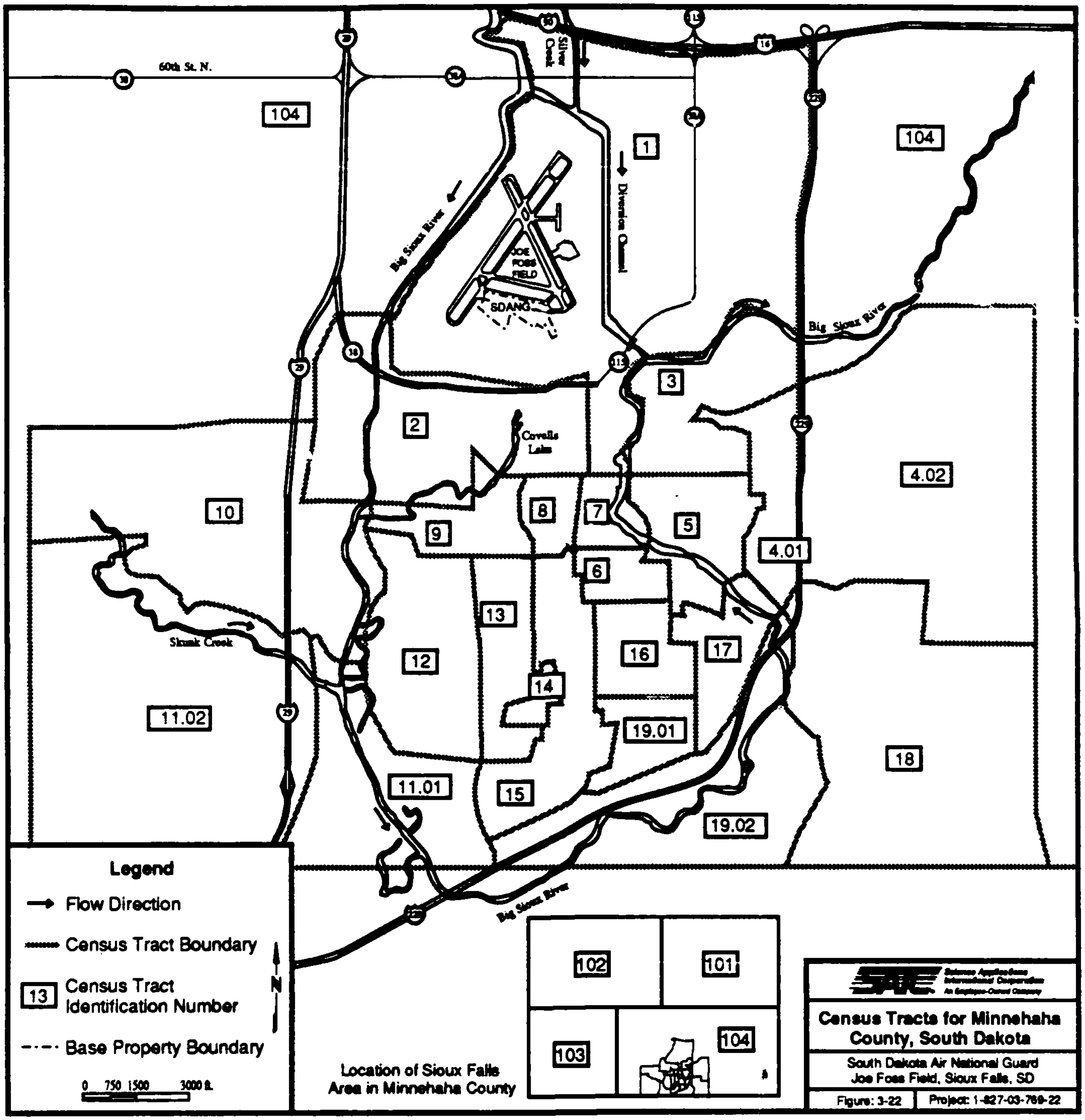
Data describing the number and age distribution of persons living near the Base are tabulated by census tracts. Figure 3-22 illustrates census tracts in Minnehaha County and the area of Sioux Falls located within 3 miles of the Base. SDANG is located within census tract 1. Table 3-11 presents 1989 census data and 1994 forecasts for these tracts, as well as general age groupings of these data. As Table 3-11 shows, more than 112,000 persons lived in tracts near the Base in 1989. This number is forecast to increase to more than 121,000 persons by 1994. Table 3-11 also shows that persons aged 0 to 21 represented 34 percent of the population near the Base in 1989; persons aged 22 to 64 represented 55 percent and persons 65 and over represented 11 percent. Forecasts in Table 3-11 show that this age distribution should change only slightly by 1994, with the youngest group (0 to 21) decreasing from 34 to 33 percent and the middle group (22 to 64) increasing 1 percent. Persons aged 65 and over are estimated to remain at roughly 11 percent through the year 1994.



Land Use Features in the Vicinity of Joe Foss Field

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-21 Project: 1-827-03-769-22



Census Tracts for Minnehaha County, South Dakota

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 3-22 Project: 1-827-03-769-22

TABLE 3-11. CENSUS DATA WITHIN 3 MILES OF SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Census Tracts	Population 1989	Ages 0-21 1989	Ages 22-64 1989	Ages 65+ 1989	Population 1994	Ages 0-21 1994	Ages 22-64 1994	Ages 65+ 1994
001	3643	1231	2047	365	3718	1261	2073	384
002	6037	1774	3427	836	6267	1775	3573	919
003	3764	1332	1958	474	3806	1349	1966	491
4.01	3769	1316	2096	357	4204	1409	2375	420
4.02	9215	3313	5285	617	10161	3511	5840	810
005	3455	1130	1886	439	3482	1143	1872	467
006	2764	719	1634	411	2795	691	1710	394
007	1453	313	722	418	1495	330	767	398
008	3464	999	2014	451	3507	979	2076	452
009	3804	1069	2145	590	3847	1053	2190	604
010	3876	1436	2171	269	4403	1597	2464	342
11.01	1393	352	799	242	1642	409	950	283
11.02	11392	4526	6098	768	13452	5176	7334	942
012	5402	1402	2954	1046	5614	1395	3007	1212
013	5575	1426	3115	1034	5650	1387	3147	1116
014	1533	1105	384	44	1600	1026	515	59
015	6948	2041	3897	1010	7089	1983	4101	1005
016	3770	1128	2061	581	3821	1110	2126	585
017	3016	914	1592	510	3047	942	1530	575
018	7459	2842	4285	332	8419	2989	5000	430
19.01	2861	800	1653	408	3264	824	1893	547
19.02	4874	1804	2807	263	5562	2001	3154	407
104	12688	5007	6862	819	14259	5534	7728	997
Total	112155	37979	61892	12284	121104	39874	67391	13839

Sioux Falls Planning and Services Department (1986).

3.10 HISTORIC/ARCHAEOLOGIC RESOURCES

There are no recorded historic or archaeological sites within the boundaries of the Base (South Dakota Historical Society 1989). Although there have been some mound sites recorded within a 1-mile radius of the Base, much of this area has been disturbed by previous construction activities.

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4. CHEMICAL ANALYSIS RESULTS AND SIGNIFICANCE OF FINDINGS

This section discusses the results of the sampling and chemical analyses performed during the Remedial Investigation (RI) field program at South Dakota Air National Guard (SDANG), Joe Foss Field, Sioux Falls, South Dakota, and summarizes the assessment of the quality (i.e., accuracy and precision) and validity of these results. Results from the 1987 Site Inspection (SI) field program and a January 1989 groundwater sampling also are incorporated. Prior to the discussion and summary, an assessment is presented of the quality assurance/quality control (QA/QC) program that was conducted to ensure that samples collected are representative of the sites, and that analytical data accurately describe the characteristics and concentrations of constituents in the samples. A summary of the QA/QC assessment appears in Subsection 4.1; the comprehensive QA/QC assessment is located in Appendix F. Following the QA/QC evaluation summary, the results of the sampling and chemical analyses at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area are discussed in Subsection 4.2 and 4.3, respectively.

There were basically three types of samples collected during the field programs: 1) groundwater probe/soil gas samples, 2) soil samples from soil borings and monitoring well boreholes, and 3) groundwater samples from the monitoring wells. All groundwater probe/soil gas and soil samples were analyzed by onsite gas chromatography (GC). Selected soil samples, usually two per borehole, and all groundwater samples were analyzed in the laboratory following standard U.S. Environmental Protection Agency (EPA) methods. Section 2 presents further discussion of sample collection and field analyses methods.

The groundwater probe/soil gas sampling results are presented within each site discussion (i.e., Subsections 4.2 and 4.3) and in Appendix C. The primary purpose of these results was to determine the extent and relative magnitude of any contamination in the horizontal plane. Because of limitations of the onsite GC analysis in regard to volatile organic compound (VOC) identification and concentration, these data are used in a qualitative sense.

The soil samples were analyzed using two methods. First, samples were subjected to onsite GC screening. Results from this screening were used to determine the vertical extent of any contamination at the sites. Onsite GC results are presented in the individual site discussions and in Appendix C. Secondly, selected samples, usually two from each borehole, were analyzed in the laboratory. These results were used to identify and quantify any soil contamination and to correlate results with the onsite GC screening.

All groundwater samples were analyzed by the laboratory, and the results were used to characterize the concentrations and composition of any groundwater contamination at the sites. In addition, results were used to correlate with the groundwater probe/soil gas surveys. Summary tables of the soil and groundwater results, including only the specific compounds detected within the soil and groundwater samples at each site, are presented in each site discussion. Laboratory and data validation qualifiers used to label analytical results presented in the summary tables immediately follow each table located in Section 4. Complete listings of all compounds analyzed in soil and groundwater are presented in Appendix E.

All laboratory analyses results are compared and assessed in reference to the results of the laboratory QA/QC assessment (Subsection 4.1) and to the background concentrations of compounds (Subsection 3.6.2). This step is taken to assess the actual impact of waste handling practices at the sites while eliminating compounds that may be present because of outside contamination during sample collection, shipment, or analysis or compounds that occur under ambient or natural conditions in the SDANG area.

4.1 QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

A program of QA/QC procedures was adhered to during the RI conducted at SDANG. The intent of this QA/QC program was to ensure that collected samples are representative of the sites, and that analytical data accurately describe the characteristics and concentrations of constituents in the samples. The QA/QC program consisted of following routine QC procedures throughout the program, as well as the preparation and analysis of both laboratory and field QA/QC samples. Field and laboratory QC procedures, including trip blanks, field blanks, equipment blanks, and field replicates, are summarized in the following discussion. Analytical results indicate the presence of metals, volatile organics, semivolatile organics, and petroleum hydrocarbons in both soil and water. In addition, analyses were conducted for miscellaneous inorganics in water and total organic carbon in soils. All analyses and sample containers were provided by Laucks Testing Laboratory, Seattle, Washington (hereafter referred to as the laboratory). A complete set of the analytical data and a detailed QA/QC discussion are contained in Appendices E and F, respectively.

4.1.1 Field Internal Quality Control Checks

Trip blanks, field blanks, equipment blanks, and field replicates were collected and analyzed along with environmental samples. These samples were intended as QC checks of the sample collection, handling, and shipping procedures, as well as of equipment decontamination procedures.

The following QC samples were collected for each day of sampling:

- One trip blank per container per sampling team for every batch of volatile organic compound (VOC) samples (soils and water).
- One field blank per sampling team to be analyzed for all parameters of interest at a particular site.
- One set of equipment blanks for every day of soil sampling for analysis of all parameters. One bailer wash was collected for every 10 groundwater samples sent to the laboratory for analysis of all parameters.
- One field replicate for every 10 samples.

Trip blanks were prepared prior to the sampling trip by pouring reagent-grade water into prepared sample bottles in the laboratory. These sample bottles were randomly selected from a supply of prepared sample bottles. Sample containers were filled and preserved to yield a representative blank for each type of VOC analysis, resulting in a complete trip blank for the sampling event. These trip blanks were shipped to SDANG along with empty sample bottles, transported to the sites, and then shipped back to the laboratory with the environmental samples collected during the sampling event. The analysis results of trip blanks were used to assess any contamination of sample containers during transport to, storage at the site, or transport back to the laboratory. They also serve to judge whether the contaminants detected in the environmental samples were contributed during transport or by sample containers or are representative of environmental conditions at SDANG. One trip blank was included in each shipping container containing samples for VOC analysis. Six trip blanks were analyzed for VOCs by the laboratory. The results of the trip blanks are shown in Table F-1, Appendix F.

Field blanks were prepared at the beginning of each sampling event at each discrete sampling site by pouring ASTM Type II water into prepared sample bottles. These sample bottles were randomly selected from the supply of prepared sample bottles received from the laboratory. A sample container was selected, filled, and preserved in a manner that was appropriate for each type of analysis for which environmental samples were collected. The field blanks were then analyzed for the same analytes as the environmental samples particular to that site. Because field blanks are collected under the same conditions as environmental samples, the results of the field blank analyses were used to indicate the presence of external contaminants that may have been introduced into samples during collection and to make an overall judgement as to whether the contaminants detected in the environmental samples were contributed by conditions independent of the media sampled or are representative of conditions at SDANG. Field blanks potentially contaminated during transport were assessed by simultaneous evaluation of trip blank results. The analytical results of the field blanks are presented in Table F-1, Appendix F.

Equipment blanks (bailer washes) were prepared for manual and small automated sampling equipment used to collect environmental samples (i.e., equipment blanks were prepared for drill rig sampling equipment). Equipment blanks were collected during the sampling day by pouring reagent-grade water into/through/over clean pieces of sampling equipment, such as bailers, split-spoon samples, shovels, and trowels, and then pouring it into prepared sample bottles. These sample bottles were randomly selected from the supply of prepared sample bottles received from the laboratory. The results of the analyses of equipment blanks are used to assess the efficiency of equipment decontamination procedures in preventing cross-contamination between samples and to judge overall whether the contaminants detected in the environmental samples were contributed by the sampling equipment or are representative of conditions at SDANG. The results of the equipment blank analyses are provided in Table F-2, Appendix F.

Field replicates were collected at the same time using the same techniques as the planned environmental samples. Replicate locations were either preselected prior to the daily sampling activities or selected based on an abnormal instrument reading or an unforeseen field condition (e.g., floating product or strong fuel odor). The identification of each replicate was coded to prevent laboratory bias.

Replicate water samples were collected with a Teflon® bailer. For the purposes of the project, water samples were designated as replicates even though several bailer volumes were needed to fill the sample containers, depending on the number required at any one location. The volatile fraction was collected first to minimize compound volatilization. The first bailer volumes were used to fill the VOC vials of the environmental samples. Subsequent volumes were used to fill the replicate VOC vials. Sample volumes for the remaining analyses were collected after the last VOC vial was filled.

Replicate soil samples were collected with a 2-inch diameter split-spoon sampler. The sample portion to be analyzed for VOCs was collected first to minimize sample volatilization. The soil core was split lengthwise using a Teflon® spatula, and the environmental sample was collected by transferring a portion of the soil to the sample container. The replicate was collected immediately after, using the same technique. After the volatile portion was collected, the remaining soil was mixed on a Teflon® board and subdivided between the remaining sample containers. This mixing was used only for the samples to be analyzed for inorganic (i.e., metals) and semivolatile organic (e.g., extractables, organochlorine pesticides) parameters.

The results of the field replicate analyses were used to assess the precision of the field sampling methods and to make an overall judgement as to whether the contaminants detected in the environmental samples are representative of conditions at SDANG. The results of the field replicate analyses are presented in Tables F-3 and F-4, Appendix F.

4.1.2 Laboratory Internal Quality Control Checks

Laboratory data validation necessitates thorough QA/QC measures to be followed by the laboratory. These measures include holding time requirements, instrument calibration, method-required blanks (e.g., preparation blanks, reagent blanks), surrogate and matrix spike/matrix spike duplicate (MS/MSD) recoveries, instrument timing, and laboratory control sample analysis. A detailed review of the results of these QA/QC procedures can be found in Appendix F. A summary of laboratory QA/QC is presented below.

MS/MSDs are prepared by adding a known amount of one or more compounds to an environmental sample, then analyzing for those compounds. The duplicate allows for determination of the reproducibility of the result. The results are used to assess the analysis precision and recovery achieved from that particular matrix.

Method blanks are prepared prior to sample preparation within the laboratory by pouring ASTM Type II water into prepared sample bottles. The analysis of these blanks are used to assess outside contamination of the sample that may occur during sample preparation and analysis.

Spike blanks are prepared by adding a known amount of one or more compounds to ASTM Type II water. The subsequent analysis is used to assess analysis precision and recovery achieved from a clean matrix.

Surrogate spikes are prepared by adding a known amount of one or more compounds to each environmental sample. The compounds used are ones that are not expected to be present in any of the environmental samples. Results of these analyses are used to identify matrix interferences on analysis results.

4.1.3 Adherence to Sampling and Analysis Protocols and Procedures

Guidelines and methods were established for the sampling and analysis of environmental samples. Specifically, there are minimum numbers of field and laboratory QC samples that must be collected and holding times (i.e., time between sampling and sample extraction or analysis) that must be met. Insufficient QC sample collection can cause data deficiencies that will make data validation questionable or impossible. Failure to meet holding time requirements can result in lowered or elevated contaminant(s) concentration(s) or no detection of compounds that actually exist at the sampling site.

4.1.4 Summary of Quality Assurance/Quality Control Assessment Results

Evaluation and review of the field and laboratory QA/QC sample results and procedures used indicate that the data accurately represent the environmental samples collected. Sampling guidelines and QC requirements were met. QC samples showed acceptance replication and that decontamination procedures were acceptable. Laboratory analyses methods and QC requirements were followed and showed adequate accuracy, precision, completeness, representativeness, and comparability. A more detailed discussion concerning the data quality objectives is found in Appendix F, Section F.1.

Concentrations of contaminants detected in laboratory and field QA/QC samples were low and can be attributed in most cases to known sources. The concentrations found in the QA/QC samples do not affect the usefulness of the environmental data. The following conclusions were made regarding the analytical data and specific compounds in question and were based on a thorough review of the QA/QC procedures conducted by both laboratory and field personnel:

- Acetone was detected in environmental samples and associated trip blanks and equipment blanks. For these environmental samples, the presence of acetone may be attributed to equipment handling and/or sampling procedures.
- Methylene chloride was detected in environmental samples and associated equipment blanks and laboratory method blanks. Therefore, methylene chloride concentrations in environmental samples may be attributed to sampling procedures or laboratory contamination.
- Xylenes and toluene were detected in equipment blanks. Therefore, sampling procedures or sampling equipment may be responsible for the presence of these compounds.
- Bis (2-ethylhexyl)phthalate was detected in environmental samples and associated field blanks, equipment blanks, and laboratory method blanks. Therefore, environmental data should be evaluated considering that the compound may have been introduced through laboratory contamination, equipment decontamination, rinse water, or other external sources.

- No holding time criteria have been established by the EPA for the extraction and analysis of soil samples for total petroleum hydrocarbons (TPH); therefore, no objective judgment of the integrity of the data based on the length of time allowed to elapse between sample collection and analysis for TPH can be made. All soil samples were extracted and analyzed on the same day. Percent recoveries and some relative percent difference (RPD) values for the MS/MSD analyses were greater than the upper control limits.

  The recoveries of TPH in method blanks spikes conducted were within the control limits. These results suggest that while the analyses were conducted properly, the enhanced spike results and greater-than-desired analytical variability were due either to the native soil matrix or to the sample holding times. Based on these QC results, the soil TPH values should be considered lower estimates.

- Various metals (i.e., lead, zinc, copper, chromium, and nickel) were detected in equipment blanks and field blanks associated with both soil and groundwater environmental samples. Depending on the concentrations of the compounds detected in equipment blanks and field blanks relative to the concentrations detected in the environmental samples, external contamination may have occurred. Sources for the external contamination are most likely attributable to the decontamination water or laboratory procedures.

A complete discussion of the QA/QC procedures and results for the RI data collected at SDANG are contained in Appendix F.

4.1.5 Onsite Sample Analysis and Screening

Tracer Research Corporation (TRC) provided onsite analytical services in support of the RI field effort. The purpose of these services was to determine which environmental samples were to be forwarded to the laboratory for detailed analysis and to provide analysis of groundwater/soil/ samples during the installation and location of groundwater monitoring wells. A detailed description of analytical procedures and QA/QC procedures used by TRC is contained in Appendix C.

4.2 SITE 1 – UNDERGROUND FUEL STORAGE AREA RESULTS

The following samples were collected during the field programs at Site 1 – Underground Fuel Storage Area:

- Site Inspection, October 1987
  - Groundwater probe survey (25 samples analyzed by onsite GC)
  - Drilling, sampling, and installation of four groundwater monitoring wells (eight soil, four groundwater samples sent to laboratory)
- Remedial Investigation, April 1989
  - Groundwater probe survey (35 samples were analyzed by onsite GC)

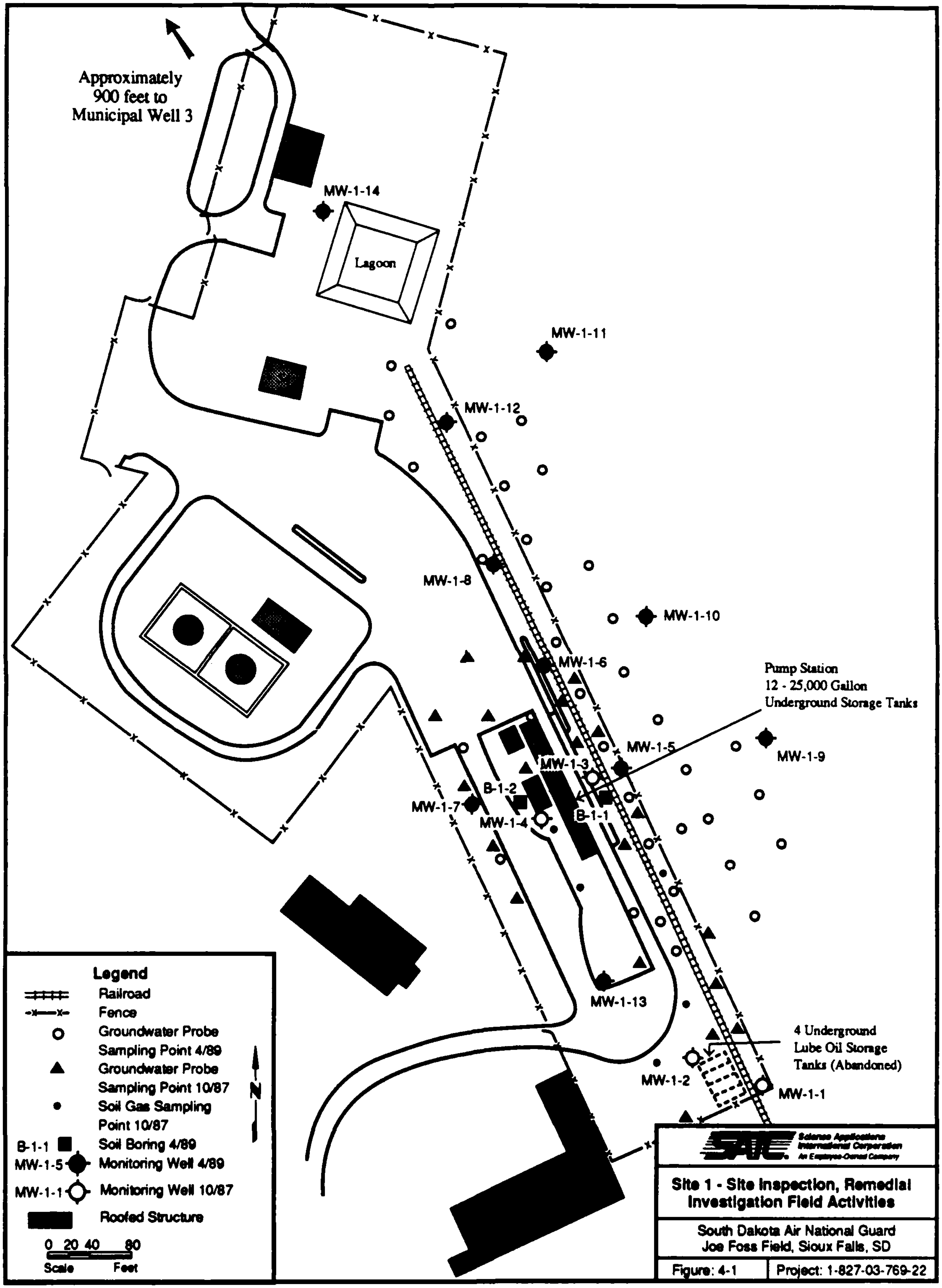
- Drilling and soil sampling of two soil borings located adjacent to previously SI-installed, contaminated wells (19 samples screened by onsite GC, four soil samples sent to the laboratory)
- Drilling, sampling, and installation of 10 additional groundwater monitoring wells (74 soil samples screened by onsite GC, 20 soil samples, and 26 groundwater samples [two rounds sent to the laboratory]).

The location of these sampling points are shown in Figure 4-1.

4.2.1 Site 1 - Underground Fuel Storage Area Groundwater Probe Survey Results

Figure 4-2 shows the total volatile hydrocarbon isoconcentration map, which is a composite of 50 samples that were collected during the two groundwater probe surveys and the onsite GC data collected at the water table (i.e., 15-foot depth). Sampling points of higher concentrations are shown on the map as reference points. A list of the groundwater probe survey results appears in Table 4-1 and the on-site GC analysis results are given in Table 4-2.

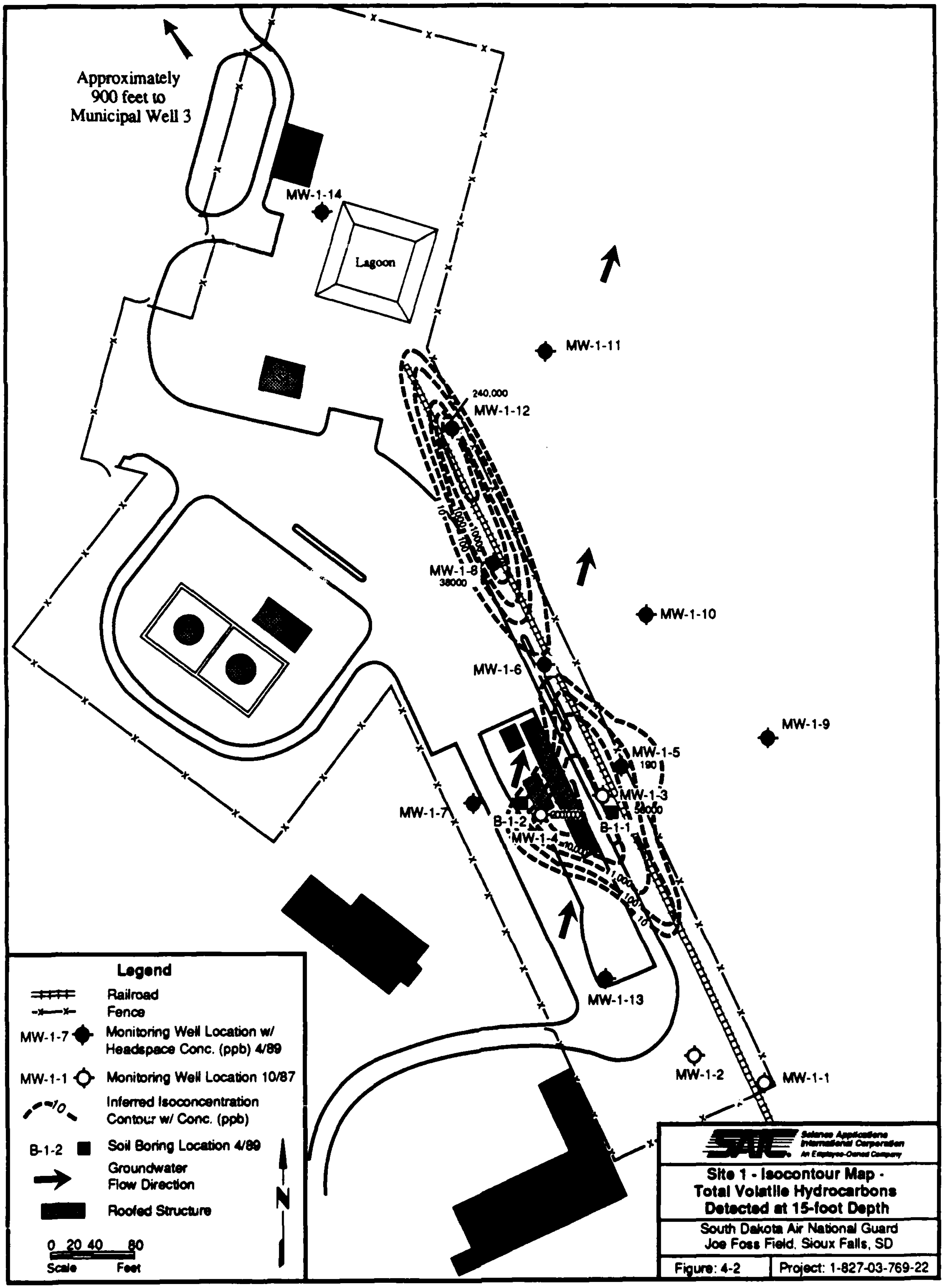
The map clearly shows the presence of two contaminated areas at the site. The southern area measures approximately 280 by 160 feet at its furtherest boundaries, encompassing a contaminated area of approximately 24,000 square feet. The highest contamination occurs in the vicinity of the underground fuel storage tanks. This area's "spreadout" shape indicates that there has been more than one source of contamination in this area and that these sources are associated with the underground tanks and/or the associated piping. The northern area measures approximately 320 by 60 feet at its furthest boundaries, encompassing a contaminated area of approximately 17,000 square feet. The narrow shape and location of this area indicate that the source is associated with the railroad ditches. Since no piping currently exists in this area and no signs of leakage were noted when the old fuel transfer piping was removed from a nearby area in 1987, a leak during the unloading of railroad tanker cars is the most probable cause. No such spills are known to have occurred through Air National Guard activities; however, there were undocumented spills during the period when the city of Sioux Falls used the former above ground storage tanks for the storage of fuel oil in the 1970s. As expected, the orientation of both contaminated areas' longest axis is northwest-southeast, similarily oriented to the northerly groundwater flow direction at the site. The maximum concentrations of total volatile organics in both areas are approximately 200,000 parts per billion (ppb), with an average concentration within the contaminated areas of approximately 1,000 ppb.



Site 1 - Site Inspection, Remedial Investigation Field Activities

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 4-1 | Project: 1-827-03-769-22



Site 1 - Isocontour Map - Total Volatile Hydrocarbons Detected at 15-foot Depth

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 4-2 Project: 1-827-03-769-22

TABLE 4-1. SUMMARY OF THE RESULTS OF TOTAL VOLATILE HYDROCARBONS FROM GROUNDWATER PROBE SURVEYS AT SITE 1 - UNDERGROUND FUEL STORAGE AREA AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

SITE INSPECTION 10/87			REMEDIAL INVESTIGATION 4/89		
SAMPLE	DATE	TOTAL VOLATILE HYDROCARBON*	SAMPLE	DATE	TOTAL VOLATILE HYDROCARBON*
WS1-1	10/15/87	2300	GP1-100	04/18/89	ND
WS1-2	10/15/87	34	GP1-101	04/18/89	ND
WS1-3	10/15/87	5400	GP1-102	04/18/89	190
WS1-4	10/15/87	530	GP1-103	04/18/89	3100
WS1-5	10/15/87	ND	GP1-104	04/18/89	1900
WS1-6	10/15/87	ND	GP1-105	04/18/89	110
WS1-7	10/15/87	ND	GP1-106	04/24/89	31
WS1-8	10/16/87	ND	GP1-107	04/24/89	ND
WS1-9	10/19/87	ND	GP1-108	04/24/89	200000
WS1-10	10/15/87	ND	GP1-109	04/18/89	43
WS1-12	10/16/87	ND	GP1-110	04/18/89	ND
WS1-13	10/16/87	18	GP1-111	04/18/89	ND
WS1-14	10/16/87	8	GP1-112	04/18/89	ND
WS1-15	10/16/87	ND	GP1-113	04/18/89	ND
WS1-16	10/16/87	ND	GP1-114	04/18/89	ND
WS1-17	10/16/87	ND	GP1-115	04/19/89	32
WS1-18	10/16/87	ND	GP1-116	04/19/89	ND
WS1-19	10/18/87	ND	GP1-117	04/19/89	6
WS1-20	10/18/87	ND	GP1-118	04/19/89	ND
WS1-22	10/18/87	ND	GP1-119	04/19/89	ND
WS1-23	10/18/87	ND	GP1-120	04/24/89	ND
WS1-26	10/18/87	1200	GP1-121	04/24/89	ND
WS1-28	10/18/87	ND	GP1-122	04/24/89	230
WS1-29	10/19/87	ND	GP1-123	04/24/89	ND
WS1-30	10/19/87	ND	GP1-124	04/24/89	76
			GP1-125	04/25/89	ND
			GP1-126	04/25/89	ND
			GP1-127	04/25/89	10000
			GP1-128	04/25/89	230
			GP1-129	04/25/89	7400
			GP1-130	04/25/89	530
			GP1-131	04/25/89	ND
			GP1-132	04/25/89	ND
			GP1-133	04/25/89	ND
			GP1-134	04/25/89	ND

ND - Indicates no analytes were detected. * - Units are PPB.

TABLE 4-2. SUMMARY OF RESULTS OF ONSITE GC SCREENING OF SOIL SAMPLES AT SITE 1 - UNDERGROUND FUEL STORAGE AREA AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

SAMPLE	DATE	TOTAL VOLATILE HYDROCARBON*	SAMPLE	DATE	TOTAL VOLATILE HYDROCARBON*
B1-1-5	04/11/89	70	MW1-8-5	04/17/89	ND
B1-1-10	04/11/89	17000	MW1-8-10	04/17/89	2500
B1-1-15	04/11/89	56000	MW1-8-15	04/17/89	38000
B1-1-20	04/11/89	18000	MW1-8-20	04/17/89	18000
B1-1-20R2	04/11/89	52000	MW1-8-25	04/17/89	660
B1-1-25	04/11/89	36000	MW1-8-30	04/17/89	ND
DRILL H20	04/11/89	ND			
B1-1-30	04/12/89	30000	MW1-9-5	04/25/89	ND
B1-1-35	04/12/89	570	MW1-9-10	04/25/89	ND
B1-1-40	04/12/89	170	MW1-9-15	04/25/89	ND
B1-1-45	04/12/89	360	MW1-9-20	04/25/89	ND
B1-1-50	04/12/89	220	MW1-9-25	04/25/89	ND
B1-2-5	04/13/89	ND	MW1-10-5	04/26/89	ND
B1-2-10	04/13/89	ND	MW1-10-10	04/26/89	ND
B1-2-15	04/13/89	200000	MW1-10-15	04/26/89	ND
B1-2-20	04/13/89	110	MW1-10-20	04/26/89	ND
B1-2-25	04/13/89	120000	MW1-10-25	04/26/89	ND
B1-2-30	04/13/89	8800			
B1-2-35	04/13/89	830	MW1-11-5	04/26/89	ND
B1-2-40	04/13/89	ND	MW1-11-10	04/26/89	ND
			MW1-11-15	04/26/89	ND
MW1-5-5	04/16/89	ND	MW1-11-20	04/26/89	ND
MW1-5-10	04/16/89	ND	MW1-11-25	04/26/89	ND
MW1-5-15	04/16/89	190			
MW1-5-20	04/16/89	79	MW1-12-5	04/27/89	ND
MW1-5-25	04/16/89	84	MW1-12-10	04/27/89	ND
MW1-5-30	04/16/89	36	MW1-12-15	04/27/89	24000U
			MW1-12-20	04/27/89	2400
MW1-6-5	04/16/89	ND	MW1-12-25	04/27/89	640
MW1-6-10	04/16/89	ND	MW1-12-30	04/27/89	ND
MW1-6-15	04/16/89	0.8			
MW1-6-20	04/16/89	140	MW1-13-5	04/27/89	ND
MW1-6-25	04/16/89	ND	MW1-13-10	04/27/89	ND
MW1-6-30	04/16/89	ND	MW1-13-15	04/27/89	ND
			MW1-13-20	04/27/89	ND
MW1-7-5	04/17/89	ND	MW1-13-25	04/27/89	ND
MW1-7-10	04/17/89	ND			
MW1-7-15	04/17/89	ND	MW1-14-5	04/28/89	ND
MW1-7-20	04/17/89	ND	MW1-14-10	04/28/89	ND
			MW1-14-15	04/28/89	ND
			MW1-14-20	04/28/89	ND
			MW1-14-25	04/28/89	ND

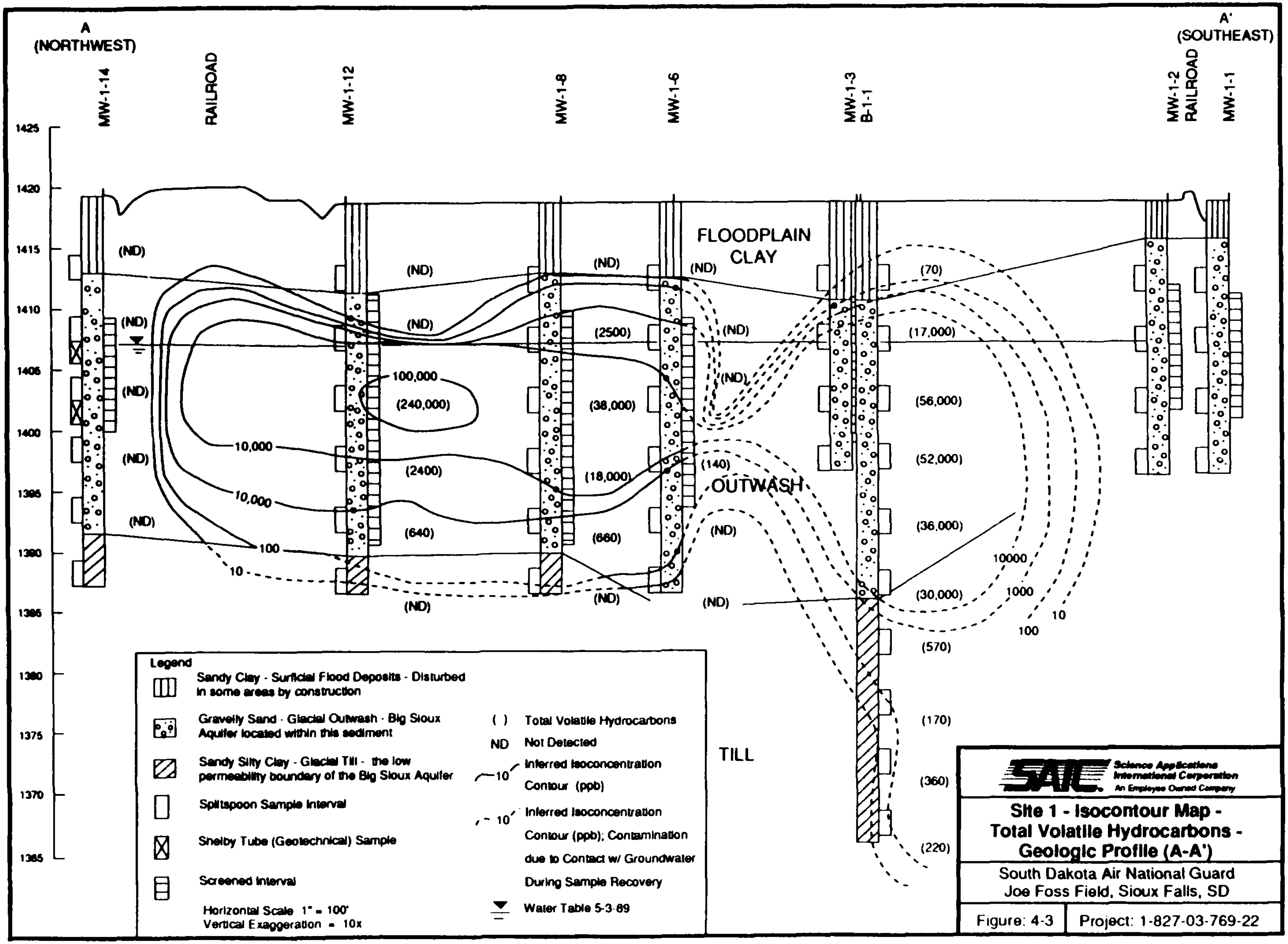
ND - Indicates no analytes were detected. * - Units are PPB.

4.2.2 Soil Sample Results

Twelve new boreholes (10 were completed as wells) were drilled during the RI field program. Field observations during the drilling of these boreholes provided evidence of the extent and severity of the contamination at Site 1 – Underground Fuel Storage Area. The field observations agreed with the extent and concentration of contamination, as defined by the groundwater probe surveys. While drilling within the source areas (i.e., MW-1-8, MW-1-12, B-1-1, and B-1-2), water table soil samples commonly showed the presence of a green foam and discolored soil with a hydrocarbon sheen and exhibited a fuel odor that could be smelled at somedistance from the drill site. Soil samples from boreholes drilled away from the source area exhibited only a slight soil discoloration and a mild fuel odor. No outward signs of contamination were noted from samples collected outside of the contaminated areas, as delineated by the groundwater probe surveys.

4.2.2.1 Onsite GC Analysis Results of Soil Samples From Site 1 – Underground Fuel Storage Area

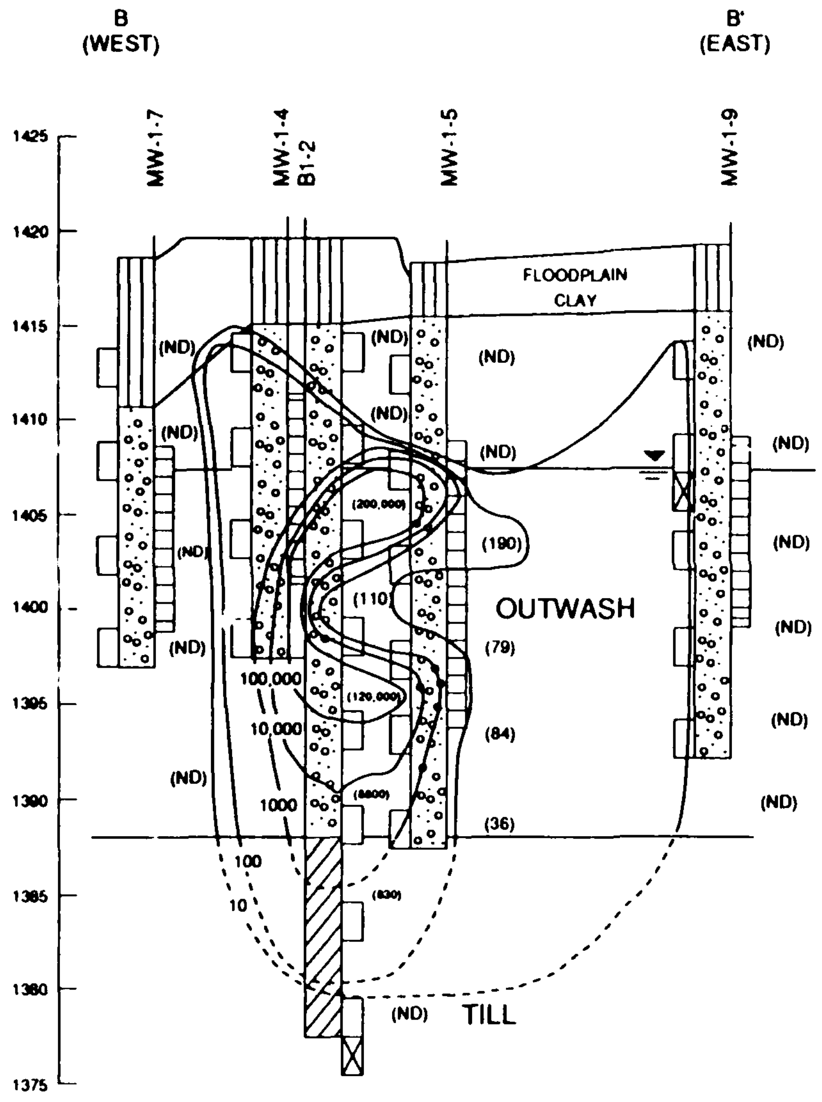
The results of the onsite GC analysis of soil samples collected at Site 1 – Underground Fuel Storage Area were superimposed on the geologic profiles that are oriented parallel and perpendicular to the principal axis of contamination, Figures 4-3 and 4-4, respectively. The location of the sampling points are shown in Figure 4-2. The profiles show the vertical extent of the two areas of contamination. In addition, the excellent agreement of concentration and location of contaminated areas between the onsite GC analysis of soil samples and the groundwater probe survey can be noted from the profile. Generally, within the contaminated areas, contamination is found at the water table (approximately 12 feet below land surface) and extending to the till/outwash contact at approximately 30 feet. Some boreholes showed low concentrations of contamination below this till/outwash contact. It is unlikely, that hydrocarbon contamination has penetrated the low permeability clay materials which are indicative of the glacial till. In most cases, the onsite GC results showed no detectable levels of total volatile hydrocarbons in the soil samples collected from the glacial till/outwash contact (see Figures 4-3 and 4-4). In the deeper boreholes, where contamination was detected in the glacial till, the concentrations of total volatile hydrocarbons were several orders of magnitude less than the concentrations detected in the sandy outwash aquifer materials. The large magnitude of difference in the sample contamination results and apparent permeability differences between the upper sandy outwash and deeper glacial till suggests that the glacial till provides a natural impermeable layer, typical of clay materials, which has not been impacted by the hydrocarbon contamination. It is suspected that the soil samples collected from the deeper till layer were contaminated during collection as they passed through the contaminated groundwater within the hollow stem augers. Using this 18 foot thickness (30-foot



Site 1 - Isocontour Map - Total Volatile Hydrocarbons - Geologic Profile (A-A')

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 4-3 Project: 1-827-03-769-22



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Site 1 - Isocontour Map - Total Volatile Hydrocarbons - Geologic Profile (B-B')

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 4-4 | Project: 1-827-03-769-22

till contact depth minus 12-foot water table depth) and the areas of contamination, as defined through the groundwater probe survey, the volumes of the contaminated soils at Site 1 – Underground Fuel Storage Area are estimated to be 432,000 and 306,000 cubic feet for the southern and northern areas of contamination, respectively. Concentrations of the contamination were highest at or just below the water table, which reflects the floating characteristic of fuel contamination. Levels as high as 200,000 ppb were found at the water table, but levels rapidly decrease with depth averaging approximately 1,000 ppb throughout the aquifer in the contaminated areas.

4.2.2.2 Laboratory Analysis of Soil Samples

The results of the laboratory analysis of soil samples at Site 1 – Underground Fuel Storage Area are shown in Table 4-3. Soil sampling locations, in relation to the areas of contamination defined by the groundwater probe surveys, are shown in Figure 4-2.

Volatile organic compounds results indicated the presence of several compounds. Of these, methylene chloride and acetone were found throughout the field and laboratory blanks, which indicates that these compounds are related to outside contamination during handling and/or analysis and are not actual site contaminants. Of the remaining compounds, only soil borings B-1-1 and B-1-2 showed significant levels of identifiable VOCs (i.e., ethylbenzene, toluene, and total xylenes). However, there were very high levels of volatile organic tentatively identified compounds (TICs). Volatile organic TICs are compounds that are not positively indentifiable using current analysis instrumentation and EPA methods and, as a result, have not been extensively regulated or studied. Volatile organic TICs in the samples at SDANG are listed in Table 4-4. Gross TIC levels range from not detected (ND [detection limits are not given but are less than 38 μg/L, the lowest result reported]) to 101,000 μg/L in soil boring B-1-2. The volatile organic TIC results compare very favorably with the extent of contamination as defined by the total volatile hydrocarbon (TVH) results from the groundwater probe survey and onsite GC results.

Semivolatile organic compound (SVOC) results indicated the presence of over 20 different identifiable compounds. Of these, bis(2-ethylhexyl)phthalate was found throughout the field and laboratory blanks and is considered a laboratory-induced contaminant and not reflective of actual site contamination. Only MW-1-12 and soil boring samples B-1-1 and B-1-2 showed significant levels of identifiable SVOCs. These sample locations are all in the vicinity of the contamination source areas, as defined by the groundwater probe surveys. As with the VOC results, there were elevated levels of tentatively identifiable SVOCs detected within the soil samples from this site.

TABLE 4-3. SITE 1 - UNDERGROUND FUEL STORAGE AREA SOIL DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Parameters	Units	Lower Limit of Detection (A)	B1-1-15	B1-1-25	B1-2-15	B1-2-25
Associated Field QC Samples			EB-1 TB-1 FB-1	EB-1 TB-1 FB-1	EB-2 TB-2 FB-1	EB-2 TB-2 FB-1
PETROLEUM HYDROCARBONS	mg/Kg DB	20	ND	ND	21	37(H)
TOTAL ORGANIC CARBON	% DB	0.1	0.4(H)	1.1(H)	0.9(H)	1.1(H)
TRACE METALS						
Lead	mg/Kg DB	0.5	2.6	3.1	3.2	3.1
Arsenic	mg/Kg DB	0.5	1.2	1.4	1.9	1.8
Selenium	mg/Kg DB	0.5	NT	NT	NT	NT
Copper	mg/Kg DB	1	NT	NT	NT	NT
Beryllium	mg/Kg DB	0.1	NT	NT	NT	NT
Nickel	mg/Kg DB	2	NT	NT	NT	NT
Cadmium	mg/Kg DB	0.5	NT	NT	NT	NT
Chromium	mg/Kg DB	1	NT	NT	NT	NT
Zinc	mg/Kg DB	1	NT	NT	NT	NT
VOLATILE ORGANIC COMPOUNDS						
Methylene Chloride	µg/Kg DB	2	ND	ND	ND	ND
Acetone	µg/Kg DB	8	ND	39	ND	ND
Toluene	µg/Kg DB	2	ND	ND	ND	ND
Ethylbenzene	µg/Kg DB	2	ND	ND	ND	920
Total Xylenes	µg/Kg DB	2	150	ND	2200	14000
TIC Total	µg/Kg DB	--	3500	1100	47000	100000
SEMIVOLATILE ORGANIC COMPOUNDS						
Naphthalene	µg/Kg DB	76	89(H,EH)	37(J,H)	330(H)	650(H)
2-Methylnaphthalene	µg/Kg DB	38	260(H,EH)	62(H)	600(H)	900(H)
Acenaphthene	µg/Kg DB	38	250(H,EH)	74(H)	77(H)	130(H)
Dibenzofuran	µg/Kg DB	38	130(H,EH)	45(H)	46(H)	81(H)
Fluorene	µg/Kg DB	38	300(H,EH)	99(H)	81(H)	150(H)
Phenanthrene	µg/Kg DB	38	1900(H,EH)	650(H)	360(H)	630(H)
Anthracene	µg/Kg DB	38	490(H,EH)	170(H)	110(H)	210(H)
Di-n-butyl phthalate	µg/Kg DB	38	10(J,H,EH)	ND	ND	9(J,H)
Fluoranthene	µg/Kg DB	38	1500(H,EH)	430(H)	360(H)	690(H)
Pyrene	µg/Kg DB	38	1600(H,EH)	510(H)	530(H)	770(H)
Benzo(a)anthracene	µg/Kg DB	38	690(H,EH)	220(H)	150(H)	330(H)
Chrysene	µg/Kg DB	38	640(H,EH)	220(H)	180(H)	320(H)
Bis(2-ethylhexyl)phthalate	µg/Kg DB	38	48(H,EH)	63(B,H)	94(H)	130(H)
Benzo(b)fluoranthene	µg/Kg DB	76	450(H,EH)	170(H)	160(H)	250(H)
Benzo(k)fluoranthene	µg/Kg DB	76	370(H,EH)	110(H)	100(H)	160(H)
Benzo(a)pyrene	µg/Kg DB	76	460(H,EH)	170(H)	140(H)	230(H)
Indeno(1,2,3-c,d)pyrene	µg/Kg DB	76	220(H,EH)	75(J,H)	71(J,H)	120(H)
Dibenzo(a,h)anthracene	µg/Kg DB	76	66(J,H,EH)	ND	ND	ND
Benzo(g,h,i)perylene	µg/Kg DB	76	180(H,EH)	62(J,H)	58(J,H)	98(H)
Diethyl phthalate	µg/Kg DB	38	ND	ND	ND	ND
Dimethyl phthalate	µg/Kg DB	38	ND	ND	ND	ND
4-Methylphenol	µg/Kg DB	38	ND	ND	ND	ND
Phenol	µg/Kg DB	38	ND	ND	23(J,H)	ND
Di-n-octyl phthalate	µg/Kg DB	38	ND	ND	ND	ND
TIC Total	µg/Kg DB		18000	9100	24000	44000

TABLE 4-3. SITE 1 - UNDERGROUND FUEL STORAGE AREA SOIL DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Parameters Associated Field QC Samples	Units	Lower Limit of Detection (A)	MW1-5-15 EB-6 TB-3 FB-1	MW1-5-20 EB-6 TB-3 FB-1	MW1-6-15 EB-6 TB-3 FB-1	MW1-6-15 DUP EB-6 TB-3 FB-1	MW1-6-20 EB-6 TB-3 FB-1	MW1-7-15 EB-7 TB-3 FB-1	MW1-7-20 EB-7 TB-3 FB-1	MW1-8-15 EB-7 TB-3 FB-1	MW1-8-20 EB-7 TB-3 FB-1
PETROLEUM HYDROCARBONS	mg/Kg DB	20	ND	ND	ND	ND	ND	ND	ND	ND	ND
TOTAL ORGANIC CARBON	% DB	0.1	1.6(H)	NT	NT	NT	1.6(H)	1.6(H)	NT	NT	1.1(H)
TRACE METALS											
Lead	mg/Kg DB	0.5	3.0	2.6	2.8	3.2	2.2	2.9	2.2	2.2	2.2
Arsenic	mg/Kg DB	0.5	1.2	1.3	4.8	7.0	5.7	4.1	3.4	4.9	5.3
Selenium	mg/Kg DB	0.5	NT	NT	NT	NT	NT	NT	NT	NT	NT
Copper	mg/Kg DB	1	NT	NT	NT	NT	NT	NT	NT	NT	NT
Beryllium	mg/Kg DB	0.1	NT	NT	NT	NT	NT	NT	NT	NT	NT
Nickel	mg/Kg DB	2	NT	NT	NT	NT	NT	NT	NT	NT	NT
Cadmium	mg/Kg DB	0.5	NT	NT	NT	NT	NT	NT	NT	NT	NT
Chromium	mg/Kg DB	1	NT	NT	NT	NT	NT	NT	NT	NT	NT
Zinc	mg/Kg DB	1	NT	NT	NT	NT	NT	NT	NT	NT	NT
VOLATILE ORGANIC COMPOUNDS											
Methylene Chloride	µg/Kg DB	2	4	7	8	3	3	4	3	ND	5
Acetone	µg/Kg DB	8	42	62	71	61	36	62	57	97	49
Toluene	µg/Kg DB	2	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	µg/Kg DB	2	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	µg/Kg DB	2	ND	ND	ND	ND	ND	ND	ND	ND	ND
TIC Total	µg/Kg DB	--	38	ND	ND	ND	ND	ND	ND	9500	3800
SEMIVOLATILE ORGANIC COMPOUNDS											
Naphthalene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzofuran	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	23(J)	ND
Phenanthrene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-butyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis(2-ethylhexyl)phthalate	µg/Kg DB	38	58(B)	70(B)	56(B)	50(B)	59(B)	62(B)	56(B)	53(B)	58(B)
Benzo(b)fluoranthene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND	ND	ND
Diethyl phthalate	µg/Kg DB	38	15(J)	ND	ND	ND	ND	ND	ND	ND	ND
Dimethyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Methylphenol	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	66
Di-n-octyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	ND
TIC Total	µg/Kg DB		5400	5500	5800	6600	6000	5700	6000	29000	11000

TABLE 4-3. SITE 1 - UNDERGROUND FUEL STORAGE AREA SOIL DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Parameters Associated Field QC Samples	Units	Lower Limit of Detection (A)	MW1-9-15 EB-8 TB-4 FB-2	MW1-9-20 EB-8 TB-4 FB-2	MW1-10-15 EB-9 TB-4 FB-2	MW1-10-15 DUP EB-9 TB-4 FB-2	MW1-10-20 EB-9 TB-4 FB-2	MW1-11-15 EB-9 TB-4 FB-2	MW1-11-20 EB-9 TB-4 FB-2
PETROLEUM HYDROCARBONS	mg/Kg DB	20	ND	ND	ND	ND	ND	34(H)	190(H)
TOTAL ORGANIC CARBON	% DB	0.1	NT	1.5(H)	NT	NT	0.9(H)	NT	1.1(H)
TRACE METALS									
Lead	mg/Kg DB	0.5	2.8	2.6	3.3	3.0	2.5	2.6	2.4
Arsenic	mg/Kg DB	0.5	2.4	2.6	2.2	2.2	1.6	4.4	3.8
Selenium	mg/Kg DB	0.5	NT	NT	NT	NT	NT	NT	NT
Copper	mg/Kg DB	1	NT	NT	NT	NT	NT	NT	NT
Beryllium	mg/Kg DB	0.1	NT	NT	NT	NT	NT	NT	NT
Nickel	mg/Kg DB	2	NT	NT	NT	NT	NT	NT	NT
Cadmium	mg/Kg DB	0.5	NT	NT	NT	NT	NT	NT	NT
Chromium	mg/Kg DB	1	NT	NT	NT	NT	NT	NT	NT
Zinc	mg/Kg DB	1	NT	NT	NT	NT	NT	NT	NT
VOLATILE ORGANIC COMPOUNDS									
Methylene Chloride	µg/Kg DB	2	8	6	6	6	6	5	4
Acetone	µg/Kg DB	8	ND	32	ND	ND	39	58	54
Toluene	µg/Kg DB	2	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	µg/Kg DB	2	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	µg/Kg DB	2	ND	ND	ND	ND	ND	ND	ND
TIC Total	µg/Kg DB	--	ND	ND	ND	ND	ND	ND	ND
SEMIVOLATILE ORGANIC COMPOUNDS									
Naphthalene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Dibenzofuran	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Fluorene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Anthracene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Di-n-butyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Pyrene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Chrysene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Bis(2-ethylhexyl)phthalate	µg/Kg DB	38	27(CC,J)	39(CC)	34(H,J,CC)	40(H,CC)	27(H,J,CC)	31(H,J,CC)	34(H,J,CC)
Benzo(b)fluoranthene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Diethyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Dimethyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
4-Methylphenol	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Phenol	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Di-n-octyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
TIC Total	µg/Kg DB		6100	6200	6400	7400	6700	6000	8500

TABLE 4-3. SITE 1 - UNDERGROUND FUEL STORAGE AREA SOIL DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Parameters	Units	Lower Limit of Detection (A)	MW1-12-15	MW1-12-15 DUP	MW1-12-20	MW1-13-15	MW1-13-20	MW1-14-15	MW1-14-20
Associated Field QC Samples			EB-10 TB-5 FB-2	EB-10 TB-5 FB-2	EB-10 TB-5 FB-2	EB-10 TB-5 FB-2	EB-10 TB-5 FB-2	EB-11 TB-5 FB-2	EB-11 TB-5 FB-2
PETROLEUM HYDROCARBONS	mg/Kg DB	20	730(H)	470(H)	46(H)	ND	270(H)	600(H)	160(H)
TOTAL ORGANIC CARBON	% DB	0.1	NT	NT	1.5(H)	NT	NT	NT	NT
TRACE METALS									
Lead	mg/Kg DB	0.5	2.6	2.8	2.3	2.4	2.0	7.1	2.1
Arsenic	mg/Kg DB	0.5	2.8	2.8	5.2	1.2	1.0	21	3.3
Selenium	mg/Kg DB	0.5	NT	NT	NT	NT	NT	NT	NT
Copper	mg/Kg DB	1	NT	NT	NT	NT	NT	NT	NT
Beryllium	mg/Kg DB	0.1	NT	NT	NT	NT	NT	NT	NT
Nickel	mg/Kg DB	2	NT	NT	NT	NT	NT	NT	NT
Cadmium	mg/Kg DB	0.5	NT	NT	NT	NT	NT	NT	NT
Chromium	mg/Kg DB	1	NT	NT	NT	NT	NT	NT	NT
Zinc	mg/Kg DB	1	NT	NT	NT	NT	NT	NT	NT
VOLATILE ORGANIC COMPOUNDS									
Methylene Chloride	µg/Kg DB	2	ND	ND	ND	ND	ND	ND	ND
Acetone	µg/Kg DB	8	ND	ND	30	61	67	75	53
Toluene	µg/Kg DB	2	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	µg/Kg DB	2	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	µg/Kg DB	2	ND	ND	ND	1(J)	ND	ND	ND
TIC Total	µg/Kg DB	--	42000	24000	290	ND	ND	ND	ND
SEMIVOLATILE ORGANIC COMPOUNDS									
Naphthalene	µg/Kg DB	76	300	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	µg/Kg DB	38	820	110	ND	ND	ND	ND	ND
Acenaphthene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Dibenzofuran	µg/Kg DB	38	17(J)	ND	ND	ND	ND	ND	ND
Fluorene	µg/Kg DB	38	43	ND	ND	ND	ND	ND	ND
Phenanthrene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Anthracene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Di-n-butyl phthalate	µg/Kg DB	38	15(J)	ND	ND	ND	ND	ND	ND
Fluoranthene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Pyrene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Chrysene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Bis(2-ethylhexyl)phthalate	µg/Kg DB	38	24(J)	22(J)	ND	21(J,CC)	18(J,CC)	ND	ND
Benzo(b)fluoranthene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND
Diethyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Dimethyl phthalate	µg/Kg DB	38	ND	14(J)	ND	ND	ND	ND	ND
4-Methylphenol	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Phenol	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
Di-n-octyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND
TIC Total	µg/Kg DB		28000	11000	6800	6500	6700	7300	6600

TABLE 4-3. SITE 1 - UNDERGROUND FUEL STORAGE AREA SOIL DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Information concerning abbreviations found on Table 4-3. can be found here.

ND	This compound/parameter was not detected at or above the detection level.
NT	This compound/parameter was not analyzed in the respective sampling round.
(A)	Lower limit of detection represents lowest detection limit reported for the samples collected at this site. Actual sample detection limits will vary due to percent moisture (soils only) and dilution factor (soils and waters). Adjusted detection limits for individual sample results can be found in Appendix E.
(B)	Compound was detected in the associated method blank.
(CC)	Continuing calibration verification relative response factor outside control limits.
(EB)	Compound/parameter was also detected in the associated equipment blank.
(EH)	The extraction holding time was exceeded for the respective sample.
(FB)	Compound/parameter was also detected on the associated field blank.
(H)	The CLP holding time was exceeded for this compound/element.
(J)	Estimated value. This flag is used when the mass spectral data indicates the presence of an analyte but the result is below the sample quantitation level.
(TB)	Compound or element also detected in the associated trip blank.
MWx-y-z	Site x at Monitoring well y and Depth z(feet) (soil sample).
Bx-y-z	Site x at Soil boring y and Depth z(feet) (background soil sample).

TABLE 4-4. REMDIAL INVESTIGATION TENTATIVELY IDENTIFIED VOLATILE ORGANIC COMPOUNDS AND SEMIVOLATILE ORGANIC COMPOUNDS DETECTED AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Volatile Compound Name	Semivolatile Compound Name
2-Azido-2,3,3-trimethylbutane	2-Bromophenol
Decane	Butylcyclohexane
1,2-Diethoxyethane	9h-Carbazole
1,2-Dimethylcyclohexane	3-Cyclohexene-1-methanol
2,6-Dimethylnonane	2-Cyclohexyloctane
2,6-Dimethyl-2-octene	1,2-Diethylbenzene
1-Ethyl-2-methylbenzene	1,2-Dimethylbenzene
1-Ethyl-3-methylbenzene	1,4-Dimethylbenzene
1-Ethyl-4-methylbenzene	3,4-Dimethyldecane
5-Ethyl-2-methylheptane	2,6-Dimethylnonane
3-Ethylpentane	3,6-Dimethylundecane
Hexane	4,8-Dimethylundecane
o-(3-Methylbutyl)hydroxylamine	1-Dotriacontanol
Methylcyclohexane	Eicosane
Methylcyclopentane	Ethylbenzene
8-Methyl-1-decene	4-Ethyl-1,2-dimethylbenzene
(1-Methylethyl)benzene	1-Ethyl-3,5-dimethylbenzene
2-Methyl-1-nitropropane	1-Ethylidene-1h-indene
3-Methylpentane	1-Ethyl-2-methylcyclohexane
4-Methyl-2-propyl-1-pentanol	3-Ethyl-2-methylhaptane
1-Propenylcyclohexane	Heptacosane
Propylbenzene	Heptadecane
4-Propylheptane	Hexadecane
2,2,3,3-Tetramethylhexane	Hexatricontane
2,2,3,4-Tetramethylpentane	3-Hexene-2,5-dione
1,2,3-Trimethylbenzene	Hexylcyclohexane
1,2,4-Trimethylbenzene	7-Hexyleicosane
1,3,5-Trimethylbenzene	3-Methyldecane
1,1,3-Trimethylcyclohexane	4-Methyldodecane
2,5,5-Trimethylhexane	6-Methyldodecane
3,4,5-Trimethylhexane	4-Methyl-2-hexanone
2,5,5-Trimethyl-1-hexene	5-Methyl-2-hexanone
2,2,3-Trimethylpentane	1-Methylnaphthalene
2,2,4-Trimethylpentane	3-Methylnonane
2,3,3-Trimethylpentane	1-Methyl-3-propylbenzene
2,2,4-Trimethylpentanol	1-Methyl-4-propylbenzene
	6-Methyltridecane
	3-Methylundecane
	4-Methylundecane
	Nonadecane
	Octacosane
	Octadecanal
	Pentadecane
	Pentatricontane
	Pentylcyclohexane
	Propylbenzene
	Tetratetracontane
	1,2,3,4-Tetrahydronaphthalene
	1,2,3,4-Tetramethylbenzene
	1,2,3,5-Tetramethylbenzene
	2,2,3,3-Tetramethylbutane
	2,6,10,15-Tetramethylheptadecane
	trans-Decahydronaphthalene
	Tridecane
	2,6,8-Trimethyldecane
	2,7,10-Trimethyldodecane
	2,6,11-Trimethyldodecane
	3,4,5-Trimethyl-1-hexene
	2,3,7-Trimethyloctane
	Tritetracontane
	Undecane
	Undecylcyclohexane

Some compounds were designated as aldol condensations and others were designated as "unknown".

Semivolatile TICs found in the samples from SDANG are listed in Table 4-4. Gross semivolatile organic TIC concentrations range from 5,450 to 43,900 µg/L throughout the site. Background sample results indicate that there is a natural background level of these compounds in soil that ranges from approximately 5,000 to 10,000 micrograms/liter (µg/L) in the SDANG area. In addition, since low levels of semivolatile organic TICs (5 to 39 µg/L) were found within the aqueous field and laboratory blanks, lower levels within the environmental samples could be attributable to laboratory contamination. Semivolatile organic TIC concentrations above the 10,000 µg/L cutoff were found within the soil samples from monitoring wells MW-1-8, MW-1-12, B-1-1, and B-1-2. These soil sample locations agree with the VOC results and the source locations, as defined by the groundwater probe surveys.

Inorganic analyses performed on soil samples from Site 1 – Underground Fuel Storage Area were limited to lead and arsenic based upon previous investigation results. Lead concentrations in aquifer sediments ranged from 2 to 7.1 milligrams per kilogram (mg/kg); this range generally agrees with the background concentrations found at background boring BK-2 (2.4 to 4.1 mg/kg). Arsenic concentrations ranged from 1.0 to 21 mg/kg. Concentrations agreed generally with the maximum background concentration of 3.3 mg/kg with the exception of the 21 mg/kg concentration found at MW-1-14. This concentration is unexpected at this location because of its extreme downgradient location, which is far beyond the maximal extent of contamination, as defined by the groundwater probe survey. No signs of site-related contamination were evident in the MW-1-14 borehole, and the arsenic concentration from a deeper sample within the same borehole showed normal background levels. In addition, there is no correlation between elevated arsenic levels and hydrocarbon contaminant levels in the borings emplaced in the source areas. Therefore, this arsenic level is most likely anomalous and not related to the hydrocarbon contamination at this site.

Petroleum hydrocarbon results ranged from no detection (>20 mg/kg) to values in excess of 730 mg/kg in the MW-1-12 borehole. Detectable concentrations were found in MW-1-11, MW-1-12, MW-1-13, MW-1-14, and B-1-2, which seem to be associated principally with the northern area of contamination in wells that otherwise show little or no other sign of contamination. The background soil borings were placed upgradient in areas distant from the site which showed no signs of past waste handling practices. However, soil samples from these borings showed the highest levels of petroleum hydrocarbons of all samples collected (970 mg/kg in soil samples BK-2) and therefore are not useful for evaluating the petroleum hydrocarbon data collected at the site. No other site-related compounds (metals, VOCs, or SVOCs) were detected in samples collected from MW-1-11, MW-1-13, and MW-1-14. In addition, the groundwater probe survey showed no signs of site-related contamination at these locations. The petroleum hydrocarbon concentrations are most likely anomalous and may not be directly attributable to site activities.

Total organic carbon levels range from 0.4 to 1.6 percent; the range is the same range as that for background concentrations (0.9 to 1.4 percent). Also, these levels showed no trends that correlate to the contamination, as defined by the groundwater probe survey.

4.2.3 Groundwater Sampling Results at Site 1 – Underground Fuel Storage Area

A total of 13 groundwater monitoring wells (10 RI and 3 SI) underwent two rounds of groundwater sampling during the RI field program. In addition, a round of groundwater samples were taken from three SI-installed monitoring wells during a treatability study in January 1989. The results of the laboratory analysis of groundwater samples at Site 1 – Underground Fuel Storage Area taken during the SI field program, the January 1989 sampling, and the RI field program are comparatively shown in Table 4-5. Sampling locations, in relation to the areas of contamination defined by the groundwater probe surveys, are shown in Figure 4-2.

Field observations made during the monitoring well completion, development, purging, and sampling agreed closely with the results of the groundwater probe survey. Wells installed in the contaminant source areas (i.e., MW-1-3, MW-1-4, MW-1-8, and MW-1-12) exhibited a foam-like deposit on the water surface, showed a dark gray discoloration of the groundwater, and exhibited a strong fuel odor. It should be noted, however, that none of the wells at the site showed the presence of any free-floating petroleum product. Wells located within the area of contamination but away from the source area exhibited a mild fuel odor, while wells outside the area of contamination showed only a faint gray color due to a small amount of suspected silt and clay present within the groundwater.

VOC results indicated the presence of several compounds. Of these, acetone was found throughout the field and laboratory blanks and the background samples, which indicates that this compound is related to outside contamination during handling and/or analysis and is not an actual contaminant at the site. Of the remaining compounds, only monitoring wells MW-1-4 and MW-1-12 showed significant levels of identifiable VOC compounds (i.e., ethylbenzene and total xylenes). Also, as with the soil samples, there were very high levels of TICs. Volatile TICs are volatile organic compounds that are not positively indentifiable using current analysis instrumentation and

TABLE 4-5. SITE 1 - UNDERGROUND FUEL STORAGE AREA GROUNDWATER DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Parameter	Units	Lower Limit of Detection (A)	GW1-1	GW1-1	GW1-1 RE	MW1-1	MW1-1 RE	GW1-1	GW1-2	GW1-3	GW1-3	MW1-3	GW1-3
Collection Date			10/87	1/89	1/89	4/89	4/89	7/89	10/87	10/87	1/89	4/89	7/89
Associated Field QC Samples			QA-7	QA-1B QA-2B	QA-1B QA-2B	EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3	QA-7	QA-7	QA-1B QA-2B	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3
PETROLEUM HYDROCARBONS	mg/L	0.5	ND	ND	NT	ND	NT	ND	0.1(FB)	4.5(FB)	ND	1.4	0.8
TRACE METALS					NT		NT						
Dissolved Arsenic	µg/L	5	ND	ND*		ND		ND	ND	13	7*	ND	ND
Dissolved Lead	µg/L	1	ND	9*		ND		ND	6	12	36*	2.2(ND)	ND
Dissolved Selenium	µg/L	5	NT	NT		NT		NT	NT	NT	NT	NT	NT
Dissolved Copper	µg/L	1	NT	NT		NT		NT	NT	NT	NT	NT	NT
Dissolved Nickel	µg/L	2	NT	NT		NT		NT	NT	NT	NT	NT	NT
Dissolved Cadmium	µg/L	1	NT	NT		NT		NT	NT	NT	NT	NT	NT
Dissolved Chromium	µg/L	1	NT	NT		NT		NT	NT	NT	NT	NT	NT
Dissolved Zinc	µg/L	1	NT	NT		NT		NT	NT	NT	NT	NT	NT
VOLATILE ORGANIC COMPOUNDS			ND	ND	NT	ND	NT	ND	ND			ND	ND
Total Xylenes	µg/L	1								2900	560		
Ethylbenzene	µg/L	1								1100	130		
Methylene Chloride	µg/L	1								ND	ND		
Toluene	µg/L	1								ND	ND		
Acetone	µg/L	5								ND	ND		
Benzene	µg/L	1								120	21		
TIC Total	µg/L	--	--	NT					--	--	NT	340	410
SEMIVOLATILE ORGANIC COMPOUNDS			NT	NT		NT			NT	NT			
Bis(2-ethylhexyl)phthalate	µg/L	2			2		5(EH,B)	3(EH)			10	44(CC)	3(EH)
Naphthalene	µg/L	4			ND		ND	ND			13	14	11(EH)
2-Methylnaphthalene	µg/L	2			ND		ND	ND			2	2	ND
Acenaphthene	µg/L	2			ND		ND	ND			7	7	7(EH)
Dibenzofuran	µg/L	2			ND		ND	ND			4	3	3(EH)
Fluorene	µg/L	2			ND		ND	ND			8	6	6(EH)
Phenanthrene	µg/L	2			ND		ND	ND			16	17	9(EH)
Anthracene	µg/L	2			ND		ND	ND			6	7	4(EH)
Fluoranthene	µg/L	2			ND		ND	ND			16	20	10(EH)
Pyrene	µg/L	2			ND		ND	ND			15	22	9(EH)
Benzo(a)anthracene	µg/L	2			ND		ND	ND			5	7	2(EH)
Chrysene	µg/L	2			ND		ND	ND			5	7	2(EH)
Benzo(b)fluoranthene	µg/L	4			ND		ND	ND			5(T)	6(X)	ND
Benzo(k)fluoranthene	µg/L	4			ND		ND	ND			5(T)	6(X)	ND
Benzo(a)pyrene	µg/L	4			ND		ND	ND			ND	4(J)	ND
Indeno(1,2,3-c,d)pyrene	µg/L	4			ND		ND	ND			ND	1(J)	ND
2,4-Dimethylphenol	µg/L	2			ND		ND	ND			ND	ND	ND
Di-n-butyl phthalate	µg/L	2			ND		ND	ND			ND	ND	ND
Di-n-octyl phthalate	µg/L	2			ND		ND	ND			ND	ND	ND
Diethyl phthalate	µg/L	2			ND		ND	ND			ND	ND	ND
TIC Total	µg/L	--			ND		ND	ND			NT	710	360

TABLE 4-5. SITE 1 - UNDERGROUND FUEL STORAGE AREA GROUNDWATER DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Parameter	Units	Lower Limit of Detection (A)	GW1-4	GW1-4 DUP	GW1-4	GW1-4 RE	MW1-4	MW1-4 DUP	MW1-4 DUP/RE	GW1-4	GW1-4 DUP	MW1-5	MW1-5 RE	GW1-5
Collection Date			10/87	10/87	1/89	1/89	4/89	4/89	4/89	7/89	7/89	4/89	4/89	7/89
Associated Field QC Samples			QA-7	QA-7	QA-1B QA-2B	QA-1B QA-2B	EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3	EB-15 TB-9 FB-3	EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3
PETROLEUM HYDROCARBONS	mg/L	0.5	4.8(FB)	4.0(FB)	130	NT	3.3(E)	2.3(H)	NT	1.3	2.2	ND	NT	ND
TRACE METALS						NT							NT	
Dissolved Arsenic	µg/L	5	5	8	ND*		ND	ND	NT	ND	ND	ND		ND
Dissolved Lead	µg/L	1	24	24	9*		3.2	2.1	NT	1.1	0.8(J)	2.0		0.8(J)
Dissolved Selenium	µg/L	5	NT	NT	NT		NT	NT	NT	NT	NT	NT		NT
Dissolved Copper	µg/L	1	NT	NT	NT		NT	NT	NT	NT	NT	NT		NT
Dissolved Nickel	µg/L	2	NT	NT	NT		NT	NT	NT	NT	NT	NT		NT
Dissolved Cadmium	µg/L	1	NT	NT	NT		NT	NT	NT	NT	NT	NT		NT
Dissolved Chromium	µg/L	1	NT	NT	NT		NT	NT	NT	NT	NT	NT		NT
Dissolved Zinc	µg/L	1	NT	NT	NT		NT	NT	NT	NT	NT	NT		NT
VOLATILE ORGANIC COMPOUNDS						NT			NT			ND	NT	ND
Total Xylenes	µg/L	1	3300	3100	1600		22	52		37(EB)	2(EB)			
Ethylbenzene	µg/L	1	220	200	65		ND	ND		ND	ND			
Methylene Chloride	µg/L	1	ND	ND	ND		ND	ND		ND	ND			
Toluene	µg/L	1	ND	ND	ND		ND	ND		ND	ND			
Acetone	µg/L	5	ND	ND	8.1		ND	ND		6(EB,TB)	6(EB,TB)			
Benzene	µg/L	1	ND	7	ND		ND	ND		ND	ND			
TIC Total	µg/L	--	--		910		630	NT		910	460			
SEMIVOLATILE ORGANIC COMPOUNDS			NT	NT	NT			NT						
Bis(2-ethylhexyl)phthalate	µg/L	2				4	27(CC)		17(B,EH)	17	14	8(CC)	3(B,EH)	6
Naphthalene	µg/L	4				ND	20		14(EH)	18	18	ND	ND	ND
2-Methylnaphthalene	µg/L	2				ND	6		4(EH)	5	5	ND	ND	ND
Acenaphthene	µg/L	2				2	2		2(EH)	2	2	ND	ND	ND
Dibenzofuran	µg/L	2				ND	1(J)		1(EH,J)	ND	ND	ND	ND	ND
Fluorene	µg/L	2				ND	2		2(EH)	2	2	ND	ND	ND
Phenanthrene	µg/L	2				ND	2		ND	ND	ND	ND	ND	ND
Anthracene	µg/L	2				ND	ND		ND	ND	ND	ND	ND	ND
Fluoranthene	µg/L	2				5	4		3(EH)	4	3	ND	ND	ND
Pyrene	µg/L	2				8	4		3(EH)	4	3	ND	ND	ND
Benzo(a)anthracene	µg/L	2				ND	ND		ND	2	ND	ND	ND	ND
Chrysene	µg/L	2				ND	ND		ND	2	ND	ND	ND	ND
Benzo(b)fluoranthene	µg/L	4				ND	ND		ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	µg/L	4				ND	ND		ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	µg/L	4				ND	ND		ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	µg/L	4				ND	ND		ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	2				42	ND		5(EH)	ND	ND	ND	ND	ND
Di-n-butyl phthalate	µg/L	2				ND	ND		ND	ND	ND	ND	ND	ND
Di-n-octyl phthalate	µg/L	2				ND	ND		ND	ND	ND	ND	ND	ND
Diethyl phthalate	µg/L	2				ND	ND		ND	ND	ND	ND	ND	ND
TIC Total	µg/L	--				800	920		710	800	820	NT	11	ND

TABLE 4-5. SITE 1 - UNDERGROUND FUEL STORAGE AREA GROUNDWATER DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Parameter	Units	Lower Limit of Detection (A)	MW1-6	MW1-6 RE	GW1-6	MW1-7	GW1-7	MW1-8	MW1-8 RE	GW1-8	MW1-9	MW1-9 RE
Collection Date			4/89	4/89	7/89	4/89	7/89	4/89	4/89	7/89	4/89	4/89
Associated Field QC Samples			EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3	EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3	EB-12 TB-7 FB-2	EB-12 TB-7 FB-2
PETROLEUM HYDROCARBONS	mg/L	0.5	ND	NT	ND	0.6(H)	ND	1.1(H)	NT	ND	ND	NT
TRACE METALS				NT					NT			NT
Dissolved Arsenic	µg/L	5	ND		ND	ND	ND	ND		ND	ND	
Dissolved Lead	µg/L	1	3.7		ND	2.4	ND	1.4		ND	1.0	
Dissolved Selenium	µg/L	5	NT		NT	NT	NT	NT		NT	NT	
Dissolved Copper	µg/L	1	NT		NT	NT	NT	NT		NT	NT	
Dissolved Nickel	µg/L	2	NT		NT	NT	NT	NT		NT	NT	
Dissolved Cadmium	µg/L	1	NT		NT	NT	NT	NT		NT	NT	
Dissolved Chromium	µg/L	1	NT		NT	NT	NT	NT		NT	NT	
Dissolved Zinc	µg/L	1	NT		NT	NT	NT	NT		NT	NT	
VOLATILE ORGANIC COMPOUNDS			ND	NT	ND	ND	ND		NT	ND	ND	NT
Total Xylenes	µg/L	1						ND				
Ethylbenzene	µg/L	1						ND				
Methylene Chloride	µg/L	1						ND				
Toluene	µg/L	1						ND				
Acetone	µg/L	5						ND				
Benzene	µg/L	1						ND				
TIC Total	µg/L	--						610				
SEMIVOLATILE ORGANIC COMPOUNDS					ND		ND					
Bis(2-ethylhexyl)phthalate	µg/L	2	57(CC)	12(HE)		14(CC)		4(CC)	2(B,EH)	ND	2(CC)	2(B,EH)
Naphthalene	µg/L	4	ND	ND		ND		4	ND	ND	ND	ND
2-Methylnaphthalene	µg/L	2	ND	ND		ND		6	ND	ND	ND	ND
Acenaphthene	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
Dibenzofuran	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
Fluorene	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
Phenanthrene	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
Anthracene	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
Fluoranthene	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
Pyrene	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
Benzo(a)anthracene	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
Chrysene	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
Benzo(b)fluoranthene	µg/L	4	ND	ND		ND		ND	ND	ND	ND	ND
Benzo(k)fluoranthene	µg/L	4	ND	ND		ND		ND	ND	ND	ND	ND
Benzo(a)pyrene	µg/L	4	ND	ND		ND		ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	µg/L	4	ND	ND		ND		ND	ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	2	ND	ND		2		ND	ND	ND	ND	ND
Di-n-butyl phthalate	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
Di-n-octyl phthalate	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
Diethyl phthalate	µg/L	2	ND	ND		ND		ND	ND	ND	ND	ND
TIC Total	µg/L	--	ND	11		190		950	710	280	ND	9

TABLE 4-5. SITE 1 - UNDERGROUND FUEL STORAGE AREA GROUNDWATER DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Parameter	Units	Lower Limit of Detection (A)	MW1-10	MW1-10 RE	GW1-10	GW1-10 DUP	MW1-11	MW1-11 RE	GW1-11
Collection Date			4/89	4/89	7/89	7/89	4/89	4/89	7/89
Associated Field QC Samples			EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3	EB-15 TB-9 FB-3	EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3
PETROLEUM HYDROCARBONS	mg/L	0.5	ND	NT	ND	ND	ND	NT	ND
TRACE METALS				NT				NT	
Dissolved Arsenic	µg/L	5	ND		ND	ND	ND		ND
Dissolved Lead	µg/L	1	3.2		ND	ND	6.3		ND
Dissolved Selenium	µg/L	5	NT		NT	NT	NT		NT
Dissolved Copper	µg/L	1	NT		NT	NT	NT		NT
Dissolved Nickel	µg/L	2	NT		NT	NT	NT		NT
Dissolved Cadmium	µg/L	1	NT		NT	NT	NT		NT
Dissolved Chromium	µg/L	1	NT		NT	NT	NT		NT
Dissolved Zinc	µg/L	1	NT		NT	NT	NT		NT
VOLATILE ORGANIC COMPOUNDS				NT	ND			NT	
Total Xylenes	µg/L	1	ND			ND	ND		1
Ethylbenzene	µg/L	1	ND			ND	ND		ND
Methylene Chloride	µg/L	1	ND			ND	ND		ND
Toluene	µg/L	1	ND			ND	ND		ND
Acetone	µg/L	5	ND			ND	ND		ND
Benzene	µg/L	1	ND			ND	ND		ND
TIC Total	µg/L	--	36			8	880		12
SEMIVOLATILE ORGANIC COMPOUNDS					ND				
Bis(2-ethylhexyl)phthalate	µg/L	2	48	48(B,EH)		3	640	17(B,EH)	ND
Naphthalene	µg/L	4	ND	ND		ND	ND	ND	ND
2-Methylnaphthalene	µg/L	2	ND	ND		ND	ND	ND	ND
Acenaphthene	µg/L	2	ND	ND		ND	ND	ND	ND
Dibenzofuran	µg/L	2	ND	ND		ND	ND	ND	ND
Fluorene	µg/L	2	ND	ND		ND	ND	ND	ND
Phenanthrene	µg/L	2	ND	ND		ND	ND	ND	ND
Anthracene	µg/L	2	ND	ND		ND	ND	ND	ND
Fluoranthene	µg/L	2	ND	ND		ND	ND	ND	ND
Pyrene	µg/L	2	ND	ND		ND	ND	ND	ND
Benzo(a)anthracene	µg/L	2	ND	ND		ND	ND	ND	ND
Chrysene	µg/L	2	ND	ND		ND	ND	ND	ND
Benzo(b)fluoranthene	µg/L	4	ND	ND		ND	ND	ND	ND
Benzo(k)fluoranthene	µg/L	4	ND	ND		ND	ND	ND	ND
Benzo(a)pyrene	µg/L	4	ND	ND		ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	µg/L	4	ND	ND		ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	2	ND	ND		ND	ND	ND	ND
Di-n-butyl phthalate	µg/L	2	ND	ND		ND	4	ND	ND
Di-n-octyl phthalate	µg/L	2	ND	ND		ND	ND	ND	ND
Diethyl phthalate	µg/L	2	ND	ND		ND	ND	ND	ND
TIC Total	µg/L	--	ND	ND		ND	ND	ND	26

TABLE 4-5. SITE 1 - UNDERGROUND FUEL STORAGE AREA GROUNDWATER DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Parameter	Units	Lower Limit of Detection (A)	MW1-12	MW1-12 DIL	MW1-12 DUP	MW1-12 DUP/RE	GW1-12	MW1-13	MW1-13 RE	GW1-13	MW1-14	MW1-14 RE	GW1-14
Collection Date			4/89	4/89	4/89	4/89	7/89	4/89	4/89	7/89	4/89	4/89	7/89
Associated Field QC Samples			EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3	EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3	EB-12 TB-7 FB-2	EB-12 TB-7 FB-2	EB-15 TB-9 FB-3
PETROLEUM HYDROCARBONS	mg/L	0.5	2.2(H)	NT	2.0(H)	NT	1.2	ND	NT	ND	ND	NT	ND
TRACE METALS				NT		NT			NT			NT	
Dissolved Arsenic	µg/L	5	5		6		20	ND		ND	ND		ND
Dissolved Lead	µg/L	1	2.1		2.2		15	9.7		ND	1.4		ND
Dissolved Selenium	µg/L	5	NT		NT		NT	NT		NT	NT		NT
Dissolved Copper	µg/L	1	NT		NT		NT	NT		NT	NT		NT
Dissolved Nickel	µg/L	2	NT		NT		NT	NT		NT	NT		NT
Dissolved Cadmium	µg/L	1	NT		NT		NT	NT		NT	NT		NT
Dissolved Chromium	µg/L	1	NT		NT		NT	NT		NT	NT		NT
Dissolved Zinc	µg/L	1	NT		NT		NT	NT		NT	NT		NT
VOLATILE ORGANIC COMPOUNDS						NT		ND	NT	ND		NT	ND
Total Xylenes	µg/L	1	840(CC)	1100(D,CC)	220(CC)		350(E8)				ND		
Ethylbenzene	µg/L	1	170	160(D)	32		58				ND		
Methylene Chloride	µg/L	1	ND	ND	ND		ND				ND		
Toluene	µg/L	1	ND	ND	ND		ND				ND		
Acetone	µg/L	5	ND	ND	ND		ND				ND		
Benzene	µg/L	1	ND	ND	ND		ND				ND		
TIC Total	µg/L	--	1800	NT	660		1200				8		
SEMIVOLATILE ORGANIC COMPOUNDS				NT	NT								
Bis(2-ethylhexyl)phthalate	µg/L	2	35			19(B,EH)	4	5(EH)	7(B,EH)	2(EH)	34	40(B)	43(EH)
Naphthalene	µg/L	4	84			72(EH)	35	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	µg/L	2	48			46(EH)	21	ND	ND	ND	ND	ND	ND
Acenaphthene	µg/L	2	ND			ND	ND	ND	ND	ND	ND	ND	ND
Dibenzofuran	µg/L	2	ND			1(J,EH)	ND	ND	ND	ND	ND	ND	ND
Fluorene	µg/L	2	1(J)			1(J,EH)	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	µg/L	2	ND			ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	µg/L	2	ND			ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	µg/L	2	ND			ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	µg/L	2	ND			ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	µg/L	2	ND			ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	µg/L	2	ND			ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	µg/L	4	ND			ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	µg/L	4	ND			ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	µg/L	4	ND			ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	µg/L	4	ND			ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	2	ND			ND	ND	ND	ND	ND	ND	ND	ND
Di-n-butyl phthalate	µg/L	2	ND			ND	ND	ND	ND	ND	2	ND	ND
Di-n-octyl phthalate	µg/L	2	ND			ND	ND	ND	ND	ND	ND	ND	ND
Diethyl phthalate	µg/L	2	ND			ND	ND	ND	ND	ND	ND	ND	ND
TIC Total	µg/L	--	1700			1400	890	ND	ND	ND	ND	ND	ND

TABLE 4-5. SITE 1 - UNDERGROUND FUEL STORAGE AREA GROUNDWATER DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Information concerning abbreviations found on Table 4-5. can be found here.

*	These samples were collected in January and filtered in the field. The units were reported as mg/L rather than µg/L; for the sake of consistency, the units were changed to µg/L. The following detection limits also changed: iron (0.01 mg/L) and manganese (0.001 mg/L). If lead was not detected at the ICP detection limit, then GFAA was used to achieve the lower limit to further analyze the samples.
ND	This compound/parameter was not detected at or above the detection level.
NT	This compound/parameter was not analyzed in the respective sampling round.
(A)	Lower limit of detection represents lowest detection limit reported for the samples collected at this site. Actual sample detection limits will vary due to percent moisture (soils only) and dilution factor (soils and waters). Adjusted detection limits for individual sample results can be found in Appendix E.
(B)	Compound was detected in the associated method blank.
(CC)	Continuing calibration verification relative response factor outside control limits.
(D)	Dilution analysis. This flag is associated with the (E) flag.
(EB)	Compound/parameter was also detected in the associated equipment blank.
(EH)	The extraction holding time was exceeded for the respective sample.
(FB)	Compound/parameter was also detected in the associated field blank.
(H)	The CLP holding time was exceeded for this compound/element.
(J)	Estimated value. This flag is used when the mass spectral data indicates the presence of an analyte but the result is below the sample quantitation level.
(MD)	MS/MSD RPD was outside the established control limits for this analyte.
(T)	The analyte in question was found to coelute from the gas chromatographic column with a similar analyte also noted. The instrument was not able to effectively separate these two constituents and normally reflects a similar, if not equal, level of contamination.
(TB)	Compound or element also detected in the associated trip blank.
(X)	Same as (T) but was used in a different round of analysis with similar results.
MWx-y	Site x at Monitoring well y (groundwater sample collected in May).
GWx-y	Site x at Monitoring well y (groundwater sample collected in Jan/Jul).
QA-x	Quality assurance samples.

EPA methods and, as a result, have not been extensively regulated or studied. A listing of the TICs in the samples at SDANG appears in Table 4-4. Volatile organic TIC levels range from ND (detection limits are not given but are less than 8 µg/L, the lowest result reported) to 1,836 µg/L in monitoring well MW-1-12. Lower levels of volatile organic TICs were found within the field and laboratory blanks and upgradient wells, indicating that low TIC levels are attributable to sample handling and analysis. Significant (>100 µg/L) volatile organic TIC results compare closely with the extent of contamination, as defined by the total volatile hydrocarbon results from the groundwater probe survey and onsite GC. When compared to previous VOC analysis results collected during the SI (October 1987) and during a Site 1 – Underground Fuel Storage Area treatability study (January 1989), levels of detectable VOCs have appeared to drop significantly in the contaminated area surrounding the underground fuel storage tanks. Although there is no hard evidence, the reduction is probably related to biodegradation of these compounds by microbes that naturally exist within the aquifer material. Other possible explanations include contaminant volatilization to the atmosphere, advection, and/or dispersion. Regardless of the cause, these reductions in the source area VOC concentrations provide evidence that the ultimate source of contamination is no longer actively releasing contamination at this site.

SVOC results indicated the presence of 20 different identifiable compounds. Of these, bis(2-ethylhexyl)phthalate was found throughout the field and laboratory blanks and is considered a laboratory-induced contaminant and not reflective of actual site contamination. Only the groundwater samples from monitoring wells MW-1-3, MW-1-4, MW-1-8, and MW-1-12 showed significant levels of identifiable SVOCs. These sample locations are all in the near vicinity of the contamination source areas, as defined by the groundwater probe surveys. As with the VOC results, there were elevated levels of tentatively identifiable SVOCs detected within the groundwater samples from this site. Semivolatile TICs found in the samples from SDANG are listed in Table 4-4. Gross semivolatile TIC concentrations range from ND (detection limits are not given but are less than 9 µg/L, the lowest result reported) to 1,681 µg/L throughout the site. Low levels of semivolatile TICs (5 to 39 µg/L) were found within the field and laboratory blanks; lower levels within the environmental samples could be attributable to laboratory contamination. Therefore, the only groundwater samples containing significant levels of semivolatile organic TICs were collected from monitoring wells MW-1-3, MW-1-4, MW-1-7, MW-1-8, and MW-1-12, which generally agrees with their location relative to the contaminated areas, as defined by the groundwater probe survey.

Inorganic analyses performed on groundwater samples from Site 1 – Underground Fuel Storage Areas were limited to lead and arsenic based upon previous investigation results. Lead concentrations in groundwater ranged from ND (<1 µg/L) to 15 µg/L at MW-1-12 and fluctuated greatly between RI samplings. Similar concentrations of lead (1.0 to 2.5 µg/L) were also found in some of the field and laboratory blanks, indicating that most of the levels found in samples may be attributable to handling and/or analysis of the samples and not indicative of site conditions. Because of the great fluctuations between results and the presence of lead in blanks, it is impossible to determine if lead is a contaminant related to site activities. Arsenic was not detected within groundwater at Site 1 – Underground Fuel Storage Area, with the exception of MW-1-12 at concentrations of 6 and 20 ug/L for the two RI samplings. This monitoring well showed high levels of hydrocarbon contamination but it is difficult to determine the relation, if any, between the presence of arsenic and the contamination at the site. When RI results are compared to results collected during previous groundwater samplings during the SI and treatability study, a large reduction in the level of inorganic compounds is noted. This reduction occurs because RI inorganic samples were field-filtered prior to analysis, which eliminated the sediment present within the groundwater samples. Filtering was performed to obtain results that are more indicative of the actual concentrations of these metals within the groundwater at the site. In the previous sampling programs, this sediment was accountable for the much higher levels of lead and arsenic within the unfiltered groundwater samples.

Elevated levels (0.6 to 2.2 mg/L) of total petroleum hydrocarbons were found only within groundwater samples collected from monitoring wells MW-1-3, MW-1-4, MW-1-7, MW-1-8, and MW-1-12. These values agree with the presence of other related VOCs and SVOCs within these wells and with the limits of contamination, as defined by the groundwater probe survey.

4.3 SITE 3 – BASE FIRE TRAINING AREA RESULTS

The following samples have been collected during the field programs at Site 3 – Base Fire Training Area:

- Site Inspection, October 1987
    - Groundwater probe survey (15 samples analyzed by onsite GC)
    - Drilling, sampling, and installation of four groundwater monitoring wells (eight soil, four groundwater samples sent to the laboratory)
- Remedial Investigation, April 1989
    - Groundwater probe survey (10 samples analyzed by onsite GC)
    - Drilling and soil sampling of five shallow soil borings (29 soil samples analyzed by on-site GC, 10 soil samples sent to the laboratory)

- Drilling, sampling, and installation of one additional groundwater monitoring well (five soil samples analyzed by onsite GC, five [includes SI wells] groundwater samples [one round] sent to laboratory).

The location of these sampling points are shown in Figure 4-5.

4.3.1 Site 3 – Base Fire Training Area Soil Gas Survey Results

Figure 4-6 shows the TVH isoconcentration map, which is a composite of the 25 samples that were collected during the two soil gas surveys. A complete listing of the results of these two surveys is presented in Table 4-6. The map clearly shows that contamination is limited to the burn pit vicinity and that the limits of contamination in all directions have been defined. The contaminated area measures approximately 100 feet in diameter and corresponds with the limits of the burn pit. Trace levels of VOCs identified during the SI were not verified by the latest survey.

4.3.2 Site 3 – Base Fire Training Area Soil Sampling Results

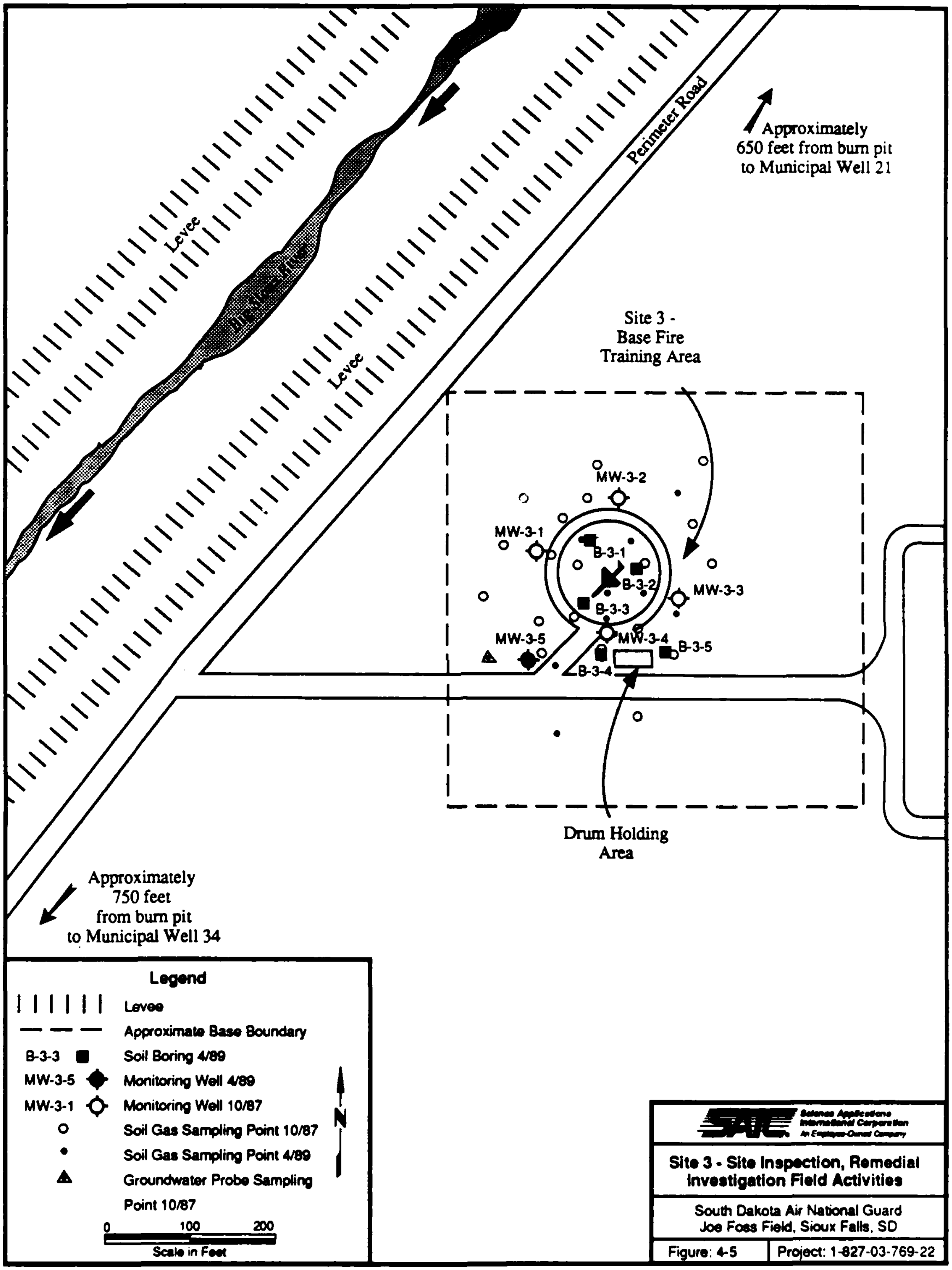
Five soil borings were emplaced at Site 3 – Base Fire Training Area, three within the burn pit and two adjacent to the drum holding area. Field observations of two of the burn pit soil boring locations (i.e., B-3-1 and B-3-3) included a strong fuel odor and discoloration of soil samples. The intensity of both of these characteristics decreased with depth of the boring. The other three borings (i.e., B-3-2, B-3-4, and B-3-5) and the monitoring well borehole (i.e., MW-3-5) showed no outward signs of contamination.

4.3.2.1 Site 3 – Base Fire Training Area Onsite GC Screening of Soil Samples

Table 4-7 presents the results of the onsite GC screening of soil samples from Site 3 – Base Fire Training Area. The only positive results were obtained from soil borings B-3-1 and B-3-3, while the three other borings showed no levels of VOC contamination. Results further show that contamination is limited to a maximum depth of approximately 10 feet. This depth is above the 14-foot depth of the water table and within the confines of the surficial clay layer. Using the 10-foot maximum depth and the areal extent of contamination as defined by the soil gas surveys, approximately 310,000 cubic feet of soil contamination exists at this site.

4.3.2.2 Site 3 – Base Fire Training Area Laboratory Analysis Results of Soil Samples

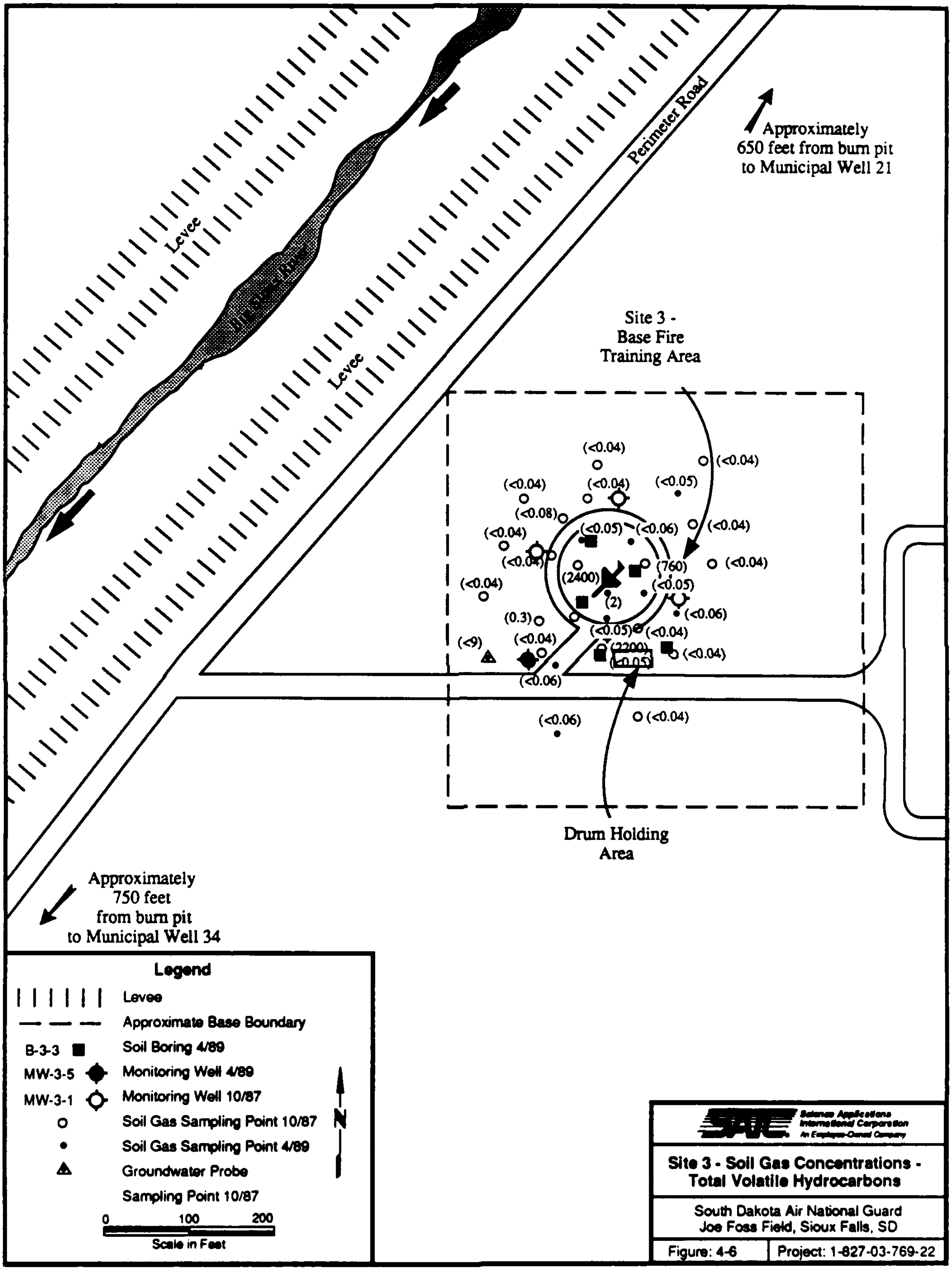
The results of the chemical laboratory analyses of samples from Site 3 – Base Fire Training Area are presented in Table 4-8. Five different VOCs were detected within the soil samples collected from soil borings at Site 3 – Base Fire Training Area. Of these compounds, methylene chloride and acetone are considered to be laboratory contaminants and are not site-related



Site 3 - Site Inspection, Remedial Investigation Field Activities

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 4-5 | Project: 1-827-03-769-22



Site 3 - Soil Gas Concentrations - Total Volatile Hydrocarbons

South Dakota Air National Guard
Joe Foss Field, Sioux Falls, SD

Figure: 4-6 | Project: 1-827-03-769-22

TABLE 4-6. SUMMARY OF SOIL GAS SURVEYS AT SITE 3 - BASE FIRE TRAINING AREA AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

SITE INSPECTION 4/87			REMEDIAL INVESTIGATION 4/89		
SAMPLE	DATE	TOTAL VOLATILE HYDROCARBON*	SAMPLE	DATE	TOTAL VOLATILE HYDROCARBON*
SG3-1	10/14/87	2400	SG3-1-4	04/13/89	ND
SG3-2	10/14/87	ND	SG3-2-4	04/13/89	ND
SG3-3	10/14/87	ND	SG3-3-3	04/13/89	ND
SG3-4	10/14/87	ND	SG3-4-4	04/13/89	ND
SG3-5	10/14/87	0.3	SG3-5-2	04/13/89	ND
SG3-6	10/14/87	ND	SG3-6-4	04/14/89	2
SG3-7	10/14/87	ND	SG3-7-4	04/14/89	ND
SG3-8	10/14/87	ND	SG3-8-4	04/14/89	ND
SG3-9	10/17/87	2200	SG3-9-4	04/14/89	ND
SG3-10	10/17/87	ND	SG3-10-4	04/14/89	ND
SG3-11	10/17/87	ND			
SG3-12	10/17/87	760			
SG3-13	10/17/87	ND			
SG3-14	10/17/87	0.08			
SG3-15	10/17/87	ND			
SG3-16	10/17/87	ND			
SG3-17	10/17/87	ND			
SG3-18	10/17/87	ND			
SG3-19	10/19/87	ND			

ND - Indicates no analytes were detected. * - Units are PPB.

TABLE 4-7. SUMMARY OF RESULTS OF REMEDIAL INVESTIGATION ONSITE SCREENING OF SOIL SAMPLES AT SITE 3 - BASE FIRE TRAINING AREA AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

SAMPLE	DATE	TOTAL VOLATILE HYDROCARBON*	SAMPLE	DATE	TOTAL VOLATILE HYDROCARBON*
B3-1-5	04/14/89	11000	B3-4-0	04/15/89	ND
B3-1-7.5	04/14/89	9200	B3-4-5	04/15/89	ND
B3-1-10	04/14/89	ND	B3-4-7.5	04/15/89	ND
B3-1-15	04/14/89	ND	B3-4-10	04/15/89	ND
B3-2-0	04/14/89	ND	B3-5-0	04/15/89	ND
B3-2-2.5	04/14/89	ND	B3-5-2.5	04/15/89	ND
B3-2-5	04/14/89	ND	B3-5-5	04/15/89	6
B3-2-7.5	04/14/89	ND			
B3-2-10	04/14/89	ND	MW3-5-5	04/15/89	ND
			MW3-5-10	04/15/89	ND
B3-3-0	04/14/89	100000	MW3-5-15	04/15/89	ND
B3-3-2.5	04/14/89	86000	MW3-5-25	04/15/89	ND
B3-3-5	04/14/89	5200			
B3-3-7.5	04/14/89	9400			
B3-3-10	04/15/89	38000			
B3-3-12.5	04/14/89	ND			
B3-3-15	04/14/89	ND			
B3-3-17.5	04/14/89	ND			

ND - Indicates no analytes were detected. * - Units are PPB.

TABLE 4-8. SITE 3 - BASE FIRE TRAINING AREA SOIL BORING DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Parameters	Units	Lower Limit of Detection (A)	B3-1-0	B3-1-5	B3-2-0	B3-2-0 DUP	B3-2-5	B3-3-0 DUP	B3-3-0 DUP	B3-3-2.5	B3-3-2.5 DIL
Associated Field QC Samples			EB-4 TB-3 FB-1	EB-4 TB-3 FB-1	EB-4 TB-3 FB-1	EB-4 TB-3 FB-1	EB-4 TB-3 FB-1	EB-4 TB-3 FB-1	EB-4 TB-3 FB-1	EB-4 TB-3 FB-1	EB-4 TB-3 FB-1
PETROLEUM HYDROCARBONS	mg/Kg DB	20	120(H)	30(H)	59(H)	96(H)	NT	34(H,MR)	130(H)	110(H)	NT
TOTAL ORGANIC CARBON	% DB	0.1	1.7(H)	NT	NT	NT	NT	NT	NT	1.4(H)	NT
TRACE METALS							NT				
Lead	mg/Kg DB	0.5	8.7	14	8	7.8		6.2	7.9	11	NT
Arsenic	mg/Kg DB	0.5	5.6	8.9	12	9.2		8.9	8.4	7	NT
Selenium	mg/Kg DB	0.5	ND	ND	ND	ND		ND	ND	ND	NT
Copper	mg/Kg DB	1	12	22	10	10		9	11	14	NT
Beryllium	mg/Kg DB	0.1	0.5	1.2	0.4	0.4		0.3	0.3	0.7	NT
Nickel	mg/Kg DB	2	17	31	23	21		23	21	22	NT
Cadmium	mg/Kg DB	0.5	ND	ND	ND	ND		ND	ND	ND	NT
Chromium	mg/Kg DB	1	15	29	15	12		12	12	20	NT
Zinc	mg/Kg DB	1	54	100	48	48		46	49	71	NT
VOLATILE ORGANIC COMPOUNDS						ND	ND				
Methylene Chloride	µg/Kg DB	2	ND	ND	4			ND	ND	ND	ND
Acetone	µg/Kg DB	8	ND	220	ND			ND	ND	ND	ND
Toluene	µg/Kg DB	2	ND	100	ND			ND	ND	ND	ND
Ethylbenzene	µg/Kg DB	2	ND	1100	ND			2700	17000	40000	33000
Total Xylenes	µg/Kg DB	2	53	1600	ND			5400	17000	70000(E)	60000(D)
TIC Total	µg/Kg DB		6800	7900	ND			180000	390000	300000	400000
SEMIVOLATILE ORGANIC COMPOUNDS											NT
Naphthalene	µg/Kg DB	76	170(H)	700	ND	ND	ND	390(J,H)	750(J,H)	2400(H)	
2-Methylnaphthalene	µg/Kg DB	38	38(J,H)	63	ND	ND	ND	ND	180(J,H)	350(J,H)	
Acenaphthene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	
Dibenzofuran	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	
Fluorene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	
Phenanthrene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	
Anthracene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	
Di-n-butyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	
Fluoranthene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	
Pyrene	µg/Kg DB	38	ND	ND	ND	25(J,H)	ND	ND	ND	ND	
Benzo(a)anthracene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	
Chrysene	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	
Bis(2-ethylhexyl)phthalate	µg/Kg DB	38	23(JB,H)	54(B)	85(B)	100(B,H)	49(B)	ND	ND	ND	
Benzo(b)fluoranthene	µg/Kg DB	76	ND	ND	ND	31(JX,H)	ND	ND	ND	ND	
Benzo(k)fluoranthene	µg/Kg DB	76	ND	ND	ND	31(JX,H)	ND	ND	ND	ND	
Benzo(a)pyrene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND	ND	
Indeno(1,2,3-c,d)pyrene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND	ND	
Dibenzo(a,h)anthracene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND	ND	
Benzo(g,h,i)perylene	µg/Kg DB	76	ND	ND	ND	ND	ND	ND	ND	ND	
Diethyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	
Dimethyl phthalate	µg/Kg DB	38	ND	ND	ND	ND	ND	ND	ND	ND	
4-Methylphenol	µg/Kg DB	38	ND	230	ND	ND	ND	ND	ND	ND	
Phenol	µg/Kg DB	38	ND	ND	ND	49(H)	ND	ND	ND	ND	
Di-n-octyl phthalate	µg/Kg DB	38	ND	ND	12(J)	ND	ND	ND	ND	ND	
TIC Total	µg/Kg DB		55000	27000	28000	31000	14000	460000	520000	640000	

TABLE 4-8. SITE 3 - BASE FIRE TRAINING AREA SOIL BORING DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Parameters Associated Field QC Samples	Units	Lower Limit of Detection (A)	B3-4-0 EB-5 TB-3 FB-1	B3-4-5 EB-5 TB-3 FB-1	B3-5-0 EB-5 TB-3 FB-1	B3-5-2.5 EB-5 TB-3 FB-1
PETROLEUM HYDROCARBONS	mg/Kg DB	20	ND	ND	79	25(H)
TOTAL ORGANIC CARBON	% DB	0.1	2.4(H)	NT	2	2.2(H)
TRACE METALS						
Lead	mg/Kg DB	0.5	15(S)	14	12	10
Arsenic	mg/Kg DB	0.5	8.9	8.6	6.2	5.9
Selenium	mg/Kg DB	0.5	ND	ND	ND	ND
Copper	mg/Kg DB	1	18	19	10	12
Beryllium	mg/Kg DB	0.1	1	1.1	0.4	0.6
Nickel	mg/Kg DB	2	25	31	17	20
Cadmium	mg/Kg DB	0.5	ND	0.5	ND	0.6
Chromium	mg/Kg DB	1	25	27	16	20
Zinc	mg/Kg DB	1	87	110	52	65
VOLATILE ORGANIC COMPOUNDS					ND	
Methylene Chloride	µg/Kg DB	2	4	4		5
Acetone	µg/Kg DB	8	ND	ND		ND
Toluene	µg/Kg DB	2	ND	ND		ND
Ethylbenzene	µg/Kg DB	2	ND	ND		ND
Total Xylenes	µg/Kg DB	2	ND	ND		ND
TIC Total	µg/Kg DB		ND	ND		ND
SEMIVOLATILE ORGANIC COMPOUNDS						
Naphthalene	µg/Kg DB	76	ND	ND	ND	ND
2-Methylnaphthalene	µg/Kg DB	38	ND	ND	ND	ND
Acenaphthene	µg/Kg DB	38	ND	ND	ND	ND
Dibenzofuran	µg/Kg DB	38	ND	ND	ND	ND
Fluorene	µg/Kg DB	38	ND	ND	ND	ND
Phenanthrene	µg/Kg DB	38	ND	ND	ND	ND
Anthracene	µg/Kg DB	38	ND	ND	ND	ND
Di-n-butyl phthalate	µg/Kg DB	38	ND	ND	ND	ND
Fluoranthene	µg/Kg DB	38	ND	ND	83(H)	ND
Pyrene	µg/Kg DB	38	ND	ND	200(H)	ND
Benzo(a)anthracene	µg/Kg DB	38	ND	ND	180(H)	ND
Chrysene	µg/Kg DB	38	ND	ND	230(H)	ND
Bis(2-ethylhexyl)phthalate	µg/Kg DB	38	80(B)	51(B)	67(JB,H)	50(B)
Benzo(b)fluoranthene	µg/Kg DB	76	ND	ND	220(H)	ND
Benzo(k)fluoranthene	µg/Kg DB	76	ND	ND	260(H)	ND
Benzo(a)pyrene	µg/Kg DB	76	ND	ND	330(H)	ND
Indeno(1,2,3-c,d)pyrene	µg/Kg DB	76	ND	ND	180(H)	ND
Dibenzo(a,h)anthracene	µg/Kg DB	76	ND	ND	ND	ND
Benzo(g,h,i)perylene	µg/Kg DB	76	ND	ND	170(H)	ND
Diethyl phthalate	µg/Kg DB	38	ND	ND	ND	ND
Dimethyl phthalate	µg/Kg DB	38	ND	ND	ND	ND
4-Methylphenol	µg/Kg DB	38	ND	ND	ND	ND
Phenol	µg/Kg DB	38	ND	ND	ND	ND
Di-n-octyl phthalate	µg/Kg DB	38	ND	ND	ND	ND
TIC Total	µg/Kg DB		13000	12000	17000	13000

TABLE 4-8. SITE 3 - BASE FIRE TRAINING AREA SOIL BORING DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Information concerning abbreviations found on Table 4-9. can be found here.

ND	This compound/parameter was not detected at or above the detection level.
NT	This compound/parameter was not analyzed in the respective sampling round.
(A)	Lower limit of detection represents lowest detection limit reported for the samples collected at this site. Actual sample detection limits will vary due to percent moisture (soils only) and dilution factor (soils and waters). Adjusted detection limits for individual sample results can be found in Appendix E.
(B)	Compound was detected in the associated method blank.
(D)	Dilution analysis. This flag is associated with the (E) flag.
(E)	The analysis was performed and the concentration exceeds the calibration range of the gas chromatograph/mass spectrometer. If one or more of the TCL's is above the detection level, the sample or extract must be reanalyzed for all of the appropriate TCL's. If dilution causes results from the first analysis to be below the detection level, both analyses would be reported.
(EB)	Compound/parameter was also detected in the associated equipment blank.
(FB)	Compound/parameter was also detected in the associated field blank.
(H)	The CLP holding time was exceeded for this compound/element.
(J)	Estimated value. This flag is used when the mass spectral data indicates the presence of an analyte but the result is below the sample quantitation level.
(JB)	Indicates that the compound/element was detected in the associated method blank but was at a quantitation level below the normal detection level. This is also an estimation of the true result.
(JX)	A combination of (J) and (X), the compound/element in question coeluted but at a level lower than the minimum level of detection.
(MR)	MS/MSD RPD was outside the established control limits for this analyte.
(S)	The surrogate recovery was below the minimum control limits.
(TB)	Compound or element also detected in the associated trip blank.
Bx-y-z	Site x at Soil boring y and Depth z(feet) (background soil sample).

contaminants because of their detection throughout the field and laboratory blank samples. The remaining VOCs, ethylbenzene, toluene, and total xylenes, were only found in soil borings B-3-1and B-3-3, which agrees with onsite GC results. Concentrations of these three compounds in the two soil borings were as high as 40,000; 1,100; and 70,000 μg/kg, respectively. In addition, there were very high levels of TICs. A list of the TICs in the samples at SDANG appears in Table 4-4. Gross TIC levels in the contaminated borings were extremely high, ranging from 177,900 to 404,000 μg/kg.

SVOC results indicated the presence of over 20 different identifiable compounds. Of these, bis(2-ethylhexyl)phthalate was found throughout the field and laboratory blanks and is considered a laboratory-induced contaminant and not reflective of actual site contamination. These compounds were found in the highest concentrations in soil boring samples from B-3-1 and B-3-3. Additionally, surficial samples from soil borings B-3-2 (located within the burn pit) and B-3-5 (located near the drum holding area) showed lower levels of SVOC soil contamination. As with the VOC results, there were elevated levels of semivolatile organic TICs detected within the soil samples from this site. Semivolatile organic TICs found in the samples are listed in Table 4-4. Gross semivolatile organic TIC concentrations range from 11,600 to 639,000 μg/kg throughout the site. Background samples indicate that there are naturally existing concentrations in soil that range from approximately 5,000 to 10,000 μg/kg in the SDANG area. In addition, since low levels of semivolatile TICs (5 to 39 μg/kg) were found within the aqueous field and laboratory blanks, lower levels within the environmental samples could be attributable to laboratory contamination. Semivolatile organic TIC concentrations significantly above the 10,000-μg/kg cutoff were found within all the soil borings, with the exception of B-3-4, and were generally limited to the surficial soil samples.

The results of inorganic analysis showed no elevated levels of metals when compared to background values for the surficial clay, indicating that there has not been any inorganic contamination of the soil due to fire training activities.

Petroleum hydrocarbon results ranged from ND (<20 mg/kg) to values exceeding 130 mg/kg in soil boring B-3-3. Detectable concentrations were found in all of the soil borings with the exception of B-3-4. As discussed previously for Site 1-Underground Fuel Storage Area, the background soil samples showed the highest concentrations of petroleum hydrocarbons of all samples collected (970 mg/Kg in sample BK-2). Therefore, a comparison of site concentrations versus background concentrations for this parameter cannot be made. Other correlations between petroleum hydrocarbon and VOC and SVOC concentrations are also difficult because relatively low levels of petroleum hydrocarbons were detected in soil samples where VOC and SVOC concentrations were significant (i.e., B-3-1-5 and B-3-3-0). In other cases, higher concentrations of petroleum hydrocarbons were detected where VOC and SVOC concentrations were significant (i.e., B-3-3-0 and B-3-3-2.5). As a result, the petroleum hydrocarbon data was not a particularly useful parameter in characterizing site-related contamination.

Total organic carbon levels range from 0.4 to 2.2 percent; the range is the same range as that of background concentrations (0.9 to 2.3 percent). Also, these levels showed no trends that correlate to the contamination, as defined by the groundwater probe survey.

4.3.3 Site 3 – Base Fire Training Area Groundwater Sampling Results

A total of five groundwater monitoring wells (one RI and four SI) underwent one round of groundwater sampling during the RI field program. The results of the laboratory analysis of groundwater samples at Site 3 – Base Fire Training Area are shown in Table 4-9. All wells sampled at Site 3 – Base Fire Training Area showed no apparent signs of contamination and displayed only a faint gray color due to a small amount of suspended silt and clay present in the groundwater.

VOC results indicated that there are no identifiable compounds within any of the samples. Gross TIC levels range from ND (detection limits are not given but are less than 8 μg/L, the lowest result reported) to 82 μg/L in monitoring well MW-3-4. However, lower levels within the field and laboratory blanks and upgradient wells indicate that low TIC levels are attributable to sample handling and analysis. Therefore, levels of TICs within these samples are not related to actual site conditions but are most likely the result of field and/or laboratory contamination. The lack of groundwater VOC contamination agrees with previous VOC analysis results from the SI.

SVOC results indicated the presence of only one identifiable compound, bis(2-ethylhexyl)phthalate. However, this compound was found throughout the field and laboratory blanks and is considered a laboratory-induced contaminant and not reflective of actual site contamination. As with the VOC results, there were low levels of tentatively identifiable SVOCs detected within the groundwater samples from this site. A listing of the semivolatile organic TICs found in the samples from SDANG is listed in Table 4-4. Gross semivolatile TIC concentrations range from ND (detection limits are not given but are less than 9 μg/L, the lowest result reported) to 20 μg/L throughout the site. Low levels of semivolatile TICs (5 to 39 μg/L) were found within the field and laboratory blanks, and the lower levels within the environmental samples are attributable to contamination during sample handling and/or laboratory contamination.

TABLE 4-9. SITE 3 - BASE FIRE TRAINING AREA MONITORING WELL GROUNDWATER DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Parameter	Units	Lower Level of Detection (A)	GW3-1	GW3-1 DUP	MW3-1	MW3-1 RE	GW3-2	MW3-2	MW3-2 RE	MW3-2 DUP	MW3-2 DUP/RE
Collection Date			10/87	10/87	05/89	05/89	10/87	05/89	05/89	05/89	05/89
Associated Field QC Samples			QA-10	QA-10	EB-13 TB-8 FB-2	EB-13 TB-8 FB-2	QA-10	EB-13 TB-8 FB-2	EB-13 TB-8 FB-2	EB-13 TB-8 FB-2	EB-13 TB-8 FB-2
PETROLEUM HYDROCARBONS	µg/L	0.5	0.1(FB)	0.2(FB)	ND	NT	ND	ND	NT	ND	NT
INORGANICS						NT			NT		NT
Dissolved Arsenic	µg/L	5	ND	ND	ND		ND	ND		ND	
Dissolved Lead	µg/L	1	ND	ND	11(FB)		ND	5.2(FB)		4.0(FB)	
Dissolved Selenium	µg/L	5	ND	ND	6		ND	ND		ND	
Dissolved Copper	µg/L	1	7(FB)	4(FB)	8		3(FB)	5		5	
Dissolved Nickel	µg/L	2	18	12	34		15	15		14	
Dissolved Cadmium	µg/L	1	ND	ND	ND		ND	ND		1	
Dissolved Chromium	µg/L	1	4	2	2		1	3		3	
Dissolved Zinc	µg/L	1	21(B)	16(B)	53(EB,FB)		14(B)	24(EB,FB)		22(EB,FB)	
VOLATILE ORGANICS			ND	ND	ND	NT	ND		NT	ND	NT
Total Xylenes	µg/L	1						ND			
Ethylbenzene	µg/L	1						ND			
Methylene Chloride	µg/L	1						ND			
Toluene	µg/L	1						ND			
Acetone	µg/L	5						ND			
Benzene	µg/L	1						ND			
TIC Total	µg/L	--						9			
SEMIVOLATILE ORGANICS			NT	NT			NT				
Bis(2-ethylhexyl)phthalate	µg/L	2			21	3(B,EH)		5	3(B,EH)	3	2(B,EH)
Naphthalene	µg/L	4			ND	ND		ND	ND	ND	ND
2-Methylnaphthalene	µg/L	2			ND	ND		ND	ND	ND	ND
Acenaphthene	µg/L	2			ND	ND		ND	ND	ND	ND
Dibenzofuran	µg/L	2			ND	ND		ND	ND	ND	ND
Fluorene	µg/L	2			ND	ND		ND	ND	ND	ND
Phenanthrene	µg/L	2			ND	ND		ND	ND	ND	ND
Anthracene	µg/L	2			ND	ND		ND	ND	ND	ND
Fluoranthrene	µg/L	2			ND	ND		ND	ND	ND	ND
Pyrene	µg/L	2			ND	ND		ND	ND	ND	ND
Benzo(a)anthracene	µg/L	2			ND	ND		ND	ND	ND	ND
Chrysene	µg/L	2			ND	ND		ND	ND	ND	ND
Benzo(b)fluoranthene	µg/L	4			ND	ND		ND	ND	ND	ND
Benzo(k)fluoranthene	µg/L	4			ND	ND		ND	ND	ND	ND
Benzo(a)pyrene	µg/L	4			ND	ND		ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	µg/L	4			ND	ND		ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	2			ND	ND		ND	ND	ND	ND
Di-n-butylphthalate	µg/L	2			ND	ND		ND	ND	ND	ND
Di-n-octylphthalate	µg/L	2			ND	ND		ND	ND	ND	ND
Diethylphthalate	µg/L	2			ND	ND		ND	ND	ND	ND
TIC Total	µg/L	--			ND	ND		ND	9	ND	10

TABLE 4-9. SITE 3 - BASE FIRE TRAINING AREA MONITORING WELL GROUNDWATER DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

Parameter	Units	Lower Level of Detection (A)	GW3-3	MW3-3	MW3-3 RE	GW3-4	MW3-4	MW3-4 RE	MW3-5	MW3-5 RE
Collection Date			10/87	05/89	05/89	10/87	05/89	05/89	05/89	05/89
Associated Field QC Sample			QA-10	EB-13 TB-8 FB-2	EB-13 TB-8 FB-2	QA-10	EB-13 TB-8 FB-2	EB-13 TB-8 FB-2	EB-13 TB-8 FB-2	EB-13 TB-8 FB-2
PETROLEUM HYDROCARBONS	µg/L	0.5	0.1(FB)	ND	NT	ND	ND	NT	ND	NT
INORGANICS					NT			NT		NT
Dissolved Arsenic	µg/L	5	6	30		ND	8		6	
Dissolved Lead	µg/L	1	ND	16(FB)		ND	8.5(FB)		13(FB)	
Dissolved Selenium	µg/L	5	ND	5		ND	9		7	
Dissolved Copper	µg/L	1	2(FB)	14		3(FB)	10		13	
Dissolved Nickel	µg/L	2	9	27		13	20		25	
Dissolved Cadmium	µg/L	1	ND	1		ND	ND		ND	
Dissolved Chromium	µg/L	1	2	7		2	6		7	
Dissolved Zinc	µg/L	1	14(B)	47(EB,FB)		14(B)	36(EB,FB)		42(EB,FB)	
VOLATILE ORGANICS			ND		NT	ND		NT		NT
Total Xylenes	µg/L	1		ND			ND		ND	
Ethylbenzene	µg/L	1		ND			ND		ND	
Methylene Chloride	µg/L	1		ND			ND		ND	
Toluene	µg/L	1		ND			ND		ND	
Acetone	µg/L	5		ND			ND		ND	
Benzene	µg/L	1		ND			ND		ND	
TIC Total	µg/L	--		22			82		31	
SEMIVOLATILE ORGANICS			NT			NT				
Bis(2-ethylhexyl)phthalate	µg/L	2		3	3(B,EH)		3	14(B,EH)	14	17(B,CC)
Naphthalene	µg/L	4		ND	ND		ND	ND	ND	ND
2-Methylnaphthalene	µg/L	2		ND	ND		ND	ND	ND	ND
Acenaphthene	µg/L	2		ND	ND		ND	ND	ND	ND
Dibenzofuran	µg/L	2		ND	ND		ND	ND	ND	ND
Fluorene	µg/L	2		ND	ND		ND	ND	ND	ND
Phenanthrene	µg/L	2		ND	ND		ND	ND	ND	ND
Anthracene	µg/L	2		ND	ND		ND	ND	ND	ND
Fluoranthrene	µg/L	2		ND	ND		ND	ND	ND	ND
Pyrene	µg/L	2		ND	ND		ND	ND	ND	ND
Benzo(a)anthracene	µg/L	2		ND	ND		ND	ND	ND	ND
Chrysene	µg/L	2		ND	ND		ND	ND	ND	ND
Benzo(b)fluoranthene	µg/L	4		ND	ND		ND	ND	ND	ND
Benzo(k)fluoranthene	µg/L	4		ND	ND		ND	ND	ND	ND
Benzo(a)pyrene	µg/L	4		ND	ND		ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	µg/L	4		ND	ND		ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	2		ND	ND		ND	ND	ND	ND
Di-n-butylphthalate	µg/L	2		ND	ND		ND	ND	ND	ND
Di-n-octylphthalate	µg/L	2		ND	ND		ND	ND	ND	ND
Diethylphthalate	µg/L	2		ND	ND		ND	ND	ND	ND
TIC Total	µg/L	--		ND	ND		ND	9	20	ND

TABLE 4-9. SITE 3 - BASE FIRE TRAINING AREA MONITORING WELL GROUNDWATER DATA FOR SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Information concerning abbreviations found on Table 4-10. can be found here.

ND	This compound/parameter was not detected at or above the detection level.
NT	This compound/parameter was not analyzed in the respective sampling round.
(A)	Lower limit of detection represents lowest detection limit reported for the samples collected at this site. Actual sample detection limits will vary due to percent moisture (soils only) and dilution factor (soils and waters). Adjusted detection limits for individual sample results can be found in Appendix E.
(B)	Compound was detected in the associated method blank.
(CC)	Continuing calibration verification relative response factor outside control limits.
(EB)	Compound/parameter was also detected in the associated equipment blank.
(EH)	The extraction holding time was exceeded for the respective sample.
(FB)	Compound/parameter was also detected in the associated field blank.
(TB)	Compound or element also detected in the associated trip blank.
MWx-y	Site x at monitoring well y (groundwater sample collected in April 1989).
GWx-y	Site x at monitoring well y (groundwater sample collected in October 1987).

Inorganic analyses performed on groundwater samples from Site 3 – Base Fire Training Area showed elevated levels of several compounds, including arsenic and lead. However, because 1) concentrations were fairly consistent between wells, 2) there is little difference between upgradient and downgradient monitoring well contaminant concentrations, and 3) there are no signs of site-related contaminants within the groundwater, these elevated levels are most likely background concentrations that occur in the SDANG area. When compared to levels found during previous SI sampling, RI values of inorganic compounds are much higher. The reason for this is unknown.

No elevated levels of total petroleum hydrocarbons were found within groundwater samples collected from Site 3 – Base Fire Training Area. This agrees with the absence of any other related VOCs and SVOCs within these monitoring wells.

5. PUBLIC HEALTH RISK EVALUATION

5.1 INTRODUCTION

This section presents the baseline risk assessment of exposure to chemicals present at or released from the South Dakota Air National Guard (SDANG) Base. Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area are currently being evaluated. At Site 1 – Underground Fuel Storage Area, leaking underground fuel storage tanks have contaminated subsurface soils and have been identified as a source of groundwater contamination. Fire training activities at Site 3 – Base Fire Training Area have resulted in the release of contaminants to the soil at the site. As discussed in Section 4.3.3, several inorganic compounds were detected in the groundwater at Site 3 – Base Fire Training Area. However, the concentrations are considered to be background levels that occur in the SDANG area because 1) concentrations were fairly consistent between monitoring wells, 2) there is little difference between upgradient and downgradient monitoring well contaminant concentrations, and 3) there are no signs of site-related contaminants in the groundwater. The presence of one organic compound (bis[2-ethylhexyl] phthalate) in the groundwater sampled at Site 3 – Base Fire Training Area is attributed to laboratory contamination and not reflective of actual site contamination. The risk evaluation presented here provides an assessment of the compounds detected in the groundwater, without consideration of background levels or laboratory contamination, as a conservative approach to evaluating the potential risks to human health.

The baseline risk assessment at SDANG is conducted for two primary purposes: to evaluate the current and potential risks to human health and to evaluate the need for site remediation. The risk assessment evaluates the potential for adverse noncarcinogenic and carcinogenic effects following long-term or chronic exposure to site-related contaminants. The assessment also incorporates comparison of environmental quality data with applicable or relevant and appropriate Federal and State requirements (ARARs).

In many instances, risk assessments must be considered a tool for use in selecting appropriate remedial alternatives. Although current exposure to humans may be negligible or even nonexistent, risk assessment may still be warranted to project potential risks of future site or environmental resource use. A projection of hypothetical risks is often developed to obtain a useful measure of the magnitude or extent of site contamination.

A diversity of inorganic and organic chemicals are present in the groundwater beneath Site 1 – Underground Fuel Storage Area at SDANG. However, the groundwater at this location is not used as a source of drinking water by Base personnel. The public drinking water supply, although not contaminated, is linked hydrogeologically to the contaminated aquifer system beneath Site 1 – Underground Fuel Storage Area. Soils at both sites have been found to be contaminated. Therefore, the baseline risk assessment includes evaluation of hypothetical exposure to groundwater as a drinking water source and to soils through inadvertent ingestion exposure.

As noted above, the baseline risk assessment is an evaluation of potential long-term risks to human health. This requires the development of chronic dose estimates for all chemicals and exposure pathways of concern. In developing these estimates, the recent Remedial Investigation monitoring data for 1989 have been "pooled" with the Site Inspection (SI) data obtained previously for 1987 to develop the most meaningful measures of long-term exposure. Mean environmental concentrations for these 2 years have been calculated and used as the basis for dose estimates and the characterization of chronic risk.

5.2 RISK ASSESSMENT

5.2.1 Hazard Identification

Sampling and analysis of environmental media at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area have revealed the presence of contaminants in the groundwater at Site 1-Underground Fuel Storage Area and the soils at both sites. As discussed more fully in Appendix H, the first step in the risk assessment process is to identify all subject chemicals of concern that will serve as the focus of the evaluation. All potentially carcinogenic compounds have been included in the evaluation. Noncarcinogenic effects are considered for all chemicals that have been detected for which verified reference doses are available or could be established based on structural and toxicological similarities.

In addition to the chemicals detected at the sites under investigation, numerous "tentatively identified compounds" (TICs) have been reported in the groundwater and soils. These compounds are primarily aliphatic and olefinic hydrocarbons that would be associated with the presence of fuel. Although these compounds have not been verified, a screening level evaluation has been incorporated into the baseline risk assessment to examine the potential significance of these additional compounds in environmental media at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area.

5.2.2 Applicable or Relevant and Appropriate Requirements

5.2.2.1 Identification of Applicable or Relevant and Appropriate Requirements

The identification and selection of ARARs is an ongoing and iterative process, beginning at the SI phase and reaching completion during the Feasibility Study. At this point in the assessment of Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area, it is appropriate to identify potential ARARs that ultimately may be used in the development of remediation goals (cleanup levels).

A chemical-specific criterion or standard becomes an ARAR if it is found to be applicable or relevant and appropriate to the particular circumstances at a waste site under investigation. Applicable requirements promulgated under Federal or State law will specifically address a hazardous substance or pollutant, action, or location at a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA [hazardous waste]) site. Relevant and appropriate requirements, while not "applicable," address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular circumstance. The U.S. Environmental Protection Agency (EPA) guidance on determining whether a requirement is applicable or relevant and appropriate is provided in CERCLA Compliance with Other Laws Manual (USEPA 1988a).

These two classes of requirements (i.e., applicable or relevant and appropriate) also differ in the amount of discretion allowed in their identification. The revised National Contingency Plan notes that applicable requirements are identified by a largely objective comparison to the circumstances at the site (USEPA 1988b). A chemical-specific requirement is concluded to be applicable if there is a one-to-one correspondence between the requirement and the circumstances at the site. EPA indicates that there is little discretion involved in this determination. Relevant and appropriate requirements, however, are determined using best professional judgement as to whether the requirement addresses problems or situations that are generally pertinent to conditions at the site (i.e., relevant) and "well-suited" (i.e., appropriate as a remediation goal).

At the SDANG sites, none of the identified Federal criteria and standards (i.e., maximum contaminant levels [MCLs], maximum contaminant level goals [MCLGs], and Federal ambient water quality criteria [FWQC]) may be considered "applicable" requirements. None of these requirements specifically address the circumstances of observed groundwater contamination. The MCLs and MCLGs would be applicable if site-related chemicals were observed in a public water supply system, and contamination was present at the tap. (The same reasoning is appropriately used for the South Dakota State drinking water standards). FWQC were developed for surface water systems and although these requirements may be relevant and appropriate for groundwater in the absence of MCLs, they are clearly not "applicable" as remediation guidelines for groundwater.

According to EPA, a requirement may be determined to be relevant and appropriate if the established health or environmental limit is based on an exposure scenario that is similar to the potential exposure at a CERCLA site (USEPA 1988b). EPA considers this to be the focal point for determining if a requirement is relevant and appropriate. The objective of the Safe Drinking Water Act (SDWA) is to ensure that potable water supplies are safe for human consumption. At SDANG the primary regulatory concern is that groundwater contamination may preclude use of a potential source of drinking water. Based on this comparison, the situation is sufficiently similar to the problems addressed by the SDWA–that MCLs would be considered relevant requirements.

EPA has determined, as a matter of policy, that MCLs will be relevant and appropriate for groundwater or surface water that currently is or may be used directly for drinking (USEPA 1988a). The Agency points out that although groundwater beneath a waste site under investigation may not be a current source of public drinking water and the wells do not belong to a public water system (and therefore do not meet the jurisdictional prerequisites for the SDWA), the water may still be a potential source of drinking water (provided it is not a Class III aquifer). EPA concludes that because the contaminated groundwater may be used directly as a potable supply in the future, MCLs should be identified as a "probable relevant and appropriate standard" (USEPA 1988a).

MCLs for a toxic chemical are enforceable EPA standards and are allowable limits for lifetime exposure to the contaminant in public drinking water supplies. The MCL is established, taking into consideration potential health effects and the feasibility of attaining such a concentration given the best available technology, treatment techniques, and costs.

As part of the process for developing a final drinking water standard MCL, MCLGs are developed. MCLGs are nonenforceable health-based guidelines established at concentrations that are associated with no known or anticipated adverse health effects for chemicals in public drinking water supplies. MCLs are set at concentrations as close to MCLGs as feasible.

FWQC are guidelines for chemicals in surface waters developed by the EPA Office of Water Regulations and Standards for the protection of aquatic life and human health. Although these are not enforceable standards, they represent scientific data and guidance to be used by the States in developing water quality standards.

State environmental standards are those promulgated by the State for the protection of environmental quality and may be applicable or relevant and appropriate for evaluating remedial actions at waste sites in that State. The availability of and numerical values for these standards vary widely from state-to-state. If State standards are available and are different from the ARARs proposed by EPA, then EPA guidance specifies that the more stringent of the two standards be used in waste site evaluation (USEPA 1988c).

MCLs, MCLGs, and FWQC are identified as potential ARARs at SDANG. As noted previously, EPA considers MCLGs relevant and appropriate for evaluating groundwater (i.e., as a potential drinking water source) when multiple contaminants or pathways may present excess lifetime cancer risks exceeding 10^{-4}. FWQC were included at this stage as an additional point of comparison for chemicals for which MCLs are not available. EPA indicates that FWQC adjusted for drinking water only may be relevant and appropriate under such circumstances.

Table 5-1 lists available Federal and State chemical-specific ARARs for the subject compounds identified at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area. A comparison of the inorganic compounds detected at Site 3 – Base Fire Training Area is made with Federal and State ARARs. However, it should be noted (as discussed in Sections 4.3.3 and 5.1) that the elevated concentrations of inorganics detected at the site are considered to be background concentrations that occur in the SDANG area. A comparison with ARARs for the organic compound [bis(2-ethylhexyl)phthalate] detected at Site 3 – Base Fire Training Area is also made, though this compound is believed to be a laboratory-induced contaminant and not reflective of actual site contamination. The presence of organic and inorganic compounds in the groundwater at Site 3– Base Fire Training Area is not considered to be site-related; however, this evaluation is conducted in order to make the most conservative assessment of the risks to human health. Table 5-1 lists 1) the EPA primary drinking water standards (MCLs), 2) EPA drinking water MCLGs, 3) EPA ambient water quality criteria for the protection of human health (FWQC), adjusted for drinking water only, and 4) South Dakota State drinking water standards. In addition, Federal Drinking Water Health Advisories are provided as an additional point of reference. Note that Drinking Water Health Advisories are not ARARs but are considered other values "to be considered" in assessing the significance of observed levels of environmental contamination.

TABLE 5-1. WATER QUALITY ARARs AND DRINKING WATER HEALTH ADVISORIES FOR CHEMICALS AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

COMPOUND	MCLs(a) (ug/L)	MCLGs(b) (ug/L)	FWQC Adjusted for Drinking Water Only (c) (ug/L)	South Dakota State Drinking Water Standards (ug/L)	Federal Drinking Water Health Advisories (h)		
					One-day 10 kg (i) (ug/L)	Ten-day 10 kg (i) (ug/L)	Longer-term 70-kg (j) (ug/L)
INORGANICS							
Arsenic	50	50 d	0.025 e	50			
Cadmium	10	5 d	10	10			
Chromium	50	120 d		50			
Copper	1300 d	1300 d	1000	1300			
Lead	50	0 d	50	20			20 ug/day
Nickel			15.4				
Selenium	10	45 d	10	10			
Zinc	5000		5000				
ORGANICS							
Acenaphthene			20				
Acetone							
Anthracene							
Benzene	5	0	0.67 e	5	235	235	
Benzo(a)anthracene			0.0031 f				
Benzo(a)pyrene			0.0031 f				
Benzo(b)fluoranthene			0.0031 f				
Benzo(k)fluoranthene			0.0031 f				
Bis(2-Ethylhexyl)phthalate			21000				
Chrysene			0.0031 f				
Dibenzofuran							
Diethylphthalate							
2,4-Dimethylphenol							
Di-n-butylphthalate							
Di-n-octylphthalate							
Ethylbenzene	700 d	700 d	2400		32000	3200	N/A
Fluoranthene			188				
Fluorene							
Indeno(1,2,3-c,d)pyrene							
Methylene Chloride			0.019 g				
2-Methylnaphthalene							
Napthalene							
PAHs			0.0031 f				
Phenanthrene							
Pyrene							
Toluene	2000 d	2000 d	15000		21500	3460	3460
Xylenes	10000 d	10000 d			12000	7800	27300

a. Maximum Contaminant Levels established under the Safe Drinking Water Act.
b. Maximum Contaminant Level Goal established under the Safe Drinking Water Act.
c. Federal Ambient Water Quality Criteria (FWQC) established under the Clean Water Act, adjusted for drinking water only.
d. Proposed MCL or MCLG.
e. FWQC corresponding to the 10-6 risk level.
f. FWQC for Polynuclear Aromatic Hydrocarbons (PAHs) as a class of compounds is 0.0031 ug/L. This corresponds to the 10-6 risk level.
g. FWQC for halomethanes as a class of compounds corresponding to the 10-6 risk level. Methylene chloride (dichloromethane) is a member of this group.
h. Federal Drinking Water Health Advisories are not ARARs but values to be considered (TBC) in evaluating the significance of observed levels of contamination in drinking water supplies. Information obtained from USEPA (1986, 1987a,b,c).
i. Drinking Water Health Advisory for a 10 kg child
j. Drinking Water Health Advisory for a 70 kg adult.

5.2.2.2 Comparison With Applicable or Relevant and Appropriate Requirements

Concentrations of chemicals in the groundwater at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area are evaluated by comparing mean and maximum observed levels with potentially relevant and appropriate Federal and State ARARs. Note that ARARs are not available currently for chemical contaminants in soil.

Table 5-2 provides a summary of mean and maximum levels of chemicals in groundwater at Site 1 – Underground Fuel Storage Area and an indication of the compounds that exceed potential ARARs. As shown, the mean concentration of lead and benzene in groundwater exceeded the MCLs (enforceable standards) or MCLGs (nonenforceable health-based guidelines) currently established or proposed for promulgation by the EPA Office of Drinking Water. Based on the observed maximum concentrations in groundwater, ethylbenzene was additionally found to exceed the proposed MCLG. At Site 1 – Underground Fuel Storage Area, chemicals for which the mean and maximum concentrations in groundwater exceeding FWQC adjusted for drinking water are as follows: arsenic, benzene, and the polynuclear aromatic hydrocarbons (PAHs).

Table 5-3 compares ARARs with mean and maximum concentrations of chemicals in groundwater samples from Site 3 – Base Fire Training Area. As shown, the mean and maximum levels of lead exceed the proposed MCLG of O.O µg/L. Concentration of chemicals did not exceed MCLs or nonzero MCLGs. The mean and maximum concentrations of arsenic and nickel exceed FWQC adjusted for drinking water only.

5.2.3 Exposure Assessment

The exposure assessment addresses several major issues: 1) the behavior of site-related contaminants in the environment, 2) identification of receptors at risk and routes of exposure; 3) projection of environmental concentrations of site-related chemicals at points of exposure; 4) and characterization of dose. It is critical that the results of risk assessment be interpreted in the context of the exposure assumptions/scenarios that form the basis of the evaluation. Much of the uncertainty in the results of risk assessment may be attributed to the assumptions used in the exposure assessment.

Derivation of risk estimates are based on estimates of the "reasonable maximum exposure" of SDANG personnel to chemicals in groundwater and soils. These estimates are measures of hypothetical risk to a maximally exposed individual. At all sites, risks are characterized separately for exposure to each environmental medium. Given that groundwater beneath the sites under

TABLE 5-2. COMPARISON OF SITE 1 - UNDERGROUND FUEL STORAGE AREA GROUNDWATER LEVELS WITH ARARs AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

CHEMICAL	Mean (a) Concentration in Groundwater (ug/L)	Maximum Concentration in Groundwater (ug/L)	Comparison: Mean Concentration vs. ARAR	Comparison: Maximum Concentration vs. ARAR
INORGANICS				
Arsenic	8.08	13.00	>FWQC, (0.025 ug/L)	>FWQC, (0.025 ug/L)
Lead	8.62	24.00	>pr. MCLG, 0 ug/L	>pr. MCLG, 0 ug/L; >State 20 ug/L
ORGANICS				
Acenaphthene	4.50	7.00	>FWQC, (0.0031 ug/L)*	>FWQC, (0.0031 ug/L)*
Acetone	7.10			
Anthracene	5.70	5.70		
Benzene	42.20	120.00	>MCL, 5 ug/L; >FWQC, (0.67 ug/L); >State 5 ug/L	>MCL, 5 ug/L; >FWQC, (0.67 ug/L); >State 5 ug/L
Benzo(a)anthracene	3.35	4.70	>FWQC, (0.0031 ug/L)*	>FWQC, (0.0031 ug/L)*
Benzo(b)fluoranthene	5.50	5.50	>FWQC, (0.0031 ug/L)*	>FWQC, (0.0031 ug/L)*
Benzo(k)fluoranthene	5.50	5.50	>FWQC, (0.0031 ug/L)*	>FWQC, (0.0031 ug/L)*
Bis(2-ethylhexyl)phthalate	63.41	640.00		
Chrysene	3.35	4.70	>FWQC, (0.0031 ug/L)*	>FWQC, (0.0031 ug/L)*
Dibenzofuran	3.30	3.30		
2,4-Dimethylphenol	12.75	23.50		
Di-n-butylphthalate	4.00	4.00		
Di-n-octylphthalate	2.00	2.00		
Ethylbenzene	372.42	1100.00		>pr. MCL, 700 UG/l; >pr. MCLG, 700 ug/L
Fluoranthene	9.65	15.30	>FWQC, (0.0031 ug/L)*	>FWQC, (0.0031 ug/L)*
Fluorene	4.35	6.70	>FWQC, (0.0031 ug/L)*	>FWQC, (0.0031 ug/L)*
2-Methylnaphthalene	11.75	34.00	>FWQC, (0.0031 ug/L)*	>FWQC, (0.0031 ug/L)*
Naphthalene	22.68	36.50	>FWQC, (0.0031 ug/L)*	>FWQC, (0.0031 ug/L)*
Phenanthrene	8.00	8.00	>FWQC, (0.0031 ug/L)*	>FWQC, (0.0031 ug/L)*
Pyrene	10.15	10.15	>FWQC, (0.0031 ug/L)*	>FWQC, (0.0031 ug/L)*
Xylenes	1725.04	3200.00		

MCL - Maximum Contaminant Level. USEPA Primary Drinking Water Standards.
MCLG - Maximum Contaminant Level Goal. USEPA health-based guideline used in the development of MCLs.
FWQC - Federal Ambient Water Quality Criteria adjusted for drinking water only.
( ) Indicates FWQC values corresponding to the 10-6 risk level.
(*):Comparison with criterion for Polycyclic Aromatic Hydrocarbons (PAH's) as a class of compounds.
pr.-proposed
(a) Arithmetic mean of yearly means for 1987 and 1989 sampling sets. Not detected results were excluded from analysis and calculation of the arithmetic mean.

TABLE 5-3. COMPARISON OF SITE 3 - BASE FIRE TRAINING AREA GROUNDWATER LEVELS WITH ARARs AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

CHEMICAL	Mean (a) Concentration in Groundwater (ug/L)	Maximum Concentration in Groundwater (ug/L)	Comparison: Mean Concentration vs. ARAR	Comparison: Maximum Concentration vs. ARAR
INORGANICS				
Arsenic	10.340	30.000	>FWQC, (0.025 ug/L)	>FWQC, (0.025 ug/L)
Cadmium	1.000	1.000		
Chromium	3.500	7.000		
Copper	6.690	14.000		
Lead	10.620	16.000	>pr. MCLG, 0 ug/L	>pr. MCLG, 0 ug/L
Nickel	18.55	34.000	>FWQC, 15.4 ug/L	>FWQC, 15.4 ug/L
Selenium	6.750	9.000		
Zinc	27.67	53.000		
ORGANICS				
Bis(2-ethylhexyl)phthalate	9.330	21.000		

MCL - Maximum Contaminant Level. USEPA Primary Drinking Water Standards.
MCLG - Maximum Contaminant Level Goal. USEPA health-based guideline used in the development of MCLs.
FWQC - Federal Ambient Water Quality Criteria adjusted for drinking water only.
( ) Indicates FWQC values corresponding to the 10-6 risk level.
(*): Based on criteria for Polycyclic Aromatic Hydrocarbons (PAH's).
pr. = proposed value
(a) Arithmetic mean of yearly means for 1987 and 1989 sampling sets. Not detected results were excluded from analysis and calculation of the arithmetic mean.

investigation is not currently used by Base personnel as a source of potable water, receptors are not projected to be exposed simultaneously to chemicals in groundwater and soils. Combined (i.e., simultaneous) exposure to chemicals originating from both sites is likewise not a concern.

Hypothetical exposure to subsurface soils is also considered in the risk assessment. Although there is currently no exposure to the soils below the land surface at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area, a risk characterization is conducted to develop a measure of the significance of the observed levels of contamination. An equilibrium partitioning approach is adopted to project the concentration of site-related contaminants in soil pore water corresponding to the measured concentrations of chemicals in the soil matrix. Appendix H presents a detailed overview of the methods used in the equilibrium partitioning analysis. An extremely conservative risk estimate is then developed by projecting the potential for adverse health effects associated with exposure to the soil pore water. The concentration of chemicals in the aquifer beneath the site would never exceed the projected concentrations in pore water. Given the effects of dilution, attenuation, and transformation, the groundwater concentrations are likely to be orders of magnitude less that the projected pore water concentrations.

5.2.3.1 Exposure Assumptions for the Groundwater Ingestion Pathway

The following assumptions are the basis of the exposure assessment for groundwater. These assumptions have been used in developing the chronic dose estimates of hypothetical exposure of human receptors to groundwater beneath Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area.

- The receptors at risk are 70-kilogram (kg) adults projected to ingest 2 liters of water per day, 5 days per week, 50 weeks per year, for 20 years of a 70-year lifetime. Note that no one at SDANG or in the vicinity currently is using water from the contaminated plume beneath the sites as a source of drinking water. A hypothetical risk estimate has been developed for comparative purposes in evaluating the magnitude of groundwater contamination at the sites under investigation.
- All chemicals in groundwater are considered to be conservative (i.e., they do not transform or degrade over the period of exposure).
- Dose estimates are derived based on mean levels of chemicals observed in groundwater samples. Sampling data were pooled for 1987 and 1989, and the overall arithmetic mean of the yearly mean samples was used in developing estimates of long-term dose. Not detected results were excluded from analysis and calculation of the arithmetic mean.
- All chemicals in groundwater are considered to be 100-percent bioavailable for uptake and absorption by humans.

5.2.3.2 Exposure Assumptions for the Surface Soil Ingestion Pathway

The receptors at greatest risk of exposure to contaminated surface soils at Site 3 – Base Fire Training Area are Base personnel. Given that the facility is fenced, the potential risks to the general population are insignificant in comparison. The pathway that is projected to drive the overall magnitude of the exposure estimate is direct, inadvertent ingestion of soils. The following assumptions have been used in the assessment of exposure of personnel at the facility to chemicals in surficial soils:

- Base personnel are the receptors at primary risk. These receptors are 70-kg adults, projected to inadvertently ingest 0.1 grams of soil, 5 days per week, 26 weeks per year (i.e., taking into consideration snow cover), for 20 years of a 70-year lifetime.
- All chemicals in surficial soils are considered to be conservative (i.e., they do not transform or degrade over the period of exposure).
- Dose estimates are derived based on mean levels of chemicals measured in surface samples (i.e., 0 to 5 feet below land surface [BLS]). Not detected results were excluded from the analysis and calculation of the arithmetic means.
- All chemicals in soils are considered to be 100-percent bioavailable for uptake and absorption by humans.

5.2.3.3 Exposure Assumptions for the Subsurface Soils

The following assumptions are the basis of the exposure assessment for chemicals in subsurface soils. These assumptions have been used in developing the chronic dose estimates of hypothetical exposure of human receptors to soils below the land surface at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area.

- The receptors hypothetically at risk are 70-kg adults projected to ingest 2 liters of water per day containing contaminant levels equal to the equilibrium pore water concentration. The receptors are assumed to ingest this water 5 days per week, 50 weeks per year, for 20 years of a 70-year lifetime. Note again that this is simply a hypothetical risk estimate developed for comparative purposes only in evaluating the magnitude of subsurface soil contamination at the sites under investigation.
- The equilibrium partitioning analysis is based on the use of the Freundlich isotherm and the soil organic carbon-water partition coefficient. This method is most appropriately used for nonionizing, nonpolar organic compounds. Because the equilibrium behavior of inorganic contaminants is not as reliably predicted by this methodology, the risk characterization focuses only on the organic chemicals found in the subsurface environment.
- All chemicals in soils and pore water are considered to be conservative (i.e., they do not transform or degrade over the period of exposure).
- Dose estimates are derived based on equilibrium pore water concentrations. These concentrations are calculated based on mean levels of chemicals observed in subsurface soil samples for the full soil column. Sampling data were pooled for 1987 and 1989, and the overall arithmetic mean of the yearly mean samples was used in developing estimates

of long-term dose. Not detected results were excluded from analysis and calculation of the arithmetic mean.

- All chemicals in pore water/groundwater are considered to be 100-percent bioavailable for uptake and absorption by humans.

5.2.4 Toxicity Assessment

Toxicity measures are required to evaluate the results of exposure assessment and derived estimates of chronic dose. The risk assessment at SDANG focuses on the potential for long-term effects of exposure to chemicals present in groundwater and soils. As discussed in Appendix H, the toxicity measures of greatest importance for evaluating risk to human receptors are the EPA reference doses (RfDs) and carcinogenic potency factors.

Table 5-4 lists available toxicity measures for all chemicals identified at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area. These measures are obtained primarily from the EPA Integrated Risk Information System on-line data base and the EPA Health Effects Assessment Summary Tables (FY 1989). The EPA Superfund Public Health Evaluation Manual (USEPA 1986) is used as a secondary alternate source. In the absence of toxicity data, RfDs may be assigned to subject chemicals based on structural/toxicological similarities. In addition to the toxicity measures in Table 5-4, an indication is provided of the primary noncarcinogenic effect of concern (i.e., the organ system or tissue that is the primary target of the toxic manifestation of the subject chemical).

5.2.5 Risk Characterization

Risk characterization brings together the results of the toxicity and exposure assessments. Estimates of chronic dose are compared and combined with the selected toxicity measures to develop an indication of the potential for adverse health effects. (See Appendix H for more detailed information on the methods used in risk characterization.)

5.2.5.1 Site 1 – Underground Fuel Storage Area

Table 5-5 presents the results of risk assessment of chemicals in groundwater at Site 1 – Underground Fuel Storage Area. A summary of mean levels of chemical contaminants observed in the environment is shown in column two. Based on these mean values, estimates of chronic lifetime dose are developed, and the measures used in risk characterization are derived: 1) a hazard index for noncarcinogenic effects, and 2) a measure of the excess lifetime probability of cancer. Risk estimates are provided separately for exposure to each chemical and then for combined exposure across all chemicals for a given site.

TABLE 5-4. INGESTION AND INHALATION TOXICITY MEASURES FOR WASTE SITE EVALUATION AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

COMPOUND	Noncarcinogenic Effects Oral Route (mg/kg/day) RfD-S (a)	Noncarcinogenic Effects Oral Route (mg/kg/day) RfD-C (b)	Source EPA RfD Chronic Exp.	Noncarcinogenic Effects Inhalation Route (mg/kg/day) RfD-S (a)	Noncarcinogenic Effects Inhalation Route (mg/kg/day) RfD-C (b)	Source EPA RfD Chronic Exp.	Noncarcinogenic Effect of Concern
INORGANICS							
Arsenic	1.00E-03	1.00E-03	d	- -	1.00E-03	d,g	Skin, Lung
Beryllium	5.00E-03	5.00E-03	d	5.00E-03	5.00E-03	d,g	Lung, Skin, Heart
Cadmium	- -	5.00E-04	d	- -	5.00E-04	d,g	Kidney
Chromium	2.00E-02	5.00E-03	d,g,h	2.00E-02	5.00E-03	d,g,h	Skin
Copper	3.70E-02	3.70E-02	d,e	0.00E+00	3.70E-02	d,e,g	GI Tract, Blood
Lead	- -	1.40E-03	d,i	- -	1.40E-03	d,g	CNS, Kidney
Nickel	2.00E-02	2.00E-02	c,d	0.00E+00	2.00E-02	c,d,g	Skin, Lung
Selenium	4.00E-03	3.00E-03	d	1.00E-03	1.00E-03	d	Liver, Kidney, Skin
Zinc	2.00E-01	2.00E-01	d	- -	2.00E-01	d,g	Anemia
ORGANICS							
Acenaphthylene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Acenaphthene	4.00E-01	4.00E-01	d,m	- -	- -		Liver, Kidney
Acetone	- -	1.00E-01	d	- -	- -		Liver, Kidney
Anthracene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Benzene	- -	- -		- -	- -		Hematopoietic Sys.
Benzo(a)anthracene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Benzo(a)pyrene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Benzo(b)fluoranthene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Benzo(g,h,i)perylene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Benzo(k)fluoranthene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Bis(2-ethylhexyl)phthalate	2.00E-02	2.00E-02	d	2.00E-02	2.00E-02	d,g	Liver
Chrysene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Dibenzofuran	1.00E-02	1.00E-03	d,l	- -	- -		Thymus, Liver, Skin
Di-n-butyl phthalate	1.00E+00	1.00E-01	d	1.00E+00	1.00E-01	d,g	
Diethyl phthalate	8.00E+00	8.00E-01	d	- -	- -		Lung Irritation
2,4-Dimethylphenol	6.00E-03	6.00E-04	d,k	- -	- -		Liver, Kidneys, Heart
Di-n-octyl phthalate	2.00E-02	2.00E-02	d,o	- -	- -		Skin
Ethylbenzene	1.00E+00	1.00E-01	d	- -	- -		Skin, Liver, Kidney
Fluoranthene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Fluorene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Hexane	- -	5.70E-01	f	- -	- -		CNS
Indeno(1,2,3-cd)pyrene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Methylene Chloride	6.00E-02	6.00E-02	d	6.00E-02	6.00E-02	d,g	Liver, Kidney, CNS
2-Methylnaphthalene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
4-Methylphenol	- -	- -		- -	- -		Liver, Kidney
Naphthalene	4.00E-01	4.00E-01	d	- -	- -		Eye, Blood
Phenanthrene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Phenol	6.00E-01	6.00E-01	d	- -	- -		Liver, Kidney, CNS
Pyrene	4.00E-01	4.00E-01	d,m	- -	- -		Skin
Toluene	4.00E-01	3.00E-01	d	2.00E+00	2.00E+00	d	CNS
Xylenes	4.00E+00	2.00E+00	d	7.00E-01	4.00E-01	d,j	CNS

a. RfD—Reference dose for subchronic (short-term) exposure.
b. RfD—Reference dose for chronic (long-term) exposure.
c. IRIS DATA BASE
d. USEPA ORD Health Effects Assessment Summary Tables (HEAST) FY 1989, or Superfund Public Health Evaluation Manual (1986).
e. RfD derived from the USEPA drinking water standard as listed in USEPA 1989 HEAST 2nd Quarter report.
f. Carcinogenic Potency Factor currently under review by EPA (IRIS Data Base). However, a unit risk factor is provided in IRIS: 5E-05 per ug/l. Potency Factor used was derived from this unit risk factor assuming ingestion of 2 liters of water per day by a 70 kg adult.
g. RfDs or potency factors for the oral exposure route have been used in the absence of toxicity data for the inhalation route.
h. References doses for hexavalent chromium, oral route.
i. Reference dose for lead is under evaluation by EPA. The RfD listed is this table has been used in the absence of more recent toxicity measures.
j. Toxicity measures presented are for mixed xylenes.
k. In the absence of toxicity data, the reference doses for 2,6-dimethyphenol are used for 2,4-dimethylphenol.
l. In the absence of toxicity data, the reference doses for furan are used for dibenzofuran.
m. In the absence of toxicity data, the RfDs for naphthalene have been adopted for this compound.
n. In the absence of toxicity data, the potency factor for benzo(a)pyrene has been adopted for this compound.
o. In the absence of toxicity data, the RfD for bis(2-ethylhexyl)phthalate has been used for this compound.
p. The chronic oral RfD was derived from the "Longer term" Drinking Water Health Advisory developed by the EPA Office of Drinking Water (USEPA 1987).

TABLE 5-4. INGESTION AND INHALATION TOXICITY MEASURES FOR WASTE SITE EVALUATION AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA (CONTINUED)

COMPOUND	Carcinogenic Potency Factor (q1*): Oral Exposure (mg/kg/day)-1	Source Carcin. Poten. Factor (Oral)	Carcinogenic Potency Factor (q1*): Inhalation Exposure (mg/kg/day)-1	Source Carcin. Poten. Factor (Inhalation)
INORGANICS				
Arsenic	1.75E+00 [A] f	c,d	5.00E+01 [A]	d
Beryllium			8.40E+00 [B2]	d
Cadmium			6.10E+00 [B1]	d
Chromium				
Copper				
Lead				
Nickel				
Selenium				
Zinc				
ORGANICS				
Acenaphthylene				
Acenaphthene				
Acetone				
Anthracene				
Benzene	2.90E-01 [A]	d	2.90E-01 [A]	d
Benzo(a)anthracene	1.15E+01 [B2]	d,n		
Benzo(a)pyrene	1.15E+01 [B2]	d		
Benzo(b)fluoranthene	1.15E+01 [B2]	d,n		
Benzo(g,h,i)perylene				
Benzo(k)fluoranthene	1.15E+01 [D]	d,n		
Bis(2-ethylhexyl)phthalate	1.40E-02 [B2]	d,n	1.40E-02 [B2]	d,g
Chrysene	1.15E+01 [B2]	d,n		
Dibenzofuran				
Di-n-butyl phthalate				
Diethyl phthalate				
2,4-Dimethylphenol				
Di-n-octyl phthalate				
Ethylbenzene				
Fluoranthene				
Fluorene				
Hexane				
Indeno(1,2,3-cd)pyrene	1.15E+01 [C]	d,n		
Methylene Chloride	7.50E-03 [B2]		4.70E-07 [B2]	d
2-Methylnaphthalene				
4-Methylphenol				
Naphthalene				
Phenanthrene				
Phenol				
Pyrene				
Toluene				
Xylenes				

a. RfD—Reference dose for subchronic (short-term) exposure.
b. RfD—Reference dose for chronic (long-term) exposure.
c. IRIS DATA BASE
d. USEPA ORD Health Effects Assessment Summary Tables (HEAST) FY 1989, or Superfund Public Health Evaluation Manual (1986).
e. RfD derived from the USEPA drinking water standard as listed in USEPA 1989 HEAST 2nd Quarter report.
f. Carcinogenic Potency Factor currently under review by EPA (IRIS Data Base). However, a unit risk factor is provided in IRIS: 5E-05 per ug/l. Potency Factor used was derived from this unit risk factor assuming ingestion of 2 liters of water per day by a 70 kg adult.
g. RfDs or potency factors for the oral exposure route have been used in the absence of toxicity data for the inhalation route.
h. References doses for hexavalent chromium, oral route.
i. Reference dose for lead is under evaluation by EPA. The RfD listed is this table has been used in the absence of more recent toxicity measures.
j. Toxicity measures presented are for mixed xylenes.
k. In the absence of toxicity data, the reference doses for 2,6-dimethyphenol are used for 2,4-dimethylphenol.
l. In the absence of toxicity data, the reference doses for furan are used for dibenzofuran.
m. In the absence of toxicity data, the RfDs for naphthalene have been adopted for this compound.
n. In the absence of toxicity data, the potency factor for benzo(a)pyrene has been adopted for this compound.
o. In the absence of toxicity data, the RfD for bis(2-ethylhexyl)phthalate has been used for this compound.
p. The chronic oral RfD was derived from the "Longer term" Drinking Water Health Advisory developed by the EPA Office of Drinking Water (USEPA 1987).

TABLE 5-5. RISK CHARACTERIZATION FOR EXPOSURE TO SITE 1 UNDERGROUND FUEL STORAGE AREA GROUNDWATER AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Chemical	Mean (a) Concentration in Groundwater (ug/L)	Hazard Quotient Noncarcinogenic Effects (b) (Dose/RfD)	Noncarcinogenic Effects: Target Organ System	Excess Lifetime Carcinogenic Risk (b) (Dose x q1*)
INORGANICS				
Arsenic	8.08	1.58E-01	Skin, Lung	8E-05
Lead	8.62	1.21E-01	CNS, Kidney	
ORGANICS				
Acenaphthene	4.50	2.21E-04	Liver, Kidney	
Acetone	7.10	1.39E-03	Liver, Kidney	
Anthracene	5.70	2.80E-04	Skin	
Benzene	42.20		Hematopoietic Sys.	7E-05
Benzo(a)anthracene	3.35	1.64E-04	Skin	2E-04
Benzo(b)fluoranthene	5.50	2.70E-04	Skin	4E-04
Benzo(k)fluoranthene	5.50	2.70E-04	Skin	4E-04
Bis(2-ethylhexyl)phthalate	63.41	6.22E-02	Liver	5E-06
Chrysene	3.35	1.64E-04	Skin	2E-04
Ethylbenzene	372.42	7.31E-02	Skin, Liver, Kidney	
Dibenzofuran	3.30	6.48E-02	Thymus, Liver, Skin	
2,4-Dimethylphenol	12.75	4.17E-01	Liver, Kidneys, Heart	
Di-n-butyl phthalate	4.00	7.85E-04		
Di-n-octyl phthalate	2.00	1.96E-03	Skin	
Fluoranthene	9.65	4.73E-04	Skin	
Fluorene	4.35	2.13E-04	Skin	
2-Methylnaphthalene	11.75	5.76E-04	Skin	
Naphthalene	22.68	1.11E-03	Eye, Blood	
Phenanthrene	8.00	3.92E-04	Skin	
Pyrene	10.15	4.98E-04	Skin	
Xylenes	1725.04	1.69E-02	CNS	
Hazard Index: Combined Exposure		9.22E-01		
Excess Lifetime Cancer Risk: Combined Exposure				1E-03

a. Arithmetic mean of yearly means for 1987 and 1989 sampling sets. Not detected results were excluded from analysis and calculation of the mean.

b. Dose calculated assuming hypothetical ingestion exposure of base personnel to contaminated groundwater. Exposure assumptions: consumption of 2 liters of water per day, by a 70 kg adult, 5 days per week, 50 weeks per year, for 20 years of a 70 year lifetime.

As shown in Table 5-5, the hazard index (HI) is calculated to be approximately 9.2 x 10^{-1}. No adverse noncarcinogenic effects would be anticipated in personnel hypothetically exposed to groundwater over the projected 20-year exposure period given the exposure assumptions presented previously. (Note that the potential noncarcinogenic effects of exposure to benzene were not evaluated. No RfD for benzene is available.) The excess lifetime cancer risk is projected to be approximately 1 x 10^{-3}. This hypothetical risk estimate exceeds the acceptable range established by EPA for protection of human health and selection of remedial alternatives under the Superfund program (NCP:55 FR 8666: an excess lifetime cancer risk of 10^{-6} to 10^{-4}).

The cancer risk estimate derived is extremely conservative in that the carcinogenic potency factor for benzo(a)pyrene has been used (in the absence of other toxicity data) in risk characterization of the other carcinogenic PAHs detected. Based on EPA studies, benzo(a)pyrene is orders of magnitude more potent a carcinogen than the other PAHs present in groundwater. The excess lifetime cancer risk estimates for exposure to the PAHs would therefore fall below 10^{-4}. The combined cancer risk estimate for arsenic and benzene alone, however, exceeds 10^{-4} (i.e., approximately 2 x 10^{-4}).

There was no chemical contamination in surficial soils at the site. Therefore, inadvertent direct ingestion exposure to surface soils was not evaluated at Site 1 – Underground Fuel Storage Area. Hypothetical exposure to subsurface soils has been considered in the risk assessment for Site 1 – Underground Fuel Storage Area. As noted previously, there is currently no exposure to the soils below the land surface at the site. However, a risk characterization is conducted to develop some measure of the significance of the observed levels of contamination. An equilibrium partitioning approach (described previously and in Appendix H) is adopted to project the concentration of site-related contaminants in soil pore water. Exposure and risk estimates are then derived for hypothetical ingestion exposure to groundwater containing site-related contaminants at the equilibrium soil pore water concentration.

Table 5-6 presents the results of this analysis. As shown, the HI is calculated to be approximately 2.0 x 10^{-1}. The magnitude of the HI score is primarily attributable to the presence of acetone. Given this result, no adverse noncarcinogenic effects would be anticipated in receptors exposed to contaminated groundwater at the equilibrium pore water concentration. With regard to carcinogenic effects, the excess lifetime cancer risk is projected to be approximately 1 x 10^{-5}. This hypothetical risk estimate is within the acceptable range established by EPA for the protection of human health and selection of remedial alternatives under the Superfund program.

TABLE 5-6. RISK CHARACTERIZATION FOR SITE 1 - UNDERGROUND FUEL STORAGE AREA: EQUILIBRIUM PARTITIONING OF SOIL CONTAMINANTS SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Chemical	Mean (a) Concentration in Soil (mg/Kg)	Equilibrium Concentration in Groundwater (ug/L)	Hazard Quotient Noncarcinogenic Effects (b) (Dose/RfD)	Noncarcinogenic Effects: Target Organ System	Excess Lifetime Carcinogenic Risk (b) (Dose x q1*)
ORGANICS					
Acenaphthene	0.13	1.45E+00	7.09E-05	Liver, Kidney	
Acetone	0.04	8.86E+02	1.74E-01	Liver, Kidney	
Anthracene	0.25	8.75E-01	4.29E-05	Skin	
Benzo(a)anthracene	0.35	1.26E-02	6.19E-07	Skin	8E-07
Benzo(b)fluoranthene	0.26	2.35E-02	1.15E-06	Skin	2E-06
Benzo(k)fluoranthene	0.19	1.68E-02	8.25E-07	Skin	1E-06
Benzo(a)pyrene	0.25	2.27E-03	1.11E-07	Skin	1E-07
Benzo(g,h,i)perylene	0.14	4.34E-03	2.13E-07	Skin	
Bis(2-ethylhexyl)phthalate	0.06			Liver	
Chrysene	0.34	8.50E-02	4.17E-06	Skin	5E-06
Dibenzofuran	0.08				
Ethylbenzene	1.61	7.32E+01	1.44E-02	Skin, Liver, Kidney	
Fluoranthene	0.75	9.80E-01	4.81E-05	Skin	
Fluorene	0.12	8.15E-01	4.00E-05	Skin	
Indeno(1,2,3-cd)pyrene	0.17	5.31E-03	2.61E-07	Skin	3E-07
Methylene Chloride	0.01	2.84E+01	9.29E-03	Liver, Kidney, CNS	1E-06
2-Methylnaphthalene	0.46			Skin	
Naphthalene	0.29	1.56E+01	7.65E-04	Eye, Blood	
Phenanthrene	0.89	3.16E+00	1.55E-04	Skin	
Phenol	0.07	2.32E+02	7.60E-03	Liver, Kidney, CNS	
Pyrene	0.85	1.12E+00	5.51E-05	Skin	
Xylenes	5.21	1.09E+03	1.07E-02	CNS	
Hazard Index: Combined Exposure			2.17E-01		
Excess Lifetime Cancer Risk: Combined Exposure					1E-05

a. Arithmetic mean of yearly means for 1987 and 1989 sampling sets. Not detected results were excluded from analysis and calculation of the mean.

b. Dose calculated assuming hypothetical ingestion exposure of base personnel to contaminated groundwater. Concentrations in groundwater are set equivalent to the equilibrium concentration of chemicals in soil pore water. Exposure assumptions: consumption of 2 liters of water per day, by a 70 kg adult, 5 days per week, 50 weeks per year, for 20 years of a 70 year lifetime.

5.2.5.2 Site 3 – Base Fire Training Area

Table 5-7 presents the results of risk assessment of chemicals in groundwater at Site 3 – Base Fire Training Area. As in the evaluation for Site 1 – Underground Fuel Storage Area, the table provides a summary of mean levels of chemical contaminants observed in the environment, the hazard index for noncarcinogenic effects, and a measure of the excess lifetime probability of cancer. Risk estimates are provided separately for exposure to each chemical and then for combined exposure across all chemicals for the exposure pathway.

As shown in Table 5-7, the HI is calculated to be approximately 4.7×10^{-1}. No adverse noncarcinogenic effects would be anticipated in personnel hypothetically exposed to groundwater over the projected 20 year exposure period given the exposure assumptions presented previously. The excess lifetime cancer risk is projected to be approximately 1.0×10^{-4}. This hypothetical risk estimate is at the upper limit of the acceptable range established by EPA for the protection of human health and selection of remedial alternatives under the Superfund program (NCP: 55 FR 8666: an excess lifetime cancer risk of 10^{-6} to 10^{-4}).

The magnitude of the excess cancer risk for groundwater at Site 3 – Base Fire Training Area is attributable to the presence of arsenic (i.e., mean concentration of 10.35 micrograms per liter [µg/L]). However, given the conservative exposure assumptions used in characterizing risk of chronic exposure to groundwater, the probability that arsenic is most likely not a site-related contaminant, and because no receptors are actually exposed to groundwater beneath the site, these results are considered to fall within the acceptable range established by EPA.

Table 5-8 presents the results of the risk assessment of hypothetical exposure to surficial soils at Site 3 – Base Fire Training Area. The table provides a summary of the mean concentrations of chemicals in soil samples obtained 0 to 5 feet BLS. Based on the arithmetic mean of all data (i.e., 1987 and 1989 sampling sets), dose estimates were derived for chronic ingestion exposure to Base personnel.

As shown in Table 5-8, the HI is calculated to be approximately 8.8×10^{-3}. No adverse noncarcinogenic effects would be anticipated in personnel inadvertently exposed to surface soils over the projected 20-year exposure period given the exposure assumptions presented previously. The excess lifetime cancer risk is projected to be approximately 4.0×10^{-6}. This hypothetical risk estimate is within the acceptable range established by EPA for the protection of human health and selection of remedial alternatives under the Superfund program.

TABLE 5-7. RISK CHARACTERIZATION FOR EXPOSURE TO SITE 3 - BASE FIRE TRAINING AREA GROUNDWATER AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Chemical	Mean (a) Concentration in Groundwater (ug/L)	Hazard Quotient Noncarcinogenic Effects (b) (Dose/RfD)	Noncarcinogenic Effects: Target Organ System	Excess Lifetime Carcinogenic Risk (b) (Dose x q1*)
INORGANICS				
Arsenic	10.34	2.03E-01	Skin, Lung	1E-04
Cadmium	1.00	3.92E-02	Kidney	
Chromium	3.50	6.87E-05	Skin	
Copper	4.19	2.22E-03	GI Tract, Blood	
Lead	10.62	1.49E-01	CNS, Kidney	
Nickel	18.55	1.82E-02	Skin, Lung	
Selenium	6.75	4.42E-02	Liver, Kidney, Skin	
Zinc	27.67	2.71E-03	Anemia	
ORGANICS				
Bis(2-ethylhexyl)phthalate	9.33	9.15E-03	Liver	7E-07
Hazard Index: Combined Exposure		4.68E-01		
Excess Lifetime Cancer Risk: Combined Exposure				1E-04

a. Arithmetic mean of yearly means for 1987 and 1989 sampling sets. Not detected results were excluded from analysis and calculation of the mean.

b. Dose calculated assuming hypothetical ingestion exposure of base personnel to contaminated groundwater. Exposure assumptions: consumption of 2 liters of water per day, by a 70 kg adult, 5 days per week, 50 weeks per year, for 20 years of a 70 year lifetime.

TABLE 5-8. RISK CHARACTERIZATION FOR EXPOSURE TO SITE 3 - BASE FIRE TRAINING AREA SURFACE SOILS AT SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Chemical	Mean (a) Concentration in Soil (mg/Kg)	Hazard Quotient Noncarcinogenic Effects (b) (Dose/RfD)	Noncarcinogenic Effects: Target Organ System	Excess Lifetime Carcinogenic Risk (b) (Dose x q1*)
INORGANICS				
Arsenic	7.99	4.08E-03	Skin, Lung	2E-06
Beryllium	0.52	5.31E-05	Lung, Skin, Heart	
Chromium	16.30	8.32E-06	Skin	
Copper	12.00	1.65E-04	GI Tract, Blood	
Lead	10.23	3.73E-03	CNS, Kidney	
Nickel	20.60	5.26E-04	Skin, Lung	
Zinc	57.70	1.47E-04	Anemia	
ORGANICS				
Benzo(a)anthracene	0.18	2.30E-07	Skin	3E-07
Benzo(a)pyrene	0.33	4.21E-07	Skin	6E-07
Benzo(b)fluoranthene	0.22	2.81E-07	Skin	4E-07
Benzo(g,h,i)perylene	0.17	2.17E-07	Skin	
Benzo(k)fluoranthene	0.26	3.32E-07	Skin	4E-07
Chrysene	0.23	2.93E-07	Skin	4E-07
Ethylbenzene	9.85	5.03E-05	Skin, Liver, Kidney	
Fluoranthene	0.08	1.06E-07	Skin	
Indeno(1,2,3-cd)pyrene	0.18	2.30E-07	Skin	
Methylene Chloride	0.004	3.40E-08	Liver, Kidney, CNS	
Naphthalene	0.17	2.17E-07	Eye, Blood	
Phenol	0.05	4.17E-08	Liver, Kidney, CNS	
Pyrene	0.20	2.55E-07	Skin	
Xylenes	3.75	9.57E-07	CNS	
Hazard Index: Combined Exposure		8.76E-03		
Excess Lifetime Cancer Risk: Combined Exposure				4E-06

a. Arithmetic mean of yearly means for 1987 and 1989 sampling sets. Not detected results were excluded from analysis and calculation of the mean.

b. Dose calculated assuming hypothetical ingestion exposure of base personnel to contaminated surface soil. Exposure assumptions: inadvertent ingestion of 0.1 grams of soil per day, by a 70 kg adult, 5 days per week, 50 weeks per year, for 20 years of a 70 year lifetime.

All risk estimates are based on observed levels of chemicals in surficial soils at the site. Background levels have not been subtracted out. In general, however, it is important to compare levels in soils at the sites with that observed in background samples. Mean levels of all of the inorganic chemicals present in surficial soils at Site 3 – Base Fire Training Area exceeded mean background soil concentrations. A large portion of the observed risk of hypothetical ingestion exposure of soils at the site is attributed to the presence of arsenic. The mean concentration of arsenic in surficial soils (7.99 milligrams per kilogram [mg/kg]) exceeds the mean background concentration (4.83 mg/kg) by less than a factor of two. None of the mean levels of the other inorganic chemicals exceeded mean background concentrations by more than a factor of 2.5.

Hypothetical exposure to subsurface soils is also considered in the risk assessment for Site 3 – Base Fire Training Area. As noted previously, there is currently no exposure to the soils below the land surface at the site. However, a risk characterization is conducted to develop some measure of the significance of the observed levels of contamination. An equilibrium partitioning approach (described previously and in Appendix H) is adopted to project the concentration of site-related contaminants in soil pore water. Exposure and risk estimates then are derived for hypothetical ingestion exposure to groundwater containing site-related contaminants at the equilibrium soil pore water concentration.

Table 5-9 presents the results of this analysis. As shown, the HI is calculated to be approximately 4.5×10^{-1}. No adverse noncarcinogenic effects would be anticipated in receptors exposed to contaminated groundwater given the projected influence of dilution and attenuation. With regard to carcinogenic effects, the excess lifetime cancer risk is projected to be approximately 6×10^{-6}. This hypothetical risk estimate is within the acceptable range established by EPA for the protection of human health and selection of remedial alternatives under the Superfund program.

5.2.5.3 Evaluation of Tentatively Identified Compounds

A number of additional compounds have been tentatively identified in soils and groundwater at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area (see Subsections 4.2 and 4.3), including aliphatic, olefinic, and aromatic hydrocarbons; aldehydes; and ketones. A summary of the total quantity of alkanes and alkenes detected at each site is presented in Table 5-10. (Note that the small quantity of aldehydes, ketones, and alcohols tentatively identified are not included in the table.)

TABLE 5-9. RISK CHARACTERIZATION FOR SITE 3 - BASE FIRE TRAINING AREA: EQUILIBRIUM PARTITIONING OF SOIL CONTAMINANTS
SOUTH DAKOTA AIR NATIONAL GUARD, JOE FOSS FIELD, SIOUX FALLS, SOUTH DAKOTA

Chemical	Mean (a) Concentration in Soil (mg/Kg)	Equilibrium Concentration in Groundwater (ug/L)	Hazard Quotient Noncarcinogenic Effects (b) (Dose/RfD)	Noncarcinogenic Effects: Target Organ System	Excess Lifetime Carcinogenic Risk (b) (Dose x q1*)
ORGANICS					
Acetone	0.12	2.75E+03	5.40E-01	Liver, Kidney	
Benzo(a)anthracene	0.18	6.52E-03	3.20E-07	Skin	4E-07
Benzo(a)pyrene	0.33	3.00E-03	1.47E-07	Skin	2E-07
Benzo(b)fluoranthene	0.13	1.14E-02	5.57E-07	Skin	7E-07
Benzo(g,h,i)perylene	0.17	5.31E-03	2.61E-07	Skin	
Benzo(k)fluoranthene	0.15	1.32E-02	6.47E-07	Skin	8E-07
Chrysene	0.23	5.75E-02	2.82E-06	Skin	4E-06
Di-n-octyl phthalate	0.01			Skin	
Ethylbenzene	15.82	7.19E+02	1.41E-01	Skin, Liver, Kidney	
Fluoranthene	0.08	1.09E-01	5.36E-06	Skin	
Indeno(1,2,3-cd)pyrene	0.18	5.63E-03	2.76E-07	Skin	
Methylene Chloride	0.004	2.41E+01	7.90E-03	Liver, Kidney, CNS	
2-Methylnaphthalene	0.16			Skin	
4-Methylphenol	0.23			Liver, Kidney	
Naphthalene	0.96	5.11E+01	2.51E-03	Eye, Blood	
Phenol	0.05	1.73E+02	5.64E-03	Liver, Kidney, CNS	
Pyrene	0.11	1.47E-01	7.23E-06	Skin	
Toluene	0.10	1.67E+01	1.09E-03	CNS	
Xylenes	19.46	4.05E+03	3.98E-02	CNS	
Hazard Index: Combined Exposure			4.48E-01		
Excess Lifetime Cancer Risk: Combined Exposure					6E-06

a. Arithmetic mean of yearly means for 1987 and 1989 sampling sets. Not detected results were excluded from analysis and calculation of the mean.

b. Dose calculated assuming hypothetical ingestion exposure of base personnel to contaminated groundwater. Concentrations in groundwater are set equivalent to the equilibrium concentration of chemicals in soil pore water. Exposure assumptions: consumption of 2 liters of water per day, by a 70 kg adult, 5 days per week, 50 weeks per year, for 20 years of a 70 year lifetime.

Table 5-10. Concentrations of Tentatively Identified Compounds at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area—Aliphatic and Olefinic Compounds

Site/Media	Alkanes	Alkenes	Total
Site 1 GW (μg/L)	6,500.	3,000.	9,500.
Site 3 GW (μg/L)	58.	0	58.
Site 1 Soils (μg/Kg)	104,000.	24,000.	128,000.
Site 3 Soils (μg/Kg)	890,000.	303,000.	1,193,000.

EPA-verified toxicity measures for use in risk assessment are not available for the specific TICs identified. To develop a measure of the significance of the observed level of contamination, it has been necessary to adopt a surrogate or signature compound for the purposes of toxicological evaluation. Hexane has been selected as the signature compound for evaluation of the TICs in groundwater and soils.

A reference dose for n-hexane has been derived from the EPA Drinking Water Health Advisory (USEPA 1987). The "longer term" health advisory for a 70-kg adult is 14,300 μg/L. The corresponding RfD, assuming ingestion of 2 liters of water per day, would be 5.1×10^{-1}. Using this RfD and the groundwater exposure assumptions presented previously, the HI corresponding to a groundwater concentration of 9,500 μg/L would be 1.64×10^{-2}. Based on this result, no adverse noncarcinogenic effects would be anticipated.

A similar qualitative assessment is developed for the TICs in soils. For the purposes of this evaluation, it is assumed that the total concentrations of TICs may be characterized by n-hexane. Inadvertent soil ingestion is the exposure route of concern. Using the RfD derived for hexane and the soil exposure assumptions presented previously, the HI corresponding to a soil concentration of 1.19×10^{6} μg/kg (Site 3–Base Fire Training Area) would be 2.05. Based on this result alone, there may be potential for adverse noncarcinogenic effects, given the hypothetical exposure scenario adopted. It is important to note, however, that the projected concentrations for TICs in soils are not derived for surface soils alone; data were summed for the full soil column from the land surface to groundwater. Base personnel coming in contact with surface soils would not be exposed to the higher subsurface levels.

There is no immediate risk to human health of exposure to TICs in subsurface soils at Site 3 – Base Fire Training Area. It would be important to reexamine potential health impacts that might be associated with excavation of the contaminated soils or construction at the site. Ingestion, inhalation, and dermal pathways would be the exposure routes of concern.

5.3 SUMMARY OF RISK EVALUATION

A baseline risk assessment was conducted to evaluate the significance of observed levels of chemicals in groundwater at Site 1 – Underground Fuel Storage Area and soils at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area. Although the chemicals detected in the groundwater at Site 3 – Base Fire Training Area were attributed to either background concentrations or laboratory contamination, a conservative approach was used and an evaluation was done to determine the significance of the chemicals. Currently, the groundwater beneath the sites is not being used as a source of drinking water. The public drinking water supply, although not affected by the groundwater plume, is linked hydrogeologically to the contaminated aquifer system beneath the sites under investigation. Therefore, the risk assessment for groundwater must be considered a hypothetical, upper-bound assessment of the potential risks to human health in the absence of site remediation.

In addition, soils at the sites have been found to be contaminated. The receptors at primary risk of exposure to surface soils (at Site 3 – Base Fire Training Area) are Base personnel. The risk assessment of surface soils assumes limited contact and exposure of Base personnel on a weekly basis. The significance of subsurface soil contamination (at Sites 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area) cannot be evaluated directly, however. If the sites remain undisturbed, there is no potential for direct contact and exposure.

Subsurface soil contamination has been evaluated therefore using a simple screening level model of chemical transport from the soil matrix to soil pore water (i.e., equilibrium partitioning). The risk assessment then evaluates hypothetical ingestion of groundwater having contaminant concentrations equal to the equilibrium pore water concentrations in the soil column. This assessment is clearly an overly conservative estimate of health risk and should be viewed simply as a device for interpreting the significance of observed levels of subsurface contamination.

The risk assessment evaluated the potential for adverse effects for combined exposure across chemicals. Because receptors are not simultaneously exposed to chemicals in soils and groundwater, risk assessment did not consider combined effects across environmental media (i.e., ingestion exposure to groundwater and soils).

The results of the baseline risk assessment may be summarized as follows:

- There is no immediate endangerment to human health because of the presence of contaminants in groundwater and soils at Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area.
- No adverse noncarcinogenic effects would be anticipated for hypothetical ingestion exposure to groundwater or surface soils at the sites under investigation.
- The excess lifetime cancer risk of hypothetical ingestion exposure to chemicals in surface soils (4 x 10^{-6}) at Site 3 – Base Fire Training Area is within the acceptable range established by EPA. Data were not obtained for surface soil samples at Site 1 – Underground Fuel Storage Area (the land area at Site 1 – Underground Fuel Storage Area is largely covered by a concrete pad).
- A large number of TICs were present in the soil at Site 3 – Base Fire Training Area. Hexane was used as a surrogate for the aliphatic and olefinic compounds detected. Based on the total quantity of these classes of chemicals found in the soil column, there may be some potential for adverse noncarcinogenic health effects in workers if the soil column is disturbed (e.g., during construction or excavation activities). Additional studies may be warranted prior to initiating these types of activities. Note that there is no immediate risk to human health of exposure to TICs in subsurface soils at Site 3 – Base Fire Training Area.
- The excess lifetime cancer risk of hypothetical ingestion exposure to chemicals in groundwater beneath Site 1 – Underground Fuel Storage Area (i.e., 6 x 10^{-4}) exceeds the acceptable range established by EPA. Approximately one-third of the estimated cancer risk is attributed to the presence of arsenic and benzene. The remainder of the estimated risk is associated with observed levels of PAHs. Note that all potentially carcinogenic PAHs were evaluated assuming cancer potency equivalent to benzo(a)pyrene. The actual combined cancer risk estimate for the four PAHs detected is likely to be an order of magnitude lower.
- The excess lifetime cancer risk of hypothetical ingestion exposure to chemicals in groundwater beneath Site 3 – Base Fire Training Area (i.e., 1 x 10^{-4}) is primarily attributable to the presence of arsenic. Given the conservative exposure assumptions adopted in this assessment, this result falls within the acceptable range established by EPA for waste site remediation. Concentrations for arsenic and nickel in groundwater beneath the site were found to exceed the corresponding FWQC (adjusted for drinking water only). Given that exposure to groundwater beneath the site does not occur and that the concentrations of inorganics detected in the groundwater are considered to be background levels which occur in the SDANG area, the presence of inorganics in the groundwater is not considered a risk to human health.

It is important to recognize the uncertainty inherent in the risk assessment process. None of the results presented are point estimates. In actuality, all estimates of potential risks should be considered distributions of potential outcomes that reflect the range of possible values of all component variables (i.e., the range of values for exposure and toxicity factors). As conducted, the baseline risk assessment of Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area yields conservative, upper-bound estimates of the potential for adverse health effects.

The major factors that lead to an overestimation of potential risks include 1) exclusion of "not detected" results from calculation of the arithmetic means that were used as the basis of exposure and dose estimates, 2) the assumption that all chemicals are conservative in the environment and do not transform or degrade over the period of exposure, 3) the assumption that all chemicals are 100-percent bioavailable for uptake and absorption, and 4) overly conservative rates for soil and groundwater ingestion .

Given the hypothetical, conservative nature of the baseline risk assessment, it is unlikely that the potential risks to human health have been underestimated.

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6. CONCLUSIONS AND RECOMMENDATIONS

The purpose of the Remedial Investigation (RI) activities at South Dakota Air National Guard (SDANG), Joe Foss Field, Sioux Falls, South Dakota, was to collect the data necessary to fully characterize contamination which had been confirmed during the Site Inspection (SI) program. Two sites were studied during the RI: Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area. To accomplish this goal, the following data objectives were set:

- Site 1 – Underground Fuel Storage Area
    - Determine the horizontal and vertical extent of soil and groundwater contamination
    - Assess the risks associated with existing contamination
    - Define the hydrogeologic and other physical properties of the environment at the site.
- Site 3 – Base Fire Training Area
    - Determine the vertical and horizontal extent of soil contamination
    - Validate existing data that indicate that groundwater contamination is not present
    - Determination of the potential of future migration of soil contamination into the groundwater
    - Assess the risks associated with existing contamination
    - Define the physical properties of the environment at the site.

Many different field and data analysis activities were conducted to meet these data objectives. Field activities included a seismic geophysical survey, soil gas/groundwater probe surveys, drilling and sampling of soil borings and monitoring wells, and aquifer testing. Data analysis activities included chemical data reduction, a quality assurance/quality control (QA/QC) program evaluation, and a public health risk evaluation.

The RI program was conducted concurrently with other activities which were designed to achieve early remediation of the groundwater at Site 1 – Underground Fuel Storage Area. As a result of the SI, volatile organic compounds (VOCs) were detected in the groundwater at concentrations such that remediation would be required. A focused feasibility study (FFS) and treatability tests were conducted for the groundwater at Site 1 – Underground Fuel Storage Area which determined that air stripping was the most cost-effective method for remediation of the VOCs in the groundwater. Discharge of the treated groundwater to the Diversion Channel of the Big Sioux River was selected as the discharge method. Draft engineering design plans and specifications were prepared for the groundwater extraction and treatment system. In addition, underground storage tank (UST) removal plans and specifications are currently being prepared to remove the source of contamination at Site 1 – Underground Fuel Storage Area. The RI program was conducted concurrently to determine the full extent of VOC contamination at Site 1 – Underground

Fuel Storage Area and to determine if additional compounds of concern were present in the soils and groundwater at the site.

The remainder of this section summarizes the environmental setting of SDANG, the QA/QC program evaluation, and Site 1 – Underground Fuel Storage Area and Site 3 – Base Fire Training Area conclusions and recommendations.

6.1 ENVIRONMENTAL SETTING

An assessment of the environmental setting shows that, because of the flat topography and poorly developed drainage patterns, the soils and groundwater at SDANG are the environmental media most susceptible to contamination by waste handling storage and/or disposal activities. The water table is shallow (10 to 15 feet below land surface) and is protected from contamination only by a 10 to 15 feet thick surficial clay layer. This clay layer provides little or no protection to contamination where it has been disturbed or where underground tanks are emplaced beneath it. The water table aquifer is located within a 20- to 50-foot bed of coarse-grained saturated sediments between the surficial clay layer and a deeper low permeability till. Because of its excellent water-bearing properties, the aquifer is used extensively for municipal water supplies. These municipal wells would be the ultimate discharge point of any groundwater contamination at the sites of concern.

6.2 QA/QC PROGRAM EVALUATION

A program of QA/QC procedures was instituted throughout the RI program to ensure that collected samples were representative of the sites and that analytical procedures accurately describe the characteristics and concentrations of compounds in the samples. In general, a review of these procedures and control data indicates that the chemical data accurately represent the sampling locations from which they were collected. Data show that excellent reproducibility and adherence to QA/QC procedures were achieved during field sampling. Laboratory data generally shows excellent precision, accuracy, and adherence to analysis methods. As is normal, several compounds were found within the field and laboratory blank samples that are attributable to contamination related to the sample collection environment, decontamination fluids, transport, storage, and/or analysis. These compounds are not indicative of site-related contamination, and their presence does not effect the usefulness of the environmental data.

6.3 SITE 1 - UNDERGROUND FUEL STORAGE AREA - CONCLUSIONS AND RECOMMENDATIONS

Evaluation of the data indicated two areas of soil and groundwater contamination at the site. The southern area, associated with leakage from the underground fuel storage tanks, measures approximately 280 by 160 feet at its furthest boundaries, encompassing a contaminated area of approximately 24,000 square feet. The northern area, associated with the railroad ditches, measures approximately 320 by 60 feet at its furthest boundaries. Contamination in both areas is restricted to the subsurface with the minimum depth and highest concentrations of contamination occurring at the water table (10 feet BLS) and extending, with decreasing concentrations, to the aquifer/glacial till contact at 30 feet. Generally, where contamination exists at the water table, it can be thought to exist through the entire saturated thickness of the aquifer. Using this assumption, volumes of contaminated material are approximately 432,000 and 306,000 cubic feet for the southern and northern areas of contamination, respectively.

The contamination is composed primarily of volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs). The contamination is not markedly different between soil and groundwater nor did it significantly differ between the southern and northern areas. Concentrations of contamination were highest at or just below the water table reflecting the floating characteristic of fuel contamination. Concentrations of total volatile hydrocarbons (TVHs), as determined through onsite gas chromatography (GC) analysis, are as high as 200,000 ppb within the soils at the water table but concentrations rapidly decrease with depth averaging approximately 1000 ppb throughout the aquifer in the contaminated areas. Laboratory analysis results show that identifiable VOC soil contamination (i.e., ethylbenzene, toluene, and total xylenes) was found only within soil samples from soil borings B-1-1 and B-1-2 located in the vicinity of highest contaminant concentrations in the southern area. Only one groundwater monitoring well, MW-1-12, located in the northern source area, showed indentifiable VOCs (i.e., ethylbenzene and total xylenes). More than 20 identifiable SVOCs were found within soil samples from the borehole of MW-1-12 and the soil borings B-1-1 and B-1-2. Four monitoring wells located near the source of contamination in both areas showed levels of SVOCs in the groundwater. No other identifiable VOCs or SVOCs were found within any other soil or groundwater samples collected from the site.

The above laboratory-derived concentrations and the number of VOC- and SVOC-contaminated samples do not explain the very high levels of TVHs noted during the groundwater probe survey and onsite GC analysis. Closer inspection of the raw laboratory data indicate that there are widespread and high concentrations of volatile and semivolatile organic tentatively identified compounds (TICs) within the samples at Site 1 - Underground Fuel Storage Area (> 100,000 µg/kg soil volatile organic TICs, > 40,000 μg/kg soil semivolatile organic TICs, > 2,000 μg/L groundwater volatile organic TICs, > 1,600 μg/L groundwater semivolatile organic TICs). TICs are compounds that are not identifiable using current analysis equipment and methods and therefore have not been extensively studied or regulated. The detection of these TICs agreed with the extent and relative concentrations of contamination as defined by onsite GC analyses.

Some elevated levels of inorganic contamination (i.e., arsenic and lead) were found within soil and groundwater samples but the concentrations 1) did not correlate with the location of hydrocarbon contamination, 2) fluctuated between samplings of the same locations, 3) did not exhibit any contamination trends, and 4) were attributable to background concentrations at SDANG. Therefore this inorganic contamination is not thought to be site-related.

The public health risk assessment evaluated the risk of human exposure to contamination at the site. Because the aquifer underlying the site is the primary water source for the city of Sioux Falls, human exposure by consumption of contaminated groundwater was the focus of the assessment while surficial soil contamination exposure was not considered because of the absence of chemical contamination in the surficial soils at the site. Hypothetical exposure to subsurface soils at Site 1 – Underground Fuel Storage Area was considered. Results of the public health risk assessment showed that 1) there is no immediate endangerment to human health from the presence of contamination at the site, 2) there are no adverse noncarcinogenic effects from the exposure to site contamination, and 3) the excess lifetime cancer risk from ingestion of groundwater exceeds the acceptable range established by the U.S. Environmental Protection Agency (EPA). Therefore, remediation of the groundwater at the site would be required based on potential risks to public health according to EPA guidelines.

It should be noted that the underground fuel storage tanks were decommissioned in the summer of 1989 and are no longer used. Engineering plans and specifications are currently being prepared for removal of the tanks. Consequently, previously active sources of contamination at the site have been eliminated. This fact is further evidenced by the decreasing concentrations of benzene, toluene, ethylbenzene, and xylenes noted within monitoring wells since 1987. Regardless, based upon the results of the RI, the following recommendations are provided:

- Actions to remediate groundwater contamination should begin as soon as possible for treatment of the VOCs present. As part of the remediation, the underground tanks and contaminated soil should be removed.
- Monitoring should be conducted for the presence of SVOCs in the groundwater and in the VOC treatment system effluent. Threshold concentrations should be established for the

SVOCs in the VOC treatment system effluent to determine if an add-on unit should be provided for SVOC treatment.

- Until the remedial action is implemented, quarterly groundwater sampling of selected wells should be performed to monitor any contaminant movement and to ensure that there is no significant migration toward the municipal wells. Monitoring wells MW-1-1, MW-1-3, MW-1-10, MW-1-11, MW-1-12, and MW-1-14 should be considered as sampling points. Analytes of concern during monitoring should include volatile organic compounds, specifically benzene, toluene, ethylbenzene, and xylenes, and semivolatile organics.

6.4 SITE 3 – BASE FIRE TRAINING AREA - CONCLUSIONS AND RECOMMENDATIONS

Evaluation of the data indicates the presence of an area of soil contamination that coincides with the limits of the burn pit. This circular area, with a diameter of approximately 100 feet, has a surficial area of approximately 7,850 square feet. Results of the onsite GC monitoring indicate that the maximum depth of VOC contamination is approximately 10 feet, a depth still within the confines of the surficial clay layer and above the water table. Using the 10-foot depth, the total volume of contaminated soil in the burn pit area is approximately 78,500 cubic feet. Additionally, low levels of SVOCs were found at land surface in the vicinity of the drum holding area. These compounds are thought to be present only in a 20- by 30- foot area in and around the drum holding area to a depth of 2.5 feet. This yields a contaminated soil volume of approximately 1,500 cubic feet. No site-related groundwater contamination was noted at the site.

Soil contamination at the burn pit was composed principally of a number of VOCs and SVOCs. Soil contamination at the drum holding area was solely composed of SVOCs. Concentrations in both areas were highest at or near the land surface and rapidly decrease with depth. Concentrations of TVH at the surface of the burn pit were as high as 100,000 ppb. Laboratory analysis results indicate the presence of the VOCs, ethylbenzene, toluene, and total xylenes within the burn pit samples. Laboratory analysis showed the presence of a multitude of SVOCs within both the burn pit and drum holding area samples. As was noted at Site 1 – Underground Fuel Storage Area, the laboratory-derived concentrations do not explain the very high levels of TVH found in the burn pit area by onsite analysis. Again, further laboratory data inspection revealed the presence of high concentrations (> 400,000 µg/kg and > 600,000 µg/kg) of volatile and semivolatile organic TICs in soil samples whose location and relative concentrations agreed with the values of TVH resulting from onsite GC analyses.

The public health risk assessment at Site 3 – Base Fire Training Area focused on the exposure to contaminated soils within the burn pit and the drum holding area. Results of this assessment show that 1) there is no immediate endangerment to human health from the soil contamination. 2) there is no adverse noncarcinogenic effects related to the soil contamination as long as the soil remains undisturbed and 3) the excess lifetime cancer risk from exposure to soils at the site is within the acceptable range established by EPA.

It should be noted that this site was decommissioned in 1987 and is no longer used. Therefore, there is no longer an active source of contamination at this site. The presence of the surficial clay layer apparently has provided sufficient protection to the underlying aquifer from the waste handling practices at the fire training area. However, RI results show that there has been noticeable migration of contaminants through the surficial clay layer to the clay/unsaturated zone interface (approximately 10 feet below land surface (BLS)). The carbon content (1 to 2 percent) and presence of the clay layer may not be sufficient to inhibit future migration through the sandy unsaturated zone toward the water table (approximately 14 feet BLS). Taking this into consideration and based upon the RI results, the following recommendations are provided:

- Removal of the contaminated soil within the burn pit and drum holding areas should be conducted in the near future.
- During this excavation, worker health and safety considerations should be given priority because of the very high levels of TICs within the surficial soils.
- Extreme care should be taken during the excavation to ensure that the integrity of the surficial clay layer be maintained where possible.

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ABBREVIATIONS AND ACRONYMS

1,1,1-TCA	Trichloroethane
ARAR	Applicable or relevant and appropriate requirements
BLS	Below land surface
CCC	Calibration check compound
CCV	Continuing calibration verification
CEC	Cation Exchange Capability
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Protocol
CRDL	Contract-required detection limit
DOD	Department of Defense
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
FWQA	Federal water quality criteria
GC	Gas chromatography/Gas chromatograph
GFAA	Graphic furnace atomic absorption
GC/MS	Gas chromatography/mass spectrometry
HEAST	Health Effects Assessment Summary Tables
HI	Hazard index
ICAP	Inductively coupled argon plasma
ICS	Interference check sample
ICV	Initial calibration verification
ID	Inside diameter
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
LCS	Laboratory control sample
LOAEL	Lowest-observable-adverse-effect level
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
MS	Matrix spike
MSD	Matrix spike duplicate
NCP	National Contingency Plan
NOAEL	No-observable-adverse-effect level
NPDES	National Pollutant Discharge Elimination System
ODW	Office of Drinking Water
ORD	Office of Research and Development
PAH	Polynuclear aromatic hydrocarbons
PCE	Tetrachloroethylene
PVC	Polyvinyl chloride
QA	Quality assurance
QC	Quality control
RfD	Reference doses
RI	Remedial Investigation
RPD	Relative percent difference
RSD	Relative standard
SAIC	Science Applications International Corporation
SDANG	South Dakota Air National Guard
SDWA	Safe Drinking Water Act
SI	Site Inspection
SPCC	System performance check compound
SVOC	Semivolatile organic compound
TCE	Trichloroethylene

TDS	Total dissolved solids
TIC	Tentatively identified compound
TOC	Total organic carbon
TPH	Total petroleum hydrocarbon
TRC	Tracer Research Corporation
TSS	Total suspended solids
TVH	Total Volatile Hydrocarbons
VOC	Volatile organic compound