KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

Quarterly Pre-Remedy Monitoring and Site Investigation Report for January – March 2011

Bulk Fuels Facility Spill
Solid Waste Management Units ST-106 and SS-111

May 2011

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2050 Wyoming Blvd. SE
Kirtland AFB, New Mexico 87117-5270

KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

QUARTERLY PRE-REMEDY MONITORING AND SITE INVESTIGATION REPORT FOR JANUARY – MARCH 2011

BULK FUELS FACILITY SPILL
SOLID WASTE MANAGEMENT UNITS ST-106 AND SS-111

May 2011

Prepared for
U.S. Army Corps of Engineers
Albuquerque District
Albuquerque, New Mexico 87109

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This Quarterly Pre-Remedy Monitoring and Site Investigation Report for January – March 2011 has been prepared in response to the June 4, 2010 correspondence from the New Mexico Environment Department Hazardous Waste Bureau (NMED-HWB) (NMED, 2010a) to the Air Force outlining the reporting, sampling, and analysis requirements related to the characterization and remediation of contaminated groundwater at Solid Waste Management Units ST-106 and SS-111, Bulk Fuels Facility Spill, Kirtland Air Force Base, New Mexico. Quarterly reporting will incorporate information and data collected in support of ongoing remediation and site characterization activities related to the Stage 2 abatement action for the Former Fuel Offloading Rack, designated as ST 106, and the phase-separated hydrocarbon impacted groundwater, designated as SS-111. As specified by the NMED-HWB, quarterly reporting for the ST-106 and SS-111 sites has been integrated due to the interrelated nature of the sites and the applicability of different data sets to characterization and remediation activities at the Bulk Fuels Facility Spill.

Quarterly remediation and site investigation reporting presents field and analytical data and information associated with the operation, maintenance, and performance of the interim remedial measures SVE and treatment systems, characterization and remediation activities associated with the groundwater and vadose zone and Former Fuel Offloading Rack investigations, and pre-remedy quarterly monitoring for groundwater and soil vapor at the Bulk Fuels Facility site.

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Commander

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PREFACE

This Quarterly Pre-Remedy Monitoring and Site Investigation Report for January – March 2011 was prepared by Shaw Environmental and Infrastructure, Inc. (Shaw) for the U.S. Army Corps of Engineers (USACE), under contract W912DY-10-D-0014, Delivery Order 0002. It pertains to the Kirtland Air Force Base (Kirtland AFB) Bulk Fuels Facility Spill, Solid Waste Management Units ST-106 and SS-111, located in Albuquerque, New Mexico. This report was prepared in accordance with all applicable federal, state, and local laws and regulations, including the New Mexico Hazardous Waste Act, New Mexico Statutes Annotated 1978, New Mexico Hazardous Waste Management Regulations, Resource Conservation and Recovery Act, and regulatory correspondence between the New Mexico Environment Department Hazardous Waste Bureau and the Air Force, dated April 2, June 4, August 6, and December 10, 2010.

This work was performed under the authority of the U.S. Army Corps of Engineers (USACE), Contract No. W912DY-10-D-0014, Delivery Order 0002. All work was conducted from January through March 2011. Mr. Walter Migdal is the Project Manager for the USACE Albuquerque District. Mr. Wayne Bitner, Jr. is the Kirtland AFB Restoration Section Chief and Mr. Tom Cooper is the Shaw Environmental & Infrastructure, Inc. Project Manager. This report was prepared by Ms. Pamela Moss, Diane Agnew, Gary Hecox, Dale Flores, and Nehemiah Thrower.

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Project Manager

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ACRONYMS AND ABBREVIATIONS

AEHD	Albuquerque Environmental Health Department
AFB	Air Force Base
AFCEE	Air Force Center for Engineering and the Environment
ARCH	air rotary casing hammer
ASTM	ASTM International
BFF	Bulk Fuels Facility
C&D	Construction and Demolition
CDRL	Contract Data Requirements List
cfm	cubic feet per minute
CFR	Code of Federal Regulations
CO	carbon monoxide
CO_2	carbon dioxide
CSS	Colorado silica sand
DO	dissolved oxygen
DOT	U.S. Department of Transportation
DRE	destruction removal efficiency
DRO	diesel range organics
DTIC	Defense Technical Information Center
EDB	1,2-dibromoethane/ethylene dibromide
EM	Engineer Manual
EPA	U.S. Environmental Protection Agency
ERP	Environmental Restoration Program
FFOR	Former Fuel Offloading Rack
ft bgs	foot/feet below ground surface
gpm	gallons per minute
GRO	gas range organics
GWQB	Ground Water Quality Bureau (NMED)
HWB	Hazardous Waste Bureau (NMED)
ICE	internal combustion engine
ID#	identification number
IDW	investigation-derived waste
K	Kelvin
KAFB	Kirtland Air Force Base
LAS	Log ASCII Standard
LNAPL	light non-aqueous phase liquid

ACRONYMS AND ABBREVIATIONS (continued)

MCL	maximum contaminant level
MEK	methyl ethyl ketone
µg/L	micrograms per liter
min/day	minutes per day
MTBE	methyl tertiary butyl ether
NAD83	North American Datum 1983
NAPL	non-aqueous phase liquid
NMAC	New Mexico Administrative Code
NMED	the New Mexico Environment Department
NMED-HWB	the New Mexico Environment Department – Hazardous Waste Bureau
NTIS	National Technical Information Service
O_2	oxygen
O.D.	outside diameter
ORP	oxidation-reduction potential
PAH	polycyclic aromatic hydrocarbon
PG	Professional Geologist
PMP	Project Management Professional
ppmv	parts per million by volume
PSH	phase-separated hydrocarbon
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPjP	Kirtland AFB BFF Spill site-specific quality assurance/quality control plan
RCRA	Resource Conservation and Recovery Act
redox	oxidation-reduction
RSI	Remediation Service International
scfm	standard cubic feet per minute
Shaw	Shaw Environmental & Infrastructure, Inc.
SWMU	solid waste management unit
SVE	soil-vapor extraction
SVEW	soil-vapor extraction well
SVMW	soil-vapor monitoring well
SVOC	semivolatile organic compound
1,2,4-TMB	1,2,4-trimethylbenzene
TPH	total petroleum hydrocarbon
TPH-DRO	total petroleum hydrocarbon – diesel range organics
TPH-GRO	total petroleum hydrocarbon – gasoline range organics
UFP-QAPP	Uniform Federal Policy Quality Assurance Project Plan
USACE	U.S. Army Corps of Engineers
USAF	United States Air Force
USCS	Unified Soil Classification System

ACRONYMS AND ABBREVIATIONS (concluded)

V.A.	Veterans Affairs
VOC	volatile organic compound

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EXECUTIVE SUMMARY

This report has been prepared in response to the June 4, 2010 correspondence from the New Mexico Environment Department Hazardous Waste Bureau (NMED-HWB) (NMED, 2010a) to the Air Force outlining the reporting, sampling, and analysis requirements related to the characterization and remediation of contaminated groundwater at Solid Waste Management Units ST-106 and SS-111, Bulk Fuels Facility Spill, Kirtland Air Force Base, New Mexico. Quarterly reporting will incorporate information and data collected in support of ongoing remediation and site characterization activities related to the Stage 2 abatement action for the Former Fuel Offloading Rack (FFOR), designated as ST-106, and the phase-separated hydrocarbon impacted groundwater, designated as SS-111. As specified by the NMED-HWB, quarterly reporting for the ST-106 and SS-111 sites has been integrated due to the interrelated nature of the sites and the applicability of different data sets to characterization and remediation activities at the Bulk Fuels Facility Spill.

Quarterly remediation and site investigation reporting presents field and analytical data and information associated with the operation, maintenance, and performance of the interim remedial measures SVE and treatment systems, characterization and remediation activities associated with the groundwater and vadose zone and FFOR investigations, and pre-remedy quarterly monitoring for groundwater and soil vapor at the Bulk Fuels Facility site.

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1. INTRODUCTION

The Bulk Fuels Facility (BFF) Spill site is located within the western portion of Kirtland Air Force Base (AFB), New Mexico (Figure 1-1) and is comprised of two solid waste management units (SWMUs), designated as ST-106 and SS-111. The component of the BFF Spill project related to investigation and remediation of the vadose zone near the Former Fuel Offloading Rack (FFOR) is designated as ST-106. The phase-separated hydrocarbon (PSH) impacted groundwater component of the project is designated as SS-111.

1.1 Report Purpose

This report has been prepared to summarize ongoing site investigation, remedial, and pre-remedy monitoring activities at ST-106 and SS-111, BFF Spill, Kirtland AFB, New Mexico (U.S. Environmental Protection Agency [EPA] identification number [ID#] NM9570024423/HWB-KAFB-10-004). As specified by the New Mexico Environment Department (NMED) – Hazardous Waste Bureau (NMED-HWB) in a June 4, 2010 regulatory letter to Kirtland AFB (NMED, 2010a), quarterly reporting for ST-106 and SS-111 has been integrated due to the interrelated nature of the sites and the applicability of different data sets to characterization and remediation activities at the BFF Spill site.

In the June 4, 2010 letter to Kirtland AFB, the NMED-HWB directed that the reporting frequency be increased to a quarterly basis, beginning with reporting of second-quarter 2010 data (NMED, 2010a). NMED-specified due dates for future quarterly reports, as follows:

Quarter	Reporting Period	Due Date
1	January 1 – March 31	May 30
2	April 1 – June 30	August 29
3	July 1 – September 30	November 29
4	October 1 – December 31	February 28 of following year

On April 2, 2010, regulatory control of the BFF Spill site was transferred from the NMED Ground Water Quality Bureau (GWQB) to the NMED-HWB (NMED, 2010b). Historically, semi-annual reports have presented data regarding ongoing remediation of ST-106 vadose zone contamination associated with the FFOR and ongoing characterization and interim remediation instituted to begin recovery of PSH on the groundwater at SS-111. Activities and data related to ST-106 were conducted as the Stage 2 abatement action under a NMED-GWQB approved *Stage 2 Abatement Plan for the Bulk Fuels Facility (ST-106)* (United States Air Force [USAF], 2002). This plan identified soil-vapor extraction (SVE) as the preferred abatement option to be implemented at ST-106 to attain abatement standards and requirements set forth in Section 4103 of Title 20 New Mexico Administrative Code (NMAC), Chapter 6, Part 2. ST-106 remediation was initiated before the discovery of PSH-impacts to groundwater. Following the discovery of SS-111, Kirtland AFB instituted PSH recovery directly from the aquifer surface at three well locations, using the same SVE technology approved as the Stage 2 abatement action for ST-106. These actions were conducted as interim measures while site characterization activities continue.

This quarterly remediation, site investigation, and pre-remedy monitoring report describes the operation, maintenance, and performance of interim remedial measures as well as site characterization and monitoring activities completed at the BFF Spill site during the period of January through March 2011. Quarterly reports present data and information related to ongoing activities at the BFF Spill site, including:

- Groundwater and vadose zone investigations,
- Pre-remedy groundwater and soil-vapor monitoring,
- Interim measure investigation at the FFOR, and
- SVE unit monitoring and maintenance.

Quarterly reports will continue to allow information regarding successive investigation phases to be regularly disseminated to stakeholders, and presented in context with other site-related data. It should be noted that only those data collected during each quarter will be presented in the quarterly report.

Reporting requirements per the June 4, 2010 letter from the NMED-HWB include the following:

- Field and laboratory analytical results for groundwater, soil, and soil vapor;
- Laboratory analysis of soil-vapor samples collected from the SVE systems;
- Graphs showing trends of major contaminants versus time;
- A table of surveyed well locations;
- Descriptions of the installation of groundwater and soil-vapor monitoring wells (if applicable);
- Measurements of light non-aqueous phase liquid (LNAPL), also referred to as PSH;
- A table of water levels and water-level map;
- Plume contaminant maps and cross-sections;
- Geologic and geophysical logs of wells and boreholes (if applicable);
- Operation, maintenance, and performance data for remedial measures;
- Quality assurance/quality control (QA/QC) data; and
- Recommendations for future site activities.

All of these requirements were incorporated into this first-quarter 2011 report, as applicable.

In the following discussions, it should be noted that the term non-aqueous phase liquid (NAPL) is used to describe the mixture of separate phase organic liquid that has been observed in the subsurface. Because this NAPL is less dense than water it is sometimes referred to as LNAPL. In this discussion the term NAPL is used for convenience.

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2. REMEDIATION SYSTEM OPERATIONS

This section provides an overview of components of the SVE systems in use at the BFF and a summary of operation, optimization, and any infrastructure modifications for each system during the reporting period. Information provided in this report is for the reporting period from January through March 2011.

2.1 Remediation Systems

2.1.1 SVE and Treatment Systems

Each of the SVE and treatment systems in use at the BFF consists of trailer-mounted units that include specialized on-board computer controllers, sensors, and a pair of 460-cubic-inch displacement Ford Model LSG-875 internal combustion engines (ICEs). These ICEs have been modified and remanufactured to the specifications of Remediation Service International (RSI). Within each SVE system, the computer controller uses the engines as both the vacuum pump to provide SVE and as a means to destroy hydrocarbon vapors removed from the vadose zone. The vacuum is used to extract soil vapor from SVE wells in the vadose zone or to volatilize PSH directly from the water table surface in groundwater monitoring wells by extracting vapor-phase hydrocarbons. Each unit is fitted with a computer-controlled carburetor that controls the mixing of hydrocarbon vapors from the subsurface and ambient dilution air to maintain the proper air/fuel ratio to support combustion. Propane is used as the fuel source during engine starting and warm-up, after which the system consumes recovered petroleum hydrocarbon vapors as the primary fuel source, using propane as needed to help stabilize engine performance. If soil-vapor concentrations are sufficiently high, minimal propane relative to recovered hydrocarbon consumption is required to maintain optimum performance. The exhaust stream of each engine is fitted with a post-combustion catalytic converter to destroy unburned hydrocarbons remaining in the exhaust.

At ST-106, the FFOR, the SVE and treatment system is connected to nine soil-vapor extraction wells (SVEWs), numbered SVEW-01 through SVEW-09, as shown in Figure 2-1. Each of the nine SVEWs is plumbed via buried conveyance piping to a central manifold located adjacent to the SVE treatment unit. Also shown on Figure 2-1 are four inactive SVEWs (SVEW-10 through SVEW-13) that could be plumbed into the treatment system in the future if needed. The three SVE and treatment systems installed at groundwater monitoring wells KAFB-1065, KAFB-1066, and KAFB-1068 are directly connected to these PSH-containing groundwater wells with no need for a manifold system or mixing with other hydrocarbon vapor sources. The application of the vacuum at the wellheads induces volatilization of fuel from the PSH surface and the volatilized fuel stream is extracted via the well casing to the ground surface to directly operate the ICEs. The KAFB-1065 system was installed during August 2008 and the KAFB-1066 and KAFB-1068 systems were installed in March 2009. The SVE systems installed at monitoring wells KAFB-1065, KAFB-1066, and KAFB-1068 have some differences from the SVE unit in place at the Former Offloading Rack. These SVE units are fitted with adjustable hydraulic-loading modules that apply resistance to the engines, therefore allowing the engines to do more work and subsequently have a greater hydrocarbon mass recovery from the subsurface.

When operating with the hydraulic-loading modules engaged, the SVE systems can operate at higher engine speeds (such as 2,000 revolutions per minute) to provide the vacuum necessary for higher extraction flow rates. However, the ability to operate the systems with the hydraulic-loading modules engaged is dependent on the fuel content of the extracted well vapor being high enough to support the increased fuel demands.

If the extracted well vapor is not of sufficiently high-fuel content, the additional energy is derived from increased supplemental fuel use and would not correlate to any greater mass removal from the subsurface. Therefore, if sufficient fuel content is not present in the subsurface vapor stream to support hydraulic load operation, the loading units are disengaged.

2.1.2 SVE and Treatment System Operational Issues

In August 2008, the Albuquerque Environmental Health Department (AEHD) provided Kirtland AFB direction that the SVE systems are considered stationary sources subject to permitting in accordance with 20.11.41 NMAC and that potential emissions should be calculated based on the worst-case fuel mixture entering the SVE system based on historical data. The 20.11.41 NMAC permit application for the SVE system was submitted to AEHD in December 2008, and 20.11.41 NMAC Permit #1984 for the eight SVE engines was issued on April 30, 2009. The permit authorizes the engines to run continuously.

However, during 2009 and the first quarter of 2010, Kirtland AFB and the AEHD were engaged in further discussions regarding the ICE systems and whether the performance testing and certification requirements stipulated by 40 Code of Federal Regulations (CFR) 60.4243(f) applied to the ICEs within the SVE systems. It has been determined that the ICEs are subject to the certification requirements. A certification testing protocol was approved by AEHD in August 2010 and the testing was performed in September 2010. A final report to AEHD regarding the certification testing was submitted in October 2010.

Certification testing indicated that one of the two engines on one SVE system (KAFB-1065) did not pass the certification requirements. Continued operation of the individual SVE engines was contingent on individual ICEs meeting 40 CFR 60.4243(f) certification requirements. The one engine that did not pass the certification requirements was removed from service and is scheduled for replacement in the next quarter. The ICE SVE system will operate with only one engine until the replacement engine is installed and certified. Certification requirements are on an individual engine basis. Therefore, each of the two engines in an ICE SVE system will need to maintain meeting certification standards and, whenever an engine is replaced or has major overhaul work conducted on the engine, it will need to go through the certification process again.

2.1.3 Fuel Remediation Attributable to Natural Attenuation

The Air Force Center for Engineering and the Environment (AFCEE) has published guidance to account for the attenuation of petroleum hydrocarbons by bioventing (Leeson et al., 1996a,b). The mass of petroleum hydrocarbons biodegraded can be calculated using the following equation:

$$HC_{Bio} = (C_{V,bkgd} - C_{V,O2})/100 \text{ x } Q \text{ x } C \text{ x } \rho_{O2} \text{ x } MW_{O2} \text{ x } (kg/1{,}000g) \text{ x } (1{,}440 \text{ min/day})$$

Where:

HC_{Bio}	=	Mass of hydrocarbons biodegraded (kilograms per day)
$C_{V,bkgd}$	=	Concentration of oxygen in background, uncontaminated area (%)
$C_{V,O2}$	=	Concentration of oxygen in extracted off-gas (%)
Q	=	Flowrate (cubic feet per minute [cfm])
C	=	Mass ratio of hydrocarbon to oxygen degraded based on stoichiometry[2] (1/3.5)
ρ_{O2}	=	density of oxygen (moles/liter)
MW_{O2}	=	Molecular weight of oxygen (grams/mole)

Based on this equation and an average oxygen deficit in the ICE influent vapor of approximately 7 percent, the amount of biodegradation occurring at the BFF is approximately 117 gallons of fuel degraded per every cfm of air extracted from the SVE systems per year, or 29.25 gallons of fuel per cfm extracted per quarter. Using this relationship, the total volume of fuel removed due to both SVE and biodegradation can be calculated, as will be discussed in subsequent sections.

2.2 ST-106 FFOR

The following sections summarize first-quarter 2011 operation of the ST-106 SVE system at the FFOR as the approved Stage 2 abatement action for vadose zone soil impacts at the site.

2.2.1 ST-106 SVE System Operation

During the reporting period of January through March 2011, the FFOR SVE system was actively extracting soil vapor from extraction wells SVEW-01 and SVEW-05, as indicated in Table 2-1. Soil vapors from the active wells comprised the system's combined influent vapor (well locations are shown in Figure 2-1). Active extraction wells open to the SVE system are optimized to extract the maximum amount of required combustion constituents (fuel and oxygen) from the subsurface in order to maximize mass removal.

Additionally, since the first quarter of 2006, the well-control manifold vapor sampling ports for the inactive vapor extraction wells have been open to the atmosphere to allow atmospheric oxygen to be drawn by vacuum into the subsurface through the inactive well screens to increase biodegradation. The ports remained open during this reporting period to allow for additional degradation of the vapor plume via bioventing.

During the first quarter of 2011, Engines 1 and 2 of the FFOR SVE system each actively removed and destroyed contaminated subsurface soil vapor. Uptime for Engines 1 and 2 during the 90-day reporting period was 92.2 percent and 96.3 percent, respectively. Operational run-time percentages for the FFOR SVE system for each month within the reporting period are provided in Appendix A. Since the SVE systems consist of ICEs that operate continuously, they require the same type of regular maintenance as an engine in any motor vehicle, such as changing the oil, oil filter, spark plugs, air filter, coolant, and other general maintenance items. Routine system maintenance is performed in accordance with the site-specific *Operations and Maintenance Manual for the Soil Vapor Extraction Systems* (USAF, 2009b). A summary of the major maintenance activities, non-routine maintenance or repair activities, and system downtime during the reporting period are presented in Appendix A.

2.2.2 ST-106 SVE System Hydrocarbon Recovery

The SVE system at the FFOR began pilot-test operation in April 2003 and full-scale operation as the approved Stage 2 abatement action (USAF, 2002) in July 2004. Hydrocarbon extraction quantities for both this reporting period and cumulative totals for the ongoing Stage 2 abatement actions are discussed in this section.

During a reporting period, vapor samples from all SVEWs, soil-vapor monitoring wells (SVMWs), and the SVE system inlet and exhausts are typically analyzed on site, using a Horiba Mexa 554J emissions analyzer for petroleum hydrocarbon concentration in parts per million by volume (ppmv) and for percent oxygen (O_2), carbon monoxide (CO), and carbon dioxide (CO_2). However, because of an oversight, Horiba measurements were only collected during the first quarter of 2011 on the SVMWs. Collection of Horiba measurements on all SVE wells will resume during the second quarter of 2011, and will include the SVE system inlet and exhausts as well as SVMWs. As required in the NMED-HWB June 4, 2010 letter, soil-vapor samples for laboratory analysis were collected from all SVEWs and SVMWs during the first quarter of 2011 (NMED, 2010a). Soil-vapor samples were collected through sample ports installed below each well's shutoff valve at the base of the well-control manifold.

Table 2-2 presents the calculated hydrocarbon recovery amounts for the reporting period as well as the cumulative hydrocarbon quantity recovered and destroyed by the SVE system at the FFOR since initiation of soil-vapor recovery at the site. For the SVE system at the FFOR, average hydrocarbon concentrations from the SVE system influent, as recorded by the equipped computer system, are used in hydrocarbon recovery calculations for the entire quarter. The average hydrocarbon concentration value was calculated by averaging the hydrocarbon concentrations for the last day of each month for the quarter. In addition to the hydrocarbon recovery volumes, other operational parameters for the FFOR SVE system are also summarized in Table 2-2. These field-measured parameters and pressure measurements are used to support system operational modification decisions.

The influent hydrocarbon vapor concentrations from Table 2-2 are used along with the molecular weight of the influent vapor stream (98), the gas constant (0.0821), and the standard temperature

(290 Kelvin [K]) to calculate the vapor concentration (C) in kilograms per cubic meter). The measured well vapor inlet flow rate in cubic meters per hour and hours of operation shown in Table 2-2 are used to calculate recovered mass. The recovered mass is then converted to equivalent gallons. The hydrocarbon recovery is calculated for each engine and then summed for the system. The hydrocarbon recovery calculations are performed using the same basic equations and assumptions during each reporting period. A detailed explanation of the calculations has been provided within the text of previous reports. Since the calculations do not change, the specific equations, constants, and conversions that are used in the hydrocarbon recovery calculations are now presented in Appendix A for reference and not repeatedly presented in the body of the text.

Additionally, a description of the basis for estimating the natural hydrocarbon remediation attributable to biodegradation was discussed in Section 2.1.3.

The SVE system extracted approximately 6,571 equivalent gallons of petroleum hydrocarbons from January through March 2011 with an additional volume of approximately 2,123 gallons destroyed from biodegradation, assuming an average flow rate of 77 standard cubic feet per minute (scfm) and an operational runtime of 94 percent, using the equation described in Section 2.1.3. A total of 8,695 gallons were destroyed during the first quarter of 2011 by SVE and biodegradation.

Through March 2011, approximately 370,000 gallons of NAPL have been removed by the SVE system.

2.2.3 ST-106 SVE System Vapor Sampling

Samples for laboratory analysis of the combined influent soil vapor, pre-catalytic converter, and post-catalytic converter exhaust streams were collected on February 24, 2010. These samples were collected into pre-evacuated stainless-steel, Summa canisters. The canisters were packaged and shipped under chain of custody to the RTI Laboratories, Inc. in Livonia, Michigan, for the following analyses:

- Volatile organic compounds (VOCs) including acetone, methyl tertiary butyl ether (MTBE), and methyl ethyl ketone (MEK; also known as 2-butanone) by Method TO-15;
- Fixed gases (oxygen, nitrogen, carbon monoxide, carbon dioxide, and methane) by Method ASTM International [ASTM]-D2504; and
- Total petroleum hydrocarbons (TPHs) by Methods TO-13A and SW3540C.

Laboratory analytical results have not returned from validation and will be presented and discussed in the quarterly report for the second quarter of 2011. Complete laboratory analytical data packages for vapor samples collected this reporting period also will be included with all other site analytical data in Appendix B. Appendix B presents the Data Quality Evaluation Report for the data collected for this quarter. Data are collected, then evaluated, and validated as specified in the BFF Spill QAPjP for the BFF Spill site (USACE, 2011d). Several iterations of the BFF Spill QAPjP have been updated over time to direct quality assurance for the BFF Spill site. The current version, updated in 2011, meets the required content guidelines of the Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) as documented in the Intergovernmental Data Quality Task Force UFP-QAPP, Evaluating, Assessing and Documenting Environmental Data Collection and Use Program (EPA, 2005).

Analytical data from the SVE system influent and exhaust streams provide information on the nature of subsurface vapor compounds and are an indicator of system performance as it relates to destruction removal efficiency (DRE). However, DRE cannot be calculated based on analytical data, until that analytical data have been validated. DRE for the first quarter of 2001 will be discussed with the second-quarter 2011 quarterly report. Horiba field samples were not taken at the SVE system inlet or post-catalytic converter exhaust during this reporting period. DREs for each of the SVE systems cannot be calculated, based on Horiba sample data, for the first quarter. Horiba sampling at the locations noted above, will resume in the second quarter.

2.3 SS-111 PSH-Impacted Groundwater Interim Remedial Action

The following subsections summarize the first-quarter 2011 operation of the three SVE systems operated as interim remedial measures being applied directly to the PSH or groundwater aspect of the site that has been designated as SS-11.

2.3.1 SS-111 SVE System Operation

During the reporting period, the individual SVE systems located at wells KAFB-1065, KAFB-1066, and KAFB-1068 each extracted vapors only from the associated well as summarized in Table 2-3. Well locations are shown in Figure 2-1.

During the reporting period, the KAFB-1065 SVE system was actively removing and destroying contaminated subsurface soil vapor. Engines 1 and 2 were operational 86.5 percent and 84.1 percent, respectively, of the 90-day reporting period. During the reporting period, the KAFB-1066 SVE system was actively removing and destroying contaminated subsurface soil vapor. Engines 1 and 2 were operational 87.7 percent and 82.7 percent, respectively, of the 90-day reporting period. During the reporting period, the KAFB-1068 SVE system was actively removing and destroying contaminated subsurface soil vapor. Engines 1 and 2 were operational 84 percent and 72.6 percent, respectively, of the 90-day reporting period. The systems were not operated 100% of the time because they periodically have to be taken offline for routine and non-routine maintenance.

Operational run-time percentages for each system, for each month, within the reporting period are provided in Appendix A. Since the SVE systems consist of ICEs that operate continuously, they require the same type of regular maintenance as an engine in any motor vehicle, such as changing the oil, oil filter, spark plugs, air filter, coolant, and other general maintenance items. Routine system maintenance is performed in accordance with the site-specific Operations and Maintenance Manual (USAF, 2009b). A summary of the major maintenance activities, non-routine maintenance or repair activities, and system downtime during the reporting period are presented in Appendix A.

2.3.2 KAFB-1065, KAFB-1066, and KAFB-1068 SVE System Hydrocarbon Recovery

The SVE remediation systems installed in 2008 and 2009 at wells KAFB-1065, KAFB-1066, and KAFB-1068 are equipped with computer systems that allow routine data downloads of a variety of system parameters. Downloaded data includes operational snapshots at 4-hour intervals that record parameters such as the system vapor flow rate and the estimated ppmv concentration of the influent well vapor to the system. By using these data, essentially the same hydrocarbon mass removal calculations that have historically been completed for the SVE system at the FFOR can be performed for each of these SVE systems. However, these data collected directly from the SVE systems, via remote connection, replace the monthly Horiba field measurements used in the cumulative recovered mass calculation at the FFOR SVE system. As previously discussed, a description of the basic calculations used in the hydrocarbon recovery calculations are provided in Appendix A for reference. Additionally, a description of the basis for estimating the natural hydrocarbon remediation attributable to biodegradation was discussed in Section 2.1.3.

The KAFB-1065 SVE system extracted approximately 1,569 equivalent gallons of petroleum hydrocarbons from January through March 2011 with an additional volume of approximately 823 gallons destroyed from biodegradation, assuming an average flow rate of 33 scfm and an operational run-time of 85 percent, using the equation described in Section 2.1.3. A total of 2,392 gallons were destroyed during the first quarter of 2011 by SVE and biodegradation combined. Total hydrocarbon recovery to date for the KAFB-1065 system is 2,392 gallons. Hydrocarbon recovery volumes are shown in Table 2-4.

The KAFB-1066 SVE system extracted approximately 7,484 equivalent gallons of petroleum hydrocarbons from January through March 2011 with an additional volume of approximately

1,646 gallons destroyed from biodegradation, assuming an average flow rate of 66 scfm and an operational run-time of 85 percent, using the equation described in Section 2.1.3. A total of 9,130 gallons were destroyed during the first quarter of 2011 by SVE and biodegradation combined. Total hydrocarbon recovery to date for the KAFB-1066 system is 9,130 gallons. Hydrocarbon recovery volumes are shown in Table 2-5.

The KAFB-1068 SVE system extracted and destroyed approximately 3,213 equivalent gallons of petroleum hydrocarbons from January through March 2011 with an additional volume of approximately 2,795 gallons destroyed from biodegradation, assuming an average flow rate of 122 scfm and an operational run-time of 78 percent, using the equation described in Section 2.1.3. A total of 6,008 gallons were destroyed during the first quarter of 2011 by SVE and biodegradation combined. Total hydrocarbon recovery to date for the KAFB-1068 system is 6,008 gallons. Hydrocarbon recovery volumes are shown in Table 2-6.

In total, the three SS-111 SVE treatment systems extracted and destroyed 12,266 equivalent gallons during the reporting period with an additional approximately 5,264 gallons destroyed from biodegradation for a total of 17,530 gallons destroyed during the first quarter of 2011. The primary variables that impact recovery amounts for individual months are system downtime due to mechanical issues, air emissions testing issues, and adjustment of operational settings to the systems to compensate for changes in well vapor fuel concentrations as a result of interference between the systems. In order to achieve a sustainable operational mode that does not require the use of substantial supplemental propane, the three SS-111 SVE systems' operating set points have remained unchanged to allow time observe system efficiency.

2.3.3 KAFB-1065, KAFB-1066, and KAFB-1068 SVE System Vapor Sampling

Monthly vapor sampling using the Horiba analyzer was not conducted throughout the reporting period, however monthly Horiba measurements will continue in subsequent reporting periods. Samples of the combined influent soil vapor and the pre-catalytic converter and post-catalytic converter exhaust streams were collected for laboratory analysis on February 24, 2011 from the KAFB-1065, KAFB-1066, and KAFB-1068 SVE systems.

Analytical vapor samples were collected as specified with the site-specific Operations and Maintenance Manual (USAF, 2009b) and in compliance with the BFF Spill Quality Assurance Project Plan (QAPjP) (U.S. Army Corps of Engineers [USACE], 2011d). Samples are collected in pre-evacuated, stainless-steel, Summa canisters. The canisters were packaged and shipped under chain of custody to RTI Laboratories, Inc. in Livonia Michigan, for the following analyses:

- VOCs including acetone, MTBE, and MEK by Method TO-15;
- Fixed gases by Method ASTM-D2504; and
- Petroleum hydrocarbons by Methods TO-13A and SW3540C.

Laboratory analytical results have not returned from validation and will be presented and discussed in the quarterly report for the second quarter of 2011. Complete laboratory analytical data packages for vapor samples collected this reporting period also will be included with all other site analytical data in Appendix B. Appendix B presents the Data Quality Evaluation Report for the data collected for this quarter. Data are collected, then evaluated, and validated as specified in the BFF Spill QAPjP for the BFF Spill site (USACE, 2011d). Several iterations of the BFF Spill QAPjP have been updated over time to direct quality assurance for the BFF Spill site. The current version, updated in 2011, meets the required content guidelines of the Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) as documented in the Intergovernmental Data Quality Task Force UFP-QAPP, Evaluating, Assessing and Documenting Environmental Data Collection and Use Program (EPA, 2005).

Analytical data from the SVE system influent and exhaust streams provide information on the nature of subsurface vapor compounds and are an indicator of system performance as it relates to destruction removal efficiency (DRE). However, DRE cannot be calculated based on analytical data, until that analytical data have been validated. DRE for the first quarter of 2001 will be discussed with the second-quarter 2011 quarterly report. Horiba field measurements were not taken at the SVE system inlet or post-catalytic converter exhaust during this reporting period. DREs for each of the SVE systems cannot be calculated, based on Horiba field data, for the first quarter. Horiba sampling at the locations noted above, will resume in the second quarter.

2.4 Waste Generation

Maintenance activities for the SVE and treatment systems generate both non-hazardous and Resource Conservation and Recovery Act (RCRA) hazardous wastes. Liquid condensate is another waste stream associated with SVE operation. The liquid condensate is primarily generated during cooler-season months (typically October through April) as warm, moisture-laden subsurface soil vapor moves up the extraction wells to the cooler ground surface where it condensates in the system piping. During this reporting period, sufficient liquid condensate was not generated to require offsite disposal.

All waste generated at the site is disposed of in compliance with the site-specific waste management procedures outlined in the site-specific Operations and Maintenance Plan (USAF, 2009b). Procedures in the Operations and Maintenance Plan are in compliance with the *Kirtland AFB, Environmental Restoration Program, Investigation-Derived Waste Management Plan*, issued in 2009 (USAF, 2009c), which incorporated specific direction and consideration of the waste streams generated in association with the BFF Spill site remediation. Disposal documentation for waste generated during this reporting period is provided in Appendix C.

2.5 SVE and Treatment System Operational Summary

Four SVE and treatment systems operated at the BFF during the period from January through March 2011. One system, referred to as the FFOR system, continued to operate as the approved Stage 2 abatement action for vadose zone contamination associated with ST-106. The other three SVE systems operated as interim remedial measures being applied directly to the PSH on the water table associated with SS-111.

During the reporting period the SVE and treatment systems recovered the following amounts:

- Cumulative hydrocarbon recovery for the FFOR SVE system and biodegradation combined was approximately 8,695 gallons from January through March 2011.
- Cumulative hydrocarbon recovery for the KAFB-1065 SVE system and biodegradation combined was approximately 2,392 gallons from January through March 2011.
- Cumulative hydrocarbon recovery for the KAFB-1066 SVE system and biodegradation combined was approximately 9,130 gallons from January through March 2011.
- Cumulative hydrocarbon recovery for the KAFB-1068 SVE system and biodegradation combined was approximately 6,008 gallons from January through March 2011.
- Cumulative hydrocarbon recovery from all SVE systems and biodegradation combined was approximately 17,530 gallons January through March 2011.

Ongoing operation of the KAFB-1065, KAFB-1066, and KAFB-1068 SVE systems has substantially changed the subsurface vapor extraction regime at the water table interface across the BFF Spill site. With the ongoing operation of these three SVE systems, continued decrease in gross hydrocarbon concentrations at the SVE inlets is expected to be observed.

Operational changes and additional infrastructure modifications continue to be evaluated to optimize the operation of the ST-106 and SS-111 interim SVE and treatment systems. The goal of the optimization efforts will be to extract the maximum amount of combustion constituents (fuel and oxygen) from the subsurface, thereby maximizing overall mass recovery rates, and achieving the highest possible total mass removal from the four combined SVE systems in their current configurations. Work planning efforts continue to identify additional modifications to the SVE approach in use at the site, which may modify the use of current SVE systems or supplement this approach with other remediation approaches in the future.

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3. SITE INVESTIGATION

3.1 Site Investigation Objectives

This quarterly report presents the monitoring methods and results performed at the Kirtland AFB BFF Spill for the period of December 17, 2010 through March 31, 2011. BFF Spill groundwater investigation and monitoring are currently being implemented in conjunction with the vadose zone investigation and interim measures for ST-106 and SS-111. Approved work plans (USACE, 2011a,b,c) for these three activities were used to guide the work activities performed during the quarter. Additionally, the activities described here comply with the NMED technical directives to Kirtland AFB for performing interim measures for the BFF spill (ST-106 and SS-111) as elaborated in the August 6, 2010 (NMED, 2010c) and December 10, 2010 letters from NMED to Kirtland AFB (NMED, 2010d). This section describes in detail the activities performed to characterize and monitor the groundwater and soil at the BFF. This section presents the monitoring methods employed, and Sections 4.0 and 5.0 present monitoring results for the vadose zone and groundwater, respectively.

3.2 Site Investigation Activities

3.2.1 Geophysics

Geophysical logging is being conducted at newly installed groundwater and SVMWs at the BFF Spill site to define the lithologic and hydrogeologic characteristics of geologic units below the site. The goal of geophysical borehole logging investigations is to use the data to refine the conceptual site model of the potential source location and the extent of LNAPL contamination, in order to optimize placement of remedial SVE and groundwater extraction wells and potential future monitoring wells.

Geophysical well logging was conducted at five groundwater and 24 SVMWs at the BFF Spill site during the first quarter of 2011, as identified in Table 3-1. Well KAFB-10624 was logged in December 2010 and again during the current mobilization to ensure the repeatability of data between different logging contractors.

Well logging, QC, and data processing were performed as described in the following sections and are included in Appendix G.

Well Logging

- Pre-logging Instrument Functional Checks:
  - The induction tool functionality check is performed at the beginning and end of each day and includes assessing background readings and using a calibrated sleeve.
  - The induction tool is placed in a 4-foot tall jig to hold the tool in a horizontal position above the ground. The tool must be far enough away from any cultural features to avoid any interference in the data being recorded.
  - Average conductivity readings are recorded over 100 samples. The attached natural gamma tool also measures the background over 100 samples.
  - A calibration disc is placed over the medium and deep receiver coils and 100 samples are recorded. A calibration sleeve is also placed over the natural gamma crystal and data are recorded.
  - The neutron tool functionality check is performed in a similar manner to the induction tool with the attached natural gamma tool being checked in a similar fashion.
  - The neutron tool is placed in a “jig” to measure the background. The neutron source is not attached while performing natural gamma measurements.
  - A calibration sleeve is placed over the neutron receiver after the neutron source is attached and the recorded values are averaged over 100 samples. Radiation warning cones are placed around the test area when the neutron source is removed from the canister.
- Record the start depth in relation to ground surface prior to tool being sent down the well.
- Record the total depth of the well when the tool reaches the bottom.
- Record the start time of the log when the tool starts coming up the well.
- Record the logging speed of the tool as the tool.
- Observe tool response and identify any significant zone(s) that could be used for the repeat section.
- Record the end time when the tool reaches the original position at the top of the well.
- Record the depth and subtract from starting depth to obtain the depth error.

- Select a repeat section after the log is reviewed.
- Perform same sequence of events listed above for the repeat log.
- Review data for the original and repeat logs and verify that significant zones or anomalies occur at the same depth and have similar log characteristics.

The geophysical logging QC program consists of the following elements:

Field QC

The Wireline Summary Sheet is used by in the field to document parameters for each logging run and instrument functional checks for each probe used. Instrument functional checks are transferred to an Excel spreadsheet so they can be assessed in graphical form over the duration of the project. Hardcopy prints of the logs are reviewed in real time by the logging engineer and QC geophysicist to determine repeat interval(s) and ensure measurements from each probe are reasonable in terms of the expected response. At the end of logging operations each day, raw digital data from the probes are transferred to the QC geophysicist for backup and the data are also transferred to the Jet West processing center for additional analysis and processing. Geophysical Logging QC Forms are included in Appendix G-5.

Data Processing QC

JetWest performs processing of the data for each logging tool and generates a Log ASCII Standard (LAS) file and hardcopy prints of the final processed data for each well. The Jet West Geophysical Logs are included in Appendix G-6. The LAS files are reviewed for consistent format, including revising the log curve names so they are compatible with input into Rockware software. After review of the LAS file format, digital data for each probe are transferred to Microsoft Excel as requested by the NMED and are included in Appendix G-7. Limited processing in Excel is performed and includes smoothing of the natural gamma data (if necessary) and plotting of the induction and neutron data on logarithmic scales. Excel logging curves are visually compared to the curves from the hardcopy prints of the final processed data from JetWest to ensure consistency.

3.2.2 Well Installation

3.2.2.1 Groundwater Monitoring Wells

A total of four groundwater monitoring wells were installed during the quarter by a subcontractor, Water Development Corporation. Groundwater monitoring wells (KAFB-106044 and KAFB-106045) were installed at NMED location No. 6 and monitoring wells KAFB-106101 and KAFB-106102 were installed at NMED location No. 26. Soil boring/ groundwater monitoring well locations are shown on Figure 3-1. All four monitoring wells were completed below the water table at depths prescribed for these locations in the Groundwater Investigation Work Plan (USACE, 2011a). The number, location, and depth completed below the water table are in accordance with Table 4 of the NMED-HWB August 6, 2010 letter (NMED, 2010c). Monitoring wells were installed at NMED location No. 6 to obtain background water quality information. Monitoring wells were installed at NMED location No. 26 to define the nature and extent of the LNAPL and groundwater dissolved-phase contaminant plumes along the plume edge. Table 3-2 presents the completion information for each well, surveyed elevations, well construction materials, and placement depths. Well reports for each well, which are included in Appendix D, consist of soil boring logs, well completion diagrams, and well development records.

Each monitoring well was completed in a separate borehole. Before beginning drilling, each borehole was tested for utility clearance to 5 feet with a hand-auger. Borehole advancement (drilling) was performed using the air rotary casing hammer (ARCH) drilling method. The ARCH method uses steel-insulator casing, advanced with a drill bit/rod, to prevent borehole collapse and to seal off any contaminated zones, so as not to cross contaminate stratographic units. The boreholes were drilled using an 11-¾-inch outside diameter (O.D.) drive casing to a depth of 200 feet below ground surface (ft bgs) and 9-⅝-inch O.D. casing was advanced to the borehole to the final depth. These drive casing sizes effectively advance a 12-inch diameter borehole to 200 ft bgs and a 10-inch borehole from 200 ft bgs to the total depth of the borehole.

During borehole advancement, the soil cuttings were logged every 5 feet by the well site geologist. The soil samples were logged according to the Unified Soil Classification System (USCS). Other details, such as changes in lithology, petrology of gravel units, mineralogy, mineralogy, observed contamination, odor, and groundwater encountered, were also noted on the soil boring log. Soil classification logs for the wells completed during the first quarter of 2011 are included in Appendix D.

All monitoring wells were constructed using 5-inch diameter, schedule 80 polyvinyl chloride (PVC) riser pipe and 0.010-slot, schedule 80 PVC well screens with a 5-foot blank schedule 80 PVC sump. All four monitoring wells were fitted with 15-foot length screens as prescribed for wells completed below the water table. Following placement of the well screen and riser pipe, 10/20 Colorado Silica Sand, Inc. (CSS) filter pack was tremied to approximately 2 feet above the top of the well screen followed by approximately one foot of fine sand seal consisting of 20/40 CSS. Thirty to 40 feet of bentonite seal, consisting of 3/8-inch bentonite chips, were placed above the filter pack. A high solids bentonite grout was placed above the bentonite seal to near ground surface. The bentonite chip seal was hydrated in lifts using a “clean” water source. A cement surface seal was placed above the bentonite grout to the ground surface. Well completion diagrams for the four wells are included in Appendix D.

All installed groundwater monitoring wells were developed within 30 days of installation. Initial development consisted of swabbing and bailing for approximately 2 hours until the sediment load was reduced as much as possible. Following initial development, the well was continuously pumped using an electric submersible pump. Temperature, pH, specific conductivity, and turbidity were monitored during pumping, and readings taken after every well casing volume during purging. The volume of water introduced into the formation during drilling was removed from the well during development. The well was developed until the column of water in each well was free of visible sediment, and the pH, temperature, conductivity, turbidity, and specific conductance had stabilized within 10 percent. Development and purge waters were containerized on site, labeled as investigation-derived waste (IDW), and sampled for waste disposal. Development water for each well was stored separately in holding tanks. Well development logs for each well are included in Appendix D.

3.2.2.2 Soil-Vapor Monitoring Wells

A total of 20 “nested” SVMWs were installed during the quarter. SVMW locations are shown on Figure 2-1. Each nested well location consisted of six individual (one 3-inch diameter and five 3/4-inch diameter), schedule 80, PVC SVMWs installed in the same borehole. Nested wells included a 10-foot length of machine-slotted (0.050-inch) screen. Planned depths of the bottom of the nested well screens were 25, 50, 150, 250, 350, and 450 ft bgs. In some cases, the screened intervals were adjusted based on lithology observed during borehole advancement (e.g., screens were placed in transmissive zones). If proposed vapor-monitoring screened intervals were observed to be in fine-grained lithology (clays or silts), screened intervals were adjusted up or down to the nearest coarser-grained unit. For screens separated by 100 feet (150, 250, 350, and 450 bgs), screens were adjusted by no more than 20 feet and screens separated by 25 feet (25 and 50 bgs) screens were adjusted by no more than 5 feet. Table 3-3 presents the well completion information for the SVMWs and actual screen interval depths. The following SVMWs, corresponding NMED number, and area of location area are provided below:

- KAFB-106108, KAFB-106109, KAFB-106110, KAFB-106111 (SVM-01, 02, 03, and 04) Fuel offloading rack.
- KAFB-106112, KAFB-106119, KAFB-106129, KAFB-106130, KAFB-106132, KAFB-106133, KAFB-106134, (SVM-05, SVM-12, SVM-12, SVM-23, SVM-25, SVM-26, and SVM-27) Fuel Percolation Area.
- KAFB-106113, KAFB-106114, KAFB-106115 (SVM-06, SVM-07, and SVM-08) Piping
- KAFB-106135, KAFB-106137, KAFB-016139, KAFB-106140, KAFB-106131, (SVM-01, SVM-03, SVM-05, SVM-06, SVM-24) Far field
- KAFB-106118 (SVM-11) stepout from fuel offloading rack

Filter pack (sand) consisting of Tacna 0.25-8 washed gravel was placed from the bottom of the screen to approximately 2 feet above the top of screen around the lowest nested well. A 3/8-inch bentonite chip seal was installed from the top of the filter pack to just below the screen for the next lowest well. Bentonite chip seals were hydrated every foot for the first 10 feet using a "clean" water source. This process was repeated for each nested well screen/riser pipe with the exception of the last (25-foot) well. Bentonite was placed to within 5 feet followed by a cement seal to the ground surface. Nested SVMWs were completed at ground surface in steel flush-mount protective covers (well vaults) with gasketed bolt-down covers. The well vaults were completed with a 4-x-4-foot concrete pad, sloped to direct runoff away from the well.

During borehole advancement, soil cuttings were logged every 5-feet by the well site geologist. Soil samples were logged according to the USCS. Other details, such as changes in lithology, petrology of gravel units, mineralogy, observed contamination, odor, and groundwater encountered, were also noted on the soil boring log. Soil classification logs for the wells completed during the first quarter of 2011 are included in Appendix D. Soil samples were collected during borehole advancement in accordance with the Vadose Zone Investigation Work Plan (USACE, 2011b) and the NMED-HWB letter, dated August 6, 2010 (NMED, 2010c). Soil samples were collected every 10 feet for the first 50 feet and every 50 feet thereafter to the total depth of the borehole. Discreet soil samples were collected using a stainless-steel, 2-inch O.D., split-spoon sampler driven into undisturbed soil using a 140-pound hammer falling 30 inches until either approximately 2 feet was penetrated or 100 blows within a 6-inch interval have been applied per ASTM D1586-08a, (*Standard Test Method for Standard Penetration Test [SPT] and Split-Barrel Sampling of Soils*). Soil samples were shipped to Gulf Coast Analytical Laboratories, Inc., Baton Rouge, LA for analysis for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), total petroleum hydrocarbons (TPH) gas and diesel, and lead. Validated analytical sample results will be presented in the second Quarter 2011 report.

3.2.3 Surveying

All wells, once fully completed, have been surveyed in accordance with the Groundwater Investigation Work Plan (USACE, 2011a) and the NMAC *Minimum Standards for Surveying in New Mexico* (NMAC Title 12, Chapter 8, Part 2), and were performed by a New Mexico licensed professional land surveyor. Horizontal coordinates were based on the New Mexico State Plane Coordinate System, central zone (North American Datum, 1983 [NAD83]), as published by the National Geodetic Survey. Elevations were determined to the nearest 0.01 foot and referenced to the 1988 National Geodetic Vertical Datum, as obtained from permanent benchmarks.

A subcontractor two-man survey crew surveyed completed wells using survey-grade Topcon, a global positioning system rover unit, and a base station tied into known control points, with horizontal and vertical accuracies within 0.01 foot. The crew would mobilize to the well location, remove the vault cover and all well caps, and collect data points of the wells and related surfaces. Survey points collected at all wells were ground surface north of the well pad, the well pad north of the well's outer steel casing, the steel casing itself on the north edge (marked with black permanent marker), and the north edge of the inner PVC casing, also marked with black permanent marker. On groundwater wells where a dedicated Bennett pump had been installed, the north edge of the sample point on top of the cap was surveyed. Nomenclature used for these elevation measurement points are as follows: well name, and either ground, concrete well pad, case, and PVC, respectively. At SVMW locations, in addition to the above, points also were taken to include the five one-inch wells. These are listed as PVC plus the depth of the well. Once all survey points were collected, a measurement was collected from the top of the outer steel casing down to the inner PVC well(s), using a steel tape, as a check of elevations for data processing by the surveyor. In addition, five shallow soil borings were also surveyed. A single point on center of the boring was collected, after the boring had been grouted. All wells and soil borings surveyed are listed in Tables 3-2 and 3-3.

3.2.4 Shallow Soil Borings

In February 2011, a total of five shallow soil borings were installed adjacent to the existing aboveground storage tanks (Figure 3-1). Three soil borings were installed using direct-push drilling methods at tank 2420 (west) and two at tank 2422 (east). Five shallow borings were advanced to 20 ft bgs and soil samples were collected from the surface and every 5 feet to the total depth of the soil boring (20 feet). During borehole advancement, soil borings were logged using the USCS system and observations, such as discolored soil, odor, and headspace, were recorded on the soil boring log. Soil boring logs are included in Appendix D. Soil samples were shipped to Gulf Coast Analytical Laboratories, Inc., Baton Rouge, LA for analysis for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), total petroleum hydrocarbons (TPH) gas and diesel, and lead. Validated analytical sample results will be presented in the second Quarter 2011 report.

3.2.5 Quarterly Groundwater Sampling Field Activities

Dedicated Bennett sample pump systems were pulled and re-installed after geophysical logging as shown on Table 3-4.

Other field activities related to groundwater monitoring well s are listed below:

- An obstruction occurred in well KAFB-10617 at approximately 394 feet below the top of the casing. On March 2, 2011, a video camera was run down the well and the obstruction was confirmed to be the white rope that had been used to hang passive diffusion bags in the well. On March 7, 2011, the rope obstruction was removed from the well.
- On March 7, 2011, the dedicated Bennett sample pump system was pulled from monitoring well KAFB-10615 after the pump had failed during a sampling attempt. Inspection of the system led to repairs being made to the tubing near the pump connection. The pump system was reinstalled that same day.

- On March 8, 2011, the dedicated Bennett sample pump system was pulled from monitoring well KAFB-1063. The fluid motor section of the Bennett sample pump was refurbished on site. The Bennett sample pump system was re-installed in KAFB-1063 on March 14, 2011.

- New Bennett sample pump systems were installed in the monitoring wells shown on Table 3-5 on the dates indicated.

No other monitoring well maintenance activities or new Bennett sample pump installations were performed during the period from January through March 2011.

4. VADOSE ZONE MONITORING

4.1 Vadose Zone Monitoring Description

The FFOR SVE remediation system includes 13 SVEWs and 15 individual SVMW locations, each completed with three to four nested wells at different depths, for a total of 58 individual vapor well screen intervals (13 SVEW and 45 SVMW wells). Well locations are shown on Figure 2-1. Additionally, the SS-111 SVE systems include wells KAFB-1065, KAFB-1066, and KAFB-1068. During first-quarter 2011 monitoring, soil-vapor samples were collected from SVMWs, SVEWs, and groundwater monitoring wells in pre-evacuated Bottle-Vac™ canisters for off-site laboratory analysis. Soil-vapor hydrocarbon concentration (ppmv), percent O_2, percent CO, percent CO_2, and pressure were measured at the SVMWs on site during the first quarter of 2011, using the Horiba emissions analyzer. Laboratory analytical sample data will be presented in the second-quarter 2011 quarterly report, once data have been validated. Horiba field measurements for SVMWs sampled are presented in Table 4-1. Horiba field measurements were not taken at SVEWs and groundwater monitoring wells during the first-quarter 2011 reporting period; however, Horiba measurements for these wells will be collected in subsequent reporting periods.

During FFOR soil-vapor sampling, samples and measurements from monitoring wells (SVMW-01 through SVMW-11) and distal monitoring wells (SVMW-12 through SVMW-15) were collected through sample ports installed at the top of each individual well casing.

Collection and field measurements of soil vapor currently follow the procedures presented in detail in Section 4.6 of the Operations and Maintenance Manual (USAF, 2009b) and the *Stage 2 Abatement Plan Summary and Performance Report for the Soil Vapor Extraction and Treatment System, Bulk Fuels Facility (ST-106)* (USAF, 2006). Collection of pressure measurements follow procedures presented in Section 4.5 of the Operations and Maintenance Manual (USAF, 2009b).

When available, pressure measurements that indicate the vadose zone is subject to vacuum are reported on Table 4-1 as negative numbers. Measurements that indicate the vadose zone is subject to positive pressure are shown as positive numbers. Measurements that indicate the vadose zone is at equilibrium with ambient atmospheric pressure and have neither pressure nor vacuum (zero gauge reading) are reported as being at atmospheric pressure.

4.2 Quarterly Soil-Vapor Data Summary

Soil-vapor data that have been presented and discussed in prior reports have primarily been Horiba field measurements. The field measured total hydrocarbon values provide a valuable real-time indicator of the general distribution of hydrocarbon vapors in the subsurface soils. First-quarter 2011 analytical laboratory data are not available at the time of this report and will be, presented in the second-quarter 2011 report.

The first quarter 2011 Horiba field measurement data for the SVMW wells were combined with the fourth quarter 2010 field measurement data to generate a 3D vapor plume using RockWorks software and an 3D inverse distance-weighting logarithmic interpolation algorithm. Plan-view maps for approximate depths of 150, 250, 350, and 450 feet below ground surface were then created by cutting sections at appropriate depths in the 3D plume. Figures 4-1 through 4-4 present a plan view of the approximate soil-vapor distribution at various depths beneath the BFF for the reporting period based on the Horiba measurement data provided in Table 4-1.

4.3 Vadose Zone Conditions Summary and Conclusion

4.3.1 Quarterly Magnitude, Extent, and Nature of Soil-Vapor Plume

During the first quarter of 2011, the magnitude of the highest vapor concentration areas and the areal extent of the 1,000 ppmv contour decreased in almost all areas at almost all depth intervals, as shown on cross-sections presented as Figures 4-1 through 4-4. The highest soil-vapor concentrations continued to persist near the FFOR and to the east of this area at depth. In addition to the field collected total hydrocarbon measurements, laboratory analysis of soil-vapor samples collected from all SVMWs and SVEWs was also conducted during this reporting period. Preliminary data are expected to show fuel-related constituents, such as benzene, toluene, ethylbenzene, xylenes, and trimethylbenzenes, are pervasive in essentially all SVMW and SVEW monitoring intervals, with the highest concentrations of speciated compounds mirroring the total hydrocarbon field data. The elevated concentrations would indicate that a significant soil-vapor mass still remains in this general area of the site, which is the known fuel release area. The data which has been collected continues to indicate a consistent overall decrease in soil-vapor concentrations across the site.

Elevated soil-vapor concentrations persist in some areas of the site away from the FFOR. The volatilization of PSH from the top of the water table is the most likely source of the persistent, elevated vapor concentrations that have been observed in the eastern and northern areas of the site. Additional investigation and data evaluation will continue to more fully determine how the elevated vapor concentrations correlate to the PSH on the water table and residual fuel that remains in the vadose zone on the eastern side of the site.

4.3.2 General Effects of Current SVE Systems on the Vadose Zone

A SVE Optimization Plan (Shaw, 2011) is has been developed and submitted to NMED for approval. This optimization plan will collect the data necessary to quantitatively evaluate the overall effectiveness of the SVE is remediating the vadose zone contamination at Kirtland. As these data are obtained, updated remediation evaluation criteria will be developed and reported in this section.

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5. GROUNDWATER MONITORING

Groundwater monitoring consists of monthly liquid level monitoring and collection of groundwater samples for measurement of field chemical parameters and laboratory chemical analysis.

5.1 Quarterly Pre-Remedy Groundwater Monitoring

The groundwater investigation and monitoring program includes collecting monthly groundwater elevation and LNAPL measurement data, and quarterly groundwater sampling at BFF site monitoring wells and nearby production wells. Groundwater elevation data and LNAPL thickness measurements are presented and discussed in Section 5.2. The wells sampled during the first quarter of 2011 include the following:

- Groundwater wells KAFB-1061 through KAFB-10628; and KAFB-3411 (installed for investigation of another adjacent site and provides a monitoring location upgradient of the FFOR);
- Newly installed groundwater wells KAFB-106044 and KAFB-106045;
- KAFB-3, KAFB-15, and KAFB-16 – KAFB drinking water production wells; and
- VA-2 – Veterans Affairs (V.A.) Medical Center drinking water production well.

Groundwater sampling was conducted between January 25 and March 9, 2011. All samples were collected in accordance with the BFF Spill QAPjP (USACE, 2011d). Sampling was performed using either dedicated Bennett sampling pumps (11 wells) or using a portable Bennett sampling pump system. Dedicated pumps will be installed for sampling in all groundwater wells at the BFF site. Groundwater sampling included purging of one well borehole volume and monitoring of field parameters for stabilization of temperature, pH, and specific conductance to within an estimated 10 percent prior to collecting water quality measurements for pH, conductivity, temperature, alkalinity, dissolved oxygen [DO], turbidity, and oxidation-reduction [redox] potential [ORP]) during well purging, testing for alkalinity, and collecting groundwater samples for laboratory analysis. After collection of water quality measurements the wells were purged at an approximate rate of 1.0 gallon per minute (gpm). Sample collection at the Kirtland AFB production wells and the V.A. Medical Center groundwater production well are purged by flushing the dedicated sample line, and then collecting the samples. Samples are collected from non-chlorinated taps for the drinking water wells.

Groundwater samples collected during the first quarter of 2011 were analyzed by Empirical Laboratories, Nashville, Tennessee, for the following list of parameters:

- VOCs – EPA 8026B;
- Ethylene dibromide/1,2-dibromomethane (EDB) – EPA 8011;
- SVOCs – EPA 8270C (newly installed wells only);
- TPH-gasoline range organics (GRO) and diesel range organics (DRO) - EPA 8015B;
- Polycyclic aromatic hydrocarbons (PAHs) – EPA 8270C low-level (VA-2 well only);
- Lead and major ions – EPA 6010C;
- Dissolved iron and manganese – EPA 6010C;
- Anions (chloride, sulfate, and nitrate (as nitrogen) – EPA 300.0;
- Ammonia nitrogen – SM 4500NHB;
- Total sulfide – SM 4500 S-2CF; and
- Carbonate/bicarbonate alkalinity – SM 2320B.

SVOCs were analyzed in groundwater from the newly installed wells KAFB-106044 and KAFB-106045 as per the August 6, 2010 NMED letter (NMED, 2010c) to Kirtland AFB, directing them to substitute SVOCs for PAHs in the Groundwater Investigation Work Plan (USACE, 2011a). Analysis for SVOCs is not required for existing BFF Spill wells per the June 4, 2010 NMED letter (NMED, 2010a), which specifies sampling and analysis requirements for quarterly monitoring at the BFF Spill site.

Field QC samples were collected in accordance with the BFF Spill QAPjP and included trip and ambient blanks for VOCs, field duplicate samples, and equipment rinse blank samples.

Groundwater analytical data was validated for precision, accuracy, representativeness, comparability and completeness in accordance with the BFF Spill QAPjP and appropriate data qualifiers are appended to the analytical data in the project database. The analytical laboratory results and field parameters are presented in Table 5-1 and the data validation results are presented in the Data Quality Evaluation report included in Appendix B. Accuracy and precision for the Quarter 1 2011 groundwater analytical data indicate data are of sufficient quality to achieve the BFF project data quality objectives.

5.2 Liquid Level Data

On a monthly frequency, liquid levels are measured in all completed wells (Figure 5-1 and Table 5-2), including those with active SVE systems. All liquid levels are measured with a Solinst Model 122 interface probe in wells that potentially can have NAPL in them or a Solinst Model 101 water-level meter for wells that do not have NAPL in them. All instruments are checked for proper operation and cable integrity before use and decontaminated between each well.

5.2.1 Groundwater Levels

Groundwater level data are presented in Table 5-2 and groundwater level contour maps for January, February, and March 2011 and the March 2011 horizontal hydraulic gradients are presented in Figures 5-2 though 5-5. All water levels used to generate the contour maps have been corrected for NAPL thickness using the density correction described by Mayer and Hassanizadeh (2005, Eq. 4.5). As presented in Figures 5-2, 5-3, and 5-4, the groundwater flow direction is approximately North 20° to 50° East with locally variable flow directions south of Ridgecrest. As presented on Figure 5-5, groundwater gradient vary from 0.0005 up to 0.002 ft/ft across the area again with the most variability in gradient south of Ridgecrest where the majority of the monitoring wells are currently located.

Based on analysis of the monitoring well hydrographs In Appendix F, since 2009, groundwater levels at the site have rise between 4 and 6 feet. This is can be attributed to the water conservation practices implemented by the City of Albuquerque to reduce groundwater withdrawals, starting in 2008 and 2009.

While only two sets of cluster wells were installed by the March 2011 round of liquid level measurements, it appears that at least in the NAPL area, there are upward groundwater hydraulic gradients between the shallow and intermediate zones but downward between the intermediate and deep zones, as shown on Table 5-3. As additional cluster wells are installed and monitored, better definition of these vertical gradients will be possible.

5.2.2 NAPL Thicknesses

As presented in Table 5-2 and Figures 5-6. 5-7, and 5-8, in the January to March 2011 time-period, NAPL was only observed in five wells in January and three wells in February and March. In the analysis of NAPL thickness data over time (Figures 5-9 and 5-10; full dataset in Appendix F), it is apparent the NAPL thickness observed in wells since 2009 has markedly declined as groundwater levels have risen. While this declining trend of NAPL thickness in wells may be taken to indicate the NAPL is no longer an issue at the site, because of the physics of NAPL migration, the reduction of NAPL thickness in wells more likely means that the NAPL interval is now flooded with most of the NAPL now submerged below the water table. This is because the buoyancy force that could make the NAPL rise along with the rising water levels is controlled by the density difference between the fuel and water that causes the LNAPL to "float" on the water table. Based on the limited data available for Kirtland, this density difference is likely to be between 0.12 and 0.15 grams per cubic centimeter. If the resulting buoyancy force is less than the displacement pressure (the capillary pressure required for NAPL to migrate into a soil pore space displacing the water), then the NAPL cannot rise when the water table rises. Quantitative analysis of the potential for the NAPL at Kirtland to rise along with the rising water table will be conducted when grain-size analyses and fluid physical properties data become available.

5.3 Groundwater Quality Data

The analysis of groundwater quality data has been divided into organic compounds that are derived from the NAPL (fuel) plume and other compounds that relate to microbial degradation of those fuel-related compounds. The water quality analysis used the following procedures:

- Water quality data were posted on "dot" maps using a graduated color scheme with postings of well names and concentrations beside the "dot." This allowed for visual point pattern analysis of concentration distribution for each compound evaluated. For the color scheme, the lowest concentration break was set at the applicable regulatory value, if such a value exists.
- Plume contour maps were prepared for compounds with sufficient detections to warrant interpolation of contours. For all plume maps, inverse distance weighting algorithm was used for the interpolations. The specific weighting and range values used were dependent on the data and are presented as notes on the individual plume maps.
- Using a combination of the "dot" and plume maps, a preliminary qualitative evaluation of fate and transport was conducted. Quantitative fate and transport analysis will be conducted as addition wells are installed and additional degradation data are collected.

5.3.1 Organic Compound Plumes

Compound-specific dot and plume maps were prepared for total petroleum hydrocarbons—gasoline range organics (TPH-GRO), total petroleum hydrocarbons—diesel range organics (TPH-DRO), benzene, toluene, xylenes, EDB, and 1,2,4-trimethylbenzene (1,2,4-TMB).

- T**PH-GRO.** The concentrations and extent of contamination are presented on Figure 5-11 for this compound group. Because no regulatory limit is available for TPH-GRO, the reporting limit of 150 µg/L was used for plume extent cutoff. As presented, the highest TPH-GRO concentrations are in the historical NAPL area with a highest observed concentration of 38,000 µg/L. The downgradient extent of the TPH-GRO plume is approximately 1,500 feet north of the edge of the historical NAPL area.
- **TPH-DRO.** The concentrations and extent of contamination are presented on Figure 5-12 for this compound group. Because no regulatory limit is available for TPH-DRO, the reporting limit of 150 µg/L was used for plume extent cutoff. As presented, the highest TPH-DRO concentrations are in the historical NAPL area with a highest observed concentration of 160,000 J µg/L. The downgradient extent of the TPH-DRO plume is approximately 1,700 feet north of the edge of the historical NAPL area.
- **Benzene.** The concentrations and extent of contamination are presented on Figure 5-13 for this compound. The EPA maximum contaminant level (MCL) of 5 µg/L was used for plume extent cutoff. As presented, the highest benzene concentrations are in the historical NAPL area with a highest

observed concentration of 7,400 µg/L. The downgradient extent of the benzene plume is approximately 600 feet north of the edge of the historical NAPL area or approximately half the extent of the overall TPH plumes.

- **Toluene.** The concentrations and extent of contamination are presented on Figure 5-14 for this compound. The New Mexico groundwater standard of 750 µg/L was used for plume extent cutoff. As presented, the highest toluene concentrations and the entire toluene plume greater than the regulatory concentration are within the historical NAPL area with a highest observed concentration of 5,600 µg/L.

- **M,P-Xylenes.** The concentrations and extent of contamination are presented on Figure 5-15 for this compound. The EPA MCL of 10,000 µg/L was used for plume extent cutoff. As presented, all m,p-xylene concentrations are below the MCL. The highest m,p-xylene concentrations are within the historical NAPL area with a highest observed concentration of 2,300 µg/L.

- **EDB.** The concentrations and extent of contamination are presented on Figure 5-16 for this compound. The EPA MCL of 0.05 µg/L was used for plume extent cutoff. As presented, the highest EDB concentrations are in the historical NAPL area with a highest observed concentration of 120 µg/L. The downgradient extent of the EDB plume is approximately 2,400 feet north of the edge of the historical NAPL area. The northern contours on the EDB plume are approximate and will be better defined as additional wells are installed in this area.

- **1,2,4-TMB.** The concentrations and extent of contamination are presented on Figure 5-17 for this compound. An arbitrary cutoff concentration of 35 µg/L was used for plume extent cutoff. As presented, the highest 1,2,4-TMB concentrations and the plume are within the historical NAPL area with a highest observed concentration of 360 µg/L.

- **Naphthalene.** The concentrations and extent of contamination are presented on Figure 5-18 for this compound. The EPA MCL of 30 µg/L was used for plume extent cutoff. As presented, the highest naphthalene concentrations and the plume are within the historical NAPL area with a highest observed concentration of 150 µg/L.

5.3.2 Microbial Degradation Indicators

Fundamentally, microbial degradation occurs when bacteria metabolize organic compounds. In this process, electron donors release electrons and become more positively charged, electron acceptors receive electrons and become more negatively charged, and nutrients are consumed. Metabolism, thereby, increases size of the bacteria population according to the following general equation (Wiedermeier et al., 1999):

Microorganisms + Electron donors + Electron acceptor + Nutrients → Metabolic by products + Energy + Additional microorganisms

As a first step in determining the final remedy for the Kirtland fuel plume, a dot map evaluation of degradation indicator compounds (Table 5-4) was performed to relate various indicators to the extent of the NAPL area and dissolved plumes. For this first step, DO, ORP, ammonia, nitrate, iron (only dissolved (filtered) iron data were available but ferric iron is relatively insoluble in water so the majority of the dissolved iron is assumed to be ferrous iron), manganese, sulfate, sulfide, and alkalinity.

- **DO.** The concentrations of this degradation indicator compound are presented on Figure 5-19. The DO concentrations are distinctly lower within and adjacent to the NAPL area and dissolved plume, indicating that microbial degradation is consuming oxygen from the groundwater. Contrary to some older degradation concepts, microbial degradation of petroleum hydrocarbons does not stop when dissolved oxygen is reduced but simply switches from and aerobic process to an anaerobic process (Wiedemeier, et al, 1999).

- **ORP.** The concentrations of this degradation indicator compound are presented on Figure 5-20. As with DO, the ORP concentrations are distinctly lower within and adjacent to the NAPL area and dissolved plume with most values within the plume range from slightly less than zero down to a -206 milliVolts. This indicates that microbial degradation is occurring within the groundwater plume.

- **Ammonia.** The concentrations of this degradation indicator compound are presented on Figure 5-21. As presented there is little to no ammonia in the groundwater system so this nutrient is not a viable degradation indicator.

- **Nitrate.** The concentrations of this degradation indicator compound are presented on Figure 5-22. Nitrate concentrations greater than 1 milligrams per liter are observed in the groundwater in the vicinity of the plume. Within the NAPL and dissolved plumes, nitrate is generally depleted but more data will be needed from the new monitoring wells to assess the viability of this electron acceptor as a degradation indicator.

- **Iron.** The concentrations of this degradation indicator compound are presented on Figure 5-23. The dissolved iron data are sufficient to allow for extent definition. As presented, the area of elevated dissolved iron is largely within the NAPL area with some iron observed in the dissolved plume downgradient from the NAPL area. Because microbial degradation causes increased groundwater concentrations, iron will be a reliable degradation indicator.

- **Manganese.** The concentrations of this degradation indicator compound are presented on Figure 5-24. As presented, the area of elevated dissolved manganese is largely within the NAPL area and the dissolved plume downgradient from the NAPL area. Because microbial degradation causes increased groundwater concentrations, manganese will be a reliable degradation indicator.

- **Sulfate.** The concentrations of this degradation indicator compound are presented on Figure 5-25. The sulfate distribution pattern is not definitive for use as a microbial degradation indicator (degradation will cause sulfate decreases). More data will be needed from the new monitoring wells to assess the viability of this electron acceptor as a degradation indicator.

- **Sulfide.** The concentrations of this degradation indicator compound are presented on Figure 5-26. As presented, there is little to no sulfide in the groundwater system so this by-product is not a viable degradation indicator and is indicative that degradation has not progressed to the sulfate reduction redox potential (Drever, 1997).

- **Alkalinity.** The concentrations of this degradation indicator compound are presented on Figure 5-27. The point pattern analysis indicates that alkalinity is elevated within the NAPL area. More data will be needed from the new monitoring wells to assess the viability of this indirect by-product as a degradation indicator. Note that the alkalinity of 1 U in well KAFB-10617 may be an analytical mistake because groundwater with negligible alkalinity is very uncommon because of carbon dioxide in the atmosphere (Drever, 1997).

5.4 Fate and Transport Evaluation

Based on the preceding organic compound and degradation indicator analysis, it is apparent that microbial degradation is having a positive effect on the migration of organic compounds at the site. The majority of the individual organic compounds are only detected within the NAPL plume footprint and the portion of the groundwater plume immediately downgradient from the NAPL area.

While additional site characterization data are needed for quantitative analysis, a simple extent comparison helps to illustrate the effect microbial degradation is having on the extent of organic compounds. If it is assumed that the hydraulic conductivity of the more permeable portions of the aquifer is 50 feet/day, the porosity is 0.30 (fraction), and the hydraulic gradient is 0.001 (Figure 5-5), the groundwater velocity is calculated to be 60 feet per year. Assuming the NAPL has been on the water table since approximately 1980 (30 years), then in that time period, the groundwater would have migrated approximately 1,800 feet.

The observed EDB plume (2,400 downgradient from the edge of the NAPL plume) has migrated about the distance that can be calculated from the groundwater velocity. This indicates any EDB microbial degradation is slow. Additional data will be necessary to refine EDB fate and transport mechanisms. None of the other individual organic compounds has migrated even one-third the distance of EDB, indicating degradation is occurring with these compounds.

Benzene has migrated only ½ the distance of the TPH-GRO plume even though benzene is one of the more mobile and soluble compounds in fuel-based NAPL (Wiedemeier et al, 1999). Absent microbial degradation, benzene should migrate at least as fast as other organic compounds that comprise TPH-GRO but it obviously has not done so. The other organic compounds are just observed in the immediate vicinity of the NAPL plume that is the source of the dissolved plume compounds. Combined with the clear degradation signature presented by the dissolved oxygen, ORP, iron, and manganese data, it can be concluded that the fate and transport benzene and the other organic compounds evaluated are being affected by microbial degradation. Additional site data will be used to refine the overall details of fate and transport and calculate degradation rates for the individual compounds.

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6. INVESTIGATION-DERIVED WASTE

6.1 Well Installation Investigation-Derived Waste

Groundwater wells and SVMWs are being installed at the BFF site to support the groundwater and vadose zone investigations. As a result of the well installations, drill cuttings, and decontamination and development water are being generated, stored, and disposed as described below.

6.1.1 Drill Cuttings

Monitoring wells at the BFF site are being drilled using ARCH, and the drill cuttings are being containerized in plastic-lined steel rolloffs, pending laboratory analysis for waste characterization and disposal. Approximately 10 to 15 cubic yards of drill cuttings are being generated for each 20-cubic yard rolloff container. A composite sample is collected from each rolloff container and sent to the subcontractor laboratory for analysis in accordance with the Kirtland AFB Construction and Demolition (C&D) Landfill Acceptance Memorandum January 2009 (USAF, 2009a). A request for disposal letter is provided to Kirtland AFB for approval for each container and approved rolloffs are transported to the C&D landfill by a subcontractor. Analytical results for all BFF drill cuttings generated during the first quarter of 2011 confirmed that the drill cuttings were not considered to be RCRA hazardous waste and met the requirements for disposal at the C&D landfill. Table 6-1 details the sampling and disposal of each rolloff generated during the first quarter of 2011.

6.1.2 Decontamination and Development Water

Drill rig and associated equipment used in monitoring well installations are decontaminated using hot pressurized water. Decontamination water is collected and stored in 250-gallon totes and combined with well development water for groundwater wells, and stored in 1,500-gallon tanks. Wastewater is stored at the BFF site pending analytical results for disposal in accordance with the "Kirtland AFB Bulk Fuels Development and Sampling Purge Water Decision Tree – 12/17/10" (NMED, 2010e). Once approval for discharge is obtained from NMED-GWQB and Kirtland AFB, the wastewater is discharged from the storage container to an approved location on the BFF site, away from any water course. Two wastewater samples from first-quarter 2011, required off-site disposal due to elevated detections of regulated contaminants. Table 6-2 details the sampling and disposal of each wastewater container.

6.2 Groundwater Sampling Investigation-Derived Waste

Quarterly groundwater sampling at BFF monitoring wells generated IDW purge water. Purge water was generated and stored at each monitoring well location pending the analytical results and subsequent disposal determination in accordance with the "Kirtland AFB Bulk Fuels Development and Sampling Purge Water Decision Tree-12/17/10" (NMED, 2010e). Purge water was stored in labeled 55-gallon polyethylene, open-top drums with sealable lids. For monitoring wells located on Kirtland AFB, the purge water drums were labeled, closed and sealed, and stored proximate to the well. Purge water generated from sampling monitoring wells located on property outside of Kirtland AFB was drummed, labeled, sealed, and transported back to Kirtland AFB and stored at the BFF site adjacent to the contractor field office, pending groundwater sample analyses and IDW disposal decisions. Exceptions to the above procedures were for monitoring wells that historically exhibit a presence of LNAPL on the groundwater. For these wells, purge water was stored at the well in 55-gallon polyethylene sealable open-top U.S. Department of Transportation (DOT) shipping drums and then manifested as hazardous waste for benzene, not otherwise specified, and removed from the site by a subcontracted waste management firm for off-site disposal. Table 6-3 details the monitoring wells and volume of purge water generated during the first-quarter 2011 sampling event. During the first quarter of 2011, purge water for five wells was disposed of off site as hazardous waste (KAFB-1065, KAFB-1066, KAFB-1068, KAFB-10610, KAFB-10614). For all other monitoring wells, purge water was stored pending analytical results to determine final disposition, which will occur during the second quarter of 2011.

6.3 SVE ICE Investigation-Derived Waste

SVE ICE systems were operating at four locations during the first quarter of 2011. SVE ICE systems are in operation at the FFOR, collectively known as ST-106, and on groundwater monitoring wells KAFB-1065, KAFB-1066, and KAFB-1068. The IDW generated by these SVE ICE systems include non-regulated or recyclable materials associated with routine, scheduled engine maintenance including used air filters, used oil filters, spark plugs, motor oil, and anti-freeze. Additionally, during periods of cold temperatures, the ICE systems generate condensate from the extracted soil vapor, which is captured in integrated knock-out system drums and manifested as hazardous waste. The condensate waste is removed by a subcontractor for off-site disposal.

Scheduled maintenance of the SVE ICE systems occur biweekly and consists of oil and filter changes at a minimum and additional maintenance tasks performed at monthly, quarterly, semi-annual, and annual intervals. Waste oil and waste anti-freeze are stored in 55-gallon, DOT, closed-top, steel drums at the ST-106 SVE ICE location. Once full, the drums are picked up for recycling by a vendor providing the service to Kirtland AFB. Drums are picked up for recycling on the vendor’s route schedule. During the first quarter of 2011, there were no pickups of waste oil or anti-freeze. Drums were stored on site awaiting pickup during the second quarter.

Soil-vapor condensate generated by the SVE ICE systems was disposed of off site as hazardous waste, four times during the first quarter of 2011. All drums of condensate are manifested as hazardous waste for flammable liquids, not otherwise specified, and containing benzene and water. The dates for condensate hazardous waste pickups and the transported quantities are shown in Table 6-4.

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7. CONCEPTUAL SITE MODEL

7.1 Regional Geology

The geology at Kirtland AFB ranges from mountainous, with elevations reaching 7,900 feet above mean sea level, in the eastern extent of the installation, to the Albuquerque Basin in the west. The mountains in the eastern portion of Kirtland AFB are composed of Precambrian metamorphic and crystalline rock and Paleozoic sedimentary rock. The Kirtland AFB BFF Spill site is located in the western portion of the installation, in the Albuquerque Basin. The geology of the Albuquerque Basin includes unconsolidated and semi-consolidated sedimentary deposits.

The Albuquerque Basin contains the through-flowing Rio Grande. Basin-wide, the deposits are primarily interbedded gravel, sand, silt, and clay. The clay layers are of variable thickness and lateral extent. The thickness of the basin fill deposits is variable throughout the basin due to faulting, but is thicker than 3,000 feet in most of the basin (Kelly, 1977).

The geologic materials of interest for the Kirtland AFB BFF are the Santa Fe Group and the piedmont slope deposits. The Santa Fe Group consists of beds of unconsolidated to loosely consolidated sediments and interbedded volcanic rocks. The materials in the Santa Fe Group range from boulders to clay and from well-sorted stream channel deposits to poorly sorted slope wash deposits. Alluvial fan materials were deposited unconformably over the Santa Fe Group and extend westward from the base of the Sandia and Manzano mountains. Within the alluvial deposits, materials range from poorly sorted mud flow material to well-sorted stream gravel. Beds consist of channel fill and interchannel deposits. The fan thicknesses range from 0 to 200 feet and thicken towards the mountains. The Santa Fe Group under the BFF is further broken down into two depositional facies called the USF-1 and USF-2 (Hawley et al., 1995).

7.2 Site-Specific Geology

NMED cross-section transects are shown on Figure 7-1. The subsurface geology at the site consists of younger deposits overlaying the Santa Fe Group, a system of unconsolidated Tertiary-aged fluvial (ancestral Rio Grande lithofacies), and alluvial deposits from the Middle Rio Grande Basin. The top 100 to 150 feet constitutes USF-1 (Figure 7-2 through 7-5) and consists primarily of sand with interbedded silt and clay layers. The silt and clay layers in this top depositional unit vary from a few feet thick to 170-feet thick (in KAFB-106135) (Figure 7-4). The silt and clay layers are low permeability and therefore are likely to impede downward flow of water and contamination. Sands range from well-graded to poorly-graded and range in thickness from 0 to 60 feet. These higher permeability layers could provide pathways for water and contamination to migrate within the upper depositional unit.

A second depositional unit, USF-2, is observed in the subsurface geology at the BFF and appears to be a highly permeable unit. This unit is at depths greater than 100 feet and consists of sands and gravels to depths of 500 ft bgs. The sands are poorly to well graded and range in thickness from 1 foot to 250 feet. Clay lenses are observed within this unit, with the most notable lens shown in the A-A’ cross section (Figure 7-2). This depositional unit also has gravel lenses, likely channel deposits, that are thick (approximately 50 feet) and of unknown lateral extent (Figure 7-3).

Geologic logs for existing and newly installed monitoring wells and geophysical logging data indicate a high amount of variability within the two depositional units. Material ranges from dry to moist to the water table.

7.3 Hydrology

The regional aquifer for the majority of the Albuquerque Basin is contained in the upper and middle units of the Santa Fe Group. The groundwater system at Kirtland AFB is also referred to as the Middle Rio

Grande Basin. In general, the upper unit of the Santa Fe Group contains the most productive portion of the regional aquifer that supplies water to the City of Albuquerque, VA, and Kirtland AFB.

Depths to water in the regional aquifer vary widely across the basin and are dependent on structural influence. The eastern extent of the basin has depths to water of approximately 190 ft bgs, whereas depths to water towards the western edge of the basin are on the order of 450 to 570 ft bgs. Depths to water measured at the BFF range from 458.44 to 498.63 ft bgs (March 2011 measurements).

Groundwater flow directions in the regional aquifer is generally westward, towards the Rio Grande. Locally to the BFF Spill site, the groundwater flow direction is approximately north-northeast with locally variable directions south of Ridgecrest. Groundwater flow direction at the BFF is influenced by production well pumping for both the City of Albuquerque and Kirtland AFB. The groundwater gradient at the BFF varies from 0.0005 to 0.002 ft/ft. A 4- to 6-foot increase in water levels has been observed at the site since 2009, which is most likely due to the water conservation practices put into place by the Albuquerque Bernalillo County Water Utility Authority to reduce groundwater withdraws from the aquifer.

7.4 Fate and Transport

Based on the analysis of current and existing organic compound and degradation data, it is apparent that microbial degradation is occurring and that it has a positive effect on the migration of organic compounds at the site. The EDB plume observed is approximately 2,400 feet downgradient from the edge of the NAPL plume and indicates that microbial degradation is slow. Benzene, one of the more mobile and soluble compounds in fuel-based NAPL, has migrated only half the distance of the TPH-GRO plume. The other organic compounds are observed within the immediate vicinity of the NAPL plume that is the source of the dissolved plume compounds. Additional support for microbial degradation comes from the signature presented by the dissolved oxygen, ORP, iron, and manganese data.

7.5 Data Gaps

Additional data is required for a more complete analysis of the conceptual site model for the BFF. Below is a list of identified data gaps:

- Aquifer properties (e.g., hydraulic conductivity, grain size, porosity, etc.);
- EDB fate and transport mechanisms;
- Subsurface contouring of contamination concentrations in soil, soil vapor, and groundwater; and
- Additional degradation indicator data (e.g., sulfate, alkalinity, etc.).

8. PROJECTED ACTIVITIES

Anticipated activities to be conducted during the second quarter of 2011 at the BFF site include but are not limited to ongoing groundwater and soil-vapor monitoring, installation of groundwater and SVMWs, and continued operation and maintenance of the BFF SVE systems. In addition, activities associated with the monitoring and remediation at the BFF site will be ongoing including analytical testing, data validation, data management, and reporting.

8.1 Quarterly Monitoring Activities

Quarterly groundwater and soil-vapor monitoring and related field activities will be ongoing in the second quarter of 2011 as follows:

- Depth to water measurements will be made in existing monitoring wells monthly and in new monitoring wells as they become available after installation and development.
- Quarterly groundwater sampling activity will sample the existing 4-inch diameter monitoring wells and new 5-inch diameter monitoring wells that have been installed and developed prior to sometime in May allowing at least 2 weeks post development.
- Quarterly sampling of SVMWs, SVEWs, SVE ICEs, and groundwater monitoring wells will begin on April 1, 2011 and continue throughout the second quarter ending June 20, 2011. All available newly installed (first quarter and early second quarter) SVMWs and SVEWs will be sampled for the first time.
- New dedicated Bennett sample pump systems are expected to be installed in the remaining 4-inch diameter monitoring wells and two new 5-inch monitoring wells. Additional dedicated Bennett sample pump installations will be made as newly manufactured equipment is received from the vendor for newly constructed and developed monitoring wells.
    - KAFB-10621,
    - KAFB-10625,
    - KAFB-10626,
    - KAFB-10628,
    - KAFB-106044, and
    - KAFB-106045.
- Dedicated Bennett sample pump systems will be specified as new wells are constructed and ordered from the vendor. Approximately ten dedicated sample pump systems per month are expected to be received and those will be scheduled for installation.

- Planned demolition and rebuilding of flush monitoring well surface completions will allow for installation of new dedicated Bennett sample pump systems in monitoring wells:
  - KAFB-10622,
  - KAFB-10623,
  - KAFB-10624, and
  - KAFB-10610.
- Pump system repairs and maintenance will be performed as needed and as determined throughout the quarter based on observations during monthly water-level sweeps and groundwater sampling.

8.2 Drilling Program

The groundwater and SVMW drilling program will progress from south to north. VA Medical Center and Bullhead Park well locations will be installed followed by neighborhood cluster locations. Groundwater monitoring well installation will continue next quarter with plume core well clusters 11, 12, 17, and 18 and plume margin well cluster No. 7.

A total of 12 SVMWs remain to be installed on Kirtland AFB. Of these 12, four are currently in progress. The remaining eight SVMWs will be installed once AST 2440 has been demolished and removed. These wells will be included in the quarterly soil-vapor sampling program starting the second quarter.

8.3 SVE Systems

With continued operations of the SVE and treatment systems at BFF, the scheduled O&M to maintain these systems, and sampling activities established to monitor presence of hydrocarbons and treatment progression will continue. Monthly vapor samples were not taken using a Horiba analyzer during the first quarter of 2011. These samples will resume during the second quarter of 2011 and will be taken to analyze system influent vapor, and pre-catalytic and post-catalytic exhaust. Quarterly sampling with a Horiba analyzer will continue at SVMWs, SVEWs, and groundwater monitoring wells. First-quarter 2011 laboratory analytical data will be reviewed and discussed in the second-quarter 2011 quarterly report, following validation of data. Treatment optimization activities will take place to evaluate and improve the effectiveness of the system. Shutting down one of the two engines from SVE units will be considered as well as replacing the ICEs with blowers for vapor extraction.

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