KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

Quarterly Pre-Remedy Monitoring and Site Investigation Report for January – March 2013

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

June 2013

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2050 Wyoming Blvd. SE
Kirtland AFB, New Mexico 87117-5270
QUARTERLY PRE-REMEDY MONITORING AND SITE INVESTIGATION REPORT JANUARY – MARCH 2013

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

June 2013

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

USACE Contract No. W912DY-10-D-0014
Delivery Order 0002

Prepared by
Shaw Environmental & Infrastructure, Inc.
(A CB&I Company)
9201 East Dry Creek Road
Centennial, Colorado 80112
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Commander, 377th Air Base Wing

This document has been approved for public release.

KIRTLAND AIR FORCE BASE
377th Air Base Wing Public Affairs
PREFACE

This Quarterly Pre-Remedy Monitoring and Site Investigation Report for January – March 2013 has been prepared by Shaw Environmental & Infrastructure, Inc. (Shaw) (a CB&I company) for the U.S. Army Corps of Engineers (USACE), under Contract No. W912DY-10-D-0014, Delivery Order 0002. It pertains to the Kirtland Air Force Base (AFB) Bulk Fuels Facility (BFF) 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 U.S. Air Force, dated April 2, June 4, August 6, and December 10, 2010.

This work was performed under the authority of USACE Contract No. W912DY-10-D-0014, Delivery Order 0002. All work was conducted from January through March 2013. Mr. Walter Migdal is the USACE Albuquerque District Project Manager; Mr. Wayne Bitner, Jr. is the Kirtland AFB Restoration Section Chief; and Mr. Thomas Cooper is the Shaw Project Manager. This Report was prepared by Diane Agnew and Gary Hecox.

Thomas Cooper, PG, PMP
Shaw Environmental & Infrastructure, Inc.
(A CB&I Company)
Project Manager
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# ACRONYMS AND ABBREVIATIONS

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<thead>
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<th>Description</th>
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<tr>
<td>%</td>
<td>percent</td>
</tr>
<tr>
<td>°C</td>
<td>degrees Celsius</td>
</tr>
<tr>
<td>μg/L</td>
<td>microgram per liter</td>
</tr>
<tr>
<td>μg/m³</td>
<td>microgram per cubic meter</td>
</tr>
<tr>
<td>3D</td>
<td>three-dimensional</td>
</tr>
<tr>
<td>AFB</td>
<td>Air Force Base</td>
</tr>
<tr>
<td>APH</td>
<td>air-phase petroleum hydrocarbons</td>
</tr>
<tr>
<td>ASTM</td>
<td>ASTM International</td>
</tr>
<tr>
<td>BFF</td>
<td>Bulk Fuels Facility</td>
</tr>
<tr>
<td>bgs</td>
<td>below ground surface</td>
</tr>
<tr>
<td>CATOX</td>
<td>catalytic oxidizer</td>
</tr>
<tr>
<td>CO</td>
<td>carbon monoxide</td>
</tr>
<tr>
<td>CO₂</td>
<td>carbon dioxide</td>
</tr>
<tr>
<td>COC</td>
<td>constituent of concern</td>
</tr>
<tr>
<td>CY</td>
<td>calendar year</td>
</tr>
<tr>
<td>DO</td>
<td>dissolved oxygen</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>DPT</td>
<td>direct-push technology</td>
</tr>
<tr>
<td>DRE</td>
<td>destruction removal efficiency</td>
</tr>
<tr>
<td>DRO</td>
<td>diesel range organic</td>
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<tr>
<td>EDB</td>
<td>1,2-dibromoethane/ethylene dibromide</td>
</tr>
<tr>
<td>EDC</td>
<td>1,2-dichloroethane</td>
</tr>
<tr>
<td>ELAP</td>
<td>Environmental Laboratory Accreditation Program</td>
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<tr>
<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
</tr>
<tr>
<td>ERP</td>
<td>Environmental Restoration Program</td>
</tr>
<tr>
<td>FFOR</td>
<td>Former Fuel Offloading Rack</td>
</tr>
<tr>
<td>FOD</td>
<td>frequency of detection</td>
</tr>
<tr>
<td>ft²/day</td>
<td>square feet per day</td>
</tr>
<tr>
<td>g/cm³</td>
<td>gram per cubic centimeter</td>
</tr>
<tr>
<td>g/mol</td>
<td>gram per molecule</td>
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<td>GRO</td>
<td>gasoline range organic</td>
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<td>GWM</td>
<td>groundwater monitoring</td>
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<td>GWQB</td>
<td>Ground Water Quality Bureau (NMED)</td>
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<td>HWB</td>
<td>Hazardous Waste Bureau (NMED)</td>
</tr>
<tr>
<td>ICE</td>
<td>internal combustion engine</td>
</tr>
<tr>
<td>ID</td>
<td>identification</td>
</tr>
<tr>
<td>IDW</td>
<td>investigation-derived waste</td>
</tr>
<tr>
<td>inWC</td>
<td>inches of water column</td>
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### ACRONYMS AND ABBREVIATIONS (continued)

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<td>Kirtland AFB</td>
</tr>
<tr>
<td>L</td>
<td>liter</td>
</tr>
<tr>
<td>lbs/day</td>
<td>pounds per day</td>
</tr>
<tr>
<td>LEL</td>
<td>lower explosive limit</td>
</tr>
<tr>
<td>LNAPL</td>
<td>light non-aqueous phase liquid</td>
</tr>
<tr>
<td>LOQ</td>
<td>limit of quantitation</td>
</tr>
<tr>
<td>MA DEP</td>
<td>Massachusetts Department of Environmental Protection</td>
</tr>
<tr>
<td>MCL</td>
<td>maximum contaminant level</td>
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<tr>
<td>mg/L</td>
<td>milligram per liter</td>
</tr>
<tr>
<td>mL</td>
<td>milliliter</td>
</tr>
<tr>
<td>msl</td>
<td>mean sea level</td>
</tr>
<tr>
<td>mV</td>
<td>millivolt</td>
</tr>
<tr>
<td>MW</td>
<td>molecular weight</td>
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<tr>
<td>NAPL</td>
<td>non-aqueous phase liquid</td>
</tr>
<tr>
<td>NMAC</td>
<td>New Mexico Administrative Code</td>
</tr>
<tr>
<td>NMED</td>
<td>New Mexico Environment Department</td>
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<tr>
<td>NOI</td>
<td>Notice of Intent</td>
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<tr>
<td>O₂</td>
<td>oxygen</td>
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<tr>
<td>ORP</td>
<td>oxidation-reduction potential</td>
</tr>
<tr>
<td>PID</td>
<td>photoionization detector</td>
</tr>
<tr>
<td>ppbv</td>
<td>part per billion by volume</td>
</tr>
<tr>
<td>ppmv</td>
<td>part per million by volume</td>
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<tr>
<td>QA</td>
<td>quality assurance</td>
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<tr>
<td>QAPjP</td>
<td>Quality Assurance Project Plan</td>
</tr>
<tr>
<td>QC</td>
<td>quality control</td>
</tr>
<tr>
<td>ROI</td>
<td>radius of influence</td>
</tr>
<tr>
<td>rpm</td>
<td>revolution per minute</td>
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<tr>
<td>scfm</td>
<td>standard cubic feet per minute</td>
</tr>
<tr>
<td>SDG</td>
<td>sample delivery group</td>
</tr>
<tr>
<td>Shaw</td>
<td>Shaw Environmental &amp; Infrastructure, Inc. (A CB&amp;I Company)</td>
</tr>
<tr>
<td>SM</td>
<td>Standard Method</td>
</tr>
<tr>
<td>SSL</td>
<td>soil screening level</td>
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<td>SVE</td>
<td>soil-vapor extraction</td>
</tr>
<tr>
<td>SVEW</td>
<td>soil-vapor extraction well</td>
</tr>
<tr>
<td>SVMW</td>
<td>soil-vapor monitoring well</td>
</tr>
<tr>
<td>SVOC</td>
<td>semivolatile organic compound</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>TMB</td>
<td>trimethylbenzene</td>
</tr>
<tr>
<td>TPH</td>
<td>total petroleum hydrocarbons</td>
</tr>
<tr>
<td>USACE</td>
<td>U.S. Army Corps of Engineers</td>
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<tr>
<td>USCS</td>
<td>Unified Soil Classification System</td>
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<tr>
<td>VA</td>
<td>Veterans Affairs</td>
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<tr>
<td>VOA</td>
<td>volatile organic analysis</td>
</tr>
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<td>VOC</td>
<td>volatile organic compound</td>
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EXECUTIVE SUMMARY

This Quarterly Pre-Remedy Monitoring and Site Investigation Report has been prepared in response to correspondence dated June 4, 2010, from the New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) (NMED, 2010a) to Kirtland Air Force Base (AFB), which outlines 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 (BFF) Spill, Kirtland AFB, New Mexico. Quarterly reporting incorporates 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 BFF Spill site.

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

While the major site characterization findings from the quarterly reports are cumulative, the text reflects investigative findings from First Quarter calendar year (CY) 2013 only. Cumulative data from past quarters can be found in the appendices of this report:
Vadose Zone

- Based on the three-dimensional (3D) distribution of soil and vapor concentrations, most of the vadose zone contaminant mass is located within 100 to 150 feet above the present-day water table at depths of 350 to 500 feet below ground surface (bgs).

- Based on the data collected to-date and the soil concentration footprints at various depths, the soil concentrations indicate that the non-aqueous phase liquid (NAPL) migrated in a predominantly vertical direction along relatively narrow pathways until it reached the capillary fringe above the water table where it spread out in horizontal directions. The PneuLog® testing has further delineated these pathways.

- 3D volumetric analysis shows that the current extent of soil contamination, as defined by soil vapor concentrations of total petroleum hydrocarbons greater than 10 milligrams per kilogram, is approximately 29 million cubic yards with 12.4 million cubic yards (43 percent) at or below an elevation of 5,000 feet above mean sea level (approximately 350 feet bgs).

- Compared to the Fourth Quarter CY 2012 and previous vapor plume maps, the First Quarter CY 2013 total volatile organic compound concentration footprints in the range greater than 1,000 parts per million by volume have decreased.

- The benzene vapor plume footprints at all elevations have decreased in the First Quarter CY 2013 compared to Fourth Quarter CY 2012. Additional data collected from future scheduled quarterly sampling events should help in determining the cause for the decrease in benzene.

- The PneuLog® data indicate that the water table was at approximately 350 feet when the NAPL releases started.

- Shakedown testing was performed on January 22 and 23, 2013, to determine the maximum running conditions of the SVE System. The system was then turned off, and the vadose zone was allowed to re-equilibrate. The first phase of radius of influence testing started on January 28, 2013, and was conducted to determine the optimal running conditions of the SVE System. Three-week-long step tests were performed with the vapor and dilutions valves set to the positions determined during shakedown testing.

- The shallow vadose zone investigation is ongoing as part of the FFOR interim measure. The original phase of sampling was completed during Second and Third Quarters 2011. The first round of step-outs based on original sampling results was collected in Second Quarter 2012. The second round of step-outs will be completed in Second Quarter 2013. Subsequent rounds of step-out sampling will continue until the area for excavation is defined in accordance with the Interim Measures Work Plan (U.S. Army Corps of Engineers, 2011d). The available data are presented in the First Quarter CY 2013 Report. Once the excavation area is defined, the complete data set will be included in the applicable quarterly report. The results from the FFOR interim measure will be incorporated into the Vadose Zone RFI Report and conceptual site model to demonstrate the nature and extent of contamination at depth, including the area near the FFOR.

Groundwater and NAPL

- Historical water level data for well Kirtland AFB (KAFB)-3 show that the groundwater table has declined approximately 140 feet since 1949 with the majority (approximately 100 feet) of this decline occurring since the mid-1970s.
• As the water table has declined as a result of regional groundwater extraction, the NAPL from the initial and subsequent releases has followed the falling water table downward. Over time, this has had the effect of creating a residual NAPL smear zone from nominal depths of 400 to 500 feet bgs.

• Based on an analysis of historical and current groundwater levels at the site, the water table has risen between approximately 4 and 8 feet since 2009. This rise can be attributed to the water conservation practices implemented by the City of Albuquerque and the San Juan-Chama Diversion Project completed in December 2008 to reduce groundwater withdrawals.

• These rising water levels have caused a number of wells to have screens that are now flooded with the top of the screen below the current water table. First Quarter CY 2013 measurements show that groundwater elevations now exceed the top of the screens in 10 shallow groundwater monitoring wells. As of January 2013, 10 Shallow Zone wells have flooded screens, 7 wells have their tops of screen within 2 feet of the water table, and 36 wells have their tops of screens more than 2 feet above the water table.

• Rising groundwater levels continue to result in decreases in NAPL thickness and observations in monitoring wells. NAPL was detected in one monitoring well (KAFB-106076) during this quarter. Additionally, the NAPL thickness at this well is the lowest it has been measured since KAFB-106076 was installed. If water levels continue to rise, there will likely be no measurable thickness in future quarters. The majority of the NAPL mass observed in 2009, the year of lowest water levels, is now trapped below the water table.

• NAPL chemical analytical results show that the trapped NAPL will be an ongoing source of dissolved groundwater contamination indefinitely. The final remedy will account for the submerged NAPL source.

• Current groundwater-flow directions are toward the KAFB-3 and Ridgecrest water supply wells with an average groundwater velocity of 95 feet per year and a range of 18 to greater than 300 feet per year, and has changed direction to a more easterly direction than was previously observed. The current flow direction is to the northeast at a direction of North 35° to 50° East depending on location.

• The groundwater-flow direction has changed in the northern portion of the site from North 25° to 35° East, to North 35° to 50° East. This may be the result of changes to the City of Albuquerque water well pumping volumes, particularly in the Ridgecrest well field. Additionally, the groundwater flow direction turns almost due east at the northern extent of the study site. This is most likely a result of pumping at the Kirtland AFB water supply well KAFB-3, which is located approximately 100 feet to the east of KAFB-106203.

• The leading edge of the 1,2-dibromoethane/ethylene dibromide (EDB) plume is approximately 4,000 feet downgradient of the leading edge of the NAPL area. The three newest monitoring well clusters are downgradient of the plume, with the nearest cluster approximately 700 feet downgradient of the leading edge, and the farthest cluster approximately 2,200 feet downgradient. The estimated EDB migration rate is between 80 and 200 feet per year (Section 5.7). The entire EDB plume, including the NAPL area, is approximately 5,900 feet long.

• Based on the analysis of the degradation indicator compounds (e.g., dissolved oxygen, oxidation-reduction potential, alkalinity, iron, and manganese), it appears that microbial degradation is limiting the extent of a majority of the organic compounds, including benzene, toluene, and total xylenes. In addition, these organic compounds have not migrated significantly beyond the historical NAPL area,
which also indicates degradation. Additional evaluations are required to quantify the degradation rates and impact on future plume migration.

• The effect of microbial degradation on EDB migration rates and extent is more uncertain, and the current extent of EDB is a strong indication that any EDB degradation rates are quite slow. Additional compound-specific microbial and isotope data are required to determine whether microbial degradation is having any effect on EDB migration. Activities to acquire these additional data are planned for the Third Quarter CY 2013.

• Based on a screening process that accounts for a frequency of detection (5 percent), and a comparison between the maximum detected concentrations and NMED and U.S. Environmental Protection Agency regulatory screening levels, the following analytes are determined to be groundwater constituents of concern:

  − Shallow Zone: EDB; 1,2-dichloroethane; benzene; bis (2-ethylhexyl) phthalate; dibenzo(a,h)anthracene; ethylbenzene; iron; manganese; methylene chloride; naphthalene; nitrogen (nitrate as N); phenol; sulfate; tetrachloroethene; toluene; trichloroethene; and xylenes (total)

  − Intermediate Zone: EDB; benzene; ethylbenzene; iron; manganese; and naphthalene

  − Deep Zone: EDB; bis (2-ethylhexyl) phthalate; and manganese
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, 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 non-aqueous phase liquid (NAPL)-impacted groundwater component of the project is designated as SS-111.

This Quarterly Pre-Remedy Monitoring and Site Investigation Report (also referred to as the First Quarter Calendar Year [CY] 2013 Report) has been prepared to summarize ongoing site investigation, and remedial and pre-remedy monitoring activities at ST-106 and SS-111 at BFF Spill site at Kirtland AFB, New Mexico (U.S. Environmental Protection Agency [EPA] Identification [ID] Number NM9570024423/HWB-KAFB-10-004). As specified by the New Mexico Environment Department (NMED) – Hazardous Waste Bureau (HWB) in its regulatory letter dated June 4, 2010, to Kirtland AFB (NMED, 2010a; Appendix I-4), 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 for characterization and remediation activities at the BFF Spill site.

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; Appendix I-4). Historically, semiannual 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 NAPL in the groundwater at SS-111. Activities and data related to ST-106 were conducted as the Stage 2 abatement action under the NMED-GWQB–approved *Stage 2 Abatement Plan for the Bulk Fuels Facility (ST-106)* (U.S. Air Force, 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 NAPL impacts to groundwater. Following the discovery of SS-111, Kirtland AFB instituted NAPL recovery directly from the aquifer surface at three well locations, using the same SVE technology approved for the Stage 2 abatement action for ST-106. These actions were conducted as interim measures while site characterization activities continued.

This First Quarter CY 2013 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 2013. Quarterly reports present data and information related to ongoing activities at the BFF Spill site, including the following:

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

Quarterly reports continue to allow information regarding successive investigation phases to be regularly disseminated to stakeholders by being presented in context with other site-related data. Data collected during each quarter are presented in the related quarterly report text; however, cumulative data or data collected from previous quarterly reports are presented in the appendices. In addition, all text discussion remains cumulative where necessary for the period of the site investigation. Reporting requirements specified in the letter from the NMED-HWB dated June 4, 2010, include the following (NMED, 2010a; Appendix I-4):

- 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 (SVMWs) (if applicable)
• Measurements of light non-aqueous phase liquid (LNAPL) (referred to as NAPL in the report text)
• 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 (QA)/quality control (QC) data
• Projected activities and future recommendations (also included in specific sections)

These requirements are incorporated into this First Quarter CY 2013 Report for January through March 2013, as applicable. The following appendices provide information that supplements this First Quarter CY 2013 Report:

• Appendix A, “Summary of SVE System Operation, Maintenance, Repair, and Hydrocarbon Recovery Calculations”
• Appendix B, “Data Quality Evaluation Reports and Data Packages”
• Appendix C, “Waste Disposal Documentation”
• Appendix D, “Well Installation Forms”
• Appendix E, “Historical Data Summaries”
• Appendix F, “Time-Series Plots”
• Appendix G, “Field Sampling Data and Records”
• Appendix H, “Slug Test Results”
• Appendix I, “Correspondence”
• Appendix J, “Additional Cross-Sections”
• Appendix K, “NAPL and Soil Hydraulic Property Laboratory Reports”
• Appendix L, “Radius of Influence Test Report”
• Appendix M, “Geophysical Records”

In the following sections of the report, the term NAPL is used to describe the mixture of separate-phase organic liquid that has been observed in the subsurface.
2. SVE REMEDIATION SYSTEM PERFORMANCE

This section describes the operations and performance of the BFF SVE System during the reporting period from January through March 2013. The SVE and SVM wells are presented on Figure 2-1. Detailed operations data and calculations are presented in Appendix A.

2.1 SVE Remediation System Description, Monitoring, and Calculations

2.1.1 Description of SVE System

As part of the Phase II Remediation Interim Measures Plan, the internal combustion engine (ICE) unit-based SVE action was replaced with a system designed for longer-term operation (U.S. Army Corps of Engineers [USACE], 2011d). The SVE System design is in compliance with federal and state regulations and requirements. The primary element of the installation of a new SVE System is to increase hydrocarbon removal from the BFF vadose zone soil. The increased hydrocarbon removal will not only increase treatment of contaminated soil in the vadose zone, but will also allow additional radius of influence (ROI) and other tests to be performed. As the SVE System operates, data gathered from the system and the surrounding monitoring wells will provide more information for characterization and evaluation of the contamination, which will provide feedback for the Corrective Measures Evaluation final remediation system design and inform any additional interim measures that may be necessary.

The new SVE System includes two SVE wells (Kirtland AFB [KAFB]-106161 and KAFB-106160), an aboveground piping manifold that transports the vapors to a blower skid, and a catalytic oxidation unit to destroy the hydrocarbon vapors in the extracted well gas. The SVE System is designed to extract up to 1,600 standard cubic feet per minute (scfm) of air, containing up to 3,450 parts per million by volume (ppmv) total hydrocarbons from the two SVE wells, which results in the removal of over 2,200 pounds per day (lbs/day) of hydrocarbon from the soil. Initially, the well gas is expected to contain roughly 6,800 ppmv total hydrocarbons, and the flow rate of the well gas will be reduced to around 800 scfm. This
is necessary to limit the hydrocarbon mass removal rate to the catalytic oxidizer (CATOX) design capacity of 2,200 lbs/day. Over time, the total hydrocarbons in the well gas are expected to decrease, and the flow rate will be increased to maximize hydrocarbon removal.

The SVE wells are installed at locations with the highest measured and estimated concentrations of constituents of concern (COCs) to maximize remediation potential. The aboveground manifold is roughly 200 feet of 8-inch-diameter and 600 feet of 6-inch-diameter polyethylene pipe mounted on sleepers. The SVE blower skid includes a knock-out pot for removing and collecting entrained NAPL and condensate, and a positive displacement blower fitted with silencers and inlet filters. The CATOX is a natural gas-fired unit designed for 98 percent (%) minimum destruction of hydrocarbons. It includes an inlet-system fan burner and burner-control systems, a catalyst bed, a heat-recovery exchanger, and an exhaust stack. With the high hydrocarbon content of the SVE well gas and the heat recovery exchanger, the CATOX will require very little natural gas until total hydrocarbon concentrations in the SVE well gas drop below 1,500 ppmv. Condensate generated from system operation will be collected in a standard, aboveground fuel storage tank that is equipped with gages and alarms that are tied into the system control panel. The tank will be maintained in accordance with Resource Conservation and Recovery Act and NMED requirements, specifically Title 40 Code of Federal Regulations, Parts 264 and 265 and 20.5 NMAC.

2.1.2 New SVE System Installation

Construction of the new SVE treatment system was started in October 2012 and was completed on January 21, 2013. Shakedown testing was performed on January 22 and 23, 2013, to determine the maximum running conditions of the SVE System. Initially, the motor speed was set to 1,400 revolutions per minute (rpm), the well vapor valves were fully closed, and all dilution valves were fully open. The well vapor valves were then opened incrementally, and the dilution valves were closed incrementally. With each change, measurements of temperature, pressure, differential pressure, and photoionization...
detector (PID) readings were recorded from different locations on the SVE System (Table 2-1). From this test, it was determined that the maximum running conditions are as follows:

- Motor speed: 1,400 rpm
- Well vapor valves: fully open
- Well dilution valves: half open
- Chain wheel dilution valve: fully closed

When the SVE well dilution valves were closed to one-fourth open, the temperature in the CATOX unit quickly increased to automatic shut-down levels, and was not able to equilibrate. Consequently, the conditions listed above were determined to be the maximum running conditions.

Following the shakedown testing, the vadose zone was allowed to re-equilibrate until January 28, 2013, at which point ROI testing started (refer to Section 3.2.9 for a complete discussion of the ROI tests). The first phase of ROI testing was conducted to determine the optimal running conditions of the SVE System. Three week-long step tests were performed with the vapor and dilutions valves set to the positions determined during shakedown testing. The motor speed was set to 700 rpm during ROI Test 1, to 1,050 rpm during ROI Test 2, and to 1,400 rpm during ROI Test 3. The SVE System lower explosive limit (LEL) meter regularly reached alarm levels during ROI Test 3. Consequently, it was determined that the system should be run at 1,050 rpm. The second phase of ROI testing consisted of performing monitoring for 4 weeks, while the system was set to optimal running conditions. After 2 weeks of testing with the system running at 1,050 rpm, the LEL meter was re-calibrated, and it was determined that the system could be run at 1,400 rpm without reaching LEL meter alarm levels. For the remaining 2 weeks of monitoring, the system was run at 1,400 rpm. The ROI of the system was determined to be isotropic and approximately 300 feet in all directions.
2.1.3 Vapor Monitoring and Sampling

During the reporting period, vapor samples from vapor extraction and monitoring wells, and SVE System inlet and exhaust ports, were analyzed using the field Horiba Mexa 554J emissions analyzer for petroleum hydrocarbon concentration in ppmv and for percent oxygen (O₂), carbon monoxide (CO), and carbon dioxide (CO₂) (Table 2-2).

Soil-vapor samples for laboratory analysis were collected from all SVE and SVM wells during the First Quarter CY 2013. Laboratory analytical data packages for vapor samples collected during the First Quarter CY 2013 are provided on compact disc at the end of this report. Appendix B-3 presents the Data Quality Evaluation Report for the SVE data collected during First Quarter CY 2013.

2.1.4 Calculation of Destructive Removal Efficiency

Field or laboratory analytical data from the SVE System influent and exhaust samples provide information on the treatment efficiency of each SVE unit. The treatment destruction removal efficiency (DRE) for each unit is calculated as follows:

\[
DRE = \frac{Influent \ Conc. - Effluent \ Conc.}{Influent \ Conc} \times 100
\]

The DRE values for each unit are presented in Table 2-3.

2.1.5 Calculation of Hydrocarbon Remediation Attributable to Natural Attenuation Through Bioventing

The Air Force Civil Engineer Center – Environmental Center of Excellence has published guidance to account for the attenuation of petroleum hydrocarbons by bioventing (Leeson and Hinchee, 1996a and b). The mass of petroleum hydrocarbons biodegraded can be calculated using the following equations:
1. \( HC_{\text{BioM}} = (C_{V,bkgd} - C_{V,O2})/100 \times Q \times C_r \times \rho_{O2} \times MW_{O2} \times (28.3 /\text{ft}^3) \times (\text{kg}/1,000\text{g}) \times (1,440 \text{ min/day}) \times (2.2 \text{ lb/kg}) \times D \)

2. \( HC_{\text{BioV}} = HC_{\text{BioM}} \times (1/6.2 \text{ gal/lb}) \)

Where:

- \( HC_{\text{BioM}} \) = Mass of hydrocarbons biodegraded (pound)
- \( HC_{\text{BioV}} \) = Volume of hydrocarbons biodegraded (gallon)
- \( C_{V,bkgd} \) = Concentration of oxygen in background, uncontaminated area (%)
- \( C_{V,O2} \) = Concentration of oxygen in extracted off-gas (%)
- \( Q \) = Flow rate (scfm)
- \( C_r \) = Mass ratio of hydrocarbon to oxygen degraded based on stoichiometry (1/3.5)
- \( \rho_{O2} \) = density of oxygen (moles/liter), 0.0346 mol/L for Albuquerque, New Mexico and 25degree Celsius
- \( MW_{O2} \) = Molecular weight of oxygen (grams/mole), 32 gram per molecule (g/mol) for \( O_2 \)
- \( D \) = Days in operation during quarter

The summary of the vapor operating data, including the calculated quarterly biodegradation, for First Quarter CY 2013 is presented in Table 2-4. Calculations for the quarterly biodegradation are presented in Appendix A.

2.2 ST-106 FFOR SVE System and SS-111 SVE System

2.2.1 System Operation

SVE Units 249, 335, 344, and 345 were turned off on December 21, 2012, for ROI testing. The SVE ICE Units are not expected to be turned on again in the foreseeable future.

2.2.2 Hydrocarbon Recovery and Degradation

Refer to Appendix E-4, Tables E-1, E-2, E-3, and E-4 for the previous hydrocarbon recovery data of SVE ICE Units 249, 335, 344, and 345, respectively.
2.3 Waste Generation

Maintenance activities for the SVE System generated liquid condensate waste for First Quarter CY 2013. 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 condenses in the system piping. During this reporting period, insufficient liquid condensate was generated to require off-site disposal. Disposal documentation for liquid condensate waste generated in previous quarterly reports is provided in Appendix C.

2.4 SVE and Treatment System Operational Summary

During First Quarter CY 2013, operational changes continued to be evaluated to optimize the operation of the SVE System. The goal of the optimization efforts was 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. The SVE cumulative mass recovery over time is presented on Figure 2-2, and the total BTEX compounds removed from the SVE System in First Quarter 2013 is presented on Figure 2-3.

The initial testing of the stack was originally scheduled for April 15 through 18, 2013 but was cancelled due to a weld failure on the unit. Repairs have been made, and the SVE unit resumed operation on April 16, 2013. The test was then rescheduled for May 6 through 9, 2013. The May testing schedule was also cancelled due to a problem with the SVE System’s thermocouple. Shaw traced readings along the system and discovered that the thermocouple readings did not match actuals measured with a specialized instrument. Shaw has been in communication with the manufacturer of the system and the engineering team, and based on the discrepancy, there is a repair that is required at the thermocouple. Thermocouple repair required that the entire system be shut down. This repair was scheduled for Monday, May 6, 2013. The stack test was rescheduled to begin on Tuesday, June 18, 2013, and is anticipated to be completed by Thursday, June 20, 2013, or sooner.
3. SITE INVESTIGATION

3.1 Site Investigation Objectives

This First Quarter CY 2013 Report presents the monitoring methods and results for First Quarter CY 2013 field activities performed at the Kirtland AFB BFF Spill site for the period of January 1, 2013 through March 31, 2013. Where appropriate, the text and data presented in this section are cumulative from First Quarter CY 2011 through First Quarter CY 2013. The groundwater investigation is currently being implemented in conjunction with the vadose zone investigation, interim measures, and NAPL containment measures for ST-106 and SS-111. Approved work plans (USACE; 2011a, 2011f, 2011d, and 2012a) for these three projects and approved letter addenda (Appendix I-2) stating requirements for the installation of the NAPL containment well and two soil-vapor extraction wells (SVEWs) provide guidance for the work activities performed during each quarter.

Additionally, the activities described herein comply with the NMED technical directives to Kirtland AFB for performing interim measures for the BFF Spill (ST-106 and SS-111) as stated in the August 6, 2010 (NMED, 2010c; Appendix I-4) and December 10, 2010 (NMED, 2010d; Appendix I-4) letters from the NMED to Kirtland AFB. This section describes in detail the monitoring methods used and activities performed to characterize and monitor the groundwater and soil at the BFF Spill site. Sections 4 and 5 present the monitoring results for the vadose zone and groundwater, respectively.

3.2 Site Investigation Activities

Site investigation activities performed during January through March 2013 comprised ROI testing, start-up of the SVE treatment system, and quarterly groundwater and soil vapor sampling activities. No geophysical logging, FFOR soil sampling, PneuLog® well testing, slug testing, well surveying, groundwater well installation, well development, or well development was conducted during the period of January through March 2013. Appendices D and G are updated each quarter, as applicable, and present
cumulative lithologic logs, well completion diagrams, well development records, and field sampling records.

### 3.2.1 Geophysical Logging

No geophysical logging was conducted during First Quarter CY 2013. Table 3-1 provides a cumulative list of when each borehole was logged using required geophysical techniques as stated in the Groundwater Investigation Work Plan (USACE, 2011a). Logs have been provided for all boreholes that have been geophysically logged in Appendix M. The absence of any logs from the quarterly report is because the corresponding wells have not been geophysically logged at this time. Wells that have not been logged at this date include the nine newly installed groundwater monitoring wells (KAFB-106201 through KAFB-106209), the nine Pneulog® wells (KAFB-106148 through KAFB-106153), and groundwater monitoring wells (KAFB-106043 and KAFB-106066). Details regarding geophysical well logging procedures and the QC regimen that was followed can be found in Sections 3.2.1.1 through 3.2.1.4 in the Fourth Quarter CY 2012 Report (USACE, 2013).

### 3.2.2 Well Installation

#### 3.2.2.1 Groundwater Monitoring Wells

No new groundwater monitoring wells were installed during the First Quarter CY 2013. During the first three quarters of 2011, 78 groundwater monitoring (GWM) wells were completed by the subcontractor drilling companies, WDC Exploration and Wells (69 wells) and Yellow Jacket Drilling (9 wells). The GWM wells were installed at all 28 NMED-prescribed locations at depths specified for these locations in the Groundwater Investigation Work Plan (USACE, 2011a) and in accordance with Table 4 of the NMED-HWB August 6, 2010 letter (NMED, 2010c; Appendix I-4).

Nine new GWM wells were installed by Yellow Jacket Drilling during Third and Fourth Quarters of CY 2012 (Figure 3-1): KAFB-106201, KAFB-106202, KAFB-106203, KAFB-106204, KAFB-106205,
KAFB-106206, KAFB-106207, KAFB-106208, and KAFB-106209. The nine newly installed wells were surveyed during the Third and Fourth Quarters of CY 2012 (Table E-5 in Appendix E-4). Details regarding the installation of all groundwater monitoring wells can be found in Table E-6 in Appendix E-4 of this report, as well as Section 3.2.2.1 of the Fourth Quarter CY 2012 Report (USACE, 2013). During borehole advancement, the soil cuttings were logged every 5 feet by the site Geologist. Soil classification logs, and completion diagrams for GWM wells are included in Appendix D-1. All developed and surveyed groundwater monitoring well locations are shown on Figure 3-1.

During Third Quarter CY 2012, a transducer was set in KAFB-106203 to record water levels. A Kirtland pumping well, KAFB-003, is located approximately 100 feet away from KAFB-106203. The transducer recorded the water-level response to pumping and recovery at water supply well KAFB-003 in KAFB-106203.

Using the transducer data, periods of pumping and recovery were analyzed using the Cooper-Jacob Method (1946) for an unconfined aquifer in AQTESOLV™ to determine aquifer transmissivity. The average transmissivity as calculated by the Cooper-Jacob Method is 68,000 square feet per day (ft²/day). All calculated transmissivities fell within two standard deviations of this average and were in the same order of magnitude with a minimum of 33,000 (ft²/day) and a maximum of 97,000 ft²/day. The curves with the best fit to data were the pumping from the early morning of September 22, 2012, and the recovery occurring on September 23, 2012. The calculated transmissivity values for these tests were 78,000 ft²/day and 97,000 ft²/day, respectively (Table E-7, Appendix E-4).

3.2.2.2 Soil Vapor Monitoring Wells

No new SVMWs were installed during First Quarter CY 2013. All proposed SVMWs were installed and completed during the first three quarters of CY 2011. Details regarding the installation of all soil vapor
monitoring wells can be found in Table E-8 in Appendix E-4 of this report as well as Section 3.2.2.2 of the Fourth Quarter CY 2012 Report (USACE, 2013). All SVMW locations are shown on Figure 3-2.

Soil boring logs and well completion diagrams for the SVMWs are provided in Appendix D-1.

### 3.2.2.3 PneuLog® Wells

No new PneuLog® wells were installed during First Quarter CY 2013. Four PneuLog® well clusters (KAFB-106148, KAFB-106149, KAFB-106150, and KAFB-106151) were previously installed during Third Quarter CY 2011, and five PneuLog® well clusters were installed during Fourth Quarter CY 2011 (KAFB-106152, KAFB-106153, KAFB-106154, KAFB-106155, and KAFB-106156). All PneuLog® well clusters are shown on Figure 3-4. Each well cluster consists of three “nested” 3-inch-diameter well casings with three screened intervals at approximately 500 to 355, 350 to 205, and 200 to 25 feet below ground surface (bgs). All nine well clusters were surveyed during Fourth Quarter CY 2011. Details regarding the installation of all PneuLog® wells can be found in Table E-9 in Appendix E-4 of this report, as well as Section 3.2.2.3 of the Fourth Quarter CY 2012 Report (USACE, 2013). Soil boring logs and well completion diagrams are presented at the end of Appendix D-1. PneuLog well testing has been performed at three on the PneuLog wells (KAFB-106148, KAFB106149, and KAFB-106150). A description of the testing procedures and results can be found in Section 3.2.6.

### 3.2.2.4 NAPL Containment Well

A technical evaluation of the proposed well location(s) and well quantity(ies) was conducted as a result of November 3, 2011 discussions with the NMED. Subsequent to this evaluation, it was determined that a single-containment well would be sufficient for containing the NAPL plume, thus meeting the primary objective of the containment system and LNAPL Containment Interim Measures Work Plan (USACE, 2011c).
A Letter Addendum to the LNAPL Containment Interim Measures Work Plan was submitted for NMED review and approval on November 16, 2011 (Appendix I-2). In accordance with the Letter Addendum, one containment well (KAFB-106157) was installed during Fourth Quarter CY 2011 (Figure 3-1). This well location was surveyed during First Quarter CY 2012. Details regarding the installation of the NAPL containment well can be found in Table E-9 in Appendix E-4 of this report as well as Section 3.2.2.4 of the Fourth Quarter CY 2012 Report (USACE, 2013).

### 3.2.2.5 Soil Vapor Extraction Wells

A technical evaluation of the proposed SVEW locations, design, and installation was conducted as a result of discussions with the NMED on November 3, 2011. A Letter Addendum to the LNAPL Containment Interim Measures Work Plan was submitted for NMED review and approval on November 18, 2011 (Appendix I-2), which discussed the proposed well locations and design. The Letter Addendum was approved by the NMED on December 23, 2011. In accordance with the Letter Addendum, two SVEWs (KAFB-106160 and KAFB-106161) were installed and surveyed during First Quarter CY 2012 (Figure 3-3). Details regarding the installation of the soil vapor extraction wells can be found in Table E-9 in Appendix E-4 of this report as well as Section 3.2.2.4 of the Fourth Quarter CY 2012 Report (USACE, 2013). Soil boring logs and well completion diagrams are presented at the end of Appendix D-1.

### 3.2.3 Surveying

No wells were surveyed during First Quarter 2013. All surveying is conducted in accordance with the Interim Measures Work Plan (USACE, 2011d) and the NMAC Minimum Standards for Surveying in New Mexico (Title 12, Chapter 8, Section 2; NMAC, 2007). All wells are surveyed by a New Mexico-licensed professional land surveyor from Albuquerque Surveying Co., Inc. Horizontal coordinates are based on the New Mexico State Plane Coordinate System, Central Zone (North American Datum of 1983), as published by the National Geodetic Survey. Elevations are determined to the nearest 0.01 foot and
referenced to the 1988 National Geodetic Vertical Datum, which are obtained from permanent benchmarks. Survey data for all wells acquired through the end of Fourth Quarter CY 2012 are presented in Appendix E-4 (Table E-5).

### 3.2.4 FFOR Investigation

No FFOR soil investigation activities were conducted during the reporting period for First Quarter CY 2013. The scope of the FFOR sampling work is to define the area of excavation through an initial sampling event and subsequent step-out sampling events. The initial sampling event was completed in Second and Third Quarters 2011. The sampling results indicated a need for a subsequent round of step-outs, which was performed in Second Quarter 2012. A third round of step-outs is planned for Second Quarter 2013. Subsequent rounds of step-outs will continue until the excavation area is fully delineated.

The objective of the FFOR soil investigation sampling is to identify areas of shallow soil containing NAPL or hazardous constituents that exceed the NMED soil screening levels (SSLs) as part of the NMED-directed interim measures investigation (USACE, 2011d). As an ongoing task, the work is performed as specified in the correspondence dated December 10, 2010, from the NMED to Kirtland AFB (NMED, 2010d) and with procedures outlined in the Interim Measures Work Plan (USACE, 2011d). Past field work was performed during Second and Third Quarters CY 2011, as well as in Second Quarter CY 2012. No additional field work was completed in First Quarter CY 2013. Analytical data for all samples collected during both the 2011 and 2012 field work are presented in Table 3-2 of this report.

#### 3.2.4.1 Field Activities

During the Second and Third Quarters CY 2011 from June 2 through August 17, 2011, direct-push technology (DPT) was used to collect soil samples along the former pipeline at the FFOR to the Pump House (Building 1033) and from Building 1033 to the former aboveground storage tanks. DPT activities were performed by the subcontractor, JR Drilling, a licensed New Mexico drilling company. A total of
288 boreholes was completed during this time period. However, five boreholes were not completed during this time due to refusal when the DPT rig came into contact with the underground concrete sleeve that formerly housed the fuel pipeline ST-106 (Figure 3-3).

During Fourth Quarter CY 2011, the remaining FFOR soil investigation samples could not be collected due to ongoing military construction and excavation by Chugach Management Services in this area. This area is directly west of the Pump House (Building 1033) (Figure 3-3). In addition, 16 step-out locations were determined by analytical data evaluation in accordance with the Interim Measures Work Plan (USACE, 2011d). On March 1, 2012, the NMED approved the Kirtland AFB-modified approach to complete DPT work in the area of the excavation, as well as to complete the first round of step-out locations.

During April 2012, the remaining FFOR soil investigation samples near the Pump House, from the 5 boreholes in conflict with the concrete sleeve and from the 15 step-out locations, were collected. The 15 step-out locations (Figure 3-3) were based on an evaluation of the results for soil samples collected from the 288 locations during Second and Third Quarters CY 2011; the analytical results were compared with the NMED SSLs effective in 2011 (NMED, 2009), and any exceedances were flagged for step-out sampling. The NMED issued revised SSLs in June 2012 (NMED, 2012), thereby resulting in the need for additional step-out samples to be collected.

The five locations in conflict with the underground concrete sleeve were completed by coring through the concrete to achieve full advancement of the boreholes. The results for the 308 investigation samples and 16 step-out samples are being re-evaluated using the updated NMED (2012) SSLs. Once this evaluation has been completed, another round of step-out samples will be collected in accordance with the updated SSLs. The completed borehole numbers, collection dates, and coordinates are presented in Table 3-3.
3.2.4.2 Procedure

DPT sampling was initiated at the westernmost point of the FFOR, continued eastward, and then turned south; sampling around the construction area near the Pump House followed the modified approach approved by the NMED in March 2012. The entirety of the DPT sampling from the former storage tanks to Building 1033 was then completed by working from the easternmost point to the westernmost point. Sampling locations between the FFOR and Building 1033 were spaced on 10-foot centers directly over the location of the former pipeline, and 5 feet to either side as directed in the NMED correspondence (NMED, 2010d) and as described in the Interim Measures Work Plan (USACE, 2011d).

Three suspected leak locations were previously identified along the pipeline at approximately 18, 150, and 200 feet from the west end of the FFOR (Figure 3-3). These three locations were marked in a 5-foot grid to better evaluate the area of the suspected leaks. Sampling locations along the former pipeline south of Building 1033 to the former fuel storage tanks were marked 20 feet apart along two lines oriented parallel to the pipe centerline and no more than 5 feet from the pipe centerline (Figure 3-3), as outlined in the Interim Measures Work Plan (USACE, 2011d).

Shallow borings were advanced to 20 feet bgs using a 3-inch-diameter by 4-foot-long, acetate-lined, open-barrel sampler. Soil samples were collected from the surface and every 5 feet to the total depth of 20 feet, and were logged every 5 feet by the site Geologist. The soil samples were described according to the Unified Soil Classification System (USCS) (ASTM International [ASTM], 2011). Other details, such as changes in lithology, color, moisture content, consistency, detailed lithology of individual gravel units, mineralogy, observed contamination, odor, and depth to groundwater, were also noted on the soil boring log (Appendix D-3).

The QA/QC samples were collected at a frequency specified in the Interim Measures Work Plan (USACE, 2011d) to verify the accuracy of field sampling and analytical procedures. The QC samples
included field duplicates, equipment rinse blanks, matrix spike and matrix spike duplicate samples, and
trip blank and field blank samples (volatile organic compound [VOC] analysis only). Sample collection
methods for sampling from the DPT core are summarized as follows:

- **Step 1**—Once sampling depth was reached, the open-barrel sampler was pulled up smoothly and
opened. Each 5-foot interval was logged according to the USCS by a qualified Geologist.
  Descriptions of soil, such as color, classification, thickness, odor, and headspace readings, were
  recorded on Soil Boring Logs (Appendix D-3). The DPT subcontractor personnel then cut the acetate
  sleeve encasing the sample. The Sampling Technician determined the appropriate sample interval, as
  approved by the Geologist, and collected the soil in a stainless steel sampling bowl.

- **Step 2**—For each soil sample, two sodium bisulfate Terra Core volatile organic analysis (VOA) vials,
two methanol Terra Core VOA vials, one 2-ounce jar for percent moisture, one 16-ounce jar, and one
  Mason jar for headspace were filled with soil from the depth interval and covered with aluminum foil.
  A headspace reading was collected from the Mason jar through the aluminum foil cover using a PID.
  Headspace readings were recorded on both the Soil Classification Logs and Sample Collection Logs
  for each sample.

- **Step 3**—The Terra Core kit (which included the four VOA vials and the 2-ounce jar in a foam holder)
  were placed inside a 1-gallon resealable plastic bag with bubble wrap. A preprinted label was affixed
to the inside of the bag to prevent water damage. The 16-ounce jar was placed into a resealable plastic
  bag with a label affixed directly onto the jar. The jar lid was then sealed with packing tape to prevent
  water from entering the sample. After properly packing and checking each sample, the samples were
  immediately placed into a cooler on ice. Sampling equipment was decontaminated after every sample
  by using de-ionized water and Alconox® to ensure that no cross-contamination occurred.

- **Step 4**—After the completion of a borehole, the coolers containing the samples for that borehole were
  taken to the project field office trailer where they were placed into a sample refrigerator. The samples
  remained in the refrigerator until they were packed and ready for shipment to the laboratory.

After the completion of each borehole, sample names, times, dates, and depth intervals were logged into
an Oracle®-based Environmental Information Management System, and an associated chain-of-custody
form was produced for that day. The chain-of-custody forms were reviewed against the samples as a QC
procedure to ensure sample names, dates, and times corresponded. Samples were packaged and shipped in
accordance with the Interim Measures Work Plan (USACE, 2011d).

FFOR soil samples were shipped to Gulf Coast Analytical Laboratories, Inc. in Baton Rouge, Louisiana,
for analysis. Samples were analyzed for VOCs, semivolatile organic compounds (SVOCs), total
petroleum hydrocarbons (TPH)-gasoline range organic (GRO), TPH-diesel range organic (DRO), and lead. FFOR soil sampling analytical data will be presented once all sampling has been completed and the analytical data have been validated.

In the case of the step-out soil sampling, selected locations were situated 5 feet from where an exceedance was identified. The DPT probe was advanced to the depth of exceedance, and a sample was collected. Samples were analyzed only for the analyte(s) exceeded in the investigation sample. Analytical data for all samples collected during both the 2011 and 2012 field work are presented in Table 3-2 of this report. Based on the data presented in this report, an additional round of step-out sampling is required and is scheduled for second Quarter 2013.

3.2.5 Slug Testing

No slug testing was conducted during First Quarter CY 2013. Based on slug tests performed in previous quarters, the aquifer in the vicinity of the Kirtland AFB wells has a geometric mean hydraulic conductivity of 63 feet per day with a minimum of 12 feet per day and a maximum of 129 feet per day. These values are within the ranges expected for units ranging in grain size from silty sand to gravel. Geometric mean specific storage is 0.002 foot⁻¹, and the geometric mean anisotropy ratio is 0.01. Appendix H contains a complete report on previous slug tests.

3.2.6 PneuLog® Testing

During Second Quarter CY 2012, PneuLog® wells KAFB-106148, KAFB-106149, and KAFB-106150 were analyzed using PneuLog® technology developed by Praxis Environmental Technologies, Inc. (Praxis). No additional Pneulog® sampling has been performed in First Quarter CY 2013, or on any additional wells. Praxis’ technology uses pneumatic well logging to measure the vertical air permeability and chemical concentration profiles in wells screened for SVE. Down-hole instruments simultaneously measure cumulative air flow and chemical vapor concentrations along the depth of the well screen. Praxis
personnel performed the testing with oversight provided by on-site Shaw personnel. The vapor and permeability profiles for data collected during PneuLog® testing are presented in the report submitted by Praxis (Appendix N). A discussion of pneulog operating procedures, methods, and results can be found in Section 3.2.6 of the Fourth Quarter CY 2012 Report (USACE, 2013). The summary statistics for the permeability data for this well are presented in Table E-10 in Appendix E-4.

3.2.7 Quarterly Groundwater Sampling Field Activities

First Quarter CY 2013 samples from GWM wells were collected using dedicated and portable Bennett pump sampling systems. The production well samples were collected from the appropriate ports at the Pump House locations. Production well samples were not collected at KAFB-016 due to malfunction of the natural gas engine that powers the pump. Samples were not collected at KAFB-015 because the pump is shut down. Samples were not collected at well KAFB-10612 due to pump failure and dropped tubing.

Field data were obtained and analyzed using the In-Situ™ Troll 9500, and parameters included the following: temperature in degrees Celsius (°C), pH, specific conductivity in micro Siemens per centimeter, dissolved oxygen in milligrams per liter (mg/L), oxidation reduction potential in millivolts (mV), and turbidity in nephelometric turbidity units. Field alkalinity data and water level were also recorded when applicable. Samples were collected using laboratory-provided 40-milliliter (mL) VOA bottles, 1-liter (L) amber bottles, and 250-mL plastic poly bottles. Samples were then sent under chain of custody to Empirical Laboratories, LLC in Nashville, Tennessee (a Department of Defense [DoD] Environmental Laboratory Accreditation Program [ELAP]-certified laboratory).

Samples were tested for the following list of analyses:

- VOCs by EPA Method SW-846 8260B
- 1,2-dibromoethane/ethylene dibromide (EDB) by EPA Method SW-846 8011
- TPH-GRO by EPA Method SW-846 8015B
Laboratory analytical data packages for groundwater samples collected during the First Quarter CY 2013 can be found in Appendix B. Appendix B-1 presents the Data Quality Evaluation Report for the groundwater data collected. It also includes an attached reference table that identifies each sample location, sample date, sample number, and associated sample delivery group (SDG) assigned by the laboratory. Drinking water compliance sampling was not conducted during the First Quarter CY 2013.

Existing dedicated Bennett sample pumps, tubing bundles, and sounding pipes were removed as needed due to malfunction. They were repaired after removal, and tested using the compressed air-delivery systems designed for use with the Bennett model 1800-7 sample system. The sample systems were then reinstalled for operations. No new sampling systems were installed during First Quarter CY 2013.

Table E-11 in Appendix E-4 summarizes the Bennett pump sampling systems installed for the BFF site wells.

The following describes the pump system removal, re-installation, and maintenance activities performed by JR Drilling during First Quarter CY 2013:

- **March 21, 2013**
  - KAFB-106022—Repaired water discharge line. Line had cracked just above well cap.
  - KAFB-106019—Repaired water discharge line. Line had cracked just above well cap.
  - KAFB-106091—Pulled sounding pipe and tubing bundle. Replaced rusted fittings where tubing bundle meets pump.
• March 25, 2013
  
  – Well KAFB-106035—Pulled sounding pipe and tubing bundle. Removed obstruction from drop tube. Obstruction was an approximate 2-inch piece of polypropylene tubing that was wedged in the sounding pipe at 450 to 460 feet bgs.

3.2.8 Quarterly Soil-Vapor Sampling Field Activities

During the First Quarter CY 2013 soil-vapor sampling activities, samples were collected from SVMWs, SVEWs, and from the SVE CATOX unit (serial number 16512). Samples were analyzed using the field Horiba Mexa 584L emissions analyzer. Analyses were gathered for petroleum hydrocarbon concentrations and measured in ppmv as well as O₂%, CO%, and CO₂%. The soil-vapor samples were collected into pre-evacuated bottle Vac™ canisters and Tedlar™ bags. Samples were then shipped under chain of custody to RTI Laboratories, Inc. (RTI) in Livonia Michigan (a DoD ELAP-certified laboratory). Samples were tested for the following list of analyses:

- VOCs, including acetone, EDB, 1,2-dichloroethane (EDC), 1,2,4-trimethylbenzene (TMB), 1,3,5-TMB, methyl tert-butyl ether, and methyl ethyl ketone (or 2-butanone) by EPA Method TO-15 (EPA, 1999)
- Fixed gases (O₂, nitrogen, CO, CO₂, and methane) by ASTM-D2504 (ASTM, 2010)
- Air-phase petroleum hydrocarbons (APH) by Massachusetts Department of Environmental Protection (MA DEP) Method (MA DEP, 2008)

Appendix B-3 presents the Data Quality Evaluation Report for the soil-vapor data collected during First Quarter CY 2013, and also includes a reference table, which identifies each sample location, sample date, sample number, and associated SDG (column labeled “SDG”), and shows which analytical data package contains specific vapor samples. The laboratory analytical data packages for soil-vapor samples collected during the Fourth Quarter CY 2012 are provided on compact disc and website in Appendix B-4.
3.2.9 SVE Radius of Influence Testing

ROI testing was conducted during First Quarter CY 2013 to determine the ROI of the new SVE System, which began operation on January 28, 2013.

ROI testing conducted previously showed that the ICE units had an ROI of approximately 200 feet in all directions (refer to Appendix L for a complete discussion of previous ROI tests).

3.2.9.1 Procedure

All operating SVE ICE units were shut down on December 21, 2012, and the vadose zone was allowed to equilibrate. Once the vadose zone had equilibrated, the only impacts on the vacuum pressure were from natural sources, such as barometric pressure changes. From December 24, 2012 through January 8, 2013, background monitoring was conducted by collecting data to characterize the response of the natural system to barometric pressure without the influence of SVE. This data was then available to use as a reference point against which to compare test data.

Shakedown testing was conducted on January 22 and 23, 2013, to determine the maximum running conditions of the SVE System (Section 2.1.2). Following shakedown testing, the SVE System was turned off to allow the vadose zone to re-equilibrate prior to ROI testing. This action ensured that when ROI testing started, the data collected was impacted only by natural changes, such as barometric pressure, and the specific SVE System running conditions chosen for the test. On January 28, 2013, the new SVE System was turned back on, and ROI testing started. This testing consisted of two phases:

- During Phase I, three step tests were performed. The SVE System motor was run at increasing speeds for a period of 1 week each. The motor speed was 700 rpm for Test 1, 1,050 rpm for Test 2, and 1,400 rpm for Test 3.
- During Phase 2, ROI testing was conducted for 4 weeks while the system ran at normal operation levels. For the first 2 weeks, the system ran at 1,050 rpm; it then ran at 1,400 rpm for the remaining 2 weeks.
**Observation Wells**

A total of 15 observation wells, 9 PneuLog® and 6 SVM wells were selected for monitoring the ROI tests (Table 3-4, Figure 3-4). Well KAFB-106121 is at least 550 feet from the extraction wells and is therefore, expected to be well outside the ROI. It was selected as a background monitoring well, and data collected from this well is referred to as the “null point” to which data collected at other monitoring wells can be compared.

**Background Monitoring**

During the period from December 24, 2012 through January 8, 2013, eight monitoring rounds were conducted. A monitoring round occurs when vacuum pressure is read from all monitoring wells in succession. This data was collected to determine the barometric efficiency and to provide a baseline set of data with which to compare ROI test data.

**Step-Tests**

Three step tests were conducted to determine the optimal running conditions for the new SVE System; each test lasted 5 days. During each test, three monitoring rounds were conducted during each of the first 3 days, and two monitoring rounds were conducted on each of the fourth and fifth days. In addition to the vacuum pressures read at the monitoring wells, the following SVE data was collected during each monitoring round:

- Vacuum pressure at each extraction well
- Differential pressure on each extraction well, which was used to calculate flow rate
- Total hydrocarbons at each extraction well
• Temperature and differential pressure prior to the vapor entering the SVE System, downstream of the convergence of the two vapor streams from the extraction wells. This data was used to calculate the flow rate from the extraction wells, plus the dilution air at the wellheads. This data was collected beginning on February 5, 2013.

• Total hydrocarbons prior to the vapor entering the SVE System, downstream of the convergence of the two vapor streams from the extraction wells. This data was collected beginning February 5, 2013.

**4-Week Monitoring**

Following the three step-tests, the optimal motor speed was determined to be 1,050 rpm. The motor speed was then set to 1,050 rpm, and monitoring rounds were conducted four times per week for 2 weeks. After 2 weeks, the LEL meter was re-calibrated, and it was determined that the motor speed could safely be increased to 1,400 rpm. Consequently, the motor speed was then increased, and monitoring rounds were conducted at least four times per week for the remaining 2 weeks.

In addition to the data collected during the step-tests, the following data was collected beginning February 27, 2013:

• Vapor data, including total hydrocarbons, CO, CO₂, and O₂ were collected downstream of the final location where dilution air is let into the system.

• CO, CO₂, and O₂ were collected at the extraction wells and prior the vapor entering the SVE System, downstream of the convergence of the two vapor streams from the extraction wells.

**3.2.9.2 Data Analysis**

Data collected during the ROI tests were overprinted by the vadose zone’s response to changes in barometric pressure. As the barometric pressure increased, vacuum pressure in the wells screened within the vadose zone increased. This effect is particularly pronounced for wells in the deeper parts of the vadose zone, which cannot equilibrate with the atmosphere as readily as wells in the more shallow regions. Consequently, the barometric pressure had a much stronger effect on vacuum pressure in wells being monitored than did the SVE System used during ROI testing (Figure 3-5).
To determine the ROI for each extraction well, the data was corrected for barometric pressure. Hourly barometric pressure was available for download from a weather station located at the Albuquerque International Sunport, which is adjacent to Kirtland AFB.

First, the barometric efficiency of the monitoring wells was determined using data collected during the background monitoring. Barometric efficiency is a measurement of how vacuum pressure in a well responds to a change in barometric pressure, and is calculated by dividing the change in vacuum pressure by the change in barometric pressure for a given period of time.

Data collected was grouped by well type and depth. For instance, all of the data from 484 feet bgs PneuLog® wells were grouped together, all of the data from the 150 feet bgs SVM wells were grouped together, and so forth. For each of the groupings, the vacuum pressure was plotted against barometric pressure, and a best-fit line was matched to each (Figure 3-6). Correlation coefficients of the data to the best-fit lines ranged from $r^2 = 0.93$ to 0.95, thus indicating a very good match to the data. The slope of the best-fit line for each grouping was the calculated barometric efficiency for that well type and depth.

Next, for each ROI test, a vacuum pressure at a chosen mid-point for each round was estimated using the observed vacuum pressures and the calculated barometric efficiencies. During each monitoring round, the vacuum pressure for each monitoring well was measured once, which took between 90 and 120 minutes. Because the barometric pressure was changing rapidly during some periods of testing, it was necessary to estimate a vacuum pressure at a mid-point time for each well during each monitoring round to accurately compare the responses of the monitoring wells. The vacuum pressure for each well was estimated for the chosen mid-point time for each round using the following method:
First, the barometric pressure at the selected mid-point time was interpolated using hourly barometric pressure downloaded from a weather station located at the Albuquerque International Sunport, which is adjacent to Kirtland AFB. The equation used is as follows:

\[
B_{tm} = P_{b_{t_0}} + \left( \frac{P_{b_{t_1}} - P_{b_{t_0}}}{t_1 - t_0} \times [t_m - t_0] \right)
\]

Where:

- \(B_{tm}\) = Calculated barometric pressure at the selected mid-round time
- \(P_{b_{t_0}}\) = Recorded barometric pressure at the last time pressure was recorded prior to the mid-round time
- \(P_{b_{t_1}}\) = Recorded barometric pressure at the first time pressure was recorded following the mid-round time
- \(t_0\) = Time of \(P_{b_{t_0}}\)
- \(t_1\) = Time of \(P_{b_{t_1}}\)
- \(t_m\) = Time of \(B_{tm}\)

Next, the barometric pressure at the time of monitoring was interpolated using the following equations:

**Equation #1:**

\[
B_{t_0} = B_{t_{0-1}} + \left( \frac{B_{t_{0+1}} - B_{t_{0-1}}}{t_{0+1} - t_{0-1}} \times [t_0 - t_{0-1}] \right)
\]

**Equation #2:**

\[
B_{t_1} = B_{t_{1-1}} + \left( \frac{B_{t_{1+1}} - B_{t_{1-1}}}{t_{1+1} - t_{1-1}} \times [t_1 - t_{1-1}] \right)
\]

Where:

- \(B_{t_0}\) = Calculated barometric pressure at the time of monitoring, if monitoring occurred prior to the mid-round time
- \(B_{t_1}\) = Calculated barometric pressure at the time of monitoring, if monitoring occurred after the mid-round time
- \(B_{t_{0-1}}\) = Recorded barometric pressure at the last time pressure was recorded prior to \(B_{t_0}\)
- \(B_{t_{0+1}}\) = Recorded barometric pressure at the first time pressure was recorded following \(B_{t_0}\)
- \(B_{t_{1-1}}\) = Recorded barometric pressure at the last time pressure was recorded prior to \(B_{t_1}\)
- \(B_{t_{1+1}}\) = Recorded barometric pressure at the first time pressure was recorded following \(B_{t_1}\)
- \(t_0\) = Time of \(B_{t_0}\)
$t_1 = \text{Time of } B_{t_1}$,
$t_{0-1} = \text{Time of } B_{t_{0-1}}$
$t_{0+1} = \text{Time of } B_{t_{0+1}}$
$t_{1-1} = \text{Time of } B_{t_{1-1}}$
$t_{1+1} = \text{Time of } B_{t_{1+1}}$

Next, the following equations were used to extrapolate the vacuum pressure at each well:

Equation #3 \[ P_{tm} = P + (BE \times [B_{tm} - B_{t_0}]) \]
Equation #4 \[ P_{tm} = P - (BE \times [B_{t_1} - B_{tm}]) \]

Where:

$P_{tm} = \text{Calculated vacuum pressure at the mid-round time}$
$P = \text{Measured vacuum pressure at the monitoring well}$
$BE = \text{Barometric efficiency}$

Equation #3 was used where the vacuum pressure in the given monitoring round was recorded prior to the selected mid-round time, while Equation #4 was used where the vacuum pressure in the given monitoring round was recorded following the selected mid-round time.

For each monitoring round and well depth, the calculated $P_{tm}$ for well KAFB-106121 was selected as the null point.

Because of the difference in well construction between the PneuLog® and the SVM wells, each type of well was analyzed independently. For each monitoring round, the difference was taken between the calculated $P_{tm}$ at each monitoring well and the null point for that depth. Both, the 484-foot-bgs PneuLog® and 450-foot-bgs SVM wells, were compared to KAFB-106121-450; the 350-foot-bgs PneuLog® and SVM wells were compared to KAFB-106121-350; and the 200-foot-bgs PneuLog® and 150-foot bgs SVM wells were compared to KAFB-106121-145.
For each monitoring well and each test, the average and standard deviation of the differences from the null points for all monitoring rounds was taken (Table 3-5). These average differences from the null point were plotted against the distance to the nearest monitoring well for each grouping of well depths and types. Additionally, the background data was included in the graphs (Figures 3-7 through 3-12).

Next, the background average differences from the null point were subtracted from the average differences from the null point for each test. The resulting values are considered the applied pressures, that is, the vacuum pressure on each well that is a result of SVE (Table 3-5). For each well type in each test, the applied pressures were plotted, and contours were created to map out the ROI of the new SVE System (Figures 3-13 through 3-27). An applied pressure of 0.2 inches of water column (inWC) was taken to be the edge of the ROI. For the most part, wells with an applied pressure of approximately 2.0 inWC varied between appearing to be within or outside of the ROI, depending on the barometric pressure.

**Mass Recovery Rates**

In order to determine the effectiveness of SVE during each test, mass recovery rates were estimated using the following equation:

\[
R = \frac{HC}{24.055} \times MW \times Q \times \frac{L}{SCF} \times 1440 \frac{min}{day} \times \frac{2.2 lbs}{kg} \times 10^{-6} \frac{\mu g}{kg}
\]

Where:

- \( R \) = Mass recovery rate in lbs/day
- \( HC \) = Total hydrocarbons in ppmv
- \( 24.055 \) = Universal gas law conversion factor for volume to mass concentration
- \( MW \) = Molecular weight. The molecular weight for hexane, 86.18, was used.
Q = Flow rate (scfm)

\[ 28.3 \frac{L_{liters}}{scf} = \text{Conversion factor between liters and standard cubic feet} \]

\[ 1440 \frac{min}{day} = \text{Conversion factor between minutes and days} \]

\[ 2.2 \frac{lbs}{kg} = \text{Conversion factor between pounds and kilograms} \]

\[ 10^{-9} \frac{\mu g}{kg} = \text{Conversion factor between micrograms and kilograms} \]

During each monitoring round, total hydrocarbons and flow rates were measured for each extraction well. The equation above was used to convert this data into mass recovery rates in lbs/day. The mass recovery rates for the two extractions wells were added together to get the combined mass recovery rate for each round. These combined rates were then averaged for each test (Table 3-6).

3.2.9.3 Results

Background Monitoring Results

The following barometric efficiencies were determined for each group of well types during background monitoring:

- 484 feet bgs PneuLog® Wells: -0.97
- 450 feet bgs SVM Wells: -0.95
- 350 feet bgs PneuLog® Wells: -0.87
- 350 feet bgs SVM Wells: -0.96
- 200 feet bgs PneuLog® Wells: -0.57
- 150 feet bgs SVM Wells: -0.76

Data collected during the background monitoring show that the average difference from null was relatively small for each monitoring well. The average difference from null ranged from -0.9 to 0.17 inWC, with standard deviations ranging from 0.03 to 0.60 inWC. For all wells, the standard deviation is greater than the absolute value of the average difference from null. No spatial patterns are apparent in the background data (Figures 3-7 through 3-12).
Phase 1 Test Results

ROI Test 1 was conducted from January 28 through February 1, 2013, with the SVE System motor speed set to 700 rpm. ROI Test 2 was conducted from February 4 through February 8, 2013, with the SVE System motor speed set to 1,050 rpm. ROI Test 3 was conducted from February 11 through February 15, 2013, with the SVE System motor speed set to 1,400 rpm.

Extraction Wells

During ROI Test 1, the volumetric flow rate ranged from 0 to 230 scfm for KAFB-106160, and ranged from 132 to 293 scfm for KAFB-106161 (Figure 3-28). For both wells, the highest flow rates occurred when the barometric pressure was low and the natural system was venting. During ROI Test 2, the volumetric flow rate ranged from 134 to 208 scfm for KAFB-106160, and ranged from 251 to 312 scfm for KAFB-106161 (Figure 3-29). During ROI Test 3, the volumetric flow rate ranged from 230 to 289 scfm for KAFB-106160, and ranged from 336 to 403 scfm for KAFB-106161 (Figure 3-30).

During ROI Test 1, the applied vacuum on KAFB-106160 ranged from 2.05 to 8.07 inWC with an average of 4.47 inWC and a standard deviation of 2.14 inWC, and the applied vacuum on KAFB-106161 ranged from 3.57 to 9.68 inWC with an average of 5.69 inWC and a standard deviation of 1.97 inWC. For both wells, the applied vacuums were greater when the barometric pressure was lower and the natural system was venting. During ROI Test 2, the applied vacuum on KAFB-106160 ranged from 4.49 to 6.42 inWC with an average of 5.60 inWC and a standard deviation of 0.50 inWC, and the applied vacuum on KAFB-106161 ranged from 6.45 to 7.97 inWC with an average of 7.29 inWC and a standard deviation of 0.40 inWC. During ROI Test 3, the applied vacuum on KAFB-106160 ranged from 7.32 to 9.34 inWC with an average of 8.26 inWC and a standard deviation of 0.58 inWC, and the applied vacuum on KAFB-106161 ranged from 8.74 inWC to 10.95 inWC with an average of 9.84 inWC and a standard deviation of 0.57 inWC. Applied vacuums are shown in Table 3-5.
In each well, both the volumetric flow rate and the applied vacuum increased as the motor speed increased. During each test, the volumetric flow rate and applied vacuum were higher for well KAFB-106161 than KAFB-106160. Well KAFB-106161 is closer to the SVE System than KAFB-106160 (341 and 579 feet, respectively, from the extraction well to the knock-out tank), which likely results in an increased influence of the system on KAFB-106161, thus resulting in the higher flow rates and vacuum pressures.

During ROI Test 1, the total hydrocarbons measured at the wellhead for KAFB-106160 ranged from 275 to 12,100 ppmv, and from 3,038 to 12,060 ppmv for KAFB-106161 (Figure 3-31). During ROI Test 2, the total hydrocarbons measured at the wellhead for KAFB-106160 ranged from 5,250 to 11,430 ppmv, and from 8,120 to 14,260 ppmv for KAFB-106161 (Figure 3-32). During ROI Test 3, the total hydrocarbons measured at the wellhead for KAFB-106160 ranged from 9,400 to 12,890 ppmv, and from 7,740 to 13,050 ppmv KAFB-106161. There was no substantial difference in the total hydrocarbons between the two extraction wells during each test. Although the total hydrocarbons were the lowest during ROI Test 1, there was no substantial difference between the total hydrocarbons at each extraction well during ROI Test 2 and ROI Test 3.

During ROI Test 1, the combined mass recovery rate ranged from 162 to 560 lbs/day, with an average of 313 lbs/day. During ROI Test 2, the combined mass recovery rate ranged from 528 to 859 lbs/day, with an average of 719 lbs/day. During ROI Test 3, the combined mass recovery rate ranged from 925 to 1,137 lbs/day, with an average of 1,034 lbs/day (Table 3-6).

Although the total hydrocarbon concentration measured at the wellhead was not significantly different between ROI Tests 2 and 3, the difference in flow rates translated into a mass recovery for ROI Test 3 that was 44% higher than the mass recovery rate for ROI Test 2. However, during ROI Test 3, the LEL meter regularly reached alarm levels. As a result, it was determined that the SVE System should be run at
1,050 rpm. Following the first 2 weeks of 4 weeks of monitoring, it was determined that the LEL meter readings were artificially high. The meter was recalibrated, and it became possible to run the system at 1,400 rpm.

**Monitoring Well Network**

The average difference from null and applied pressures for each monitoring well during each ROI test are presented in Table 3-5. Maps contouring applied pressure for each well depth, and ROI test are presented on Figures 3-13 through 3-21.

During ROI Test 1, 2, and 3, all 484-foot-bgs PneuLog® and 450-foot-bgs SVM wells within 293 feet of the nearest extraction well (Table 3-4) had applied pressures of greater than 0.20 inWC (Figures 3-13, 3-16, and 3-19). The next closest well, KAFB-106156 (295 feet from KAFB-106160), had an applied pressure of less than 0.15 inWC, while the next closest well after that, KAFB-106153 (308 feet from KAFB-106161), had an applied pressure of greater than 0.20 inWC for all tests. Extraction well KAFB-106161 experienced a higher vacuum pressure and flow rate than KAFB-106160 during all tests, which could result in a slightly larger ROI. Well KAFB-106131 (369 feet from KAFB-106160) had an applied pressure of greater than 0.20 inWC for two out of the three tests. None of the remaining wells had an applied pressure of greater than 0.20 inWC for any of the tests.

With the exception of KAFB-106148 (230 feet from KAFB-106160), all 350-foot-bgs PneuLog® and SVM wells within 296 feet of an extraction well had applied pressures of greater than 0.20 inWC for ROI Test 1 (Figures 3-14, 3-17, and 3-20). All of the SVM wells within this distance had applied pressures of greater than 0.20 inWC for all three ROI tests. However, of the PneuLog® wells, only KAFB-106150 (100 feet from KAFB-106160) had an applied pressure of greater than 0.20 inWC during ROI Test 2, and none did during ROI Test 3. Consequently, only applied pressures from the SVM wells were used in creating the contours on Figure 3-20. KAFB-106131 (371 feet from KAFB-106160), had an applied
pressure of greater than 0.20 inWC during ROI Tests 2 and 3. None of the remaining wells had an applied pressure of greater than 0.20 inWC during any of the ROI tests.

Of the 200-foot-bgs PneuLog® and 150-foot-bgs SVM wells, only the following had applied pressures of greater than 0.20 inWC during ROI Test 1 (Figures 3-15, 3-18, and 3-21):

- KAFB-106150, 211 feet from KAFB-106160, had an applied pressure of 0.35 inWC.
- KAFB-106149, 245 feet from KAFB-106161, had an applied pressure of 0.24 inWC.
- KAFB-106148, 299 feet from KAFB-106160, had an applied pressure of 0.23 inWC.
- KAFB-106153, 362 feet from KAFB-106160, had an applied pressure of 0.24 inWC.
- KAFB-106156, 363 feet from KAFB-106160, had an applied pressure of 0.21 inWC.

However, the differences from null for all of these wells varied significantly depending on the barometric pressure. None of the 200-foot-bgs PneuLog® or 150-foot-bgs SVM wells had an applied pressure of greater than 0.20 inWC during ROI Tests 2 and 3.

Overall, the ROI observed during Phase I of testing did not change significantly when the motor speed increased. However, the applied pressure generally increased in each well with an increase in motor speed for the 484-foot-bgs PneuLog® and 450-foot-bgs SVM wells. Using the data from these wells, the ROI appears to be approximately 300 feet. The data from the 350-foot-bgs PneuLog® wells were not adequate to define an ROI. However, the data from the 350-foot-bgs SVM wells indicate an ROI of approximately 300 feet. While the 350-foot-bgs PneuLog® wells have screen lengths of approximately 150 feet and extending up to 200 feet bgs, the 350-foot-bgs SVM wells have screen lengths of only 10 feet. Consequently, the vacuum pressure measured in the PneuLog® wells may be less sensitive to SVE than that measured in the SVM wells. Using the results from the 484-foot-bgs PneuLog® and 450- and 350-foot-bgs SVM wells, the ROI is similar in all directions and is approximately 300 feet.
Phase II Test Results

Four weeks of monitoring was conducted from February 19 through March 15, 2013. The SVE System was set to 1,050 rpm for the first 2 weeks of monitoring, and to 1,400 rpm for the last 2 weeks.

Extraction Wells

During the first 2 weeks of monitoring, the volumetric flow rate ranged from 75 to 236 scfm for KAFB-106160, and from 232 to 355 scfm for KAFB-106161 (Figure 3-34). During the last 2 weeks of monitoring, the volumetric flow rate ranged from 156 to 286 scfm for KAFB-106160, and from 330 to 412 scfm for KAFB-106161 (Figure 3-35).

During the first 2 weeks of monitoring, the applied vacuum on KAFB-106160 ranged from 3.82 to 8.17 inWC with an average of 6.09 inWC and a standard deviation of 1.72 inWC. The applied vacuum on extraction well KAFB-106161 ranged from 5.99 to 9.20 inWC, with an average of 7.54 inWC and a standard deviation of 1.22 inWC. During the last 2 weeks of monitoring, the applied vacuum on KAFB-106160 ranged from 5.73 to 9.53 inWC with an average of 7.18 inWC and a standard deviation of 1.18 inWC. The applied vacuum on KAFB-106161 ranged from 8.93 to 11.05 inWC with an average of 9.81 inWC and a standard deviation of 0.80 inWC.

In each well, both the flow rate and the applied vacuum increased as the motor speed increased. Additionally, both the flow rate and the applied vacuum were higher in KAFB-106161 during the 4 weeks of monitoring. Well KAFB-106161 is closer to the SVE System than KAFB-106160, which likely results in an increased influence of the system on KAFB-106161, thus resulting in the higher flow rates and vacuum pressures.

During the first 2 weeks of monitoring, the total hydrocarbons on KAFB-106160 ranged from 9,120 to 12,250 ppmv and from 7,200 to 14,400 ppmv for KAFB-106161. During the last 2 weeks of
monitoring, the total hydrocarbons on KAFB-106160 ranged from 8,730 to 10,100 ppmv and from 9,120 to 12,050 ppmv for KAFB-106161. There is no substantial difference in the total hydrocarbons between the two wells, or between the first and last 2 weeks of monitoring.

During the first 2 weeks of monitoring, the combined mass recovery rate ranged from 349 to 1,065 lbs/day with an average of 771 lbs/day. During the last 2 weeks of monitoring, the combined mass recovery rate ranged from 638 to 1045 lbs/day with an average of 857 lbs/day (Table 3-6). The barometric pressure was high during the last 2 weeks of monitoring, which resulted in the natural system working against the SVE System. This result most likely explains the low mass recovery rate during the last 2 weeks of SVE monitoring as compared the mass recovery rate estimated for ROI Test 3.

**Monitoring Well Network**

The average difference from null and applied pressures for each monitoring well during 4 weeks monitoring are presented in Table 3-5. Maps contouring applied pressure for each well depth, and each of the 2-week periods during the 4 weeks of monitoring are presented on Figures 3-22 through 3-27.

During all weeks of monitoring, all 484–foot-bgs PneuLog® and 450-foot-bgs SVM wells within 293 feet of an extraction well had applied pressures of greater than 0.20 inWC (Figures 3-22 and 3-25). Additionally, well KAFB-106153, which is 308 feet from extraction well KAFB-106161, had an applied pressure of 0.33 inWC during the last 2 weeks of 4 weeks of monitoring. None of the remaining wells had an applied pressure of greater than 0.20 inWC during monitoring.

During all weeks of monitoring, the following 350-foot-bgs SVM wells had applied pressures of greater than 0.20 inWC (Figures 3-23 and 3-26):
• KAFB-106116, 55 feet from KAFB-106161, had applied pressures of 0.72 and 0.87 inWC during the first and last 2 weeks of monitoring, respectively.

• KAFB-106114, 293 feet from KAFB-106161, had an applied pressure of 0.31 inWC during both the first and last 2 weeks of monitoring.

Additionally, KAFB-106113 (296 feet from KAFB-106160) had an applied pressure of 0.25 inWC during the last 2 weeks of monitoring. None of the remaining 350-foot-bgs SVM wells or any of the 350-foot-bgs PneuLog® wells had an applied pressure of greater than 0.20 inWC during the 4 weeks of monitoring. Consequently, only SVM wells were used to contour Figures 3-23 and 3-26.

During all weeks of the 4 weeks of monitoring, none of the 200-foot-bgs PneuLog® or 150-foot-bgs SVM wells had an applied pressure of greater than 0.20 inWC (Figures 3-24 and 3-27).

The observed ROI did not change between the first and last 2 weeks of monitoring. Using the data from the 484-foot-bgs PneuLog® and 450- and 350-foot-bgs SVM wells, the ROI observed during the 4 weeks of monitoring is approximately 300 feet. The reasons for only using these wells for defining the ROI are described in the Phase I results section.
4. VADOSE ZONE SAMPLING AND MONITORING

In the following sections, the three-dimensional (3D) analysis of the soil and vadose zone vapor plume concentrations were evaluated by presenting the results of the 3D plume modeling in a series of two-dimensional, horizontal, plan-view maps at different elevations, and north-south and east-west cross-sections through the contaminated soil area and vadose zone vapor plume. Figure 4-1 presents the SVMW and SVEW locations.

- RockWorks™ 3D inverse-distance-weighting gridding algorithm of logarithms of concentrations was used for development of all vadose zone 3D plumes. A horizontal exponent of 2 and a vertical-weighting exponent of 4 were used in conjunction with horizontal and vertical gridding extent ranges of 300 and 50 feet, respectively. All applicable data points were used in the gridding. For nondetected results, one-half the method detection limit concentration was used in the gridding.

- By presenting all plan-view maps on one drawing, the reader can readily see concentration changes with elevation across the vapor plume without resorting to 3D views that may be difficult to understand.

- In a similar manner, the cross-sections through the 3D plumes present the vertical distribution of vapor concentrations.

- Vapor samples are available only for the SVMWs and SVEWs. For clarity in presentation, the data location symbols are presented on the respective plan-view maps without labels.

- The soil data used in this evaluation are presented in the Third Quarter 2011 Report (USACE, 2011e). Vapor data used for First Quarter CY 2013 are presented in Tables 4-1 and 4-2.

- Sampling analytical results within 25 feet of a given cross-section line are posted on the cross-sections. Analytical data within 25 feet of the 5,300-foot elevation map or 50 feet of the other four elevation maps are posted on the plan-view maps. For this reason, multiple samples may be posted on the plan-view maps for a single borehole and elevation.

4.1 Soil Sampling Results

All soil sampling activities were completed by the end of Third Quarter CY 2011; therefore, all results and conclusions are presented in the Third Quarter CY 2011 quarterly report (USACE, 2011b).

Appendix E-1 of this First Quarter CY 2013 Report contains historical soil data. Soil sampling data packages are provided on compact disc in Appendix B.
4.2 Vadose Zone Vapor Monitoring Results

The soil vapor monitoring/remediation system currently consists of 287 individual vapor wells (SVMWs and SVEWs). Most of the wells are installed within 55 SVMW clusters that contain between two to six individual wells at different depths in each cluster. Cluster well locations are shown on Figure 4-1.

Soil-vapor hydrocarbon concentration (ppmv), percent O₂, percent CO, percent CO₂, and pressure were measured at the SVEWs during First Quarter CY 2013 sampling using a Horiba Model MEXA 584 L portable auto emissions analyzer. Horiba field measurements for SVEWs are presented in Table 4-1. Pressure measurements that indicate the vadose zone is subject to vacuum are reported in 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.

The First Quarter CY 2013 soil-vapor samples were collected from SVEWs and SVMWs using pre-evacuated bottle Vac™ canisters and Tedlar™ bags sampled through sampling ports installed at the top of each individual well casing. Soil-vapor samples were collected in accordance with the Vadose Zone Investigation Work Plan procedures (USACE, 2011f) and Kirtland AFB BFF Spill Quality Assurance Project Plan (QAPjP) requirements (USACE, 2011g). Soil-vapor samples were shipped to RTI in Livonia, Michigan, for the following list of analytical parameters:

- VOCs – EPA Method TO-15 (EPA, 1999)
- Fixed gases – ASTM Method D2504 (ASTM, 2010)

Field QC samples were collected in accordance with the BFF Spill QAPjP (USACE, 2011g) and include field duplicate samples and trip blanks for VOCs.
The First Quarter CY 2013 soil-vapor analytical data were validated for precision, accuracy, representativeness, comparability, and completeness in accordance with the BFF Spill QAPjpP (USACE, 2011g), and appropriate data qualifiers are appended to the analytical data in the project database. The analytical laboratory results for the First Quarter CY 2013 event are presented in Table 4-2. The data validation results are presented in the Data Quality Evaluation Report presented in Appendix B-3. Accuracy and precision for the First Quarter CY 2013 soil-vapor analytical results indicate data are of sufficient quality to achieve the BFF Spill project data quality objectives.

### 4.3 Soil-Vapor Data Evaluation

First Quarter CY 2013 laboratory analytical vapor total VOC and benzene results reported for SVMWs and SVEWs (locations shown on Figure 4-2) were used to generate 3D vapor plumes from which plan-view maps and cross-sections were generated (Figures 4-3 through 4-16). In the grid analysis, nondetected results were incorporated using one-half the method detection limit as the concentrations used to calculate total VOC concentrations. For the laboratory analytical data, the total VOC concentration was calculated by totaling the individual compound vapor concentrations plus the TPH results. The TPH conversion from units of microgram per cubic meter (μg/m³) to parts per billion by volume (ppbv) formula is as follows:

$$ ppbv = \frac{\mu g}{m^3} \cdot \frac{0.08205 \cdot T}{MW} $$

Where:

- ppbv = vapor concentration in parts per billion by volume vapor
- μg/m³ = micrograms of compound per cubic meter of air
- 0.080205 = Universal Gas Constant in (atm L)/(molecule K)
- T = vapor temperature in Kelvin = 273.15 + °C
- MW = molecular weight of compound
The molecular weight (MW) of 65.15 g/mol was used for C5-C8 aliphatic hydrocarbons, 142.3 g/mol for C9-C12 aliphatic hydrocarbons, and 120.2 g/mol for C9-C10 aromatic hydrocarbons in the above equation. A temperature of 293.15 Kelvin was used.

From these two 3D plumes, plan-view maps at elevations of 5,300; 5,200; 5,100; 5,000; and 4,900 feet above mean sea level (msl) (corresponding to approximate depths of 50, 150, 250, 350, and 450 feet bgs) were created by horizontal plan-view “slices” at appropriate elevations, and six vertical cross-sections were cut through the 3D plume at the same locations used for the soil cross-sections (Figures 4-3 and 4-4). Concentrations are posted on the plan-view maps and cross-sections using the same posting procedure used on the soil maps. Vadose zone vapor data locations are presented on Figure 4-2, because there is insufficient space on the plan-view concentration maps to clearly show well names along with the concentrations.

Figure 4-3 presents the five plan-view maps of the vapor total VOC distribution, and Figure 4-4 presents the benzene plan-view maps at the selected elevations beneath the BFF Spill site. Figures 4-5 through 4-10 present six total VOC cross-sections, and Figures 4-11 through 4-16 present the six benzene cross-sections through the vadose zone vapor plume. As illustrated in the 10 maps and 12 cross-sections, the vadose zone total VOC vapor concentrations can be characterized as follows:

- Compared to the Fourth Quarter CY 2012 and previous vapor plume maps, the First Quarter CY 2013 total VOC concentration footprints in the greater-than-1,000-ppmv range have marginally decreased. It is uncertain what is causing the fluctuation of VOC concentrations. Whether these changes are due to operation of the SVE System, seasonal changes, the rising water table, or all is uncertain. Additional data should help in determining the cause.

- Total VOC vapor concentrations at the elevation of 5,300 feet above msl (approximately 50 feet bgs) are less than 1,000 ppmv, except for two small areas with concentrations between 1,000 and 36,000 ppmv in the area in the vicinity of SVM-08 (along the westernmost portion of the former underground fuel transfer lines) and at the well cluster KAFB-106136.

- The benzene vapor plume footprints at all elevations have decreased in the First Quarter CY 2013 compared to Fourth Quarter CY 2012. It is uncertain what the cause of this overall increase may be. Additional data should help in determining the cause.
4.4 Selection of Vadose Zone Constituents of Concern

During First Quarter CY 2012, a COC screening analysis was performed on soil vapor data to distinguish which compounds were the most frequently detected within the vadose zone. The discussion and results are presented in the First Quarter CY 2012 (USACE, 2012b).

4.5 Vapor Concentrations Over Time

The 2007 through First Quarter CY 2013 soil vapor time-series concentration graphs with four or more samples and selected compounds are presented in Appendix F-4. Historical TPH-GRO concentration results in micrograms per liter (μg/L) were converted to ppbv by multiplying the μg/L results by 308, assuming a TPH-GRO MW of 78 g/mol. TPH aromatic and aliphatic compound concentrations were converted from μg/m³ to ppbv using the procedure described in Section 4.3.

The aforementioned decrease in VOC concentrations in a number of wells are reflected in the trend graphs for a number of individual compounds. Additional interpretation of the concentration changes over time will be contingent on determination of the cause of this concentration change.
5. GROUNDWATER MONITORING

Groundwater monitoring consists of collecting quarterly liquid-level groundwater elevation and NAPL measurement data and performing quarterly groundwater sampling for field chemical parameters and off-site laboratory analysis. In the following discussions, the aquifer beneath the Kirtland AFB BFF Spill site has been classified into the following four zones for purposes of data analysis:

- **Shallow Zone**—This is the monitored zone that intersects the water table and extends 5 to 15 feet below the 2011 measured water table. As the water table has continued to rise (Section 5.2), a number of these wells has become flooded to where the water level is now above the top of the screens (Section 5.6.1). Based on ongoing water conservation practices in the Albuquerque area, the water table will continue to rise, and additional wells will become flooded over the next several years.

- **Intermediate Zone**—This is the aquifer zone that is monitored by wells that extend 15 to 30 feet below the 2011 measured water table elevation. As the water table continues to rise, this zone will become deeper in the aquifer.

- **Deep Zone**—This is the aquifer zone that is monitored by wells that extend 30 to 100 feet below the 2011 measured water table elevation. As the water table continues to rise, this zone will become deeper in the aquifer.

- **Regional Aquifer**—This is the aquifer zone where most of the water supply wells in the area are completed. Generally, these wells are completed 500 feet or more below the 2009 water table elevation (typically greater than 1,000 feet bgs).

5.1 Quarterly Pre-Remedy Groundwater Monitoring

The groundwater investigation and monitoring program includes collecting quarterly groundwater elevation and NAPL measurement data, and conducting quarterly groundwater sampling at BFF Spill site monitoring wells and nearby production wells. Groundwater elevation data and NAPL thickness measurements are presented and discussed in Section 5.2. The groundwater wells sampled during First Quarter CY 2013 include the following (Figure 5-1):

- Wells installed prior to 2011 that consist of KAFB-1061 through KAFB-10628; and KAFB-3411 (installed for an investigation of another adjacent site and provides a monitoring location upgradient of the FFOR).
Well KAFB-10612 could not be sampled due to pump failure and dropped tubing as discussed in Section 3.2.7. Shaw is continuing to work towards a solution of this issue, and will communicate with the NMED if abandonment is determined to be the only option.

Wells installed during 2011 that consist of KAFB-106029 through KAFB-106107 with the exception of well KAFB-106041, which is dry.

Additional wells installed during 2012 that consist of KAFB-106201 through KAFB-106209.

KAFB-3 which is a Kirtland AFB drinking water production well. Kirtland AFB drinking water production wells KAFB-15 and KAFB-16 were not sampled during First Quarter 2013 due to mechanical problems, as discussed in Section 3.2.7.

VA-2 – Veterans Affairs (VA) Medical Center drinking water production well.

Groundwater sampling was conducted between January 6 and March 25 2013. All samples were collected in accordance with the Groundwater Investigation Work Plan (USACE, 2011a) and BFF Spill QAPjP (USACE, 2011g). Sampling was performed using either dedicated Bennett sampling pumps or a portable Bennett pump sampling system.

Groundwater sampling included purging one well bore volume and monitoring field parameters for stabilization of temperature, pH, and specific conductance to within an estimated 10% prior to collecting water-quality measurements. Field parameters that were recorded prior to collecting groundwater samples for laboratory analysis were pH, conductivity, temperature, alkalinity, dissolved oxygen (DO), turbidity, oxidation-reduction potential (ORP), and alkalinity.

After collection of water-quality measurements, the wells were purged at an approximate rate of 1.0 L per minute. Prior to sample collection, the Kirtland AFB production wells and the VA Medical Center groundwater production well were purged by flushing the dedicated sample line and then collecting the samples. Samples were collected through non-chlorinated taps from the production wells. Groundwater samples collected during First Quarter CY 2013 were analyzed by Empirical Laboratories in Nashville, Tennessee (a DoD ELAP-certified laboratory) for the following list of parameters:
Field QC samples were collected in accordance with the BFF Spill QAPjP (USACE, 2011g) and included trip and ambient field blanks for VOCs, field duplicate and equipment rinse blank samples (as needed for nondedicated sampling), and extra sample volume collected and submitted for laboratory matrix spike and matrix spike duplicate QC measurements.

Groundwater analytical data were validated for precision, accuracy, representativeness, comparability, and completeness in accordance with the BFF Spill QAPjP (USACE, 2011g), 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; the data validation results are presented in the Data Quality Evaluation Report included in Appendix B-1. The COCs are listed in Section 5.3.4.
5.2 Liquid-Level Data

Starting with First Quarter CY 2012, liquid levels were measured on a quarterly basis as opposed to monthly basis in all Kirtland AFB BFF Spill site wells (Table 5-2). As stated in the accepted NMED letter dated 27 August 2013, groundwater level and LNAPL measurements will be conducted on a quarterly basis for years 2012 through 2014. All liquid levels were measured with either a Solinst Model 122 interface probe in wells that potentially contained NAPL, or a Solinst Model 101 water-level meter for wells that did not contain NAPL. All instruments were checked for proper operation and cable integrity before use and were decontaminated between mobilizations for each well.

5.2.1 Groundwater Levels

Groundwater-level data are presented in Table 5-2, and groundwater-level contour maps for January 2013 for the Shallow, Intermediate, and Deep Zones are presented on Figures 5-2, 5-3, and 5-4, respectively. Figure 5-5 shows comprehensive groundwater levels for January 2013, including all wells currently under the monitoring program for the BFF Spill site project, and Figure 5-6 shows NAPL thickness in monitor wells. 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). The NAPL correction formula is automatically applied to all water levels. As such, a measurement of zero NAPL would yield a correction of zero. In the January 2013 data set, only well KAFB-106076 had measurable NAPL thickness (0.04 feet).

Water-level measurement data are maintained in the project database. During the QC process, water levels are compared with historical water levels for each well. If the liquid level being measured differs by more than 2 feet from the previous quarter’s liquid level and is inconsistent with liquid-level changes in nearby wells, the liquid level is judged to be invalid. These data are posted as such on the maps and are not used in the generation of liquid-level contours.
Starting in Fourth Quarter CY 2011, Shaw implemented an improved QC process for the monthly/quarterly water-level measurements. Shaw follows the process described below to ensure that the water-level data met data quality requirements. This level of QC was required because of the flat groundwater gradients and the effect that barometric pressure has on the water levels within the aquifer underneath the Kirtland AFB BFF Spill site (Section 7.3). The following procedure was used throughout the First Quarter CY 2013 monitoring event and will remain in practice for future quarterly liquid-level data collection.

- Field technicians are provided with a standardized field form for water-level measurements.

- Field technicians record the serial number/ID of the water-level meter used to collect measurements on the field form.

- Field technicians measure water levels and field-check to verify that measurements within a given cluster are within plus or minus 0.5 feet, or are similar to previous quarterly measurements. If not, the field team will then re-measure the water level in the well with the discrepancy.

- All field measurements are submitted to the Field Sampling Coordinator for QC, who checks to make sure the measurements are within plus or minus 0.5 foot of each other for a given cluster. The historical data are also taken into consideration. If a certain cluster consistently differs by more than 0.5 feet, a recheck is not performed. If it is determined that this is not the case, the wells are flagged and measured again the following day. This QC evaluation is documented on the water-level measurement field form.

- Additionally, the Field Sampling Coordinator compares the measurements against the measurements from the preceding quarter. If any measurements fail a plus or minus 1.0-foot check, they are marked and measured again the following day. This QC evaluation is documented on the water-level measurement field form.

- The field and Field Sampling Coordinator QC checks are repeated for all measurements collected, including re-measurements of wells. Once the Field Sampling Coordinator verifies that the data collected have met the QC metrics, he/she signs the form and submits it for entry into the database. The Field Sampling Coordinator redlines any measurements that should not be entered into the database.

- All measurements (including re-measurements) are entered into the database along with associated flags noting that the QC checks were performed. The database entry form has an internal checking routine to flag any suspected data entry mistakes.
A comprehensive historical groundwater-level table is presented in Appendix E-2, and water-level elevation and NAPL thickness hydrographs are presented in Appendices F-1 and F-2.

As presented on Figures 5-2 through 5-4, the groundwater-flow direction has changed in the northern portion of the site from North 25° to 35° East, to North 35° to 50° East. This may be the result of changes to the City of Albuquerque water well pumping volumes, particularly in the Ridgecrest well field. Additionally, the groundwater-flow direction turns almost due east at the northern edge of the monitoring well network. This is most likely a result of pumping at the Kirtland AFB water supply well KAFB-3, which is located approximately 100 feet to the east of the KAFB-106201 well cluster.

As presented on Figure 5-5, it is unclear from well cluster to well cluster what the vertical gradients are across the site between the Shallow, Intermediate, and Deep Zones. Some well pairs indicate downward gradients, while other well pairs indicate upward gradients. As wells continue to be monitored, better definition of these vertical gradients may be possible; however, because of the slight differences in water-level elevations between wells in a given cluster, and because the difference between the water levels is within the margin of error, this may be difficult. Overall, based on water levels in the deep water supply wells, the vertical groundwater-flow direction is downward (Section 5.6.1).

5.2.2 NAPL Thicknesses

As presented in Table 5-2, during the January through March 2013 reporting period, NAPL was observed in one well, KAFB-106076, at a thickness of 0.04 feet (Figure 5-6). This is the lowest NAPL thickness observed in KAFB-106076 since it was installed. All other wells that historically had NAPL now have no observable NAPL; this change is attributed to the rising groundwater levels (Section 5.6.2). Should the water level continue to rise, it is likely that there will be no measurable NAPL thickness in any monitoring wells in future quarters.
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. This section presents a narrative discussion of the distribution of organic compounds based on the analytical data presented in Table 5-1. The water-quality analysis used the following procedures:

- Field and laboratory analytical water-quality data were posted on “dot” maps using a graduated color scheme with postings of well names and concentrations beside the dot. This method allowed for visual point-pattern analysis of concentration distributions for each compound evaluated. For the color scheme, the lowest concentration break was set at the applicable regulatory value, if such a value existed.

- Shallow and Intermediate Zone concentration plume contour maps were prepared for selected compounds with sufficient detections to warrant interpolation of contours. For all contour maps, an 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 maps.

- In previous reports, it was possible to generate a TPH-DRO plume map with a lower concentration of 150 μg/L. A plume map was not produced for this quarter because of elevated detection limits for TPH-DRO of 380 μg/L in samples from a number of wells. Therefore, a standard dot-map presentation was used for this compound. Because of a change in analytical methods for TPH-DRO, future definition of the DRO plume will not be attempted. The analytical method for TPH as diesel analysis is the same (SW8015B) for all quarterly events. The change has occurred with the limit of quantitation (LOQ). During the previous quarterly events, the laboratory reported the LOQ of 100 μg/L for TPH as diesel in groundwater samples. In the Fourth Quarter 2011, the laboratory reported TPH as diesel at 191 μg/L, 182 μg/L, and 195 μg/L at wells KAFB-106032, KAFB-106033, and KAFB-106034, respectively. These detected concentrations were slightly above the LOQ of 100 μg/L. A review of the groundwater sample results indicated that TPH as diesel has not been detected at these locations for the previous quarterly events.

- At Shaw’s request, the laboratory re-evaluated TPH as diesel sample preparation and quantitation procedures and indicated that due to uncertainty in the low-level TPH as diesel results, high biased results could have been reported. To minimize potentially high-biased results or false positive results, the laboratory has since raised the LOQ for TPH as diesel from 100 μg/L to 400 μg/L. As required by the DoD and project QAPjP (USACE, 2011g), the laboratory has been conducting the quarterly LOQ and limit of detection studies to support this higher LOQ. Since there is no regulatory standard for TPH as diesel in groundwater, the higher LOQ has no adverse impact on the project data quality objectives.

- Using a combination of the dot and contour maps, a preliminary qualitative evaluation of fate and transport was conducted. Quantitative fate and transport analysis will be conducted as additional wells are installed and additional degradation data are collected.
5.3.1 Organic Compound Results

The following section describes the key First Quarter CY 2013 analytical findings based on the results presented in Table 5-1 and the associated maps generated from these data (Figures 5-7 through 5-30). As compared to previous quarterly reports (USACE; 2011b, 2011e, 2011h, 2012b, and 2012c), other than EDB, the compound plumes and concentrations have not changed appreciably in the past 12 months.

The analytical data in Table 5-1 indicate that the vast majority of the groundwater contamination is concentrated in the Shallow Zone, but detections of some compounds are present in the Intermediate and Deep Zones as described in this section.

Compound-specific dot and/or plume maps were prepared for TPH-GRO, TPH-DRO, EDB, benzene, toluene, total xylenes, 1,2,4-TMB, and naphthalene.

- **TPH-GRO**—The well concentrations and concentration contours for the Shallow and Intermediate Zones are presented on Figures 5-7 and 5-8, respectively, for this compound group. Deep Zone well concentrations are presented on Figure 5-9. Because no regulatory limit is established for TPH-GRO, the reporting limit of 150 \( \mu \text{g/L} \) is used for the lower concentration contour limit.
  - The highest Shallow Zone TPH-GRO concentrations are in the historical NAPL area with the highest detected concentration at 62,000 \( \mu \text{g/L} \). The downgradient extent of the TPH-GRO plume is approximately 2,500 feet north of the edge of the historical NAPL area.
  - TPH-GRO concentrations in the Intermediate Zone correlate with the TPH-GRO plume in the Shallow Zone. The highest concentration in the Intermediate Zone is 4,200 \( \mu \text{g/L} \) in the NAPL area. The TPH-GRO plume extends approximately 2,500 feet downgradient of the historical NAPL area.
  - TPH-GRO was detected in the sample from one well in the Deep Zone, KAFB-106084, at a concentration of 63 \( \mu \text{g/L} \) (J-qualified result).
  - The TPH-GRO plume has not changed appreciably in the past 12 months.
• **TPH-DRO**—The well concentrations for the Shallow, Intermediate, and Deep Zones are presented on Figures 5-10, 5-11, and 5-12, respectively, for this compound group. The TPH-DRO concentrations were not contoured due to the high non-detect values. No regulatory limit is available for TPH-DRO.

  - The highest Shallow Zone TPH-DRO concentrations are in the historical NAPL area with the highest detected concentration at 210,000 μg/L.
  
  - TPH-DRO concentrations in the Intermediate Zone correlate with the TPH-DRO plume in the Shallow Zone. The highest concentration in the Intermediate Zone is 12,000 μg/L within the historical NAPL area.
  
  - TPH-DRO was not detected any Deep Zone well samples during First Quarter CY 2012.

• **EDB**—The EPA Method SW-846 8011 analytical data are used in preparing the EDB concentration contours. The concentrations and concentration contours for the Shallow and Intermediate Zones are presented on Figures 5-13 and 5-14, respectively, for EDB. Deep Zone well concentrations are presented on Figure 5-15. The EPA maximum contaminant level (MCL) of 0.05 μg/L (EPA, 2009) is used for the lower concentration contour limit.

  - As presented on Figure 5-13, the highest Shallow Zone EDB concentrations are in the historical NAPL area with the highest detected concentration at 160 μg/L for wells KAFB-106059 and KAFB-106076. The downgradient extent of the EDB plume is between 3,500 and 4,000 feet north of the edge of the historical NAPL area. The entire EDB plume, including the NAPL area, is approximately 5,900 feet long. All of the wells in the three most recent well clusters are downgradient of the leading edge of the EDB plume. The nearest is approximately 700 feet downgradient, while the most distant is approximately 2,200 feet downgradient.
  
  - The southern edge of the Intermediate Zone EDB plume is shifted to the north of the overall footprint of the Shallow Zone EDB plume. Only two of the nine wells in which EDB concentration was greater than 0.10 μg/L are located within the historical NAPL area. The highest concentration is 0.39 μg/L, and the plume extends approximately 3,500 feet downgradient of the historical NAPL area.
  
  - There are two detections of EDB for groundwater samples from the Deep Zone in the northeast portion of the study area: KAFB-106037 at 0.26 μg/L and KAFB-106058 at 0.25 μg/L.

• **Benzene**—The concentrations and concentration contours for the Shallow Zone are presented on Figure 5-16 for this compound. Intermediate and Deep Zone well concentrations are presented on Figures 5-17 and 5-18, respectively. The EPA MCL of 5 μg/L (EPA, 2009) was used for the lower concentration contour limit.

  - In the Shallow Zone, the highest benzene concentrations and the majority of the benzene plume greater than the regulatory concentrations are in the historical NAPL area with the highest detected concentration of 12,000 μg/L reported at KAFB-1069.
− In the Intermediate Zone, only KAFB-106080 had a reported benzene concentration (530 μg/L) greater than the EPA MCL of 5 μg/L.

− Benzene was not detected in samples from wells within the Deep Zone for First Quarter CY 2013.

• Toluene—The concentrations and concentration contours for the Shallow Zone are presented on Figure 5-19 for this compound. Intermediate and Deep Zone well concentrations are presented on Figures 5-20 and 5-21, respectively. The NMED groundwater standard of 750 μg/L (20.6.4 NMAC) was used for the lower concentration contour limit.

− In the Shallow Zone, the highest toluene concentrations and the majority of the toluene plume greater than the regulatory concentration are within the historical NAPL area with the highest detected concentration at 13,000 μg/L. Toluene detections above the NMED groundwater standard are reported only within the historical NAPL area.

− In the Intermediate Zone, no toluene concentrations exceeded the groundwater standard of 750 μg/L, and toluene was only detected in one Intermediate Zone well at a concentration of 76 μg/L.

− Toluene was not detected in samples from wells within the Deep Zone for First Quarter CY 2013.

• Total Xylenes—The concentrations and concentration contours for the Shallow Zone are presented on Figure 5-22 for this compound. Intermediate and Deep Zone well concentrations are presented on Figures 5-23 and 5-24, respectively. The NMED groundwater standard of 620 μg/L (20.6.4 NMAC) was used for the lower concentration contour limit.

− In the Shallow Zone, xylene concentrations for six wells exceeded the NMED groundwater standard, with all total xylene exceedances occurring within the historical NAPL area. The highest detected total xylene concentration is 3,700 μg/L.

− In the Intermediate Zone, no xylene concentrations exceeded the groundwater standard, and total xylenes were detected in samples in only one Intermediate Zone well at a concentration of 19 μg/L.

− Total xylene was not detected in samples from wells within the Deep Zone for First Quarter CY 2013.

• 1,2,4-TMB—The concentrations and concentration contours for the Shallow Zone are presented on Figure 5-25 for this compound. Intermediate and Deep Zone well concentrations are presented on Figures 5-26 and 5-27, respectively. Because no regulatory limit is available for 1,2,4-TMB, an arbitrary cut-off concentration of 35 μg/L was used for the lower concentration contour limit.

− In the Shallow Zone, the highest 1,2,4-TMB concentrations and the total extent of the plume are within the historical NAPL area, with the highest detected concentration at 490 μg/L.
− In the Intermediate Zone, 1,2,4-TMB was detected above 35 μg/L only in the sample from one well, which is located outside of the historical NAPL area, at a concentration of 44 μg/L.

− 1,2,4-TMB was not detected in any Deep Zone monitoring wells for First Quarter CY 2013.

- **Naphthalene**—The concentrations and concentration contours for the Shallow Zone are presented on Figure 5-28 for this compound. Intermediate and Deep Zone well concentrations are presented on Figures 5-29 and 5-30, respectively. The EPA MCL of 30 μg/L (EPA, 2009) was used for the lower concentration contour limit.

  − In the Shallow Zone, all naphthalene detections are within the historical NAPL area with a highest detected concentration of 420 μg/L.

  − In the Intermediate Zone, no naphthalene concentrations exceeded the groundwater standard, and naphthalene was detected in only three Intermediate Zone wells. The highest detected naphthalene concentration was 21 μg/L.

  − Naphthalene was not detected in samples from wells within the Deep Zone for First Quarter CY 2013.

### 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 the bacteria population according to the following general equation (Wiedemeier et al., 1999):

\[
\text{Microorganisms + Electron donors + Electron acceptor + Nutrients} \rightarrow \\
\text{Metabolic by products + Energy + Additional microorganisms}
\]

As a first step in evaluating data for remedy selection for the Kirtland AFB BFF fuel plume, a dot-map evaluation of selected degradation indicator compounds (Table 5-3) was performed to relate various indicators to the extent of the NAPL area and dissolved plumes. For this first step, dot maps were prepared for DO, ORP, ammonia, nitrate, manganese, sulfate, sulfide, alkalinity, iron, manganese, sulfate, sulfide, and alkalinity. Only dissolved (filtered) iron data were available; however, as ferric iron is relatively insoluble in water, the majority of the dissolved iron is assumed to be ferrous iron. For this First
Quarter CY 2013 Report, dot maps of ammonia and sulfide were not prepared because these two compounds were not detected in a sufficient number of wells to allow meaningful map analysis.

- **DO**—Concentrations of this degradation indicator compound for the three aquifer zones are presented on Figures 5-31 through 5-33. Microbial degradation results in decreased DO concentrations (Table 5-3).
  - In the Shallow Zone, DO concentrations, overall, are lower within and adjacent to the NAPL area and dissolved plume, thus indicating that microbial degradation is consuming oxygen from the groundwater. Away from the organic compound plume area, the DO concentrations are in the range of 7 to 10 mg/L, which is near the atmospheric saturation concentration at the elevation and temperature of the groundwater.
  - In the Intermediate Zone wells, DO depletion is observed in only three wells (KAFB-106083, KAFB-106065, and KAFB-106080) within and adjacent to the historical NAPL area, thus indicating a slow rate of microbial degradation consistent with the overall concentrations of most organic compounds in this zone.
  - In Deep Zone wells, DO depletion is not observed in any wells based on the First Quarter CY 2013 analytical results. The lowest DO concentrations are observed within and adjacent to the historical NAPL area.

- **ORP**—Measurements of this degradation indicator compound for the three aquifer zones are presented on Figures 5-34 through 5-36.Microbial degradation will result in decreased ORP values (Table 5-3).
  - As with DO, the ORP concentrations in the Shallow Zone overall are lower within and immediately downgradient of the historical NAPL area, with most values in that area ranging from 50 to -330 mV. Further downgradient within the plume area, the ORP becomes strongly positive with values greater than 100 mV. In comparing the ORP results with the various plume maps, it appears that microbial degradation is occurring within the Shallow Zone within the majority of the TPH-GRO plume area with the exception of the far downgradient area beyond well KAFB-106091.
  - In the Intermediate Zone wells, ORP less than zero was observed in only three wells within and downgradient of historical NAPL area, thus indicating a slow rate of microbial degradation consistent with the overall concentrations of most organic compounds in this zone.
  - In Deep Zone wells, ORP less than zero was not observed in any wells during First Quarter CY 2013.
- **Alkalinity**—Concentrations of this degradation indicator compound are presented on Figures 5-37 through 5-39. Microbial degradation can result in increased alkalinity concentrations because of elevated CO₂ concentrations, which result in the lowering of the pH, thereby causing an increased rate of mineral dissolution (Table 5-3).
  
  - The point-pattern analysis indicates that alkalinity is elevated within and adjacent to the Shallow Zone NAPL area, with most values ranging from 210 to 520 mg/L. Alkalinity concentrations farther away from the historical NAPL area are consistently lower than concentrations within the NAPL area, with most values falling below 160 mg/L.
  
  - In the Intermediate Zone wells, alkalinity is elevated in only one well within the NAPL area. Well KAFB-106080 shows an alkalinity concentration of 244 mg/L. This well also is among those with the highest TPH-GRO, TPH-DRO, benzene, toluene, total xylene, 1,2,4-TMB, and naphthalene concentrations in the Intermediate Zone for this quarter and the previous quarter.
  
  - In Deep Zone wells, alkalinity concentrations are not elevated and show no pattern in relation to the NAPL area and individual plume constituents.

- **Iron**—Concentrations of this degradation indicator compound are presented on Figures 5-40 through 5-42. Microbial degradation can result in increased iron concentrations as mineral dissolution reactions occur (Table 5-3).
  
  - In the Shallow Zone, iron is distinctly elevated in the NAPL area and the area of the dissolved plume immediately downgradient of the NAPL area. Because microbial degradation causes increased iron groundwater concentrations, elevated iron concentrations indicate the presence of active microbial degradation of organic compounds.
  
  - In the Intermediate Zone, elevated iron was detected in samples from three wells: KAFB-106065, KAFB-106083, and KAFB-106080. All are inside of, or immediately adjacent to, the historical NAPL area. KAFB-106080 has had elevated benzene detections during the Third Quarter CY 2011 through First Quarter CY 2013 events.
  
  - In the Deep Zone, iron concentrations are not elevated and show no pattern in relation to the NAPL area and individual plume constituents.

- **Manganese**—Concentrations of this degradation indicator compound are presented on Figures 5-43 through 5-45. Microbial degradation can result in increased manganese concentrations (Table 5-3).
  
  - In the Shallow Zone, manganese, like iron, is distinctly elevated in the NAPL area and the area of the dissolved plume immediately downgradient of the NAPL area. Manganese is elevated in samples from those wells with detections of TPH-GRO. Microbial degradation causes increased manganese groundwater concentrations, thus indicating the presence of active microbial degradation of organic compounds in these areas.
In the Intermediate Zone, manganese is elevated in samples from three wells (KAFB-106083, KAFB-106065, and KAFB-106080) located inside and immediately adjacent to the historical NAPL area footprint.

In the Deep Zone, manganese concentrations are not elevated and show no pattern in relation to the NAPL area and individual plume constituents.

- **Nitrogen (Nitrate/Nitrite)**—Concentrations of this degradation indicator compound are presented on Figures 5-46 through 5-48. Microbial degradation will cause decreases in nitrate/nitrite concentrations. No obvious pattern is apparent in the Shallow, Intermediate, and Deep Zone nitrate/nitrite results. Nitrate/nitrite may not be a robust degradation indicator, as it seems that background nitrate concentrations are sufficiently low, thus inhibiting any pattern recognition of the analytical results.

- **Sulfate**—Concentrations of this degradation indicator compound are presented on Figures 5-49 through 5-51. Microbial degradation can cause decreases in sulfate concentrations (Table 5-3). No obvious pattern is apparent in the Shallow, Intermediate, and Deep Zone sulfate results. Sulfate may not be a robust degradation indicator, as it seems that background sulfate concentrations are sufficiently low, thus inhibiting any pattern recognition of the analytical results.

Based on this analysis of the degradation indicator compounds and the spatial extent of the organic compounds discussed in Section 5.3.1, it appears that microbial degradation is substantially slowing the migration rate and limiting the extent of a majority of the organic compounds, including benzene, toluene, and total xylenes. Additional evaluations are required to quantify the degradation rates and impact on future plume migration.

The effect of microbial degradation on EDB migration rates and extent is much more problematic with no obvious plume pattern of degradation compounds that indicate EDB degradation. Additional compound-specific data are required to determine whether microbial degradation is having any effect on EDB.

### 5.3.3 Piper and Stiff Diagram Inorganic Chemistry Evaluation

The major inorganic ion Piper and Stiff diagrams are presented on Figures 5-52 through 5-63. The diagrams are grouped by well location with respect to the NAPL area, and color-coded by Shallow, Intermediate, Deep, and Regional Zones of the aquifer. From the Piper diagrams (Figures 5-52 through 5-55), it is apparent that the bicarbonate + carbonate (HCO$_3^-$ + CO$_3^{2-}$) concentrations within the...
contaminant plume are clustered in the range from 40 to 90%, while the upgradient wells and those with nondetected results have bicarbonate concentrations ranging from 20 to 80%. These ranges are to be expected because microbial degradation can cause bicarbonate concentrations to increase as CO₂ is generated in the degradation process. The CO₂ increase will lower the pH, thereby dissolving carbonate minerals in the aquifer, and will have the overall effect of increasing the bicarbonate/sulfate ratio. In the NAPL-area and plume-area wells, there is an overall increase in calcium in the Shallow Zone wells compared to the Intermediate and Deep Zone wells. The highest contaminant concentrations are in the Shallow Zone, so this is presumably where the microbial degradation is most active, thus resulting in more CO₂ increase and carbonate mineral dissolution, and an increase in calcium concentrations.

The Stiff diagrams on Figures 5-56 through 5-63 show a similar pattern with the obvious increase in bicarbonate in the NAPL-area and downgradient-plume wells. Overall, the Shallow Zone NAPL-area and plume wells have higher calcium and bicarbonate concentrations (in milli-equivalents per liter) than the Intermediate and Deep Zone wells. Thus, the calcium/bicarbonate increases observed in the Piper diagrams are observed in the Stiff diagrams.

### 5.3.4 Selection of Groundwater Constituents of Concern

During First Quarter CY 2012 (USACE, 2012b), a comprehensive COC screening analysis was performed on groundwater data to identify which compounds were the most frequently detected within the aquifer. The results of this screening analysis are discussed in Section 5.3.4 of the Fourth Quarter CY 2012 Report (USACE, 2013). The COC analysis will be updated in the Groundwater Resource Conservation and Recovery Act Facility Investigation Report.
The groundwater COCs for the Shallow Zone are listed as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CAS Number</th>
<th>Parameter</th>
<th>CAS Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2-dibromoethane (EDB)</td>
<td>106-93-4</td>
<td>Naphthaene</td>
<td>91-20-3</td>
</tr>
<tr>
<td>1,2-dichloroethane (EDC)</td>
<td>107-06-2</td>
<td>Nitrogen, Nitrate (as N)</td>
<td>7727-37-9</td>
</tr>
<tr>
<td>Benzene</td>
<td>71-43-2</td>
<td>Phenol</td>
<td>108-95-2</td>
</tr>
<tr>
<td>bis (2-ethylhexyl) phthalate</td>
<td>117-81-7</td>
<td>Sulfate (as SO4)</td>
<td>14808-79-8</td>
</tr>
<tr>
<td>Dibenzo(a,h)anthracene</td>
<td>53-70-3</td>
<td>Tetrachloroethene</td>
<td>127-18-4</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>100-41-4</td>
<td>Xylenes, total</td>
<td>1330-20-7</td>
</tr>
<tr>
<td>Iron</td>
<td>7439-89-6</td>
<td>Trichloroethene</td>
<td>79-01-6</td>
</tr>
<tr>
<td>Manganese</td>
<td>7439-96-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>75-09-2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CAS = Chemical Abstract Service

The groundwater COCs for the Intermediate Zone are listed as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CAS Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2-dibromoethane (EDB)</td>
<td>106-93-4</td>
</tr>
<tr>
<td>Benzene</td>
<td>71-43-2</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>100-41-4</td>
</tr>
<tr>
<td>Iron</td>
<td>7439-89-6</td>
</tr>
<tr>
<td>Manganese</td>
<td>7439-96-5</td>
</tr>
<tr>
<td>Naphthaene</td>
<td>91-20-3</td>
</tr>
</tbody>
</table>

The groundwater COCs for the Deep Zone are listed as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CAS Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2-dibromoethane (EDB)</td>
<td>106-93-4</td>
</tr>
<tr>
<td>bis (2-ethylhexyl) phthalate</td>
<td>117-81-7</td>
</tr>
<tr>
<td>Manganese</td>
<td>7439-96-5</td>
</tr>
</tbody>
</table>

5.4 Production-Well Data

As part of the Kirtland AFB BFF Spill Site Pre-Remedy Quarterly Monitoring Program, groundwater samples were collected and analyzed during First Quarter CY 2013 at the Kirtland AFB production well, KAFB-3, and the VA production well, VA-2. Kirtland AFB production wells KAFB-15 and KAFB-16 were not sampled this quarter due to mechanical problems. Although the production wells are deeper and the screened interval is not consistent with the BFF groundwater monitoring wells, they are being monitored to ensure that no contamination associated with the BFF Spill has impacted the drinking water aquifer in the area associated with the BFF Spill. Results for these wells during First Quarter CY 2013...
were nondetections for BFF COCs, including VOCs, SVOCs, and TPH compounds. The analytical results are presented along with all First Quarter CY 2013 groundwater monitoring results in Table 5-1.

### 5.5 NAPL and Soil Hydraulic Property Laboratory Test Results

During Third Quarter CY 2011 and Fourth Quarter CY 2012, chemical and physical properties tests were conducted on NAPL and soil samples for two reasons: 1) to quantify key parameters important to future analysis and modeling of NAPL and groundwater migration and 2) to determine the overall contaminant source strength presented by the NAPL on or below the water table. Tests were conducted for total and effective porosity; hydraulic conductivity; grain size; total organic carbon; air/water/NAPL capillary curve tests and calculation of van Genuchten parameters; and NAPL flash point, density, viscosity, and interfacial tension. Other than the capillary curve tests that were conducted on intact cores, all soil hydraulic properties were conducted on remolded samples. The results and laboratory reports are presented in Appendix K, and discussed in Section 5.5 of the Fourth Quarter CY 2012 Report (USACE, 2013).

### 5.6 Time-Series Data Analysis

Time-series graphs are presented in Appendix F. Water-level and NAPL-elevation hydrographs are presented in Appendix F-1, NAPL-thickness graphs in Appendix F-2, and groundwater-concentration graphs in Appendix F-3. The summary evaluations of these time-series graphs are presented in the following sections.

#### 5.6.1 Groundwater Levels

Time-series hydrographs of groundwater and NAPL elevations are presented in Appendix F-1 for 2007 through First Quarter CY 2013. Based on analysis of these hydrographs, the water level in most wells rose between 0.25 and 1 foot from Fourth Quarter CY 2012 to First Quarter CY 2013. However, groundwater levels at the site, overall, have risen between 6 and 8.5 feet since 2009. This rise can be
attributed to the water-conservation practices implemented by the City of Albuquerque and the San Juan-Chama Diversion Project completed in December 2008 to reduce groundwater withdrawals.

These rising water levels have caused a number of wells to have screens that are now flooded with the top of the screen below the current water table. Figure 5-2 and Table 5-4 illustrate the wells at which the screens are now below the water table. As of January 2013, 10 Shallow Zone wells have flooded screens, 7 wells have tops of screen within 2 feet of the water table, and 36 wells have tops of screens more than 2 feet above the water table.

Of particular importance to the conceptual site model and remediation design is the amount of water table decline that has occurred in the aquifer over the past 60 years. KAFB-3 (northeastern corner of Figure 5-1) is screened from a depth of 448 to 900 feet bgs. The initial depth to water was 407 feet (as measured in 1949), and the current depth to water is 481 feet (Appendix E-2). The historical water levels over time were from the original installation and subsequent pump repair events when the repair contractor measured the depth to water. As shown, water levels have declined approximately 80 feet (4,953 feet downward to a 4,873-foot elevation) since 1949 with the majority of the water-level decline (over 100 feet) since 1975.

The timing and magnitude of this observed water-level decline had a profound effect on the volume of contaminated soil and vapor in the vadose zone. Assuming that surface releases of fuel occurred starting in the mid-1960s, the NAPL would reach the water table and capillary fringe sometime over the next decade and spread out horizontally in a downgradient direction. This occurrence would place the NAPL at an elevation of approximately 400 feet bgs. As the water table declined in the 1970s through the 1990s and, presumably, additional NAPL was released from inadvertent leaks or spills, this created what essentially is a 100-foot-thick NAPL “smear zone” extending from a nominal depth of 400 feet to the current depth of 480 to 490 feet bgs. The smear zone explains why the highest soil and vapor
concentrations (and presumably most of the contaminant mass) are primarily found at depths greater than 400 feet bgs.

It is apparent from the cluster well data discussed in Section 5.2.1 that the vertical gradients within the upper 100 feet of the aquifer are less than can be quantified from standard groundwater-level measurements. The thickness of the EDB plume in the northern portion of the plume indicates that there may be a slight downward gradient in that area. However, vertical gradients can vary across a site, and may not be consistent between the shallow and deep parts of an aquifer.

5.6.2 NAPL Thickness

Based on the analysis of NAPL thickness data (measured in feet) over time (Appendix F-2), it is apparent that the NAPL thickness observed in wells since 2009 has overall markedly declined as groundwater levels have risen. While this declining trend of NAPL thickness in wells could be mistaken to indicate that 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 indicates that the NAPL interval is now flooded, with most of the NAPL being submerged below the water table. This submerging 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 NAPL to “float” on the water table.

Based on the NAPL data available for Kirtland AFB, this density difference is approximately 0.23 gram per cubic centimeter (g/cm³). If the resulting buoyancy force is less than the displacement pressure (i.e., 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.
5.6.3 Groundwater Concentrations

Time-series graphs for 2007 through First Quarter CY 2013 for selected groundwater parameters of TPH-GRO, TPH-DRO, benzene, ethylbenzene, toluene, total xylenes, naphthalene, and EDB are presented in Appendix F-3. Because the results for the majority of the wells with four or more sampling events are nondetected, installed in or near the NAPL area, or were only installed a few years ago, the time-series graphs show no obvious increasing or decreasing concentration trends over time. Stable concentrations indicate that the portions of the groundwater plume monitored by the existing wells have stable concentrations downgradient of the NAPL area.

5.7 Groundwater Plume Migration Analysis

The estimated EDB migration velocity is between 80 and 200 feet/year. Section 5.7 of the Fourth Quarter CY 2012 Report (USACE, 2013) describes the method used to estimate this velocity.

The farthest downgradient EDB-contaminated well is the KAFB-106055 well cluster. The Shallow, Intermediate, and Deep Zone wells have reported EDB concentrations between 0.25 and 2.0 μg/L using analytical results from EPA Method SW-8011 for First Quarter CY 2013. This cluster is located approximately 2,500 feet downgradient of the edge of the NAPL area.
6. INVESTIGATION-DERIVED WASTE

6.1 Well Installation Investigation-Derived Waste
During First Quarter 2013, there was no drilling activity at the BFF Spill site to support the groundwater and vadose zone investigations. Since there was no drilling activity between January to March 2013, drill cuttings, decontamination water, and development water were not generated.

6.1.1 Drill Cuttings
No drill cuttings or soil waste were generated during the First Quarter CY 2013. No soil was sampled or disposed of from January to March 2013. Table C-1 in Appendix C details the sampling and disposal of each roll-off container generated from First Quarter CY 2011 to First Quarter CY 2013.

6.1.2 Decontamination and Development Water
No decontamination or development water was generated during the First Quarter CY 2013. No wastewater due to drilling activities was sampled or disposed of from January to March 2013. Table C-2 in Appendix C details the sampling and disposal of each wastewater container from First Quarter CY 2011 to First Quarter CY 2013.

6.2 Groundwater Sampling Investigation-Derived Waste
Quarterly groundwater sampling at the Kirtland AFB BFF Spill site monitoring wells generated investigation-derived waste (IDW) purge water. All purge water was stored at the BFF Spill site pending analytical results and subsequent disposal determination in accordance with the Kirtland AFB Bulk Fuels Development and Sampling Purge Water Decision Tree – 2/14/2011(NMED, 2011). Purge water was stored in labeled, 55-gallon, polyethylene, and open-top drums with sealable lids, or bulked and stored in large tanks pending Notice of Intent (NOI) to discharge. For monitoring wells located on Kirtland AFB, the purge water drums were labeled, closed and sealed, and stored at the BFF Spill site. Purge water
generated from sampling of monitoring wells located on property outside of Kirtland AFB was contained in drums, labeled, sealed, transported back to Kirtland AFB, and stored at the BFF Spill site, or bulked and stored in large tanks pending NOI to discharge, pending groundwater sampling analyses and IDW disposal determination. Exceptions to these procedures were for monitoring wells that historically, or presently, exhibit the presence of NAPL on the groundwater. For these wells, purge water was containerized in 55-gallon, closed-topped, polyethylene, U.S. Department of Transportation-approved shipping drums and then manifested as hazardous waste for benzene, unless otherwise specified, and removed from the site by a subcontracted waste management firm for off-site disposal. Table 6-1 details the monitoring well, volume of purge water generated during the First Quarter CY 2013 sampling event, and storage location of purge water.

Purge water from 13 wells during First Quarter CY 2013 will be disposed of off site as hazardous waste in Second Quarter CY 2013 (KAFB-1065, KAFB-1066, KAFB-1068, KAFB-1069, KAFB-10610, KAFB-10614, KAFB-10628, KAFB-106059, KAFB-106065, KAFB-106076, KAFB-106079, KAFB-106080, and KAFB-106094). For all other monitoring wells, purge water was stored pending analytical results to determine final disposition, which will occur during Second Quarter CY 2013.

6.3 **SVE System Investigation-Derived Waste**

The handling and disposal of condensate waste generated by the SVE System is presented in Section 2.3.
7. CONCEPTUAL SITE MODEL

7.1 Regional Geology

The geology at Kirtland AFB ranges from mountainous in the eastern extent of the installation to the Albuquerque Basin in the western portion of the installation. The area lies within the Rio Grande Rift, a major tectonic zone that represents the continental extension during the Cenozoic Age. The tilted fault-block mountains in the eastern portion of Kirtland AFB are composed of Precambrian metamorphic and crystalline bedrock and Paleozoic sedimentary rock. The Kirtland AFB BFF Spill site is located in the western portion of the installation within the Albuquerque Basin. The dominant lithology of the Albuquerque Basin comprises unconsolidated and semiconsolidated sedimentary deposits.

The Albuquerque Basin contains the through-flowing Rio Grande. Basinwide, the sedimentary deposits are primarily interbedded gravel, sand, silt, and clay. Well-graded and poorly-graded gravel and sand are heterogeneous in vertical and lateral extent throughout the basin. In addition, silt and clay layers are of variable thickness and laterally discontinuous. The thickness of the basin fill deposits is variable throughout the basin due to normal faulting, but is thicker than 3,000 feet in most of the basin (Kelley, 1977).

The geologic materials of interest for the Kirtland AFB BFF Spill site are the upper portion of the Santa Fe Group and the piedmont slope deposits. The Santa Fe Group consists of beds of unconsolidated to loosely consolidated sediments and interbedded volcaniclastic and mafic rocks. The sedimentary materials within the Santa Fe Group range from boulders to clays and from well-sorted stream channel deposits to poorly sorted slope-wash deposits. Silty alluvial fan sediments 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.

### 7.2 Site-Specific Geology

The NMED cross-section transects, A-A’, B-B’, C-C’, D-D’, and E-E’, are shown on Figure 7-1. The cross-sections show that the lithology consists of silty younger deposits (Unit A) overlaying the Santa Fe Group (Unit B), a system of unconsolidated Tertiary-aged fluvial deposits (ancestral Rio Grande lithofacies), and alluvial deposits from the Middle Rio Grande Basin (Figures 7-2 through 7-6). Unit A is approximately the top 100 to 200 feet bgs, which consists primarily of silt and silty sand with interbedded clay and poorly graded sand layers. Generally, this silty unit thickens eastward with the silt and clay layers varying from a few feet to 170 feet bgs in thickness as seen in KAFB-106135 (Figure 7-5). Sand deposits within this unit consist of silty, well-graded, and poorly graded sand intervals that range in thickness from 0 to 60 feet.

Underlying the silty slope deposits of Unit A is the upper portion of the Santa Fe Group (Unit B). This loose, unconsolidated depositional unit is observed in the subsurface geology at the BFF Spill site and is highly porous and permeable. As presented in the cross-sections, the upper portion of the Santa Fe Group is present at depths greater than 100 to 200 feet bgs and primarily consists of interbedded sand and gravel layers. The sand is generally poorly-to well-graded, and sand layers range in thickness from 1 to 250 feet. Discontinuous gravel lenses, likely channel deposits, can be up to 50 feet in thickness within some regions, particularly to the north, and are of unknown lateral extent (Figures 7-3 and 7-4). Clay lenses are also observed heterogeneously within the Santa Fe Group with the most notable lens shown in the A-A’ cross-section (Figure 7-2). This clay lens is approximately 35 feet in thickness at a depth of approximately 255 feet bgs and is documented in the lithology logs for KAFB-106081 and KAFB-106066 (Figure 7-2 and Appendix D-1).
Geologic logs for existing and newly installed monitoring wells and geophysical logging data indicate a considerable amount of variability within the two depositional units. However, based on the lithologic logs and all five cross-sections, coarser materials (including gravel lenses) appear to be more concentrated in the central portion of the study area (Figures 7-3 and 7-4); while finer, silt-rich sediments appear to be more ubiquitous in the northern and southern portions of the site (Figures 7-2, 7-5, and 7-6).

Presumably, the discontinuous silt and clay layers are zones of lower permeability and can possibly locally impede downward flow of water and NAPL through the sedimentary column. Whereas, the higher permeability sandy layers provide pathways for water and NAPL to easily migrate downward within the silty upper unit. Based on the detailed lithologic logs across the BFF Spill site, there appears to be no continuous silt/clay layers that impeded the downward migration of the NAPL.

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, the VA Medical Center, and Kirtland AFB.

Depths to water in the Regional Aquifer vary widely across the basin and are dependent on structural influence and pumping rates/volumes at production wells. Within the eastern extent of the basin, depths to water are approximately 190 feet bgs; however, towards the western edge of the basin, depths to water are 450 to 570 feet bgs. Non-pumping depths to water measured at the BFF Spill site range from approximately 450 feet (Shallow Zone) to 544 feet bgs (Regional Aquifer). As discussed in Section 5.6.1, there is a 36-foot vertical head difference between the Shallow Zone and Regional Aquifer. This results in a non-uniform (downward) gradient of minus 0.2 feet per feet.
Historically, groundwater-flow directions in the Regional Aquifer and at the BFF Spill site were generally westward toward the Rio Grande River. However, due to significant production well pumping for both the City of Albuquerque and Kirtland AFB, the groundwater-flow direction for the BFF Spill site was historically approximately North 25° to 35° East. Currently, the groundwater-flow direction has changed to approximately North 35° to 50° East.

Based on analysis of historical water-table elevations, water levels have declined approximately 140 feet (4,953 feet downward to a 4,811-foot elevation) since 1949 with the majority of the water-level decline (over 100 feet) since 1975. However, in recent years, groundwater levels at the site have risen between 4 and 8 feet since 2009 due to conservation practices implemented by the City of Albuquerque and the San Juan-Chama Diversion Project completed in December 2008.

A transducer was installed in well KAFB-106027 from September 26 through October 10, 2012 to observe fluctuations in water level. It was observed that the water level rose approximately 0.8 feet with every 1 in mercury (Hg) increase in barometric pressure. During this time period, the range in water level was 0.31 feet, as the range in barometric pressure was 0.37 feet.

The physical aquifer properties were quantified on remolded soil samples from screened intervals within the aquifer in order to model the NAPL and groundwater migration through time at the BFF Spill site. Soil test results on the remolded soil samples are discussed in the Fourth Quarter CY 2012 Report (USACE, 2013), and laboratory data are presented in Appendix K.
7.4 Contaminant Fate and Transport Conceptual Model Contaminant

7.4.1 Vadose Zone

Based on the 3D distribution of soil and vapor concentration data in the vadose zone discussed in Section 4 and previous quarterly reports, a relatively simple vadose zone NAPL and vapor migration model becomes apparent:

- Based on historical analysis of water-level data for water supply well KAFB-3, in the 1940s through most of the 1970s, the groundwater table was at a depth approximately 100 feet higher than the current 2013 water table. Beginning in 2009, the water table started rising in response to water-conservation practices and municipal use of surface water resources. Water-table changes have had a profound impact on the distribution of vadose zone contamination.

- The low TPH and benzene soil concentrations and constant contaminant footprint at elevations of 5,000 feet above msl (350 feet bgs) and above, and the expansion of the aerial extent and increase in concentrations at the elevation of 4,900 feet above msl (450 feet bgs), are definitive indicators that NAPL did not spread out substantially; it migrated through the vadose zone until it encountered the historical capillary fringe and water table, where it spread out in horizontal directions. If the vertical NAPL migration occurred over a widespread area or had spread out along vadose zone capillary barriers, it would be expected that higher soil and vapor concentrations would be observed at shallower elevations.

- As surface or near-surface releases of NAPL occurred at the facility, the NAPL essentially migrated vertically downward. Once the NAPL encountered the historical capillary fringe above the water table at a nominal depth of 400 feet bgs, the NAPL spread out horizontally away from the release areas. The NAPL then accumulated on the water table and started migrating in a northeasterly direction following the downgradient groundwater-flow direction.

- As the water table declined as a result of regional groundwater extraction, the NAPL from the initial and subsequent releases followed the falling water table downward. Over time, this had the effect of creating a residual NAPL smear zone from nominal depths of 400 to 500 feet bgs. The recently acquired PneuLog® data indicate that the water table was at approximately 350 feet bgs when the NAPL releases started.

- As the water table started rising in 2009, the NAPL that could flow into monitoring wells (i.e., NAPL not already at residual saturation) became trapped below the water table. The reason is that the NAPL buoyancy force resulting from a density difference of approximately 0.2 g/cm³ is not sufficient to overcome the entry pressures and generate the upward hydraulic gradient required for the NAPL to rise along with the rising water table.

- Because vapor can migrate in the vadose zone, the vapor concentrations define the overall volume of the vadose zone that is affected by residual NAPL contamination in the soil. To a lesser extent, the vapor concentrations do define the areas of highest vadose zone contamination.

- Based on the 3D distribution of soil and vapor concentrations, the majority of the vadose zone contaminant mass is located within 100 to 150 feet above the present-day water table at depths of 350 to 500 feet bgs.
Based on a screening process that accounts for frequency of detection (FOD), the following compounds are determined to be COCs: 1,2,4-TMB; 1,3,5-TMB; 2-butanone; acetone; benzene; C5-C8 aliphatic hydrocarbons; C9-C10 aromatic hydrocarbons; C9-C12 aliphatic hydrocarbons; cyclohexane; ethylbenzene; heptane; isopropanol; m,p,o-xylenes; methylene chloride; n-hexane; propene; propylene; toluene; and total xylenes (in lieu of quantifying individual m,p,o-xyylene isomers). COC screening analysis is discussed and results are presented in the First Quarter 2012 Report (USACE, 2012b).

The ROI testing of SVEWs KAFB-106160 and KAFB-106161 conducted in January 2013 shows that the ROI of the new SVE system is isotropic and approximately 300 feet in all directions.

The shallow vadose zone investigation is ongoing as part of the FFOR interim measure. These data have not been incorporated into the quarterly report because they are incomplete. Once the final phase of sampling is completed, the data will be included in the applicable quarterly report. Analytical samples for all FFOR soil samples collected during both the 2011 and 2012 field work is presented in Table 3-2. Once FFOR step-out sampling is complete, results from the FFOR interim measure will be incorporated into the Vadose Zone RFI Report and conceptual site model in order to demonstrate the nature and extent of contamination at depth, including the area near the FFOR.

### 7.4.2 Groundwater

As with the vadose zone model, the groundwater contamination conceptual site model is relatively straightforward and includes data from discussed in Section 5 and previous quarterly reports:

- Current groundwater-flow directions are toward the Ridgecrest water supply wells (Ridgecrest-5 and Ridgecrest-3) with average groundwater velocity of 95 feet per year and a range of 18 to over 300 feet per year to the northeast at a direction of North 35° to 50° East. Vertical groundwater gradients across the site have not been established. As previously discussed in the Fourth Quarter 2011 Report (USACE, 2012c), EDB and TPH-GRO plume maps confirm this plume migration direction and general velocity. The EDB plume is moving between 80 and 200 feet per year to the northeast simply based on plume extent.

- The rising water table has resulted in much of the NAPL being trapped below the water table. NAPL chemistry defines the source strength for groundwater contamination. For example, the benzene concentration in KAFB-1066 NAPL, similar to gasoline, is 2,200,000 μg/L, and the benzene concentration in KAFB-106076 NAPL, similar to jet fuel, is 400,000 μg/L. While EDB was not detected in either NAPL samples, the detection limit was 1,000 μg/L.

- The NAPL on top of and below the water table will act as a persistent source of groundwater contamination for the indefinite future. The final remedy will account for the submerged NAPL source. Appendix F presents the time-series plots.
Microbial degradation of organic compounds has fundamentally limited the downward gradient of the vast majority of the individual compounds in the NAPL, except for EDB, as well as the TPH-DRO compounds. Furthermore, there is sufficient organic carbon in the aquifer (average concentration of 230 milligrams per kilogram to retard the migration of organic compounds that will partition onto carbon. The compounds that are currently being actively degraded and/or retarded include benzene, ethylbenzene, toluene, xylene, 1,2,4-TMB, and naphthalene. Other NAPL compounds are almost certainly being degraded and retarded; more definitive analysis will be conducted and presented in future monitoring reports.

Based on a screening process that accounts for FOD (5%) and a comparison between maximum detected concentrations and the NMED and EPA regulatory screening levels, the following analytes are determined to be groundwater COCs:

- Shallow Zone: EDB, EDC, benzene, bis (2-ethylhexyl) phthalate, dibenzo(a,h)anthracene, ethylbenzene, iron, manganese, methylene chloride, naphthalene, nitrogen (nitrate as N), phenol, sulfate, tetrachloroethene, toluene, trichloroethene, and xylenes (total)
- Intermediate Zone: EDB, benzene, ethylbenzene, iron, manganese, and naphthalene
- Deep Zone: EDB, bis (2-ethylhexyl) phthalate, and manganese

Additional screening will be conducted over the next year to determine which, if any, of these inorganic analytes in this COC list are related to background concentrations. Those constituents determined to be related to background will be deleted from the COC list.

EDB has migrated approximately 4,000 feet from the leading edge of the NAPL area and was detected above the EPA MCL (0.05 μg/L) in samples from 30 of the 53 Shallow Zone wells, 11 of the 30 Intermediate Zone wells, and 2 of the 31 Deep Zone wells during the First Quarter CY 2013 monitoring event. EDB is the one compound that was detected in the Shallow, Intermediate, and Deep Zones in well cluster GWM 10 (KAFB-106055, KAFB-106057, and KAFB-106058) for the last five quarters. (Figures 7-7 through 7-11).

The concentration patterns of both EDB and TPH-GRO indicate two release periods of NAPL containing EDB. EDB concentrations (Shallow Zone) in the immediate vicinity of the NAPL plume mostly range from 1 to 100 μg/L with hot spots of up to 160 μg/L. Approximately 500 feet downgradient of the northern edge of the NAPL plume, the concentrations decline to less than 1 μg/L, followed by concentration increases to greater than 1 μg/L at KAFB-106055. TPH-GRO (Intermediate Zone) has a similar pattern with high concentrations in the NAPL area, a low concentration area approximately 500 feet downgradient of the northern edge of the NAPL plume, and higher concentrations in the downgradient monitoring wells.

The leading edge of the EDB plume is approximately 4,000 feet downgradient of the leading edge of the NAPL area. EDB migration is therefore occurring at a rate of between 80 and 200 feet per year (Section 5.7).
7.5 Data Gaps

One outstanding data gap is data related to the EDB degradation and fate and transport mechanisms. This data gap will be addressed using microbial and compound-specific isotope analyses scheduled for Third Quarter CY 2013.
8. PROJECTED ACTIVITIES AND RECOMMENDATIONS

Anticipated activities to be conducted during Second Quarter CY 2013 at the BFF Spill site include, but are not limited to, ongoing groundwater and soil-vapor monitoring, and continued operation of the new SVE treatment system. Construction and start of operation of the Phase II Remediation Interim Measure SVE treatment system began in Fourth Quarter CY 2012. In addition, activities associated with the monitoring and remediation at the BFF Spill site, including analytical testing, data validation, data management, and reporting, will be ongoing. Stack testing of the SVE treatment system is scheduled for Second Quarter 2013. Additionally, a second round of FFOR step-out sampling is scheduled to be completed during Second Quarter 2013.

8.1 Quarterly Monitoring Activities

Quarterly groundwater and soil-vapor monitoring, and related field activities will be ongoing during Second Quarter CY 2013 as follows:

- Depth to water and NAPL measurements will be collected the first week of April for existing GWM wells and will continue on a quarterly basis.

- Quarterly groundwater sampling activities will begin the second week of April and will continue until mid-May. This will include sample collection from all existing 4- and 5-inch GWM wells. Production wells will be sampled at the VA Medical Center and at the appropriate Kirtland AFB locations. Pump system repairs and maintenance will be performed throughout the quarter as needed. This will be determined based on observations during water-level measurement collection and groundwater-sampling activities.

- Additional quarters of groundwater data collection are recommended. This will aid in determining if supplementary GWM wells are necessary for plume delineation and will allow for evaluation for future recommendations to reduce quarterly sampling parameters.

- Quarterly sampling of SVMWs, SVEWs, and the SVE-CATOX unit will begin mid-May. Sampling will continue throughout the Second Quarter CY 2013 and end on June 30, 2013.
REFERENCES


REFERENCES (continued)

NMED. 2010a. June 4, 2010 correspondence from Mr. James P. Bearzi, Chief, NMED-HWB, to Colonel Robert L. Maness, Base Commander, 377 ABW/CC, Kirtland AFB, NM, and Mr. John Pike, Director, Environmental Management Section, 377 MSG/CEANR, Kirtland AFB, NM, re: Reporting, Sampling, and Analysis Requirements, SWMUs ST-106 and SS-111, Bulk Fuels Facility Spill, Kirtland AFB, EPA ID# NM9570024423, HWB-KAFB-10-004.

NMED. 2010b. April 2, 2010 correspondence from Mr. James P. Bearzi, Chief, NMED-HWB, to Colonel Michael S. Duvall, Base Commander, 377 ABW/CC, Kirtland AFB, NM, and Mr. John Pike, Director, Environmental Management Section, 377 MSG/CEANR, Kirtland AFB, NM, re: SWMUs ST-106 and SS-111, Bulk Fuels Facility, Kirtland AFB, EPA ID# NM9570024423, HWB-KAFB-10-004.


REFERENCES (continued)


REFERENCES (concluded)

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PneuLog® Evaluation Report
Praxis Environmental Technologies, Inc.