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HOLLOMAN AIR FORCE BASE, NEW MEXICO



MEMORANDUM FOR NEW MEXICO ENVIRONMENT DEPARTMENT

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SUBJECT: Final Accelerated Corrective Measures Work Plan SS-17 BX Gas Station Fuel Leak Site (March 2009) Holloman AFB, NM6572124422 HWB-HAFB

1. The subject work plan is hereby submitted to NMED for review.
2. I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.
3. If you have any questions, please feel free to contact Mr. David Scruggs at (575) 572-5395.

for Michael A. Lorto
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FINAL

**SS-17 BX GAS STATION FUEL LEAK SITE
ACCELERATED CORRECTIVE MEASURES WORK PLAN
HOLLOMAN AIR FORCE BASE
ALAMOGORDO, NEW MEXICO**

Prepared for:

**Air Force Center for Engineering and the Environment
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**Contract No. FA4890-06-D-0009
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ACRONYMS

ACC	Air Combat Command
ACM	Accelerated Corrective Measure
AFB	Air Force Base
AFCEE	Air Force Center for Engineering and the Environment
AMC	Air Materiel Command
AOC	Area of Concern
AST	Aboveground Storage Tank
bgs	below ground surface
BX	Base Exchange
COC	Chemical of Concern
CRDL	Contract-Required Detection Limits
DPT	Direct Push Technology
EPA	Environmental Protection Agency
ERP	Environmental Restoration Program
FID	Flame Ionization Detector
GEO	geochemical fingerprint
HAFB	Holloman Air Force Base
HHMSSL	Human Health Media Specific Screening Levels
ID	Inside Diameter
IRP	Installation Restoration Program
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNA	Monitored Natural Attenuation
MW	Monitoring Well
NMAC	New Mexico Administrative Code
NMED	New Mexico Environmental Department
NMWQCC	New Mexico Water Quality Control Commission
OD	Outside Diameter
PID	Photo Ionization Detector
PLFA	Phospholipid fatty acids

Psi	Pounds per square inch
PVC	Polyvinyl Chloride
PR/VSI	Preliminary Review/Visual Site Inspection
RCRA	Resource Conservation Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
SOP	Standard Operating Procedure
SSL	Soil Screening Level
SVE	Soil Vapor Extraction
SWMU	Solid Waste Management Unit
TDS	Total Dissolved Solids
Tetra Tech	Tetra Tech, Inc.
TOC	Top of Casing
TPH	Total Petroleum Hydrocarbons
UST	Underground Storage Tanks
VOC	Volatile Organic Compound

1.0 INTRODUCTION

This Accelerated Corrective Measure (ACM) Work Plan was prepared by Tetra Tech, Inc. (Tetra Tech) on behalf of Holloman Air Force Base (HAFB) for the SS-17 Base Exchange (BX) Gas Station Fuel Leak Site at HAFB, New Mexico. This plan applies to the area immediately north and east of the former BX Gas Station (i.e., Off-Site Area); the remainder of the former BX Gas Station site is currently being addressed under a separate plan. In this case, Off-Site refers to the areas of contamination that are contiguous to but not within the footprint of the former BX Gas Station site and are still within the boundaries of HAFB. Tetra Tech has prepared this document under contract to the U.S. Air Force Center for Engineering and the Environment (AFCEE), Contract No. FA4890-06-D-0009, Task Order No. 5002.

1.1 INSTALLATION BACKGROUND

1.1.1 Location

HAFB is situated in south-central New Mexico, in the northwest-central part of Otero County. The Base is located approximately 75 miles northeast of El Paso, Texas, and seven miles west of Alamogordo, New Mexico. The Base occupies about 50,000 acres in the northeast quarter of section Township 17 South, Range 8 East. Additional land extending northward is occupied by the White Sands Missile Range testing facilities. An installation location map is included as Figure 1-1.

1.1.2 History

Holloman AFB, formally Alamogordo Army Airfield, was initiated as a temporary facility during World War II, with construction commencing on 6 February 1942. Its status, mission, and Command have periodically changed over the years. Today, HAFB is under the Air Combat Command (ACC).

Prior to 1942, the property occupied by HAFB was undeveloped rangeland. The Alamogordo Army Airfield was established in 1942 and was deactivated in 1945. The facility was again reactivated in 1945 and was operated by the Air Materiel Command (AMC) until 1951. AMC tested pilot-less aircraft, guided missiles, and other equipment. The facility mission remained largely unchanged until 1971, although the facility identification changed several times during the 20-year span: Air Force Missile Test Center (1951-1952), Holloman Air Development Center (1952-1957), and Air Force Missile Test Center (1957-1971). The Tactical Air Command operated the facility from 1972 to 1992 and housed the 49th Tactical Fighter Wing, 479th Tactical Training Wing, 833rd Air Division, and 4449th Mobile Support Squadron. In 1992, HAFB was realigned under the ACC where it operates today.

1.2 SS-17 BX GAS STATION FUEL LEAK AREA

1.2.1 Location

The former BX Gas Station was located in a densely populated portion of HAFB across from the Base Medical Facility. The gas station occupied approximately 1.5 acres and previously contained five underground storage tanks (USTs). The gas station has been in its present location since the early 1950s and some of the USTs were in use for more than 20 years. The USTs were abandoned and the gas station was relocated 0.5 miles to the north in 2001. The former gas station is currently abandoned. The location of SS-17, with respect to HAFB, is shown on Figure 1-2.

1.2.2 Site Description

SS-17 is an 8-acre site with numerous former buildings including the gas station, convenience store, car wash, and several residences. The Base Medical Facility is located approximately 420 feet northeast, an elementary school is located 600 feet northwest, and Base residential housing is located 200 feet to the southeast of the former gas station. The site features are shown on Figure 1-3.

1.2.3 Contamination History

The site history in this subsection is reproduced primarily from the Corrective Action Plan Report prepared by Walk, Haydel & Associates, Inc. for SS-17 (WHA, 1992).

Discrepancies in gasoline storage tank inventories prompted an investigation of Site SS-17 in January 1981. It was believed that the highly corrosive nature of the groundwater underlying HAFB (high total dissolved solids [TDS], chlorides, and sulfates) had corroded underground fuel lines causing them to leak. Subsequent excavation of the area around the tanks verified that fuel had leaked from these lines. Initial estimates of the total volume of the spill ranged from 100,000 to 150,000 gallons. The underground fuel lines were replaced with fiberglass lines to reduce the potential for future leakage. A tank pressure testing program was implemented and the underground fuel storage system reported to be in satisfactory condition.

In February 1981, test borings were drilled around the station to assess the extent of gasoline contamination. Gasoline thicknesses up to 4 feet were found in monitoring wells at depths of 6 to 10 feet below ground surface (bgs).

In 1983, a Phase I evaluation performed by CH2M Hill under the Installation Restoration Program (IRP) identified the BX Gas Station as the site with the highest potential for environmental impact at HAFB. A

Phase II evaluation performed by Dames & Moore in 1984 included the installation of 17 monitoring wells and 12 test holes in the suspected area of the gasoline plume. Product was detected in 21 of the 29 borings at thickness levels ranging from trace amounts to 2.3 feet. The Phase II report estimated that about 71,000 gallons of gasoline remained.

In January 1987, recovery operations were resumed using three recovery wells and two recovery trenches. Based on information provided by base personnel, approximately 14,500 gallons of gasoline were recovered during the period from January to December 1987. The recovery operation was subsequently stopped in December 1987 in order to determine natural groundwater flow patterns without the influence of pumping.

In 1988, a comprehensive Technical Report was prepared to better define the extent and volume of contamination, review the effectiveness of the present recovery system, and recommend a conceptual design for improvements to the existing recovery system. As per the report, it was estimated that about 30,000 gallons of gasoline remained. The Technical Report recommended the installation of two additional recovery trenches, the modification of two existing recovery trenches, and the cessation of operation of existing recovery wells. The recommendations were implemented in 1989 and recovery began in October 1989.

A Resource Conservation Recovery Act (RCRA) Investigation/Feasibility Study (RI/FS) was completed in 1990 and 1991. In February 1992, USTs at the site were removed and replaced with aboveground storage tanks (ASTs). In July 1993, a 30-day Soil Vapor Extraction (SVE) pilot test was conducted on a small area of the site. Borings completed prior to the pilot testing revealed Total Petroleum Hydrocarbons (TPH) (8,340 parts per million [ppm]) and benzene (53.6 ppm) in soil. TPH concentrations in the subsurface soil were reduced by 48 percent and benzene concentrations were reduced by 70 percent.

In late 1994, investigations revealed a pipe leak under a dispenser island. It is estimated that 4,000 gallons of free product was released. Construction and operation of a full-scale SVE/bioremediation system began in September 1995. As of January 2000, 69,000 pounds of TPH had been removed. The SVE system at SS-17 was in operation until May 2002.

Bhate Environmental (Bhate) was subsequently contracted for removal of contaminated soil underlying the BX Gas Station. Excavation of contaminated soil was initiated in 2003 and has continued to the present

day. The Bhate excavation areas are shown on Figure 1-3 along with the Off-Site Area that is being addressed by this ACM Work Plan.

1.3 SCOPE AND OBJECTIVE

This document provides an accelerated corrective measures plan and remedial strategy for the Off-Site Area immediately northeast of the former BX Gas Station. This area of concern underlies First Street and may extend some distance further east and north of the street (Figure 1-3). Previous remedial actions at the site have addressed the high concentration source areas. This ACM Work Plan is designed to address the residual low concentration hydrocarbons that remain under the road and lateral to the already treated source area. Together, these actions should achieve a determination of Remedy in Place. Once completed, No Further Action (NFA) Site Closure with or without soil and groundwater land use controls (LUCs) which may include MNA can be achieved.

1.4 WORK PLAN ORGANIZATION

This work plan is organized into five sections. Section 1 is the introduction; Section 2 presents the site specific environmental setting of the SS-17 BX Gas Station Fuel Leak Site; Section 3 provides the previous site investigations; Section 4 presents the ACM for the SS-17 site; and Section 5 presents the references cited in this work plan.

A site specific Activity Hazardous Analysis is provided in Appendix A, and HAFB's Standard Operating Procedures (SOPs) are included as Appendix B. In addition to the HAFB SOPs, the Basewide Quality Assurance Project Plan (Bhate, 2003) will be adopted to use in conjunction with this ACM Work Plan.

2.0 SITE-SPECIFIC ENVIRONMENTAL SETTING

The environmental setting information in the following subsections is reproduced primarily from the Corrective Action Plan Report prepared by Walk, Haydel & Associates, Inc. for SS-17 (WHA, 1992).

2.1 DEMOGRAPHICS

Alamogordo is the county seat of Otero County and the only town of appreciable size within 30 to 50 miles of the Base. The population of Alamogordo was 23,535 in 1975 and has since grown to approximately 35,000 (2000 census). The economy of Alamogordo depends largely upon HAFB and other military installations in the area. Approximately 5,500 people live at HAFB.

2.2 CLIMATE

The climate in the Tularosa Basin is arid with low annual rainfall and low relative humidity. The surrounding mountain ranges greatly influence the local weather. They modify approaching weather systems and provide orographic lifting which produces summer thunderstorms.

Holloman AFB receives most of its total annual rainfall from thunderstorm activity from May through October. Winter is generally dry and is characterized by clear skies and erratic snowfall. The period from March through May is characterized by strong southerly wind flow and periods of blowing dust and sand. Mean annual precipitation is 7.9 inches. The mean annual lake evaporation rate, commonly used as an estimate of the mean annual evapotranspiration rate, is approximately 67 inches per year. As presented by Huff in the 49th Annual New Mexico Water Conference Proceedings (New Mexico Water Resources Research Institute [WRRI], 2005), approximately 30,000 acre-feet per year of groundwater left the Tularosa basin through evapotranspiration under 1995 conditions.

2.3 SURFACE WATER

No surface water bodies are present within SS-17.

2.4 GEOLOGY

Surficial soils in the vicinity of HAFB are generally thin, well drained soils composed of fine silts and sands formed from gypsiferous sediments of eolian or alluvial origin. A few feet below the surface,

occasional white calcareous layers up to one inch thick and lenses of gypsum-cemented sandstone up to one foot thick in sediments have been encountered.

Borings installed at SS-17 indicate that the soils in this area consist primarily of silty-sand, sand-silt mixtures (SM) down to depths of approximately 15 to 20 feet below grade with strata of clayey sand, sand clay mixtures (SC), and inorganic silts and very fine sands (ML) commonly present. Also present within the SM matrix are smaller less continuous lenses of poorly-graded sands (SP) and well-graded sands (SW). Below this upper zone is a layer of red, lean, inorganic clays (CI) which appears to be fairly continuous across the subject area. The average soil porosity is estimated to be approximately 10 percent based on laboratory tests by El Paso Testing Laboratories.

2.5 HYDROGEOLOGY

The groundwater at HAFB contains high concentrations of dissolved minerals (>10,000 mg/L TDS). The water table at SS-17 has been observed to vary from approximately 5 to 10 feet below grade. The overall hydraulic gradient in the vicinity of the site is to the south-southeast. Hydraulic gradients observed at the site were found to vary from 0.002 to 0.009 foot/foot.

The hydraulic conductivity at the site has been estimated by performing slug tests on nine site wells. Based on the slug test results, the overall site hydraulic conductivity is estimated to be approximately 8×10^{-5} cm/sec. This estimate is in reasonable agreement with the hydraulic conductivity estimates obtained from pump tests during the Phase II Investigation. The average hydraulic conductivity estimate from the Phase II Investigation is 5.6×10^{-5} cm/sec.

3.0 SITE INVESTIGATIONS

3.1 BASE ENVIRONMENTAL RESTORATION PROGRAM (ERP)

In September 1988, the RCRA Facility Assessment (RFA) Preliminary Review (PR) / Visual Site Inspection (VSI) were completed by A.T. Kearney and DPRA Incorporated for U.S. EPA Region VI. In accordance with RCRA, HAFB had initially submitted a RCRA Part A Permit Application (a request for interim status for existing facilities and the initial permitting step for new facilities) in November 1980 for 11 SWMUs and a Part B Permit Application (describing how the facility is designed, constructed, maintained, and operated to be protective of public health and the environment, as well as release prevention measures and a contingency plan in the event of a spill or release) for the Defense Reutilization and Marketing Office (DRMO). The RCRA permit for the Hazardous Waste Storage Facility was submitted by HAFB at U.S. EPA's request in July 1985. The 1984 Hazardous and Solid Waste Amendments (HSWA) provided new authority to U.S. EPA to require comprehensive corrective actions at SWMUs and other areas of concern (AOCs) at interim status facilities. These corrective actions were intended to address unregulated releases of hazardous constituents. The intent of the RFA PR/VSI was to support this authority by identifying releases or potential releases warranting further investigation. The RFA PR/VSI process identified 228 SWMUs (35 of which no longer existed or could not be located) and 21 AOCs at HAFB. Five additional SWMUs and one AOC were identified at the Primate Research Institute operated by New Mexico State University on HAFB property. The SWMUs and AOCs included all 43 ERP sites previously identified by Holloman AFB.

3.2 REGULATORY CRITERIA FOR ANALYTICAL DATA EVALUATION

Analytical data obtained from previous investigations was evaluated against applicable regulatory screening data as specified in Appendix 4-F Section III.1.2 of the H AFB Hazardous Waste Permit No. NM6572124422 (New Mexico Environmental Department [NMED], 2004). Data evaluation consisted of a direct comparison to applicable screening criteria. The associated screening criteria are included on the individual analytical data tables. Specifically, the following regulatory criteria were and will be used to evaluate the analytical data (Figure 3-1).

3.2.1 Soil/Sediment

- NMED residential, industrial and construction worker Soil Screening Levels (SSLs) (NMED, 2006a and 2006b).

- U.S. EPA Region VI Human Health Media Specific Screening Levels (HHMSSL) (U.S. EPA Reg VI, 2007), if NMED SSLs were not available (NMED, 2004).
- The U.S. EPA Region VI HHMSSL for total chromium was used to evaluate chromium analytical data since the HHMSSL for total chromium assumes a 1:6 ratio between hexavalent and trivalent chromium.

3.2.2 Groundwater

- New Mexico Water Quality Control Commission (NMWQCC) standards, New Mexico
- Administrative Code (NMAC) 20.6.2.3103.
- U.S. EPA Maximum Contaminant Levels (MCLs).

3.3 PREVIOUS INVESTIGATIONS

Several investigations have been conducted at SS-17 (Section 1.2.3). Given below are the recent investigations that attempt to define the residual contamination present at SS-17:

1. Soil Investigation (April 2004) (Bhate, 2008)
2. Soil and Groundwater Investigation (May 2006) (Bhate, 2008)
3. Soil and Groundwater Investigation (October 2006) (Bhate, 2008)
4. Long Term Monitoring (Bhate, 2006)

A report containing the investigations performed in April 2004, May 2006, and October 2006 has not been published at the time of this ACM Work Plan. Therefore, a general discussion of these investigations is presented below.

3.3.1 Soil Investigation (April 2004)

A soil investigation was conducted at SS-17 in April 2004 using a Direct Push Technology (DPT) rig. The samples were collected at 10 locations as depicted on Figure 3-2. Soil analytical results are presented in Table 3-1. Constituents that exceeded the SSLs are shown on Figure 3-3. Listed below is a summary assessment related to the sampling performed in 2004.

- The samples were collected between 5 and 7 feet bgs.
- Of the samples collected and analyzed from 10 DPT locations, constituents from only three locations (SB02, SB03, and SB10) showed exceedances above NMED SSLs.

- 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene exceeded NMED SSLs in all three locations (SB02, SB03, and SB10) at 7 feet bgs.
- Total xylene exceeded NMED SSLs in SB03 and SB10 at 7 feet bgs.
- Additionally, benzene, ethylbenzene, naphthalene, and toluene exceeded NMED SSLs in SB10 only at 7 feet bgs.

3.3.2 Soil and Groundwater Investigation (May 2006)

To further delineate the extent of contamination at SS-17, a soil and groundwater investigation was conducted in May 2006 using a DPT rig. The samples were collected at three locations as depicted on Figure 3-2. Soil and groundwater analytical results are presented in Tables 3-2 and 3-3, respectively. Soil constituents that exceeded SSLs are shown on Figure 3-3. Groundwater constituents that exceeded NMWQCC standards are shown on Figure 3-4. Listed below is a summary assessment related to the sampling performed in May 2006.

Soil Assessment

- The samples were collected between 7 and 8 feet bgs.
- Of the samples collected and analyzed from three DPT locations, constituents from only one location (SB11) showed exceedances above NMED SSLs.
- SB11 showed 1,2,4-trimethylbenzene exceeding the NMED SSLs at 8 feet bgs.

Groundwater Assessment

- Of the samples collected and analyzed from two DPT locations, constituents from only one location (SB11) showed exceedances above NMWQCC standards.
- SB11 showed a benzene concentration of 20.5 micrograms per liter ($\mu\text{g/L}$) exceeding the NMWQCC standard of 10 $\mu\text{g/L}$.
- TDS content in SB11 and SB13 were 887 and 3060 milligrams per liter (mg/L), respectively as compared to the NMWQCC standard of 1000 mg/L .

3.3.3 Soil and Groundwater Investigation (October 2006)

In an attempt to fully delineate the residual contamination present at SS-17, a soil and groundwater investigation was again conducted in October 2006. The samples were collected using a DPT rig at 11 locations as depicted on Figure 3-2. Soil and groundwater analytical results are presented in Tables 3-4 and 3-5, respectively. Soil constituents that exceeded NMED SSLs are shown on Figure 3-3. Groundwater constituents that exceeded NMWQCC standards are shown on Figure 3-4. Soil geotechnical data collected from several borings during the October 2006 event is presented in Table 3-6. Listed below is a summary assessment related to the sampling performed in October 2006.

Soil Assessment

- The samples were collected between 5 and 14 feet bgs.
- None of the samples collected and analyzed from the 11 DPT locations showed exceedances above NMED SSLs.

Groundwater Assessment

- Of the samples collected and analyzed from three DPT locations, constituents from all three locations (SB17, SB19, and SB21) showed exceedances above NMWQCC standards.
- Concentrations of ethylbenzene and naphthalene detected in all three borings (SB17, SB19, and SB21) sampled and analyzed exceeded the NMWQCC standards.
- Concentrations of benzene and m,p-xylene detected in borings SB17 and SB19 exceeded the NMWQCC standards.
- Concentrations of o-xylene and toluene detected in boring SB17 exceeded the NMWQCC standards.

3.3.4 Long Term Monitoring (LTM) Program

During previous investigations, 20 groundwater monitoring wells were installed. However, because of construction activities and well abandonment, only three monitoring wells currently remain operational in the vicinity of SS-17. Groundwater samples were collected from monitoring wells W-4 (upgradient), MW-BX-01, and MW-BX-02. Monitoring well TH-22 was abandoned in 2003 as a result of base housing construction and was therefore not sampled in 2005. Groundwater samples collected in December 2005 were analyzed for volatile organic carbons (VOCs) and TDS. Various field parameters,

including pH, temperature, and specific conductivity, were measured prior to the collection of groundwater samples at each well.

Water level measurements collected in 2005 were used to develop a potentiometric surface map of the site (Figure 3-5). Depth-to-groundwater measurements at SS-17 in December 2005 ranged from 5.30 to 8.42 feet below top of casing (TOC). Groundwater elevations ranged from 4067.24 (W-4) to 4062.32 (MW-BX-01) feet above mean sea level (amsl). The contour map indicates that groundwater generally flows to the southeast across the site at a gradient of approximately 0.01 foot/foot. The hydraulic gradient and groundwater flow direction observed at SS-17 during the 2005 LTM Program are comparable with the results from the 2001 and 2003 LTM events.

Table 3-7 summarizes the analytical results for the LTM Program between 1997 and 2005 at SS-17. SS-17 was added to the LTM Program in 1997; therefore, sample results from 1997 serve as baseline concentrations for this site. The analytes exceeding the standards during 2005 LTM events are presented in Figure 3-4.

Nine VOCs were detected above contract-required detection limits (CRDLs) in monitoring wells MW-BX-01 and MW-BX-02 at SS-17 during the 2005 event. Concentrations of benzene (45.1 µg/L) and 1,2-dichloroethane (76.3 µg/L) exceeded the NMWQCC Standards in the groundwater sample collected from the downgradient well MW-BX-02. Overall, the concentrations of VOCs are consistent from previous LTM events with the exception of the benzene detection in well MW-BX-02, which increased from 0.32 µg/L in 2003 to 45.1 µg/L in 2005. No VOCs were detected above the CRDL in the groundwater sample collected from upgradient well W-4. An estimated concentration of chloroform (0.79 µg/L) was the only VOC detected in W-4 (including the duplicate sample).

TDS concentrations ranged from 3,080 to 6,270 mg/L and exceeded the NMWQCC standard (1,000 mg/L) at each of the three wells sampled.

3.4 CONCLUSIONS

The following conclusions can be inferred based on the data presented on Figures 3-3 and 3-4 for soil and groundwater, respectively.

- The constituents that exceed the NMED SSLs beyond the edge of the road to the northeast are primarily present in the capillary fringe and smear zone created by the fluctuating water table (i.e., estimated depth of 5 to 9 feet).
- Primary contaminants of concern in soil beyond the edge of the road towards the northeast are trimethylbenzenes, benzene, ethylbenzene, xylenes, and naphthalene.
- Historical data from multiple monitoring wells (most abandoned) shows that groundwater typically has a TDS concentration greater than 10,000 mg/L (consistent with base-wide results) and is not suitable for potable or domestic use.
- Primary contaminants of concern in groundwater beyond the edge of the road towards the northeast are benzene, ethylbenzene, and naphthalene.

4.0 ACCELERATED CORRECTIVE MEASURES ACTIVITIES

This section presents the recommended accelerated corrective measures based on the results of the previous investigations. Additional site characterization activities are proposed to collect data needed to support, and possibly refine, the corrective measures that are proposed.

4.1 OBJECTIVES

The primary objectives of this work plan are to present a plan for corrective measures that will ultimately support remedy in place for the Off-Site Area immediately north and east of the former BX Gas Station. The strategy for this area consists of cleaning up soils to reduce concentrations below NMED SSLs and demonstrating that the area of groundwater impact is not increasing in size or concentration. Key components of this strategy are:

- Perform limited additional site characterization to identify the area that requires corrective measures, and conduct analyses to support remedial design.
- Conduct corrective measures for soil to remove mass or reduce the concentration of chemicals associated with the release of petroleum hydrocarbons that exceed the NMED soil screening criteria.
- Install a monitoring well network for groundwater and conduct monitoring to evaluate chemical concentrations and trends.

Key components of the work to be performed in the Off-Site Area of SS-17 are presented below:

- Conduct soil and groundwater sampling in the Off-Site Area to delineate soils that exceed NMED regulatory standards and define the area of concern for corrective measures and monitoring.
- Install monitoring wells to establish baseline groundwater conditions, to monitor remedial activities, and to provide for long-term monitoring of the plume.
- Conduct a simple, short-term water injection test in the lower portion of the vadose zone, where high soil concentrations have been documented, to estimate the capacity of the formation for injection and to observe the hydraulic response of the water table.
- Conduct slug tests in up to five new wells to better characterize formation hydraulic conductivity in the area of concern.

- Collect water level measurements in wells to define the local groundwater flow direction, gradient, and to monitor water table fluctuations.
- Perform an in situ microcosm study to evaluate the performance of electron acceptors in biodegradation of petroleum hydrocarbons in the presence of high TDS using Bio-Trap units. The Bio-Trap studies serve as cost effective, in situ microcosms providing microbial, chemical, and geochemical evidence to substantiate biodegradation as the treatment mechanism.
- Use the additional site characterization data and injection test results to refine the interim remedial design presented in the following sections.

4.2 AREAS OF CONCERN WITHIN THE OFF-SITE AREA

The historical sampling data presented in Section 3 was used to identify the area of concern, (i.e., the area requiring corrective measures), within the Off-Site Area included in this ACM Work Plan. Chemical concentrations in both soil and groundwater were identified that exceed NMED SSLs and NMWQCC standards, respectively, to delineate the area of concern. As shown on Figure 4-1, two areas have been identified for soil. For the northern area, the lateral limits are supported by soil samples that did not contain concentrations above the SSLs (SB23, SB13, SB01, and SB25). The area of concern incorporates SB22 because the soil samples for this location are deeper than the depth of the most highly contaminated soil (i.e., 7 to 9 feet bgs), based on other borings, and because SB10 to the immediate west contained numerous chemicals at concentrations above the SSLs. For the southern area, the lateral limits are supported by SB25 and SB24, but the area of concern incorporates SB20 and SSB21 because the soil samples for this location are deeper than the depth of the most highly contaminated soil (i.e., 7 to 9 feet bgs), but chemicals related to the petroleum release were detected at 9 feet bgs. It was also noted that the groundwater sample from SB21 contained petroleum-related chemicals at concentrations above the NMWQCC standards. The eastward extent of impacts to soil is deemed a data gap.

Figure 4-2 presents the areas of concern that have been identified for groundwater; they are the same as for soil. As indicated in the figure, there are limited groundwater data in the Off-Site Area. The eastward extent of the northern area of concern is bounded by well W-4 and SB13, but the impacts to groundwater beneath First Street have not been determined. Because soil concentrations in this area are higher than soil leaching to groundwater concentrations, groundwater beneath the area is suspect. The southern area contains two recent groundwater sample points that show concentrations greater than NMWQCC standards, and the area of concern is generally coincident with the historical extent of free product. However, the lateral extent of impacts to groundwater in the area is not defined and is deemed a data gap.

4.3 ADDITIONAL CHARACTERIZATION

A limited number of soil and groundwater sampling points will be installed to confirm the lateral extent of the area that will require remediation to reduce chemical concentrations. Up to 11 DPT sampling locations are proposed; soil sampling will be conducted at all 11 locations, and 8 of the 11 locations will be completed as a 1.5-inch inner diameter (ID) monitoring well. The proposed locations are shown on Figure 4-3. One new well will be installed in proximity to existing well W-4 that has been reported to be compromised (obstruction in the well).

The soil sampling will focus on the soil interval from approximately 4 feet to 10 feet bgs, which may include the upper portion of the water table depending on seasonal and recent rainfall conditions. This interval contains the depth of highest known and suspected soil contamination. Continuous soil cores will be collected and screened with a photo ionization detector (PID) for VOCs to aid in selection of soil samples for laboratory VOC analysis. The proposed locations are shown on Figure 4-3. Up to two soil samples for laboratory analysis of VOCs are planned from each location; additional intervals may be sampled at the discretion of the field geologist.

The DPT subsurface soil investigations will be performed in accordance with the HAFB SOP-4 (Direct Push Sampling for Soil and Groundwater) and HAFB SOP-10 (Borehole Abandonment and Site Restoration).

Eight of the proposed 11 soil sampling locations have been selected for the installation of monitoring wells. These wells will be sampled after installation to help characterize current (baseline) groundwater conditions, and will be used for long term plume monitoring. The layout of the wells is intended to provide monitoring locations upgradient, within the plume, and along the downgradient perimeter of the plume. Additional monitoring locations may be required based on the additional characterization and baseline monitoring. The proposed locations are also shown on Figure 4-3.

A key element of the corrective measure design is the capacity of the formation to accept injection of a water-based amendment solution for in situ treatment and understanding the hydraulic response of the water table in the vicinity of the injection. A simple potable water injection test will be performed during the site characterization activities using a temporary injection well installed in close proximity to a new monitoring well installed to replace existing well W-4. The temporary well will include a 5-foot well screen that extends approximately 1-foot into the water table (estimated at a depth of 6 to 8 feet bgs based on water table conditions) that is completed with a filter pack and an annular grout seal. The test will consist of connecting a temporary tank of potable water to the well and monitoring the flow rate and

pressure into the well and the water level in the nearby monitoring well over a period of 1 to 2 days. A maximum injection pressure of about 8 ft of head (3.5 pounds per square inch [psi]) is anticipated during the test, but may be temporarily increased pending the well response. The temporary injection well will subsequently be properly abandoned.

4.4 MONITORING WELL INSTALLATION AND SAMPLING

The installation of eight monitoring wells is proposed during the additional site characterization activities described in the previous section (Figure 4-3). The wells will be relatively shallow with a total depth of approximately 15 feet bgs and screened across the water table. The wells are planned to be installed with a DPT rig using a minimum 2.625-inch ID, 3.25-inch outside diameter (OD), probe rod. Well materials will be placed through the rods using 1.5-inch ID, Schedule 40 polyvinyl chloride (PVC) casing and well screen. The screen will be factory-cut 0.01-inch slotted pipe 10 feet in length. All casing will be flush-threaded and a threaded bottom cap will be installed. The top of the riser pipe will extend to an 8-inch diameter manhole that is set in a concrete pad. The well riser will be fitted with a weather-tight, lockable cap. A filter pack consisting of 20/40 mesh, clean, silica sand with uniform sorting, or similar size compatible with the well slot size, will be installed in the annulus around the well screen using the DPT push rods as a tremie pipe. Alternatively, a pre-pack filter containing similar filter sand will be fitted to the well screen prior to installation, and any void space around the pre-pack filter will be filled with compatible, loose filter sand. The filter pack will extend a minimum of 1 foot above and below the screen, but no more than 2 feet. A grout barrier consisting of a minimum of 1 foot of granular bentonite that is hydrated will be placed on top of the filter pack to prevent grout intrusion. The remainder of the well annulus will be filled with grout that is placed using the probe rods as a tremie pipe. The typical monitoring well construction is presented in Figure 4-4.

Once the wells are developed and fully recharged, a groundwater sample will be retrieved from the wells using disposable Teflon-lined polyethylene tubing fitted to a peristaltic pump. The tubing will be inserted into the well so that the tubing inlet will be positioned approximately between the bottom of the well and the top of the water table. The wells will then be purged and sampled using low flow purging and sampling techniques, in accordance with HAFB SOP-8 (Groundwater Sampling for Chemical Analysis) (Appendix B). Three times the tubing volume of purge water will be pumped from the well prior to sampling. After purging the required tubing volume from the wells, the appropriate sample bottles will be filled using direct filling techniques.

Groundwater sample collection and management will be conducted in accordance with HAFB SOP-1 (Documentation, Sample Handling, Chain-of-Custody, and Shipping) and HAFB SOP-8 (Groundwater Sampling for Chemical Analysis) (Appendix B).

4.5 IN SITU MICROCOSM TESTING

An in situ microcosm study will be conducted to evaluate biodegradation of petroleum hydrocarbons in the groundwater at the SS-17 site. The study will be conducted using Bio-Trap samplers that provide microbial, chemical, and geochemical evidences to evaluate biodegradation as a treatment mechanism and to screen remedial alternatives. At SS-17, biodegradation will be evaluated for site contaminants using a mixture of oxygen and nitrates as electron acceptors in a high TDS environment.

The Bio-Trap unit consists of a MICRO sampler that contains Bio-sep beads, an engineered composite of Nomex and powdered activated carbon which provides a large surface area that is readily colonized by subsurface microorganisms. In addition to a matrix for microbial growth, the Bio-sep beads can be “baited” with electron acceptors to investigate biostimulation approaches and estimate biodegradation rates. Additionally, the Bio-Trap units also contain a chemical of concern (COC) sampler to measure contaminant concentrations, daughter product formation, and dissolved gases and a geochemical fingerprint (GEO) sampler for quantification of geochemical parameters (nitrate, iron, sulfate, etc.).

The in situ microcosm study at SS-17 will consist of three Bio-Trap Units deployed within one monitoring well. The monitoring well will be located inside the contaminated plume. The first Bio-Trap Unit will represent the monitored natural attenuation (MNA) condition while the second and third Bio-Trap units (BioStim) will consist of an amendment designed to stimulate biodegradation. Combining one Control MNA Unit and two BioStim Units will form a Bio-Trap Assembly that provides the microbiological, chemical, and geochemical lines of evidence to evaluate MNA and biostimulation as remedial alternatives in a single in situ microcosm study. One BioStim unit will contain only nitrate as an electron acceptor while the second BioStim unit will contain the mixture of oxygen and nitrate as electron acceptors at concentrations shown in Table 4-1. All the Bio-Trap units will contain COC and GEO samplers for chemical and geochemical analyses. The Bio-Trap assembly will be installed and maintained in a monitoring well for approximately 30 days. After that time the Bio-Trap assembly will be recovered from the monitoring well and sent to the laboratory (Microbial Insights) for following analysis and evaluation:

- Pre-deployment and post-deployment concentrations of ^{13}C benzene on Bio-Traps to determine percent loss and to estimate a first order rate constant.
- Phospholipid fatty acids (PLFA) to determine total biomass and profiling microbial community composition.
- ^{13}C enriched PLFA to demonstrate contaminant incorporation into biomass.
- ^{13}C enriched dissolved inorganic carbon (DIC) to quantify contaminant mineralization to CO_2 .
- Standard VOC analysis of passive diffusion samplers to determine the impact of treatment approaches on aqueous contaminant concentrations.
- Anion (nitrate, sulfate, phosphate) concentrations to document amendment release and determine concentrations of terminal electron acceptors.
- Quantitative PCR of *bssA* (functional gene for anerobic BTEX degradation) and/or PHE (aerobic benzene degradation).

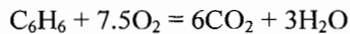
4.6 DESIGN AND IMPLEMENTATION

The selected technology consists of enhanced bioremediation to destroy chemical mass and reduce chemical concentrations in soils within in the capillary fringe and smear zone lying directly above the shallow water table. The approach relies on multiple injection points to flood soils overlying the water table with low levels of oxygen in combination with a nitrate source to promote degradation of petroleum hydrocarbons. The mixing of substrates (oxygen, nitrates, and sometimes sulfates) has been suggested based on numerous research/tests performed at sites contaminated with petroleum hydrocarbons (US EPA, 1997). Based on the tests, it was concluded that:

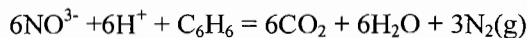
- In general, providing some level of oxygen resulted in better substrate removal than anaerobic denitrifying conditions.
- There were no benefits to providing microaerophilic levels of oxygen (< 2 mg/L) in combination with nitrate when compared with higher levels of oxygen (7 and 30 mg O_2/L).
- Moderate, yet aerobic levels of oxygen (7-10 mg O_2/L) in combination with nitrate rather than high concentrations (30 mg O_2/L) resulted in comparable substrate removal and faster kinetics.

An example of the process, assuming complete mineralization of benzene to carbon dioxide and water, showing the reactions for aerobic respiration and denitrification are as follows:

Aerobic Respiration



Denitrification



Providing low levels of oxygen in combination with nitrate during in situ bioremediation also accomplishes the following benefits:

- Low levels of oxygen are not toxic to denitrifying bacteria allowing for facultative use of both oxygen and nitrate as electron acceptors;
- Low levels of oxygen are less expensive to maintain in the subsurface; and
- It is easier to maintain a low residual oxygen concentration in the subsurface than a high concentration due to the many oxygen demands/sinks.

An in situ bioremediation scheme which combines moderate aerobic (7 mg/L O₂) and denitrifying conditions will likely prove more successful than solely aerobic remediation for the long term remediation of aromatic hydrocarbons. Oxygen is consumed preferentially over nitrate or sulfate and would be consumed within a very short distance of the injection well. This is particularly true because the solubility of O₂ in water is relatively low at ambient conditions (about 9-10 mg/L) and because oxygen is highly reactive in reduced groundwater. Also, the electron-donating capacity of oxygen is low as compared to those of nitrate and sulfate. Nevertheless, petroleum hydrocarbons (including benzene) are biodegraded rapidly under aerobic conditions, so injection of oxygen would only be expected to improve the overall system performance.

For in situ biodegradation with mixtures of oxygen and nitrate to be successful, bacteria that are capable of using both oxygen and nitrate (facultative anaerobic bacteria) as electron acceptors must be present at the remediation site.

Given below are the sequential phases of implementation of bioremediation technology for the treatment of petroleum hydrocarbons at the SS-17 site:

- Baseline soil and groundwater sampling (conducted during site characterization activities) that document the current lateral and vertical distribution of the contaminants;
- Infrastructure construction consisting of the installation of injection wells (and additional monitoring wells if needed);
- Installation of any site facilities needed to conduct injection (e.g., trenches, header piping, mixing and storage tanks);
- Injection of electron acceptors at concentrations determined during in situ microcosm study; and
- Sampling of soils and groundwater to evaluate the impacts of electron acceptors in the aquifer including geochemical and COC sampling.

The following sections present the design for the biodegradation of petroleum hydrocarbons at the SS-17 site. The design is based on making certain assumptions including radius of influence during electron acceptor injection, concentration of electron acceptors (oxygen and nitrate) in the aquifer after injection, and treatment area configuration. These design components will be updated, as needed, after performing the additional site characterization, injection test, in situ microcosm study, and monitoring well sampling.

4.6.1 Injection Goal

The goal of each injection event is to partially flood the capillary fringe and the contaminated soil smear zone directly overlying the water table across the area of concern. The injection will wet dry areas in the target zone and provide amendments to support a favorable environment for biological degradation of the COCs. Injections will be conducted primarily immediately before and during seasonal high rainfall (July through October) to take advantage of the anticipated rising and seasonally higher water table, or may occur throughout the year when rainfall or high water table conditions may exist. Once developed, the zone of enhanced biological activity is expected to spread vertically with the rise and fall of the water table for a period of several months. A series of four injections is proposed over a period of 1 to 1.5 years.

A notice of intent to conduct injections will be submitted to the New Mexico Groundwater Quality Bureau per regulation 20.6.2.1200 to determine if a permit is required.

4.6.2 Injection Well Installation

The treatment area of concern presented in Figure 4-5 is based on the soil and groundwater data available at the time of this work plan preparation. The area of concern consists of two parcels with a total area of approximately 47,600 square feet. Assuming a radius of influence of 25 feet for an injection well, 25 injection wells will be installed within the treatment area of concern. The layout of the injection well grid is presented in Figure 4-5. The details of the injection wells are presented in Table 4-2. The injection wells will be constructed of a 1.5-inch diameter, 5-foot long, 0.010-slotted Schedule 40 PVC well screen wrapped with a stainless steel wire mesh containing a 0.25 inch thick, pre-pack filter. The screen will be capped with a flush-jointed well cap and attached to a 1.5-inch diameter, Schedule 40 PVC riser pipe. The pre-pack wells will be installed through DPT push rods with an OD of 3.25 inches. A typical injection well construction is presented in Figure 4-6.

To assess the initial spacing of the injection wells, a computer program for an unconfined water table aquifer (*Groundwater Pumping Test*, William C. Walton, Lewis Publishers, 1988) was used to predict the impacts of pumping a theoretical well installed in the water table aquifer at the site. Using SS-17 specific hydraulic conductivity and porosity data from existing reports and a groundwater pumping rate of 0.5 gpm resulted in a drawdown of 1.1 feet at a radius of 25 feet after 3 days. The results are suggestive that a similar radius may be achieved by injecting in a similar well. However, the need for additional or closer-spaced injection points will be evaluated based on the results of the additional characterization and water injection test proposed in Section 4.5.

4.6.3 Injection Procedure

Each injection event will utilize the following equipment:

- 5,000 to 20,000 gallon mixing tank(s), portable or temporarily located on site;
- A 10 gallons per minute (gpm) capacity pump;
- Well head valve and control assembly; and
- Temporary, reusable supply header (1" PVC piping).

The electron acceptors (oxygen and nitrate) will be mixed using potable water in a 5,000 gallon mixing tank(s) and transferred to 10,000 to 20,000 gallons holding tank that will supply flow directly to the injection wells using gravity head through a temporary, reusable 1-inch diameter PVC pipe header system. Potential locations for mixing tanks are shown of Figure 4-5. A small centrifugal pump (e.g., 10 gpm capacity) may be used to provide additional pressure, if required, to each group of injection wells to

attain the optimal injection flow rate and radius. However, the injection flowrate at each injection well is estimated to range between 0.25 and 0.5 gpm. The PVC header pipe will be laid on the ground during the injection period, stabilized using sand bags, and will be attached to local groups of injection wells. At each injection well location, a flexible hose and a portable, reusable well head assembly consisting of a valve, pressure gauge, and flow meter will be used to connect the supply header pipe to each injection well head using a quick-disconnect coupling. The injection well head control valve assembly shown in Figure 4-7 will be used to control injection pressure and flow rate of the electron acceptors and monitor the volume of fluids injected. The injection well head connection will be pressure tight such that increased pressures can be applied using a pump to attain the optimal radius of influence. Each injection event is estimated to last approximately two weeks during which time the temporary header piping and well head valve assembly will be protected by barriers and cones. Water levels in all Off-Site Area monitoring wells and wells MW-BX-01 and -02 will be monitored prior to the start of each injection, and wells located near the active injection points will also be monitored during injection. The process flow diagram is presented in Figure 4-8.

One trench is proposed from the southwest side of First Street extending out the central turning lane. An underground supply header pipe will be installed in this trench with stub outs located in manholes on each end. This structure will allow a mixing tank located on the former BX Gas Station site to be connected to the temporary header lying along the central turning lane (temporarily barricaded) that distributes the injection fluid to injection wells located along the center of First Street. At the end of each injection event, all above grade equipment (with the possible exception of mixing tanks) will be removed from the site and stored for reuse during subsequent injections.

4.6.4 Injection Implementation

Following the injection and monitoring well installation, baseline sampling, and system installation, electron acceptors will be injected in the groundwater through injection wells. Calcium peroxide, an oxygen source along with potassium nitrate, a nitrate source will be mixed in water before injecting into the subsurface. An optimum mix of oxygen and nitrate determined during the bench scale experiments performed on petroleum hydrocarbons at other sites are 8 mg/L of oxygen and 10 mg/L of nitrates in aquifer, respectively. The optimum mix of oxygen and nitrate in high TDS environment at SS-17 will be determined during in situ microcosm study (see Section 4.5). The source of oxygen and nitrate will be injected in the subsurface so that the concentrations determined during the study are attained in the aquifer. If the microcosm testing indicates the absence of facultative bacteria in the aquifer, commercially available bacteria will be injected to promote biodegradation.

The goal of each injection event is to distribute the injectate across the smear zone lying within the seasonal high and low water table around each injection well with a solution that will enhance biological growth and lead to degradation of the COCs. The injected solution is expected to mix with the aquifer groundwater and be distributed by the injection hydraulic head and the seasonal fluctuation of the water table. The volume and concentration of the injectate is based on the following:

- an assumed average injection rate of 0.5 gpm per injection well
- an injection period of 3 days per well, or approximately 2,160 gallons per well per event
- an assumption that the injectate will mix with a volume of aquifer groundwater contained in a 25 ft radius by 5 ft vertical interval

Based on the above assumptions, calculations show that approximately 3.3 and 1.5 lbs of Calcium Peroxide and Potassium Nitrate, respectively, should be mixed in 2,160 gallons of water resulting in an injectate concentration of approximately 0.018% and 0.0083 % of Calcium Peroxide and Potassium Nitrate, respectively. Based on the above assumption for aquifer mixing, injecting this volume of injectate at an injection well will result in achieving 8 mg/L of oxygen and 10 mg/L of Nitrate in the aquifer.

The initial injection event will be timed to precede the expected rising water table in late spring or early summer (late May, early June). This will allow the initial injection to penetrate to the lower portion of the contaminated soil smear zone, when the water table is expected to be low. The rising water table will then promote upward distribution of microbes and geochemical substrate. The second and third injections are planned for 2 months and 5 months after the initial injection. These events will take advantage of the seasonally higher water table (July to October) to impact the entire smear zone, that is, the zone between the low and high water table. A fourth injection will likely be performed the following spring or summer, pending review of groundwater monitoring results that will be used as indicators of changes in the local geochemical environment. Each injection event is expected to last approximately 1-2 weeks.

4.6.5 Performance Sampling

Baseline sampling will be conducted as part of the additional site characterization described in Section 4.3. As shown in Figure 4-5, placement of the monitoring wells during additional site characterization is anticipated to provide monitoring points in proximity to injection wells that will allow monitoring of changes in the water table geochemistry and chemical concentrations. However, additional

monitoring wells may be installed to provide sufficient monitoring points if deemed necessary (e.g., to account for system design changes resulting from the additional site characterization).

The installed monitoring wells are also expected to provide upgradient, in-plume, and downgradient monitoring points to evaluate groundwater impacts over time. Up to four rounds of performance groundwater sampling are anticipated at the following intervals:

- 2 months after the initial injection, prior to the second injection
- 3 months after the second injection, prior to the third injection
- 4 months after the third injection, and prior to the anticipated fourth injection
- 5 months after the fourth injection, or approximately 1 to 1.5 years after the initial injection

Three additional rounds of groundwater monitoring are anticipated to demonstrate that the remedial goals for groundwater are being achieved and will be performed at 3 to 6 month intervals.

Monitoring results will be evaluated following each injection and a determination will be made as to the necessity of further injections. If the results indicate that biodegradation is not progressing at the site, an alternative remedial approach will be developed to meet the NMED requirements.

Groundwater will be monitored for standard water quality parameters during purging and prior to sample collection (pH, temperature, specific conductivity, dissolved oxygen, and oxidation-reduction potential). All groundwater samples will be analyzed for VOCs, Fe²⁺ sulfide, sulfate, nitrite, nitrate, alkalinity, methane, carbon dioxide, and Quantitative PCR (functional genes) (qPCR) (Table 4-3). The results of the groundwater monitoring will be used to evaluate the progress of changes in the geochemistry indicative of biological processes and to evaluate COC trends in the aquifer.

The groundwater data will also be used to select a time for post-injection soil sampling that will target the contaminated soil zone that lies between approximately 5 to 9 feet bgs. Geochemical signatures and changes in COC concentrations in groundwater will be considered indicators that biological degradation is occurring. Soil samples will be collected immediately adjacent to baseline sampling locations using DPT, analyzed for VOCs and nitrate, and the results compared to baseline samples to evaluate effectiveness of the corrective measure. These samples are intended to demonstrate that the remedial

strategy is effectively lowering the concentrations of COCs in the target soil zone. Additional rounds of soil sampling may be required.

4.6.6 Reporting

The results of the additional site characterization, field tests, boring and well logs, injection events, and performance sampling data will be presented in an Accelerated Corrective Measures Completion Report.

4.6.7 Conclusions

The closure strategy for the on-site source area at and near the former BX Gas Station involves multiple remedial actions. To date, these have included:

- Free product removal using recovery wells and trenches;
- Operation of a full-scale SVE/bioremediation system; and
- Soil/source removal.

In addition to the above actions that have already been taken at the site, the corrective measures presented in this ACM Work Plan are designed to address the residual low concentration hydrocarbons that remain under the road and lateral to the already treated source area.

The technical approach in this ACM Work Plan has been developed to overcome site specific constraints that include:

- Low hydraulic conductivity;
- High total dissolved solids in the groundwater;
- Several utilities in the area; and
- Remediation under the road with limited traffic interruption.

The combination of the actions already taken at this site, plus the actions outlined in this ACM Work Plan, is designed to lead to a determination of Remedy in Place. Once completed, No Further Action (NFA) Site Closure with or without soil and groundwater land use controls (LUCs) which may include MNA can be achieved.

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5.0 REFERENCES

- Bhate (Bhate Environmental) 2003. Basewide Quality Assurance Project Plan, Holloman Air Force Base, Alamogordo, New Mexico. November.
- Bhate (Bhate Associates) 2006. 2005 Long Term Groundwater Monitoring Report for SS-17, Holloman Air Force Base, Alamogordo, New Mexico. May.
- Bhate (Bhate Associates) 2008. Data Tables Provided by Bhate Associates for SS-17, Holloman Air Force Base, Alamogordo, New Mexico. May.
- NMAC (New Mexico Administrative Code) 20.6.20.3103. Standards for Ground Water of 10,000 mg/L TDS Concentration or Less, Human Health Standards, Other Standards for Domestic Water Supply, and Standards for Irrigation Use.
- NMED (New Mexico Environment Department), 2004. Holloman AFB Hazardous Waste Facility Permit No. NM65721244122. February.
- NMED (New Mexico Environment Department), 2006a. New Mexico Environment Department TPH Screening Guidelines. October
- NMED (New Mexico Environment Department), 2006b. Technical Background Document for Development of Soil Screening Levels, Revision 4.0; June.
- U.S. EPA (U.S. Environmental Protection Agency), 1986. Guidelines for Groundwater Classification Under the USEPA Groundwater Protection Strategy, Final Draft. Office of Groundwater Protection (WH-550G), Washington, D.C. December.
- U.S. EPA (U.S. Environmental Protection Agency), 1997. Bioremediation of BTEX, Naphthalene, and Phenanthrene in Aquifer Material Using Mixed Oxygen/Nitrate Electron Acceptor Conditions, EPA/600/SR-97/120, October.

U.S. EPA (U.S. Environmental Protection Agency), 2000. Soil Screening Guidance for Radionuclides: Technical Background Document (EPA/540-R-00-006). October.

U.S. EPA Reg VI (U.S. Environmental Protection Agency Region VI), 2007. Region 6 Human Health Medium Specific Screening Levels 2007.

WHA (Walk, Haydel & Associates, Inc.) 1992. Corrective Action Plan for SS-17, Holloman Air Force Base, Alamogordo, New Mexico. September.

WRRI (New Mexico Water Resources Research Institute), 2005. Proceedings, 49th Annual New Mexico Water Conference, Water Desalination and Reuse Strategies for New Mexico.

TABLES