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TECHNICAL MEMORANDUM

DATE: February 15, 2011

FROM: INTERA Incorporated

TO: Mr. John Stomp III, PE, Mr. Rick Shean, and Ms. Barbara Gastian, Albuquerque Bernalillo County Water Utility Authority

SUBJECT: **Review of *Vadose Zone Work Plan Part 1: Field Investigation Activities for the Bulk Fuels Facility Spill, Solid Waste Management Units ST-106 and SS-111*, by Shaw Environmental & Infrastructure, dated November, 2010**

1.0 Introduction

INTERA, Incorporated (INTERA) was retained by the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) to provide technical expertise and analytical support in reviewing the work plans for characterization and remediation of the Kirtland Air Force Base (KAFB) bulk jet fuel spill. INTERA's review is focused on identifying concerns or improvements in the work plan activities or schedule that will help achieve the ABCWUA's objective of minimizing long term damage to aquifer water quality and infrastructure. The long duration and large quantity of fuel released to the vadose zone and aquifer can pose a significant threat to soil and water quality and to water supply wells downgradient of the light density non-aqueous phase liquid (LNAPL) lens that extends roughly northward from the bulk fuel transfer and handling areas, underneath Bullhead Park towards the intersection of San Pedro and Gibson Boulevards SE in Albuquerque, NM (Figure 1).

KAFB has contracted Shaw Environmental & Infrastructure Inc (Shaw) to characterize the extent of the contamination in the vadose zone and aquifer and to implement containment and remediation of the soil and groundwater. Shaw and KAFB have submitted four work plans, the most recent version of each is dated November 2010, to the Hazardous Waste Bureau (HWB) of the New Mexico Environment Department (NMED):

1. *LNAPL Interim Measure Containment Work Plan*, which is directed at establishing temporary containment of the dissolved phase and LNAPL (Shaw, 2010a);
2. *Interim Measures Work Plan, Part I: Field Investigation Activities*, which focuses on removal of near surface fuel-contaminated soils and characterization of the distribution of LNAPL and dissolved phase in the deep vadose zone (Shaw, 2010b);
3. *Groundwater Investigation Work Plan, Part I: Field Investigation Activities*, which focuses on installing 78 wells to establish the extent of the dissolve phase plume (Shaw, 2010c); and
4. *Vadose Zone Investigation Work Plan, Part I: Field Investigation Activities* (VZIWP), which focuses on the vadose zone properties and contaminant distribution beneath source areas (Shaw, 2010d).

NMED has already reviewed and commented on items 2, 3, and 4, most recently in its notice of partial approval with modification and notice of disapproval, dated December 10th, 2010. This memorandum reviews item 4 above, *Vadose Zone Investigation Work Plan*, as well as NMED's comments on the work plan. NMED's comments were issued in the December 10th, 2010 notice of partial approval with modification and notice of deficiencies (NMED, 2010).

INTERA's review focused on the work plan's strengths and weaknesses in achieving the ABCWUA's paramount priorities: characterizing and remediating the dissolved phase plume without damaging the aquifer. Section 2 summarizes the work plan; key findings are presented in Section 3, and recommendations in Section 4.

2.0 Summary of Vadose Zone Investigation Work Plan

As stated in its executive summary, the vadose zone investigation work plan's (VZIWP) primary objectives are to acquire a sufficient understanding of the vadose zone hydrogeology and contaminant distribution:

> *"Estimate the amount of fuel that exists within the vadose zone as absorbed or residual liquid, or as soil gas;*
>
> *Identify the probable source of the LNAPL fuel plume; and*
>
> *Characterize the vadose zone geology, hydrology, hydrogeology, and soil/soil vapor contamination in sufficient detail to prepare an updated conceptual site model, which*

> *incorporates current and potential soil and groundwater contamination pathways, vadose zone sources, and the distribution, fate, and transport of contaminants.”* (Shaw, 2010d, page ES-1).

The VZIWP identified two data gaps (Shaw, 2010d, page 1-5) to be addressed in order to achieve its objectives:

1. “…lateral and vertical definition of vadose zone contamination…”;
2. “…the nature and extent of fuels-related soil and soil-vapor contamination…”.

NMED issued a partial approval of the VZIWP so that specific activities could begin immediately and disapproved parts of the work plan (NMED, 2010). NMED required Shaw to make the work plan compliant by March 31st, 2011 (NMED, 2010).

2.1 Vadose Zone Investigation Activities

Shaw proposed to achieve the work plan’s objectives by drilling 35 boreholes, collecting geophysical logs and soil samples, and constructing soil vapor monitoring wells within five investigation areas in and around the source areas. The work plan specified the number of borings for each investigation area:

- *Tank Farm - Eight deep and five shallow soil borings/soil-vapor wells will be completed in the tank farm area. Depending on what is found, additional soil borings/soil-vapor wells may be needed. Eight deep soil borings to 450 ft and five shallow soil borings to a depth of at least 20 ft will be completed at Tank Farm locations (Figure 1).*

- *Pipeline - The pipeline that runs between the tank farm, the pump house, and the FFOR has not been investigated. Five deep soil borings/soil-vapor wells will be completed along the buried and exposed portions of the pipeline. Five deep soil borings/soil-vapor wells will be completed to 450 ft. Figure 1 shows locations of soil boring/soil-vapor wells.*

- *Former Fuel Offloading Rack (FFOR) - Six deep soil borings/soil-vapor wells will be completed at the FFOR to determine the full extent of contamination. Soil borings/soil-vapor wells will be completed at the locations shown on Figure 1.*

- *Fuel Percolation Area - Eight deep soil borings/soil-vapor wells will be completed in order to significantly improve characterization of this area. The eight soil borings/soil-vapor wells locations are shown on Figure 1.*

- *Farfield Area of Soil-Vapor Plume - Eight soil-vapor wells will be completed at locations north of the Fuel Offloading Rack and the fuel percolation area to investigate the concentrations of hazardous constituents in soil gas that overlies groundwater in these areas. Soil-vapor well locations are shown on Figure 1.*

NMED issued a partial approval of the work plan (NMED, 2010) with the following modifications

- *The Permittee shall immediately complete the 35 deep and 5 shallow soil borings provided for in Section 5.2.10 of the revised Vadose Zone Investigation Work Plan. The work shall be completed by February 11, 2011(Appendix B of the Vadose Zone Investigation Work Plan). Each deep boring at each location shall be drilled from the surface to the water table.*

- *Soil samples from the deep borings shall be collected at a frequency of at least one sample every 10 feet for the first 50 feet, and at least one sample thereafter every 50 feet to total depth, and at least one sample at total depth in each boring. The soil samples shall be analyzed for TPH, VOCs, SVOCs, and lead.*

- *Soil samples from shallow borings shall be collected at depths of 0,5, 10, 15, and 20 feet and shall be analyzed for TPH, VOCs, SVOCs, and lead.*

- *Each soil boring shall be logged in accordance with Permit Part 6.5.15 by a registered professional geologist.*

- *The Permittee shall immediately install the 35 soil-gas monitoring wells provided for in Section 5.2.11 of the revised Vadose Zone Investigation Work Plan submitted November 4, 2010. The well installations shall be completed by February 11, 2011 (Appendix B of the Vadose Zone Investigation Work Plan).*

- *The soil-gas monitoring wells shall be capable of yielding discrete samples of soil gas recovered from depths of 25,50, 150,250,350, and 450 feet below the ground surface.*

- *The borehole of each well shall be logged in accordance with Permit Part 6.5.15 by a professional geologist.*

- *Vapor sampling and reporting requirements shall be conducted as directed in NMED's letter of June 4, 2010.*

- *NMED approves the Permittee's proposal to conduct borehole geophysical logging (medium and deep induction, gamma, and neutron) at all new groundwater and soil-vapor monitoring wells. Copies of the logs must be submitted to the NMED by no later than June 1, 2011.*

Geophysical logging includes induction, neutron, and gamma logs, just as for the groundwater wells to be constructed at the same time. NMED listed a number of deficiencies in the methodology for geophysical logging for both the VZIWP and the groundwater investigation work plan, of which the most relevant is whether logging can be conducted on the VZIWP soil borings given their diameters (NMED, 2010).

The work plan specified collection of soil samples at five ft intervals in the shallow borings and over irregular intervals in the deep borings: at ten ft intervals over the top 50 ft and then at 50 ft intervals to the bottom of the boring. Samples are to be analyzed for lead, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), volatile petroleum hydrocarbons (VPH), and extractable petroleum hydrocarbons (EPH).

Following logging and soil sampling, 35 soil vapor monitoring wells are to be installed in the boreholes. According to the VZIWP,

> *"Each nested well location will include six individual (one 2-inch diameter and five 3/4-inch diameter), schedule 80, PVC soil vapor monitoring wells installed in the same borehole. The nested wells will include a 10-ft length of machine slotted (0.050-inch) screen. Anticipated depths of the nested wells will be 25-, 50-, 150-, 250-, 350-, and 450-ft bgs. Actual well depths may vary and are dependent on lithology observed during the advancement (drilling) of each borehole (e.g., screens will be placed in transmissive zones)."* (Shaw, 2010d)

NMED cited an inadequate description of the soil vapor sampling to be conducted at these wells and requested a detailed explanation of the methods to be employed (NMED, 2010).

3.0 Key Findings

Our review has identified significant flaws in the work plan. In brief, the work plan presents a set of generally reasonable first steps towards delineating the nature and extent of vadose zone contamination, but Shaw cannot achieve the work plan's stated objectives without increasing in concert the number of soil samples collected and the frequency of collection with depth.

Understanding the mass, spatial distribution and rates of movement of the contamination in the vadose zone is critical to understanding the long-term contaminant loading to the aquifer. This knowledge is also the key to determining the expected operational life span of any remediation efforts both the vadose zone and the aquifer. Quantifying the spatial distribution of contaminant mass based on regular sampling will provide an estimate of future vadose zone contaminant loading to the aquifer that is more likely to be defensible and have less uncertainty than an estimate based on irregular sampling.

3.1 Insufficient Soil Sampling

For depths below 50 ft, collecting samples every 50 ft will not provide sufficient vertical resolution to adequately delineate the presence and mass of LNAPL or associated contamination, or identify potential preferential migration pathways in the vadose zone. Given the heterogeneous nature of subsurface lithology and the non-wetting phase's preference for larger pores, LNAPL may be moving through the subsurface via relatively thin, preferential pathways. LNAPL is thought to be following a tortuous, three-dimensional pathway, such as "stair-stepping" from one clay lens to another, as it moves through the subsurface, according to Shaw (2010d page 3-9) and presentations made by CH2M Hill to the ABCWUA Board. Sampling at intervals of only 50 ft is likely to miss significant amounts of LNAPL mass, such as that contained in "fingers" or lobes of LNAPL, present in the vadose zone. This will likely result in significant underestimation of several important quantities, including total vadose zone mass of contamination, time required for soil vapor extraction (SVE) to reach remediation goals, solute flux rate from vadose zone to aquifer, and time required for the contaminant flux from the vadose zone to the aquifer to drop to rates that are not injurious to water quality standards.

We have noted potentially confusing inconsistencies in the language used to soil sampling for contamination in the VZIWP. In Section 6, Monitoring and Soil Sampling, the work plan states that sampling will focus on volatile organic compounds only (first paragraph on page 6-1), whereas the first paragraph in Section 6.1 (same page) refers to characterizing residual fuel and the subsequent paragraphs state that samples will be analyzed for volatiles, semi-volatiles, VPH, and EPH. The various jet fuels comprise volatile, semi-volatile, and aliphatic organic compounds as well as other components, e.g., lead and ethylene dibromide. The work plan should be revised to state that analyses will be conducted for all contaminants of potential concern and provide a list of those contaminants.

3.2 Hydraulic Property Measurements

The 35 boreholes should provide an important first-cut examination of the lithology and contaminant distribution, assuming samples are collected at sufficiently small depth intervals. Representative intervals should be sampled throughout the entire vadose zone thickness and analyzed for unsaturated hydraulic properties, including measurements of in situ gravimetric water content, bulk density, porosity, saturated volumetric water content, residual volumetric water content, saturated hydraulic conductivity, and measurements to determine the moisture retention curve (also known as the characteristic curve or pore pressure – saturation curve) and the relative permeability curve. Fitting appropriate constitutive relations to these latter two curves will provide important information for variably saturated flow and transport simulations or multi-phase transport simulations, such as the air entry matric potential (inverse of van Genuchten alpha parameter) and the van Genuchten *n* parameter. Particle size distributions should also be collected from each representative interval. These parameters and constitutive relations are necessary inputs for simulations of flow and transport under variably saturated conditions (or multi-phase transport) to quantify the potential future vadose zone loading to the aquifer and to evaluate potential remedial alternatives. Additional parameters, such as LNAPL density, composition, and interfacial tension, will be needed to if multi-phase transport simulations are required in the future.

3.3 Characterizing Contaminant Mass in Vadose Zone

The work plan does not list any analyses to be undertaken using the results of the soil sampling data. Given the importance of understanding the total contaminant mass within the vadose zone, the work plan should be revised to include analyses that use the newly collected data to characterize the nature and extent of contamination within the vadose zone. Such analyses should include at a minimum estimating the total mass of contamination, the spatial distributions of contaminants of potential concern and each fuel type, and cross-correlation between soil vapor measurements and soil sample measurements. Ideally, the analyses should be based on samples collected at regular depth intervals and should employ more than one method of estimation. The analyses should also include estimates of the uncertainty.

3.4 Soil Vapor Extraction System

According to NMED, it directed KAFB to install and operate additional soil vapor extraction systems to 16 additional locations in its August 2010 Notice of Deficiency (NMED, 2010). However, KAFB did not add more SVE systems nor did it propose an alternative, with the end result, in NMED's judgment, that "…the Permittee has not done anything in the past four months to accelerate the reduction of the soil-vapor mass in the vadose zone at the Bulk Fuels Facility" (NMED 2010). NMED also requested that Shaw develop and submit by March 31st, 2011 a soil vapor extraction optimization plan for the four existing SVE systems (NMED, 2010).

4.0 Recommendations

Collect soil samples at regular depth intervals throughout the entire vadose zone in all soil borings. The depth interval should not exceed 10 ft and would ideally be smaller than that.

Analyze soil samples for all contaminants of potential concern, particle size distribution, and the suite of hydraulic properties necessary to carry out flow and transport simulations under variably saturated or multi-phase conditions.

Revise the work plan to include descriptions of the analyses to be made using newly collected data to characterize the nature and extent of contamination within the vadose zone.

ABCWUA should inquire of NMED why there has been no acceleration of SVE and request that NMED pursue such acceleration. ABCWUA should also review the SVE optimization plan when it is submitted to NMED on March 31st, 2011.

5.0 References

New Mexico Environment Department (NMED), 2010. Letter from James P. Bearzi, NMED to Colonel Robert L. Maness and Mr. John Pike, Kirtland Air Force Base. Dated December 10, 2010.

Shaw, 2010a. LNAPL Interim Measure Containment Work Plan for the Bulk Fuels Facility Spill, Solid Waste Management Units ST-106 and SS-111, November, 2010.

Shaw, 2010b. Interim Measures Work Plan, Part I: Field Investigation Activities for the Bulk Fuels Facility Spill, Solid Waste Management Units ST-106 and SS-111, November, 2010.

Shaw, 2010c. Groundwater Investigation Work Plan, Part I: Field Investigation Activities for the Bulk Fuels Facility Spill, Solid Waste Management Units ST-106 and SS-111, November, 2010.

Shaw, 2010d. Vadose Zone Investigation Work Plan, Part I: Field Investigation Activities for the Bulk Fuels Facility Spill, Solid Waste Management Units ST-106 and SS-111, November, 2010.

FIGURES

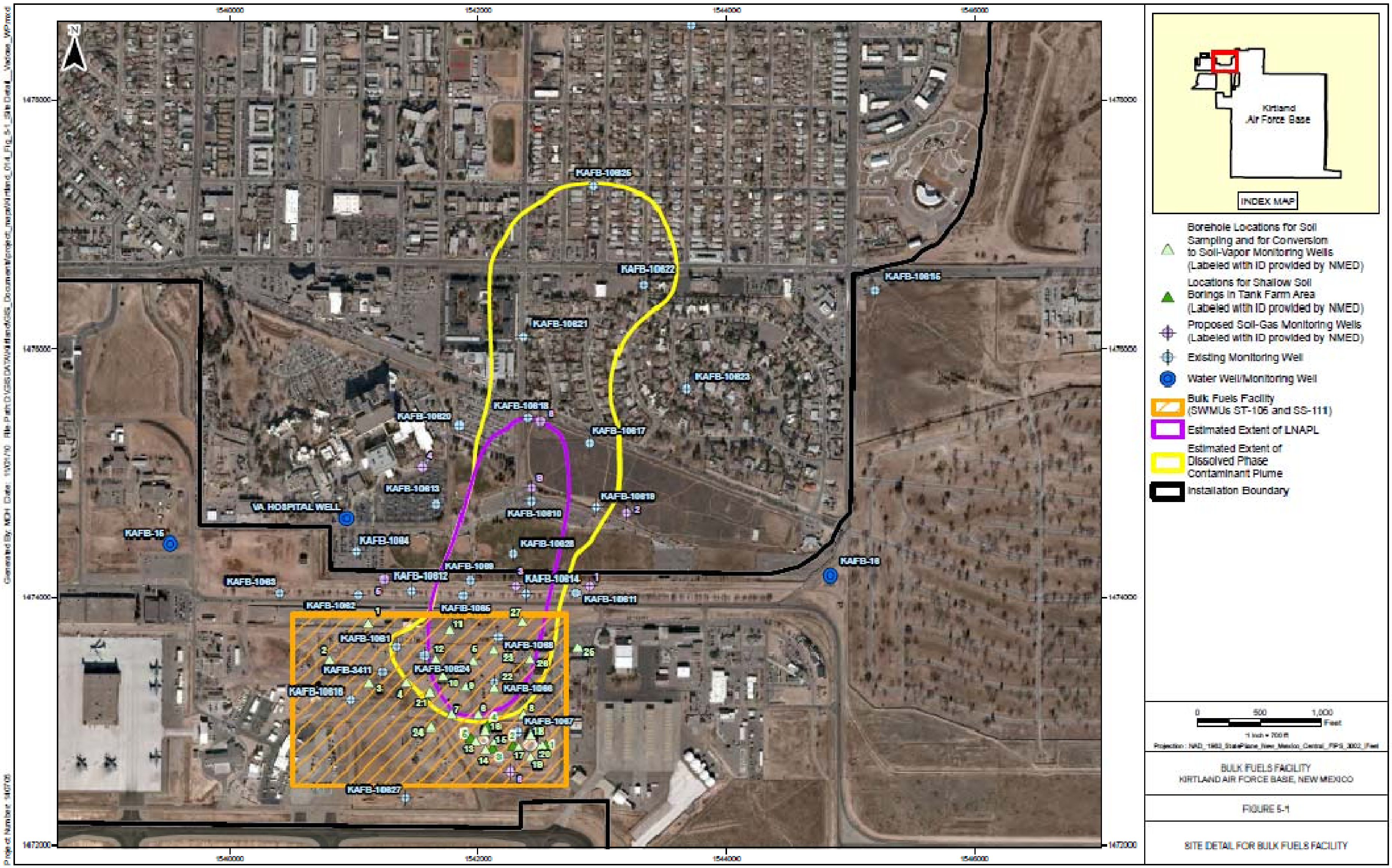

Figure 1 Soil Borings and Investigation Areas (taken from Shaw, 2010d).