NEW MEXICO
ENVIRONMENT DEPARTMENT

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CERTIFIED MAIL - RETURN RECEIPT REQUESTED

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Deputy Secretary

MAR 0 4 2020

Colonel David S. Miller
Base Commander
377 ABW/CC
2000 Wyoming Blvd SE
Kirtland AFB, NM 87117

Lt. Colonel Wayne J. Acosta
Civil Engineer Office
377 Civil engineer Division
2050 Wyoming Blvd SE, Suite 116
Kirtland AFB, NM 87117

RE: DISAPPROVAL
ETHYLENE DIBROMIDE IN SITU BIODEGRADATION PILOT TEST REPORT
BULK FUELS FACILITY SOLID WASTE MANAGEMENT UNITS ST-106 AND SS-111
KIRTLAND AIR FORCE BASE, NEW MEXICO
EPA ID# NM6213820974
HWB-KAFB-19-011

Dear Colonel Miller and Lt. Colonel Acosta:

The New Mexico Environment Department (NMED) is in receipt of the Kirtland Air Force Base (Permittee) *Ethylene Dibromide In Situ Biodegradation Pilot Test Report* (Report), dated April 2019. NMED has reviewed the Report and hereby issues this Disapproval. Although the Permittee demonstrated that in-situ biodegradation of 1,2-dibromoethane (EDB) had occurred during the pilot test, deficiencies were identified throughout the Report. This should not be construed to mean that the approach would be an effective remedial option, but simply that biodegradation of EDB was observed to occur during the pilot test.

The attached comments are related to general inadequacies and inaccuracies, technical inadequacies and inaccuracies, and direction for future light nonaqueous phase liquids (LNAPL) delineation and mitigation. Determining the extent of LNAPL is necessary for establishment of an effective monitoring system and the evaluation of future remedial alternatives. The Permittee must address the attached comments.

KAFB4942

The Permittee must submit a revised Report that addresses all comments contained in the attachment to this Disapproval. Two hard copies and an electronic version of the revised Report must be submitted to the NMED. The Permittee must also include a redline-strikeout version in electronic format showing where all revisions to the Report have been made. The revised Report must be accompanied with a response letter that details where all revisions have been made, cross-referencing NMED's numbered comments. The Revised Report must be submitted to NMED no later than **June 5, 2020**.

Should you have any questions or wish to meet with us to discuss these comments, please contact me at (505) 476-6035 or have your staff contact Michiya Suzuki of my staff at (505) 476-6046.

Sincerely,

Kevin M. Pierard, Chief
Hazardous Waste Bureau

cc: D. Cobrain, NMED HWB
B. Wear, NMED HWB
M. Suzuki, NMED HWB
L. King EPA Region 6 (6LCRRC)
S. Clark, KAFB
K. Lynnes, KAFB

File: KAFB 2020 Bulk Fuels Facility Spill and Reading

Attachment

GENERAL COMMENT

1. Inconsistency in the Designations of Wells

NMED Comment: The Permittee used multiple designations for wells in the Report. For instance, on Figure 2 of the Report, well KAFB-106008 is designated as KAFB-1068. Use of multiple designations for wells results in confusion for document reviewers and the public. The Permittee must use the official full designation for each well in every instance in all future documents submitted to NMED.

SPECIFIC COMMENTS

2. Executive Summary, page ES-3

Permittee Statement: "The modified Phase 3 was approved by the NMED in a letter dated August 7, 2018 (NMED, 2018)."

NMED Comment: It should be noted that the NMED's letter dated August 7, 2018 approved the proposed modification under the following conditions: 1. Bioaugmentation shall remain as an approved, but deferred, component of the pilot test, and 2. The biochemistry/LNAPL technical working group shall meet as soon as practicable to review pilot test results and to discuss the deferral of bioaugmentation. The response letter must include details of the technical work group meeting where the deferral of bioaugmentation was discussed and along with any conclusions reached.

3. Section 1, Introduction, page 1-1

Permittee Statement: "[Anaerobic in- situ bioremediation] ISB, with and without bioaugmentation, is a common remedial approach to treat chlorinated solvents such as trichloroethene and is a promising technology for promoting the degradation of EDB to nontoxic products."

NMED Comment: Anaerobic in-situ bioremediation of chlorinated solvents (e.g., trichloroethene) produces toxic byproducts such as vinyl chloride. Some byproducts are recalcitrant under anaerobic conditions. Although Section 4.5.2, *EDB, EDB Degradation Products,* pages 4-20, discusses EDB degradation products, the discussion lacks detail; therefore, it is not clear whether or not EDB produces toxic byproducts under anaerobic conditions (e.g., bromoethane, bromoethanol, vinyl bromide). Provide a more detailed discussion regarding EDB toxic degradation byproducts under anaerobic conditions in the revised Report.

4. Section 1.3, Site History, page 1-3

Permittee Statement: "Based on historical Air Force fuel usage, AvGas containing EDB as a lead scavenger would have been in use from approximately the 1940s to 1975."

NMED Comment: Aviation fuels are known to contain additives. Clarify whether or not the fuels currently used at the site contain other potentially toxic fuel additives in the revised Report.

5. Section 1.4, Site Conditions, pages 1-3 and 1-4

Permittee Statement: "Based on data reviewed for the pilot test design, the groundwater gradient in the pilot test area was less than 0.002 foot/foot (First Quarter 2016), and the direction of groundwater flow had shifted from north-northeast to a more east-southeast direction, likely due to continuing water-conservation practices and seasonal fluctuations, as discussed in the Second Quarter 2018 Quarterly Monitoring Report (USACE, 2018b)."

NMED Comment: According to Figure 2, *Site Location Map,* extraction well KAFB-106EX1 is located downgradient (east-southeast) from injection well KAFB-106IN1 that is consistent with current groundwater flow direction; hence, well KAFB-106EX1 is likely effective to enhance the hydraulic gradient, recirculate groundwater in the vicinity, and facilitate the distribution of the injection fluid. However, extraction well KAFB-106EX2 is located upgradient (west-northwest) from injection well KAFB-106IN1. Well KAFB-106EX2 is less effective for the distribution of the injection fluid as demonstrated during the tracer test. In the response letter, provide an explanation for the purpose of using well KAFB-106EX2.

6. Section 1.4, Site Conditions, page 1-4

Permittee Statement: "Additionally, treatability testing using Kirtland AFB soil and groundwater showed that bioaugmentation with a known debrominating culture (SDC-9) significantly enhanced EDB degradation rates (Figure 3). These results indicated that ISB, by stimulating the activity of indigenous EDB degrading organisms (i.e., biostimulation) or bioaugmenting with a debrominating culture (e.g., SDC-9), showed promise for enhancing EDB degradation at Kirtland AFB."

NMED Comment: According to Figure 3, *Concentrations of EDB in Anaerobic Microcosms Prepared with Aquifer Samples Collected from the BFF Source Area,* the microcosm vessel augmented with the debrominating culture demonstrated EDB degradation. However, other vessels amended with nutrients but only aimed to stimulate indigenous microbes did

not appear to demonstrate EDB degradation. Accordingly, the statement is inaccurate and misleading. Correct the statement for accuracy or provide an additional explanation regarding other vessels/methods that did not appear to demonstrate EDB degradation in the revised Report.

7. **Section 2.3, Well Design and Installation, page 2-3**

Permittee Statement: "Existing monitoring wells KAFB-106063 (screened from 505 to 520 feet bgs [below ground surface], with top of screen approximately 25 feet below the water table) and KAFB-106064 (screened from 485 to 505 feet bgs, with top of screen approximately 5 feet below the water table) were used for groundwater monitoring during the pilot test, along with the other newly installed wells."

NMED Comment: According to Appendix A, *Site Photographs,* a photograph shows that light non-aqueous phase liquid (LNAPL) was detected in well KAFB-106S2. Presumably, KAFB-106S2 is the same well identified as KAFB-1068 in Figure 2, *Site Location Map.* In the revised Report, correct the well nomenclature in Figure 2 as necessary to be consistent. Additionally, since well KAFB-106S2 is located upgradient of the pilot test area, LNAPL may be present in the pilot test area as well. Wells with screened intervals submerged below the water table are not appropriate to evaluate the presence or absence of LNAPL. Well KAFB-106063 was used to evaluate the intermediate groundwater zone for the purpose of the pilot test; therefore, the submerged screen is acceptable. However, well KAFB-106064 was used to evaluate the shallow groundwater zone; therefore, the screened interval must not be submerged. It is critical that the extent of LNAPL plume is delineated. If this issue has not already been addressed, submit a work plan to propose to replace submerged screened intervals of all monitoring wells installed to evaluate the shallow groundwater zone in the source area (e.g., KAFB-106064).

8. **Section 2.3, Well Design and Installation, page 2-4**

Permittee Statement: "The two pairs of nested groundwater monitoring wells, two extraction wells, and one injection well were installed by Cascade Drilling (formerly National Exploration Wells & Pumps) using an Air Rotary Casing Hammer (ARCH) drill rig from January through March 2017. During borehole advancement, soil cuttings were logged every 5 feet by the site geologist in accordance with the Unified Soil Classification System and American Standard Test Method International D1586-84."

NMED Comment: The Air Rotary Casing Hammer (ARCH) drilling method pulverizes soil cuttings and prevents the ability to observe details in soil cores such as presence or absence of fractures and exact locations of hydrocarbon stains. Undisturbed soil cores characterize the subsurface conditions more accurately and such information can maximize the

effectiveness of remediation later on. Acknowledge the shortcomings related to the drilling method used in the revised Report.

9. Section 2.3, Well Design and Installation, page 2-4

Permittee Statement: "Soil drill cuttings from just above and in the saturated zone were screened for presence of NAPL and volatile organic compounds (VOCs) using a photo ionization detector (PID) to collect headspace measurements. Drill cuttings were also visually inspected for evidence of staining. PID readings were recorded on the soil boring logs (Appendix C)."

NMED Comment: The collection of soil samples for laboratory analyses is necessary for every boring in the source area. The soil sampling data will provide useful information to determine the extent of soil contamination. The described field screening method does not provide sufficient data for site characterization. Propose to collect soil samples from every boring at the site in all future work plans.

10. Section 2.3, Well Design and Installation, page 2-4

Permittee Statement: "Table 1 presents the completion details for the wells, including surveyed elevations and coordinates, and screen depths."

NMED Comment: According to Table 1, *Well Completion and Survey Data,* the depth to groundwater and the depth to the screened interval in injection well KAFB-106IN1 are recorded as 477.00 feet bgs and 477 – 497 feet bgs, respectively. The depth to the top of the screened interval coincides with the depth of the water table. However, the depth to the top of the filter pack is recorded as 467 feet bgs according to Appendix C, *Well Installation Forms*, which is 10 feet above the depth to the water table. Since the filter pack is positioned above the water table, the injection fluid applied from the well is likely to follow the least resistant pathway above the water table, rather than in the aquifer matrix due to the lack of the hydrostatic pressure. The screen and filter pack intervals should have been positioned below the water table. The pilot test data obtained from the injection wells with screened intervals positioned above the water table may generate positively biased results for the shallow groundwater zone because injection fluids will be distributed in larger lateral extent on the groundwater interface. No revision required.

11. Section 2.3.1, Groundwater Monitoring Well Installation, page 2-5

Permittee Statement: "The two shallow monitoring wells (KAFB-106MW1-S and KAFB 106MW2-S) were constructed with 4-inch diameter, Schedule 80, polyvinyl chloride (PVC) riser pipe; and the two intermediate wells (KAFB-106MW1-I and KAFB-106MW2-I) were constructed with 3-inch diameter, Schedule 80, PVC riser pipe."

NMED Comment: The screened intervals for intermediate wells KAFB-106MW1-I and KAFB-1062-I were both installed at 513 – 523 feet bgs. According to Section 1.4, *Site Conditions,* the deepest depths of the water table at the site ranged from 500 to 502 feet bgs in 2009, which is approximately 25 feet below the current groundwater table. According to Appendix C, *Well Installation Forms,* the elevated PID readings are recorded at the depths ranging from 485 feet to 510 feet bgs in the borings installed in the pilot test area. Adsorbed and submerged LNAPL may be present at depths of 485 feet to 510 feet bgs. The PID readings corresponding with the depth of the screened intervals for the intermediate wells (513 - 523 feet bgs) are relatively low; therefore, adsorbed LNAPL is unlikely to be present at the screened depth. These intermediate wells may be useful to evaluate the distribution of the injection fluids at the deeper groundwater bearing zone during the pilot test; however, since the screened intervals of the wells do not correspond with the depths where adsorbed/submerged LNAPL is present, these wells are not suitable for future LNAPL monitoring and remediation purposes. No revision required.

12. Section 2.4.4, Pump Installation, page 2-11

Permittee Statement: "A 6-inch sanitary well seal and a 1.5-inch-diameter threaded steel pipe were installed in the injection well casing to convey water from the piping exiting the system Conex box to the screened interval of the injection well. The injection pipe extended down into the water column and was fitted with a 4-inch diameter, custom designed and fabricated down-hole flow control valve (FCV, manufactured by Baski, Inc.) to limit risks of cavitation within the pipe, and to minimize volatilization and aeration of the anaerobic recirculation water."

NMED Comment: The flow control valve was used to regulate the injection flowrate, indicating that the injection was controlled by flowrate rather than pressure. Explain whether the injection flowrate was regulated by the height of the water column or the groundwater extraction flowrate or both. In addition, during the Phase 2 and Phase 3 periods of the pilot test, the height of the water column in the injection well significantly increased due to the biofouling of the screen. Unless this issue is resolved, the tested remedial approach would not be practicable for long-term or large-scale operations due to well screens clogging from biofouling and restricting the ability to add amendments to the contaminated groundwater. Discuss potential measures to resolve the issue in the revised Report.

13. Section 2.6, Recirculation Pilot System Equipment and Materials, page 2-13

Permittee Statement: "The system was designed to extract groundwater from the two extraction well locations and reinject that groundwater in the injection well after tracer or amendment addition, at a design flow rate of up to 24 gpm."

NMED Comment: According to Figure 6, *Process Flow Diagram,* and Figure 5, *Recirculation and Amendment System Piping and Instrumentation Diagram,* an injection or transfer pump that delivers the injection fluid is not depicted in the system. Explain how the fluid is delivered to the injection well without a transfer pump in the response letter. In addition, LNAPL is present at the site; however, the components depicted in the system do not appear to have a mechanism to remove LNAPL, if present, from the recovered groundwater. Explain how LNAPL is handled by the recirculation system in the response letter. The system must have a mechanism to remove LNAPL from the recovered groundwater.

14. Section 3.3, Phase 1 – Tracer Testing, page 3-3

Permittee Statement: "During the entire Phase 1 recirculation period, approximately 1,024,000 gallons of water were extracted and reinjected."

NMED Comment: Based on the distance from the injection well to the extraction wells, aquifer thickness, effective porosity, and volume of groundwater extracted and reinjected, provide an estimate for how many pore volumes of groundwater were exchanged in the treatment zone. Additionally, provide the estimate of pore volumes exchanged for the subsequent phases of the pilot test. Include the calculations and discussion in the revised Report.

15. Section 3.3, Phase 1 – Tracer Testing, page 3-4

Permittee Statements: "The likely cause of the inaccurate [pressure transducer] readings was electrical interference from the extraction well pumps' power leads running down the well to the pump near the drop tubes where the transducers and their control wires were housed. As a result, manual water level readings were periodically measured using the Solinst water level meter. Manual water level readings are summarized in Table 5."
and,
"During recirculation system operation, it became apparent that the water level readings from pressure transducers located in the extraction well drop pipes were not accurate. While the readings returned to the SCADA were erratic, the overall trends in the data were decipherable."

NMED Comment: The recirculation operation during the Phase 1 period was conducted from October 2 to November 3, 2017. According to Table 5, *Manual Extraction Well Water Level Measurements,* only three measurements (October 17, 23, and 31, 2017) were collected during that time. The data should have been collected more frequently, particularly at the beginning of the recirculation process because the drawdown data would be useful to determine the properties of the aquifer. In the revised Report, provide the original data initially collected from the pressure transducers and demonstrate how the data is decipherable. Additionally, correlate the erratic data collected from the pressure

transducers with the limited data collected manually and provide interpreted data for the missing portion of the drawdown data between October 2 and 17, 2017, if possible.

16. Section 3.3, Phase 1 – Tracer Testing, page 3-5

Permittee Statement: "The field water quality parameters, NAPL, and water level measurements were recorded on the purge logs for each well. Purge logs and sample collection logs are included as Appendix F."

NMED Comment: Appendix F, *Field Sampling Records,* does not clearly indicate whether NAPL was detected in the wells. A photograph included in Appendix A shows the presence of LNAPL in the vicinity of the test site. In the response letter explain whether LNAPL was detected from the wells, and if so, provide the gauging data in the revised Report.

17. Section 3.4, Phase 2 – Biostimulation, page 3-6

Permittee Statement: "During the recirculation period, groundwater was extracted and an easily fermentable sodium lactate-based substrate (WilClear Plus®, manufactured by JRW Bioremediation), nutrient (DAP), and conservative tracer (KI) were added to the recirculated process water stream."

NMED Comment: Commercially available remediation products were used for the pilot test. The Report does not include information for the products. Provide all available information for the products (e.g., safety data sheets) in the revised Report.

18. Section 3.4, Phase 2 – Biostimulation, page 3-7

Permittee Statement: "A pulsed amendment injection scenario was implemented in an attempt to minimize biofouling in the injection well."

NMED Comment: Explain how a pulsed amendment injection scenario would minimize biofouling in the injection well in the revised Report.

19. Section 3.4, Phase 2 – Biostimulation, page 3-7

Permittee Statement: "... an increase in mounding (up to 9 feet above static [476 feet bgs]) at the injection well was observed."

NMED Comment: The water column increased to 467 feet bgs due to the mounding in the injection well. The depth to the top of the filter pack is 467 feet bgs according to Appendix C. The mounded water laterally asserts pressure through the interval of the filter pack and

spreads above the groundwater interface. Based on the inappropriate design of the injection well, the data collected from the pilot test is likely biased (see Comment 10).

20. Section 3.4, Phase 2 – Biostimulation, page 3-8

Permittee Statement: "Introduction of amendments using the new concentrations began on December 29, 2017. The active portion of Phase 2 was extended until February 7, 2018 to deliver the planned mass of amendments."

NMED Comment: Clarify the design (target) concentrations of the amendments in the aquifer beneath the pilot test area and explain the basis for the design concentrations. Provide the calculations and explanation in terms of the total volume of groundwater to be recirculated, the mass and volume of amendments, and the stoichiometric/theoretical requirement of the amendments in the revised Report.

21. Section 3.4, Phase 2 – Biostimulation, page 3-8

Permittee Statement: "During Phase 2, approximately 11 feet of water level drawdown was observed at KAFB-106EX2 during active Phase 2 system operations. The flowrate at KAFB-106EX2 was incrementally reduced to 7 gpm beginning on January 8 through January 22, 2018 to prevent drawdown of water below the top of the screened interval."

NMED Comment: Contrary to the action taken during the operation of the Phase 2 period, it is appropriate to reduce the water level to intersect the screened interval in the extraction well. Eleven feet of water level drawdown is sufficient to reduce the water level below the top of the screened interval and it should have been maintained. The drawdown would have allowed LNAPL that may be present at the interface to be recovered from the extraction well. However, despite the benefit of potential LNAPL recovery, the flowrate was reduced to prevent drawdown of water below the top of the screened interval. The reduction of flowrate was intended to minimize aeration of groundwater. LNAPL recovery must be a primary focus of remedial efforts and must not be compromised. The issues associated with aeration of groundwater must be resolved by other means, as necessary. No revision necessary.

22. Section 3.5, Phase 3 – Biostimulation, page 3-9

Permittee Statement: "Therefore, similar to Phase 2, the purpose of Phase 3 was to continue to evaluate biostimulation in the subsurface after distribution of treatment amendments in recirculated groundwater. Phase 3 also consisted of two operational periods, a recirculation/mixing (active) period, and a subsequent passive monitoring period (no recirculation)."

NMED Comment: Since the Permittee did not implement an evaluation of bioaugmentation during the Phase 3 period of the pilot test, the testing conducted during Phases 2 and 3 appears to be almost identical. Explain the significance of conducting Phase 3 of the pilot test in the revised Report. Revise the Report to combine the discussion of Phase 3 with that of Phase 2, as appropriate.

23. Section 3.5, Phase 3 – Biostimulation, page 3-10

Permittee Statement: "Increased mounding was also observed throughout the active portion of Phase 3 at the injection well (see Figure 7), increasing to approximately 35 feet above the static level by the end of Phase 3 active recirculation."

NMED Comment: Since the filter pack of the injection well is set above the water table, an excessive injection pressure (35 feet of water) likely further pushed the fluid laterally above the water table, rather than within the aquifer matrix. Due to the design of the injection well, the distribution of amendments is likely limited to the interface (see Comments 10 and 19). Additionally, the issue of well screen fouling must be resolved, if this remedy is to be considered as part of a future remedy. No revision necessary.

24. Section 3.5, Phase 3 – Biostimulation, page 3-11

Permittee Statement: "After approximately 40 minutes of pumping, the water level in the well was manually checked and found to have drawn down below the transducer to the level of the pump intake (492 feet bgs). Thus, it seemed the loss of well capacity suggested by the increased mounding at the injection well (shown on Figure 7) was preventing groundwater from flowing into the well to sustain pumped flow to the surface; likely due to fouling of the well screen."

NMED Comment: Explain whether measures to remediate the biofouling were developed during the pilot test. If so, provide a detailed explanation in the revised Report. Unless the issue is resolved, the remedial approach would not be practicable for long-term or larger scale implementation (see Comments 12 and 23).

25. Section 3.5, Phase 3 – Biostimulation, page 3-11

Permittee Statement: "As a result, of the decreased well capacity, sample collection using the injection well pump was no longer possible, and samples from KAFB-106IN1 were collected using a 0.85-inch by 36-inch stainless steel bailer lowered to the groundwater through the transducer drop tube."

NMED Comment: It should be noted that the sample collected from the injection well was not representative of groundwater conditions. The sample collected from the injection well

was likely the remaining injection fluid that is stagnant in the injection well. The data obtained from the sample must not be used in any decision-making process, such as the evaluation and selection of remedial alternatives, confirmation that an area meets contaminant standards, or conclusion that a site meets the requirements for a Corrective Action Complete status. No revision necessary.

26. Section 3.7, NAPL Sampling, page 3-12

Permittee Statement: "Measurable NAPL was detected in the shallow nested well KAFB 106MW1-S during QED pump installation on September 5, 2017. Three separate measurements were collected using a Solinst interface probe and confirmed a thickness of approximately 0.27 to 0.31 feet. NAPL was not detected at any other shallow monitoring wells within or around the treatment zone, or in the injection well."

NMED Comment: LNAPL was also present in well KAFB-106S2 that is located near the pilot test area. Unless the extent of the LNAPL plume is delineated and eliminated, the groundwater that is treated for dissolved phase constituents (e.g., EDB) will be re-contaminated by residual LNAPL. LNAPL will act as a source of the dissolved phase contaminants. It is essential to eliminate all recoverable LNAPL from the site (see Comment 30).

27. Section 3.7, NAPL Sampling, page 3-12

Permittee Statement: "The extraction wells were not gauged for NAPL, as the top of the well screens were designed to be installed below the static water level."

NMED Comment: A primary focus for the remedy at the site is an abatement of LNAPL. Once LNAPL is abated, the concentrations of the dissolved constituents are likely to gradually decrease. Therefore, the screened intervals of the extraction wells should not have been designed to be submerged below the water table. In the future, the screened intervals of all shallow groundwater monitoring and recovery wells must intersect the water table to capture LNAPL unless otherwise pre-approved by NMED.

28. Section 3.7, NAPL Sampling, page 3-13

Permittee Statement: "Additional product recovery was attempted on September 13 and 14, 2017, and approximately 60 milliliters [of LNAPL] were recovered and sent to the APTIM Lawrenceville laboratory."

NMED Comment: APTIM executed the pilot test and prepared the Report. APTIM should not have sent the samples to an internal corporate-owned laboratory. Industry standards provide that all laboratory analyses should have been conducted by a certified and

independent third-party laboratory to avoid the perception of conflict of interest. The analytical results reported from the laboratory affiliated with the consultant must be identified as such in the Report. Revise the Report accordingly.

29. Section 3.7, NAPL Sampling, page 3-13

Permittee Statement: "The $\delta^{13}C$ value of the EDB in the NAPL, as determined by the University of Oklahoma, was approximately -21±2‰."

NMED Comment: In the revised Report, discuss the implication of the finding associated with the C^{13} isotope analysis for the EDB in the NAPL in comparison to the ratios of isotopes for the EDB in the groundwater samples collected during the pilot test.

30. Section 3.7, NAPL Sampling, page 3-13

Permittee Statement: "The fall and rise of the water table during well installation and development may have impacted the vertical transport and subsequent distribution of NAPL in the lower vadose zone, capillary fringe, and top of the unconfined aquifer; causing the measureable [sic] NAPL at KAFB-106MW1-S."

NMED Comment: Section 1.4 states, "[t]he deepest depth to water, representing the lowest historical groundwater elevation, measured at groundwater wells in the BFF source area ranged from approximately 500 to 502 feet bgs in 2009. In recent years, the water table has been rising due to water-conservation efforts by the Albuquerque community and reduction of pumping of production wells by Albuquerque Bernalillo County Water Utility Authority. As a result, the current vadose zone at the BFF site is approximately 455 to 480 feet thick." At the time the LNAPL release occurred, the water table was approximately 20 to 30 feet below the current depth of the water table. Therefore, adsorbed and submerged LNAPL may also be present at depths below the current groundwater interface. Propose to submit a work plan to investigate the vertical and lateral extent of LNAPL at the current groundwater interface and at depths below the current water table where LNAPL was likely trapped as the water table rose.

31. Section 3.10, Quality Control, page 3-15

Permittee Statement: "Laboratory data packages are also provided in Appendix G-2."

NMED Comment: Appendix G-2 was not included in the Report. Ensure that Appendix G-2 is included in the revised Report.

32. Section 3.11.1, Soil IDW, page 3-16

Permittee Statement: "All drill cuttings were containerized in plastic-lined, steel roll-off containers pending laboratory analysis for waste characterization and disposal. Each roll-off was sampled for waste characterization."

NMED Comment: Provide more detailed information regarding the sampling method for waste characterization in the revised Report. More specifically, explain the frequency of sample collection (e.g., soil volume per sample), whether composite or discrete samples were collected, and the number of subsamples in a composite sample, if collected, in the revised Report.

33. Section 3.11.2, Liquid IDW – Development and Decontamination, page 3-18

Permittee Statement: "Non-hazardous waste manifests are included in Appendix H-3. Hazardous liquid IDW generated from development and decontamination activities was disposed of by Chemical Transportation, Inc. and Clean Harbors at Clean Harbors Deer Trail, LLC in Colorado. Hazardous waste manifests are included in Appendix H-4."

NMED Comment: Non-hazardous waste manifests are included in Appendix H-4 and hazardous waste manifests are included in Appendix H-3 of the Report. Correct the typographical errors in the revised Report.

34. Section 4.2.2, Tracer Distribution During Phase 2 and 3, Phase 2, page 4-5

Permittee Statements: "Also evident in the iodide data is that final concentrations observed at the nearest monitoring wells of 17 mg/L (KAFB-106MW2-S) and 18 mg/L (KAFB-106064) are equivalent with injected iodide concentrations (KAFB-106IN), which indicates that most of the groundwater observed at these wells was previously amended and reinjected."
and,
"Overall, iodide concentrations observed during the Phase 2 recirculation period indicated good distribution of injected waters, particularly within the treatment zone encompassing the shallow monitoring wells nearest to the injection well."

NMED Comment: The tracer volume injected into the aquifer is estimated to be less than 30% of pore volume for the radial distance between the injection well and well KAFB-106MW2-S. Therefore, the highest concentrations of the tracer detected in the wells cannot be equivalent to the tracer concentrations of the injection fluid if uniform distribution of the injection fluid was achieved within the aquifer matrix. The top depth to the filter pack was set above the water table; therefore, the injection fluid may have migrated above the groundwater interface without being adequately mixed in the aquifer. Consequently, an

undiluted or less diluted tracer solution may have reached the wells and been detected in the samples collected from the wells. The injection well construction likely provides positively biased data (see Comments 10, 19 and 23).

35. Section 4.2.3, Distribution of Fermentable Substrate, page 4-7

Permittee Statement: "Recirculated groundwater during Phase 2 and Phase 3 was amended with WilClear Plus®, which served as a fermentable substrate to stimulate debrominating organisms in the subsurface during the pilot test."

NMED Comment: Although the Permittee asserts that debrominating organisms are present at the site, the data provided in Figure 3, *Concentrations of EDB in Anaerobic Microcosms Prepared with Aquifer Samples Collected from the BFF Source Area,* indicate otherwise (see Comment 6). The result of the microcosm study appears contradictory; however, the pilot test successfully demonstrated the occurrence of in-situ EDB degradation through carbon isotope analysis of EDB. No revision necessary.

36. Section 4.2.3, Distribution of Fermentable Substrate, page 4-8

Permittee Statement: "While lactate was introduced to the subsurface at around 110 mg/L, concentrations at monitoring wells never exceeded 4 mg/L."

NMED Comment: Provide information regarding the volume of the lactate solution introduced through the injection well in the revised Report.

37. Section 4.2.3, Distribution of Fermentable Substrate, page 4-8

Permittee Statement: "The observed increases in acetate and propionate strongly suggest that organic substrate capable of stimulating reductive debromination of EDB was distributed to most wells during the pilot test."

NMED Comment: Lactate is fermented to acetate and propionate by various bacteria and is not limited by debrominating bacteria. The statement is speculative and can be misleading. Revise the statement for accuracy.

38. Section 4.3, Microbial Analysis, page 4-9

Permittee Statement: "This increase in EBAC [eubacteria] after Phase 1 recirculation activity may be the result of organic carbon and nutrient redistribution in the treatment zone along with the increased groundwater flows due to recirculation."

NMED Comment: Although the carbon substrate and nutrients were not distributed during the Phase 1 period of the pilot test, the measured microbial population increased approximately two orders of magnitude. The increase in microbial population occurred before the biostimulation period was implemented. The observation indicates that microbial population can be increased with or without biostimulation amendments. Since hydrocarbon constituents (e.g., benzene, toluene) are ubiquitous in the groundwater, they may also be utilized as carbon substrates by anaerobic bacteria. In this case, an amendment of appropriate electron acceptors (e.g., sulfate) may further increase microbial populations and enhance biodegradation of the contaminants. Figure 19, *APS Concentrations – All Wells,* indicates that the population of sulfate reducing bacteria in groundwater samples collected from all wells except injection well KAFB-106IN plateaued during the Phase 2 and Phase 3 biostimulation period of the pilot test; sulfate may be a limiting factor for the population growth. Evaluate whether an amendment of appropriate electron acceptors enhances biodegradation of contaminants without compromising EDB degradation. Provide the discussion in the revised Report.

39. Section 4.3, Microbial Analysis, page 4-9

Permittee Statement: "As with the high cell numbers prior to recirculation and amendments at the site, the large numbers of organisms capable of reductive debromination (10^5 to 10^6 cells/mL for DHBt, and around 10^5 cells/mL for DSB) after biostimulation, suggest that EDB debromination activity may have been stimulated during the pilot test."

NMED Comment: According to Figure 21, *DHBt Concentrations – All Wells*, and Figure 24, *DSB Concentrations – All Wells,* the populations of DHBt and DSB appear to have plateaued during the Phase 2 and Phase 3 biostimulation period of the pilot test in all wells. These figures suggest that EDB debromination activity may not be stimulated by carbon substrate and nutrient amendments. The increase of the DHBt and DSB population was observed in groundwater samples collected from intermediate wells KAFB-106063, KAFB-106MW1-I and KAFB-106MW2-I during the Phase 1 period that was not related to biostimulation. Correct the statement for accuracy, discuss the implication of the observed population growth, acknowledge that other conclusions could be reached, and state that the data is not conclusive in the revised Report.

40. Section 4.4, Geochemistry, pages 4-10 and 4-11

Permittee Statement: "DO [dissolved oxygen] concentrations were below 1 mg/L at all wells, with most concentrations below 0.5 mg/L."
and,
"The low DO concentrations within the treatment zone reflect favorable conditions for reductive debromination of EDB."

NMED Comment: The site groundwater is anaerobic due to the presence of hydrocarbons which favors reductive debromination of EDB. Hydrocarbons in the aquifer may serve as carbon substrate to degrade EDB anaerobically. When dissolved hydrocarbons are utilized for EDB debromination, the concentrations of hydrocarbons may also decrease which provides synergistic degradation. However, carbon substrates (e.g., lactic acid) that were amended to stimulate indigenous bacteria are more readily utilized in comparison to hydrocarbons. Subsequently, the degradation of hydrocarbons may potentially be hindered. Since EDB may be naturally degrading due to the current site conditions (e.g., anaerobic conditions, presence of hydrocarbons), the amendment of the carbon substrate may not be useful. Evaluate the necessity of the amendment to balance the EDB and hydrocarbon constituents degradation and provide the discussion in the revised Report.

41. Section 4.4, Geochemistry, page 4-11

Permittee Statement: "With the exception of KAFB-106EX2 (25 mg/L), sulfate concentrations in shallow wells were low (<5 mg/L) under baseline conditions presumably due to past sulfate reduction to sulfide."

NMED Comment: Sulfate is a critical component for anaerobic biodegradation of dissolved hydrocarbon constituents. Since hydrocarbons are present in addition to EDB at the site, hydrocarbons must be remediated as well. According to Figure 19, *APS Concentrations – All Wells,* the population of sulfate reducing bacteria is abundant; however, sulfate concentrations appear to be insufficient to increase the activity of the sulfate reducing bacteria. Evaluate the viability of sulfate amendment to promote biodegradation of dissolved phase hydrocarbons in the revised Report (see Comment 38) and propose to submit a work plan for a pilot test to evaluate the effect of sulfate amendment, as appropriate.

42. Section 4.4, Geochemistry, page 4-11

Permittee Statement: "The low sulfate concentrations within the treatment zone reflect favorable conditions for reductive debromination of EDB."

NMED Comment: Clarify whether elevated sulfate levels inhibit reductive debromination of EDB in the revised Report. Also, propose to submit a work plan to evaluate the sulfide concentrations in the groundwater; if sulfide levels are too high in the groundwater, sulfate amendment may not increase the activity of sulfate reducing bacteria.

43. Section 4.4, Geochemistry, page 4-12

Permittee Statement: "Due to the low solubility of ferric (Fe(III)) iron under circumneutral conditions as found at the site, dissolved iron concentrations are often assumed to reflect concentrations of more reduced ferrous (Fe(II)) iron. Minerals containing oxidized Fe(III) are fairly ubiquitous and elevated dissolved iron concentrations are usually indicative of iron reducing environments. Baseline measurements at the site indicated dissolved iron concentrations ranging from 1 mg/L (KAFB-106MW1-S) to 12 mg/L (KAFB-106MW2-S) in shallow wells, but concentrations at deeper, less impacted wells were all less than 1 mg/L."

NMED Comment: According to Figure 27, *Iron (Dissolved) Concentrations – All Wells,* the dissolved iron concentration in the baseline groundwater sample collected from intermediate well KAFB-106MW2-I exceeds 11 mg/L. Accordingly, the statement is not accurate. Correct the statement or Figure 27 to resolve the discrepancy in the revised Report. Additionally, the dissolved oxygen concentration in the baseline groundwater sample collected from the same intermediate well KAFB-106MW2-I is recorded as approximately 1.8 mg/L, which is higher than the most wells according to Figure 25, *Dissolved Oxygen – All Wells*. The inverse relationship between the levels of dissolved iron and oxygen is not clearly demonstrated by the data collected during the pilot test. Remove or revise the statement, as appropriate.

44. Section 4.4, Geochemistry, page 4-12

Permittee Statement: "During the Phase 2 recirculation period when lactate amendments were introduced, methane concentrations generally fell again, but increased by many OOM [(orders of magnitude)] at several wells during the following passive period, with concentrations exceeding 10,000 µg/L at the injection well and KAFB-106MW2-S."

NMED Comment: Methane may be beneficial to EDB remediation since it is considered a viable substrate for similar halogenated compounds (e.g., chlorinated ethenes). However, methanogens are known to produce ethene and ethane under the presence of brominated compounds (e.g., EDB). If methanogens produce more ethene and ethane which are main end products of EDB, they may potentially hinder degradation of EDB (e.g., via Le Chatelier's principle). Regardless, the increased methane production is merely an indicator of bacterial activity but not necessarily effective remediation. No revision or response required.

45. Section 4.5.1, Benzene and Toluene, page 4-14

Permittee Statements: "With the exception of the injection well (KAFB-106IN1) and monitoring well KAFB-106MW1-S, benzene concentrations in shallow monitoring wells for the remainder of the pilot test ranged in concentration from 1,680 µg/L at KAFB-106MW2S to 4,400 µg/L at KAFB-106EX2, indicating limited losses due to biodegradation or abiotic mechanisms (e.g., volatilization, dilution)."
and,
"Interestingly, benzene increased during the passive periods at the shallow well KAFB-106MW1-S to concentrations as high as 9,800 µg/L. The higher concentration at KAFB-106MW1-S is similar to baseline conditions prior to recirculation and may be the result of increased mass transfer from residual NAPL phases, as NAPL had previous[ly] been observed at that location."

NMED Comment: Unless LNAPL is eliminated, LNAPL constituents will constantly leach into the groundwater and re-contaminate the aquifer. In order to abate LNAPL, the extent of LNAPL plume must be delineated laterally and vertically (see Comment 30). The reduction of all dissolved phase constituent concentrations will likely occur once the bulk of LNAPL is removed from the site.

46. Section 4.5.1, Benzene and Toluene, page 4-15

Permittee Statement: "Interestingly, toluene concentrations decreased during Phase 4 passive monitoring at shallow wells KAFB-106MW2-S to 150 µg/L (from 4,900 µg/L in the previous sampling event) and KAFB-106064 to 960 µg/L (from 11,000 µg/L in the previous sampling event). These decreases were far greater than for benzene and may indicate some anaerobic biodegradation of toluene."

NMED Comment: Toluene is known to be more bioavailable as a carbon substrate than benzene. Presumably, anaerobic bacteria responsible for hydrocarbon degradation depleted the amended carbon substrates (e.g., lactate) during the Phase 4 passive monitoring period and initiated utilization of subsequently bioavailable hydrocarbon constituent, toluene. Further decline of toluene levels may be expected along with the decline of benzene level later in the passive monitoring period. Clarify whether the passive monitoring is on-going at this time and provide a reference that presents the most recent analytical data in the revised Report.

47. Section 4.5.2, EDB, EDB Degradation Products, pages 4-20 and 4-21

Permittee Statements: "Based the assumption of reductive debromination and its stoichiometry, equivalent quantities of EDB degraded can be estimated using measured concentrations of ethene and ethane..."

and,
"During and after the Phase 2 recirculation period, estimates of EDB equivalents degraded based on ethene and ethane increased to magnitudes similar to initial EDB concentrations, suggesting substantial conversion. The highest estimate of EDB equivalents degraded occurred at KAFB-106MW1-S after Phase 3 biostimulation efforts with an estimated concentration of approximately 270 µg/L."

NMED Comment: According to Tables 7 through 15, the concentrations of ethane, ethene, and methane were detected in the baseline groundwater samples collected from the pilot test wells. These dissolved gas constituents may or may not be degradation products of EDB. Since other hydrocarbon constituents (e.g., benzene and toluene) are concurrently present with EDB and the degradation products (ethane, ethene, and methane) are not exclusive to EDB biodegradation products, the quantity of degraded EDB cannot be estimated by measured concentrations of ethene and ethane. It should be noted that methanogens produce ethane and ethene under the presence of halogenated compounds and the presence of brominated compounds drives methanogens to produce even more ethane and ethene from small organic compounds such as carbon dioxide. Remove the statements from the revised Report.

48. Section 4.5.2, EDB, EDB Degradation Products, page 4-22

Permittee Statement: "The largest apparent increase in bromide to chloride ratio occurred during and after the Phase 3 recirculation period. This coincided with use of a new certified analytical laboratory after the original analytical laboratory measuring bromide ceased operations. Several of the increases in bromide appear to be on the order of 1 mg/L, which corresponds to degradation of approximately 1,200 µg/L of EDB – much more than was observed in aqueous phase measurements during the pilot test."

NMED Comment: Since the notable increase occurred when an analytical laboratory was changed, the data generated from the new laboratory may or may not be accurate. Even if the analytical method is consistent and the new laboratory is certified for the analysis, the observed increase may potentially be caused by changes associated with various differences among laboratories. The samples should have been analyzed by two independent certified laboratories to confirm the results. Incorporate this measure when an analytical laboratory is to be changed during the course of periodic groundwater monitoring and sampling in the future. No revision required.

49. Section 4.5.2, EDB, Carbon Isotope Analysis of EDB, page 4-22

Permittee Statement: "As EDB degrades, its carbon (C) stable isotope composition can change as EDB with a heavy C isotope substitution (^{13}C) degrades slightly slower than EDB with only ^{12}C (Koster van Groos et al, 2018)."

NMED Comment: Provide information regarding the difference in degradability of EDB with ^{12}C and ^{13}C in the revised Report. Additionally, according to Figure 38, *EDB $\delta^{13}C$ – Shallow Wells,* EDB $\delta^{13}C$ values notably increased in groundwater samples collected from wells KAFB-106MW2-S and KAFB-106064 prior to Phase 2 of the pilot test, in which biostimulation was initiated. Provide an explanation for whether the occurrence of abiotic degradation (e.g., hydrolysis, oxidation) can also increase the fraction of ^{13}C EDB in the revised Report.

50. Section 5.1, Conclusions, pages 5-1 and 5-2

Permittee Statements: "Baseline measurements indicated that EDB was likely degrading prior to the pilot test."
and,
"ISB appears to be a promising approach targeting EDB source areas in Kirtland AFB groundwater. While debromination may be occurring at Kirtland AFB without additional support, the addition of biostimulation amendments and mixing of water appeared to enhance reductive debromination."

NMED Comment: The degradation of hydrocarbon constituents (e.g., benzene and toluene) appeared to be hindered by the amended carbon substrates (see Comment 46). The pilot test demonstrated in-situ anaerobic biodegradation of EDB in the most pilot test wells; however, future remediation must focus on the abatement of LNAPL. Once the LNAPL plume is delineated and remediated, EDB levels will likely reduce naturally. The vertical and lateral extent of LNAPL must be investigated (see Comment 30).

51. Figure 9, Fluoroscein [sic] Concentrations – Shallow Wells

NMED Comment: The tracer concentrations in injection well KAFB-106IN1 are depicted below 10 ug/L during the baseline, Phase 1 Tracer Test, and Non-pumping Passive Phase according to Figure 9. Section 4.2.1, *Tracer Distribution During Phase 1,* page 4-2, states that three measurements of fluorescein concentrations of injected water collected directly from the KAFB-106IN1 sample port averaged 570 µg/L during the 24 hours of tracer injection, while background concentrations were not detected. The data presented in the figure is therefore not accurate. Revise the figure to show that the tracer concentration in the injection well was 570 ug/L during the injection period.

52. Figure 11, δ^2H Concentrations – Shallow Wells

NMED Comment: The δ^2H values of deuterium labeled water in injection well KAFB-106IN1 are depicted between -80‰ and -100‰ during the baseline, Phase 1 Tracer Test, and Non-pumping Passive Phase according to Figure 11. Section 4.2.1, *Tracer Distribution During Phase 1,* page 4-3, states that three measurements of δ^2H values of the injected water

averaged +590‰ during the 24 hours of tracer injection, while background δ2H values at the test area ranged from -97‰ to -92‰. The data presented in the figure is therefore not accurate. Revise the figure to show that the δ^2H value in the injection well was +590‰ during the injection period.

53. Figure 13, Iodide Concentrations – Shallow Wells

NMED Comment: The tracer concentrations in injection well KAFB-106IN1 are depicted below 9 mg/L during the Phase 2 and 3 Biostimulation Recirculation, Non-pumping Passive Phase according to Figure 13. Section 4.2.2, *Tracer Distribution During Phase 2 and 3,* page 4-4, states that iodide results from the injectate ranged from 18 to 26 mg/L. The data presented in the figure is therefore not accurate. Revise the figure to show that the tracer concentration in the injection well was 18 to 26 mg/L during the injection period.

54. Figure 15, Lactic Acid Concentrations – All Wells (Except 106IN1)

NMED Comment: The lactic acid concentrations were positively detected in groundwater samples collected from wells KAFB-106MW2-S, KAFB-106MW2-I, KAFB-106MW1-S, and KAFB-106064 prior to Phase 1 Tracer Recirculation according to Figure 15 although lactic acid was not amended to the injection fluid during Phase 1. Provide an explanation for the detections in the revised Report.