To: Carolyn d'Almeida, RPM

From: Eva

Subject: ST012 Decision Tree and Criteria for Enhanced Bioremediation, Former Williams Air Force Base, Mesa, Arizona

Dear Carolyn,

I have reviewed the Decision Tree and Criteria for Enhanced Bioremediation ("Decision Tree") for the Former Williams Air Force Base located in Mesa, Arizona, and compared it to the May 2014 Final Remedial Design and Remedial Action Work Plan (RD/RAWP), the March 2016 Draft Final Addendum #2 to the RD/RAWP, and to proposed Phase 1 Enhanced Bioremediation (EBR) activities presented during the May 11, 2017 Base Closure Team (BCT) conference call, along with other data from the site. Although it is still my technical opinion that EBR cannot reduce the estimated 400,000+ gallons of jet fuel remaining in the subsurface at ST012 to volatile organic compound (VOC) concentrations that will not contaminate groundwater to levels above their Maximum Contaminant Levels (MCLs) in the next 20 years, I understand that it is the desire of the Air Force to proceed with EBR. This changes the discussion that we have been engaged in from whether or not to proceed with EBR to what the Environmental Protection Agency (EPA) requires for the Air Force to be able to proceed with EBR considering the present condition of the site. I have reviewed these documents and the latest data received from the site in biweekly reports with this in mind. It appears that a couple issues related to moving forward with EBR may have been inadvertently lost or been ignored. Also, the plans for implementing EBR have been evolving too quickly for me to adequately comprehend the proposed plans and comment on them. The purpose of this memorandum is to try to provide my comments on where I understand the Air Force is now on implementation of EBR at ST012. My comments are provided in detail below.

General Comments

1.A full delineation of the benzene contaminated areas has not been completed. Without knowing the full extent of the plume now, it cannot be determined if the plume continues to migrate. Slides from the February 14, 2017 BCT meeting clearly indicate that benzene concentrations in groundwater greater than 5 µg/L have not been fully delineated, as large portions of the line delineating this concentration are dashed (indicating the delineation is inferred) in the Cobble Zone (CZ) and UpperWater Bearing Zone (UWBZ), with smaller portions of the line being dashed in the Lower Saturated Zone (LSZ).

a) Observation of the benzene isoconcentration line in the CZ (slide 22) also shows that the downgradient perimeter wells in the CZ are generally 250 feet or more from the SEE wells, thus, migration of the dissolved phase in the hydrologic unit is effectively masked by the distance to the downgradient wells. Besides the lack of plume delineation to the north and east as shown in slide 23, the extent of the plume to the southwest may not be defined. According to the data provided in June 2017, CZ22 was last sampled on 10/10/2016, and benzene was less than 1 µg/L. However, the weekly field reports show that 0.66 feet of LNAPL were found in this well on 11/4/2016. Thus, it is not clear that the benzene concentration in this well remains below

5 μg/L. The boring for LSZ57 had numerous photoionization detector (PID) readings in the range of 40 to 74 parts per million volume (ppmv) from 140 to 160 feet below ground surface. According to Attachment 4, Locations and Drilling Plan, footnote f of Field Variance #4, Additional Site Characterization, "If PID screening results are >15 ppmv . . . location may not bound dissolved phase contamination." Additional sampling of well CZ22 is needed, and a CZ monitoring well is needed in the area of LSZ57 to verify the extent of the dissolved phase plume in the CZ in this area.

b)In the UWBZ, wells UWBZ36 and UWBZ35 are above 5 μg/L, indicating that the dissolved phase plume is not delineated to the west in this hydrologic zone. PID readings as high as 50 ppmv in the UWBZ of soil boring LSZ57 raise a question about the extent of the dissolved phase in that area. Recent groundwater concentration data for perimeter monitoring wells U02 (1.7 μg/L on 3/1/2017 and 2.2 μg/L on 4/18/2017) and U38 (0.18 μg/L on 2/6/2017, the first time benzene has been detected in this well) indicate that the line delineating the extent of benzene concentrations above 5 μg/L should be extended significantly to the east in slide 24.

c)Slide 26 shows that the extent of the dissolved phase has not been delineated in the area of SB-19 to the west, in the area of LSZ46 to the south, in the area of SB18 to the southeast, and in the area of W36 to the northeast.

2. A full delineation of the light nonaqueous phase liquid (LNAPL) contaminated areas has not been completed. Without knowing the full extent of the LNAPL at ST012, the extent of the area that requires remediation has not been defined. Slides from the March 16, 2017 BCT meeting clearly show that the extent of LNAPL has not been defined: 1) in the UWBZ to the southeast (UWBZ30 area, see slides 17 and 18) and 2) in the LSZ to the southeast in the areas of SB18, to the south in the area of LSZ46, and to the west at SB19. Also, there is considerable distance between the borings that contained LNAPL in the UWBZ and LSZ on the northern side of the site (LSZ43 and LSZ51) and the one LNAPL-free boring to the north (LSZ59), creating considerable uncertainty in the extent of LNAPL in this direction.

3.Post- Steam Enhanced Extraction (SEE) characterization need is within the thermal treatment zone (TTZ) of SEE. The May 2014 Final RD/RAWP states (page 4-9) that the target benzene concentrations in the thermal treatment zone is 100 to 500 ug/L, as "This concentration range is predicted to achieve cleanup levels within the 20-year remedial timeframe based on modeling of groundwater contaminant attenuation outside the TTZs after active EBR". However, no groundwater samples have been obtained from within the central portion of the SEE treatment zone since the termination of SEE to determine if this target groundwater concentration was achieved. Samples obtained during see are not reliable due to the samples having been obtained from the eductor pumps, which contained both eductor motive water and groundwater. Since the termination of SEE, LNAPL has been recovered from many of these interior wells, indicating the likelihood of significant benzene concentrations remaining in the TTZ. Discussions between the Air Force team and the agencies' teams has highlighted the fact that there is considerable uncertainty in the modeling performed by Amec. Additional modeling using an agreed-upon modeling approach should be used to determine whether or not the SEE TTZ requires additional treatment, based on post-SEE soil and groundwater concentrations.

4.Soil borings from within the SEE TTZ are also required in order to support mass remaining estimates, as the current Air Force estimates (dated 9/28/15) assumed apparently arbitrary

reductions in each area and zone due to SEE without providing justification in terms of case study results or other data (ADEQ letter dated May 16, 2017, to Ms. Catherine Jerrard).

5.An important consideration for the success of EBR will be ensuring that the injected terminal electron acceptor (TEA) is distributed throughout the area of remaining contamination. The EBR and SEE Containment Modeling Report in Appendix E of the May 2014 Final RD/RAWP states (page 4-1), "This 60-foot well spacing was determined to be optimal by an iterative process using the groundwater flow model to assess various configurations of the well fields within the geometry of the treatment areas. Beyond an approximate well spacing of 75 feet results from the model revealed that sufficient extraction pumping could not be achieved because of limitations associated with the permeability and storage of the aquifer and subsequent loss of injectate to the natural gradients in these gaps between extraction well capture zones." Despite this modeling result, Addendum #2 and the May 11, 2017 BCT presentation propose injection-extraction well spacings as much as 250 feet or more. Figures E-1, E-8 and E-15 of Addendum #2, which are titled, Modeled TEA Injection Pathlines for the CZ, UWBZ, and LSZ, respectively, show that injected TEA would not be distributed throughout the ovals of Target Area of Sulfate Distribution by Injection-Extraction shown on slides 25 – 27 of the May 11, 2017 BCT presentation, but would travel in relatively narrow paths. Specific examples of discrepancies between the Modeled TEA Injection Pathlines and the Target Area of Sulfate Distribution include the fact the TEA pathlines show TEA injected at CZ12 to migrate downgradient (Figure E-1), rather than being extracted at CZ21, as suggested by slide 25; Figure E-8 shows TEA injected at UWBZ32 and UWBZ33 to migrate downgradient rather than be captured at UWBZ22 as suggested by slide 26; and Figure E-15 show TEA injected at W34 to migrate downgradient rather than be captured by LSZ29, as suggested by slide 27. It is clear from the TEA Pathline figures that the proposed injection and extraction schemes are not adequate to distribute TEA throughout the residual saturation areas.

The Time of Remediation Estimates for Enhanced Bioremediation at ST012 (provided to the Air Force on May 30, 2017) states that the hydraulic conductivity values for the LSZ and UWBZ used in the modeling reported in Appendix E are significantly lower than what was used in previous modeling. It is not clear how incorporating more realistic hydraulic conductivities into the model will affect the flow of the TEA, either under pumping or non-pumping conditions.

6.It is not clear what sulfate concentrations are ideal for BTEX degradation at the ST012 site, or what concentration may be inhibitory to the microorganisms. The Decision Tree in the first blue box states that sulfate concentrations in the range 2,000 – 10,000 mg/L are ideal for microbial growth, and that concentrations as high as 30,000 mg/L are non-inhibitory. However, Suthersan et al. (2011) suggests that maintaining relatively stable sulfate concentrations in the range of 100 to 2000 mg/L increases the efficiency of the process, and that sulfate concentrations greater than 2000 mg/L do not yield increased hydrocarbon oxidation rates. Al-Zuhair et al. (2008) found that sulfate concentrations above 4,000 mg/L may begin to inhibit sulfate reduction.

7. Addendum #2 proposes to inject sulfate at a concentration of 320,000 mg/L (March 2016 Addendum #2, page 4-7). After pumping only for a short time during the injection of sulfate to help distribute it, Addendum #2 and the Decision Tree then proposes to terminate extraction and allow the sulfate to distribute by diffusion. Addendum #2 provides figures to illustrate the

concentrations of a conservative tracer (meant to represent sulfate) injected at a concentration of 320,000 mg/L in each of the three hydrologic zones over the next 1990 days (Figures E-2 to E-7, E-9 to E-14, and E-16 to E-21). These figures show significant migration of sulfate offsite at concentrations greater than the secondary MCL for sulfate of 250 mg/L (Figures E-7 and E-21), and sulfate concentrations high enough to inhibit microbial growth over large portions of the UWBZ and LSZ 1990 days (approximately five and one half years) after sulfate injection (Figure E-14 and E-21).

Another thing to note on the figures from Appendix E depicting tracer concentrations due to diffusion effects is that these figures predict that it would take as much as 5.5 years (1990 days) for the sulfate concentrations to reach the 1000 mg/L range where sulfate reduction is maximized throughout the areas that are believed to contain LNAPL. This situation is not likely to be alleviated by the addition of a couple injection or extraction wells as proposed in the May 11, 2017 BCT presentation.

Specific Comments on Decision Tree

8.The first yellow box calls for monitoring LNAPL levels, and that '<1 ft/week' accumulation in a well is ideal and '< 5 ft/week' is non-inhibiting. It is not clear in which wells LNAPL levels will be monitored. LNAPL monitoring in proposed extraction wells was terminated when the pumps were installed as Amec claims they cannot monitor for LNAPL with the pumps in place. The March 2016 Draft Addendum #2 to the RD/RAWP states on page 4-11, "If mobile LNAPL is observed in a new or existing injection well, the LNAPL will be removed, to the extent practical prior to injections. If sustained recovery of LNAPL is possible, TEA injection at that location will be delayed." This would seem to indicate that LNAPL levels in injection wells is to be monitored.

What is the basis for saying that '<1 ft/week' is ideal and '< 5 ft/week' is non-inhibiting and EBR should proceed? In the second yellow box of the Decision Tree, it states, "LNAPL removal is generally more efficient than EBR. LNAPL not removed can increase EBR timeframe." This statement appears to be contradictory to the implication that LNAPL accumulations of up to 1 ft/week in an injection well are acceptable for proceeding with EBR. Several of the planned injection wells, including CZ11, UWBZ10, UWBZ33, UWBZ16, W11, W37, LSZ50, LSZ48, and LSZ49, have recently and continuously contained LNAPL under nonpumping conditions, and thus are not likely to be useable as injection wells in the immediate future.

9.The first yellow box states that if the hydraulic response is not consistent with expectation, then the distribution (I assume of sulfate) may be affected. What is the expected hydraulic response? What are the planned extraction rate for each extraction well and expected drawdown in each of the wells?

10.The first yellow box states that if temperatures are changing rapidly at extraction or injection locations, potentially temperature should be monitored and wait for stabilization. This appears to be contradictory to the objections of the Air Force and Amec that continuous groundwater extraction for containment would have a negative effect on EBR because we would adversely affect the temperatures that are currently advantageous to EBR, and would pull dissolved oxygen into the system, and thereby alter the redox conditions. The May 2014 Final RD/RAWP that was

approved stated "The approach to remediating the LNAPL impacted zone outside the TTZ combines the technologies of groundwater recirculation with the addition of terminal electron acceptor (TEA), and plume containment." (Section 3.5, first sentence). The description of the EBR design goes on to say "Process equipment will be installed for integrated operations for active remediation and containment of the three hydrologic zones (CZ, UWBZ and LSZ)," and "The overall system will be hydraulically designed to capture and maintain the plume geometry." The EBR and SEE Containment Modeling Report in Appendix E states "The approach to remediating the LNAPL impacted zone outside the TTZ combines the technologies of groundwater recirculation with the addition of terminal electron acceptor (TEA), and plume containment, followed by a period of natural attenuation and groundwater monitoring." Based on the May 2014 Final RD/RAWP, containment was an integral part of the planned EBR. It is not clear why this was not a part of the proposed plan in Addendum #2.

It should be noted that temperature data provided in Section VI of the April 29 – May 12, 2017 ST012 Site Operations Report shows that virtually all of the area in the three hydrologic zones of the site that are proposed for Phase 1 EBR (see slides 25 to 27 of the May 11, 2017 BCT conference call) remain at significantly elevated temperatures, with temperatures as high as 270°F in May 2017. Thus, it is not likely that these areas will be good candidates for initiation of EBR in the near future. Pumping to extract hot groundwater and pull ambient temperature groundwater into the area may increase the rate of cooling and create conditions amenable to EBR more quickly than allowing cooling only by natural groundwater flow.

11.The first gray box seems to indicate that sulfate is expected to arrive at the extraction wells 10 weeks to one year after injections start. What is the basis for this rather significant range in travel times expected between injection and extraction wells?

12.The parameters to be monitored in the first blue box must include VOCs in groundwater. With an estimated 400,000+ gallons of LNAPL remaining in the subsurface at ST012 (Amec estimate dated March 17, 2017), most of the remaining VOCs are in the LNAPL, not dissolved in groundwater. In order to demonstrate that EBR is having the desired effect, benzene concentrations in the LNAPL must be measurably and significantly decreasing.

13.The first blue box states "Decreasing VOCs in the presence of sulfate may indicate degradation." While this statement is true, it must be recalled that injection of large volumes of water containing sulfate will definitely dilute VOC concentrations in groundwater, and displace the contaminated groundwater. This should not be mistaken for degradation. Decreasing VOC concentrations should only be considered to indicate degradation after it has been determined that the appropriate biological communities are present and that they degrading VOCs (including benzene). Groundwater data from across the site after TEA injection should be used in the evaluation.

14.The first blue box and the final gray box state that "If degradation by SRB can not be demonstrated after other measures, consider alternate technologies" and lists pump and treat and chemical oxidation as the technologies to be evaluated. Neither of these technologies are appropriate for large quantities of LNAPL such as the more than 400,000 gallons of LNAPL that

are believed to be at this site. SEE has been found to be affective for LNAPL at this site and should be considered if EBR is not found to be effective.

15.The second blue box and the white box (page 3) list Target Numerical Conditions of average and maximum benzene concentrations in each of the three hydrologic zones that are presented in the modeling in Appendix E of the RD/RAWP. Comments on this modeling exercise have been provided to the Air Force. Discussions between the Air Force team and the agencies' teams has highlighted the fact that there is considerable uncertainty in the modeling performed by Amec. Additional modeling using an agreed-upon modeling approach should be used to determine whether or not the SEE TTZ requires additional treatment, based on post-SEE soil and groundwater concentrations.

16.Second blue box: Shows that for the UWBZ, the maximum permissible benzene concentration for transition to Monitored Natural Attenuation (MNA) is 1400 ug/L. The May 2014 Final RD/RAWP states on page 4-9 that the target benzene concentrations in the thermal treatment zone is 100 to 500 ug/L, as "This concentration range is predicted to achieve cleanup levels within the 20-year remedial timeframe based on modeling of groundwater contaminant attenuation outside the TTZs after active EBR". Thus, these two criteria appear contradictory. Discussions between the Air Force team and the agencies' teams has highlighted the fact that there is considerable uncertainty in the modeling performed by Amec. Additional modeling using an agreed-upon modeling approach should be used to determine whether or not the SEE TTZ requires additional treatment, based on post-SEE soil and groundwater concentrations.

17.The second yellow box states that the Desired Trend for Sulfate migration is that it not migrate outside of the EBR area. Figure E-4 predicts that sulfate will be migrating out of the EBR area in the CZ within 150 days of injection at wells CZ12, CZ14, and CZ16, and Figure E-7 of Addendum #2 predicts that this will continue for more than 1990 days. Figure E-15 predicts that sulfate injected at W34 will migrate out of the EBR area. This would indicate the need for recirculation/containment throughout EBR.

18.The second yellow box states that the Desired Trend for Arsenic Concentrations is "Arsenic concentrations exceed MCLs". The desired trend should be for the arsenic concentrations to <u>not</u> exceed MCLs. Arsenic should not be injected with the sulfate solution at concentrations that exceed the MCLs.

If you would like to discuss any of these comments, I would be happy to do so. I can be reached at (580) 43608548 or davis.eva@epa.gov.