TECHNICAL MEMORANDUM

DATE: **29 June 2017**

FROM: **John Sigda, Ph.D. and Eileen Marcillo, INTERA Incorporated**

TO: **Rick Shean, Water Quality Hydrologist, Albuquerque Bernalillo County Water Utility Authority (ABCWUA)**

SUBJECT: **Review Findings for RCRA Facility Investigation Report Bulk Fuels Facility Release Solid Waste Management Unit ST-106/SS-111 dated January 2017**

1.0 INTRODUCTION

On behalf of the Albuquerque Bernalillo County Water Utility Authority (Water Authority), INTERA Incorporated (INTERA) reviewed the document entitled "*RCRA Facility Investigation Report Bulk Fuels Facility Release Solid Waste Management Unit ST-106/SS-111*" prepared by Sundance Consulting Inc. (Sundance) for the U.S. Army Corps of Engineers. This document (Sundance, 2017) was reviewed in conjunction with the relevant sections from relevant quarterly monitoring reports and correspondence between the New Mexico Environment Department (NMED) and Kirtland Air Force Base (KAFB).

The RFI document describes the site's background and setting, the activities carried out by KAFB contractors since 2011 on which the RFI is based, results from subsurface investigation, the nature and extent of the contamination, and the contractors' analysis of groundwater contamination fate and transport. The objective of the RFI is to provide the evidentiary basis for implementing a Corrective Measures Evaluation (CME) under the Resource Conservation and Recovery Act (RCRA) process.

Sundance list three conclusions for the RFI (Executive Summary, pages ES-6 and ES-7):

1. *Sufficient data were collected to characterize the nature and extent of fuel-related contamination at the Site with the exception of the data gaps listed below.*

2. *Sufficient data were collected in the AOIs to proceed forward in the RCRA process.*

3. *The source of the jet fuel releases, the underground pipeline from the FFOR to the pump house, has been removed.*

According to Sundance (2017), the remaining data gaps are limited to

1. *LNAPL: Due to the rising groundwater levels, it is unclear how much and where the LNAPL remains vertically smeared beneath the water table, how weathered the existing LNAPL is, and how that may be contributing to the dissolved contamination in the groundwater.*

2. *Groundwater: The dissolved-phase EDB [ethylene dibromide] plume boundary is not fully defined in the northwestern most area of the plume in AOI 9*.

INTERA's evaluation of the Sundance (2017) RFI report has determined that the first two of the three conclusions purported by Sundance are not substantiated by the data and analyses described in the report. The data and analyses presented in this RFI report do not support Sundance's conclusions that the nature and extent of contamination are sufficiently well understood or that there are sufficient data to move forward with the RCRA process. Our evaluation found that the RFI document does not provide the evidentiary basis for conducting a CME and its conceptual model contains errors and omissions that could lead to an inappropriate or ineffective set of corrective measures. Specifically, our review demonstrates that the RFI report lacks important data needed for the CME, inaccurately characterizes important features and processes in the subsurface, underestimates contaminant sources, and overestimates degradation rates. Any future addenda to the RFI planned by KAFB and the Air Force should address the issues and data gaps described below to prevent implementation of corrective measures that will be unsuccessful in protecting the drinking water supply for Albuquerque.

The data gaps about contaminant source mass in the vadose zone and the aquifer and unjustifiable overestimates of groundwater contaminant degradation are likely the issues of greatest concern to the ABCWUA. In our opinion, this RFI document downplays the remediation challenges ahead. It tries to show degradation is quickly removing contaminant mass, especially ethylene dibromide (EDB) mass, at rates that are not justified by the actual data and it underestimates the mass of EDB and other contaminants remaining in the vadose zone and the groundwater.

2.0 MAJOR RFI COMMENTS

This section explains INTERA's most important findings from our review of Sundance (2017). Specific comments from our detailed review of the executive summary and of Section 7 Conceptual Site Model are presented in **Table 1**.

2.1 Insufficient Soil Data to Estimate Vadose Zone Source Mass and Mass Flux

The RFI document establishes the nature of the contamination to be contaminants of concern (COCs) in the light non-aqueous phase liquid (LNAPL), dissolved, and vapor phases, but fails to adequately determine the extent of the LNAPL contaminants in the vadose zone or the mass flux of COCs from the vadose zone to the aquifer. The RFI report correctly states that fuels migrated through the entire thickness of the vadose zone over a lengthy period, so it is likely that fuel contaminants are present throughout the vadose zone thickness in the source area. Missing from the RFI are the following data that are critical for determining future actions: a) the vertical and lateral distribution of LNAPL saturation in the vadose zone, b) the location and mass of EDB contained in vadose zone LNAPL, c) estimates of contaminant mass in the vadose zone using continuous core sampling, and d) the rate of mass transfer of contaminants from the vadose zone to the saturated zone (mass flux).

Without appropriate and defensible definition of the contamination extents, Conclusion 1 above is unfounded. These serious flaws in the RFI determination of contamination extents must be rectified before cost effective corrective measures can be identified or designed.

The RFI report overstates the understanding of LNAPL extent and mass in the vadose zone provided by site investigation activities. The number of soil samples collected is stated to be 2,267 soil samples (Section 4.4.1), but there is no explanation of the sampling protocol and the representativeness of the sampled volume to put this number into context. As we stated in our review (INTERA, 2011) of the KAFB vadose zone work plan (Shaw Environmental, 2010), collecting a soil sample every 50 feet (ft) of depth below the first 50 feet would not provide sufficient vertical resolution to adequately delineate the presence and mass of LNAPL or associated contamination in the vadose zone. The numerous soil samples collected in this manner represent less than 6% of the vadose zone thickness intersected by the borings, which is a very small fraction of the vadose zone in the BFF source area.

The Air Force's sampling protocol required that soil samples were collected from predetermined depths without regard to lithology, field screening, perched zones, and/or visual - olfactory observations. The 2,267 soil samples were collected in the absence of any evidence that would

indicate where fuel contaminants were actually located in the vadose zone. This means that the RFI data set most likely does not represent the actual presence of LNAPL in the vadose zone, but only an arbitrary 50-ft sampling interval below the topmost 50 feet of the vadose zone. Consequently, it is imperative that the Air Force remedy this data gap in the source area before the RFI is approved so that all stakeholders understand the potential contaminant loading from fuel in the vadose zone to the drinking water aquifer.

The RFI states in several locations that continuous sampling was conducted in the vadose zone, but this is supported at only a few locations. Continuous sampling was limited to only a few borings, such as SB-106-C (Section 4.2.5) and the eight groundwater monitoring and two extraction wells installed in 2015 as described in Section 6.2.2.2. Despite the RFI's statements, review of Appendix B reveals that continuous sampling did not occur in the six borings described in Section 5.2.2.3, but rather 5-foot-long acetate sleeves were used to extract about 5 feet of subsurface material, which is a very small fraction of the contaminated vadose zone. The Air Force should carry out continuous coring through the entire vadose zone thickness in the source area to provide the information needed to make defensible estimates of contaminant mass.

The Air Force's vadose zone field investigations did not quantify LNAPL saturation or composition across the entire depth, so there are no data available to assess the potential for future LNAPL migration into the drinking water aquifer. If LNAPL saturation is in the mobile range, fuel in the LNAPL phase could still be migrating slowly through the vadose zone and causing continued contamination of the groundwater over long time periods. The RFI does not cite any studies of the migration rates or travel times through the vadose zone, but given the more than 450 feet of thickness, the possibility remains that fuel is still migrating through the vadose zone. Given the persistence of ethylene dibromide (EDB) in the subsurface at the site, it is vital that the mass of EDB be quantified across the vadose zone in the source area. The RFI should identify this missing information about LNAPL saturation migration, and composition as critical data gaps so that the CME will appropriately address continued contamination of the regional aquifer by the vadose zone. These data gaps can be resolved by continuous coring and analysis of LNAPL saturation and composition through the entire vadose zone.

RFI text describing the LNAPL in the vadose zone as the "smear zone" should be corrected throughout the report. LNAPL distribution in the vadose zone is a function of the fuel release migration history, grain/pore size distributions, and the interactions between the vapor, water, and LNAPL phases. Smearing is commonly restricted to changes in LNAPL distribution (saturation) from fluctuations in the water table (see Sections 3.5 and 4.1.2 in Tomlinson, et al., 2014). Thus,

the smear zone should be restricted to describing the spatial distribution of LNAPL mass below the water table.

2.2 Insufficient Data and Inaccurate Description of LNAPL in and near Aquifer

By ignoring available data, the RFI report incompletely characterizes the extent of LNAPL in and near the aquifer. Understanding the location and mass of LNAPL in aquifer is critical for corrective measures to address long-term sources and the RFI correctly identifies that the amount and composition of smeared LNAPL are important data gaps that must still be resolved before proceeding to the CME. While the RFI uses LNAPL thickness to indicate LNAPL presence, it says nothing about how LNAPL presence is also demonstrated by groundwater concentrations of fuel constituents that exceed their effective solubility values. Effective solubility is the maximum concentration of a LNAPL component expected in the dissolved phase and is based on Raoult's Law, which states that the maximum concentration that can dissolve out from an LNAPL is governed by the mole fraction of the constituent in the LNAPL (see Section 4.1.1 of Tomlinson et al., 2014).

Groundwater concentrations of an LNAPL constituent that are at or above its effective solubility indicate LNAPL is present in the well even if there is no measured LNAPL thickness in the well. Based on the two LNAPL compositions reported by the Air Force, we calculate that benzene has site-specific effective solubility values of 1,424 µg/L and 6,408 µg/L. According to ATSDR (2016), the effective solubility for diesel range petroleum hydrocarbons (TPH-DRO) in jet fuels is 5,000 µg/L. The lack of any discussion or analysis about effective solubility and historical concentration data in the RFI is a serious deficiency.

The RFI states that LNAPL has only been observed at one or two monitoring wells since 2012 (Figure 5-4). In fact, the RFI presents an incomplete picture of all the information about LNAPL extent, greatly underestimating its extent in the aquifer. **Figures 1** and **2** show that benzene and TPH-DRO concentrations exceeded their estimated effective solubility values at 12 locations in the fourth quarter of 2014 and at 11 locations in the fourth quarter of 2015. In comparison, RFI Figure 5-4 depicts LNAPL is present at two locations in the fourth quarter of 2014 and at one location in the fourth quarter of 2015. The RFI should be revised to discuss all indicators of LNAPL presence, including effective solubility for benzene, TPH-DRO, and other constituents.

The RFI identified a data gap about the location of LNAPL below the water table and the effects of weathering. This data gap should be revised to state that the Air Force will determine the saturation and composition of LNAPL at to depths that extend below the estimated minimum water table elevation in the source area. One cannot estimate the future production of dissolved EDB or

other constituents of concern (COCs) from the smeared LNAPL without knowing the mass and composition, especially the mass of EDB. The RFI appears to be advocating for the long-discredited pancake model of LNAPL on water table (unconfined) aquifers (see for example https://rtdf.clu-in.org/public/napl/training/module1.pdf), because it repeatedly and incorrectly states that LNAPL floats on the water table and that it would not be found below the minimum water table elevation in the source area (Sections ES-4.2, 5.1, and 5.3.1.3), even though there are frequent citations of Tomlinson et al. (2014) which clearly shows that LNAPL saturation extends below the regional water table. RFI Sections 5 and 7 should be revised to correctly discuss saturation variations with depth below the regional water table and with grain size (see Figure 3.5 in Tomlinson et al., 2014). This trapped or smeared LNAPL will act as long-term contaminant sources, thus the RFI should be revised to include the full extent of the smear zone because proper selection and design of corrective measures depends on delineation of the extent and mass of this source.

2.3 Analysis Misrepresents Groundwater Contaminant Trends

The RFI report's characterization of benzene and EDB concentration trends over time is seriously flawed and overestimates degradation rates in groundwater. The statistical analysis summarized in Section 6.2.2.3 and detailed in Appendix T is not scientifically defensible because it assumes all concentration changes are solely a function of degradation when there are many other controls on concentration changes over time. The concentration time trends must be re-analyzed with corrected data sets and Section 6.2.2.3, Appendix T, and all references to their findings should be revised throughout the RFI report. The end result is that degradation of benzene and EDB is proceeding much more slowly than is purported in the RFI report.

Many factors potentially affect concentration changes at this and other LNAPL sites. Active remediation such as the soil vapor extraction, LNAPL skimming, and bioslurping conducted at the KAFB BFF should cause large changes in concentration that are independent of degradation. If LNAPL presence in or near the monitoring well changes over time (i.e., changes caused by a rising water table and differences in grain/pore size distributions or LNAPL redistribution), it will cause very large changes in dissolved phase concentrations that are independent of degradation. A rising water table that submerges the monitoring well screens displaces the shallow contaminant plumes upward and so can also cause large changes in concentration that are independent of degradation. However, the RFI statistical analyses for EDB and benzene concentration changes over time assume all concentration changes are from degradation, which is not only not scientifically defensible but overestimates the actual degradation rates and severely underestimates the half-lives of COCs at the site.

As shown in **Figures 3** through **7**, the RFI statistical analysis is applied to all data from the time period of interest, even when remediation was active, LNAPL was present, or the screen was submerged. Including measurements when LNAPL was present (either by measured thickness or effective solubility) is not appropriate or defensible when trying to estimate degradation rates or half-lives. These measurements and those taken when remediation was active or the screen is submerged should be removed from the statistical data set to create a corrected data set before estimating the degradation rate. **Figures 8** through **12** show examples of the data sets corrected for remediation and LNAPL presence. Examination of these figures shows that remediation and the presence of LNAPL are associated with high concentrations whereas submergence of the monitoring well screens is commonly associated with large decreases in measured EDB concentrations. The RFI's estimates of degradation rates and half-lives are invalid because other processes are changing concentrations. Appendix T and all related text should be removed from the RFI report until the analyses are carried out in a correct and scientifically defensible way.

The RFI text and Figures 6-15 and 6-16 are misleading because they state that decreasing trends are apparent before screen submergence. There are no data to support this conclusion and numerous data to show the contrary. The RFI presents no evidence that any concentration decreases prior to submergence were not influenced by remediation, presence of LNAPL, and/or change in flow paths due to rising water table. The RFI presents little to no evidentiary basis for concentration decreases by degradation prior to submergence. Examination of **Figures 8** through **12** shows that submergence of the monitoring well screens is commonly associated with large decreases in measured EDB concentrations, indicating that the shallow plume, which has historically had the highest EDB concentrations, has moved above the screened intervals so that the wells no longer represent the highest concentrations in the plume. This calls for the installation of new shallow monitoring wells to determine how the groundwater plume is increasing in volume vertically.

The RFI states "In the downgradient aerobic portion of the plume, data indicate that hydrolysis, an abiotic process is a significant factor in the degradation of EDB". Abiotic degradation of EDB is reported to have been observed in the laboratory but there are no reports of it being observed in field conditions anywhere. The RFI presents no site-specific evidence to demonstrate that there is abiotic EDB degradation in the downgradient groundwater plume. Such concentration changes may be caused by drowning, migration of degradation products from source area, or other factors. Calling abiotic degradation "a significant factor" is unsupported interpretation and should be removed from the RFI report.

2.4 Incomplete Delineation of Groundwater Plume

The RFI report states that the horizontal extent of the EDB groundwater plume is well defined except for the data gap at the northwest margin of the plume. We agree that there is a data gap at the northwest margin of the plume, but there much more important data gaps in the vertical extents of the EDB plumes. The vertical extent of the distal EDB plume at depth remains undefined. The deepest EDB was detected at monitoring wells KAFB-106037 and KAFB-106058 for a number of years, with concentrations that were several to many multiples of the MCL. A recent cross-section created by Colin Plank of AECOM in April 2016 from those wells northward to the extraction well KAFB-106234 is shown in **Figure 13**. The deep screen location (KAFB-106227) at the next cluster downgradient of KAFB-106058 is about 55 ft below the screen for KAFB-106058 and there are one or more silt-dominated intervals that may have acted to divert plume migration, leaving question about the EDB location (**Figure 13**). The most downgradient deep screen, KAFB-106206, is about 70 below the bottom of the KAFB-106058 screen and could be isolated from EDB migration by a slightly thicker silt-dominated interval (**Figure 13**). Similarly, the screen bottom for intermediate monitoring well KAFB-106232 is about 70 ft above the top of the screen for KAFB-106206 (**Figure 13**). These vertical gaps between the monitoring well screens and the location and orientation of the silt-dominated intervals demonstrate there is an important data gap about the EDB plume with depth. The data gap extends to locations downgradient of the most distal extraction well (KAFB-106234) and so should be resolved as soon as possible before finalizing the extraction well system.

The upper vertical extent of the groundwater contaminant plumes is no longer defined and is increasing as the water table rises. Most of the shallow screened intervals in the monitoring well network within the source area have been submerged for a few years. The high concentration part of the EDB plume is now located above the tops of these screens, so it is not possible to know the extent of the plume. Furthermore, the rising water table may be intercepting fuel LNAPL in the deep vadose zone, which may cause dissolved phase concentrations to increase significantly. Consequently, the RFI should be revised to describe these vital data gaps and all text about shrinking or stable plume size should be removed from the current document.

2.5 Remove Unsupported Interpretation and Incorrect Text

As shown in **Table 1**, the RFI report contains many instances of unsupported interpretation and incorrect statements. All unsupported interpretation should be removed from the report as it is intended to provide the evidentiary basis for carrying out the CME. All instances of incorrect statements should be removed or revised.

3.0 REFERENCES

ATSDR, 2016. 2016. Draft Toxicological Profile for JP-5, JP-8, and Jet A Fuels. Draft for public comment. TP-121. February, 2016.

INTERA, 2011, Technical Memorandum to J. Stomp, R. Shean, and B. Gastian, ABCWUA. *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*. 15 February 2011.

Shaw Environmental, 2010. *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*. Prepared for Prepared for U.S. Army Corps of Engineers Albuquerque District, Albuquerque, New Mexico 87109 by Shaw Environmental & Infrastructure, Inc., Denver, CO. November, 2010.

Sundance Consulting, 2017. *Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report for the Bulk Fuels Facility Release Solid Waste Management Unit (SWMU) ST-106/SS-111*. Prepared for U.S. Army Corps of Engineers Albuquerque District, Albuquerque, New Mexico 87109 by Sundance Consulting, Inc., Albuquerque, NM. January 2017.

Tomlinson, D. W., Thornton S. F., Thomas, A. O., Leharne, S. A. and Wealthall, G. P., 2014. An Illustrated Handbook of LNAPL Transport and Fate in the Subsurface, Contaminated Land: Application in Real Environments (CL:AIRE), 32 Bloomsbury Street, London WC 1B 3QJL.

Tables

#	Source	Comment
1	P ES-3: Section ES-2 para 3 last sentence	Interpretation: It is possible to make an estimate of the leaked fuel. Remove or revise sentence.
2	P ES-3: Section ES-2 para 5 first sentence	The leaked fuels are LNAPLs regardless of their location. LNAPL definition is independent of location. Revise or remove sentence.
3	P ES-3: Section ES-2 para 5 sentence 2	Many constituents of fuel LNAPLs are water soluble, e.g., BTEX compounds. Revise sentence to eliminate incorrect text.
4	P ES-3: Section ES-2 para 5 sentence 3	Head gradient also drove LNAP migration in vadose zone, especially near release points. Revise sentence to eliminate incorrect text.
5	P ES-5: Section ES-2 para 1 last sentence	LNAPL does not float on top of water table: head and capillary forces create variable saturation of LNAPL below the water table. Revise sentence to eliminate incorrect text.
6	P ES-5: Section ES-2 para 2 sentence 3	LNAPL viscosity differences are not important for LNAPL saturation differences here compared to interfacial tension/wettability and capillarity. Revise sentence to eliminate incorrect text.
7	P ES-5: Section ES-2 para 2 sentence 4	Interpretation: Without any support, this sentence assume only flow direction was north-northeast, but dissolved phase plume could have and likely did move in different directions depending on the flow system when NAPL reached the water table. Also ignores the likely effects of channel structure and permeability structure in the ancestral Rio Grande sediments. Revise sentence to eliminate interpretation.
8	P ES-7: Section ES-4.1 para 1 sentence 2	Samples collected represented only approximately 6% of vadose zone, so the 2,267 samples say nothing about 94% of the vadose zone. Revise sentence to provide accurate description of the unknown volume of vadose zone.
9	P ES-7: Section ES-4.1 para 1 last sentence	Interpretation: There are no LNAPL saturation data from vadose zone, so saturations are not known. LNAPL will not displace water from small pores in fine-grained materials unless the pressure head overcomes the oil entry pressure. High hydrocarbon content likely found in the coarser grained material overlying the low-permeability lens. Revise sentence to remove unsupported interpretation.
10	P ES-7: Section ES-4.1 para 2 last sentence	Interpretation: See comment 9. Revise sentence to remove unsupported interpretation.
11	P ES-9: Section ES-4.2 entire section	This section lacks any discussion of LNAPL presence indicated by concentrations at or above effective solubility values for fuel constituents and TPH. Numerous concentration measurements show that benzene and TPH-D concentrations exceed the effective solubility values and so demonstrate the presence of NAPL even when there is no measurable NAPL thickness. Revise all text and Figure ES-6 to include LNAPL presence from exceedance of effective solubility values.
12	P ES-12: Section ES-4.2 para 2 sentence 3	There are no data to show that groundwater heads in the unconfined aquifer dropped 142 ft (or any other elevation change). USGS historic head contours represent composite heads for the two confined aquifers and unconfined aquifer and are not appropriate for the unconfined aquifer. ABCWUA has estimated that heads dropped about 80 ft in the unconfined aquifer. Remove or revise this sentence.
13	P ES-12: Section ES-4.2 para 2	Floating LNAPL is not the only LNAPL mass in the system. The author appears to consider LNAPL distribution follows the long-discredited pancake model, particularly by focusing on changes on "LNAPL thickness". Several decades of science have shown that LNAPL saturation is the only important measure of LNAPL mass, not LNAPL thickness. There is significant LNAPL mass below even the historic minimum elevation for the water table. Remove all instances of "floating LNAPL" and revise text to describe all LNAPL mass that must be addressed by RFI and CME.

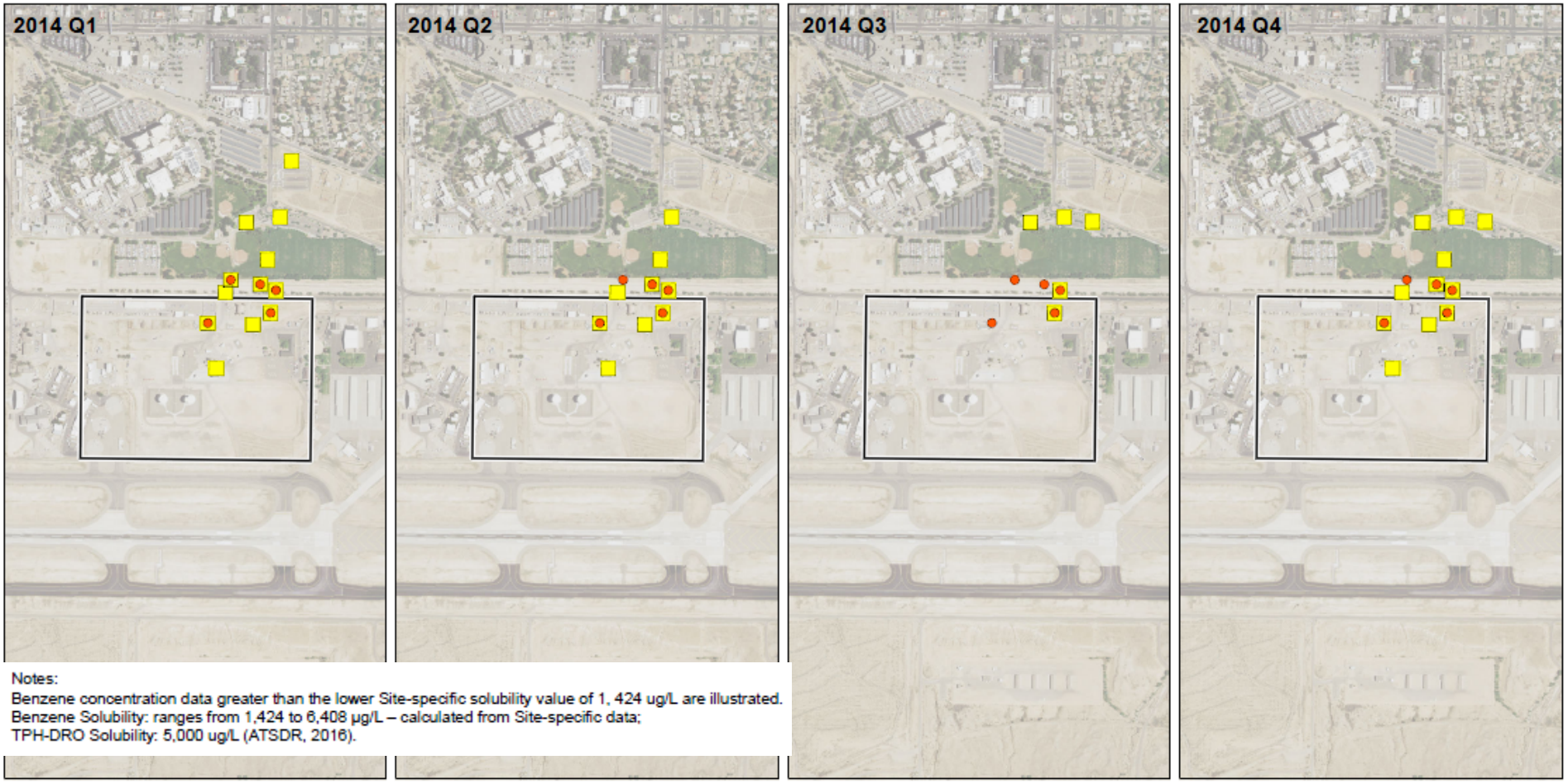
#	Source	Comment
14	P ES-12: Section ES-4.2 para 3 sentence 1	Given the lack of discussion of either LNAPL presence by effective solubility or LNAPL saturation, the RFI does not have sufficient data to discern the horizontal extent of the LNAPL in the saturated zone or the vadose zone.
15	P ES-12: Section ES-4.2 para 3	The entire paragraph should be rewritten to explain that there is LNAPL throughout the vadose zone thickness in the source area and that given the lack of LNAPL saturation measurements from vadose zone soil samples, some of that LNAPL may be present at saturations that allow migration and some LNAPL may be held at residual saturations. Also, the paragraph should have text that explains that the rising water table has and will continue to encounter this vadose zone LNAPL throughout the source area, adding to the source mass. Furthermore, the author continues to incorrectly state that LNAPL cannot be present below the historic minimum water table elevation. Please remove all text that promotes the long-discredited pancake model and replace with text about LNAPL saturations can be quite significant beneath the regional water table following the "shark fin" saturation distribution expected in porous media.
16	P ES-12: Section ES-4.3 para 1 sentence 1	The rising water table means that the shallow plume interval is located above the screens of many shallow monitoring wells. The RFI provides no data to show that the vertical extent of the plume is defined or monitored. In the source area the rising water table likely encounters vadose zone contamination (LNAPL, vapor, and dissolved phase), so the concentrations may be increasing by a large factor. Outside the source area, the shallow well network intercepts the water table plume at only a few locations yet the water table plume had contained some of the highest observed concentrations in the past. Given there are plume intervals outside the Air Force's ability to measure for most well nests, the RFI does not define the plume extent adequately. This text should be revised to explain that the vertical plume extent is no longer understood and has become a new data gap that must be resolved for the CME.
17	P ES-12: Section ES-4.3 para 1 last sentence	Add text to this sentence to explain that 1 microgram per liter is still 20 times larger than the MCL.
18	P ES-12: Section ES 4.3 para 2	This entire paragraph should be removed or revised because average concentration is poorly defined that it is not possible to determine whether the number of wells changed over the time periods and whether concentration data showing LNAPL presence (effective solubility or thickness) or remediation were screened out. Average concentration must be rigorously defined and consistently applied over the time period. Remove all mention of average concentration.
19	P ES-15: Section ES 4.3 para 1	The statistical analysis combined concentrations measured when processes other than degradation were occurring, including active remediation, presence of LNAPL in the well, and screen submergence. All data points for each of these should be removed from the data sets for the statistical analysis (and calculation of average concentration) before calculating degradation rates and assessing whether there was a statistically significant decrease in concentration over time. This entire paragraph should be removed or rewritten.
20	P ES-15: Section ES 4.3 para 4 last sentence	Interpretation: There are no site-specific data cited to demonstrate that abiotic degradation occurs in the field, including this site, and is measurable under field conditions. There are no data to support that abiotic degradation is a "significant factor" in EDB degradation. Remove this sentence.
21	P ES-15: Section ES 4.3 para 5 first sentence	See comment 12. There are no data to show that groundwater heads in the unconfined aquifer dropped 142 ft (or any other elevation change). USGS historic head contours represent composite heads for the two confined aquifers and unconfined aquifer. Remove or revise this sentence.

#	Source	Comment
22	P ES-15: Section ES 4.3 para 6 last sentence	The full GWTS has not been completed. This system is to include up to 8 extraction wells per the agreement between the Air Force, NMED, and ABCWUA. Only 3 extraction wells have been completed by 2017. Revise this sentence to state that the full GWTS is still under construction.
23	P ES-19: Section ES-5 bullet 2	Interpretation: The LNAPL present at the site is most likely not a mixture of the 3 fuels because it is not necessary that the fuels released later traveled the same flow paths as the earlier fuels. Remove this sentence.
24	P ES-19: Section ES-5 bullet 3	Interpretation: The RFI presents no analyses or calculations to show that the applied vacuum always overcame the pressure head driving fuel out of the holes when fuel was passing through the pipe. This bullet should be revised to state that fuel could have migrated out of the pipe when fuel was flowing under vacuum.
25	P ES-19: Section ES-5 bullet 6	Interpretation: CB&I modeling assumed that fuel reached the groundwater table in the 1980s. The RFI neither presents data demonstrating arrival date or decade nor provides a description of a calculated arrival estimate. This sentence should be removed.
26	P ES-21: Section ES-5 bullet 6	The only question of concern is the mass of LNAPL in the sub-surface. Some of that mass manifested as freely migrating LNAPL, some as mobile, and some as residual. Remediation can remove mass but the water table rise simply smears free-phase LNAPL without reducing mass. This sentence should be revised to focus on the changes of total LNAPL mass so as to provide a meaningful context for understanding what changes in free-phase LNAPL mean.
27	P ES-21: Section ES-5 bullet 7	The rising water table did not "mobilize" all residual LNAPL it encountered, some residual LNAPL remained as residual. There is no evidence that the rising water table encountered only residual LNAPL. Mobile LNAPL may also be present.
28	P ES-21: Section ES-5 bullet 9	See comment 19. The statistical analysis combined concentrations measured when processes other than degradation were occurring, including active remediation, presence of LNAPL in the well, and screen submergence. All data points for each of these should be removed from the data sets for the statistical analysis (and calculation of average concentration) before calculating degradation rates and assessing whether there was a statistically significant decrease in concentration over time. As advection velocities decrease, it takes longer for solutes dissolved from blebs to migrate. This entire paragraph should be removed or rewritten.
29	P ES-24: Section ES-5 bullet 1	The RFI provides no evidence that the debromination is occurring across the entire area where EBD and benzene are found together in groundwater. Debromination may be localized to relatively small areas containing the conditions required for debromination (which are more restrictive than those for benzene biodegradation) and advecting into downgradient areas. The RFI presents no data or analyses to demonstrate the extent of debromination but simply says that the byproducts were observed and such observation do not demonstrate that debromination occurs everywhere the byproducts are found. This sentence should be revised or removed.

#	Source	Comment
30	P ES-24: Section ES-6 paragraph 1	The first two of the three conclusions purported by Sundance are not substantiated by the data and analyses described in the report. The data and analyses presented in this RFI report do not support Sundance's conclusions that the nature and extent of contamination are sufficiently well understood or that there are sufficient data to move forward with the RCRA process. Our evaluation found that the RFI document does not provide the evidentiary basis for conducting a CME and its conceptual model contains errors and omissions that could lead to an inappropriate or ineffective set of corrective measures. Specifically, our review demonstrates that the RFI report lacks important data needed for the CME, inaccurately characterizes important features and processes in the subsurface, underestimates contaminant sources, and overestimates degradation rates. Any future addenda to the RFI planned by the Air Force should address the issues and data gaps described below (see comment 31) to prevent implementation of corrective measures that will be unsuccessful in protecting the drinking water supply for Albuquerque
31	P ES-24: Section ES-6 paragraph 5	This paragraph is incomplete. There are more important data gaps that haven't been addressed in the RFI, including mass flux of EDB, other COPCs, and LNAPLs from vadose zone to aquifer, expansion of the dissolved phase plume and source mass from the rising water table, lack of understanding of COPC concentrations at the water table. and the nature and magnitude of site-specific processes acting on COPCs in the dissolved and LNAPL phases.
32	P 6-39: Section 6.5 bullet 1	The groundwater plume delineation is not complete because the vertical extent is expanding above the shallow screens from the rising water table.
33	P 6-40: Section 6.5 bullet 2	Interpretation: the RFI concentration trends are based on incorrectly combined data points and are not defensible. This bullet should be revised or removed.
34	P 6-40: Section 6.5 bullet 6	See comment 19. Remove or revise this sentence.
35	P 7-10: Section 7.9.1 paragraph 3	This paragraph ignores how LNAPL saturation is significant below the capillary fringe and below the regional water table. Revise to include description of saturation variations with depth (e.g., shark-fin saturation pattern).
36	P 7-13: Section 7.9.2 paragraph 3	Add text to this paragraph to explain the differences between water solubility and effective solubility of COPCs and how the effective solubility can be used to determine the presence of LNAPL near a monitoring well if the COPC concentrations exceed the effective solubility. The text should also explain that effective solubility is the appropriate quantity for NAPL contamination, not water solubility. The last sentence should be revised or removed. Solubility difference is irrelevant since Raoult's law governs NAPL dissolution. The difference between BTEX and EDB dissolved concentrations is that BTEX is readily degraded by microorganisms whereas EDB is not.
37	P 7-14: Section 7.9.2.1	This section should be revised to describe the possibility of vapor phase migration of COPCs from the vadose zone to the groundwater.
38	P 7-19: Section 7.9.2.2 Paragraph 3	The RFI presents no data to demonstrate that hydrolysis is occurring at the site. Whether the observed EDB concentrations are consistent with hydrolysis is irrelevant and misleading because the concentrations are also consistent with other important transport processes, such as dispersion. The paragraph should be revised or removed since the RFI presents no site specific data and only cites laboratory studies for EDB hydrolysis.

#	Source	Comment
39	P 7-20: Section 7.10 bullet 2 last sentence	Interpretation. See comment 23. Remove this sentence.
40	P 7-21: Section 7.10 bullet 2	Interpretation. See comment 25. This sentence should be removed.
41	P 7-21: section 7.10 bullet 9	See comment 26. Revise sentence to state rising water table could encounter both residual and mobile NAPL saturations.
42	P 7-22: section 7.10 bullet 1	See comments 19 and 28. This entire paragraph should be removed or rewritten.
43	P 7-22: section 7.10 bullet 2	See comment 29. The RFI provides no evidence that the debromination is occurring across the entire area where EBD and benzene are found together in groundwater. This sentence should be revised or removed.

FIGURES



Notes:
Benzene concentration data greater than the lower Site-specific solubility value of 1, 424 ug/L are illustrated.
Benzene Solubility: ranges from 1,424 to 6,408 µg/L – calculated from Site-specific data;
TPH-DRO Solubility: 5,000 ug/L (ATSDR, 2016).

N

1,000 0 1,000

Feet

- Benzene (µg/L)
- TPH-DRO (µg/L)
- Bulk Fuels Facility

INTERA

Figure 1
LNAPL Presence in 2014
ABCWUA

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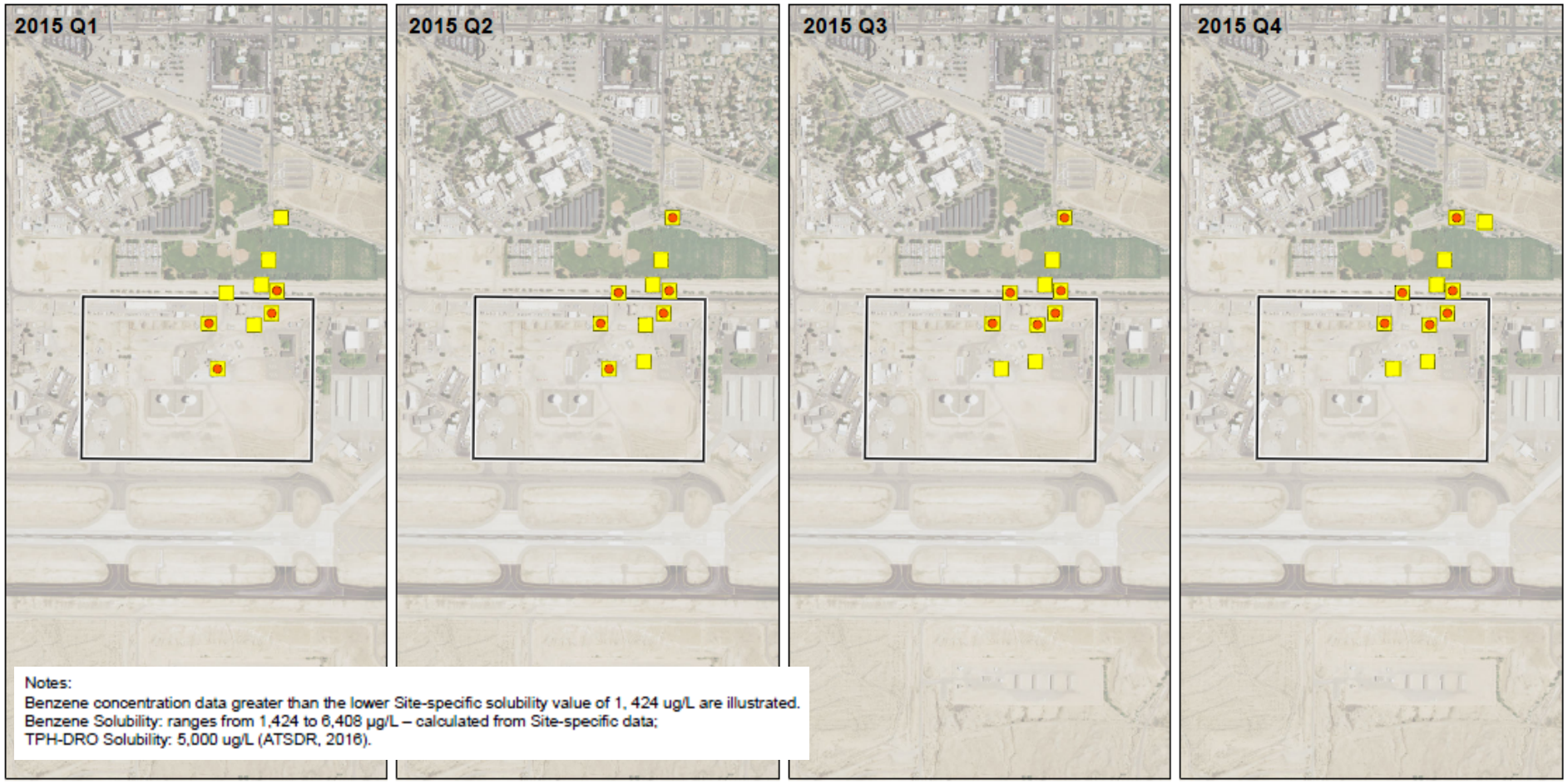

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N

1,000 0 1,000

Feet

- Benzene (µg/L)
- TPH-DRO (µg/L)
- Bulk Fuels Facility

Figure 2
LNAPL Presence in 2015
ABCWUA

INTERA

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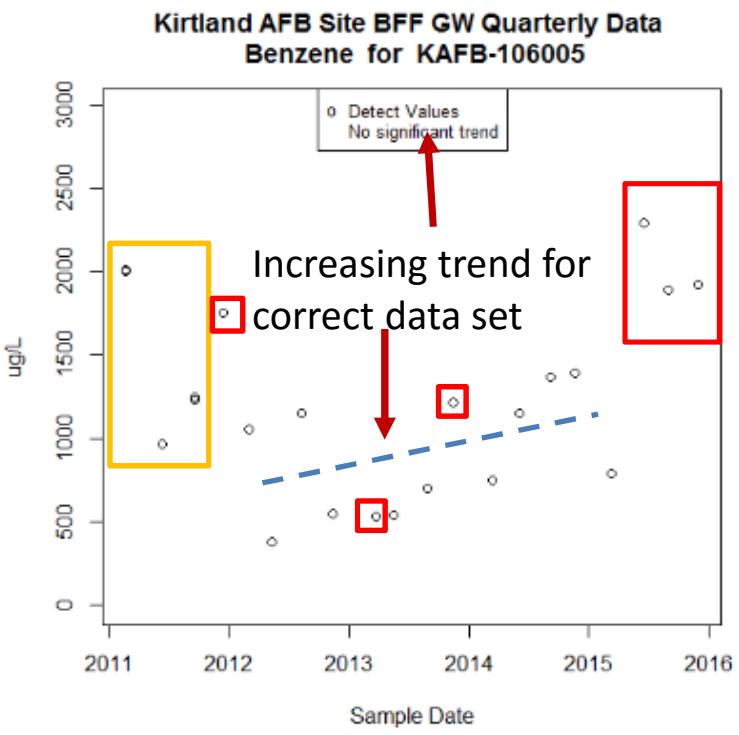

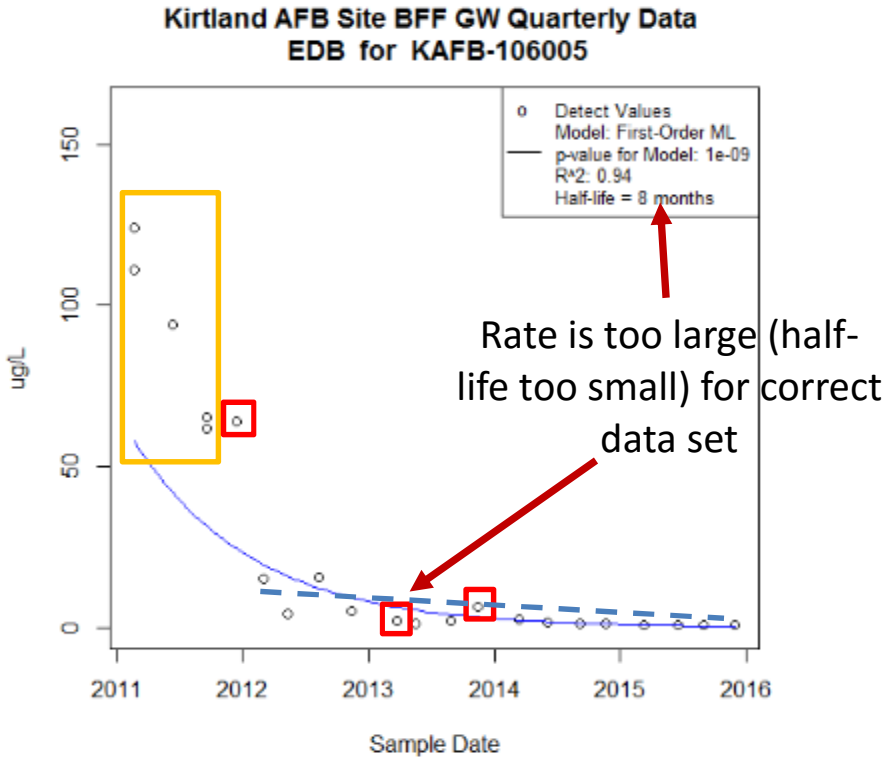

SVE system operating

Concentration > effective solubility and/or measureable LNAPL thickness

- Degradation rate calculations should exclude data when remediation is active or LNAPL is present based on thickness or effective solubility
- Correct data sets show benzene concentration is increasing over time (as is LNAPL presence) and very slow decrease in EDB concentration

Figure 3
Non-Degradation Mechanisms for Concentration Changes at KAFB-1065
ABCWUA

INTERA

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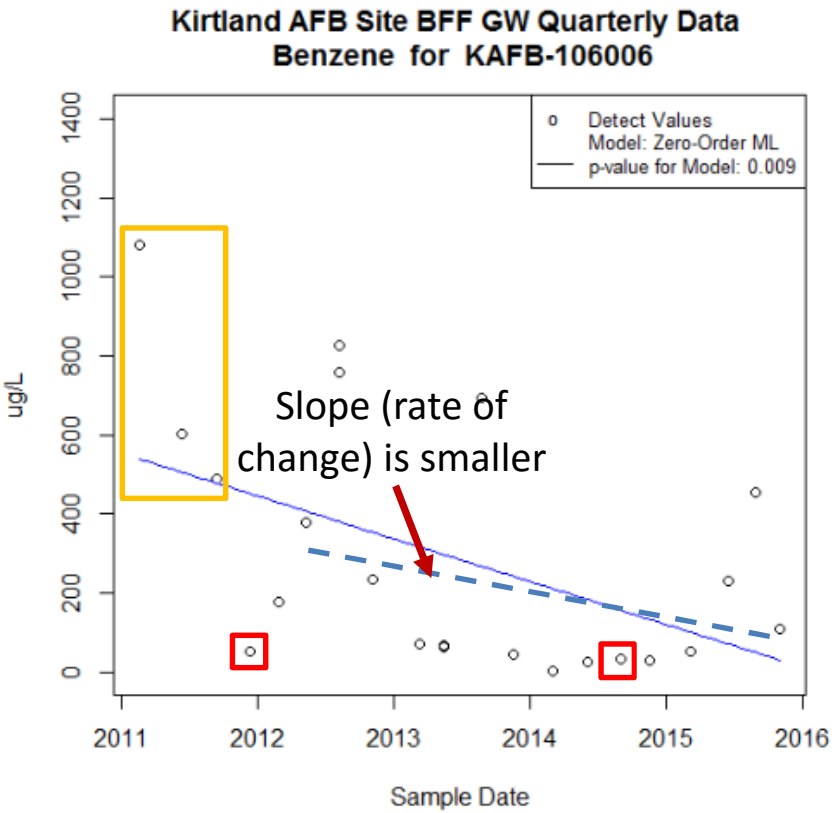

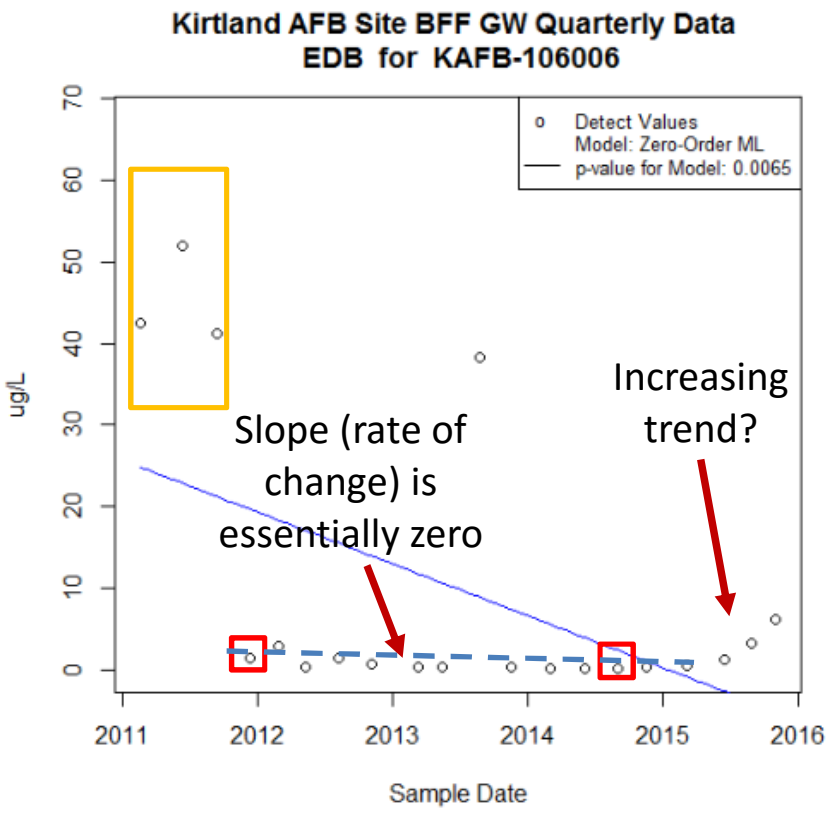

SVE system operating

Concentration > effective solubility and/or measureable LNAPL thickness

- Degradation rate calculations should exclude data taken when remediation is active or LNAPL is present based on thickness or effective solubility
- Correct data sets show benzene concentration is slowly decreasing and EDB concentration is unchanging until an increase during 2015

Figure 4
Non-Degradation Mechanisms for Concentration Changes at KAFB-1066
ABCWUA

INTERA

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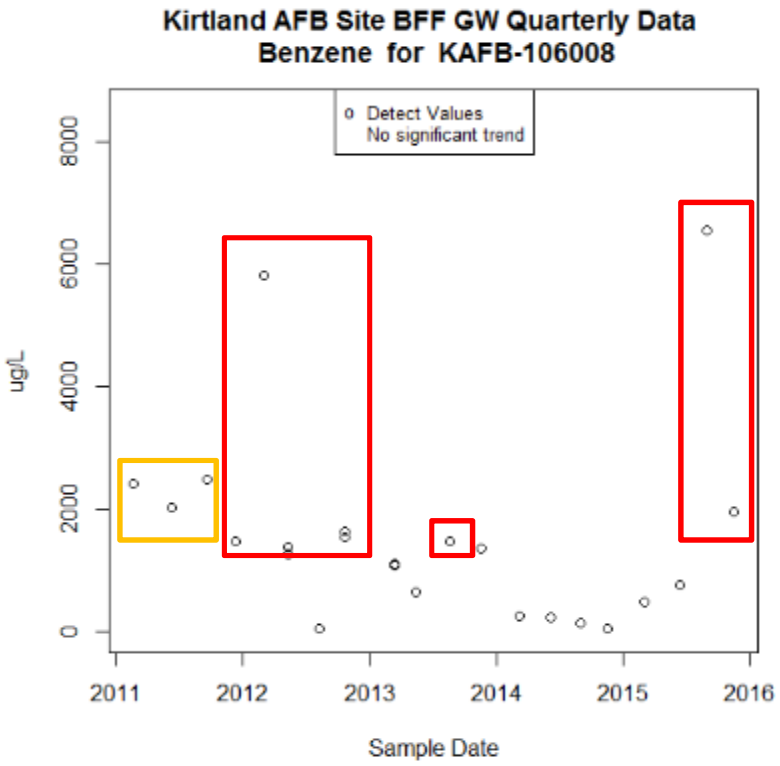

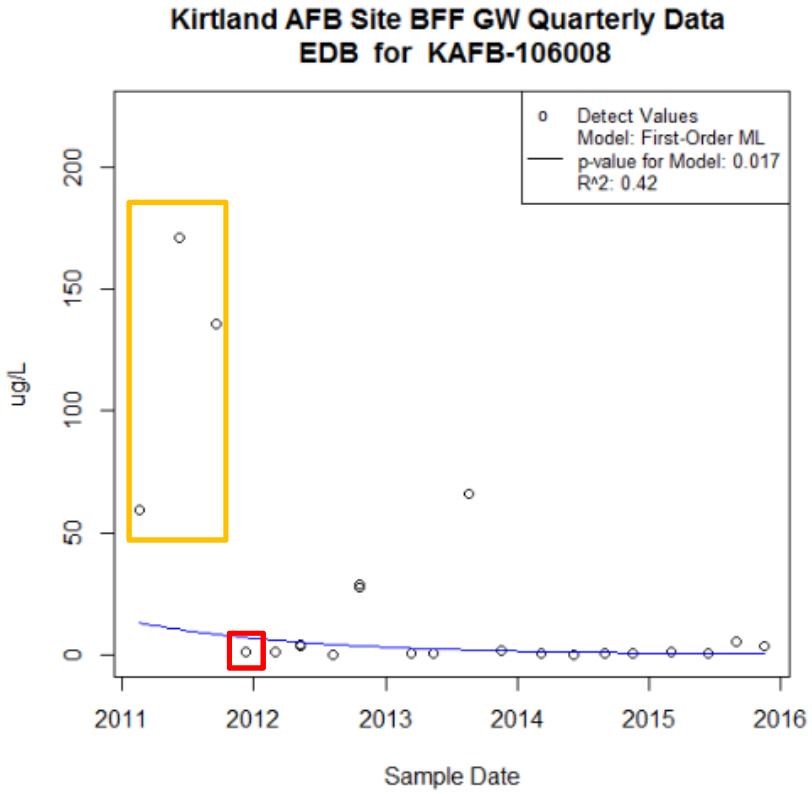

SVE system operating

Concentration > effective solubility and/or measureable LNAPL thickness

- After remediation ended, benzene concentrations show LNAPL is persistent, even in recent quarters
- LNAPL presence may cause EDB concentrations to always exceed MCL and to show minimal to negligible degradation

Figure 5
Non-Degradation Mechanisms for Concentration Changes at KAFB-1068
ABCWUA

INTERA

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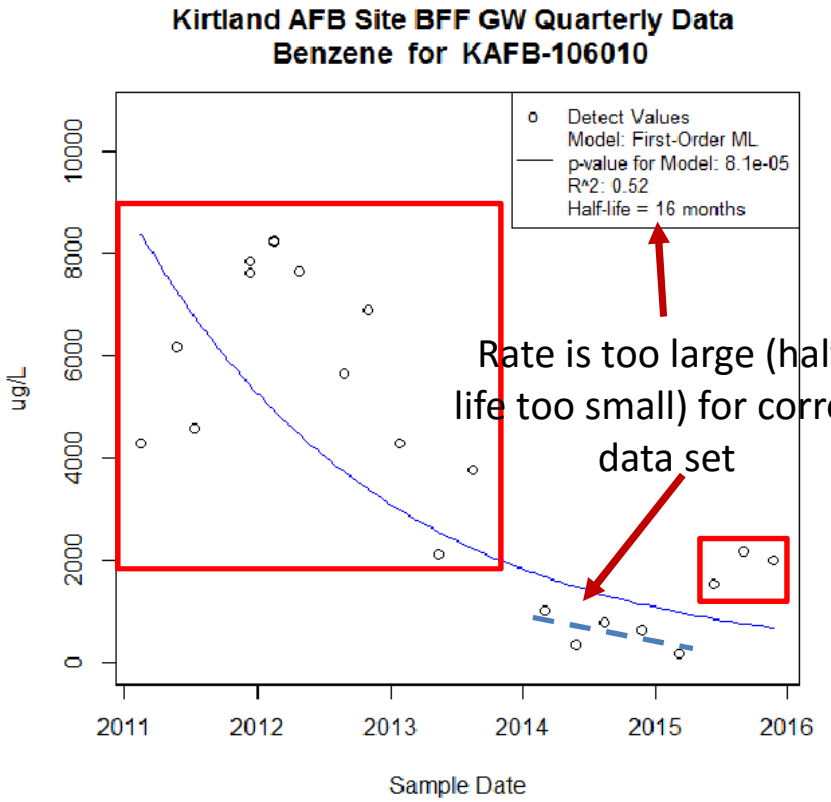

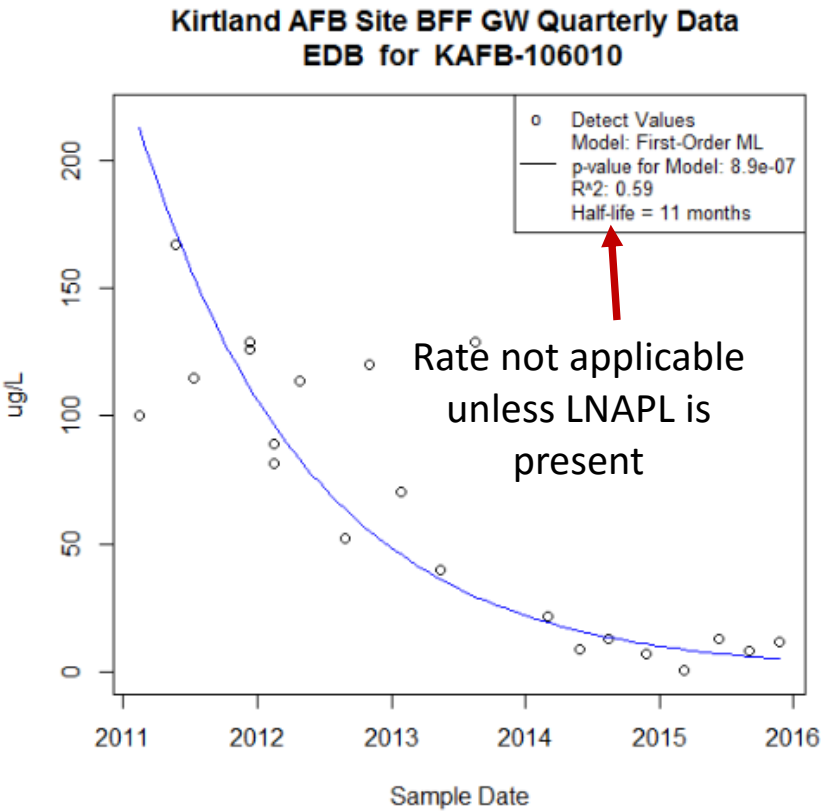

Concentration greater than effective solubility and/or measureable LNAPL thickness

- 14 of 19 quarters of benzene measurements cannot be used to estimate degradation because LNAPL was present
- EDB degradation in LNAPL presence is not representative of degradation away from LNAPL

Figure 6
Non-Degradation Mechanisms for Concentration Changes at KAFB-10610
ABCWUA

INTERA

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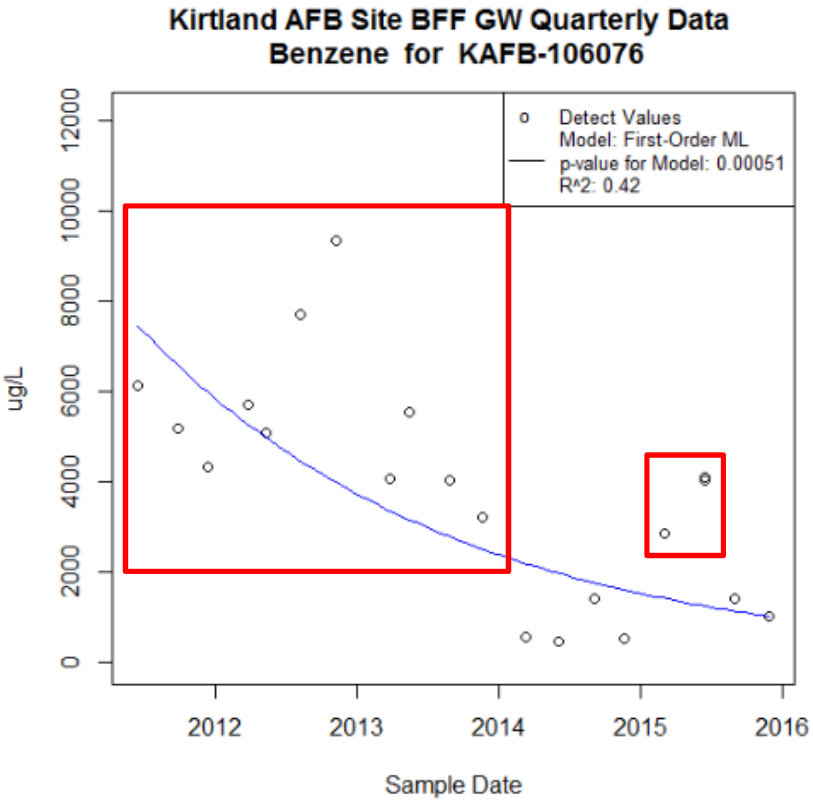

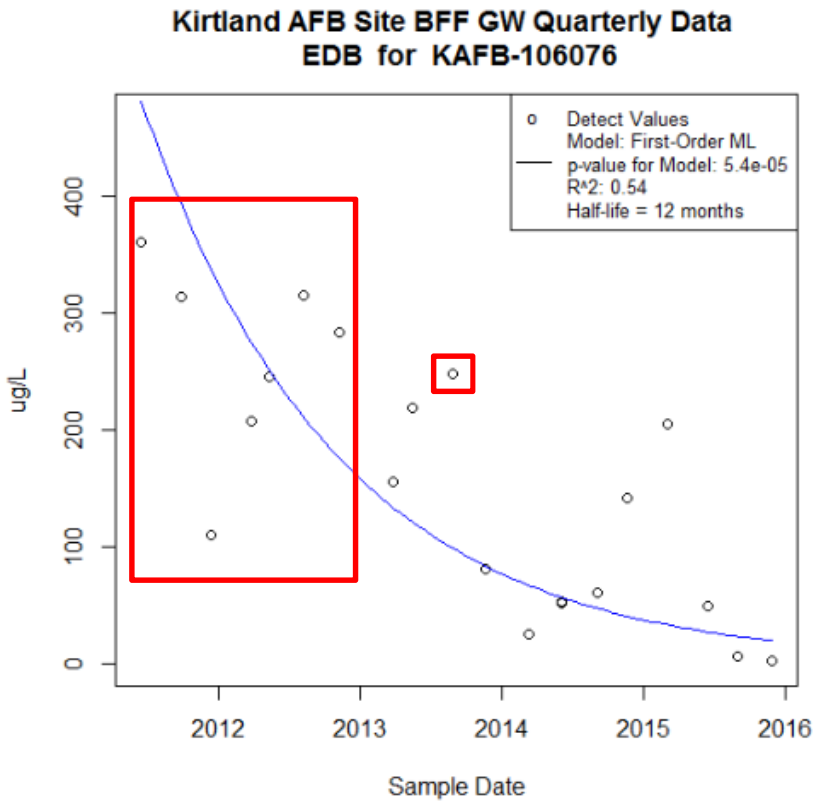

Concentration greater than effective solubility and/or measureable LNAPL thickness

- LNAPL has been consistently present in 13 of 19 quarters of benzene measurements and 8 of the first 10 quarters of EDB measurements
- Cannot use measurements when LNAPL is present to estimate either EDB or benzene degradation

Figure 7
Non-Degradation Mechanisms for Concentration Changes at KAFB-106076
ABCWUA

INTERA

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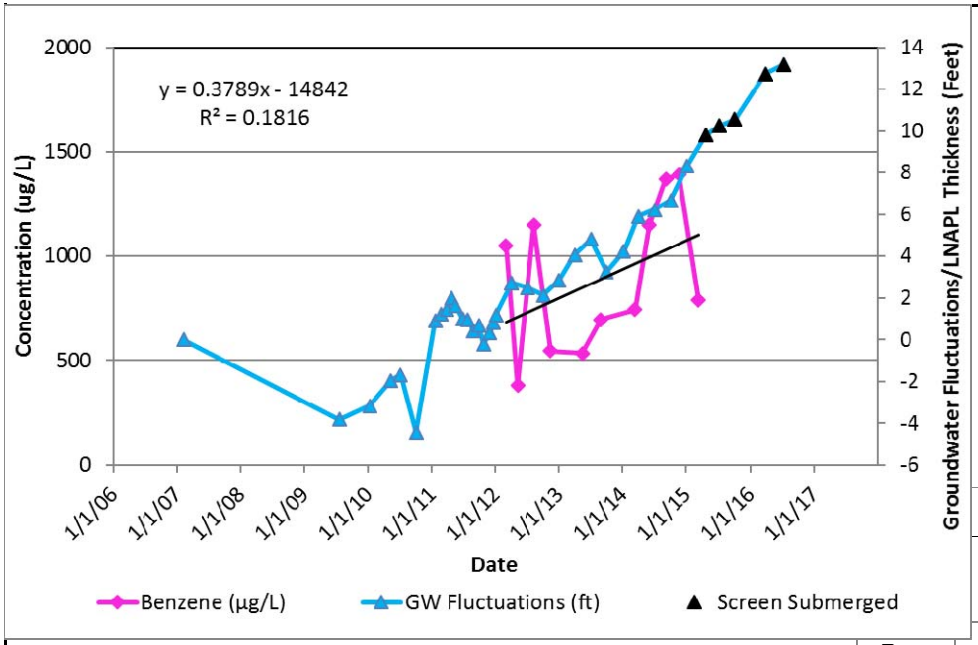
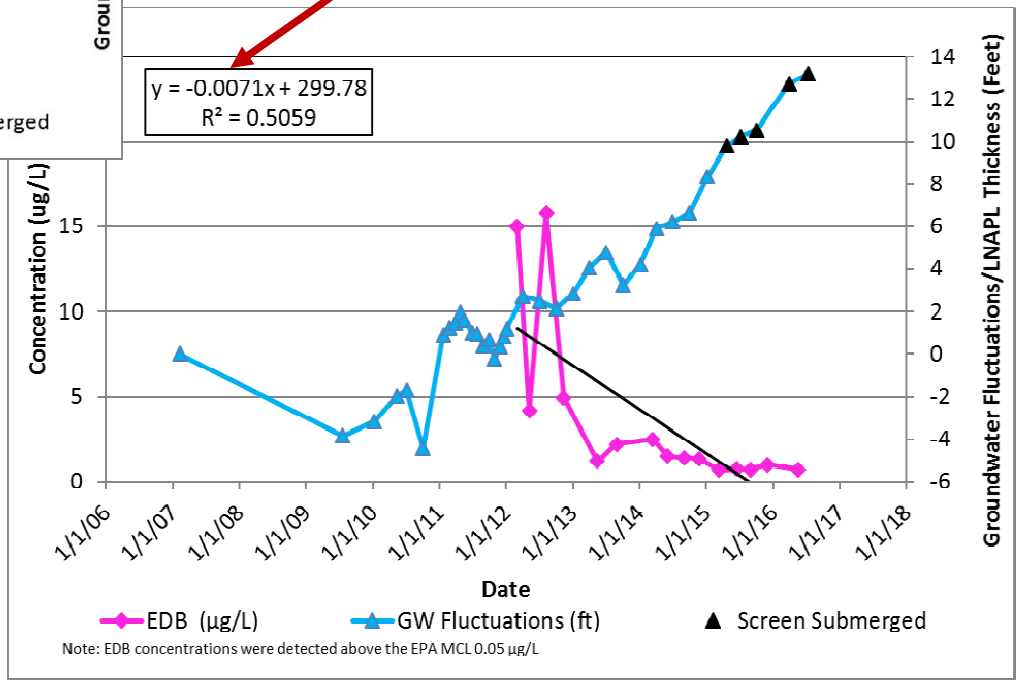


Slope (rate of change) is essentially zero



How much of the EDB concentration decrease from late 2012 to present was caused by the large increase (about 10 feet) in water level?

Figure 8
Partially Corrected Data Set for Non-Degradation Mechanisms at KAFB-1065
ABCWUA

INTERA

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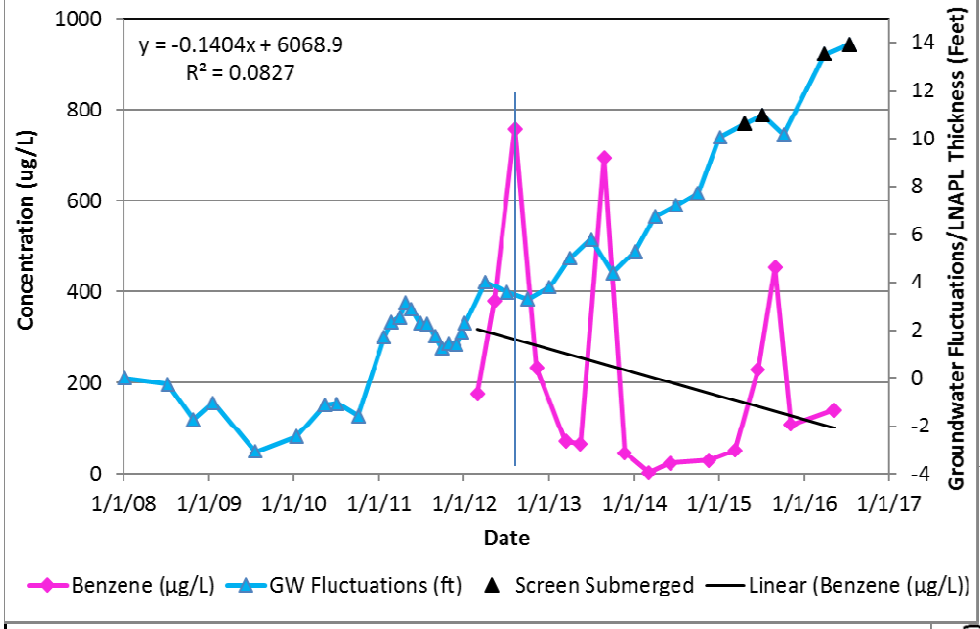
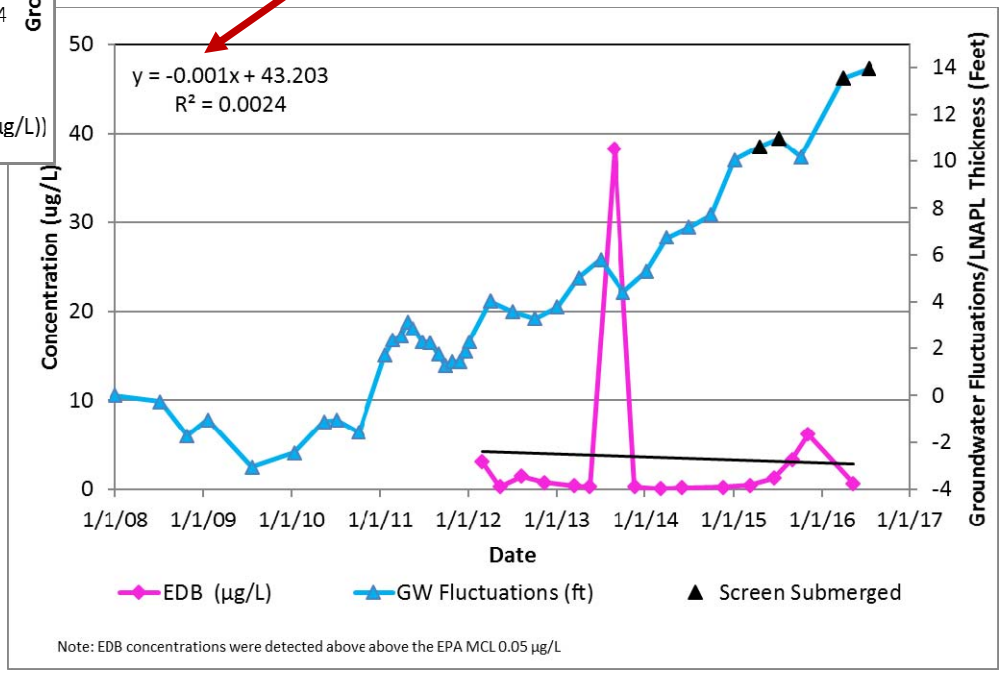


Slope (rate of change) is essentially zero



Note concentration spikes occur as or when groundwater level drops

Figure 9
Partially Corrected Data Set for Non-Degradation Mechanisms at KAFB-1066
ABCWUA

INTERA

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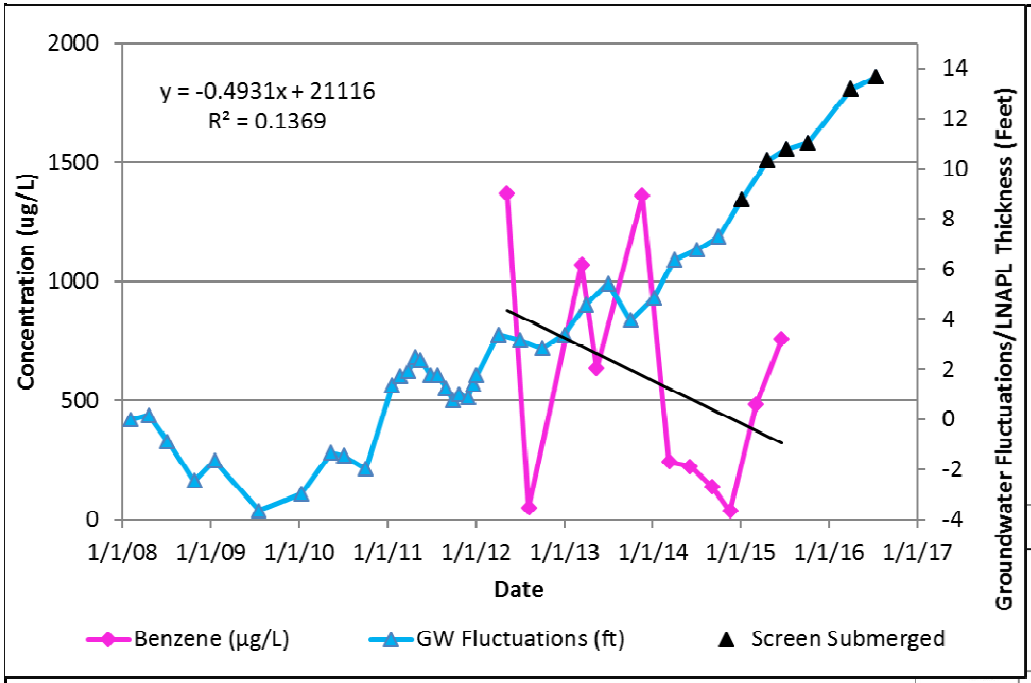

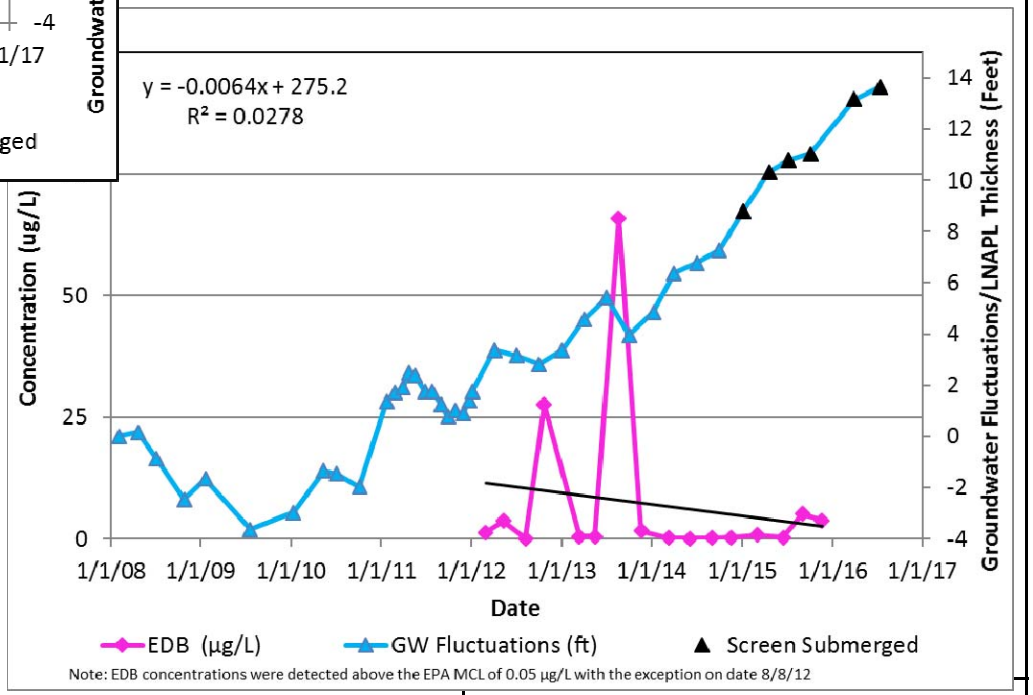

Figure 10
Partially Corrected Data Set for Non-Degradation Mechanisms at KAFB-1068
ABCWUA

INTERA

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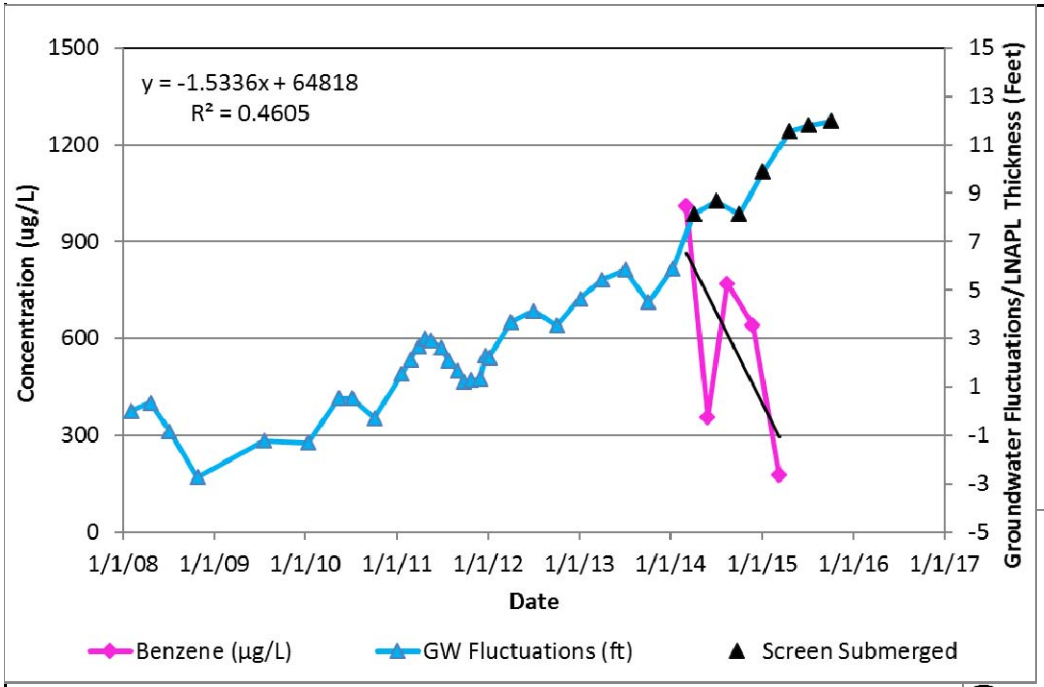

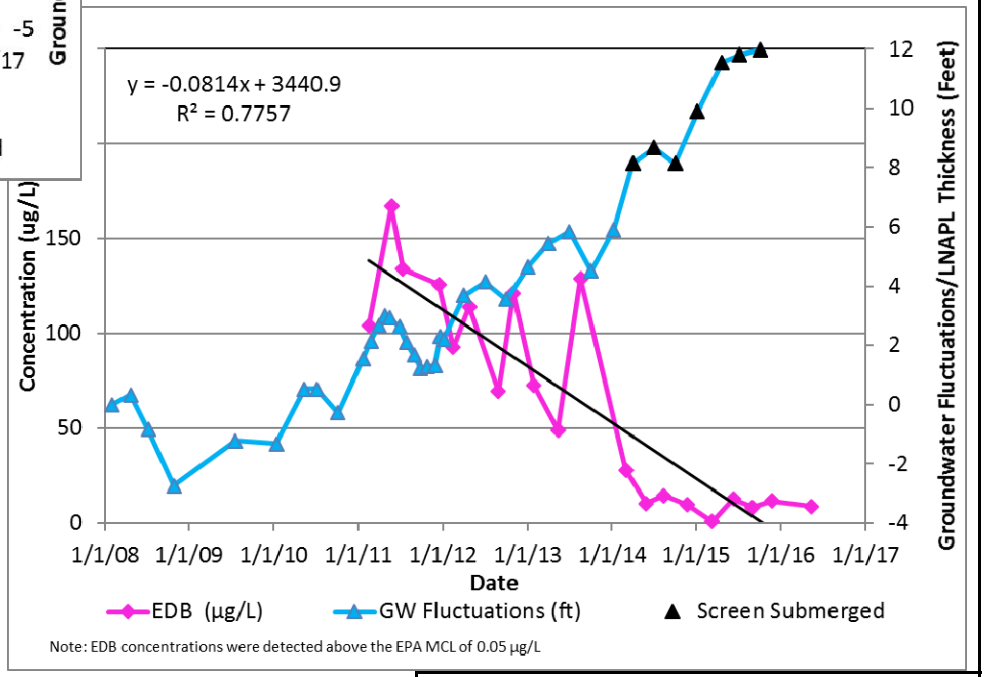

How much of the EDB concentration decrease from late 2013 to present was caused by the large increase (about 8 feet) in water level?

Figure 11
Partially Corrected Data Set for Non-Degradation Mechanisms at KAFB-10610
ABCWUA

INTERA

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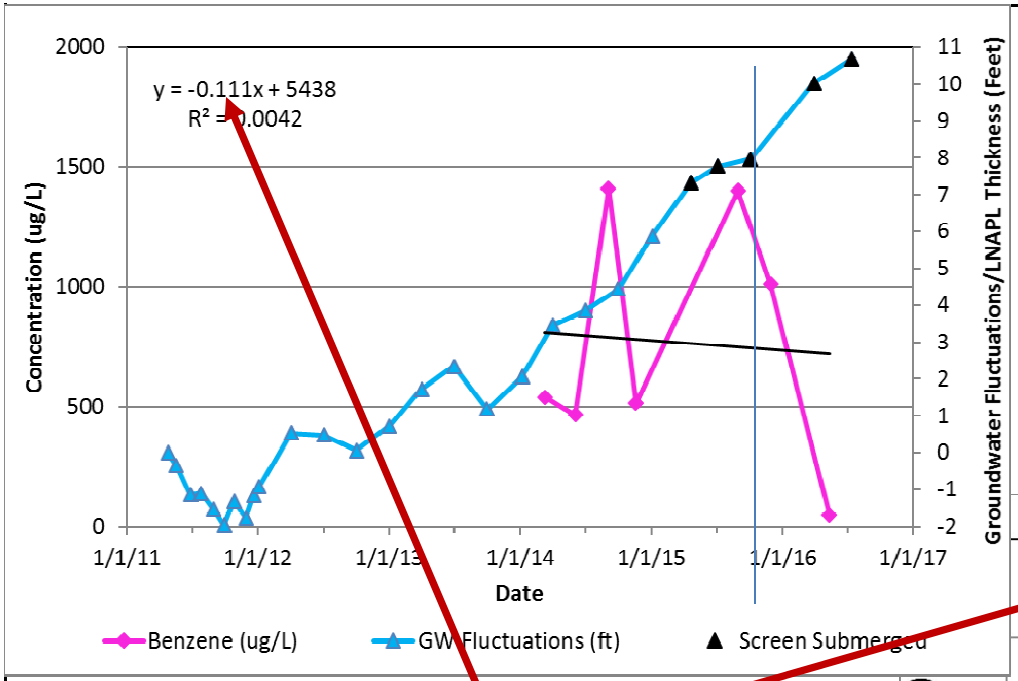

Are the recent decreases caused more by drowning than degradation?

Slopes (rates of change) are fairly flat (zero) for correct data sets

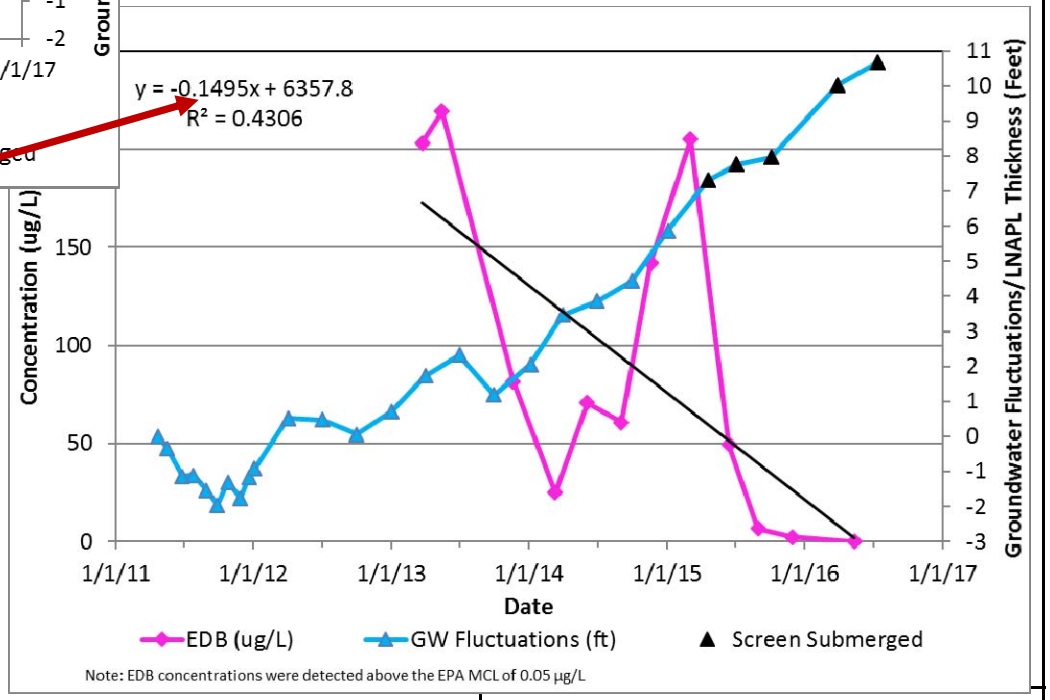

Figure 12
Partially Corrected Data Set for Non-Degradation Mechanisms at KAFB-1065
ABCWUA

INTERA

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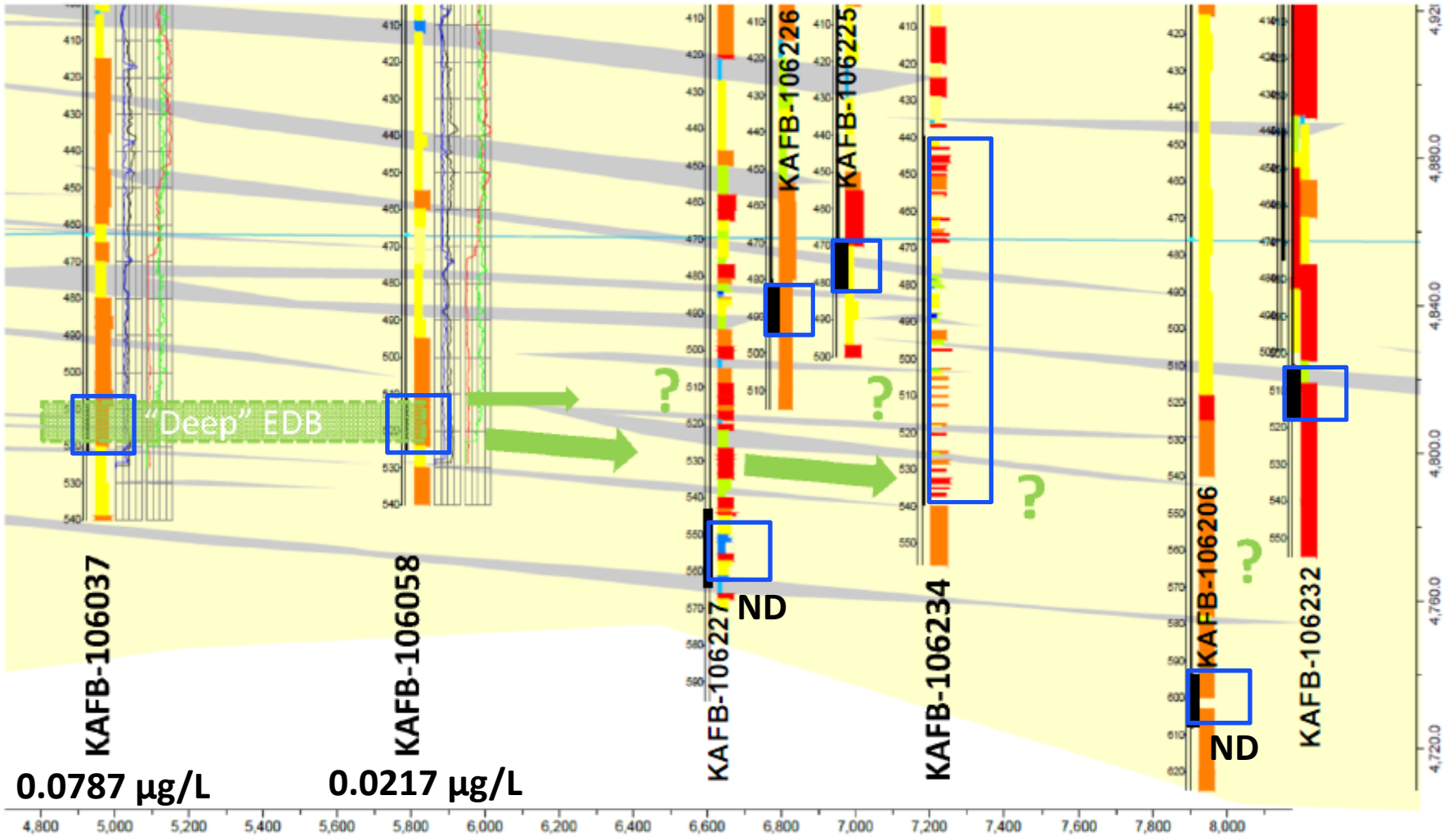

Q4 2015 EDB Concentrations

Cross-section courtesy of C. Plank, AECOM

Screened intervals

INTERA

Figure 13
Vertical Gaps in Screened Intervals at Distal EDB Plume
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