Revised

Hydraulic Testing Summary Report
Potrero Canyon Unit (Lockheed Martin Beaumont Site 1)
Beaumont, California

Prepared for:

LOCKHEED MARTIN

TETRA TECH

301 E. Vanderbilt Way, Suite 450
San Bernardino, California 92408

TC# 26205-01.0505 / February 2013

TJV-T26205-2492

TETRA TECH

February 7, 2013

Mr. Daniel Zogaib
Southern California Cleanup Operations
Department of Toxic Substances Control
5796 Corporate Avenue
Cypress, CA 90630

Subject: Submittal of the Revised *Hydraulic Testing Summary Report, Potrero Canyon Unit (Lockheed Martin Beaumont Site 1), Beaumont, California*

Dear Mr. Zogaib:

Please find enclosed one hard copy of the report body and two compact disks of the report body and appendices of the *Hydraulic Testing Summary Report, Potrero Canyon Unit (Lockheed Martin Beaumont Site 1), Beaumont, California.* The document has been revised in accordance with responses to comments accepted by DTSC in your letter dated January 7, 2013.

If you have any questions regarding this submittal, please contact Brian Thorne at 818-847-9901 or brian.thorne@lmco.com.

Sincerely,

Tom Villeneuve, Program Manager

Enclosure: Revised *Hydraulic Testing Summary Report, Potrero Canyon Unit (Lockheed Martin Beaumont Site 1), Beaumont, California*

Copy: Gene Matsushita, LMC (electronic and hard copy)
Brian Thorne, LMC (electronic copy)
Barbara Melcher, CDM (electronic copy)
Tom Villeneuve, Tetra Tech (electronic copy)
Alan Bick, Gibson, Dunn & Crutcher (electronic copy)

Department of Toxic Substances Control

Matthew Rodriquez
Secretary for
Environmental Protection

Deborah O. Raphael, Director
5796 Corporate Avenue
Cypress, California 90630

Edmund G. Brown Jr.
Governor

January 7, 2012

Mr. Brian T. Thorne
Remediation Analyst Senior Staff
Lockheed Martin Corporation
Energy, Environment, Safety & Health
2950 North Hollywood Way, Suite 125
Burbank, California 91505-1072

HYDRAULIC TESTING SUMMARY REPORT, POTRERO CANYON UNIT, LOCKHEED MARTIN CORPORATION, BEAUMONT SITE 1, BEAUMONT, CALIFORNIA (Site Code: 400200)

Dear Mr. Thorne:

The Department of Toxic Substances Control (DTSC) has reviewed your responses to our comments regarding the subject Report. Since we have documented our problems with the modeling and will be using performance monitoring to determine if the proposed remedies are effective, DTSC sees no reason to continue to trade responses regarding this report. Therefore, DTSC will consider the Report as completed.

Should you have any questions or comments, please contact me at (714) 484-5483.

Sincerely,

Daniel K. Zogaib
Project Manager
Brownfields and Environmental Restoration Program

cc Mr. Gene Matsushita
Senior Manager
Environmental Remediation
Lockheed Martin Corporation
Energy, Environment, Safety & Health
2950 North Hollywood Way, Suite 125
Burbank, California 91505

Printed on Recycled Paper

Department of Toxic Substances Control

Matthew Rodriquez
Secretary for
Environmental Protection

Deborah O. Raphael, Director
5796 Corporate Avenue
Cypress, California 90630

Edmund G. Brown Jr.
Governor

September 26, 2012

Mr. Brian T. Thorne
Remediation Analyst Senior Staff
Lockheed Martin Corporation
Energy, Environment, Safety & Health
2950 North Hollywood Way, Suite 125
Burbank, California 91505-1072

HYDRAULIC TESTING SUMMARY REPORT, POTRERO CANYON UNIT, LOCKHEED MARTIN CORPORATION, BEAUMONT SITE 1, BEAUMONT, CALIFORNIA (Site Code: 400200)

Dear Mr. Thorne:

The Department of Toxic Substances Control (DTSC) has reviewed your responses to our comments regarding the Subject Report. Enclosed are responses (in red) from DTSC's Geological Services Unit (GSU).

Please address the enclosed comments by October 26, 2012.

Should you have any questions or comments, please contact me at (714) 484-5483.

Sincerely,

Daniel K. Zogaib

Daniel K. Zogaib
Project Manager
Brownfields and Environmental Restoration Program

Enclosure

cc: See next page.

cc Mr. Gene Matsushita
Senior Manager
Environmental Remediation
Lockheed Martin Corporation
Energy, Environment, Safety & Health
2950 North Hollywood Way, Suite 125
Burbank, California 91505

Responses to DTSC Comments on the Hydraulic Testing Summary Report, Potrero Canyon Unit, Lockheed Martin Corporation, Beaumont Site 1, Beaumont, California

Tetra Tech, Inc

March 2012

General Comments		
Comment	**Response**	**Proposed Action**
1. The report references studies conducted by Dr. Beth Parker and others regarding the attenuation effects of matrix diffusion which has been observed in fractured sandstone at other sites. However, the descriptions of the Mount Eden Formation (MEF) Sandstone indicate that the sandstone is generally moderately to weakly indurated (to the point of being friable). Consistent with this, the data reviewed do not indicate that there is a developed or definable fractured network. The MEF Sandstone, therefore, does not appear to be comprised of the distinct matrix blocks bounded by an interconnected fracture network that is associated with matrix diffusion at other sites. Additional data presented in the report such as the conductivity profiles and the core data from BH-1 also did not provide convincing support that there is a hydraulically significant fracture at the site and therefore, that matrix diffusion is occurring. The GSU recommends that effects of matrix diffusion should not be considered in the site conceptual model as a process retarding the groundwater plume(s) and as a process that would potentially affect remedial alternatives.	One of the objectives of this study was to evaluate if the MEF Sandstone within the Burn Pit Area (BPA) was fractured and exhibiting fracture flow characteristics. Information specific to the physical nature of the MEF Sandstone in the BPA was not available since previous drilling methods did not include rock coring. Therefore, Tetra Tech and LMC consulted with Beth Parker, John Cherry, and Seth Pitkin (Stone Environmental) to incorporate several investigative tools into the bedrock coring in order to better characterize contamination within the bedrock and evaluate the presence/absence of fractures. Some of the studies that evaluated these tools were therefore referenced in this report. However, based on the results of this investigation and the absence of a fracture flow system, matrix diffusion is not considered part of the CSM with respect to contaminant transport. However, aside from matrix diffusion, it may be that there is slow transport of COCs from tight interbeds within the MEF adjacent to the primary water bearing zones between 60 and 100 ft bgs, and slow transport from these interbeds may be causing the persistent	No change to the document. In section 3.8.2, the report states, *"The absence of fractures and vertical contaminant distribution at the source are indicates that the contaminant mass is tied up in the low permeability rock matrix. This is consistent with the bedrock studies conducted by Dr. [sic] Beth Parker and John A. Cherry utilizing the Discrete Fracture Network (DFN) Approach for characterization of contaminated bedrock sites (Parker et al, 2010, Cherry et al, 2007, and Parker 2007). Their bedrock characterization studies indicate that the slow release of contaminant mass from the low-permeability contaminant matrix between fractures may degrade water quality for centuries or more depite complete removal of the source zone mass (Parker et al, 2010). These studies have also shown that from a remediation perspective, matrix diffusion can create significant challenges for contaminant mass*

General Comments		
Comment	**Response**	**Proposed Action**
	COCs that have been observed in groundwater beneath the BPA for the last 20 years.	*removal due to the difficulties in assessing contaminant mass in the rock matrix."* It was not clear due to the inclusion of these statements if the RP was or was not including matrix diffusion in the CSM. This response/clarification is sufficient.
2. The GSU believes that the anisotropy at the site associated with the faults, fractures, buried stream drainages, and/or spatial variations in cementations is critical to the understanding of groundwater flow and the fate and transport of contaminants. The report does not clearly address the nature of groundwater flow along or across these hydrogeologic features. It is not possible to develop a dependable numerical approximation of groundwater flow and contaminant transport, an adequate groundwater monitoring system, or an effective remedial approach without accounting for the effects of these structures. The northwest trending parallel faults presented in Figure 2-1 would suggest that there should be a. regional anisotropy. The aquifer test and slug tests presented in the report provided the general sense of variation in hydraulic conductivity across the site but was at an insufficient scale and scope to provide insight to spatial trends in hydraulic conductivity that should be part of the site conceptual model and incorporated into the numerical model. The GSU recommends that the facility conduct a series of additional aquifer tests across the site to better assess the spatial hydrogeological variations and trends.	Tetra Tech agrees that features such as faults and buried stream drainages have a considerable impact on the site groundwater flow, which is why considerable effort was extended in the field investigations, geophysical surveys (Terra Physics, 2006a, 2006b; Tetra Tech, 2009a), lineament study (Tetra Tech, 2009b), development of the site CSM (Tetra Tech, 2010d), and numerical groundwater flow (Tetra Tech, 2010a) and transport model (Tetra Tech, 2011), to identify and incorporate these features into the site CSM, water budget, and mass flux budget. For example, please see the site modeling reports (Tetra Tech, 2010a, 2011) which detail the incorporation of faults in the CSM and numerical model (using the MODFLOW horizontal flow barrier	No change to the document. DTSC will follow-up with further evaluation of the groundwater model which should be utilized to test the sensitivity of the nature and values assigned to the geologic structures at the site. The model should be used to assist in identifying parameters (i.e. hydraulic conductivity of the faults) that are not well constrained and, to which, the model is sensitive to.

General Comments		
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	package), and the buried stream channel underlying Bedsprings Creek valley. Also, please note the good comparison for a 16 year model calibration period between the observed and simulated water levels; observed and simulated water budgets; observed and simulated COC concentrations; observed and simulated mass flux budgets; and observed and simulated COC plume morphology. Significant effort has already been extended to conduct many site aquifer tests (constant-rate aquifer tests, slug tests, and specific capacity tests) both at the source areas and in many locations along the length of the plume including the RMPA, riparian area, and along Potrero Creek (Tetra Tech, 2010a, 2010b, 2010c, 2011). The hydraulic testing included recent use of coring and FLUTe conductivity profiles to define small scale variations in flow that may be indicative of fractures, but as noted in this report, the overwhelming evidence suggests that flow within the MEF Sandstone is not fracture controlled. Differences in the spatial variations in cementation of the sandstone may not	

General Comments		
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	be laterally continuous between borings and would be extremely difficult to map since the degrees of induration within the cores varied and were not drastic. Based on the FLUTe conductivity profiling in BH-1 and BH-2 and the rock core matrix sampling in BH-1, no correlation could be made that would indicate that these less indurated zones have higher conductivities or significant differences in contaminant concentrations to warrant a detailed investigation of cementation within the sandstone. In addition, the MEF Sandstone is a fanglomerate that does not lend itself to easy correlation across any distance (identical to alluvial fan deposits which vary considerably within a few feet). Review of the Acoustic Borehole Televiewer Logs from both BH-1 and BH-2 do not show distinct bedding planes or significant variability in lithology (as seen in the borehole logs themselves). In many cases, the televiewer data shows a fairly homogenous rock from the top to the bottom of the hole (within the MEF Sandstone). A review of the dual induction log can lend some interpretation to the density of the	

General Comments		
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	sandstone (higher resistivity with more dense rock), but a review of the dual-induction log for BH-1 cannot be correlated to conductivity values generated by the FLUTe conductivity profiles. Therefore, trying to map or correlate the variation in cementation/induration in the buried bedrock would be extremely difficult at best and would likely be near impossible even with considerable expense (many more coreholes and geophysical logs).	
	References have been included at the end of the response to comments table for the documents referenced above. It should be noted that the *Summary Remedial Investigation Report* (Tetra Tech, 2010d) includes many of the key site reports prior to 2010 on CDs in Appendix A.	

Specific Comments		
Comment	**Response**	**Proposed Action**
1. **2.3 Water Quality Sampling and Analysis page 2-5** *"Both equipment blanks and trip blanks were collected at the beginning of each sampling day"* Equipment blanks should be collected during the day between sampling points to assess the efficiently of the decontamination activities.	In accordance with the DTSC-approved Programmatic Sampling and Analysis Plan for the Beaumont sites, equipment blanks (EBs) are collected prior to sampling the first well of the day. After decontaminating the pump and discharge line, distilled water is pumped through the system. When two hose volumes have been allowed to clear the lines, the samples are collected. For reusable sampling devices such as pumps, an EB will be collected immediately after the sampling equipment has been decontaminated. These procedures ensure that all samples collected on a single day can be associated with the EB collected at the beginning of the day. If the EB was collected in the middle of the day between sampling points, the samples collected after the EB would need to be associated with that blank while the samples collected before the EB would need to be associated with the EB from the prior day. For the purpose of data validation, this creates an unnecessary level of complication with respect to associating environmental samples with the appropriate field blanks. The	No change to the report. The GSU still disagrees. Collecting equipment blanks between sampling points test decontamination procedures and ensures that contaminants are not carried over between sampling points. Collecting an equipment blank prior to the sampling for the day, simply ensures that the equipment is clean prior to collecting a sample from the first sampling point. In addition, it is likely, although not explicitly stated, that the equipment is also decontaminated at the end of the day after the last sample is collected. The GSU maintains its recommendation for future sampling events.

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Comment	**Response**	**Proposed Action**
	current procedures do allow for an appropriate evaluation of the efficiency of the decontamination activities during the sampling event.	
2. **2.4.1 Soil Sampling and Analysis** **page 2-7** *"These samples were collected using 66-inch [sic] stainless steel or brass…"* Typographical error noted.	Typo, should be 6-inch.	Correction will be made in the final document. No response needed.
3. **2.6 Aquifer Testing** **page 2-8** *"A step draw down test was performed on October 11, 2011, following development of the extraction well (EW-20) and piezometer (P-09)."* Please submit the well development logs. In addition, please provide the data (sieve analysis, etc.) used to select the well screen and filter pack for (EW-20)	Well development field sheets will be included in the revised report. A sieve analysis was conducted on the sandstone for the selection of well screen and filter pack. Given the extremely low flow rates (<0.5 gpm) within the MEF sandstone, 0.02" wire-wrap screen with #2/12 filter pack was selected for this well.	Well development logs will be included in the final document. No response needed.
4. **2.6 Aquifer Testing** **page 2-9** *"The constant-rate aquifer test commenced on October 18, 2011, following a 7-day recovery from the step drawdown test. The constant-rate aquifer test was conducted at a rate of 0.125 gpm in EW-20. The vacuum-enhanced aquifer test ran from Friday, October 21, 2011 through October 23, 2011…"* This statement indicates that the vacuum-enhanced aquifer test was conducted within 24 hours after the conclusion of the constant-rate aquifer test, which did not have a recovery period. Please verify and	A recovery period was not conducted prior to the vacuum-enhanced aquifer test. As stated in the approved work plan, the vacuum-enhanced extraction would follow immediately after the constant-rate aquifer test to evaluate the effectiveness of vacuum-enhanced extraction with respect to the potential increase in the extraction rate within the MEF Sandstone using dual-phase extraction.	No change to the document. No response needed.

Specific Comments		
Comment	**Response**	**Proposed Action**
explain why a recovery period was not conducted and monitored before the vacuum-enhanced aquifer test.		
5. **3.1.2 Feature C-22, BPA** **page 3-4** *"The range of hydraulic conductivity values varied from less than 0.00001 to 0.2 feet per day…"* There is no discussion regarding the measurement "less than" 0.00001 feet per day (not shown on Table 3-1). This extremely low hydraulic conductivity value would typically be associated with the lowest conductivity rate for clays. A discussion of this low hydraulic conductivity value is warranted and should have been included in the report. 6. It should be noted that the "0.2 feet per day" stated as the maximum hydraulic conductivity value disagrees with Table 3-1 which indicates that 0.249 feet per day is the maximum value.	The 0.00001 feet per day hydraulic conductivity value is a typo and should be 0.0001. The lowest hydraulic conductivity value in Table 3-1 is 0.00008 (less than 0.0001) in MW-61A located in the Burn Pit Area near EW-20. Correct, maximum hydraulic conductivity value from Table 3-1 is 0.249 feet per day.	The corrections will be made in the final document. No response needed.
7. **3.3 Soil Results** **page 3-7** *"positive detections of TOC occurred in 22 samples (excluding duplicates) at concentrations ranging from 510 to 1,800 mg/kg. The TOC concentrations were detected in P-09 at 20 feet bgs and at 40 feet bgs. The results of these analyses as shown in Table 3-2 indicate that there is very little variation in the TOC concentrations versus depth. This trend is in agreement with the coring data that shows relatively homogenous lithology within the MEF sandstone;"* All the TOC detections are "J" flagged and are therefore below the	Although the numerical results are estimated, the estimated TOC concentrations for the samples collected are nearly the same within the analytical accuracy of this method. Therefore, it is not unreasonable to include a statement in the report stating that the results show that there is very little variation in the TOC concentrations versus depth.	No change to the document. The GSU still disagrees with the specific statement "little variation in the TOC concentrations versus depth." This implies a quantitative comparison of values which, as stated previously, are "estimated" and qualitative in nature.

Specific Comments

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method reporting limits (MRLs). The values reported are estimated and no conclusions can be made regarding ranges, maximum concentrations; or trends for data that are not quantified.		
8. **3.6 Vadose Zone Permeability Tests** **page 3-17** *"Well VRW-1, which apparently has the highest permeability of all of the locations tests, is located in the southern portion of the BPA, where very high infiltration rates were found during previous testing (Tetra Tech, 2009a)."* The raw data from these tests was not presented in the report and should be presented for DTSC's evaluation.	Field data sheets will be provided.	The final document will include the field data sheets for the vadose zone permeability tests. No response needed.
9. **3.6 Constant-Rate Aquifer Test** **page 3-18** *"During the constant-rate aquifer test, drawdown in EW-20 was up to 12.78 feet..."* Please note that the maximum drawdown recorded was 12.87 feet.	Typo, should be 12.87 feet.	The text will be revised to correct the typographical error in the final document. No response needed.
10. **3.7.1 Constant-Rate Aquifer Test** **page 3-18** *"The hydraulic conductivity value for a 37-foot thick saturated zone would then be approximately 0.054 fed per day."* Please clarify why the assumed thickness of the aquifer is 37 feet when the boring logs to not indicate any lithologic or other changes at that depth.	Prior site investigations indicated the main water bearing zone is in this 37 foot interval, which is supported by the site water level data; site water quality data; and site slug test data. Deeper zones were thought to be separated from the main shallow zone by low permeability layers in the MEF Sandstone. This is why the prior site extraction system was focused in this interval. Please note that the FLUTe conductivity profiles conducted as part	The text will be revised to discuss this point, and note that the extraction well is considered fully penetrating. Assuming that the low permeability layers in the MEF Sandstone are extensive and the nature of this "aquitard" is understood, the GSU will concur.

Specific Comments		
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	of this study found that the main water bearing zone is between the first encountered water around 70 feet bgs and roughly 105 feet bgs, independently confirming the prior site CSM.	
11. **3.7.1 Constant-Rate Aquifer Test** **page 3-18** *"No response was observed in wells EW-13, MW-31, and MW-61A, which is attributed to either the large distance to the wells (EW-13 (approximately 110 feet away and MW-31 (approximately 110 feet away)) or the deep depth of the well screens (MW-31 and MW-61D)."* Please note that MW-61D responded in the aquifer test.	Thank you for noting this typographical error; the text "..deep depth of the well screens (MW-31 and MW-61D)." should have been "MW-31 and MW-61A". Tetra Tech and DTSC both agree that MW-61A did not respond to the test, and MW61D did respond to the test, and above referenced typographical error was the source of confusion on this issue.	The text will be revised to correct the typographical error. No other changes required as Tetra Tech and DTSC both agree that MW-61A did not respond to the test, and MW61D did respond to the test. For clarity, the report states that there was no response in MW-61A. DTSC simply accepts that statement as correct.
12. **3.7.1 Constant-Rate Aquifer Test** **page 3-18** *"Although responses were observed in MW-61C and MW-61D, the magnitude and nature of the response, along with the deeper location of the well screens, indicated that these wells are screened in a water bearing zone that is somewhat vertically separated from the main pumping water bearing zone at 70 to 110 feet bgs.* The GSU disagrees. Vertical hydraulic conductivities are typically less than the horizontal hydraulic conductivities which would account for	Please see the response to Specific Comment #9 above, and note that the FLUTe conductivity profiles show that the hydraulic conductivity is orders of magnitude lower than the primary pumped interval in these deeper wells. Also note the site water level, water quality data, and slug test data, which show the separation of these intervals. Please also note that if vertical	No change to the document. For clarity, it is response indicating that there is NO anisotropy between horizontal hydraulic conductivity and vertical hydraulic conductivity OR there is a distinct hydrogeologic unit that is acting as an aquitard? The original

Specific Comments		
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the responses observed in the deeper monitoring wells. The report does not present any data to support the presence of a confining layer or a large contrast in hydraulic conductivity with depth at the site that is not associated with expected vertical anisotropy.	conductivity values caused this difference, then the site transmissivity values would appear to increase with distance from the pumping location due to partial penetration effects, however, the data indicate the transmissivity values do not increase with distance from the pumping well, supporting the notion that the deeper wells are vertically separated from the main pumping zone.	statement could be revised since it is vague (i.e. "somewhat vertically separated")
13. **3.7.1 Constant-Rate Aquifer Test** **page 3-18** *"The EW-20 constant-rate aquifer test was conducted by pumping the well for 77 hours..."* It should be acknowledged that the data from the aquifer test indicate that steady-state conditions were not reached. It is also not clear in the report how the 37-foot aquifer thickness was determined and if the monitoring wells (especially EW-20) are considered fully-penetrating or partially-penetrating. These issues should be clearly addressed as it has a significant impact on the interpretations of the data.	Please see the response to Specific Comment #9 above regarding the 37 foot interval and the fully penetrating nature of the extraction well. The report text will also add a statement to highlight that the 77 hour test had not reached steady-state.	The revised text will add a statement to highlight that the 77 hour test had not reached steady-state. No response needed.
14. **3.7.1 Constant-Rate Aquifer Test** **page 3-21** *"The drawdown data from the pumping well EW-20 and the observation wells had a shape that is generally consistent with the Theis Aquifer Model, with generally no flattening of drawdown at late times, although extraction well EW-20 and observation location PZ09 did show limited drawdown flattening effects at late times that may be indicative of leakage."*	Tetra Tech disagrees that the aquifer appears to behave more as an unconfined aquifer as the data clearly fit the Theis Model rather well, and no late time rise in drawdown was ever observed (i.e., the third line segment did not occur). Also, Tetra Tech believes the data strongly support	No change to the document. The geologic/hydrogeologic description of the site needs to be consistent with the data being collected. Again, the description of the hydrogeologic system is

Specific Comments		
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After evaluating the log-log and semi-log plots of the time-drawdown data, the aquifer appears to behave more as an unconfined aquifer with delayed yield or as a confined fractured aquifer (dual-porosity). Both curves exhibit the typical three distinct segments associated with these types of aquifers which create an S-shaped curve. It is unlikely that the flat segment represents leakage since steeper drawdown is observed at later time and leakage usually results in a general flattening of the time-drawdown curve for the duration of the test. It should be also noted that storage values are most reliable if taken from the data contained in the third segment. Given the description of the site geology and hydrogeology, the presence of confined conditions is not supported.	confined conditions: for example, the cone of depression created in the monitoring wells has an aquifer bulk volume of over 250,000 gallons, which is about 500 times greater than the extraction volume of about 500 gallons. This would suggest a specific yield of only 0.002, far too low for the site conditions. Also, even at distances of almost 70 feet the storage values are all very small, no matter where the straight line is drawn, and the drawdown very large. Clearly, this is a confined response. With regard to a dual porosity confined fractured aquifer, please note that the other site data do not indicate that the MEF Sandstone is a dual porosity system. For example, (1) with roughly 20 extraction wells installed at the site, the yields for these 20 wells are remarkably uniform, and do not show a single well with the much higher yields one would expect from a fractured system, and (2) the angled borehole conductivity profiles and core do not show any signs of fracture controlled flow (the FLUTe profiles and core data are consistent with a single porosity	unconfined. If the interpretation of the aquifer data conflicts, as it does in this case, an additional evaluation and discussion is necessary. The facility should consider inverse modeling of the aquifer test as the test data may not match well with the Thesis Model. Are these low storativity values support by the groundwater model?

Specific Comments

Comment	Response	Proposed Action
	system). Therefore, since (1) a dual porosity system is inconsistent with the site CSM, and (2) the data does not display a classic dual porosity response, a dual porosity model was not considered appropriate for this site.	
15. **3.7.2 Vacuum-Enhanced Aquifer Test** The GSU request references to published studies that have use a similar approach. In addition, time-drawdown plots were not provided for this portion of the test and should be included in any response to this memorandum.	No studies were referenced for the dual-phase extraction approach since the objective of the vacuum-enhanced extraction was simply to estimate the increased extraction rate that could be achieved under vacuum. The data from this phase of the test was not used for aquifer test interpretation and therefore no time-drawdown plots were created. It is not possible to interpret the time drawdown data from the vacuum test because: (1) vacuum data was not collected downhole using a transducer (the only vacuum data was wellhead measured only 5 or 6 times during the test); there are no analytical methods available to interpret data from these dual phase tests; the only possible interpretation method would be using a multiphase flow model, which is inherently uncertain and expensive, and would not improve the test analysis beyond what was conducted during the	No change to the document. No response needed.

Specific Comments		
Comment	**Response**	**Proposed Action**
	single phase test.	
16. **3.8.2 Rock Matrix Sampling and Analysis page 3-29** *"The absence of fractures and vertical contaminant distribution at the source area indicates that the contaminant mass is tied up in the low permeability rock matrix. This is consistent with the bedrock studies conducted by Dr. Beth Parker and John A. Cherry utilizing the Discrete Fracture Network (DFN) Approach for characterization of contaminated bedrock sites (Parker et al, 2010, Cherry et al, 2007, and Parker 2007). Their bedrock characterization studies indicate that the slow release of contaminant mass from the low-permeability matrix between fractures may degrade water quality for centuries or more despite complete removal of the source zone mass (Parker et al, 2010). These studies have also shown that from a remediation perspective, matrix diffusion can create significant challenges for contaminant mass removal due to the difficulties in accessing contaminant mass in the rock matrix."* The first statement in this quotation is not clear. Additional explanation is needed to explain how the absence of fractures and the vertical contaminant distribution (assuming the statement refers to the limited vertical extent) are supported and that the contaminant mass is "tied up in the low permeability rock matrix." Additionally, the GSU does not believe that these conditions (i.e., the site conditions as presented in the report) are consistent with the bedrock studies conducted by Drs. Parker and Cherry (see General Comment #1). The statement later states "matrix diffusion can create significant challenges for contaminant mass removal…" but there were no definitive data presented in the report to support that this process is occurring at the	The report will be revised to clarify that the contaminant transport mechanism in the MEF Sandstone is not matrix diffusion but rather is a single porosity system with a very low permeability matrix. However, it should be noted that similar to matrix diffusion in fractured rock, this source may continue to degrade water quality from the slow release of contaminant mass from the low permeability sandstone matrix into the more permeable alluvium downgradient of the source. Therefore, the statement is still true that from a remediation perspective there are still significant challenges in accessing the contaminant mass in the low permeability rock matrix within the BPA. In fact, the absence of fractures may make it even more difficult to access contaminant mass within the matrix as much of the porewater within the sandstone may be stagnant except for the less indurated zones where the majority of the groundwater flow most likely occurs.	The report will be revised to clarify that the contaminant transport mechanism in the MEF Sandstone is not matrix diffusion but rather is a single porosity system with a very low permeability matrix. No response needed.

Specific Comments

Comment	Response	Proposed Action
site. The GSU would request clarification of these statements.		
17. **3.8.4 Hydraulic Conductivity Profiling Figure 3-8** More variability is shown in the profile for BH-1. Were there any observations or data that may explain the differences between the two profiles (e.g., geophysical logs, laboratory tests, drilling rates, or boring logs)?	There were no differences observed in the cores, geophysical logs, or drilling rates to explain the greater variability in the BH-1 conductivity profile. No laboratory samples were collected from BH-2 to compare with BH-1. However, no large concentration swings were observed in the rock core analytical results for BH-1 which correspond with the observed conductivity changes.	No change to the document. No response needed.
18. **Recommendations page 4-55** The GSU would concur with the recommend that the CSM and groundwater flow and transport models be updated with the information from this report. The GSU, however, believe that additional work is needed as commented in this memorandum. Specifically, additional work is needed to understand the faults, fractures, buried stream drainage, and/or spatial variations in cementation that occur at the site at a scale sufficient to support the data needs of any Feasibility Study. The information presented in the report does not support that matrix diffusion has a significant effect at the site. The facility may consider conducting additional studies at the site to demonstrate its effect, if any. The GSU, however, believes that in the absence of a developed fracture system and due to the poorly-indurated nature of the	The CSM and groundwater flow and transport models are currently being updated based on the data collected during the hydraulic testing investigation. Flow and transport Model updates will include updating the hydraulic conductivity to be consistent with the test results in the BPA hot spot area, reevaluating the flow model water level calibration for the prior flow model calibration, reevaluating the transport model COC calibration for the prior transport model calibration, and updating the mass flux budgets. The model update will also include updating the flow and transport model stress periods and water level	DTSC will follow-up with further evaluation of the groundwater model which should be utilized to test the sensitivity of the nature and values assigned to the geologic structures at the site. The model should be used to assist in identifying parameters (i.e. hydraulic conductivity of the faults) that are not well constrained and, to which, the model is sensitive to.

Specific Comments		
Comment	**Response**	**Proposed Action**
sandstone, matrix diffusion is not occurring at a significant amount.	and COC data to also cover the 3 year period from 2008-2011, so the updated model covers the 1992 to 2011 period (currently it covers 1992 to 2008). This will make the model more current and provide more credibility in the model by testing the model against a period outside the original calibration (i.e., a bit of model validation). Based on the geologic and hydrogeologic investigations conducted to date (see response to General Comment #2), additional work at the Site is not needed to better understand the faults, fractures, buried stream drainage, and/or spatial variations in cementation to support the data needs of the Feasibility Study. Tetra Tech agrees with GSU that the data does not support a fracture system within the BPA and due to the poorly-indurated nature of the sandstone, matrix diffusion is most likely not occurring.	

References:

1. Terra Physics, 2006a. Seismic Reflection Survey to Detect Bedrock Faults, Former Lockheed Beaumont Site 1, South of Beaumont, California. February 2006.

2. Terra Physics, 2006b. Correlations of Seismic Velocity and Stratigraphy in Nine Borings, Former Lockheed Beaumont Site 1, Potrero Creek, South Beaumont, California. March 2006.

3. Tetra Tech, Inc. 2009a. Dynamic Site Investigation Report, Historical Operational Areas B, C, F, G, and H, Beaumont Site 1, Lockheed Martin Corporation, Beaumont, California, July 2009.

4. Tetra Tech, Inc. 2009b. Lineament Study, Lockheed Martin Corporation, Beaumont Site 1, Beaumont California, December 2009.

5. Tetra Tech, Inc., 2010a. Transient Groundwater Model Report, Numerical Flow Model Development, Lockheed Martin Beaumont Site 1, Beaumont, California, January 2010.

6. Tetra Tech, Inc., 2010b. Potrero Creek Groundwater Pumping Test Report, Numerical Flow Model Development, Lockheed Martin Beaumont Site 1, Beaumont, California, January 2010.

7. Tetra Tech, Inc., 2010c. Supplemental Groundwater Monitoring Well Installation Report, Lockheed Martin Corporation, Beaumont Site 1, July 2010.

8. Tetra Tech, Inc., 2010d. Summary Remedial Investigation Report, Lockheed Martin Corporation, Beaumont Site 1, November 2010.

9. Tetra Tech, Inc., 2011. Numerical Groundwater Transport Model Development, Lockheed Martin Beaumont Site 1, Beaumont, California, July 2011.

Responses to DTSC Comments on the Hydraulic Testing Summary Report,
Potrero Canyon Unit, Lockheed Martin Corporation, Beaumont Site 1, Beaumont, California
Tetra Tech, Inc
March 2012

General Comments				
Original Comment	**Original Response**	**Proposed Action**	**Additional Comment**	**Additional Response**
1. The report references studies conducted by Dr. Beth Parker and others regarding the attenuation effects of matrix diffusion which has been observed in fractured sandstone at other sites. However, the descriptions of the Mount Eden Formation (MEF) Sandstone indicate that the sandstone is generally moderately to weakly indurated (to the point of being friable). Consistent with this, the data reviewed do not indicate that there is a developed or definable fractured network. The MEF Sandstone, therefore, does not appear to be comprised of the distinct matrix blocks bounded by an interconnected fracture network that is associated with matrix diffusion at other sites. Additional data presented in the report such as the conductivity profiles and the core data from BH-1 also did not provide convincing support that there is a hydraulically significant fracture at the site and therefore, that matrix diffusion is occurring. The GSU recommends that effects of matrix diffusion should not be considered in the site conceptual model as a process retarding the groundwater plume(s)	One of the objectives of this study was to evaluate if the MEF Sandstone within the Burn Pit Area (BPA) was fractured and exhibiting fracture flow characteristics. Information specific to the physical nature of the MEF Sandstone in the BPA was not available since previous drilling methods did not include rock coring. Therefore, Tetra Tech and LMC consulted with Beth Parker, John Cherry, and Seth Pitkin (Stone Environmental) to incorporate several investigative tools into the bedrock coring in order to better characterize contamination within the bedrock and evaluate the presence/absence of fractures. Some of the studies that evaluated these tools were therefore referenced in this report. However, based on the results of this investigation and the absence of a fracture flow system, matrix diffusion is not considered part of the CSM with respect to contaminant transport. However, aside from matrix diffusion, it may be that there is slow transport of COCs from tight interbeds within the MEF adjacent to the primary water bearing zones between 60 and 100 ft bgs, and slow transport from these interbeds may be causing the	No change to the document.	In section 3.8.2, the report states "The absence of fractures and vertical contaminant distribution at the source area indicates that the contaminant mass is tied up in the low permeability rock matrix. This is consistent with the bedrock studies conducted by Dr. [sic] Beth Parker and John A. Cherry utilizing the Discrete Fracture Network (DFN) Approach for characterization of contaminated bedrock sites (Parker et al, 2010, Cherry et al, 2007, and Parker 2007). Their bedrock characterization studies indicate that the slow release of contaminant mass from the low-permeability matrix between fractures may degrade water quality for centuries or more despite complete removal of the source zone mass (Parker et al, 2010). These studies have also shown that from a remediation perspective, matrix diffusion can create significant challenges for	No additional response required.

General Comments				
Original Comment	**Original Response**	**Proposed Action**	**Additional Comment**	**Additional Response**
and as a process that would potentially affect remedial alternatives.	persistent COCs that have been observed in groundwater beneath the BPA for the last 20 years.		contaminant mass removal due to the difficulties in accessing contaminant mass in the rock matrix. It was not clear due to the inclusion of these statements if the RP was or was not including matrix diffusion in the CSM. This response/clarification is sufficient.	
2. The GSU believes that the anisotropy at the site associated with the faults, fractures, buried stream drainages, and/or spatial variations in cementations is critical to the understanding of groundwater flow and the fate and transport of contaminants. The report does not clearly address the nature of groundwater flow along or across these hydrogeologic features. It is not possible to develop a dependable numerical approximation of groundwater flow and contaminant transport, an adequate groundwater monitoring system, or an effective remedial approach without accounting for the effects of these structures. The northwest trending parallel faults presented in Figure 2-1 would suggest that there should be a.	Tetra Tech agrees that features such as faults and buried stream drainages have a considerable impact on the site groundwater flow, which is why considerable effort was extended in the field investigations, geophysical surveys (Terra Physics, 2006a, 2006b; Tetra Tech, 2009a), lineament study (Tetra Tech, 2009b), development of the site CSM (Tetra Tech, 2010d), and numerical groundwater flow (Tetra Tech, 2010a) and transport model (Tetra Tech, 2011), to identify and incorporate these features into the site CSM, water budget, and mass flux budget. For example, please see the site modeling reports (Tetra Tech, 2010a, 2011) which detail the incorporation of faults in the CSM and numerical model (using the MODFLOW horizontal flow barrier	No change to the document.	DTSC will follow-up with further evaluation of the groundwater model which should be utilized to test the sensitivity of the nature and values assigned to the geologic structures at the site. The model should be used to assist in identifying parameters (i.e. hydraulic conductivity of the faults) that are not well constrained and, to which, the model is sensitive to.	No additional response required.

General Comments				
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regional anisotropy. The aquifer test and slug tests presented in the report provided the general sense of variation in hydraulic conductivity across the site but was at an insufficient scale and scope to provide insight to spatial trends in hydraulic conductivity that should be part of the site conceptual model and incorporated into the numerical model. The GSU recommends that the facility conduct a series of additional aquifer tests across the site to better assess the spatial hydrogeological variations and trends.	package), and the buried stream channel underlying Bedsprings Creek valley. Also, please note the good comparison for a 16 year model calibration period between the observed and simulated water levels; observed and simulated water budgets; observed and simulated COC concentrations; observed and simulated mass flux budgets; and observed and simulated COC plume morphology. Significant effort has already been extended to conduct many site aquifer tests (constant-rate aquifer tests, slug tests, and specific capacity tests) both at the source areas and in many locations along the length of the plume including the RMPA, riparian area, and along Potrero Creek (Tetra Tech, 2010a, 2010b, 2010c, 2011). The hydraulic testing included recent use of coring and FLUTe conductivity profiles to define small scale variations in flow that may be indicative of fractures, but as noted in this report, the overwhelming evidence suggests that flow within the MEF Sandstone is not fracture controlled. Differences in the spatial variations in cementation of the sandstone may not			

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	be laterally continuous between borings and would be extremely difficult to map since the degrees of induration within the cores varied and were not drastic. Based on the FLUTe conductivity profiling in BH-1 and BH-2 and the rock core matrix sampling in BH-1, no correlation could be made that would indicate that these less indurated zones have higher conductivities or significant differences in contaminant concentrations to warrant a detailed investigation of cementation within the sandstone. In addition, the MEF Sandstone is a fanglomerate that does not lend itself to easy correlation across any distance (identical to alluvial fan deposits which vary considerably within a few feet). Review of the Acoustic Borehole Televiewer Logs from both BH-1 and BH-2 do not show distinct bedding planes or significant variability in lithology (as seen in the borehole logs themselves). In many cases, the televiewer data shows a fairly homogenous rock from the top to the bottom of the hole (within the MEF Sandstone). A review of the dual induction log can lend some interpretation to the density of the sandstone (higher resistivity with			

General Comments				
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	more dense rock), but a review of the dual-induction log for BH-1 cannot be correlated to conductivity values generated by the FLUTe conductivity profiles. Therefore, trying to map or correlate the variation in cementation/induration in the buried bedrock would be extremely difficult at best and would likely be near impossible even with considerable expense (many more coreholes and geophysical logs). References have been included at the end of the response to comments table for the documents referenced above. It should be noted that the *Summary Remedial Investigation Report* (Tetra Tech, 2010d) includes many of the key site reports prior to 2010 on CDs in Appendix A.			

Specific Comments				
Original Comment	**Original Response**	**Proposed Action**	**Additional Comments**	**Additional Response**
1. **2.3 Water Quality Sampling and Analysis page 2-5**	In accordance with the DTSC-approved Programmatic Sampling and Analysis Plan for the	No change to the report.	The GSU still disagrees. Collecting equipment blanks between sampling points test	Recommendation noted. Since dedicated pumps have been installed at all routine

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"Both equipment blanks and trip blanks were collected at the beginning of each sampling day" Equipment blanks should be collected during the day between sampling points to assess the efficiently of the decontamination activities.	Beaumont sites, equipment blanks (EBs) are collected prior to sampling the first well of the day. After decontaminating the pump and discharge line, distilled water is pumped through the system. When two hose volumes have been allowed to clear the lines, the samples are collected. For reusable sampling devices such as pumps, an EB will be collected immediately after the sampling equipment has been decontaminated. These procedures ensure that all samples collected on a single day can be associated with the EB collected at the beginning of the day. If the EB was collected in the middle of the day between sampling points, the samples collected after the EB would need to be associated with that blank while the samples collected before the EB would need to be associated with the EB from the prior day. For the purpose of data validation, this creates an unnecessary level of complication with respect to associating environmental samples with the appropriate field blanks. The current procedures do allow for an appropriate evaluation of the efficiency of the decontamination activities during the sampling event.		decontamination procedures and ensures that contaminants are not carried over between sampling points. Collecting an equipment blank prior to the sampling for the day, simply ensures that the equipment is clean prior to collecting a sample from the first sampling point. In addition, it is likely, although not explicitly stated, that the equipment is also decontaminated at the end of the day after the last sample is collected. The GSU maintains its recommendation for future sampling events.	groundwater monitoring locations, equipment blanks are only collected occasionally when samples are collected from non-routine monitoring locations. Therefore, equipment blanks are not routinely collected as part of te groundwater monitoring program. Tetra Tech will consider the recommendation for future sampling events and will address with DTSC further if an approach different from that recommended by DTSC is proposed.

Specific Comments				
Original Comment	**Original Response**	**Proposed Action**	**Additional Comments**	**Additional Response**
2. **2.4.1 Soil Sampling and Analysis page 2-7** *"These samples were collected using 66-inch [sic] stainless steel or brass…"* Typographical error noted.	Typo, should be 6-inch.	Correction will be made in the final document.	No response needed.	
3. **2.6 Aquifer Testing page 2-8** *"A step draw down test was performed on October 11, 2011, following development of the extraction well (EW-20) and piezometer (P-09)."* Please submit the well development logs. In addition, please provide the data (sieve analysis, etc.) used to select the well screen and filter pack for (EW-20)	Well development field sheets will be included in the revised report. A sieve analysis was conducted on the sandstone for the selection of well screen and filter pack. Given the extremely low flow rates (<0.5 gpm) within the MEF sandstone, 0.02" wire-wrap screen with #2/12 filter pack was selected for this well.	Well development logs will be included in the final document.	No response needed.	
4. **2.6 Aquifer Testing page 2-9** *"The constant-rate aquifer test commenced on October 18, 2011, following a 7-day recovery from the step drawdown test. The constant-rate aquifer test was conducted at a rate of 0.125 gpm in EW-20. The vacuum-enhanced aquifer test ran from Friday, October 21, 2011 through October 23, 2011…"*	A recovery period was not conducted prior to the vacuum-enhanced aquifer test. As stated in the approved work plan, the vacuum-enhanced extraction would follow immediately after the constant-rate aquifer test to evaluate the effectiveness of vacuum-enhanced extraction with respect to the potential increase in the extraction rate within the MEF Sandstone using dual-phase extraction.	No change to the document.	No response needed.	

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This statement indicates that the vacuum-enhanced aquifer test was conducted within 24 hours after the conclusion of the constant-rate aquifer test, which did not have a recovery period. Please verify and explain why a recovery period was not conducted and monitored before the vacuum-enhanced aquifer test.				
5. **3.1.2 Feature C-22, BPA page 3-4** *"The range of hydraulic conductivity values varied from less than 0.00001 to 0.2 feet per day…"* There is no discussion regarding the measurement "less than" 0.00001 feet per day (not shown on Table 3-1). This extremely low hydraulic conductivity value would typically be associated with the lowest conductivity rate for clays. A discussion of this low hydraulic conductivity value is warranted and should have been included in the report. 6. It should be noted that the "0.2 feet per day" stated as the maximum hydraulic conductivity value disagrees with Table 3-1 which	The 0.00001 feet per day hydraulic conductivity value is a typo and should be 0.0001. The lowest hydraulic conductivity value in Table 3-1 is 0.00008 (less than 0.0001) in MW-61A located in the Burn Pit Area near EW-20. Correct, maximum hydraulic conductivity value from Table 3-1 is 0.249 feet per day.	The corrections will be made in the final document.	No response needed.	

Specific Comments				
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indicates that 0.249 feet per day is the maximum value.				
7. **3.3 Soil Results** **page 3-7** *"positive detections of TOC occurred in 22 samples (excluding duplicates) at concentrations ranging from 510 to 1,800 mg/kg. The TOC concentrations were detected in P-09 at 20 feet bgs and at 40 feet bgs. The results of these analyses as shown in Table 3-2 indicate that there is very little variation in the TOC concentrations versus depth. This trend is in agreement with the coring data that shows relatively homogenous lithology within the MEF sandstone;"* All the TOC detections are "J" flagged and are therefore below the method reporting limits (MRLs). The values reported are estimated and no conclusions can be made regarding ranges, maximum concentrations; or trends for data that are not quantified.	Although the numerical results are estimated, the estimated TOC concentrations for the samples collected are nearly the same within the analytical accuracy of this method. Therefore, it is not unreasonable to include a statement in the report stating that the results show that there is very little variation in the TOC concentrations versus depth.	No change to the document.	The GSU still disagrees with the specific statement "little variation in the TOC concentrations with depth." This implies a quantitative comparison of values which, stated previously, are "estimated" and qualitative in nature.	The statement will be removed and replaced with the following statements. "The TOC concentrations reported in Table 3-2 were below the practical quantitation limit for all depths sampled. No TOC concentrations were reported above the practical quantitation limit in either boring (EW-20 or P-09) and therefore are estimated values."
8. **3.6 Vadose Zone Permeability Tests** **page 3-17** *"Well VRW-1, which apparently has the highest permeability of all of the*	Field data sheets will be provided.	The final document will include the field data sheets for the vadose zone permeability tests.	No response needed.	

Specific Comments					
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	locations tests, is located in the southern portion of the BPA, where very high infiltration rates were found during previous testing (Tetra Tech, 2009a).” The raw data from these tests was not presented in the report and should be presented for DTSC’s evaluation.				
9.	**3.6 Constant-Rate Aquifer Test page 3-18** *“During the constant-rate aquifer test, drawdown in EW-20 was up to 12.78 feet…”* Please note that the maximum drawdown recorded was 12.87 feet.	Typo, should be 12.87 feet.	The text will be revised to correct the typographical error in the final document.	No response needed.	
10.	**3.7.1 Constant-Rate Aquifer Test page 3-18** *“The hydraulic conductivity value for a 37-foot thick saturated zone would then be approximately 0.054 fed per day.”* Please clarify why the assumed thickness of the aquifer is 37 feet when the boring logs to not indicate any lithologic or other changes at that depth.	Prior site investigations indicated the main water bearing zone is in this 37 foot interval, which is supported by the site water level data; site water quality data; and site slug test data. Deeper zones were thought to be separated from the main shallow zone by low permeability layers in the MEF Sandstone. This is why the prior site extraction system was focused in this interval. Please note that the FLUTe conductivity profiles conducted as part of this study found that the main water bearing zone is between the first encountered water around 70 feet bgs	The text will be revised to discuss this point, and note that the extraction well is considered fully penetrating.	Assuming that the low permeability layers in the MEF Sandstone are extensive and the nature of this “aquitard” is understood, the GSU will concur.	No additional response required.

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	and roughly 105 feet bgs, independently confirming the prior site CSM.			
11. **3.7.1 Constant-Rate Aquifer Test page 3-18** *"No response was observed in wells EW-13, MW-31, and MW-61A, which is attributed to either the large distance to the wells (EW-13 (approximately 110 feet away and MW-31 (approximately 110 feet away)) or the deep depth of the well screens (MW-31 and MW-61D)."* Please note that MW-61D responded in the aquifer test.	Thank you for noting this typographical error; the text "..deep depth of the well screens (MW-31 and MW-61D)." should have been "MW-31 and MW- 61A". Tetra Tech and DTSC both agree that MW-61A did not respond to the test, and MW61D did respond to the test, and above referenced typographical error was the source of confusion on this issue.	The text will be revised to correct the typographical error. No other changes required as Tetra Tech and DTSC both agree that MW-61A did not respond to the test, and MW61D did respond to the test.	For clarity, the report states that there was no response in MW-61A. DTSC simply accepts that statement as correct.	No additional response required.
12. **3.7.1 Constant-Rate Aquifer Test page 3-18** *"Although responses were observed in MW-61C and MW-61D, the magnitude and nature of the response, along with the deeper location of the well screens, indicated that these wells are screened in a water bearing zone that is somewhat vertically separated from the main pumping water bearing zone at 70 to 110 feet bgs.* The GSU disagrees. Vertical hydraulic conductivities are typically less than the horizontal hydraulic	Please see the response to Specific Comment #9 above, and note that the FLUTe conductivity profiles show that the hydraulic conductivity is orders of magnitude lower than the primary pumped interval in these deeper wells. Also note the site water level, water quality data, and slug test data, which show the separation of these intervals. Please also note that if vertical conductivity values caused this difference, then the site transmissivity values would appear to increase with distance from the pumping location due to partial penetration effects, however, the data	No change to the document.	For clarity, it is response indicating that there is NO anisotropy between horizontal hydraulic conductivity and vertical hydraulic conductivity OR there is a distinct hydrogeologic unit that is acting as an aquitard? The original statement could be revised since it is vague (i.e. "somewhat separated")	There is anisotropy between horizontal hydraulic conductivity and vertical conductivity, and it is given as 10 to 1 as documented in the site modeling report. Please note that if vertical anisotropy/partial penetration were the cause of the lower drawdown in the deeper wells, then the apparent aquifer transmissivity value would increase with observation well distance from the pumping

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conductivities which would account for the responses observed in the deeper monitoring wells. The report does not present any data to support the presence of a confining layer or a large contrast in hydraulic conductivity with depth at the site that is not associated with expected vertical anisotropy.	indicate the transmissivity values do not increase with distance from the pumping well, supporting the notion that the deeper wells are vertically separated from the main pumping zone.			well, however that is not what was observed in the pumping test data. Therefore, vertical anisotropy can be ruled out as the cause of the lower drawdown in the deeper wells. The term "somewhat separated' was used and is appropriate, since the deeper wells are hydraulically separated from the pumping well, while water quality data showing very low/trace COC concentrations in the deep wells suggest some very limited degree of vertical communication likely exists. Hence the term "somewhat separated"; please see the site CSM given in site modeling report.
13. **3.7.1 Constant-Rate Aquifer Test page 3-18** *"The EW-20 constant-rate aquifer test was conducted by pumping the well for 77 hours…"* It should be acknowledged that the data from the aquifer test indicate that steady-state conditions were not reached. It is also not clear in the	Please see the response to Specific Comment #9 above regarding the 37 foot interval and the fully penetrating nature of the extraction well. The report text will also add a statement to highlight that the 77 hour test had not reached steady-state.	The revised text will add a statement to highlight that the 77 hour test had not reached steady-state.	No response needed.	

Specific Comments				
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report how the 37-foot aquifer thickness was determined and if the monitoring wells (especially EW-20) are considered fully-penetrating or partially-penetrating. These issues should be clearly addressed as it has a significant impact on the interpretations of the data.				
14. **3.7.1 Constant-Rate Aquifer Test page 3-21** *"The drawdown data from the pumping well EW-20 and the observation wells had a shape that is generally consistent with the Theis Aquifer Model, with generally no flattening of drawdown at late times, although extraction well EW-20 and observation location PZ09 did show limited drawdown flattening effects at late times that may be indicative of leakage."* After evaluating the log-log and semi-log plots of the time-drawdown data, the aquifer appears to behave more as an unconfined aquifer with delayed yield or as a confined fractured aquifer (dual-porosity). Both curves exhibit the typical three distinct segments associated with these types of aquifers which create an S-shaped curve. It is unlikely that	Tetra Tech disagrees that the aquifer appears to behave more as an unconfined aquifer as the data clearly fit the Theis Model rather well, and no late time rise in drawdown was ever observed (i.e., the third line segment did not occur). Also, Tetra Tech believes the data strongly support confined conditions: for example, the cone of depression created in the monitoring wells has an aquifer bulk volume of over 250,000 gallons, which is about 500 times greater than the extraction volume of about 500 gallons. This would suggest a specific yield of only 0.002, far too low for the site conditions. Also, even at distances of almost 70 feet the storage values are all very small, no matter where the straight line is drawn, and the drawdown very large. Clearly, this is a confined response. With regard to a dual porosity	No change to the document.	The geologic/hydrogeologic description of the site needs to be consistent with the data being collected. Again, the description of the hydrogeologic system is unconfined. If the interpretation of the aquifer data conflicts, as it does in this case, an additional evaluation and discussion is necessary. The facility should consider inverse modeling of the aquifer test as the test data may not match well with the Thesis Model. Are these low storativity values support by the groundwater model?	The low storativity values are supported by the groundwater model; please see the storativity values given in the model calibration report. Please note that "inverse modeling" has already been done, since pumping test analysis is considered a form of inverse modeling, especially when regression methods are applied to fit the type curves. Tetra Tech therefore assumes that this comment refers to inverse modeling using a numerical model as opposed to a traditional pumping test type curve. Inverse modeling cannot be done with the existing numerical model, as inverse modeling of this pumping test would require a

Specific Comments				
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the flat segment represents leakage since steeper drawdown is observed at later time and leakage usually results in a general flattening of the time-drawdown curve for the duration of the test. It should be also noted that storage values are most reliable if taken from the data contained in the third segment. Given the description of the site geology and hydrogeology, the presence of confined conditions is not supported.	confined fractured aquifer, please note that the other site data do not indicate that the MEF Sandstone is a dual porosity system. For example, (1) with roughly 20 extraction wells installed at the site, the yields for these 20 wells are remarkably uniform, and do not show a single well with the much higher yields one would expect from a fractured system, and (2) the angled borehole conductivity profiles and core do not show any signs of fracture controlled flow (the FLUTe profiles and core data are consistent with a single porosity system). Therefore, since (1) a dual porosity system is inconsistent with the site CSM, and (2) the data does not display a classic dual porosity response, a dual porosity model was not considered appropriate for this site.			more refined grid. This type of analysis is beyond the scope of this traditional pump test analysis, and Tetra Tech believes there is little to be gained from such an analysis, especially in regards to the inverse modeling cost. Please note that while the alluvial aquifer is unconfined, the MEF sandstone aquifer in which this test was conducted is confined by the alluvium. Therefore, the geologic/hydrogeologic description of the site is consistent with the data being collected; please see the modeling report for more details on the site CSM and the three separate HSUs at the site (alluvium, MEF sandstone, and granitic bedrock).
15. **3.7.2 Vacuum-Enhanced Aquifer Test** The GSU request references to published studies that have use a similar approach. In addition, time-drawdown plots were not provided	No studies were referenced for the dual-phase extraction approach since the objective of the vacuum-enhanced extraction was simply to estimate the increased extraction rate that could be achieved under vacuum. The data from this phase of the test was not	No change to the document.	No response needed.	

Specific Comments				
Original Comment	**Original Response**	**Proposed Action**	**Additional Comments**	**Additional Response**
for this portion of the test and should be included in any response to this memorandum.	used for aquifer test interpretation and therefore no time-drawdown plots were created. It is not possible to interpret the time drawdown data from the vacuum test because: (1) vacuum data was not collected downhole using a transducer (the only vacuum data was wellhead measured only 5 or 6 times during the test); there are no analytical methods available to interpret data from these dual phase tests; the only possible interpretation method would be using a multiphase flow model, which is inherently uncertain and expensive, and would not improve the test analysis beyond what was conducted during the single phase test.			
16. **3.8.2 Rock Matrix Sampling and Analysis** **page 3-29** *"The absence of fractures and vertical contaminant distribution at the source area indicates that the contaminant mass is tied up in the low permeability rock matrix. This is consistent with the bedrock studies conducted by Dr. Beth Parker and John A. Cherry utilizing the Discrete Fracture Network (DFN) Approach for characterization of contaminated*	The report will be revised to clarify that the contaminant transport mechanism in the MEF Sandstone is not matrix diffusion but rather is a single porosity system with a very low permeability matrix. However, it should be noted that similar to matrix diffusion in fractured rock, this source may continue to degrade water quality from the slow release of contaminant mass from the low permeability sandstone matrix into the more permeable alluvium downgradient of	The report will be revised to clarify that the contaminant transport mechanism in the MEF Sandstone is not matrix diffusion but rather is a single porosity system with a very low permeability matrix.	No response needed.	

Specific Comments				
Original Comment	**Original Response**	**Proposed Action**	**Additional Comments**	**Additional Response**
bedrock sites (Parker et al, 2010, Cherry et al, 2007, and Parker 2007). Their bedrock characterization studies indicate that the slow release of contaminant mass from the low-permeability matrix between fractures may degrade water quality for centuries or more despite complete removal of the source zone mass (Parker et al, 2010). These studies have also shown that from a remediation perspective, matrix diffusion can create significant challenges for contaminant mass removal due to the difficulties in accessing contaminant mass in the rock matrix." The first statement in this quotation is not clear. Additional explanation is needed to explain how the absence of fractures and the vertical contaminant distribution (assuming the statement refers to the limited vertical extent) are supported and that the contaminant mass is "tied up in the low permeability rock matrix." Additionally, the GSU does not believe that these conditions (i.e., the site conditions as presented in the report) are consistent with the bedrock studies conducted by Drs. Parker and Cherry (see General	the source. Therefore, the statement is still true that from a remediation perspective there are still significant challenges in accessing the contaminant mass in the low permeability rock matrix within the BPA. In fact, the absence of fractures may make it even more difficult to access contaminant mass within the matrix as much of the porewater within the sandstone may be stagnant except for the less indurated zones where the majority of the groundwater flow most likely occurs.			

Specific Comments				
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Comment #1). The statement later states "matrix diffusion can create significant challenges for contaminant mass removal…" but there were no definitive data presented in the report to support that this process is occurring at the site. The GSU would request clarification of these statements.				
17. **3.8.4 Hydraulic Conductivity Profiling** **Figure 3-8** More variability is shown in the profile for BH-1. Were there any observations or data that may explain the differences between the two profiles (e.g., geophysical logs, laboratory tests, drilling rates, or boring logs)?	There were no differences observed in the cores, geophysical logs, or drilling rates to explain the greater variability in the BH-1 conductivity profile. No laboratory samples were collected from BH-2 to compare with BH-1. However, no large concentration swings were observed in the rock core analytical results for BH-1 which correspond with the observed conductivity changes.	No change to the document.	No response needed.	
18. **Recommendations** **page 4-55** The GSU would concur with the recommend that the CSM and groundwater flow and transport models be updated with the information from this report. The GSU, however, believe that additional work is needed as commented in this memorandum. Specifically, additional work is	The CSM and groundwater flow and transport models are currently being updated based on the data collected during the hydraulic testing investigation. Flow and transport Model updates will include updating the hydraulic conductivity to be consistent with the test results in the BPA hot spot area, reevaluating the flow model water level calibration for the prior flow model calibration, reevaluating the transport model COC		DTSC will follow-up with further evaluation of the groundwater model which should be utilized to test the sensitivity of the nature and values assigned to the geologic structures at the site. The model should be used to assist in identifying parameters (i.e. hydraulic conductivity of the faults) that are not well constrained	No additional response required.

Specific Comments				
Original Comment	**Original Response**	**Proposed Action**	**Additional Comments**	**Additional Response**
needed to understand the faults, fractures, buried stream drainage, and/or spatial variations in cementation that occur at the site at a scale sufficient to support the data needs of any Feasibility Study. The information presented in the report does not support that matrix diffusion has a significant effect at the site. The facility may consider conducting additional studies at the site to demonstrate its effect, if any. The GSU, however, believes that in the absence of a developed fracture system and due to the poorly-indurated nature of the sandstone, matrix diffusion is not occurring at a significant amount.	calibration for the prior transport model calibration, and updating the mass flux budgets. The model update will also include updating the flow and transport model stress periods and water level and COC data to also cover the 3 year period from 2008-2011, so the updated model covers the 1992 to 2011 period (currently it covers 1992 to 2008). This will make the model more current and provide more credibility in the model by testing the model against a period outside the original calibration (i.e., a bit of model validation). Based on the geologic and hydrogeologic investigations conducted to date (see response to General Comment #2), additional work at the Site is not needed to better understand the faults, fractures, buried stream drainage, and/or spatial variations in cementation to support the data needs of the Feasibility Study. Tetra Tech agrees with GSU that the data does not support a fracture system within the BPA and due to the poorly-indurated nature of the sandstone, matrix diffusion is most likely not occurring.		and, to which, the model is sensitive to.	

References:

1. Terra Physics, 2006a. Seismic Reflection Survey to Detect Bedrock Faults, Former Lockheed Beaumont Site 1, South of Beaumont, California. February 2006.

2. Terra Physics, 2006b. Correlations of Seismic Velocity and Stratigraphy in Nine Borings, Former Lockheed Beaumont Site 1, Potrero Creek, South Beaumont, California. March 2006.

3. Tetra Tech, Inc. 2009a. Dynamic Site Investigation Report, Historical Operational Areas B, C, F, G, and H, Beaumont Site 1, Lockheed Martin Corporation, Beaumont, California, July 2009.

4. Tetra Tech, Inc. 2009b. Lineament Study, Lockheed Martin Corporation, Beaumont Site 1, Beaumont California, December 2009.

5. Tetra Tech, Inc., 2010a. Transient Groundwater Model Report, Numerical Flow Model Development, Lockheed Martin Beaumont Site 1, Beaumont, California, January 2010.

6. Tetra Tech, Inc., 2010b. Potrero Creek Groundwater Pumping Test Report, Numerical Flow Model Development, Lockheed Martin Beaumont Site 1, Beaumont, California, January 2010.

7. Tetra Tech, Inc., 2010c. Supplemental Groundwater Monitoring Well Installation Report, Lockheed Martin Corporation, Beaumont Site 1, July 2010.

8. Tetra Tech, Inc., 2010d. Summary Remedial Investigation Report, Lockheed Martin Corporation, Beaumont Site 1, November 2010.

9. Tetra Tech, Inc., 2011. Numerical Groundwater Transport Model Development, Lockheed Martin Beaumont Site 1, Beaumont, California, July 2011.

Department of Toxic Substances Control

Matthew Rodriquez
Secretary for
Environmental Protection

Deborah O. Raphael, Director
5796 Corporate Avenue
Cypress, California 90630

Edmund G. Brown Jr.
Governor

May 22, 2012

Mr. Brian T. Thorne
Remediation Analyst Senior Staff
Lockheed Martin Corporation
Energy, Environment, Safety & Health
2950 North Hollywood Way, Suite 125
Burbank, California 91505-1072

HYDRAULIC TESTING SUMMARY REPORT, POTRERO CANYON UNIT, LOCKHEED MARTIN CORPORATION, BEAUMONT SITE 1, BEAUMONT, CALIFORNIA (Site Code: 400200)

Dear Mr. Thorne:

The Department of Toxic Substances Control (DTSC) has reviewed the subject Report. Enclosed are comments from DTSC's Geological Services Unit (GSU).

Please address the enclosed comments by June 22, 2012.

Should you have any questions or comments, please contact me at (714) 484-5483.

Sincerely,

Daniel K. Zogaib

Daniel K. Zogaib
Project Manager
Brownfields and Environmental Restoration Program

Enclosure

cc: See next page.

cc Mr. Gene Matsushita
Senior Manager
Environmental Remediation
Lockheed Martin Corporation
Energy, Environment, Safety & Health
2950 North Hollywood Way, Suite 125
Burbank, California 91505

Matthew Rodriquez
Secretary for
Environmental Protection

Department of Toxic Substances Control

Deborah O. Raphael, Director
5796 Corporate Avenue
Cypress, California 90630

Edmund G. Brown Jr.
Governor

MEMORANDUM

To: Daniel Zogaib
Project Manager
Brownfields and Environmental Restoration Program

From: Thomas M. Seckington, CHg. TS
Senior Engineering Geologist
Geology and Remediation Engineering Branch

Date: May 14, 2012

Re: Hydraulic Testing Summary Report
Potrero Canyon Unit (Lockheed Martin Beaumont Site 1)
Beaumont, California

PCA: 11050 Site Code: 400200-00

Geologic Services Unit (GSU) Staff from the Department of Toxic Substances Control (DTSC) reviewed the Hydraulic Testing Summary Report, Potrero Canyon Unit (Lockheed Martin Beaumont Site 1; report). The report is dated March 2012 and was prepared by Tetra Tech, Inc. The report summarizes hydraulic testing conducted at the site and the results.

The GSU disagrees with several of the conclusions and recommendations presented in the report. GSU comments are presented below.

GENERAL COMMENTS

1. The report references studies conducted by Dr. Beth Parker and others regarding the attenuation effects of matrix diffusion which has been observed in fractured sandstone at other sites. However, the descriptions of the Mount Eden Formation (MEF) Sandstone indicate that the sandstone is generally moderately to weakly indurated (to the point of being friable). Consistent with this, the data reviewed do not indicate that there is a developed or definable fractured network. The MEF Sandstone, therefore, does not appear to be comprised of the distinct

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matrix blocks bounded by an interconnected fracture network that is associated with matrix diffusion at other sites.

Additional data presented in the report such as the conductivity profiles and the core data from BH-1 also did not provide convincing support that there is a hydraulically significant fracture network at the site and therefore, that matrix diffusion is occurring. The GSU recommends that effects of matrix diffusion should not be considered in the site conceptual model as a process retarding the groundwater plume(s) and as a process that would potentially affect remedial alternatives.

2. The GSU believes that the anisotropy at the site associated with the faults, fractures, buried stream drainages, and/or spatial variations in cementation is critical to the understanding of groundwater flow and the fate and transport of contaminants. The report does not clearly address the nature of groundwater flow along or across these hydrogeologic features. It is not possible to develop a dependable numerical approximation of groundwater flow and contaminant transport, an adequate groundwater monitoring system, or an effective remedial approach without accounting for the effects of these structures. The northwest trending parallel faults presented in Figure 2-1 would suggest that there should be a regional anisotropy. The aquifer test and slug tests presented in the report provided the general sense of variation in hydraulic conductivity across the site but was at an insufficient scale and scope to provide insight to spatial trends in hydraulic conductivity that should be part of the site conceptual model and incorporated into the numerical model. The GSU recommends that the facility conduct a series of additional aquifer tests across the site to better assess the spatial hydrogeological variations and trends.

Specific Comments

1. **2.3 Water Quality Sampling and Analysis**
   page 2-5
   "Both equipment blanks and trip blanks were collected at the beginning of each sampling day."

   Equipment blanks should be collected during the day between sampling points to assess the efficiently of the decontamination activities.

2. **2.4.1 Soil Sampling and Analysis**
   page 2-7
   "These samples were collected using 66-inch [sic] stainless steel or brass…"

Typographical error noted.

3. **2.6 Aquifer Testing**
page 2-8
"A step draw down test was performed on October 11, 2011, following development of the extraction well (EW-20) and piezometer (P-09)."

Please submit the well development logs. In addition, please provide the data (sieve analysis, etc.) used to select the well screen and filter pack for EW-20.

4. **2.6 Aquifer Testing**
page 2-9
"The constant-rate aquifer test commenced on October 18, 2011, following a 7-day recovery from the step drawdown test. The constant-rate aquifer test was conducted at a rate of 0.125 gpm in EW-20. The vacuum-enhanced aquifer test ran from Friday, October 21, 2011, through October 23, 2011..."

This statement indicates that the vacuum-enhanced aquifer test was conducted within 24 hours after the conclusion of the constant-rate aquifer test, which did not have a recovery period. Please verify and explain why a recovery period was not conducted and monitored before the vacuum-enhanced aquifer test.

5. **3.1.2 Feature C-22, BPA**
page 3-4
"The range of hydraulic conductivity values varied from less than 0.00001 to 0.2 feet per day..."

There is no discussion regarding the measurement "less than" 0.00001 feet per day (not shown on Table 3-1). This extremely low hydraulic conductivity value would typically be associated with the lowest conductivity range for clays. A discussion of this low hydraulic conductivity value is warranted and should have been included in the report.

It should be noted that the "0.2 feet per day" stated as the maximum hydraulic conductivity value disagrees with Table 3-1 which indicates that 0.249 feet per day is the maximum value.

6. **3.3 Soil Results**
page 3-7
"Positive detections of TOC occurred in 22 samples (excluding duplicates) at concentrations ranging from 510 to 1,800 mg/kg. The TOC concentrations were detected in P-09 at 20 feet bgs and at 40 feet bgs. The results of these analyses as shown in Table 3-2 indicate that there is very little variation in the TOC concentrations versus depth. This trend is in agreement with the coring data that

shows relatively homogenous lithology within the MEF sandstone."

All the TOC detections are "J" flagged and are therefore below the method reporting limits (MRLs). The values reported are estimated and no conclusions can be made regarding ranges, maximum concentrations, or trends for data that are not quantified.

7. **3.6 Vadose Zone Permeability Tests**
page 3-17
"Well VRW-1, which apparently has the highest permeability of all of the locations tested, is located in the southern portion of the BPA, where very high infiltration rates were found during previous testing (Tetra Tech, 2009a)."

The raw data from these tests was not presented in the report and should be presented for DTSC's evaluation.

8. **3.7.1 Constant-Rate Aquifer Test**
page 3-18
"During the constant-rate aquifer test, drawdown in EW-20 was up to 12.78 feet..."

Please note that the maximum drawdown recorded was 12.87 feet.

9. **3.7.1 Constant-Rate Aquifer Test**
page 3-18
"The hydraulic conductivity value for a 37-foot thick saturated zone would then be approximately 0.054 feet per day."

Please clarify why the assumed thickness of the aquifer is 37 feet when the boring logs do not indicate any lithologic or other changes at that depth.

10. **3.7.1 Constant-Rate Aquifer Test**
page 3-18
"No response was observed in wells EW-13, MW-31, and MW-61A, which is attributed to either the large distance to the wells (EW-13 (approximately 110 feet away) and MW-31 (approximately 110 feet away)) or the deep depth of the well screens (MW-31 and MW-61D)."

Please note that MW-61D responded in the aquifer test.

11. **3.7.1 Constant-Rate Aquifer Test**
page 3-18
"Although responses were observed in MW-61C and MW-61D, the magnitude

and nature of the response, along with the deeper location of the well screens, indicated that these wells are screened in a water bearing zone that is somewhat vertically separated from the main pumping water bearing zone at 70 to 110 feet bgs."

The GSU disagrees. Vertical hydraulic conductivities are typically less than the horizontal hydraulic conductivities which would account for the responses observed in the deeper monitoring wells. The report does not present any data to support the presence of a confining layer or a large contrast in hydraulic conductivity with depth at the site that is not associated with expected vertical anisotropy.

12. **3.7.1 Constant-Rate Aquifer Test**
page 3-18
"The EW-20 constant-rate aquifer test was conducted by pumping the well for 77 hours…"

It should be acknowledged that the data from the aquifer test indicate that steady-state conditions were not reached. It is also not clear in the report how the 37-foot aquifer thickness was determined and if the monitoring wells (especially EW-20) are considered fully-penetrating or partially-penetrating. These issues should be clearly addressed as it has a significant impact on the interpretations of the data.

13. **3.7.1 Constant-Rate Aquifer Test**
Transient Drawdown Interpretation
page 3-21
"The drawdown data from the pumping well EW-20 and the observation wells had a shape that is generally consistent with the Theis Aquifer Model, with generally no flattening of drawdown at late times, although extraction well EW-20 and observation location PZ09 did show limited drawdown flattening effects at late times that may be indicative of leakage."

After evaluating the log-log and semi-log plots of the time-drawdown data, the aquifer appears to behave more as an unconfined aquifer with delayed yield or as a confined fractured aquifer (dual-porosity). Both curves exhibit the typical three distinct segments associated with these types of aquifers which create an S-shaped curve. It is unlikely that the flat segment represents leakage since steeper drawdown is observed at later time and leakage usually results in a general flattening of the time-drawdown curve for the duration of the test.

It should be also noted that storage values are most reliable if taken from the data contained in the third segment. Given, the description of the site geology and hydrogeology, the presence of confined conditions is not supported.

14. **3.7.2 Vacuum-Enhanced Aquifer Test**

The GSU request references to published studies that have use a similar approach. In addition, time-drawdown plots were not provided for this portion of the test and should be included in any response to this memorandum.

15. **3.8.2 Rock Matrix Sampling and Analysis**
page 3-29
"The absence of fractures and vertical contaminant distribution at the source area indicates that the contaminant mass is tied up in the low permeability rock matrix. This is consistent with the bedrock studies conducted by Dr. [sic] Beth Parker and John A. Cherry utilizing the Discrete Fracture Network (DFN) Approach for characterization of contaminated bedrock sites (Parker et al, 2010, Cherry et al, 2007, and Parker 2007). Their bedrock characterization studies indicate that the slow release of contaminant mass from the low-permeability matrix between fractures may degrade water quality for centuries or more despite complete removal of the source zone mass (Parker et al, 2010). These studies have also shown that from a remediation perspective, matrix diffusion can create significant challenges for contaminant mass removal due to the difficulties in accessing contaminant mass in rock matrix."

The first statement in this quotation is not clear. Additional explanation is needed to explain how the absence of fractures and the vertical contaminant distribution (assuming the statement refers to the limited vertical extent) are supported and that the contaminant mass is "tied up in the low permeability rock matrix." Additionally, the GSU does not believe that these conditions (i.e., the site conditions as presented in the report) are consistent with the bedrock studies conducted by Drs. Parker and Cherry (see General Comment #1). The statement later states "matrix diffusion can create significant challenges for contaminant mass removal…" but there were no definitive data presented in the report to support that this process is occurring at the site. The GSU would request clarification of these statements.

16. **3.8.4 Hydraulic Conductivity Profiling**
Figure 3-8

More variability is shown in the profile for BH-1. Were there any observations or data that may explain the differences between the two profiles (e.g., geophysical logs, laboratory tests, drilling rates, or boring log)?

17. **Recommendations
page 4-55**

The GSU would concur with the recommend that the CSM and groundwater flow and transport models be updated with the information from this report. The GSU, however, believes that additional work is needed as commented in this memorandum. Specifically, additional work is needed to understand the faults, fractures, buried stream drainages, and/or spatial variations in cementation that occur at the site at a scale sufficient to support the data needs of any Feasibility Study.

The information presented in the report does not support that matrix diffusion has a significant effect at the site. The facility may consider conducting additional studies at the site to demonstrate its effect, if any. The GSU, however, believes that in the absence of a developed fracture system and due to the poorly-indurated nature of the sandstone, matrix diffusion is not occurring at a significant amount.

If you have any questions or concerns, please contact Thomas Seckington at (714) 484-5424 or tseckington@dtsc.ca.gov.

Peer reviewed by: Dina Kourda, CEG, CHg

cc: Alfredo Zahoria, CEG, CHg

Responses to DTSC Comments on the Hydraulic Testing Summary Report, Potrero Canyon Unit, Lockheed Martin Corporation, Beaumont Site 1, Beaumont, California
Tetra Tech, Inc
March 2012

General Comments		
Comment	**Response**	**Proposed Action**
1. The report references studies conducted by Dr. Beth Parker and others regarding the attenuation effects of matrix diffusion which has been observed in fractured sandstone at other sites. However, the descriptions of the Mount Eden Formation (MEF) Sandstone indicate that the sandstone is generally moderately to weakly indurated (to the point of being friable). Consistent with this, the data reviewed do not indicate that there is a developed or definable fractured network. The MEF Sandstone, therefore, does not appear to be comprised of the distinct matrix blocks bounded by an interconnected fracture network that is associated with matrix diffusion at other sites. Additional data presented in the report such as the conductivity profiles and the core data from BH-1 also did not provide convincing support that there is a hydraulically significant fracture at the site and therefore, that matrix diffusion is occurring. The GSU recommends that effects of matrix diffusion should not be considered in the site conceptual model as a process retarding the groundwater plume(s) and as a process that would potentially affect remedial alternatives.	One of the objectives of this study was to evaluate if the MEF Sandstone within the Burn Pit Area (BPA) was fractured and exhibiting fracture flow characteristics. Information specific to the physical nature of the MEF Sandstone in the BPA was not available since previous drilling methods did not include rock coring. Therefore, Tetra Tech and LMC consulted with Beth Parker, John Cherry, and Seth Pitkin (Stone Environmental) to incorporate several investigative tools into the bedrock coring in order to better characterize contamination within the bedrock and evaluate the presence/absence of fractures. Some of the studies that evaluated these tools were therefore referenced in this report. However, based on the results of this investigation and the absence of a fracture flow system, matrix diffusion is not considered part of the CSM with respect to contaminant transport. However, aside from matrix diffusion, it may be that there is slow transport of COCs from tight interbeds within the MEF adjacent to the primary water bearing zones between 60 and 100 ft bgs, and slow transport from these interbeds may be causing the persistent	No change to the document.

General Comments		
Comment	**Response**	**Proposed Action**
	COCs that have been observed in groundwater beneath the BPA for the last 20 years.	
2. The GSU believes that the anisotropy at the site associated with the faults, fractures, buried stream drainages, and/or spatial variations in cementations is critical to the understanding of groundwater flow and the fate and transport of contaminants. The report does not clearly address the nature of groundwater flow along or across these hydrogeologic features. It is not possible to develop a dependable numerical approximation of groundwater flow and contaminant transport, an adequate groundwater monitoring system, or an effective remedial approach without accounting for the effects of these structures. The northwest trending parallel faults presented in Figure 2-1 would suggest that there should be a. regional anisotropy. The aquifer test and slug tests presented in the report provided the general sense of variation in hydraulic conductivity across the site but was at an insufficient scale and scope to provide insight to spatial trends in hydraulic conductivity that should be part of the site conceptual model and incorporated into the numerical model. The GSU recommends that the facility conduct a series of additional aquifer tests across the site to better assess the spatial hydrogeological variations and trends.	Tetra Tech agrees that features such as faults and buried stream drainages have a considerable impact on the site groundwater flow, which is why considerable effort was extended in the field investigations, geophysical surveys (Terra Physics, 2006a, 2006b; Tetra Tech, 2009a), lineament study (Tetra Tech, 2009b), development of the site CSM (Tetra Tech, 2010d), and numerical groundwater flow (Tetra Tech, 2010a) and transport model (Tetra Tech, 2011), to identify and incorporate these features into the site CSM, water budget, and mass flux budget. For example, please see the site modeling reports (Tetra Tech, 2010a, 2011) which detail the incorporation of faults in the CSM and numerical model (using the MODFLOW horizontal flow barrier package), and the buried stream channel underlying Bedsprings Creek valley. Also, please note the good comparison for a 16 year model calibration period between the observed and simulated water levels; observed and simulated water budgets; observed	No change to the document.

General Comments		
Comment	**Response**	**Proposed Action**
	and simulated COC concentrations; observed and simulated mass flux budgets; and observed and simulated COC plume morphology. Significant effort has already been extended to conduct many site aquifer tests (constant-rate aquifer tests, slug tests, and specific capacity tests) both at the source areas and in many locations along the length of the plume including the RMPA, riparian area, and along Potrero Creek (Tetra Tech, 2010a, 2010b, 2010c, 2011). The hydraulic testing included recent use of coring and FLUTe conductivity profiles to define small scale variations in flow that may be indicative of fractures, but as noted in this report, the overwhelming evidence suggests that flow within the MEF Sandstone is not fracture controlled. Differences in the spatial variations in cementation of the sandstone may not be laterally continuous between borings and would be extremely difficult to map since the degrees of induration within the cores varied and were not drastic. Based on the FLUTe conductivity profiling in BH-1 and BH-2 and the rock core matrix sampling in	

General Comments		
Comment	**Response**	**Proposed Action**
	BH-1, no correlation could be made that would indicate that these less indurated zones have higher conductivities or significant differences in contaminant concentrations to warrant a detailed investigation of cementation within the sandstone. In addition, the MEF Sandstone is a fanglomerate that does not lend itself to easy correlation across any distance (identical to alluvial fan deposits which vary considerably within a few feet). Review of the Acoustic Borehole Televiewer Logs from both BH-1 and BH-2 do not show distinct bedding planes or significant variability in lithology (as seen in the borehole logs themselves). In many cases, the televiewer data shows a fairly homogenous rock from the top to the bottom of the hole (within the MEF Sandstone). A review of the dual induction log can lend some interpretation to the density of the sandstone (higher resistivity with more dense rock), but a review of the dual-induction log for BH-1 cannot be correlated to conductivity values generated by the FLUTe conductivity profiles. Therefore, trying to map or correlate	

General Comments		
Comment	**Response**	**Proposed Action**
	the variation in cementation/induration in the buried bedrock would be extremely difficult at best and would likely be near impossible even with considerable expense (many more coreholes and geophysical logs). References have been included at the end of the response to comments table for the documents referenced above. It should be noted that the *Summary Remedial Investigation Report* (Tetra Tech, 2010d) includes many of the key site reports prior to 2010 on CDs in Appendix A.	

Specific Comments		
Comment	**Response**	**Proposed Action**
1. **2.3 Water Quality Sampling and Analysis page 2-5** *"Both equipment blanks and trip blanks were collected at the beginning of each sampling day"* Equipment blanks should be collected during the day between sampling points to assess the efficiently of the decontamination activities.	In accordance with the DTSC-approved Programmatic Sampling and Analysis Plan for the Beaumont sites, equipment blanks (EBs) are collected prior to sampling the first well of the day. After decontaminating the pump and discharge line, distilled water is pumped through the system. When two hose volumes have been allowed to	No change to the report.

Specific Comments		
Comment	**Response**	**Proposed Action**
	clear the lines, the samples are collected. For reusable sampling devices such as pumps, an EB will be collected immediately after the sampling equipment has been decontaminated. These procedures ensure that all samples collected on a single day can be associated with the EB collected at the beginning of the day. If the EB was collected in the middle of the day between sampling points, the samples collected after the EB would need to be associated with that blank while the samples collected before the EB would need to be associated with the EB from the prior day. For the purpose of data validation, this creates an unnecessary level of complication with respect to associating environmental samples with the appropriate field blanks. The current procedures do allow for an appropriate evaluation of the efficiency of the decontamination activities during the sampling event.	
2. **2.4.1 Soil Sampling and Analysis page 2-7** *“These samples were collected using 66-inch [sic] stainless steel or brass…”*	Typo, should be 6-inch.	Correction will be made in the final document.

Specific Comments		
Comment	**Response**	**Proposed Action**
Typographical error noted.		
3. **2.6 Aquifer Testing** **page 2-8** *"A step draw down test was performed on October 11, 2011, following development of the extraction well (EW-20) and piezometer (P-09)."* Please submit the well development logs. In addition, please provide the data (sieve analysis, etc.) used to select the well screen and filter pack for (EW-20)	Well development field sheets will be included in the revised report. A sieve analysis was conducted on the sandstone for the selection of well screen and filter pack. Given the extremely low flow rates (<0.5 gpm) within the MEF sandstone, 0.02" wire-wrap screen with #2/12 filter pack was selected for this well.	Well development logs will be included in the final document.
4. **2.6 Aquifer Testing** **page 2-9** *"The constant-rate aquifer test commenced on October 18, 2011, following a 7-day recovery from the step drawdown test. The constant-rate aquifer test was conducted at a rate of 0.125 gpm in EW-20. The vacuum-enhanced aquifer test ran from Friday, October 21, 2011 through October 23, 2011…"* This statement indicates that the vacuum-enhanced aquifer test was conducted within 24 hours after the conclusion of the constant-rate aquifer test, which did not have a recovery period. Please verify and explain why a recovery period was not conducted and monitored before the vacuum-enhanced aquifer test.	A recovery period was not conducted prior to the vacuum-enhanced aquifer test. As stated in the approved work plan, the vacuum-enhanced extraction would follow immediately after the constant-rate aquifer test to evaluate the effectiveness of vacuum-enhanced extraction with respect to the potential increase in the extraction rate within the MEF Sandstone using dual-phase extraction.	No change to the document.
5. **3.1.2 Feature C-22, BPA** **page 3-4** *"The range of hydraulic conductivity values varied from less than 0.00001 to 0.2 feet per day…"*	The 0.00001 feet per day hydraulic conductivity value is a typo and should be 0.0001. The lowest hydraulic conductivity value in Table 3-1 is 0.00008 (less than 0.0001) in MW-61A	The corrections will be made in the final document.

Specific Comments			
	Comment	**Response**	**Proposed Action**
	There is no discussion regarding the measurement "less than" 0.00001 feet per day (not shown on Table 3-1). This extremely low hydraulic conductivity value would typically be associated with the lowest conductivity rate for clays. A discussion of this low hydraulic conductivity value is warranted and should have been included in the report.	located in the Burn Pit Area near EW-20.	
6.	It should be noted that the "0.2 feet per day" stated as the maximum hydraulic conductivity value disagrees with Table 3-1 which indicates that 0.249 feet per day is the maximum value.	Correct, maximum hydraulic conductivity value from Table 3-1 is 0.249 feet per day.	
7.	**3.3 Soil Results** **page 3-7** *"positive detections of TOC occurred in 22 samples (excluding duplicates) at concentrations ranging from 510 to 1,800 mg/kg. The TOC concentrations were detected in P-09 at 20 feet bgs and at 40 feet bgs. The results of these analyses as shown in Table 3-2 indicate that there is very little variation in the TOC concentrations versus depth. This trend is in agreement with the coring data that shows relatively homogenous lithology within the MEF sandstone;"* All the TOC detections are "J" flagged and are therefore below the method reporting limits (MRLs). The values reported are estimated and no conclusions can be made regarding ranges, maximum concentrations; or trends for data that are not quantified.	Although the numerical results are estimated, the estimated TOC concentrations for the samples collected are nearly the same within the analytical accuracy of this method. Therefore, it is not unreasonable to include a statement in the report stating that the results show that there is very little variation in the TOC concentrations versus depth.	No change to the document.
8.	**3.6 Vadose Zone Permeability Tests** **page 3-17** *"Well VRW-1, which apparently has the highest permeability of all of the locations tests, is located in the southern portion of the BPA, where very high infiltration rates were found during previous testing (Tetra*	Field data sheets will be provided.	The final document will include the field data sheets for the vadose zone permeability tests.

Specific Comments		
Comment	**Response**	**Proposed Action**
Tech, 2009a).” The raw data from these tests was not presented in the report and should be presented for DTSC’s evaluation.		
9. **3.6 Constant-Rate Aquifer Test** **page 3-18** *“During the constant-rate aquifer test, drawdown in EW-20 was up to 12.78 feet…”* Please note that the maximum drawdown recorded was 12.87 feet.	Typo, should be 12.87 feet.	The text will be revised to correct the typographical error in the final document.
10. **3.7.1 Constant-Rate Aquifer Test** **page 3-18** *“The hydraulic conductivity value for a 37-foot thick saturated zone would then be approximately 0.054 fed per day.”* Please clarify why the assumed thickness of the aquifer is 37 feet when the boring logs to not indicate any lithologic or other changes at that depth.	Prior site investigations indicated the main water bearing zone is in this 37 foot interval, which is supported by the site water level data; site water quality data; and site slug test data. Deeper zones were thought to be separated from the main shallow zone by low permeability layers in the MEF Sandstone. This is why the prior site extraction system was focused in this interval. Please note that the FLUTe conductivity profiles conducted as part of this study found that the main water bearing zone is between the first encountered water around 70 feet bgs and roughly 105 feet bgs, independently confirming the prior site CSM.	The text will be revised to discuss this point, and note that the extraction well is considered fully penetrating.

Specific Comments		
Comment	**Response**	**Proposed Action**
11. **3.7.1 Constant-Rate Aquifer Test page 3-18** *"No response was observed in wells EW-13, MW-31, and MW-61A, which is attributed to either the large distance to the wells (EW-13 (approximately 110 feet away and MW-31 (approximately 110 feet away)) or the deep depth of the well screens (MW-31 and MW-61D)."* Please note that MW-61D responded in the aquifer test.	Thank you for noting this typographical error; the text "..deep depth of the well screens (MW-31 and MW-61D)." should have been "MW-31 and MW-61A". Tetra Tech and DTSC both agree that MW-61A did not respond to the test, and MW61D did respond to the test, and above referenced typographical error was the source of confusion on this issue.	The text will be revised to correct the typographical error. No other changes required as Tetra Tech and DTSC both agree that MW-61A did not respond to the test, and MW61D did respond to the test.
12. **3.7.1 Constant-Rate Aquifer Test page 3-18** *"Although responses were observed in MW-61C and MW-61D, the magnitude and nature of the response, along with the deeper location of the well screens, indicated that these wells are screened in a water bearing zone that is somewhat vertically separated from the main pumping water bearing zone at 70 to 110 feet bgs.* The GSU disagrees. Vertical hydraulic conductivities are typically less than the horizontal hydraulic conductivities which would account for the responses observed in the deeper monitoring wells. The report does not present any data to support the presence of a confining layer or a large contrast in hydraulic conductivity with depth at the site that is not associated with expected vertical anisotropy.	Please see the response to Specific Comment #9 above, and note that the FLUTe conductivity profiles show that the hydraulic conductivity is orders of magnitude lower than the primary pumped interval in these deeper wells. Also note the site water level, water quality data, and slug test data, which show the separation of these intervals. Please also note that if vertical conductivity values caused this difference, then the site transmissivity values would appear to increase with distance from the pumping location due to partial penetration effects, however, the data indicate the transmissivity values do not increase with distance from the pumping well, supporting the	No change to the document.

Specific Comments		
Comment	**Response**	**Proposed Action**
	notion that the deeper wells are vertically separated from the main pumping zone.	
13. **3.7.1 Constant-Rate Aquifer Test** **page 3-18** *"The EW-20 constant-rate aquifer test was conducted by pumping the well for 77 hours…"* It should be acknowledged that the data from the aquifer test indicate that steady-state conditions were not reached. It is also not clear in the report how the 37-foot aquifer thickness was determined and if the monitoring wells (especially EW-20) are considered fully-penetrating or partially-penetrating. These issues should be clearly addressed as it has a significant impact on the interpretations of the data.	Please see the response to Specific Comment #9 above regarding the 37 foot interval and the fully penetrating nature of the extraction well. The report text will also add a statement to highlight that the 77 hour test had not reached steady-state.	The revised text will add a statement to highlight that the 77 hour test had not reached steady-state.
14. **3.7.1 Constant-Rate Aquifer Test** **page 3-21** *"The drawdown data from the pumping well EW-20 and the observation wells had a shape that is generally consistent with the Theis Aquifer Model, with generally no flattening of drawdown at late times, although extraction well EW-20 and observation location PZ09 did show limited drawdown flattening effects at late times that may be indicative of leakage."* After evaluating the log-log and semi-log plots of the time-drawdown data, the aquifer appears to behave more as an unconfined aquifer with delayed yield or as a confined fractured aquifer (dual-porosity). Both curves exhibit the typical three distinct segments associated with these types of aquifers which create an S-shaped curve. It is unlikely that the flat segment represents leakage since steeper drawdown is observed at later time and leakage usually results in a general flattening of the	Tetra Tech disagrees that the aquifer appears to behave more as an unconfined aquifer as the data clearly fit the Theis Model rather well, and no late time rise in drawdown was ever observed (i.e., the third line segment did not occur). Also, Tetra Tech believes the data strongly support confined conditions: for example, the cone of depression created in the monitoring wells has an aquifer bulk volume of over 250,000 gallons, which is about 500 times greater than the extraction volume of about 500 gallons. This would suggest a specific yield of only 0.002, far too low for the site	No change to the document.

Specific Comments		
Comment	**Response**	**Proposed Action**
time-drawdown curve for the duration of the test. It should be also noted that storage values are most reliable if taken from the data contained in the third segment. Given the description of the site geology and hydrogeology, the presence of confined conditions is not supported.	conditions. Also, even at distances of almost 70 feet the storage values are all very small, no matter where the straight line is drawn, and the drawdown very large. Clearly, this is a confined response. With regard to a dual porosity confined fractured aquifer, please note that the other site data do not indicate that the MEF Sandstone is a dual porosity system. For example, (1) with roughly 20 extraction wells installed at the site, the yields for these 20 wells are remarkably uniform, and do not show a single well with the much higher yields one would expect from a fractured system, and (2) the angled borehole conductivity profiles and core do not show any signs of fracture controlled flow (the FLUTe profiles and core data are consistent with a single porosity system). Therefore, since (1) a dual porosity system is inconsistent with the site CSM, and (2) the data does not display a classic dual porosity response, a dual porosity model was not considered appropriate for this site.	

Specific Comments		
Comment	**Response**	**Proposed Action**
15. **3.7.2 Vacuum-Enhanced Aquifer Test** The GSU request references to published studies that have use a similar approach. In addition, time-drawdown plots were not provided for this portion of the test and should be included in any response to this memorandum.	No studies were referenced for the dual-phase extraction approach since the objective of the vacuum-enhanced extraction was simply to estimate the increased extraction rate that could be achieved under vacuum. The data from this phase of the test was not used for aquifer test interpretation and therefore no time-drawdown plots were created. It is not possible to interpret the time drawdown data from the vacuum test because: (1) vacuum data was not collected downhole using a transducer (the only vacuum data was wellhead measured only 5 or 6 times during the test); there are no analytical methods available to interpret data from these dual phase tests; the only possible interpretation method would be using a multiphase flow model, which is inherently uncertain and expensive, and would not improve the test analysis beyond what was conducted during the single phase test.	No change to the document.
16. **3.8.2 Rock Matrix Sampling and Analysis page 3-29** *"The absence of fractures and vertical contaminant distribution at the source area indicates that the contaminant mass is tied up in the low permeability rock matrix. This is consistent with the bedrock studies*	The report will be revised to clarify that the contaminant transport mechanism in the MEF Sandstone is not matrix diffusion but rather is a single porosity system with a very low permeability	The report will be revised to clarify that the contaminant transport mechanism in the MEF Sandstone is not matrix diffusion but rather is a single porosity

Specific Comments		
Comment	**Response**	**Proposed Action**
conducted by Dr. Beth Parker and John A. Cherry utilizing the Discrete Fracture Network (DFN) Approach for characterization of contaminated bedrock sites (Parker et al, 2010, Cherry et al, 2007, and Parker 2007). Their bedrock characterization studies indicate that the slow release of contaminant mass from the low-permeability matrix between fractures may degrade water quality for centuries or more despite complete removal of the source zone mass (Parker et al, 2010). These studies have also shown that from a remediation perspective, matrix diffusion can create significant challenges for contaminant mass removal due to the difficulties in accessing contaminant mass in the rock matrix." The first statement in this quotation is not clear. Additional explanation is needed to explain how the absence of fractures and the vertical contaminant distribution (assuming the statement refers to the limited vertical extent) are supported and that the contaminant mass is "tied up in the low permeability rock matrix." Additionally, the GSU does not believe that these conditions (i.e., the site conditions as presented in the report) are consistent with the bedrock studies conducted by Drs. Parker and Cherry (see General Comment #1). The statement later states "matrix diffusion can create significant challenges for contaminant mass removal…" but there were no definitive data presented in the report to support that this process is occurring at the site. The GSU would request clarification of these statements.	matrix. However, it should be noted that similar to matrix diffusion in fractured rock, this source may continue to degrade water quality from the slow release of contaminant mass from the low permeability sandstone matrix into the more permeable alluvium downgradient of the source. Therefore, the statement is still true that from a remediation perspective there are still significant challenges in accessing the contaminant mass in the low permeability rock matrix within the BPA. In fact, the absence of fractures may make it even more difficult to access contaminant mass within the matrix as much of the porewater within the sandstone may be stagnant except for the less indurated zones where the majority of the groundwater flow most likely occurs.	system with a very low permeability matrix.
17. **3.8.4 Hydraulic Conductivity Profiling** **Figure 3-8** More variability is shown in the profile for BH-1. Were there any observations or data that may explain the differences between the two profiles (e.g., geophysical logs, laboratory tests, drilling rates, or	There were no differences observed in the cores, geophysical logs, or drilling rates to explain the greater variability in the BH-1 conductivity profile. No laboratory samples were collected from BH-2 to compare with BH-1. However, no large concentration	No change to the document.

Specific Comments		
Comment	**Response**	**Proposed Action**
boring logs)?	swings were observed in the rock core analytical results for BH-1 which correspond with the observed conductivity changes.	
18. **Recommendations page 4-55** The GSU would concur with the recommend that the CSM and groundwater flow and transport models be updated with the information from this report. The GSU, however, believe that additional work is needed as commented in this memorandum. Specifically, additional work is needed to understand the faults, fractures, buried stream drainage, and/or spatial variations in cementation that occur at the site at a scale sufficient to support the data needs of any Feasibility Study. The information presented in the report does not support that matrix diffusion has a significant effect at the site. The facility may consider conducting additional studies at the site to demonstrate its effect, if any. The GSU, however, believes that in the absence of a developed fracture system and due to the poorly-indurated nature of the sandstone, matrix diffusion is not occurring at a significant amount.	The CSM and groundwater flow and transport models are currently being updated based on the data collected during the hydraulic testing investigation. Flow and transport Model updates will include updating the hydraulic conductivity to be consistent with the test results in the BPA hot spot area, reevaluating the flow model water level calibration for the prior flow model calibration, reevaluating the transport model COC calibration for the prior transport model calibration, and updating the mass flux budgets. The model update will also include updating the flow and transport model stress periods and water level and COC data to also cover the 3 year period from 2008-2011, so the updated model covers the 1992 to 2011 period (currently it covers 1992 to 2008). This will make the model more current and provide more credibility in the model by testing the model against a period outside the original calibration (i.e., a bit of model validation).	

Specific Comments		
Comment	**Response**	**Proposed Action**
	Based on the geologic and hydrogeologic investigations conducted to date (see response to General Comment #2), additional work at the Site is not needed to better understand the faults, fractures, buried stream drainage, and/or spatial variations in cementation to support the data needs of the Feasibility Study. Tetra Tech agrees with GSU that the data does not support a fracture system within the BPA and due to the poorly-indurated nature of the sandstone, matrix diffusion is most likely not occurring.	

References:

1. Terra Physics, 2006a. Seismic Reflection Survey to Detect Bedrock Faults, Former Lockheed Beaumont Site 1, South of Beaumont, California. February 2006.

2. Terra Physics, 2006b. Correlations of Seismic Velocity and Stratigraphy in Nine Borings, Former Lockheed Beaumont Site 1, Potrero Creek, South Beaumont, California. March 2006.

3. Tetra Tech, Inc. 2009a. Dynamic Site Investigation Report, Historical Operational Areas B, C, F, G, and H, Beaumont Site 1, Lockheed Martin Corporation, Beaumont, California, July 2009.

4. Tetra Tech, Inc. 2009b. Lineament Study, Lockheed Martin Corporation, Beaumont Site 1, Beaumont California, December 2009.

5. Tetra Tech, Inc., 2010a. Transient Groundwater Model Report, Numerical Flow Model Development, Lockheed Martin Beaumont Site 1, Beaumont, California, January 2010.

6. Tetra Tech, Inc., 2010b. Potrero Creek Groundwater Pumping Test Report, Numerical Flow Model Development, Lockheed Martin Beaumont Site 1, Beaumont, California, January 2010.

7. Tetra Tech, Inc., 2010c. Supplemental Groundwater Monitoring Well Installation Report, Lockheed Martin Corporation, Beaumont Site 1, July 2010.

8. Tetra Tech, Inc., 2010d. Summary Remedial Investigation Report, Lockheed Martin Corporation, Beaumont Site 1, November 2010.

9. Tetra Tech, Inc., 2011. Numerical Groundwater Transport Model Development, Lockheed Martin Beaumont Site 1, Beaumont, California, July 2011.

REVISED
HYDRAULIC TESTING SUMMARY REPORT POTRERO CANYON UNIT (LOCKHEED MARTIN BEAUMONT SITE 1) BEAUMONT, CALIFORNIA

Prepared for:
Lockheed Martin Corporation

Prepared by:
Tetra Tech, Inc.

February 2013

Benjamin M. Weink, P.G. California 8037
Potrero Canyon Unit Manager

PROFESSIONAL GEOLOGIST
BENJAMIN MICHAEL WEINK
No. 8037
Exp. 3/31/13
STATE OF CALIFORNIA

Bob Johns, PhD
Principal Engineer

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Revised

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ACRONYMS

AQMD	Air Quality Management District
ASTM	American Society of Testing Materials
BPA	Burn Pit Area
bgs	below ground surface
CO_2	carbon dioxide
COC	chemical of concern
COD	chemical oxygen demand
1,1-DCE	1,1-dichloroethene
DFN	Discrete Fracture Network
DTSC	Department of Toxic Substances Control
DWNL	drinking water notification level
ECD	Electron Capture Detector
FLUTe	Flexible Liner Underground Technologies
FS	feasibility study
GC	gas chromatograph
gpm	gallons per minute
HASP	Health and Safety Plan
HT	High Torque
IDW	investigation derived waste
LCS	laboratory control samples
LMC	Lockheed Martin Corporation
m	meter
m^2/day	square meters per day
m^3/day	cubic meters per day
MCL	maximum contaminant level
MDL	method detection limit
MEF	Mount Eden formation

mg/kg	milligram per kilogram
mg/L	milligram per liter
µg/L	microgram per liter
µg/kg	microgram per kilogram
MS/MSD	matrix spike/matrix spike duplicate
$Na_2S_2O_8$	sodium persulfate
NaOH	sodium hydroxide
pcf	pounds per cubic foot
PHPA	partially hydrolyzed polyacrylamide/polyacrylate
PPE	personal protective equipment
ppmv	parts per million by volume
PQL	Practical Quantitation Limit
PSAP	Programmatic Sampling and Analysis Plan
PVC	polyvinyl chloride
QA	Quaternary alluvium
QC	quality control
RPD	Relative Percent Difference
RQD	Rock Quality Designation
RWQCB	Regional Water Quality Control Board
SCAQMD	South Coast Air Quality Management District
SKR	Stephens' kangaroo rat
SM	silty sand
SW-SM	well graded sand with silt
scfm	standard cubic feet per minute
TDS	total dissolved solids
TCE	trichloroethene
TOC	total organic carbon
VOCs	volatile organic compounds

EXECUTIVE SUMMARY

Hydraulic testing was conducted at five features within the Potrero Canyon Unit (Lockheed Martin Beaumont Site 1) to provide additional data and information needed to better evaluate the range of remedial alternatives in the upcoming feasibility study (FS). Although characterization of the nature and extent of contamination is complete, hydraulic testing at these five features will fill data gaps to better understand the fate of groundwater impacts at these features and provide valuable information for evaluating alternatives and assessing the effectiveness of remedial technologies during the FS.

In the Burn Pit Area (Feature C-22), the primary source area for the Site, vadose zone permeability testing, slug testing, ex situ waste water treatment, and a constant-rate aquifer test including vacuum-enhanced extraction were conducted to provide additional data to evaluate the feasibility of remedial technologies in this area. In addition, bedrock coring, borehole geophysics, and hydraulic testing of the sandstone matrix was performed to evaluate faults, fracture systems and secondary permeability within the Burn Pit Area that could affect contaminant fate and transport and potentially the design and operation of any remedial technologies in the source area.

The water quality sampling results from eight BPA wells were consistent with surrounding wells but fill in gaps where data wasn't previously available. Physical properties of the BPA soils and TOC were collected for contaminant attenuation and any engineering geologic aspects needed for the FS.

Slug testing was also conducted in other areas of the Site where groundwater contamination exists but no information on hydraulic conductivity is available to adequately evaluate alternatives and understand the fate and transport of these impacts. These areas include the Pad with Dry Well (Feature B-14), Large Motor Washout Area (Feature F-33), Maintenance Shop and Warehouse Area (Feature F-34), and the Test Bays (Feature F-39).

The slug tests for the vast majority of the locations were in wells screened in the Mount Eden formation sandstone, while only a few of the well locations were screened in the alluvium/weathered Mount Eden sandstone. The average (geometric mean) hydraulic conductivity value was 0.021 feet per day for wells screened in the sandstone and 2.9 feet per day for wells screened in the alluvium/weathered sandstone. The range of hydraulic conductivity values within the Burn Pit Area varied from less than 0.00001 to 10 feet per day. The EW-20 constant rate aquifer test was conducted by pumping the well for 77 hours (3 days and 5 hours) at a steady rate of 0.125 gpm with drawdowns reaching up to 12.87 feet in the pumping well. Aquifer transmissivity values ranged from 0.58 $feet^2$ per day to 4.37 $feet^2$ per day with a geometric mean value of 1.46 $feet^2$ per day. Storage values were in the confined range averaging 0.0017, and indicate the main permeable zone feeding the pumping well is overlain by a lower permeability aquitard where the water table is located. The groundwater extraction rate for the vacuum-enhanced phase of the aquifer test was 0.26 gpm with an applied vacuum of about 10 feet of water. The effect of vacuum enhancement increased the groundwater extraction rate to 2.1 times the rate without vacuum. As expected, air flow and vapor concentrations were fairly low in the sandstone matrix.

Three angled boreholes were installed in the Burn Pit Area to characterize the Mount Eden sandstone and contaminant concentrations with depth. While very few fractures or changes in lithology were noted in the cores, differences in the hardness (induration) of the sandstone were considered the characteristic that varied the most. Overall, the MEF sandstone is a weakly to moderately indurated arkosic sandstone that is massively bedded. Results of the rock core analyses show that the contaminant mass (perchlorate, 1,1-DCE, and TCE) is primarily between 57 and 101 feet bgs and concentrations decrease rapidly below 101 feet and are nearly non-detect below 105 feet.

Results of the hydraulic conductivity profiling of BH-1 and BH-2 showed that both boreholes had very low conductivities and did not indicate fracture flow except at a depth of between 92 and 107 linear feet in BH-2 in the area of the potential fault. The average hydraulic conductivity value for BH-1 was 0.009 feet per day, which is roughly a factor of two lower than the sitewide average MEF hydraulic conductivity value of 0.019 feet per day. The range of hydraulic conductivity values in BH-1 varied from 0.00003 to 0.57 feet per day while the range in BH-2 varied from 0.007 to 6.3 feet per day.

Well installations occurred in all three angled boreholes. Boreholes BH-1 and BH-2 were installed with Water FLUTe multilevel monitoring systems (five ports in BH-1/MW-111 and three ports in BH-2/MW-112). BH-3/MW-110 was installed with a 2-inch diameter single completion pre-pack well across the zone of flowing sands from 110 to 130 linear feet along the borehole (95.3 to 112.6 vertical feet).

In order to support Lockheed Martin's goals of waste minimization and sustainability, water generated as part of the constant rate aquifer test was used to conduct a bench-scale wastewater treatment test using sodium persulfate for the 1,4-dioxane and VOCs and a carbon substrate for perchlorate. Overall, samples collected and analyzed for perchlorate for the glycerin treatment test with diammonium, phosphate showed minimal reduction of perchlorate over a two month period. The activation of sodium persulfate in the presence of a naturally occurring iron in the soil or a strong base (NaOH) yielded favorable results with a VOC reduction (TCE, 1,1-DCE and 1,4-dioxane) by more than 98%. Overall, chemical oxidation resulted in an increase in sulfate concentrations from 17 to 38 mg/L. The treatment process had little to no effect on perchlorate.

SECTION 1 INTRODUCTION

Tetra Tech, Inc. (Tetra Tech) has prepared this *Hydraulic Testing Summary Report* for the Potrero Canyon Unit, former Lockheed Martin Corporation (LMC) Beaumont Site 1 (the Site), located in Beaumont, California. A Site location map is provided in Figure 1-1. The report documents the testing of hydraulic properties at five features where additional hydraulic information is needed to better evaluate potential remedial alternatives in the upcoming feasibility study (FS). The five areas were selected based on a preliminary evaluation of areas with data gaps for the development and screening of remedial alternatives as part of the FS. The selection of these areas does not imply that remedial actions will be conducted at each of these areas; nor does it imply that remedial actions will not be conducted in other areas of the Site. The five features where the hydraulic testing was performed are shown in Figure 1-2 and include the Pad with Dry Well (Feature B-14), the Burn Pit Area (BPA) (Feature C-22), Large Motor Washout Area (Feature F-33), Maintenance Shop and Warehouse Area (Feature F-34), and the Test Bays (Feature F-39). A special focus of testing was the BPA where the hydrogeology is complex and previous remedial actions have been implemented, but high concentrations of perchlorate, 1,4-dioxane, and chlorinated volatile organic compounds (VOCs) remain.

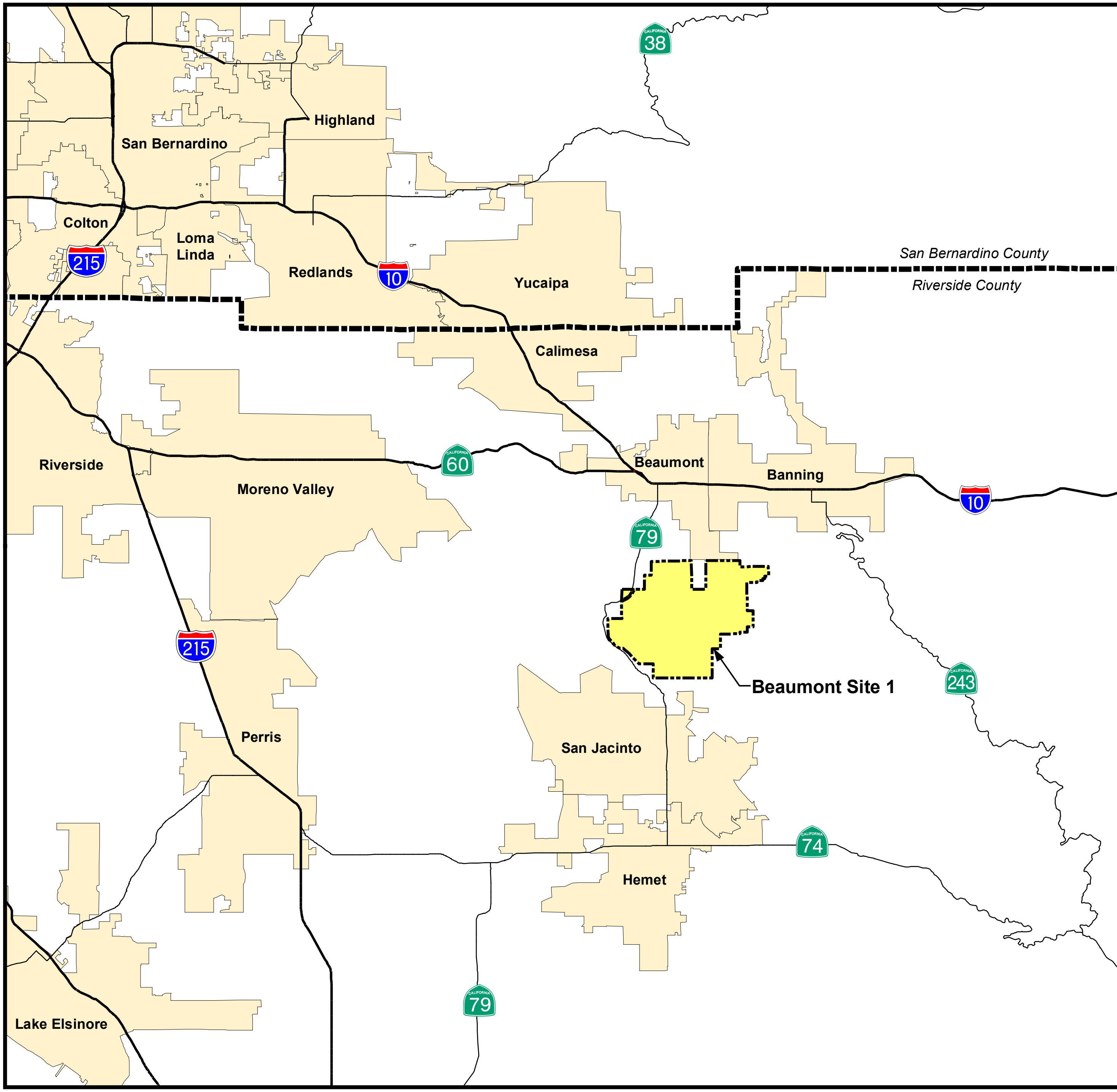
1.1 OBJECTIVES

The overall objectives of the additional hydraulic testing conducted at the Site were to fill data gaps and provide additional hydraulic data to support the evaluation of remedial alternatives at the Site as part of the upcoming FS. The main specific objective of the hydraulic testing is listed below:

- Estimate the lateral and vertical variability in hydraulic conductivity at five features (B-14, C-22, F-33, F-34, and F-39).

Additional objectives for hydraulic testing within the BPA (Feature C-22) are to:

- Estimate the range of vadose zone permeabilities in order to evaluate surface infiltration as a source area treatment during the FS.
- Determine the maximum sustainable extraction rate for a groundwater extraction well with and without a vacuum, including the influence of any aquifer constraints that may impact the long-term aquifer yield.



Adapted from:

U.S. Census Bureau TIGER line data, 2000.

LEGEND

- County Boundary
- Property Boundary
- City

Beaumont Site 1

Figure 1-1

Regional Location Map of Beaumont Site 1

TETRA TECH

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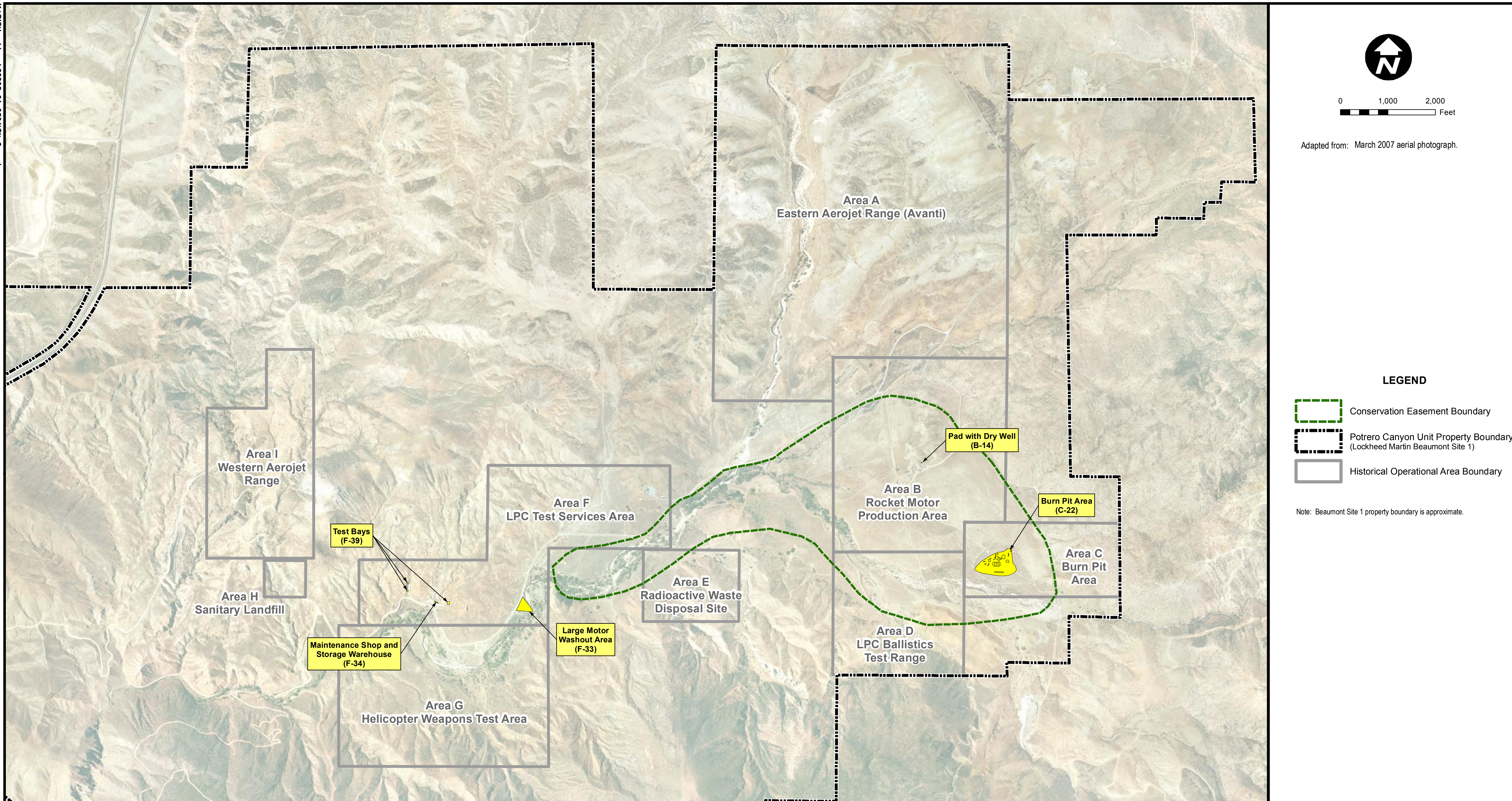


Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 1-2
Site Features for Hydraulic Testing

TETRA TECH

- Estimate aquifer properties (transmissivity, storativity, specific yield, and specific capacity) in the vicinity of the BPA groundwater extraction well; estimate the radius of influence around the extraction well; and evaluate the effectiveness of dewatering within the Mount Eden formation (MEF) sandstone.
- Evaluate bedrock fracture systems, rock-quality designations (RQDs), and secondary porosity and permeability that may be influencing groundwater contaminant distribution and transport.
- Evaluate *ex situ* treatment of extracted groundwater.

In the BPA, technologies that may be analyzed in the FS include surface infiltration to treat perchlorate in the vadose zone and pump-and-treat or vacuum-enhanced extraction to treat groundwater. Therefore, vadose zone permeability testing, slug testing, and a constant-rate aquifer test which included vacuum-enhancement were conducted to provide additional data to evaluate the feasibility of these technologies in this area. In addition, faulted and/or fractured bedrock may be present in the BPA, and possible secondary permeability could affect the distribution of contaminants and potentially the design and operation of any remedial technologies in this source area. To date, no coring of the sandstone has been conducted at the Site and thus no information is available on the nature and physical characteristics of the subsurface MEF sandstone. Thus, bedrock coring, borehole geophysics, and hydraulic testing of the sandstone matrix and fracture zones were recommended to evaluate faults, fracture systems, and secondary permeability within the BPA.

Slug testing was proposed in other areas of the Site where groundwater contamination exists and extraction and treatment or *in situ* treatment may be considered, but limited information on hydraulic conductivity is available to evaluate the feasibility of different technologies. The hydraulic conductivity data are also needed to evaluate the fate and transport of groundwater contaminants in each of these areas. These areas include the Pad with Dry Well (Feature B-14), Large Motor Washout Area (Feature F-33), Maintenance Shop and Warehouse Area (Feature F-34), and the Test Bays (Feature F-39).

In general, the hydraulic testing scope of work consisted of the following tasks:

- Slug testing
- Bedrock coring, borehole geophysics, and fracture permeability testing
- Constant-rate aquifer testing, including a test of vacuum-enhanced extraction

- Vadose zone permeability testing
- Waste characterization, on-site treatment, and disposal

1.2 CHANGES TO THE WORK PLAN

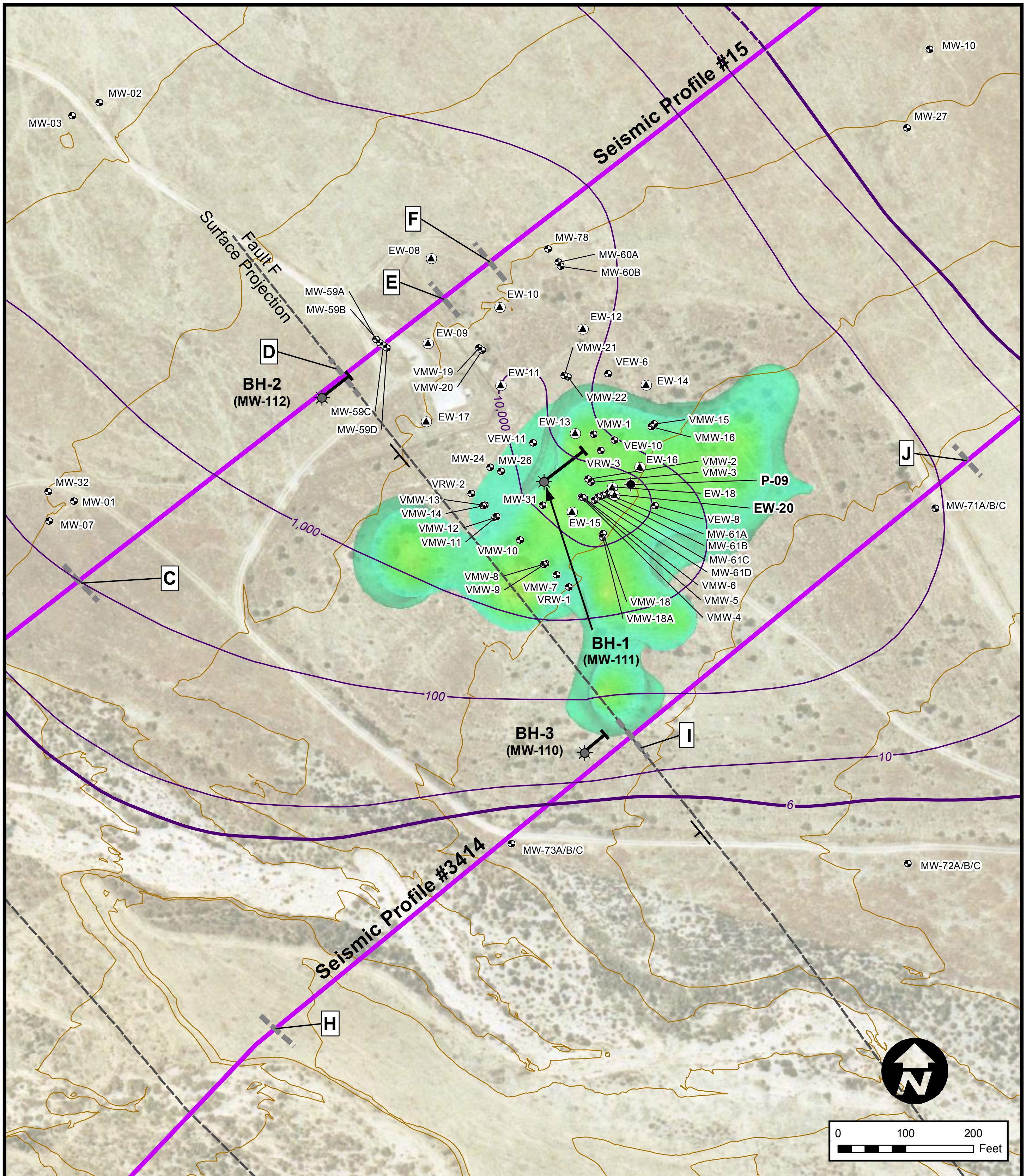
Based on recommendations from LMC's Strategic Evaluation Team, additional hydraulic testing, remedial characterization, and the installation of multi-level groundwater monitoring systems were proposed as part of the hydraulic testing planned for the Site, as described in the Hydraulic Testing Work Plan (Tetra Tech, 2011). The proposed changes and expansion of the original remedial characterization activities were discussed with the Department of Toxic Substances Control (DTSC) on July 26, 2011 and documented in an LMC letter dated August 12, 2011, revised on September 8, 2011, and approved by DTSC on September 9, 2011. The proposed changes, which are listed below, are further described in the subsequent sections.

- Borehole #1 (BH-1) would be advanced another 50 linear feet to a total borehole depth of 200 linear feet (173.2 vertical feet) with rock core sampling and analysis for VOCs and perchlorate (angled borehole approximately 30° from vertical).
- Installation of up to 11 multilevel monitoring systems within the three angled bedrock boreholes BH-1, Borehole #2 (BH-2), and Borehole #3 (BH-3). (See Figure 1-3.)
- Perform vertical vadose zone permeability testing during the installation of the piezometers proposed for the constant rate aquifer test. Collect soil samples for total organic carbon (TOC) and physical properties from representative lithologies.

1.2.1 Rock Core Sampling and Analysis

In order to better characterize the vertical distribution of contaminants within the MEF sandstone, BH-1 was drilled an additional 50 linear feet (total depth of 200 linear feet) with rock matrix sampling and analysis for VOCs and perchlorate following the Discrete Fracture Network (DFN) Approach developed by Dr. Beth Parker and her colleagues at the University of Guelph, Canada. The DFN Approach has been developed as a framework for characterization of contaminated sites in fractured rock utilizing different tools including rock core analyses, Flexible Liner Underground Technologies , and multilevel monitoring systems. The DFN method recommends the collection of closely spaced discrete rock matrix samples in order to obtain a high resolution of the contaminant mass distribution and which fractures or fracture zones are actively involved in transmitting contaminant mass. The high- density sampling also provides information regarding the diffusion profile in the matrix block away from the fracture zone. An average of one sample every two feet was collected and analyzed within the sandstone and analyzed for VOCs using

X:\GIS\Lockheed 26205_01_0505\Borehole_Locs2.mxd



LEGEND

- Angled Borehole Location
- Monitoring Well
- Extraction Well
- Piezometer
- Seismic Feature Location
- Dip Direction
- Seismic Profile Line
- Fault, Approximately Located
- Topographic Elevation Contour
- Groundwater Perchlorate Concentration Contour
- Groundwater Perchlorate MCL Contour

Soil Perchlorate Concentration

- >100,000 μg/kg
- 30,000 μg/kg
- 10,000 μg/kg
- 3,000 μg/kg
- 1,000 μg/kg
- 300 μg/kg
- 100 μg/kg
- 30 μg/kg
- <10 μg/kg

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 1-3

Location of Angle Boreholes, New Extraction Well and Piezometer

TETRA TECH

EPA Method SW8260 and perchlorate by EPA Method 6860. The analysis of 1,4-dioxane was not conducted due to the very high detection limit (4,000 micrograms per kilogram [µg/kg]) for the methods available for rock cores. This high of a detection limit would not provide usable data since the maximum concentration of 1,4-dioxane detected in groundwater during the most recent sampling event was 570 micrograms per liter (µg/L). Approximately 5% of the rock matrix samples collected were also analyzed for physical properties (bulk density, percent moisture, and porosity) and fraction of organic carbon content. Samples were collected at significant changes in lithology or approximately every 20 feet.

1.2.2 Installation of Multilevel Monitoring Systems

In accordance with the DFN Approach, multilevel monitoring systems were installed in place of the single completion pre-packed monitoring wells specified in the Work Plan (Tetra Tech, 2011) in two of the three angled boreholes (BH-1 and BH-2). As described later in Section 3.4, a single pre-packed monitoring well was installed in angled borehole BH-3 since bedrock was not encountered until near the total depth of the borehole and therefore no bedrock coring was conducted. Utilizing the FLUTe impermeable flexible liner upon completion of the coring helped minimize cross-connecting flows and cross-contamination within the borehole. The multilevel monitoring systems (Water FLUTes) were designed (number of ports and depths) after the hydrogeologic (cores, geophysical/televiewer logs, and conductivity profiles) information and rock core sampling data had been collected and reviewed, since the blank liners installed after drilling kept the boreholes sealed. Installation of the Water FLUTe was conducted after the blank liner was removed to minimize the time that the borehole was open, which might allow cross - contamination between fracture zones could occur.

1.2.3 Extraction Well Installation

A new extraction well (EW-20) was installed for the constant-rate aquifer test since the existing well (EW-18) selected for the test had an obstruction near the top of the screen that would not allow the submersible pump and transducer to be lowered into the screened interval. EW-20 was installed near the MW-61A-D well cluster just south of EW-18 (Figure 1-3).

1.2.4 Vertical Vadose Zone Permeability Testing

As part of the installation of the extraction well and piezometer for the constant rate aquifer test, vadose zone permeability tests were conducted in EW-20 and the newly installed piezometer PZ-

09 to supplement the vadose zone permeability tests planned for the existing vapor extraction/recovery wells screened above the current water table (Figure 1-3). These tests would help to evaluate permeability changes with depth. As stated in the Work Plan, the vadose zone permeability tests were conducted to evaluate the feasibility of surface infiltration at the BPA as a potential treatment option for vadose zone soils if needed.

1.3 REFERENCE DOCUMENTS

The field procedures for hydraulic testing were conducted in accordance with the documents listed below. All onsite activities were done in accordance with the approved *Habitat Conservation Plan* (USFWS, 2005) and subsequent clarifications (LMC, 2006a and 2006b).

- *Low Effect Habitat Conservation Plan* (USFWS, 2005)
- *Programmatic Sampling and Analysis Plan* (PSAP) (Tetra Tech, 2010)
- *Engineering Geology Field Manual, Volume II*: (USBR, 2001)
- *Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core [American Society of Testing Materials* (ASTM) Standard D6032-08] (ASTM, 2008)

SECTION 2 SUMMARY OF HYDRAULIC TESTING FIELD ACTIVITIES

This section summarizes the hydraulic testing activities conducted, including site preparation activities, slug testing, water quality sampling, extraction well/piezometer installation, vadose zone permeability testing, aquifer testing, bedrock characterization, and investigation derived waste (IDW) treatment and disposal.

2.1 SITE PREPARATION ACTIVITES

Pre-drilling activities that were part of this investigation include: well installation permitting, underground utility clearance, biological monitoring, health and safety, and air permitting.

Well Installation Permits

Prior to commencing field activities, well permit applications for each groundwater monitoring/extraction well were submitted to the Riverside County Department of Environmental Health Services. Copies of the approved permits are provided in Appendix A.

Underground Utility Clearance

Prior to commencement of intrusive activities, drilling locations were marked for subsurface utility clearance. Underground Service Alert was contacted prior to the commencement of drilling activities in order to identify potential underground utility or service lines near the proposed drilling locations. Prior to drilling, the hollow stem auger borings were hand augered to five feet below ground surface (bgs) or refusal to ensure clearance of subsurface utilities or obstructions. No underground utility or service lines were encountered during the drilling activities.

Biological Monitoring

Prior to initiating field sampling activities, biological surveys of proposed groundwater monitoring/extraction well locations were performed by a Section 10A permitted or sub permitted biologist to evaluate the potential for impacts to sensitive species and habitats (e.g., Stephens' Kangaroo rat [SKR]). As part of the biological survey, the biologist identified and marked potential or suspected SKR burrows that were located within the vicinity of each drilling location to avoid the potential "take" of SKR or disruption of sensitive habitat. The biologist also clearly marked the ingress and egress routes at each drilling location in an effort to minimize the overall footprint of the field activities and to prevent potential SKR "take".

Health and Safety

Selection of personal protective equipment (PPE) was made prior to the commencement of field work. Based on previous field activities at the Site and the site-specific Health and Safety Plan (HASP), modified Level D was utilized at the start of field activities. As site conditions and field activities changed, the PPE level was reevaluated and kept unchanged throughout the field program.

Air Permitting

Tetra Tech submitted the application for the permit to construct/operate a soil vapor extraction system to aid in the constant rate aquifer test. The soil vapor extraction equipment was permitted to treat VOCs, but was not specifically permitted to treat 1,4-dioxane and halogenated hydrocarbons. Therefore, Tetra Tech submitted the application to add the treatment of 1,4-dioxane and halogenated hydrocarbons as part of the off-gas treatment system. Tetra Tech was issued Permit No. G14342 on July 21, 2011. Pursuant to Permit Condition No. 22, Tetra Tech notified the South Coast Air Quality Management District (SCAQMD) in writing 45 days after startup documenting the results of the tests, including grab sample analysis, inlet flow rate and temperature readings, and vapor outlet VOC concentrations. see Appendix B.

2.2 SLUG TESTING

Slug tests were conducted at 30 wells located in five areas of the Potrero Canyon Unit: Feature B-14 (Pad with Dry Well); Feature C-22 (the BPA); Feature F-33 (Large Motor Washout Area); Feature F-34 (Maintenance Shop and Warehouse Area); and Feature F-39 (Test Bays), see Figure 2-1. Thirty slug tests were conducted between June and July 2011. Two additional slug tests were performed in newly installed wells (EW-20 and MW-110) in December 2011. These five features represent source areas where groundwater monitoring or mitigation may be required and therefore an understanding of the aquifer permeability is needed to support an evaluation of the feasible remedial alternatives applicable at each feature. Table 2-1 lists the Area/Feature and wells in which slug tests were performed.

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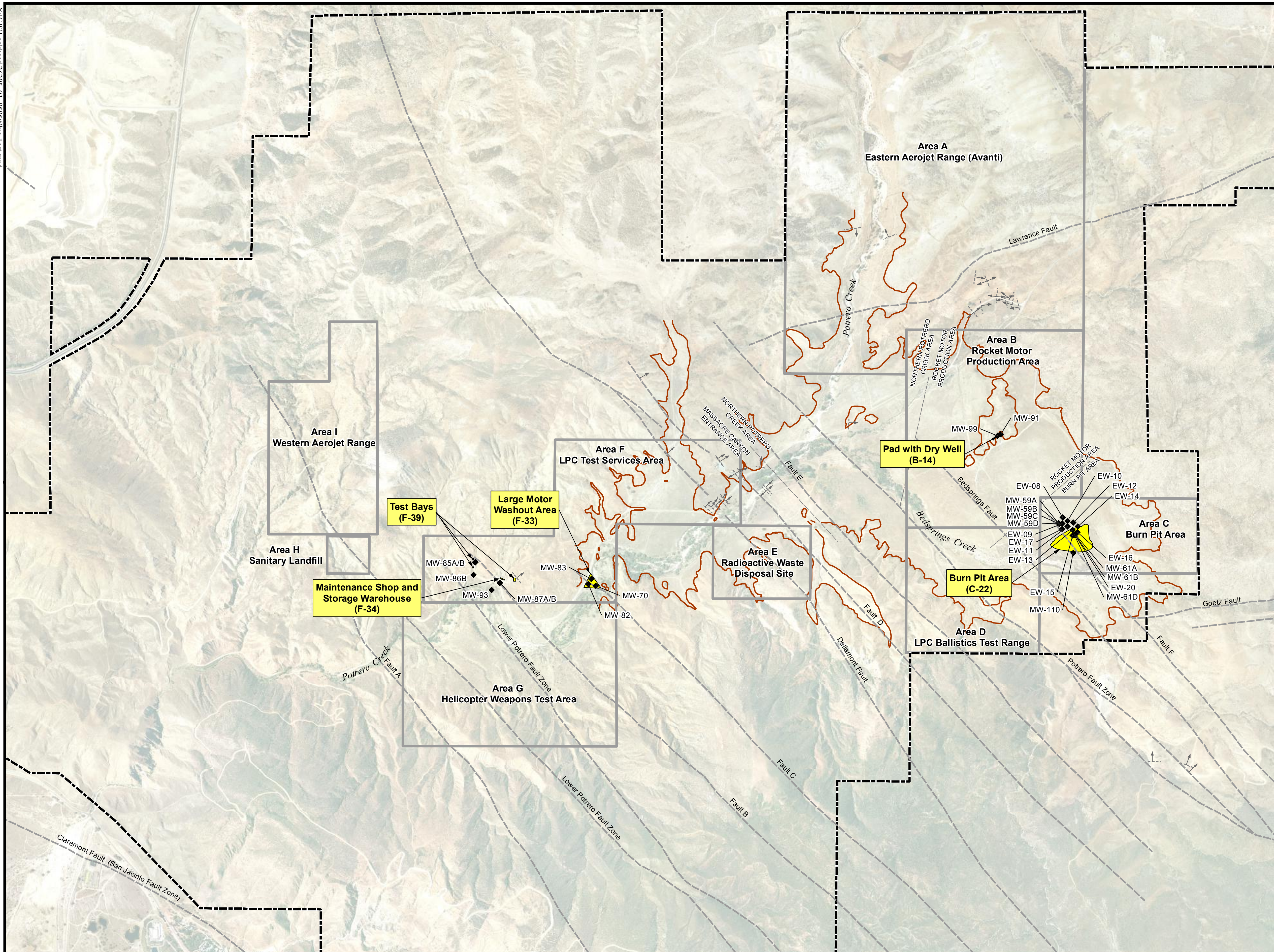

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

- ◆ Slug Testing Well
- Fault, Accurately Located Showing Dip
- Fault, Approximately Located
- Bedrock/Alluvium Surface Contact
  Dashed where inferred
- Historical Operational Area Boundary
- Beaumont Site 1 Property Boundary

Note:

Beaumont Site 1 property boundary is approximate.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 2-1
Slug Testing Locations
Features B-14, C-22, F-33, F-34, and F-39

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Table 2-1 Slug Testing Locations

Area	Well ID		
Burn Pit Area (Feature C-22)	EW-08	EW-15	MW-61A
	EW-09	EW-16	MW-61B
	EW-10	EW-17	MW-61D
	EW-11	MW-59A	EW-20
	EW-12	MW-59B	MW-110
	EW-13	MW-59C	-
	EW-14	MW-59D	-
Large Motor Washout Area (Feature F-33)	MW-70		
	MW-82		
	MW-83		
Test Bay (Feature F-39)	MW-85A		
	MW-85B		
	MW-86B		
Maintenance Shops and Storage Warehouse (Feature F-34)	MW-87A		
	MW-87B		
	MW-93		
Pad with Dry Well (Feature B-14)	MW-68		
	MW-91		
	MW-99		

Slug tests were performed on three wells at the Pad with Dry Well (MW-68, MW-91, and MW-99) and on three wells in the Large Motor Washout Area (MW-70, MW-82, and MW-83) to evaluate the range of hydraulic conductivities near the perchlorate source areas. At the Maintenance Shop and Warehouse Area, slug tests were performed on three wells (MW-87A, MW-87B, and MW-93) to assess both the lateral and vertical hydraulic conductivity in the area where the highest groundwater contaminant concentrations have been detected. At the Test Bays, slug tests were performed on wells MW-85A, MW-85B, and MW-86B to estimate the hydraulic conductivities within the shallow and deeper MEF near the trichloroethene (TCE) source area.

Slug tests were performed on 17 wells at the BPA in June through July 2011 to evaluate the range of hydraulic conductivities at the BPA, to determine if a long -term aquifer test was needed, and to help identify which well should be used for the aquifer test. Subsequent to well installation and the constant -rate aquifer test, slug tests were performed on wells EW-20 and well MW-110 in December 2011 to aid in this evaluation.

2.3 WATER QUALITY SAMPLING AND ANALYSIS

Water quality samples were collected from seven extraction wells located in the BPA (: EW-08, EW-09, EW-10, EW-11, EW-12, EW-14, EW-17 and monitoring well MW-61D). MW-61D (see Figure 2-2). Groundwater samples were collected on August 29 through August 31, 2011, and analyzed for VOCs, 1,4-dioxane, and perchlorate, since water quality data were not available for these wells. The groundwater sampling was performed with portable sampling equipment. Both equipment blanks and trip blanks were collected at the beginning of each sampling day. The additional water quality data were collected to help evaluate which extraction well displayed both a high hydraulic conductivity and elevated groundwater contaminant concentrations for the constant -rate aquifer test.

2.4 EXTRACTION WELL AND PIEZOMETER INSTALLATIONS

The installation of one piezometer and one groundwater extraction well was performed between 26 September and 30 September, 2011. 2011 (see Figure 2-2). All wells were installed in accordance with the approved Work Plan. The groundwater piezometer and extraction well were installed using a CME 75 High Torque (HT) drill rig from Tri County Drilling out of San Diego, California. Groundwater piezometer P-09 and groundwater extraction well EW-20 were installed near monitoring well cluster MW-61A through MW-61D using hollow stem auger drilling techniques. P-09 was drilled to a total depth of 111 feet bgs and was installed with nominal 2-inch diameter well casing to a total depth of 110 feet bgs. Well casing material consisted of 2-inch schedule 40 polyvinyl chloride (PVC) blank casing and stainless steel wire-wrapped 0.020-inch slot screen. The piezometer was screened from 70 to 110 feet bgs. Extraction well EW-20 was constructed using nominal 4-inch diameter PVC blank casing and 4-inch diameter, 0.020-inch wire-wrapped stainless steel screen. The extraction well was screened from 70 to 110 feet bgs. Field procedures used for drilling, lithologic logging, and borehole abandonment are described in the PSAP (*Programmatic Sampling and Analysis Plan* (PSAP; Tetra Tech, 2010). Copies of the soil boring logs and well completion diagrams are provided in Appendix C. Well development field sheets are provided in Appendix L.

2.4.1 Soil Sampling and Analysis

Soil samples were collected to evaluate the distribution of total organic carbon in the vadose zone. Procedures for soil sampling and analysis are described in the PSAP. To provide profiles of organic carbon with depth to support the contaminant attenuation conceptual site model, samples

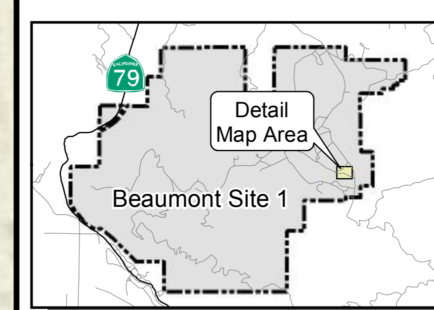
X:\GIS\Lockheed 26205_01_0505Burn Pit.mxd

0 50 100Feet

LEGEND

- Vadose Zone Permeability/ Slug Test Well
- Constant Rate Aquifer Test Pumping/ Slug Test/Vadose Zone Permeability Test Well
- Water FLUTe Multiport Monitoring Well
- Vadose Zone Permeability Test Well
- Water Quality / Slug Test Well
- Slug Test Well
- Existing BPA Well
- Fault Location
- Former Burn Pit Location
- Burn Pit Boundary

Note: Orange highlighted text indicates observation well for constant rate aquifer test.



Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 2-2
Hydraulic Testing and Bedrock Characterization Locations- Burn Pit Area (Feature C-22)

TETRA TECH

were typically collected at 5-foot intervals and submitted to E.S. Babcock Laboratory for analysis of (TOC) by EPA Method 9060 and total solids by Method SM 2540B. Subsets of these samples (up to 10 per site) were collected based on lithology to determine the soils' physical properties to support the contaminant attenuation model, the forthcoming feasibility studies, treatability studies, and/or remedial actions. These samples were collected using 6-inch stainless steel or brass sleeves and were submitted to Environmental Geotechnology Laboratory Inc. for the following analyses: including sieve analysis (ASTM D422), specific gravity (ASTM D854), total porosity (API RP40), moisture content and dry bulk density (ASTM D2937).

Sampling was conducted using an 18-inch split spoon sampler. Soil samples were collected from the relatively undisturbed formation by advancing an 18-inch split spoon sampler, lined with the three 6-inch sleeves, ahead of the auger bit. The recovered soil within the sleeves, if chosen based on lithology, was analyzed for geotechnical parameters. Samples selected for TOC analysis were collected from the following split spoon sampler driven in the next 5-foot interval which did not contain the 6-inch sleeves.

2.5 VADOSE ZONE PERMEABILITY TESTING

Vadose zone permeability tests were conducted in boreholes EW-20 and P-09 between September 26 and 30, 2011. The tests were conducted at multiple depths in each borehole during drilling, as indicated in Table 2-2. Vadose zone permeability tests were also performed in four vapor extraction wells (VEW-6, VEW-8, VEW-10, and VRW-1) on October 28, 2011, to obtain additional data on vadose zone permeability in the BPA. The test locations are shown in Figure 2-2.

Table 2-2 Vadose Zone Permeability Testing Locations

Location	Type	Depths (ft bgs)
EW-20	Borehole	20, 40, 50
P-09	Borehole	20, 40, 50, 65
VEW-6	Vapor Extraction Well	67.45
VEW-8	Vapor Extraction Well	50.49
VEW-10	Vapor Extraction Well	54.41
VRW-1	Vapor Recovery Well	49.65

The borehole tests in EW-20 and P-09 were conducted using the U.S. Bureau of Reclamation Gravity Permeability Test Method 1, from Chapter 17 of the *Engineering Geology Field Manual,* *2nd Edition* (USBR, 2001). 1998). The borehole was advanced to the bottom of the desired test interval, and the hollow stem augers were raised approximately 10 feet. Two hand -perforated PVC pipes (one 2-inch fill pipe and one ¾-inch monitoring pipe) were suspended in the borehole, and the lower 10 feet of the borehole were backfilled with coarse sand. Testing was conducted by injecting potable water into the borehole through the fill pipe, while simultaneously monitoring the depth to water in the monitoring pipe with a water level meter. The rate of flow into the borehole was measured and adjusted until the depth to water had stabilized (i.e., three successive water level measurements taken at 5-minute intervals were within 0.2 foot). The stable flow rate and height of the water column in the borehole were recorded for estimation of the saturated hydraulic conductivity of the test interval. After each test was completed, the fill and monitoring pipes were removed and the augers advanced to the bottom of the next test interval. The vapor extraction well permeability tests were conducted in a similar manner, except that water was poured directly into the well casing and water levels were measured without using an observation pipe.

Stable water levels could not be obtained during the 65-foot test in boring P-09 and the test in vapor extraction well VEW-6 at the lowest readily measurable flow rate (~0.1 gallon per minute). In addition, no accumulation of water was noted during the test in vapor extraction well VRW-1 at the highest attainable flow rate (~6 gallons per minute). Although numerical estimates of saturated hydraulic conductivity could not be calculated from these tests, the results indicate that the saturated hydraulic conductivities from P-09 (65-foot depth) and VEW-6 were lower than the lowest calculated value recorded. Similarly, the saturated hydraulic conductivity in VRW-1 would be higher than the maximum saturated hydraulic conductivity estimated from the other permeability tests.

2.6 AQUIFER TESTING

A step draw down test was performed on October 11, 2011, following development of the extraction well (EW-20) and piezometer (P-09). Prior to this test, the extraction well was allowed to stabilize for approximately one week. Electronic pressure transducers were initially placed in these wells and in the surrounding extraction/monitoring wells (EW-13, EW-15, EW-16, EW-18, MW-31 and MW-61A, B, C, D) to monitor the barometric and diurnal effects on static water levels and to ensure stable conditions prior to the start of the long -term pumping test. The purpose of the stepdraw down test was to determine the amount of groundwater drawdown at various pumping rates to identify the optimal pumping rate for the constant -rate test.

The step test was conducted on EW-20 by pumping the well at three pumping rates (0.055, 0.10, and 0.30 gallons per minute (gpm). Pumping continued at each pumping rate for a minimum of one hour after water levels stabilized. Measured drawdowns in the extraction well were 2.14, 4.36, and 13 feet, respectively. Pre- and post-water level measurements were collected to adequately document local background conditions in the aquifer. All water level measurements were recorded within 0.01 foot precision. Because water levels dropped rapidly within the first several minutes of pumping, water level measurements were taken manually and electronically using pressure transducers. Additional test data recorded during the step drawdown test includes the start and stop time, pumping rate, cumulative flow, and drawdown at each pumping rate. By the end of the step test, approximately 55 gallons of extracted groundwater were discharged to a dewatering bin.

The constant rate aquifer test was performed in two stages: (1) using a long-term sustainable pumping rate and (2) under vacuum-enhanced conditions. Prior to conducting the constant rate aquifer test, a soil vapor extraction and treatment system and associated piping were connected to well EW-20.

The constant-rate aquifer test commenced on October 18, 2011, following a 7-day recovery from the step drawdown test. The constant-rate aquifer test was conducted at a rate of 0.125 gpm in EW-20. The vacuum -enhanced aquifer test ran from Friday, October 21, 2011, through October 23, 2011, at which time the blower shut down due to mechanical difficulties and required replacement. The blower was replaced and the vapor extraction system was started up again on October 26, 2011, and was shut down at the end of the test on Thursday, October 27, 2011. The soil vapor extraction and treatment system operated continuously for a total of 5 days during the two periods. Vapor samples were collected throughout the test at the inlet and the outlet of the soil vapor extraction and treatment system in accordance with Tetra Tech's AQMD Permit to Construct/Operate, Permit No. G14342. EnviroSupply sampled the treatment medium prior to removing equipment from the site. The medium was deemed non-hazardous and the soil vapor extraction and treatment system was removed on October 27, 2011.

Pre- and post-aquifer test water level measurements were collected to adequately document local background conditions in the aquifer. Similar to the step test, water levels were monitored with transducers in well EW-20, piezometer P-09, and in the observation wells in the surrounding area, including EW-13, EW-15, EW-16, EW-18, MW-31 and MW-61A, B, C, D. Aquifer recovery was also monitored in these same wells using transducers for a 7-day period after pumping ceased.

2.7 BEDROCK CHARACTERIZATION ACTIVITIES

to better understand the detailed lithology, structural implications of the projected faults in the area, and contaminant distribution within the MEF sandstone, three angled borehole locations were identified for drilling through the alluvium into more competent MEF sandstone, see Figure 2-2 (Tetra Tech, 2011). The MEF sandstone was then cored using a stainless steel, triple-tube coring device to collect continuous cores through the sandstone. These three boreholes were identified as BH-1, BH-2, and BH-3 in the work plan. These boreholes were later converted to monitoring wells MW-111, MW-112, and MW-110, respectively. Monitoring well MW-110 was installed in BH-3 using a nominal 2-inch diameter pre-pack well because depth to MEF was much deeper than originally thought, and the lithology was consistent with alluvium to a depth of 133 linear feet (115 vertical feet). (The planned borehole depth was 150 linear feet.). Given the depth of the sandstone, no coring was conducted in BH-3. MW-111 was installed in BH-1 using a Water FLUTe sampling system that included five sampling ports (total borehole length, 200 linear feet). MW-112 was installed in BH-2 using a Water FLUTe sampling system with three sampling ports (total borehole length, 150 linear feet). All three boreholes were drilled at an angle of 30° from vertical. In addition to HQ coring in BH-1, the core was sampled on average once every 2 linear feet for chemical analysis to determine contaminant distribution within the MEF sandstone using the DFN sampling approach developed by Dr. Beth Parker from the Center for Applied Groundwater Research at the University of Guelph, in Guelph, Canada. Borehole BH-2 was also drilled and logged using continuous coring methods; however, BH-2 was not sampled every 2 linear feet; the cored sandstone was simply logged in detail to note fractures and changes in lithology and texture. Both BH-1 and BH-2 were logged using downhole geophysical techniques and both boreholes had hydraulic profile testing performed to determine the hydraulic properties of the MEF sandstone. Borehole 3 experienced unstable borehole conditions at depth, and flowing sands between 112 and 122 linear feet required the installation of a pre-pack well rather than the proposed FLUTe multiport sampling system. Therefore, the full suite of borehole geophysics and hydraulic testing using the FLUTe system was not possible in BH-3.

2.7.1 Bedrock Coring

Bedrock coring was accomplished using a CME-75 HT drill rig. The CME 75 HT was used in hollow stem auger mode to drill through the alluvium and to set a permanent conductor casing once MEF sandstone was encountered. The CME 75 HT was then converted to drill using mud rotary drilling techniques. The drill rig used water and a partially hydrolyzed polyacrylamide /polyacrylate (PHPA) synthetic polymer drilling additive to cool the drill bit, lift cuttings to the surface, and to maintain rock samples in as near to original condition as possible when pulling the core from the borehole. A stainless steel, triple tube coring system allowed HQ-size core (63.5-millimeter or approximately 2.5-inch diameter core) to be collected from the MEF sandstone in 5-foot intervals. Each borehole was aligned roughly perpendicular to the trace of the known faults that projected into the BPA. Each borehole was also angled 30° from vertical with the intent to penetrate any faults or fractures associated with the projected faults in the area and to intercept them as near to perpendicular to the fault plane/fracture surface as possible (Tetra Tech, 2011).

As described in the approved work plan, three boreholes were drilled in the BPA with the intent to collect continuous cores from the MEF sandstone. The drilling process included using hollow stem auger drilling techniques to drill through the alluvium and set PVC conductor casing in the alluvium to prevent borehole collapse while coring. Once the conductor casing was set in concrete and allowed to cure for 12 to 24 hours, coring of the MEF sandstone began. In Borehole 1 and 2, the estimated depth to bedrock was fairly accurately predicted. Depth to the MEF in Borehole 3, the borehole to the southwest, was not encountered as predicted. Depth to the MEF in Borehole 3 was encountered at 138 linear feet (about 119.5 vertical feet).

2.7.2 FLUTe Installation

Following completion of the rock coring, FLUTe blank liners were installed in boreholes BH-1 and BH-2 after drilling was completed to prevent cross-contamination from occurring. BH-3 was immediately installed with a nominal 2-inch diameter single completion pre-pack well screen because of the high potential for borehole cave in and because MEF sandstone was not encountered where it was predicted. The FLUTe blank liners were removed immediately prior to conducting the downhole geophysics and the hydraulic conductivity profiling (BH-1 and BH-2 only). Upon completion of the hydraulic conductivity profiling, the blank liners were reinstalled and remained in the boreholes until the Water FLUTe multilevel monitoring systems were installed.

2.7.3 Rock Matrix Sampling & Analysis

Rock matrix sampling and VOC analysis were conducted by Stone Environmental Inc. on rock core retrieved from BH-1 which is located in the area of the highest contaminant concentrations in groundwater, per the approved work plan (Tetra Tech, 2011). Samples were also submitted to E.S. Babcock & Sons for perchlorate analysis. A total of 145 linear feet of coring was conducted and 112.5 linear feet of rock core were retrieved (77.6 % recovery overall). Samples were collected at and adjacent to fractures, at changes in lithology, and at changes in rock core density/degree of induration. A total of 68 rock samples were collected for laboratory analysis (VOCs and perchlorate). A total of seven rock core samples were also collected separately for physical parameter tests. A copy of Stone Environmental’s rock core sampling and analysis report, which describes the detailed sampling and analytical approach and procedures, is included in Appendix D.

2.7.4 Borehole Geophysics

Borehole geophysics were conducted on each angled borehole to collect data on permeability, fractures, and potential changes in lithology. The borehole geophysics were conducted after the FLUTe blank liners were removed in BH-1 and BH-2 prior to the hydraulic conductivity profiling. The borehole geophysical tools included dual induction gamma ray logs, resistivity logs, deviation survey logs, acoustic borehole televiewer surveys, and caliper borehole logs. Since BH-3 was drilled in mostly alluvium and was set with a 2-inch diameter pre-packed well immediately following the completion of drilling, only dual induction gamma ray and deviation logs were collected for this borehole.

2.7.5 Hydraulic Conductivity Profiling

Hydraulic conductivity profiles were conducted in BH-1 and BH-2 following drilling and prior to installing permanent groundwater sampling systems. Hydraulic conductivity profiling was conducted by FLUTe personnel and equipment using the FLUTe blank liners installed after drilling was completed. Hydraulic conductivity profiling was not performed on BH-3 since a pre-pack monitoring well was installed in the borehole immediately following drilling completion.

Results from the hydraulic conductivity profiling were used to design the location of the permanent monitoring ports that were installed later.

Hydraulic conductivity profiling was completed by FLUTe personnel on BH-1 and BH-2 in November 2011. The hydraulic profiling was completed using the FLUTe blank liner and hydraulic conductivity profiling equipment and software. This technique, patented by FLUTe, LLC, uses the installation of a blank liner by everting the liner down the borehole, and allows the operator to map the flow paths within the borehole as the blank liner is being installed. Upon completion of the conductivity profiling, the blank liner used for the measurements was left in the hole to seal the hole against any contaminant migration until the multiport sampling system had been designed and installed.

The system consists of the basic blank liner and a machine which controls the liner tension, records the depth and velocity of installation, and records the water level in the liner (the driving force) in time. From these data, transmissivity was calculated for the entire length of the open borehole past the PVC conductor casing, and the distribution of that transmissivity was plotted for each borehole. This technique allows the identification of all significant flow paths from the borehole. The data are recorded onto a laptop into a spreadsheet which reduces the data to a transmissivity plot of each borehole. The plot is post-processed to estimate hydraulic conductivities in 1-foot intervals.

2.7.6 Monitoring Well Installations

The Water FLUTe was installed in two boreholes (BH-1 and BH-2) and a pre-pack, 2-inch diameter monitoring well was installed in BH-3. The Water FLUTe was installed in BH-1 with five discrete sampling ports and in BH-2 with three discrete sampling ports. As previously stated, BH-3 was installed with a 2-inch diameter pre-pack well system because of depth of bedrock and the instability in the borehole once drilling was completed.

2.8 INVESTIGATION DERIVED WASTE CHARACTERIZATION, TREATMENT, AND DISPOSAL

Groundwater impacted by the BPA typically contains perchlorate, 1,4-dioxane, and VOCs. In order to support LMC's goals of waste minimization and sustainability, it was proposed that the water generated as part of the aquifer pump test and stored in the 6,000 -gallon dewatering tank be treated using sodium persulfate for the 1,4-dioxane and VOCs and a carbon substrate for perchlorate. Glycerin (electron donor) is one of a number of soluble electron donors (substrates) that can be used for the biological anaerobic degradation of perchlorate. Additional chemical aids sometimes required for biotreatment include sodium hydroxide (pH adjuster), citric acid (neutralizer), and diammonium phosphate, DAP (micronutrient). Reagents employed for chemical oxidation of 1,4-dioxane and VOCs include sodium persulfate, $Na_2S_2O_8$, sodium hydroxide, NaOH (pH activator), and sometimes soluble iron (activator). The treatment of water which contains 1,4-dioxane, chlorinated VOCs, and perchlorate can occur in a sequential biological/chemical steps (depending on site specific conditions, logistics, and goals, the sequence of biological and chemical techniques are interchangeable). The objective of the following preliminary (screening) bench-scale test was to evaluate chemical/biological treatment effectiveness and proper sequencing of chemical versus biological treatment sequencing prior to treatment of the 6,000 gallons of water at the Site. . Pending results of the bench test and approval by the Regional Water Quality Control Board (RWQCB) and the DTSC, the intent was to use the treated water in the vadose zone permeability tests in the BPA and/or discharge the water to the ground surface, into the dry streambed, or into existing injection wells.

2.8.1 Bench Scale Test

Brief Technology Description

The chemical oxidation of 1,4-dioxane and VOCs by activated sodium persulfate is a well-known technique for organic contaminant destruction. *Treatment Options for Remediation of 1,4-dioxane in Groundwater* published by the American Academy of Environmental Engineers in Spring 2007 was reviewed for the techniques used in the treatment of 1,4-dioxane. Consultation with FMC Klozur showed that sodium persulfate is typically added to groundwater in excess (10-fold of persulfate to 1,4-dioxane and VOC on a mole to mole basis) with an activator such as, sodium hydroxide (NaOH). Sodium hydroxide is used to increase the pH to a range of 10-12. Activated persulfate produces a free radical sulfate moiety that is a powerful oxidizer.

The University of California, Riverside, and Tetra Tech, Inc. performed extensive laboratory microcosm and column studies on perchlorate-contaminated source area groundwater and vadose zone soil at Beaumont Site 2. A November 2009 technical memorandum to DTSC presented the experimental methods and results (Tetra Tech and UCR, 2009). The study showed that glycerin effectively stimulated biological perchlorate reduction in aquifer material. The biochemical process consumes the added nutrients, utilizing perchlorate as an electron acceptor.

In 2009, per the approval of the RWQCB, a water treatment pilot test was performed at the Laborde Canyon Site to treat perchlorate in the investigation derived water. The test was performed in a 55-gallon drum containing IDW. The drum was amended with glycerin, diammonium phosphate (as a nutrient) and a pre-determined quantity of sediment for native microbial innoculation. The drum was then sealed to allow anaerobic conditions to develop and was briefly stirred once per day. The results showed biotreatment reduced perchlorate concentrations in the water to essentially non-detectable levels within approximately two to three weeks and treatment process did not result in significant changes in dissolved metals concentrations, indicating that the anaerobic conditions under which biodegradation occurred did not result in undesirable solubilization of metals.

Baseline Sampling

Baseline samples were collected from aquifer pump test water and analyzed for perchlorate by Method E332.0, VOCs by Method SW8260B, 1,4-dioxane by Method SW8270C SIM, nitrate, sulfate, chloride by Method E300.0, metals by Method SW6020 (including magnesium, sodium, potassium, calcium and iron), TOC by Method 9060, chemical oxygen demand (COD) by Method 410.1 / 410.4, total dissolved solids (TDS) by Method SM2540C, alkalinity by Method SM2320B. Field parameters were obtained using field instrumentation including turbidity, pH, dissolved oxygen, oxidation reduction potential, and electrical conductivity.

Bench-Scale Set-Up

At the time of sampling, water was collected into three 5-gallon containers during the constant - rate aquifer test to implement three tests to evaluate treatment effectiveness and optimal treatment sequence. The tests were setup in three 5-gallon poly containers with air tight lids. The containers and treatment sequences are shown in Table 2-3. Due to the time required for contaminant reduction, only step 1 was completed and the optimal treatment sequence (chemical/biological) was not evaluated under this study.

Table 2-3 Water Treatment Bench Tests

Container	Step 1 Treatment	Proposed Step 2 Treatment
#1	Perchlorate	1,4-Dioxane & VOCs
#2	1,4-Dioxane & VOCs	Perchlorate
#3	1,4-Dioxane & VOCs	Perchlorate

Container #1 - Step 1 consisted of adding glycerin to the water in addition to small quantities of soil cuttings generated during drilling activities for the treatment of perchlorate. Diammonium phosphate, a nutrient, was added to the water as a micronutrient to aid in the biotreatment. A 0.3 percent weight-to-weight of carbon amendment to groundwater was used to determine the amount of glycerin to be added to the water for treatment (Tetra Tech and UCR, 2009). Samples were collected from the containers on a weekly and/or semiweekly basis to evaluate the perchlorate reduction. Several chemical and biochemical parameters including COCs, including TOC, nitrate, iron, sulfate, and chloride, were analyzed throughout the test to evaluate the progress of biotreatment. Transient and time-sensitive water quality parameters such as, temperature, pH, conductivity, dissolved oxygen, and oxidation reduction potential were measured throughout the test duration onsite periodically during the test.

Container #2 - Step 1 consisted of adding sodium persulfate to the water to treat 1,4-dioxane and VOCs. Sodium hydroxide was added as an activator to increase the pH of the system to an optimal 10-12 pH range. The 1,4-dioxane and VOC concentrations were analyzed on a weekly and/or semiweekly basis to evaluate contaminant reduction and treatment progress in the system. Water quality parameters, temperature, pH, conductivity, dissolved oxygen, and oxidation reduction potential were measured periodically onsite.

Container #3 - Step 1 consisted of adding sodium persulfate and soil cuttings to the water to determine if there was a sufficient amount of naturally occurring iron in soil that could activate the persulfate. 1,4-dioxane, VOC concentrations and iron were analyzed on a weekly and/or semiweekly basis to evaluate contaminant reduction and treatment progress. Water quality parameters, temperature, pH, conductivity, dissolved oxygen, and oxidation reduction potential were measured periodically onsite.

The containers were agitated frequently to promote mixing of the substrate/chemical reagents with the groundwater and stored at room temperature. Results of the treatment test are presented in Section 3.5.1. Laboratory samples were submitted to E.S. Babcock & Sons Inc. and A & R Laboratories for analyses.

2.8.2 Waste Storage and Characterization

Soil waste generated as a result of bedrock coring, and extraction well and piezometer installation activities were placed in covered roll-off bins. Due to the small amount of water generated during the aquifer test and the long treatment period required, water in the dewatering bin was characterized to allow for transport and offsite disposal. Samples were collected to characterize and properly dispose of the waste in accordance with *Waste Management Plan, Lockheed Martin Corporation, Beaumont Sites 1, Beaumont, California* (Tetra Tech 2009c).

SECTION 3 HYDRAULIC TESTING RESULTS

This section summarizes the results of the hydraulic testing activities conducted, including the slug testing, vadose zone permeability testing, bedrock characterization, aquifer testing, soil/groundwater/rock matrix sampling, hydraulic conductivity profiling, and IDW treatment.

3.1 SLUG TESTING

Slug tests were conducted at wells located in five areas of the Potrero Canyon Unit: Feature B-14 (Pad with Dry Well); Feature C-22 (the BPA); Feature F-33 (Large Motor Washout Area); Feature F-34 (Maintenance Shop and Warehouse Area); and Feature F-39 (Test Bays). (see Figure 2-1.) The slug test data were interpreted using AQTESOLV aquifer test interpretation software (Duffield and Rumbaugh, 1991). Based on hydrogeologic conditions at the site, the Bouwer-Rice graphical semi-log analysis method (Dawson and Istok, 1991) was used to interpret the rising- and falling-head test data. Copies of the slug test interpretation figures and the AQTESOLV input and output files are provided in Appendix E, and summarized by feature in Table 3-1.

The slug tests for the vast majority of the locations were in wells screened in the MEF, while only a few of the well locations were screened in the alluvium/weathered MEF sandstone. The average (geometric mean) hydraulic conductivity value for the wells screened in the MEF was 0.021 foot per day. In contrast, the average hydraulic conductivity value for the wells screened in the alluvium/weathered MEF was 1.1 feet per day (this value is 2.9 feet per day if well MW-86B is excluded; see discussion below). Thus, hydraulic conductivity of the alluvium/weathered MEF wells was almost two orders of magnitude higher than the hydraulic conductivity of the MEF wells. Results by feature area are summarized below.

3.1.1 Feature B-14, Pad with Dry Well

The average hydraulic conductivity value for the wells screened in the MEF at B-14 was 0.095 foot per day, which is roughly five times higher than the site wide average MEF hydraulic conductivity value of 0.019 foot per day. The range of hydraulic conductivity values varied from 0.06 to 0.15 foot per day, or approximately a factor of three.

Revised

Table 3-1 Slug Test Results for Potrero Canyon Unit

		Hydraulic Conductivity Values (feet per day)			
		Falling Head (Slug In)	Rising Head (Slug Out)		
Well	Formation	Bouwer-Rice	Bouwer-Rice	Average	Comments
Feature C-22 (BPA) Wells					
EW-08	MEF	0.011	0.017	0.014	long screen (50 ft)
EW-09	MEF	0.0436	0.048	0.046	long screen (50 ft)
EW-10	MEF	0.0682	0.124	0.096	long screen (50 ft)
EW-11	MEF	0.00017		0.00017	long screen (40 ft)
EW-12	MEF	0.0582	0.113	0.085	average screen length (20 ft)
EW-13	MEF	0.0033	0.018	0.010	long screen (40 ft)
EW-14	QAL/MEF	0.0017	0.0017	0.002	long screen (40 ft)
EW-15	MEF	0.0042		0.004	long screen (40 ft), no slug out data
EW-15 Duplicate	MEF	0.0064	0.0083	0.007	repeat test
EW-16	MEF	0.0148	0.0146	0.015	long screen (40 ft)
EW-17	MEF	0.0636		0.064	long screen (50 ft)
EW-20	MEF	0.0762	0.0436	0.060	long screen (40 ft)
MW-59A	MEF	0.017	0.010	0.0139	very short screen (2 ft)
MW-59B	MEF	0.032	0.018	0.0250	somewhat short screen (10 ft)
MW-59C	MEF	0.0034	0.0021	0.003	very short screen (2 ft)
MW-59D	MEF	0.0692	0.0622	0.066	very short screen (2 ft)
MW-61A	MEF	0.00008		0.00008	very short screen (2 ft), no slug out data
MW-61B	MEF	0.05371		0.05371	short screen (10 ft), no slug out data
MW-61D	MEF	0.173		0.173	very short screen (2 ft), no slug out data
MW-61D Duplicate	MEF	0.288	0.211	0.249	repeat test
MW-110	QAL	10.598	10.872	10.735	located in alluvium south of buried bedrock high, screen length (30 ft)
BPA Average				0.0198	
Feature F-33 Wells					
MW-70	QAL	6.858	4.485	5.6712	somewhat short screen (10 ft)
MW-82	QAL	1.935	0.843	1.3888	average screen length (20 ft)
MW-83	QAL	0.706	1.253	0.9791	average screen length (20 ft)
Feature F-33 Average				1.8812	

Revised

		Hydraulic Conductivity Values (feet per day)			
		Falling Head (Slug In)	Rising Head (Slug Out)		
Well	Formation	Bouwer-Rice	Bouwer-Rice	Average	Comments
		Feature F-39 Wells			
MW-85A	MEF	0.026	0.020	0.0233	somewhat short screen (10 ft)
MW-85B	MEF	0.025	0.020	0.0223	average screen length (20 ft)
MW-86B	QAL/MEF	0.014	0.052	0.0331	slug in conducted in 2 steps; data recording time increment somewhat large given response time
Feature F-39 Average				0.0241	
		Feature F-34 Wells			
MW-87A	MEF	0.102	0.150	0.1258	somewhat short screen (10 ft)
MW-87B	MEF	0.0041	0.0027	0.0034	average screen length (20 ft)
MW-93	MEF	0.010	0.004	0.0070	
Feature F-34 Average				0.0138	
		Feature B-14 Wells			
MW-91	MEF	0.165	0.138	0.1515	average screen length (20 ft)
MW-99	MEF	0.065	0.054	0.0599	somewhat short screen (10 ft)
Feature B-14 Average				0.0949	
Average MEF Wells				0.0210	
Average QALWells				1.1423	

3.1.2 Feature C-22, BPA

The average hydraulic conductivity value for the wells screened in the MEF at the BPA was 0.020 feet per day, which is roughly equal to the average MEF hydraulic conductivity value of 0.021 feet per day for all the features tested during this study. The range of hydraulic conductivity values varied from less than 0.0001 to 0.249 feet per day, or approximately a factor of four orders of magnitude. Thus, there is a wide range of MEF hydraulic conductivity values, with some wells having extremely low hydraulic conductivity values. An average BPA well transmissivity value is estimated to be 0.6 feet^2 per day using a saturated thickness of 37 feet. Well EW-14 is listed as screened in the alluvium/weathered MEF, but the hydraulic conductivity values are very similar to the MEF wells, while the new angled monitoring well MW-110 screened in the alluvium has a very high conductivity of 10 feet/day. The new extraction well EW-20, screened in the MEF sandstone had a hydraulic conductivity of 0.06 feet per day, roughly three times the average value as the Site.

3.1.3 Feature F-33, Large Motor Washout Area

The average hydraulic conductivity value for the wells screened in the alluvium/weathered MEF at F-33 was 1.9 feet per day, which is much higher than the results at the other features since these wells are screened in the alluvium/weathered MEF. The range of hydraulic conductivity values varied from 0.71 to 6.9 feet per day, or approximately one order of magnitude.

3.1.4 Feature F-34, Maintenance Shop and Warehouse Area

The average hydraulic conductivity value for the wells screened in the MEF at F-34 was 0.014 feet per day, which is slightly below the average MEF hydraulic conductivity value of 0.019 feet per day. The range of hydraulic conductivity values varied from 0.003 to 0.13 feet per day, or almost two orders of magnitude.

3.1.5 Feature F-39, Test Bays

The average hydraulic conductivity value for the wells screened in the MEF at F-39 was 0.022 feet per day, which is comparable to the average MEF hydraulic conductivity value of 0.019 feet per day. The average hydraulic conductivity value for the one well screened in the alluvium/weathered MEF at F-39 was 0.033 feet per day, which is far below the average alluvium/weathered MEF hydraulic conductivity value of 0.65 feet per day. Although well MW-86B is listed as screened in the alluvium/weathered MEF, the hydraulic conductivity value is very similar to the MEF wells at F-39.

Laboratory analytical data packages for the groundwater well samples, soil TOC, and waste characterization samples analyzed by E.S. Babcock and Sons Laboratories Inc. in Riverside, CA, are included in Appendix F. The analytical data packages for the rock core matrix samples analyzed by Stone Environmental Inc. in Montpellier, VT, are included in Stone Environmental's rock core sampling and analysis report in Appendix D. The rock core matrix sampling results are discussed in Section 3.4.2 as part of the bedrock characterization section. The laboratory packages include all environmental, field quality control (QC) and laboratory QC results reported. A complete list of analytes tested, along with the validated sample results by analytical method, is provided in Appendix G.

3.2 DATA QUALITY REVIEW

The quality control samples were reviewed as described in the PSAP (Tetra Tech, 2010). The data for the groundwater sampling activities were contained in analytical data packages generated by Stone Environmental Inc. in Montpellier, VT, and E.S. Babcock and Sons Laboratories Inc. in Riverside, CA. These data packages were reviewed using the latest versions of the National Functional Guidelines for Organic and Inorganic Data Review documents from the EPA.

Preservation criteria, holding times, field blanks, laboratory control samples (LCS), method blanks, duplicate environmental samples, spiked samples, and surrogate and spike recovery data were reviewed. Within each environmental sample, the sample specific quality control spike recoveries were examined. These data examinations include comparing statistically calculated control limits to percent recoveries of all spiked analytes and duplicate spiked analytes. Relative Percent Difference (RPD) control limits are compared to actual matrix spiked/matrix spiked duplicate (MS/MSD) RPD results. Surrogate recoveries were examined for all organic compound analyses and compared to their control limits.

Environmental samples were analyzed by the following methods: Method SM2320 for alkalinity, Method E300.0 for nitrate, Method E332.0 for perchlorate, Method A5310 for TOC, Method SW8270C SIM for 1,4-dioxane, Methods SW6010B, SW6020, and E200.8 for metals, Method SW8260B for VOCs, and a non-EPA preparation method that uses a gas chromatograph (GC) and an Electron Capture Detector (ECD) to detect VOCs. The closest EPA method equivalent is SW8021B.

Unless otherwise noted below, all data results met required criteria, are of known precision and accuracy, did not require qualification, and may be used as reported.

Method SW8270C SIM for 1,4-dioxane had holding time errors and caused 41.7% (5 out of twelve)12 of the total SW8270C SIM data to be qualified as estimated. The data qualified as estimated are usable for the intended purpose. The samples were extracted one day past holding times and the negative effects on the data are minimal. Corrective action was performed by the laboratory to prevent recurrence of the holding time errors.

Method SW8260B for VOCs had field blank contamination that caused 1.2 percent of the (6 out of 516) total SW8260B data to be qualified for blank contamination. The blank qualified results should be considered not detected at elevated detection levels.

Method SW6020 for metals had blank contamination that caused 3.1% of the (1 out of thirty-two)32 total metals data to be qualified for blank contamination. The blank qualified results should be considered not detected at elevated detection levels.

Method SW6020 had an LCS error that caused 3.1% (1 out of 32) of the 32 total SW6020 data to be qualified as estimated. The data qualified as estimated is usable for the intended purpose. Corrective action was performed by the laboratory to prevent recurrence of the LCS error.

The rock matrix sampling procedures and analytical reporting conducted by Stone Environmental Inc. was reviewed for overall data quality and compliance with the PSAP. The sandstone was drilled and cores were taken to the sample processing area for rock core sample processing. Preparing solid samples for VOC analysis comes under Method SW5035A protocol. Stone Environmental used appropriate care in processing the samples with little loss of VOCs. Any loss of analytes through processing was minimal and well within the associated error of the analytical method itself. The data were determined to be of known accuracy and precision. The data may be used as stated.

3.3 SOIL RESULTS

A total of 25 soil samples (including 3 duplicate samples) were collected from two borings (EW-20 and P-09) and analyzed for TOC and total solids. Positive detections of TOC occurred in 22 samples (excluding duplicates) at concentrations ranging from 510 to 1,800 mg/kg. The highest TOC concentrations were detected in P-09 at 20 feet bgs and at 40 feet bgs. The TOC concentrations reported in Table 3-2 were below the practical quantitation limit for all depths sampled. No TOC concentrations were reported above the practical quantitation limit in either boring (EW-20 or P-09) and therefore are estimated values.

Table 3-2 Soil Sampling Results for Total Organic Carbon

Sample Name	Depth (feet bgs)	Sample Date	Total Organic Carbon (mg/kg)
EW-20-10	10	9/26/2011	910 Jq
EW-20-20	20	9/26/2011	810 Jq
EW-20-30	30	9/26/2011	830 Jq
EW-20-40	40	9/26/2011	560 Jq
EW-20-50	50	9/27/2011	910 Jq
EW-20-60	60	9/27/2011	510 Jq
EW-20-70	70	9/27/2011	590 Jq
EW-20-80	80	9/27/2011	610 Jq
EW-20-90	90	9/28/2011	750 Jq
EW-20-100	100	9/28/2011	900 Jq
EW-20-110	110	9/29/2011	780 Jq
P-09-10	10	9/30/2011	950 Jq
P-09-20	20	9/30/2011	1800 Jq
P-09-30	30	9/30/2011	670 Jq
P-09-40	40	9/30/2011	1100 Jq
P-09-50	50	9/30/2011	860 Jq
P-09-60	60	9/30/2011	640 Jq
P-09-70	70	9/30/2011	650 Jq
P-09-80	80	10/3/2011	590 Jq
P-09-90	90	10/3/2011	540 Jq
P-09-100	100	10/3/2011	670 Jq
P-09-110	110	10/3/2011	610 Jq

Notes:

bgs - below ground surface.

J - The analyte was positively identified, but the analyte concentration is an estimated value.

q - The analyte detection was below the Practical Quantitation Limit (PQL).

Four samples were collected from each boring to determine physical properties. Geotechnical test results show the soil types vary only slightly depending on the location and samples depths. The soil types determined for the samples collected were either silty sand or well graded sand with silt. The geotechnical laboratory testing results are summarized in Table 3-3.

Table 3-3 Soil Sampling Results for Physical Properties

Sample Name	Depth (ft bgs)	USCS Soil Type	Moisture Content (%) (ASTM D2216)	Dry Density (pcf) (ASTM D2937)	Specific Gravity (ASTM D854)	Total Porosity (%) (API RP40)
EW-20-10	10	SW-SM	4.9	102.3	2.690	39.05
EW-20-20	20	SW-SM	5.1	105.2	2.704	37.65
EW-20-30	30	SM	17.8	99.4	2.734	41.74
EW-20-40	40	SM	13.0	96.1	2.727	43.53
P-09-10	10	SW-SM	3.6	98.9	2.689	41.06
P-09-20	20	SM	8.2	107.4	2.706	36.36
P-09-30	30	SW-SM	7.0	111.5	2.692	33.62
P-09-40	40	SM	16.9	101.6	2.715	40.03

Notes:

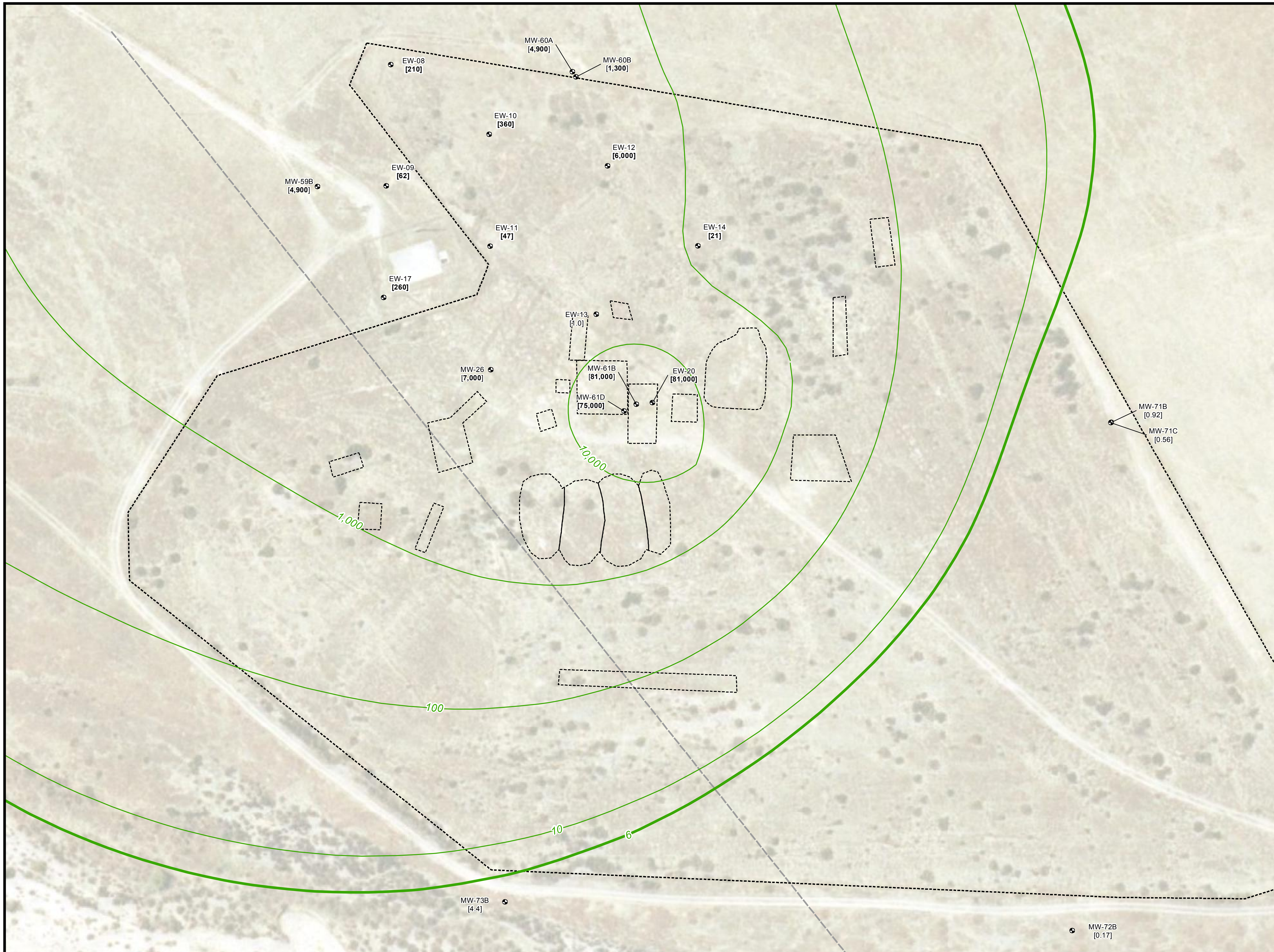
ft bgs – feet below ground surface.
pcf – pounds per cubic foot
SM – silty sand
SW-SM – well graded sand with silt

3.4 BPA WATER QUALITY RESULTS

Summaries of validated analytical results for organic (VOCs and 1,4-dioxane) and inorganic (perchlorate) analytes detected above their respective method detection limits (MDLs) from samples collected from the seven extraction wells and one monitoring well in August 2011 are presented in Tables 3-1 through 3-4. The results are generally consistent when compared to contaminant concentrations in nearby monitoring wells, and help fill in gaps within the BPA where water quality data were not available. Samples were collected from wells with screen lengths of 2 feet, 20 feet, 40 feet, and 50 feet, and contaminant concentrations can vary due to the screen intervals. Figures 3-1 through 3-4 show the data incorporated into the Second Quarter 2011 maps which, with the added data, represent the period from June through August 2011. The figures show that the high concentrations are still centered on the area near EW-13 and the MW-61A/B/C/D well cluster.

3.5 CONSTANT -RATE AQUIFER TEST WATER QUALITY RESULTS

In October 2011, groundwater samples were collected at the beginning, middle, and end of the constant-rate aquifer test from EW-20 to evaluate if there were any changes in concentration for VOCs, perchlorate, and 1,4-dioxane during pumping. Summaries of validated analytical results for organic (VOCs and 1,4-dioxane) and inorganic (perchlorate) analytes detected above their respective MDLs from EW-20 are presented in Tables 3-5 and 3-6. Additional parameters, Path: X:\GIS\Lockheed 26205_01_0505Perc.mxd



0 50 100 Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

MW-22 [340] — Well ID, Perchlorate Concentration (µg/L)

Fault, Approximately Located

Perchlorate in Groundwater Concentration Contour (µg/L) - Dashed where inferred

MCL Contour (6.0 µg/L) - Dashed where inferred

Former Burn Pit Locations

Notes:

MCL - Maximum Contaminant Level.
Concentrations shown are in microgram per liter (µg/L)

Highest concentration shown is contoured for clustered or nested well locations.

Bold indicates MCL value exceeded.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 3-1
Perchlorate Isoconcentration Map for Alluvium and Shallow Mt. Eden Formation Burn Pit Area - Summer 2011

TETRA TECH

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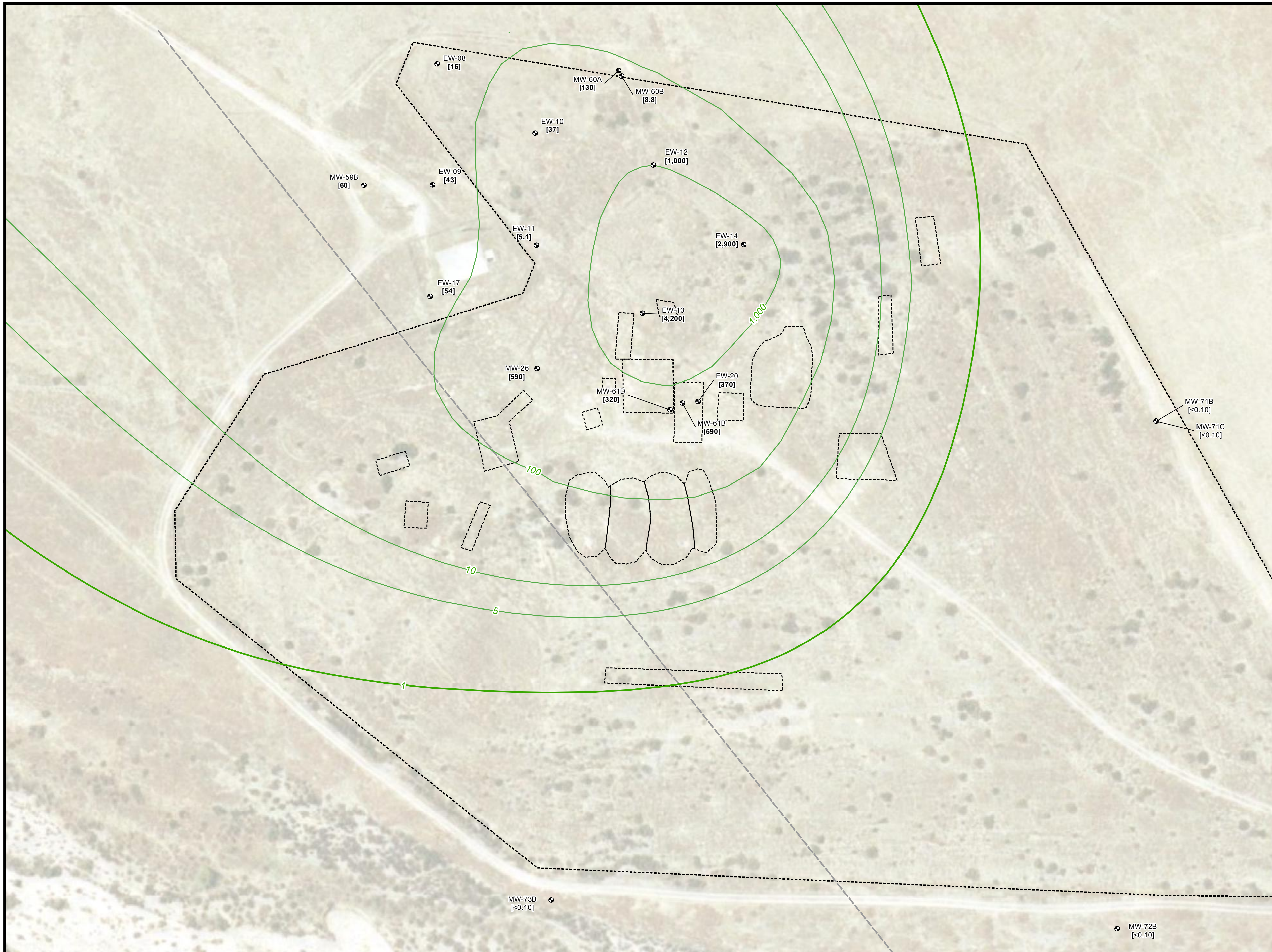

0 50 100
Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

MW-22 [340] Well ID
1,4-Dioxane Concentration (µg/L)

1,4-Dioxane in Groundwater Concentration Contour
(µg/L) - Dashed where inferred

DWNL Contour
(1.0 µg/L) - Dashed where inferred

Fault, Approximately Located

Former Burn Pit Locations

Notes:

DWNL - Drinking water notification level.
Concentrations shown are in microgram per liter (µg/L)

Highest concentration shown is contoured for clustered or nested well locations.

Bold indicates DWNL value exceeded.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 3-2
1,4-Dioxane Isoconcentration Map for Alluvium and Shallow Mt. Eden Formation Burn Pit Area - Summer 2011

TETRA TECH

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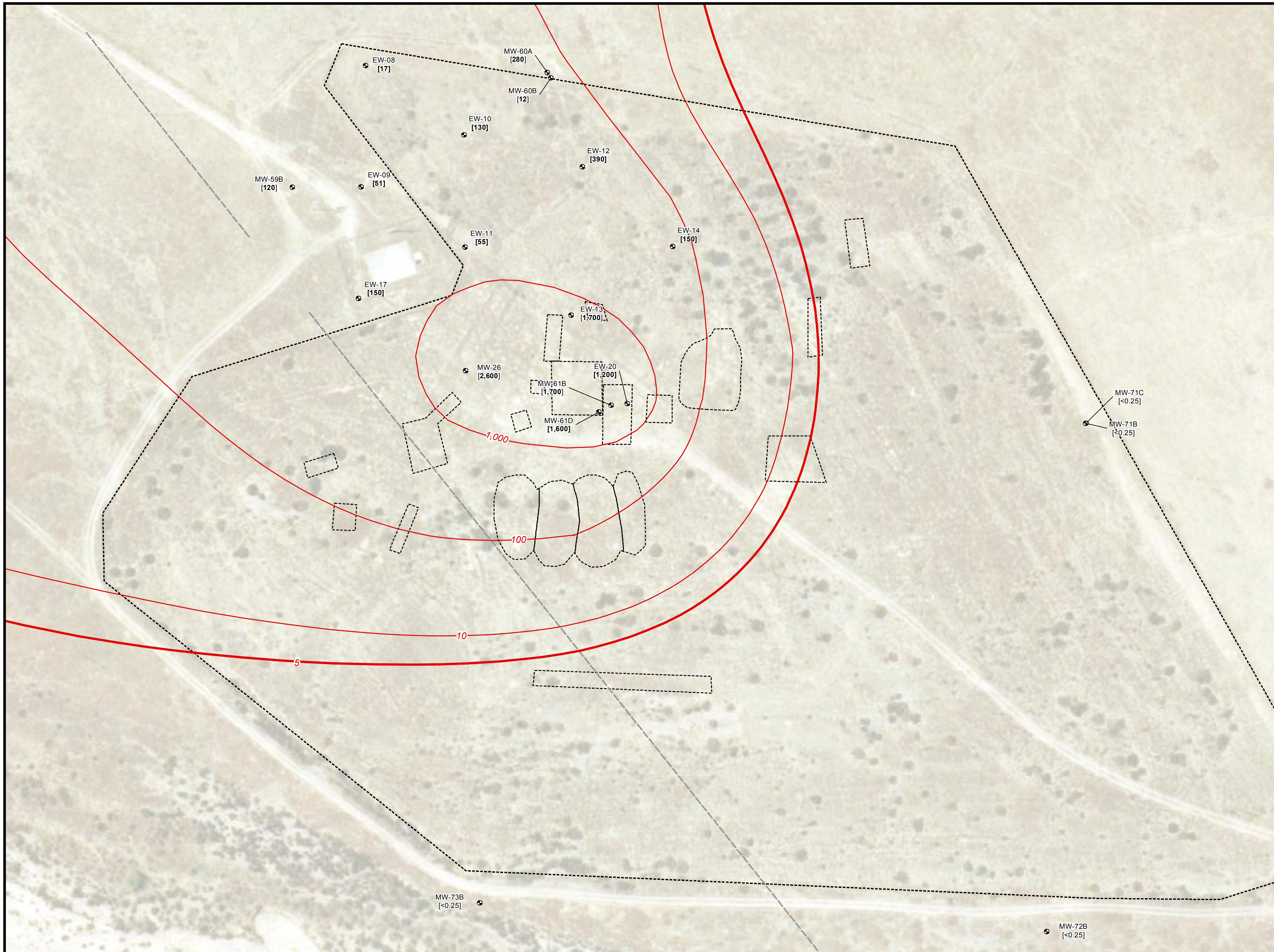

0 50 100 Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

MW-22 [340] — Well ID, TCE Concentration (µg/L)

TCE in Groundwater Concentration Contour (µg/L) - Dashed where inferred

MCL Contour (5.0 µg/L) - Dashed where inferred

Fault, Approximately Located

Former Burn Pit Locations

Notes:

MCL - Maximum Contaminant Level. Concentrations shown are in microgram per liter (µg/L)

TCE - Trichloroethene.

Highest concentration shown is contoured for clustered or nested well locations.

Bold indicates MCL value exceeded.

Portero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 3-3
TCE Isoconcentration Map for Alluvium and Shallow Mt. Eden Formation Burn Pit Area - Summer 2011

TETRA TECH

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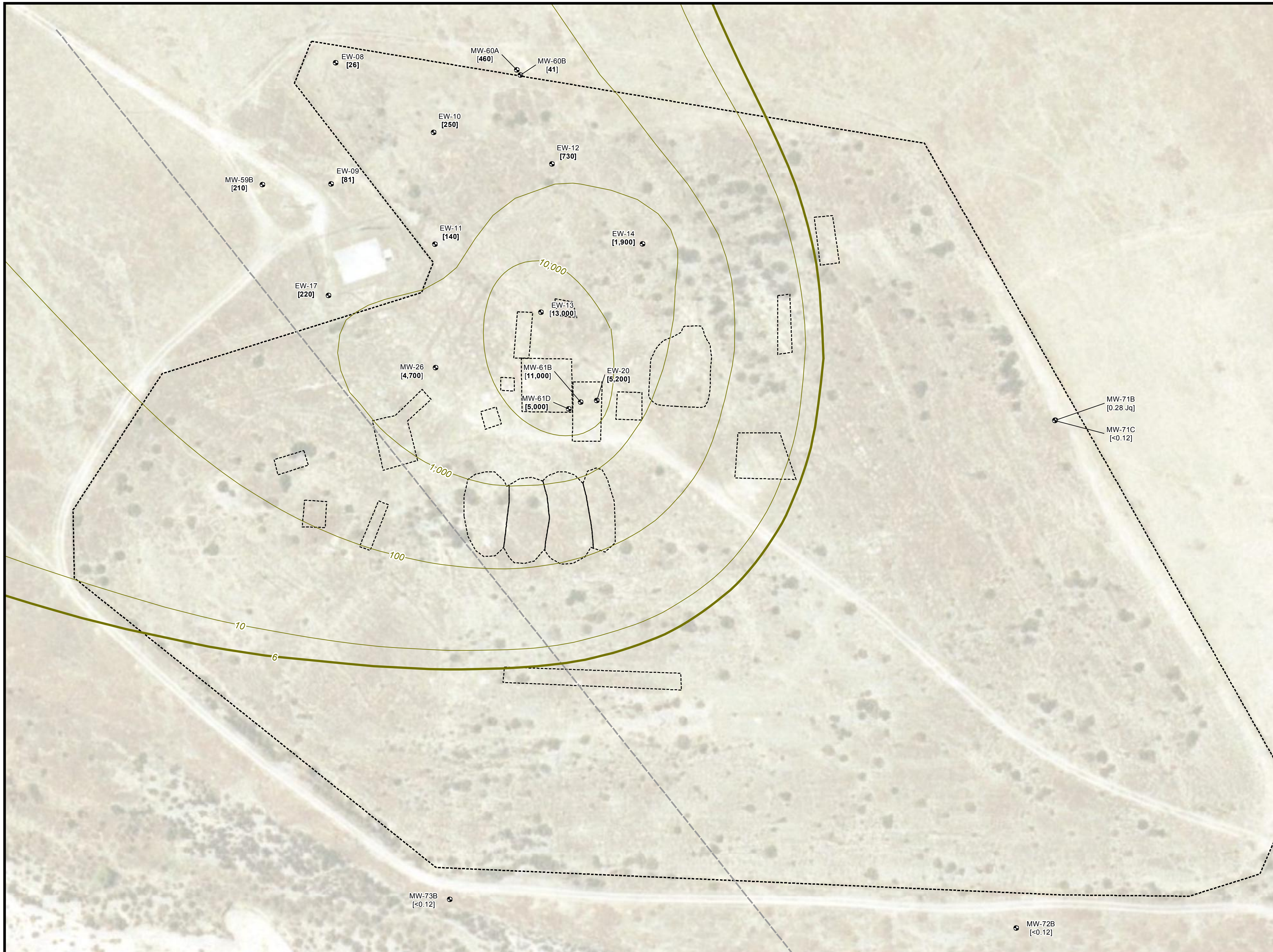


N

0 50 100
Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

MW-22 [340] — Well ID, 1,1-DCE Concentration (µg/L)

1,1-DCE in Groundwater Concentration Contour (µg/L) - Dashed where inferred

MCL Contour (6.0 µg/L) - Dashed where inferred

Fault, Approximately Located

Former Burn Pit Locations

Notes:

MCL - Maximum Contaminant Level. Concentrations shown are in microgram per liter (µg/L)

DCE - 1,1-Dichloroethene.

Highest concentration shown is contoured for clustered or nested well locations.

Bold indicates MCL value exceeded.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 3-4

1,1-DCE Isoconcentration Map for Alluvium and Shallow Mt. Eden Formation Burn Pit Area - Summer 2011

TETRA TECH

including metals and general mineral parameters, were analyzed to aid in the wastewater treatment tests. Perchlorate and 1,4-dioxane were detected in samples collected from EW-20 in all three sampling events with concentrations relatively unchanged by the end of the test. The average concentrations of perchlorate and 1,4-dioxane detected during the test were 75,000 and 410 µg/L, respectively. There were several VOCs detected in the samples, including the primary chemicals of potential concern 1,1-dichloroethene (1,1-DCE) and TCE. VOCs exceeding the California Department of Public Health maximum contaminant level (MCL) and/or California Department of Public Health drinking water notification level (DWNL) include carbon tetrachloride, 1,1-diochloroethane, 1,2-dichloroethane, 1,1-DCE, *cis*-1,2-dichloroethene, 1,1,2-trichloroethane, TCE, tetrachloroethene, and vinyl chloride. Similar to perchlorate, the concentrations of VOCs by the end of the test remained relatively unchanged.

Sample results detected above the published MCL or the DWNL are bolded in Tables 3-4, 3-5 and 3-6.

Table 3-4 Summary of Detected Organic Analytes in Monitoring Wells

Sample Name	Sample Date	1,4-Dioxane	Per-chlorate	Benzene	Chloro benzene	Chloro ethane	Carbon Tetra chloride	Chloro-form	1,1-Dichlor oethane	1,2-Dichloro ethane	1,1-Dichloro ethene	c-1,2-Dichloro ethene	t-1,2-Dichloro ethene	Methyl tert-butyl ether	Methylene Chloride	Styrene	Toluene	1,1,1-Trichloro ethane	1,1,2-Trichloro ethane	Trichloro ethene	Tetrachloro ethene	Vinyl Chloride
		All results are reported in µg/L unless otherwise stated.																				
EW-08	8/29/2011	**16**	**210**	0.32 Jq	0.74	<0.35	<0.15	<0.46	1.1	**2.2**	**26**	0.35 Jq	<0.10	<0.43	0.22 BJkq	<0.22	0.58	<0.12	<0.31	**17**	<0.23	<0.13
EW-09	8/29/2011	**43**	**62**	0.37 Jq	0.44 Jq	<0.35	<0.15	<0.46	3.3	**6.7**	**81**	1.7	0.13 Jq	0.61 Jq	0.20 BJkq	<0.22	0.40 Jq	<0.12	<0.31	**51**	<0.23	0.14 Jq
EW-10	8/30/2011	**37**	**360**	0.42 Jq	<0.23	<0.35	<0.15	0.54	**6.1**	**10**	**250**	2.5	0.20 Jq	<0.43	0.29 Jq	<0.22	0.39 Jq	<0.12	0.66	**130**	0.55	0.18 Jq
EW-11	8/31/2011	**5.1**	**47**	0.41 Jq	0.65	<0.35	<0.15	<0.46	1.5	**1.6**	**140**	**6.1**	0.13 Jq	<0.43	0.27 Jq	0.24 Jq	0.71	<0.12	<0.31	**55**	0.29 Jq	0.20 Jq
EW-12	8/31/2011	**1,000 Je**	**6,000**	0.54	<0.23	<0.35	**0.65**	3.7	**15**	**36**	**730**	**6.8**	0.36 Jq	<0.43	0.20 Jq	<0.22	<0.22	0.65	**11**	**390**	1.6	<0.13
EW-14	8/30/2011	**2,900 Je**	**21**	**2.4**	1.2	0.47 Jq	<0.15	1.4	**38**	**93**	**1,900**	**260**	0.54	<0.43	1.0 Jq	<0.22	1.4	0.96	5	**150**	0.65	**3.1**
EW-17	8/30/2011	**54**	**260**	0.40 Jq	<0.23	<0.35	<0.15	<0.46	**8.2**	**14**	**220**	**54**	0.23 Jq	1.1 Jq	0.31 Jq	<0.22	0.30 Jq	<0.12	0.94	**150**	0.37 Jq	0.34 Jq
MW-61D	8/31/2011	**320 Je**	**75,000**	**1.8**	1.1	<0.35	**3**	28	**110**	**91**	**5,000**	**40**	2.2	<0.43	0.58 Jq	<0.22	2.2	3.6	**8.3**	**1600**	4	0.33 Jq
MCL/DWNL		1 (1)	6	1	-	-	0.5	-	5	0.5	6	6	10	13	-	100	150	200	5	5	5	0.5

Notes: Only analytes positively detected are presented in this table. For a complete list, refer to the laboratory data package.

µg/L - micrograms per liter
mg/L - milligrams per lite.
MDL - Method detection limit
DWNL - California Department of Public Health drinking water notification level
MCL - California Department of Public Health Maximum Contaminant Level
(1) DWNL
"-" - MCL or DWNL not available

Bold - MCL or DWNL exceeded
<# - Analyte not detected; method detection limit concentration is shown.
B - The result is < 5 times the blank contamination.
J - The analyte was positively identified, but the analyte concentration is an estimated value.
k - The analyte was found in a field blank.
q - The analyte detection was below the Practical Quantitation Limit (PQL).
e - a holding time violation occurred.

Table 3-5 Summary of Detected Organic Analytes in Extraction Well EW-20

Sample Name	Sample Date	1,4-Dioxane	Benzene	Chloro benzene	Carbon Tetra chloride	Chloro-form	1,1-Dichloro ethane	1,2-Dichloro ethane	1,1-Dichloro ethene	c-1,2-Dichloro ethene	t-1,2-Dichloro ethene	Methylene Chloride	Toluene	1,1,1-Trichloro ethane	1,1,2-Trichloro ethane	Trichloro ethene	Tetrachloro ethene	Vinyl Chloride
		All results are reported in µg/L unless otherwise stated.																
EW-20	10/18/2011	**500 Je**	1.9	<0.23	**3.5**	22	**200**	**220**	**6,600**	**52**	3.2	0.57 BJkq	0.39 Jq	3.6	**19**	**1,200**	3.4	**0.73**
EW-20	10/21/2011	**370 Je**	1.5	0.49 Jq	**5**	35	**110 Jq**	**70**	**5,200**	**29**	2.6	1.3 BJkq	<0.22	3	**14**	**1,200**	4.8	0.35 Jq
EW-20	10/27/2011	**360**	1.7	0.47 Jq	**5.6**	34	**130**	**88**	**6,300**	**34**	2.9	0.91 BJkq	<0.22	3.6	**14**	**1,600**	**6.6**	0.44 Jq
MCL/DWNL		1 (1)	1	-	0.5	-	0.5	0.5	6	6	10	-	150	200	5	5	5	0.5

Notes: Only analytes positively detected are presented in this table. For a complete list, refer to the laboratory data package.

DWNL - California Department of Public Health drinking water notification level
MCL - California Department of Public Health Maximum Contaminant Level
µg/L - micrograms per liter
mg/L - milligrams per liter
(1) DWNL
"-" - MCL or DWNL not available
Bold - MCL or DWNL exceeded

<# - Analyte not detected; method detection limit concentration is shown.
B - The result is < 5 times the blank contamination.
J - The analyte was positively identified, but the analyte concentration is an estimated value.
k - The analyte was found in a field blank.
q - The analyte detection was below the Practical Quantitation Limit (PQL).
e - A holding time violation occurred.

Table 3-6 Summary of Detected Inorganic and General Mineral Analytes in Extraction Well EW-20

Sample Name	Sample Date	Per-chlorate µg/L	Alkalinity Total (as CaCO3)	Bicarbonate (as CaCO3)	Chloride	Chemical Oxygen Demand	Dissolved Solids	Nitrate as N	Sulfate	Total Organic Carbon	Anti-mony	Barium	Calcium	Cobalt	Chromium	Copper	Iron	Lead	Mag-nesium	Molyb-denum	Nickel	Pota-ssium	Sodium	Zinc
			All results are reported in mg/L unless otherwise stated.																					
EW-20	10/18/2011	75,000																						
EW-20	10/21/2011	81,000	55	67	51	8.5 Jq	460	21	15	0.92	<0.00018	0.089 Jq	43	<0.00019	0.0039 Jq	0.0034 Jq	0.14	0.0017 Jq	5.2	0.0030 Jq	0.0028 Jq	3.7	51	0.053
EW-20	10/27/2011	69,000	53	65	100	<6.3	500	44	30	0.54 Jq	0.00067 Jdq	0.12	46	0.00027 Jq	0.0040 Jq	0.0027 Jq	0.56	<0.00019	6.3	0.0023 Jq	0.0024 Jq	3.8	50	0.0056 BJaq
MCL/DWNL		6	-	-	250 (2)	-	500 (2)	10	250	-	0.006	1	-	-	0.05	1.3	300	0.015	-	-	0.1	-	-	5 (2)

Notes: Only analytes positively detected are presented in this table. For a complete list, refer to the laboratory data package.

DWNL - California Department of Public Health drinking water notification level
MCL - California Department of Public Health Maximum Contaminant Level
µg/L - micrograms per liter
mg/L - milligrams per liter
(1) DWNL
"-" - MCL or DWNL not available
Bold - MCL or DWNL exceeded

<# - Analyte not detected; method detection limit concentration is shown.
B - The result is < 5 times the blank contamination.
J - The analyte was positively identified, but the analyte concentration is an estimated value.
a - The analyte was found in a field blank.
d - The laboratory control sample recovery was outside control limits.
q - The analyte detection was below the Practical Quantitation Limit (PQL).

3.6 VADOSE ZONE PERMEABILITY TESTS

Stable water levels could not be obtained at the lowest readily measurable flow rate (~0.05 gpm) for the 65 -foot test interval in boring P-09, or for the test in vapor extraction well VEW-6. In addition, no accumulation of water was noted during the test in vapor extraction well VRW-1 at the highest attainable flow rate (~6 gpm). Stable water levels and flow rates were obtained for the remainder of the tests. Field data sheets for the vadose zone permeability tests are included in Appendix L.

The permeability test data were interpreted using an analytical solution developed by Glover (1953) for radial flow from a line source whose strength varies linearly with depth in response to gravity:

$$K_s = \frac{Q_s}{rH} \cdot \frac{1}{C_u}$$

and

$$C_u = \frac{2\pi H}{r} \cdot \left[\sinh^{-1}\left(\frac{H}{r}\right) - 1\right]^{-1}$$

where K_s is the saturated hydraulic conductivity, Q_s is the steady-state infiltration rate, H is the height of water in the borehole, and r is the borehole radius. Estimated K_s values are summarized in Table 3-7.

Table 3-7 Vadose Zone Permeability Test Results

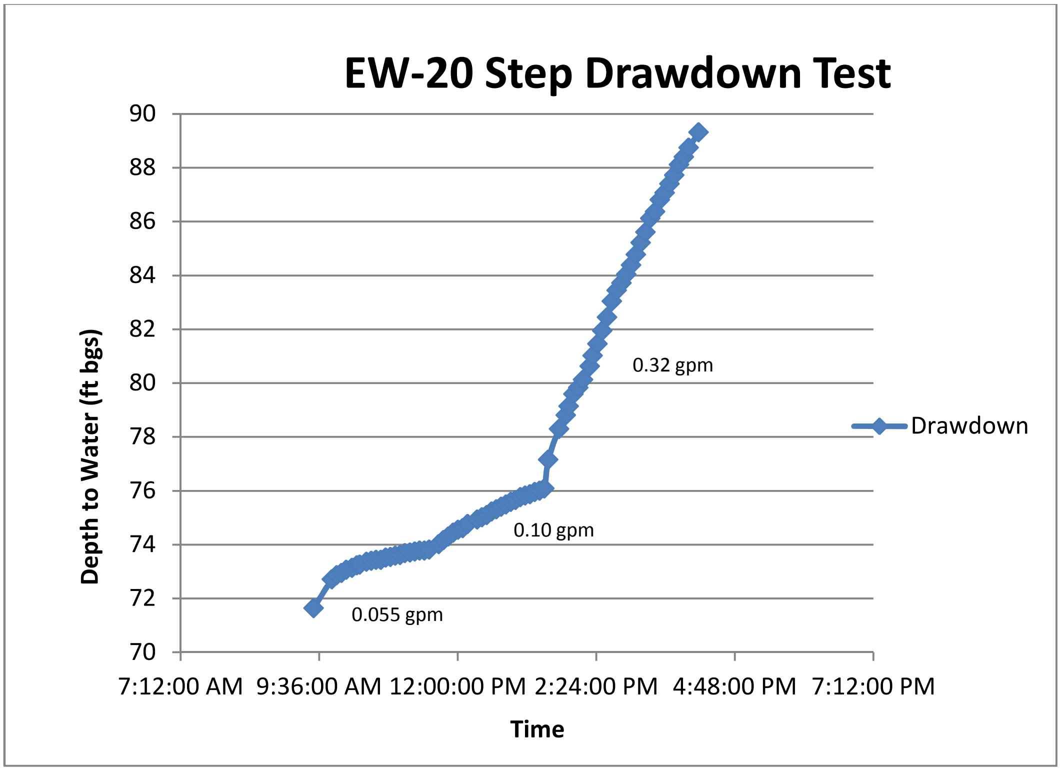
Boring/ Well ID	Nominal Test Depth (feet bgs)	r (feet)	H (feet)	Q_s (gal/min)	K_s (ft/day)
P-09	20	0.33	4.15	0.41	1.6
	40	0.33	4.83	0.27	0.83
	50	0.33	5.57	0.14	0.35
EW-20	20	0.46	4.34	0.85	2.7
	40	0.46	4.32	0.34	1.1
	50	0.46	4.85	0.12	0.31
VEW-8	50	0.33	7.08	0.12	0.51
VEW-10	54	0.33	4.02	0.085	0.14

Overall, the data in Table 3-7 show a trend with decreasing vadose zone permeability with depth, which is generally consistent with the presence of more permeable Quaternary alluvium at shallow depth, and less permeable alluvium/weathered MEF sandstone at greater depth. Well VRW-1, which apparently has the highest permeability of all of the locations tested, is located in the southern portion of the BPA, where very high infiltration rates were found during previous testing (Tetra Tech, 2009a).

3.7 AQUIFER TESTING

3.7.1 Constant-Rate Aquifer Test

A step test was conducted on EW-20 to determine the optimum extraction rate for the long-term test. The EW-20 step test was conducted by pumping the newly installed extraction well at rates of 0.055, 0.10, and 0.32 gpm for a total time period of approximately 6.5 hours. (see graph below.) Drawdowns measured in the extraction well at each step were 2.14, 4.36, and 13 feet, respectively. Specific capacity values during the step test were 0.026, 0.023, and 0.019 gpm/feet, respectively. Drawdown had not reached a stable condition, and was still declining at the end of each of the three step-test periods. Based upon the step test results, a rate of 0.125 gpm was selected for the constant-rate aquifer test.



During the constant -rate aquifer test, drawdown in EW-20 was up to 12.87feet at a pumping rate of 0.125 gpm, so that the specific capacity was 0.01 gpm/feet, lower than that recorded during the step test. The lower specific capacity in the long-term test is attributed to the lack of stabilization during the step test.

Specific capacity values can be used to approximate the transmissivity of the pumping well screened interval using the following empirical correlation: transmissivity in $feet^2$ per day equals 200 times specific capacity in gpm/feet (from Dawson and Istok, 1991). This equates to a value of approximately 2 $feet^2$ per day. The hydraulic conductivity value for a 37-foot thick saturated zone would then be approximately 0.054 feet per day. Prior site investigations indicated that the main water bearing zone is in this 37-foot interval, which is supported by the site water level data; site water quality data; and site slug test data. Deeper zones were thought to be separated from the main shallow zone by low permeability layers in the MEF sandstone. This is why the prior site extraction system was focused in this interval. Please note that the FLUTe conductivity profiles conducted as part of this study found that the main water bearing zone is between the first encountered water around 70 feet bgs and roughly 105 feet bgs, independently confirming the prior site CSM. Therefore, extraction well EW-20 which is screened from 70 to 110 feet bgs, is considered to be fully penetrating with respect to the aquifer test interpretations.

The drawdown data during the constant -rate aquifer test were interpreted with both type curve and graphical semi-log analysis methods (Dawson and Istok, 1991), using the AQTESOLV program for pumping test interpretation (Duffield and Rumbaugh, 1991). The reader is referred to the summary tables and figures in Appendix H for supporting information. AQTESOLV input and output files have also been provided in this appendix.

The EW-20 constant-rate aquifer test was conducted by pumping the well for 77 hours (3 days and 5 hours) at a steady rate of 0.125 gpm with drawdowns reaching up to 12.87 feet in the pumping well. After 77 hours of pumping, the test did not reach steady state as the water levels were continuing to decline. Water levels were monitored with transducers in both the pumping well EW-20, and the observation wells EW-18, MW-61B, MW-61C, PZ-09, MW-61D, EW-16, EW-15, EW-13, MW-31, and MW-61A. No response was observed in wells EW-13, MW-31, and MW-61A, which is attributed to either the large distance to the wells (EW-13 (approximately 110 feet away) and MW-31 (approximately 110 feet away) or the deep depth of the well screens (MW-31 and MW-61A). The analysis of the response for all the other wells is summarized in Table 3-8;

note that no directional trends in either transmissivity or drawdown are apparent in the data. Although responses were observed in MW-61C and MW-61D, the magnitude and nature of the response, along with the deeper location of the well screens, indicated that these wells are screened in a water bearing zone that is somewhat vertically separated from the main pumping water bearing zone at 70 to 110 feet bgs.

Drawdown-Distance Interpretation

The maximum drawdowns recorded during the pumping test for each well (Table 3-8) were used along with the distance to the well to develop a drawdown-distance plot (Figure 3-5). The drawdown-distance plot was based only upon the wells screened at the same depth as pumping well EW-20, and specifically excludes data for wells MW-61C and MW-61D, which are screened in deeper water bearing zones than the pumping well. The slope of the semi-log line on the drawdown-distance plot varied from approximately 4 to 5 feet per log cycle, which can be used to estimate aquifer transmissivity values of 2.2 and 1.75 ft^2 per day, respectively.

Transient Drawdown Interpretation

The drawdown data from the pumping well EW-20 and the observation wells had a shape that is generally consistent with the Theis Aquifer Model, with generally no flattening of drawdown at late times, although extraction well EW-20 and observation location PZ09 did show limited drawdown flattening effects at late times that may be indicative of leakage. Based upon the site hydrogeologic conditions and the observed pumping test response, the data were tested against the following common aquifer models:

- The Theis Aquifer Model
- The Hantush Leaky Aquifer Model

At intermediate times, the Cooper-Jacob semi-log straight line method also was used to estimate aquifer properties, and the Cooper-Jacob method yields aquifer transmissivity and storage values that are in good agreement with those from the Theis and Leaky Aquifer Model. The pump test analysis results are summarized in Table 3-8, and in the semi-log and type curve interpretation figures included in Appendix H.

Aquifer transmissivity values - excluding wells MW-61C and MW-61D, which are screened in deeper water bearing zones - ranged from 0.58 ft^2 per day to 4.37 ft^2 per day with a geometric mean value of 1.46 ft^2 per day. The aquifer hydraulic conductivity was estimated from the ratio of

Table 3-8 EW-20 BPA Pumping Test Interpretation

Well	Radial Distance to EW-20 (ft)	Screened Interval (ft bgs)	Maximum Drawdown (ft)	Drawdown							
				Theis Type Curve Method		Cooper-Jacob Method		Leaky Aquifer Type Curve Method			
				T (ft^2/day)	S	T (ft^2/day)	S	T (ft^2/day)	S	r/B	Comment
EW-20	0.167	70-110	12.87	0.73	NA	0.60	NA	0.58	NA	1.65E-01	late time drawdown stabilizes; may represent leakage
EW-18	12	60-101	3.27	1.45	5.64E-03	1.93	3.50E-03	NA	NA	NA	late time drawdown stabilizes; may represent leakage
MW-61B	17	92-102	3.21	1.81	2.17E-03	2.01	1.69E-03	NA	NA	NA	
MW-61C	24	128-130	0.56	2.89	2.02E-02	4.95	1.46E-02	NA	NA	NA	weak response likely effected due to deeper screen location
PZ-09	29	70-110	5.03	1.36	3.10E-04	1.16	2.81E-04	1.02	3.26E-04	3.02E-01	strongly confined storage value, late time drawdown stabilizes; may represent leakage
MW-61D	30	114-116	0.12	4.00	5.05E-03	5.15	3.60E-03	NA	NA	NA	weak response likely effected due to deeper screen location
EW-16	57	64.4-105	0.90	4.05	1.58E-03	4.37	1.31E-03	NA	NA	NA	no leakage in response; weak response
EW-15	68	64.4-105	1.41	1.39	1.01E-03	1.96	7.18E-04	NA	NA	NA	no leakage in response

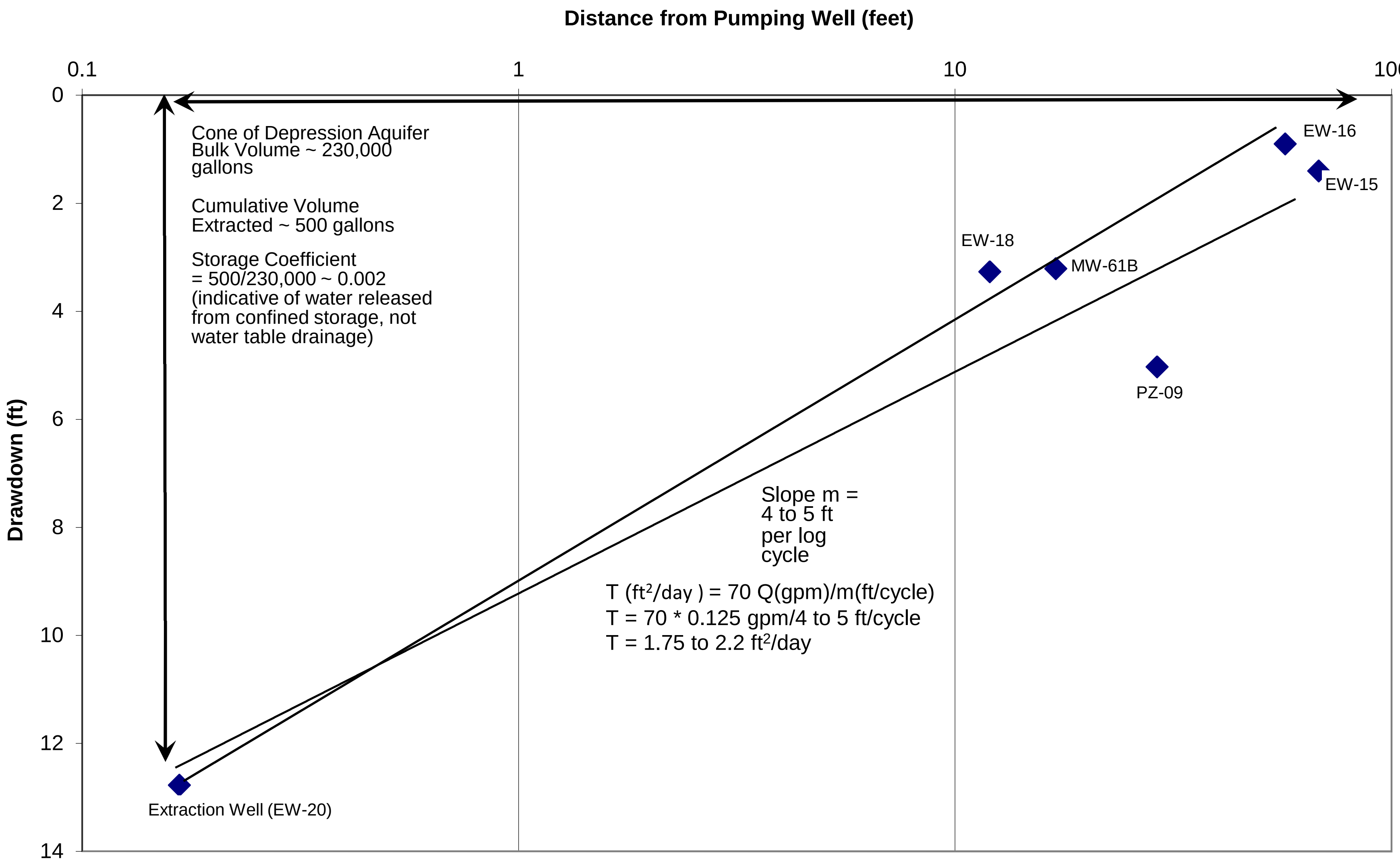
EW-20 Pumping Rate is 0.125 gpm for drawdown

T = Transmissivity
S = Storativity

NA = not applicable

Revised

Figure 3-5 – Drawdown versus Distance from BPA Pumping Well EW-20



the aquifer transmissivity value divided by the 37-foot aquifer thickness, and was found to be between 0.016 to 0.12 feet per day, with a geometric mean value of 0.039 feet per day. Storage values were in the confined range, varying between 0.00028 and 0.00564, and averaging 0.0017. Due to the proximity of the water table, which prior to pumping was located 3 feet below the top of the well screen at EW-20 and PZ-09, and the long duration of the pumping test, the small storage values and lack of any water table effects indicate that the water table is most likely located in an aquitard that overlies and confines the main permeable zone feeding the pumping well.

Aquifer Properties

Considering the aquifer transmissivity values derived from the specific capacity values (2 $feet^2$ per day), the drawdown-distance analysis (1.75 to 2.2 $feet^2$ per day), and the transient pumping test analyses (0.58 $feet^2$ per day to 4.37 $feet^2$ per day with a geometric mean value of 1.46 $feet^2$ per day), the most likely aquifer transmissivity value is estimated to average approximately 2 $feet^2$ per day. Given the aquifer thickness of 37 feet, the hydraulic conductivity value derived from the pumping test would be 0.04 feet per day; for comparison this is very similar to the value of 0.06 feet per day from the EW-20 slug test (Table 3-1). Generally, there is not a lot of variation in aquifer transmissivity for the various pumping test observation well locations, so little variation in well yields would be expected at the various pumping test observation well locations, with the typical pumping test observation location well yield estimated at approximately 0.125 gpm. The EW-20 hydraulic conductivity value is roughly 4 times the BPA average value determined in the slug tests (Table 3-1), but still far below the values used in the previous site CSM and numerical model, which were based upon the 1 gpm well yield and transmissivity values recorded in the only prior BPA pumping test.

Storage values were in the confined range averaging 0.0017, and indicate the main permeable zone feeding the pumping well is overlain by a lower permeability aquitard where the water table is located. Thus, drainage from the water table may be significantly delayed from flowing into the pumping interval zone.

COC Mass Removals

During the constant-rate aquifer test, the groundwater extraction rate (0.125 gpm) and chemicals of concern (COC) concentrations (Table 3-5 and 3-6) were used to estimate the following COC masses removed during the test: 0.58 pounds of perchlorate; 0.044 pounds of 1,1-DCE; 0.009 pounds of TCE; and 0.003 pounds of 1,4-dioxane.

3.7.2 Vacuum-Enhanced Aquifer Test

At the end of the constant-rate aquifer test, a vacuum was applied to the EW-20 wellhead to conduct a vacuum-enhanced aquifer test. During the first phase of the vacuum-enhanced aquifer test, the groundwater extraction rate was held steady at 0.125 gpm while a vacuum of up to 6 feet of water(5.3 inches of mercury [in. Hg]) was applied to the wellhead, which caused the water level in the well to rise approximately 6 feet, decreasing the drawdown in water level from 12.87 feet to 6.78 feet. During the second phase of the vacuum-enhanced aquifer test, the groundwater extraction rate was held steady at 0.26 gpm while a vacuum of up to 10 feet of water (8.8 in Hg) was applied to the wellhead, which caused the water level in the well to equilibrate at a drawdown in water level of approximately 12.6 feet, or very near the 12.87 feet of drawdown in water level recorded without a vacuum at a pumping rate of 0.125 gpm. Thus, the effect of vacuum enhancement increased the well EW-20 groundwater extraction rate to 2.1 times the rate without vacuum.

Given that the absolute change in pressure (defined as the combination of the change in pressure due to changes in groundwater level plus the change in pressure due to the applied vacuum) was 22.6 feet of water during the second phase of the vacuum -enhanced aquifer test, or 1.77 times the absolute change in pressure of 12.87 feet of water without vacuum, 83% of the increased rate during SVE could be attributed to the increased absolute change in pressure during SVE; therefore, the remaining 17% of the increased rate during SVE is likely attributed to the increased saturated thickness of the aquifer caused by the rising water level induced by the vacuum.

COC Mass Removals

During the second phase of the vacuum-enhanced aquifer test, the groundwater extraction rate (0.26 gpm) and COC concentrations (Table 3-5 and 3-6) were used to estimate the following COC masses removed during the test: 0.22 pounds of perchlorate; 0.020 pounds of 1,1-DCE; 0.005 pounds of TCE; and 0.001 pounds of 1,4-dioxane. During the second phase of the vacuum-enhanced aquifer test, the SVE vapor extraction rate (19.7 standard cubic feet per minute [scfm]) and vapor COC concentrations (Table 3-9 on the following page) were used to estimate the following COC masses removed by SVE: 0 pounds for perchlorate; 0.008 pounds of 1,1-DCE; 0.0008 pounds of TCE; and 0 pounds of 1,4-dioxane.

Thus, the increase in the COC removal rates during the second phase of the vacuum-enhanced aquifer test relative to the single-phase constant-rate test is as follows: perchlorate mass removal rate increased 85%, 1,1-DCE mass removal rate increased 153%, TCE mass removal rate increased 195%, and 1,4-dioxane mass removal rate increased 73%. Since the groundwater extraction rate increased 110% during the second phase of the vacuum-enhanced aquifer test, any changes in COC removal rates greater or less than 110% for VOCs could be attributed to the effects of the SVE system on COC removals, although the inherent variability in COC concentration measurements also influences the results.

Therefore, the total COC masses removed during both phases (constant-rate and vacuum-enhanced) of the aquifer test due to groundwater extraction and SVE combined are as follows: 0.80 pounds of perchlorate; 0.072 pounds of 1,1-DCE; 0.015 pounds of TCE; and 0.004 pounds of 1,4-dioxane.

Table 3-9 Vapor Concentrations – Vacuum -Enhanced Extraction Test

Sample ID	**INFLUENT -102111**	**EFFLUENT -102111**	**INFLUENT -102311**	**EFFLUENT -102311**	**INFLUENT -102711**	**EFFLUENT -102711**
Date Sampled	**10/21/2011**	**10/21/2011**	**10/23/2011**	**10/23/2011**	**10/27/2011**	**10/27/2011**
Parameter	**Units are in parts per million by volume (ppmv)**					
Acetone	**0.514**	**0.290**	**0.0674**	**0.0520**	**0.0724**	<0.0421
2-Butanone (MEK)	**0.298**	**0.206**	**0.0109**	**0.0414**	**0.0143**	**0.0273**
1,1-Dichloroethene	**0.535**	<0.0106	**0.270**	<0.0106	**0.366**	<0.0106
Trichloroethene	**0.0423**	<0.0106	**0.018**	<0.0106	**0.0302**	<0.0106
1,4-Dioxane	<0.0055	<0.0055	<0.0055	<0.0055	<0.0055	<0.0055

3.7.3 Recovery Aquifer Test

At the end of the constant -rate aquifer test and the vacuum -enhanced aquifer test, groundwater extraction and soil vapor extraction was abruptly terminated, and the recovery of water levels was measured with transducers in the extraction well and monitoring wells for a one -week period. Because the recovering water levels are influenced by both recovering pressure in the aquifer and recovering pressure in the overlying soil gas, the data do not meet the assumptions inherent in traditional groundwater pumping test analysis methodologies. There are also no published protocols for interpretation of water level recovery data influenced by both rising water levels and recovering soil gas pressures. Therefore, there is no theoretically well accepted basis for the interpretation of the vacuum -enhanced aquifer test recovery data.

However, since the SVE vacuum was thought to be generally small at all locations expect the pumping well EW-20, it is possible that from a practical perspective, the vacuum -enhanced aquifer test recovery data for the monitoring wells could be interpreted using conventional aquifer drawdown and/or recovery analysis methods. Thus, the vacuum -enhanced aquifer test recovery data were interpreted using conventional drawdown and recovery analysis methods as summarized in Appendix H. The aquifer transmissivity values derived from the recovery data in Appendix H; however, were consistently 2 to 4 times higher than the aquifer transmissivity values estimated by the time-drawdown data (Section 3.4.2); the specific capacity data (Section 3.4.1); the distance-drawdown data (Section 3.4.2); and the slug test analysis (Section 3.1.2). Therefore, despite the small vacuum present at the monitoring locations, it appears that the effects of the vacuum on water level recovery appear to invalidate the use of traditional pumping test drawdown and recovery analysis methods on the vacuum -enhanced aquifer test. Since the vacuum -enhanced aquifer test interpretation results are deemed invalid, these data were not used in estimating aquifer characteristics, though the results are given in Appendix H for documentation purposes.

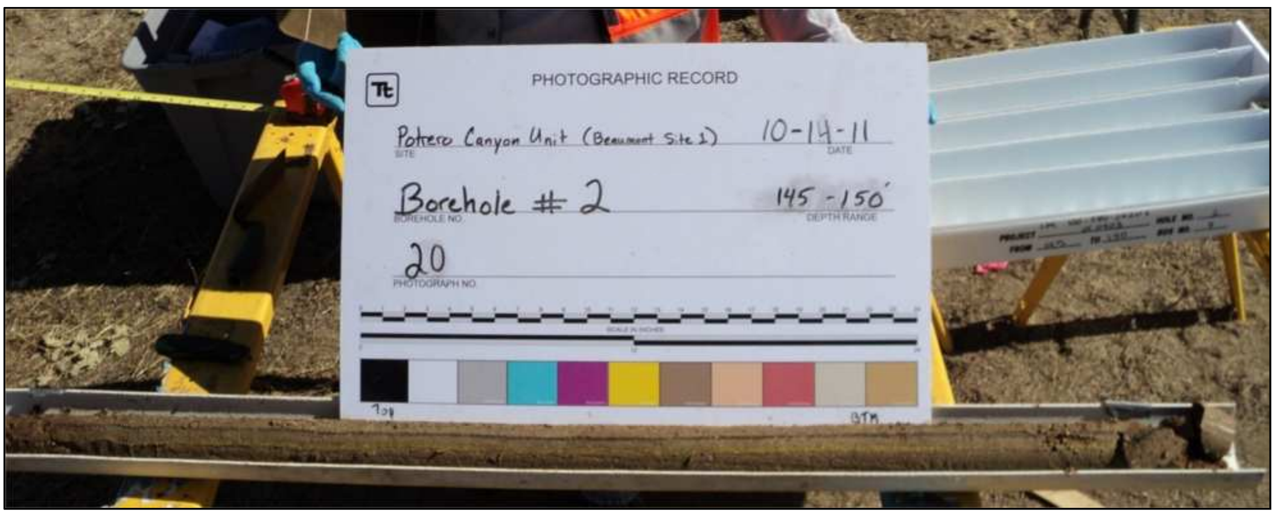
3.8 BEDROCK CHARACTERIZATION – BURN PIT AREA

Three boreholes were advanced with the intent to core MEF sandstone in three areas of the BPA so that detailed lithology, structural relationships, and hydraulic properties could be evaluated. Two boreholes (BH-1 and BH-2) were successful, and one borehole (BH-3) encountered alluvium and flowing sands that prevented coring and physical parameter tests from being conducted.

3.8.1 Bedrock Coring

Borehole BH-1

The location of borehole BH-1 was selected next to the highest concentrations of contaminants detected in groundwater near monitoring well cluster MW-61A/B/C/D. To better understand the variation in contaminant concentrations with depth, rock hardness (induration), and changes in lithology, rock core from BH-1 was sampled on average every two feet along the entire length of the collected core and analyzed for VOCs and perchlorate. The intent was to characterize the distribution of contaminants within the MEF sandstone. Variations in cementation, presence of fractures, and changes in composition were all possible factors that could affect the vertical distribution of contaminants within the sandstone. While very few fractures or changes in lithology were noted in the recovered core, differences in the hardness (induration) of the sandstone were considered the characteristic that varied the most. Only minor changes in lithology were noted with changes in the clay content being the most noted variation. Overall, the MEF sandstone is a weakly to moderately indurated, coarse- to fine -grained, arkosic sandstone that is massively bedded. Little variation in sediment size and content was observed. The unit is not very laminated and a lack of bedding appears to be characteristic of the sandstone near the BPA. The photo shown below of BH-2 is representative of the core observed at both boreholes BH-1 and BH-2, and shows the homogeneous and unfractured nature of the MEF sandstone at the BPA. RQD values on the recovered core consisted of all fragments being greater than 4-inches in length.



Borehole BH-2

Borehole BH-2 was selected based on seismic profile #15 and the projected Fault F identified during the lineament study. The borehole was sited to intercept the MEF sandstone at about Fault F at approximately 60 to 70 linear feet along the borehole (52 to 60.6 vertical feet) based on seismic reflection data and data reviewed from boring logs from the MW-59 well cluster. Based on the seismic reflection data, it was anticipated to encounter Fault F at between 85 and 95 linear feet. Competent MEF sandstone was encountered at about 58 feet linear feet (about 50 vertical feet bgs), where HQ coring began. At approximately 92 linear feet, a highly fractured section of sandstone was encountered, which resulted in the loss of core and all drilling fluids. The recovery of the core went from 100% to less than 40% and remained that way for approximately 15 linear feet. Corehole recovery began to improve at about 110 linear feet, but drilling fluid recovery never returned. It is interpreted that the fault was most likely encountered at about 92 linear feet and continued through a shear zone about 7.5 feet thick assuming a vertical fault plane. The fault zone appears to be a zone of high conductivity due to the loss of drilling fluid throughout this zone. Coring continued to the planned depth of 150 linear feet. Some fractures were noted below the fault zone, but for the most part, the MEF sandstone was not extensively fractured except around the interpreted fault zone. RQD values on the recovered core consisted of all fragments being greater than 4-inches in length.

Borehole BH-3

In Borehole #3, the fault could be seen in the seismic reflection data and, based on the lineament study, it was assumed that the fault was oriented roughly North 37o West (N37oW). Two seismic reflection profiles were generated in the fall of 2008 to look for faults that crossed the BPA. As part of that study, one refraction profile was generated to support the seismic reflection work. That refraction profile was along profile 3414. The refraction profile identified three velocity zones (1220 ft/sec, 2340 ft/sec, and 6800 ft/sec). In previous reports where completely weathered MEF sandstone was exposed at the surface, seismic velocities were on the order of 2150 to 2250 ft/sec, and were interpreted to represent completely weathered MEF sandstone based on exposures of weathered MEF along the profiles (Pad with Dry Well and Pad on Berm/Motor Washout Area).

To intercept the fault as near to perpendicular as possible, the drill rig was oriented on Borehole 3 to drill along an azimuth of North 52°East (N52°E). The borehole was also setup to drill an angled borehole at about 30° from vertical in an attempt to core through the fault as close to perpendicular as possible to the fault plane. The subsequent lineament study and fault investigation conducted by Dr. Morton showed that Fault F (defined by Morton) correlated somewhat with Terra Physics anomaly “Unnamed Fault #4” on profile 3414.

Dr. Morton’s Fault F projected through the BPA and could be correlated to anomalies on Terra Physics’ profiles 3414 and Profile #15 that showed offset. The boreholes were located based on the seismic reflection profiles. In the area of BH-3, while the seismic reflection profile did not identify the top of the MEF, it did show reflectors at depth that appeared to have some offset. A subsequent review of the refraction profile that was also generated on profile 3414 shows a thick section of “dry unconsolidated alluvium” having a seismic velocity of 2340 ft/sec. The more competent MEF sandstone has a seismic velocity of 6800 ft/sec. Based on the seismic velocities and MEF call outs in borehole MW-73 to the west and MW-71 to the east, weathered MEF sandstone was expected at a depth of between 50 and 80 feet bgs. Information collected during drilling of this angled boring however, indicated that weathered MEF sandstone was not encountered, but rather very sandy alluvial material that might represent a paleochannel of Bedsprings Creek (coarse-grained, relatively clean sands at a depth of 112 to 122 linear feet in the angled borehole). Review of other seismic reflection and refraction data further north (down gradient from the BPA) did not show indications of a paleochannel. While the intent of the earlier seismic work was to develop stratigraphic correlations to seismic data and to delineate MEF topography, the profiles to the north were much shorter in length and might not have been long enough to adequately characterize a buried paleochannel if one did exist.

Based on seismic data and borehole data from monitoring wells MW-71 and MW-73, it was estimated that weathered MEF sandstone should have been encountered at approximately 90 to 100 linear feet along the borehole length and that the fault should have been intercepted at between 115 and 125 feet along the borehole. Drilling using hollow stem auger techniques relied on drill rig motion and the driller’s informing the site geologist of varying drilling conditions that would be indicative of potential weathered sandstone. At approximately 112 to 122 linear feet (95.3 to 112.6 vertical feet), flowing sands were encountered. The drilling was difficult from this point on. Split-spoon samples were driven at several depths where harder drilling was encountered, but rig chatter and the occasional split spoon did not identify weathered MEF sandstone until a borehole depth of about 138 linear feet (about 119.5 vertical feet). Drilling was stopped at 140 linear feet (about 121 vertical feet) based on limited penetration and the presence of MEF sandstone. Because the total depth of the augered borehole was 140 linear feet and the total planned depth of this borehole was 150 linear feet, it was decided to install a pre-pack well in the area of flowing sands that was encountered at between 112 and 122 linear feet. A 2-inch diameter single completion pre-pack well and associated materials were installed such that a 20-foot screened interval crossed the zone of flowing sands from 110 to 130 linear feet (95.3 feet to 112.6 feet vertically).

3.8.2 Rock Matrix Sampling and Analysis

Rock matrix sampling and analysis were only conducted on core collected from borehole BH-1 since it was located at the source area where the highest contaminant concentrations at the site have been detected. Continuous core was collected from BH-1 from 55 linear feet to 200 linear feet (47.6 to 173.2 vertical feet) for a total of 145 linear feet of coring. A total of 112.5 linear feet of core was recovered for a total recovery of 77.6% total recovery. Samples were collected at changes in lithology, changes in density, and at, and adjacent to, identified fractures. In general, whole rock samples were collected every 1.65 linear feet on average along the entire length of core recovered. All samples were analyzed for VOCs and perchlorate. Perchlorate analysis was performed by E.S. Babcock & Sons. Figure 3-6 shows a graph of the rock core contaminant concentrations with depth in vertical feet below ground surface (corrected from the angled borehole, 30° from vertical).

Rock matrix analytical results are tabulated in Table 3-10 with depths presented in linear feet along the angled borehole (30° from vertical). Maximum concentrations detected in BH-1 were found at approximately 75.5 vertical feet (87.4 linear feet) with perchlorate at a concentration of 4,700 µg/kg, 1,1-DCE at 610 µg/kg, and TCE at 340 µg/kg. The depth to water during drilling was 71.7 vertical feet or about 82.75 linear feet. Results of the rock core analyses show that the contaminant mass is primarily between 57 and 101 feet bgs, and that concentrations decrease rapidly below 102 feet and are nearly non-detect below 105 feet. Rock core samples collected in the weathered, unsaturated zone contained contaminants, but concentrations were the highest in the area just below the current water table. The water table in this area has fluctuated from a high of 40 feet bgs to a low of 95 feet bgs between 1992 and 2011.

The rock matrix sampling results show that the highest VOC (1,1-DCE and TCE) and perchlorate concentrations were detected between 86.4 and 102.2 linear feet (75 to 88.5 vertical feet) in poorly to moderately indurated sandstone with no fractures present. Above this zone, several horizontal fractures were identified in the cores which were most likely mechanical breaks from the drilling and core recovery since no fractures were seen in the borehole televiewer at these depths. The data collected during this investigation show that the contaminant mass has a fairly limited vertical extent and is located within the low permeability rock matrix where there is an absence of fractures. The contaminant mass that is present within the low permeability sandstone may continue to degrade water quality from the slow release of contaminants from the sandstone into the more permeable alluvium downgradient of the source. Although on a much larger scale, this process may be similar to the matrix diffusion process as described in the bedrock studies conducted by Dr. Beth Parker and John A. Cherry utilizing the Discrete Fracture Network (DFN) Approach (Parker et al, 2010, Cherry et al, 2007, and Parker 2007). Their bedrock characterization studies indicate that the slow release of contaminant mass from the low-permeability matrix between fractures may degrade water quality for centuries or more despite complete removal of the source zone mass (Parker et al, 2010). These studies have also shown that from a remediation perspective, matrix diffusion can create significant challenges for contaminant mass removal due to the difficulties in accessing contaminant mass in the rock matrix. In fact, the absence of fractures may make it even more difficult to access contaminant mass within the matrix at this site as much of the porewater within the sandstone may be stagnant except for the less indurated zones where the majority of the groundwater flow most likely occurs.

Estimated rock porewater concentrations were determined based on physical property results for bulk density, porosity and organic carbon content in conjunction with the VOC data and are tabulated in Table 3-11. The methods and data used to estimate the porewater concentrations are discussed in the Stone Environmental Report in Appendix D. The estimated porewater concentrations for TCE and 1,1-DCE range from 1.7 to 3,100 µg/L and 12 to 5,800 µg/L. The range of rock porewater VOC concentrations are consistent with the contaminant concentrations observed in nearby monitoring wells at the BPA.

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Figure 3-6 Rock Core Sample Concentrations versus Depth below Ground Surface - BH-1

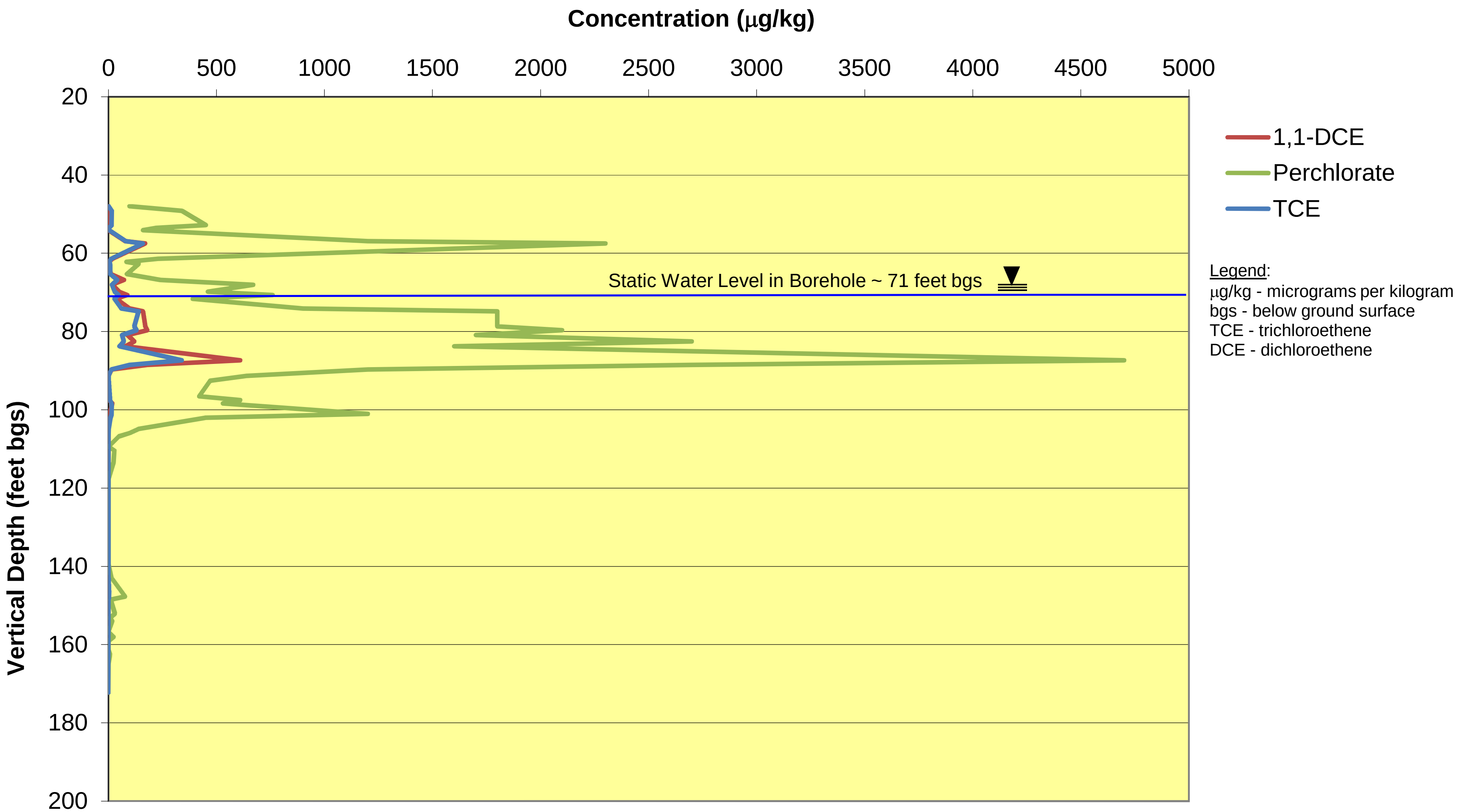

Table 3-10 Rock Core Analytical Results – BH-1

Sample Name – depth (linear feet)	Vertical Depth (bgs)	Sample Date	Per-chlorate	Carbon Tetrachloride	Chloro-form	1,1-Dichloro-ethane	1,2-Dichloro-ethane	1,1-Dichloro-ethene	c-1,2-Dichloro-ethene	1,1,2-Trichloro ethane	Trichloro-ethene	Tetrachloro-ethene
			Results are reported in µg/kg									
BH1-55.4	47.98	11/14/2011	**97**	<0.18	<0.13	<7.9	<2.3	<1.7	<7.3	<0.41	**1.6**	<0.13
BH1-56.8	49.19	11/14/2011	**340**	<0.17	<0.12	<7.4	**2.2 Jq**	**9.3 Jq**	<6.8	<0.38	**16**	<0.12
BH1-61.0	52.83	11/14/2011	**450**	<0.16	<0.12	<7.1	**4.3 Jq**	**6.6 Jq**	<6.5	<0.37	**16**	<0.12
BH1-61.8	53.52	11/14/2011	**220**	<0.14	<0.10	<6.2	<1.8	<1.3	<5.7	<0.32	**1.5**	<0.10
BH1-62.5	54.13	11/14/2011	**160**	<0.20	<0.14	<8.8	<2.6	<1.8	<8.1	<0.46	**2.6**	<0.14
BH1-65.7	56.90	11/14/2011	**1200**	<0.15	<0.11	<6.6	**34**	**79**	<6.1	<0.34	**79**	**0.31 Jq**
BH1-66.4	57.50	11/14/2011	**2300**	**0.19 Jq**	**1.1**	<6.7	**54**	**170**	<6.1	<0.35	**160**	**0.96**
BH1-70.9	61.40	11/14/2011	**230**	<0.11	<0.081	<5.0	**1.6 Jq**	**18**	<4.6	<0.26	**12**	<0.081
BH1-71.8	62.18	11/14/2011	**83**	<0.11	<0.079	<4.9	<1.4	**1.5 Jq**	<4.5	<0.25	**5.6**	<0.079
BH1-72.4	62.70	11/14/2011	**140**	<0.15	<0.11	<6.5	<1.9	<1.4	<6.0	<0.34	**8**	<0.11
BH1-75.4	65.30	11/14/2011	**86**	<0.11	<0.081	<4.9	<1.5	**11**	<4.5	<0.26	**8.2**	<0.081
BH1-77.2	66.86	11/14/2011	**240**	<0.14	<0.099	<6.0	**11**	**72**	<5.6	<0.31	**41**	**0.099 Jq**
BH1-78.6	68.07	11/14/2011	**670**	<0.13	<0.092	<5.7	**4.8 Jq**	**17**	<5.2	<0.29	**16**	<0.092
BH1-80.6	69.80	11/14/2011	**460**	<0.12	<0.082	<5.0	**6.4 Jq**	**50**	<4.6	<0.26	**29**	<0.082
BH1-81.6	70.67	11/14/2011	**760**	**0.14 Jq**	<0.098	<6.0	**11**	**88**	<5.5	<0.31	**47**	**0.21 Jq**
BH1-82.7	71.62	11/14/2011	**390**	<0.14	<0.096	<5.9	**7.7 Jq**	**37**	<5.4	<0.31	**28**	<0.096
BH1-85.6	74.13	11/14/2011	**900**	<0.12	<0.083	<5.1	**15**	**99**	<4.7	<0.26	**59**	**0.21 Jq**
BH1-86.4	74.82	11/14/2011	**1800**	<0.16	**0.78 Jq**	<7.1	**40**	**160**	<6.5	**8.8**	**140**	**0.34 Jq**
BH1-90.9	78.72	11/14/2011	**1800**	**0.16 Jq**	**0.95**	<5.9	**17**	**170**	<5.5	<0.31	**120**	**0.14 Jq**
BH1-92.0	79.67	11/14/2011	**2100**	**0.20 Jq**	**1.1**	<5.3	**20**	**180**	<4.9	<0.27	**130**	**0.25 Jq**
BH1-93.4	80.89	11/14/2011	**1700**	**0.13 Jq**	**0.19 Jq**	<4.9	**11**	**88**	<4.5	<0.25	**63**	<0.080
BH1-95.3	82.53	11/14/2011	**2700**	**0.16 Jq**	**0.15 Jq**	<5.8	**9.2**	**120**	<5.3	<0.30	**71**	<0.095
BH1-96.7	83.74	11/14/2011	**1600**	<0.12	<0.087	<5.3	**8.4**	**79**	<4.9	<0.27	**51**	<0.087
BH1-100.9	87.38	11/14/2011	**4700**	**0.59 Jq**	**3.6**	**17**	**48**	**610**	**7.9**	<0.29	**340**	**1.1**
BH1-102.2	88.51	11/14/2011	**2700**	**0.24 Jq**	**0.78 Jq**	<6.2	**13**	**180**	<5.7	**2.4**	**99**	**0.12 Jq**
BH1-103.6	89.72	11/14/2011	**1200**	<0.14	<0.095	<5.8	<1.7	**15**	<5.4	<0.30	**14**	<0.095
BH1-105.5	91.37	11/14/2011	**640**	<0.17	<0.12	<7.3	<2.1	<1.5	<6.7	<0.38	**2.2**	<0.12
BH1-106.9	92.58	11/14/2011	**470**	<0.14	<0.099	<6.1	<1.8	<1.3	<5.6	<0.31	**1.7**	<0.099
BH1-111.5	96.56	11/15/2011	**420**	<0.18	<0.12	<7.6	<2.3	<1.6	<7.0	<0.39	**6.9**	<0.12

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Sample Name – depth (linear feet)	Vertical Depth (bgs)	Sample Date	Per-chlorate	Carbon Tetrachloride	Chloro-form	1,1-Dichloro-ethane	1,2-Dichloro-ethane	1,1-Dichloro-ethene	c-1,2-Dichloro-ethene	1,1,2-Trichloro ethane	Trichloro-ethene	Tetrachloro-ethene
BH1-112.6	97.51	11/15/2011	**610**	<0.14	<0.096	<5.9	<1.7	**1.3 Jq**	<5.4	<0.30	**7.8**	<0.096
BH1-113.6	98.38	11/15/2011	**530**	<0.13	<0.093	<5.7	**1.7 Jq**	**18**	<5.2	<0.29	**15**	<0.093
BH1-116.7	101.07	11/15/2011	**1200**	<0.15	<0.11	<6.5	**3.8 Jq**	**5.5 Jq**	<5.9	<0.33	**16**	<0.11
BH1-117.8	102.02	11/15/2011	**450**	<0.16	<0.12	<7.1	<2.1	<1.5	<6.5	<0.37	**9.8**	<0.12
BH1-121.1	104.88	11/15/2011	**140**	<0.11	<0.078	<4.8	<1.4	<1.00	<4.4	<0.25	**2.1**	<0.078
BH1-122.3	105.91	11/15/2011	**99**	<0.14	<0.096	<5.9	<1.7	<1.2	<5.4	<0.30	**1.4**	<0.096
BH1-123.3	106.78	11/15/2011	**49**	<0.15	<0.10	<6.3	<1.9	<1.3	<5.8	<0.33	<0.10	<0.10
BH1-126.3	109.38	11/15/2011	<4.3	<0.098	<0.069	<4.2	<1.3	<0.88	<3.9	<0.22	<0.069	<0.069
BH1-127.5	110.42	11/15/2011	**28**	<0.13	<0.092	<5.6	<1.7	<1.2	<5.2	<0.29	<0.092	<0.092
BH1-130.9	113.36	11/15/2011	**24**	<0.10	<0.071	<4.4	<1.3	<0.91	<4.0	<0.23	**0.62**	<0.071
BH1-135.8	117.61	11/15/2011	<4.3	<0.15	<0.11	<6.5	<1.9	<1.3	<5.9	<0.33	<0.11	<0.11
BH1-136.9	118.56	11/15/2011	<4.5	<0.12	<0.082	<5.0	<1.5	<1.0	<4.6	<0.26 UJc	<0.082	<0.082
BH1-140.6	121.76	11/15/2011	<4.3	<0.16	<0.12	<7.1	<2.1	<1.5	<6.5	<0.37	<0.12	<0.12
BH1-145.7	126.18	11/15/2011	<4.4	<0.15	<0.11	<6.5	<1.9	<1.3	<6.0	<0.34	<0.11	<0.11
BH1-147.2	127.48	11/15/2011	<4.4	<0.12	<0.081	<5.0	<1.5	<1.0	<4.6	<0.26	<0.081	<0.081
BH1-148.3	128.43	11/15/2011	<4.3	<0.099	<0.070	<4.3	<1.3	<0.89	<3.9	<0.22	<0.070	<0.070
BH1-151.4	131.12	11/15/2011	<4.4	<0.13	<0.091	<5.6	<1.6	<1.2	<5.1	<0.29	<0.091	<0.091
BH1-153.7	133.11	11/15/2011	<4.3	<0.14	<0.10	<6.2	<1.8	<1.3	<5.7	<0.32	<0.10	<0.10
BH1-156.0	135.10	11/15/2011	<4.4	<0.14	<0.096	<5.9	<1.7	<1.2	<5.4	<0.30	<0.096	<0.096
BH1-157.2	136.14	11/15/2011	<4.4	<0.13	<0.090	<5.5	<1.6	<1.1	<5.1	<0.29	<0.090	<0.090
BH1-158.4	137.18	11/15/2011	<4.4	<0.12	<0.082	<5.0	<1.5	<1.0	<4.6	<0.26	<0.082	<0.082
BH1-161.2	139.60	11/15/2011	<4.3	<0.11	<0.080	<4.9	<1.5	<1.0	<4.5	<0.25	<0.080	<0.080
BH1-165	142.89	11/16/2011	**14**	<0.11	<0.080	<4.9	<1.5	<1.0	<4.5	<0.25	<0.080	<0.080
BH1-170.6	147.74	11/16/2011	**77**	<0.11	<0.080	<4.9	<1.4	<1.0	<4.5	<0.25	**4.5**	<0.080
BH1-171.5	148.52	11/16/2011	**9.7**	<0.14	<0.097	<6.0	<1.8	<1.2	<5.5	<0.31	**0.61 Jq**	<0.097
BH1-175.6	152.07	11/16/2011	**30**	<0.12	<0.085	<5.2	<1.5	<1.1	<4.8	<0.27	**0.31 Jq**	<0.085
BH1-176.9	153.20	11/16/2011	**6**	<0.11	<0.080	<4.9	<1.5	<1.0	<4.5	<0.25	<0.080	<0.080
BH1-177.9	154.07	11/16/2011	**18**	<0.11	<0.080	<4.9	<1.4	<1.0	<4.5	<0.25	<0.080	<0.080
BH1-181.0	156.75	11/16/2011	<4.3	<0.11	<0.079	<4.8	<1.4	<1.0	<4.4	<0.25	<0.079	<0.079
BH1-182.5	158.05	11/16/2011	**24**	<0.11	<0.079	<4.8	<1.4	<1.0	<4.4	<0.25	**0.19 Jq**	<0.079
BH1-183.7	159.09	11/16/2011	<4.6	<0.11	<0.078	<4.8	<1.4	<1.00	<4.4	<0.25	<0.078	<0.078
BH1-186.4	161.43	11/16/2011	<4.5	<0.12	<0.086	<5.3	<1.6	<1.1	<4.8	<0.27	<0.086	<0.086

Sample Name – depth (linear feet)	Vertical Depth (bgs)	Sample Date	Per-chlorate	Carbon Tetrachloride	Chloro-form	1,1-Dichloro-ethane	1,2-Dichloro-ethane	1,1-Dichloro-ethene	c-1,2-Dichloro-ethene	1,1,2-Trichloro ethane	Trichloro-ethene	Tetrachloro-ethene
BH1-187.8	162.64	11/16/2011	**7.3**	<0.10	<0.073	<4.5	<1.3	<0.93	<4.1	<0.23	<0.073	<0.073
BH1-190.5	164.98	11/16/2011	<4.3	<0.15	<0.11	<6.5	<1.9	<1.4	<6.0	<0.34	<0.11	<0.11
BH1-191.8	166.10	11/16/2011	<4.4	<0.11	<0.077	<4.7	<1.4	<0.98	<4.3	<0.24	<0.077	<0.077
BH1-192.9	167.06	11/16/2011	<5.2	<0.11	<0.076	<4.6	<1.4	<0.97	<4.3	<0.24	<0.076	<0.076
BH1-196.1	169.83	11/16/2011	<4.3	<0.13	<0.095	<5.8	<1.7	<1.2	<5.4	<0.30	<0.095	<0.095
BH1-197.7	171.21	11/16/2011	<4.3	<0.13	<0.090	<5.5	<1.6	<1.2	<5.1	<0.29	<0.090	<0.090
BH1-198.9	172.25	11/16/2011	<4.3	<0.11	<0.080	<4.9	<1.5	<1.0	<4.5	<0.25	<0.080	<0.080

Notes: Only analytes positively detected are presented in this table. For a complete list, refer to the laboratory data package.
µg/kg - micrograms per kilogram
J - Estimated gene copies below PQL but above LQL
U - The analyte was not detected above the method detection limit (MDL).
q - The analyte detection was below the Practical Quantitation Limit (PQL).
c - The MS and/or MSD recoveries were outside control limits.

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Table 3-11 Estimated Pore Water Concentrations – BH-1

						Comments/Interpretation (3)			Estimated Pore Water Concentration (ug/L) (5)																	
			Depth from	Depth to	Avg. Depth																					
Sample ID	Location ID	Interval (linear feet)	linear ft	linear ft	linear ft	Sample Lithology (3a)	Position Relative to Fracturing (3b)	Fracture Type (3c)	1,2-Dichloroethane		1,1,2-Trichloroethane		1,1-Dichloroethane		1,1-Dichloroethene		Carbon Tetrachloride		Chloroform		cis-1,2-Dichloroethene		Tetrachloroethene		Trichloroethene	
BH1-55.40-VOC	BH1	55.4 - 55.5	55.4	55.5	55.45	Sandstone	NA	NA	23	UJ	4	UJ	78	UJ	16	UJ	1.3	UJ	1.3	UJ	69	UJ	1	UJ	15	
BH1-56.80-VOC	BH1	56.8 -55.9	56.8	56.9	56.85	Sandstone	NA	NA	22	J	3.7	UJ	73	UJ	89	J	1.3	UJ	1.2	UJ	64	UJ	0.94	UJ	150	
BH1-61.00-VOC	BH1	61 - 61.1	61	61.1	61.05	Sandstone	NA	NA	43	J	3.6	UJ	70	UJ	63	J	1.2	UJ	1.2	UJ	61	UJ	0.94	UJ	150	
BH1-61.80-VOC	BH1	61.8 - 61.9	61.8	61.9	61.85	Sandstone	NA	NA	18	UJ	3.1	UJ	61	UJ	12	UJ	1	UJ	0.97	UJ	54	UJ	0.78	UJ	14	
BH1-62.50-VOC	BH1	62.5 - 62.6	62.5	62.6	62.55	Sandstone	NA	NA	26	UJ	4.4	UJ	87	UJ	17	UJ	1.5	UJ	1.4	UJ	76	UJ	1.1	UJ	24	
BH1-65.70-VOC	BH1	65.7 - 65.8	65.7	65.8	65.75	sandstone	NA	NA	340		3.3	UJ	65	UJ	760		1.1	UJ	1.1	UJ	58	UJ	2.4	J	720	
BH1-66.40-VOC	BH1	66.4 - 66.5	66.4	66.5	66.45	Sandstone	NA	NA	540		3.4	UJ	66	UJ	1600		1.4	J	11		58	UJ	7.5		1500	
BH1-70.90-VOC	BH1	70.9 - 71.0	70.9	71.0	70.95	Sandstone	NA	NA	16	J	2.5	UJ	49	UJ	170		0.82	UJ	0.79	UJ	43	UJ	0.64	UJ	110	
BH1-71.80-VOC	BH1	71.8 - 71.9	71.8	71.9	71.85	Sandstone	NA	NA	14	UJ	2.4	UJ	48	UJ	14	J	0.82	UJ	0.77	UJ	42	UJ	0.62	UJ	51	
BH1-72.40-VOC	BH1	72.4 - 72.5	72.4	72.5	72.45	Sandstone	NA	NA	19	UJ	3.3	UJ	64	UJ	13	UJ	1.1	UJ	1.1	UJ	57	UJ	0.86	UJ	73	
BH1-75.40-VOC	BH1	75.4 - 75.5	75.4	75.5	75.45	Sandstone	BF	HF	15	UJ	2.5	UJ	48	UJ	110		0.82	UJ	0.79	UJ	42	UJ	0.64	UJ	75	
BH1-77.20-VOC	BH1	77.2 - 77.3	77.2	77.3	77.25	sandstone	NA	NA	110		3	UJ	59	UJ	690		1	UJ	0.96	UJ	53	UJ	0.78	J	380	
BH1-78.60-VOC	BH1	78.6 - 78.7	78.6	78.7	78.65	Sandstone	NA	NA	48	J	2.8	UJ	56	UJ	160		0.97	UJ	0.9	UJ	49	UJ	0.72	UJ	150	
BH1-80.60-VOC	BH1	80.6 - 80.7	80.6	80.7	80.65	Sandstone	BET	HF	64	J	2.5	UJ	49	UJ	480		0.9	UJ	0.8	UJ	43	UJ	0.64	UJ	270	
BH1-81.60-VOC	BH1	81.6 - 81.7	81.6	81.7	81.65	Sandstone	BF	HF	110		3	UJ	59	UJ	840		1	J	0.95	UJ	52	UJ	1.6	J	430	
BH1-82.70-VOC	BH1	82.7 - 82.8	82.7	82.8	82.75	Sandstone	BET	HF	77	J	3	UJ	58	UJ	350		1	UJ	0.94	UJ	51	UJ	0.75	UJ	260	
BH1-85.60-VOC	BH1	85.6 - 85.7	85.6	85.7	85.65	Sandstone	BF	HF	150		2.5	UJ	50	UJ	950		0.9	UJ	0.81	UJ	44	UJ	1.6	J	540	
BH1-86.40-VOC	BH1	86.4 - 86.5	86.4	86.5	86.45	Sandstone	NA	NA	400		85		70	UJ	1500		1.2	UJ	7.6	J	61	UJ	2.7	J	1300	
BH1-90.90-VOC	BH1	90.9 - 91.0	90.9	91.0	90.95	Sandstone	NA	NA	170		3	UJ	58	UJ	1600		1.2	J	9.3		52	UJ	1.1	J	1100	
BH1-92.00-VOC	BH1	92.0 - 92.1	92.0	92.1	92.05	Sandstone	NA	NA	200		2.6	UJ	52	UJ	1700		1.5	J	11		46	UJ	2	J	1200	
BH1-93.40-VOC	BH1	93.4 - 93.5	93.4	93.5	93.45	Sandstone	NA	NA	110		2.4	UJ	48	UJ	840		0.97	J	1.9	J	42	UJ	0.63	UJ	580	
BH1-95.30-VOC	BH1	95.3 - 95.4	95.3	95.4	95.35	Sandstone	NA	NA	92		2.9	UJ	57	UJ	1200		1.2	J	1.5	J	50	UJ	0.74	UJ	650	
BH1-96.70-VOC	BH1	96.7 - 96.8	96.7	96.8	96.75	Sandstone	NA	NA	84		2.6	UJ	52	UJ	760		0.9	UJ	0.85	UJ	46	UJ	0.68	UJ	470	
BH1-100.90-VOC	BH1	100.9 - 101.0	100.9	101.0	100.95	Sandstone	NA	NA	480		2.8	UJ	170		5800		4.4	J	35		75		8.6		3100.0	
BH1-102.20-VOC	BH1	102.2 - 102.3	102.2	102.3	102.25	Sandstone	NA	NA	130		23		61	UJ	1700		1.8	J	7.6	J	54	UJ	0.94	J	910	
BH1-103.60-VOC	BH1	103.6	103.6	103.7	103.65	Sandstone	NA	NA	17	UJ	2.9	UJ	57	UJ	140		1	UJ	0.93	UJ	51	UJ	0.74	UJ	130	
BH1-105.5-VOC	BH1	105.5	105.5	105.6	105.55	Sandstone	NA	NA	21	UJ	3.7	UJ	72	UJ	14	UJ	1.3	UJ	1.2	UJ	63	UJ	0.94	UJ	20.0	
BH1-106.9-VOC	BH1	106.9	106.9	107	106.95	Sandstone	NA	NA	18	UJ	3	UJ	60	UJ	12	UJ	1	UJ	0.96	UJ	53	UJ	0.78	UJ	16	
BH1-111.50-VOC	BH1	111.5	111.5	111.6	111.55	Sandstone	NA	NA	23	UJ	3.8	UJ	75	UJ	15	UJ	1.3	UJ	1.2	UJ	66	UJ	0.94	UJ	63	
BH1-112.60-VOC	BH1	112.6 - 112.7	112.6	112.7	112.65	Sandstone	NA	NA	17	UJ	2.9	UJ	58	UJ	12	J	1	UJ	0.94	UJ	51	UJ	0.75	UJ	72	
BH1-113.60-VOC	BH1	113.6 - 113.7	113.6	113.7	113.65	Sandstone	NA	NA	17	J	2.8	UJ	56	UJ	170		0.97	UJ	0.91	UJ	49	UJ	0.73	UJ	140	
BH1-116.70-VOC	BH1	116.7 - 116.8	116.7	116.8	116.75	Sandstone	NA	NA	38	J	3.2	UJ	64	UJ	53	J	1.1	UJ	1.1	UJ	56	UJ	0.86	UJ	150	

Table 3-11 Estimated Pore Water Concentrations – BH-1 (Cont'd)

						Comments/Interpretation (3)			Estimated Pore Water Concentration (ug/L) (5)																	
Sample ID	Location ID	Interval (linear feet)	Depth from (linear ft)	Depth to (linear ft)	Avg. Depth (linear ft)	Sample Lithology (3a)	Position Relative to Fracturing (3b)	Fracture Type (3c)	1,2-Dichloroethane		1,1,2-Trichloroethane		1,1-Dichloroethane		1,1-Dichloroethene		Carbon Tetrachloride		Chloroform		cis-1,2-Dichloroethene		Tetrachloroethene		Trichloroethene	
BH1-117.80-VOC	BH1	117.8 - 117.9	117.8	117.9	117.85	Sandstone	NA	NA	21	UJ	3.6	UJ	70	UJ	14	UJ	1.2	UJ	1.2	UJ	61	UJ	0.94	UJ	90	
BH1-121.10-VOC	BH1	121.1 - 121.2	121.1	121.2	121.15	Sandstone	NA	NA	14	UJ	2.4	UJ	47	UJ	9.6	UJ	0.82	UJ	0.76	UJ	42	UJ	0.61	UJ	19	
BH1-122.30-VOC	BH1	122.3 - 122.4	122.3	122.4	122.35	Sandstone	NA	NA	17	UJ	2.9	UJ	58	UJ	12	UJ	1	UJ	0.94	UJ	51	UJ	0.75	UJ	13	
BH1-123.30-VOC	BH1	123.3 - 123.4	123.3	123.4	123.35	Sandstone	NA	NA	19	UJ	3.2	UJ	62	UJ	12	UJ	1.1	UJ	0.97	UJ	55	UJ	0.78	UJ	0.92	UJ
BH1-126.30-VOC	BH1	126.3 - 126.4	126.3	126.4	126.35	Sandstone	NA	NA	13	UJ	2.1	UJ	41	UJ	8.4	UJ	0.73	UJ	0.67	UJ	37	UJ	0.54	UJ	0.63	UJ
BH1-127.50-VOC	BH1	127.5 - 127.6	127.5	127.6	127.55	Sandstone	NA	NA	17	UJ	2.8	UJ	55	UJ	12	UJ	0.97	UJ	0.9	UJ	49	UJ	0.72	UJ	0.84	UJ
BH1-130.90-VOC	BH1	130.9 - 131.0	130.9	131.0	130.95	Sandstone	NA	NA	13	UJ	2.2	UJ	43	UJ	8.7	UJ	0.75	UJ	0.69	UJ	38	UJ	0.56	UJ	5.7	
BH1-135.80-VOC	BH1	135.8 - 135.9	135.8	135.9	135.85	Sandstone	NA	NA	19	UJ	3.2	UJ	64	UJ	12	UJ	1.1	UJ	1.1	UJ	56	UJ	0.86	UJ	1	UJ
BH1-136.90-VOC	BH1	136.9 - 137.0	136.9	137.0	136.95	Sandstone	NA	NA	15	UJ	2.5	UJ	49	UJ	9.6	UJ	0.9	UJ	0.8	UJ	43	UJ	0.64	UJ	0.75	UJ
BH1-140.60-VOC	BH1	140.6 - 140.7	140.6	140.7	140.65	Sandstone	NA	NA	21	UJ	3.6	UJ	70	UJ	14	UJ	1.2	UJ	1.2	U	61	UJ	0.94	UJ	1.1	UJ
BH1-145.70-VOC	BH1	145.7 - 145.8	145.7	145.8	145.75	Sandstone	NA	NA	19	UJ	3.3	UJ	64	UJ	12	UJ	1.1	UJ	1.1	UJ	57	UJ	0.86	UJ	1	UJ
BH1-147.20-VOC	BH1	147.2 - 147.3	147.2	147.3	147.25	Sandstone	NA	NA	15	UJ	2.5	UJ	49	UJ	9.6	UJ	0.9	UJ	0.79	UJ	43	UJ	0.64	UJ	0.74	UJ
BH1-148.30-VOC	BH1	148.3 - 148.4	148.3	148.4	148.35	Sandstone	NA	NA	13	UJ	2.1	UJ	42	UJ	8.5	UJ	0.74	UJ	0.68	UJ	37	UJ	0.55	UJ	0.64	UJ
BH1-151.40-VOC	BH1	151.4 - 151.5	151.4	151.5	151.45	Sandstone	NA	NA	16	UJ	2.8	UJ	55	UJ	12	UJ	0.97	UJ	0.89	UJ	48	UJ	0.71	UJ	0.83	UJ
BH1-153.70-VOC	BH1	153.7 - 153.8	153.7	153.8	153.75	Sandstone	NA	NA	18	UJ	3.1	UJ	61	UJ	12	UJ	1	UJ	0.97	UJ	54	UJ	0.78	UJ	0.92	UJ
BH1-156.00-VOC	BH1	156.0 - 156.1	156.0	156.1	156.05	Sandstone	NA	NA	17	UJ	2.9	UJ	58	UJ	12	UJ	1	UJ	0.94	UJ	51	UJ	0.75	UJ	0.88	UJ
BH1-157.20-VOC	BH1	157.2 - 157.3	157.2	157.3	157.25	Sandstone	NA	NA	16	UJ	2.8	UJ	54	UJ	11	UJ	0.97	UJ	0.88	UJ	48	UJ	0.71	UJ	0.83	UJ
BH1-158.40-VOC	BH1	158.4 - 158.5	158.4	158.5	158.45	Sandstone	NA	NA	15	UJ	2.5	UJ	49	UJ	9.6	UJ	0.9	UJ	0.8	UJ	43	UJ	0.64	UJ	0.75	UJ
BH1-161.20-VOC	BH1	161.2 - 16.3	161.2	161.3	161.25	Sandstone	NA	NA	15	UJ	2.4	UJ	48	UJ	9.6	UJ	0.82	UJ	0.78	UJ	42	UJ	0.63	UJ	0.73	UJ
BH1-165.00-VOC	BH1	165.0 - 165.1	165	165.1	165.05	Sandstone	NA	NA	15	UJ	2.4	UJ	48	UJ	9.6	UJ	0.82	UJ	0.78	UJ	42	UJ	0.63	UJ	0.73	UJ
BH1-170.60-VOC	BH1	170.6 - 170.7	170.6	170.7	170.65	Sandstone	NA	NA	14	UJ	2.4	UJ	48	UJ	9.6	UJ	0.82	UJ	0.78	UJ	42	UJ	0.63	UJ	41	
BH1-171.50-VOC	BH1	171.5 - 171.6	171.5	171.6	171.55	Sandstone	NA	NA	18	UJ	3	UJ	59	UJ	12	UJ	1	UJ	0.94	UJ	52	UJ	0.76	UJ	5.6	J
BH1-175.60-VOC	BH1	175.6 - 175.7	175.6	175.7	175.65	Sandstone	NA	NA	15	UJ	2.6	UJ	51	UJ	11	UJ	0.9	UJ	0.83	UJ	45	UJ	0.67	UJ	2.8	J
BH1-176.90-VOC	BH1	176.9 - 177.0	176.9	177.0	176.95	Sandstone	NA	NA	15	UJ	2.4	UJ	48	UJ	9.6	UJ	0.82	UJ	0.78	UJ	42	UJ	0.63	UJ	0.73	UJ
BH1-177.90-VOC	BH1	177.9	177.9	178.0	177.95	Sandstone	NA	NA	14	UJ	2.4	UJ	48	UJ	9.6	UJ	0.82	UJ	0.78	UJ	42	UJ	0.63	UJ	0.73	UJ
BH1-181.00-VOC	BH1	181.0 - 180.1	181.0	181.1	181.05	Sandstone	NA	NA	14	UJ	2.4	UJ	47	UJ	9.6	UJ	0.82	UJ	0.77	UJ	42	UJ	0.62	UJ	0.72	UJ
BH1-182.50-VOC	BH1	182.5 - 182.6	182.5	182.6	182.55	Sandstone	NA	NA	14	UJ	2.4	UJ	47	UJ	9.6	UJ	0.82	UJ	0.77	UJ	42	UJ	0.62	UJ	1.7	J
BH1-183.70-VOC	BH1	183.7 - 183.8	183.7	183.8	183.75	Sandstone	NA	NA	14	UJ	2.4	UJ	47	UJ	9.6	UJ	0.82	UJ	0.76	UJ	42	UJ	0.61	UJ	0.72	UJ
BH1-186.40-VOC	BH1	186.4 - 186.5	186.4	186.5	186.45	Sandstone	NA	NA	16	UJ	2.6	UJ	52	UJ	11	UJ	0.9	UJ	0.84	UJ	45	UJ	0.67	UJ	0.79	UJ
BH1-187.80-VOC	BH1	187.8 - 187.9	187.8	187.9	187.85	Sandstone	NA	NA	13	UJ	2.2	UJ	44	UJ	8.9	UJ	0.75	UJ	0.71	UJ	39	UJ	0.57	UJ	0.67	UJ
BH1-190.50-VOC	BH1	190.5 - 190.6	190.5	190.6	190.55	Sandstone	NA	NA	19	UJ	3.3	UJ	64	UJ	13	UJ	1.1	UJ	1.1	UJ	57	UJ	0.86	UJ	1	UJ
BH1-191.80-VOC	BH1	191.8 - 191.9	191.8	191.9	191.85	Sandstone	NA	NA	14	UJ	2.3	UJ	46	UJ	9.4	UJ	0.82	UJ	0.75	UJ	41	UJ	0.6	UJ	0.71	UJ

Table 3-11 Estimated Pore Water Concentrations – BH-1 (Cont'd)

			Depth from	Depth to	Avg. Depth	Comments/Interpretation (3)			Estimated Pore Water Concentration (ug/L) (5)																	
Sample ID	Location ID	Interval (linear feet)	linear ft	linear ft	linear ft	Sample Lithology (3a)	Position Relative to Fracturing (3b)	Fracture Type (3c)	1,2-Dichloroethane		1,1,2-Trichloroethane		1,1-Dichloroethane		1,1-Dichloroethene		Carbon Tetrachloride		Chloroform		cis-1,2-Dichloroethene		Tetrachloroethene		Trichloroethene	
BH1-192.90-VOC	BH1	192.9 - 193.0	192.9	193.0	192.95	Sandstone	NA	NA	14	UJ	2.3	UJ	45	UJ	9.3	UJ	0.82	UJ	0.74	UJ	41	UJ	0.6	UJ	0.7	UJ
BH1-196.10-VOC	BH1	196.1 - 196.2	196.1	196.2	196.15	Sandstone	NA	NA	17	UJ	2.9	UJ	57	UJ	12	UJ	0.97	UJ	0.93	UJ	51	UJ	0.74	UJ	0.87	UJ
BH1-197.70-VOC	BH1	197.7 - 197.8	197.7	197.8	197.75	Sandstone	NA	NA	16	UJ	2.8	UJ	54	UJ	12	UJ	0.97	UJ	0.88	UJ	48	UJ	0.71	UJ	0.83	UJ
BH1-198.90-VOC	BH1	198.9 - 199.0	198.9	199.0	198.95	Sandstone	NA	NA	15	UJ	2.4	UJ	48	UJ	9.6	UJ	0.82	UJ	0.78	UJ	42	UJ	0.63	UJ	0.73	UJ

Notes:

1. This table presents data recorded in conducting field sampling and laboratory analysis of rock core samples from one coring location designated BH1. The rock core drilling was conducted by Tri-County Drilling, Inc. and was observed and logged by Tetra Tech personnel during the period of November 14 through 16, 2011. The samples were collected, processed and preserved in the field by Stone Environmental Inc. (Stone) personnel then transported under COC to Stone's fixed lab in Barre, VT where they were extracted and analyzed for the listed target Volatile Organic Compounds (VOCs) using methods developed by the University of Guelph. Refer to the Stone report text and tables for additional details regarding sampling, sample preparation, extraction, and analysis.

2. Field sampling information includes corehole location, the depth interval of each nominally five-foot core run, and the sample depth in linear feet from the drilling platform.

3. The Comments/Interpretation section include general notes regarding the sample characteristics, field classified lithology, position relative to fracturing, and type of fracturing according to Stone standard protocols as explained further below.
   a) Lithology includes Sandstone and reflect Stone personnel classification of the sample at the time of collection.
   b) Position relative to fracturing indicates the position of the sample relative to observed fractures inferred to reflect insitu features with the following legend:
   "bet"= between closely spaced fractures; "af"=above fracture surface; "bf"=below fracture surface; "bkn"=broken or crumbled region; "#" = sampled distance in tenths of feet from fracture surface; "NA" = not applicable.
   c) Fracture type denotes relative orientation of fracture relative to the axis of the core with "hf" denoting a horizontal fracture, "vf" a nominally vertical fracture, "ang" an angled fracture, "bkn" a highly fractured/broken zone, and "mech" a mechanical (drilling induced) break; "NA" not applicable.

4. The laboratory results for volatile organic compounds in rock are expressed in units of micrograms per kilogram (ug/kg) of rock sample at field moisture conditions at the time of sampling for the target compounds including:1,2-Dichloroethane (1,2-DCA), 1,1,2-Trichloroethane (1,1,2-TCA), 1,1-Dichloroethane (1,1-DCA), 1,1-dichloroethene (1,1-DCE), carbon tetrachloride (CT), chloroform (CF), cis-1,2-dichloroethene (cis-DCE), tetrachloroethene (PCE), trichloroethene (TCE). The values are rounded to two significant figures. "ND" denotes that the compound was not detected, please refer to the report text and appendices for information regarding detection and quantitation limits. The second column for each compound denotes quality assurance flags including: "U" denoting that the analyte was analyzed for, but was not detected above the reported quantitation limit; "J" the analyte was positively identified, the associated numerical value is the approximate concentration of the analyte in the sample; "UJ" the analyte was analyzed for, but was not detected, the sample reported limit is an estimated quantity; "B" indicates the analyte was found in the associated laboratory blank as well as the sample; "R" denotes sample result rejected due to chromatographic interference causing inadequate peak separation or resolution or other deficiency in data generation process.

5. The Estimated Pore Water Concentration in micrograms per liter (ug/L) represents an estimate of the equivalent matrix porewater concentrations (Cw) computed based on the laboratory determined total mass concentration (mg/kg of wet rock), as outlined in the report text, using estimated or measured parameters including rock wet bulk density (g/cm3) as received in the field, matrix porosity, and matrix retardation factor (R). This simplified partitioning analysis assumes the rock matrix porosity was fully saturated with water, and that mass occurs at equilibrium in the dissolved and sorbed phase. Refer to the Stone report text for additional details. Estimated Pore Water Concentrations were not calculated for unconsolidated deposits as physical property samples to measure the above mentioned parameters were not collected to represent these deposits.

3.8.3 Borehole Geophysics

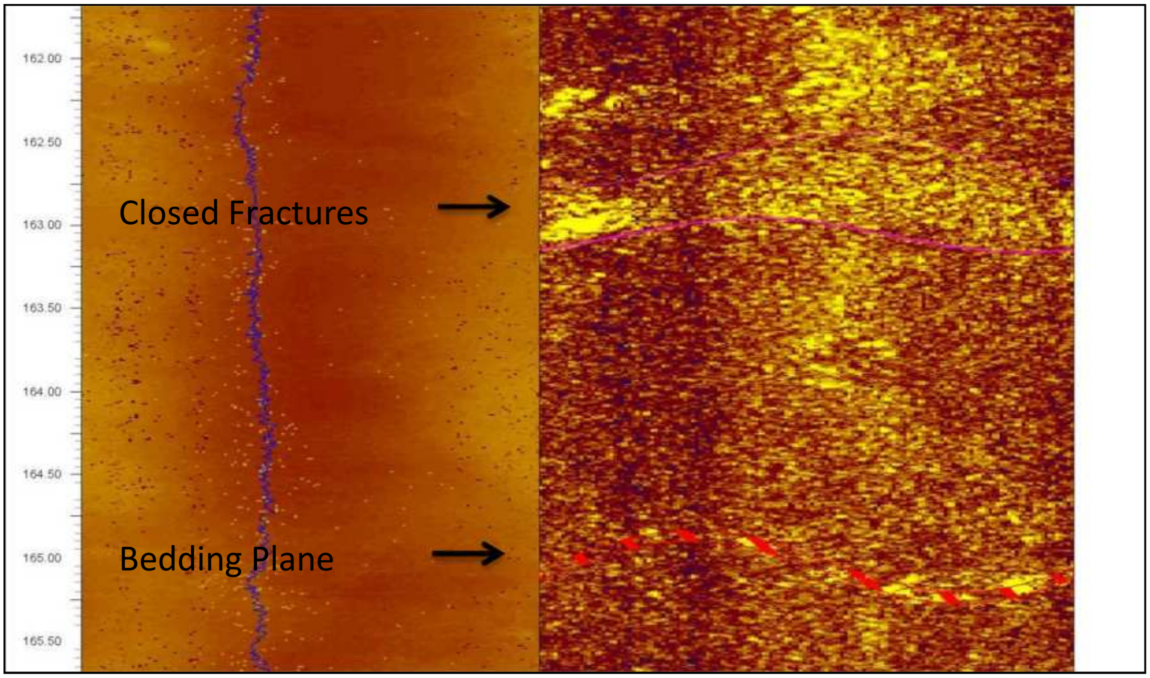
Borehole geophysical logs were collected on all three angled boreholes. The suite of borehole geophysics proposed for each borehole included resistivity logs, gamma logs, caliper logs, directional (deviation surveys) logs, and acoustic borehole televiewer logs. Copies of the borehole geophysics data collected in each borehole are presented in Appendix I. The planned suite of geophysical logs was collected from BH-1 and BH-2. In BH-3, only the deviation log and the gamma log were collected because the borehole had been completed with a 2-inch diameter pre-packed well.

Results of the borehole geophysics varied from each borehole. In general, the MEF sandstone appeared fairly homogeneous in that few bedding planes were noted both in the borehole geophysics and in the boring logs. Differences in induration (or hardness of the sandstone) noted in the core logs were not distinctly apparent on any of the borehole geophysics with a few exceptions. Open and closed fractures were noted in both BH-1 and BH-2 in the acoustic televiewer logs. In addition, the few bedding planes that were noted in the corehole logs were also identified in the acoustic televiewer logs in boreholes BH-1 and BH-2. Figure 3-7 shows an example of the fractures and bedding planes identified in the acoustic televiewer logs for BH-1 and BH-2. The complete televiewer logs for BH-1 and BH-2 are included in Appendix I.

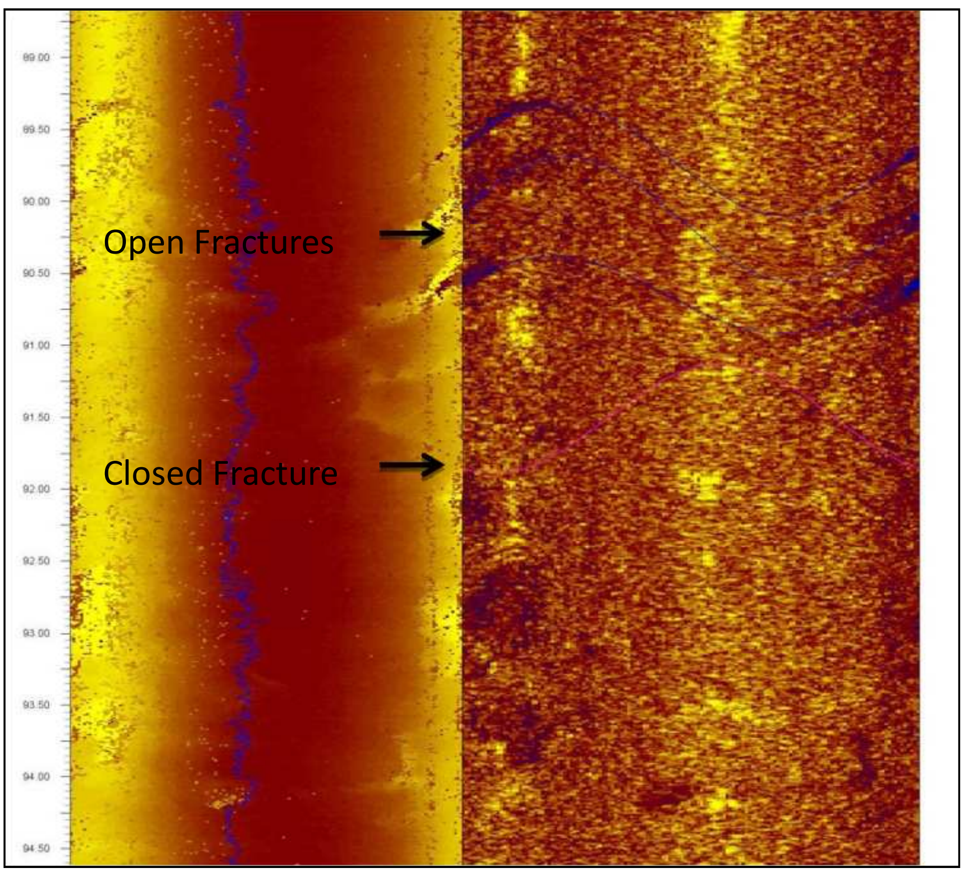
In BH-1, closed fractures were noted at depths of 162.6, 163.07, 165.02, and 187.46 linear feet based on the acoustic televiewer borehole log. Bedding planes were notable in BH-1 at depths of 165.06, 172.05, and 182.12 linear feet. The caliper log shows that the corehole diameter ranged from 4.0 inches in diameter near the beginning of the core run to a maximum of 5.0 inches in diameter between 131 and 135 linear feet. The average borehole diameter was roughly 4.3 inches. Variations in borehole diameter (up to 5 inches in diameter) may be attributed to the overall poorly indurated nature of the MEF sandstone, not necessarily to the fractured nature of the sandstone. The deviation survey showed that the borehole had an average azimuth direction of approximately N47°E but ranged from N48.8°E to N44.9°E down the borehole. The dip angle ranged from 31.4° off vertical to 29.1° off vertical with an average dip angle of 29.98° off vertical. The dual induction and gamma log for BH-1 did not provide useful information within the MEF sandstone. The scale on both the gamma log and the dual induction log was expanded so that details could be seen. The gamma log can be used to identify areas of increased feldspar content. Since the MEF

Figure 3-7 Select Portion of Acoustic Televiewer Logs- Boreholes BH-1 and BH-2

BH-1



BH-2



sandstone is dominated by feldspar, this log did not provide valuable information in determining lithology changes. The dual induction log in combination with the gamma log shows some areas with large feldspar crystals versus areas where the rock is apparently much harder and less permeable. The more useful geophysical tools included the acoustic televiewer and the caliper logs.

In BH-2, fractures and a few bedding planes were noted that correlated well to the boring logs. The apparent fault in BH-2 encountered at about 92 linear feet in the core was identified in the borehole geophysics (acoustic televiewer) as open fractures at 89.71, 90.13, and 90.65 linear feet and as a closed fracture at 91.51 linear feet. Also in the acoustic televiewer log a distinct bedding plane was encountered at 122.3 linear feet. The deviation logs show that this borehole was much more uniform in diameter and maintained a borehole diameter of 4 inches on average throughout the borehole except near the reported fault, where it was slightly wider. Overall the diameter of the borehole ranges from 3.8 inches to about 4.6 inches in diameter (see the acoustic televiewer log for details in Appendix I). The deviation survey showed that the borehole was oriented roughly N46oE and had an average dip 33.2° from vertical. The gamma and dual induction logs again were not too useful due to the abundance of feldspar in the MEF sandstone. The gamma log scale has been expanded to show details from the log, but high feldspar content is likely what causes the increase in gamma scatter. The dual induction logs also do not correlate very well with observations from the core logs.

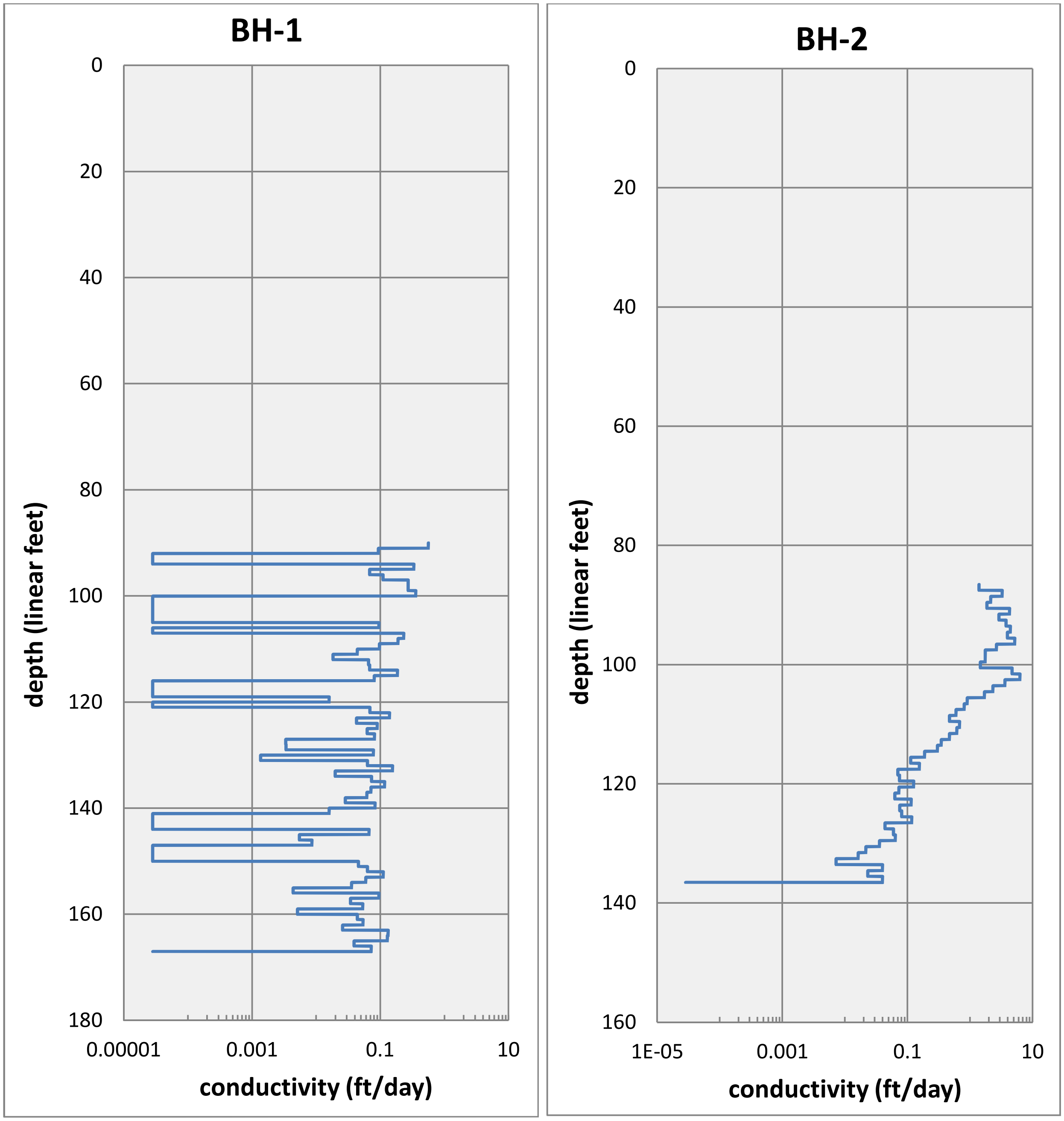
BH-3 is the borehole that was completed with a 2-inch diameter pre-packed well immediately following the completion of drilling due to flowing sands. The well was constructed using PVC well blank and 20 feet of stainless steel screen from 110 to 130 linear feet. A deviation log and gamma log was run through the well casing to measure dip angle and azimuth and to see if the gamma log could help to interpret lithology. Similar to BH-1 and BH-2, the gamma log was not too useful due to the abundance of feldspar in the sediment. The deviation log showed that the borehole was set an average azimuth of approximately N43E but varied from N54°E to N46°E. The large variation in azimuth direction is attributed to drilling the entire length with 11-inch diameter hollow stem augers and the problems encountered with flowing sands at depth. The angle of the borehole remained fairly constant considering the drilling method and conditions, with the average borehole inclined at an average of 30.9° from vertical. The inclination ranged from 30.2 to 32.5° from vertical throughout the 130 linear feet of well casing installed.

3.8.4 Hydraulic Conductivity Profiling

Results of the hydraulic conductivity profiling of BH-1 and BH-2 showed that both boreholes had very low conductivities and did not indicate fracture flow except at a depth of between 92 and 107 linear feet in BH-2 in the area of the potential fault. The average (geometric mean) hydraulic conductivity value for BH-1 was 0.009 feet per day, which is roughly a factor of two lower than the site wide average MEF hydraulic conductivity value of 0.019 feet per day. The range of hydraulic conductivity values in BH-1 varied from 0.00003 to 0.57 feet per day. The average hydraulic conductivity value for BH-2 was 0.38 feet per day, a factor of 20 higher than the site wide average MEF hydraulic conductivity value. The range of hydraulic conductivity values in BH-2 varied from 0.007 to 6.3 feet per day. In addition to the higher permeabilities in the apparent fault zone, the higher conductivities observed in BH-2 are consistent with the conceptual site model that shows increasing conductivities downgradient of the BPA. Figure 3-8 presents the interval hydraulic conductivity profiles for BH-1 and BH-2. As shown in the figure, both profiles show decreasing conductivity with depth, but BH-2 has a much more drastic decline with a decrease of almost two orders of magnitude between 102 and 120 linear feet (88 to 104 vertical feet). Overall, the conductivities in BH-1 are much lower than BH-2 and show zones of very low conductivities that may indicate differences in the hardness or induration of the sandstone at these depths. Copies of the hydraulic conductivity profiling graphs and analysis prepared by FLUTe are included in Appendix K.

Revised

Figure 3-8 Hydraulic Conductivity Profiles – Boreholes BH-1 and BH-2



3.8.5 Well Installations

Well installations occurred in all three angled boreholes. Boreholes BH-1 and BH-2 were installed with the Water FLUTe (monitoring wells MW-111 and MW-112). BH-3 was installed with a 2-inch diameter pre-pack well across the zone of flowing sands (MW-110).

3.8.5.1 Pre-Pack Well (MW-110)

A pre-packed well was installed in BH-3 due to the high potential for borehole collapse following the completion of drilling. BH-3 was drilled using hollow stem auger drilling techniques and competent MEF sandstone was not encountered until about 138 linear feet (see boring logs and well completion diagrams in Appendix C). In addition, flowing sands were encountered at between 112 and 122 linear feet, which created a condition for a very unstable borehole. A decision was made to halt drilling at 140 linear feet and install a pre-packed well in the borehole before the borehole collapsed and no monitoring point(s) could be installed. The pre-pack screen and well casing was a nominal 2-inch diameter PVC well casing with 2-inch diameter PVC screen surrounded by a mesh-covered gravel pack around the well screen (pre-pack). The screen was set from 110 to 130 linear feet along the borehole (95.3 to 112.6 vertical feet). The screen was placed in the area of flowing sands identified during drilling.

3.8.5.2 Water FLUTe Multilevel Monitoring Systems (MW-111 and MW-112)

Water FLUTe multilevel monitoring systems were installed in Boreholes BH-1 and BH-2. BH-1 was a total of 200 linear feet in length and had a vertical total depth of 173 feet bgs. During drilling, rock core samples were collected and analyzed for VOCs and perchlorate, and these analytical results (in combination with a review of the borehole logs, well screened intervals in adjacent wells, the downhole geophysical logs, and hydraulic profiling) were used to identify five sampling port locations for BH-1. Sampling ports were set at 97 to 102 linear feet (84.0 to 88.3 vertical feet); 121 to 126 linear feet (104.8 to 109.1 vertical feet); 131 to 136 linear feet (113.4 to 117.8 vertical feet); 161 to 166 linear feet (139.4 to 143.8 vertical feet); and, 180 to 185 linear feet (155.9 to 160.2 vertical feet). The BH-1 designation was changed to monitoring well MW-111 and each depth interval was identified from A to E (deepest to shallowest), as has been done in the past on other well clusters at the Site. Table 3-12 identifies the linear depth, vertical depth, and the well designation assigned to each sampling port.

BH-2 was a total of 150 linear feet in length and had a vertical total depth of 129.9 feet bgs. Rock core samples were not collected or analyzed for VOCs and perchlorate for BH-2. A review of the borehole logs, well screened intervals in adjacent wells, the downhole geophysical logs, and hydraulic profiling was used to identify the three sampling port locations installed in BH-2. Sampling ports were set at 87 to 92 linear feet (75.3 to 79.7 vertical feet); 100 to 105 linear feet (86.6 to 90.9 vertical feet); and from 125 to 130 linear feet (108.3 to 112.6 vertical feet). The BH-2 designation was changed to monitoring well MW-112 and each depth interval was identified from A to C (deepest to shallowest), as has been done in the past. Table 3-12 identifies the well designation assigned to each sampling port, and the linear depth and vertical depth for each interval.

Table 3-12 Well Designations

Borehole Number	Monitoring Port Well ID	Linear Depth (Feet)	Vertical Depth (Feet)
BH-1	MW-111A	180 to185	155.9 to 160.2
BH-1	MW-111B	161 to 166	139.4 to 143.8
BH-1	MW-111C	131 to 136	113.4 to 117.8
BH-1	MW-111D	121 to 126	104.8 to 109.1
BH-1	MW-111E	97 to 102	84.0 to 88.3
BH-2	MW-112A	125 to 130	108.3 to 112.6
BH-2	MW-112B	100 to 105	86.6 to 90.9
BH-2	MW-112C	87 to 92	75.3 to 79.7
BH-3	MW-110	110 to 130	95.3 to 112.6

3.8.6 Scheduled Sampling of New Monitoring Wells

Quarterly monitoring of the new wells MW-110, MW-111, and MW-112 will begin in the first quarter of 2012 (Q1 2012). Samples will be analyzed for the standard suite of analytes in the groundwater monitoring program, which includes perchlorate by Method E332.0, 1,4-dioxane by Method SW 8270C SIM, and VOCs by Method SW8260B. Samples were not collected after well installation to allow the aquifer to equilibrate after well installation, given the extremely low permeabilities in the BPA and the fact that the Water FLUTe systems cannot be developed following traditional well development procedures.

3.9 INVESTIGATION DERIVED WASTE CHARACTERIZATION, TREATMENT, AND DISPOSAL

3.9.1 Bench Scale Test Results

This section presents the results of the IDW treatment study and provides information on the amendments used in the treatment process. Water samples were collected and analyzed from three containers over a two-month period to evaluate treatment of perchlorate and VOCs. The sampling frequency and laboratory turnaround times varied throughout the test based on the rate of contaminant reduction. Water samples were initially collected from EW-20 to establish baseline conditions prior to conducting this study. A soil sample was collected from the soil cuttings used as part of the test to confirm the levels of iron. Progress samples were analyzed for perchlorate, VOCs and additional parameters (i.e. sulfate, TOC, etc.) as needed. The final confirmation samples were analyzed for most of the same compounds as the initial samples. The laboratory results from the bench-scale test are summarized in Table 3-13.

Samples collected from Containers #2 and #3 from 14 November through 8 December 2011 were analyzed for VOCs using Method SW8260B due to the volume requirements of Method SW8270C SIM and future anticipated sampling events required for this evaluation. Additionally, due to instrumentation down time at E.S. Babcock & Sons, samples 4 November through 23 November were submitted to ARL for VOC analysis. The use of these laboratories has negligible impacts on the results.

Revised

Table 3-13 IDW Groundwater Treatment Test

	Sample Date	Time Lapsed (Days)	Matrix	Iron mg/kg	Perchlorate µg/L	1,4-Dioxane µg/L	1,4-Dioxane µg/L (In VOC list)	TCE µg/L	1,1-DCE µg/L	COD mg/L	Nitrate as N mg/L	Iron µg/L	TOC mg/L	TDS mg/L	Chloride mg/L	Sulfate mg/L
Baseline																
Soil Baseline	7/8/2011		S	14,000	-	-	-	-	-	-	-	-	-	-	-	-
EW-20	10/21/2011		W	-	81,000	340	500	1,200	5,200	8.5	21	140	0.92	460	51	15
Container #1	11/2/2011	0	W	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/4/2011	2	W	-	81,000	-	-	-	-	-	-	-	1300	-	-	-
	11/7/2011	5	W	-	73,000	-	-	-	-	-	-	-		-	-	-
	11/14/2011	12	W	-	85000	-	-	-	-	-	<0.2	-	1200	-	-	-
	11/23/2011	21	W	-	65,000	-	-	-	-	-	-	-	2200	-	-	-
	12/8/2011	36	W	-	58,000	-	460	230	76	-	-	-	-	1500	50	90
	12/29/2011	57	W	-	63,000	-	470	120	15		-	12000	2100	2200	55	140
Container #2	11/2/2011	0	W	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/4/2011	2	W	-	-	420	395	360	2,222	20	21		1.7	-	53	17.0
	11/7/2011	5	W	-	-	400	213	290	1,600	-	-	-	-	-	-	-
	11/14/2011	12	W	-	-	-	223	210	850	-	-	-	-	-	-	-
	11/23/2011	21	W	-	-	-	273	130	270	-	-	-	-	-	-	-
	12/8/2011	36	W	-	-	-	48	24	<0.12	-	-	-	-	-	-	30
	12/29/2011	57	W	-	68000	7.5	<9.3	25	3.2	22	18	290	0.54	1600	52	40
Container #3	11/2/2011	0	W	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/4/2011	2	W	-	-		397	380	2110	31	21	-	1.2	-	53	17
	11/7/2011	5	W	-	-	450	240	300	1700	-	-	-	-	-	-	-
	11/14/2011	12	W	-	-	-	225	260	1200	-	-	-	-	-	-	-
	11/23/2011	21	W	-	-	-	217	210	700	-	-	-	-	-	-	-
	12/8/2011	36	W	-	-	-	150	37	<0.12	-	-	3700	-	-	-	-
	12/29/2011	57	W	-	70000	4.9	99	14	<0.12	160	19	55000	0.59	810	53	38

Notes:

µg/L - micrograms per liter.
mg/L - milligrams per liter.
mg/kg - milligrams per kilogram.

Synopsis of Container #1 Results

The chemical of concern for treatment in Container #1 was perchlorate. Based on bench-scale and previous pilot tests, the water from the BPA was amended with native site soil, glycerin and diammonium phosphate. As part of the Container #1 setup, 62.1 grams of glycerin and 0.5 pounds of soil were added to the water. The perchlorate results from the first two sampling events, showed little to no change in the reduction of perchlorate. As a consequence, 2.3 grams of diammonium phosphate were added to the water. Subsequent sampling results from 14 November 2011 showed minimal change; in perchlorate concentration. However, nitrate decreased from 21 to <0.2 mg/L, over approximately 3.5 weeks, suggesting that this electron acceptor was being preferentially consumed in bacterial anaerobic respiration. Furthermore, the container was pressurized and required venting to prevent container rupture. The cause of the pressurization is most likely due to biological respiration and fermentation a reaction taking place in this system resulting in gas production CO_2. Since the perchlorate results from 14 November 2011 showed minimal change, an additional 62.1 grams of glycerin were added to the system plus 5 grams of NaOH to increase the pH from 4.75 (which was considered problematic for optimal perchlorate biotreatment) to 8.4. NaOH was added on two subsequent and separate occasions to increase the pH of the system within the range 6 to 7. Throughout the test period, the container was agitated frequently to promote mixing of the substrate/chemical reagents. The dissolved oxygen levels generally were below 1 mg/L throughout the test with some fluctuation, and the temperature ranged from 17 - 21 °C.

Overall, samples collected and analyzed for perchlorate showed minimal reduction of perchlorate over a -month2- period. There was considerable bio-fouling (slimy and odor attributes) observed in the samples and container. VOCs were not the chemical of concern for treatment; therefore, only initial, intermediate, and final samples were collected and analyzed. The results for TCE and 1,1-DCE showed decreasing concentrations by more than 90% and, as expected, there was little to no concentration change in 1,4-dioxane. Contributions to VOC reduction may include volatilization attributed to off -gassing due to pressurization of the system, mixing, and some biodegradation. Based on the final results, the container had a sufficient amount of TOC present and was not a limiting factor in perchlorate biotreatment. Two Factors that could have affected the treatment of perchlorate include insufficient amounts of perchlorate degrading microbes andhad and intermediate toxic chemicals produced affecting the strength and effectiveness of the substrate.

Several factors could have affected the treatment of perchlorate. These include the lack of buildup of the appropriate and specific perchlorate reducing microorganism in this set-up. The creation and persistence of inhibitory constituents or metabolites sometimes could result in toxicity. Previous bench-scale results have indicated that even though nitrate-reducers and denitrification occurs quite readily in site groundwater, perchlorate reduction may not quite follow. The continuing fluctuation in pH could have prevented a stable perchlorate-reducing population from developing. Excessive fermentation or unbalanced fermentation could also have hampered perchlorate reduction. In suspended-growth systems which are static (absence of a shaker), there could be a short supply of the appropriate microoganisms to degrade perchlorate (as opposed to attached growth systems) favorably. Finally, the accumulation of TDS even at low levels could be problematic to specific perchlorate-reducing microorganisms. Often, once adverse conditions are created in a reactor, they are difficult to overcome even with the addition of further substrates, changes in substrate, or pH adjustment, and such may have been the case with Container #1.

Synopsis of Container #2 Results

The primary chemicals of concern for treatment in Container #2 were VOCs and 1,4-dioxane. Based on literature reviews and vendor consultation, the water from the BPA was amended with sodium persulfate and NaOH (pH activator) to evaluate the chemical oxidation potential of 1,4-dioxane andVOCs. As part of the Container #2 setup, 1.52 grams of sodium persulfate and 0.52 grams of NaOH were added to the water. The VOC results from the first two sampling events (4 and 7 November 2011) showed decreased concentrations of 1,1-DCE, TCE, and 1,4-dioxane. It is assumed that the persulfate added initially to the water had been consumed; therefore, an additional 1.52 grams of sodium persulfate and 0.52 grams of NaOH were added to the water.

Sampling on 14 November 2011 resulted in further reduction of TCE and 1,1-DCE but minimal change in 1,4-dioxane; therefore an additional 4.9 grams of sodium persulfate and 2 grams of NaOH were added to the water to raise the pH to 12 pH. The sample results from two sequential events (23 November and 8 December) ultimately resulted in non-detectable concentrations of 1,1-DCE, and a reduction in TCE and 1,4-dioxane. The final sampling results showed little to no change in TCE, and 1,4-dioxane.

The activation of sodium persulfate in the presence of a strong base such as NaOH yielded favorable results with a VOC reduction (TCE, 1,1-DCE and 1,4-dioxane) by more than 98%. Overall, chemical oxidation resulted in an increase in sulfate concentrations from 17 to 40 mg/L. The treatment process had little to no effect on perchlorate, which was expected. Although, some of the chlorinated VOCs could have volatilized, the surge in reduction in the last three events indicates that a substantial portion could have been due to chemical oxidation, spurred on by additional dosages of persulfate and NaOH. While this technology in the past has been demonstrated for the treatment of 1,4-dioxane in soil (based on previous studies), this test demonstrated that treatment of 1,4-dioxane in the presence of a strong oxidizer was effective. Results also showed that a stronger dosage envisioned and estimated at the inception of the study would likely be required to enhance the kinetics of chemical oxidation; and, the optimal pH for this set-up could be at 12.0 or > 12.0 pH units.

Synopsis of Container #3 Results

The primary chemicals of concern for treatment in Container #3 were 1,4-dioxane and VOCs. This test was performed similarly to the test carried out in Container #2; however, a strong base activator was not used. The water from the BPA was amended with sodium persulfate and soil to evaluate if the naturally occurring iron in soil was sufficient to activate the sodium persulfate to chemically oxidize 1,4-dioxane and VOCs. As part of the Container #3 setup, 1.52 grams of sodium persulfate and 0.5 pounds of soil were added to the water. An additional 5 grams of sodium persulfate were added to the system to ensure that a sufficient amount was present to oxidize 1,4-dioxane and VOCs during the test period. TCE, 1,1-DCE and 1,4-dioxane steadily declined over the two-month test period as shown in Table 3-13, with the greatest decreases occurring following supplementation of persulfate in the latter half of the test.. The pH and temperature generally remained in the range of 6 - 9 pH and 17 - 21 °C, with minor fluctuations.

The iron concentrations in the water increased from 140 µg/L to 3,700 µg/L (8 November 2011) over a five-week period. The final results of the test showed that the iron levels increased from 3,700 µg/L to 55,000 µg/L (29 December 2011) over a two-week period. The elevated iron in the last sample is considered to be an anomaly and is likely due to the inadvertent addition of soil in the sample sent to the laboratory. When the soil in the water sample contacted the acid preservative in the sample bottle, the undissolved iron in the soil could have solubilized, resulting in a significant increase in iron levels in the water.

The activation of sodium persulfate in the presence of a naturally occurring iron in the soil yielded favorable results with a VOC reduction (TCE, 1,1-DCE and 1,4-dioxane) by more than 98%. Overall, chemical oxidation resulted in an increase in sulfate concentrations from 17 to 38 mg/L. The treatment process had little to no effect on perchlorate, as expected.

Overall Results and Conclusions

The bench-scale test for perchlorate biotreatment did not respond very favorably in the set-up that was implemented. The reasons for the unfavorable response to perchlorate biodegradation, despite the fact that microbial activity was occurring (as indicated by the pressure buildup) and denitrification proceeded quite rapidly have been evaluated and summarized in the previous section. Previous bench-scale and pilot tests have shown that perchlorate biodegradation should not be problematic at this site. With a modified set-up that optimizes the opportunity for perchlorate-reducing microorganisms to be cultured and developed, the balanced and cautious addition of carbon substrates, micronutrients, and pH adjusters, there is no reason to believe that perchlorate cannot be biologically reduced in site groundwater.

Either of the activators (NaOH and native iron) appears to be appropriate for 1,4-dioxane and VOC chemical oxidation via the addition of sodium persulfate. The fact that native iron at the dosages applied showed a good response and could be taken advantage of in field applications of cleanup. The dosage of persulfate would need to be optimized to ensure that there is a sufficient factor of safety that does not limit chemical oxidation. This could be determined from further controlled tests using different dosages of persulfate and iron, as well as NaOH on site water, in addition to oxidant demand tests.

The proper sequence of chemical versus biological treatment was not determined in this screening bench-scale test. There are obvious pros and cons (logistics, lag times, timeframe, interferences, cost) of one versus the other. These can be ascertained with more robust testing in controlled environments and will be an important consideration when implementing pilot testing and actual cleanup.

3.9.2 Waste Characterization, Transport and Disposal

Waste management activities were conducted in accordance with the *Waste Management Plan, Lockheed Martin Corporation, Beaumont Sites 1* & 2*, Beaumont, California* (Tetra Tech, 2009b). IDW generated from the field activities at Site 1 included soil cuttings from drilling, and decontamination water and purge water from sampling activities. Excess soil and water generated from drilling activities were temporarily stored onsite in three 20 -cubic -yard roll -off containers prior to disposal, pending characterization. Water generated during the aquifer pump test was placed in a 6,000-gallon dewatering bin. All IDW was characterized prior to final transportation and disposal to an approved waste recycling/disposal facility. Copies of the analytical data and IDW manifests are included in Appendices F and J, respectively.

SECTION 4 CONCLUSIONS AND RECOMMENDATIONS

This section presents the conclusions and recommendations based on the results of the hydraulic testing conducted at the Potrero Canyon Unit in 2011.

4.1 CONCLUSIONS

4.1.1 Slug Testing

Slug testing results in four areas of the Site (Pad with Dry Well, Large Motor Washout Area, Maintenance Shop and Warehouse Area, and the Test Bays), where hydraulic conductivity information was previously not available, confirmed the low hydraulic conductivities in the sandstone previously estimated in other areas of the Site. The average hydraulic conductivity value for the sandstone in these four areas (0.021 feet per day) is two orders of magnitude less than the previous sitewide average for the MEF sandstone which was 1 foot per day. These results indicate that the MEF sandstone in these four areas is less weathered and more indurated than other areas of the Site. The low hydraulic conductivities will limit the contaminant transport in these areas where impacts to groundwater have been detected. The 1.9 feet per day average conductivity estimated for wells screened in the alluvium/weathered sandstone at the Large Motor Washout Area is reasonable based on the sitewide average conductivities for alluvium (5.7 feet/day) and MEF sandstone (1 foot/day).

4.1.2 BPA Hydraulic Testing

Overall, the vadose zone permeability testing showed saturated hydraulic conductivity estimates that ranged from <0.14 to >2.7 feet/day with a decreasing vadose zone permeability trend with depth. This is consistent with the presence of more permeable Quaternary alluvium at shallow depths, and less permeable alluvium/weathered MEF sandstone at greater depths. The highest permeability of all of the locations tested (VRW-1) is located in the southern portion of the BPA, where very high infiltration rates were observed during previous testing. Given the results of the vadose zone permeability tests and the previous double-ring infiltrometer tests, it appears that surface infiltration as a source area treatment at the BPA could be a viable remedial technology. However, pilot testing would be needed prior to any full-scale application given the low-permeability MEF sandstone beneath the BPA which could possibly create a perched water zone above the water table.

The average hydraulic conductivity value for the wells screened in the MEF at the BPA was 0.020 feet per day with the range of hydraulic conductivity values varying from less than 0.00001 to 0.2 feet per day. These results are consistent with vertical hydraulic conductivity profiling conducted in BH-1 which ranged from 0.00003 to 0.57 feet per day. The wide range of MEF conductivities is a result of the amount of weathering or degree of induration within the sandstone. Generally the shallow MEF is more weathered and slightly more permeable than the deeper more indurated and competent sandstone but there is also lateral variability within the sandstone. The results of the slug testing and vertical conductivity profiling show that groundwater flow within the BPA is not a fracture dominated system. Furthermore, the vertical distribution of groundwater flux/transmissivity within the sandstone does not indicate the presence of fractures.

The results of the constant rate aquifer test and vacuum-enhanced extraction test showed that the maximum sustainable pumping rate at the BPA for a newly installed extraction well in the area with the highest contaminant concentrations is between 0.125 and 0.26 gpm (with vacuum). Based on the aquifer test results there was not a lot of variation in aquifer transmissivity for the various pumping test observation well locations, so little variation in well yields would be expected at the observation well locations. Given a maximum sustainable rate of 0.125 to 0.26 gpm, pump and treat or dual-phase extraction do not appear to be viable groundwater remedial technologies for the BPA sandstone aquifer.

4.1.3 BPA Soil and Groundwater Sampling & Analysis

Soil and groundwater samples were collected from the BPA to provide additional data for the upcoming feasibility study. Physical soil properties and samples for TOC analysis were collected from the newly installed extraction well (EW-20) and piezometer (P-09). The samples collected were either silty sand or well graded sand with silt with an average TOC concentration of 784 mg/kg. The TOC concentrations did not vary significantly with depth and are consistent with more coarse grained sandy soil at the BPA in comparison to the high TOC concentrations (average of 11,600 mg/kg in the vadose zone and 2,330 mg/kg in the aquifer) detected in the finer grained sediments found further down the valley and in the riparian area.

The results from the groundwater sampling of the former BPA extraction wells not part of the routine monitoring network were generally consistent when compared to contaminant concentrations in nearby monitoring wells. The spatial trend still shows the high concentrations are centered on the area near EW-13, MW-61A/B/C/D, and the new extraction well EW-20.

4.1.4 BPA Bedrock Characterization

Overall, the MEF sandstone is a weakly to moderately indurated, coarse- to fine -grained, arkosic sandstone that is massively bedded. The unit is not very laminated and a lack of bedding appears to be characteristic of the sandstone near the BPA. While very few fractures or changes in lithology were noted in the recovered core, differences in the hardness (induration) of the sandstone were considered the characteristic that varied the most. Only minor changes in lithology were noted with changes in the clay content being the most noted variation.

No fracture zones or faults were identified in boreholes BH-1 or BH-3. However, in BH-2 at approximately 92 linear feet, a highly fractured section of sandstone was encountered, which resulted in the loss of core and all drilling fluids. It is interpreted that the fault was most likely encountered at about 92 linear feet and continued through a shear zone about 7.5 feet thick assuming a vertical fault plane. The fault zone appears to be a zone of high conductivity due to the loss of drilling fluid throughout this zone. In borehole BH-3, it was estimated that the MEF sandstone should have been encountered between 90 and 100 linear feet (78 to 87 vertical feet) but wasn’t observed until a depth of 138 linear feet (119.5 vertical feet). In addition, very sandy alluvial material that might represent a paleochannel of Bedsprings Creek was observed at a depth of 112 to 122 linear feet (97 to 106 vertical feet).

The rock matrix sampling results show that the highest VOC and perchlorate concentrations were found between 86.4 and 102.2 linear feet (75 to 88.5 vertical feet) in poorly to moderately indurated sandstone with no fractures present. The absence of fractures and vertical contaminant distribution at the source area indicates that the majority of the contaminant mass is tied up in the low permeability rock matrix. From a remediation perspective, extraction in this the tight sandstone creates significant challenges for contaminant mass removal due to the difficulties in accessing contaminant mass in the very low permeability rock matrix.

4.1.5 Bench Scale Wastewater Treatment Test

The bench-scale test for perchlorate biotreatment did not respond very favorably in the set-up that was implemented. Several factors could have affected the treatment of perchlorate including: a lack of buildup of the appropriate and specific perchlorate reducing microorganisms in this set-up; the creation and persistence of inhibitory constituents or metabolites that could result in toxicity; excessive fermentation or unbalanced fermentation; or the accumulation of TDS. Previous bench-scale and pilot tests have shown that perchlorate biodegradation should not be problematic at this Site.

The bench-scale test showed that either of the activators (NaOH and native iron) are appropriate for 1,4-dioxane and VOC chemical oxidation via the addition of sodium persulfate. The fact that native iron at the dosages applied showed a good response is promising for any future field applications for chemical oxidation.

4.2 RECOMMENDATIONS

Based on the results of the hydraulic testing, no further treatability studies are recommended at this time. Given the low hydraulic conductivities at the five features investigated in this report, the physical characteristics of the MEF sandstone at the BPA, and the vertical distribution of contaminants within the sandstone, no additional data are needed to adequately evaluate remedial alternatives during the feasibility study. However, further analysis of the waste water treatment results may be warranted, should *ex situ* batch treatment of extracted groundwater at the BPA be considered as a potential treatment technology.

Based on the results of the hydraulic testing, it is recommended that the CSM and groundwater flow and transport models be updated with the new data and aquifer parameters from this study. For example, the aquifer transmissivity in the BPA high concentration area near EW-20 is about 2 ft^2/day based on the recent constant rate aquifer test while the model currently uses a value of about 40 to 60 ft^2/day. Although the model change wouldn’t impact the overall water budget much, it could have a big impact on the mass flux of COCs from the BPA high concentration area.

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