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CORRECTIVE MEASURES STUDY ADDENDUM SOLID WASTE MANAGEMENT UNIT 55 WITH TRANSMITTAL AND RESPONSE TO COMMENTS NAVAL ACTIVITY PUERTO RICO
6/1/2012
AGVIQ/CH2M HILL

AGVIQ ENVIRONMENTAL SERVICES
CH2M HILL
JOINT VENTURE

June 15, 2012

U.S. Environmental Protection Agency - Region II
290 Broadway - 22nd Floor
New York, New York 10007-1866

Attn: Mr. Phil Flax

RE: Contract No. N62470-08-D-1006
Task Order No. JM04
Solid Waste Management Unit (SWMU) 55
Naval Activity Puerto Rico - Ceiba, Puerto Rico
Corrective Measures Study Addendum for SWMU 55

Dear Mr. Flax:

AGVIQ-CH2M HILL Constructors Inc. Joint Venture III (AGVIQ-CH2M HILL), on behalf of the Navy, is pleased to provide one hard copy and one electronic copy provided on CD of the Corrective Measures Study Addendum for SWMU 55 at Naval Activity Puerto Rico. Additional distribution has been made as indicated below.

If you have any questions regarding this submittal, please contact Mr. Stacin Martin at (757) 322-4080.

Sincerely,

AGVIQ-CH2M HILL Constructors Inc. Joint Venture III

Tom Beisel, P.G.
Project Manager

cc: Ms. Debra Evans-Ripley/BRAC PMO SE (letter only)
Mr. David Criswell/BRAC PMO SE (letter only)
Mr. Tim Gordon/USEPA Region II (2 hard copies and 2 CDs)
Mr. Mark E. Davidson, BRAC PMO SE (1 hard copy and 1 CD)
Mr. Stacin Martin/NAVFAC Atlantic (1 hard copy and 1 CD)
Mr. Pedro Ruiz/NAPR (1 CD)
Mr. Carl Soderberg/USEPA Caribbean Office (1 hard copy and 1 CD)
Ms. Gloria Toro/PR EQB (1 hard copy and 1 CD)
Ms. Wilmarie Rivera/PR EQB (1 CD)
Ms. Connie Crossley/Booz Allen Hamilton (1 hard copy and 1 CD)
Ms. Bonnie Capito/NAVFAC LANTDIV (1 hard copy)
Ms. Lisamarie Carrubba/NMFS (1 CD)
Mr. Felix Lopez/U.S. Fish & Wildlife Service (1 CD)
Mr. Mark Kimes/Michael Baker Jr., Inc. (1 CD)

Responses to Comments Summary	
Regulatory Comments from:	Timothy R. Gordon (EPA Project Coordinator), Cathy Dare (TechLaw, Inc.), Wilmarie Rivera (PREQB Federal Facilities Coordinator)
Document:	*Corrective Measures Study Addendum*, Naval Activity Puerto Rico (NAPR), EPA ID PR2170027203, Ceiba, Puerto Rico, dated January 2012
Regulatory Letter Date:	Email Dated: February 28, 2012
Response Due Date:	June 18, 2012
Response Submittal Date:	June 18, 2012

The following comments were generated based on a technical review of the Response to EPA Comments dated October 3, 2011 on the *Corrective Measures Study Addendum for SWMU 55*, dated August 2011. The revised *Corrective Measures Study Addendum for SWMU 55*, dated January 2012 (CMS Addendum) was also evaluated for compliance with the responses. An evaluation of the Responses to Comments (RTCs) is presented first below. Only those comments which were not adequately addressed are included below. After the RTC evaluation, additional general and specific comments on the January 2012 CMS Addendum are presented.

EPA GENERAL COMMENTS

Evaluation of Response to EPA General Comment 1, EPA Specific Comment 1, Specific Comment 2, and Specific Comment 4: The responses partially address the comments. However, since the CMS Addendum is the determination of the final corrective measures remedy, the supporting basis should be sufficiently robust to support the subsequent EPA corrective action Statement of Basis and Final Decision document. With this in mind, additional data and justification should be provided to demonstrate the basis for the bioreactor design. In addition, the previously requested "100% Design Basis" was not provided. Additional data relative to the case studies presented in Table 2-1 should include (1) trend analysis graphs of trichloroethene (TCE) and associated daughter product concentrations in the performance monitoring wells with indication of start and end dates of treatment; (2) resulting treated plume delineation figures; (3) basic as-built construction diagrams; (4) method of application; and (5) soil lithology cross section in the bioreactor area. Table 2-1 should include the horizontal dimensions of the bioreactor, date treatment began, monitoring frequency, and time required for indicated percent of concentration reduction, and an indication of whether rebound has occurred. The comparison evaluation should also discuss whether the case studies determined the extent of plume expansion (or lack thereof) that may have been attributed to the bioreactor injections. Section 2.3 should also include a 'conclusions and recommendations' sub-section with a discussion of the basis for selecting the design parameters indicated in Table 2-1 due to the comparisons with the previous applications. The comparison analysis should clearly provide the relationship between the case studies and the supporting basis for the design. Revise the CMS Plan to present a robust, defensible basis for the proposed remedy design which includes the additional supporting data and discussions as indicated above.

Response:
The use of an in-situ bioreactor to reduce TCE concentrations in the source area is a relatively new technology with limited long-term operating data. This is a simple modification to the enhanced reductive dechlorination technology that has been in widespread use for over 15 years. A summary of key design factors for several successful bioreactors has been provided in Table 2-1. The most complete report on bioreactor performance available is the Sustainable Bioreactor Demonstration Site DP039 Travis Air Force Base, which will be provided to the EPA and PREQB with these responses to comments.

(1) Trend analysis graphs for TCE, DCE, and VC are provided in Figures 4-2 and B-1 through B-6 of the Travis AFB Report.
(2) Plume maps were not developed in the Travis AFB Report.
(3) An as-built construction diagram was not created for the Travis AFB Report. However, photos taken during construction of the bioreactor are provided in Appendix A.
(4) The bioreactor construction is described in section 3 of the Travis AFB Report.
(5) A soil lithology cross section is not provided in the Travis AFB Report, however, the site lithology is described in Section 2.1.

Evaluation of the Response to EPA General Comment 2: The response partially addresses the comment. The referenced text is included in the CMS Addendum; however, the text was included in Section 4.0, Recommended Corrective Measure, rather than Section 1.2 as stated in the response and as requested in the comment. For clarity, revise the response to comments to specify the actual location where the text was added to the CMS Addendum.

Response:
Comment acknowledged.

Evaluation of the Response to EPA General Comment 3 and EPA General Comment 4: The responses do not adequately address concerns raised as a result of the near future transfer of the SWMU 55 site to the Puerto Rico Local Reuse Authority (LRA). Section 1.2.1 indicates that "the transfer is expected to be completed by January 2012." There are two major concerns relative to the effect of the revised land use and the transfer of the SWMU 55 site prior to the completion of the corrective measures implementation. The concerns include:

a) The CMS Addendum does not discuss the LRA's responsibility to insure that the proposed land-use controls (LUCs) are implemented following transfer of the SWMU 55 area.
b) The CMS Addendum remedy does not address the characterization and corrective action associated with the soil vapor / air media pathway or vapor intrusion (VI) considerations. The CMS Addendum does not provide any data or supporting documentation that indicates this pathway has been fully evaluated and that the proposed remedy is protective of potential receptors sufficient for an early transfer. See also Additional General Comment 2 below.

Revise the CMS Addendum to address the concerns stated above.

Response:

a) The LRA's responsibilities concerning the LUCs are detailed in the Quitclaim Deed for CDR Parcel 2 (SWMU 55) signed by the Navy and the LRA on December 20, 2011.
b) According to the Deed, installation of any groundwater extraction wells or the use of any groundwater shall be prohibited. Before constructing any improvements on the property, the potential for vapor intrusion from groundwater and possible resulting impacts to indoor air quality shall be considered and, as needed, addressed during building design and construction. This will be the responsibility of the site developer.

Evaluation of the Response to EPA General Comment 6: The response does not adequately address the comment. The CMS Addendum indicates that a dose concentration of 84-grams per liter (g/L) $NaMnO_4$ solution will be used, but this concentration is significantly higher than the 16.5 g/L solution used for the pilot study. The CMS Addendum does evaluate the potential impact the higher dose concentration will have on the extent of the treatment area, the potential for migration of $NaMnO_4$ outside the intended treatment area (e.g., when significant precipitation infiltrates through the gravel-filled excavation, or whether there is an increased potential for precipitates to impact the permeability of the aquifer (e.g., by reducing pore space). Revise the CMS Addendum to discuss the potential impacts associated with the use of a 84-gram per liter (g/L) $NaMnO_4$ solution as compared to the 16.5 g/L solution used for the pilot study.

Response:

The $NaMnO_4$ application proposed in the CMS Addendum will result in the same mass of $NaMnO_4$ being introduced to the subsurface as was achieved during the pilot testing. Based on modeling, now presented in the CMI Plan, all but 0.5 foot of $NaMnO_4$ solution will infiltrate into the ground within 1 day. Because this material will infiltrate into the groundwater under gravity flow conditions, a smaller initial distribution area can be expected than was obtained during pressurized injection. Like pressurized injection, secondary distribution is dependent on migration with groundwater flow and diffusion. The secondary distribution is expected to be similar under both scenarios. Therefore, the higher initial $NaMnO_4$ dose will not significantly impact the extent of the treatment area.

The $NaMnO_4$ migration will occur in the subsurface after draining from the infiltration gallery. As explained in the previous paragraph, this migration will occur because of the same processes that caused post-injection $NaMnO_4$ migration during the pilot test. Based on the pilot test results, most of the secondary distribution occurred due to migration of $NaMnO_4$ with groundwater, and a significant rain event could accelerate this process. The extent of the migration potential was demonstrated during pilot testing to be approximately 50 feet downgradient of the injection area. Therefore, it is unlikely $NaMnO_4$ will migrate outside the intended treatment area, regardless of precipitation impacts.

Again, the $NaMnO_4$ is expected to infiltrate through the source area soils and into groundwater quickly and behave similarly to the pilot test results. In the pilot test report, the dispersion of $NaMnO_4$ was attributed to rapid groundwater flow, indicating there was no significant change to porosity resulting from the $NaMnO_4$ injections.

EPA SPECIFIC COMMENTS

Evaluation of Response to EPA Specific Comment 12: The response does not address the comment. The response does not include tidal information and the time over which the water level information was collected to ensure that water level data is not skewed by tidal influence. The explanation for the apparent southeasterly movement of the TCE plume on page 1-10 is not sufficient and it is contradicted by the statement (also on page 1-10) that groundwater flows to the south/southwest. The groundwater flow direction must be understood for the remedy to be successful. Figures 1-3 and 1-4 indicate that the TCE plume is flowing to the southeast. However, Figure 3-4 in Appendix A indicates that groundwater is flowing to the southwest, except in the most eastern part of the site (i.e., northeast of the line between wells 55MW04 and 55MW18). The text also states that tidal action causes the water to stagnate and changes the gradient (second bullet on page 1-10), but this is not sufficient to explain the southeasterly flow of the TCE plume. Groundwater flow and migration of contaminant plumes should revert to flowing toward the bay during low tide, unless there is a subsurface obstruction that prevents direct flow to the bay. Possible explanations for the discrepancy include the tidal influence when water levels were collected, not collecting all of the water levels during a single event within two hours of lowest low tide, not allowing wells to equilibrate to atmospheric pressure before water level measurements are made, not considering that some wells are installed in fractured bedrock and others in another unit (see Figures 3-1 and 3-2), or a subsurface barrier to groundwater flow between the source area and the bay. The CMS Addendum needs to either cite where all of this information can be found and provide groundwater elevation contour maps (potentiometric surface maps for deeper aquifers) that use data collected within two hours of lowest low tide, or this data needs to be collected before injection wells are installed. Revise the CMS Addendum to either cite where the above information can be found and provide groundwater elevation contour maps (potentiometric surface maps for deeper aquifers) that use data collected within two hours of lowest low tide or provide for the collection of the necessary data as part of the CMS, CMI, and the Sampling and Analysis Plan (SAP).

In addition, Figure 4-1 shows all of the injection wells in a line oriented northeast-southwest, which appears to substantiate a southeasterly TCE migration direction. However, if groundwater flow is stagnant, as stated on Page 1-10, or if groundwater is flowing to the southwest, the proposed arrangement of injection wells in a line is unlikely to be successful (because it assumes that contaminated groundwater will flow to the southeast through this line). For a stagnant plume, injection wells should be installed throughout the plume in a grid. Revise the CMS Addendum and CMI to resolve the inconsistency between the groundwater flow direction and apparent direction of TCE plume migration. Also, ensure that the CMI includes a 100% Design Basis with sufficient details to justify the proposed injection well configuration.

Response:
The text in Section 1.3 has been revised.

EPA ADDITIONAL GENERAL COMMENTS

1. The text should provide a discussion of the relationship between the original 2005 CMS and the CMS Addendum. It is not clear in the CMS Addendum whether the proposed remedy is the only remedy for completion of corrective action at SWMU 55. This should be made clear in the CMS Addendum. In addition, the CMS Addendum discussion and schedule does not include provisions for public participation. For clarity, revise the CMS Addendum to discuss of the relationship between the 2005 CMS and this CMS Addendum which also explains how public review of the SWMU 55 remedy will be implemented.

   Response:
   The relationship between the original 2005 CMS and the CMS Addendum is explained in the first paragraph of the document, "This document revises the *Corrective Measures Study Final Report for SWMUs 54 and 55* (Baker Environmental, Inc. [Baker], 2005) because implementation of the in situ chemical oxidation (ISCO)

remedy proposed in the CMS is only partially viable, based on evaluation of newly acquired pilot-scale test data."
Only one remedy, the proposed remedy, was selected for completion of corrective action at SWMU 55. Since this is the selected remedy, as detailed in Section 4 of the CMS Addendum, it is clear that this is the selected remedy at SWMU 55.

Provisions for public participation were added to Section 4 of the CMS Addendum and to the project schedule.

2. The CMS Addendum proposed remedy does not provide any data or documentation that the potential vapor intrusion (VI) pathway has been adequately investigated and that the remedy is protective of potential receptors. VI and the soil vapor/air pathway must be considered whenever volatile organic compounds (VOCs) (e.g. TCE and vinyl chloride) are a contaminant of concern (COC). The CMS Addendum states "land use controls (LUCs) to prevent use of the groundwater is [*sic*] included as part of the remedy (during cleanup and after reaching the CAOs [corrective action objectives]) in order to be protective of human health. The LUCs will be included in any lease or transfer deed." Section 1.2, Media Cleanup Standards, indicates that "any lease or transfer deed associated with SWMU 55 will state that vapor intrusion will be considered by the new owner during the design/ construction of any future structures on the parcel." However, there is no indication that Institutional Controls (ICs) or LUCs will be developed for the VI pathway in order to be protective of human health. In addition, if the VI pathway has not been adequately investigated there is no basis by which to determine what ICs /LUCs would be necessary to be protective of human health. The CMS Addendum should include a summary of the characterization of the VI pathway or propose delineation of the nature and extent of soil vapor contamination prior to the completion of the CMS or CMI process in order to determine what specific ICs / LUCs are necessary, under what conditions an early transfer may be considered, and what liabilities any new owner must assume with acceptance of the transfer. The investigation of the VI pathway should be in accordance with the *US EPA OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)* dated November 2002. Revise the CMS Addendum to include a summary of, or a proposal for delineation of the nature and extent of the VI pathway and a discussion relative to subsequent corrective action needs.

Response:
The LRA's responsibilities concerning the LUCs are detailed in the Quitclaim Deed for CDR Parcel 2 (SWMU 55) signed by the Navy and the LRA on December 20, 2011.

According to the Deed, installation of any groundwater extraction wells or the use of any groundwater, shall be prohibited. Before constructing any improvements on the property, the potential for vapor intrusion from groundwater and possible resulting impacts to indoor air quality shall be considered and, as needed, addressed during building design and construction. This will be the responsibility of the site developer.

3. The CMS Addendum should include discussion of a monitored natural attenuation (MNA) study which will determine if MNA is justified as a component of the proposed remedy. The evaluation of MNA as a remedy component should be conducted in accordance with the US EPA *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (EPA/600/R-98/128) dated September 1998 (MNA Guidance). The CMS Addendum indicates that MNA will be considered as part of the site corrective action through monitoring of the applicable parameters; however, it does not address the need for a MNA study meeting the standards of the MNA Guidance. The CMS should indicate the need for inclusion of a MNA study work plan as part of the corrective measures implementation (CMI) Plan, or as a separate document, as well as establishment and justification of goals and objectives to be addressed by the work plan. Revise the CMS Addendum to justify the inclusion of MNA as a remedy component in accordance with the MNA Guidance and to provide direction for the inclusion of a MNA study work plan in the CMI Plan.

   Response:
   The CMS Addendum and the CMI Plan have been revised to include text addressing the potential need for an MNA study .

4. As described in the CMS Addendum, the bioreactor design may be flawed in that it may allow the $NaMnO_4$ in situ chemical oxidation (ISCO) reagent to come into contact with the mulch mixture. ISCO reagent contact with the mulch organics likely will consume the ISCO reagent (e.g., events associated with water table rise due to infiltrating precipitation and/or tidal influence). Adequate separation between the ISCO reagent and the mulch must be maintained in order to facilitate the ISCO treatment as intended. Ensure that the CMI work plan includes a 100% design basis with associated construction engineering schematics and detailed construction steps which provide a clear understanding of how the bioreactor design will be constructed and function. Provide the design basis which includes detailed engineered schematics as well as detailed construction and treatment steps.

   Response:
   The majority of the $NaMnO_4$ is expected to drain into the subsurface in 1 day and potential rise in the water table due to precipitation infiltration will not be a

significant issue. Groundwater levels were measured at multiple time points on April 29, 2010. The data were collected within 2.5 hours of the morning low tide, during the morning high tide, and within 30 minutes of the afternoon low tide. The maximum change in water elevation of 0.26 feet (about 3 inches) was measured at well 55MW19, located near Ensenada Honda.

Additional groundwater level measurements in the source area were collected at multiple times on June 21, 2011. These measurements were collected within 0.5 hour of the morning low tide and 1.5 hours of the afternoon high tide. The maximum change in elevation of 0.04 foot (about 0.5 inch) was measured at well 55IW01.

Therefore, ISCO reagent is not expected to come into contact with the mulch as a result of fluctuations in the groundwater level.

The water level data is tabulated in Appendix A of the CMI Plan.

EPA ADDITIONAL SPECIFIC COMMENTS

1. **Section 2.0, Corrective Measure Alternatives, Page 2-1:** The CMS Addendum discussion relative to LUCs should include details of the specific LUC conditions, monitoring requirements, contingencies if the conditions are not met, and the requirements and process for removal of the LUCs. The CMS Addendum does not provide the detailed information necessary to verify if the LUCs will be effective in the protection of human health and the environment. Revise the CMS Addendum to provide details, including the items discussed above, for the LUC portion of the remedy such that a determination of protectiveness can be made.

   Response:
   The LUCs were summarized in Section 2.0; however, details of the LUCs are provided in the Deed.

2. **Section 2.3, Previous Bioreactor Applications and Lessons Learned, Page 2-7:** This section should include a discussion of all previous bioreactor applications listed on Table 2-1. Fairchild Air Force Base (AFB) and Beale AFB are included on Table 2-1; however there is no discussion of these sites within the text of Section 2.3. For consistency and comparison purposes, revise Section 2.3 to include all sites listed on Table 2-1.

   Response:
   These bioreactors are in the first year of testing and the results have not yet been released by the Air Force. Therefore, discussion of these sites will not be added to the text.

3. **Section 2.3, Table 2-1, Comparable Design Table, Page 2-9:** The CMS Addendum should provide additional justification and more accurate estimation of the anticipated remedy design radius of influence. Table 2-1 indicates an estimated radius of influence of 40 to 60 feet from the center of the bioreactor; however, justification and supporting site-specific data are not provided as a basis for this estimate. Section 1.4 of the CMS indicates that the ISCO pilot-scale test "results showed an injection radius of approximately 25 feet was achieved during active injection, though the delivery was not uniform in the subsurface" and Appendix A, Section 3.5.1 indicates "that the injection fluid was dispersed in a few primary (preferential) paths instead of uniformly distributing throughout the aquifer." These statements indicate that a uniform radius is unlikely to occur. Appendix A includes Figures 3-9 and 3-10 which depict the $NaMnO_4$ Concentrations in the shallow and mid-aquifer zones respectively. These figures were not discussed as part of the determination of the anticipated radius of influence or treatment area. The CMS should discuss a multiple lines of evidence approach to determining the estimated radius of influence / treatment area. The multiple lines of evidence should include the pilot study data and observed ISCO treatment area of influence, the determination of preferential path flows, the case studies data, and the anticipated effects of treatment via the proposed infiltration gallery rather than injection. Revise the CMS Addendum to provide additional supporting basis for the determination of the estimated radius of treatment influence which considers multiple lines of evidence.

   Response:
   The injection radius achieved during the permanganate pilot study, where sodium permanganate was injected under pressure, is not related to the estimated radius of influence resulting from bioreactor operations, where recirculated groundwater infiltrates into the formation under gravity flow. Therefore, the pilot study data, the observed ISCO treatment area of influence, and the observed preferential path flows during pressurized injection should not be used as evidence to estimate the radius of influence that could be achieved using a bioreactor.

   The zone of influence expected to be achieved by the bioreactor was based on results from previous bioreactor applications at sites with similar geology.

4. **CMS Addendum, Appendix C, Detailed Cost Estimate:** The CMS Addendum cost estimate should be consistent with the US EPA *Guide to Documenting Cost and Performance for Remediation Projects* (EPA/542/B-95/002) dated March 1995 (Cost Estimate Guidance). The costs presented in Appendix C are high level, lump sum values which do not provide the detail consistent with the Cost Estimate Guidance. The lack of cost details prevents the verification of project associated costs and the development of subsequent bid requests for completion of the work. The costs as

presented do not provide transparency of costs to stakeholders or the public. In addition, the cost estimate does not provide any information concerning the potential costs which may be associated with the future need for VI investigation or remediation and which may be passed to future land owners as a result of early transfer of the SWMU 55 site. Revise the CMS Addendum to include cost estimates which are detailed, complete, and consistent with the Cost Estimate Guidance.

Response:
The guidance document provided for compliance of the cost estimate, US EPA *Guide to Documenting Cost and Performance for Remediation Projects* (EPA/542/B-95/002) dated March 1995 (Cost Estimate Guidance), is not applicable as it "… provides site remediation project managers with a standardized set of parameters to document completed remediation projects." However, the cost estimate format has been revised to more closely resemble Exhibit 6 of the US EPA *Guide to Documenting Cost and Performance for Remediation Projects*.

PREQB GENERAL COMMENT

The responses to the PREQB's comment regarding establishing CAOs based on future land use according to 2004 Reuse Plan amended by the 2010 Reuse Plan according to the 2007 Order on Consent is repeated on the first three responses to our Evaluation of Response. The same situation is encountered when PREQB stated that the Puerto Rico's Water Quality Standards Regulation has been updated since the original Corrective Measures Study was prepared and the current version, dated March 2010, classifies all groundwater as SG, water intended for use as a drinking water supply. PREQB's position regarding the response is stated below:

PREQB acknowledges that the future development of the site is subject to what is agreed on the Naval Activity Puerto Rico 2004 Reuse Plan and its 2010 Addendum. The 2007 Consent Order between the Navy and EPA specifies that the cleanup levels will be established based on the planned future use. This should not be confused with the ARARs for the site. The 2010 Water Quality Standards Regulation of PREQB classifies all groundwater in Puerto Rico as potable, regardless of future land development.

Currently, the Navy submitted a Groundwater Usability Assessment to EPA and PREQB. The document was commented by PREQB and we are still awaiting response to the comments and revision of the document. PREQB is requiring compliance with our Regulation.

Response:
Comment acknowledged.

Corrective Measures Study Addendum
SWMU 55

Naval Activity Puerto Rico
Ceiba, Puerto Rico

Revision No. 00

Contract No. N62470-08-D-1006
Task Order No. JM04

Submitted to:

NAVFAC
Naval Facilities Engineering Command

U.S. Naval Facilities
Engineering Command
Southeast

Prepared by:

AGVIQ
ENVIRONMENTAL SERVICES
CH2M HILL
JOINT VENTURE

1000 Abernathy Road
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Atlanta, GA 30328

June 2012

Certification Page

Corrective Measures Study Addendum
SWMU 55

(Revision No. 00)

I certify under penalty of law that I have examined and am familiar with the information submitted in this document and all appendices, and that this document and its appendices were prepared either by me personally or under my direction or supervision in a manner designed to ensure that qualified and knowledgeable personnel properly gathered and presented the information contained herein. I further certify, based on my personal knowledge or on my inquiry of those individuals immediately responsible for obtaining the information, that the information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowingly and willfully submitting a materially false statement.

Signature: ______________________

Name: Mark. E. Davidson

Title: BRAC Environmental Coordinator

Date: June 15, 2012

Executive Summary

AGVIQ-CH2M HILL Constructors, Inc. Joint Venture III (AGVIQ-CH2M HILL) has been retained by the Department of the Navy, Naval Facilities Engineering Command Southeast (NAVFAC SE) to prepare a Corrective Measures Study (CMS) Addendum to address the cleanup of trichloroethene (TCE) in groundwater beneath Solid Waste Management Unit (SWMU) 55. SWMU 55 is located at Naval Activity Puerto Rico, formerly known as Naval Station Roosevelt Roads, in Ceiba, Puerto Rico. The CMS Addendum was performed under Contract No. N62470-08-D-1006, Task Order JM04. This document revises the *Corrective Measures Study Final Report for SWMUs 54 and 55* (Baker Environmental, Inc. [Baker], 2005) because implementation of the in situ chemical oxidation (ISCO) remedy proposed in the CMS is only partially viable, based on evaluation of newly acquired pilot-scale test data.

Between July 2009 and October 2010, AGVIQ-CH2M HILL performed an ISCO pilot-scale test to evaluate to the ability of sodium permanganate ($NaMnO_4$) to address TCE in groundwater. Testing involved the installation of four injection wells (55IW01 through 55IW04) and 25 monitoring wells (55MW01 through 55MW25) to monitor the vertical and horizontal distribution of $NaMnO_4$ following injection and delineate the TCE plume. The TCE CAO was revised in May 2012 to 193 μg/L. Also, area groundwater has been assessed as unsuitable for potable use.

The pilot-scale test indicated that full-scale ISCO would not be an effective or economical long-term remedy for the SWMU 55 TCE plume. Rather, AGVIQ-CH2M HILL proposes to amend the remedial approach to include the following activities:

- Excavate impacted soil within the known source area, thereby removing the bulk of the TCE source mass.
- Install a dual-purpose infiltration gallery/bioreactor within the excavation.
- Complete $NaMnO_4$ application in the infiltration gallery during construction to reduce elevated TCE concentrations in soil and groundwater within the source area that could not be removed through excavation.
- After TCE concentrations decrease within and immediately adjacent to the bioreactor and data indicate the oxidant is completely consumed, convert the infiltration gallery into an in situ bioreactor that will be amended with an emulsified vegetable oil (EVO) substrate for long-term treatment.
- Install a solar-powered pump in a well within the TCE source area and pump the water into the in situ bioreactor to promote enhanced reductive dechlorination.
- Install a series of mid-plume substrate injection wells to enhance natural attenuation in the downgradient portion of the plume.

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A *Revised Corrective Action Objectives for Solid Waste Management Units 7&8, 54, and 55* Technical Memorandum
B *Groundwater Usability Assessment, Naval Activity Puerto Rico, Ceiba, Puerto Rico* Technical Memorandum
C Pilot-Scale Test Report
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Acronyms and Abbreviations

AFB	Air Force Base
AGVIQ-CH2M HILL	AGVIQ-CH2M HILL Constructors, Inc. Joint Venture III
Baker	Baker Environmental, Inc.
bgs	below ground surface
CAO	corrective action objective
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
COPC	contaminant of potential concern
CVOC	chlorinated volatile organic compound
DCE	cis-1,2-dichloroethene
DNAPL	dense non-aqueous phase liquid
DoD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
ERD	enhanced reductive dechlorination
EVO	emulsified vegetable oil
g/L	grams per liter
gpm	gallons per minute
ISB	in situ bioremediation
ISCO	in situ chemical oxidation
$KMnO_4$	potassium permanganate
LRA	Puerto Rico Local Reuse Authority
LUC	land use control
µg/L	microgram per liter
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNA	monitored natural attenuation
$NaMnO_4$	sodium permanganate
NAPR	Naval Activity Puerto Rico
NAVFAC SE	Naval Facilities Engineering Command Southeast

NPDES	National Pollution Discharge Elimination System
NSRR	Naval Station Roosevelt Roads
O&M	operation and maintenance
PPE	personal protection equipment
PREQB	Puerto Rico Environmental Quality Board
PTOD	permanganate total oxidant demand
RAB	Restoration Advisory Board
RSL	regional screening levels
SWMU	solid waste management unit
TCE	trichloroethene
TWFF	Tow Way Fuel Farm
VC	vinyl chloride
VOC	volatile organic compound

1.0 Introduction

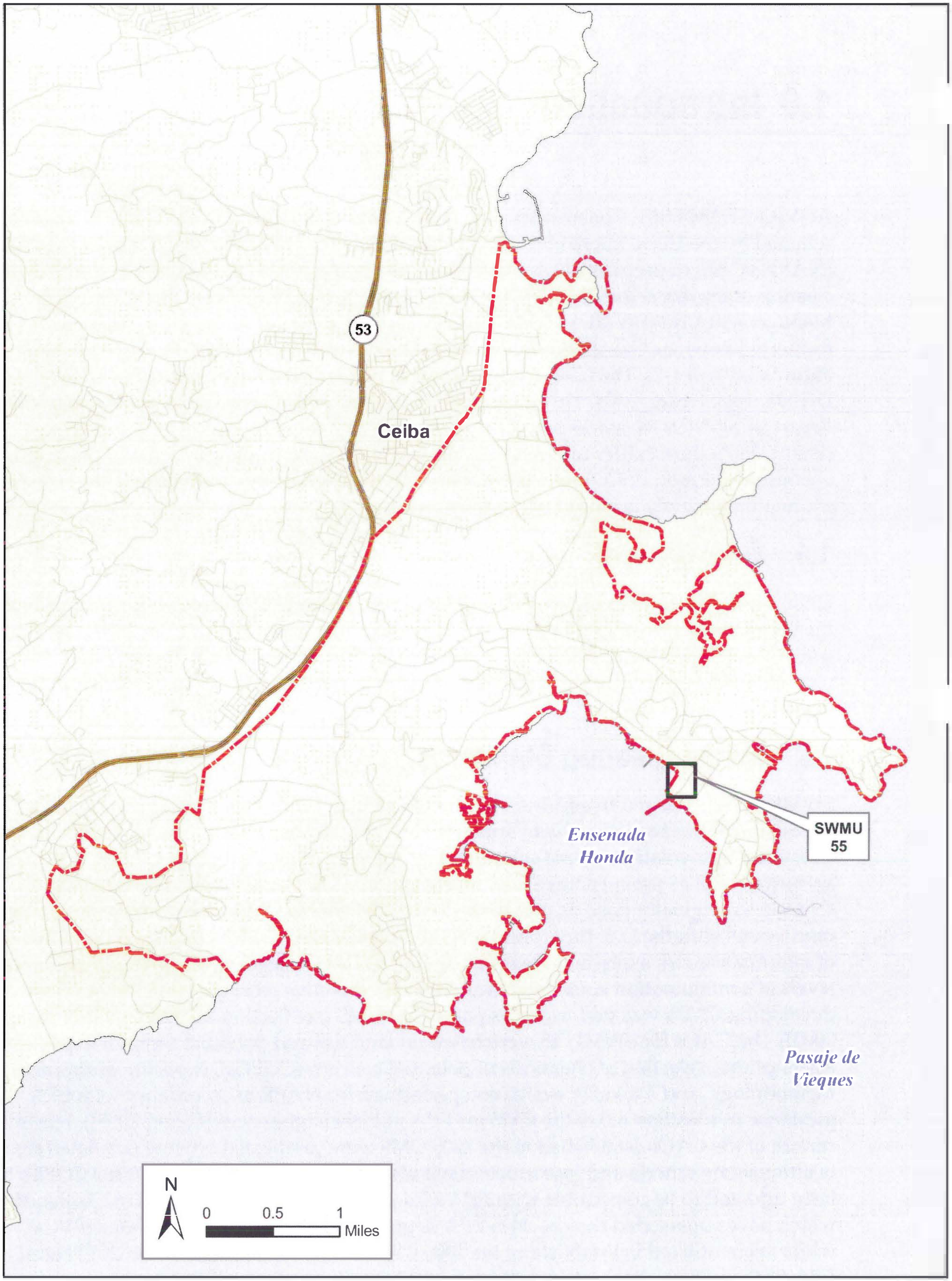
AGVIQ-CH2M HILL Constructors, Inc. Joint Venture III (AGVIQ-CH2M HILL) has been retained by the Department of the Navy, Naval Facilities Engineering Command Southeast (NAVFAC SE) to prepare a Corrective Measures Study (CMS) Addendum to address the cleanup of trichloroethene (TCE) contamination in groundwater beneath Solid Waste Management Unit (SWMU) 55. SWMU 55 is located at Naval Activity Puerto Rico (NAPR), formerly known as Naval Station Roosevelt Roads (NSRR), in Ceiba, Puerto Rico (refer to Figures 1-1 and 1-2). The CMS Addendum was performed under Contract No. N62470-08-D-1006, Task Order JM04. This document revises the *Final Corrective Measures Study Final Report for SWMUs 54 and 55* previously prepared by Baker Environmental, Inc. (Baker) (Baker, 2005) (hereinafter referred to as the CMS), because implementation of the in situ chemical oxidation (ISCO) remedy proposed in the CMS is only partially viable, based on evaluation of newly acquired pilot-scale test data.

1.1 Background

Under the CMS, human health and ecological risk assessments were conducted to develop the corrective action objective (CAO) of 22 micrograms per liter (µg/L) in 2005. The CAO was revised to 193 µg/L in 2012 for cleanup of TCE in groundwater. The originally recommended remedial approach of ISCO using permanganate is also described in this report.

1.2 Media Cleanup Standards

SWMU 55 was created to address TCE identified in groundwater during investigations conducted at the Tow Way Fuel Farm (TWFF). Investigations have focused primarily on TCE and other volatile organic compounds (VOCs) in groundwater, as well as VOCs in subsurface soil as part of source area investigations. The development of the SWMU 55 CAOs was originally done as part of the SWMU 54 and 55 CMS (Baker, 2005). Based on discussions with the U.S. Environmental Protection Agency (EPA) Region 2, the initial step of quantitative risk assessment was omitted for SWMU 55 since it was presumed that the levels of contamination warranted evaluation of corrective measures and the next step of developing CAOs was performed as part of the CMS (see Section 2.4.1 of the CMS [Baker, 2005]).The CAOs for SWMU 55 were based on land use and potential receptor exposure assumptions, selection of chemicals of potential concern (COPCs), exposure assessment and methodology, and a toxicity evaluation performed for NAPR in accordance with EPA guidance (see Section 6.0 of the CMS for EPA guidance references [Baker, 2005]). However, certain of the CAOs established in the 2005 CMS were predicated on now out-dated human health toxicity criteria and assessment methodologies. Therefore, the CAOs for COPCs have been updated to be compatible with EPA's Regional Screening Levels (RSLs) (Appendix A), which have superseded the pre-2005 EPA Region 3 Risk Based Concentrations (RBCs), which were utilized in establishing the 2005 CAOs. The revised CAOs from 2012 based on EPA RSLs are included in Appendix A for SWMU 55 groundwater VOCs.



Road

Expressway

Naval Activity Puerto Rico Boundary

FIGURE 1-1
SWMU 55 Location
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MANAGED.LOCAL\CRITIGEN\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55\2011\CMSREPORT\FIG_1-1_SWMU55_LOCATION.MXD JCARR 5/16/2012 3:18:14 PM

Monitoring Well Screened Primarily Less than 25 ft bgs

Injection Well Screened Primarily Less than 25 ft bgs

Monitoring Well Screened Primarily Greater than 25 ft bgs

Injection Well Screened Primarily Greater than 25 ft bgs

Monitoring Well

SWWU 55 Boundary

N 0 60 120 Feet

1 inch = 120 feet

FIGURE 1-2
Site Layout
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MANAGED.LOCAL\CRITIGEN\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55\2011\CMSREPORT\FIG_1-2_SWMU55_SITELAYOUT.MXD JCARR 5/16/2012 3:19:37 PM

EPA conditionally approved the CMS report on October 13, 2005 contingent upon completion of the pilot tests and Corrective Measures Implementation (CMI) Plan. The groundwater CAOs were developed based on an industrial use of the site as was originally proposed in the 2004 Reuse Plan submitted to the Puerto Rico Local Reuse Authority (LRA) (NAVFAC, 2004). Since groundwater CAOs developed in the CMS were risk-based for industrial use, land use controls (LUCs) to prevent use of the groundwater is included as part of the remedy (during cleanup and after reaching the CAOs) in order to be protective of human health. The LUCs are described in the Quitclaim Deed for CDR Parcel 2 signed by the Navy and the LRA on December 20, 2011. In addition, the December 2011 transfer deed associated with SWMU 55 states that vapor intrusion must be considered by the new owner during the design/construction of any future structures on the parcel.

If development other than industrial use (i.e., residential, or per the April 2010 amended reuse plan [NAVFAC, 2010]) is proposed, the new owner must complete any additional investigation/risk assessment/cleanup activities which EPA determines are warranted to support a proposed site usage other than industrial. If the property owner wishes to remove the LUC on the groundwater from the deed in the future, it will be the responsibility of the property owner to demonstrate the groundwater meets all state and federal maximum contaminant levels (MCLs), and to obtain approval from the Navy, EPA, and Puerto Rico Environmental Quality Board (PREQB) prior to LUC removal.

These previously derived CAOs have been used to design the remedy and define the residual concentrations within and around the source area.

1.2.1 Land Use and Potentially Exposed Receptors

SWMU 55 was formed to address TCE contamination in groundwater in the downgradient area of the former TWFF. Prior to the CMS (Baker, 2005), all information related to SWMU 55 was published in the Tow Way Fuel Farm (TWFF) reports and referred to as the TCE Plume. The TWFF and SWMU 55 area are an industrial area and future property use of the SWMU 55 area is expected to remain industrial, as described in the Quitclaim Deed.

Future onsite residential land use was quantitatively considered as an additional hypothetical exposure scenario; however, it is not considered a reasonably anticipated exposure scenario for this area. Therefore, target levels were not derived for this exposure scenario (Baker, 2003 and Baker, 2005).

Based on the CMS and guidance from the Department of Defense (DoD), the CAOs were derived to be protective of industrial workers. The CAOs were also derived to be protective of construction workers who may be exposed to shallow groundwater up to a depth of 10 feet below ground surface (bgs). During the CAO development, it was anticipated that the TWFF and the SWMU 55 area would not be developed into an unrestricted use area (e.g., residential area).

Existing LUCs are described in the Quitclaim Deed for CDR Parcel 2 signed by the Navy and the LRA on December 20, 2011. Those LUCs must be included as part of the corrective action to prevent the unintended use of groundwater. If development other than industrial use is proposed, the new owner/leasee will be responsible for any additional investigation, risk assessment, or corrective actions that may be required.

The proposed future usage of SWMU 55 is described in the *Final Supplemental Environmental Assessment for Disposal of Naval Activity Puerto Rico* (NAVFAC, 2011). The Navy has advised EPA that the LRA application for an Economic Development Conveyance transfer has been approved for the proposed "Caribbean Riviera" development and that the "Port Parcel," including SWMU 55, was transferred to the LRA on January 25, 2012 pursuant to an approved Covenant Deferral Request allowing transfer prior to completion of the required clean-ups.

1.2.2 Groundwater CAOs

As previously stated, the TCE and several other VOCs in groundwater were identified as COPCs at SWMU 55. This TCE contamination area is located in the downgradient portion of the former TWFF. Thus, the primary medium of concern for SWMU 55 is the groundwater, and CAOs were developed for groundwater VOCs, including TCE.

During subsequent investigations, site TCE and other VOCs were investigated in subsurface soil to identify the potential presence of a continuing source contributing to groundwater TCE contamination. No soil VOCs were identified as a continuing source area; therefore, no soil CAOs were developed for SWMU 55 (Baker, 2004 and Baker, 2005).

The 2005 CAO development is summarized below and is described in the CMS report (Baker, 2005). The EPA conditionally approved the CMS (Baker, 2005) on October 13, 2005, contingent upon completion of the pilot-scale tests and CMI Plan.

Appendix B of the CMS (Baker, 2005) included a derivation of groundwater CAOs for VOCs. The 2005 groundwater CAOs were developed based on an industrial use of SWMU 55. The CAOs were estimated using the Johnson-Ettinger Model for the target groundwater levels protective of industrial worker exposure to indoor air in an industrial building and construction workers having direct contact with shallow groundwater.

The 2005 CAO for TCE was used to delineate the plume and design the corrective action during the pilot-scale testing in 2009 to 2010. In May 2012, the 2005 CAOs were revised using EPA's RSLs (November 2011) based calculation methods and toxicity factors, as recommended by EPA Region 2 during their review of the CMS Addendum. The revised CAOs are based on continued industrial land use. The revised CAOs were developed for industrial (indoor) worker and construction worker scenarios as presented in the *Revised Corrective Action Objectives for Solid Waste Management Units 7&8, 54, and 55* Technical Memorandum (Appendix A).

The groundwater beneath SWMU 55 was demonstrated to be unusable as a potable water supply due to the brackish/saline nature of the area groundwater, with high levels of total dissolved solids and salinity, as detailed in the *Groundwater Usability Assessment, Naval Activity Puerto Rico, Ceiba, Puerto Rico* Technical Memorandum (Appendix B). Therefore, potable use based drinking water standards (e.g., maximum contamination levels) are not applicable for SWMU 55.

Under current land use, no direct exposure to site groundwater is occurring at or downgradient of SWMU 55, as area groundwater is expected to discharge to the Ensenada Honda, thus future use of groundwater is unlikely. However, indirect exposure pathway through volatilization of TCE to ambient air and indoor air could occur in the SWMU 55

TCE plume area. Therefore, this indirect exposure pathway was considered complete for deriving the CAOs for the site groundwater.

The revised CAO for TCE in groundwater is 193 µg/L.

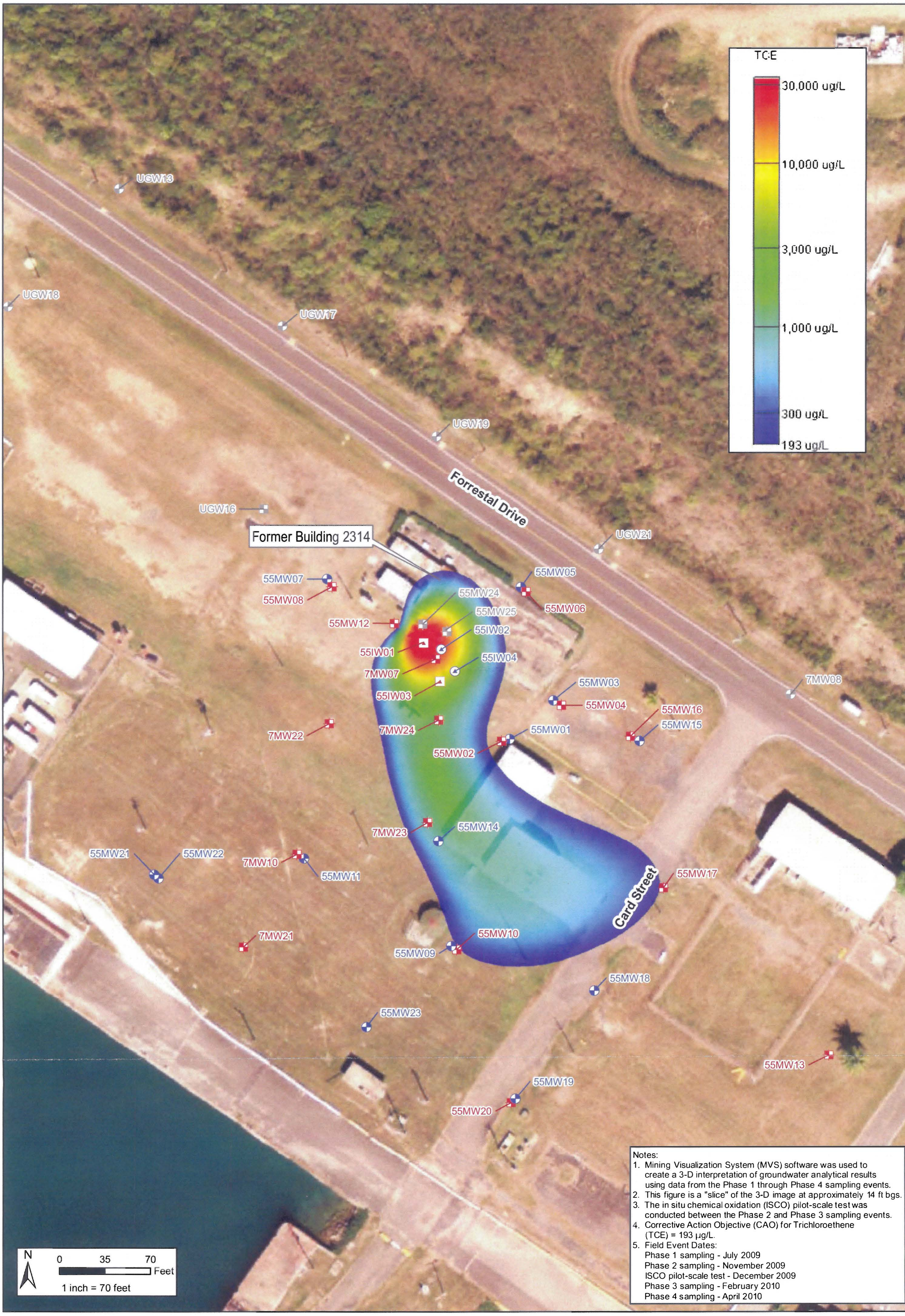
The revised plume map for TCE based on the CAO of 193 µg/L is presented in Figures 1-3 to 1-5 for various aquifer depths at SWMU 55.

1.3 Contaminant Migration Potential

Groundwater samples collected from the SWMU 55 area in April 1998 (Baker, 2004) as part of the CMS for the TWFF indicated TCE contamination in groundwater resulting from an unknown source. Based on interviews with Base personnel, a building destroyed during Hurricane Hugo in 1989 was formerly located immediately northeast of well 7MW07 (former Building 2314). This building was used for the storage and maintenance of small watercraft, and cleaning and degreasing operations at this building may have released TCE to soil and groundwater. Soil samples collected during the CMS (Baker, 2005) measured a maximum TCE concentration in soil of 110 µg/kg at the soil boring 7TCESB05. In the corresponding groundwater sample, TCE was measured at 2,000 µg/L, which was later detected at 28,000 µg/L. However, the overall area with high TCE concentration is very small and thus the soil results do not represent a significant continuing soil source.

SWMU 55 is situated above saprolite, weathered bedrock and bedrock that, near the bayshore, abuts sandy marine sediments artificially filled in to level and raise the wharf areas (Appendix C Figure 3-2). To the south-southwest of 55MW23 (on the right in the section) is a retaining wall (seawall) that reportedly extends below the fill and is anchored in original materials (saprolite or possibly bedrock) at least 40 feet bgs. This retaining wall extends northwest far beyond 55MW21 and southeast far beyond 55MW13 (Appendix C Figures 3-6 and 3-7). The proximity of SWMU 55 to Ensenada Honda and the presence of the retaining wall greatly influence groundwater flow and the migration of the TCE plume. In particular, the proximity to the bay causes tidal effects on water levels measured in inland wells. Likewise, the presence of the saltwater-freshwater interface may affect water levels and groundwater chemistry in wells near the bay. The retaining wall locally blocks freshwater discharge directly to the bay. Near the inland side of the wall, fresh groundwater is forced to flow either to the northwest or southeast to find a point of connection (discharge) to the bay.

Eleven nested well sets were installed during the site investigation to determine horizontal and vertical gradients across SWMU 55. Water levels were measured on April 29, 2010 and August 17, 2010, and vertical gradients were calculated using the online EPA Vertical Gradient Calculator (EPA, 2011a), as shown in Table 1-1. Nested well pairs 55MW05/55MW06, 55MW07/55MW08, 7MW10/55MW11, and 55MW21/55MW22 had upward vertical gradients for both gauging events, while nested well pairs 55MW01/55MW02, 55MW03/55MW04, 55MW15/55MW16, and 7MW23/55MW14 had downward vertical gradients for both gauging events, and gradients at nested well pairs 55MW09/55MW10 (upward/downward) and 55MW19/55MW20 (downward/upward) varied during the gauging events. These results suggest that a tidal influence to head measurements must be considered in order to interpret the potentiometric surface of the aquifer properly.

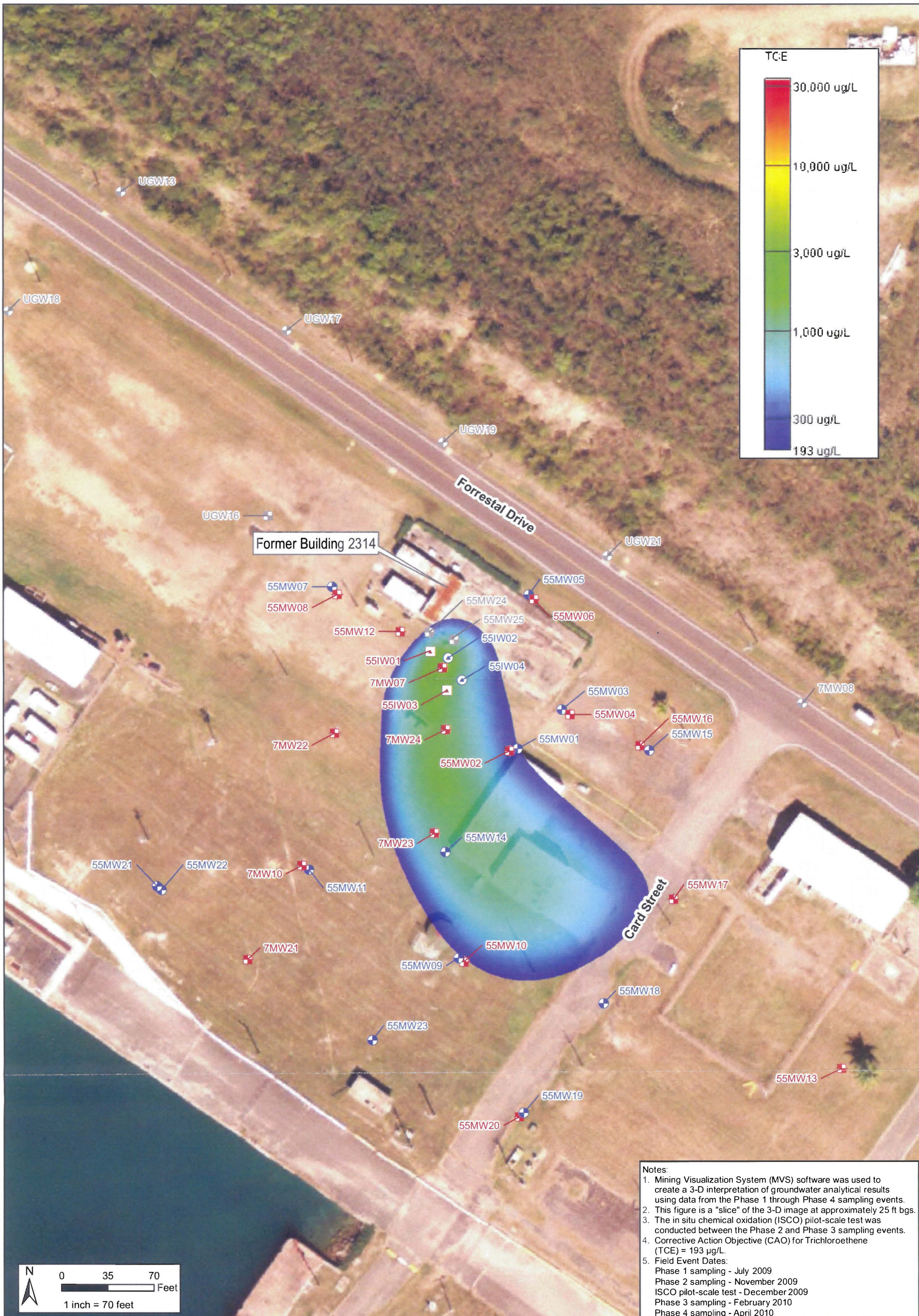


Notes:
1. Mining Visualization System (MVS) software was used to create a 3-D interpretation of groundwater analytical results using data from the Phase 1 through Phase 4 sampling events.
2. This figure is a "slice" of the 3-D image at approximately 14 ft bgs.
3. The in situ chemical oxidation (ISCO) pilot-scale test was conducted between the Phase 2 and Phase 3 sampling events.
4. Corrective Action Objective (CAO) for Trichloroethene (TCE) = 193 μg/L.
5. Field Event Dates:
   Phase 1 sampling - July 2009
   Phase 2 sampling - November 2009
   ISCO pilot-scale test - December 2009
   Phase 3 sampling - February 2010
   Phase 4 sampling - April 2010

Monitoring Well Screened Primarily Less than 25 ft bgs
Injection Well Screened Primarily Less than 25 ft bgs
Monitoring Well Screened Primarily Greater than 25 ft bgs
Injection Well Screened Primarily Greater than 25 ft bgs
Existing monitoring wells not used to develop 3-D interpretation.

FIGURE 1-3
Shallow Aquifer Zone TCE Concentrations – Baseline
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

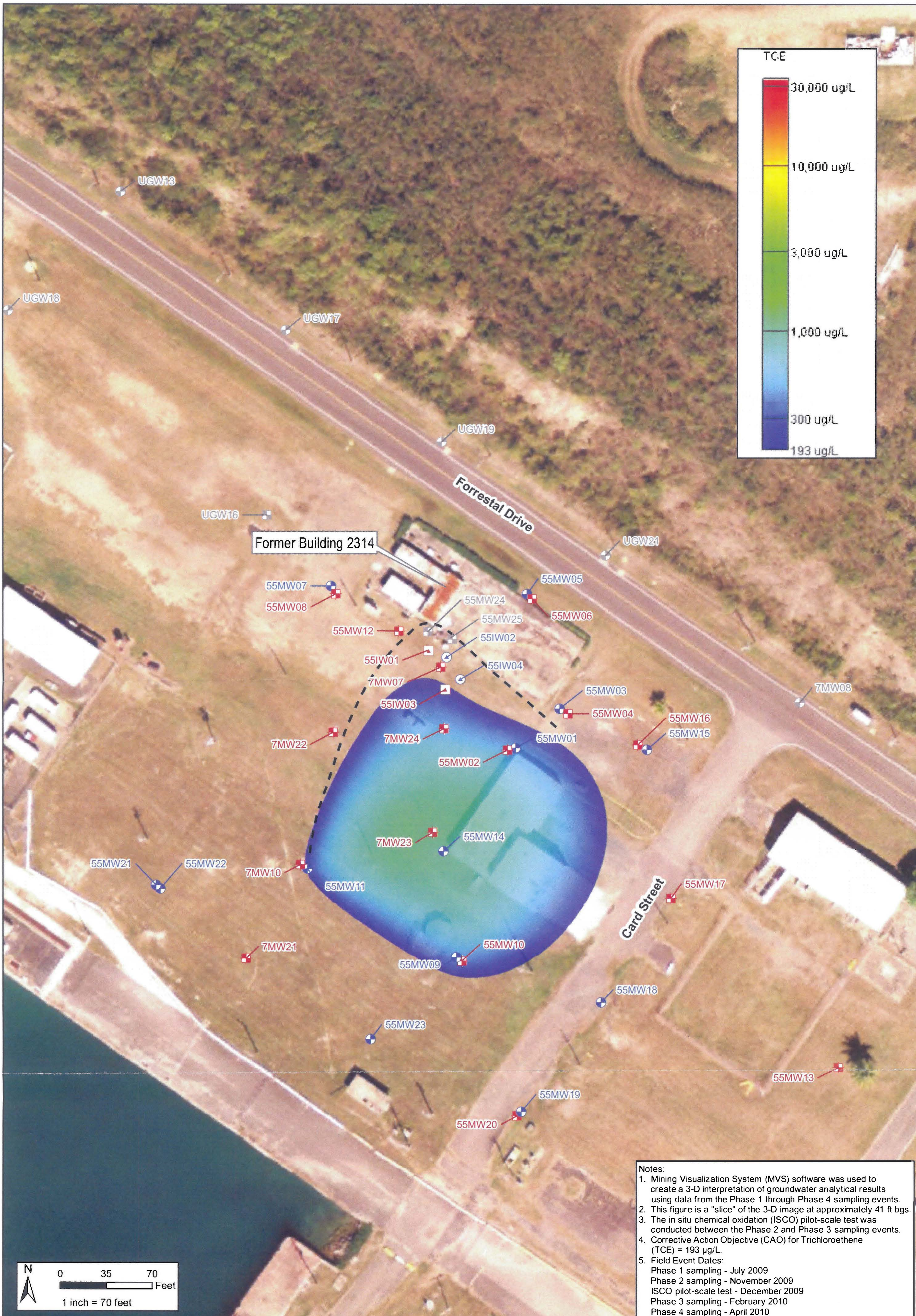


Monitoring Well Screened Primarily Less than 25 ft bgs
Injection Well Screened Primarily Less than 25 ft bgs
Monitoring Well Screened Primarily Greater than 25 ft bgs
Injection Well Screened Primarily Greater than 25 ft bgs
Existing monitoring wells not used to develop 3-D interpretation.

FIGURE 1-4
Mid-Aquifer Zone TCE Concentrations – Baseline
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55\2011\CMSREPORT\FIG_1-4_BASELINE_MID.MXD JCARR 6/1/2012 10:30:10 AM



Notes:
1. Mining Visualization System (MVS) software was used to create a 3-D interpretation of groundwater analytical results using data from the Phase 1 through Phase 4 sampling events.
2. This figure is a "slice" of the 3-D image at approximately 41 ft bgs.
3. The in situ chemical oxidation (ISCO) pilot-scale test was conducted between the Phase 2 and Phase 3 sampling events.
4. Corrective Action Objective (CAO) for Trichloroethene (TCE) = 193 µg/L.
5. Field Event Dates:
   Phase 1 sampling - July 2009
   Phase 2 sampling - November 2009
   ISCO pilot-scale test - December 2009
   Phase 3 sampling - February 2010
   Phase 4 sampling - April 2010

- Monitoring Well Screened Primarily Less than 25 ft bgs
- Injection Well Screened Primarily Less than 25 ft bgs
- Monitoring Well Screened Primarily Greater than 25 ft bgs
- Injection Well Screened Primarily Greater than 25 ft bgs
- Existing monitoring wells not used to develop 3-D interpretation.
- Estimated extent of TCE in excess of 193 µg/L

FIGURE 1-5
Deep Aquifer Zone TCE Concentrations – Baseline
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55\2011\CMSREPORT\FIG_1-5_BASELINE_DEEP.MXD JCARR 6/6/2012 12:06:44 PM

TABLE 1-1
Summary of Groundwater Vertical Gradients within the SWMU 55 site
SWMU 55
Naval Activity Puerto Rico

Well Identification	Interval	Top of Casing (TOC) Elevation (feet NGVD29)	Depth to Top of Well Screen (feet BTOC)	Screen Length (feet)	Depth to Water (feet BTOC)	Bottom of Screen to Top of Screen (L:H)		Top of Screen to Top of Screen (H:H)		Mid-point of Screen to Mid-point of Screen (M:M)		Bottom of Screen to Bottom of Screen (L:L)		Top of Screen to Bottom of Screen (H:L)	
						(feet/ feet)	(up/ down)	(feet/ feet)	(up/ down)	(feet/ feet)	(up/ down)	(feet/ feet)	(up/ down)	(feet/ feet)	(up/ down)
						April 29, 2010									
55MW-01D	Deep	14.89	27.50	15.0	12.69	0.008	Down	0.016	Down	0.016	Down	0.016	Down	0.558	Down
55MW-02S	Shallow	14.82	12.00	15.0	12.38										
55MW-03D	Deep	16.66	27.10	15.0	14.39	0.002	Down	0.005	Down	0.045	Down	0.044	Down	0.044	Up
55MW-04S	Shallow	16.40	13.20	15.0	14.07										
55MW-05D	Deep	13.81	28.30	15.0	11.12	0.002	Up	0.003	Up	0.003	Up	0.003	Up	0.192	Up
55MW-06S	Shallow	13.87	13.10	15.0	11.23										
55MW-07D	Deep	14.59	27.80	15.0	12.43	0.006	Up	0.013	Up	0.013	Up	0.013	Up	3.167	Up
55MW-08S	Shallow	14.55	12.70	15.0	12.58										
55MW-09D	Deep	10.16	27.80	15.0	8.91	0.001	Up	0.001	Up	0.001	Up	0.001	Up	0.010	Up
55MW-10S	Shallow	10.16	10.80	15.0	8.93										
55MW-11D	Deep	10.49	27.30	15.0	9.24	0.008	Up	0.015	Up	0.012	Up	0.010	Up	0.023	Up
7MW-10S	Shallow	7.03	1.90	10.0	6.05										
55MW-14D	Deep	12.69	27.80	15.0	11.18	0.002	Down	0.004	Down	0.004	Down	0.003	Down	0.012	Down
7MW-23S	Shallow	9.06	8.30	10.0	7.48										
55MW-15D	Deep	14.29	43.10	15.0	11.73	0.001	Down	0.002	Down	0.002	Down	0.002	Down	0.005	Down
55MW-16S	Shallow	14.36	18.00	15.0	11.75										
55MW-17S	Shallow	9.62	7.10	15.0	8.13	0.011	Down	0.014	Down	0.015	Down	0.015	Down	0.021	Down
55MW-18D	Deep	8.87	48.80	10.0	7.96										
55MW-19D	Deep	8.08	49.10	10.0	6.65	0.004	Down	0.005	Down	0.006	Down	0.006	Down	0.010	Down
55MW-20S	Shallow	8.18	14.20	15.0	6.56										
55MW-21I	Intermediate	10.03	28.00	15.0	9.27	0.002	Up	0.003	Up	0.003	Up	0.003	Up	0.007	Up
55MW-22D	Deep	10.03	55.30	15.0	9.18										

TABLE 1-1
Summary of Groundwater Vertical Gradients within the SWMU 55 site
SWMU 55
Naval Activity Puerto Rico

Well Identification	Interval	Top of Casing (TOC) Elevation (feet NGVD29)	Depth to Top of Well Screen (feet BTOC)	Screen Length (feet)	Depth to Water (feet BTOC)	Bottom of Screen to Top of Screen (L:H) (feet/ feet)	Bottom of Screen to Top of Screen (L:H) (up/ down)	Top of Screen to Top of Screen (H:H) (feet/ feet)	Top of Screen to Top of Screen (H:H) (up/ down)	Mid-point of Screen to Mid-point of Screen (M:M) (feet/ feet)	Mid-point of Screen to Mid-point of Screen (M:M) (up/ down)	Bottom of Screen to Bottom of Screen (L:L) (feet/ feet)	Bottom of Screen to Bottom of Screen (L:L) (up/ down)	Top of Screen to Bottom of Screen (H:L) (feet/ feet)	Top of Screen to Bottom of Screen (H:L) (up/ down)
August 17, 2010															
55MW-01D	Deep	14.89	27.50	15.0	10.90	0.007	Down	0.013	Down	0.013	Down	0.013	Down	0.465	Down
55MW-02S	Shallow	14.82	12.00	15.0	10.63										
55MW-03D	Deep	16.66	27.10	15.0	12.60	0.003	Down	0.007	Down	0.007	Down	0.007	Down	0.066	Up
55MW-04S	Shallow	16.40	13.20	15.0	12.25										
55MW-05D	Deep	13.81	28.30	15.0	8.91	0.001	Up	0.002	Up	0.002	Up	0.002	Up	0.115	Up
55MW-06S	Shallow	13.87	13.10	15.0	9.00										
55MW-07D	Deep	14.59	27.80	15.0	11.04	0.001	Up	0.002	Up	0.002	Up	0.002	Up	0.500	Up
55MW-08S	Shallow	14.55	12.70	15.0	11.03										
55MW-09D	Deep	10.16	27.80	15.0	8.50	0.001	Down	0.002	Down	0.002	Down	0.002	Down	0.020	Down
55MW-10S	Shallow	10.16	10.80	15.0	8.46										
55MW-11D	Deep	10.49	27.30	15.0	8.87	0.00	Up	0.00	Up	0.00	Up	0.00	Up	0.00	Up
7MW-10S	Shallow	7.03	1.90	10.0	5.45										
55MW-14D	Deep	12.69	27.80	15.0	10.53	0.01	Down	0.01	Down	0.01	Down	0.01	Down	0.04	Down
7MW-23S	Shallow	9.06	8.30	10.0	6.69										
55MW-15D	Deep	14.29	43.10	15.0	9.55	0.00	Down	0.01	Down	0.01	Down	0.01	Down	0.00	Down
55MW-16S	Shallow	14.36	18.00	15.0	9.60										
55MW-17S	Shallow	9.62	7.10	15.0	7.34	0.00	Up	0.00	Up	0.00	Up	0.00	Up	0.00	Up
55MW-18D	Deep	8.87	48.80	10.0	6.53										
55MW-19D	Deep	8.08	49.10	10.0	6.11	0.01	Up	0.01	Up	0.01	Up	0.01	Up	0.02	Up
55MW-20S	Shallow	8.18	14.20	15.0	6.53										
55MW-21I	Intermediate	10.03	28.00	15.0	9.10	0.00	Up	0.00	Up	0.00	Up	0.00	Up	0.01	Up
55MW-22D	Deep	10.03	55.30	15.0	9.00										

Notes:
BTOC = below top-of-casing
NGVD29 = National Geodetic Vertical Datum of 1929
Source:
Vertical gradients calculated using the EPA on-line tools for site assessment calculation: Vertical Gradients with Well Screen Effects.
At URL: http://www.epa.gov/athens/learn2model/part-two/onsite/vgradient02.htm

Based on potentiometric levels in wells near Forrestal Drive, the direction of groundwater flow in the shallow and deeper portions of the aquifer appears to be south or southwest toward Ensenada Honda. The water table aquifer has an estimated average hydraulic conductivity of 13.5 feet/day and an approximate hydraulic gradient of 0.006. Combining hydraulic conductivity, gradient and an estimated porosity range from 0.2 to 0.4, the groundwater velocity at SWMU 55 ranges between 74 and 148 feet per year. Estimating conservatively, the last TCE release may have occurred in 1989. Because TCE has a low retardation factor (that is, it moves readily with groundwater), it is expected that the TCE plume would have reached Ensenada Honda in the 21 years between the estimated last release and the last sampling event, and as a result, groundwater monitoring wells near Ensenada Honda should have measurable levels of TCE. However, TCE was not measured above the detection limit of 5 µg/L near Ensenada Honda during the 2009 – 2010 investigation in monitoring wells 55MW19, 55MW20, 55MW21, 55MW22, and 55MW23, or historically at monitoring well 7MW07. The potential reasons for the lack of measurable levels of TCE in groundwater close to Ensenada Honda may include:

- The TCE plume is diluted by infiltration as it migrates toward the bay.
- Natural degradation processes are reducing TCE levels in the plume.
- The direction of plume migration is not directly toward Ensenada Honda.

Separate from using groundwater gradients to infer direction of plume migration, measurements of the TCE concentrations in groundwater provide direct evidence of the location and direction of plume migration. As indicated in Appendix C Figures 3-3 and 3-4, fresh groundwater and the TCE contamination are migrating to the south and southeast. There is little to no TCE near the seawall because groundwater flow is parallel to the wall toward the southeast. Available groundwater-level data suggest that the saltwater-freshwater interface near the retaining wall is less than 40 feet bgs, and deepens inland. Appendix C Figure 3-5 appears to demonstrate the effect of the saltwater-freshwater interface. The deeper TCE plume naturally migrates toward the bay, but encounters the interface and is forced to rise up into the shallower parts of the aquifer. The retaining wall is deep enough that the presence of the interface prevents the plume from migrating under the wall. Overall, the CSM indicates the TCE plume will continue to migrate to the south-southeast until the fresh groundwater can pass around (or through) the retaining wall and discharge to the bay.

The potential for groundwater to release TCE to Ensenada Honda surface water was evaluated previously by sampling the storm sewers within and contiguous to the TWFF and associated stormwater outfalls (Baker, 2005). The mass of TCE reaching Ensenada Honda was previously estimated at 98.2 grams per day using a maximum flow velocity of site groundwater of 113 feet/day and assuming a linear flow from the source area toward Ensenada Honda. These calculations conservatively estimated the possible TCE concentration in Ensenada Honda surface water to not exceed 61.9 µg/L, and compared these values against the ecological protection-based CAO of 200 µg/L (Baker, 2005). In addition, cumulative discharge-based concentrations in Ensenada Honda were estimated, indicating that it would take 118.5 years for the site contamination discharge to surpass TCE concentrations of 200 µg/L. However, this model does not take into account the dilution, degradation, and other loss mechanisms that are characteristic of TCE, and the calculations are based on TCE migration directly from SWMU 55 to the bay. The current CSM indicates the plume will travel much further to the southeast before finding a gap in the retaining wall, and discharging to the bay.

According to the CMS (Baker, 2005), the only outfall that can discharge surface runoff originating from the TWFF is Outfall 010 (a National Pollution Discharge Elimination System [NPDES]-permitted outfall). As such, the Outfall 010 storm sewer system represents the only potential transport pathway for chemicals in surface soil to migrate with surface runoff to Ensenada Honda. This outfall was sampled and there were no measurable levels of TCE in the surface water sample. Because levels of TCE in soil at SWMU55 are low, the potential for offsite migration of TCE in surface water is negligible.

1.4 Summary of Recent Work

Between July 2009 and August 2010, AGVIQ-CH2M HILL performed an ISCO pilot-scale test to evaluate the ability of sodium permanganate ($NaMnO_4$) to reduce TCE concentrations in groundwater to the 2005 CAO of 22 µg/L. The pilot-scale test work is described in detail in Appendix C and summarized below.

The pilot-scale test involved the installation of four injection wells (55IW01 through IW04) and 25 monitoring wells (55MW01 through 55MW25) to delineate the TCE plume and monitor the vertical and horizontal distribution of $NaMnO_4$ in groundwater during the ISCO injection. Additional work completed during the pilot-scale test includes aquifer slug tests and permanganate total oxidant demand (PTOD) bench-scale testing. Details of the additional characterization and pilot-scale test work are presented in Appendix C. The major findings from the pilot-scale test are summarized below and serve as the basis for this amendment of the CMS (Baker, 2005).

The results of the groundwater sampling data indicate that TCE contamination above the revised CAO of 193 µg/L is present throughout the aquifer and extends south and southeast from former Building 2314 beyond Card Street (refer to Figures 1-3, 1-4, and 1-5). Comparison of the TCE plume map illustrated on Figure 1-3 (14 feet bgs) with that shown on Figure 1-4 (TCE concentrations at 25 feet bgs) and Figure 1-5 (TCE concentrations at 41 feet bgs) shows that the areal extent of TCE in groundwater increases with depth, while concentrations decrease. Finally, comparison of the recent characterization data (Figures 1-3, 1-4, and 1-5) with the CMS September 2003 data (provided in Appendix D) shows that the extent of TCE contamination above the revised CAO of 193 µg/L is greater than originally estimated in the CMS (Baker, 2005).

Aquifer test results indicate that the hydraulic conductivity of the water table aquifer ranges from approximately 1.7 to 327 feet/day and averages 13.5 feet/day. The hydraulic conductivity value of 326.9 feet/day was measured in well 7MW10 located near the center of the recently installed injection well network (Figure 1-3) and is considered to be anomalous (see Appendix C). The range of hydraulic conductivities measured is between silty sand to clean sand for unconsolidated sediments and as fractured igneous rock for consolidated rocks. The variability in the range of hydraulic conductivities measured is likely attributable to the fact that the area south of Forrestal Drive is comprised of fill material of varying porosity and permeability.

Based on the results of the PTOD bench-scale test, the optimal potassium permanganate ($KMnO_4$) injection concentration for the pilot-scale test was determined to be 10,000 to 20,000 milligrams per liter (mg/L) $KMnO_4$ (approximately 9,000 to 18,000 mg/L $NaMnO_4$). Using these results, an average concentration of 16,500 mg/L (approximately 1.6 percent) was selected for the injection of $NaMnO_4$. The results of the PTOD bench-scale test also indicated that the oxidant demand of the formation was low (less than 2 milligrams per kilogram [mg/kg]) and $NaMnO_4$ would not be depleted by reaction with the formation instead of TCE.

The ISCO pilot-scale test was conducted between December 3 and 17, 2009. During this time, 10,000 gallons of an approximate 1.6 percent $NaMnO_4$ solution was injected at four injection wells (55IW01 through 55IW04). Each injection well received 2,500 gallons of injection solution, and a total of approximately 1,300 pounds of $NaMnO_4$ were injected at SWMU 55. Test results showed an injection radius of approximately 25 feet was achieved during active injection, though the delivery was not uniform in the subsurface.

Initially, significant decreases in TCE concentrations were observed in the test area; however, within 3 months, permanganate concentrations had decreased substantially and significant TCE rebound was observed. AGVIQ-CH2M HILL determined that because the formation was found to have a low oxidant demand during the PTOD bench-scale testing, the rapid depletion of $NaMnO_4$ was a result of oxidant migration along zones of higher permeability within the fill rather than degradation of the oxidant alone.

Additionally, groundwater conductivity data collected during the pilot testing were used to evaluate the potential impact to the ISCO process due to high salinity. The higher salinity zone was found to be confined primarily close to groundwater near Ensenada Honda and does not appear to impact the TCE source area. Analytical results from August 2010 indicated reductive dechlorination of TCE was already occurring in areas of the plume impacted by permanganate, high salinity, and areas not impacted by either.

The rapid dissipation of oxidant during pilot-scale testing indicates multiple injections would be required to attain sufficient permanganate residence time to oxidize the TCE and achieve the CAO. Additionally, because the interconnectivity of the higher permeability zones is unknown, the possibility exists that the injection of large volumes of oxidant over the entire plume may result in the unintentional discharge of $NaMnO_4$ into Ensenada Honda. The minimal $NaMnO_4$ persistence, combined with rapid rebound, indicates that full-scale ISCO would not be a cost-effective remedy for the SWMU 55 TCE plume. Rather, AGVIQ-CH2M HILL proposes to amend the remedial approach to include the following activities:

- Excavate impacted soil within the source area, thereby removing the bulk of the TCE source mass.
- Install a dual-purpose infiltration gallery/bioreactor within the excavation.
- Place $NaMnO_4$ into the infiltration gallery to reduce elevated TCE concentrations in soil and groundwater beneath the excavation that could not be removed through excavation.
- After TCE concentrations decrease within and immediately adjacent to the bioreactor and data indicate the oxidant is completely consumed, convert the infiltration gallery into a bioreactor that will be amended with an emulsified vegetable oil (EVO) substrate.
- Install a solar-powered pump in one well within the TCE source area and pump the water into the bioreactor to promote enhanced reductive dechlorination (ERD) of TCE in the source area.
- Install a series of mid-plume substrate injection wells to enhance natural attenuation in the downgradient portion of the plume.

The amended remedial approach, along with a revised implementation schedule, is described in the remainder of this report. A summary of the current conditions at SWMU 55 is provided in Appendix C.

2.0 Corrective Measure Alternatives

In addition to ISCO, in situ bioremediation (ISB) through ERD was also evaluated as a corrective measure for SWMU 55 (Baker, 2005). In the CMS, ISCO was selected over ISB because the potential for the formation of vinyl chloride (VC) during the ISB process was considered non-beneficial to human health. However, the ISCO pilot-scale test results demonstrated that ISCO alone is not an economically viable technology for full-scale implementation at SWMU 55, as summarized in Section 1.3 and Appendix C.

Because ISB was successfully implemented at SWMU 54 for the treatment of TCE, ISB was re-evaluated as a corrective measure alternative for SWMU 55 and it was determined that the ISB process could be actively managed to ensure TCE is completely degraded to carbon dioxide and water, and to ensure the accumulation of VC would not occur. At SWMU 54, the ISB implementation has resulted in a maximum VC formation of less than 4 µg/L (AGVIQ-CH2M HILL, 2012a). However, the source area concentration at SWMU 54 is two orders of magnitude less than at SWMU 55, and it was determined that the revised technical approach at SWMU 55 would require a combination of technologies, including excavation and ISCO, in addition to ISB. The combined approach will reduce the source area TCE concentrations prior to implementing ISB and will reduce the time required to complete the overall remedial action. The remedial action will start with an excavation of the source zone to immediately eliminate TCE concentrations exceeding 10,000 µg/L and dense non-aqueous phase liquid (DNAPL), if present. An infiltration gallery will be installed in the excavation to be used for the ISCO and ISB phases of work. The infiltration gallery will allow chemical oxidation and bioremediation amendments to be passively introduced to the aquifer, following the same "top down" migratory paths as the TCE when it was released. In addition, EVO will be injected in the mid-plume area to accelerate naturally occurring attenuation of the TCE plume downgradient of the source area.

The ISCO application will aggressively reduce TCE mass in soil and groundwater in the immediate vicinity of the infiltration gallery, further eliminating the source zone and reduce the time to complete cleanup. When the ISCO phase is complete, the bioreactor will be established to address residual TCE concentrations in the plume. All TCE degradation will be achieved inside the in situ bioreactor or in the aquifer surrounding the bioreactor. While this alternative will not achieve the revised CAOs as quickly as a successful full-scale ISCO implementation, the limited impact of the ISCO injection in this aquifer requires an alternate approach. ISB will significantly accelerate monitored natural attenuation (MNA).

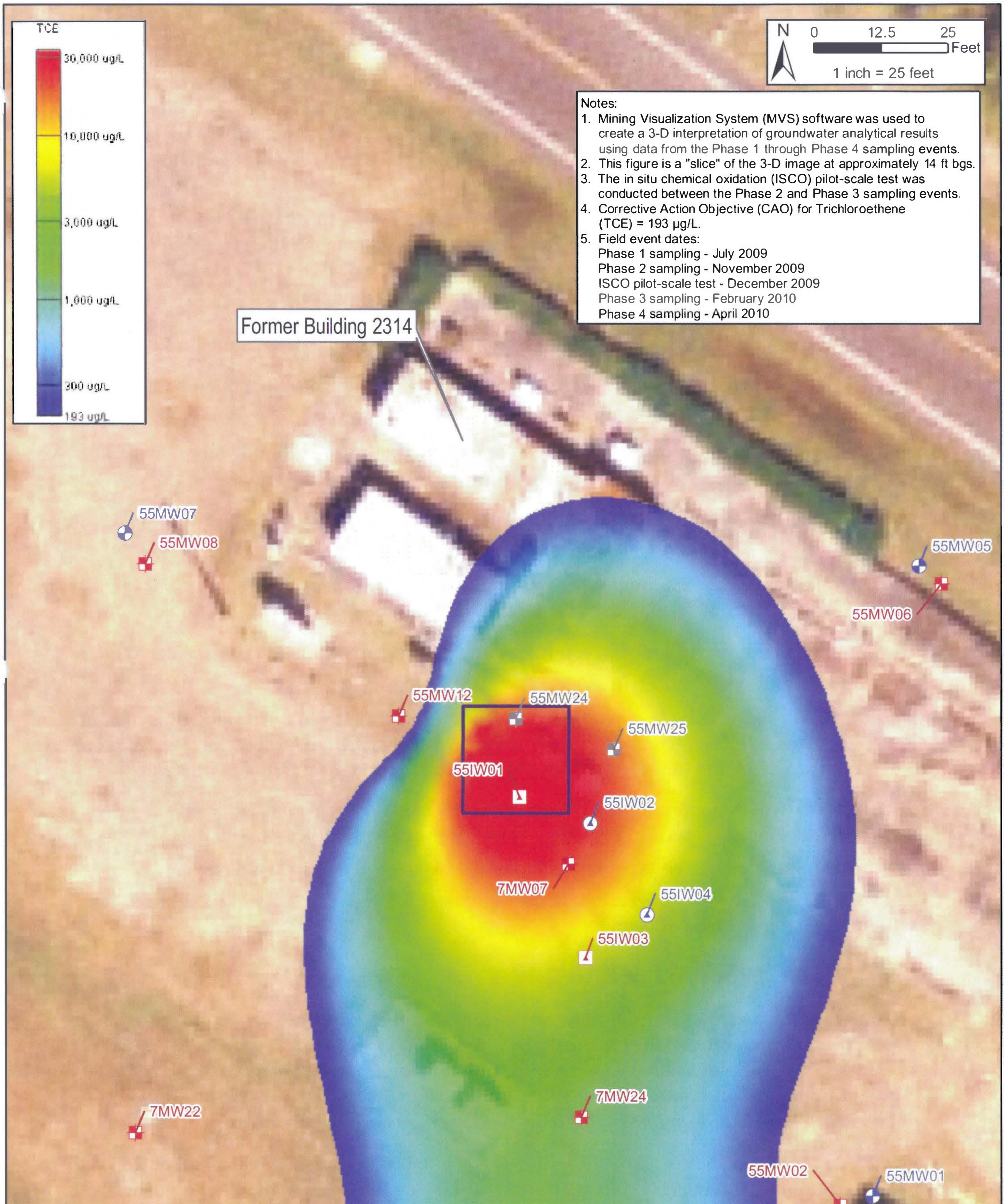
Because groundwater revised CAOs (Appendix A) were risk-based for industrial use, the LUCs will be included in any lease or transfer deed, as outlined in number 7 below.

The phased approach is summarized as follows:

1. One source area well will be installed to further define the source area.

2. An approximately 20-foot by 20-foot excavation encompassing 55IW01 and 55MW24 will be completed to a depth of 12 feet bgs (see Figure 2-1). The backfill will then consist of 4 feet of gravel and 7 feet of a 70/30 mixture of organic mulch and gravel. The gravel backfill will provide an infiltration gallery for the two-step treatment of soil and groundwater. The infiltration gallery will allow ISCO and ISB agents to passively migrate from the removed source area, following the likely migration paths of the TCE as it migrated from the source area. Because potential for settling of the backfill is not an issue at SWMU 55, a higher than average mulch to gravel ratio can be used to maximize the organic material available for ISB.
3. The first step of treatment will involve the application of $NaMnO_4$ into the clean gravel backfill at the bottom of the infiltration gallery. Approximately 1,300 pounds of $NaMnO_4$ will be introduced to the infiltration gallery as an 84-gram per liter (g/L) solution. This concentration is significantly greater than that injected during pilot testing. However, PTOD bench-scale testing determined a very low oxidant demand for the soils at SWMU 55 and the permanganate solution will become diluted as it migrates away from the infiltration gallery through gravity flow and diffusion.

   Based on the pilot-scale test results, permanganate will move down through the source area and destroy higher levels of TCE concentrations immediately beneath and downgradient of the infiltration gallery. By using a minimal solution volume to achieve the permanganate distribution, this approach will also minimize the potential for mobilizing TCE.
4. The ISB phase will not begin until the $NaMnO_4$ has been consumed or has been flushed out of the TCE source area (estimated to be approximately 4 months).The second step of treatment will involve injection of EVO into the bottom of the infiltration gallery, followed by recirculation of 1 to 1.5 gallons per minute (gpm) of source area groundwater through the mulch/gravel layer of the backfill to create an in situ bioreactor where TCE will be degraded via ERD. Over time, the longer-term injection and recirculation of organic substrate will impact a large volume of TCE-contaminated groundwater downgradient of the bioreactor.
5. Groundwater will be recovered at low-flow rates (1 to 1.5 gpm) from a monitoring well within the source area and pumped into the top of the bioreactor. Based on AGVIQ-CH2M HILL's experience, summarized in Section 2.3, these flow rates provide adequate residence time in the bioreactor to achieve complete degradation of TCE. Recovered groundwater may be amended with EVO, fructose, or other soluble organics to sustain long-term ERD. Micronutrients, pH stabilizers, or bioaugmentation cultures could also be added if necessary. In addition to being treated as it passes through the bioreactor, amended groundwater will promote the recirculation of soluble organics in the surrounding aquifer and increase the aerial impact of ERD. The recirculation pump will be powered using solar energy and will require little to no maintenance. It is estimated that the bioreactor will operate for 3 to 5 years and will require semiannual groundwater monitoring for 1 year after construction to evaluate the system performance and necessity for reinvigorating the bioreactor. Based on CH2M HILL's experience, annual monitoring is sufficient for evaluation of system operations after the first year.



Monitoring Well Screened Primarily Less than 25 ft bgs

Injection Well Screened Primarily Less than 25 ft bgs

Monitoring Well Screened Primarily Greater than 25 ft bgs

Injection Well Screened Primarily Greater than 25 ft bgs

Existing monitoring wells not used to develop 3-D interpretation.

Excavation Area

FIGURE 2-1
Extent of Excavation and Bioreactor Location
SWMU 55
Naval Activity Puerto Rico

CH2MHILL

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVYPUERTORICO200003171MAPFILES\SWMU55\2011\CMSREPORT\FIG_2-1_EXCAVATION.MXD JCARR 6/14/2012 8:52:12 AM

6. EVO will be injected at a row of injection wells installed across the middle of the plume as a 1.5 percent solution to enhance the natural attenuation of the downgradient plume. Additional EVO injections may be required every 2 to 5 years to maintain a zone of ISB in the mid-plume area. The injection will be completed under low pressure to target areas of high permeability without mobilizing TCE.
7. Current LUCs will be maintained until the revised CAOs are achieved in both the source area and downgradient plume. The LUCs are detailed in the CDR Parcel 2 (SWMU 55) Deed and include:
   - No permanent residences may be installed on the property.
   - No groundwater extraction wells may be installed by the deed grantee.
   - Potential for vapor intrusion must be considered by the developer and addressed by the developer, as needed.
   - The grantee may not interfere with any existing or future groundwater remedial systems.
   - The grantee must complete annual inspections of the property to ensure all LUCs are being complied with and provide written certification of the inspection.
   - The grantee must comply with the RCRA Administrative Order on Consent for this property (provided to the LRA by the U.S. Navy).
   - Release of environmental conditions and grantee covenants can be considered only with EPA concurrence.
   - If the grantee wishes to develop, improve, use, or maintain the property in a manner inconsistent with the LUCs, they must submit a written request seeking approval to the Director at the NAVFAC BRAC Program Management Office Southeast.
8. Groundwater monitoring will be conducted to assess the remedial action effectiveness and develop site-specific attenuation rates for the downgradient plume.
9. The bioreactor will be expanded to include a 1,000 μg/L TCE area after 2 years.

The ISCO and ISB technologies are described in the CMS (Baker, 2005), and a summary of the bioreactor is provided below.

2.1 Bioreactor Technology

The in situ bioreactor is a simple and cost-effective application of ERD technology. As proposed for this project, the bioreactor would be used to accelerate the removal of TCE from groundwater in a known source area. This technology is particularly well suited for treating smaller source areas and shallow aquifers, such as found at SWMU 55. The proposed bioreactor technology for this project will consist of the following:

- Contaminated soils in a known source area will be excavated. Some disposal of soils will be required, but reuse of soils for backfill will be implemented to the extent practicable.
- The excavation will be backfilled with a bioreactor mixture of organic mulch and gravel to promote the long-term generation of organic carbon and allow a permeable and well-mixed environment for enhancing reductive dechlorination. Additives, such as iron and

gypsum, can promote the formation of reactive iron sulfides for enhancing abiotic reduction, if the desired rate of TCE degradation is not achieved.

- A pumping system to collect and recirculate groundwater through the bioreactor and source area aquifer will be installed. This recirculation distributes organic substrate below or downgradient of the bioreactor and increases the residence time, promoting complete dechlorination. Solar-powered pumps are suited for many low-yield aquifers and provide a renewable energy source to drive the remediation. Figure 2-2 provides a cross section schematic of the bioreactor design proposed for SWMU 55.

The potential benefits of in situ bioreactors are provided in Section 2.2. It should be noted that the in situ bioreactor is not intended to duplicate the function of a source area groundwater extraction system; rather, it will focus on retaining source area groundwater for treatment in multiple passes through the bioreactor instead of contaminating thousands of gallons of clean groundwater drawn in from around the source area. Because the recirculation well is located within 10 feet of the downgradient side of the bioreactor, the pumping from the well through the bioreactor will establish a small recirculation pattern below and within 10 to 15 feet of the bioreactor. Groundwater mounding beneath the reactor is not expected and TCE will not spread outside the historical source area.

Recirculated groundwater will be loaded with organic carbon as it passes through the bioreactor, and this organic loading will create anaerobic conditions around the bioreactor to stimulate TCE degradation. Some of the dissolved organic carbon will move downgradient of the bioreactor stimulating reductive dechlorination. The movement of lesser concentrations of daughter products into the downgradient plume will not impact the risk or size of the plume. These compounds are expected to degrade completely within the bioreactor or the existing plume.

2.2 Potential Benefits of In Situ Bioreactors

Bioreactors have several potential advantages over other technologies. The limitations of groundwater extraction systems to remediate source areas are well documented, particularly in heterogeneous formations, such as SWMU 55. Pumping systems depend on the slow processes of desorption and diffusion of chlorinated volatile organic compounds (CVOCs), such as TCE, from the aquifer matrix to remove mass. Extracted groundwater must then be treated with other technologies, such as activated carbon, creating a separate waste stream. Bioreactors create the anaerobic environment in the subsurface needed to degrade and destroy CVOCs in situ, eliminating the need for aboveground treatment and extending the treatment into the soil/aquifer matrix. The use of a small solar-powered pump for groundwater recirculation provides a sustainable, low-energy remedy when compared to traditional pump and treat systems.

The excavation of accessible unsaturated soils removes residual levels of CVOCs and reduces the potential for future leaching into groundwater. The mulch and gravel in the bioreactor provides a uniform media for contacting groundwater contaminants with organic substrates and bacteria. This uniformity is difficult to achieve in standard injections of edible oils and other substrates, particularly in heterogeneous formations.

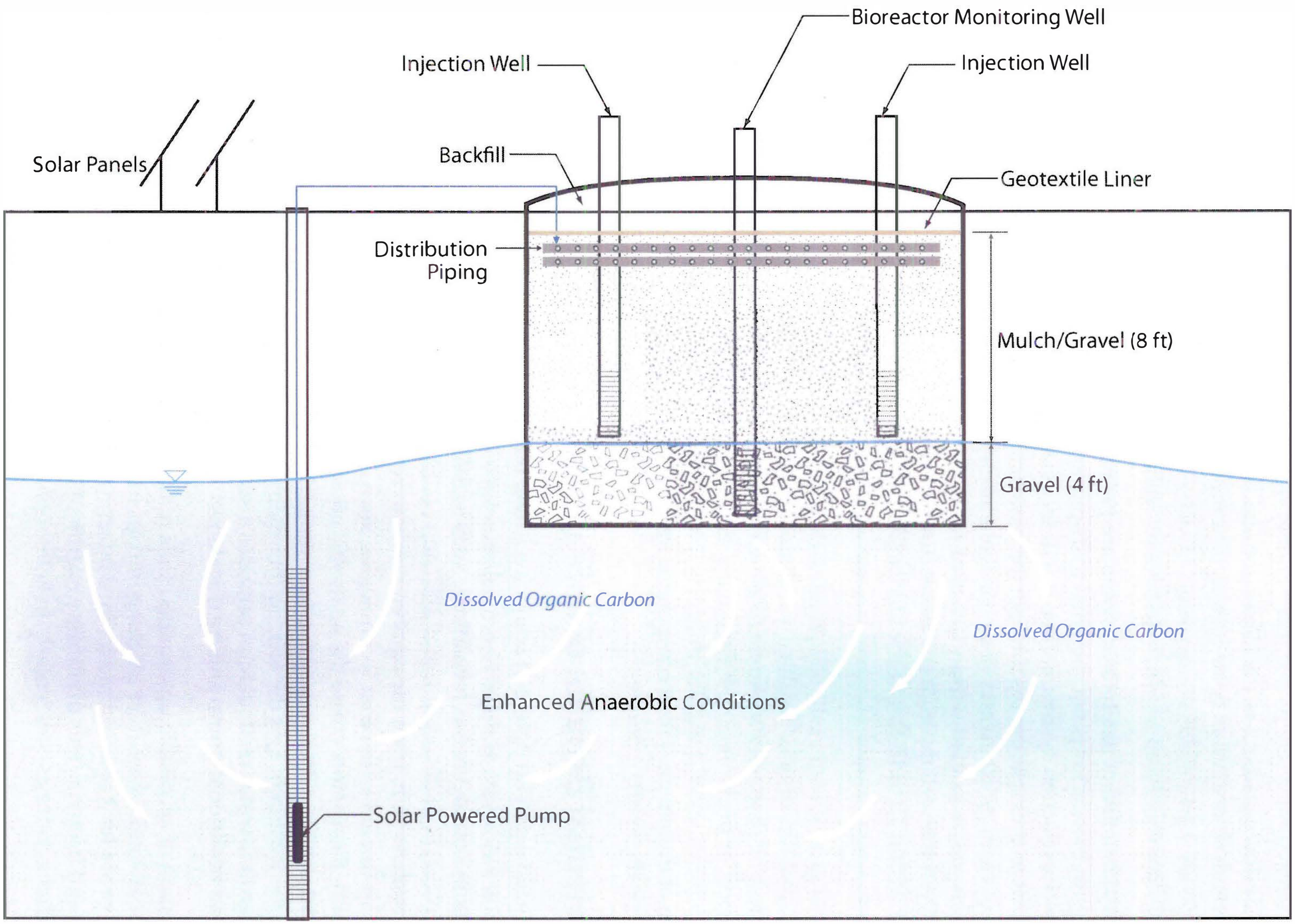


FIGURE 2-2
In Situ Bioreactor Cross Section
SWMU 55
Naval Activity, Puerto Rico

CH2MHILL

The recirculation of contaminated groundwater through the bioreactor will increase the average treatment residence time, resulting in more complete dechlorination of chlorinated daughter products. The mixed culture of dehalococcoides bacteria required for complete dechlorination is much easier to maintain or augment within a small bioreactor than it is throughout a larger heterogeneous aquifer.

Many chlorinated compounds can be biodegraded through the process of reductive dechlorination. This includes common contaminants at U.S. Navy sites, such as perchloroethene, TCE, carbon tetrachloride, dichlorobenzene, and perchlorates. Daughter products, such as cis-1,2-dichloroethene (DCE), VC, chloroform, and 1,1-DCE, are also degraded. Because bioreactors can circulate organic-rich and reduced groundwater through both unsaturated and saturated soils, they have the potential to treat both contaminated soils and groundwater in the source area. If the reductive dechlorination process appears to stall at either cis-1,2-DCE or VC, the addition of a mixed culture of dehalococcoides bacteria can be completed by adding the culture to the water recirculated into the bioreactor. VC is more mobile and toxic than its parent compound TCE. However, in addition to anaerobically degrading in the bioreactor, VC is oxidized rapidly under more aerobic conditions downgradient of the bioreactor. Therefore, VC is not likely to further degrade downgradient water quality.

2.3 Previous Bioreactor Applications and Lessons Learned

The bioreactor design is based on previous applications of the bioreactor technology at other sites with CVOCs in groundwater. The characteristics of some of these sites and the performance results of the bioreactor installed at those sites are summarized in Table 2-1. A description of select bioreactor installations and the lessons learned are provided in the following sections.

2.3.1 Altus Air Force Base, Oklahoma

In 2003, a bioreactor concept similar to that summarized in Section 2.2 was tested at an Altus Air Force Base (AFB) landfill site and is currently continuing to operate (Downey, et al., 2005). A small bioreactor was constructed in a landfill to enhance the removal of a TCE source area. The Altus AFB demonstration showed that the recirculating bioreactor concept was feasible. Results from the project indicated that the total molar CVOC concentrations within the bioreactor were reduced by more than 70 percent in 2 years. The onsite shallow downgradient well had a pre-treatment TCE concentration of 17.9 mg/L in March 2003 and a post-treatment concentration of 5 µg/L in November 2005 (after 2 years of bioreactor operation). The test results for areas outside the bioreactor were inconclusive. The bioreactor was not located directly over the source area, and TCE entered the aquifer under the bioreactor from a continuous upgradient source. This made it impossible to determine aquifer removal efficiencies.

2.3.2 Travis Air Force Base, California

Between November 2008 and January 2009, CH2M HILL constructed and began testing another similar in situ bioreactor demonstration at Site DP039 at Travis AFB, California. Site DP039 was the location of a former battery and electric shop, where battery acid and chlorinated solvents were disposed of in a gravel-filled sump, resulting in TCE and other solvent contamination within the soil and groundwater. To reduce site contamination, a dual-phase extraction system was operated in the source area from February 2001 to

October 2008, before implementation of the in situ bioreactor demonstration. The Travis AFB demonstration project included constructing an in situ bioreactor and monitoring the performance of the bioreactor for approximately 2 years. After 2 years of operation, the total molar reduction of TCE, DCE, and VC in the source area groundwater is at 95 percent and 550,000 gallons of groundwater have been processed through the bioreactor (CH2M HILL, 2010).

2.3.3 McConnell Air Force Base, Kansas

From September 2009 to January 2010, CH2M HILL designed, constructed, and began testing an in situ bioreactor at Site FT07 at McConnell AFB, Kansas. Site FT07 was formerly used as a fire training area, during which flammable materials, including fuel, waste oil, paint thinners and paints, and possibly fuel sludge, were poured into shallow, unlined earthen ditches, ignited, and then extinguished with fire retardants or water. Inevitably, some of the discharged flammable materials containing TCE and fuels percolated into the subsurface soil and groundwater. A remedial investigation conducted at the site indicated that TCE, its daughter products, and inorganics were present above EPA MCLs in the uppermost groundwater-bearing unit downgradient from the site. The mixture of fuel hydrocarbons with CVOCs has historically supported the reductive dechlorination of TCE in groundwater. The McConnell AFB in situ bioreactor was constructed to distribute organic substrate within the Site FT07 source area, promote the highly anaerobic conditions necessary for ERD of TCE and daughter products, and demonstrate the reliability and sustainability of the solar-powered bioreactor to achieve source reduction and final remedy-in-place status. Results from the most recent performance monitoring event indicated that over 95 percent of the TCE entering this bioreactor is being degraded (CH2M HILL, 2009).

TABLE 2-1
Comparative Design Table
SWMU 55
Naval Activity Puerto Rico

Parameter	Altus AFB LF-03	Travis AFB DP039	McConnell AFB FT-07	Fairchild AFB SD-37	Beale AFB Site 35	Recommended Design	SWMU55 Design
Aquifer Soil Type	Clay	Silt/Sand	Clay/Silt/Sand	Silt/ Fractured Bedrock	Clay/Silt/Sand	NA	Silt/Sand
Bioreactor Depth (ft)	12	20	20	15	20	Site Specific	12
Bioreactor Volume (CY)	150	200	100	117	960	Site Specific	150
Vegetable Oil (lbs/CY)	6	3	30	17	4	10-20	16
Mulch: Gravel Ratio (wt)	60:40	50:50	70:30	70:30	70:30	70:30	70:30
Avg Pumping Rate (gpd)	912	744	231	634	370	Site Specific	744 (estimated)
Avg Residence Time (days)	12	19	30	13	189	>12	14
Maximum Initial TCE Concentration (μg/L)	28,000	8,000	110,000	6,100	1,800	NA	33,000
PERFORMANCE RESULTS							
Radius of Influence from Center of Bioreactor (ft)	25	40	60	35	70	Site Specific	40 – 60 (estimated)
TCE Treatment in Bioreactor (%)	97 to 100	99 to 100	90 to 98	98 to 100	76	>90	>95 (estimated)
CVOC Treatment in Bioreactor (%)	66 to 99	65 to 78	65 to 90	67 to 75	76	>75	>75 (estimated)
TCE Mass Removed in ROI-First Year (%)	90	95	95	50	63	>80	>80 (estimated)

Notes:

ft = feet

CY = cubic yard

wt = by weight

gpd = gallons per day

% = percent

3.0 Corrective Measure Evaluation

Evaluation of the combined ISCO/ISB alternative is provided in the following subsections. Other alternatives were previously evaluated in the CMS (Baker, 2005).

3.1 Technical Evaluation

3.1.1 Protect Human Health and the Environment

The corrective action protects both human health and the environment by removing TCE contamination from groundwater, preventing any possibility of future exposure.

There is minimal exposure risk to site workers during well installation and bioreactor construction. However, engineering controls and personal protective equipment (PPE) will be used to prevent worker exposure.

3.1.2 Attain Media Cleanup Standards

Excavation, ISCO, and ISB are well established technologies that have been widely used to address TCE in groundwater. Based on substantial experience with these technologies, this approach can be expected to reduce source area TCE concentrations to the CAO of 193 µg/L. The estimated time required to achieve the CAO is 3 to 5 years within the source area. This estimate is based on the results achieved at Travis AFB (Table 2-1). The bioreactor phase can be fortified with ISB injections within the bioreactor or at select downgradient locations, if necessary.

The time required to achieve the CAO in the downgradient plume will be determined based on MNA data collected during the corrective action. A mid-plume line of substrate injection wells will reduce the total plume remediation timeframe by accelerating reductive dechlorination.

3.1.3 Source Control

As described in the CMS, the TCE plume resulted from historic site operations and there are no current TCE releases at SWMU 55. Release of TCE mass from the source area will be controlled by aggressively removing the material through excavation and the ISCO and bioreactor applications. Both ISCO and ISB are well documented for use in treating TCE. Additionally, both technologies have been shown to be effective at NAPR (see Appendix C and Pilot Study Report for SWMU 54 TCE Plume [AGVIQ-CH2M HILL, 2012b]).

3.1.4 Comply with ARARs

This approach will achieve the CAO of 193 µg/L for TCE.

3.1.5 Reliability and Effectiveness

Excavation, ISCO, and ISB systems rely on several pieces of mechanical equipment, including earth moving equipment, pumps, and process controls. Excavation of the most contaminated soil at the site will prevent recontamination of groundwater. All the necessary equipment for ISCO and ISB is common and readily available and widely demonstrated for use in this application. Therefore, the equipment is expected to perform reliably. The bioreactor has no aboveground equipment except for the solar panels and control box required to operate a small pump. Other bioreactor systems have been operational for over 4 years with minimal operation and maintenance (O&M) input (Downey, et al., 2005; CH2M HILL, 2009; and CH2M HILL, 2010). Monthly inspections of the bioreactor system will be required to record flows and injection pressures. Otherwise, the system will be fully automated. However, tropical climates, such as at NAPR, may require additional services to protect the equipment. An O&M plan would be developed after system installation to ensure proper operation and longevity of the equipment.

ISB has a slower reaction rate than ISCO and therefore is better suited for sites where TCE is slowly diffusing out of fine-grained soils, such as is likely occurring at SWMU 55. Fast ISCO reactions are not as effective at treating rebound without multiple oxidant injections. However, the ISB system will still be actively biodegrading TCE when contaminant rebound occurs at the site. The combined ISCO and ISB approach will accelerate the MNA processes at the site and shorten the MNA monitoring period.

These technologies have been independently demonstrated to achieve degradation of TCE at SWMUs 54 and 55. By combining technologies, the remedial approach will quickly achieve significant reduction in contaminant mass in groundwater, potential for additional TCE mass migration from the source area, and potential for human exposure.

Based on CH2M HILL's experience, bioreactors have been demonstrated to operate reliably with minimal maintenance requirements for 4 years or more. Because the bioreactor will be installed 8 to 12 feet bgs, this system will not be significantly impacted by any type of weather or adversely affected by occasional extreme fluctuations in groundwater elevation.

Semiannual groundwater monitoring will be conducted for 1 year after construction to evaluate the system performance and necessity for reinvigorating the bioreactor.

3.1.6 Implementability

Because excavation, ISCO, and ISB are commonly used technologies, the installation and operation of these systems is well defined and requires commonly available equipment. At SWMU 55, the implementation can be completed quickly (less than 1 year) and can be completed in phases to enhance system optimization.

The PREQB will be provided with an amendment to the SWMU 55 injection notification detailing the ISCO application, the bioreactor operations, and the mid-plume EVO injection.

3.1.7 Safety

There are minimal safety issues associated with excavation or installation and operation of ISCO and ISB systems. Special chemical handling requirements are associated with $NaMnO_4$; however, these have already been addressed during the pilot-scale test. Engineering controls and PPE will be used to protect workers during construction of the bioreactor.

3.2 Environmental Evaluation

This alternative would benefit the environment through rapid removal of the source of TCE from groundwater. In addition, the groundwater extraction pump required during the bioreactor phase will operate on solar power and will not create a separate greenhouse gas footprint.

3.3 Cost Estimate

The cost estimate prepared for this alternative includes the following assumptions:

- Source zone excavation and bioreactor construction is estimated to require approximately 14 days to complete.
- ISCO application is estimated to require approximately 2 days to complete, with 2 days allotted for each sampling event.
- Permanganate depletion is expected to occur after approximately 4 months.
- Addition of EVO and startup of the bioreactor is estimated to require 7 days.
- A second injection of EVO into the bioreactor will be conducted after 2 to 3 years of bioreactor operations.
- Installation of the six mid-plume wells and the additional characterization monitoring well is expected to require about 8 days to complete.
- The mid-plume EVO injection will require about 7 days to complete.
- A second mid-plume EVO injection may be conducted after 2 to 3 years of operation, as necessary.
- Fourteen O&M events will be conducted per year of operation of the bioreactor to monitor the system.
- Twenty-one groundwater samples will be collected during annual monitoring events to evaluate source area TCE reductions, bioreactor operations, mid-plume ERD zone, and plume stability.

The cost to complete the excavation, ISCO application, bioreactor construction and 5 years of operation, well installation, mid-plume EVO injection, and all associated monitoring is estimated to be $1,320,000. Detailed cost estimate information is provided in Appendix E.

4.0 Recommended Corrective Measure

AGVIQ-CH2M HILL agrees with the CMS in the selection of MNA and institutional controls as the most economical remedy for the SWMU 55 TCE plume. Consistent with the site goals at the time the CMS was written, a more aggressive source removal approach, leading to earlier site closure, is desired. Based on this information and the information presented in this CMS Addendum, a combined approach, including source area excavation, ISCO, and ISB, is the selected corrective measure recommendation.

To complete the horizontal delineation of the source area and potentially improve the siting of the bioreactor, one shallow well will be installed about 20 feet north of 55MW24 (Figure 4-1).

First, high-level TCE contamination will be removed from the source area through excavation, followed by construction of an infiltration gallery/bioreactor in the excavation. The infiltration gallery will first be used to distribute $NaMnO_4$ in the aquifer to rapidly oxidize residual TCE in the soils directly beneath the excavation. When permanganate is no longer detected in site groundwater, estimated to take approximately 4 months, the infiltration gallery will be converted into a bioreactor by injecting EVO into the infiltration gallery and recirculating groundwater through the bioreactor.

Because uniform distribution of $NaMnO_4$ was not achieved during the pilot-scale testing, an infiltration gallery is recommended for the distribution of $NaMnO_4$, rather than injection wells, to mimic the migration paths followed by TCE in the subsurface. Additionally, an infiltration gallery maximizes the $NaMnO_4$ mass that can be introduced to the source area while minimizing displacement of TCE. This remedial approach will aggressively remove TCE contamination from the source area, leading to TCE concentration reductions in the downgradient plume over time. As described in Appendix C, significant TCE mass reduction was initially observed during the ISCO pilot test.

The intent of the ISCO phase of the corrective action is the rapid, aggressive removal of as much TCE mass as can be achieved with one application of $NaMnO_4$ to shorten required bioreactor operation duration. The $NaMnO_4$ dose was selected based on the pilot test results where substantial TCE degradation was achieved in the source area, but $NaMnO_4$ did not migrate significantly outside the treatment area. Therefore, the ISCO application will shorten the time required for the bioreactor operations without risking release of $NaMnO_4$ to the Ensenada Honda. Because the bioreactor is designed to treat the dissolved phase (and a potentially continued release to the dissolved phase, if NAPL is present), no specific amount of TCE mass must be removed before bioreactor operations may be started.

After the immediate reduction in TCE mass through excavation and oxidation, the bioreactor will be established to address higher level TCE contamination in the soil and groundwater of the source area as a longer-term treatment system. The recirculation of downgradient groundwater through the bioreactor system will also extend the anaerobic treatment zone downgradient to further reduce downgradient plume concentrations. Other than the excavation and active injections, the bioreactor will operate automatically using a solar-powered pump to recirculate groundwater. With time, estimated at 2 years, the treatment area will be expanded to include 1,000 µg/L TCE. During this phase, one or more additional extraction wells may be incorporated into the bioreactor.

- Monitoring Well Screened Primarily Less than 25 ft bgs
- Injection Well Screened Primarily Less than 25 ft bgs
- Monitoring Well Screened Primarily Greater than 25 ft bgs
- Injection Well Screened Primarily Greater than 25 ft bgs
- Proposed Injection Well
- Proposed Monitoring Well
- Monitoring Well

FIGURE 4-1
Proposed Monitoring and Injection Well Locations
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55\2011\CMSREPORT\FIG_4-1_PROPOSED_MW_AND_IW_LOCATIONS.MXD JCARR 6/6/2012 8:33:07 AM

The design for the bioreactor system will be based on CH2M HILL's experience of successfully installing and operating bioreactors at other sites with similar contaminant concentrations (Table 2-1). In some cases, the in situ bioreactor has been successfully implemented with TCE concentrations exceeding 100,000 µg/L, three times greater than the TCE concentrations encountered at SWMU 55. In addition, CVOC data collected at these sites demonstrate the residence time achieved within the bioreactor is sufficient to achieve complete degradation of TCE.

CH2M HILL has implemented bioreactors in a variety of silty, clay, sandy, and bedrock aquifer conditions. The use of a small solar-powered pump to capture and recirculate groundwater through the bioreactor is a very sustainable source area treatment method. At other sites, the recirculation of TCE-contaminated water through the bioreactor has resulted in average TCE removals of over 90 percent within the groundwater recirculation cell with no significant spreading of TCE vertically or laterally and no accumulation of degradation products. A summary of specific CH2M HILL bioreactor installations is presented in Section 2.3.

A series of EVO injection wells will be installed downgradient of the source area to enhance the TCE degradation occurring in the downgradient plume. The design for the EVO injection will be based on the successful EVO pilot-scale testing completed at SWMU 54 and the injection work conducted during pilot-scale testing at SWMU 55. Performance monitoring data will be used to evaluate the bioreactor operation, mid-plume EVO injection, MNA rates occurring at SWMU 55, and plume stability. The MNA data will be evaluated to determine if an MNA study should be completed.

The performance monitoring schedule will be based on the pilot-scale test results for the ISCO portion and CH2M HILL's experience in implementing ERD at dozens of sites. Annual sampling allows for sufficient assessment of the ERD process such that the progress of the treatment can be assessed and appropriate corrective actions implemented, if required. ERD can be a relatively slow process (compared to ISCO, for example), and more frequent monitoring is not required.

To minimize the chance of dragging TCE contamination from the upper 40 feet of the aquifer down to depth with drilling tooling, the Navy proposes delaying further vertical characterization until the TCE concentrations in the upper 40 feet have been reduced below 500 µg/L. This reduction is expected to take place over the next three years through bioreactor operation and the mid-plume injection of EVO to enhance biodegradation. At this time, the downgradient zone of the plume has been fully defined to depth where TCE in monitoring wells 55MW21 (screened 25 - 40 ft bgs), 55MW22 (screened 52 - 67 ft bgs), 55MW23 (screened 28 - 43 ft bgs), 55MW19 (screened 49 - 59 ft bgs), 55MW18 (screened 49 - 59 ft bgs), and 55MW15 (screened 43 - 58 ft bgs) was measured below 193 µg/L. Therefore, the plume is not migrating off site in the deep zone.

After the TCE concentration as been reduced to 500 µg/L or less, deep zone monitoring wells will be considered for installation in the source zone and the vicinity of 55MW01, 55MW09, 55MW11, and 55MW14.

The public participation process for the CMS Addendum will follow provisions of the 2007 RCRA Administrative Order on Consent. The public participation process will conform with guidance set forth in the *1996 RCRA Public Participation Manual* and EPA's Office of

Solid Waste and Emergency Response Directives 9901.3 *"Guidance for Public Involvement In RCRA Section 3008(h) Actions (May 5, 1987)"* and 9902.6 *"RCRA Corrective Action Decision Documents: The Statement of Basis and Response to Comments (April 29, 1991)"* and other guidance as appropriate.

The following are public participation activities expected to be implemented after EPA's conditional[1] approval of the CMS Addendum:

- A public notice in both English and Spanish will be prepared that provides a brief description of the development and evaluation corrective measure alternative(s) for SWMU 55, directs readers to the local information repository and website to review the Statement of Basis, provides instructions on how to submit comments during a 45-day public comment period, and announces the time, date and location of a public meeting, if one is requested. The public notice will be published in *El Horizonte* and *El Vocero* newspapers.
- The Statement of Basis, translated into both English and Spanish, will be included in the local information repository, online, distributed at a public meeting, if requested, and sent to the site mailing list.
- If requested, hold a public meeting to present information about the Revised Corrective Measures Study Addendum and Statement of Basis and obtain comments from stakeholders. The meeting would be conducted at a convenient location in the community. Simultaneous interpretation (English/Spanish) would be provided, and an official transcript of the proceedings would be prepared.

In addition, information about CMS Addendum and Statement of Basis will be shared with members of the former Naval Station Roosevelt Roads Restoration Advisory Board (RAB). Members of the RAB will be encouraged to provide comments during the public comment period.

An implementation schedule is presented on Figure 4-2.

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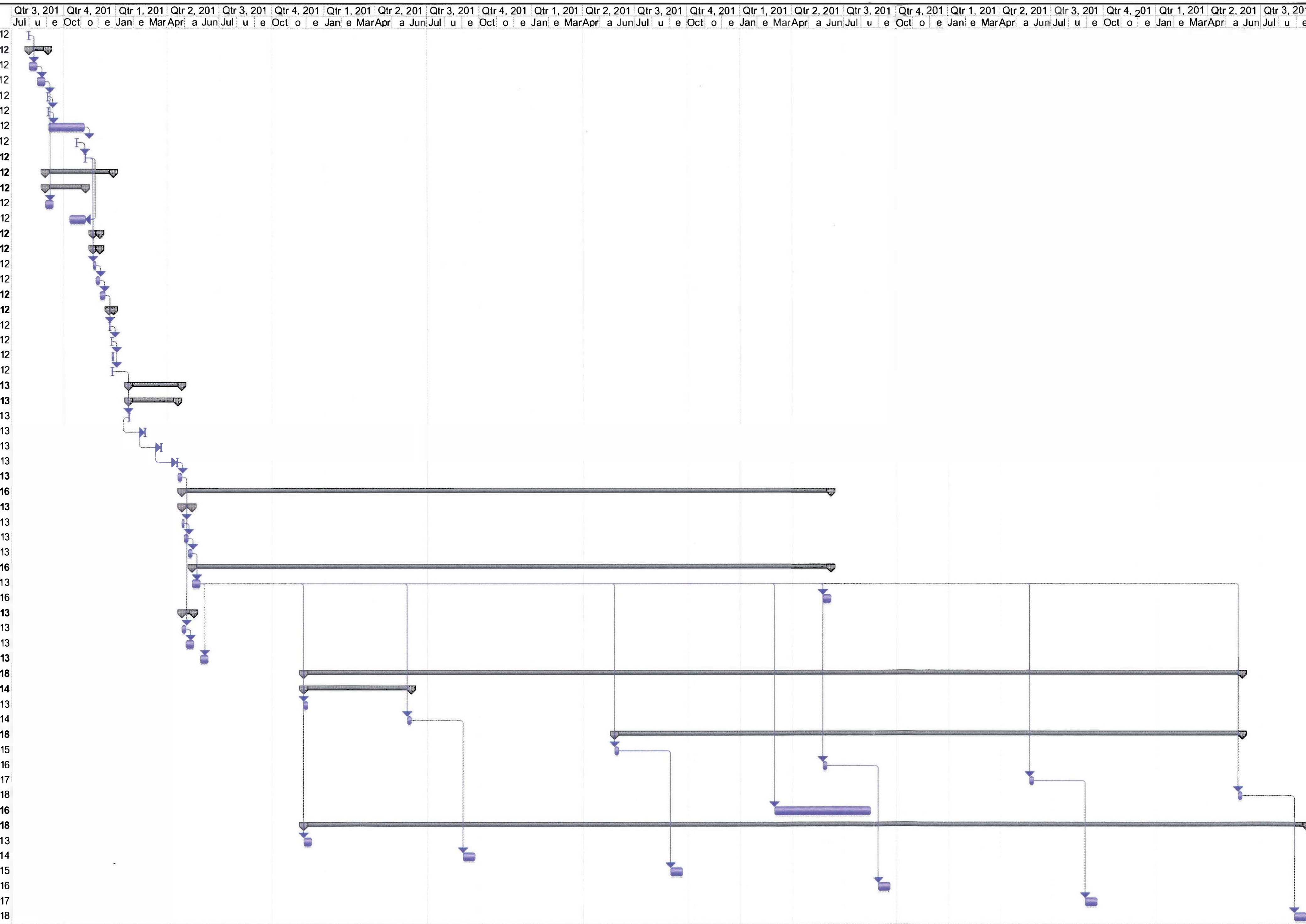
[1] EPA's Final approval is contingent on completion of acceptable Public Review for the CMS Addendum.

Bioreactor Implementation Schedule
SWMU 55

ID		Task Name	Duration	Start	Finish
1		**CMS Addendum Approval by EPA**	1 day	Wed 8/1/12	Wed 8/1/12
2		**Statement of Basis**	**23 days**	**Thu 8/2/12**	**Mon 9/3/12**
3		Development	10 days	Thu 8/2/12	Wed 8/15/12
4		EPA Approval	10 days	Thu 8/16/12	Wed 8/29/12
5		Include in Repository	1 day	Mon 9/3/12	Mon 9/3/12
6		**Public Notice**	1 day	Tue 9/4/12	Tue 9/4/12
7		**Public Comment and RAB Involvement**	45 days	Wed 9/5/12	Tue 11/6/12
8		**Public Meeting**	1 day	Wed 10/24/12	Wed 10/24/12
9		**Notice to Proceed**	**1 day**	**Thu 11/8/12**	**Thu 11/8/12**
10		**Bioreactor Installation**	**86 days**	**Thu 8/30/12**	**Thu 12/27/12**
11		**Pre-Mobilization**	**51 days**	**Thu 8/30/12**	**Thu 11/8/12**
12		Procurement	10 days	Thu 8/30/12	Wed 9/12/12
13		Injection Notification	20 days	Fri 10/12/12	Thu 11/8/12
14		**Field Implementation**	**8 days**	**Thu 11/22/12**	**Mon 12/3/12**
15		**Well Installation**	**8 days**	**Thu 11/22/12**	**Mon 12/3/12**
16		Monitoring Well	3 days	Thu 11/22/12	Mon 11/26/12
17		Mid-Plume Injection Well	5 days	Tue 11/27/12	Mon 12/3/12
18		**Baseline Monitoring**	**7 days**	**Tue 12/4/12**	**Wed 12/12/12**
19		**Infiltration Gallery Construction and ISCO**	**6 days**	**Thu 12/20/12**	**Thu 12/27/12**
20		Site Prep	2 days	Thu 12/20/12	Fri 12/21/12
21		Excavation	1 day	Mon 12/24/12	Mon 12/24/12
22		Construction	3 days	Tue 12/25/12	Thu 12/27/12
23		ISCO Application	1 day	Tue 12/25/12	Tue 12/25/12
24		**Monitoring**	**67 days**	**Wed 1/23/13**	**Thu 4/25/13**
25		**Performance Monitoring - ISCO**	**62 days**	**Wed 1/23/13**	**Thu 4/18/13**
26		30-Day Monitoring	2 days	Wed 1/23/13	Thu 1/24/13
27		60-Day Monitoring	2 days	Wed 2/20/13	Thu 2/21/13
28		90-Day Monitoring	2 days	Wed 3/20/13	Thu 3/21/13
29		120-Day Monitoring	2 days	Wed 4/17/13	Thu 4/18/13
30		**Pre-ISB Monitoring**	**5 days**	**Fri 4/19/13**	**Thu 4/25/13**
31		**Bioreactor Installation and Operations**	**812 days**	**Fri 4/26/13**	**Mon 6/6/16**
32		**Field Effort**	**12 days**	**Fri 4/26/13**	**Mon 5/13/13**
33		Site Prep	2 days	Fri 4/26/13	Mon 4/29/13
34		Equipment Installation	5 days	Tue 4/30/13	Mon 5/6/13
35		Shakedown Testing	5 days	Tue 5/7/13	Mon 5/13/13
36		**Bioreactor EVO Injection**	**800 days**	**Tue 5/14/13**	**Mon 6/6/16**
37		Intial Injection	10 days	Tue 5/14/13	Mon 5/27/13
38		Reinjection	10 days	Tue 5/24/16	Mon 6/6/16
39		**O&M Plan**	**15 days**	**Fri 4/26/13**	**Thu 5/16/13**
40		O&M Plan Generation	5 days	Fri 4/26/13	Thu 5/2/13
41		Navy Review	10 days	Fri 5/3/13	Thu 5/16/13
42		**Mid Plume EVO Injection**	**10 days**	**Tue 5/28/13**	**Mon 6/10/13**
43		**Monitoring**	**1175 days**	**Tue 11/26/13**	**Mon 5/28/18**
44		**Semi-Annual Monitoring**	**135 days**	**Tue 11/26/13**	**Mon 6/2/14**
45		6-Month	5 days	Tue 11/26/13	Mon 12/2/13
46		Year 1	5 days	Tue 5/27/14	Mon 6/2/14
47		**Annual Monitoring**	**785 days**	**Tue 5/26/15**	**Mon 5/28/18**
48		Year 2	5 days	Tue 5/26/15	Mon 6/1/15
49		Year 3	5 days	Tue 5/24/16	Mon 5/30/16
50		Year 4	5 days	Tue 5/23/17	Mon 5/29/17
51		Year 5	5 days	Tue 5/22/18	Mon 5/28/18
52		**Deep Zone Characterization**	**120 days**	**Tue 3/1/16**	**Mon 8/15/16**
53		**Reporting**	**1255 days**	**Tue 11/26/13**	**Mon 9/17/18**
54		Progress Report	10 days	Tue 11/26/13	Mon 12/9/13
55		Annual Report for Year 1	15 days	Tue 9/2/14	Mon 9/22/14
56		Annual Report for Year 2	15 days	Tue 9/1/15	Mon 9/21/15
57		Annual Report for Year 3	15 days	Tue 8/30/16	Mon 9/19/16
58		Annual Report for Year 4	15 days	Tue 8/29/17	Mon 9/18/17
59		Annual Report for Year 5	15 days	Tue 8/28/18	Mon 9/17/18



Project: Worksheet 16
Date: Mon 6/11/12

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Figure 4-2
Project Schedule
SWMU 55 Naval Activity Puerto Rico

5.0 References

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