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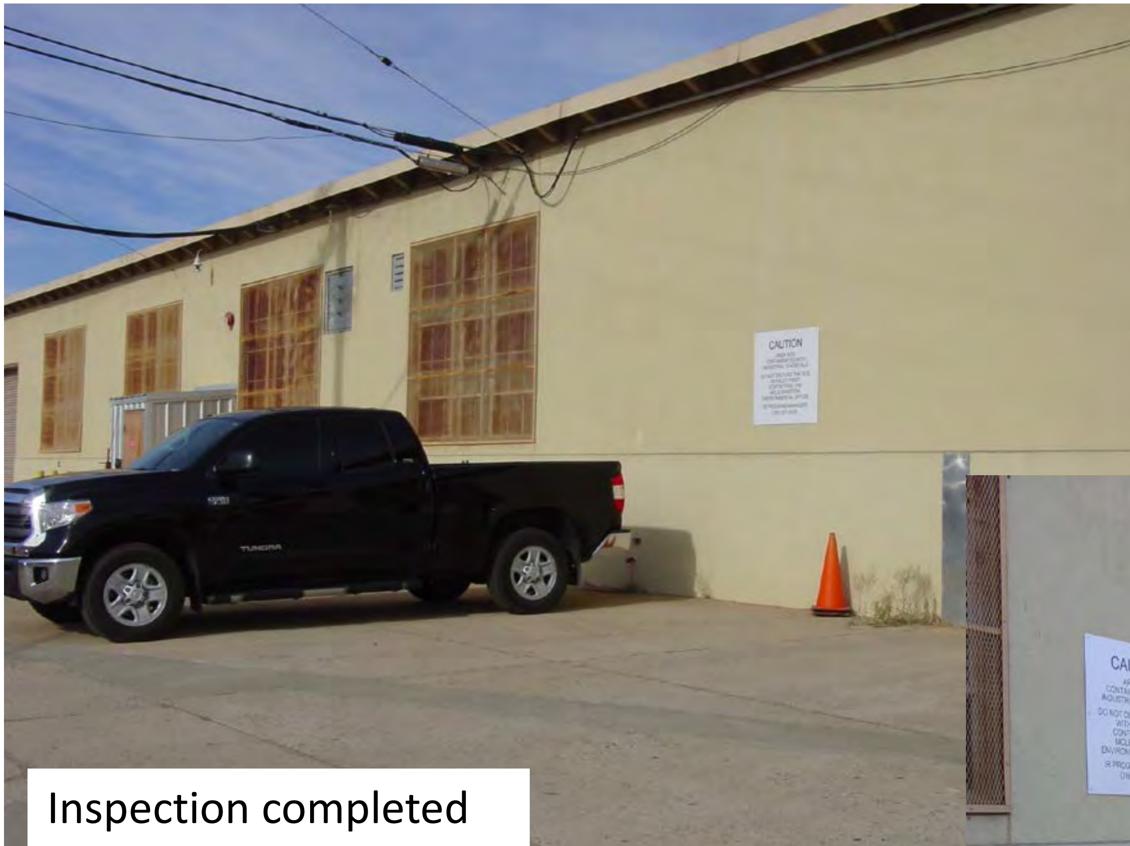
Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

CAOC 10.4 (Warehouse 3)

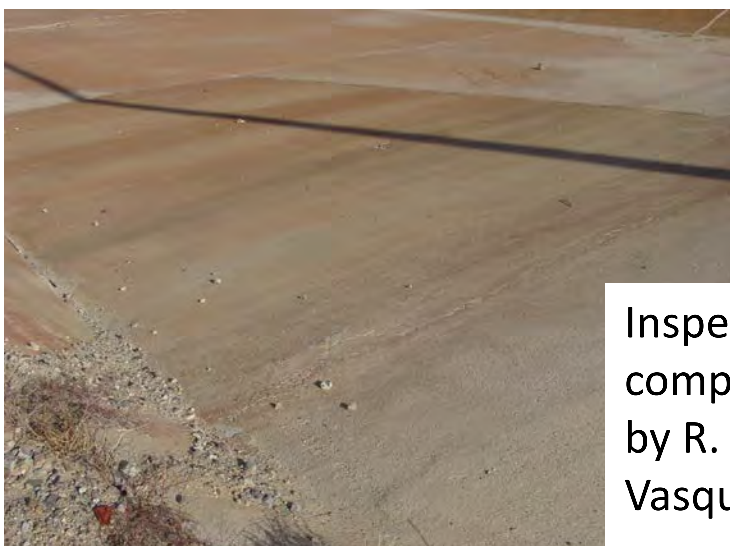


Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

CAOC 10.5 (Warehouse 4)

Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

CAOC 10.37 (Former IWTP)



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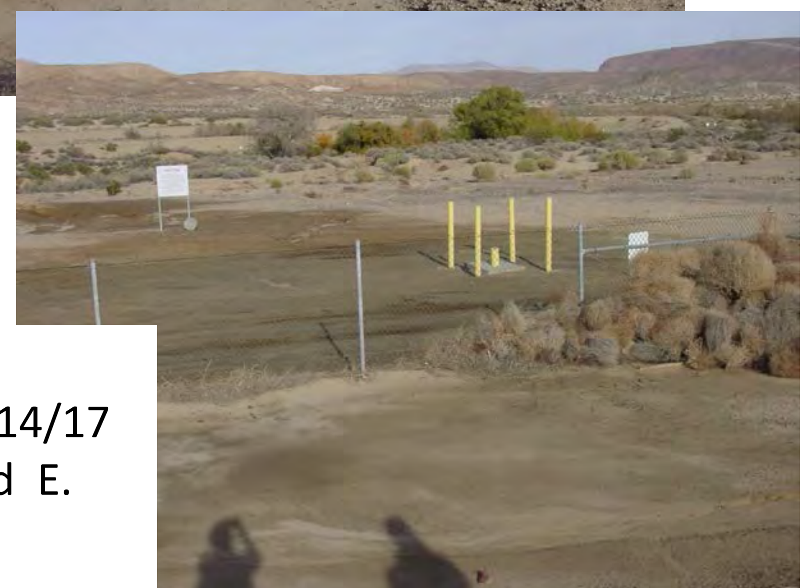
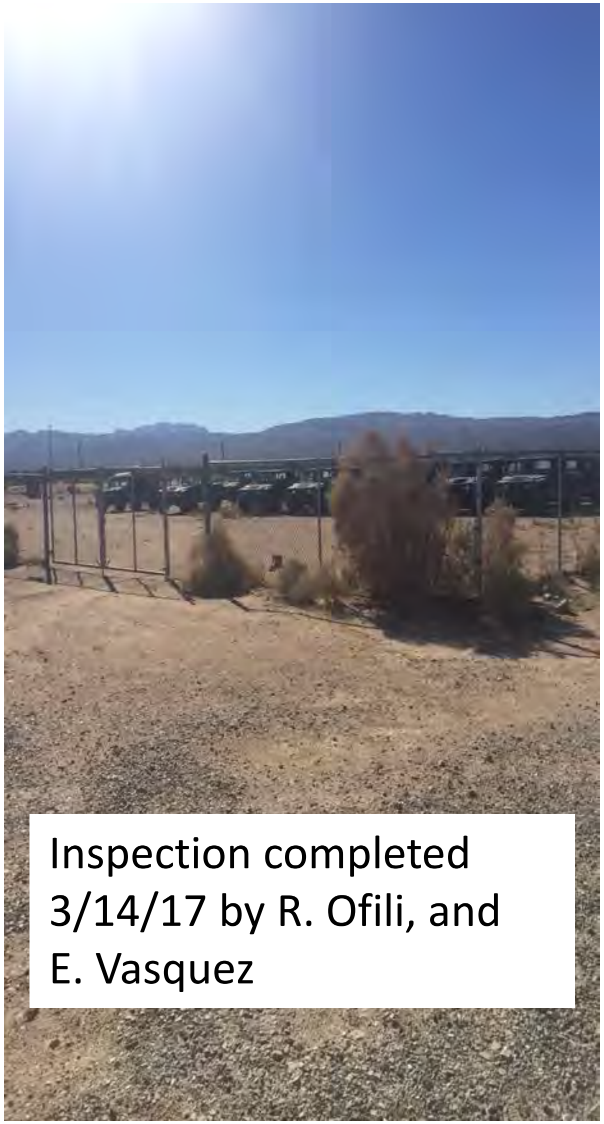


CAOC 7 Stratum 1

Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

CAOC 7 Stratum 1 (continued)

CAOC 9.60



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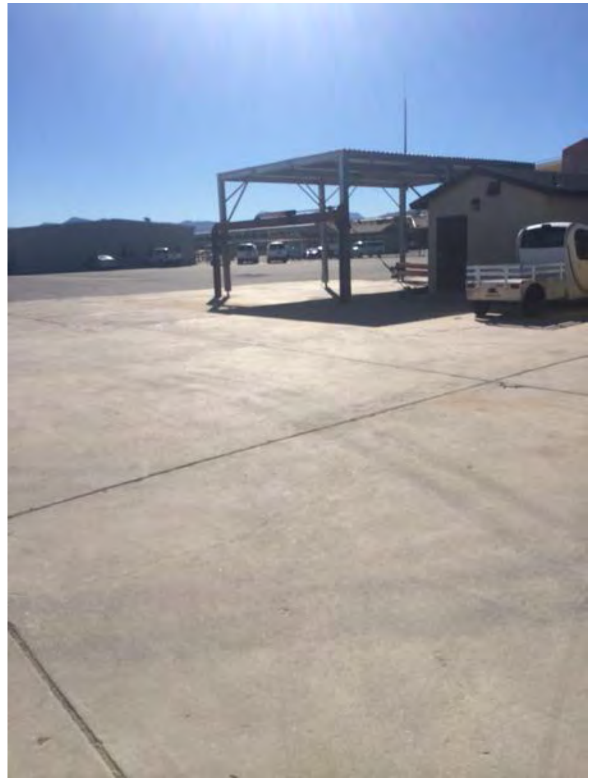
CAOC 9.68

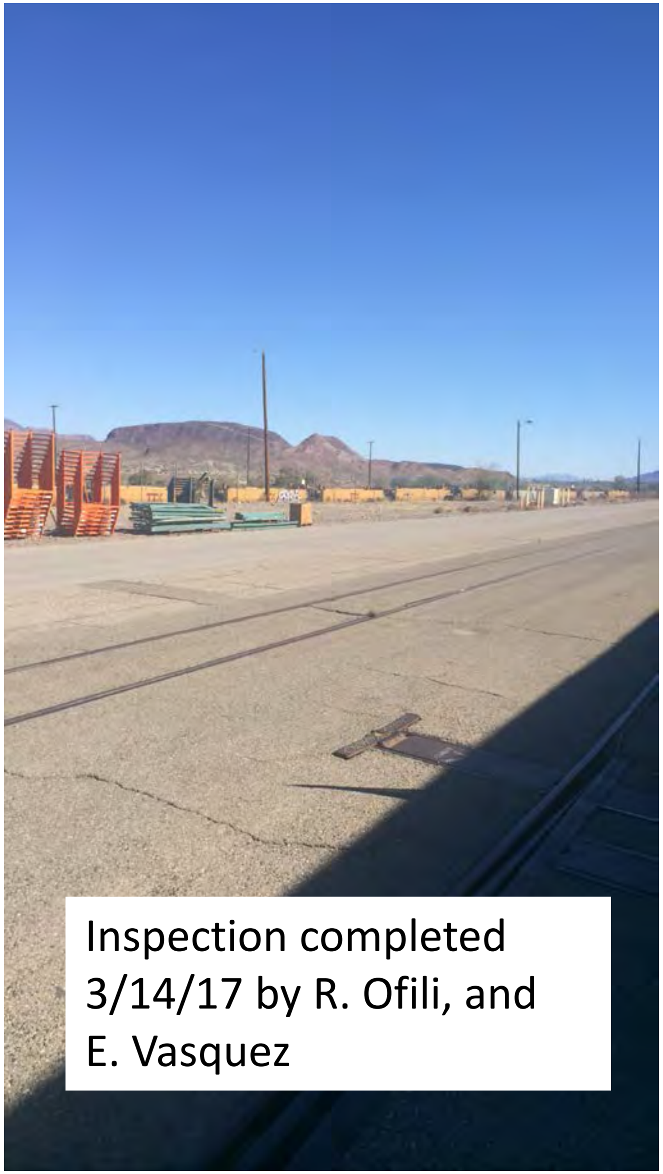


Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

CAOC 10 Metallic Debris Burial Area

Inspection completed 3/14/17 by R. Ofili, and E. Vasquez.

CAOC 10.27



Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

CAOC 10.35

Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

CAOC 10.38/10.39 Unit 7

Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

CAOC 10.38/10.39 Unit 7, continued

CAOC 10.80

Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

CAOC 32 Stratum 2

Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

CAOC N-2 Area 1

Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

NPZ-14

Inspection completed 3/14/17 by R. Ofili, and E. Vasquez

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APPENDIX C

Review of Exposure Assumptions, Toxicity Data, Cleanup Levels, and RAOs for OU 1 through OU 7

Marine Corps Logistic Base Barstow, California

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ACRONYMS

µg/L	microgram per liter
°C	degrees Celsius
°F	degrees Fahrenheit
1,1-DCE	1,1-Dichloroethene
BAT	best available technology
CAOC	Comprehensive Environmental Response, Compensation, and Liability Act Area of Concern
COCs	Contaminants of concern
DON	Department of the Navy
DTSC	Department of Toxic Substances Control
HERO	Office of Human and Ecological Risk
LUCs	Land Use Controls
MCL	Maximum Contaminant Level
MCLB	Marine Corps Logistics Base
OU	Operable Unit
PAHs	polynuclear aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	Tetrachloroethene (also known as Perchloroethylene)
PRG	preliminary remediation goals
RAOs	Remedial Action Objectives
ROD	Record of Decision
RSL	Regional Screening Level
SVI	soil vapor intrusion
TCE	Trichloroethene
U.S. EPA	United States Environmental Protection Agency
UST	underground storage tank
VOC	Volatile Organic Compound

1.0 INTRODUCTION

This Technical Memorandum has been prepared to document the technical assessment of the protectiveness of the remedies implemented under the Record of Decisions (RODs) for Operable Units (OUs) 1 through 7 at the Marine Corps Logistics Base (MCLB) Barstow, California. This evaluation was completed in support of the 2017 Fourth Five-Year Review by Oneida Total Integrated Enterprises (OTIE) for the Department of the Navy (DON) under Contract No. N39430-16-D-1818, Contract Task Order 0006.

The purpose of this Technical Memorandum is to address the five-year review question:

> Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of the remedy selection still valid?

2.0 EVALUATION OF EXPOSURE ASSUMPTIONS

2.1 YERMO ANNEX EXPOSURE ASSUMPTIONS

The identified potential exposure pathways to contaminants of concern (COCs) at the Yermo Annex include ingestion of contamination groundwater via drinking water wells, inhalation of volatile contaminants during beneficial reuse of groundwater, inhalation of contaminated vapors due to soil vapor intrusion (SVI), and direct contact or ingestion of contaminated soils or wastes left in place.

2.1.1 Ingestion Exposure Assumptions – Yermo Annex

The OUs 1 and 2 ROD (DON, 1998a) identified the primary potential exposure pathway for Yermo Annex Groundwater COCs as ingestion of contaminated drinking water by Base personnel and off-site residents at the Younts and Hodges properties which are affected by the off-site portion of the VOC plume. The ROD further identified contaminant migration routes in the vadose zone as including percolation of infiltrated water through contaminated soils and vapor migration resulting in contamination of groundwater and/or vapor migration to the surface.

The potential exposure pathways identified in the ROD remain the same because there has been no significant change in land use, groundwater use, or general site conditions at Yermo Annex since the 1998 ROD signing. During the 2012 – 2016 five year review period, the two off-site residences, located east of the Base boundary, remained as potential receptors of the off-site portion of the Yermo North VOC plume.

Baseline risk assessments for groundwater under OU 1 identified tetrachloroethene (PCE), trichloroethene (TCE), and 1,1-dichloroethene (1,1-DCE) as chemicals of concern contributing the most to estimated cancer risk and non-cancer health effects (see OUs 1 and 2 ROD Section 3.2.3). The COCs detected at the site remain the same; however, 1,1-DCE was generally not detected above the clean-up limit during this review period. The OUs 1 and 2 ROD RAOs are based on the lower of the federal or state Maximum Contaminant Level (MCLs) for the primary COCs; the MCLs have not changed since the prior review period. Additionally, the best-available technology (BAT) for treatment of VOCs is being used prior to consumption to prevent exposure to site contaminants.

The selected groundwater remedies, as implemented by the DON, are the BAT to treat groundwater as a drinking water source at the Yermo Annex and two off-site residences. The BAT consists of granular-activated carbon that removes VOCs to below MCLs and, based on monitoring data, to non-detect levels. Therefore, even if groundwater RSLs or MCLs were to be lowered for the Yermo Annex groundwater COCs, the existing remedy would continue to be the BAT for eliminating the exposure risk.

2.1.2 Inhalation Exposure Assumptions – Yermo Annex

Exposure to dissolved-phase VOCs during beneficial re-use of groundwater (e.g., for landscape watering) was not identified as an exposure pathway in the OUs 1 and 2 ROD. However, all groundwater used at the Yermo Annex is either drawn from unaffected areas of the aquifer or treated through GAC to non-detection levels before any use at the Base. Therefore, the existing BAT remedy in place would be protective for beneficial reuse of groundwater at the Yermo Annex should it occur. This potential pathway is not further evaluated.

An additional potential exposure pathway for COCs is VOC inhalation due soil vapor intrusion (SVI) into occupied buildings. As part of the Third Five Year Review technical evaluations, modeling of the potential risks due to SVI into two representative buildings at CAOC 16 was performed using the Johnson-Ettinger model (Johnson and Ettinger 1991). For both buildings, the model output indicated that the predicted cumulative excess lifetime cancer risks for the maximum soil gas concentrations of all chemicals detected exceeded the lower end of the U.S. EPA acceptable risk range of 10^{-4} to 10^{-6} but all risk levels were well within the acceptable range. The cumulative non-cancer Hazard Index (HI) values were lower than the threshold value of 1.0.

Based on the Third Five-Year Review SVI evaluation at CAOC 16, the DON determined that no further evaluation of SVI exposure was required during this five-year review.

2.1.3 Direct Contact Exposure Assumptions – Yermo Annex

Three CAOCs under OUs 3 and 5 at the Yermo Annex have selected remedies of wastes remaining in place. These include: CAOCs 20 (concrete cap and soil cover areas), 23 (concrete capped area), and 35 (covered landfill). Engineering controls and land-use controls (LUCs) for these CAOCs were routinely inspected and maintained during the review period. LUCs are in place to prevent land use changes, cover removal, or subsurface work. Therefore, the ROD exposure assumptions for the selected remedies at OUs 3 and 5 remained valid during this review period.

Several CAOCs under OUs 3, 5, and 7 have LUC-only remedies (including those identified in the respective RODs as “no further action with Base Master Plan modifications”) (see Report Section 6 for details). The LUCs-only remedies are generally intended to prevent exposure to residual soil contamination or contaminated soil vapors (at CAOC 16). The MCLB Barstow Environmental Division is responsible for reviewing proposed land use changes and/or subsurface work at these sites to prevent uncontrolled exposures. The LUCs were maintained in accordance with the Base Master Plan during the review period. Therefore, the ROD exposure assumptions for the selected remedies at OUs 3, 5, and 7 at the Yermo Annex remained valid during this review period.

2.2 NEBO MAIN BASE EXPOSURE ASSUMPTIONS

2.2.1 Ingestion Exposure Assumptions – Nebo Main Base

Drinking water at Nebo Main Base is provided by a private water purveyor from production wells that are located upgradient of the Base. Established LUCs to prevent use of groundwater in contaminated areas at the Nebo Main Base remained in place during the review period.

Two groundwater production wells operate at Nebo Main Base for the purpose of supplying irrigation water to the Base golf course. The production wells are not within the extent of identified VOCs plumes. Furthermore, groundwater contour maps indicate no draw-down effect related to these wells that would indicate potential capture of contaminated groundwater. Based on the available information, no potential exposure risks are associated with use of groundwater for irrigation at Nebo Main Base.

Based on this review, the groundwater ingestion exposure assumptions in place at the time of the RODS for OUs 2 and 7 remained valid during this review period.

2.2.2 Inhalation Exposure Assumptions – Nebo Main Base

OUs 4, 6, and 7 at Nebo Main Base do not include sites with identified soil vapor exposure risks due to incomplete exposure pathways. There are five existing VOC groundwater plumes that could potentially contribute to a vapor inhalation risk that are briefly reviewed below:

- The OU 2 Nebo North VOC plume has been largely addressed by the selected remedy; only one monitoring well remains with PCE above cleanup levels. This residual contaminant plume is located at the north end of CAOC 10.5, Warehouse 4 (see Figure E-1.2 of Appendix E), and is likely associated with former underground storage tank (UST) and/or historical operations at this site. The potential for vapor intrusion from this area was evaluated as part of the Third Five Year Review and no inhalation risks were found on the basis of Johnson-Ettinger modeling (Johnson and Ettinger 1991). Based on that evaluation, the DON determined that no further analysis of inhalation risks at this site would be performed as part of the fourth five-year review.
- The OU 2 Nebo South VOC plume (CAOC 6) is located in an unused area of the Base (see Figure 8-3 of the main report) with no occupied structures within the plume area or on the adjacent off-Base property. Therefore, the Nebo South VOC plume does not represent a completed pathway for vapor inhalation.
- Three OU 7 groundwater plumes - NPZ-14 groundwater area, CAOC 10.38/10.39 Unit 7, and CAOC 7 Stratum 1 - are each located in areas of the Base with no occupied structures (see Figure 8-1 of the main report). Therefore, the OU 7 VOC plumes do not represent a completed pathway for vapor inhalation.

Based on the Third Five-Year Review SVI evaluation at Nebo Main Base, the DON determined no further evaluation of the SVI exposure at the Nebo Main Base would be performed during this five-year review.

2.2.3 Direct Contact Exposure Assumptions – Nebo Main Base

Soil cleanup levels were established in OU 7 ROD (2014) for lead, polynuclear aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). These cleanup levels were developed based on a baseline human health risk assessment for site workers and trespassers under an industrial land-use scenario. The direct contact exposure assumptions have not changed since the OU 7 ROD signing in December 2014.

The selected remedy for CAOC 7 Strata 1 and 2 (OU 5) at Nebo Main Base is wastes remaining in place under caps and with LUCs. Engineering controls and land-use controls (LUCs) for this CAOC were routinely inspected and maintained during the review period. LUCs are in place to prevent land use changes, cover removal, or subsurface work. Therefore, the ROD exposure assumptions for the selected remedies at CAOC 7 Strata 1 and 2 remained valid during this review period.

Several CAOCs under OUs 4, 6, and 7 at Nebo Main Base have LUC-only remedies (including those identified in the respective RODs as "no further action with Base Master Plan modifications") (see Table 8-8 of Main Report for review of Nebo Main Base LUCs-only sites). The LUCs-only remedies are intended to prevent exposure to residual soil, soil vapor, or groundwater contamination. The MCLB Barstow Environmental Division is responsible for reviewing proposed land use changes and/or subsurface work at these sites to prevent uncontrolled exposures. The Base Master Plan was amended to incorporate the LUCs for Nebo Main Base CAOCs in 2010 and 2015. The LUCs were maintained in accordance with the Base Master Plan amendments during the review period. Therefore, the ROD exposure assumptions for the selected remedies at OUs 4, 6, and 7 at the Nebo Main Base remained valid during this review period.

3.0 EVALUATION OF CHANGES IN TOXICITY DATA AND REGULATORY STANDARDS

This section describes relevant changes to toxicity data and published regulatory standards that have occurred since the 2012 Third Five-Year Review that may affect the underlying assumptions for protectiveness of the selected remedies at the MCLB Barstow.

Chemicals of concern (COCs) for groundwater were established in the OUs 1 and 2 ROD (1998), OU 2 ROD (2006), and OU 7 ROD (pertaining to Nebo Main Base only, 2014). A summary of the maximum concentration of groundwater VOCs detected in groundwater between 2012 and 2016, along with their respective frequency of detection is presented in Table C-1 for Yermo Annex and Table C-2 for Nebo Main Base.

3.1 TOXICITY DATA REVIEW

The United States Environmental Protection Agency (U.S. EPA) published updated the toxicity data for tetrachloroethene (PCE) in February 2012. The reference dose for chronic oral exposure was reduced from 0.01 milligram per kilogram per day (mg/kg-day) to 0.006 mg/kg-day. A chronic inhalation exposure was established at 0.04 milligrams per meter cubed (mg/m3); the carcinogenicity assessment for lifetime exposure determined PCE is a human carcinogen (U.S.EPA 2012).

The U.S. EPA updated the toxicity data for TCE in May 2012. The reference dose for chronic oral exposure was established at 0.0005 mg/kg-day. A chronic inhalation exposure was established at 0.002 mg/m3; the carcinogenicity assessment for lifetime exposure determined TCE is a human carcinogen (U.S.EPA 2012).

The changes in toxicity data did not result in changes to the regulatory standards underlying the selected cleanup levels for groundwater or soil under the existing RODs.

3.2 GROUNDWATER REGULATORY LIMITS

The section reviews changes to state and federal groundwater regulatory limits for the ingestion pathway. The groundwater at the Yermo Annex is used for drinking water purposes, but drinking water is provided by an external water purveyor at the Nebo Main Base. Therefore, this evaluation focuses on the OU 1 Yermo Annex groundwater cleanup levels and remedial action objectives (RAOs).

3.2.1 Drinking Water Limits

The OUs 1 and 2 ROD references the lower of the state or federal maximum contaminant levels (MCLs) for groundwater cleanup limits. MCLs published by the U.S. EPA and State of California were reviewed to identify if MCLs have decreased since ROD publication; additionally the groundwater database was searched detected compounds not identified as COCs in OUs 1, 2, and 7 RODs. Maximum concentrations of all detected groundwater VOCs at both Yermo Annex (OU 1) and Nebo Main Base (OUs 2, 7), established cleanup levels, and current (2016) regulatory standards are shown on Tables C-1 and C-2 respectively.

The following is a summary of findings from this review:

- The MCLs for groundwater COCs detected at Yermo Annex were not revised during the review period and remain the same since ROD was signed. A review of the COCs detected in Yermo Annex groundwater (Table C-1) and Nebo Main Base (Table C-2) confirmed that PCE and TCE are the predominant COCs in groundwater at both bases, with 1,2-dichloroethane also present at Yermo Annex above its cleanup level at a few wells. The COC 1,1-DCE has declined to be below the cleanup level at both Bases.

- Other VOC were detected above the lower of the state maximum contaminant limit (MCL), federal MCL, or federal tap water screening level, but their infrequent detection or magnitude of exceedance do not warrant classifying them a COCs in this evaluation

- The maximum detected concentrations of some VOCs in Yermo groundwater have exceeded the 2016 tap water screening level. However, the Navy has implemented the best available technology (BAT) to treat the groundwater extracted at Yermo Annex, so no additional engineering controls could be implemented. Drinking water at Nebo Main Base is provided by a private water purveyor and thus is not subject to review.

There were no other changes to MCLs that would affect the original assumptions for the cleanup levels selected in the RODs.

3.2.2 Groundwater Discharge Limits

The current Regional Water Quality Control Board – Lahontan Region (RWQCB) order pertaining to Waste Discharge Requirement (WDR) for Land Disposal of Treated Groundwater is Order Number R6T-2004-0015 (RWQCB, 2004). No changes were made to the WDR limits during the review period.

3.3 Soil Screening Level Changes

A comparison of previous and current industrial soil RSL values and the maximum detected soil chemicals left in place at CAOCs closed with NFA are summarized in Table C-3. No exceedances of revised RSLs were identified in the historical soil data at CAOCs closed with NFA at OUs 3, 4, 5, 6 or 7. There were no changes to soil COCs or soil remedies during the review period and no significant land use changes at soil CAOCs with LUCs only remedies.

The latest State of California screening levels for soils at industrial sites (June 2016) were compared to soil CAOCs with residual contamination that were closed with NFA under the RODs for OUs 3, 4, 5, 6 and 7 (Table C-3). The earlier RODs (1997, 1998) reference the U.S. EPA Preliminary Remediation Goal (PRGs) (DON 1997, 1998b). The U.S. EPA has since replaced PRGs with Regional Screening Levels (RSLs) which were most recently updated in May 2016 (U.S.EPA 2016). RSLs have the same general purpose as PRGs. The California Department of Toxic Substances Control, Office of Human and Ecological Risk (HERO) evaluated the EPA's RSLs and provided guidance on when the PRG values should be used instead of the RSL (HERO 2016).

3.4 VAPOR DISCHARGE LIMITS

The OUs 1 and 2 remedial systems currently do not include treatment of the emissions to the atmosphere (three AS/SVE systems). The emissions from these systems must comply with the MCLB Barstow's general permit for emission of organic air contaminants issued by the Mojave Desert Air Quality Management District (MDAQMC). The following is background information for the general permit and how it applies to the remedial systems.

- The Clean Air Act (CAA) establishes the National Ambient Air Quality Standards (NAAQS). NAAQS are not enforceable in and of themselves but are translated into source-specific emission limitations by the State (EPA 1989). Substantive requirements of the Mojave Desert Air Quality Management District (MDAQMD) rules are federal ARARs for air emissions (CAA Section 110).
- MDAQMD Rule 442 (implementing Clean Air Act 40 U.S.C. 7401 et seq.) requires a reduction of air emissions by 65 percent for facilities that discharge organic materials into the atmosphere from equipment in which organic materials are extracted. Historical data from the Nebo South AS/SVE system indicate that the maximum potential emissions are below set limits for solvents. Because the AS/SVE system discharges VOCs into the air, this rule is considered applicable to Nebo South (OU 2 ROD, page 2-45) (DON 2006).
- MDAQMD Rule 212 Standard for approving permits requires that equipment be designed, controlled, or equipped with air pollution control equipment so that it may be expected to operate without emitting air contaminants in violation of Section 41700 or 41701 of the State Health and Safety Code or of the Mojave Desert AQMD Rules. The OU 1 and OU 2 AS/SVE systems (CAOC 16, Nebo North and Nebo South, as well as SVE pilot study at CAOC 7 Stratum 1) had the potential to cause issuance of air contaminants. On-site actions under CERCLA are exempt from procedural requirements such as permitting. However, the DON considers reporting of remedial system air emissions to be a substantive requirement.

The IRP O&M contractor submits quarterly air emissions reports for each active remedial system with emissions to the MCLB Barstow Air Quality Manager, Mr. Benjamin Leslie. According to Mr. Leslie, the Yermo Annex operates under a Title V Federal Operating Permit (008700587) for nitrous oxide (NOx), VOCs, and particulate matter under MDAQMD oversight. The Base Environmental Division maintains MDAQMD permits for specific operations at the MDMC (Facility ID 587). The MCLB Barstow must also comply with facility-wide emission limits under its Title V permit. The emission limits in Part II.A.25 (Page II-15) of the permit limits emissions from VOC containing materials to 1,190 lbs/month (or approximately 39.6 lbs/day for a 30-day month). The DON interprets the Part II.A.25 facility-wide requirement for VOC emissions as the substantive compliance point for air emissions from each of the IRP's remedial equipment operations at the MCLB Barstow. The remedial equipment with atmospheric emissions that operated during the 2012 – 2017 review period included the CAOC 16 AS/SVE, CAOC 6 AS/SVE, Nebo North AS/SVE, and CAOC 7 Stratum 1 pilot-study SVE systems. Based on the quarterly emissions reports for these systems, there were no exceedances of the 39.6 lbs/day limit for VOC emissions during the review period.

4.0 CLEANUP LEVELS AND REMEDIAL ACTION OBJECTIVES

The groundwater cleanup levels for OUs 1, 2, and 7 are based on the lower of the federal or state MCLs for the identified COCs. No changes in MCLs for OUs 1, 2, or 7 COCs were promulgated during the five-year review period by either the State of California or U.S. EPA. Remedial action objectives (RAOs) for groundwater are, therefore, still valid for on-going groundwater cleanup at the MCLB Barstow.

There are no COC-specific cleanup levels for soil vapor contaminants; the pertinent RODs require cleanup of soil vapors to the extent that further contamination of groundwater is prevented. The active remedial systems at OU 1 (CAOCs 16, 15/17, and 35) and OU 2 (Nebo North, Nebo South) continued to be operated treat soil vapor at these sites. The OU 7 soil vapor extraction (SVE) system at CAOC 7 Stratum 1 is in the remedial design phase.

Soil COC cleanup levels were established in the RODs only for OU 7. These cleanup levels were based on human health risk assessments; at CAOC N-2 Area 1 (former skeet and trap range) the lead shot RAO is removal to prevent ingestion by birds. The RAOs for soil contamination for OU 7 CAOCs N-2 Area 1 and 10 remain valid for these sites. The soil remedies for the other soil sites in OUs 3, 4, 5, and 6 are either completed or under LUCs only.

5.0 SUMMARY AND CONCLUSION

The Five-Year Review process includes addressing the question: "Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of the remedy selection still valid?"

The review of this question, as documented in this technical memorandum, has found that the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of remedy selection for OUs 1 through 7 are still valid.

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TABLES

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TABLE C-1
Groundwater Cleanup Levels, Revised Regulatory Limits, and Maximum COCs in Groundwater
(2012 - 2016) - Yermo Annex
MCLB BARSTOW, CA

Detected VOC[a]	unit	Lowest Regulatory Limit	2016 State MCL	2016 Federal Tap Water RSL	2016 Federal MCL	ROD Cleanup Level[b]	Maximum Detected Concentration[c]	Number of Samples with Detections (out of 408 analyses)				
								2012	2013	2014	2015	2016
1,1-Dichloroethane	µg/L	2.8	5	2.8	--	5	2.1	6	6	5	7	8
1,1-Dichloroethene	µg/L	6	6	280	7	6	5.1	10	11	8	13	13
1,2-Dichloroethane	µg/L	0.17	0.5	0.17	5	0.5	0.89	2	1	1	1	6
2-Butanone	µg/L	5600	--	5600	--	N	40	1	0	0	1	0
Acetone	µg/L	14000	--	14000	--	N	170	1	4	2	1	0
Bromodichloromethane	µg/L	0.13	--	0.13	80	100[d]	0.27	1	1	0	1	0
Chloroform	µg/L	0.22	--	0.22	80	100[d]	1.0	4	7	5	8	12
cis-1,2-Dichloroethene	µg/L	6	6	36	70	6	2.1	3	4	3	2	4
Dichlorodifluoromethane	µg/L	200	--	200	--	n/a	0.53	1	0	0	0	0
Isopropylbenzene	µg/L	450	--	450	--	--	1.1	0	0	0	0	1
Methyl Tert-Butyl Ether	µg/L	13	13	14	--	--	0.41	1	0	0	0	0
Tetrachloroethene	µg/L	5	5	11	5	5	54	41	40	39	39	58
Toluene	µg/L	150	150	1100	1000	42[e]	0.34	0	0	0	1	0
Trichloroethene	µg/L	0.49	5	0.49	5	5	110	48	43	43	46	56
Trichlorofluoromethane	µg/L	150	150	5200	--	150	2.8	1	2	0	1	2

Bolded VOCs are ROD-identified COCs (OUs 1and 2 ROD, and/or 7)
gray shaded cells indicate COC exceedance of ROD cleanup level.
-- = no regulatory limit or cleanup level established
N = no promulgated drinking water standard at time of OUs 1 and 2 ROD, therefore no cleanup level selected (DON 1998a)

Notes:

a. Detected volatile organic compounds (VOCs) in groundwater samples collected between October 2012 and November 2016 (latest available data) at Yermo Annex.
b. 1998 OUs 1 and 2 ROD groundwater cleanup levels
c. Field duplicate samples excluded from counts unless the compound was only detected in the field duplicate.
d. OUs 1 and 2 ROD selected 100 µg/L as the cleanup level; the 2006 OU 2 ROD selected the then-current federal MCL of 80 µg/L as the cleanup level (DON 1998a, 2006)
e. OUs 1 and 2 ROD, Table 2-1: DON agrees to implement taste and odor objectives for toluene proposed by EPA, but not promulated, as "to be considered" standards (DON 1998a)

TABLE C-2
Groundwater Cleanup Levels, Revised Regulatory Limits, and Maximum COCs in Groundwater
(2012 - 2016) - Nebo Main Base
MCLB BARSTOW, CA

Detected VOC[a]	unit	Lowest Regulatory Limit	2016 State MCL	2016 Federal Tap Water RSL	2016 Federal MCL	ROD Cleanup Level[b]	Maximum Detected Concentration[c]	Number of Samples with Detected Concentrations (out of 485 samples)				
								2012	2013	2014	2015	2016
1,1-Dichloroethane	µg/L	2.8	5	2.8	--	5	0.45	1	1	2	1	1
1,1-Dichloroethene	µg/L	6	6	280	7	6	0.45	0	0	0	0	1
1,2-Dichloroethane	µg/L	0.17	0.5	0.17	5	0.5	1.8	7	6	6	6	5
Acetone	µg/L	14000	--	14000	--	N	12	0	1	0	4	0
Benzene	µg/L	0.46	1	0.46	5	1	0.2	2	1	0	0	0
Bromodichloromethane	µg/L	0.13	--	0.13	80	80[d]	0.46	4	4	4	2	2
Carbon disulfide	µg/L	810	--	810	--	N	0.55	0	0	0	0	2
Chloroform	µg/L	0.22	--	0.22	80	80[d]	2.0	8	10	12	11	13
cis-1,2-Dichloroethene	µg/L	6	6	36	70	6	42	3	3	3	3	4
Ethylbenzene	µg/L	1.5	300	1.5	700	--	0.17	1	0	0	0	0
Isopropylbenzene	µg/L	450	--	450	--	--	1.6	1	1	1	0	0
N-Butylbenzene	µg/L	1000	--	1000	--	--	0.69	1	1	1	0	1
N-Propylbenzene	µg/L	660	--	660	--	--	1.4	1	1	1	0	0
Sec-Butylbenzene	µg/L	2000	--	2000	--	--	2.7	2	2	2	1	2
Tetrachloroethene	µg/L	5	5	11	5	5	14	16	3	3	3	2
Toluene	µg/L	150	150	1100	1000	42[e]	12	0	0	0	1	0
trans-1,2-Dichloroethene	µg/L	10	10	360	100	10	1.1	3	3	3	3	2
Trichloroethene	µg/L	0.49	5	0.49	5	5	28	43	44	42	55	59

Bolded VOCs are ROD-identified COCs (OUs 1and 2 ROD, and/or 7)
gray shaded cells indicate COC exceedance of ROD cleanup level.
-- = no regulatory limit or cleanup level established
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b. Groundwater cleanup levels selected in the OUs 1 and 2 ROD (1998), OU 2 ROD (2006), and OU 7 ROD (2014).
c. Field duplicate samples excluded from counts unless the compound was only detected in the field duplicate.
d. OUs 1 and 2 ROD selected 100 µg/L as the cleanup level; the 2006 OU 2 ROD selected the then-current federal MCL of 80 µg/L at the cleanup level.
e. OUs 1 and 2 ROD, Table 2-1: DON agrees to implement taste and odor objectives for toluene proposed by EPA, but not promulated, as "to be considered" standards (DON 1998a)

Table C-3

Comparison of Risk-Based Screening Level Criteria and Maximum Concentration of Detected Chemical in Soil at CAOCs Closed with No Further Action

	Industrial Screening Levels		OUs 3 & 4 ROD [c]	OUs 5 & 6 [d]													OU 7 ROD
	Previous [a]	Current [b]	CAOC 9	CAOC 19	CAOC 22	CAOC 24	CAOC 27	CAOC 28	CAOC 29	CAOC 30	CAOC 31	CAOC 4	CAOC 6	CAOC 8	CAOC 12	CAOC 13	Y-7 TA-12
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Volatile Organic Compounds [e]																	
1,2-Dichloroethane	2.2	2.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2-Butanone	--	190,000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11J
2-Hexanone	1400	1,300	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Benzene	--	5.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.65J
Carbon disulfide	--	3,500	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.48J
Chloroform	--	1.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.31J
Ethylbenzene	--	25.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.18J
Tert-Butyl Alcohol	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9.0J
Tetrachloroethene	--	100	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.28J
Toluene	--	47000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.66J
Xylenes, m & p	27	25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.57J
Semivolatile Organic Compounds																	
2-Methylnaphthalene	2,200	3,000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dibenzofuran	1,000	1,000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dimethyl Phthalate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	380J
Fluorene	22,000	30,000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pyrene	17,000	23,000	--	--	--	--	--	--	--	--	--	130J	--	--	580J	--	--
Pesticides																	
4,4'-DDD	7.2	9.6	--	--	0.76J	--	1.1J	--	--	--	1.6J	--	0.065J	--	--	--	--
4,4'-DDE	5.1	9.3	2.5J	--	0.53J	--	3.6J	--	--	0.5J	1.3J	--	0.110J	--	--	--	--
Alpha-BHC	0.27	0.36	--	0.2J	--	--	--	0.29J	--	--	--	0.3J	--	--	--	--	--
beta-BHC	0.96	1.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Polychlorinated Biphenyls																	
Aroclor-1242	0.74	0.95	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Aroclor-1248	0.74	0.95	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Aroclor-1260	0.74	0.99	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Metals																	
Cobalt	300	350	12.4	8.3J	1.7J	7.9J	6.5J	13.3	0.73J	7.6J	10.2J	6.2J	7.1	4.1J	8.7	5.2J	--
Tentatively Identified Compounds																	
Trichloroaniline	18	25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

(a) May 2012 U.S. EPA Regional Screening Levels for soil, except where overridden by HERO
(b) May 2016 U.S. EPA Regional Screening Levels for soil, except where overridden by HERO
(c) CAOC closed with NFA and soil concentrations detected during remedial investigation. DON 1997. OUs 3 and 4: Operable Units 3 and 4, Final Record of Decision Report. June.
(d) CAOCs closed with NFA and soil concentrations detected during remedial investigations. DON 1998b. Operable Units 5 and 6, Record of Decision Report. January.
(e) Volatile Organic Compounds (VOCs) with decreased industrial screening levels are shown, even when no residual concentration was detected.
-- = no soil concentration reported
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Acronyms:

COPCs = chemicals of potential concern
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Detected VOC[a]	unit	Lowest Regulatory Limit	2016 State MCL	2016 Federal Tap Water RSL	2016 Federal MCL	ROD Cleanup Level[b]	Maximum Detected Concentration[c]	Number of Samples with Detected Concentrations (out of 485 samples)				
								2012	2013	2014	2015	2016
1,1-Dichloroethane	µg/L	2.8	5	2.8	--	5	0.45	1	1	2	1	1
1,1-Dichloroethene	µg/L	6	6	280	7	6	0.45	0	0	0	0	1
1,2-Dichloroethane	µg/L	0.17	0.5	0.17	5	0.5	1.8	7	6	6	6	5
Acetone	µg/L	14000	--	14000	--	N	12	0	1	0	4	0
Benzene	µg/L	0.46	1	0.46	5	1	0.2	2	1	0	0	0
Bromodichloromethane	µg/L	0.13	--	0.13	80	80[d]	0.46	4	4	4	2	2
Carbon disulfide	µg/L	810	--	810	--	N	0.55	0	0	0	0	2
Chloroform	µg/L	0.22	--	0.22	80	80[d]	2.0	8	10	12	11	13
cis-1,2-Dichloroethene	µg/L	6	6	36	70	6	42	3	3	3	3	4
Ethylbenzene	µg/L	1.5	300	1.5	700	--	0.17	1	0	0	0	0
Isopropylbenzene	µg/L	450	--	450	--	--	1.6	1	1	1	0	0
N-Butylbenzene	µg/L	1000	--	1000	--	--	0.69	1	1	1	0	1
N-Propylbenzene	µg/L	660	--	660	--	--	1.4	1	1	1	0	0
Sec-Butylbenzene	µg/L	2000	--	2000	--	--	2.7	2	2	2	1	2
Tetrachloroethene	µg/L	5	5	11	5	5	14	16	3	3	3	2
Toluene	µg/L	150	150	1100	1000	42[e]	12	0	0	0	1	0
trans-1,2-Dichloroethene	µg/L	10	10	360	100	10	1.1	3	3	3	3	2
Trichloroethene	µg/L	0.49	5	0.49	5	5	28	43	44	42	55	59

Bolded VOCs are ROD-identified COCs (OUs 1and 2 ROD, and/or 7)
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TABLE C-1
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(2012 - 2016) - Yermo Annex
MCLB BARSTOW, CA

Detected VOC[a]	unit	Lowest Regulatory Limit	2016 State MCL	2016 Federal Tap Water RSL	2016 Federal MCL	ROD Cleanup Level[b]	Maximum Detected Concentration[c]	Number of Samples with Detections (out of 408 analyses)				
								2012	2013	2014	2015	2016
1,1-Dichloroethane	µg/L	2.8	5	2.8	--	5	2.1	6	6	5	7	8
1,1-Dichloroethene	µg/L	6	6	280	7	6	5.1	10	11	8	13	13
1,2-Dichloroethane	µg/L	0.17	0.5	0.17	5	0.5	0.89	2	1	1	1	6
2-Butanone	µg/L	5600	--	5600	--	N	40	1	0	0	1	0
Acetone	µg/L	14000	--	14000	--	N	170	1	4	2	1	0
Bromodichloromethane	µg/L	0.13	--	0.13	80	100[d]	0.27	1	1	0	1	0
Chloroform	µg/L	0.22	--	0.22	80	100[d]	1.0	4	7	5	8	12
cis-1,2-Dichloroethene	µg/L	6	6	36	70	6	2.1	3	4	3	2	4
Dichlorodifluoromethane	µg/L	200	--	200	--	n/a	0.53	1	0	0	0	0
Isopropylbenzene	µg/L	450	--	450	--	--	1.1	0	0	0	0	1
Methyl Tert-Butyl Ether	µg/L	13	13	14	--	--	0.41	1	0	0	0	0
Tetrachloroethene	µg/L	5	5	11	5	5	54	41	40	39	39	58
Toluene	µg/L	150	150	1100	1000	42[e]	0.34	0	0	0	1	0
Trichloroethene	µg/L	0.49	5	0.49	5	5	110	48	43	43	46	56
Trichlorofluoromethane	µg/L	150	150	5200	--	150	2.8	1	2	0	1	2

Bolded VOCs are ROD-identified COCs (OUs 1and 2 ROD, and/or 7)
gray shaded cells indicate COC exceedance of ROD cleanup level.
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Table C-3
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	Industrial Screening Levels		OUs 3 & 4 ROD [c]	OUs 5 & 6 [d]													OU 7 ROD
	Previous [a]	Current [b]	CAOC 9	CAOC 19	CAOC 22	CAOC 24	CAOC 27	CAOC 28	CAOC 29	CAOC 30	CAOC 31	CAOC 4	CAOC 6	CAOC 8	CAOC 12	CAOC 13	Y-7 TA-12
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Volatile Organic Compounds [e]																	
1,2-Dichloroethane	2.2	2.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2-Butanone	--	190,000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11J
2-Hexanone	1400	1,300	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Benzene	--	5.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.65J
Carbon disulfide	--	3,500	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.48J
Chloroform	--	1.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.31J
Ethylbenzene	--	25.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.18J
Tert-Butyl Alcohol	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9.0J
Tetrachloroethene	--	100	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.28J
Toluene	--	47000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.66J
Xylenes, m & p	27	25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.57J
Semivolatile Organic Compounds																	
2-Methylnaphthalene	2,200	3,000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dibenzofuran	1,000	1,000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dimethyl Phthalate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	380J
Fluorene	22,000	30,000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pyrene	17,000	23,000	--	--	--	--	--	--	--	--	--	130J	--	--	580J	--	--
Pesticides																	
4,4'-DDD	7.2	9.6	--	--	0.76J	--	1.1J	--	--	--	1.6J	--	0.065J	--	--	--	--
4,4'-DDE	5.1	9.3	2.5J	--	0.53J	--	3.6J	--	--	0.5J	1.3J	--	0.110J	--	--	--	--
Alpha-BHC	0.27	0.36	--	0.2J	--	--	--	0.29J	--	--	--	0.3J	--	--	--	--	--
beta-BHC	0.96	1.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Polychlorinated Biphenyls																	
Aroclor-1242	0.74	0.95	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Aroclor-1248	0.74	0.95	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Aroclor-1260	0.74	0.99	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Metals																	
Cobalt	300	350	12.4	8.3J	1.7J	7.9J	6.5J	13.3	0.73J	7.6J	10.2J	6.2J	7.1	4.1J	8.7	5.2J	--
Tentatively Identified Compounds																	
Trichloroaniline	18	25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

(a) May 2012 U.S. EPA Regional Screening Levels for soil, except where overridden by HERO
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mg/kg = milligrams per kilogram
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APPENDIX D

Yermo Annex OU 1 (CAOC 37) – Supporting Information for

Five-Year Review of Remedial Systems

Appendix D-1	Technical Assessment Report – CAOC 37 (OU 1) Remedial Account Performance Evaluation
Appendix D-2	Technical Assessment Report – OUs 1 and 2 Remedial Actions Operations, Maintenance, Repairs, Electrical Costs 2013 – 2017
Appendix D-3	Technical Assessment Report – Evaluation of Nickel and Chromium Groundwater Data - Yermo Annex

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APPENDIX D-1

Technical Assessment Report – CAOC 37 (OU 1) Remedial Account Performance Evaluation

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For Acronyms and Abbreviations, please see Fourth Five Year Review report text.

1.0 INTRODUCTION

This Technical Assessment Report has been prepared to evaluate performance of the groundwater remedies in place for Operable Unit 1 (OU 1) Yermo Annex groundwater. This evaluation was completed in support of the Fourth Five-Year Review and covers the timeframe from October 2012 through September 2017 (data from system startup up through November 2016 were reviewed). This memorandum was prepared by Oneida Total Integrated Enterprises (OTIE) for the Department of the Navy (DON) under Contract No. N39430-16-D-1881, contract task order 0006.

1.1 OU 1 Site Description and Selected Remedy

OU 1 is defined as the groundwater and vadose zone contamination underlying the Yermo Annex. The 1996 remedial investigation identified one large commingled VOC plume emanating from several sources including Comprehensive Environmental Responses, Compensation, and Liability Act Areas of Concern (CAOCs) CAOCs 16, 15/17, 23, 26, and 35 (Figure D-1.1). The OU 1 contaminants of concern (COCs) include of dissolved-phase volatile organic compounds (VOCs), with the primary risk-drivers identified in the ROD as trichloroethene (TCE), tetrachloroethene (PCE), and 1,1-dichloroethene (1,1-DCE). The selected remedy for this plume is pump and treat via the Groundwater Extraction And Treatment System (GETs) with recharge of treated groundwater back into the aquifer, and air sparge/soil vapor extraction (AS/SVE) systems for groundwater and vadose zone VOC mass removal, as described in Table 5-2 of the main Report. In addition, two on-Base groundwater production wells and two off-Base private residential wells that are connected to granular-activated carbon (GAC) treatment systems are operated, monitored, and maintained as part of the OU 1 selected remedy.

1.2 Cleanup Levels and Remedial Action Objectives

Per the OUs 1 and 2 Record of Decision (ROD) (DON 1998), the groundwater contamination in the northern part of the Yermo Annex, the "*Yermo North*" plume is associated with former industrial wastewater pipeline leaks at CAOC 16, past waste water treatment practices at CAOC 15/17, and landfill activities at CAOC 35. The southern Yermo Annex plume was associated with past landfill operations at CAOC 23. The central and most upgradient portion of the Yermo Annex VOC plume is attributed to CAOC 26, a former packing and maintenance plant. The plumes associated with CAOC 23 and 26 have diminished to below the cleanup levels and are no longer plotted on groundwater monitoring report maps (monitoring for CAOC 23 continues; monitoring for CAOC 26 has been reduced to once-every-five-years). The Yermo North plume is the remaining groundwater plume above cleanup levels at the Yermo Annex.

The OUs 1 and 2 ROD established groundwater cleanup levels for VOCs to prevent human exposure to unsafe levels of COCs. Because the OU 1 contaminant plume is in an aquifer classified as a source of drinking water (Class 1 aquifer) in the Comprehensive Water Quality Control Plan by the Regional Water Quality Control Board - Lahontan Region (RWQCB-Lahontan 2015), the more stringent of the federal or state maximum contaminant levels (MCLs) were selected as VOC cleanup levels. This remedial action performance evaluation considers how the existing remedy, as implemented and operating during this review period, is performing to meet the remedial action objectives (RAOs) established in the ROD. The RAOs are defined by CAOCs and are summarized below:

- CAOCs 16 and 26 groundwater contamination - the RAO is to achieve and maintain compliance with groundwater cleanup standards throughout the contaminant plumes at these CAOCs;

- CAOCs 16 and 26 vadose zone contamination - the RAO for vadose zone cleanup at these CAOCs is to remove contaminant mass in the subsurface soils to the degree necessary to 1) prevent further degradation of the groundwater above groundwater cleanup standards and 2) minimize the aquifer clean up time; and
- CAOCs 15/17, 23 and 35 groundwater contamination - the RAO is to attain groundwater cleanup levels at that "point of compliance", which is the downgradient edges of these units (the selected remedy did not include vadose zone cleanup at these CAOCs).

Performance standards set by the OUs 1 and 2 ROD for the OU 1 remedy include:

- Meeting the substantive requirements of the Regional Water Quality Control Board (RWQCB) – Lahontan Region requirements for Land Disposal of Treated Groundwater;
- Groundwater and vadose zone monitoring to verify that the remedial action is being effective towards achieving the RAOs. The OU 1 long-term monitoring plan includes the monitoring and verification plan for both groundwater and soil vapor;
- Groundwater monitoring for CAOCs 23 and 35 will entail collection and analysis of groundwater samples for compliance monitoring per CCR Title 22 (RCRA landfill closure requirements). The long-term monitoring (LTM) plan established that VOCs were the primary constituents of concern for these CAOCs; monitoring is on-going as VOCs continue to be detected; and
- Groundwater monitoring will be conducted to measure the concentrations of five metals (nickel, chromium, antimony, thallium and aluminum) in a few selected groundwater monitoring wells in the area of CAOC 16 for a minimum of four quarters (1 year). This performance standard is evaluated in Appendix D, D-3 Metal Assessment Report.

The following sections review progress in OU 1 remedy implementation and in achieving the performance standards for groundwater and source reduction.

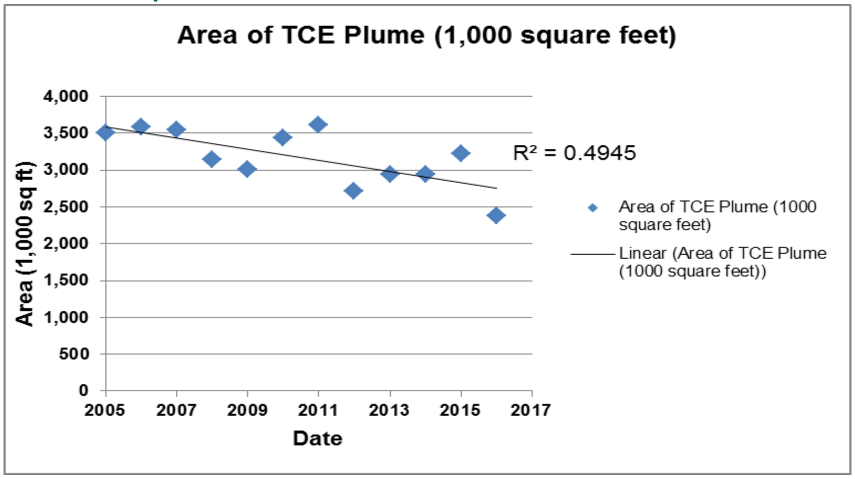
2.0 OU 1 PLUME REMEDIAL PROGRESS

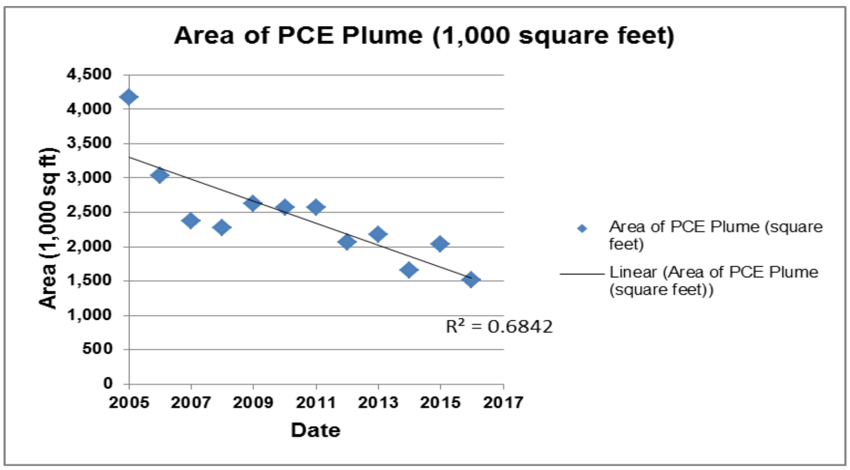
2.1 YERMO NORTH PLUME CHARACTERISTICS AND COC CONCENTRATION TRENDS

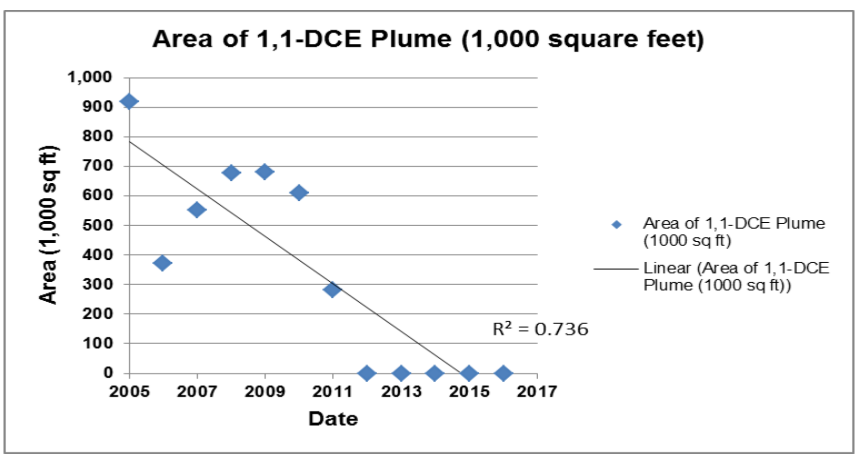
The original extent of the commingled VOC plume at the Yermo Annex was estimated to comprise approximately 6.13 billion gallons over a 12,000- by 4,000-foot area (DON 1998a). The interpreted extents of the remaining Yermo Annex primary COCs, PCE and TCE, for 1996 to 2006 and 2007 through 2016 are presented on Figures D-1.2 and D-1.3, respectively. During this review period, the COC 1,1-DCE was below the cleanup level at all monitoring locations and presented on plume maps in this assessment. The overall Yermo Annex plume extents declined between 1996 and 2006 due primarily to source cleanup efforts at CAOC 26 and the capping of CAOC 23. The extent of the Yermo North TCE and PCE plumes also decreased between 1996 and 2006 with operation of the GETS and CAOC 16 AS/SVE system. The Yermo North plume through the years 2007 – 2016 was more stable and continued to extend off-Base (Figure D-1.3).

For a closer look, the areas of the Yermo North TCE, PCE, and 1,1-DCE plumes were graphed over time (2005 – 2016), as presented on Graph D-1.1 (page 3). Based on this analysis, the TCE plume area is gradually declining while the PCE and 1,1-DCE plume areas show more consistent and definitive downward trends. The change in plume extent may be attributed to the combined action of the GETS and AS/SVE system.

Graph D-1.1 Yermo North Plume Areas over Time

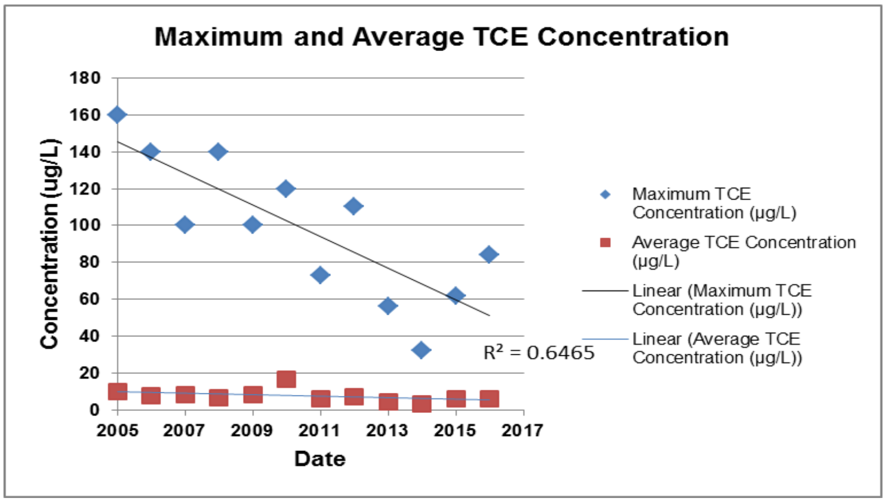


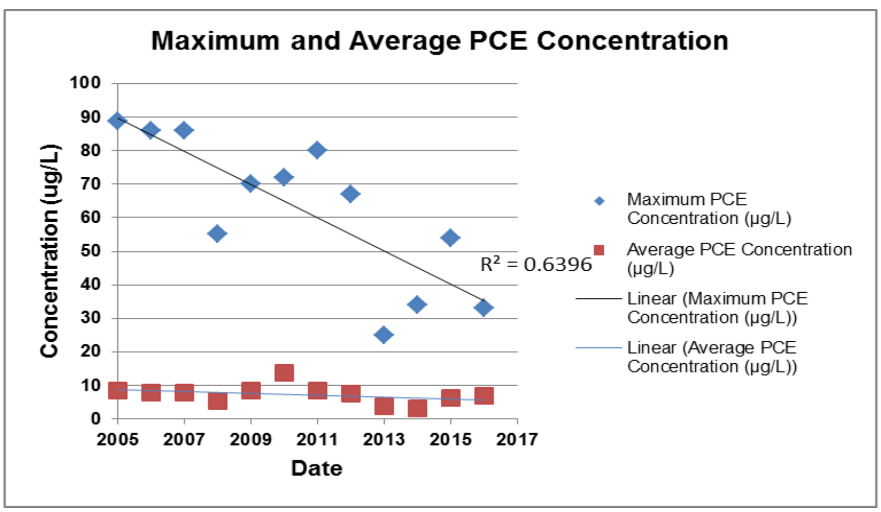




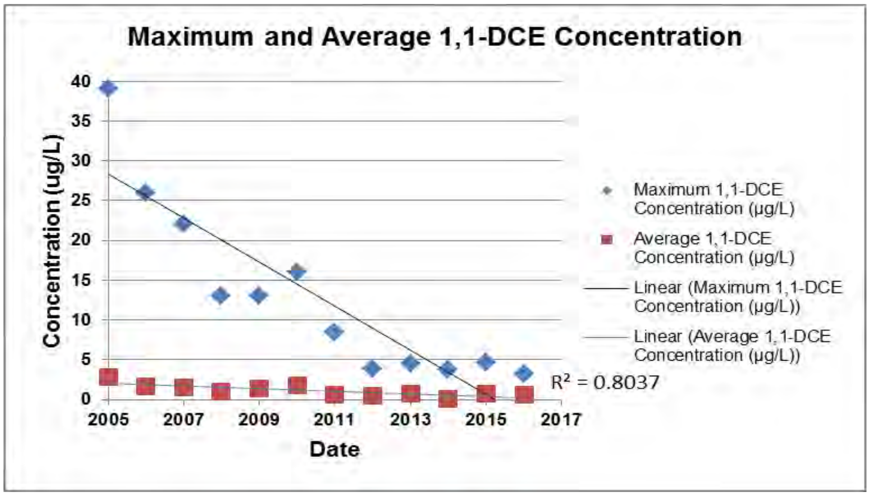
An analysis of the Yermo North plume primary COC concentrations was performed to reveal general trends from 2005 – 2016 (11 year period). Graph D-1.2 (below) shows the trends in maximum and average groundwater concentrations of TCE, PCE, and 1,1-DCE across the plume. The maximum concentration detected per monitoring event for each of the COCs has decreased since 2005, with all three VOCs showing strong declining trends. The low average concentrations over time are consistent with a large diffuse plume.

Graph D-1.2 Maximum and Average Primary COC Concentrations, Yermo North Plume



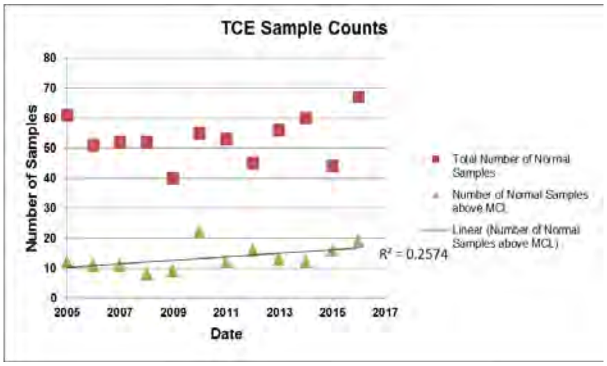


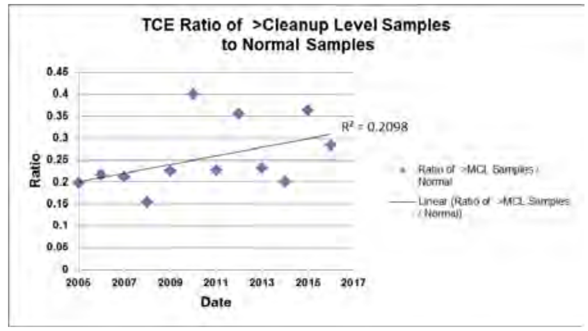
Graph D-1.2 (continued)

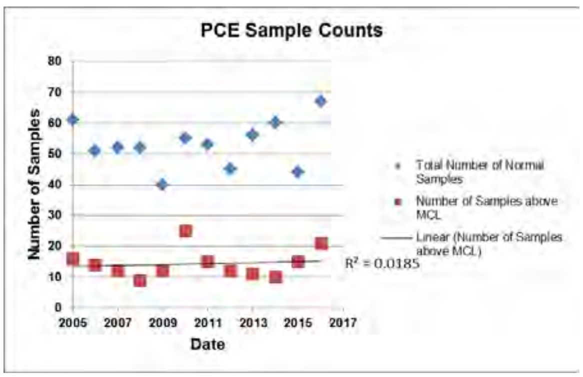


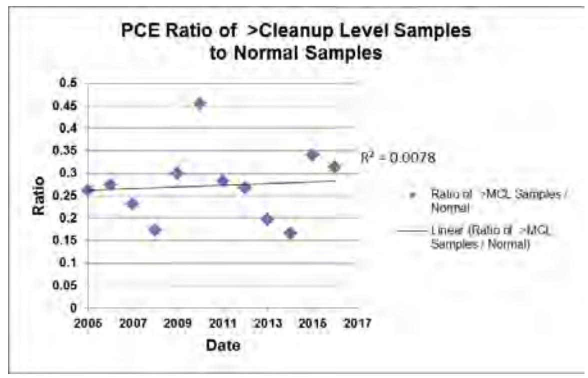
The number of wells sampled during the 2005 – 2016 review period varied from 40 to 67 wells. To account for the variable in the total number of normal samples, the ratio of wells exceeding the cleanup level to the total number of wells sampled was calculated as shown on Graph D-1.3 (next page) for TCE and PCE, and 1,1 DCE. For both TCE and PCE, the ratio of wells exceeding the cleanup level to the total number of wells sampled is weakly correlated and without obvious trend; however, 1,1-DCE has not been detected about the cleanup level since 2011. This analysis, along with declining maximum concentrations and relatively steady low average concentrations, indicate a "mature remedy" with opportunities for optimization steps to improve the time-line of the remedy.

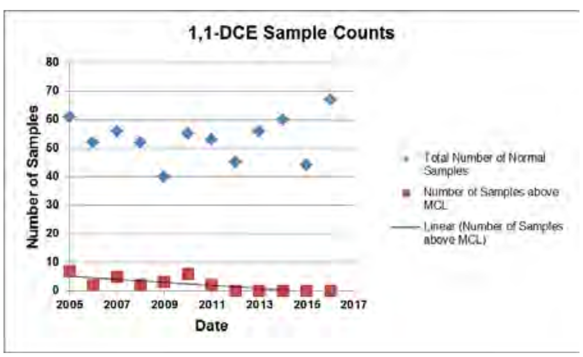
Graph D-1.3 Sample Counts and Cleanup Level Exceedances, Yermo North Plume

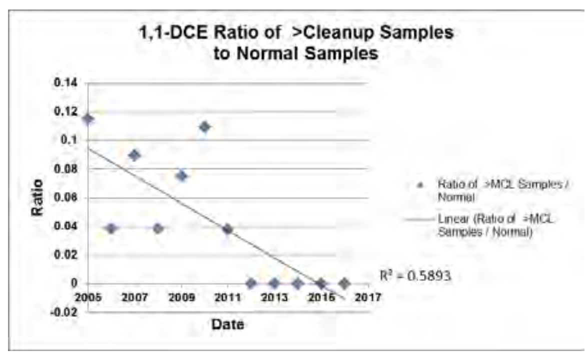






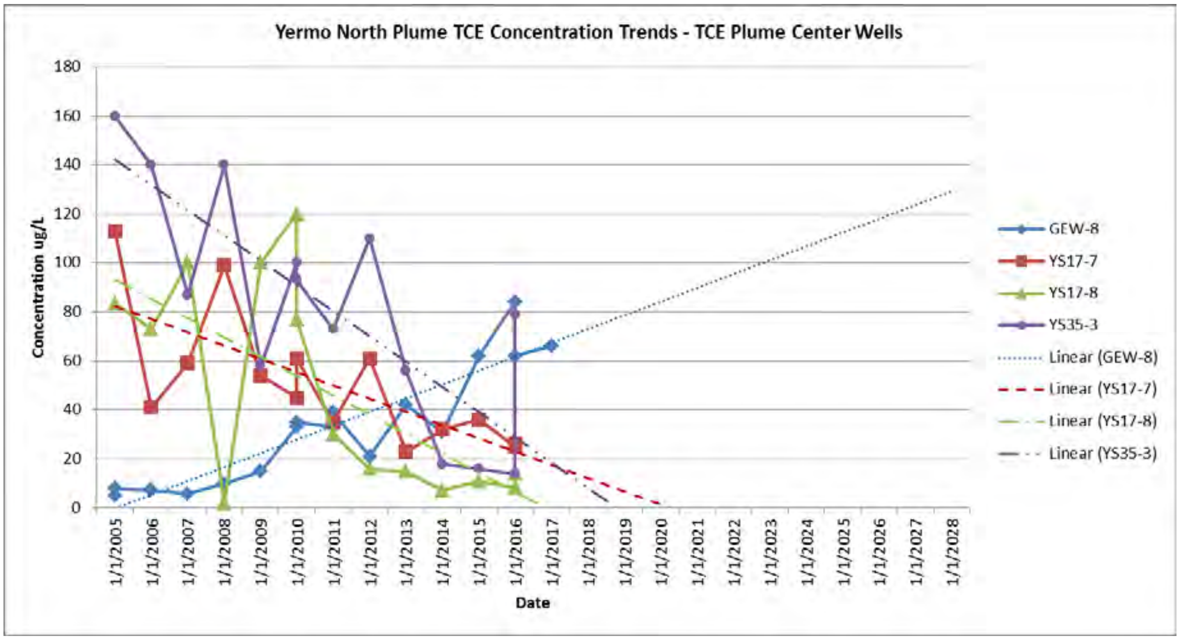


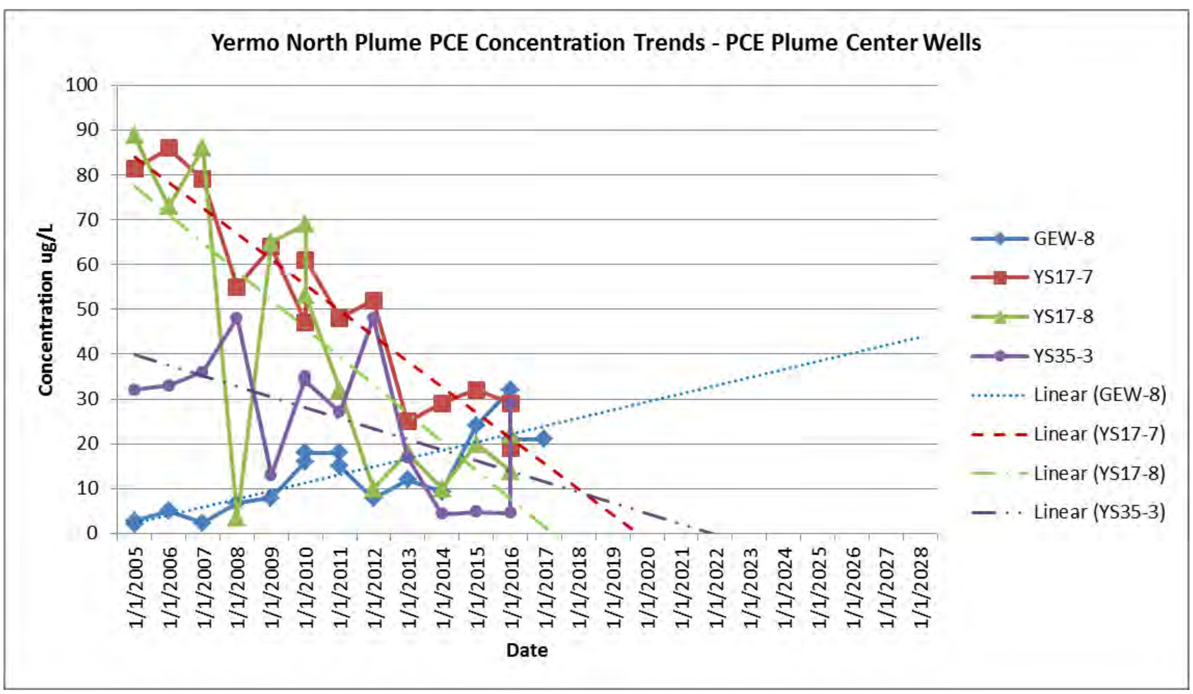




The plume TCE and PCE concentrations in on-Base monitoring wells located approximately along the main plume axis (generally the highest concentrations) were plotted to evaluation trends. Concentrations are generally declining for both TCE and PCE, with the exception of the increasing trends at monitoring well, GEW-8, located at the eastern Base boundary (*see* Graph D-1.4 below).

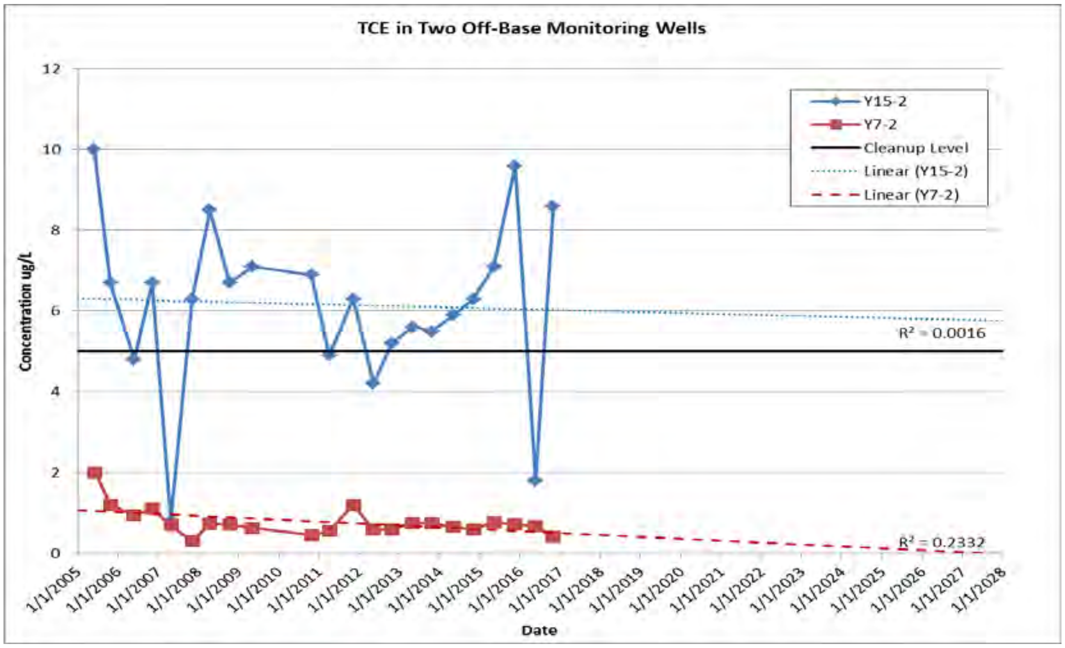
Graph D-1.4 TCE and PCE Trends in Selected On-Base Monitoring Wells, Yermo North Plume

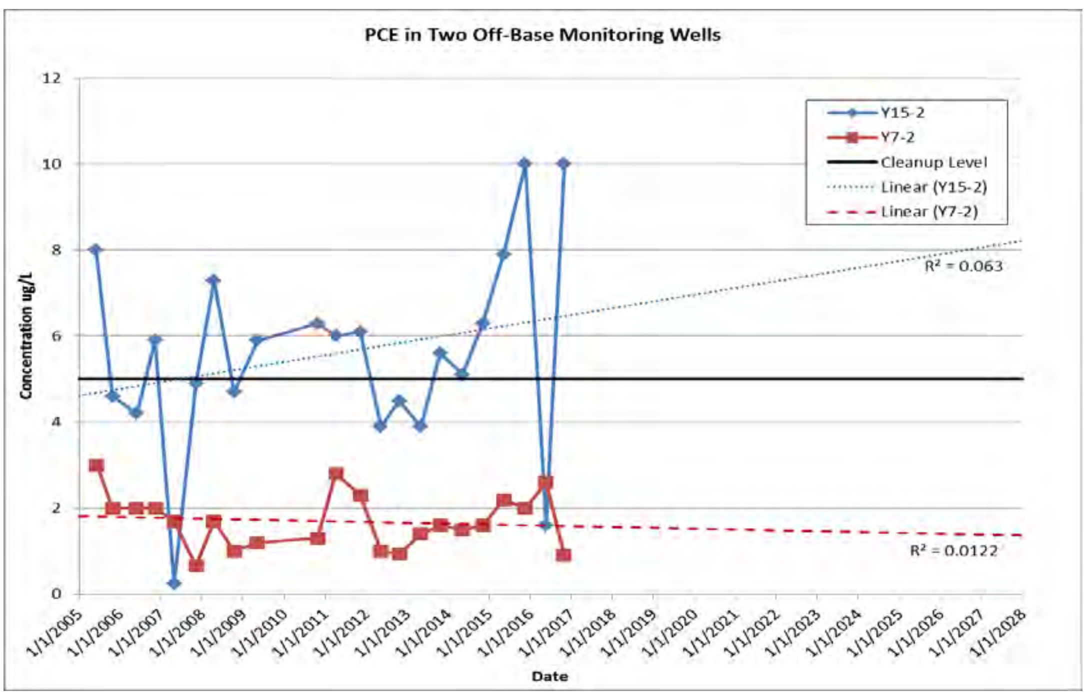




Concentrations of the primary COCs, TCE and PCE, in groundwater samples at off-Base wells do not show clear trends as illustrated in Graph D-1.5 below. Both monitoring wells Y15-2 and Y7-2 went dry in early 2017. The associated deeper-screened monitoring wells, Y15-3 and Y7-3 continue to be monitored and, while TCE and PCE are below cleanup levels, concentrations are rising (not graphed).

Graph D-1.5 TCE and PCE Trends in Off-Base Monitoring Wells, Yermo North Plume





2.2 OU 1 GETS AND AS/SVE SYSTEM PERFORMANCE

The purpose of the GETS is to both hydraulically control the OU 1 plume and remove dissolved-phase VOC mass. The purpose of the AS/SVE system is to remove vadose zone contamination in order to prevent groundwater contamination and reduce groundwater cleanup time. System operation uptime percentages are summarized below for the current Five-Year Review period.

Table D-1.2 OU 1 Remedy Uptimes during 2012 - 2016

Percent Uptime	2012	2013	2014	2015	2016	Average	
GETS	79	85	89	96	95	89	(2012 – 2016)
CAOC 16 AS/SVE	27*	44*	90	91	93	91	(2014 - 2016)

Notes:

*Includes routine bi-weekly shutdown and non-routine repairs.

O&M of the OU 1 systems is performed on a continuous basis, is compliant with the annually updated O&M Manual, and documented in the annual groundwater monitoring reports. The GETS system repairs and upgrades have improved the overall system operational uptimes and efficiency as evidenced by an increase in measured VOC mass removal. Electrical costs to operate the systems were relatively high due to the nature of the remedy. To minimize the systems total operational costs, the systems were optimized by only operating the extraction wells required to meet the RAOs. System Repair and upgrade costs have been relatively high due to the need to repair and upgrade the aging system components, as recommended in the prior Five-Year Reviews. Refer to the O&M costs review provided in Appendix D, O&M Costs Review D-2.

2.2.1 Infiltration Water Quality Substantive Compliance

Per Section 3.6.2 of the OUs 1 and 2 ROD, the GETS treated groundwater will be recharged into the aquifer through infiltration galleries. The infiltrated water quality must substantively comply with the general waste discharge requirements for land disposal of treated groundwater, which are currently defined in Board Order No. R6T-2004-0015 (RWQCB 2004). The general discharge requirements of Board Order No. R6T-2004-0015 also include monitoring requirements to verify compliance.

Treated discharge was in substantive compliance with the discharge limitations set by the RWQCB Lahontan Regional Order Number R6T 2004-0015 during the review period. The OTIE supervising engineer reviewed treatment system monitoring analytical results upon receipt. Concentrations of OU 1 chemicals of concern in the GETS Effluent were below the discharge limits and were therefore determined to be in substantive compliance with the discharge limitations (Table D-1.1, next page).

GETS GAC monitoring is performed on a 60-day (influent and intermediate) and 90-day (effluent) cycle schedule. Based on monitoring results, the GETS GAC is periodically changed-out and vessel inspected and repaired as needed. The next GAC change-out is scheduled for July 2017, in accordance with the O&M Manual and the current VOC concentrations detected at the systems intermediate sampling location.

Table D-1.1 OU 1 GETS - Substantive Compliance with Discharge Limits - Sept. 2012 - Dec. 2016

Detected Analytes[a]	Chromium, Total[b]	Nickel[b]	1,1-Dichloroethene	2-Butanone	Acetone	Bromoform	Carbon tetrachloride	Dichloro-difluoromethane	Tetrachloroethene	Trichloroethene
Discharge Limits[c]	none	none	**6**	none	none	none	none	none	**5**	**5**
Units:	ug/l	ug/L	ug/l	ug/L	ug/l	ug/L	ug/l	ug/L	ug/L	UG/L
Sample Date[d]										
9/19/2012	**1.65**	**1.13**	0.5U	5U	10U	2U	0.5U	0.5U	0.5U	0.5U
12/12/2012	**1.13**	**1.14**	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
3/13/2013	0.5U	**2.55**	0.5U	5U	10U	**2**	**0.5**	**0.5**	0.5U	0.5U
5/7/2013	--	--	0.43U	2.2U	6U	0.5U	0.23U	0.46U	0.39U	0.37U
6/12/2013	0.402U	**1.57**	0.43U	**2.2**	**6**	0.5U	0.23U	0.46U	**0.39**	0.37U
8/6/2013	--	--	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
9/11/2013	**0.631J**	**1.32**	0.5U	5u	10u	1U	0.5U	0.5u	0.5U	0.5U
12/10/2013	0.5U	**1.28**	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
6/17/2014	**1.2**	**3.13**	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
12/10/2014	**0.697J**	**1.04**	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
2/3/2015	--	--	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
3/3/2015	**1.34**	**1.17**	0.43U	2.2U	6U	0.5U	0.23U	0.46U	0.39U	0.37U
6/9/2015	0.5U	**1.86**	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
9/9/2015	**0.487J**	**1.27**	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
12/9/2015	--	--	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
3/9/2016	--	--	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
6/1/2016	--	--	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
9/7/2016	--	--	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
12/6/2016	--	--	0.5U	5U	10U	1U	0.5U	0.5U	0.5U	0.5U
Maximum Detected	1.65	3.13	0	2.2	6	2	0.5	0.5	0.39	0

Bold indicates detected value

-- = not sampled

Notes

a. Analytes shown are detected OU 1 groundwater chemicals of concern (COCs); no other detected analytes exceeded the WDR limits

b. Chromium and nickel were suspected COCs to be evaluated based on monitoring data, per the OU 1 remedy. Metals monitoring in GETS effluent was discontinued in 2015 based on long-term data due to low concentrations.

c. Regional Water Quality Control Board - Lahontan Region, Board Order No. R6T-2004-0015, Waste Discharge Requirements for Land Disposal of Treated Groundwater

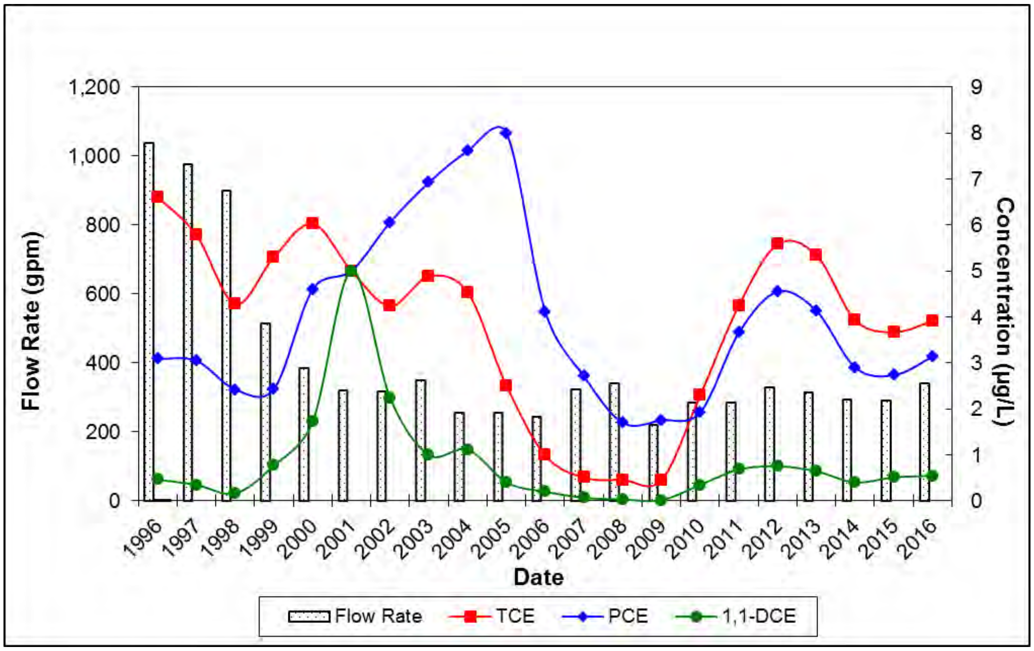
d. Samples collected from sampling port located after GAC treatment; samples representative of water quality discharged to the aquifer via the infiltration galleries

2.2.2 GETS Performance

The GETS was operated with three extraction wells, GAC treatment of extracted groundwater, and treated water re-infiltration, per the selected remedy.

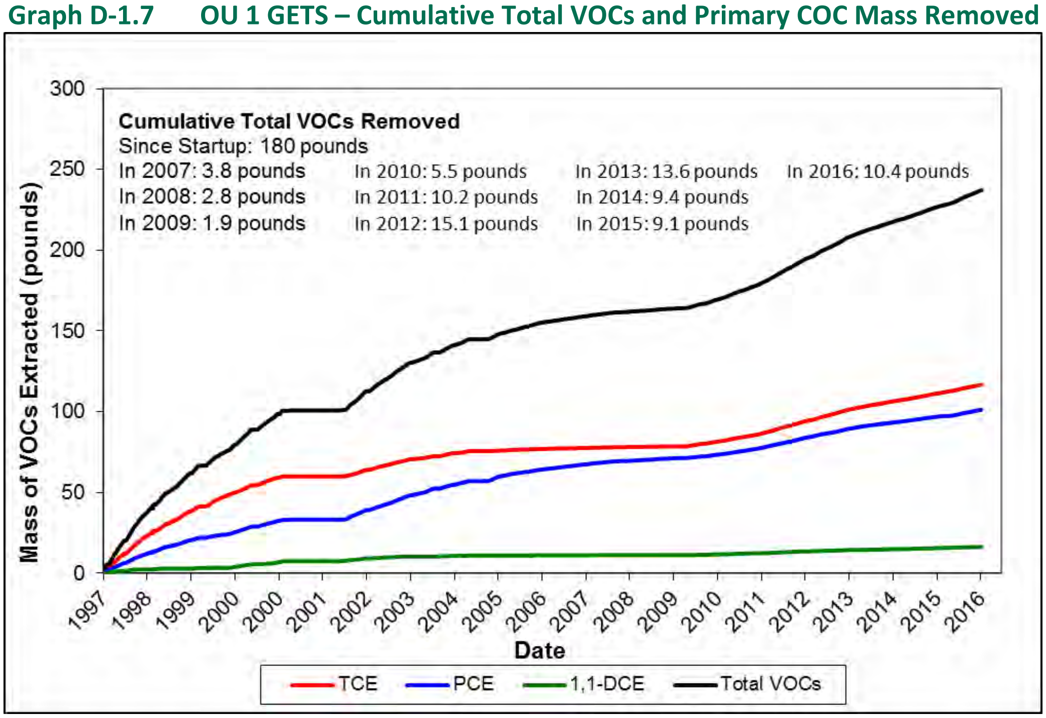
Performance metrics for the GETS system since 1996 are presented in Graph D-1.6, next page. The volume of water treated annually has decreased from its maximum operating year in 1996 as the southern portions of the plume were cleaned up and extraction wells taken off-line. However since about 2001, the volume of treated groundwater has varied within a relatively small range. COC concentrations in the influent of the GETS system had been decreasing since 2005, but began increasing again in 2009. The increase in COC influent concentrations is explained by optimization measures that improved extraction well performance and by the addition of GEW 16 (2010) and GEW-17 (2012) which more effectively captured contaminated groundwater. Hydraulic capture is modeled annually; the latest groundwater flow map with particle tracking is provided on Figure D-1.4 (after-text).

Graph D-1.6 OU 1 GETS – Annual Average Flow Rates and Influent COC Concentrations Over Time



Cumulative VOC mass removal tracks the changes in GETS influent concentration; long-term trends are shown on Graph D-1.7 below. The rate of cumulative mass removal (calculated from influent concentrations and pumping rates) began slowing in 2005 but improved after 2010 because of increased pumping rates in the plume center and increased influent concentrations as discussed above.

Graph D-1.7 OU 1 GETS – Cumulative Total VOCs and Primary COC Mass Removed



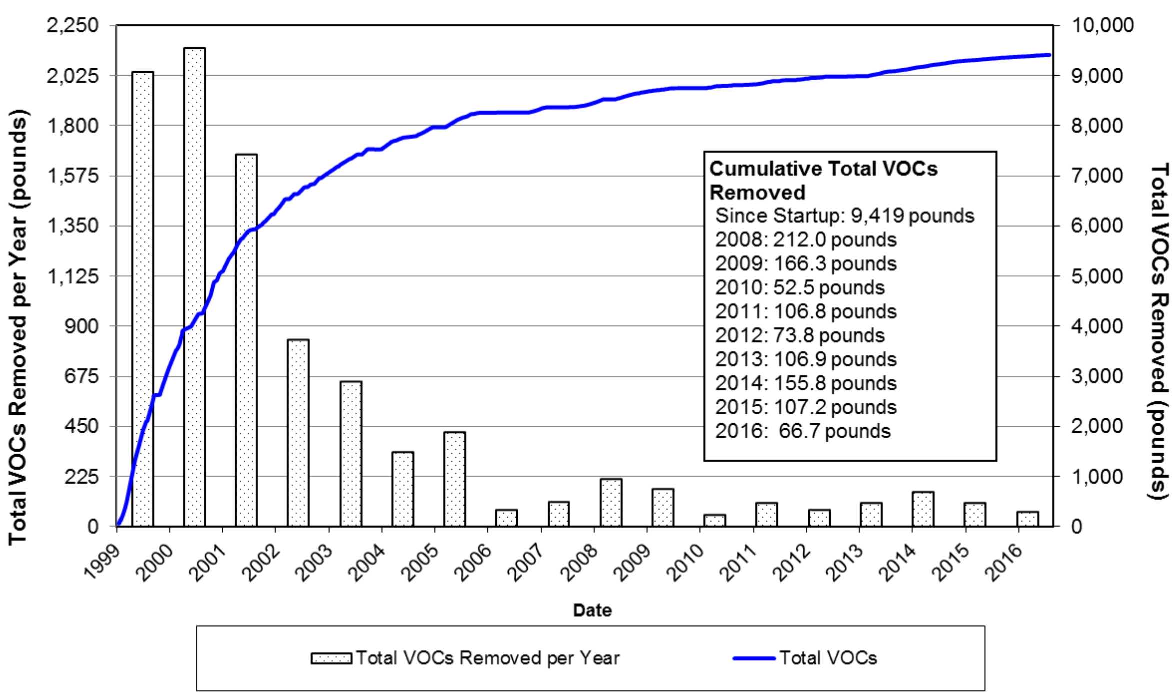
2.2.3 AS/SVE System Performance

Beginning in late 2013, AS/SVE system operations were increased from biweekly to continuous to increase VOC mass removal from the vadose zone and groundwater. Historical AS/SVE system performance, as indicated by the rate of total VOCs removed, is presented on Graph D-1.8. VOC mass was removed at an average rate of 102 pounds per year during 2012 - 2016. As shown in Graph D-1.9 (next page), average annual influent concentrations have declined over time.

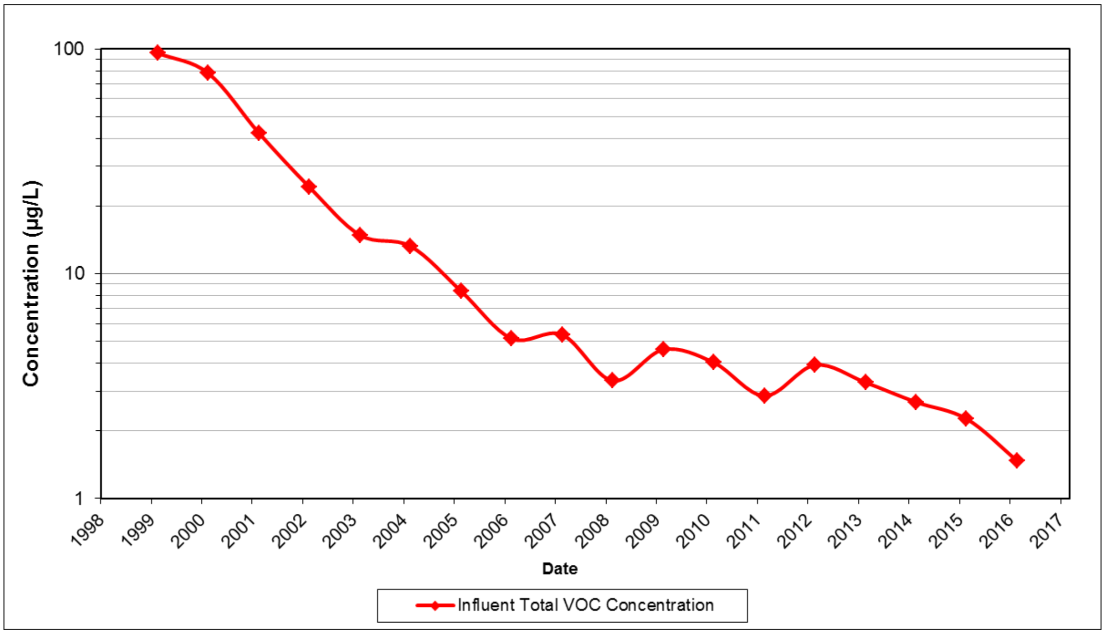
Other considerations affecting the effectiveness of the AS/SVE system are remedial well locations and density of the AS wells.

- The AS wells were installed at a spacing of 100 - 300 feet, which greatly exceeds the general industry practice of 20 to 30 feet well spacing. Declining groundwater levels have eliminated use of the shallow AS wells thus further limiting AS effectiveness; and
- The vapor extraction wells (VEW-1 through -6) are located proximal to the AS wells and their zones of influence are effective at removing contaminant mass within the current area of operation; however, the SVE wells are located over 800 feet from the eastern edge of Building 573 and even further from other suspected sources at CAOCs 16 and 15/17. The SVE wells were operated continuously in 2014 at an average flow rate of 1,975 standard cubic feet per minute (scfm). Vacuum influence is routinely measured to calculate the SVE well radii of influence (ROIs). In 2014 the ROIs were confirmed at up to 1,300 feet at CAOC 16 (OTIE 2015).

Graph D-1.8 OU 1 AS/SVE – Cumulative Total VOCs Mass Removed



Graph D-1.9 OU 1 AS/SVE – Average Influent Total VOCs Concentration over Time



O&M costs are relatively reasonable and within anticipated cost range for operating an AS/SVE system; however, the electrical costs are high due to the operation of the large air compressor and blower required for the deep wells and vast extent of the well field system. Refer to the O&M and monitoring costs for OU-1 (Appendix D, D-2 report). Repair and upgrade costs were reasonable and included repairs and upgrades to aging system components, as recommended in the prior Five-Year Review. The AS/SVE system upgrades and sparge well sediment cleanouts have improved the overall system performance effectiveness. However, as is evident on Graphs D-1.8 and D-1.9, the system as currently configured and operated is likely at the limits of effectiveness.

2.2.4 Air Emissions Substantive Compliance

Samples of the SVE system effluent were collected every 30 days for VOC analysis (GAC treatment was discontinued in 2006). Analytical results are reported in monthly air discharge reports submitted to the DON. The average removal rate of VOCs was approximately 0.20 pounds per day, which is below the MDAQMD discharge limit of 39.6 pound per day (see Appendix C for more details on MCLB Barstow air permits and emissions regulation).

2.3 ARE OU 1 RAOS BEING MET BY THE CURRENT REMEDY?

2.3.1 CAOC 16 Groundwater

The RAO for CAOC 16 groundwater contamination is to achieve and maintain compliance with groundwater cleanup standards throughout the contaminant plume. The groundwater RAO will be achieved through continued operation of the Yermo Annex plume groundwater pump and treat system and the AS/SVE system downgradient of CAOC 16. The RAO for vadose zone cleanup at CAOC 16 is to remove contaminant mass in the subsurface soils to the degree necessary to 1) prevent further degradation of the groundwater above groundwater cleanup standards and 2) minimize the aquifer clean uptime.

As presented in the above analysis, the Yermo North plume areas are generally declining, but with only slow decline seen in the TCE portion of the plume.

- Primary COC maximum concentrations are declining on Base, but COC concentrations at the Base boundary and off-Base are either increasing or exhibit uncertain trends.
- Groundwater concentrations trends for TCE, PCE, and 1,1-DCE (three identified risk-driver COCs in the OUs 1 and 2 ROD) at selected monitoring wells located downgradient of CAOCs 16, 15/17, and 35 are presented in Graph D-1.10 (after-text).
- The current data analysis is limited by data gaps in monitoring locations at the northern and off-Base eastern extent; however, the DON is addressing the data gaps through additional monitoring well installations on-Base and off-Base.

2.3.2 CAOC 16 Soil Vapor

The RAO for CAOC 16 vadose zone cleanup is to remove contaminant mass in the subsurface soils to the degree necessary to 1) prevent further degradation of the groundwater above groundwater cleanup standards and 2) minimize the aquifer clean uptime. The groundwater RAO is be achieved through continued operation of the Yermo Annex plume groundwater pump and treat system and the AS/SVE system downgradient of CAOC 16 (systems were installed as interim measures in 1996). The selected remedy for groundwater includes AS/SVE, which was intended to reduce contaminant mass in the CAOC 16 vadose zone to prevent further degradation of groundwater.

The AS/SVE system is operated and maintained on a continuous basis, in compliance with the annually updated O&M Manual. Upgrades and repairs have improved the overall system operational uptimes and efficiency as evidenced by continued VOC mass removal; however the system is probably at its limits of effectiveness (Graphs D-1.8 and D-1.9, above).

Three vadose zone vapor monitoring wells (YCW-16-1, -16-2, and -16-3) were installed within CAOC 16 (adjacent to Building 573) as part of the remedy (Figure D-1.1). Concentrations of TCE and PCE in the three wells are shown in Graph D-1.11 (after-text). It should be noted that the YCW data were collected as grab samples during AS/SVE system operation and hence represent dynamic site conditions. Both PCE and TCE are generally declining in YCW-16-2 and YCW-16-3. Sample data from YCW-16-1 indicate the highest concentrations and variability during review period. YCW-16-1 (located southeast corner of Building 573) has an upward trend in TCE concentrations at 60 and 85 feet below ground surface (bgs). In general, the data indicate some residual mass remains beneath Building 573.

2.3.3 CAOCS 15/17 AND 35 Groundwater

The RAO for CAOCs 15/17 and 35 groundwater contamination is to attain groundwater cleanup levels at a "*point of compliance*" at the downgradient edges of these units. There is no vadose zone remedy selected for these CAOCs; however the OUs 1 and 2 ROD (Section 2.8.3) recognizes both CAOCs as vadose zone sources.

During the five-year review period, there were no viable groundwater or soil vapor monitoring wells at the downgradient edge of CAOC 15/17; several key monitoring wells installed in the 1990s (YE-14, YE-15, and YE-12, on Figure D.1-1) have long been dry. In March 2017, the DON installed a new multi-screened soil vapor/groundwater monitoring well (YCW-16-4) at the eastern edge of this CAOC downgradient of the former industrial wastewater dry well and east of wastewater evaporation ponds (Figure D-1.1). Monitoring data from this well indicate relatively low TCE and PCE concentrations consistent with prior plume interpretations (see results on Figure D-1.1). For groundwater analytical results, please refer to the *2016 Annual Groundwater Monitoring Report* (OTIE 2017).

Groundwater potentially affected by CAOCs 15/17 and 35 is within the capture zone of extraction wells GEW-17 and GEW-16. TCE and PCE concentration trends in monitoring wells downgradient from these two CAOCs (and CAOC 16) are shown on Graph D-1.12 (after-text).

2.3.4 CAOC 23 Groundwater

The RAO for CAOC 23 groundwater contamination is to attain groundwater cleanup levels at a "*point of compliance*" at the downgradient edges of this unit. The CAOC 23 concrete cap (Figure D-1.5) is maintained and appears to prevent infiltration that could result in further groundwater contamination. Since the groundwater downgradient of CAOC 23 is currently below the groundwater cleanup levels, the RAO is being met. However, COC concentrations have temporarily spiked above the cleanup levels and at some wells, hover just below the cleanup limit. COC concentration trends at CAOC 23 are shown on Graph D-1.13 (after-text)

The cap at CAOC 23 (wastes-in-place area) has likely resulted in decreased infiltration and hence groundwater contamination; a review of the downgradient monitoring data indicate TCE and PCE concentrations are below cleanup levels but persistent during the October 2012 – October 2017 review period. The long-term groundwater data includes occasional “spikes” of TCE and/or PCE to above cleanup-level concentrations. These spikes maybe related to large precipitation events that mobilize vadose zone contaminants. Additionally, certain monitoring wells exhibit COC concentrations that “*hover*” just below the cleanup level (for example, see YS23-16 on Graph D-1.13)

2.3.5 CAOC 26 Groundwater

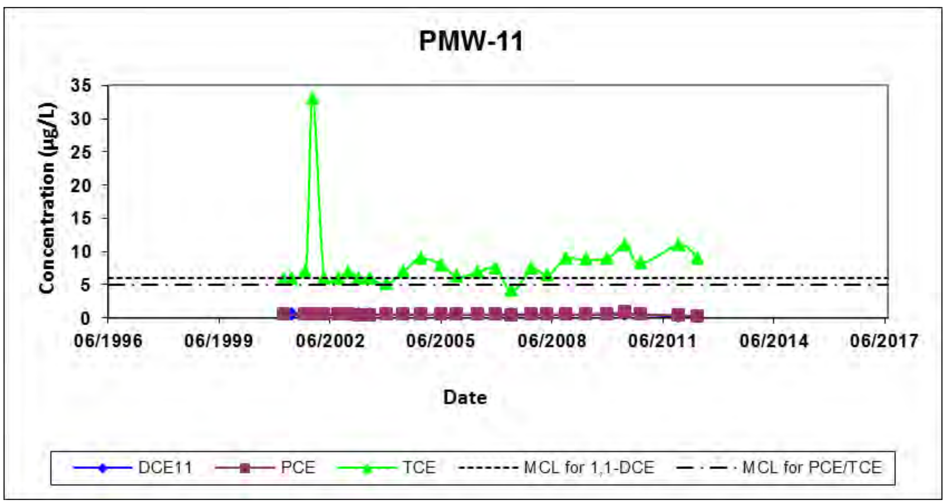
The RAO for CAOC 26 groundwater contamination is to achieve and maintain compliance with groundwater cleanup standards throughout the contaminant plume. The RAO for vadose zone cleanup is to remove contaminant mass in the subsurface soils to the degree necessary to 1) prevent further degradation of the groundwater above groundwater cleanup standards and 2) minimize the aquifer clean up time.

An AS/SVE system was operated at CAOC 26 (Figure D-1.6) between 1996 to 1998, and was formally shut down in 2002 after meeting cleanup objectives, as discussed in the CAOC 26 Technical and Economic Feasibility (TEF) Report (FWENC 2001). Additionally, the CAOC 26 remedy included four on-base extraction wells (GEW 9, 10, 11, and 12). Wells GEW-10, -11, and -12 were shut down in 2003 and the fourth well, GEW-9, was shut down in 2005 after COC concentrations dropped below the MCLs. Long-term monitoring found the CAOC 26 plume had declined to below cleanup levels at all downgradient monitoring locations by about 2007. The pump and treat portion of the remedy for CAOC 26 was shut-down in 2003 - 2005 due to both declining COC concentrations and declining groundwater levels. The CAOC 26 AS/SVE equipment was removed in 2015, and the former GETS wells are scheduled for full decommissioning during 2017.

Since 1998, the CAOC 26 plume has significantly attenuated and concentrations of COCs in both soil vapor and groundwater are greatly reduced (OTIE 2011b). Consequently, the groundwater monitoring frequency was reduced from annual to once every five years at most locations, as recommended in the Second Five-Year Review (DON 2007). Soil vapor monitoring at CAOC 26 was reduced from annual to once every five years (ATJV 2013); the most recent soil vapor monitoring event, completed in 2013, indicated low and over-all declining trends in CAOC 26 related concentrations. Based on these results, and no indications of impact to groundwater, no further soil vapor monitoring was recommended in the *2014 Annual Groundwater Monitoring Report* (OTIE 2015).

Two nested monitoring wells, PMW-11 (shallow) and PMW-12 (deep) are located approximately 3,160 feet down-gradient of the CAOC 26 area and were included in the CAOC 26 monitoring program. The shallow well PMW-11 (156 – 175 ft bgs) showed persistent concentrations of TCE above the cleanup level until it went dry in 2012 (*see* Graph D-1.15, below). However, VOCs detected at PMW-11 may not be associated with CAOC 26 based on the presence of clean monitoring wells between CAOC 26 and PMW-11/-12 area. An alternative source for the VOCs detected at PMW-11 has not been identified. Groundwater at the deeper nested well, PMW-12, is not impacted by VOCs. The PMW-11/-12 well-nest is located within the CAOC 16 hardstand and is upgradient of the OU 1 AS/SVE and pump-and-treat remedies. Therefore, the PMW-11/-12 well nest was proposed for continued monitoring under the OU 1 groundwater monitoring program. Monitoring well PMW-12 will be sampled on a once-every-five-year frequency (OTIE 2016a). The FFA Stakeholders concurred with the recommendation upon approval of the OUs 1 – 7 Sampling and Analysis Plan in February 2016.

Graph D-1.10 CAOC 26 – Monitoring Location PMW-11



3.0 PROTECTION OF DRINKING WATER WELLS

3.1 ON-BASE PRODUCTION WELLS

The RAO to prevent exposure of humans to groundwater COCs is addressed through on-going monitoring and maintenance of GAC treatment at two on-Base groundwater production wells (YDW-5 and YDW-6). O&M of the drinking water system is the responsibility of the MCLB Barstow Public Works Division under the direction of the Base Water Resources Manager. However, monthly monitoring of VOCs and GAC change-out is performed as part of OU 1 remedial activities.

The GAC in the lead vessel of YDW -5 was changed out during November 2013 in response to detections of VOCs in the intermediate samples; the new carbon vessel was configured to be the lag vessel to ensure clean water was delivered to the system. Production well YDW-6 was inoperable between August 2011 and June 2013 and has been offline since January 2016 due to pump problems. Production well YDW-7 was inoperable between July 2013 and November 2015, due to pump problems.

The DON monitors both the GAC treatment systems on a monthly basis. A third production well, YDW-7, does not have treatment and is beyond the Yermo North plume boundaries; however, as a precaution, the DON monitors the raw water at this well for VOCs. The drinking water protection RAO was met throughout the Fourth Five-Year Review period based on monthly reports filed with the MCLB Barstow Water Resources Manager and periodic GAC change outs.

3.2 TWO OFF-BASE PRIVATE RESIDENTIAL WELLS

Additionally, two off-Base private residential wells have GAC treatment systems that are monitored and maintained as part of the remedy. Monitoring and O&M activities are summarized below.

- **Monitoring**: Quarterly monitoring was performed at the Yount's private well between 2012 and 2014. Sampling frequency was increased from quarterly to bimonthly beginning in 2015 as a precautionary measure by the DON in response to rising groundwater concentrations at the Yount well. Sampling data of the GAC influent, intermediate and effluent (treated water entering the household) showed the treatment systems were functioning as intended to protect the drinking water. Samples indicated no detectable VOC concentrations in the effluent (treated) drinking water samples. If the intermediate samples indicate the presence of VOCs, GAC replacement was conducted. The Yount's treatment system GAC was replaced in July 2012, May 2013 (vessels were also replaced), and in May 2016. COCs in treated water were consistently non-detect during the review period; and
- **O&M:** The DON is responsible for treatment system O&M and monitoring. The off-Base owners are responsible for O&M of their wells and well pumps. Regular planned GAC change-out at the once/five-year interval is scheduled for May 2021 at the Yount's residence. To the DON's knowledge, the Hodges residence has been unoccupied and the well has been inoperable since 2010:
    - One of these residences (Hodges) does not have an operational well and the access agreement with the owner has lapsed. The Hodges residential well is reportedly non-operational since December 2008 and the property has been unoccupied since 2010; however the Navy has not been able to contact the property owner to confirm the current status since 2010. The Hodges well is observable from the public right-of-way and it appears the pump has been removed from the well and that power to the well has been disconnected at the power pole. No direct exposure or ingestion of groundwater COCs is suspected as the well is non-operational. The DON continues to try to contact the property owner who lives out of state; and
    - The other private residence (Yount) had a functional well and the GAC system was properly monitored and maintained until May 2016 when the well went dry. The DON continues to communicate with the resident on status of the well. The GAC treatment system at this location is non-operational, but no direct exposure or ingestion of the groundwater COCs is possible as the well is non-operational.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 YERMO NORTH PLUME

The remaining OU 1 groundwater plume above cleanup levels, the Yermo North plume, is being addressed by the GETS for hydraulic containment and groundwater cleanup. This technical assessment reviewed the GETS remedial system performance, groundwater plume extent, and COC concentration trends.

Yermo North Plume Conclusions:

- The GETS was properly operated, maintained, and optimized to the extent practicable during the review period;
- The GETS treated discharge met the substantive requirements of the current RWQCB-Lahontan Region Order No. R6T-2004-0015 (2014) throughout the current review period;
- Analysis of the Yermo North VOC plume indicates that the remedy is reducing TCE, PCE and 1,1-DCE extent and concentrations on Base.
- The continued presence of off-Base COC concentrations (TCE and PCE) in groundwater indicate the hydraulic containment RAO is not yet being attained despite remedy optimization measures;
- Data gaps in the monitoring well network along the northeastern on-Base and eastern off-Base plume boundaries hinder full evaluation of remedy effectiveness and protectiveness;
- The cause of the persistent rise in COC concentrations in GEW-8 is uncertain. However, the GEW-8 area is within the capture zone of GEW-16 and off-site migration is not suspected based on continued operation of the GETS.

Recommendations:

- Perform a data gaps investigation of the Yermo North plume to improve delineation of the northern and off-site extent.
- Investigate the residual contaminant mass in the vadose zone at CAOCs 16, 15/17, and 35; based on the results evaluate if optimization of the AS/SVE system is required to ensure long-term effectiveness of the remedy.

4.2 CAOC 16 VADOSE ZONE AND GROUNDWATER

CAOC 16 is an identified as source for the OU 1 northern plume. The remedy for CAOC 16 includes AS/SVE to reduce vadose zone VOC mass and the GETS to address groundwater. The RAO for CAOC 16 vadose zone cleanup is to remove contaminant mass in the subsurface soils to the degree necessary to 1) prevent further degradation of the groundwater above groundwater cleanup standards and 2) minimize the aquifer clean uptime. The RAO for groundwater related to CAOC 16 is to achieve and maintain compliance with groundwater cleanup standards throughout the contaminant plumes. The technical assessment reviewed groundwater and soil vapor COC concentration trends in the available monitoring wells.

CAOC 16 Conclusions:

- The groundwater RAO for CAOC 16 is not yet attained, although declining COC concentrations within the on-Base portions of the plume indicate progress is being made on mass removal;
- The AS/SVE system is operated, maintained, and optimized to the extent practicable. Continuous operation of the AS/SVE system beginning in 2014 increased the mass removal rate but that had begun to decline by 2016 and is expected to be lower in 2017. The soil vapor sampling data at the three CAOC 16 monitoring locations indicate generally declining TCE and PCE concentrations, with some variability and continued elevated concentrations notably at the southeast corner of Building 573;
- The AS/SVE system is somewhat distant (800 feet or more east) of CAOC 16, but the radius of influence of the SVE wells is estimated to extend to at least the eastern portion of the site;
- SVE well distance from CAOC 16 and a lack of data on the residual mass existing beneath the CAOC hampers the DON's ability to evaluate and optimize the SVE portion of the remedy; and
- The AS wells are spaced 100 -300 feet apart which is many times the standard industry practice for design of an effective "sparge curtain" to effectively treat groundwater. Additionally, declining groundwater levels have further reduced the effectiveness of the AS wells.

Recommendations:

- Optimization measures to improve remedy performance should be based on further study of the residual vadose zone mass at CAOC 16. Rebound testing should be performed during the next review period. The cost of optimization measures such as expanding the AS/SVE remedy should be evaluated against possible cost savings through reduction in the time required for the pump and treat remedy to achieve RAOs.
- Turn off the AS portion of the remedy because it is now cost-ineffective to operate and there would be no impact to overall remedy effectiveness and protectiveness.

4.3 CAOCs 15/17 and 35 Groundwater

CAOCs 15/17 and 35 are identified as sources for the OU 1 northern plume. There is no vadose zone remedy selected in the OUs 1 and 2 ROD for CAOCs 15/17 and 35 based on the RI/FS. Groundwater contamination related to these two sites is addressed by the OU 1 pump and treat remedy and the CAOC 16 AS/SVE remedy. Per the OUs 1 and 2 ROD (1998), groundwater cleanup levels must be met at the CAOC boundary for each site.

Conclusions:

- If CAOC 15/17 and 35 are contributing to OU 1 groundwater contamination, which is not certain, the plume would probably be contained by pumping at GEW-17 and GEW-16, based on modeling;
- There are limited monitoring locations to assess the RAO compliance point for CAOC 15/17;
- The potential for CAOC 35 contributions to the Yermo North plume is not well understood due to uncertainties as to the wastes landfilled at this site and lack of data (soil and soil vapor) in the subsurface at this site; and

- Likely the existing SVE system is treating the vadose zones of the eastern portions of CAOC 15/17 and 35, however lack of monitoring locations hinders the ability to fully assess remedial system effectiveness.

Recommendations:

- Although the selected remedy does not include vadose zone treatment for either site, investigation of the residual mass residing under CAOCs 15/17 and 35 would ensure long-term protectiveness and effectiveness of the OU 1 groundwater remedy.

4.4 CAOC 23 GROUNDWATER

The cap remedy is protective of direct exposure to contaminants and prevents precipitation infiltration (*See main text for evaluation of this portion of the remedy*).

Conclusion:

- The groundwater VOC concentrations downgradient of CAOC 23 remain below the groundwater cleanup levels; therefore the RAOs for prevention of groundwater contamination were met during the review period.

Recommendation: None.

4.5 CAOC 26 VADOSE ZONE AND GROUNDWATER

Conclusions:

- The RAOs for the CAOC 26 vadose zone contamination reduction and the RAO for compliance with the groundwater cleanup levels throughout the plume have been met.

Recommendations:

- Document in the Administrative Record that the vadose zone and groundwater remedy is completed at CAOC 26.

4.6 PROTECTION OF DRINKING WATER

Conclusions:

- The RAO to prevent exposure to OU 1 contaminated groundwater was met during the five-year review period at both on-Base and off-Base locations; and
- Problems with wells (dry or non-operational) and site access (Hodges property) have prevented the DON from fully implementing the remedy at the Yount and Hodges off-Base private residences. However, no current exposures to contaminated groundwater are suspected based on inoperable wells.

Recommendations:

- Maintain contact with Yount residence on status of their private well. Continue to pursue access agreement with off-Base Hodges property owner; the situation is being elevated to the DON legal counsel who will review and pursue options to gain access to the Hodges property to ascertain status of the well and GAC system, and to make necessary repairs (if the well is operable) to meet requirements of the ROD. Additionally, upon securing access to the property, the DON will provide notification to the occupants regarding potentially contaminated groundwater.

5.0 REFERENCES

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FIGURES

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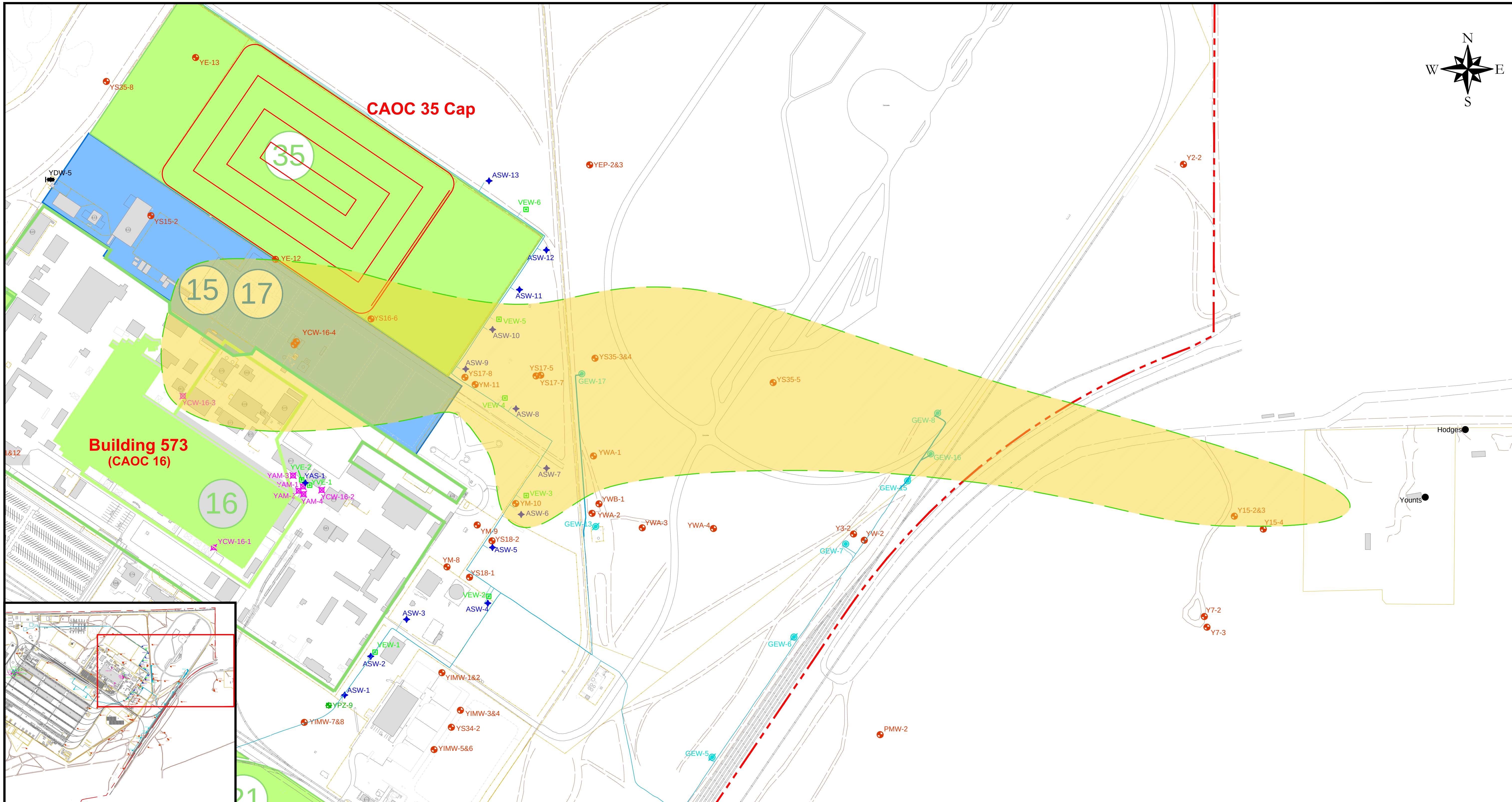


Legend

	Paved Road
	Dirt Road
	Railroad Tracks
	Fence Line
	Remediation Line
	Operable Unit 3 (CAOC ##)
	Operable Unit 5 (CAOC ##)
YMP-2	Groundwater Monitoring Well
YPZ-2	Piezometer
GEW-16	Groundwater Extraction Well (Active)
GEW-5	Groundwater Extraction Well (Inactive)
YCW16-1	Combination Well
VEW-1	Vapor Extraction Well
ASW-1	Air Sparge Well
Younts	Residential Well
	Approximate OU1 Groundwater VOC Plume

Notes

1) Analytical results used to delineate the OU 1 (Operable Unit 1) groundwater plume are a combination of wells sampled during the November 2016 event.

2) CAOC - CERCLA Area of Concern
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act

Approximate Scale in Feet

0 400 800

Figure D-1.1
OU 1, Yermo North Site Map

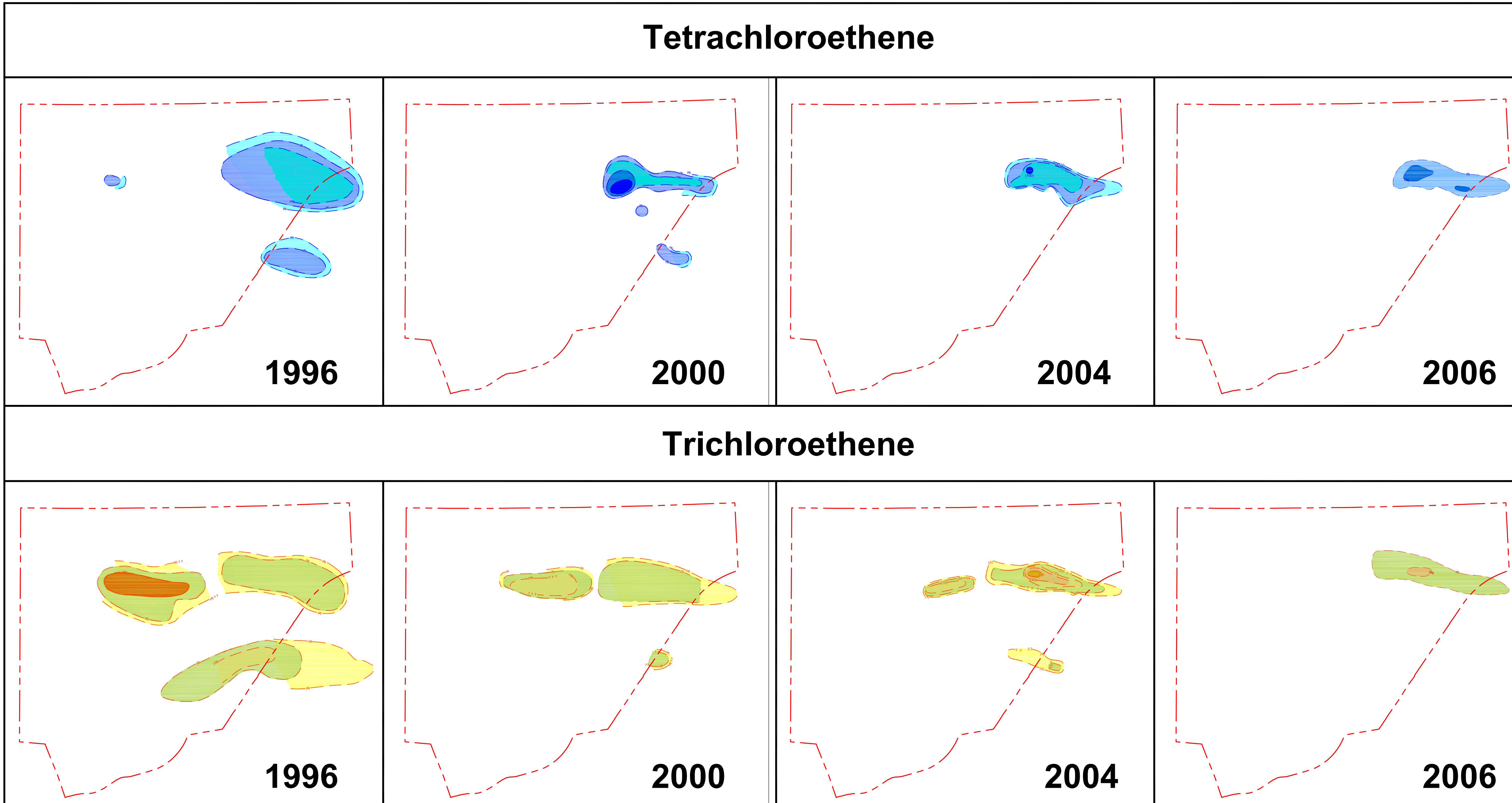
Yermo Annex
Marine Corps Logistics Base
Barstow, California

OTIE
An Oneida Nation Company

Date: March 8, 2016

File: Barstow_5yrRev - 2017.dwg

Plotted By: Geoff Brink



Legend

Yermo Boundary	4 ug/L TCE Concentration Area
4 ug/L PCE Concentration Area	5 ug/L TCE Concentration Area
5 ug/L PCE Concentration Area	10 ug/L TCE Concentration Area
10 ug/L PCE Concentration Area	25 ug/L TCE Concentration Area
50 ug/L PCE Concentration Area	50 ug/L TCE Concentration Area
100 ug/L PCE Concentration Area	110 ug/L TCE Concentration Area

Notes

1) ug/L = Micrograms per Liter
TCE = Trichloroethene
PCE = Tetrachloroethene

N
W E
S

Approximate Scale in Feet

0 3,300 6,600

Figure D-1.2
Historical Extents of PCE/TCE in Groundwater (Select Years from 1996 - 2006)

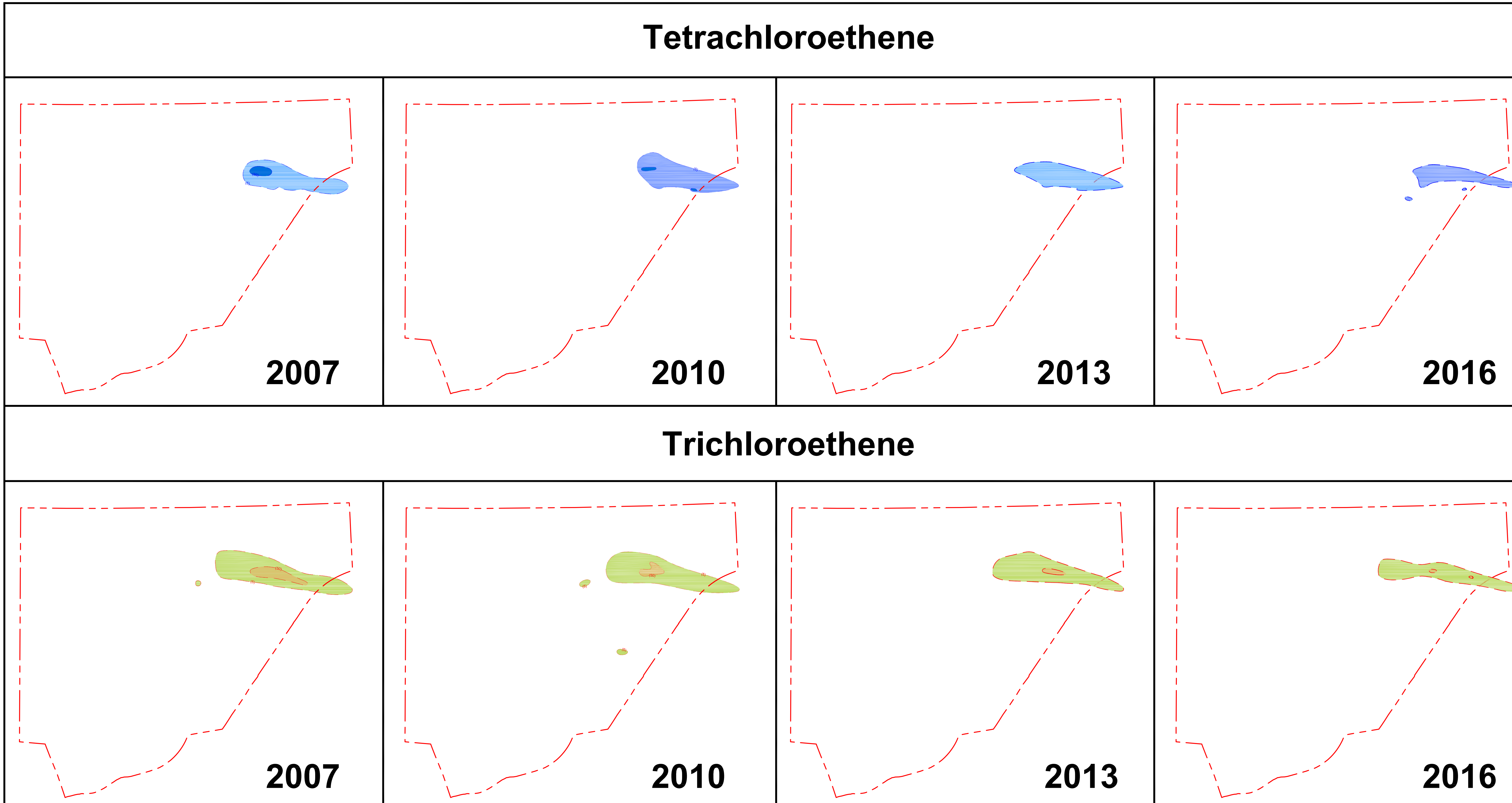
Yermo Annex
Marine Corps Logistics Base
Barstow, California

OTIE
An Oneida Nation Company

Date: June 20, 2017

File: Barstow_5yrRev - 2017.dwg

Plotted By: Elizabeth Vasquez



Legend

- Yermo Boundary
- 4 ug/L PCE Concentration Area
- 5 ug/L PCE Concentration Area
- 10 ug/L PCE Concentration Area
- 50 ug/L PCE Concentration Area
- 100 ug/L PCE Concentration Area
- 4 ug/L TCE Concentration Area
- 5 ug/L TCE Concentration Area
- 10 ug/L TCE Concentration Area
- 25 ug/L TCE Concentration Area
- 50 ug/L TCE Concentration Area
- 110 ug/L TCE Concentration Area

Notes

1) ug/L = Micrograms per Liter
TCE = Trichloroethene
PCE = Tetrachloroethene

Approximate Scale in Feet

0 3,300 6,600

Figure D-1.2
Historical Extents of TCE/PCE in
Groundwater (Select Years from 2007 - 2016)

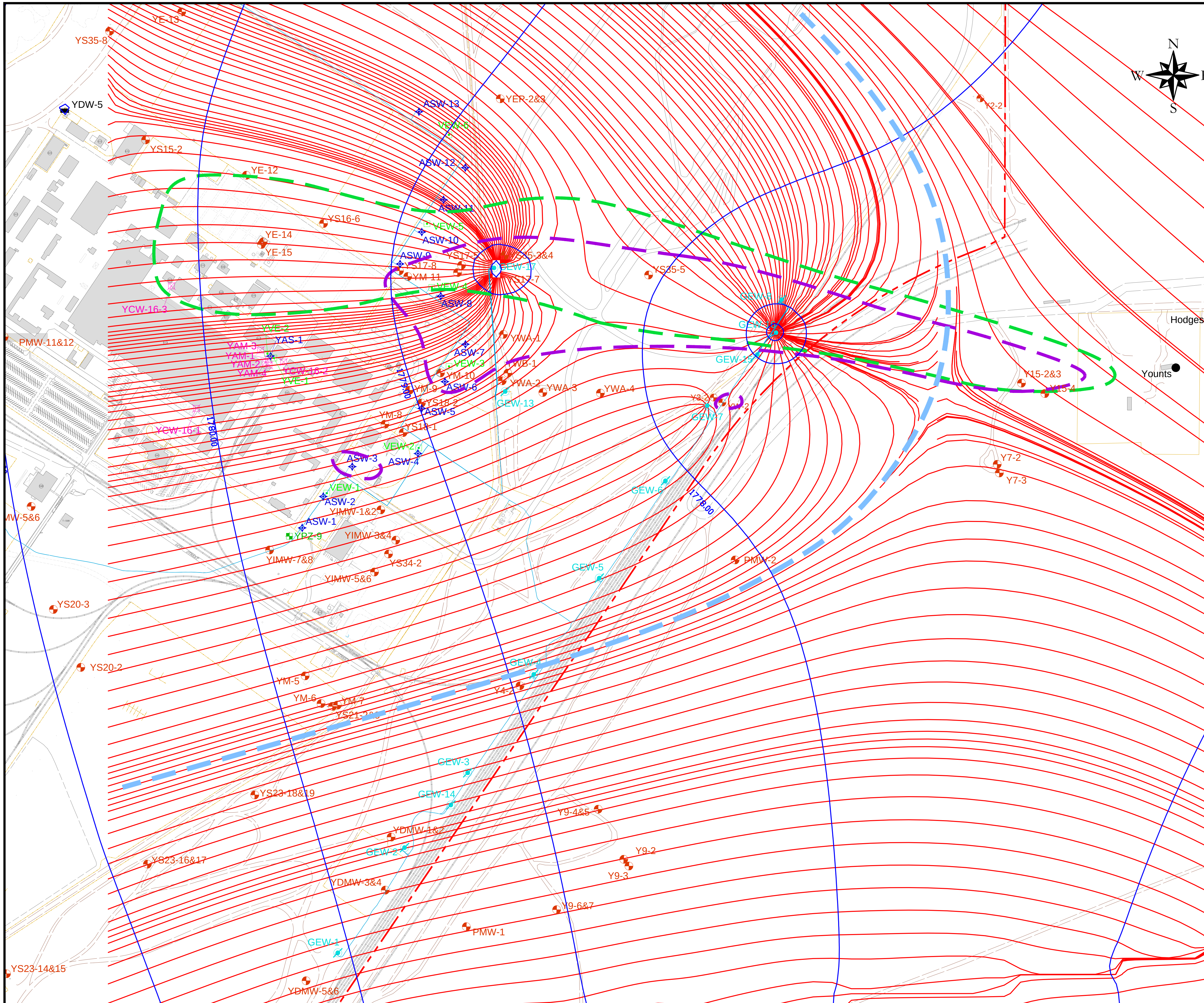
Yermo Annex
Marine Corps Logistics Base
Barstow, California

OTIE
An Oneida Nation Company

Date: June 20, 2017

File: Barstow_5YrRev-2017-Hist.dwg

Plotted By: Elizabeth Vasquez



Legend

- Yermo Annex Boundary
- Y2-2 Groundwater Monitoring Well
- YPZ-2 Piezometer
- YDW-6 Base Groundwater Supply Well
- GEW-16 Groundwater Extraction Well (Active)
- GEW-2 Groundwater Extraction Well (Inactive)
- VEW-1 Vapor Extraction Well
- ASW-1 Air Sparge Well
- YCW16-1 Combination Well
- Younts Domestic Well
- 1789 Model Calculated Groundwater Elevations (ft amsl)
- 5 Approximate TCE Isoconcentration Contour (ug/L)
- 5 Approximate PCE Isoconcentration Contour (ug/L)
- Predicted Particle Pathlines
- Modeled Capture Zone
  - GEW-7 @ 39.5 gpm
  - GEW-16 @ 198.6 gpm
  - GEW-17 @ 145.7 gpm

Notes

1) Groundwater pumping rates used for this model are average rates over the specified dates and do not represent any instantaneous point in time.

Acronyms

ft amsl = feet above mean sea level
gpm = gallons per minute
ug/L = micrograms per liter

Approximate Scale in Feet

0 500 1000

Figure D-1.4
Model Simulated Groundwater Flow and Particle Pathways Upgradient of Plume (June - December 2016)

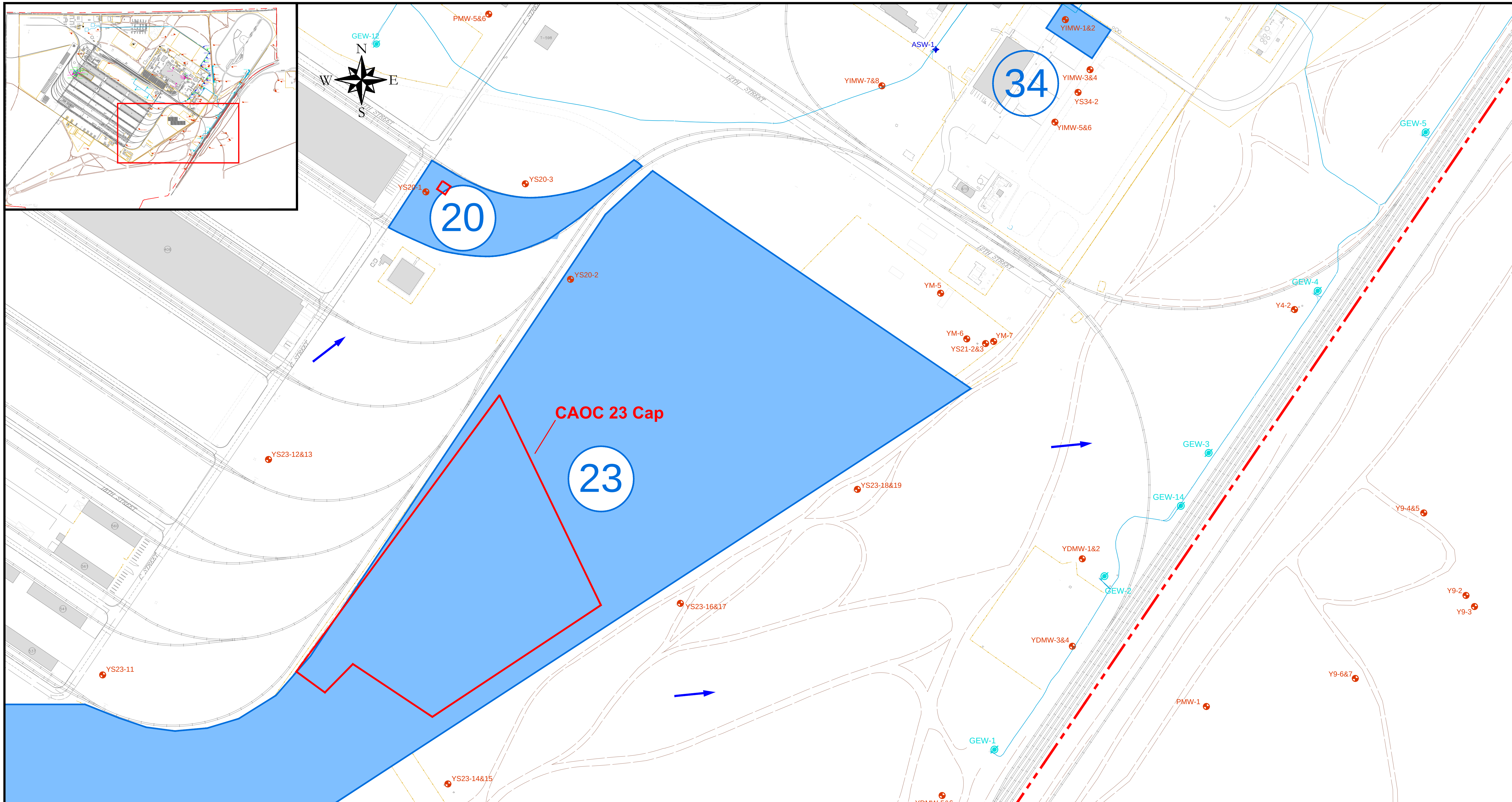
Yermo Annex
Marine Corps Logistics Base
Barstow, California

OTIE An Oneida Nation Company

Date: April 17, 2017

File: Barstow_A16.dwg

Plotted By: Geoff Brink



Legend

- Paved Road
- Dirt Road
- Railroad Tracks
- Fence Line
- Remediation Line
- YS23-11 Groundwater Monitoring Well
- ASW-1 Air Sparge Well
- PZ-A Piezometer
- GEW-1 Groundwater Extraction Well (Inactive)
- Operable Unit 3 (CAOC ##)
- Base Boundary
- Site Boundary
- Groundwater Flow Direction

Notes

1) CAOC - CERCLA Area of Concern
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act

Approximate Scale in Feet

0 300 600

Figure D-1.5
Site Map for CAOC 23 (OU 1
Groundwater Monitoring)

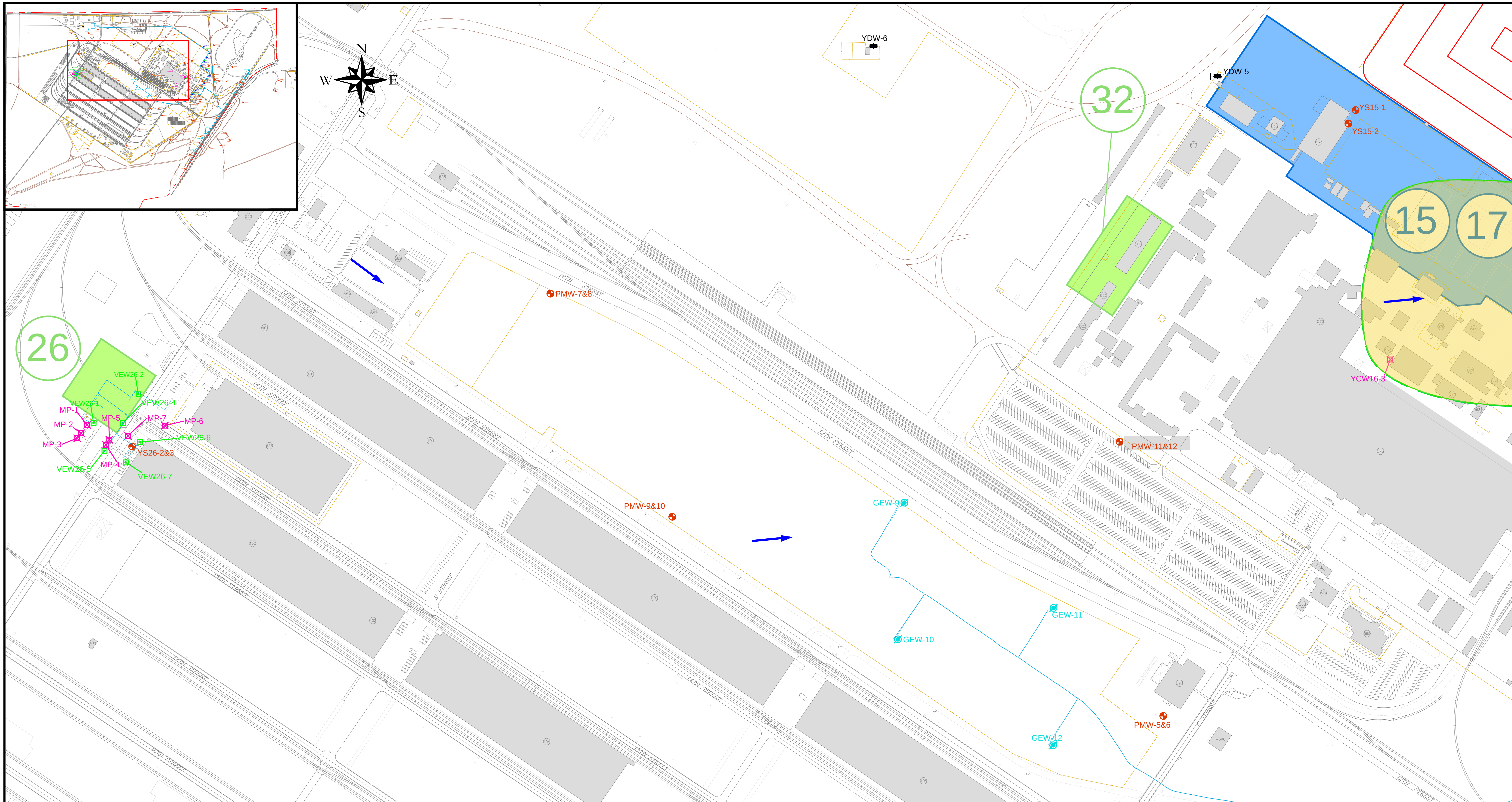
Yermo Annex
Marine Corps Logistics Base
Barstow, California

OTIE
An Oneida Nation Company

Date: May 30, 2017

File: Barstow_5yrRev - 2017.dwg

Plotted By: Geoff Brink



Legend

- Paved Road
- Dirt Road
- Railroad Tracks
- Fence Line
- Remediation Line
- YS23-11 Groundwater Monitoring Well
- YCW16-1 Combination Well
- VEW-1 Vapor Extraction Well
- GEW-9 Groundwater Extraction Well (Inactive)
- Operable Unit 3 (CAOC ##)
- Operable Unit 5 (CAOC ##)
- Approximate OU1 Groundwater VOC Plume
- Groundwater Flow Direction

Notes

1) Analytical results used to delineate the OU 1 (Operable Unit 1) groundwater plume are a combination of wells sampled during the November 2016 event.

2) CAOC - CERCLA Area of Concern
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act

Approximate Scale in Feet

0 300 600

Figure D-1.6
Site Map for CAOC 26
(OU 1 Groundwater Remedy)

Yermo Annex
Marine Corps Logistics Base
Barstow, California

OTIE
An Oneida Nation Company

Date: May 30, 2017

File: Barstow_5yrRev - 2017.dwg

Plotted By: Geoff Brink

GRAPHS

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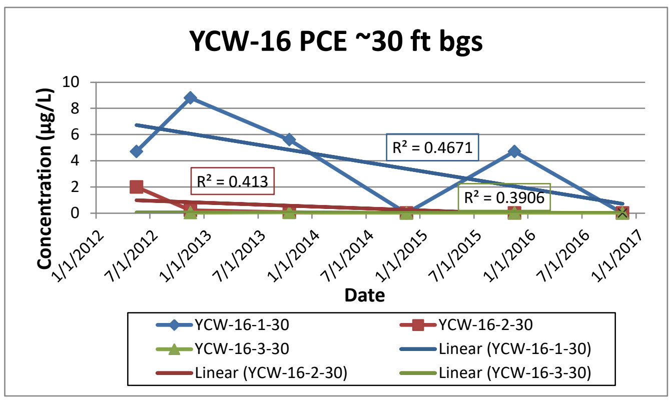
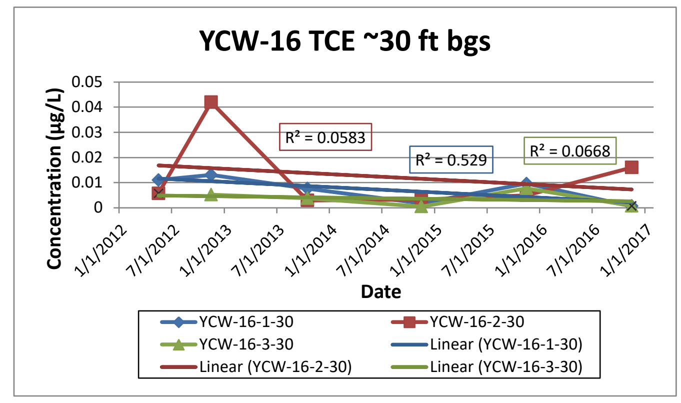
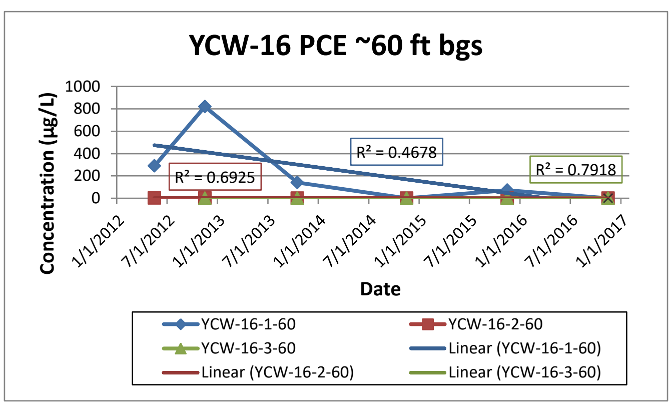
Appendix D - OU 1 Remedy Evaluation
GRAPH D-1.11
CAOC 16 Soil Vapor PCE, TCE Trends over Time
at Monitoring Wells YCW-16-1, YCW-16-2, YCW-16-3

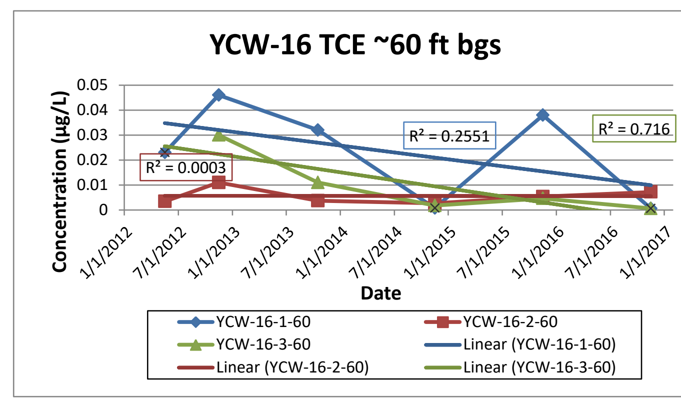
PCE

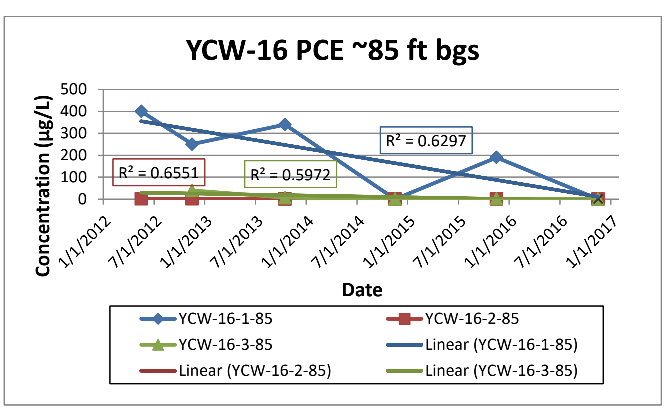
TCE

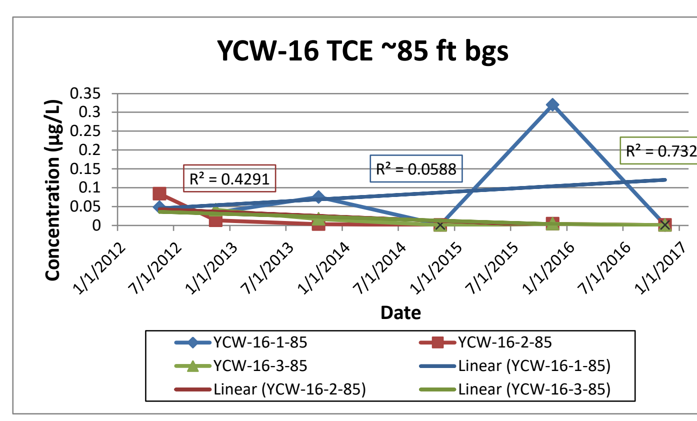


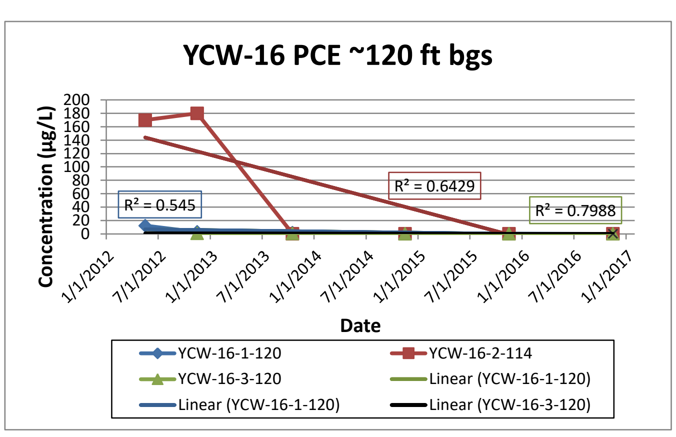


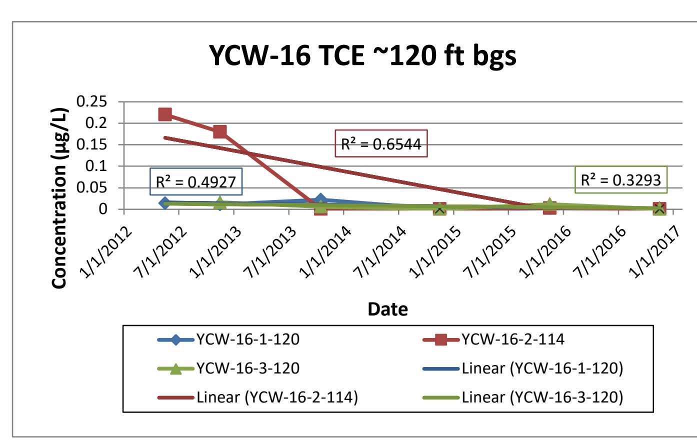


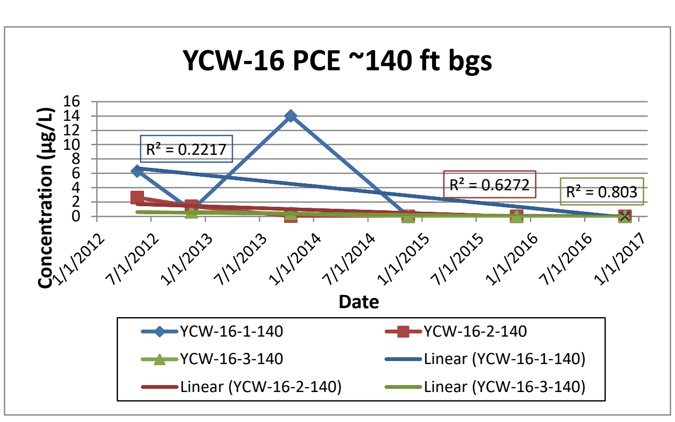


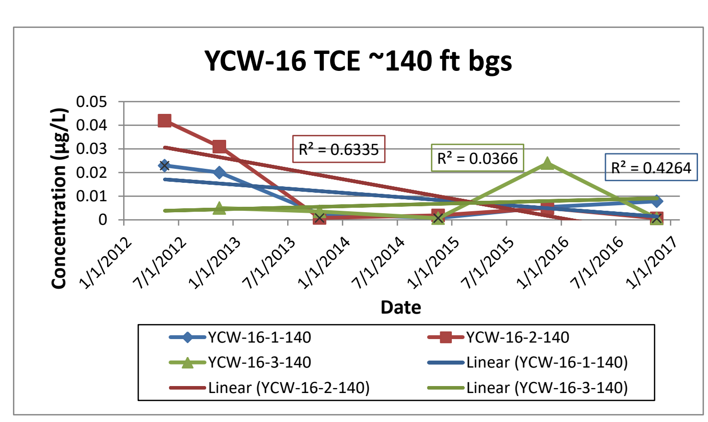












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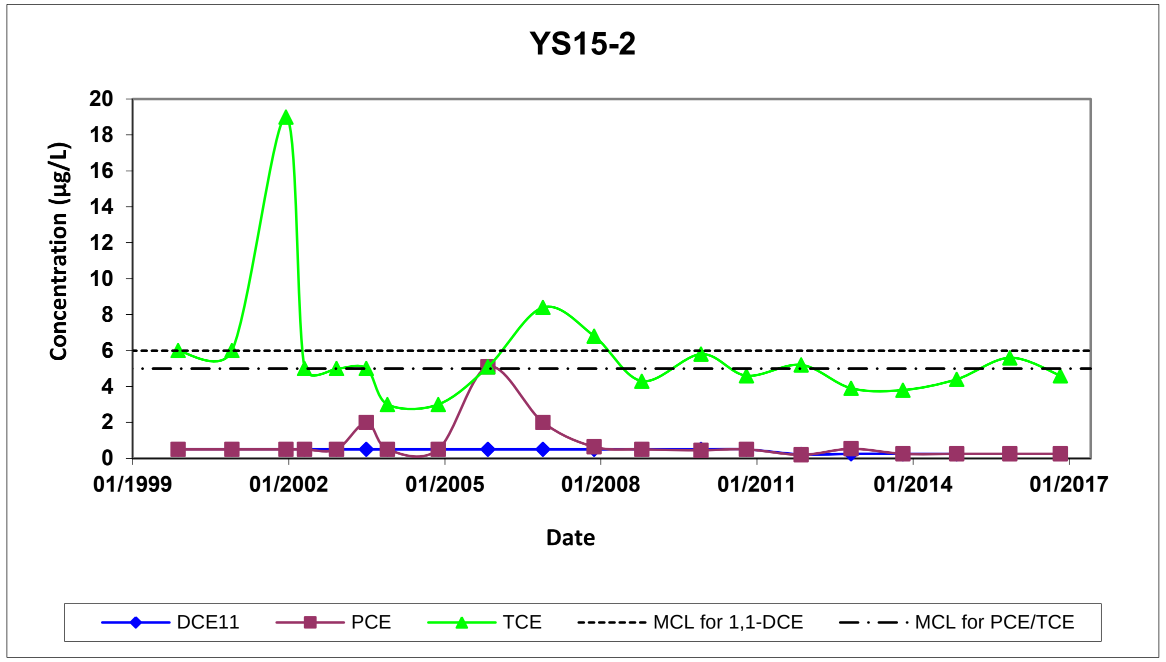
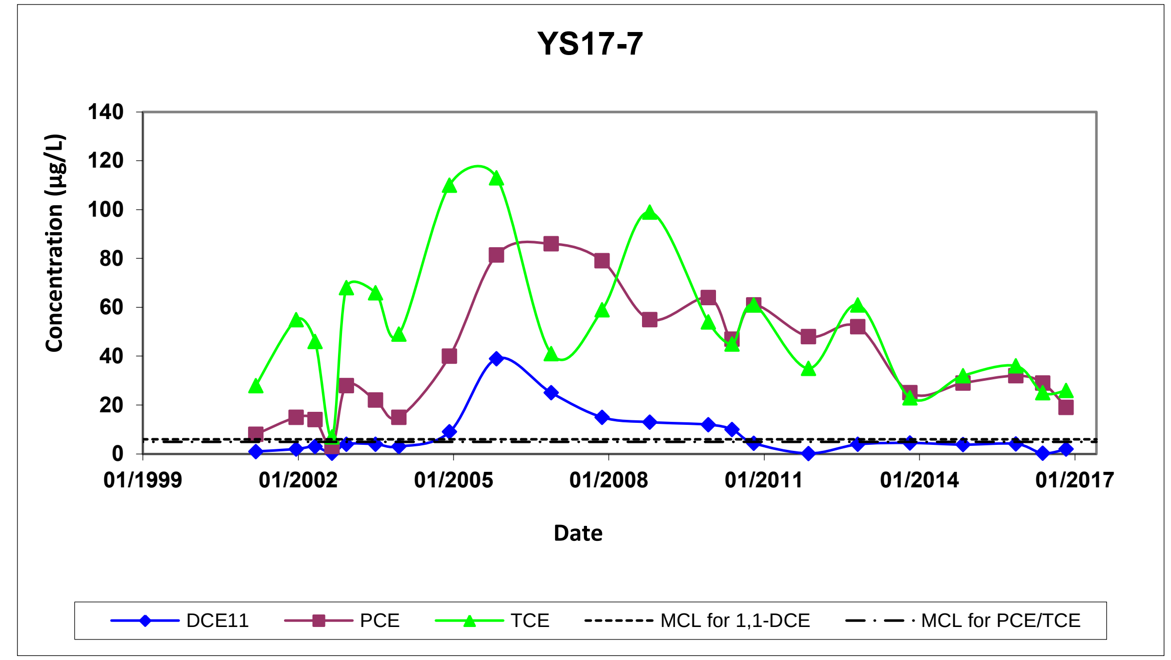
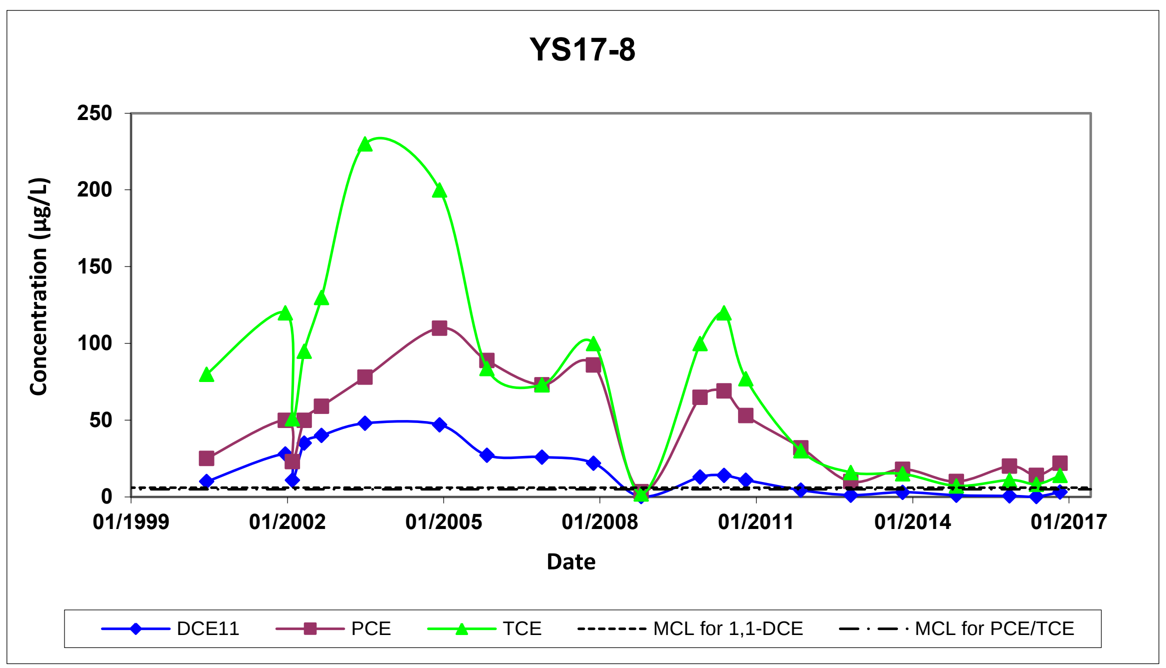
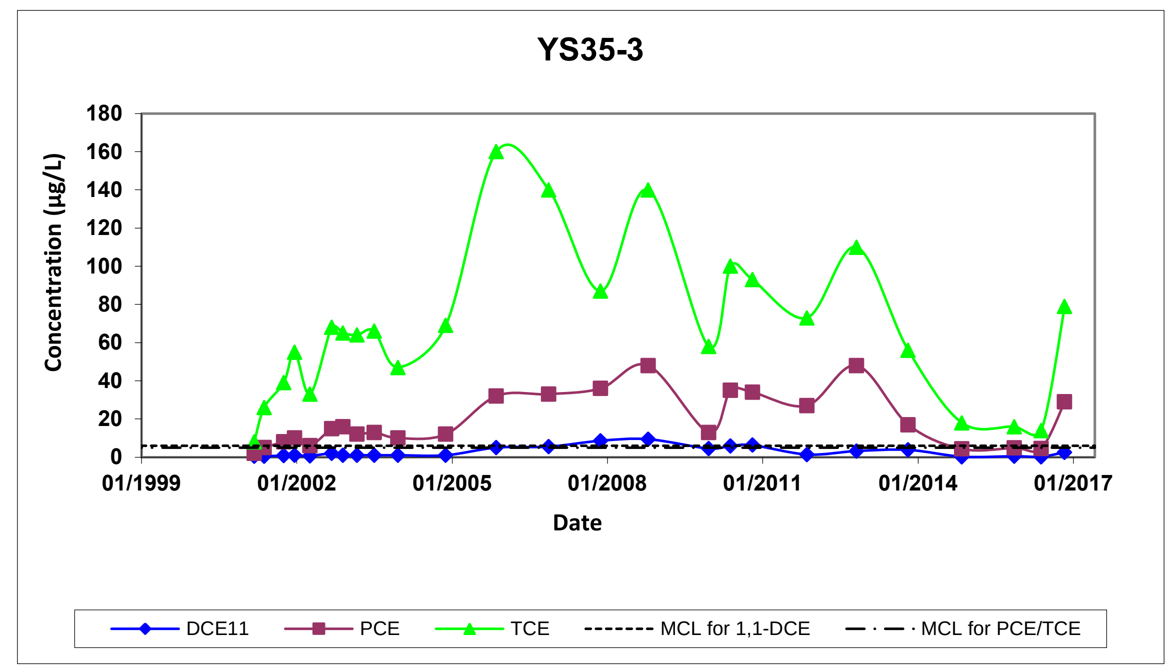
Graph D-1.12
Data Trends in Key Downgradient Monitoring Wells for CAOCs 15/17, 16 and 35
Yermo Annex, MCLB Barstow, CA









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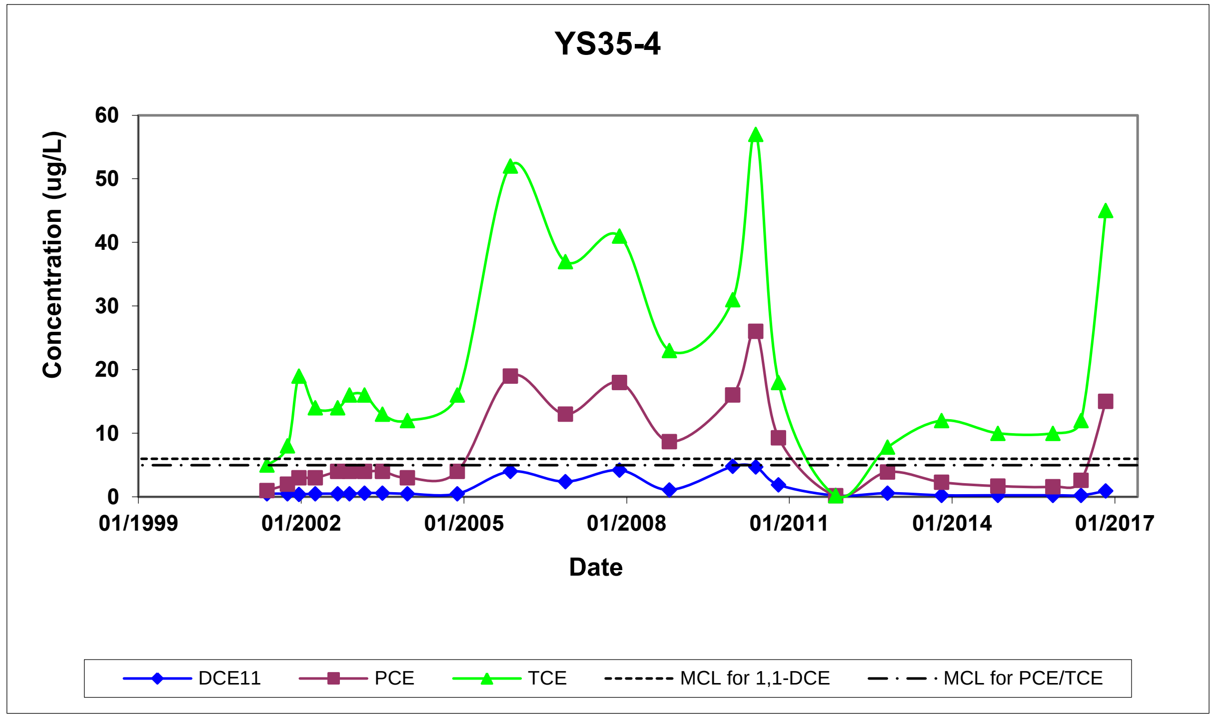
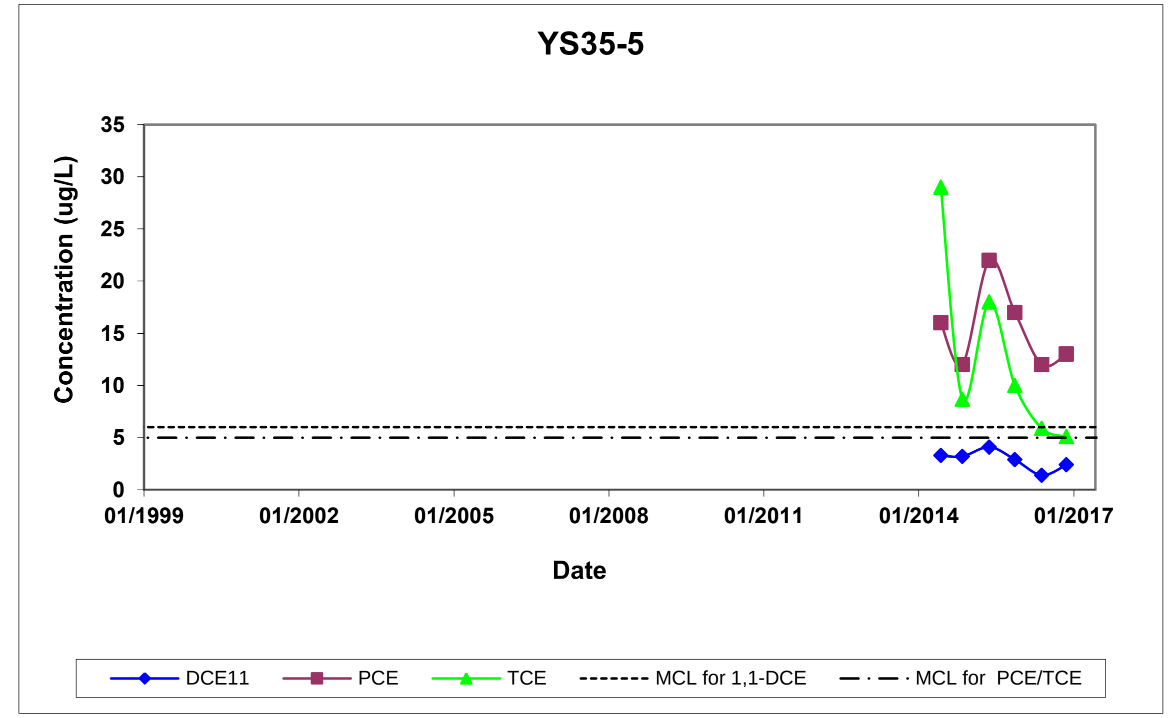
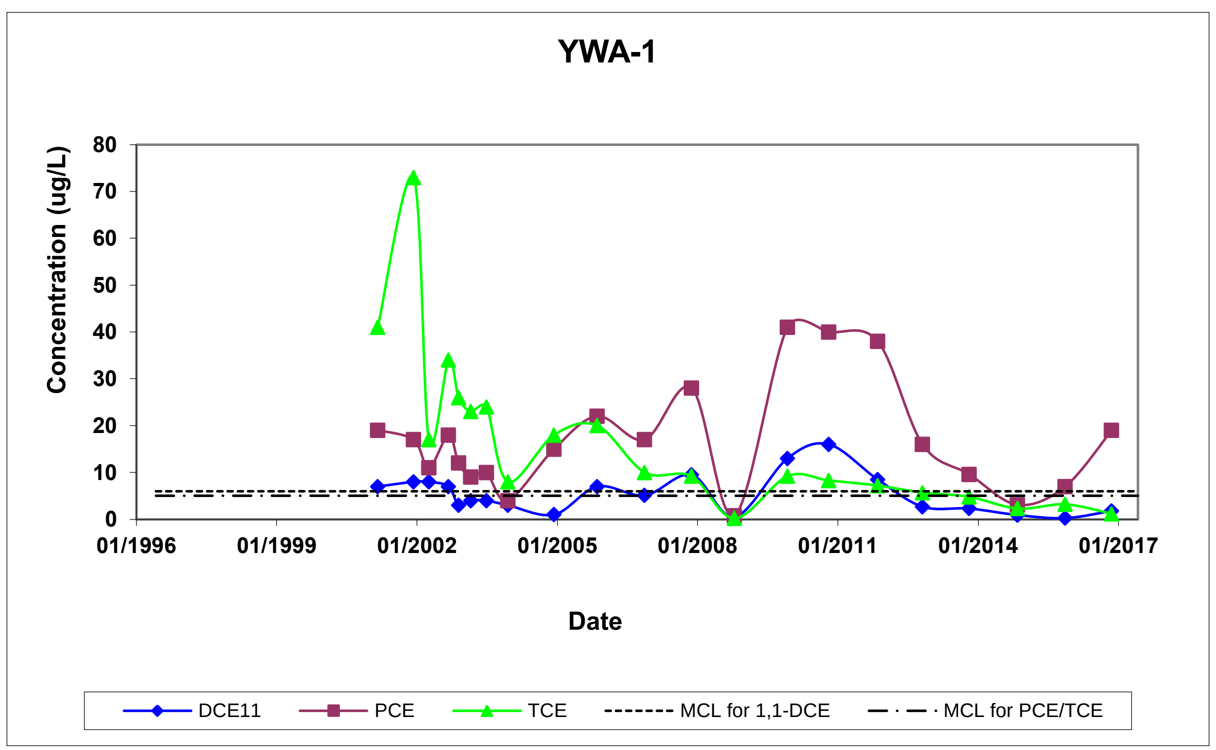
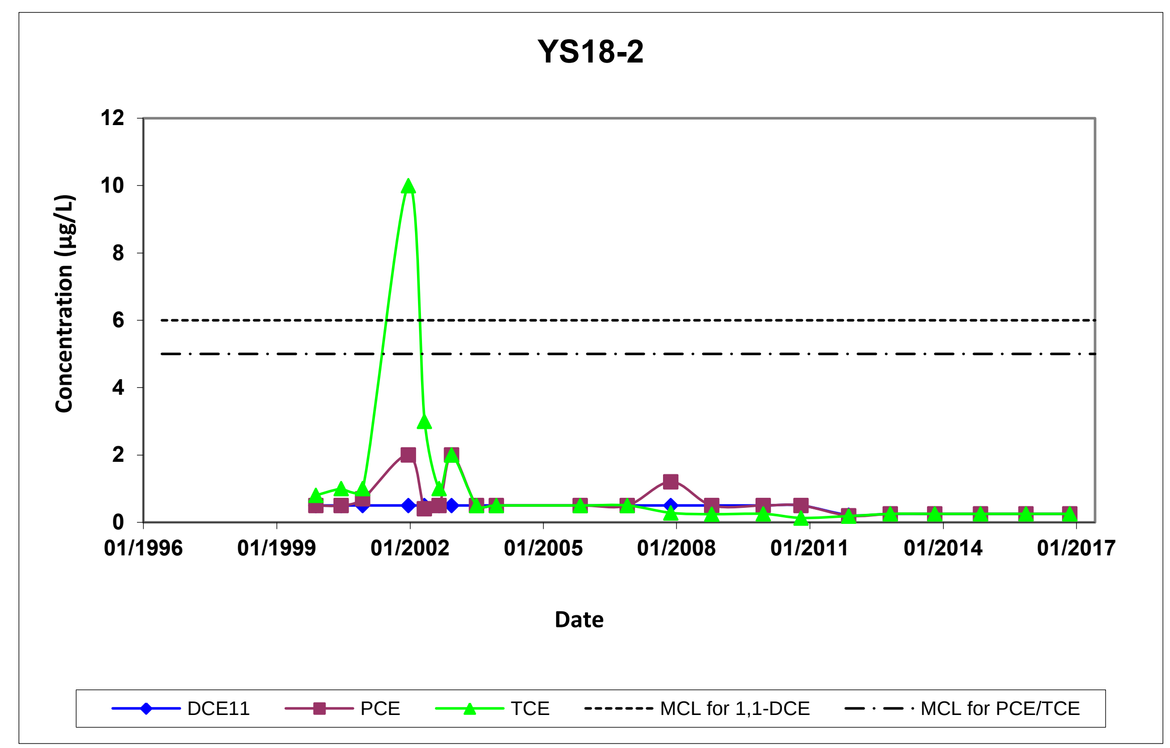
Yermo Annex, MCLB Barstow, CA



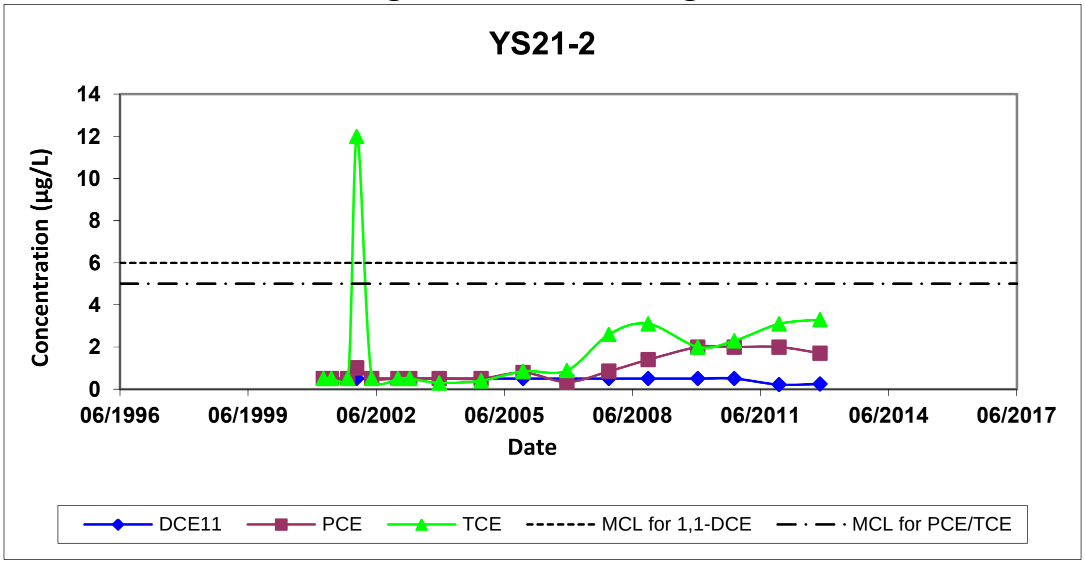


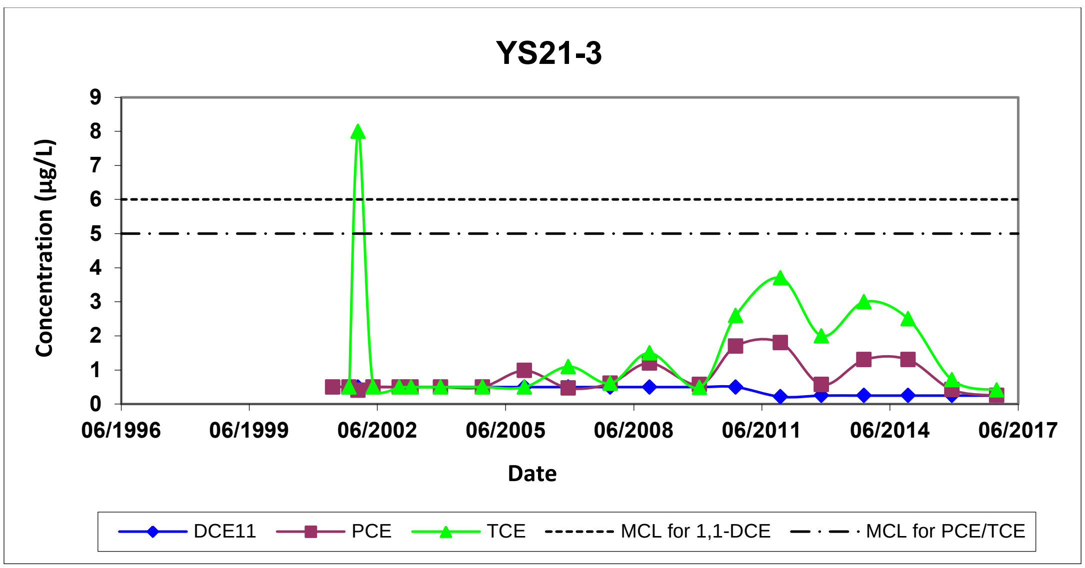


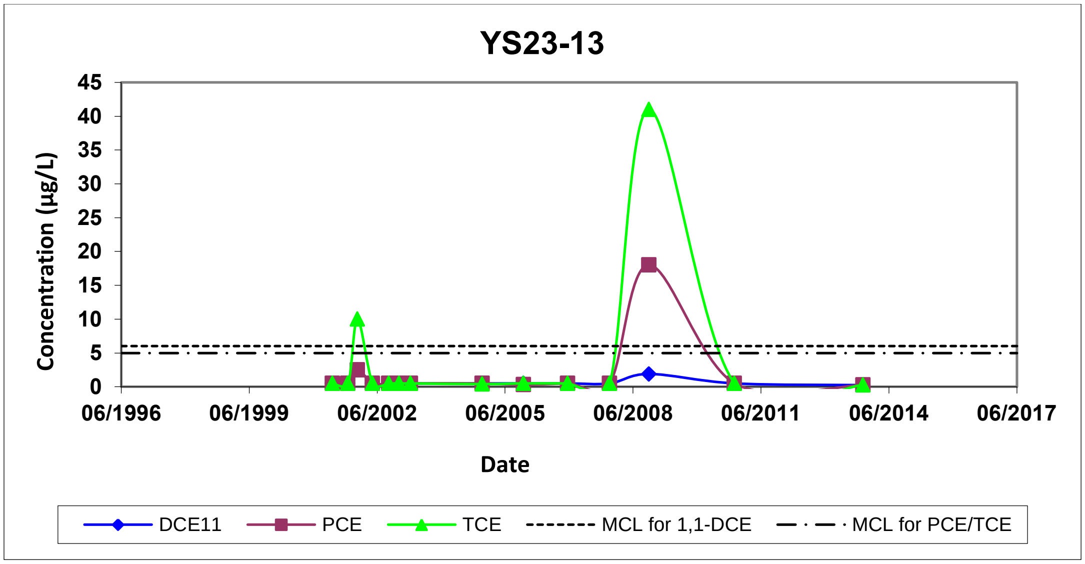


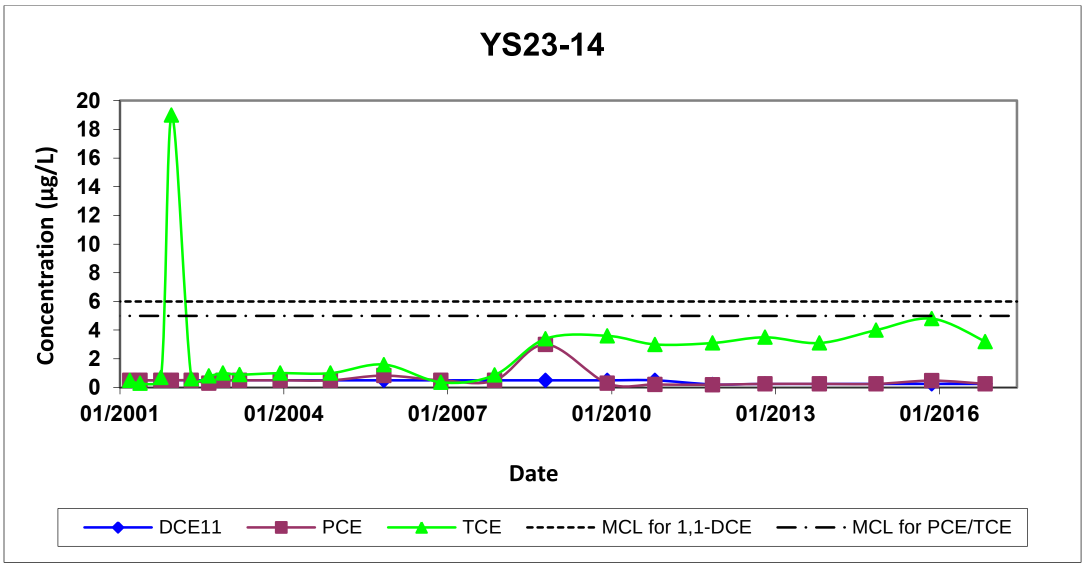
Graph D-1.13
CAOC 23 Groundwater COC Trends
Yermo Annex, MCLB Barstow, California

Downgradient Monitoring Wells






YS23-13
Concentration (µg/L)
45
40
35
30
25
20
15
10
5
0
06/1996
06/1999
06/2002
06/2005
06/2008
06/2011
06/2014
06/2017
Date
DCE11
PCE
TCE
MCL for 1,1-DCE
MCL for PCE/TCE


YS23-14
Concentration (µg/L)
20
18
16
14
12
10
8
6
4
2
0
01/2001
01/2004
01/2007
01/2010
01/2013
01/2016
Date
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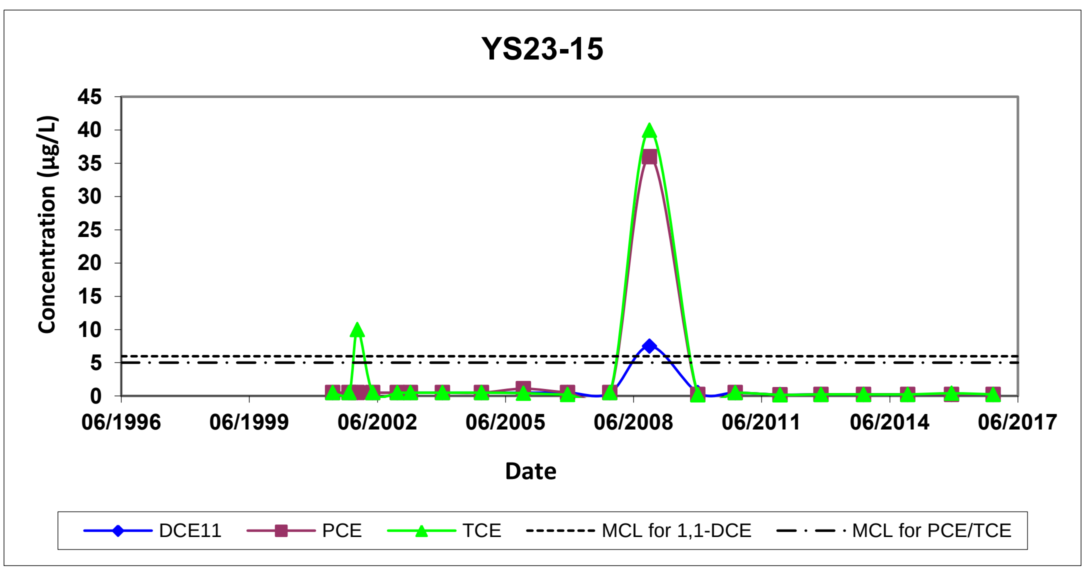
MCL for PCE/TCE


YS23-15
Concentration (µg/L)
45
40
35
30
25
20
15
10
5
0
06/1996
06/1999
06/2002
06/2005
06/2008
06/2011
06/2014
06/2017
Date
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PCE
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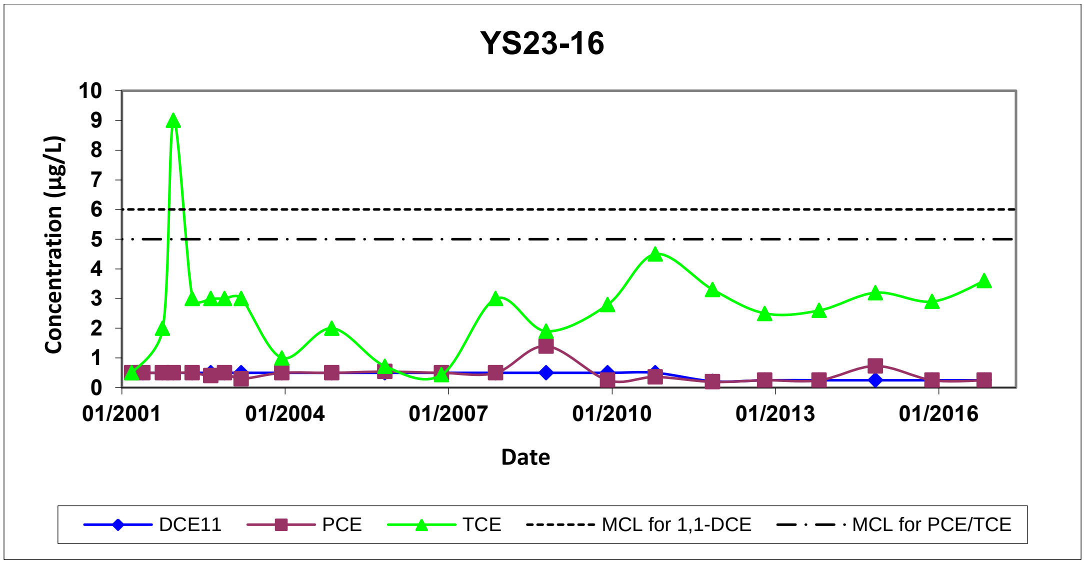
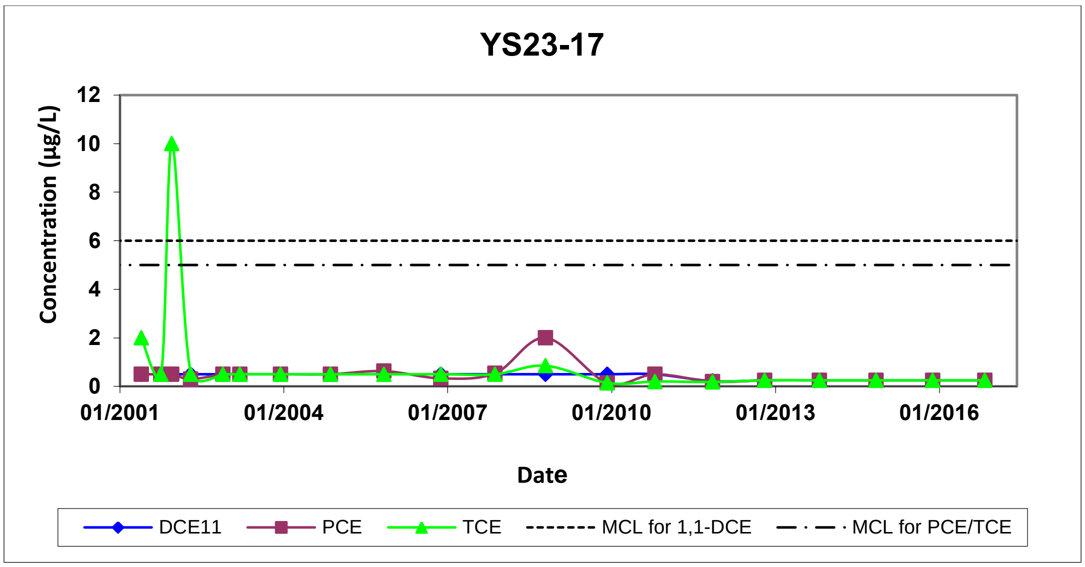
MCL for 1,1-DCE
MCL for PCE/TCE


YS23-16
Concentration (µg/L)
10
9
8
7
6
5
4
3
2
1
0
01/2001
01/2004
01/2007
01/2010
01/2013
01/2016
Date
DCE11
PCE
TCE
MCL for 1,1-DCE
MCL for PCE/TCE


YS23-17
Concentration (µg/L)
12
10
8
6
4
2
0
01/2001
01/2004
01/2007
01/2010
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01/2016
Date
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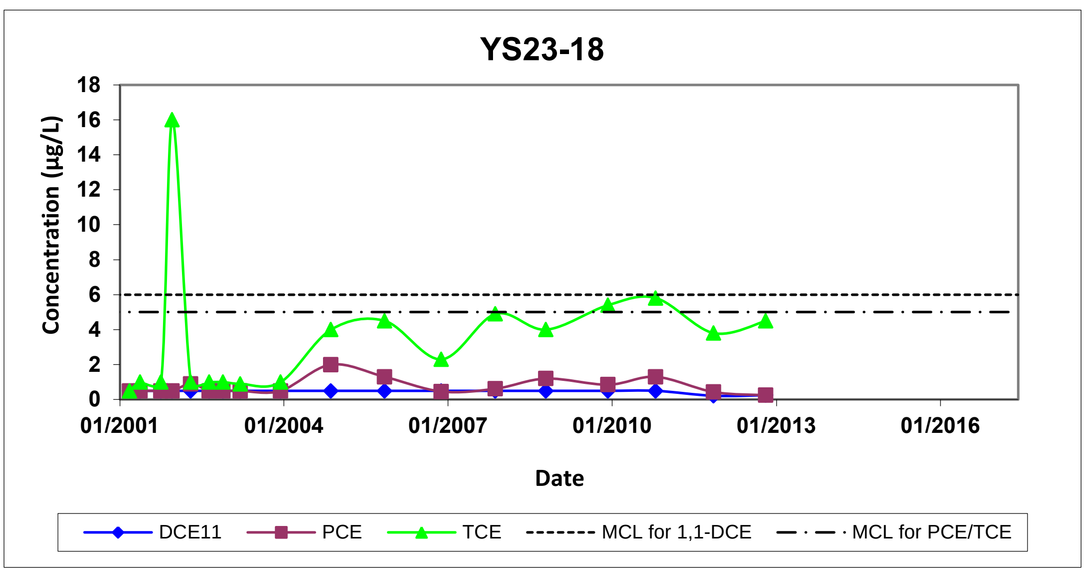
MCL for 1,1-DCE
MCL for PCE/TCE


YS23-18
Concentration (µg/L)
18
16
14
12
10
8
6
4
2
0
01/2001
01/2004
01/2007
01/2010
01/2013
01/2016
Date
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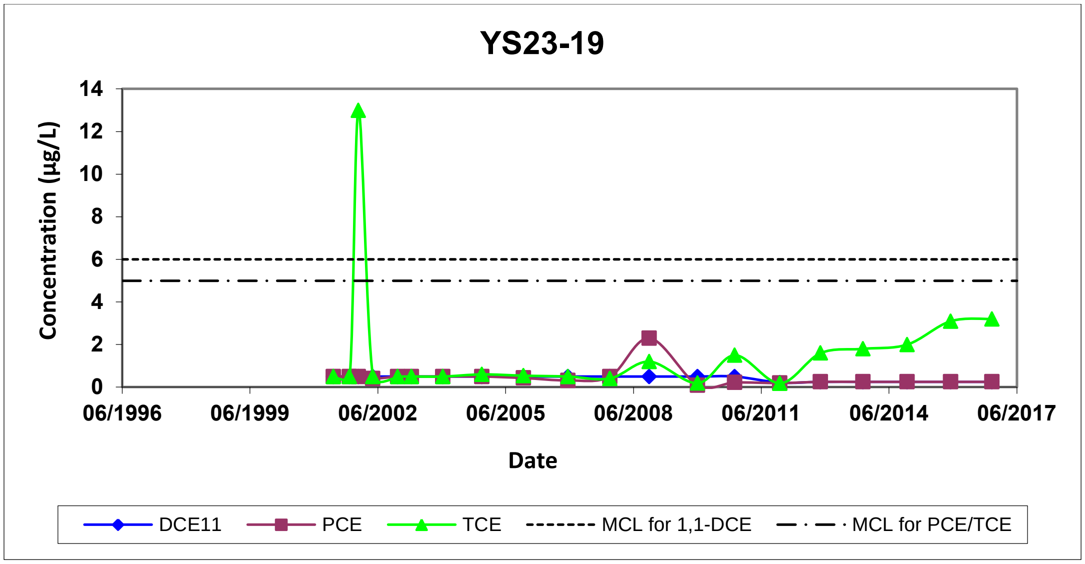
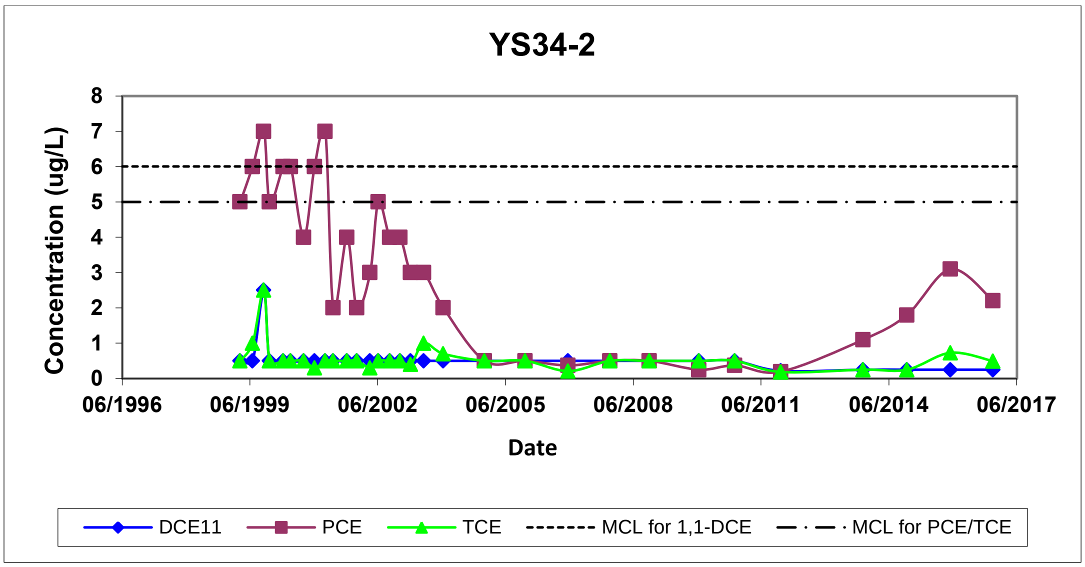
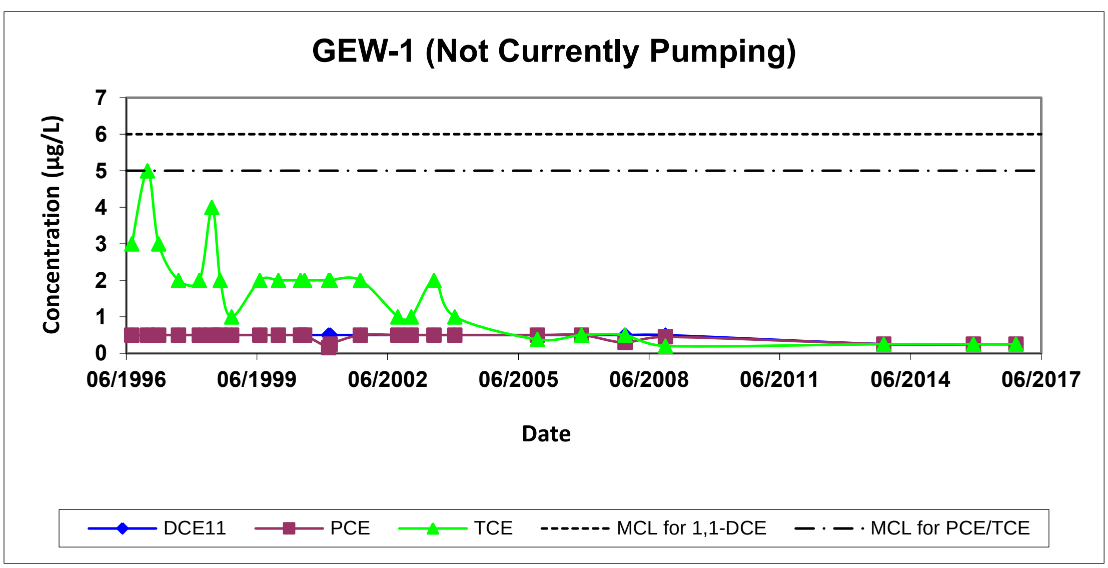
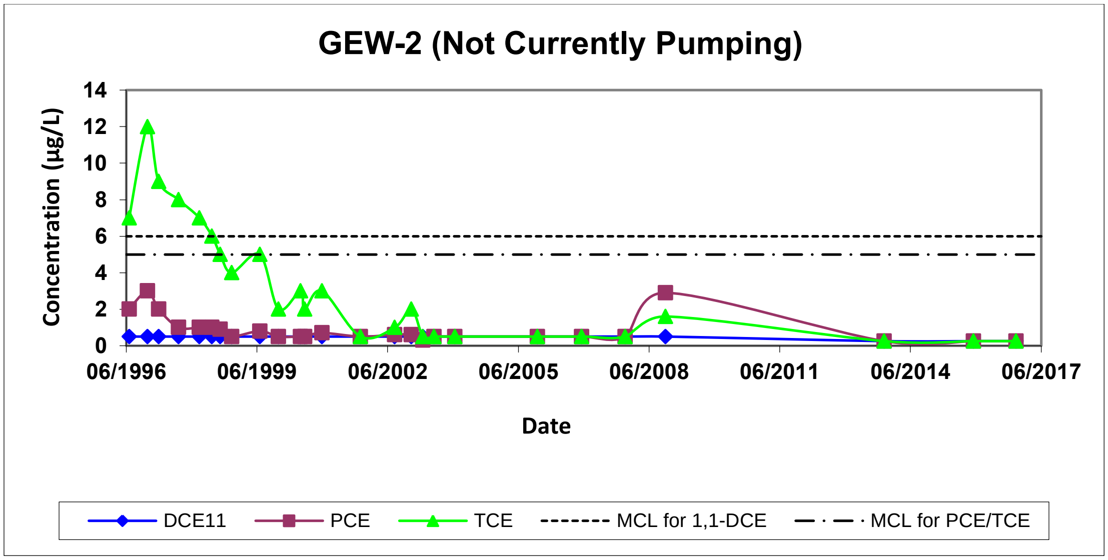
TCE
MCL for 1,1-DCE
MCL for PCE/TCE

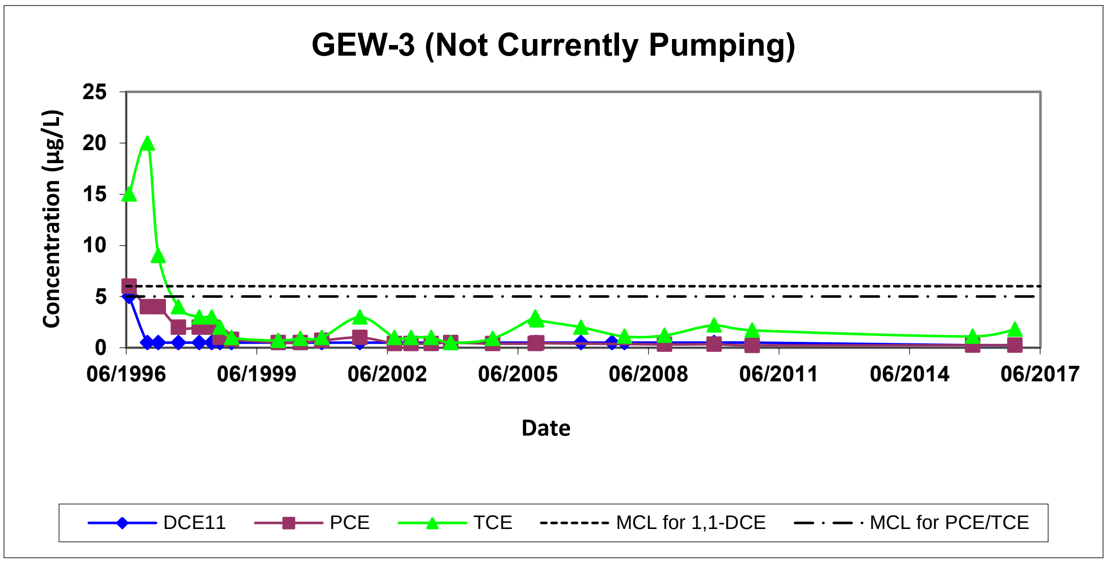




Yermo East Boundary Monitoring Wells




GEW-2 (Not Currently Pumping)
Concentration (µg/L)
0
2
4
6
8
10
12
14
06/1996
06/1999
06/2002
06/2005
06/2008
06/2011
06/2014
06/2017
Date
DCE11
PCE
TCE
MCL for 1,1-DCE
MCL for PCE/TCE


GEW-3 (Not Currently Pumping)
Concentration (µg/L)
0
5
10
15
20
25
06/1996
06/1999
06/2002
06/2005
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06/2014
06/2017
Date
DCE11
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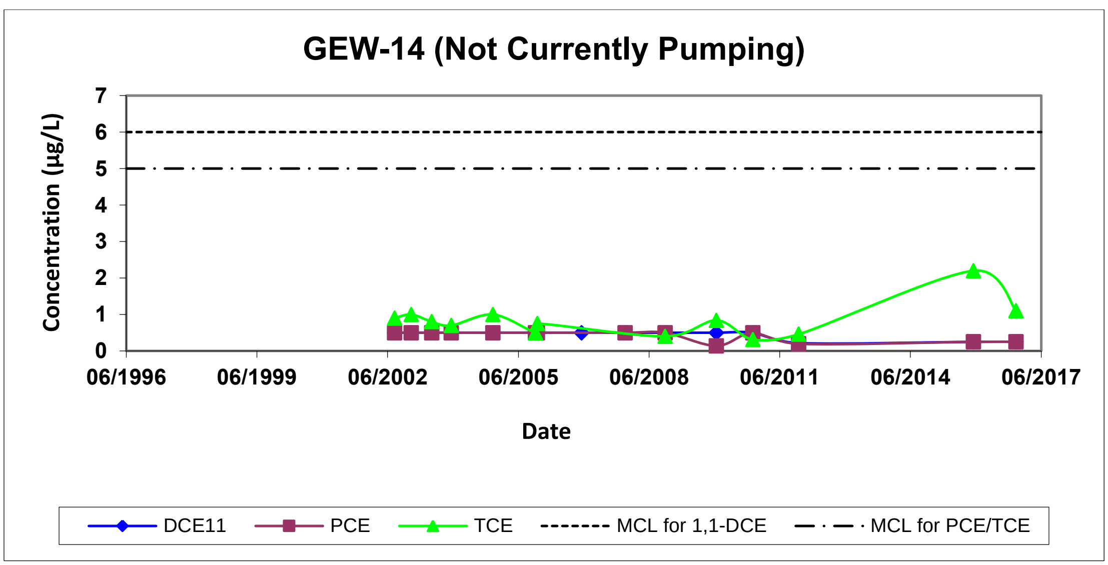
MCL for PCE/TCE


GEW-14 (Not Currently Pumping)
Concentration (µg/L)
0
1
2
3
4
5
6
7
06/1996
06/1999
06/2002
06/2005
06/2008
06/2011
06/2014
06/2017
Date
DCE11
PCE
TCE
MCL for 1,1-DCE
MCL for PCE/TCE

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APPENDIX D-2

Technical Assessment Report – OUs 1 and 2

Remedial Actions Operations, Maintenance, Repairs,

Electrical Costs 2013 - 2017

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APPENDIX D

D-2 Technical Assessment Report
OUs 1 and 2 Remedial Systems O&M Cost Review

The remedial systems that were operational during the Fourth Five-Year Review period (2012 – 2017) included:

- Yermo Annex Groundwater Extraction and Treatment System (GETS), CAOC 16 air sparge/soil vapor extraction (AS/SVE) system, and three landfill caps (CAOC 20, 23, and 35); and
- Nebo Main Base: "Nebo North" AS/SVE system, "Nebo South" AS/SVE system, and CAOC 7 landfill cap.

For a description of the remedial systems and landfill caps please refer to Sections 3.4 and 3.5 of the main text.

The costs reported herein and in Tables 6-2 and 6-3 of the main report were obtained from contractors responsible for operation and maintenance (O&M), monitoring, repair, and upgrades of remedial systems and from the Department of the Navy's (DON's) Remedial Project Manager, Lindsey White, P.E.

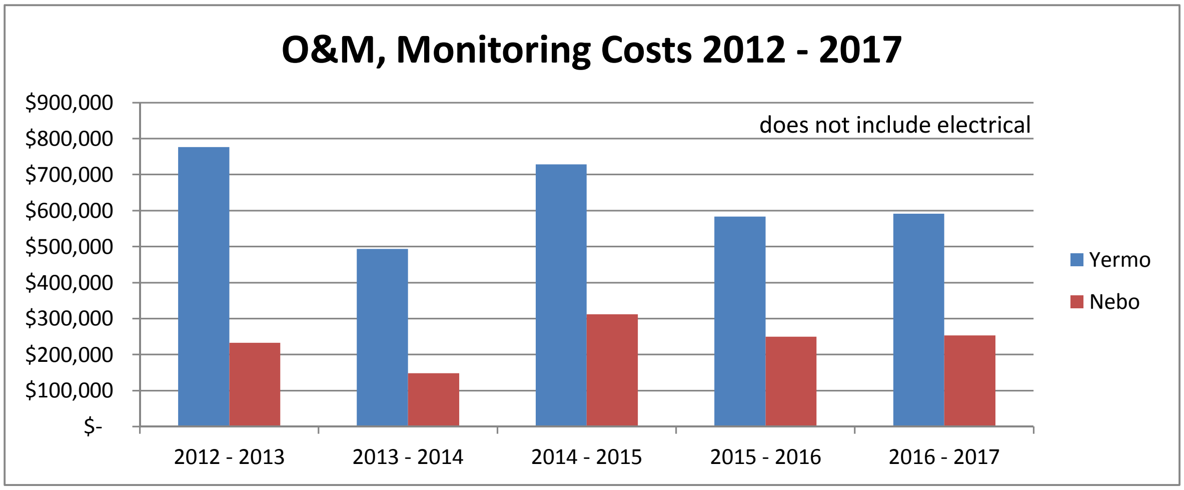
Definitions:

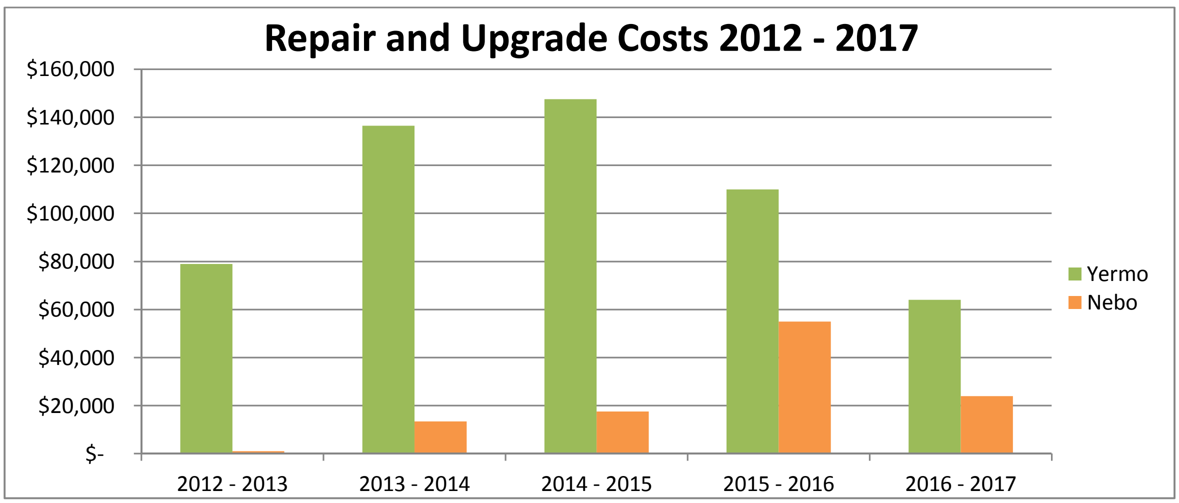
- O&M refers to regular operations and maintenance tasks, including field inspections, trouble-shooting, minor repairs, data collection, and sampling. These tasks are defined in the related remedy O&M Manuals;
- Repairs and Upgrades refers to major remedial system component repairs or replacements (e.g., repair of air compressors/blowers, computer system replacements, worn out part replacements); and
- Electrical costs: The DON's Installation Restoration Program (IRP) pays for the electrical cost of running the OUs 1 and 2 remedial systems.

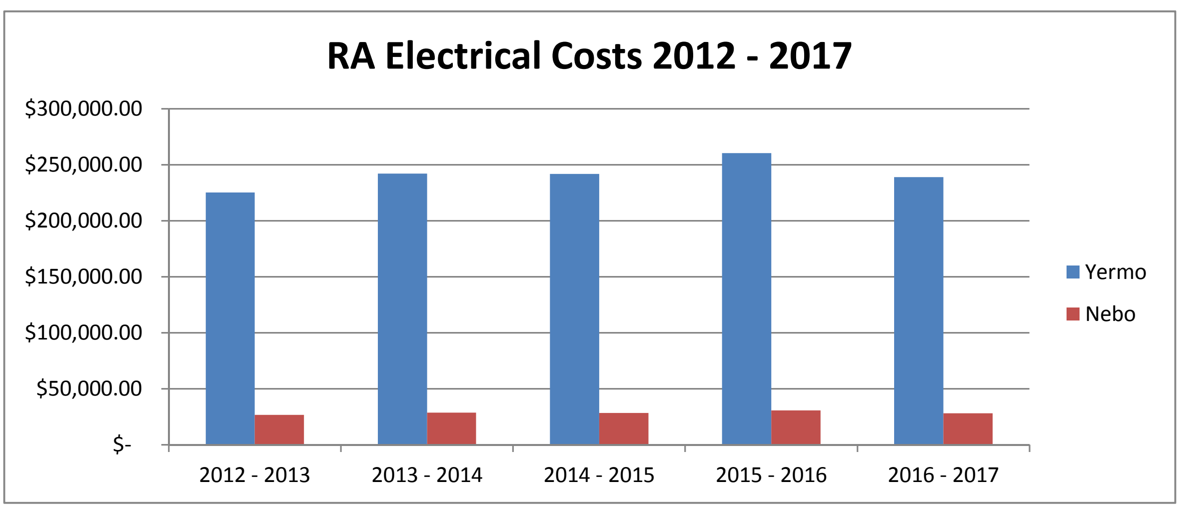
The following page provides a summary table and graphs of trends in costs for the active remedial systems (not including landfills) over the fourth five-year review period by Yermo Annex and Nebo Main Base. The major O&M expense is the Yermo Annex GETS. As reported in the 2016 Annual Groundwater Monitoring Report (OTIE 2017), the GETS is extracting approximately 171 million gallons of groundwater per year.

OU 1 / 2 Remedial Systems

Operation Year	O&M, Monitoring Costs		Repairs & Upgrades		Electrical Costs	
	Yermo	Nebo	Yermo	Nebo	Yermo	Nebo
2012 - 2013	$ 776,532	$ 232,960	$ 79,000	$ 1,000	$ 225,343	$ 26,565
2013 - 2014	$ 493,363	$ 148,009	$ 136,500	$ 13,500	$ 242,244	$ 28,558
2014 - 2015	$ 728,297	$ 312,127	$ 147,500	$ 17,500	$ 242,019	$ 28,531
2015 - 2016	$ 583,089	$ 249,895	$ 110,000	$ 55,000	$ 260,497	$ 30,710
2016 - 2017	$ 591,037	$ 253,302	$ 64,000	$ 24,000	$ 238,977	$ 28,173







APPENDIX D-3

Technical Assessment Report – Evaluation of Nickel and Chromium Groundwater Data - Yermo Annex

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1.0 INTRODUCTION

This technical memorandum was prepared by Oneida Total Integrated Enterprises (OTIE) under contract N39430-16-D-1881, contract task order 0006 in support of the Fourth Five-Year Review.

1.1 PURPOSE AND SCOPE

The purpose of this technical memorandum is to provide data evaluations that will support Navy's resolution of the "*metals question*" posed by the OUs 1 and 2 ROD (DON 1998): are the dissolved metals detected in Yermo Annex groundwater site-related COCs or not, and if they are, should the ROD be amended to incorporate an appropriate remedy? The OUs 1 and 2 ROD (Section 1.4.1 Page 1-4) required groundwater monitoring data to address the question. The ROD specifically states:

> *"Sample groundwater quarterly for 1 year for five dissolved metals (nickel, chromium, antimony, thallium and aluminum) at selected wells in the area of CAOC 16 to ascertain if these metals are naturally occurring or the result of Base activities."*

To date, monitoring for dissolved metals at Yermo has been performed since 1998 without resolution of the "*metals question*" due to various data quality issues. These data quality issues have been largely addressed and the Navy believes there are sufficient comparable data now available to perform the necessary metals data evaluations required by the ROD.

This technical memorandum will:

1. Briefly review the history of groundwater monitoring performed to address the metals question, including elimination of antimony, thallium and aluminum from the monitoring program;
2. Evaluate the groundwater chromium and nickel data set; and
3. Present conclusions and recommendations for future monitoring.

2.0 BACKGROUND AND HISTORY

2.1 OUS 1 AND 2 ROD STATEMENTS ON METALS IN GROUNDWATER

OU 1 consists of CAOC 37, which is the groundwater at Yermo Annex. The remedy for OU 1 was established in the OUs 1 and 2 ROD signed in 1998. The ROD primarily addressed identified groundwater VOC plumes and groundwater monitoring for landfill/capped disposal site remedies under other RODs. In addition, the OU 1 and 2 ROD required monitoring to determine if dissolved metals, particularly chromium and nickel, are site-related contaminants in the CAOC 16 area.

The OUs 1 and 2 ROD sections describing the "*metals question*" are presented below

ROD Section 3.1.1.2 Inorganics (page 3-2).

> Various metal analytes are present in groundwater throughout the Yermo Annex. These analytes are typically present in all natural waters in various Amounts depending on geologic setting, contact time between the water and mineral-rich sediments or bedrock, and other factors.
>
> Most of the metal analytes detected in groundwater at the Yermo Annex, including common ions such as calcium, iron, magnesium, potassium, and sodium, exhibit concentration distributions that can be explained simply as natural variations due to heterogeneity of the subsurface environment.

> Two metal analytes, nickel and chromium, were found to exceed MCLs and to be elevated relative to their statistically defined background levels in several wells near the highly industrial operations at Building 573 on the northern section of the Yermo Annex (i.e., wells YS34 1, YS35-1, YEP-1, YS16-4, and YS16-5). Three other metal analytes, antimony, thallium and aluminum, were also detected in this area at slightly elevated levels relative to their background concentrations. However, an evaluation of the spatial and temporal distributions for these metals indicates that similarly elevated levels were also detected in other on- and off-Base areas (e.g., Well Y8-1) not associated with industrial activities.
>
> In addition to spatial variation, large temporal variations in the concentrations of these metals throughout 4 years of sampling suggest that turbidity or sampling techniques may have also been a factor in the higher reported concentrations. Turbidity during sampling has been an ongoing issue due to the nature of the interbedded sands, silts, and clays in the alluvial aquifers at MCLB Barstow. Changes in iron concentrations from each sampling event (an indicator of Sample turbidity) correlate closely to nickel and chromium concentrations in the suspected wells. All five wells around Building 573 reported their highest iron and chromium concentrations, and three of the five wells exhibited their highest nickel concentrations, during the same January 1994 sampling event. The RI yielded inconclusive answers to the questions of whether the concentrations of these five metals are naturally occurring or the result of Base activities. To resolve this issue, the Marine Corps and regulatory agencies have agreed to measure the concentrations of these five metals in a few selected groundwater monitoring wells for a minimum of four additional quarters (1-year). MCLB Barstow has agreed to amend this ROD to address cleanup options if metals are determined to be a problem after this additional sampling.

ROD Section 3.6.3 Groundwater and Vadose Zone Monitoring (page 3-34), states:

> As discussed in Section 3.1.1.2, groundwater monitoring will be conducted to measure the concentrations of five metals (nickel, chromium, antimony, thallium and aluminum) in a few selected groundwater monitoring wells in the area of CAOC 16 for a minimum of four additional quarters (1-year). The exact wells to be sampled and the sampling schedule will be specified in the Remedial Action Groundwater Monitoring Plan for the Yermo Annex. Data will be provided to the agencies in the Quarterly Groundwater Monitoring Report for the Yermo Annex. The conclusions and recommendations resulting from this sampling will be submitted to the agencies in a primary FFA document.

2.2 MONITORING HISTORY AND FIVE-YEAR REVIEWS RECOMMENDATIONS

The Long-Term Monitoring (LTM) plan for the MCLB Barstow (Jacobs Engineering Group [JEG] 1998) provided the following data quality objective (DQO) for the “*metals question*”.

> **Decision:** Does a statistical comparison of upgradient and downgradient monitoring data in conjunction with an evaluation of other pertinent data indicate that detected metals are likely site related?
>
> **Decision Rule:** If evaluation indicates that groundwater quality has been degraded at concentrations statistically above groundwater cleanup standards, then evaluate need for additional remedial response.

The First Five-Year Review (DON 2002) found that inadequate data were available to establish background levels for metals in groundwater at Yermo Annex. Continued monitoring of chromium and nickel and no further monitoring of aluminum, thallium, and antimony was recommended. The review also recommended additional sampling to establish background chromium and nickel in groundwater.

- Chromium and nickel monitoring continued after 2002 and several wells were added to the on-going monitoring program for the purpose of establishing background concentrations; and
- Despite the recommendation of no further monitoring for aluminum, thallium, and antimony, monitoring of these metals continued until 2010 (*see* Section 1.5 for further information).

The Second Five-Year Review (DON, 2007) determined that sufficient data had been conducted between 2003 and 2007 to evaluate background chromium and nickel. The report concluded analytical results for the wells that were upgradient, cross-gradient, and downgradient of CAOC 16 indicated chromium and nickel concentrations were below the respective MCLs. The report also recommended the DON address the on-going problem of turbidity in the YCW series wells, while continuing to monitor chromium and nickel at these wells. The report recommended a statistical evaluation of chromium and nickel concentrations once relatively stable concentrations were achieved over a period of at least four monitoring events.

- In response to the Second Five-Year Review recommendations, the DON performed a down-hole well video survey of the YCW and other monitoring wells at Yermo in 2007. The survey revealed extensive clogging of well screens by organic flocculent and inorganic mineralization, generally described as "*biofouling*". A strong correlation between elevated chromium and nickel concentrations and elevated turbidity in these wells established that the biofouling was negatively impacting data quality at these sampling locations (TN&A 2008);
- Based on recommendations from the 2009 annual groundwater monitoring report (OTIE 2010e), wells associated with the metals monitoring program were cleaned and redeveloped prior to the *2010 Annual Groundwater Monitoring Event*. Monitoring wells YS20-1, YS20-2, YS17 7, YCW-16-3, YCW-16-2, YCW-16-1, YS34-2 and YS29-2 were physically cleaned and redeveloped until turbidity measurements were below 10 Nephelometric Turbidity Units (NTUs) in the post-development water (OTIE 2010); and
- All metals samples were field filtered before preservation beginning in 2010 to provide a comparable data set.

The Third Five-Year Review (DON 2013) reviewed the 2007 - 2011 monitoring data for chromium and nickel as part of the OU 1 Technical Assessment. The review report concluded that, due to inconsistencies in sampling methods over time (some samples filtered, some not) and biofouling in certain wells (which affected data quality), the chromium and nickel data set generated during the review period was not consistent enough to allow statistical evaluation. Recommendations and follow-up actions were to continue of updated sampling procedures to generate a representative data set for statistical analysis.

Upon review of the monitoring data post 2011, the DON decided that corrosion of the stainless steel well screens had affected the metals data quality, rending it unreliable. Chromium and nickel data from PVC-screened wells were retained in the data set; however, data from monitoring wells downgradient from CAOC 16 and CAOC 20 was insufficient for the analysis. Three PVC wells were installed, as described in Section 2.4.

2.3 Elimination Of Aluminum, Thallium, Antimony As Possible COCs

An evaluation of available aluminum, thallium, and antimony groundwater data for the period of 2006-2010 was performed in 2012 to support optimization of the LTM program. Based on evaluation, the DON concluded that aluminum, antimony, and thallium do not pose a threat to human health and/or the environment; hence these metals were recommended to be eliminated from the *OU 1 Groundwater Monitoring Program* in the *Draft 2012 Sampling and Analysis Plan* for the LTM program (ATJV 2012). The FFA Stakeholders reviewed and concurred with the recommendation (DTSC 2012; RWQCB 2012) and the three metals were removed from the groundwater monitoring program as of the November 2012 Annual Monitoring Event.

2.4 Replacement Monitoring Wells and 2014-2016 Monitoring Data

Despite prior well cleaning efforts in 2010, nickel and chromium remained elevated in YCW16-1, YCW16-2, YCW16-3, PMW-2 and YS20-1; turbidity levels trended upwards indicating return of fouled conditions in these wells. A review of well construction logs found that these monitoring wells were constructed with stainless-steel well screens. Long-term exposure of stainless steel to corrosive conditions (such as microbiologically influenced corrosion) may result in corrosion and the subsequent contamination of groundwater samples by chromium and nickel. The DON decided to replace stainless-steel screened wells with polyvinyl chloride [PVC] screened wells for future metals monitoring efforts.

Wells YS20-3, YS35-5, and YS16-6 were installed during March – April 2014 and were constructed with PVC-screens (OTIE 2015) (Figure D-3.1). Following development, the three new monitoring wells were sampled for chromium and nickel during regularly scheduled monitoring events.

2.5 Groundwater Monitoring Data

2.5.1 Background Cr and Ni Groundwater Data

During routine monitoring events between November 2006 and October 2013, a total of 42 samples were collected from selected monitoring wells to establish Cr and Ni background in groundwater at the Yermo Annex. The monitoring well locations were selected if they were upgradient or side-gradient to CAOCs 16 and/or 20. Additionally, only wells with PVC-well screen construction and with groundwater within the well-screen interval were selected. Of these 42 samples, 19 samples had detected concentrations of total Cr ranging from 0.38 to 8.60 µg/L and 13 samples had detected concentrations of Ni ranging from 0.79 to 18.20 µg/L. These samples were selected as the comparison data set for comparison with data from downgradient of CAOCs 16 and 20. The selected background data are summarized on Table D-3.1.

2.5.2 Cr and Ni in Groundwater Downgradient from Potential Sources CAOCs 16 and 20

Groundwater samples for Cr and Ni were collected from the three new wells during routine sampling events in November 2014, May and November 2015, and May and November 2016. Results are shown on Figure D-3.2. Additionally, historical monitoring data from two other wells (YS35-3 and YS18-2) downgradient of CAOC 16 were added into the downgradient data pool are summarized on Table D-3.1.

3.0 EVALUATION OF CHROMIUM AND NICKEL DATA

3.1 TECHNICAL APPROACH

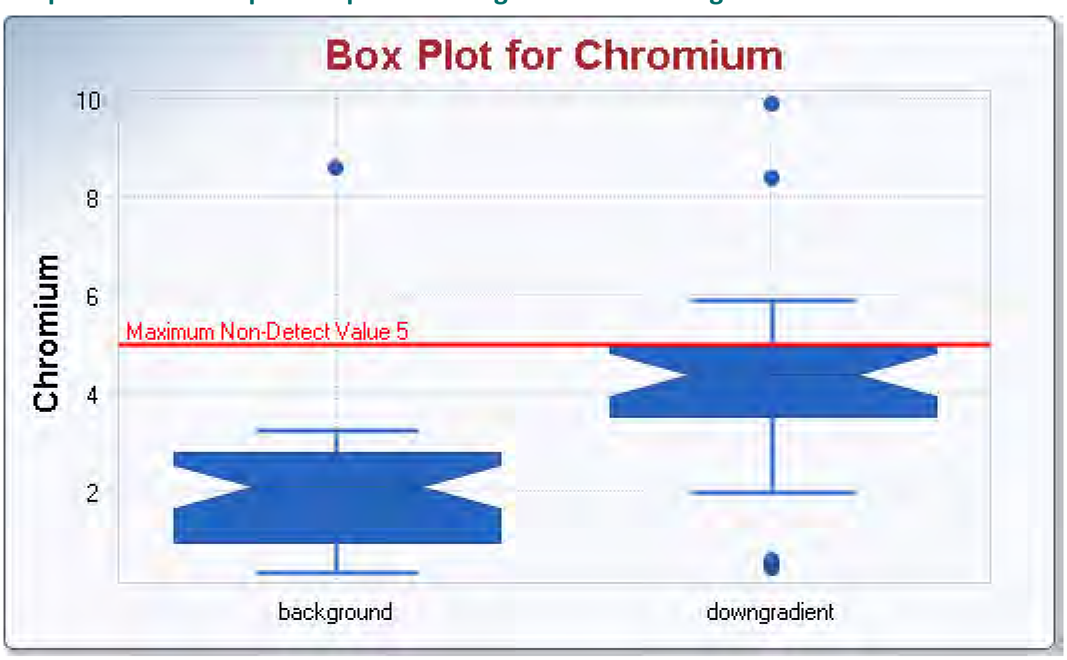
A statistical analysis of the groundwater concentrations of Cr and Ni was conducted following the methods described in EPA (2009). All calculations and graphs were performed using the EPA ProUCL 5.1 software package (EPA 2015).The pooled background and downgradient data were first examined for outliers using box plots and Dixon's formal test for outliers. The downgradient data was then compared to background using a non-parametric two sample hypothesis test, to evaluate whether there was sufficient evidence that the downgradient concentrations were not representative of naturally occurring background. Finally, 95% upper confidence levels (UCLs) of the mean were calculated for downgradient wells to determine if there was sufficient evidence that the site groundwater concentrations exceeded the maximum contaminant levels (MCLs).

Sufficient evidence was found to conclude that the downgradient concentrations of Cr and Ni were significantly higher than naturally occurring background at the 95% confidence level. The 95% UCLs for both Cr and Ni for all downgradient wells were less than the respective MCLs. However, all detected concentrations of Cr were below the current MCL of 50 µg/L and only one occurrence of Ni was above the MCL of 100 µg/L.

3.2 OUTLIER EVALUATION

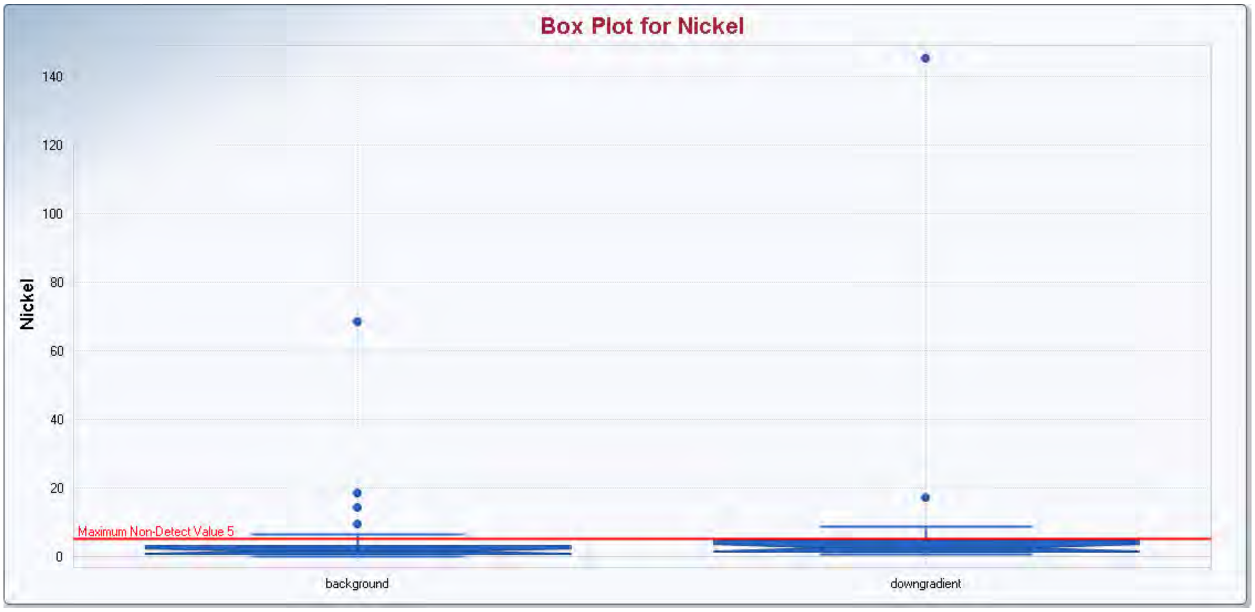
Box plots for Cr suggested that outliers did exist in the background as well as the downgradient datasets (Graph D-1). The boxplot for Cr suggested that the concentration value of 8.6 µg/L from background well PMW-9 was an extreme outlier. The 8.6 µg/L Cr concentration was confirmed to be an outlier at the 1% significance level using Dixon's test for outliers. Because this single value was an extreme outlier from the rest of the background dataset, inclusion of this data point in the analysis would have resulted in an increase chance of false negative errors. Therefore this value was excluded from further analysis.

Graph D-3.1 Box plot for pooled background and downgradient wells for chromium.



The highest downgradient Cr concentration of 9.9 µg/L was reported from a single reporting period for well YS35-4. This result was determined to be an outlier at the 5% significance level, but not at the 1% significance level using Dixon's test for outliers. Because this result was from a potentially impacted downgradient well, it was retained for further analysis.

Graph D-3.2 Box plot for pooled background and downgradient wells for nickel.



Box plots for Ni suggested that outliers did exist in the background as well as the downgradient datasets (Graph D-2). The boxplot for Ni suggested that the concentration value of 68.3 µg/L from background well PMW-9 was an extreme outlier. The 68.3 µg/L Ni concentration was confirmed to be an outlier at the 1% significance level using Dixon's test for outliers. Because this single value was an extreme outlier from the rest of the background dataset, inclusion of this data point in the analysis would have resulted in an increase chance of false negative errors. Therefore this value was excluded from further analysis.

The highest downgradient Ni concentration of 145 µg/L was reported for well YS16-6. This result was determined to be an outlier at the 1% significance level using Dixon's outlier test. Although this result was from a potentially impacted downgradient well, it was inconsistent with other results from the same well during other monitoring periods. Well YS16-6 was sampled 5 times during the period of 2014 to 2016 and the result of 145 µg/L was markedly different from the other analytical results which ranged from 1.22 to 3.61 µg/L. Also there was no apparent trend in concentrations over time and two subsequent results from well YS16-6 were 2.27 and 1.22 µg/L. Therefore this value was excluded for further analysis

3.3 COMPARISON OF DOWNGRADIENT TO BACKGROUND

The downgradient data were then compared to background using a non-parametric two sample hypothesis test, to evaluate whether there was sufficient evidence that the downgradient concentrations were not representative of naturally occurring background. Because the datasets for both Cr and Ni included nondetect values with multiple reporting limits the Gehan (EPA 2015) two sample hypothesis test was used with $\alpha=0.05$. The null hypothesis was that the downgradient concentrations were less than or equal to background. There was sufficient evidence for both Cr and Ni to reject the null hypothesis (Excel Objects D-3.1 and D-3.2, beginning next page). Therefore it is concluded that downgradient groundwater concentrations of Cr and Ni are not consistent with naturally occurring background.

3.4 CALCULATION OF 95% UPPER CONFIDENCE LIMITS FOR INDIVIDUAL DOWNGRADIENT WELLS

The 95% upper confidence level (95UCL) of the mean for Cr and Ni concentrations in the downgradient wells were calculated using ProUCL 5.1 (EPA, 2015) for comparison to the respective maximum contaminant levels (MCLs). The data were first examined to determine whether the data distribution fit a normal distribution. The data for Cr were found to fit a normal distribution at the 5% significance level (Excel Object D-3.3). The data for Ni were found to fit a gamma distribution at the 5% significance level (Excel Object D-3.4). The 95UCLs were calculated for each analyte using the Kaplan-Meier method which takes into account multiple MDLs when calculating these statistics (EPA, 2015). The 95UCL for Cr was calculated to be 4.9 µg/L which is below the MCL of 50 µg/L. The 95UCL for Ni was calculated to be 5.2 µg/L which is below the MCL of 100 µg/L. Additional details on the number of samples, detection limits, and range of concentrations observed is provided in Excel Objects D-3.3 and D-3.4 (after-text).

4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the statistical analysis of the background and downgradient datasets for Cr and Ni, it appears downgradient groundwater concentrations of Cr and Ni are slightly elevated when compared with the on-Base background data. However, the concentrations of Cr and Ni in groundwater downgradient from CAOC 16 are relatively low and below the federal MCLs.

The following recommendations are made:

1. Cease future monitoring of Cr and Ni at the Yermo Annex;
2. Based on the ROD section 3.6.3 requirement, the Navy is to report its findings to the FFA in a primary document. This technical assessment report, appended to the Fourth Five-Year Review (a primary document) fulfills this obligation; and
3. Submit for FFA Stakeholder review and concurrence a "Memorandum to File" clarifying the OUs 1 and 2 ROD on the "metals question" and stating that no further monitoring and no action is required for metals in groundwater at the Yermo Annex.

5.0 REFERENCES

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Excel Object D-1 Gehan Two Sample Hypothesis Test for Chromium Downgradient vs Background.

Gehan Sample 1 vs Sample 2 Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.15/24/2017 9:51:30 AM
From File	Yermo Metals_PUCL_wo1Outlier_052317.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Chromium(downgradient)
Sample 2 Data: Chromium(background)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	25	42
Number of Missing Observations	0	1
Number of Non-Detects	4	22
Number of Detect Data	21	20
Minimum Non-Detect	0.5	0.5
Maximum Non-Detect	5	3
Percent Non-detects	16.00%	52.38%
Minimum Detect	0.412	0.376
Maximum Detect	9.9	3.2
Mean of Detects	4.373	1.778
Median of Detects	4.43	1.75
SD of Detects	2.215	0.88
KM Mean	3.999	1.29
KM SD	2.251	0.878

Sample 1 vs Sample 2 Gehan Test

H0: Mean/Median of Sample 1 <= Mean/Median of background

Gehan z Test Value	5.236
Critical z (0.05)	1.645
P-Value	8.1932E-8

Conclusion with Alpha = 0.05

Reject H0, Conclude Sample 1 > Sample 2

P-Value < alpha (0.05)

Excel Object D-3.2 Gehan Two Sample Hypothesis Test for Nickel Downgradient vs Background

Gehan Sample 1 vs Sample 2 Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.15/23/2017 11:54:35 AM
From File	Yermo Metals_PUCL_wo1Outlier_052317.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Nickel(downgradient)

Sample 2 Data: Nickel(background)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	24	42
Number of Missing Observations	1	1
Number of Non-Detects	6	28
Number of Detect Data	18	14
Minimum Non-Detect	0.952	0.315
Maximum Non-Detect	5	3
Percent Non-detects	25.00%	66.67%
Minimum Detect	0.845	0.479
Maximum Detect	17	18.2
Mean of Detects	3.758	4.899
Median of Detects	2.495	3.155
SD of Detects	3.924	5.365
KM Mean	3.203	1.942
KM SD	3.468	3.653

Sample 1 vs Sample 2 Gehan Test

H0: Mean/Median of Sample 1 <= Mean/Median of background

Gehan z Test Value	2.699
Critical z (0.05)	1.645
P-Value	0.00348

Conclusion with Alpha = 0.05

Reject H0, Conclude Sample 1 > Sample 2

P-Value < alpha (0.05)

Excel Object D-3.3 95% Upper Confidence Level of the Mean for Downgradient Chromium

Normal UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.15/25/2017 10:23:02 AM		
From File	Yermo Metals_PUCL_wo1Outlier_DGrdOnly_052317.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
Chromium (downgradient)			
General Statistics			
Total Number of Observations	24	Number of Distinct Observations	23
Number of Detects	21	Number of Non-Detects	3
Number of Distinct Detects	21	Number of Distinct Non-Detects	3
Minimum Detect	0.412	Minimum Non-Detect	0.5
Maximum Detect	9.9	Maximum Non-Detect	5
Variance Detects	4.907	Percent Non-Detects	12.5%
Mean Detects	4.373	SD Detects	2.215
Median Detects	4.43	CV Detects	0.507
Skewness Detects	0.495	Kurtosis Detects	1.314
Mean of Logged Detects	1.284	SD of Logged Detects	0.762
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.941	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.908	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.156	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.188	Detected Data appear Normal at 5% Significance Level	
Detected Data appear Normal at 5% Significance Level			
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	4.07	KM Variance	0.481
KM SD	2.253	KM Standard Error of Mean	5.076
95% KM (BCA) UCL	4.781	97.5% KM (BCA) UCL	5.072
95% KM (t) UCL	4.894	95% KM (Percentile Bootstrap) UCL	4.831
95% KM (z) UCL	4.86	95% KM Bootstrap t UCL	4.959
90% KM Chebyshev UCL	5.512	95% KM Chebyshev UCL	6.165
97.5% KM Chebyshev UCL	7.072	99% KM Chebyshev UCL	8.854
Suggested UCL to Use			
95% KM (t) UCL	4.894		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			

Excel Object D-3.4 95% Upper Confidence Level of the Mean for Downgradient Nickel

Gamma UCL Statistics for Data Sets with Non-Detects			
User Selected Options			
Date/Time of Computation	ProUCL 5.15/25/2017 10:27:28 AM		
From File	Yermo Metals_PUCL_wo1Outlier_DGrdOnly_052317.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
Nickel (downgradient)			
General Statistics			
Total Number of Observations	23	Number of Distinct Observations	22
		Number of Missing Observations	1
Number of Detects	18	Number of Non-Detects	5
Number of Distinct Detects	18	Number of Distinct Non-Detects	4
Minimum Detect	0.845	Minimum Non-Detect	0.952
Maximum Detect	17	Maximum Non-Detect	5
Variance Detects	15.39	Percent Non-Detects	21.74%
Mean Detects	3.758	SD Detects	3.924
Median Detects	2.495	CV Detects	1.044
Skewness Detects	2.565	Kurtosis Detects	7.582
Mean of Logged Detects	0.974	SD of Logged Detects	0.814
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	3.295	KM Standard Error of Mean	0.759
KM SD	3.514	95% KM (BCA) UCL	4.593
95% KM (t) UCL	4.599	95% KM (Percentile Bootstrap) UCL	4.607
95% KM (z) UCL	4.544	95% KM Bootstrap t UCL	5.724
90% KM Chebyshev UCL	5.573	95% KM Chebyshev UCL	6.605
97.5% KM Chebyshev UCL	8.038	99% KM Chebyshev UCL	10.85
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	0.569	**Anderson-Darling GOF Test**	
5% A-D Critical Value	0.756	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.136	**Kolmogorov-Smirnov GOF**	
5% K-S Critical Value	0.207	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	1.575	k star (bias corrected MLE)	1.35
Theta hat (MLE)	2.386	Theta star (bias corrected MLE)	2.784
nu hat (MLE)	56.71	nu star (bias corrected)	48.59
Mean (detects)	3.758		
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	3.295	SD (KM)	3.514
Variance (KM)	12.35	SE of Mean (KM)	0.759
k hat (KM)	0.879	k star (KM)	0.793
nu hat (KM)	40.44	nu star (KM)	36.5
theta hat (KM)	3.748	theta star (KM)	4.153
80% gamma percentile (KM)	5.388	90% gamma percentile (KM)	8.029
95% gamma percentile (KM)	10.72	99% gamma percentile (KM)	17.08
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (36.50, α)	23.67	Adjusted Chi Square Value (36.50, β)	22.92
95% Gamma Approximate KM-UCL (use when n>=50)	5.081	95% Gamma Adjusted KM-UCL (use when n<50)	5.247
95% Gamma Adjusted KM-UCL (use when k<=1 and 15 < n < 50)			
Suggested UCL to Use			
95% KM Adjusted Gamma UCL	5.247		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			

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APPENDIX E

OU 2 – Groundwater at Nebo Main Base
Technical Assessment Reports

Appendix E-1	Technical Assessment Report Nebo North Plume Remedy
Appendix E-2	Technical Assessment Report Nebo South Plume Remedy

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APPENDIX E

OU 2 – Groundwater at Nebo Main Base

Technical Assessment Reports

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ATTACHMENTS

Attachment 1 UST Site Investigation Report (Figure 5-1)

For Acronyms and Abbreviations, please see Fourth Five Year Review report text.

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1.0 INTRODUCTION

This Technical Assessment has been prepared to document the evaluation of the Nebo North groundwater plume, specifically around former T 22A/B area. This evaluation was completed in support of the 2017 Five-Year Review. This memorandum was prepared by Oneida Total Integrated Enterprises (OTIE) for the Department of the Navy under Contract No. N39430 16 D 1818, contract task order 0006.

The contaminants of concern (COCs) consist of dissolved-phase volatile organic compounds (VOCs), primarily tetrachloroethene (PCE), trichloroethene (TCE), and 1,1-dichloroethene (1,1-DCE). The Nebo North groundwater plume is described in Section 3.5.1 of the main report. The selected remedy for the Nebo North groundwater plume is air sparge/soil vapor extraction (AS/SVE) of the source area and natural attenuation of the downgradient portions of the plume.

Previously, the remedy included the maintenance of a standby GETS as a contingency plume containment system in the event natural attenuation does not stop plume migration. As part of the third five year review, a statistical analysis of the Nebo North monitoring well data, in accordance with OUs 1 and 2 ROD requirements, was performed. The result of the analysis concluded that the Nebo North GETS was no longer needed and was recommended for decommissioning. The Nebo North GETS was decommissioned and all surface equipment removed in March 2015.

The location of the Nebo North wells and current plume are shown on Figure E-1.1. The remedy is further described in Section 8.2 of the main report.

1.1 Wash Pad Area Soil Vapor VOC Rebound And Treatment

Soil vapor COC concentration rebounded at two wells, OU2N-T1-M2 (7.8 9.8 feet bgs) and OU2N T1 M3 (7.8-9.8 feet bgs), following AS/SVE system shutdown in March 2011 (see in-text Table E-1.1). Based on a rebound evaluation completed in 2014, the SVE system was recommended to operate within the wash pad area two weeks every six months to address rebound in soil vapor VOC concentrations (OTIE 2015a). A soil vapor rebound evaluation following approximately two to six months of inactivity was also recommended to determine if continued SVE operations are necessary. Because soil vapor VOC rebound was observed following inactivity, the SVE system generally operated two weeks every 6 months since 2014.

Since the system was shut down in 2011, VOC rebound (following 2-week SVE operation events and two to six months of inactivity) in OU2N-T1-M2 and OU2N T1 M3 has had a decreasing trend (see in-text Graph E-1.2 below).

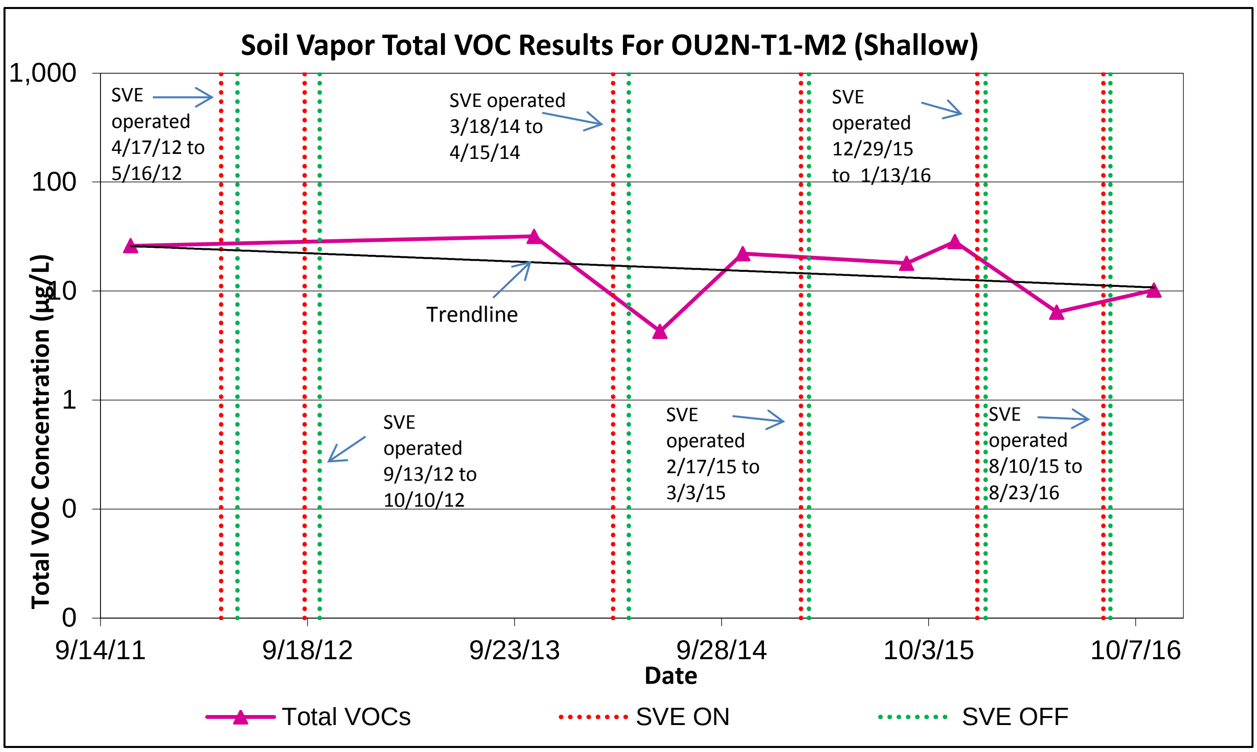
Table E-1.1 Rebound in Wash Pad Area - Summary of Soil Vapor Total VOC Following Focused Nebo North SVE Operation (two weeks on, twice per year)

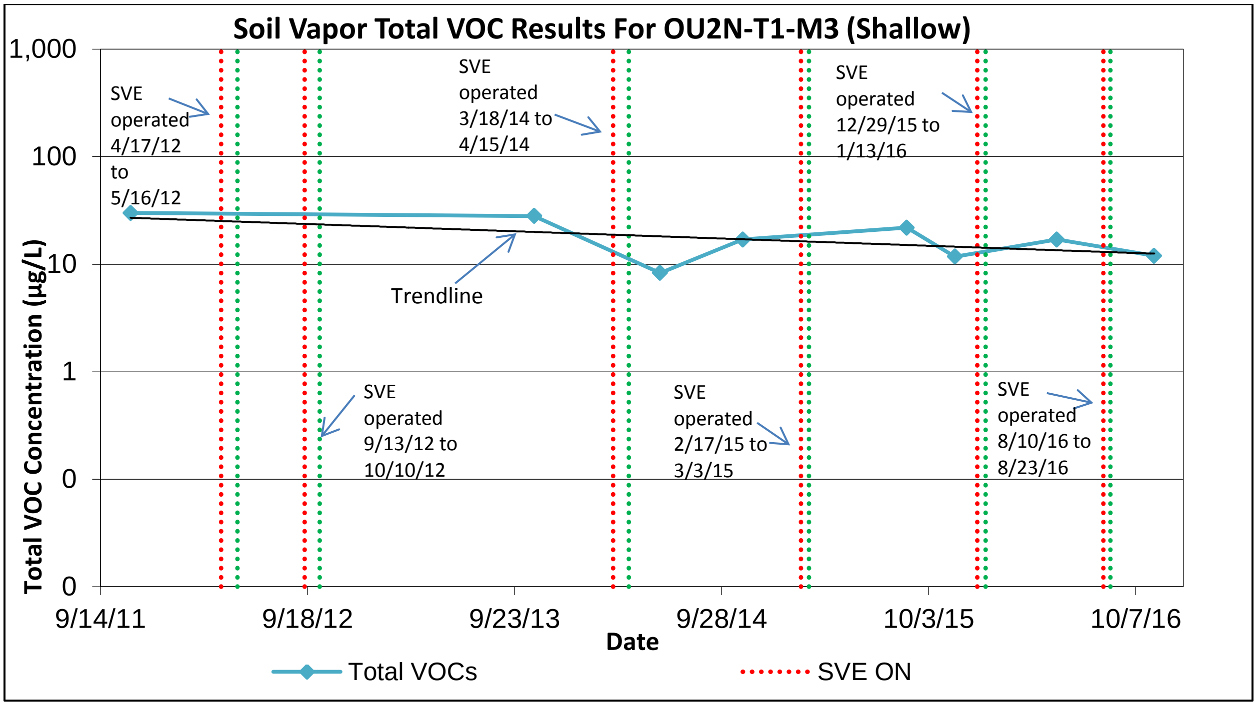
Wash Pad Area Well ID	Total VOCs in Soil Vapor (micrograms per liter)									
	June 2003 (Pre-AS/SVE)	Nov. 2010	Nov. 2011	Nov. 2013	June 2014	Nov. 2014	Aug. 2015	Nov. 2015	May 2016	Nov. 2016
Rebound Post SVE Event Period (months)	N/A	N/A	12	12	2	6	5	8	4	3
OU2N-T1-M2	557	2.6	26	31.7	4.3	22	18.3	28.4	6.4	10.2
OU2N-T1-M3	992.3	12	30	28.1	8.3	17	24.1	11.8	17	12.4

NOTES:

Aug. = August; Nov. = November; N/A = not analyzed; ft bgs = feet below ground surface

Graph E-1.2 Nebo North Soil Vapor VOC Rebound Results for Wash Pad Area Monitoring Wells OU2N-T1-M2 and OU2N-T1-M3





NOTES:

Graphs shows VOC sample results following at least 2 months of SVE system inactivity.

2.0 NEBO NORTH RESIDUAL PLUME

Since the source area (former Building 50 – CAOC 10.12) was cleanup by the AS/SVE system, the Nebo North plume has diminished significantly. The Nebo North plume area decreased from 905,000 square feet in 2006 to 36,000 square feet in 2016. The interpreted extents of the Nebo North plume for the years 2013, 2014, 2015 and 2016 are presented on Figure E-1.2.

There were no other COCs in groundwater above the respective cleanup level identified within the Nebo North plume area between 2012 and 2016, with all monitoring locations except one exhibiting concentrations below the cleanup levels or method detection limits by 2007. The exception is monitoring well T 22A/B-MW1 located northwest of Warehouse 4. A figure from the 2004 report on this area (BEI 2004) is included for reference (see attached Figure 5-1). Relevant background information is summarized below:

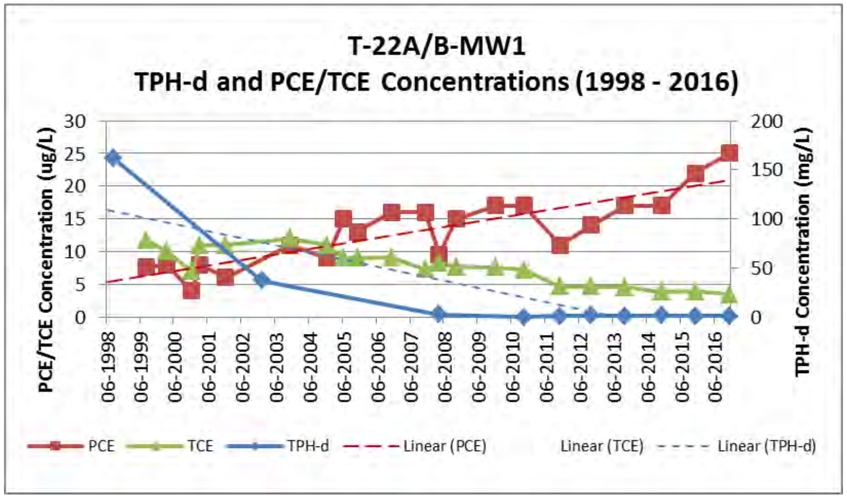
- T 22A/B-MW1 was originally installed to monitoring groundwater downgradient from former Underground Storage Tanks (UST) T-22A and T-22B. These USTs were associated with the former Equipment Maintenance Shop Building 22 (removed) and reportedly stored waste oil (SDV Engineering and Construction 2011). The USTs were removed in early 1950s; no closure documentation was found;

- There are three are functional monitoring wells related to the UST: T-22A/B-MW1, -MW3, and -MW4. Monitoring wells T 22A/B-MW1, T 22A/B MW3 are both downgradient of the former UST/Building 22 area and well T-22A/B-MW4 is upgradient of the area;

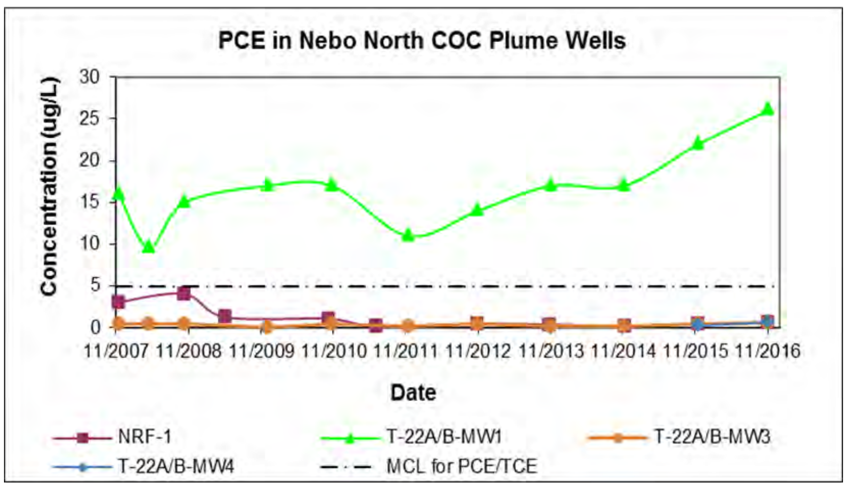
- Of these wells, T 22A/B-MW1 and T 22A/B MW3 have been integrated into the Nebo North plume long-term monitoring program since 1998 and are currently sampled annually for VOCs. The upgradient well, T 22A/B MW4, was only added to the monitoring program beginning in 2015 to better characterize the plume in the T-22A/B area;
- Additionally, the T-22A/B monitoring wells are or were tested for total petroleum hydrocarbons as diesel (TPH-d) per Regional Water Quality Control Board-Lahontan Region (RWQCB) leaking underground fuel tank (LUFT) program requirements. TPH-d concentrations have significantly declined at T-22A/B-MW1 and regulatory closure for the LUFT case files for T-22A/B was recommended in 2011 (SDV Engineering and Construction 2011). TPH-d continues to be tested for annually at T-22A/B-MW1; and
- As VOCs have not been detected in upgradient monitoring well T-22A/B-MW4, the residual plume appears to be related to for the former UST/Building 22 area. Migration of the plume is not suspected based on non-detect monitoring wells downgradient from the site.

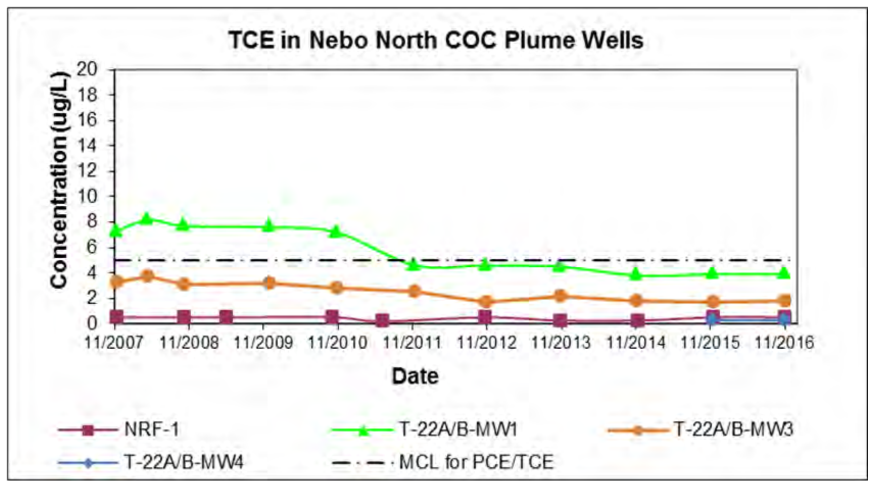
Historical PCE, TCE, and TPH-d trend graphs at monitoring well T 22A/B MW1 are presented on Graphs E-1.1 and E-1.2 (next page). It is notable that PCE concentrations at T 22A/B-MW1 have been consistently above the cleanup level since 1998 and show an increasing concentration trend in recent years (Graph E 1.2). Concurrently, TCE and TPH-d concentrations at T 22A/B MW1 have decreased since 1998, likely attributed to natural attenuation processes.

Graph E-1.1 T-22A/B-MW-1 Concentrations of TPH-d, PCE, and TCE (1998 – 2016)



Graph E-1.2 PCE and TCE Concentrations in Selected Wells – Nebo North Residual Plume (2007 – 2016)





3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1 WASH PAD AREA REBOUND

Conclusions:

- The Nebo North SVE system was operated in the former wash pad area for 2-week increments since 2012 because of rebound observed in two shallow soil vapor wells as a protective measure for groundwater. Groundwater VOC concentrations in the source area treated by the Nebo North AS/SVE system have remained below cleanup levels and were not detected in the latest 2016 annual monitoring sample; and
- Soil vapor VOC concentrations in the wash pad area vadose zone are rebounding at a decreasing trend since 2011.

Recommendation:

- Conduct two rounds of targeted SVE at the Wash Pad Area during 2017 and evaluate if soil vapor VOC rebound concentrations indicate the need for further SVE treatment. Document the evaluation and recommendations in the 2017 Annual Groundwater Monitoring Report.

3.2 RESIDUAL PLUME IN T-22A/B AREA

Conclusions:

- The residual Nebo North groundwater contamination area at T-22A/B is relatively small and does not appear to be migrating based on clean downgradient monitoring wells;
- The persistent and increasing PCE concentrations in samples from monitoring well T 22A/B MW1 do not fit the overall pattern of the diminished Nebo North groundwater plume and are likely due to residual source at the former UST T-22A/B and/or former Building 22 (Equipment Maintenance Shop). The USTs reportedly stored engine motor oil and were removed in the early 1950s (BNI 1998a); and
- TPH-d has also been detected in groundwater samples from T-22A/B-MW1. A localized reducing environment associated with petroleum compound releases from T-22A/B is demonstrated by low DO, negative ORP, and the presence of chlorinated VOC breakdown products in groundwater samples from wells downgradient of the former tanks.

Recommendations:

- Given the increasing trend in PCE concentrations at T-22A/B-MW1, the long-term protectiveness of the remedy would be assured with an improved understanding of the source and extent of the T-22A/B area groundwater contamination. Consider a limited subsurface investigation to identify the source and determine if there is a need for additional response action in this area; and
- The OUs 1 and 2 ROD did not identify Warehouse 4 (CAOC 10.5), Building 22, or the T-22 USTs as sources for the Nebo North plume. A Memorandum to File clarifying the ROD to include this area as a source for the Nebo North plume and remedy would ensure proper long-term management of the residual plume under OU 2.

4.0 REFERENCES

Department of the Navy (DON). 1998. Operable Units 1 and 2, Final Record of Decision Report. April.

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Bechtel National, Inc. (BNI). 1998. *Draft Final RCRA Facility Assessment Report. Marine Corps Logistics Base, Barstow*. February.

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FIGURES

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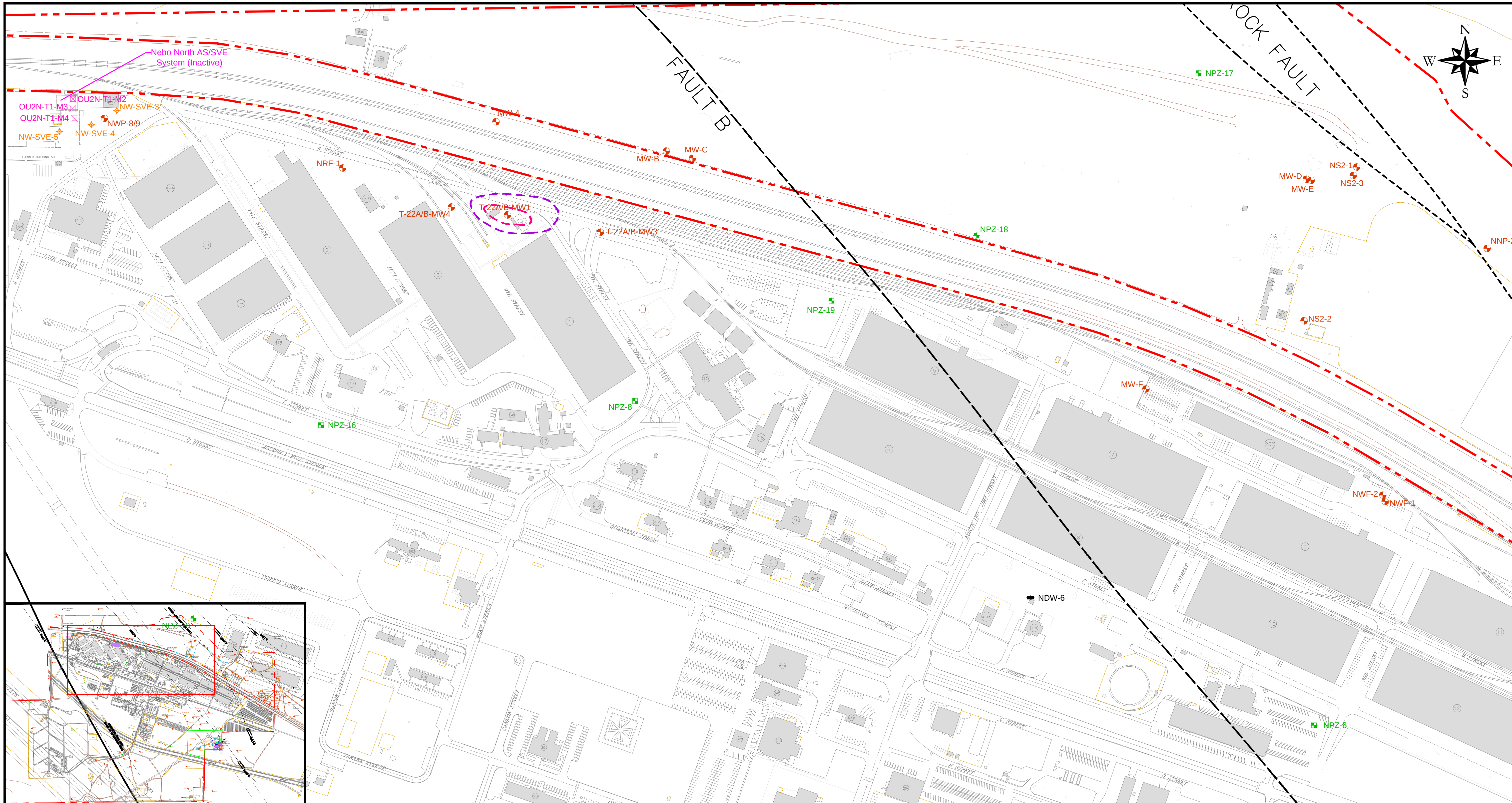


Legend

Paved Road	
Dirt Road	
Railroad Tracks	
Fence Line	
Base Boundary	
Fault Traces (strike-slip)	
MW-B	Groundwater Monitoring Well
NPZ-8	Piezometer
NDW-6	Base Groundwater Supply Well
EW-B	Groundwater Extraction Well (Inactive)
NW-SVE-3	Vapor Extraction Well
OU2N-T1-M2	Combination Well
5	Approximate PCE Isoconcentration Contour (ug/L)
10	Approximate PCE Isoconcentration Contour (ug/L)

Notes

1) Analytical results shown in ug/L (micrograms per liter) for the wells sampled during the 2016 Annual Groundwater Monitoring Event.
2) The highest detection is reported when a duplicate sample is collected.
3) TCE = Trichloroethene
PCE = Tetrachloroethene
MCL = Maximum Contaminant Level
ft bgs = feet below ground surface

Approximate Scale in Feet

0 350 700

Figure E-1.1
Nebo North Data Evaluation
(November 2016)

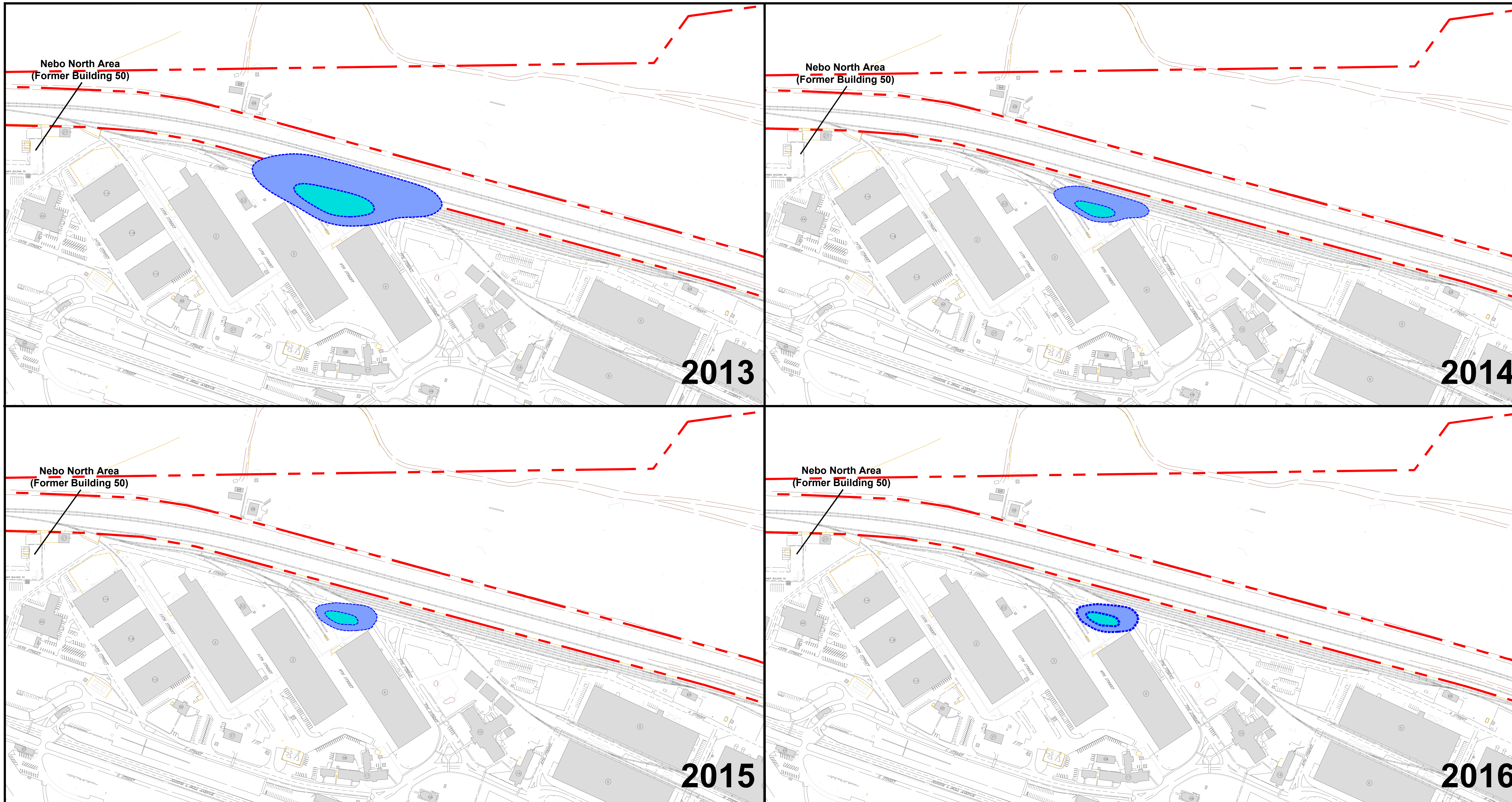
Nebo Main Base
Marine Corps Logistics Base
Barstow, California

OTIE
An Oneida Nation Company

Date: March 27, 2017

File: Barstow_5yrRev - 2017.dwg

Plotted By: Mario Camacho



Legend

- Nebo Boundary
- 5 ug/L PCE Concentration Area
- 10 ug/L PCE Concentration Area

Notes

1. TCE has not exceeded the MCL of 5 ug/L in any of the Nebo North groundwater monitoring wells since 2011.

2. ug/L = Micrograms per Liter
   TCE = Trichloroethene
   PCE = Tetrachloroethene

N
W E
S

Approximate Scale in Feet

0 500 1,000

Figure E-1.2
Nebo North Historical Groundwater
PCE TCE Extents, 2013-2016

Nebo Main Base
Marine Corps Logistics Base
Barstow, California

OTIE
An Oneida Nation Company

Date: April 4, 2017

File: NeboHist_5YrRev.dwg

Plotted By: Mario Camacho

ATTACHMENTS

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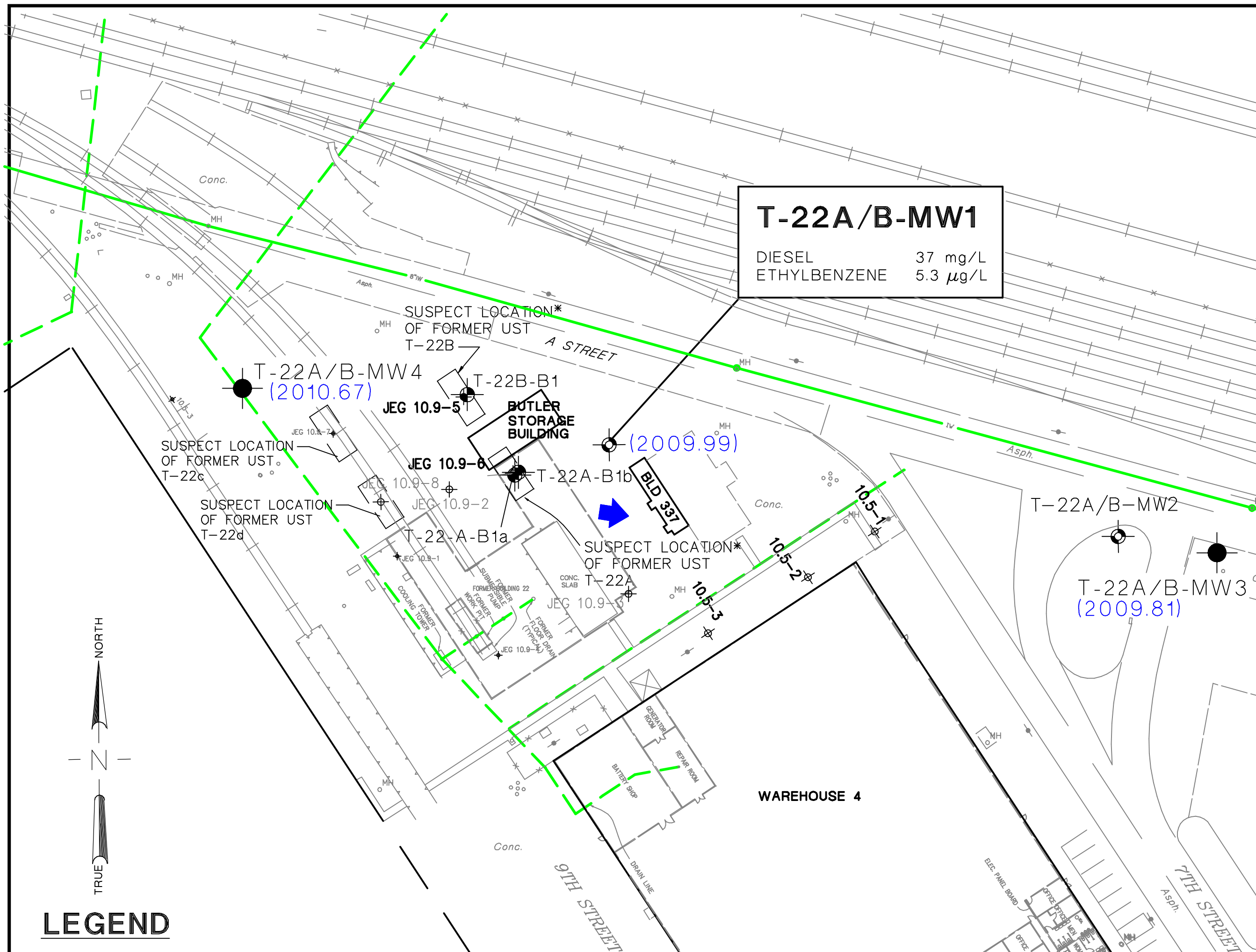

LEGEND

MONITORING WELL INSTALLED BY BEI (MARCH 2003)

T-22B — SOIL BORING DRILLED BY BNI (NOVEMBER 1997)

T-22A/B-MW1 — MONITORING WELL INSTALLED BY BNI (AUGUST 1998)

ESTIMATED DIRECTION OF GROUNDWATER FLOW

(2010.67) — WATER-LEVEL ELEVATION IN FEET ABOVE MEAN SEA LEVEL (MSL)

RAILROAD

FENCE

ROAD/CURB/OTHER SURFACE FEATURE

BUILDING OR STRUCTURE

SAMPLE IDENTIFICATION

T-22A/B-MW1

DIESEL 37 mg/L — CONCENTRATION UNITS

ANALYTE NAME — CONCENTRATION

0 100 200

FEET

NOTES:

BEI - BECHTEL ENVIRONMENTAL, INC.

BNI - BECHTEL NATIONAL, INC.

µg/L - MICROGRAMS PER LITER

mg/L - MILLIGRAMS PER LITER

UST - UNDERGROUND STORAGE TANK

* - LOCATION BASED ON JACOBS ENGINEERING GROUP 1992, TANK SIZE UNKNOWN

AN OBSTRUCTION WAS ENCOUNTERED IN MW2 AT 33.3 FEET BELOW TOP OF CASING AND WAS NOT SAMPLED

SOURCE:

PHOTOGRAMMETRY MAP BY INLAND SURVEYS INC.
PHOTOGRAPHY DATE: 1-14-98, COORDINATE SYSTEM IN NAD 83

UST Site Investigation Report

Figure 5-1

USTs T-22A/B - Groundwater Analytical Results - Nebo Main Base

MCLB Barstow, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 7/22/03
File No: 026A11014
Job No: 23818-026
Rev No: G

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APPENDIX E-2

Technical Assessment Report
Nebo South Plume Remedy

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For Acronyms and Abbreviations, please see Fourth Five-Year Review report text.

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1.0 INTRODUCTION

This Technical Assessment has been prepared to document the technical assessment of the performance of the groundwater remedy for the Operable Unit 2 (OU 2) Nebo South groundwater plume. This evaluation was completed in support of the Fourth Five-Year Review and covers the timeframe from October 2012 through October 2017 (data from system startup up through November 2016 were reviewed). This memorandum was prepared by Oneida Total Integrated Enterprises (OTIE) for the Department of the Navy (DON) under Contract No. N39430 16 D 1818 task order 0006.

The Nebo South groundwater plume and the plume source area, the Comprehensive Environmental Response, Compensation, and Liability Act Area of Concern (CAOC) 6, are described in Section 3.5 of the Fourth Five-Year Report. The Nebo South groundwater plume contaminants of concern (COCs) consist of dissolved-phase volatile organic compounds (VOCs), primarily trichloroethene (TCE), tetrachloroethene (PCE), and 1,1-dichloroethene (1,1-DCE). The selected remedy for this plume is operation of an air sparge/soil vapor extraction (AS/SVE) systems for groundwater and vadose zone VOC mass removal as described in Section 8.2 of the Fourth Five-Year Report. The OU 2 Record of Decision (ROD) selected air sparge/soil vapor extraction (AS/SVE) as the final remedy along with land use controls for the CAOC 6 source area (DON 2006).

1.1 TCE Plume Area

The interpreted extents of the Nebo South TCE plume from 2013 to 2016 are presented on Figure E-2.1. As shown below on Graph E-2.1, the overall TCE plume area has decreased since 2007; however, the current trend is relatively flat with a slight increase from 2012 – 2016.

Graph E-2.1. Area of Nebo South TCE Plume