THE UNITED STATES NAVY

INSTALLATION RESTORATION PROGRAM

FINAL

RECORD OF DECISION AMENDMENT
FOR
MARBO ANNEX OPERABLE UNIT

ANDERSEN AIR FORCE BASE, GUAM

December 2010

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14. ABSTRACT

This Record of Decision (ROD) Amendment for MARBO Annex Operable Unit presents the rationale for selection of the amended cleanup alternative for MARBO Annex Groundwater at Andersen AFB, Guam. This ROD Amendment summarizes the history, environmental background, extent of contamination, associated human health and ecological risks, evaluation of remedial alternatives, and public involvement, and invokes a technical impracticability waiver.

15. SUBJECT TERMS

- Andersen AFB
- Installation Restoration Program
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List of Acronyms and Abbreviations

AFB	Air Force Base
AR	Administrative Record
ARAR	Applicable or Relevant and Appropriate Requirement
BCO	Base Commanding Officer
bgs	Below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CES	Civil Engineering Squadron
CEVR	Civil Engineering Installation Restoration Program
CFR	Code of Federal Regulations
EA	EA Engineering, Science, and Technology, Inc.
FFS	Focused Feasibility Study
ft	Feet
FWENC	Foster Wheeler Environmental Corporation
GPA	Guam Power Authority
Guam EPA	Guam Environmental Protection Agency
IC	Institutional Control
ICF	ICF Technology, Inc.
ID	Identification
IR	Information Repository
IRP	Installation Restoration Program
LTGM	Long-Term Groundwater Monitoring
LUC	Land Use Control
µg/L	Micrograms per Liter
MARBO	Marianas/Bonins Command
MCL	Maximum Contaminant Level
mg/L	Milligrams per Liter
MNA	Monitored Natural Attenuation
MW	Monitoring Well
MWH	Montgomery Watson Harza
NCP	National Oil and Hazardous Substances Pollution Contingency Plan of 1990

List of Acronyms and Abbreviations (continued)

O&M	Operations and Maintenance
OU	Operable Unit
PCE	Tetrachloroethene
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act of 1976
ROD	Record of Decision
RPM	Remedial Project Manager
SARA	Superfund Amendments and Reauthorization Act of 1986
TBC	To Be Considered
TCE	Trichloroethene
TI	Technical Impracticability
USAF	United States Air Force
USEPA	United States Environmental Protection Agency
USN	United States Navy
ZVI	Zero Valent Iron

1.0 Declaration

1.1 Site Name and Location

Facility Name: Andersen Air Force Base (AFB), Guam

Site Location: Yigo, Guam

Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) Identification (ID) Number: GU6571999519

Operable Unit/Site: Marianas/Bonins Command (MARBO) Annex Operable Unit (OU) / MARBO Annex Groundwater

1.2 Statement of Basis and Purpose

The United States Navy (USN)[1] is updating the selected remedy, *Natural Attenuation with Wellhead Treatment*, for MARBO Annex Groundwater at Andersen AFB, Yigo, Guam, by amending certain aspects of the May 1998 MARBO Annex OU Record of Decision (ROD) (Figures 1-1 and 1-2).

The USN is amending the prior remedy decision in accordance with Section 117 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and Section 300.435(c)(2)(ii) of the National Oil and Hazardous Substances Pollution Contingency Plan of 1990 (NCP). In accordance with Section 300.825(a)(2) of the NCP, this ROD Amendment will become part of the Administrative Record (AR) for Andersen AFB and will be made available at the local Information Repositories (IRs). Section 2.1.5 of this ROD

[1] The Department of Defense is in the process of realigning installation management functions at Andersen AFB. On October 1, 2009, pursuant to the 2005 Defense Base Closure and Realignment Commission Report, administrative custody of all real property on Andersen AFB and responsibility for installation support functions, including Environmental Restoration Program responsibilities, transferred within the Department of Defense from the Department of the Air Force to the Department of the Navy. Title to Andersen AFB real property will remain with the United States and the Air Force will continue to utilize the Base. The Navy will also utilize portions of the Base. In accordance with the April 15 2008, Department of Defense Environmental Supplemental Guidance for Implementing and Operating a Joint Base, at the time of property transfer the Navy, as the new property manager at the Base, assumed responsibility "for all existing and future environmental permits, requirements, plans, and agreements" at the Base (Ch. 1.1.2) and was required to "honor all existing, previously negotiated Federal Facility Agreements in place" (Ch. 2.17.5 of the Guidance).

In January 2009, the Navy and the Air Force entered into a separate Memorandum of Agreement, which delegated installation support and authority back to the Air Force General who is the Andersen BCO under the authority, control, and direction of the Joint Region Commander, who is a Navy Admiral. This delegation includes the authority to sign Records of Decision. The Andersen BCO and Andersen environmental staff continue to administer the FFA under Navy direction. Both the Air Force and the Navy notified the USEPA of the change of administrative responsibility under the FFA (See Appendix A).

Amendment provides the locations and hours of operation of the local IRs where relevant documents from the AR can be reviewed.

This document is issued by the USN as the lead agency. The USN is managing remediation of contamination at the MARBO Annex OU in accordance with CERCLA as required by the Defense Environmental Restoration Program. The USN and the United States Environmental Protection Agency (USEPA) have jointly selected the remedy and the Guam Environmental Protection Agency (Guam EPA) has concurred with the decision, under the guidelines established in the Federal Facility Agreement signed in February 1993 by representatives of the USEPA Region 9, Guam EPA, and United States Air Force (USAF) (USEPA et al., 1993).

1.3 Assessment of Site

The response action selected in this ROD Amendment is necessary to protect the public health and the environment from actual or threatened releases of hazardous substances into the environment.

1.4 Description of Amended Selected Remedy

The amended selected remedy is *Long-Term Groundwater Monitoring with Contingency for Wellhead Treatment*. The amended selected remedy complies with or waives applicable or relevant and appropriate requirements (ARARs) and provides the same level of protection to human health and the environment. A detailed description of the amended selected remedy is presented in Section 2.6, and is summarized below:

- **Long-Term Groundwater Monitoring (LTGM)** will be performed at selected monitoring wells and production wells. Groundwater samples will be analyzed for trichloroethene (TCE), tetrachloroethene (PCE), and other parameters that are useful in monitoring the immobility of TCE and PCE in groundwater.

- **Land Use Controls (LUCs)** selected in the 1998 ROD remain unchanged. They have been implemented through the Base Master Plan and the Guam EPA's Wellhead Protection Program. The USAF has not installed any additional wells within the TCE/PCE contamination area and has advised Guam that any well installation which is proposed in the vicinity could result in the extraction of contaminated groundwater. As part of its Wellhead Protection Program, Guam EPA limits the location of newly installed wells (must be at least 1,000 feet [ft] from existing wells) and requires that any new well be sampled prior to being connected to the water supply system. If sampling at a newly installed well indicates that TCE/PCE is present, the USN will evaluate the need to install and operate wellhead treatment whenever levels exceed one half of the respective maximum contaminant level (MCL), as described above.

- **Contingency for Wellhead Treatment** at on-MARBO Annex water production wells or existing or future off-MARBO Annex production wells within the extent of the TCE and PCE plumes. Upon TCE or PCE concentrations exceeding half of the MCL, the USN will perform additional sampling and analysis to determine if the concentration is likely to approach the MCL (5 µg/L). If statistical significance is found, the well will continue

to be monitored for potential exceedance of the MCL. If PCE or TCE concentrations exceed the MCL, wellhead treatment will be applied to the affected well. Treatment units would be installed by the USN if no treatment system exists on that well or the USAF would pay the incremental cost caused by the presence of TCE and/or PCE if a well already had a treatment system.

- **Technical Impracticability (TI) Waiver** for the ARAR of achieving MCLs in the aquifer. The TI Waiver, as explained in Section 2.4.2, is necessary because site conditions make it impracticable for remediating the aquifer in a reasonable time frame.

- **Five-Year Reviews** would continue to be performed to determine if the remedy is still effective and if the remedy has achieved its goals, and thus can be discontinued.

The following table illustrates the similarities and differences between the 1998 selected remedy and the amended selected remedy.

1998 Selected Remedy	Amended Selected Remedy
Groundwater Similarities	
Long-Term Groundwater Monitoring	Long-Term Groundwater Monitoring
Existing[2] Wellhead Treatment	Contingency for Wellhead Treatment
Land Use Controls	No new Land Use Controls
Five-Year Reviews	Five-Year Reviews
Groundwater Differences	
Monitored Natural Attenuation	TI Waiver
Updated Estimated Present Value: $2,925,000	Estimated Present Value: $3,013,000

1.5 Statutory Determinations

The amended selected remedy for MARBO Annex Groundwater is protective of human health and the environment, complies with or meets the requirements for a waiver of Federal and state (territory) requirements that are legally applicable or relevant and appropriate to the remedial action, is cost effective, and utilizes permanent solutions and alternative treatment (or resource recovery) technologies to the maximum extent practicable. It provides the best balance or trade-offs in terms of balancing criteria, while also considering the bias against offsite treatment and disposal and considering state and community acceptance.

The NCP establishes the expectation that treatment will be used to address principal threats posed by a site whenever practicable (40 Code of Federal Regulations [CFR] 300.430[a][1][iii][A]). The amended selected remedy does not meet the statutory preference for treatment because no source materials constituting principal threats are addressed within the scope of this action.

[2] The 1998 Selected Remedy name includes 'Existing Wellhead Treatment'; however, in early1998, the wellhead treatment component was discontinued when MW-2, the only well requiring treatment), was taken off production. While wellhead treatment would have been implemented on any new production wells installed within the PCE- and TCE-contaminated groundwater zones, no new production wells were proposed or installed in these areas.

Because the amended selected remedy will result in hazardous substances, pollutants, or contaminants remaining in groundwater above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within five years after initiation of remedial action to ensure that the remedy is, or will be, protective of human health and the environment.

1.6 Data Certification Checklist

The information included in the Decision Summary (Section 2) of this ROD Amendment is summarized in Table 1-1. Additional information can be found in the AR file for Andersen AFB, Yigo, Guam, which is available for public review at the Robert F. Kennedy Library at the University of Guam and the Nieves M. Flores Memorial Library in Hagåtña.

1.7 Authorizing Signatures

The following signature sheets document the decision by USN and USEPA Region 9 to select *Long-Term Groundwater Monitoring with Contingency for Wellhead Treatment* as the amended selected remedy for MARBO Annex Groundwater, Andersen AFB, Guam, and the concurrence of Guam EPA in that decision.

This signature sheet documents the USN and Andersen AFB co-selection of *Long-Term Groundwater Monitoring with Contingency for Wellhead Treatment* as the remedial action in this ROD Amendment for MARBO Annex Groundwater, Andersen AFB, Guam.

16 Nov 11

JOHN W. DOUCETTE
Brigadier General, USAF
Base Commanding Officer[3]

Date

[3] Under Delegation of Authority from Commander Joint Region Marianas. See Footnote 1.

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This signature sheet documents the U.S. EPA Region 9 co-selection of *Long-Term Groundwater Monitoring with a Contingency for Wellhead Treatment* as the remedial action in this ROD Amendment for MARBO Annex Groundwater, Andersen AFB, Guam.

Michael M. Montgomery
Assistant Director
Federal Facility and Site Cleanup Branch, U.S. EPA Region 9

2/14/12
Date

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This signature sheet documents the Guam EPA concurrence in the selection of *Long-Term Groundwater Monitoring with Contingency for Wellhead Treatment* as the remedial action in this ROD Amendment for MARBO Annex Groundwater, Andersen AFB, Guam.

02/19/13

ERIC M. PALACIOS
Administrator
Guam Environmental Protection Agency

Date

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2.0 Decision Summary

The Decision Summary provides a description of the specific factors that led to the amendment of the selected remedy, compares the original and alternative amended remedies, provides a substantive summary of the AR file that supports the amended selected remedy decision, and explains how the amended selected remedy fulfills statutory and regulatory requirements.

2.1 Introduction to the Site and Statement of Purpose

2.1.1 Site Name, Location, and Brief Description

Full Site Name:	MARBO Annex Groundwater
CERCLIS ID Number:	GU6571999519
Site Location:	Yigo, Guam
Site Type:	Groundwater

MARBO Annex is located on a broad, uplifted limestone plateau that is underlain by volcanic rocks (Figure 1-2). The limestone plateau includes numerous sinkholes and ranges in elevation from 300 to over 500 ft above mean sea level. The sinkholes are very porous and provide rapid infiltration of surface water to the underlying freshwater aquifer, rendering no permanent surface water bodies at the MARBO Annex. According to groundwater monitoring data, groundwater at MARBO Annex is encountered at approximately 281-399 ft below ground surface (bgs) (EA Engineering, Science, and Technology, Inc. [EA], 2008b).

Water extracted from production wells located in the MARBO Annex is distributed to Andersen AFB. Currently, seven of the eight Andersen AFB production wells located in the MARBO Annex are in operation, and can yield approximately 2.1 million gallons per day to meet the average Base consumption of 1.6 million gallons per day. The Guam Waterworks Authority has also installed production wells on the northern and eastern side of MARBO Annex; however, these wells are located upgradient or cross gradient of the TCE and PCE contamination (EA, 2008c).

Currently, there is no active land use on USN property located within the "footprint" of the PCE- and TCE-contaminated groundwater. Re-development of some of these areas is likely in the near future, given the recent ROD for Guam and CNMI military relocations (September 2010).

2.1.2 Public Participation Requirements

The USN is amending the prior remedy decision in accordance with Section 117 of CERCLA, and Section 300.435(c)(2)(ii) of the NCP, which establish a number of public participation activities that the lead agency must conduct during the ROD Amendment process. Components of these items and documentation of how each component was satisfied for the MARBO Annex OU ROD Amendment are described in Table 2-1.

Responses to comments received during the public comment period are provided in the Responsiveness Summary in Section 3 of this ROD Amendment.

2.1.3 Date of Original Record of Decision

The original MARBO Annex OU ROD is dated May 1998, and was signed on 17 July 1998.

2.1.4 Summary of Circumstances Leading to the Record of Decision Amendment

The 1998 ROD selected the *Natural Attenuation with Wellhead Treatment* remedial alternative, to achieve the remediation goal of decreasing TCE and PCE concentrations in the aquifer to levels below MCL. Through physical processes of dispersion and dilution, the timeframe to achieve cleanup goals (MCLs) was estimated at 10 to 40 years, assuming a continued source of PCE and TCE did not exist (EA and Montgomery Watson Harza [EA/MWH], 1998). The 1998 selected remedy consisted of: natural attenuation of TCE and PCE in the aquifer, continued wellhead treatment at those wells which were undergoing Air Stripping until influent TCE and PCE concentrations were consistently below MCLs, and long-term sampling and monitoring of select production and monitoring wells in and adjacent to the MARBO Annex. The original selected remedy has been operating since 1998 and is classified as an operating remedial action, as it has been implemented; however, residual contaminants of concern have been left in place at concentrations that do not allow for unrestricted use of or unlimited access to the land.

During the first five-year review, it was determined that the overall timeframe for the groundwater remedy to effectively reduce concentrations of TCE and PCE to below MCLs may take longer than 40 years. The first five-year review recommended that if, during the second five-year review period, monitored natural attenuation (MNA) did not appear to be effectively remediating the TCE and PCE in the MARBO Annex groundwater, that the 1998 ROD should be amended to either specify an active remediation or a TI Waiver (EA, 2004).

Subsequent to the first five-year review, residual levels of dissolved-phase TCE and PCE (in the deep freshwater lens) has persisted at concentrations that indicate that attenuation rates will not allow for unrestricted use of the property within an acceptable timeframe. In preparing for the upcoming second five-year review, the USN concluded that specific fundamental changes are needed to modify the MARBO Annex Groundwater remedy of *Natural Attenuation with Wellhead Treatment* selected in the 1998 ROD (EA, 2008c).

2.1.5 Administrative Record

This ROD Amendment will become part of the AR file for Andersen AFB, Yigo, Guam, in accordance with the NCP, Section 300.825(a)(2). This AR file is available for public review at the following repositories:

- *Installation Restoration Program*
  36 CES/CEVR
  Unit 14007
  APO AP 96543-4077
  Phone: (671) 366-5080
  Contact: Gregg Ikehara, Installation Project Manager

- *University of Guam Government Documents Department*
  Robert F. Kennedy Library, University of Guam Station
  Mangilao, Guam 96923
  Phone: (671) 735-2316, -2315
  Hours: Monday-Friday: 8:00 a.m. – 5:00 p.m.
  Contact: Walfrid Benavente

- *Nieves M. Flores Memorial Library*
  254 Martyr Street
  Hagåtña, Guam 96910
  Phone: (671) 475-4751, -4752, -4753, or -4754
  Hours: Monday-Thursday: 7:00 a.m. – 6:00 p.m.
  Friday: 12:00 p.m.–5:00 p.m.
  Saturday: 8:00 a.m.–5:00 p.m.
  Contact: Teresita Kennimer

2.2 Site History, Site Characteristics, and 1998 Selected Remedy

This section of the ROD Amendment provides a summary of the site history and enforcement activities, nature and extent of contamination, site risks, and presents the 1998 selected remedy.

2.2.1 Site History and Enforcement Activities

Due to its primary mission in national defense, the USAF has long been engaged in a wide variety of operations that involve the use, storage, and disposal of hazardous materials. On 14 October 1992, Andersen AFB was formally listed on the National Priorities List by the USEPA to investigate abandoned sites that may have been impacted by the use, storage, and disposal of hazardous materials.

Historical land use at the MARBO Annex consisted of residential housing, military warehousing, and industrial support facilities. The USN and USAF have conducted numerous environmental investigations for the MARBO Annex. Six Installation Restoration Program (IRP) sites were identified at the MARBO Annex OU: Sites 20, 22, 23, 24, 37, and 38. Sites 41, 42, and 43 are also located within in the MARBO Annex; however, they were identified at a later date and are included in the Site-wide OU. Remedial investigations were performed at all nine IRP sites located within the MARBO Annex. Site 38, a former laundry facility, was found to be a potential source for the TCE and PCE contamination in groundwater; however, there does not appear to be residual contamination in soils as the release was likely more than 40 years ago (ICF Technology, Inc. [ICF], 1997). Site 38 PCE trends observed over time in the freshwater lens (from nearby shallow well IRP-14) indicate there is no current PCE source (EA, 2008c).

Since 1989, through a network of groundwater monitoring points, MARBO Annex groundwater has been sampled and analyzed semi-annually (EA, 2008b). The LTGM Program for Andersen AFB was initiated in October 1995 to ensure compliance with the CERCLA, Resource Conservation and Recovery Act, Clean Water Act, Safe Drinking Water Act, and all ARARs.

The 1998 ROD summarizes the following investigations which were conducted for MARBO Annex Groundwater:

- *Installation Restoration Program Phase II Confirmation/Quantification Stage 1, Final Report, Main Report, for Andersen AFB Guam* (Battelle Columbus Division, 1989)

- *Installation Restoration Program Stage 2 Remedial Investigation/Feasibility Study, Technical Report, Final, for Andersen AFB Guam* (Science Applications International Corporation, 1991)

- *Andersen AFB Guam, Operable Unit 2 – MARBO Annex Remedial Investigation Report* (ICF, 1997)

- *Final MARBO Annex Operable Unit 2 FFS Report for Andersen AFB Guam* (EA/MWH, 1997).

The 1998 ROD for MARBO Annex Groundwater selected *Natural Attenuation with Wellhead Treatment* as the preferred remedial alternative, and the LUCs stipulated in the remedial action were fully implemented by 1998. However, the wellhead treatment component was discontinued in early 1998 when MW-2 was taken off production, as it was no longer required to meet USAF water demand and the stripping tower used to treat the water was fouling due to severe carbonate precipitation on the packing media. The remaining MARBO Annex production wells, MW-1, MW-3, and MW-5 through MW-9, have never required wellhead treatment. While wellhead treatment would have been implemented on any new production wells installed within the PCE- and TCE-contaminated groundwater zones, no new production wells have been proposed or installed in these areas. The LTGM Program that was initiated in the MARBO Annex prior to the ROD signing has continued through the present. The natural attenuation component of the remedy required no implementation as it is a remediation strategy that relies on naturally occurring degradation processes to reduce contaminant concentrations present in the groundwater. However, as discussed in Section 2.3, natural attenuation has not been effective in reducing contaminant concentrations in the deep portion of the freshwater lens.

Since the 1998 ROD, MARBO Annex Groundwater has been evaluated in the following environmental reports:

- *Final Groundwater Summary Report for Andersen AFB, Guam* (EA, 1998a)

- *Final Spring 1998 Groundwater Data Monitoring Report for Andersen AFB, Guam* (EA, 1998b)

- *Final Fall 1998 Groundwater Data Monitoring Report for Andersen AFB, Guam* (EA, 1999a)

- *Final Spring 1999 Groundwater Data Monitoring Report for Andersen AFB, Guam* (EA, 1999b)

- *Final Fall 1999 Groundwater Data Monitoring Report for MARBO Annex, Andersen AFB, Guam* (EA and Dames & Moore, 2000)

- *Final Spring 2000 Groundwater Monitoring MARBO Annex and Northwest Field Operable Units, Andersen AFB, Guam* (EA and URS – Dames & Moore, 2000)

- *Final Fall 2000 Groundwater Monitoring Main Base, Northwest Field, and MARBO Annex Operable Units, Andersen AFB, Guam* (URS – Dames & Moore, 2001)

- *Final Spring 2001 Semiannual Groundwater Monitoring Main Base, Northwest Field, and MARBO Annex Operable Units (OUs), Andersen AFB, Guam* (URS Corporation, 2001)

- *Final Fall 2001 Groundwater Data Monitoring Report for Andersen AFB, Guam* (Foster Wheeler Environmental Corporation and EA [FWENC/EA], 2002a)

- *Final Spring 2002 Groundwater Monitoring Report for Andersen AFB, Guam* (FWENC/EA, 2002b)

- *Final Fall 2002 Groundwater Monitoring Report for Andersen AFB, Guam* (FWENC/EA, 2003a)

- *Final Spring 2003 Groundwater Monitoring Report for Andersen AFB, Guam* (FWENC/EA, 2003b)

- *Technical Memorandum: Reduction of Monitoring Points, Sampling Frequency, and Analytical Parameters for LTGM at MARBO Annex Operable Unit* (EA, 2003)

- *Final First Five-Year Review of ROD for MARBO Annex Operable Unit, Andersen AFB, Guam* (EA, 2004)

- *Final Fall 2004 Groundwater Monitoring Report for Andersen AFB, Guam* (EA, 2005a)

- *Final Spring 2005 Groundwater Monitoring Report for Andersen AFB, Guam* (EA, 2005b)

- *Final Fall 2005 Groundwater Monitoring Report for Andersen AFB, Guam* (EA, 2006a)

- *Final Spring 2006 Groundwater Monitoring Report for Andersen AFB, Guam* (EA, 2006b)

- *Final Fall 2006 Groundwater Monitoring Report for Andersen AFB, Guam* (EA, 2007a)

- *Final Spring 2007 Groundwater Monitoring Report for Andersen AFB, Guam* (EA, 2007b)

- *Final Fall 2007 Groundwater Monitoring Report for Andersen AFB, Guam* (EA, 2008a)

- *Final Spring 2008 Groundwater Monitoring Report for Andersen AFB, Guam* (EA, 2008b)

- *Final FFS to Support a ROD Amendment with a TI Waiver for the MARBO Annex Operable Unit, Andersen AFB, Guam* (EA, 2008c).

Based on the results of the investigations completed for MARBO Annex groundwater, the USN has concluded that *Natural Attenuation with Wellhead Treatment* is a failed remedy and that specific fundamental changes are needed for the original groundwater remedy.

2.2.2 Occurrence, Fate, and Distribution of Groundwater Contamination

A complete description of the nature and extent of contamination in MARBO Annex groundwater is presented in the 2008 Focused Feasibility Study (FFS) (EA, 2008c).

Since the LTGM Program was initiated in 1995, 26 groundwater sampling events have been conducted at the MARBO Annex. Based on the results of the OU 2 Remedial Investigation and the LTGM Program, two potential contaminants of concern were identified: TCE and PCE (ICF, 1997; EA, 2008b). These contaminants of concern have historically been detected in deep groundwater samples collected from two monitoring wells, IRP-31 and IRP-29, at concentrations above their respective MCLs (5 μg/L, each). The historic distribution of TCE and PCE concentrations in groundwater exceeding the MCL are depicted on Figure 2-1.

The dissolved-phase TCE and PCE have been identified as being two immobile, geographically distinct plumes; therefore, a common source for contaminants is not plausible. The estimated volumes of TCE- and PCE-contaminated groundwater are 340 million gallons and 280 million gallons, respectively[4]. Though a significant number of potential sources have been investigated at IRP sites, no surface or subsurface sources for the TCE and PCE have been identified. Also, the fact that the shallow freshwater lens has shown a consistent decline in TCE and PCE concentrations over the past 15 years is indicative that there is not continued contaminant sourcing from the vadose zone (EA, 2008c).

TCE and PCE have either been non-detect or detected at concentrations below the MCL in all shallow monitoring wells, except IRP-14. In groundwater samples collected from IRP-14 PCE concentrations have decreased linearly over the past 11 years to concentrations below the

[4] The estimated volumes of TCE- and PCE-contaminated groundwater were calculated by multiplying the plume volumes by the soil porosity using the following assumptions:

PCE Plume:	Length = 2,500 feet	TCE Plume: Length = 3,000 feet
	Width = 1,000 feet	Width = 1,000 feet
	Height = 50 feet	Height = 50 feet
	Porosity = 30% (ICF, 1997)	Porosity = 30% (ICF, 1997)

MCL. This trend suggests that PCE in the shallow aquifer is being attenuated through the physical process of hydrodynamic dispersion. This is likely due to strong horizontal flow components in the shallow portion of the freshwater lens that result in rapid turnover rates.

TCE and PCE concentrations in groundwater samples collected from deep monitoring wells, IRP-31 and IRP-29, are one to two orders of magnitude higher than groundwater from nearby shallow wells. This is likely due to the density driven flow of dissolved phase TCE and PCE through the shallow part of the fresh water aquifer until the vertical flow component declines and the concentrations equilibrate with the denser transition zone. This indicates that the brackish water transition zone and the deep portion of the freshwater lens is significantly more static and less mobile than the shallow part of the freshwater lens. TCE and PCE concentrations have cyclically fluctuated over time in relation to changes in the lens thickness in response to intense rain events, seasonal rainfall, and long-term El Niño/Southern Oscillation effects, but have stayed within an established concentration range and show no appreciable increase or decrease, on average, over the past 11 years. The highest concentrations of TCE and PCE (detected at IRP-31 and IRP-29, respectively) have been observed in groundwater samples collected near the base of the freshwater lens, where these contaminants appear to be relatively immobile.

2.2.3 Geology and Hydrogeology

The northern half of Guam exhibits characteristics of a Simple Carbonate Island, a Carbonate-Cover Island, and a Composite Island according to the type of Carbonate Island Karst Model (Mylroie et al., 2001). Although a freshwater lens (overlying marine water) exists in the subsurface for all model types observed on Guam, the types differ by location of the limestone-volcanics contact relative to the elevation of the water table and relative to the elevation of the ground surface. Two volcanic peaks, Mount Santa Rosa and Mataguac Hill, control this relationship and, therefore, affect the distribution and migration of groundwater in the vicinity of these features. The result is a channeling of groundwater flow within the limestone, toward Tumon Bay.

Groundwater is the principal source of drinking water for Guam and is the source of freshwater for other uses. The karst limestone of the Northern Guam Lens produces approximately 40 million gallons of freshwater per day for these uses. The Northern Guam Lens was designated as a principal sole-source aquifer by the USEPA in 1978, under the provisions of the Safe Drinking Water Act. Even though Guam receives approximately 100 inches per year of rainfall, surface water does not exist on northern Guam due to the highly permeable, eogenetic, karst limestone. The general hydrogeology of the Northern Guam Lens is summarized below:

- The Barrigada and Mariana limestone formations are the primary groundwater aquifers underlying the MARBO Annex.

- Groundwater flow (and contaminant migration) at MARBO Annex is very complex due to karstic geologic features, secondary solution channelizing, and production well pumping.

- The vadose zone consists of approximately 400 ft of coralline-reef limestone, which has a heterogeneous porosity distribution with diffuse groundwater flow within primary porosity and discrete, channelized groundwater flow in secondary, dissolution-enhanced porosity.

- Though some infiltrating precipitation is captured as storage in vadose zone primary porosity, the vast majority of infiltration percolates through the vadose secondary porosity and, due to density effects, creates a freshwater lens that floats atop a transition zone underlain by marine water.

- This freshwater aquifer is approximately 100 ft thick and is highly conducive to groundwater flow. Hydraulic conductivities as high as 20,000 ft per day were observed during the MARBO Annex OU remedial investigation (ICF, 1997) and during dye trace studies conducted on the Main Base during the MARBO Annex OU remedial investigation field work.

- A brackish transition zone (mixing zone), approximately 20 ft in thickness, exists between the freshwater lens and the underlying marine water.

- The rapid infiltrating recharge to the upper portion of the freshwater lens propagates quickly (weeks to months) to coastal discharge areas (seeps and/or large-scale dissolution features).

- The rapidly infiltrating recharge has created strongly oxidized groundwater conditions throughout the freshwater lens, as evidenced by shallow and deep dissolved oxygen concentrations generally ranging from 5 to 8 milligrams per liter (mg/L) and oxidation-reduction potential ranging from 100 to 500 millivolts.

- The strong lateral flow component that is observed in the upper portion of the freshwater lens is not evident (based on contaminant trends) in the basal portion of the lens.

- The elevation of the water table and thickness of the freshwater lens vary in response to rapid stimuli (large short-term rain events), moderate-term stimuli (seasonal rainfall and monsoonal wind effects on sea level), and long-term stimuli (precipitation fluctuations due to El Niño/Southern Oscillation events and eustatic sea level rise).

- The effect of short- and long-term stimuli on the thickness of the freshwater lens has lead to cyclic variation on the observed chloride levels in deep groundwater when observed at a vertically fixed sampling point. For example, chloride levels in groundwater at IRP-29 and IRP-31 have cyclically varied between approximately 20 and 200 mg/L.

2.2.4 Summary of Site Risks

A complete description of site risks and exposure assumptions for MARBO Annex Groundwater is presented in the OU 2 Remedial Investigation Report (ICF, 1997). The following excerpt and table were taken from the 1998 ROD.

The groundwater risk assessment utilized conservative assumptions, resulting in estimated risks that are likely higher than actual risks. As seen in the table below, the potential risk for production wells where contaminants of concern were detected is within the risk management range of 1×10^{-6} to 1×10^{-4}. Production wells MW-1, MW-2, and MW-3 are additionally treated with Air Stripping to remove low level concentrations of TCE and PCE, though MW-2 is the only production well where concentrations have recently exceeded MCLs[5]*. Because risk is within an acceptable range for production wells at the MARBO Annex, groundwater quality goals at the MARBO Annex are primarily determined by federally allowable concentrations of TCE or PCE in the groundwater (i.e., MCLs). Remedial alternatives were evaluated to assess the feasibility of achieving concentrations of TCE and PCE in the aquifer to below the Federal MCL of 5 µg/L. Monitoring wells where contaminants of concern were detected are generally within EPA's risk management range of 1×10^{-6} to 1×10^{-4} and below a Hazard Index of 1, with the exception of IRP-31. Monitoring well IRP-31 exceeds the Hazard Index of 1; however, this is a deep well with high chloride content and not meant for consumption… No ecological risks were identified.* (EA/MW, 1998)

ESTIMATED HUMAN HEALTH RISK				
Well ID[a]	***Hazard Index***	***Potential Health Risk***[b]	***Estimated Current Risk***	***Well ID***[a]
D-5[c]	*0.044*	*$1x10^{-6}$*	*$1x10^{-6}$*	*D-5*[c]
MW-1[c,d]	*0.033*	*$3x10^{-6}$*	*$<1x10^{-6}$*	*MW-1*[c,d]
MW-2[c,d]	*0.181*	*$4x10^{-6}$*	*$<1x10^{-6}$*	*MW-2*[c,d]
MW-5[c]	*0.004*	*$2x10^{-7}$*	*$2x10^{-7}$*	*MW-5*[c]
GPA-1 - 420'[e,f]	*0.075*	*$2x10^{-6}$*	*NA*	*GPA-1 - 420'*[e,f]
GPA-1 - 480'[e,f]	*0.182*	*$4x10^{-6}$*	*NA*	*GPA-1 - 480'*[e,f]
GPA-2 - 423'[e,f]	*0.085*	*$2x10^{-6}$*	*NA*	*GPA-2 - 423'*[e,f]
GPA-2 - 483'[e,f]	*0.063*	*$2x10^{-6}$*	*NA*	*GPA-2 - 483'*[e,f]
IRP-14[e]	*0.180*	*$1x10^{-5}$*	*NA*	*IRP-14*[e]
IRP-15[e]	*0.130*	*$6x10^{-6}$*	*NA*	*IRP-15*[e]
IRP-25[e]	*0.057*	*$1x10^{-6}$*	*NA*	*IRP-25*[e]
IRP-27[e]	*0.018*	*$1x10^{-6}$*	*NA*	*IRP-27*[e]
IRP-29 (D)[e]	*0.224*	*$9x10^{-6}$*	*NA*	*IRP-29 (D)*[e]
IRP-31 (D)[e]	*4.34*	*$1x10^{-4}$*	*NA*	*IRP-31 (D)*[e]

[a] *Production wells not shown did not detect TCE or PCE during the monitoring rounds utilized for the risk assessment.*

[b] *Based on risk assessment conducted in OU 2 RI.*

[c] *Production well.*

[d] *Production well presently treated with Air Stripping. The estimated current risk is less than $1x10^{-6}$ because the water from these wells is treated with the Air Stripper before distribution, removing the TCE and PCE.*

[e] *Monitoring well. Water from these wells is not consumed.*

[f] *GPA wells are sampled at different depths.*

NA - not applicable. Monitoring well groundwater not consumed.

[5] TCE concentrations have been below Federal MCLs since 1989 in MW-1, and have never exceeded MCLs in MW-3. PCE has never been detected above MCLs in either MW-1, 2, or 3.

2.2.5 1998 Selected Remedy

The selected remedy of *Natural Attenuation with Wellhead Treatment*, as described in the 1998 ROD, is presented below:

This alternative utilizes Natural Attenuation of TCE/PCE in the aquifer to achieve the remediation goal of decreasing TCE/PCE concentrations in the aquifer to concentrations below MCLs. Supplemental to this remedy are three ICs, including: (1) Land Use Restrictions (to monitor and restrict groundwater access in areas impacted by TCE/PCE), (2) Groundwater Monitoring (to monitor the decrease of TCE/PCE and confirm the stability of TCE/PCE plumes in the MARBO Annex), and (3) Existing Wellhead Treatment (to ensure public health risk is within acceptable range at existing Air Force production wells).

Natural Attenuation. *As noted in the previous section, the decreasing trends of TCE and PCE in the groundwater at the MARBO Annex would be due to the physical processes of dispersion and dilution, which are largely dependent on the volume and rate of water traveling through the vadose zone and aquifer. The conditions at the MARBO Annex favor both of these factors. Average precipitation on the island of Guam is in the range of 100 inches per year. Over the 3.8 square mile area of the MARBO Annex, and assuming a 50 percent evapotranspiration rate, this equates to a recharge rate in the range of 3.3 billion gallons per year, or nine million gallons per day. The combination of these high recharge rates in a transmissive limestone aquifer provides a supportive environment for accelerated physical natural attenuation of TCE and PCE. The natural attenuation would occur by "flushing" out any residual TCE/PCE remaining in the vadose zone and/or aquifer.*

As illustrated earlier, there is good evidence that natural attenuation has occurred, and continues to occur, at the MARBO Annex. All of the production wells which have had either TCE or PCE detected in them show a decrease, and all of the monitoring wells which have had TCE or PCE detected in them, which have been monitored for greater than two years, also show a decrease. This is summarized on the table below:

SUMMARY OF TCE/PCE CONCENTRATION CHANGES

Well Type	*Number of Wells Indicating Changes in TCE/PCE Concentrations*			*Total Wells*
	Decrease	*Increase*	*No Change*	
Production wells (8+ years of monitoring)	*10*	*0*	*3 (All non-detect)*	*13*
IRP wells (>2 years of monitoring)	*6*	*0*	*2 (All no- detect)*	*8*
IRP wells (2 years of monitoring)	*1*	*3*	*9 (5 non-detect)*	*13*
GPA monitoring wells (1+ years of monitoring)	*2*	*0*	*0*	*2*
TOTAL:	*19*	*3*	*14 (10 non-detect)*	*36*

Thus, all of the production wells, and all of the IRP monitoring wells that have been monitored for greater than 2 years, which have had concentrations of TCE or PCE detected in the past, indicate decreasing TCE and/or PCE concentrations. The monitoring wells which indicate an

increase in TCE/PCE concentrations have been monitored for only 2 years. These monitoring wells are expected to follow the same decreasing trend as the other wells which have been monitored over a longer time period.

A degradation rate was estimated in order to estimate potential times for TCE and PCE to attenuate below MCLs. The range of degradation rates is considered roughly representative of how TCE and/or PCE reacts in the aquifer. The primary limitation to these estimates includes the uncertainty of total TCE/PCE mass that may exist in the subsurface, which likely varies between the locations where wells presently exceed MCLs. Thus estimated cleanup times should take this into consideration, with the understanding that actual cleanup times may exceed the high end of the range.

There are presently two locations (three monitoring wells) that exceed MCLs: IRP-31 exceeds the MCL for TCE, and IRP-14 and IRP-29 (located adjacent to each other) exceed the MCL for PCE. The estimated time to achieve the TCE MCL in IRP-31 may range from approximately 10 to 40 years. The estimated time to achieve the PCE MCL in IRP-14 may range from approximately 1 to 10 years. The estimated time to achieve the PCE MCL in IRP-29 may range from 2 to 10 years. Again, these are estimates which have limitations that should be considered.

ICs. *As noted earlier, there are three IC mechanisms which are included with the Natural Attenuation remedy, as shown below:*

- ***Land Use Restrictions*** *involve placing restrictions on the property deeds pertaining to the installation of water supply wells on properties affected by PCE and TCE-contaminated groundwater. The intent of land use restrictions is to reduce potential exposure to contaminants by legally restricting future groundwater development from those areas that are known to be impacted. The implementation mechanism for this component would be through Guam EPA's Wellhead Protection Program and Well Installation licensing and permitting. As part of the Wellhead Protection program, Guam EPA has developed a Groundwater Protection Zone Map which identifies those areas where surface activities above the resource or recharge zone have the ability to impact the water quality. The metes and bounds descriptions of the land are designated on this map along with other pertinent information (Guam EPA, 1993). Guam EPA reviews groundwater data from the Andersen AFB CERCLA process, and all well installation applications are reviewed by Guam EPA first prior to installation. Also, as part of the Wellhead Protection Program, well installation within 1,000 ft of an existing production well is prohibited. As Guam EPA has been involved with the development of this ROD, this would easily facilitate the necessary transfer of information from Andersen AFB to Guam EPA, for implementation of the above-mentioned ICs.*

- ***Existing Wellhead Treatment*** *is in place for three of the production wells on the MARBO Annex (MW-1, MW-2, and MW-3) until TCE and/or PCE concentrations are consistently below MCLs. Two of these wells (MW-1 and MW-2) have slightly exceeded the MCL for TCE in the past*[6]*. The endorsement and recommendation of continued wellhead treatment in these production wells would provide additional health risk benefit to those wells which exceed MCLs for TCE and/or PCE. Treatment status would be evaluated every two years in conjunction with the Andersen AFB LTGM Plan.*

- ***LTGM*** *involves the sampling and monitoring of the groundwater at the MARBO Annex through existing monitoring wells and production wells. The groundwater would be analyzed for TCE, PCE, and other constituents which would be deemed pertinent for monitoring. Long-term monitoring is consistent with existing plans for monitoring under the IRP (EA/MW, 1995), and would monitor constituents in select IRP wells as well as production wells in and around the MARBO Annex. Monitoring would continue until TCE and PCE concentrations are consistently below MCLs.* (EA/MW, 1998)

2.3 Basis for Amending the 1998 Selected Remedy

Since the implementation of 1998 selected remedy, semi-annual groundwater sampling and analysis at the MARBO Annex has shown that MNA has not been effectively attenuating TCE and PCE in deep wells IRP-31 and IRP-29, respectively. The reasoning for the failure of MNA is that these TCE and PCE concentrations have been highly variable over the last five years, and have not shown any appreciable decrease.

The conceptual model is that TCE (or PCE) is trapped in the transition zone limestone matrix and releases very slowly into a karst-dominated system that is static with respect to lateral flow. The concentration variability results from the frequent changes in the karst-flow dynamics from intense rain events, seasonal rainfall, long-term El Niño/Southern Oscillation effects, and resulting changes in the transition zone depth. There is no evidence that the TCE and PCE bound to the limestone matrix are decreasing.

According to the 1998 ROD, MNA was intended to achieve TCE and PCE reductions to levels below the 5 µg/L MCL in an estimated 10-40 years. However, based on 11 years of historical groundwater data for MARBO Annex, the TCE and PCE concentrations in the deep portion of the freshwater lens have remained cyclical and for all practical purposes unchanged. Therefore, MNA is considered a failed remedy in addressing the presence of the TCE and PCE in the deep portion of MARBO Annex freshwater lens.

2.4 Description of Alternatives

Since the 1998 ROD was approved, additional information has been obtained through the LTGM Program resulting in the need for a fundamental change to the 1998 selected remedy. This section presents a comparison of the 1998 selected remedy and the alternatives studied in the

[6] This is an incorrect statement from the 1998 ROD. Wellhead treatment was only placed on MW-2. TCE concentrations have been below Federal MCLs since 1989 in MW-1, and have never exceeded MCLs in MW-3. PCE has never been detected above MCLs in MW-1, 2, or 3.

2008 Focused Feasibility Study. The *No Action* alternative was included in the 1998 ROD and is therefore not re-addressed in this ROD Amendment.

Alternative Name	Description
1998 Selected Remedy Natural Attenuation with Wellhead Treatment	MNA, LUCs, Groundwater Monitoring, Existing Wellhead Treatment
FFS Alternative 1 Enhanced Anaerobic Bioremediation (*In-Situ*)	Biological treatment: substrate injection to acquire stable anaerobic conditions.
FFS Alternative 2 Chemical Oxidation (*In-Situ)*	Chemical treatment: substrate injection to break the bonds in hydrocarbon compounds.
FFS Alternative 3 Micro-Scale Zero Valent Iron (*In-Situ*)	Chemical treatment: slurry injection into aquifer to destroy chlorinated hydrocarbons through abiotic reduction.
FFS Alternative 4 In-Well Air Stripping (*In-Situ*)	Physical treatment: groundwater is drawn through a collection and treatment well, with infused air acting as an air stripper.
FFS Alternative 5 Pump and Treat (*Ex-Situ*)	Physical treatment: remove contaminated groundwater, treat it with ex situ technology, and discharge accordingly.
FFS Alternative 6 LTGM with Contingency for Wellhead Treatment[7]	Groundwater monitoring, contingency for wellhead treatment, LUCs, TI Waiver for achieving MCLs in the aquifer.

The 2008 FFS concluded that Alternatives 1 through 5 were not feasible or practicable from an engineering and technological viewpoint to remediate the dissolved-phase TCE or PCE or to remediate the sources (Table 2-2). A discussion of the components of these alternatives, as well as the justification as to why they are not feasible is presented in Section 2.4.1. Section 2.4.2 discusses the site conditions that further substantiate the dismissal of Alternatives 1 through 5 as feasible alternatives. Section 2.4.3 presents a detailed discussion of the remedy components, common elements and distinguishing features, and expected outcomes for the remaining two alternatives, the 1998 Selected Remedy and Alternative 6, *LTGM with Contingency for Wellhead Treatment*.

2.4.1 FSS Alternatives

FFS Alternatives 1 through 5 are described in the following section and are summarized on Table 2-2.

Alternative 1: Enhanced Anaerobic In Situ Bioremediation

Enhanced Anaerobic *In-Situ* Bioremediation requires the injection of a substrate to facilitate biological activity. Stable anaerobic conditions and the presence of appropriate microbial populations are required for this method to be effective. A considerable drilling effort would be required, with tightly spaced injections up to approximately 400 ft bgs. Accurate placement of injections is extremely difficult because the depth and geology cause deflection of drill strings in unpredictable ways. Site characterization is limited (due to logistics as discussed above).

[7] Per USEPA guidance at the July 2009 Remedial Project Manager (RPM) Meeting, land use controls from the original remedy remain unchanged.

Monitoring the effectiveness of the remedy would require installing and sampling wells in addition to those used for substrate injection resulting in the same difficulties.

This alternative was found to not be implementable because there is an insufficient aquifer surface area for the colonization of degrading microorganisms, the depth to the contamination would result in inaccurate spatial delivery, and high oxygen levels in groundwater and transient and episodic flow conditions will disallow stable, reducing conditions required for biological reductive dechlorination. The estimated cost of this alternative is $92,200,000.

Alternative 2: In Situ Chemical Oxidation

Logistical problems with the successful implementation of Chemical Oxidation technology are much the same as those for enhanced *in-situ* bioremediation. The depth to groundwater is such that each injection point would require a considerable drilling effort. The installation of a sufficient number of tightly spaced injection points (i.e. 10 ft on center) across the area of the PCE and TCE plumes may be difficult. Accurate placement of injection points at a depth of approximately 400 ft bgs is complex because the site geology causes deflection of drill strings in unpredictable ways. The site characterization is limited due to the difficulties in gathering accurate information at these depths. Monitoring the effectiveness of this remedy would also require installing and sampling wells in addition to those used for substrate injection. This alternative was found to not be implementable because the spatial delivery at this depth of contamination in this complex geologic setting would most likely be inaccurate or insufficient, and the optimization of pH-dependent oxidants is not possible due to carbonate buffering in the karst setting of the aquifer. The estimated cost of this alternative is $57,418,000.

Alternative 3: In Situ Micro-Scale Zero Valent Iron

Micro-Scale Zero Valent Iron (ZVI) is a technology by which abiotic reduction is induced by oxidation of the ZVI to destroy chlorinated hydrocarbons (e.g., PCE and TCE). A common method of *in-situ* groundwater remediation with ZVI involves the "funnel and gate" approach, which sets up an impermeable barrier that funnels groundwater through a permeable reactive barrier filled with a ZVI mixture. Additionally, ZVI can be injected as a slurry mixture into an aquifer with the same methods as described in the previous alternatives. The depth to groundwater and site geology presents the same issues with this alternative as it does with Alternatives 1 and 2 since the use of a funnel and gate approach in conditions such as those present at the MARBO Annex is impossible. Monitoring the effectiveness of the remedy would require installing and sampling of wells, adding to the logistical issues.

This alternative was found to not be implementable because the spatial delivery at this depth of contamination in this complex geologic setting would most likely be inaccurate or insufficient, and a significant decrease in ZVI reactivity in short time frames would occur due to carbonate scaling in the karst setting of the aquifer. The estimated cost of this alternative is $57,790,000.

Alternative 4: In Situ In-Well Air Stripping

In-Well Air Stripping provides in situ treatment of the groundwater, using circular groundwater flow current between screens. Extensive testing would be required to ensure that the system design is accurate. Groundwater recharge conditions in the aquifer are highly unstable, making system balance operations unreasonably complex. Operation and maintenance (O&M) of in-well stripper systems can be very complicated due to carbonate fouling of well screens and the associated changes the system balance and the inability to produce or inject sufficient water. O&M of in-well stripper systems with a large number of extremely deep wells like the ones required for the MARBO Annex would be extremely difficult. Another difficulty is that TCE has been detected at depth, creating the potential to extract TCE-impacted groundwater and discharge insufficiently treated groundwater to the upper portion of the aquifer. This would result in cross contaminating a sectional volume of the aquifer. A similar problem could occur if saline water were extracted from the lower part of the aquifer and injected into the upper part of the aquifer as well; increasing saline contamination in the upper portion of the aquifer. Restoration potential is low with this technology because of the difficulty in creating an adequate circulation cell between the upper and lower screens due to preferential pathways inherent in the dual porosity and high flow characteristics of the aquifer.

This alternative was found to not be implementable because of the high volume of pumping that would be required, the potential short circuiting due to directional flow from secondary porosity conduits, and the mass transfer limitations from primary diffuse porosity. The estimated cost of this alternative is $55,992,000.

Alternative 5: Ex Situ Pump and Treat

The Pump and Treat alternative involves the removal of contaminated groundwater and its treatment with ex situ technologies, after which it is discharged accordingly. Logistical problems associated with this alternative are much the same as with the prior alternatives, with a considerable drilling effort and the requirement of drilling additional monitoring wells. Extraction of large amounts of water from the freshwater part of the aquifer at the MARBO Annex could cause significant problems with saltwater intrusion, which is highly undesirable. Groundwater recharge conditions in the aquifer are highly unstable, which could require significant effort by operators to avoid over pumping (exacerbating saltwater intrusion) or under pumping (with the associated loss of sufficient capture and/or hydraulic control of the plume). Pump and Treat technology historically has not always been effective in obtaining sufficient mass removal to attain site closure.

This alternative was found to not be implementable because of the high volume of pumping required, the potential for the upwelling of marine water, the mass transfer limitations from primary diffuse porosity, and carbonate scaling of the treatment system. The estimated cost of this alternative is $55,992,000.

2.4.2 Site Conditions Limiting the Implementability of Alternatives 1 through 5

Depth to groundwater is approximately 400 ft at the MARBO Annex. The depth to groundwater and the complex hydrogeology at the MARBO Annex make drilling difficult and expensive, and therefore has placed severe limitations on the ability to investigate and remediate the TCE and PCE occurrences observed in the deep freshwater lens.

The aquifer exists within a complex karst limestone, with large, solution channels created by secondary porosity and low-permeability, diffuse flow within primary porosity. The design and proper implementation of a pump and treat system is made difficult by the negative effects potentially created by the vertical upwelling of TCE and PCE as well as the upwelling of salt water that would damage the aquifer. The highly transmissive, channelized aquifer would provide a vehicle for the transmission of either the contaminants or the salt water from the deep portion to shallower portions of the aquifer, where nearby production wells actively produce from.

Source remediation at the MARBO Annex presents several problems. After significant effort, the sources of the TCE and PCE have not been identified and there is no guarantee that additional investigations could locate the sources. If the sources were located, the USAF could still do no better than provide containment through pump and treat because the depth to groundwater and the complex karst setting preclude any type of physical barriers. One possible explanation for the lack of TCE and PCE attenuation within the deep portion of the freshwater lens over time is that the impacted zone of the deep freshwater lens is not flushed adequately, and thus static, relative to shallower portions of the aquifer. This complication is compounded by the finding that some dissolved (and potentially sorbed) phase TCE and PCE mass is likely trapped within the diffuse primary porosity, with only slow, mass-limited diffusion to conduit flow zones. The release of dissolved phase TCE and PCE from the diffuse porosity is not likely to occur within an acceptable timeframe for any potentially viable technology.

In addition, the high aquifer transmissivity (up to 200,000 square ft per day) and the associated high volume of water flowing through the system would require tremendous extraction and treatment capacities to address the TCE and PCE plumes. Extraction and treatment of the large volume of water required to reach plume containment also would not address remediating the sources (EA, 2008c).

Additionally, the water balance on Guam is extremely important because of the population's dependence on groundwater for both potable uses and for maintaining a salt water intrusion barrier. Water quality may be treated, but quantity cannot be replaced and a large-scale pump and treat system may have detrimental side effects on the island's water balance.

2.4.3 Description of Remedy Components for the 1998 Selected Remedy and Alternative 6

This section provides an overview of the components of the original remedy and the components of Alternative 6, *LTGM with Contingency for Wellhead Treatment*. Details related to the 1998 selected remedy can be found in Section 2.2.5 above and in the 1998 ROD. Alternative 6 was originally evaluated in the 2008 FFS, and is a variation of the 1998 selected remedy (EA, 2008c).

The primary difference is that Alternative 6 includes a TI Waiver which waives the requirement to restore TCE and PCE concentrations in the aquifer to below MCLs. Also, MNA is not included as a component of Alternative 6.

1998 Selected Remedy: ***Natural Attenuation with Wellhead Treatment***

- **MNA** of the TCE and PCE plumes to achieve the remediation goal of decreasing concentrations in the aquifer to levels below USEPA established MCLs. The combination of high recharge rates in the transmissive limestone aquifer was believed to provide a supportive environment for accelerated physical MNA of TCE and PCE. The MNA would occur by "flushing" out any residual TCE/PCE remaining in the vadose zone and/or aquifer. The timeframe to achieve MCLs was estimated to range from approximately 10 to 40 years.

- **Land Use Controls** involve placing restrictions on the property deeds pertaining to the installation of water supply wells on properties affected by PCE- and TCE-contaminated groundwater.[8] The intent of land use restrictions is to reduce potential exposure to contaminants by legally restricting future groundwater development from those areas that are known to be impacted. The implementation mechanism for this component is through Guam EPA's Wellhead Protection Program and Well Installation licensing and permitting.

- **Existing Wellhead Treatment** for three of the production wells on the MARBO Annex (MW-1, MW-2, and MW-3) until TCE and/or PCE concentrations are consistently below MCLs. Two of these wells (MW-1 and MW-2) have slightly exceeded the MCL for TCE in the past[9]. The endorsement and recommendation of continued wellhead treatment in these production wells would provide additional health risk benefit to those wells which exceed MCLs for TCE and/or PCE. Treatment status would be evaluated every two years in conjunction with the Andersen AFB LTGM Program.

- **LTGM** involves the sampling and monitoring of MARBO Annex Groundwater through existing monitoring wells and production wells. The groundwater would be analyzed for TCE, PCE, and other relevant constituents and parameters. Long-term monitoring is consistent with the current LTGM Program, and would monitor constituents in select IRP wells as well as production wells in and around the MARBO Annex. Monitoring would continue until TCE and PCE concentrations are consistently below MCLs.

- **Five-Year Reviews** would be performed to determine if the remedy is still effective and if the remedy has achieved its goals, and thus can be discontinued.

[8] Although not specified in the 1998 ROD, property deed restrictions would have applied to affected properties located both on and off of Andersen AFB. However, the only well to ever require wellhead treatment was MW-2, a USAF production well located at the MARBO Annex.

[9] This is an incorrect statement from the 1998 ROD. Wellhead treatment was only placed on MW-2. TCE concentrations have been below Federal MCLs since 1989 in MW-1, and have never exceeded MCLs in MW-3. PCE has never been detected above MCLs in MW-1, 2, or 3.

Alternative 6: ***LTGM with Contingency for Wellhead Treatment***

- **LTGM** would be performed at selected monitoring wells and production wells. Groundwater samples would be analyzed for TCE, PCE, and other parameters that are useful in monitoring the immobility of TCE and PCE in groundwater.

- **LUCs** selected in the 1998 ROD remain unchanged. They have been implemented through the Base Master Plan and the Guam EPA's Wellhead Protection Program.

- **Contingency for Wellhead Treatment** at on-MARBO Annex production wells or existing or future off-MARBO Annex production wells within the extent of the TCE and PCE plumes. Upon TCE or PCE concentrations exceeding designated levels, wellhead treatment would be applied to the affected well. Treatment units would be installed by the USN if no treatment system exists on that well or the USAF would pay the incremental cost caused by the presence of TCE and/or PCE if a well already had a treatment system.

- **TI Waiver** for the ARAR of achieving MCLs in the aquifer. The TI Waiver, as explained in Section 2.4.2, is necessary because site conditions make it impracticable for remediating the aquifer in a reasonable time frame.

- **Five-Year Reviews** would continue to be performed to determine if the remedy is still effective and if the remedy has achieved its goals, and thus can be discontinued.

2.4.3.1 Common Elements and Distinguishing Features of Each Alternative

Table 2-3 provides a summary of the elements common to each alternative and features that distinguish one alternative from the other.

2.4.3.2 Effects on Remedial Action Objectives

The Remedial Action Objectives (RAOs) established for the 1998 selected remedy were designed to address unacceptable risks to human health and the environment and to restore groundwater quality in the aquifer. Alternative 6 would invoke a TI Waiver, waiving the ARAR requiring reduction of TCE and PCE contamination levels to below MCLs and modifying the RAOs. Specifically, the following RAO would be eliminated under Alternative 6:

- Restore MARBO Annex Groundwater to concentrations below MCLs for PCE and TCE (5 µg/L, respectively).

The following three RAOs for the 1998 selected remedy would remain unchanged under Alternative 6:

- Prevent ingestion of water having concentrations of PCE/TCE exceeding the Federal MCLs (5 µg/L, respectively).

- Establish a means to monitor and confirm that the human health risks associated with the presence of PCE and TCE within MARBO Annex Groundwater do not exceed established acceptable levels.

- Maintain the human health risk associated with the presence of PCE and TCE within MARBO Annex Groundwater to a technically practical level that is within the USEPA's risk range of 10^{-4} to 10^{-6}.

2.4.3.3 Changes in Expected Outcomes

Table 2-4 provides a summary of the expected outcome for the 1998 selected remedy and Alternative 6. While the 1998 ROD did not specify expectations for the outcome of the selected remedy, the document stated that MNA would return the groundwater to a quality acceptable for unlimited use and unrestricted access in a time period of 10-40 years. Until such quality was achieved, risks to human health and the environment were to be mitigated through the implementation of LUCs, which included land use restrictions, groundwater monitoring, and wellhead treatment. LTGM results compiled since the completion of the 1998 ROD have shown that MNA will not effectively remediate the TCE or PCE plumes within the timeframe originally specified.

The expected outcome of Alternative 6 with the TI Waiver invoked is that risks to human health and the environment would be addressed through long-term groundwater monitoring and wellhead treatment. Wellhead treatment would be used, if necessary, to ensure that groundwater is suitable for human consumption.

2.5 Comparative Analysis of the Alternatives

In accordance with the NCP, the groundwater alternatives for MARBO Annex were evaluated using the nine criteria described in Section 121(b) of CERCLA and the NCP §300.430(f)(5)(i). These criteria are classified as threshold criteria, balancing criteria, and modifying criteria. Because Alternatives 1 through 5 were not considered feasible given the site conditions, they are not included in this comparative analysis of alternatives.

Threshold criteria are standards that an alternative must meet to be eligible for selection as a remedial action. There is little flexibility in meeting the threshold criteria—the alternative must meet them or it is unacceptable. The following are classified as threshold criteria:

- Overall protection of human health and the environment
- Compliance with ARARs.

Balancing criteria weigh the tradeoffs between alternatives. These criteria represent the standards upon which the detailed evaluation and comparative analysis of alternatives are based. In general, a high rating on one criterion can offset a low rating on another balancing criterion.

Five of the nine criteria are considered balancing criteria:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume through treatment
- Short-term effectiveness
- Implementability
- Cost.

Modifying criteria are as follows:

- Community acceptance
- State/support agency acceptance.

2.5.1 Overall Protection of Human Health and the Environment

LTGM data collected since the 1998 ROD was signed show that MNA is not effectively attenuating the PCE and TCE concentrations in the deep portions of the freshwater lens. However, the 1998 selected remedy is protective of human health and the environment under current site conditions through the use of LUCs, as described above.[10]

For Alternative 6, groundwater monitoring requirements provide the same level of protection as the 1998 selected remedy based on current site conditions. Additionally, Alternative 6 allows for the contingency to perform wellhead treatment on any existing or future well within the extent of the TCE and PCE plumes that is impacted at concentrations above the designated levels. Therefore, Alternative 6 may be considered as protective of human health and the environment as the 1998 selected remedy, as it would protect against any current or potential future use scenario.

Although the RAO to restore groundwater quality in the aquifer will be eliminated with the TI Waiver, Alternative 6 will be protective of human health and the environment by implementing, if appropriate, wellhead treatment. Wellhead treatment will prevent ingestion of water having concentrations of PCE or TCE above the MCL, including if the contaminant plumes migrate or grow offsite. MARBO Annex production wells will continue to be monitored to assure that TCE and PCE concentrations remain consistently below the MCLs.

2.5.2 Compliance with Applicable or Relevant and Appropriate Requirements

Section 121(d) of CERCLA and NCP §300.430(f)(1)(ii)(B) require that remedial actions at CERCLA sites at least attain legally applicable or relevant and appropriate federal and state requirements, standards, criteria, and limitations which are collectively referred to as "ARARs," unless such ARARs are waived under CERCLA Section 121(d)(4).

[10] The closest Andersen AFB production well (MW-2) to the TCE and PCE groundwater contamination was taken offline in early 1998.

Applicable requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility citing laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. State standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility citing laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site address problems or situations sufficiently similar to those encountered at the CERCLA site (relevant) that their use is well-suited (appropriate) to the particular site. Only those State standards that are identified in a timely manner and are more stringent than Federal requirements may be relevant and appropriate.

Compliance with ARARs addresses whether a remedy will meet all of the ARARs of other federal and state environmental statutes or provides a basis for invoking a waiver.

Both remedies would comply with location-specific and action-specific ARARs.

Alternative 6 would waive chemical-specific ARARs with a TI Waiver. The TI Waiver will waive the 1998 ROD chemical-specific ARAR to comply with MCLs for TCE and PCE (both 5 µg/L) in the aquifer. According to CERCLA, the point of compliance is in the aquifer, even though the MCLs are Safe Drinking Water Act promulgations with compliance at the point of use. Wellhead treatment will meet the compliance requirements for the Safe Drinking Water Act, ensuring that MCLs are met at the point of use. The spatial extent of the TI Waiver is depicted in Figure 2-2.

The 1998 selected remedy would not comply with chemical-specific ARARs, as MNA is expected to fail to achieve Federal MCLs in the aquifer within a reasonable time period.

2.5.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once cleanup levels have been met. This criterion includes the consideration of residual risk that would remain onsite following remediation and the adequacy and reliability of controls.

Both alternatives provide the same level of long-term protection. The 1998 ROD stated that the *Natural Attenuation alternative provides long-term effectiveness through the natural attenuation of TCE and PCE. Long-term monitoring and continued wellhead treatment at production wells which are impacted by TCE/PCE will continue. Future groundwater development in impacted areas will be precluded through the establishment of land use restrictions and the wellhead protection regulations. This alternative is suited for long-term effectiveness, as long-term effectiveness of naturally decreasing TCE/PCE to below MCLs has been shown at other wells on*

the MARBO Annex which have exceeded MCLs in the past. The high precipitation flux through the vadose zone, and rapid groundwater movement through the aquifer, effectively flushes potentially remaining TCE/PCE from the vadose zone and/or aquifer. This alternative does not have significant overhead and maintenance concerns beyond those which are required under the existing program to monitor existing wells.

Although the 1998 ROD overestimated the effectiveness of MNA to remediate TCE and PCE in the aquifer, the above statements regarding long-term monitoring, wellhead treatment, and operation and maintenance remain accurate.

Similarly, Alternative 6 will include LTGM and wellhead treatment at production wells impacted by the TCE and PCE. As natural attenuation is a naturally occurring degradation process, it will continue to occur at the same rate as the 1998 selected remedy; however, it is not included as a component of the remedy.

Reviews at least every five years, as required, would be necessary to evaluate the effectiveness of these alternatives because hazardous substances would remain onsite in concentrations above health-based levels.

2.5.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Reduction of toxicity, mobility, or volume through treatment refers to the anticipated performance of the treatment technologies that may be included as part of a remedy.

The 1998 ROD states that the selected alternative *slightly reduces the mobility and volume of contaminants in the aquifer through continued pumping of production wells, and eliminates the toxicity through wellhead treatment, on an as-needed basis. Thus, the Natural Attenuation alternative provides some toxicity reduction through wellhead treatment.*

In early 1998, the continued pumping and treatment of MW-2 at the MARBO Annex was discontinued; therefore, any further reduction in mobility or volume was also discontinued at that time.

Based on current conditions, both the 1998 selected remedy and Alternative 6 provide the same level of reduction of toxicity through wellhead treatment, as any well affected by MARBO Annex Groundwater TCE or PCE plumes will be treated, as appropriate.

2.5.5 Short-Term Effectiveness

Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy until cleanup levels are achieved.

Both the 1998 selected remedy and Alternative 6 are expected to be highly effective in the short term, as risk is currently within acceptable limits.

2.5.6 Implementability

Implementability addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered.

As stated in the 1998 ROD, the 1998 selected remedy *consists of very little implementation, as natural attenuation is occurring and will continue to occur. Groundwater monitoring procedures are already in place. Land use restrictions would need to be implemented and operation and maintenance considerations for the existing air strippers would need to be implemented for the long term. Equipment issues with this alternative may include the periodic replacement of monitoring well piston pumps and operation and maintenance associated with the existing air strippers.*

The LUCs selected in the 1998 ROD remain unchanged; therefore, no additional implementation is necessary. However, under Guam EPA's Wellhead Protection Program, new wells will be sampled prior to being connected to the water supply system. If sampling at a newly installed well indicates that TCE/PCE is present, the USN will evaluate the need to install and operate wellhead treatment whenever levels exceed one half of the respective MCL. The monitoring component of Alternative 6 would involve preparing a Post-ROD Remedial Design document to update the LTGM Program for MARBO Annex. This would be easy to implement as the LTGM Program at MARBO Annex has been in place for eleven years. Five-year reviews would be required for both alternatives, and would require little implementation as the first five-year review has already been completed for this site.

2.5.7 Cost

The estimated present value for the 1998 selected remedy and Alternative 6 and cost summaries are presented in the table below:

Alternative	Present Value	Short-Term and Long-Term Costs Considered
1998 Selected Remedy	$2,925,000	This alternative consists entirely of present worth operation and maintenance and other periodic costs.
Alternative 6 – LTGM with Contingency for Wellhead Treatment	$3,013 ,000	This alternative includes $88,000 for capital costs and $2,925,000 in present worth operation and maintenance and other periodic costs.

The present value for the 1998 selected remedy was updated by: 1) removing costs for the wellhead treatment component, as it was discontinued in early 1998; 2) updating costs for groundwater monitoring to reflect the current LTGM Program; 3) updating costs for the five-year review; 4) including costs for well abandonment, which were omitted from the original cost estimate; and 5) updating the discount rate to the Office of Solid Waste and Emergency Response recommended 7 percent (USEPA, 1999).

The updated estimated present value for the 1998 selected remedy is $2,925,000, which includes costs for the LTGM Program with 20 percent contingency ($228,000 annually), five-year reviews ($24,900 for each review; one every five years), and well abandonment with 20 percent

contingency ($348,900). The original detailed cost estimate for the 1998 selected remedy can be found in the OU 2 FFS and is summarized in the 1998 ROD (EA/MW, 1997; EA/MW, 1998).

The costs for Alternative 6 are the same as above, but also include capital costs for preparing the Post-ROD Remedial Design ($87,500). This results in a total estimated present value of $3,013,000.

Overall, the costs for Alternative 6 are slightly higher than that of the 1998 selected remedy; however, it is expected that implementing the Post-ROD Remedial Design will reduce operation and maintenance costs by 30 to 50 percent by reducing the LTGM Program monitoring points. This operation and maintenance savings will significantly outweigh the associated capital costs in the long term.

2.5.8 State/Support Agency Acceptance

The Government of Guam has expressed its support for Alternative 6, *LTGM with Contingency for Wellhead Treatment*. The Government of Guam no longer supports the 1998 selected remedy, *Natural Attenuation with Wellhead Treatment* on the basis that this alternative will not remediate the aquifer in a timely manner and does not meet ARARs.

2.5.9 Community Acceptance

During the public comment period, the community expressed its support for Alternative 6, *LTGM with Contingency for Wellhead Treatment.*

2.6 Summary of the Amended Selected Remedy

The amended selected remedy for groundwater was selected based upon the ability to comply with ARARs (with the exception of the chemical-specific ARARs, i.e. achieving MCLs in the aquifer, which requirements are being waived) and protect human health and the environment. This section describes the amended selected remedy. It is anticipated that successful implementation, operation and maintenance, and completion of the performance measures will achieve a protective and legally compliant remedy for MARBO Annex Groundwater.

Remedy selection is based on the detailed evaluation of remedial alternatives presented in the 2008 FFS (EA, 2008c). It is expected that the amended selected remedy will remain in effect and be protective of human health and the environment until such time as the concentrations of TCE and PCE in groundwater may decrease below applicable MCLs.

The USN is responsible for implementing, maintaining, enforcing, and monitoring the remedial action identified herein for the duration of the remedy selected in this ROD Amendment. The USN will exercise this responsibility in accordance with CERCLA and the NCP. Concurrence by USEPA and Guam EPA is required for any modification of the remedy selected in this ROD Amendment.

2.6.1 Summary of the Rationale for the Amended Selected Remedy

The amended selected remedy for MARBO Annex Groundwater is Alternative 6, *LTGM with Contingency for Wellhead Treatment*. The USN and USEPA believe that the amended selected remedy meets the threshold criteria and provides the best balance of tradeoffs over the other alternative with respect to the balancing and modifying criteria. The remedy is expected to satisfy the following statutory requirements of CERCLA § 121(b):

- Threshold Criteria
  - — Protection of human health and the environment
  - — Compliance with, or appropriate waiver of, ARARs
- Balancing Criteria
  - — Long-term effectiveness and permanence
  - — Toxicity, mobility, or volume reduction through treatment
  - — Short-term effectiveness
  - — Implementability
  - — Cost
- Modifying Criteria
  - — State agency acceptance
  - — Community acceptance.

The USN has selected Alternative 6, *LTGM with Contingency for Wellhead Treatment*, as the preferred alternative on the basis of the criteria above. Alternative 6 is slightly more expensive than the 1998 selected remedy; however, it complies with or waives ARARs and provides the same level of protection to human health and the environment. Additionally, five other alternatives were screened and not found implementable based on site conditions described in Section 2.4.2.

The following table summarizes the RAOs and performance standards for the groundwater remedy at MARBO Annex:

RAOs	Performance Standard
• Prevent access to or use of water having concentrations of PCE/TCE exceeding the Federal MCLs (5 µg/L).	• Perform wellhead treatment on wells containing concentrations of PCE/TCE exceeding designated levels.
• Establish a means to monitor and confirm that the human health risks associated with the presence of PCE and TCE within MARBO Annex Groundwater do not exceed established acceptable levels.	• Perform routine groundwater sampling (e.g., annual) under the LTGM Program in accordance with the Post-ROD Remedial Design document. • Communicate LTGM results to Andersen AFB Bioenvironmental Engineering (36 MDOS/SGOAB), Guam EPA, and Guam Waterworks Authority.

2.6.2 Description of the Amended Selected Remedy

This section provides a detailed description of the amended selected remedy that expands on the summary provided in Section 2.4.3.

2.6.2.1 Long-Term Groundwater Monitoring Program

The LTGM Program at Andersen AFB will be performed at selected monitoring wells and production wells at the MARBO Annex. Groundwater samples will be analyzed for TCE, PCE, and other parameters that are useful in monitoring the extent of the TCE and PCE groundwater plumes. The LTGM Program will undergo Remedial Process Optimization upon completion of the ROD Amendment, and will be updated in a Post-ROD Remedial Design document. The Post-ROD Remedial Design document will specify the wells which will be sampled and the sampling frequency.

2.6.2.2 Land Use Controls

LUCs selected in the 1998 ROD remain unchanged. They have been implemented through the Base Master Plan and the Guam EPA's Wellhead Protection Program. The USAF has not installed any additional wells within the TCE/PCE contamination area and has advised Guam that any well installation which is proposed in the vicinity could result in the extraction of contaminated groundwater. As part of its Wellhead Protection Program, Guam EPA limits the location of newly installed wells (must be at least 1,000 ft from existing wells) and requires that any new well be sampled prior to being connected to the water supply system. If sampling at a newly installed well indicates that TCE/PCE is present, the USN will evaluate the need to install and operate wellhead treatment whenever levels exceed one half of the respective MCL, as described below.

2.6.2.3 Contingency for Wellhead Treatment

A wellhead treatment program would be implemented where TCE or PCE concentrations exceed the designated levels at on-MARBO Annex water production wells and existing or future off-MARBO Annex production wells within the extent of the TCE and PCE plumes (Figure 2-1). The USN strongly advises that new pumping wells not be placed in these areas of historic detection. Upon TCE or PCE concentrations exceeding half of the MCL, the USN will perform additional sampling and analysis to determine if the concentration is likely to approach the MCL (5 µg/L). If statistical significance is found, the well will continue to be monitored for potential exceedance of the MCL. If PCE or TCE concentrations exceed or are likely to exceed the MCL, wellhead treatment will be applied to the affected well. Treatment units would be installed by the USN if no treatment system exists on that well or the USN would pay the incremental cost caused by the presence of TCE and/or PCE if a well already had a treatment system.

2.6.2.4 Technical Impracticability Waiver

A TI Waiver has been prepared and is being invoked to waive the requirement to achieve MCLs for TCE and PCE in the aquifer (Figure 2-2). The spatial extent of the TI Waiver is depicted in Figure 2-2. The justification for the TI Waiver is as follows:

Remediating groundwater within the basal freshwater lens at the MARBO Annex is not practicable because the depth of contamination (approximately 400 ft bgs), the karst type aquifer and the transient, rapid groundwater-flow conditions all limit applications of groundwater treatment. In-situ treatment effectiveness would be limited because there is not a practicable method to deliver treatment additives in sufficient quantity throughout the deep karst aquifer. In addition, natural attenuation has not decreased the contaminant concentrations over 15+ years, indicating that conditions are not conducive to de-chlorination and that there may be an ongoing source in either a dual porosity system or in the fresh/brackish water transition zone. Pump and treat is not practicable because the high conductivities and flow rates limit the ability to create sufficient drawdown to effectively remediate the aquifer. More importantly, the fresh water lens floats in a thin layer over brackish water and pumping volumes are carefully controlled in Guam to minimize salt water intrusion. As a result of the TI Waiver, the 1998 selected remedy will be amended by removing MNA as a component of the remedy, as it is no longer considered a timely remediation technique.

2.6.3 Summary of Estimated Remedy Costs

A cost estimate for Alternative 6, *LTGM with Contingency for Wellhead Treatment*, is presented in Table 2-5. The information in the cost estimate table is based on the available information regarding the anticipated scope of the remedial alternative. Costs for the wellhead treatment component of the remedy are not included in the cost estimate as they are not currently being performed at the site.

Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. Major changes may be documented in the form of a memorandum in the AR file, an Explanation of Significant Difference, or a ROD Amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.

2.6.4 Expected Outcomes of Amended Selected Remedy

The amended selected remedy, Alternative 6, *LTGM with Contingency for Wellhead Treatment*, would effectively eliminate the potential for exposure to groundwater containing concentrations of PCE or TCE above the MCL. This would be accomplished by implementing wellhead treatment on production wells with concentrations of TCE or PCE exceeding designated levels. There are currently no wells that require treatment. The site would remain suitable for continued use by the USAF as industrial/open space and industrial worker/occasional user exposures and would be available for residential use, but would not be suitable for unlimited use and unrestricted exposure (e.g., further production well installation). The time frame to achieve use as industrial/open space is immediate as there are no unacceptable risks to current human or

ecological receptors at the site. Five-year reviews will be required until concentrations of TCE and PCE in MARBO Annex Groundwater are consistently below MCLs.

2.7 Statutory Determination

Under CERCLA §121 (as required by NCP §300.430[f][5][ii]), the lead agency must select a remedy that is protective of human health and the environment, complies with ARARs (with the exception of the chemical-specific ARARs, i.e. achieving MCLs in the aquifer, which requirements are being waived), is cost-effective, and uses permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, CERCLA includes: (1) a preference for remedies that employ treatment which permanently and significantly reduces the volume, toxicity, or mobility of hazardous wastes as a principal element; and (2) a bias against offsite disposal of untreated wastes. The following sections discuss how the amended selected remedy meets these statutory requirements.

2.7.1 Protection of Human Health and the Environment

The amended selected remedy, Alternative 6, *LTGM with Contingency for Wellhead Treatment*, will protect human health and the environment through implementation of wellhead treatment, as required.

2.7.2 Compliance with Applicable or Relevant and Appropriate Requirements

Remedial actions must comply with both federal and state ARARs. ARARs are legally ARARS, legal standards, criteria, or limitations of federal and state environmental laws and regulations.

ARARs fall into three categories: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs are health-based or risk-management-based numbers that provide concentration limits for the occurrence of a chemical in the environment. Location-specific ARARs restrict activities in certain sensitive environments. Action-specific ARARs are activity-based or technology-based, and typically control remedial activities that generate hazardous wastes (such as with those covered under the Resource Conservation and Recovery Act of 1976 [RCRA]). Criteria to be considered, or To Be Considered (TBC), are non-promulgated advisories or guidance issued by the federal or state government that are not legally binding and do not have the status of potential ARARs. However, in many circumstances, TBCs are considered along with ARARs.

Table 2-6 summarizes the ARARs and TBCs for the amended selected remedy for MARBO Annex Groundwater and describes how the amended selected remedy addresses each one.

The amended selected remedy complies with location-specific and action-specific ARARs. The implementation of a remedy is required to meet the substantive portions of these requirements and is exempt from administrative requirements, such as permitting and notifications. The TI Waiver waives the requirement to comply with chemical-specific ARARs.

2.7.3 Cost Effectiveness

In the USN's judgment, the amended selected remedy is cost-effective and represents a reasonable value for the money to be spent. In making this determination, the following definition was used: "A remedy shall be cost-effective if its costs are proportional to its overall effectiveness" (40 CFR 300.430[f][1][ii][D]). This determination was accomplished by evaluating the "overall effectiveness" of those alternatives that satisfy the threshold criteria (that is, is protective of human health and the environment and ARAR-compliant).

Overall effectiveness was evaluated by assessing three of the five balancing criteria in combination: long-term effectiveness and permanence; reduction in toxicity, mobility, and volume through treatment; and short-term effectiveness. Overall effectiveness was then compared to costs to determine cost-effectiveness. The overall effectiveness of the amended selected remedy for MARBO Annex Groundwater was demonstrated in the comparative analysis of alternatives (Section 2.5) and is summarized below:

Alternative	Present Value	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume through Treatment	Short-Term Effectiveness
1998 Selected Remedy	$2,925,000	Yes	Yes	Yes
Amended Selected Remedy	$3,013,000	Yes	Yes	Yes

Although the costs for the amended selected remedy are approximately $100,000 higher due to the capital costs of generating the Post-ROD Remedial Design, it is expected that implementing the Post-ROD Remedial Design will reduce operation and maintenance costs by 30 to 50 percent by reducing the LTGM Program monitoring points. This operation and maintenance savings will significantly outweigh the associated capital costs in the long term.

2.7.4 Utilization of Permanent Solutions and Alternative Treatment Technologies

The USN has determined that the amended selected remedy, *LTGM with Contingency for Wellhead Treatment* represents the maximum extent to which permanent solutions and treatment technologies can be used in a practicable manner at the site. The USN has determined that the amended selected remedy provides the best balance of trade-offs in terms of the five balancing criteria, while also considering the statutory preference for treatment as a principal element and bias against offsite treatment and disposal, and considering state and community acceptance.

The amended selected remedy manages the potential risks to human health and the environment by having a contingency to implement wellhead treatment should concentrations of PCE or TCE exceed designated levels. No unacceptable risks were identified for current human receptors or ecological receptors.

2.7.5 Preference for Treatment as a Principal Element

Section 121(b) of CERCLA establishes the preference that treatment will be used to address the principal threats posed by a site wherever practicable. The amended selected remedy does not

meet the statutory preference for treatment because no source materials constituting principal threats are addressed within the scope of this action. However, wellhead treatment will be used as a contingency if any wells are installed in the plume area.

2.7.6 Five-Year Review Requirements

Pursuant to CERCLA §121(c) and NCP §300.430(f)(5)(iii)(C), because the amended selected remedy will result in hazardous substances, pollutants, or contaminants remaining in MARBO Annex Groundwater above levels that allow for unlimited use and unrestricted exposure, a statutory review will be required within five years after initiation of the amended remedial action to verify that the remedy is, or will be, protective of human health and the environment.

Five-year reviews will be conducted until concentrations of hazardous substances, pollutants, or contaminants remaining onsite are reduced to levels that allow for unlimited use and unrestricted exposure.

2.8 Documentation of Significant Changes

The Proposed Plan for the proposed amended selected remedy was released for public comment on December 2, 2009. The Proposed Plan identified *LTGM with Contingency for Wellhead Treatment* as the preferred amended selected remedy for MARBO Annex Groundwater. The USN reviewed all written and verbal comments submitted during the public comment period. It was determined that no significant changes to the amended selected remedy, as originally identified in the Proposed Plan, were necessary or appropriate.

3.0 Responsiveness Summary

This section provides a summary of the public comments regarding the Proposed Plan for the amended selected remedy for MARBO Annex Groundwater, Andersen AFB, Yigo, Guam. At the time of the public review period, the USN had identified *LTGM with Contingency for Wellhead Treatment* as the amended selected remedy for groundwater. Based upon the verbal comments received, the Proposed Plan was accepted by the public.

3.1 Stakeholder Comments and Lead Agency Responses

A public meeting was held on 2 December 2009 at the Guam Marriot Hotel in Tumon, Guam. The meeting officially began at 6:43 p.m. and concluded at 8:00 p.m., according to the transcript. The meeting was attended by 13 members of the community. Mr. Gregg Ikehara, Andersen AFB 36 Civil Engineer Squadron/Civil Engineer Environmental Flight (36th CES/CEVR), provided an opening statement. Mr. Danny Agar, 36th CES/CEVR, gave a PowerPoint presentation discussing the proposed plan for MARBO Annex Groundwater. The presentation provided a brief site history, summary of past investigative studies and related analytical results, and when applicable a summary of the human health and ecological risk assessments. The preferred remedial alternative was also presented.

Public Meeting Comments

After the presentation, seven members of the community spoke. The questions and comments received were primarily focused on clarifying details of the presented material and were adequately answered during the meeting. A brief summary of individual questions and comments are included on the following pages. The complete transcript is available in the AR file for Andersen AFB, which is available for public review at the Robert F. Kennedy Library at the University of Guam and Nieves M. Flores Memorial Library in Hagåtña.

Mr. Cruz asked for clarification regarding cancer risk. Mr. Ikehara explained that because the TCE and PCE are 400-500 ft bgs, there's no pathway for the contaminants to get to humans, and therefore there is no risk, unless it is being pumped out of the ground. If TCE and PCE are present in production wells, it will become a risk to humans, but wellhead treatment will be implemented to mitigate this risk.

Mr. Cruz asked if treatment would be applied at well D5. Mr. Ikehara replied that well D5 was included in the list of wells that would be treated if TCE and PCE levels were found to be above the MCL.

Mr. Cruz asked for clarification that the proposed remedy is not to put in a treatment, but to have it as a contingency. Mr. Ikehara confirmed that this is the case.

Mr. Cruz asked if USAF had looked into a correlation between rainfall and the spike that has been seen at IRP29. Mr. Ikehara responded that they have found a strong correlation between fluctuations of the TCE and PCE with the chloride concentrations at depth.

Mr. Jocson asked if USAF had a model for what is causing the trends to go up and down. He suggested comparing historical mean sea level records to see if they match up with the fluctuating levels of TCE and PCE. Mr. Ikehara explained that there is an inverse correlation between chlorides and the concentration of the chlorinates. The spikes correlate to the thickening and thinning of the lens as rain recharges it or as it is depleted during a drought.

Mr. Marquez and Mr. Jocson asked what the method of determining what an exceedance is. Mr. Ikehara explained that one exceedance would be followed up with additional sampling to confirm prior to doing any wellhead treatment. He also stated that there would be no dilution of the samples, meaning that the samples are taking at the wellhead, not at the points of compliance for Safe Drinking Water Act. He emphasized that USAF is not looking at samples taken within the water distribution system.

Mr. San Nicholas asked what the Installation Restoration Program's main purpose is. Mr. Agar explained that the purpose of IRP is to address contaminants at sites that have been affected by activities of the Air Force. The purpose is to restore those areas and make sure it is clean and not affecting human health and the environment.

Mr. San Nicholas asked about the future uses of Andy South housing, including the barracks, and if they were to be used as housing during the base buildup. Mr. Ikehara responded that to his knowledge, the area was to remain being used for training purposes and there were no plans to use as housing.

Mr. Jocson asked if it would be feasible to do a dye trace study to see how quickly the contaminants are moving. Mr. Ikehara replied that they could do a dye trace study, but that currently there are not enough deep lens monitoring wells to have adequate coverage for the study. Mr. Shambach added that the tritium samples have been done.

Mr. San Nicholas asked if, when the underground flow of water goes out to the Tumon area, the water affects people who are in Tumon or the marine life. Mr. Ikehara stated that so far the Air Force has not been able to make that connection. He reiterated that the highest concentration of chlorinate is deep in the water lens, not shallow. If it was shallow, then there would be a potential for vapor to be inhaled by people living in the area.

Mr. Gawel asked about the differences between the previous treatment, which was air stripping on the production of water, and pump and treat. Mr. Ikehara explained that pump and treat for water that was deep in the fresh water lens, near the salt water bottom, would entail a lot of aeration for very little space. In this situation, Air Force would be pumping salt water out and treating with it without any real beneficial use. Furthermore, Air Force would need to pump and treat for hundreds before there was any noticeable effect. Five years from now the same discussion would have to happen again because the time line for the five year review will not have been met.

Mr. Gawel asked if there is a relationship between the MARBO Annex and the contamination in the Tumon Maui well. Mr. Ikehara stated that they had looked for connectivity between the two but were not able to find a relationship. There are other potential source areas within the Harmon Industrial area.

Mr. Gawel asked if that meant there were isolated pools or volumes of PCE contamination that are not connected. Mr. Ikehara responded that this is very possible. PCE is used for dry cleaning, so it is very possible that any dry cleaning company not following proper disposal practices could be affecting the groundwater.

Ms. Brown asked about the air stripper constructed in the late 1990s to address actually retaing water from the Tumon Maui well and why it was turned off. Mr. Ikehara explained that it was actually plumed to take care of the Tumon Maui well and production wells 1, 2, and 3. It was subsequently turned off because Air Force no longer needed the water due to downsizing. Additionally, there was a problem with calcium buildup in the stripping towers due to the high concentration of calcium carbonate in the aquifer.

Mr. Kasperbauer asked for clarification that the purpose of the meeting was to state that there is no real solution other than to monitor the levels of contaminant and that the public has 30 days to comment. Mr. Ikehara responded that the Air Force is monitoring both the upper and lower portions of the lens and that the highest concentrations are in the lower part of the lens. Additionally, a lot of the wells that are monitored do not show any signs of chlorinates in them.

Mr. Kasperbauer asked about specific wellhead treatment methods. Mr. Ikehara explained that there are two available. One is the granular activated carbon. Water passes through the filter and the filter adsorbs contaminants and reduces levels of TCE and PCE. The second is an air stripper, mentioned earlier, which would actually aerate the water and get rid of TCE and PCE before the water is consumed.

Mr. Jocson responded that aeration will not work at MARBO Annex. Mr. Ikehara and Mr. Agar agreed and stated that was not an option being considered at this point.

Mr. Marquez suggested lowering the MCL and sampling quarterly rather than semi-annually. Mr. Ikehara stated that sampling frequency and the MCL is something that was determined concurrently with the agency, the late Victor Wuerd, Guam EPA, as well as Mr. Cruz and Mr. Ripperda from U.S. EPA. The point was taken, but not being considered at this juncture.

Mr. Kasperbauer asked when the two samples are taken each year. Mr. Ikehara replied that a wet season and a dry season sample are taken annually to capture the range of variability.

Mr. Shambach stated that he assumed the Air Force would not unilaterally put a well head treatment on a GWA production well, and that Guam EPA, U.S.EPA, and GWA would be involved in the decision making. Mr. Ikehara replied that he was correct. Before wellhead treatment would be implemented, a decision would have to be made collectively under the Federal Facility Agreement

Mr. San Nicholas asked if contaminants from a Laundromat were to get into the sewer system now, do the contaminants get treated at the treatment plan before it goes out to the ocean or is it a problem for marine life. Mr. Ikehara explained that TCE is now a banned substance and no one should be using it on island. PCE is still being used, but it has to be separately contained. If it's recaptured it needs to go into a separate disposal method and shipped off island. Mr. Cruz clarified that dry cleaners should be operating closed loop systems, so none of it should enter the sewer system.

Mr. Gawel asked if anyone had looked at records of how much TCE was brought on base. Mr. Ikehara replied that there is only one report documenting TCE use, and there is no real discussion about disposal practices.

Written Comment

Mr. Gawel submitted a written comment during the comment period. He stated he was pleased that Andersen AFB is proposing a contingency treatment plan, but a more proactive approach would be better for future DoD public relations. He suggested two remedial alternatives that should be explored, in addition to the six already examined.

> *1) Lower costs would result from converting the unused Andersen AFB air stripping facility along Route 1 at the northwest end of MARBO Annex to a carbon filter process, as used at the former NSA (now GIAA) at Tiyan.* Mr. Ikehara's response is as follows: Using the air stripper converted to carbon is not an option since the towers are non-functional at present and require demolition. A whole new unit needs to be installed, preferably at the wellhead of the affected well. It may not even be feasible to retrofit an air stripper tower to granular activated carbon and even less likely to be cost effective, i.e. it may cost more in the long run.
>
> *2) Since contamination has been found at the Andersen AFB Maui Well which receives water from MARBO via the Yigo Trough, the alternative of pumping and treating there with carbon filtration could lead to removal of TCE and PCE from its threat to the Yigo Trough Sub-basin of the Northern Guam Aquifer. Water would not need to be pumped as deeply, and monitoring would not require new deep monitoring wells. This action would avoid upsetting the balance of the utilized lens at wells near MARBO.* Mr. Ikehara's response is as follows: Installing a treatment system in the Tumon Maui well to address the water quality impacts to the Dededo well field will not address the wells down gradient of the MARBO Annex, but upgradient of the Tumon Maui well. In theory, the potential PCE- and TCE-contaminated ground water flowing towards Tumon Bay will still impact wells in between MARBO Annex and Tumon, thereby still posing a threat to the Yigo Trough. Also, the Tumon Maui well is much closer to the ocean and therefore is more subject to tidal fluctuations, not less as the comment indicates.

Additionally, Mr. Gawel suggested that TCE and PCE should be called trichloroethylene and tetrachloroethylene, respectively. Mr. Ikehara's response is as follows: TCE can be either trichloroethylene or trichloroethene. Same with PCE: interchangeable usage.

3.2 Technical and Legal Issues

No technical or legal issues were identified during the public review period of the Proposed Plan.

4.0 References

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APPENDIX A

FEDERAL FACILITY AGREEMENT
CHANGE LETTERS

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS, 36TH WING (PACAF)
UNIT 14007, APO AP 96543-4007

06 November 2009

36 CES/CEVR
Unit 14007
APO AP 96543-4007

Mr. Mark Ripperda
Project Manager
U.S. Environmental Protection Agency
75 Hawthorne St., H-9-4
San Francisco, CA 94105-3901

Dear Mr. Ripperda

This letter provides notice of a change in administrative responsibility pursuant to paragraph 28 of Federal Facility Agreement (FFA) Docket Number 93-117 (FFA).

As you are aware, Andersen Air Force Base is in the process of realigning installation management functions to a newly established Joint Region Marianas pursuant to the 2005 Defense Base Closure and Realignment Commission Final and Approved Recommendations. Title to Andersen Air Force Base real property will remain in the United States and the property will continue to be utilized by the Air Force. As of October 1, 2009, however, administrative custody and responsibility for managing real property assets will transfer from the Air Force to the Navy. The Air Force will become a supported component of the Joint Region Marianas and the Navy will become the supporting component.

In accordance with the April 2008 Department of Defense Environmental Supplemental Guidance for Implementing and Operating a Joint Base, the Navy, as the supporting component, *"will be responsible for all existing and future environmental permits, requirements, plans, and agreements at the installations to become the Joint Base."* (Ch. 1.1.2). As the supporting component, the Navy will be required to *"honor all existing, previously negotiated Federal Facility Agreements in place at the installations to become the Joint Base at the time of transfer."* (Ch. 2.17.5). The Navy is being supplied with an Environmental Condition of Property Report and with access to current environmental files including the FFA. No change to the FFA will be necessary in order for the Navy to assume responsibility for implementation of the FFA and the transfer of responsibility will not change the rights of the parties under the FFA or impede any action under the FFA. The Environmental staff will remain located at Andersen Air Force Base following 01 October 2009 and will be available to assist with any issues related to the FFA. However, the civilian environmental staff will become Navy employees and, likewise, funding responsibility will reside with the Navy.

Please contact Mr. Russell Littlejohn, Environmental Flight Chief, at (671) 366-2556 if you have any questions or concerns or would like to discuss possible changes/addendums to the FFA to further document the substitution of the United States Navy for the United States Air Force as the entity responsible for implementation of the FFA.

Sincerely

GREGG IKEHARA
Chief, Installation Restoration Program

cc:
Ms. Lorilee Crisostomo, GEPA
Mr. Rich Howard, Tech Law Inc.

DEPARTMENT OF THE NAVY
COMMANDER, JOINT REGION MARIANAS
PSC 455, BOX 152
FPO AP 96540-1000

IN REPLY REFER TO
9510
Ser J4/1235
November 23, 2009

Mr. Mark Ripperda
US Environmental Protection Agency
75 Hawthorne St. H-9-4
San Francisco, CA 94105-3901

Dear Mr. Ripperda,

SUBJECT: NOTIFICATION OF TRANSFER OF ENVIRONMENTAL RESTORATION PROGRAM RESPONSIBILITY

This letter serves as notification that all Environmental Restoration Program responsibilities for Andersen Air Force Base (AAFB), a property listed on the National Priorities List, will be officially transferred to the United States Navy under the Commander, Joint Region Marianas (CJRM), effective October 1, 2009, pursuant to chapter 2.17 of the April 2008 Department of Defense Environmental Supplemental Guidance (EVSG) for Implementing and Operating a Joint Base. This action is being taken to implement the 2005 Defense Base Realignment and Closure (BRAC) Act which requires the transfer of all installation support functions and administrative custody of real property from AAFB to the U.S. Navy.

In accordance with the EVSG, the Navy, as the supporting component, "will assume responsibility for environmental restoration data reporting, budgeting, record keeping, and financial liability" (Ch. 2.17.6), "will assume responsibility for all Restoration Advisory Boards" (Ch. 2.17.8), and will be required to "honor all existing, previously negotiated Federal Facility Agreements in place at the installations to become the Joint Base [Region] at the time of transfer." (Ch. 2.17.5).

If you have any questions, please contact Mr. Richard Raines, P.E., at telephone (671) 339-8420 or at richard.raines@fe.navy.mil.

Sincerely,

P. S. LYNCH
Captain, CEC, U.S. NAVY
Regional Engineer
By direction of the Commander

Copy to:
Guam Environmental Protection Agency
CNIC (N45)
NAVFAC Pacific (EV)
36CES

APPENDIX B

NOTICE OF PUBLIC MEETING AND DOCUMENT AVAILABILITY

ANDERSEN AFB
INSTALLATION RESTORATION PROGRAM

Public Meeting
December 02, 2009 at 6:30pm
Guam Marriott Resort & Spa, The View
627 Pale San Vitores Rd., Tumon, Guam 96913

The Anderson Air Force Base Installation Restoration Program will hold a public meeting on December 02, 2009 to discuss the Proposed Plan for the MARBO Annex ROD Amendment, MARBO Annex Operable Unit, Andersen Air Force Base, Guam.

The Proposed Plan describes the amended selected remedy, Long-Term Groundwater Monitoring with Contingency for Wellhead Treatment, evaluates the potential risks posed to human and ecological receptors, and establishes a risk-based cleanup standard. The final remedy will be selected based on new information or after the public comments are received.

The Proposed Plan and supporting documents are available for public review at the following locations.

University of Guam (UOG)
Government Documents Department
Robert F. Kennedy Library, UOG Station
Mangilao, Guam 96932
(671) 735-2316 or 2315
Hours: Monday - Thursday
8:00 a.m. - 5:00 p.m.
Friday 9:00 a.m. - 5:00 p.m.
Contact: Walfrid Benavente

Nieves M. Flores Memorial Library
245 Martyr Street
Hagatna, Guam 96910
(671) 475-4751, - 4753 or - 4754
Hours: Monday - Thursday
8:00 a.m. - 6:00 p.m.
Friday 1:00 p.m. - 5:00 p.m.
Saturday 8:00 a.m. - 5:00 p.m.
Contact: Teresita Kennimer

The 30-day public comment period will end on December 17, 2009. Written comments must be postmarked on or before December 17, 2009. For further information please contact the following:

Andersen AFB Public Affairs Office
(671) 366-4202 / 5601

TABLES

Table 1-1
Data Certification Checklist

Decision Summary Sections	
List of contaminants of concern and their respective concentrations	Section 2.2.2, Page 2-6 to 2-7 and Figure 2-1
Baseline risk represented by the contaminants of concern	Section 2.2.4, Pages 2-8 to 2-9
Cleanup levels established for contaminants of concern and the basis for these levels	Section 2.6.1, Page 2-25
How source materials constituting principal threats will be addressed	Section 2.7.5, Page 2-29 to 2-30
Current and reasonably anticipated future land use assumptions and current and potential future beneficial uses of groundwater used in the baseline risk assessment and Record of Decision	Section 2.1.1, Page 2-1, and Figure 2-3
Potential land and groundwater use that will be available at the site as a result of the selected remedy	Section 2.4.3.3, Page 2-19 and Table 2-3
Estimated capital, annual operation and maintenance, and total present worth costs, discount rate, and the number of years over which the remedy cost estimates are projected	Section 2.5.7, Pages 2-23 to 2-24 and Table 2-5
Key factor(s) that led to selecting the remedy (i.e., describe how the selected remedy provides the best balance of tradeoffs with respect to the balancing and modifying criteria, highlighting criteria key to the decision)	Section 2.5, Pages 2-19 to 2-24

Table 2-1
Community Relations Requirements

Requirement		Satisfied by
Notice of Availability / Brief Description of Proposed ROD Amendment Responsiveness Summary	Lead agency (USN) must issue a notice of availability and brief description of the proposed amendment to the ROD in a major local newspaper of general circulation. CERCLA 117 and NCP Section 300.435(c)(2)(ii)(A).	Notice of availability of the proposed amendment to the ROD and information supporting the decision was published in the Guam Pacific Daily News on 2 December 2009. A copy of this notice is included in Appendix B of this ROD Amendment.
	Notice of availability should occur at least two weeks prior to the beginning of the public comment period.	The public comment period began on 17 November 2009.
	Notice of availability should consist of the following information: • Site name and location • Date and location of public meeting • Identification of lead and support agencies • Alternatives evaluated in the detailed analysis • Identification of preferred alternative • Request for public comments • Public participation opportunities including: — Location of information repositories and Administrative Record file — Methods by which the public may submit written and oral comments, including a contact person — Dates of public comment period — Contact person for the Restoration Advisory Board.	See notice in Appendix B.
	Lead agency (USN) must make the proposed amendment to the ROD and information supporting the decision available for public comment. CERCLA 117 and NCP Section 300.435(c)(2)(ii)(B).	Documents were made available to the public on 17 November 2009.
Public Comment Period	Lead agency (USN) must provide the public with a reasonable opportunity (not less than 30 calendar days) to submit written or oral comments on the amendment to the ROD. CERCLA 117 and NCP Section 300.435(c)(2)(ii)(C).	The USN provided a public comment period for the remedial investigation/feasibility study and the Proposed Plan from 17 November 2009 to 17 December 2009.
	Lead agency (USN) must extend the public comment period by at least 30 additional days upon timely request. NCP Section 300.435(c)(2)(ii)(C).	The USN received no requests to extend the public comment period.
Public Meeting	Lead agency (USN) must provide the opportunity for a public meeting to be held during the public comment period at or near the site. CERCLA 117 and NCP Section 300.435(c)(2)(ii)(D).	A public meeting was held on 2 December 2009 at the Guam Marriott Resort & Spa, Tumon.

Table 2-1 (Continued)
Community Relations Requirements

Requirement		Satisfied by
Meeting Transcript	Lead agency (USN) must keep a transcript of comments received at the public meeting held during the public comment period. CERCLA 117 and NCP Section 300.435(c)(2)(ii)(E).	A transcript of this meeting has been added to the Administrative Record file.
Responsiveness Summary	Lead agency (USN) must include in the amended ROD a brief explanation of the amendment and the response to each of the significant comments, criticisms, and new relevant information submitted during the public comment period. CERCLA 117 and 300.435(c)(2)(ii)(F).	See Section 3.0 of the ROD Amendment.
Notice of Availability of ROD Amendment	Lead agency (USN) must publish a notice of availability of the amended ROD in a major local newspaper of general circulation. CERCLA 117 and NCP Section 300.435(c)(2)(ii)(G).	See notice in Appendix B.
	Lead agency (USN) must ensure that the amended ROD and all supporting information is included as part of the Administrative Record file and made available to the public prior to the commencement of the remedial action affected by the amendment. NCP Section 300.435(c)(2)(ii)(H).	The USN maintains information repositories for the Andersen Air Force Base Administrative Record file at the Robert F. Kennedy Library at the University of Guam and the Nieves M. Flores Memorial Library in Hagåtña. Data and supporting CERCLA primary documents produced for Andersen Air Force Base are maintained as part of these files and are available to the public.

NOTE: CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980
NCP = National Oil and Hazardous Substances Pollution Contingency Plan of 1990
ROD = Record of Decision
USN = United States Navy

Table 2-2
Focused Feasibility Study Remedial Technology Screening Matrix

REMEDIAL ALTERNATIVE[1]	TARGETED MEDIA	UTILIZATION STATUS	RELATIVE EFFECTIVENESS	IMPLEMENTABILITY
BIOLOGICAL TREATMENT				
Enhanced Anaerobic Bioremediation (In-Situ)	Deep Groundwater (450 to 500 feet bgs)	Available	Low	Difficult
CHEMICAL TREATMENT				
Chemical Oxidation (In-Situ)	Deep Groundwater (450 to 500 feet bgs)	Available	Low	Difficult
Micro-Scale Zero Valent Iron (In-Situ)	Deep Groundwater (450 to 500 feet bgs)	Available	Low	Difficult
PHYSICAL TREATMENT				
In-Well Air Stripping (In-Situ)	Deep Groundwater (450 to 500 feet bgs)	Available	Low	Difficult
Pump and Treat (Ex-Situ)	Deep Groundwater (450 to 500 feet bgs)	Available	Low	Difficult
ICs and Contingency for Wellhead Treatment[1]	Deep Groundwater (450 to 500 feet bgs)	Available	High	Implementable

[1] Per USEPA guidance at the July 2009 RPM Meeting, Institutional Controls have been removed from this alternative; the alternative is referred to in the ROD Amendment as Alternative 6, *Long-Term Groundwater Monitoring with Contingency for Wellhead Treatment.*

Table 2-2 (Continued)
Focused Feasibility Study Remedial Technology Screening Matrix

REMEDIAL ALTERNATIVE[1]	ESTIMATED CONSTRUCTION COST[2]	OVERALL RESTORATION POTENTIAL	SCREENING	TI WAIVER RATIONALE[3]
BIOLOGICAL TREATMENT				
Enhanced Anaerobic Bioremediation (In-Situ)	$92,200,000	Low	Eliminate	• Insufficient aquifer surface area in karst setting for colonization of degrading microorganisms • Inaccurate or insufficient spatial delivery of biostimulants and/or degrading microorganisms at depth of contamination • High oxygen levels in groundwater and transient, episodic flow conditions will disallow stable, reducing conditions required for biological reductive dechlorination
CHEMICAL TREATMENT				
Chemical Oxidation (In-Situ)	$57,418,000	Low	Eliminate	• Inaccurate or insufficient spatial delivery at depth of contamination in complex geologic setting • Optimization of pH-dependent oxidants (e.g., Fenton's, activated persulfates/peroxygens) not possible due to carbonate buffering in karst setting
Micro-Scale Zero Valent Iron (In-Situ)	$57,790,000	Low	Eliminate	• Inaccurate or insufficient spatial delivery at depth of contamination in complex geologic setting • Significant decrease in zero valent iron reactivity in short time frames due to carbonate scaling in karst setting
PHYSICAL TREATMENT				
In-Well Air Stripping (In-Situ)	$55,992,000	Low	Eliminate	• High volume of pumping required • Short circuiting due to directional flow from secondary porosity conduits • Mass transfer limitations from primary diffuse porosity
Pump and Treat (Ex-Situ)	$55,992,000	Low	Eliminate	• High volume of pumping required • Potential for upwelling of marine water • Mass transfer limitations from primary diffuse porosity • Carbonate scaling of treatment system
ICs and Contingency for Wellhead Treatment[2]	$992,000	Low	Retain	• Remedial alternative would be implemented under a TI waiver determination

NOTE:
bgs = below ground surface

[2] Per USEPA guidance at the July 2009 RPM Meeting, Institutional Controls have been removed from this alternative; the alternative is referred to in the ROD Amendment as Alternative 6, *Long-Term Groundwater Monitoring with Contingency for Wellhead Treatment.*

Table 2-2 (Continued)
Focused Feasibility Study Remedial Technology Screening Matrix

IC = institutional control
TI = technical impracticability

1. No Action was not evaluated because it did not meet Remedial Action Objectives as specified in ROD (EA, 1998), and it was eliminated as an alternative in previous FFS (EA, 1997). Remedial alternatives evaluated within this FFS were selected on the basis of: A) currently applicable technologies (including presumptive remedies), B) findings of previous FFS (EA, 1998), and C) 2006-2008 RPM meeting correspondence.
2. Estimated construction costs based on well installation costs and technology unit costs to treat entire plume (3 Pore Volumes for physical treatments). System O&M costs not included. Estimated costs based on the following assumptions:
   -Spatial extent of PCE exceedance in area of IRP-29
   Length of PCE plume: 2500 ft
   Width of PCE plume: 1000 ft
   Height of PCE plume: 50 ft
   Volume of aquifer treatment: 4.6E06 cu yds
   Volume of groundwater with PCE above 5 ug/L: 2.8E08 gal
   -Spatial extent of TCE exceedance in area of IRP-31
   Length of TCE plume: 3000 ft
   Width of TCE plume: 1000 ft
   Height of TCE plume:50 ft
   Volume of aquifer treatment: 5.6E06 cu yds
   Volume of groundwater with TCE above 5 ug/L: 3.4E08 gal
   -Estimated number of required injection or extraction wells (@$100,000 each) per technology:
   In-Well Air Stripping (In-Situ): 550 (based on 100 ft well spacing)
   Pump and Treat (Ex-Situ): 550 (based on 100 ft well spacing)
   Chemical Oxidation (In-Situ): 550 (based on 100 ft well spacing)
   Zero-Valent Iron (In-Situ): 550 (based on 100 ft well spacing)
   Enhanced Anaerobic Bioremediation (In-Situ): 550 (based on 100 ft well spacing)
   -Average Unit Treatment Cost (EPA Clu-In; http://www.frtr.gov/matrix2/section4/4_2.html) per technology for large scale, difficult sites:
   In-Well Air Stripping (In-Situ): $4/10,000 gal
   Pump and Treat (Ex-Situ): $4/10,000 gal (for air ex-situ air stripping)
   Chemical Oxidation (In-Situ): $39/10,000 gal
   Zero-Valent Iron (In-Situ): $45/10,000 gal
   Enhanced Anaerobic Bioremediation (In-Situ): $60/1000 gal
3. Rationale relating to the performance potential of the remedial alternatives evaluated. The low performance potential support the justification for a TI Waiver
4. The cost for continued promotion of ICs, including the contingency for wellhead treatment at any water supply wells impacted by the plume, has not been included within this evaluation.

Table 2-3
Common Elements and Distinguishing Features of the 1998 Selected Remedy and Alternative 6

	1998 Selected Remedy	Alternative 6 – Long-Term Groundwater Monitoring with Contingency for Wellhead Treatment
Summary of Key ARARs	Maximum Contaminant Levels would not be achieved in a resonable timeframe; ARARs would not be met. Institutional controls and wellhead treatment would protect against groundwater ingestion at levels greater than the Maximum Contaminant Levels. Will meet performance and air release requirements for air strippers; NPDES discharge requirements will be met.	ARARs to achieve Maximum Contaminant Levels in the aquifer would be waived with a Technical Impracticability Waiver. Wellhead treatment would protect against groundwater ingestion at levels greater than the Maximum Contaminant Levels. Will meet performance and air release requirements for air strippers; NPDES discharge requirements will be met.
Long-term reliability of remedy	High	High
Quantity of untreated waste and treatment residuals to be disposed of offsite and the degree of hazard remaining in such material	None	None
Estimated time for design and construction	Not applicable (remedy already implemented)	Short; post-Record of Decision Amendment Remedial Design will be completed within six months
Estimated time to reach remediation goals	Originally 10-40 years; however, long-term groundwater monitoring results show that monitored natural attenuation will take significantly longer.	Immediate
Estimated capital cost	None (remedy already implemented)	$97,500
Estimated annual operation and maintenance cost	$190,000	$190,000
Estimated total present value	$2,925,000	$3,013,000
Discount rate	7%	7%
Number of years over which cost is projected	30	30
Use of presumptive remedies and/or innovative technologies	Monitored natural attenuation	None
NOTE: ARAR = Applicable or Relevant and Appropriate Requirement NPDES = National Pollutant Discharge Elimination System		

Table 2-4
Expected Outcomes of the 1998 Selected Remedy and Alternative 6

	1998 Selected Remedy	Alternative 6 – Long-Term Groundwater Monitoring with Contingency for Wellhead Treatment
Available uses of land upon achieving cleanup levels	Land would be available for most types of use (including residential); however, restrictions would be emplaced on production well installation.	Land would be available for most types of use (including residential). Wellhead treatment would be implemented on existing or future production wells if TCE or PCE were to exceed MCLs.
Timeframe to achieve available land use	Immediate.	Same as 1998 selected remedy.
Available uses of groundwater upon achieving cleanup levels	Wellhead treatment would be used, if necessary, to ensure that groundwater is suitable for human consumption.	Same as 1998 selected remedy.
Timeframe to achieve available groundwater use	Immediate. There are no unacceptable risks to current human or ecological receptors.	Same as 1998 selected remedy.
Other impacts or benefits associated with alternative	ARARs would not be met.	All ARARs would be met or waived with a Technical Impracticability Waiver

NOTE: ARAR = Applicable or Relevant and Appropriate Requirement
MCL = Maximum Contaminant Level
PCE = Tetrachloroethene
TCE = Trichloroethene

Table 2-5
Cost Estimate for Alternative 6, Long-Term Groundwater Monitoring with Contingency for Wellhead Treatment, for MARBO Annex Groundwater, Andersen AFB, Guam

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Post ROD Remedial Design	1	EA	$87,500	$87,500	RPO in support of Post ROD Remedial Design document
TOTAL CAPITAL COST				**$87,500**	

ANNUAL O&M COSTS:

List of Assumptions

Annual and semi-annual O&M events will be performed every year for 30 years.
Long-Term Groundwater Monitoring costs estimate using actual costs for the past 5 years of sampling at MARBO Annex.
Number of groundwater samples based on current number of samples collected at MARBO Annex (EA, 2008a)
Site inspection performed in conjunction with multiple IRP sites.

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Long-Term Groundwater Monitoring	30	EA	$190,000	$5,700,000	22 groundwater samples; 2 events per year
Contingency	20%			$1,140,000	
TOTAL O&M COST				**$6,840,000**	

PERIODIC COSTS:

List of Assumptions

Periodic site review will be coordinated with the five-year ROD Review.
Includes fact sheets.
Cost model assumes periodic site review & public education costs shared with multiple IRP sites.
Well abandonment is based on current number of monitoring wells sampled at MARBO Annex under the LTGM Program; does not include production wells.

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Five-Year Review Report	5	1	EA	$24,900	$24,900	1 report at end of Year 5
Five-Year Review Report	10	1	EA	$24,900	$24,900	1 report at end of Year 10
Five-Year Review Report	15	1	EA	$24,900	$24,900	1 report at end of Year 15
Five-Year Review Report	20	1	EA	$24,900	$24,900	1 report at end of Year 20
Five-Year Review Report	25	1	EA	$24,900	$24,900	1 report at end of Year 25

Table 2-5 (Continued)
Cost Estimate for Long-Term Groundwater Monitoring with Contingency for Wellhead Treatment Alternative for MARBO Annex Groundwater, Andersen AFB, Guam

PERIODIC COSTS Continued:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Well Abandonment	30	18	EA	$15,000	$270,000	
Contingency		20%			$54,000	% of well abandonment
Remedial Action Report	30	1	EA	$24,900	$24,900	1 report at end of Year 30
SUBTOTAL (Year 30)					$348,900	
TOTAL PERIODIC COST					**$473,400**	

PRESENT VALUE ANALYSIS:

List of Assumptions

Discount factors were taken from Exhibits 4-4 and 4-6 in *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (USEPA, 2000)

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (7%)	PRESENT VALUE	NOTES
Capital Cost	0	$87,500	$87,500	1.000	$87,500	Post ROD Remedial Design
Annual O&M Cost	1-30	$6,840,000	$228,000	12.409	$2,829,252	Groundwater monitoring
Periodic Cost	5	$24,900	$24,900	0.713	$17,754	Five-year ROD review
Periodic Cost	10	$24,900	$24,900	0.508	$12,649	Five-year ROD review
Periodic Cost	15	$24,900	$24,900	0.362	$9,014	Five-year ROD review
Periodic Cost	20	$24,900	$24,900	0.258	$6,424	Five-year ROD review
Periodic Cost	25	$24,900	$24,900	0.184	$4,582	Five-year ROD review
Periodic Cost	30	$348,900	$348,900	0.131	$45,706	Well abandonment, remedial action report
		$7,410,900			$3,012,880	
TOTAL PRESENT VALUE OF ALTERNATIVE					**$3,013,000**	

NOTE:

IC = Institutional Control
IRP = Installation Restoration Program
LTGM = Long-Term Groundwater Monitoring
LUCMP = Land Use Control Management Plan
O&M = Operation and Maintenance
QTY = Quantity
ROD = Record of Decision
RPO = Remedial Process Optimization

Table 2-6
Description of ARARs and TBCs for the Amended Selected Remedy

Authority	Medium	Requirement	Status	Synopsis of Requirement	Action to be Taken to Attain Requirement
Chemical-Specific					
Federal Regulatory Requirement	Water	Safe Drinking Water Act, 40 CFR 141.11 to 141.16	Relevant and Appropriate	Enforceable standards for public water systems. Identifies MCLs.	TI Waiver invoked to waive requirement to achieve MCLs in the aquifer. However, wellhead treatment will ensure that the MCL is met at point of use, if necessary.
Territorial Regulatory Requirement	Water	Guam Safe Drinking Water Act, 10 GCA, Chapter 53	Relevant and Appropriate	Establishes primary and secondary standards and MCLs.	TI Waiver invoked to waive requirement to achieve MCLs in the aquifer. However, wellhead treatment will ensure that the MCL is met at point of use, if necessary.
Location-Specific					
Federal Regulatory Requirement	Historical Artifacts	National Historic Preservation Act, 16 USC Section 469; 36 CFR 65; 40 CFR 6.301(b)	Relevant and Appropriate	Action to recover and preserve artifacts if in an area where action may cause irreparable harm, loss, or destruction of significant artifacts.	Will consult with Guam and National Register of Historic Places if necessary.
Territorial Regulatory Requirement	Historical Objects and Sites	Conservation of Archaeological Resources, 21 GCA, Chapter 76	Relevant and Appropriate	Provides for the historic preservation, restoration, and presentation of historic objects and sites.	Will consult with Guam and National Register of Historic Places if necessary.
Territorial Regulatory Requirement	Groundwater	Guam Wellhead Protection Program Adopted March 4, 1993 and Guam's Water Resource and Development Operating Regulations, 10 GCA, Chapter 46	Applicable	Protects groundwater resources in areas that supply drinking water. Regulates permitting of production and monitoring wells, and contractor licensing.	Meets requirements by imposing land use controls on permits.

NOTE: CFR = Code of Federal Regulations.
GCA = Guam Code Annotated .
RCRA = Resource Conservation and Recovery Act.
USC = United States Code.

Table 2-6 (Continued)
Description of ARARs and TBCs for the Amended Selected Remedy

Authority	Medium	Requirement	Status	Synopsis of Requirement	Action to be Taken to Attain Requirement
Action-Specific					
Federal Regulatory Requirement	Air	Clean Air Act (CAA), Section 109 and 40 CFR 50	Applicable	Permits and regulates air emissions if considered a major source.	If air stripping is used for wellhead treatment, VOC off-gas discharge would not be considered a major source; therefore, off gas treatment would not be required.
Territorial Regulatory Requirement	Water	Water Pollution Control Act, 10 GCA, Chapter 47	Applicable	Determines ways and means of eliminating and/or preventing pollution to surface water and groundwater.	Meets regulatory requirements by restricting extraction from the transitional zone and by using appropriate treatment technologies if necessary.
Territorial Regulatory Requirement	Air	Air Pollution Control Act, 10 GCA, Chapter 49	Applicable	Establishes air quality criteria; sampling, testing, monitoring, record keeping requirements, source permitting system; and specific control requests.	VOC off-gas discharge will be kept within acceptable regulatory limits.
Territorial Regulatory Requirement	Groundwater	Water Resources Conservation Act, 10 GCA, Chapter 48	Applicable	Restricts development of groundwater through licensing and permit issuance for well drilling and operation, and sets construction standards.	Meets requirements by imposing land use controls on permits.

FIGURES

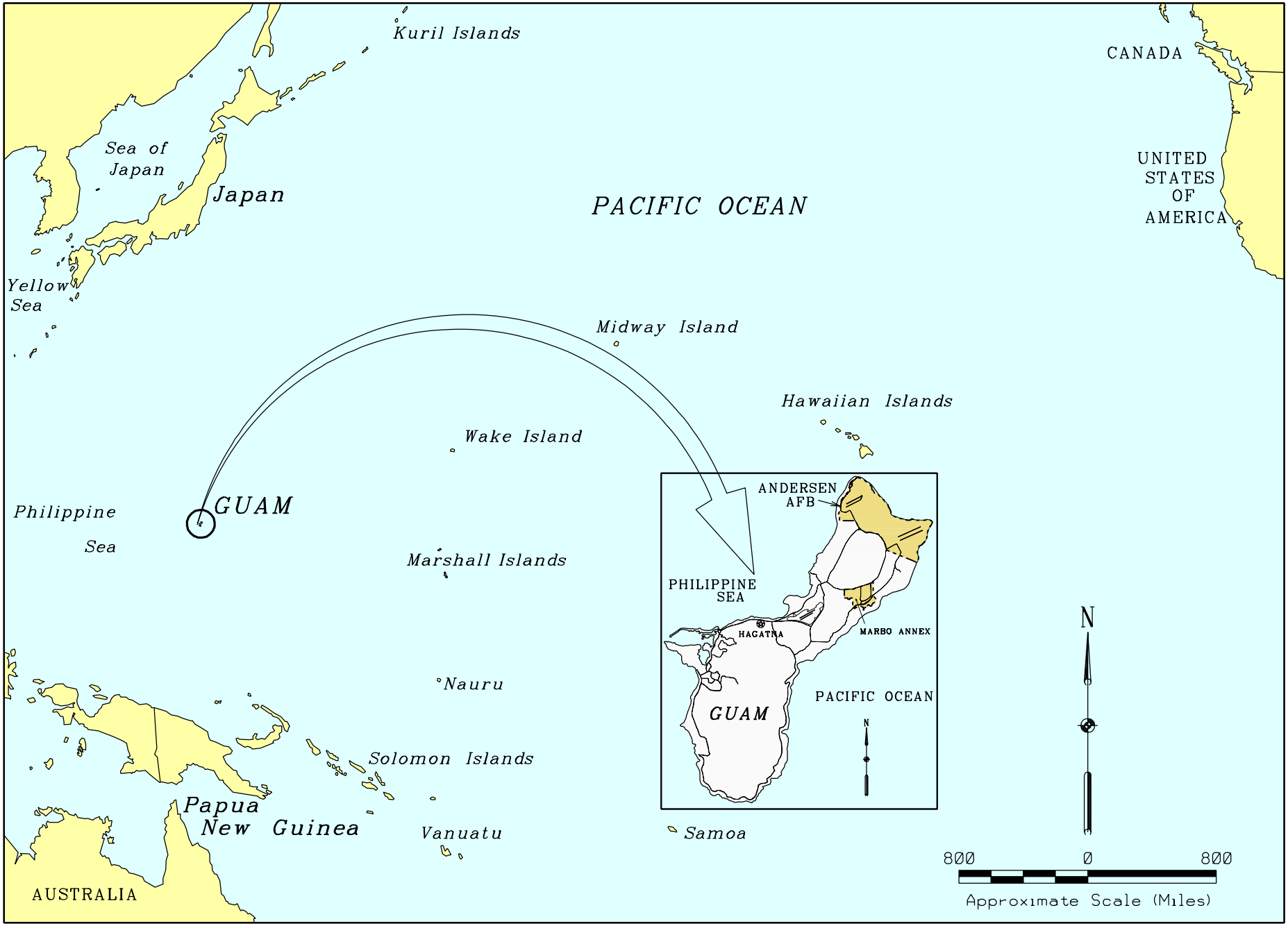
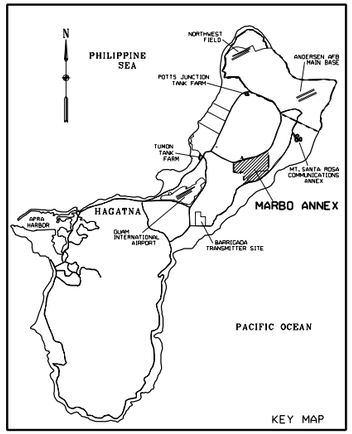


Figure 1-1. Location Map of Guam.

Figure 1–2. Location Map of Andersen Air Force Base on Guam.



D-3
1996 - 1997
VOCs - ND

D-2
1996 - 2003
TCE
ND TO 0.5

D-4
1996 - 1997
VOCs - ND

D-1
1996 - 1997
VOCs - ND

D-5
1996 - 2003
PCE
ND TO 0.2
TCE
ND TO 2.2

GPA-2
1996 - 2007
1,1-DCE
ND TO 0.3
PCE
ND TO 0.4
TCE
ND TO 6.7

MW-2
1996 - 2006
PCE
ND TO 0.2
TCE
ND TO 6

D-14
1996 - 2007
TCE
ND TO 0.5

EX-6
2000 - 2000
VOCs - ND

NOTE: MONITORING WELL EX-6 IS LOCATED APPROXIMATELY 100 FEET WEST

MW-1
1996 - 2007
PCE
ND TO 0.2
TCE
ND TO 2.7

IRP-30
1996 - 2007
PCE
ND TO 0.2
TCE
ND TO 0.5

IRP-61
2007 - 2007
VOCs - ND

IRP-23
1996 - 2003
VOCs - ND

IRP-24
1996 - 2007
PCE
ND TO 0.7

M-6
1996 - 2003
PCE
ND TO 0.2

M-5
1996 - 1997
PCE
ND TO 0.6

M-7
1996 - 2003
PCE
ND TO 0.3

M-15
1996 - 1997
VOCs - ND

Historical Footprint of TCE Exceeding MCL

MUNICIPAL WASTE TRANSFER STATION

WATER TANK

IRP-31
1996 - 2007
CIS-1,2-DCE
ND TO 0.3
1,1-DCE
ND TO 7.6
PCE
0.9 TO 6.4
TCE
110 TO 605

IRP-12
1996 - 2003
PCE
ND TO 0.3

IRP-26
1996 - 2003
PCE
ND TO 0.6
TCE
ND TO 0.9

IRP-1
1996 - 2003
VOCs - ND

IRP-35
1996 - 2007
PCE
ND TO 1.2
TCE
ND TO 2.3

IRP-15
1996 - 2007
VOCs - ND

IRP-16
1996 - 2007
VOCs - ND

IRP-62B

IRP-62

IRP-62
2007 - 2007
PCE
1.3 - 2.5

SITE 37

SITE 41

SITE 24

SITE 23

SITE 22

SITE 20

SITE 43

SITE 38

SITE 42

ODD CEMETERY

MW-3
1996 - 2003
PCE
ND TO 0.2

GPA-1
1996 - 2007
1,1-DCE
ND TO 0.3
PCE
ND TO 0.4
TCE
ND TO 14

IRP-2
1996 - 2003
VOCs - ND

IRP-25
1996 - 2007
CIS-1,2-DCE
ND TO 1
PCE
ND TO 0.3
TCE
ND TO 2

MW-9
1996 - 2007
PCE
ND TO 0.6

IRP-27
1996 - 2007
PCE
ND TO 1.6

IRP-8
1996 - 2007
PCE
ND TO 0.6

IRP-10
1996 - 2007
TCE
ND TO 0.3

Historical Footprint of PCE Exceeding MCL

SANITARY SEWAGE PUMP STATION

IRP-14
1996 - 2007
PCE
0.7F TO 11

IRP-29
1996 - 2007
PCE
4.1 TO 18
TCE
ND TO 2

IRP-28
1996 - 1997
VOCs - ND

MARBO POWER PLANT

VOLLEYBALL COURT

MISC. OUTDOOR RECREATION FACILITIES

BOOSTER PUMP STATION

Y-6
1996 - 1997
VOCs - ND

Y-5
1996 - 1997
VOCs - ND

TO PRODUCTION WELL Y-3

Y-3
1996 - 1997
VOCs - ND

Y-2
1996 - 2003
PCE
ND TO 0.3

Y-4
1996 - 1997
VOCs - ND

Y-18
2004
VOCs - ND

Y-19

IRP-32B
1996 - 1997
VOCs - ND

Y-20
2004
VOCs - ND

IRP-33
1996 - 2007
TCE
ND TO 0.4

IRP-34
1996 - 2007
VOCs - ND

MW-5
1996 - 2003
VOCs - ND

MW-8
1996 - 2003
VOCs - ND

MW-7
1996 - 2003
VOCs - ND

MW-6
1996 - 2003
VOCs - ND

N

1100' 0 1100'

GRAPHIC SCALE IN FEET

LEGEND:

- EXISTING AIR FORCE PROPERTY LINE
- EXISTING BUILDING
- EXISTING ROADS
- EXISTING UNIMPROVED ROADS
- INSTALLATION RESTORATION PROGRAM (IRP) SITE
- SHALLOW SCREENED MONITORING WELL
- DEEP SCREENED MONITORING WELL
- FULL SCREENED MONITORING WELL ACROSS THE WATER TABLE
- PRODUCTION WELL
- BOREHOLE LOCATION

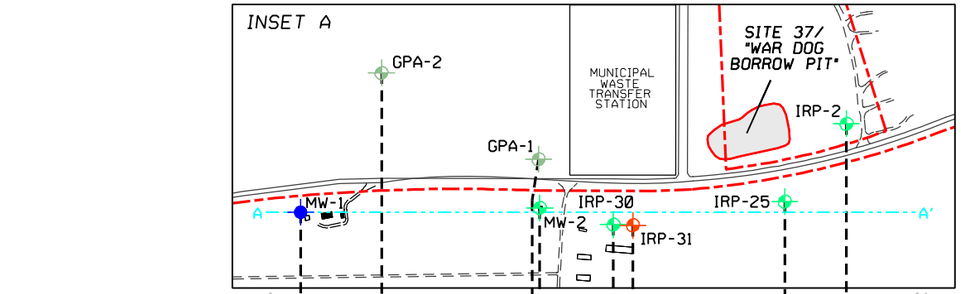
SAMPLE LOCATIONS IN RED EXCEED MCLs

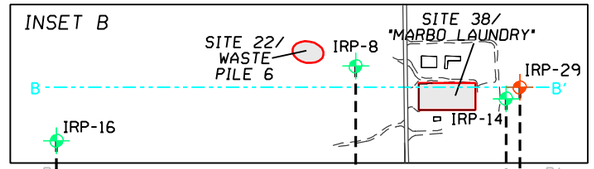
IRP-14
1996 - 2007
PCE
0.9F TO 11

WELL ID
SAMPLE PERIOD
DETECTED VOLATILE ORGANIC COMPOUNDS CONCENTRATION RANGE, ug/L

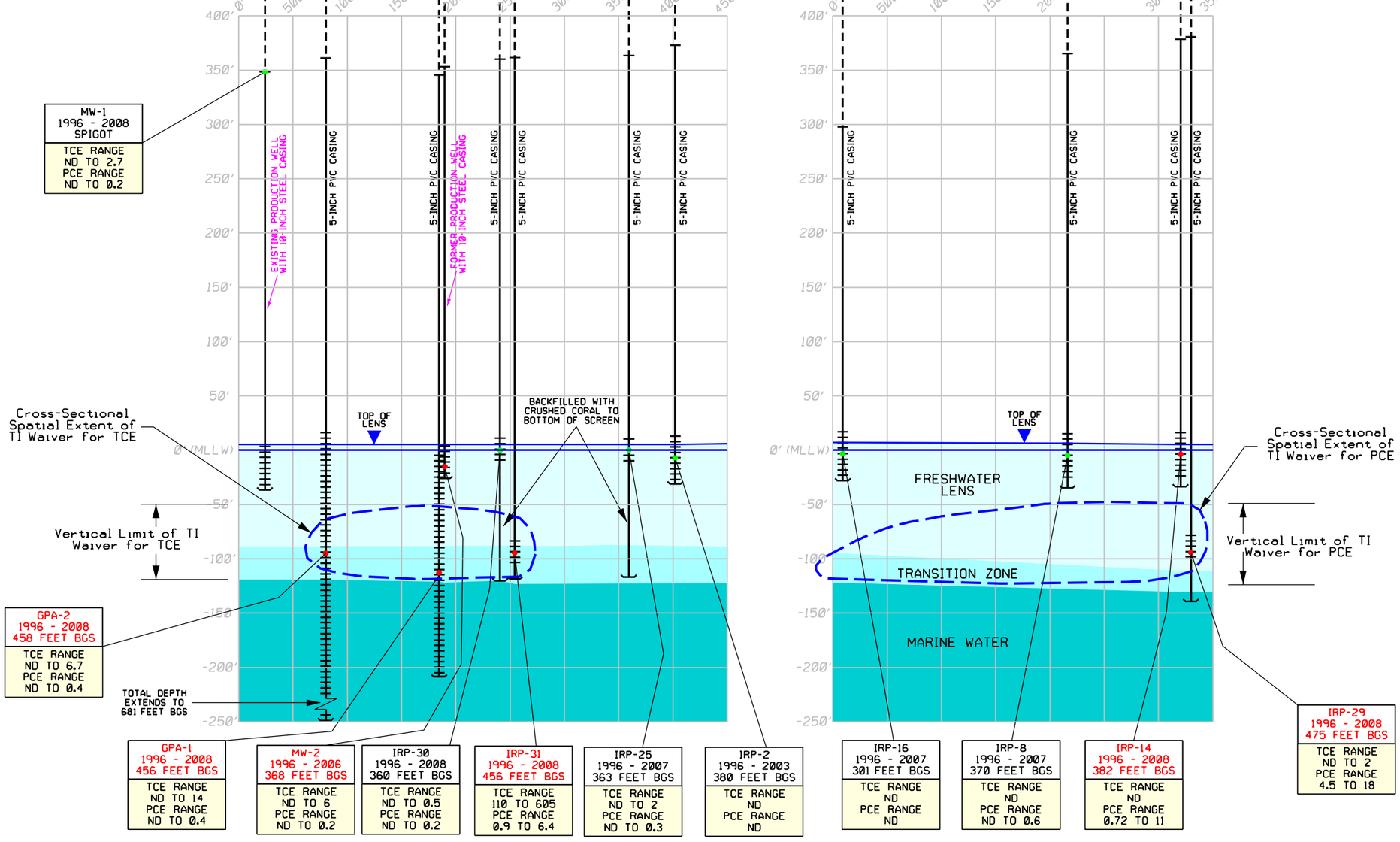
BOLDED VALUES EXCEED MCLs
ND - NOT DETECTED
ug/L - MICROGRAM PER LITER
DCE - DICHLOROETHENE
PCE - TETRACHLOROETHENE
TCE - TRICHLOROETHENE

Figure 2-1.
Historical Footprint of TCE and PCE Exceeding MCL in Groundwater at MARBO Annex, Andersen AFB, Guam.





RELATIVE HORIZONTAL DISTANCE BETWEEN GROUNDWATER MONITORING WELLS



MW-1
1996 - 2008
SPIGOT
TCE RANGE
ND TO 2.7
PCE RANGE
ND TO 0.2

GPA-2
1996 - 2008
458 FEET BGS
TCE RANGE
ND TO 6.7
PCE RANGE
ND TO 0.4

GPA-1
1996 - 2008
456 FEET BGS
TCE RANGE
ND TO 14
PCE RANGE
ND TO 0.4

MW-2
1996 - 2006
368 FEET BGS
TCE RANGE
ND TO 6
PCE RANGE
ND TO 0.2

IRP-30
1996 - 2008
360 FEET BGS
TCE RANGE
ND TO 0.5
PCE RANGE
ND TO 0.2

IRP-31
1996 - 2008
456 FEET BGS
TCE RANGE
110 TO 605
PCE RANGE
0.9 TO 6.4

IRP-25
1996 - 2007
363 FEET BGS
TCE RANGE
ND TO 2
PCE RANGE
ND TO 0.3

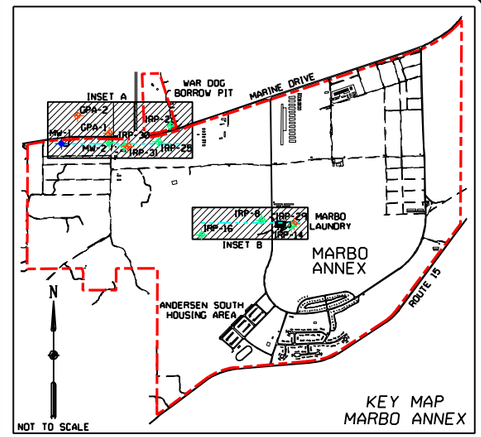
IRP-2
1996 - 2003
380 FEET BGS
TCE RANGE
ND
PCE RANGE
ND

IRP-16
1996 - 2007
301 FEET BGS
TCE RANGE
ND
PCE RANGE
ND

IRP-8
1996 - 2007
370 FEET BGS
TCE RANGE
ND
PCE RANGE
ND TO 0.6

IRP-14
1996 - 2008
382 FEET BGS
TCE RANGE
ND
PCE RANGE
0.72 TO 11

IRP-29
1996 - 2008
475 FEET BGS
TCE RANGE
ND TO 2
PCE RANGE
4.5 TO 18



LEGEND:

- EXISTING AIR FORCE PROPERTY LINE
- EXISTING BUILDING
- EXISTING ROADS
- INSTALLATION RESTORATION PROGRAM (IRP) SITE
- SHALLOW SCREENED MONITORING WELL
- DEEP SCREENED MONITORING WELL
- FULL SCREENED MONITORING WELL ACROSS THE WATER TABLE
- PRODUCTION WELL
- SAMPLE LOCATION
- SAMPLE LOCATION IN RED EXCEEDS MAXIMUM CONTAMINANT LEVELS
- THREADED END CAP
- SCREENED INTERVAL

SAMPLE LOCATIONS IN RED EXCEED MAXIMUM CONTAMINANT LEVELS

IRP-29
1996 - 2008
475 FEET BGS
TCE RANGE
ND TO 2
PCE RANGE
4.5 TO 18

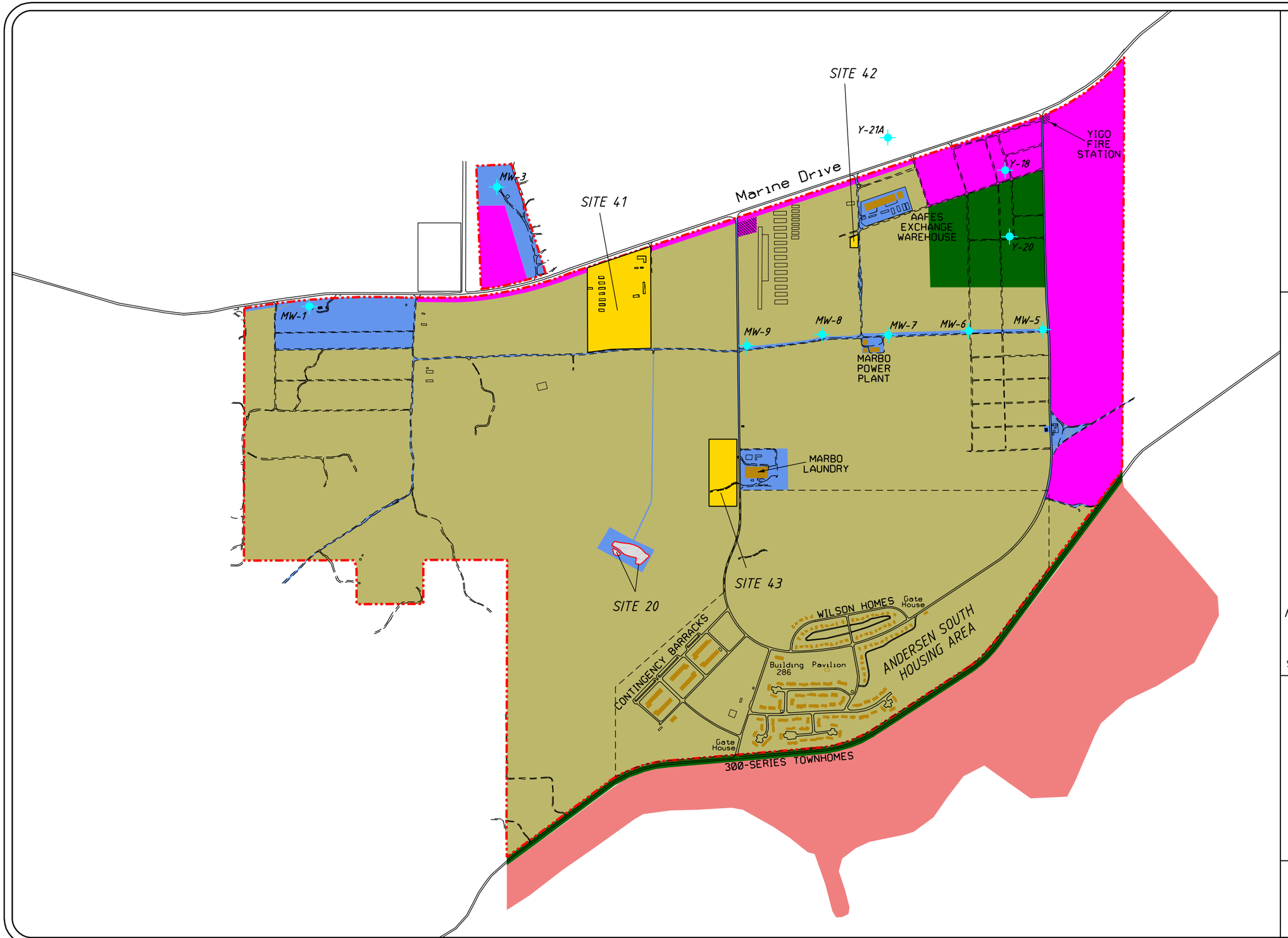
- WELL ID
- SAMPLING PERIOD
- SAMPLE DEPTH BGS
- TCE AND PCE IN ug/L

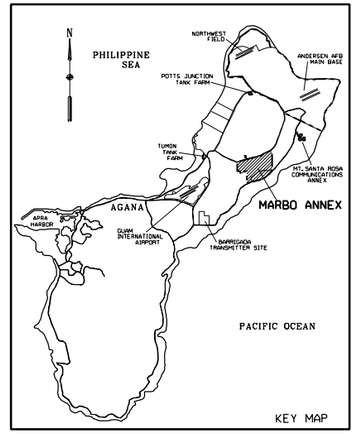
ND - NOT DETECTED
ug/L - MICROGRAM PER LITER

PCE - TETRACHLOROETHENE
TCE - TRICHLOROETHENE
BGS - BELOW GROUND SURFACE
MLLW - MEAN LOWER LOW WATER

TRANSITION ZONE - BASED ON CHLORIDE AND CONDUCTIVITY READINGS COLLECTED FROM GROUNDWATER SAMPLES AND GEOPHYSICAL LOGS DURING THE 1995 MONITORING WELL BOREHOLE INSTALLATION (ICF TECHNOLOGY INC. OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT, MARBO ANNEX, APPENIDX B AND APPENDIX D, 1997.)

Figure 2-2.
Cross-Sectional View of Spatial Extent of Technical Impracticability Waiver Based on Historic Long Term Groundwater Monitoring Data, MARBO Annex, Andersen AFB, Guam.





LEGEND:

- EXISTING AIR FORCE PROPERTY LINE
- EXISTING ROADS
- EXISTING UNIMPROVED ROADS
- FORMER BUILDING OR PAD
- EXISTING BUILDING NOT INCLUDED IN THE FIRST FIVE-YEAR REVIEW OF THE MARBO ANNEX OPERABLE UNIT RECORD OF DECISION.
- 224 ACRE AREA - AIR FORCE RETAINED PROPERTY
- 1569 ACRE AREA - STILL PROPOSED FOR EXCESS
- 81 ACRE AREA - GOVERNMENT OF GUAM
- 395 ACRE AREA - CONVEYED TO GOVERNMENT OF GUAM IN 2000
- 231 ACRE AREA - UNDERWOOD PROPOSAL
- 6 ACRE AREA - GOVERNMENT OF GUAM FIRE AND POLICE STATION
- MW-9 PRODUCTION WELL

SOURCE: ANDERSEN AFB REAL PROPERTY

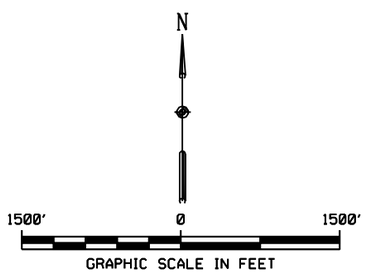


Figure 2-3.
MARBO Annex Operable Unit
Land Use