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Revised Final
Corrective Measures Study
Final Report
Tow Way Fuel Farm
Naval Activity Puerto Rico
RCRA/HSWA Permit No. PR2170027203
Ceiba, Puerto Rico

Prepared For

Department of the Navy

Naval Facilities Engineering Command
Atlantic Division

Norfolk, Virginia

Under the
LANTDIV CLEAN Program

Contract No. N62470-95-D-6007
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November 22, 2005

Prepared by

CH2M HILL

Baker
Environmental, Inc.

CDM
Federal Programs Corp.

REVISED FINAL

CORRECTIVE MEASURES STUDY
FINAL REPORT
TOW WAY FUEL FARM

NAVAL ACTIVITY PUERTO RICO
RCRA/HSWA PERMIT NO. PR2170027203
CEIBA, PUERTO RICO

CONTRACT TASK ORDER 0033

NOVEMBER 22, 2005

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DEPARTMENT OF THE NAVY
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Prepared by:

CH2M Hill
Herndon, Virginia

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

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LIST OF ACRONYMS AND ABBREVIATIONS

AOC	Area of Concern
Baker	Baker Environmental, Inc.
Bgs	below ground surface
CAO	Corrective Action Objective
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMI	Corrective Measures Investigation
CMS	Corrective Measures Study
COC	Contaminants of Concern
COPCs	Chemicals of Potential Concern
DoN	Department of the Navy
DRMO	Defense Reutilization and Marketing Office
ECGO	Electrochemical Geo-Oxidation
FFCA	Federal Facilities Compliance Agreement
FOSET	Finding of Suitability for Early Transfer
HSWA	Hazardous and Solid Waste Amendments
HTTD	High Temperature Thermal Desorption
IR	Installation Restoration
LANTDIV	United States Navy, Atlantic Division
mg/kg	milligrams per kilogram
MNA	Monitored natural attenuation
NAPR	Naval Activity Puerto Rico
NEC	National Electrical Code
NPDES	National Pollutant Discharge Elimination System
NPV	Net Present Value
NSRR	Naval Station Roosevelt Roads
O & M	Operation and Maintenance
PAH	Polynuclear Aromatic Hydrocarbons
PREQB	Puerto Rico Environmental Quality Board
PSH	Phase Separated Hydrocarbon
RAC	Remedial Action Contractor
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SVE	Soil vapor extraction
SWMU	Solid Waste Management Unit
TCE	Trichloroethene
TWFF	Tow Way Fuel Farm
USEPA	United States Environmental Protection Agency
UIC	Underground Injection Control
UST	Underground Storage Tank
VOC	Volatile Organic Compound
WWTP	Waste Water Treatment Plant

EXECUTIVE SUMMARY

INTRODUCTION

This document presents the Corrective Measure Study (CMS) Final Report for the Tow Way Fuel Farm (TWFF) located at Naval Activity Puerto Rico (NAPR) formerly known as Naval Station Roosevelt Roads (NSRR), Ceiba, Puerto Rico under the Corrective Action provisions of NAPR's Resource Conservation and Recovery Act (RCRA) permit (RCRA/HSWA Permit No PR 2170027203). Baker Environmental, Inc. (Baker) has prepared this report under contract to the Atlantic Division, Naval Facilities Engineering Command (LANTDIV), Contract Number N62470-95-D-6007.

On May 23, 2003, on behalf of the Navy, Baker submitted the Final Corrective Measure Study Task I Report to the EPA for review. EPA approved the CMS Task I report on June 10, 2003 and requested that the remaining tasks of the CMS for the TWFF be completed. This document presents the remaining tasks of the CMS.

This report was developed to meet the requirements of Tasks II, III, and IV under Module III, Appendix B (Scope of Work for a Corrective Measure Study) as contained in NAPR's RCRA Part B Permit (USEPA, 1994). The Final Corrective Measures Study Task I Report (Baker, 2003a) identified the preliminary corrective measure technologies to address the soil and groundwater contamination present at the site from the site operations. The technologies identified were screened and developed for removal, containment, treatment and/or other remediation of the contamination based on the objectives established for the corrective action. Alternatives using various combinations of these technologies to address the contamination at the TWFF were also formulated during this task. Task II provides an evaluation of the identified alternatives with respect to technical requirements, environmental assessments, protection of human health, and institutional needs. A cost estimate for each alternative is also included in this task. Task III provides a recommendation and justification of the preferred alternative or alternatives. Task IV is simply the reporting task, of which the Final Task I CMS report was the first part, with the subsequent tasks documented in this report.

CORRECTIVE MEASURE STUDY ALTERNATIVES

Five alternatives using a variety of process options were developed as a result of the technology screening provided in the Task I report. These five alternatives are presented below.

<u>Alternative 1</u>

- Institutional Controls, Monitored Natural Attenuation (MNA), and Containment/Collection (PSH Skimming)

<u>Alternative 2</u>

- Institutional Controls, MNA, In-situ Biological Treatment (Bioventing), Containment/Collection (Dual Phase Extraction and Steam Flushing), Ex-situ Physical/Chemical Treatment (Air Stripping), and Discharge (National Pollutant Discharge Elimination System [NPDES])

Alternative 3

- Institutional Controls, MNA, Excavation/Disposal (Off Site), Containment/Collection (Extraction Wells and Surface Oil/Water Separators), Ex-situ Biological Treatment (Bioreactors), and Discharge (Re-injection)

Alternative 4

- Institutional Controls, MNA, Excavation/Ex-situ Thermal Treatment (High Temperature Thermal Desorption [HTTD]), In-situ Physical/Chemical Treatment (Soil Vapor Extraction), In-situ Physical/Chemical Treatment (Air Sparging), Containment/Collection (Skimmer Pumps for PSH)

Alternative 5

- Institutional Controls, MNA, Excavation/Ex-situ Biological Treatment (Land Farming), In-situ Biological Treatment (Biodegradation), In-situ Biological Treatment (CleanOx®), In-situ Physical/Chemical Treatment (ECGO®)

OBJECTIVES OF THE CORRECTIVE MEASURES STUDY--TASK II, III AND IV

The objective of Task II is to provide an evaluation of the above-identified alternatives with respect to technical requirements, environmental assessments, protection of human health, and institutional needs. A cost estimate for each alternative is also included in this task. Once Task II is complete, at least one preferred alternative would be brought into Task III for discussion.

The objective of Task III is to recommend and justify the preferred alternative or alternatives. Additionally, performance expectations, preliminary design considerations, operation and maintenance (O & M) requirements, and precautions necessary for design and implementation of the recommended alternatives are provided in this Task. The objective of these two tasks will be to recommend to the United States Environmental Protection Agency (USEPA) a preferred alternative for implementation of the corrective measure at TWFF.

The objective of Task IV is to provide a minimum format of the CMS Final Report.

EVALUATION OF ALTERNATIVES

The soil, groundwater and PSH areas with COCs are, for the most part, not co-located. The location of the majority of the COCs for soil is in the upper TWFF. The location of the majority of the groundwater contamination is near the 470-wells in the western part of the lower TWFF. The primary locations of the PSH plumes are in the central portion of the lower TWFF just north of Forrestal Road. Because of this, the configuration of the alternatives allow for different process options to be used on different media in one alternative when one process option may be effective on more than one medium. Also, different processes may be used on the same medium, but in different locations. It is, therefore, logical to address the alternatives as a whole because the alternatives are configured to address all the media and all the COCs.

The various alternatives are evaluated with regard to the criteria set up in Appendix B of Module III of the RCRA Part B Permit. The technical, environmental, human health, and institutional concerns associated with each alternative were discussed.

In the technical evaluation, the performance, reliability, implementability, and safety of each alternative were evaluated. The performance is measured by the effectiveness and useful life of the alternative. The effectiveness is the ability of the alternative to perform the intended functions, such as contain, divert, remove, destroy, or treat the COCs. The combination of various technologies in the alternatives will be evaluated as a whole. Should a particular technology or process within the alternative be responsible for reducing the performance of the alternative, this will be evident during these evaluations. The reliability is measured by the operation and maintenance requirements of the alternative and the risk and effect of failure of the alternative. Implementability criteria reflect the constructability of the alternative, the time it takes to implement the alternative, and the time of expected beneficial results. Any threat to the safety of the nearby communities and environments as a result of the alternative, including worker safety during implementation, is also evaluated.

In the environmental assessment of the alternative, the short and long term beneficial and adverse effects of the alternative on environmentally sensitive areas were assessed.

The protection of human health criteria examines the extent to which each alternative mitigates short and long term potential exposure to contamination. Residual levels expected from each alternative were compared to the CAOs.

Each alternative was assessed as to the requirements needed to meet relevant Federal, State, and local standards, regulations, ordinances and community relations.

A cost estimate of each alternative, including capital costs and operation and maintenance costs, was also provided.

JUSTIFICATION AND RECOMMENDATION OF THE CORRECTIVE MEASURES

When all factors are weighed, it is apparent that given enough time, Alternative 1 is effective at addressing contaminants within the groundwater and PSH media of concern. Alternative 3 is effective at addressing all contaminants within the soil media. The combination of Alternatives 1 and 3 is the quickest to implement, the easiest to maintain, and offers a high level of protection to human health and the environment.

Impacted groundwater has been limited to the 470-well area. Previous sampling has showed that the dissolved plume has not moved and has favorable natural attenuation parameters. If the PSH could be removed from this area, the naturally occurring parameters should mitigate this plume. Active remediation of the groundwater plume does not necessarily speed up the remediation time. This is evident in the need to discharge treated groundwater. Either option, permitted NPDES or UIC discharge, delays the implementation of any recovered groundwater treatment system. In the case of the NPDES discharge, it is apparent that treatment levels will be extremely stringent and would require additional post-treatment technologies in order to meet discharge limits.

Soils are addressed adequately under Alternative 3. Under this alternative, excavation and disposal of all soil 0 – 2' below ground surface (bgs) above the CAOs would be done. The additional effort and cost to remove the soils will benefit the site if land use controls would not be required.

The PSH must be reduced to 0.01 feet or less. Alternative 1 uses a simple, proven technology to capture the maximum PSH recoverable. Some alternatives use a total groundwater/PSH collection/treatment system. As previously stated, this becomes an issue when dealing with discharge options available for the treated groundwater. These options become less effective as a result of available discharge options. CleanOX® could be used at this site as a "polishing" option to remove PSH that becomes difficult to capture (e.g. between 0.1 and 0.01 feet). CleanOX® is not recommended to remove large amounts of PSH.

Another positive aspect of the PSH skimming system is its flexibility. The design calls for at least two self-contained portable skimming systems to be used. These systems would be trailer mounted with small tanks for PSH recovery located on the trailer. Solar cells that charge on-board batteries would be used to operate the pumps and controls. These systems would allow the Navy to respond to newly identified wells with measurable PSH in them.

The areas where the interim skimming system was used, still has PSH available for recovery. Alternative 1 would use the existing interim skimming system to the maximum extent practicable. A permanent skimming system would be placed in these wells to capture PSH. Sanitary well seals will be placed on these wells to prevent storm water runoff from entering the well. Previous operations of the interim skimming system have resulted in capture of large volumes of water. Proper operation and maintenance will reduce the production of groundwater and greatly increase recoverable PSH.

After two years of operation of the passive skimming system option, an Engineering Evaluation Report (EER) will be developed to evaluate the effectiveness of passive skimming to meet the CAO of 0.01 feet or less of measurable PSH in wells at the TWFF or alternatively a PSH thickness level, subject to USEPA review and approval, that will result in no approved risk-based CAOs for dissolved petroleum-related constituents in the groundwater being exceeded. Other technologies may also be evaluated in the EER should the passive skimming system prove ineffective at removing the PSH.

The cost estimate of these combined alternatives is $6,204,079.

1.0 INTRODUCTION

This document presents the Corrective Measure Study (CMS) Final Report for the Tow Way Fuel Farm (TWFF) located at Naval Activity Puerto Rico (NAPR) formerly known as Naval Station Roosevelt Roads (NSRR), Ceiba, Puerto Rico under the Corrective Action provisions of NAPR's Resource Conservation and Recovery Act (RCRA) permit (RCRA/HSWA Permit No PR 2170027203). Baker Environmental, Inc. (Baker) has prepared this report under contract to the Atlantic Division, Naval Facilities Engineering Command (LANTDIV), Contract Number N62470-95-D-6007.

On October 20, 1994, the United States Environmental Protection Agency (USEPA) Region II issued a Final RCRA Part B Permit to NAPR. This permit contains requirements for RCRA Facility Investigations (RFI) activities at 24 solid waste management units (SWMUs) and three areas of concern (AOC). Prior to 1993, environmental activities at NAPR, exclusive of underground storage tanks (USTs), were conducted in compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulations under the Department of the Navy's (DoN's) Installation Restoration (IR) Program. The RCRA Part B Permit issued for the Defense Reutilization and Marketing Office (DRMO) at NAPR, included provisions for corrective action under the Hazardous and Solid Waste Amendments (HSWA) provisions of RCRA.

On May 23, 2003, on behalf of the Navy, Baker submitted the Final Corrective Measure Study Task I Report to the EPA for review. EPA approved the CMS Task I report on June 10, 2003 and requested that the remaining tasks of the CMS for the TWFF be completed. This document presents the remaining tasks of the CMS.

At this time NAPR controls the former NSRR and is maintaining it in the same manner as during its use as an active naval facility. Land use is remaining industrial at the Tow Way Fuel Farm and corrective action requirements are still addressed under the Final RCRA Part B Permit. The Navy and EPA are currently negotiating a RCRA 7003 Order on Consent that is expected to include, among other things, requirements that institutional and/or engineering controls be maintained for any SWMUs and AOCs at the NAPR facility where clean-up levels based on unrestricted (i.e., residential) land-usage are not achieved. The RCRA 7003 Order on Consent is also expected to include requirements addressing responsibility for maintaining such institutional and/or engineering controls for a SWMU or AOC in the event of the sale or transfer of that portion of the NAPR facility to an entity other than the U.S. Navy. The Navy has indicated to EPA that it expects any entity acquiring a portion of the NAPR facility where clean-up levels based on unrestricted (i.e., residential) land-usage have not been achieved, will be required to enter into an "enforceable agreement" (such as an Administrative Order) with EPA. If the acquired parcel is subject to institutional and/or engineering controls, it would be the Navy's expectation that continued maintenance of those institutional and/or engineering controls would be required under any "enforceable agreement" (such as an Administrative Order) between the acquiring entity and EPA.

1.1 Context of the Corrective Measures Study Final Report

This report was developed to meet the requirements of Tasks II, III, and IV under Module III, Appendix B (Scope of Work for a Corrective Measure Study) as contained in NAPR's RCRA Part B Permit (USEPA, 1994). The Final Corrective Measures Study Task I Report (Baker, 2003a) identified the preliminary corrective measure technologies to address the soil and groundwater contamination present at the site from the site operations. The technologies identified were screened and developed for removal, containment, treatment and/or other remediation of the contamination based on the objectives established for the corrective action. Alternatives using various combinations of these technologies to address the contamination at the TWFF were also formulated during this task. Task II provides an evaluation of the identified alternatives with respect to technical requirements, environmental assessments, protection of human health, and institutional needs. A cost estimate for each alternative is also included in this task. Task III provides a recommendation and justification of the preferred alternative or alternatives. Task IV is simply the reporting task, of which the Final Task I CMS report was the first part, with the subsequent tasks documented in this report.

1.2 Summary and Conclusions of the Final Corrective Measures Study Task I Report

1.2.1 Summary of Site Investigations

The TWFF is located on NAPR north of the Ensenada Honda as shown in pink on the east side of Puerto Rico (Figure 1-1). Figure 1-2 depicts an aerial photo of the site in the context of NAPR. A site map is provided on Figure 1-3 showing the sampling locations of all investigations done at the TWFF to date.

The Task I report documented results of previous investigations and the current conditions of the soil and groundwater contamination resulting from releases of diesel and jet fuel at the TWFF. Numerous environmental investigations, one interim corrective measure, and two pilot tests have been performed and documented at this site. Investigations include an Initial Assessment Study (1982), Confirmation Study (1986), Underground Fuel Investigation (1991), Preliminary Site Assessment Underground Storage Tank Site No. 443 (1992), Draft Corrective Action Plan (1992), Site Characterization and CAP (1994), Multi-Stage Product Recovery Test Report (1996), Closure Report for Tank 56A/B (1996), RCRA Facility Investigation Report (1997), Corrective Measures Study Investigation (1998), and the Additional Data Collection Investigation (2002), found as Appendix E to the CMS Task I report. The interim corrective measure was documented in the Project Close-Out Report Interim Corrective Measure Free Product Recovery System (1997). A CleanOX® Pilot Study was conducted in January 1999. A pneumatic fracturing pilot test to evaluate enhancement of product recovery at the TWFF was completed in August 2000.

Ongoing reporting of water table measurements, product thickness, and product removal information done by the Remedial Action Contractor (RAC) at various wells at the TWFF are documented in Attachment 1 (TWFF Quarterly Summary Progress Report) of each RCRA Final Permit Required Quarterly Progress Report (Baker, 2003b, etc.).

1.2.2 Establishment of Corrective Action Objectives

Also presented in the Task I report were the corrective action objectives (CAOs) for the Contaminants of Concern (COCs) as determined through a human health risk assessment and a screening level ecological risk assessment. These are summarized in Table 1-1. One metal and four semi-volatile organic compounds were determined to be COCs in the soil and four volatile organic compounds (VOCs) were found to be COCs in groundwater.

1.2.2.1 Soil

Soil COCs present at the TWFF include arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene. Zinc was also identified in the soil as a chemical of potential concern (COPC) in the screening level ecological risk assessment. The Final CMS Task I Report (Baker, 2003a) identified the need to further characterize the surface soils immediately down gradient of 7MW17. On September 15, 2003, three surface soil samples immediately down gradient from 7MW17 were collected and analyzed for zinc. Results from the analysis can be found in the Additional Zinc Data Collection Investigation report that is located in Appendix A. The conclusion of the report shows that zinc is not a COC.

Figures 1-4 through 1-9 depict the extent of the COCs above the CAOs for the soil. It should be noted that benzo(a)pyrene was found to be a COC in both surface and subsurface soil (Figure 1-9), but the CAO for the subsurface soil was higher (7.3 milligrams/kilogram [mg/kg]) than the surface soil (2.9 mg/kg). As shown, there is one primary area of soil contamination at the site, located near the bottom of the upper TWFF. Arsenic and benzo(a)pyrene are found in more than one place, but still primarily in the lower part of the upper TWFF.

1.2.2.2 Groundwater

Groundwater COCs include 1,2,4-trimethylbenzene, benzene, and ethylbenzene. The extent of the dissolved plume of these COCs above their respective CAOs are shown in Figures 1-10 through 1-12. All contamination above the CAOs is found in the area around the 470-wells.

Trichloroethene (TCE) was also found to be a COC at the TWFF. However, TCE will not be addressed in this CMS Final Report. In the CMS Task I Report, the Navy recommended a TCE Plume Delineation and Source Investigation field effort be conducted in order to address the TCE plume because of the order of magnitude increase in concentration. Subsequent to this field investigation, a separate CMS report will be written to address the TCE plume at the TWFF. This site has been designated as SWMU 55. It should be noted that TCE contamination in the groundwater is not co-located with any contamination associated with the release of diesel and jet fuel. Rather, it is found in the lower TWFF, south of Forrestal Road near Building Pad 46.

1.2.2.3 Phase Separated Hydrocarbon

Phase separated hydrocarbon (PSH) is present at the TWFF. PSH may not, in the strictest sense, be a COC. PSH will be treated as a source for remedial purposes. The CAO for PSH will be either 0.01 feet or less of measurable PSH in wells at the TWFF or alternatively a PSH thickness level, subject to USEPA review and approval, that will result in no approved risk-based CAOs for dissolved petroleum-related constituents in the groundwater being exceeded. The current extent of the PSH in the wells is shown in Figure 1-13. Two primary areas of PSH are shown on this figure, one in the vicinity of UGW25 and RW01 and one stretching west to east along the north side of Forrestal Road. A cross section of the subsurface conditions in the area of UGW-25, MTMW-03, UGW-03, and RW-1, as well as the PSH present in this area is shown in Figure 1-14. As can be seen by the geologic descriptions located next to each well, there are very heterogeneous conditions encountered in the area of the PSH plume, in particular in the area around MTMW-03, UGW-03 and RW-1.

1.2.3 Corrective Measure Study Alternatives

Five alternatives using a variety of process options were developed as a result of the technology screening provided in the Task I report. These five alternatives are presented below. In addition, the process options within the alternative to their respective media of concern (soil, groundwater, and PSH) are presented in Table 1-2.

Alternative 1

- Institutional Controls, Monitored Natural Attenuation (MNA), and Containment/Collection (PSH Skimming)

<u>Alternative 2</u>

- Institutional Controls, MNA, In-situ Biological Treatment (Bioventing), Containment/Collection (Dual Phase Extraction and Steam Flushing), Ex-situ Physical/Chemical Treatment (Air Stripping), and Discharge (National Pollutant Discharge Elimination System [NPDES])

<u>Alternative 3</u>

- Institutional Controls, MNA, Excavation/Disposal (Off Site), Containment/Collection (Extraction Wells and Surface Oil/Water Separators), Ex-situ Biological Treatment (Bioreactors), and Discharge (Re-injection)

<u>Alternative 4</u>

- Institutional Controls, MNA, Excavation/Ex-situ Thermal Treatment (High Temperature Thermal Desorption [HTTD]), In-situ Physical/Chemical Treatment (Soil Vapor Extraction), In-situ Physical/Chemical Treatment (Air Sparging), Containment/Collection (Skimmer Pumps for PSH)

Alternative 5

- Institutional Controls, MNA, Excavation/Ex-situ Biological Treatment (Land Farming), In-situ Biological Treatment (Biodegradation), In-situ Biological Treatment (CleanOx®), In-situ Physical/Chemical Treatment (ECGO®)

1.3 Objectives of the Corrective Measures Study--Task II, III and IV

The objective of Task II is to provide an evaluation of the above identified alternatives with respect to technical requirements, environmental assessments, protection of human health, and institutional needs. A cost estimate for each alternative is also included in this task. Once Task II is complete, at least one preferred alternative would be brought into Task III for discussion.

The objective of Task III is to recommend and justify the preferred alternative or alternatives. Additionally, performance expectations, preliminary design considerations, operation and maintenance (O & M) requirements, and precautions necessary for design and implementation of the recommended alternatives are provided in this Task. The objective of these two tasks will be to recommend to the United States Environmental Protection Agency (USEPA) a preferred alternative for implementation of the corrective measure at TWFF.

The objective of Task IV is to provide a minimum format of the CMS Final Report. The report will, at a minimum, have the following areas of discussion.

1. A description of the facility to include a site topographic map and preliminary layouts.
This can be found in the CMS Task I Report (Baker, 2003a).

2. Summary of corrective measure or measures;
    - Description of the corrective measure or measures and rationale for selection;
    - Performance expectations;
    - Preliminary design criteria and rationale;
    - General operation and maintenance requirements; and
    - Long-term monitoring requirements.

This can be found in Section 2.0 of this report.

3. A summary of the RCRA Facility Investigation and impact on the selected corrective measure or measures;
    - Field studies (groundwater, surface-water, soil, air); and
    - Laboratory studies (bench scale, pick scale).

This can be found in the RFI Report (Baker, 1997).

4. Design and Implementation Precautions;
    - Special technical problems;
    - Additional engineering data required;
    - Permits and regulatory requirements;
    - Access, easements, right-of-way;
    - Health and safety requirements; and
    - Community relations activities.

This can be found in Section 3.0 of this report.

5. Cost Estimates and Schedules;
    - Capital cost estimates;
    - Operation and maintenance cost estimates; and
    - Project schedule (design, construction, operation).

This can be found in Section 3.0 of this report.

For the purposes of this CMS Final Report, each alternative will be evaluated against the criteria identified in the Part B Permit. If, after the evaluation process in Task II, it becomes apparent that an alternative would be more acceptable if a process option was removed and/or replaced with a different process option, that alternative will be adjusted as necessary. Necessary justification and revised cost estimates will be provided should this adjustment occur.

1.4 Organization of the Corrective Measures Study Final Report

This report is divided into six sections. Section 1.0 of this document includes this introduction and the objectives of this CMS Final Report. Task II, the evaluations of the corrective measure alternatives, are provided in Section 2.0. Justification, recommendation, and preliminary design information for the corrective measure alternative(s) is given in Section 3.0. The recommendation of the preferred corrective measure along with the proposed project schedule for this corrective measure are also provided in Section 3.0 of this document. The references utilized in development of this report are provided in Section 4.0.

2.0 TASK II—EVALUATION OF THE CORRECTIVE MEASURE ALTERNATIVES

This section will provide the evaluation of the alternatives as specified in Task II of Module III—Appendix B of the RCRA Part B Permit. Once this evaluation is complete, a recommendation for a preferred alternative or alternatives will be made in Task III of this CMS.

As shown in Section 1.2.2, the soil, groundwater and PSH areas with COCs are, for the most part, not co-located. The location of the majority of the COCs for soil is in the upper TWFF. The location of the majority of the groundwater contamination is near the 470-wells in the western part of the lower TWFF. The primary locations of the PSH plumes are in the central portion of the lower TWFF just north of Forrestal Road. Because of this, the configuration of the alternatives allow for different process options to be used on different media in one alternative when one process option may be effective on more than one medium. Also, different processes may be used on the same medium, but in different locations. It is, therefore, logical to address the alternatives as a whole because the alternatives are configured to address all the media and all the COCs.

Because each alternative consists of several components (or process options) in order to address the soil, groundwater, and PSH contamination, a brief description of each process option listed in the CMS Task I Report will be given in this section, prior to the alternative evaluations. Similar descriptions were presented in Section 6.0 of the Final CMS Task I Report. In addition, alternate technologies similar to the listed process option will be named, should a substitution be warranted based on current site conditions or other reasons, such as uncertainty in the demonstrated effectiveness of the listed process option.

2.1 Process Option Descriptions

Details on how the process options were identified, screened, and evaluated can be found in the Final Corrective Measure Study Task I Report (Baker, 2003a).

2.1.1 Soil

- Institutional/Engineering Controls

With regard to soil, institutional controls consist of restricting the location of new buildings and/or installing environmental controls in existing buildings so as to avoid any environmental pathway of exposure to the contaminants. Physical barriers that restrict access to the site, such as fences, would be considered an engineering control. Any fencing would have appropriate signs to warn of potential hazards on site.

- Bioventing

In-situ bioventing consists of oxygen delivery to the contaminated soils by forcing air, either through extraction or injection, through the soil to promote biodegradation. Limitations include soil permeability and amenability of the contaminant to biodegradation.

- Excavation/Disposal

Excavation and disposal removes the source of the soil contamination. Limitations include site conditions, such as slope stability, any landfill disposal restrictions based on the soil contamination, and underground obstructions (i.e. piping, utilities, etc.). Also, location of disposal facility with respect to the site is a potential limitation.

- High Temperature Thermal Desorption (HTTD)

HTTD is an ex-situ process where wastes are heated to 600°F – 1000 °F to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to the gas treatment system. Limitations include level of clays in soil, availability of the treatment equipment and availability of power.

- Soil Vapor Extraction

In soil vapor extraction a vacuum is applied to the soil matrix through the use of extraction wells to create a pressure/concentration gradient that induces gas-phase volatiles to diffuse through soil to extraction wells. The process includes a system for handling off-gases. This technology is also knows as in-situ soil venting, in-situ volatilization, enhanced volatilization, or soil vacuum extraction. It differs from bioventing in that the flow rate is higher, reflecting a physical process, rather than a biological process. Limitations include soil permeability.

- Land Farming

Contaminated soils are applied onto the soil surface and periodically turned over or tilled into the soil to aerate the waste. Limitations include suitable land availability.

- Biodegradation

Naturally occurring microbes are stimulated by circulating water-based solutions through contaminated soils to enhance in-situ biological degradation of organic contaminants. Nutrients, oxygen, or other amendments may be used to enhance biodegradation and contaminant desorption from subsurface materials. CleanOx® and other oxygen enhancing technologies are included in this process option. Limitations include soil permeability and the amenability of the contaminants to biodegradation.

2.1.2 Groundwater

- Institutional/Engineering Controls

With regard to groundwater, institutional controls include the restriction of groundwater extraction at the site, thereby avoiding exposure to groundwater to any receptor at the site. Physical barriers that restrict access to the site, such as fences, would be considered an engineering control.

- Monitored Natural Attenuation

MNA is the documentation of the natural processes occurring in the groundwater that act to reduce contaminant concentrations to acceptable levels. These processes include dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials. Limitations may include the prediction of an acceptable time frame for remediation and lack of site characterization needed for accurate documentation.

- Electrochemical Geo-Oxidation (ECGO®)

ECGO® is an in-situ technology that uses induced electric current to create oxidation-reduction reactions leading to complete mineralization of organic (or mobilization of inorganic constituents) present in a volume of soil and groundwater between the electrode locations. Limitations include soil moisture content (must be close to saturation), heterogeneity of soil, location of underground conductive utilities and availability of electrical power.

- Air Sparging

In this process air is injected into saturated matrices to remove contaminants through volatilization. In some cases, soil vapor extraction is used in conjunction with this technology.

Limitations include a potential for a small radius of influence due to poor interconnectivity of the soil pores.

- CleanOX®

CleanOX® technology is an in-situ process utilizing the injection of proprietary liquid chemical formulations through monitoring wells into the contaminated portion of the aquifer. The technology involves the application of a Fenton-like chemistry to create and migrate hydroxyl radicals, which in turn degrade organic contamination to carbon dioxide and water, either through biological action through the use of enhanced dissolved oxygen, or through chemical action with the hydroxyl radicals. Another patented in-situ oxidation technology similar to this one is ISOTEC®. A gaseous oxidation technology for benzene related contamination is ozone injection. Limitations include safety in delivery, soil permeability and injection regulatory requirements.

- Dual Phase Extraction and Steam Flushing

Dual phase extraction involves the application of a high vacuum system to simultaneously remove liquid and gas from low permeability or heterogeneous formations. Steam flushing is an enhancement to this process whereby steam is forced into the aquifer through injection wells to vaporize volatile and semivolatile contaminants. Vaporized components rise to the unsaturated zone where they are removed by vacuum extraction and then treated. Limitations include high level of energy required to produce steam, soil permeability and injection regulatory requirements.

- Vacuum Vapor Extraction

In this process air is drawn out of the well, lifting contaminated groundwater in the well and allowing additional groundwater flow into the well. Once inside the well, some of the VOCs in the contaminated groundwater are transferred from the water to air bubbles, which rise and are collected at the top of the well by vapor extraction. Limitations include location of vacuum extraction system near extraction wells to reduce sizing requirements of piping and treatment of off gases.

- Extraction Wells and Oil/Water Separator

In this process, groundwater and PSH are removed from the extraction well and transferred to an oil/water separator. PSH is collected and disposed of at a recycle/reuse facility. Groundwater can be discharged if levels do not exceed permit requirements. Limitations include lack of disposal options and the potential need for additional post treatment of groundwater to meet regulatory permit requirements for discharge.

- Air Stripping (post-extraction)

When groundwater is extracted, the air stripping treatment process relies on the transfer of volatile organic compounds from water into air. Contaminated water enters the top of the air stripping tower and flows down through the packing material in a thin film. An air stream is forced upward through the tower. Within the tower, the contaminants are transferred from the thin film of contaminated water into the flowing air stream. Treated water exits from the bottom of the tower, while air containing the volatilized contaminants is exhausted through the top of the tower. Limitations may include additional treatment of off gases, regulatory requirements for discharge and availability of power.

- Bioreactor (post-extraction)

Contaminants are put into contact with microorganisms in attached or suspended growth biological reactors. In suspended systems, such as activated sludge, contaminated groundwater is circulated in an aeration basin. In attached system, such as rotating biological contactors and trickling filters, microorganisms are established on an inert support matrix. Limitations include space requirements, reactivation of biological media after an upset event and regulatory requirements for discharge.

- Discharge (NPDES) (post-extraction and treatment)

When groundwater is extracted and treated via any of the above processes, the treated water is discharged to a nearby surface water body. Regulations require that an NPDES permit be applied for and granted prior to this action. Limitations include extremely low organic/inorganic allowable discharge levels that may require additional treatment prior to discharge and regulatory requirements for disposal.

- Re-Injection (post-extraction and treatment)

When groundwater is extracted and treated via any of the above processes, the treated groundwater is re-injected into the aquifer at a location and rate approved by regulators. Limitations include soil permeability and regulatory requirements.

2.1.3 PSH

- PSH Skimming

Free product removal using skimming equipment is used when product is encountered on top of a water table or in an open excavation. Little or no recovery of water is associated with this technology. Limitations include free product mobility and volume of removal.

- Dual Phase Extraction

Dual phase extraction involves the application of a high vacuum system to simultaneously remove liquid and gas from low permeability or heterogeneous formations. Vaporized components rise to the unsaturated zone where they are removed by vacuum extraction and then treated.

- Extraction Wells and Oil/Water Separation

In this process, groundwater and PSH are removed from the extraction well and transferred to an oil/water separator. PSH is collected and disposed of at a recycle/reuse facility. Groundwater can be discharged if levels do not exceed permit requirements. Limitations include lack of disposal options and the potential need for additional post treatment of groundwater to meet regulatory permit requirements for discharge.

- CleanOx®

CleanOX® technology is an in-situ process utilizing the injection of proprietary liquid chemical formulations through monitoring wells into the contaminated portion of the aquifer. The technology involves the application of a Fenton-like chemistry to create and migrate hydroxyl radicals, which in turn degrade organic contamination to carbon dioxide and water, either through biological action through the use of enhanced dissolved oxygen, or through chemical action with the hydroxyl radicals. Another patented in-situ oxidation technology similar to this one is ISOTEC®. A gaseous oxidation technology for benzene related contamination is ozone injection. Limitations include safety in delivery, soil permeability and injection regulatory requirements.

2.2 Evaluation of Alternatives

In this section the various alternatives are evaluated with regard to the criteria set up in Appendix B of Module III of the RCRA Part B Permit. The technical, environmental, human health, and institutional concerns associated with each alternative will be discussed.

In the technical evaluation, the performance, reliability, implementability, and safety of each alternative will be evaluated. The performance is measured by the effectiveness and useful life of the alternative. The effectiveness is the ability of the alternative to perform the intended functions, such as contain, divert, remove, destroy, or treat the COCs. The combination of various technologies in the alternatives will be evaluated as a whole. Should a particular technology or process within the alternative be responsible for reducing the performance of the alternative, this will be evident during these evaluations. The reliability is measured by the operation and maintenance requirements of the alternative and the risk and effect of failure of the alternative. Implementability criteria reflect the constructability of the alternative, the time it takes to implement the alternative, and the time of expected beneficial results. Any threat to the safety of the nearby communities and environments as a result of the alternative, including worker safety during implementation, is also evaluated.

In the environmental assessment of the alternative, the short and long term beneficial and adverse effects of the alternative on environmentally sensitive areas are assessed.

The protection of human health criteria examines the extent to which each alternative mitigates short and long term potential exposure to contamination. Residual levels expected from each alternative shall be compared to the CAOs. The development of CAOs can be found in the Final Corrective Measure Study Task I Report (Baker, 2003a).

Each alternative will be assessed as to the requirements needed to meet relevant Federal, State, and local standards, regulations, ordinances and community relations.

A cost estimate of each alternative, including capital costs and operation and maintenance costs, is also provided.

2.2.1 Alternative 1

Alternative 1 consists of the following processes: institutional controls for soil, institutional controls and MNA for groundwater, and PSH skimming for the PSH. A preliminary process flow sheet is provided in Figure 2-1. Figure 2-2 details the conceptual layout of the alternative for the site. Skimming wells are expected to achieve a 25-foot radius of influence to capture PSH. A PSH recovery pad will be constructed near the front gate of the TWFF to collect recovered PSH. Figure 2-3 identifies the conceptual component layout. This figure shows the major components associated with this alternative and the media that will be addressed.

The volume calculations for PSH have been identified in the Appendix G of the Final Corrective Measures Study Task I Report (Baker, 2003a). It is estimated that 79,750 gallons of PSH is present. The skimming system within this alternative will address the PSH as indicated. The soil volume calculations are in Appendix B of this report. For this alternative, the soil and groundwater volumes have not been calculated because no active remediation will occur. Land use controls will be implemented to remove the pathway associated with COCs within each of these media.

After two years of operation of the passive skimming system option, an Engineering Evaluation Report (EER) will be developed to evaluate the effectiveness of passive skimming to meet the CAO for PSH as defined in Section 1.2.2.3. Other technologies may also be evaluated in the EER should the passive skimming system prove ineffective at removing the PSH.

2.2.1.1 Technical

Performance

Institutional controls in the form of land use restrictions on the contaminated soil are both effective and have a long useful life in the form of land use restrictions maintained in perpetuity. Institutional controls, in a certain sense, provide containment of the COCs in the soil. The Navy intends to use a Finding of Suitability for Early Transfer (FOSET) to administratively document the conditions and restrictions at the site. The FOSET is intended to provide the information necessary for approval of the early transfer of certain NSRR property by the Governor of the Commonwealth of Puerto Rico. The Navy may enter into an agreement to transfer by deed real property or facilities with any person who agrees to perform all environmental restoration and environmental compliance activities that are required for the property or facilities under Federal and State laws or administrative decisions, agreements and concurrences as stated in CERCLA Section 2905 (e). To prevent unacceptable risks to human health during the deferral period, the Navy will impose post-conveyance use restrictions to current use, and additional controls.

Additional engineering controls are in place at the TWFF. A fence with locked gates surrounds the TWFF and access is restricted. The fence would have signs located periodically along the length identifying the potential hazards at the site and give contact information as appropriate. Fencing requires little to no maintenance and has an expected long life. Since the risk drivers for the site are exposure from soil COCs under an industrial future use scenario, land use restrictions would be effective in addressing human health exposure risks. The potential future risk pathway would be removed by restricting future development of building on site that may be occupied on a regular basis by humans. Institutional controls on groundwater in the form of water use restrictions are also effective for the same reason. Currently, NAPR does not use groundwater for potable purposes. Institutional controls are appropriate and required to address soil and groundwater at the site. Institutional controls offer a high level of effectiveness that requires no physical maintenance. A building use restriction will be added to the FOSET to assure no buildings are constructed or occupied by humans before beneficial results are realized. Institutional controls have an indefinite useful and service life.

MNA is effective for groundwater, once the PSH is removed from the surface of the groundwater. Typically, sampling programs in support of MNA have a useful life beyond five years, with re-evaluation of the program occurring on the fifth year. The groundwater contamination at the TWFF has not shown any movement toward the Ensenada Honda, with the primary benzene-related contamination remaining around the 470-wells (470-MW1 and 470-MW3) on the west side of the lower TWFF. Concentrations of benzene and ethylbenzene in these wells have decreased since April 1998. Additionally, the dissolved benzene and ethylbenzene plume has not significantly changed in size since April 1998. The technology is effective in monitoring the natural degradation of the constituents in the dissolved plume at the site. A full evaluation of the MNA efficacy can be found in the Additional Data Collection Investigation Report (Baker, 2003). In addition, an MNA evaluation would be performed at the TWFF prior to implementation of this remedy.

PSH pneumatic skimming, when diligently operated and maintained, will effectively reduce the quantity of free product in the subsurface, provided no continuing source of product is present. However skimming in conjunction with MNA would speed the time to see beneficial results. Limitations include the mobility of the product in the subsurface and the ability of the skimmers to capture all the PSH without additional physical influences applied. Baildown tests in the lower TWFF along Forrestal Road have not produced favorable results because of lack of recovery after initial baildown (Baker, 1999). However, recent evidence at UGW25, where a majority of the

PSH is located, has indicated that large quantities of product are available for removal at this well (Baker, 2003a). Monthly removals of PSH at this well had increased by an order of magnitude or more since July 2002. A review of the quarterly reports for the site has showed a reduction in the size of the PSH plume both horizontally and vertically. The useful life of skimmers is five to ten years if maintained properly. The technology is appropriate for removing PSH from the site.

Reliability

The reliability, implementability, and safety of these processes are all adequate for the COCs present at the site. In addition, should unexpected changes to site conditions occur, these processes are readily dismantled or modified to accommodate changing site conditions.

The reliability of skimmer technology is measured by the dependence on operation and maintenance of the skimmers. If the operation and maintenance of the skimmers should fail, or be inadequate, the consequences would be representative of the current scenario, where it appears that there is no migration of the product toward the Ensenada Honda.

Skimmer technology has been used over the past decades at similar sites with favorable results. The components that make up a skimmer system are reliable and readily available.

Implementability

Implementability of the technologies identified for Alternative 1 is not difficult. Minimal efforts are involved with developing and implementing land use restrictions at the site.

Construction of the pneumatic skimmer system would not be difficult when using the existing interim recovery piping as conduits for the new skimmer system. A total of 60 skimmers would be installed in new recovery wells. The radius of influence associated with each skimmer is expected to be 25-foot with the recovery wells spaced accordingly. Previous RCRA Quarterly Reports have identified measurable PSH near UGW02. To address remote access to PSH recovery, two self-contained, trailer-mounted, portable skimmers would be used to collect PSH in remote locations such as the upper TWFF on an as needed basis.

Pneumatic skimming equipment is very common and would not be difficult to obtain. Much of the existing interim system could be used with some replacement of hoses and fittings. No special permits are required for this system. PSH recovered by the skimmers would be stored in an on-site tank. The PSH would periodically be collected from the holding tank and trucked to a local recovery facility.

The equipment would be located in the same area the interim system resides. The pneumatic skimming equipment would be located immediately inside the TWFF just north of Forrestal Road and west of the main gate to the TWFF. Ample space is available for all the pneumatic skimming equipment at this location. Utilities and existing conduit runs for the pneumatic skimming hoses are readily available at this location.

The estimated time to construct the pneumatic skimmer system would be three to six months. The pneumatic skimmer system should immediately reduce the level of PSH available in each well. The recharge rate in each well would have the greatest impact on the PSH recovery time. It is expected that the recovery rate would decline quickly given the fact that no additional physical influence is exerted on the PSH plume. It is estimated that the site should see beneficial reduction of PSH within seven to ten years, but this time frame is subject to uncertainty given the heterogeneity of the subsurface environment.

Safety

Safety concerns for the nearby community and for the workers during implementation are minimal and can be addressed in a site-specific health and safety plan. Since most of the existing interim system (e.g. underground conduit runs) will be used to the greatest extent possible, exposure to on-site workers will be greatly reduced. No explosion or fire hazards will exist at the well points since no electrical components will be placed in the wells. All electrical components within the equipment area will need to address National Electrical Codes (NEC) concerning petroleum products to minimize explosion/fire hazards. Additionally, a high-level, cut-off switch will need to be installed in the PSH recovery tank to prevent overfill. This will reduce the potential environmental impact created by an overflow condition. Alternative 1 offers a relatively high level of safety.

2.2.1.2 Environmental

The ability of this alternative to benefit the environment is evident by the reduction in groundwater concentrations of the COCs due to naturally occurring processes and reduction of PSH on the groundwater table through active removal. There would be no short or long term adverse effects of the alternative on environmentally sensitive areas.

2.2.1.3 Human Health

This alternative is protective of human health by removing the potential exposure pathways, through land use control restrictions, to humans. The pathway for potential exposure to industrial workers would be removed by land use restrictions. These restrictions would prevent industrial development of the areas impacted by soil COCs. Similarly, exposure to groundwater would be removed by land use control restrictions. Land use control restrictions are immediate and would mitigate the potential exposure to any residual contamination before and after implementation of the alternative. Restrictions would be recorded in the FOSET.

Table 1-1 identifies the COCs and associated CAOs for groundwater and soil. Figure 1-4 through Figure 1-13 shows the location and extent of each COC above the associated CAO. The potential exposure route for groundwater is from volatilization of groundwater COCs into buildings occupied by industrial workers. This pathway is removed by restricting the future building of offices that may be occupied by industrial workers. Similarly in soils, the potential exposure route from COCs in soil places the industrial worker at elevated risk. This pathway is removed by restricting future building of offices that may be occupied by industrial worker.

The exposure to groundwater and soil COCs is removed with land use control restrictions. The contaminant levels in groundwater will be reduced over time while the contaminant levels in soil may not be reduced over a similar timeframe.

2.2.1.4 Institutional

The requirements necessary to meet institutional needs would require a limited effort because this alternative represents only a limited extension of the current conditions. Alternative 1 satisfies Federal, State, and local environmental requirements.

2.2.1.5 Cost Estimate

The estimated net present value (NPV) cost to implement and maintain this alternative is $3,334,526. All cost estimate backup information can be found in Appendix B.

2.2.2 Alternative 2

Alternative 2 consists of the following processes: in-situ biological treatment for soil, a combination of institutional controls, MNA, containment/collection with ex-situ physical treatment and discharge for groundwater, and containment/collection for PSH. A preliminary process flow sheet is provided in Figure 2-4. Figure 2-5 details the conceptual layout of the alternative for the site. Each Dual phase extraction/ steam flushing well is expected to achieve a 50-foot radius of influence to capture groundwater and PSH. The anticipated pumping rate for each well is one gallon per minute. Similarly, each bioventing well is expected to achieve a 50-foot radius of influence to encompass the PAH impacted soils in the three areas identified on Figure 2-5. A remedial recovery pad will be constructed near the front gate of the TWFF to collect and treat recovered groundwater and PSH. Additionally, a separate bioventing pad will be constructed north of Tank 83 to facilitate closer access to the bioventing wells. Figure 2-3 identifies the conceptual component layout. This figure shows the major components associated with this alternative and the media that will be addressed. Because of the expected stringent NPDES requirements, a reverse osmosis, post-treatment unit was added to this alternative to remove inorganics prior to discharge. Similarly, an oil/water separator was included to capture PSH prior to treatment.

Approximately 79,750 gallons of PSH has been calculated on the water table (Baker, 2003a). The dual phase extraction/steam flushing process option will collect the PSH volume identified and the impacted groundwater underlying the area. The soil volume calculations for bioventing are included in Appendix B. It is estimated that 4,797 cubic yards of PAH impacted soil will be treated by the bioventing system. The estimated volume calculations for soil impacted by arsenic is also presented in Appendix B. It is estimated that 5,852 cubic yards of soil is impacted by arsenic. Land use controls will be implemented to remove the pathway associated with arsenic.

2.2.2.1 <u>Technical</u>

<u>Performance</u>

Bioventing for biological treatment of soil is effective for most of the organic COCs in the soil. Arsenic remediation through bioventing is not effective. Therefore, arsenic will be addressed through land use restrictions. The FOSET is intended to provide the information necessary for approval of the early transfer of certain NSRR property by the Governor of the Commonwealth of Puerto Rico. The Navy may enter into an agreement to transfer by deed real property or facilities with any person who agrees to perform all environmental restoration and environmental compliance activities that are required for the property or facilities under Federal and State laws or administrative decisions, agreements and concurrences as stated in CERCLA Section 2905 (e). To prevent unacceptable risks to human health during the deferral period, the Navy will impose post-conveyance use restrictions to current use, and additional controls. A fence with locked gates surrounds the TWFF and access is restricted. The fence would have signs located periodically along the length identifying the potential hazards at the site and give contact information as appropriate. Bioventing would effectively destroy the organic COCs by reducing them to innocuous by-products through biodegradation. With diligent O & M, the useful life of bioventing is three to five years.

A combination of institutional controls, MNA, and dual phase extraction with steam flushing enhancement is recommended for the groundwater, with dual phase extraction with steam flushing also removing the PSH from the subsurface. This combination would effectively remove the COCs from the subsurface environment, provided that the mobility of the PSH would be increased through the use of steam in a predicable manner. If the predictability of the increased mobility of the PSH cannot be determined prior to installation, it may result in mobilization of the PSH to previously unimpacted areas of the site. The recovered PSH and groundwater would be routed to an oil/water separator prior to treatment. Subsequently the groundwater, air stripping would be used to treat recovered groundwater. Discharge to the Ensenada Honda would be done post-treatment through a NPDES permitted outfall.

Institutional controls in the form of land use restrictions on the arsenic-contaminated soil are both effective and has a long useful life in the form of deed restrictions maintained in perpetuity. Institutional controls, in a certain sense, provide containment of all the COCs in the soil. Additional engineering controls are in place at the TWFF. A fence with locked gates surrounds the TWFF and access is restricted. The fence would have signs located periodically along the length identifying the potential hazards at the site and give contact information as appropriate. Fencing requires little to no maintenance and has an expected long life. Since the risk drivers for the site are exposure from soil COCs under an industrial future use scenario, land use restrictions would be effective in addressing human health exposure risks. The potential future risk pathway would be removed by restricting future development of building on site that may be occupied on a regular basis by humans. Institutional controls on groundwater in the form of water use restrictions are also effective for the same reason. NAPR does not use groundwater. Institutional controls are appropriate and required to address soil and groundwater at the site until remedial activities have reduced the COCs below their respective CAO. Institutional controls offer a high level of effectiveness that requires no physical maintenance. A building use restriction will be added to the FOSET to assure no buildings are constructed or occupied by humans before beneficial results are realized. Institutional controls have an indefinite useful and service life.

After a reasonable time frame for active remediation, the remainder of the groundwater contamination, including the areas not addressed through the dual phase extraction, would be subject to MNA. An MNA evaluation would be performed at the TWFF prior to implementation of this portion of the remedy. MNA is effective for groundwater, once the PSH is removed from the surface of the groundwater. Typically, sampling programs in support of MNA have a useful life beyond five years, with re-evaluation of the program occurring on the fifth year. The useful life of the dual-phase extraction/steam flushing system would be subject to diligent O & M and generally would be expected to operate three to five years. However, maintaining the extraction, steam flushing, and treatment systems beyond a period of five years without significant overhaul would likely not be cost effective. The expected useful life of the bioventing system is three to five years. The technology is effective in monitoring the natural degradation of the constituents in the dissolved plume at the site.

Reliability

The reliability of the proposed alternative would be high for the portions that are not actively undergoing remediation. Bioventing reliability is moderate to high because of the simple process involved of injecting or extracting air to the upper portions of the contaminated soil. Additionally, O & M for bioventing would be moderate to low. Dual-phase extraction, treatment, and discharge reliability is dependent on O & M. The reliability of the dual-phase extraction, steam flushing, air stripping, and discharge is moderate to high when O & M concerns are addressed on a periodic basis. Labor and materials are readily available for this combination of technologies.

The effect of failure of any of the processes in this alternative would be equivalent to the current conditions. Electronic controls would be put in place to avert discharge of untreated groundwater in the unlikely event of air stripper failure. Therefore, no additional risk would be anticipated. Flexibility in this alternative, should site conditions change, would require dismantling and/or relocation of all point-source equipment to other contaminated areas since the PSH is wide spread across the site. However, depending on the distance between the recovery wells and the treatment skid, the treatment skid may not have to be relocated. The combination of these technologies is expected to be reliable.

Implementability

Implementability of the bioventing would be dependent on getting the equipment necessary to inject or extract the air into the contaminated soil. The bioventing system was conceptually located as close as possible to the treatment area to minimize head loss and keep conveyance piping size to a minimum. The equipment would need to be obtained and shipped from the United States to Puerto Rico since the equipment is generally not readily available on the island. The heterogeneity of the subsurface may affect the location of injection/recovery well points. Power at the site is readily available and would not present an obstacle to constructability at this time. This has the potential to change as the base moves through post closure.

The timing of expected beneficial results is dependent on the amenability of the COCs to biodegradation. Typically, the polynuclear aromatic hydrocarbons (PAHs) are somewhat biodegradable, but the time frame for this process to occur is site dependent. Implementability of the dual-phase extraction, steam flushing, treatment, and discharge is also dependent on getting the necessary equipment to the site. The equipment is readily available in the United States and would need to be shipped to Puerto Rico. Overall, the expected time frame for beneficial results is expected to be achieved within three to five years, but this estimate could change based on the results of the associated pump test and pilot test and because of the inherent uncertainty of conditions in the subsurface. However, the PSH removal rate is expected to taper off once the initial removal of product is complete shortly after start up. Arsenic would be left in place with no treatment, so land use controls would be necessary.

Permits associated with construction of the system are obtainable and should not present an obstacle to construction. However, a NPDES permit for discharge would be necessary and would present an obstacle to the constructability of this alternative. NAPR’s wastewater treatment plant (WWTP) currently operates under a NPDES discharge permit with a permitted outfall into the Ensenada Honda. The inorganic limitations under the WWTP’s NPDES permit are extremely low. These low discharge limits became an issue when discharging recovered groundwater as described in the Draft Pilot Test to Evaluate Enhancement of Product Recovery Report TWFF SWMU 7/8 (Baker, 2000). A pumping test was performed on two areas of the TWFF. The pilot test work plan called for the recovered groundwater to be discharged to the WWTP with subsequent discharge through the NPDES permitted outfall. The recovered groundwater did not meet the extremely low discharge levels for inorganics. Several attempts were made to pre-treat the recovered groundwater prior to discharge to the WWTP in an attempt to meet the NPDES inorganic discharge requirements of the WWTP. A 10 micron filter was used followed by a one micron filter. All attempts failed. Ultimately, the recovered groundwater was collected and contained on site then transported off site to a permitted treatment facility. Additionally, a NPDES permit could take several years to obtain which may delay the construction of the alternative. The implementability of the alternative would be moderate to low given all the pitfalls associated with obtaining a NPDES permit. Also, based on the current closure activities, obtaining a permit for discharge may not be possible since NAPR is currently negotiating a Federal Facilities Compliance Agreement (FFCA) that will enable them to maintain its facilities operational ready until transfer. An air emission construction and operating permits shall also be obtained from the Puerto Rico Environmental Quality Board for the bioventing wells.

Safety

The safety of this alternative is expected to be moderately high. Short and long term benefits to the environmentally sensitive areas are expected to be reasonably high due to the removal of contamination in all three media of concern at TWFF. The same is true for the mitigation of potential human health exposure to the COCs. The residual concentrations of the COCs are expected to be near the CAOs for the soil, with the exception of arsenic, which would not be treated. In the groundwater, the residual concentrations of the COCs are also expected to be near or below the CAOs, depending on the presence of a continuing source. Removal of the PSH to less than 0.01 feet over the site will depend on the effectiveness of the extraction system.

The safety risks to workers during implementation would be low. The risk of fire, explosion, or exposure to contaminants is unlikely under normal circumstances. These risks would be addressed and mitigated through the use of a site-specific health and safety work plan. There would be no risk to nearby community given the remote location of the site.

2.2.2.2 Environmental

The ability of this alternative to benefit the environment is evident by the reduction in groundwater concentrations of the COCs from active removal of the impacted groundwater and PSH and subsequent naturally occurring processes. However, arsenic would be left in place and land use controls would be put in place to remove any potential pathway. There would be no short or long term adverse effects of the alternative on environmentally sensitive areas.

2.2.2.3 Human Health

This alternative is protective of human health by removing the potential exposure pathways, through land use control restrictions, to humans. Bioventing would also reduce the level of PAHs in the soil that present risk to industrial workers at the site. Additional protection of industrial workers to PAHs would be obtained through land use restrictions while remediation was occurring. The pathway for potential arsenic exposure to industrial workers would be removed by land use restrictions. These restrictions would prevent industrial development of the areas impacted by arsenic and residual PAHs in the soil. Similarly, exposure to groundwater would be removed by land use control restrictions until the groundwater remedial action is complete. NAPR does not use groundwater for potable or other purposes. The Navy will impose a restriction on use of groundwater in the Sale Property Deed. Land use control restrictions are immediate and would mitigate the potential exposure to any residual contamination before and after implementation of the alternative.

Table 1-1 identifies the COCs and associated CAOs for groundwater and soil. Figure 1-4 through Figure 1-13 shows the location and extent of each COC above the associated CAO. The potential exposure route for groundwater is from volatilization of groundwater COCs into buildings occupied by industrial workers. This pathway is removed by restricting the future building of offices that may be occupied by industrial workers while active groundwater remediation is occurring. Similarly in soils, the potential exposure route from COCs in soil places the industrial worker at elevated risk. This pathway is removed by restricting future building of offices that may be occupied by industrial worker while active bioventing is occurring. The area is currently being used as an industrial site and would remain as such through land use controls to prevent access by potential future residential receptors.

The exposure to groundwater and soil COCs is removed with land use control restrictions while remediation is occurring. The contaminant levels in groundwater will be reduced over time through active pumping and treating while the contaminant levels in soil may not be reduced over a similar timeframe. However, arsenic would not be remediated and would therefore require continued land use restrictions to prevent future exposure.

2.2.2.4 Institutional

Alternative 2 satisfies Federal, State, and local environmental requirements. Regulatory requirements for implementation of this alternative are expected to be reasonably high due to the application and approval process of obtaining the NPDES permit.

2.2.2.5 Cost Estimate

The estimated NPV cost to implement and maintain this alternative is $4,546,705. All cost estimate backup information can be found in Appendix B.

2.2.3 Alternative 3

Alternative 3 consists of the following processes: excavation/disposal of soils, institutional controls with MNA, and containment/collection, in-situ physical/chemical treatment, ex-situ biological treatment and discharge for groundwater, and containment/collection for the PSH. Figure 2-7 provides a preliminary process flow diagram. Figure 2-8 details the conceptual layout of the alternative for the site. Each vacuum vapor extraction/groundwater recovery well is expected to exert a 50-foot radius of influence to capture groundwater and PSH. The anticipated pumping rate for each well is one gallon per minute. A remedial recovery pad will be constructed near the front gate of the TWFF to collect and treat recovered groundwater and PSH. Figure 2-9 identifies the conceptual component layout. This figure shows the major components associated with this alternative and the media that will be addressed. Because of the expected stringent UIC requirements, a reverse osmosis, post-treatment unit was added to this alternative to remove inorganics prior to discharge.

Approximately 79,750 gallons of PSH has been calculated on the water table (Baker, 2003a). The vacuum vapor extraction/groundwater recovery wells will collect the PSH volume identified and the impacted groundwater underlying the area. The soil volume calculations for excavation and disposal are presented in Appendix B. It is estimated that 1,919 cubic yards of PAH impacted soil will be excavated from three different areas. Figure 2-8 depicts the locations for these areas. In addition, an estimated 5,852 cubic yards of arsenic contaminated soil will be excavated and taken to an approved landfill facility. Volume calculations for arsenic contaminated soils can also be found in Appendix B, and all calculations assume a depth of excavation of 2 feet bgs. This will effectively remove all COC contaminated soils on the site that are above their respective CAO. The pathway for soils will no longer exist. Land use controls will be implemented while remediation is on going.

2.2.3.1 Technical

Performance

In this alternative, excavation and disposal of soil contaminated areas would be effective in removing the COCs from the soil at TWFF. The groundwater would be treated by a combination of institutional controls, extraction wells, and vacuum vapor extraction. Each extraction well will be fitted with a pneumatic pump to collect groundwater and PSH. The extraction wells would serve to contain the COCs. Treatment of extracted groundwater through the use of an ex-situ bioreactor would destroy the COCs. Following treatment of the groundwater, discharge via re-injection would also occur. Volatilization (removal) of the COCs would occur through the use of the vacuum vapor extraction system on extraction wells. PSH removal would occur though the same extraction wells and be separated from the groundwater via an oil/water separator.

The FOSET is intended to provide the information necessary for approval of the early transfer of certain NSRR property by the Governor of the Commonwealth of Puerto Rico. The Navy may enter into an agreement to transfer by deed real property or facilities with any person who agrees to perform all environmental restoration and environmental compliance activities that are required for the property or facilities under Federal and State laws or administrative decisions, agreements and concurrences as stated in CERCLA Section 2905 (e). To prevent unacceptable risks to human health during the deferral period, the Navy will impose post-conveyance use restrictions to current use, and additional controls.

A fence with locked gates surrounds the TWFF and access is restricted. The fence would have signs located periodically along the length identifying the potential hazards at the site and give contact information as appropriate. Fencing requires little to no maintenance and has an expected long life. The addition of the existing fence and land use restrictions are combined to form the basis of institutional controls. A building use restriction will be added to the FOSET to assure no buildings are constructed or occupied by humans before beneficial results are realized.

The effectiveness of this combination of technologies would be dependent on the ability of the wells to produce water and PSH and the ability of the vacuum vapor extraction system to enhance groundwater and PSH removal. Previous pilot tests at TWFF using vacuum assisted recovery were shown to be marginally more effective than simply skimming (Baker, 2000). Institutional controls in the form of groundwater restrictions would be added to remove the potential human pathway until the groundwater CAOs have been achieved. Additionally, MNA will be necessary to adequately address the complete site, both spatially, and over time. An MNA evaluation would be performed at the TWFF prior to implementation of this portion of the remedy. Vacuum vapor extraction in conjunction with MNA would speed the time to see beneficial results. The useful and service life for the vacuum vapor extraction system is five years.

A reasonable time frame for soil remediation under this scenario is less than one year. Reasonable time frames for the groundwater and PSH systems would be three to five years, depending on the ability of the system to target and extract the desired quantities of groundwater and PSH. The bioreactor and oil/water separator would likely be effective at their respective functions beyond this time frame, but are unnecessary links in the process should the extraction technology fail. More precise time estimates would depend on accurate pilot test results.

Excavation and disposal of PAH soil would be done in essentially three areas: one area north of Tank 84 (see Figure 2-8), one area southeast of Tank 83, and the larger area between Tank 1088 and Tank 83 where there are PAHs above their respective CAOs. In addition, arsenic would be excavated from three areas (see Figure 2-8) and transported to a permitted landfill. All excavations would occur to a depth of 2 feet bgs. Upon further investigation with disposal facilities on Puerto Rico, Allied Waste (formerly BFI) in Ponce was identified as having the capacity and capability to accept the excavated soils for disposal. The facility uses Environmental Management Specialists, Inc. (EMS) as their broker. EMS was used to procure a quote for soils disposal under this alternative. Permit for the disposal of excavated soils shall be obtained form PREQB.

Effective O & M on the remaining system components (vacuum vapor extraction system, pneumatic pumps, oil/water separator, biological treatment, and injection) would require periodic maintenance to slow the deterioration process. It is expected that a major overhaul of these system components would be required after five years should it be necessary to extend remediation schedule.

The biological treatment system would need to be monitored very closely throughout the useful life of the system. The climate in Puerto Rico is moderate which is advantageous to an ex-situ biological treatment system. Upsets of the biological system, normally associated with colder climates, would not be expected. However, failure of the oil/water separator (e.g. a slug of PSH flowing into the biological treatment system) may effectively reduce or kill the biological organisms and compromise the treatment capabilities of the system. Down time associated with an upset would force the entire groundwater treatment system to be shut down until the biological system could be brought into equilibrium again. The useful life of a biological treatment system is five to seven years.

An obstacle to re-injection at the TWFF would be the inability of the shallow aquifer to accept large volumes of treated groundwater. Hydraulic control of the capture zone may become more difficult with re-injection. Additional tests may be necessary to determine the appropriateness of this option given site-specific constraints.

Reliability

The reliability of the excavation and disposal of the soil is high. Operation and maintenance requirements for this alternative are high for the groundwater and PSH process options. The effect of failure in the extraction systems in place would be simply to revert to the current scenario. The effect of failure of any of the processes used to treat the groundwater and PSH are slightly more complicated. Should a failure in the oil/water separator occur, such as a leak, there would be a possibility of the product spilling on the ground, although secondary containment facilities should mitigate this possibility. A failure in the ability of the bioreactor to adequately treat the groundwater would result in levels of COCs in the treated water remaining above the CAOs, thereby making it unacceptable for re-injection into the aquifer. Additionally, a reverse osmosis system, which is necessary to treat groundwater to drinking water standards, would require moderate O & M. The most likely failure associated with the reverse osmosis system would create a reduction in volume of water discharged because of build up. It is not likely that the system would fail such that unacceptable levels of inorganics would by pass the system. The vacuum vapor extraction technology is still in the pilot stage as a technology (FRTR, 2003). This alternative is not flexible once all systems are in place. The excavation and disposal option is irreversible and permanent. Site conditions requiring dismantling/remobilization of all processes would require a large effort.

The re-injection system will require more frequent O & M to prevent blockages. Any blockage of the discharge lines would create a loss of discharge volume and increase in discharge pressures. Re-injection systems work well in very permeable aquifers, however the expected reliability in a weathered-bedrock aquifer would be moderate to low.

Failure of the re-injection system may impact potential receptors. However, engineering controls on the system would minimize any anticipated catastrophic failure. Similar measures would be put into place for the other components of the system. Should a failure occur, the most likely impact would be to ecological receptors in the immediate vicinity of the release.

The remedial alternative has limited ability to adjust to changes at the site. One of the limiting factors would be the ability to treat and re-inject greater volumes of groundwater.

O & M on the re-injection and biological treatment portions of this alternative would require specialized laborers. This would make the alternative less reliable.

Implementability

Implementation of Alternative 3 ranges from simple to complex. The implementation of the excavation and disposal would be simple in the projected areas. Implementation of the groundwater and PSH extraction systems, including the vacuum vapor extraction would be moderately complex, requiring construction of the oil/water separator and the bioreactor. Additionally, the bioreactor would take some time to achieve the correct balance of microbes. Pump and/or pilot tests should be done to determine likely extraction rates and volumes. In addition, injection location(s) would need to be determined through pilot testing via tracers at suitable locations to verify hydraulic control. Permits from the PREQB for the construction and operation of the extraction systems may be required.

An UIC permit would be required to complete the alternative. The UIC permit would be obtained from the PREQB. The time to acquire this permit may be relatively long. Since some components of this alternative will emit air pollutants for a long term, an operating air permit shall be obtained from the PREQB. Additionally, the alternative becomes more complex with the drinking water standards for re-injection imposed by the PREQB.

All of the equipment associated with the alternative would be shipped from the United States to the TWFF, which would affect the constructability schedule for the alternative. Additional time would need to be budgeted to account for the acquisition of equipment. Heterogeneity of the subsurface may impact the size and location of re-injection wells. Additional equipment may need to be acquired to compensate. Permitted disposal facilities for soils are located on the island (Allied Waste), so no additional resources are anticipated. A solid waste generating permit will be obtained from the PREQB for the disposal of the excavated soil.

The time to implement the alternative would be longer than usual given the need for pilot tests to determine size, number, and location of components. It is estimated that the implementation phase for this alternative may be two to three years. Upon completion of the pilot tests and implementation of the groundwater remedial system, it is estimated that beneficial results would be recognized within three to five years depending on recovery rates for PSH, but this engineering time estimate is subject to change given that pilot tests have not been implemented and given the uncertainty in the geologic environment. It is estimated that the soil could be remediated within a year after implementation.

Safety

The safety of this alternative is expected to be moderately high. Short and long term benefits to the environmentally sensitive areas are expected to be reasonably high due to the complete removal of contamination in all three media of concern at TWFF. The same is true for the mitigation of potential human health exposure to the COCs. The residual concentrations of the COCs are expected to be below the CAOs for the soil. In the groundwater, the residual concentrations of the COCs are also expected to be near or below the CAOs, depending on the presence of a continuing source. Removal of the PSH to less than 0.01 feet over the site will depend on the effectiveness of the extraction system.

The safety risks to workers during implementation would be low. The risk of fire, explosion, or exposure to contaminants is not likely under normal circumstances. These risks would be addressed and mitigated through the use of a site-specific health and safety work plan. There would be no risk to nearby community given the remote location of the site.

2.2.3.2 Environmental

The environmental effects of this alternative would be an improvement on the current situation. There would be no short or long term adverse effects of the alternative on environmentally sensitive areas. The only exception would be in the re-injection of the treated groundwater. Should adequate hydraulic control not be achieved or maintained, a deterioration of the groundwater quality in previously unimpacted areas of the aquifer would result. The deterioration of the groundwater quality assumes that the re-injected groundwater would be treated to drinking water standards or better.

2.2.3.3 Human Health

Protection of human health would be done through the reduction of the COCs to levels below current levels. It is expected that the CAOs would be met for the groundwater and PSH given the current time estimate. All the soil CAOs would be met.

This alternative is protective of human health by removing the potential exposure pathways, through removal of soils, to humans. Similarly, exposure to groundwater would be removed by land use control restrictions until the groundwater remedial action is complete. Land use control restrictions are immediate and would mitigate the potential exposure to any residual contamination before and after implementation of the alternative.

Table 1-1 identifies the COCs and associated CAOs for groundwater and soil. Figure 1-4 through Figure 1-13 shows the location and extent of each COC above the associated CAO. The potential exposure route for groundwater is from volatilization of groundwater COCs into buildings occupied by industrial workers. This pathway is removed by restricting the future building of offices that may be occupied by industrial workers while active groundwater remediation is occurring. Similarly in soils, the potential exposure route from COCs in soil is removed through excavation.

The exposure to groundwater and soil COCs is removed with land use control restrictions. The contaminant levels in groundwater will be reduced over time through active pumping and treating while the contaminant levels in soil would be reduced to their respective CAOs over a shorter timeframe.

2.2.3.4 Institutional

Alternative 3 satisfies Federal, State, and local environmental requirements. An UIC permit would be required for the re-injection of the treated groundwater at the site, and an air emission operating permit for the vacuum vapor extraction. Regulatory requirements for implementation of this alternative are expected to be reasonably high due to the application and approval process of obtaining the UIC permit given the unfamiliarity with positive pressure re-injection by PREQB.

2.2.3.5 Cost Estimate

The estimated NPV cost to implement and maintain this alternative is $7,381,243. All cost estimate backup information can be found in Appendix B.

2.2.4 Alternative 4

Alternative 4 consists of the following processes: excavation/ex-situ thermal treatment and in-situ physical chemical treatment of soils; institutional controls, in-situ physical/chemical treatment, and MNA for the groundwater. This alternative provides for containment/collection of PSH through skimming. A preliminary process flow sheet for Alternative 4 is provided in Figure 2-10. Figure 2-11 details the conceptual layout of the alternative for the site. Each air sparging well is expected to exert a 25-foot radius of influence in the areas near the 470-wells, which have the highest dissolved concentration of COCs in the groundwater. A remedial recovery pad will be constructed near the front gate of the TWFF to collect and treat recovered PSH. An SVE pad will be located north of Tank 83 to facilitate access to the near by SVE wells. The SVE wells are expected to exert a 25-foot radius of influence on the surrounding vadose. Figure 2-12 identifies the conceptual component layout. This figure shows the major components associated with this alternative and the media that will be addressed.

Approximately 79,750 gallons of PSH has been calculated on the water table (Baker, 2003a). The skimming system will collect the PSH volume identified. The air sparging wells in the 470-well area as identified in Figure 2-11 will treat the dissolved COCs in the groundwater. The soil volume calculations for in-situ biological treatment and HTTD are presented in Appendix B. It is estimated that 1,903 cubic yards of PAH impacted soil will be treated by in-situ biological treatment. An additional 1,157 cubic yards of PAH contaminated soil will be excavated and treated via HTTD area north of Tank 83. Figure 2-11 depicts the locations for these areas. In addition, an estimated 5,852 cubic yards of arsenic contaminated soil will not be treated. The arsenic contaminated soil will rely on land use controls to mitigate potential pathways. Calculations for arsenic contaminated soils can be found in Appendix B. This will effectively remove all PAH contaminated soils on the site that are above their respective CAO. Land use controls will be implemented to while remediation is on going.

2.2.4.1 Technical

Performance

The soil treatment process of excavation and ex-situ thermal treatment using HTTD will likely be effective in removing the organic COCs from the soil. Arsenic will not be addressed through this process. Soil vapor extraction (SVE) will be used to remove the COCs from the remaining soil. Three SVE wells will be installed to treat PAH near Tank 83 and Tank 84. Again, only the organic COCs will be addressed through this process. It is likely that the soil permeability will limit the effectiveness of the SVE system and some asymptotic removal rate will occur. Also, SVE is not highly effective for the PAH contamination at the site. However, SVE would address the soils that are affected by the PSH, given adequate soil permeability. The useful life for HTTD is two years, however it is expected to take less than a year to complete soil remediation using HTTD. The useful life for SVE is three to five years. SVE may not be the best process option when treating PAHs in soil, however it is appropriate when combined with other process options in this alternative.

The FOSET is intended to provide the information necessary for approval of the early transfer of certain NSRR property by the Governor of the Commonwealth of Puerto Rico. The Navy may enter into an agreement to transfer by deed real property or facilities with any person who agrees to perform all environmental restoration and environmental compliance activities that are required for the property or facilities under Federal and State laws or administrative decisions, agreements and concurrences as stated in CERCLA Section 2905 (e). To prevent unacceptable risks to human health during the deferral period, the Navy will impose post-conveyance use restrictions to current use, and additional controls.

Institutional controls in the form of land use restrictions on the arsenic-contaminated soil are both effective and has a long useful life in the form of deed restrictions maintained in perpetuity. Additionally, land use controls would be put in place when SVE has reached asymptotic levels and no further reductions in PAHs is feasible. Institutional controls, in a certain sense, provide containment of all COCs in the soil. Additional engineering controls are in place at the TWFF. A fence with locked gates surrounds the TWFF and access is restricted. The fence would have signs located periodically along the length identifying the potential hazards at the site and give contact information as appropriate. Fencing requires little to no maintenance and has an expected long life. The addition of the existing fence and land use restrictions are combined to form the basis of institutional controls. Since the risk drivers for the site are exposure from arsenic in the soil under an industrial future use scenario, land use restrictions would be effective in addressing human health exposure risks. The potential future risk pathway would be removed by restricting future development of building on site that may be occupied on a regular basis by humans. Institutional controls on groundwater in the form of water use restrictions are also effective for the same reason. NAPR does not use groundwater. Institutional controls are appropriate and required to address soil and groundwater at the site. Institutional controls offer a high level of effectiveness that requires no physical maintenance. A building use restriction will be added to the FOSET to assure no buildings are constructed or occupied by humans before beneficial results are realized. Institutional controls have an indefinite useful life.

In-situ air sparging would be used to treat the groundwater. Air sparging would be used in the 470-well location. The air sparging wells will be slightly down gradient from the PSH plume that allows the system to be operated in conjunction with the skimming system. Air sparging would be used to remove the COCs via volatilization from the groundwater. The process is likely to remediate the site groundwater in the area immediately around the sparging well to levels below the CAOs for all COCs, however the dissolved plume outside of this area will require institutional controls and MNA as necessary follow-on measures for groundwater corrective measures until CAOs are met. An MNA evaluation would be performed at the TWFF prior to implementation of this portion of the remedy. The useful life of the components of this system would be five years. A reasonable treatment time for this alternative is seven to ten years when operated with the skimming system. This technology is appropriate for treating groundwater.

PSH skimming, when diligently operated and maintained, will effectively reduce the quantity of free product in the subsurface, provided no continuing source of product is present. Limitations include the mobility of the product in the subsurface and the ability of the skimmers to capture all the PSH without additional physical influences applied. Baildown tests in the lower TWFF along Forrestal Road have not produced favorable results because of lack of recovery after initial baildown (Baker, 1999). However, recent evidence at UGW25, where a majority of the PSH is located, has indicated that large quantities of product are available for removal at this well (Baker, 2003). Monthly removals of PSH at this well have increased by an order of magnitude or more since August 2002. A review of the quarterly reports for the site has showed a reduction in the size of the PSH plume both horizontally and vertically. The useful life of skimmers is five to ten years if maintained properly. The technology is appropriate for removing PSH from the site.

<u>Reliability</u>

The reliability of the excavation and HTTD are moderate to high, given bench scale testing for HTTD removal efficiency. The reliability of the SVE is dependent on the operation and maintenance of the system. When an adequate radius of influence is obtained, there is a high likelihood of good removal, provided the COCs are amenable to volatilization. PAHs generally are less receptive to volatilization and more likely to biodegrade under these conditions. Flexibility in this alternative for soil is high for the excavation and treatment should site conditions change. The SVE system can be reconfigured to accommodate site changes with a moderate effort given the central location of the SVE pad.

The reliability of the air sparging operation is low to moderate due to lack of efficiency. The determination of the optimal radius of influence of an air sparging system would also require a pilot test. Flexibility in this alternative for groundwater is low due to the permanent construction of an air sparging system. In the event of site conditions changing, a large effort would be required for relocation and/or dismantling of this system. However, the dissolved plume is not expected to move beyond the current area of interest.

The reliability of skimmer technology is measured by the dependence on operation and maintenance of the skimmers. If the operation and maintenance of the skimmers should fail, or be inadequate, the consequences would be representative of the current scenario, where it appears that there is no migration of the product toward the Ensenada Honda. This process option is flexible to changing site conditions, as some skimmers are portable and have the ability to be relocated with minimal effort.

The O & M requirements for air sparging and SVE systems are expected to be low to moderate, which is favorable. However, the air sparging injection wells will, over time, need to be periodically cleaned to prevent biofouling. With periodic maintenance, this can be kept under control.

The remedial alternative has limited ability to adjust to changes at the site. However, the skimmer system has two portable skimmers that can be moved to areas not covered by the fixed system.

Implementability

Implementation requirements range from simple to complex for soils. The excavation would be simple to implement, but the HTTD would require specialized equipment that would be shipped from the United States. The SVE system would require an average implementation effort of one year, and likely a pilot scale test which could increase the time. The time required to treat the excavated soil is a year. The time frame for the SVE system is estimated to be three to five years. One unknown is the ability for the SVE system to remediate the soil to below the CAOs before reaching an asymptotic level. The service life of the SVE components is expected to be 3 to five years. The expected service life of HTTD is two years, however the process should be complete in one year. Failure in the soil corrective measure process of HTTD would result in soil stockpiling. Failure in the SVE system would result in site conditions remaining at the current scenario.

Implementation requirements are somewhat complex, requiring system construction and operation and maintenance of two separate systems for groundwater and soil. Failure of the air sparging system would potentially create a situation that pushes the plume away from the injection points prior to obtaining any remedial benefit. It is critical that the air sparging wells be located down gradient of the PSH plume. Careful observation of the air sparging injection wells will be important for this alternative. The air emission construction and operating permits will be obtained from the PREQB for the air sparging system.

Implementability of the skimmer technology is not difficult, and the time frame for remediation is dependent on the mobility of the PSH in the area of the skimmers, which in turn is dependent on the immediate site geology. It is expected that the recovery rate would decline quickly given the fact that no additional physical influence is exerted on the PSH plume. The estimated time to implement a skimmer system is three to six months. Re-evaluation of the skimmer efficiency should occur yearly with potential for re-mobilization of the portable skimmers to different locations.

All of the equipment associated with the alternative would be shipped from the United States to the TWFF, which would affect the constructability schedule of the alternative. Additional time would need to be budgeted to account for the acquisition of equipment. Heterogeneity of the subsurface may impact the size and location of air sparging wells. Additional equipment may need to be acquired to compensate.

The time to implement the alternative could be longer than usual given the need for a pilot test to determine size, number, and location of components. It is estimated that the implementation phase for this alternative would be one year. Upon completion of the pilot test and implementation of the groundwater remedial system, it is estimated that beneficial results would be recognized within seven to ten years depending on recovery rates for PSH. It is estimated that the soil could be remediated within a year after implementation. However the arsenic contaminated soil would be left in place and land use controls applied to mitigate potential pathways.

Safety

The safety of this alternative is expected to be moderately high. Short and long term benefits to the environmentally sensitive areas are expected to be reasonably high due to the removal of contamination in all three media of concern at TWFF. The same is true for the mitigation of potential human health exposure to the COCs. The residual concentrations of the COCs are expected to near the CAOs for the soil except for arsenic. In the groundwater, the residual concentrations of the COCs are also expected to be near or below the CAOs. Removal of the PSH to less than 0.01 feet over the site will depend on the effectiveness of the skimming system.

The safety risks to workers during implementation would be low. The risk of fire, explosion, or exposure to contaminants is present under abnormal circumstances. These risks would be addressed and mitigated through the use of a site-specific health and safety work plan. There would be no risk to nearby community given the remote location of the site.

2.2.4.2 Environmental

The environmental effects of this alternative would be an improvement on the current situation. There would be no short or long term adverse effects of the alternative on environmentally sensitive areas. The only exception would be in the air sparging wells. Should adequate hydraulic control not be achieved or maintained, a deterioration of the groundwater quality in previously unimpacted areas of the aquifer would result.

2.2.4.3 Human Health

Protection of human health would be done through the reduction of the COCs to levels below current levels. It is unknown at this time whether the CAOs would be met for the groundwater and PSH. Soil CAOs would likely be met with the exception of arsenic and to a lesser degree, PAHs.

This alternative is protective of human health by removing the potential exposure pathways, through treatment of soils where available, to humans. HTTD would also reduce the level of PAHs in the excavated soil that present risk to industrial workers at the site. Similarly, exposure to groundwater would be removed by land use control restrictions until the groundwater remedial action is complete. Land use control restrictions are immediate and would mitigate the potential exposure to any residual contamination before and after implementation of the alternative.

Table 1-1 identifies the COCs and associated CAOs for groundwater and soil. Figure 1-4 through Figure 1-13 shows the location and extent of each COC above the associated CAO. The potential exposure route for groundwater is from volatilization of groundwater COCs into buildings occupied by industrial workers. This pathway is removed by restricting the future building of offices that may be occupied by industrial workers while active groundwater remediation is occurring. Similarly in soils, the potential exposure route from COCs in soil places the industrial worker at elevated risk. This pathway is removed by restricting future building of offices that may be occupied by industrial worker while active HTTD and SVE are occurring.

The exposure to groundwater and soil COCs is removed with land use control restrictions. The contaminant levels in groundwater will be reduced over time through active air sparging while the contaminant levels in soil may not be reduced over a similar timeframe.

2.2.4.4 Institutional

Reasonable requirements would be likely for the remaining processes in this alternative, including revising the deed to reflect water use restrictions. Additionally, land use restrictions for building would be required because of the likelihood of PAHs levels not being achieved with SVE treatment.

Alternative 4 satisfies Federal, State, and local environmental requirements. Reasonable requirements would be likely for the remaining processes in this alternative, including revising the land use control document (FOSET) to reflect water use restrictions and building restrictions.

2.2.4.5 Cost Estimate

The estimated NPV cost to implement and maintain this alternative is $6,370,025. All cost estimate backup information can be found in Appendix B.

2.2.5 Alternative 5

Alternative 5 provides for excavation/ex-situ biological treatment, and in-situ biological treatment of soils, institutional controls, MNA and in-situ physical/chemical treatment of groundwater, and in-situ biological treatment of PSH. Figure 2-13 shows a preliminary process flow sheet for this alternative. Figure 2-14 details the conceptual layout of the alternative for the site. An ECGO groundwater system will be used to treat a 25-foot square area of the aquifer near the 470-wells. The ECGO system will be collocated near the 470-wells to facilitate access. Figure 2-15 identifies the conceptual component layout. This figure shows the major components associated with this alternative and the media that will be addressed.

Approximately 79,750 gallons of PSH has been calculated on the water table (Baker, 2003a). CleanOX will be applied in a batch process to each PSH recovery well to facilitate PSH removal. Approximately 1,740 cubic yards (351,000 gallons equivalent) of groundwater will be treated via ECGO. The volume calculation can be found in Appendix B. The soil volume calculations for in-situ and ex-situ biological treatment are presented in Appendix B. It is estimated that 1,903 cubic yards of PAH impacted soil will be treated by in-situ biological treatment. An additional 1,157 cubic yards of PAH contaminated soil will be excavated and treated via ex-situ biological in the land farming area north of Tank 83. Figure 2-14 depicts the locations for these areas. In addition, an estimated 5,852 cubic yards of arsenic contaminated soil will not be treated. The arsenic contaminated soil will rely on land use controls to mitigate potential pathways. Calculations for arsenic contaminated soils can be found in Appendix B. This will effectively remove all PAH contaminated soils on the site that are above their respective CAO. Land use controls will be implemented to while remediation is on going.

2.2.5.1 Technical

Performance

In this alternative, excavation of contaminated soil and subsequent land farming would remove the COCs from the soil and subsequently destroy them through biodegradation. In the other areas, in-situ biodegradation would be allowed to destroy the COCs through natural processes. These processes would remove the organic COCs from the soil, but would be ineffective on the arsenic. Institutional controls would be used to address arsenic in soil. The useful life and service life of land farming and in-situ biodegradation are longer than the remedial time required for soils. It is estimated the land farming will take two to three years while the in-situ biodegradation would take three to five years from implementation.

The FOSET is intended to provide the information necessary for approval of the early transfer of certain NSRR property by the Governor of the Commonwealth of Puerto Rico. The Navy may enter into an agreement to transfer by deed real property or facilities with any person who agrees to perform all environmental restoration and environmental compliance activities that are required for the property or facilities under Federal and State laws or administrative decisions, agreements and concurrences as stated in CERCLA Section 2905 (e). To prevent unacceptable risks to human health during the deferral period, the Navy will impose post-conveyance use restrictions to current use, and additional controls.

A fence with locked gates surrounds the TWFF and access is restricted. The fence would have signs located periodically along the length identifying the potential hazards at the site and give contact information as appropriate. Fencing requires little to no maintenance and has an expected long life. The addition of the existing fence and land use restrictions are combined to form the basis of institutional controls.

The site soils are clayey and are interspersed with medium to large rocks. This heterogeneity in composition would make it difficult to turn in a land farm scenario. Additionally, the same heterogeneity would make it more difficult to biodegrade in-situ. It would be anticipated that the remedial timeframe would increase as heterogeneity in soil increased.

The groundwater would be treated through a combination of institutional controls, in-situ physical/chemical treatment using ECGO® for destruction, and MNA for containment and destruction. This process would require a pilot test to properly design the system. In addition, an MNA evaluation would be performed at the TWFF prior to implementation of this remedy. These processes would be effective in reducing the COCs in the groundwater. The useful and service life of this technology is longer than the actual remedial time. ECGO® is appropriate for groundwater treatment. A reasonable treatment time for this alternative is three to five years.

The PSH at the site would be treated biologically through the use of an oxygen enhancing technology, potentially CleanOX®. This treatment would destroy the PSH by converting it to innocuous by-products. The useful life would be dependent on the PSH recharge rates. It is anticipated that several applications of CleanOX® would be necessary over a period of time. A reasonable estimate to clean up the site would be five years. CleanOX® is somewhat appropriate for PSH removal. Data from the previous pilot test using CleanOx was questionable. Monitor well upsets from over application of hydrogen peroxide forced unmeasured amounts of PSH to spill onto the ground. This was not accounted for when the recommendations were written. Only the product levels in the monitor well prior to the test and after the upset were measured. Conclusions were drawn without consideration of quantities spilled on the ground.

Institutional controls in the form of land use restrictions on the arsenic-contaminated soil are both effective and have a long useful life in the form of deed restrictions maintained in perpetuity. Institutional controls, in a certain sense, provide containment of all COCs in the soil. Additional engineering controls are in place at the TWFF. A fence with locked gates surrounds the TWFF and access is restricted. Since the risk drivers for the site are exposure from arsenic in the soil under an industrial future use scenario, land use restrictions would be effective in addressing human health exposure risks. The potential future risk pathway would be removed by restricting future development of building on site that may be occupied on a regular basis by humans. Institutional controls on groundwater in the form of water use restrictions are also effective for the same reason. NAPR does not use groundwater and the Sale Property Deed will restrict the use of groundwater. Institutional controls are appropriate and required to address soil and groundwater at the site. Institutional controls offer a high level of effectiveness that requires no physical maintenance. A building use restriction will be added to the FOSET to assure no buildings are constructed or occupied by humans before beneficial results are realized. Institutional controls have an indefinite useful life.

Alternative 5 uses several technologies in combination to address impacted media at the site. The effectiveness of each of the technologies alone may not be sufficient, however the combination of technologies does make the alternative more effective.

Failure of the CleanOx system may cause upsets or explosions in the treated wells. Product may spill onto the ground or a small fire may be started by the chemical reaction. Either scenario would leave the site in worse condition.

Reliability

The demonstrated reliability of the soil processes is high. These technologies have been successfully used together in the past. The expected reliability of the groundwater and PSH process options is moderate and dependent on operations and maintenance (ECGO®) and accurate delivery (CleanOX®). It is not certain that the groundwater and PSH process options have been combined successfully in the past.

Flexibility to site changes is possible for all three media. Soil process flexibility can be accomplished through additional excavation and land farming should more contamination be discovered, although the land farming operation is not flexible as far as relocation and/or reducing the time of treatment. Groundwater process option flexibility can be done by relocating/dismantling the ECGO® operation, requiring some level of effort. The PSH process option is not flexible although additional treatment to other areas can be accomplished if necessary.

CleanOX® has been used at the TWFF to remove PSH from monitoring wells. Results of the pilot study (ManTech, 1998) were mixed for PSH removal. However, the conclusions developed from the data may be questionable give the number of upsets during testing.

Operation and maintenance requirements for this alternative are moderate for the ECGO® option and low for the PSH process option. The effect of failure in any process option would be simply to revert to the current scenario. However, CleanOX application may present an upset situation if not applied properly. This situation would leave the site in a worse situation. Biodegradation requires some O & M to assure proper application and maintenance of nutrients, water, and/or additives.

Specialized laborers are required for the implementation of the PSH process option (CleanOX) because the process is proprietary. ECGO® also requires specialized laborers. This would make the alternative less reliable.

Implementability

Implementability of the soil options require space for the land farming operations. The time frame for soil remediation is estimated between one to two years, depending on the amenability of the soil COCs to biodegrade. The implementability of the groundwater processes range from moderate requirements (ECGO®) to minimal requirements (MNA). The time frame for remediation using ECGO® is moderate and any time estimates obtained from the vendor would likely be under optimal conditions, while the MNA time frame should be re-evaluated regularly, provided that no continuing source is present. The time frame for CleanOX® remediation is short, usually less than one year, but reapplication may need to be done to ensure adequate coverage. Rebound may also occur and require reapplication. Again, a more precise knowledge of site heterogeneity and information resulting from pilot studies for ECGO® will dictate actual time frames for time of expected results.

All of the equipment associated with the alternative would be shipped from the United States to the TWFF, which would affect the constructability of the alternative. Additional time would need to be budgeted to account for the acquisition of equipment.

It is estimated that the implementation phase for this alternative may be one to two years. Upon completion of the implementation of the groundwater remedial system, it is estimated that beneficial results would be recognized within three to five years depending on recovery rates for PSH. It is estimated that the soil could be remediated within three to five years after implementation. However, arsenic contaminated soil would not be remediated under this alternative.

Safety

Safety concerns are minimal for these processes, with the exception of the CleanOX®. Previous experience at the site indicates that care must be taken when determining the proper quantities and rates of delivery of the CleanOX® in order to avert any safety concerns with regard to this process. Any failure in these processes would result in reverting to the current site conditions, or a potentially hazardous situation due to CleanOX® misapplication.

The safety of this alternative is expected to be moderately high. Short and long term benefits to the environmentally sensitive areas are expected to be reasonably high due to the removal of contamination in all three media of concern at TWFF. The same is true for the mitigation of potential human health exposure to the COCs. The residual concentrations of the COCs are expected to near the CAOs for the soil except for arsenic. In the groundwater, the residual concentrations of the COCs are also expected to be near or below the CAOs, depending on the presence of a continuing source. Removal of the PSH to less than 0.01 feet over the site will depend on the effectiveness of the application of CleanOX® to the PSH wells.

The safety risks to workers during implementation would be low for all the process options except for CleanOX®. The risk of fire, explosion, or exposure to contaminants is present under normal circumstances when operating with peroxide and PSH. Every precaution should be exercised when working with potentially reactive chemicals. These risks would be addressed and minimized through the use of a site-specific health and safety work plan. There would be no risk to nearby community given the remote location of the site.

2.2.5.2 Environmental

The environmental effects of this alternative would be an improvement on the current situation. It is likely that some short-term environmental changes will be present in the geochemistry at the site due to the electrochemical and chemical applications to the soil and groundwater. Long-term residual effects on the environment are unlikely. There would be no short or long term adverse effects of the alternative on environmentally sensitive areas.

2.2.5.3 Human Health

Human health exposure to contamination will be mitigated when implementation of this alternative is complete. Protection of human health would be done through the reduction of the COCs to levels below the current levels. It is unknown at this time what the residual levels of the COCs will be. However, it is likely that the soil and groundwater CAOs will be met except for arsenic in soil. In addition, it is unlikely that the PSH CAO will be met with only one application of the CleanOX® process option for addressing this COC in this alternative.

This alternative is protective of human health by removing the potential exposure pathways, through treatment of soils where available, to humans. Land use controls would protect industrial workers from potential exposure to arsenic in soil. Landfarming and in-situ biological treatment would reduce the level of PAHs in the excavated soil that present risk to industrial workers at the site. Similarly, exposure to groundwater would be removed by land use control restrictions until the groundwater remedial action is complete. Land use control restrictions are immediate and would mitigate the potential exposure to any residual contamination before and after implementation of the alternative.

Table 1-1 identifies the COCs and associated CAOs for groundwater and soil. Figure 1-4 through Figure 1-13 shows the location and extent of each COC above the associated CAO. The potential exposure route for groundwater is from volatilization of groundwater COCs into buildings occupied by industrial workers. This pathway is removed by restricting the future building of offices that may be occupied by industrial workers while active groundwater remediation is occurring. Similarly in soils, the potential exposure route from COCs in soil places the industrial worker at elevated risk. This pathway is removed by restricting future building of offices that may be occupied by industrial worker while active land farming and in-situ biological treatment are occurring.

The exposure to groundwater and soil COCs is removed with land use control restrictions. The contaminant levels in groundwater will be reduced over time through ECGO® while the contaminant levels in soil may not be reduced over a similar timeframe.

2.2.5.4 Institutional

An injection permit will likely be required for the CleanOX® injection. An air emission permit for the land farming may also be required from PREQB. Other institutional requirements necessary for implementation of these processes are minimal.

Alternative 5 satisfies Federal, State, and local environmental requirements. An UIC permit would be required for injecting peroxide into the formation. It is likely that the requirements would be moderate for the application and approval of this permit. Reasonable requirements would be likely for the remaining processes in this alternative.

2.2.5.5 Cost Estimate

The estimated NPV cost to implement and maintain this alternative is $7,407,689. All cost estimate backup information can be found in Appendix B.

3.0 TASK III—JUSTIFICATION AND RECOMMENDATION OF THE CORRECTIVE MEASURE(S)

3.1 Comparison of Alternatives

This section provides a discussion of the alternatives as they compare to each other in terms of meeting the goals of the corrective measure at TWFF, NAPR. This will be a qualitative discussion, ranking the alternatives with regard to technical aspects, human health benefits, environmental benefits, and costs. The ranking process is not a quantitative ranking but is a qualitative ranking. The ranking merely shows the relative benefit of an alternative in relation to the subordinate alternatives. Throughout the comparative process, a recommended alternative will be presented and justified. The basis of this qualitative ranking will be the criteria evaluation of each alternative as presented to satisfy the Part B Permit in Section 2.0. Process options within each alternative may be added, substituted, or eliminated to create a more favorable alternative.

3.1.1 Comparison of Alternatives on Technical Merits

Before a comparative analysis can occur, summary tables were developed from information supplied in Section 2.0. The summary tables were developed for each media of concern. Table 3-1 presents a qualitative analysis of the alternatives and the evaluation of the alternative against each criterion for soil. Similarly, Table 3-2 and 3-3 were developed for groundwater and PSH, respectively. The summary tables were color coded to more easily discern qualitative differences between each alternative within the media of concern. The color-coding scale goes from green, which identifies the alternative as most favorable, to red, which identifies the alternative as least favorable. Blue, yellow, and orange are used to qualitatively identify alternatives as more favorable, favorable, and less favorable, respectively. A qualitative rating was given to each alternative as it meets each evaluation criterion. Additional information that supports the rating is also presented within the table.

The alternatives were ranked on their respective technical merits. Because the alternatives were considered as a whole, this ranking is subject to a good deal of flexibility, depending on which medium is to be considered the most important. For comparative purposes only, each sub-criteria was given equal weight. In general, the overall ranking, considering all media equal, is shown in Table 3-4.

The technical merit criterion is subdivided into many sub-criteria. Alternative 1 was ranked first because of its ability to meet the overall effectiveness for all media of concern. Alternative 1 is the most effective at performing its intended function and will maintain that performance over the expected life of the alternative. Institutional controls for soil and groundwater will remove potential pathways to the contaminated media while concentrations are reduced through MNA. There are no O & M requirements beyond MNA sampling that may deteriorate the effectiveness of the alternative. Since most of the PSH skimming equipment is readily accessible and an interim PSH skimming system is already installed, the constructability and time to implement would be extremely favorable. Alternative 1 has the highest level of safety as compared to most of the other alternatives. Risks to workers and the community will be minimized because of the limited construction necessary to implement this alternative.

As previously stated in Section 2.0, the dissolved groundwater plume near the 470-well has not showed any significant movement. The plume seems to be contained. It would be more beneficial to allow the dissolved constituents to attenuate naturally while removing the source that is PSH. Some of the skimmers would be self-contained portable units that would allow the skimmers to be placed in existing wells that have PSH. This would allow for flexibility in the PSH skimming system without additional construction of recovery lines.

Because SVE is not effective for PAHs, Alternative 4 is ranked a distant second. Again, the major reason for ranking this alternative low is the overall ability of the alternative to be effective. This alternative uses in-situ options to remediate the groundwater plume. The effectiveness of air sparging is moderate to low. Air sparging is hard to control and will require a pilot test to determine the effects of mounding around the air sparging wells. The mounding effect could cause the plume to migrate away from the sparging wells before any beneficial results could be realized.

Even thought there are some drawbacks to this alternative, the primary advantage this alternative has over the other active remedial alternatives is that it does not have to address discharge issues. This is a major reason this alternative is second. All groundwater is treated in-situ.

Alternative 4 uses active ex-situ physical treatment of the soils. Those areas of the TWFF that are not accessible, generally in and around active pipelines, will be addressed using SVE. SVE has limited success at removing PAHs and would therefore be less advantageous than other process options presented in other alternatives. However, institutional controls would be implemented in the event that CAOs for PAHs in soil are not achieved.

The O & M for this alternative is favorable over other active remedial alternatives. The HTTD system would require more maintenance than other process options, however it is expected that the remediation time would be a year. This would not significantly impact the O & M requirements due to a relatively short duration.

Alternative 3 is ranked third because of limited constructability and groundwater discharge considerations.

Alternative 3 would be more difficult to implement than Alternatives 1 or 4. Reinjection discharge option will require a pilot test to properly engineer the final design; this will reduce the constructability of this alternative. An UIC permit would be required and it is anticipated that some effort would be required to obtain this permit. However, an UIC permit would be more favorable than a NPDES permit because of the extremely low discharge limits anticipated. Additional polishing equipment is necessary to meet a NPDES permit discharge limit. In addition, UIC requires drinking water standards to be met for discharge.

Like most of the alternatives, Alternative 3 will require periodic maintenance that will affect the reliability of the alternative. This would be more prevalent in the groundwater/PSH treatment system than the soil remedial system where no maintenance will be required once implemented. Once the alternative is implemented, the time to realize beneficial results would be minimal.

Safety concerns associated with Alternative 3 are in line with the other alternatives. The alternatives that require longer construction time will introduce somewhat more risk to personnel than less complicated alternatives such as Alternative 1.

Alternative 5 is ranked fourth because of the unfavorable pilot test results of CleanOX® on the PSH. If the PSH process option were replaced with skimming, this alternative would be more favorable. This alternative does not address the treatment of arsenic in soil. Land use controls would be necessary to address arsenic in soil. Additionally, ECGO® requires a pilot test to confirm the design parameters. Given the size of the dissolved plume, it is more feasible to use a less cumbersome remedial option. The heterogeneity of the aquifer may also impact the effectiveness of the process option.

In Alternative 5, the PSH should be removed before any groundwater treatment is performed. CleanOX® would be used to remove the PSH. The ability of CleanOX® to remove PSH to less than 0.01 is questionable. With the relatively large amounts of PSH available in some of the wells, the application of the peroxide component must be performed precisely. There are other alternatives that give better results without the possible negative impacts.

Alternative 2 is ranked last because of the lack of effectiveness on the soil media. Arsenic is not actively remediated through this alternative. Bioventing will be somewhat effective at reducing PAH levels in the soil, but the CAO may not be reached by bioventing alone. Institutional controls will be necessary to address recalcitrant PAHs.

Groundwater contaminants will be effectively treated with an ex-situ air stripper. In general, treating groundwater ex-situ is effective, however the discharge of treated groundwater becomes a critical concern. This alternative uses an NPDES permitted outfall as a discharge option. As previously stated, NPDES discharge permits, if obtainable, are expected to have extremely low discharge limits, as evidenced by NAPR's WWTP NPDES discharge limits. Obtaining a NPDES permit will take a relatively long period of time that would affect the constructability and ultimately the effectiveness of this alternative.

The stripper system is very common and effective when treating petroleum contaminants. The relative simplicity of the system will make O & M requirements low to moderate. Similarly, the bioventing system is relatively simple and requirements for the treatment system will be low to moderate.

The dual phase extraction system will encourage the migration of product along the oil/water interface into the well where it will be captured. Alternative 2 will collect the PSH in an oil/water separator prior to groundwater treatment in the air stripper. The combination of these technologies is effective for collecting and treating groundwater contaminants, however the ability to discharge treated groundwater is vital to this alternative.

The steam flushing of groundwater to encourage the mobility of the PSH would be difficult to control. The downside to steam flushing is the PSH may be encouraged to migrate into areas the recovery system is not designed to capture, thus potentially spreading and contaminating previously uncontaminated areas. It is more favorable to use a combination of technologies that enhance the reduction of PSH or impacted groundwater without potentially moving PSH into unimpacted areas.

3.1.2 Comparison of Alternatives for Human Health Benefits

Each alternative was ranked on how well the alternative addressed short and long-term mitigation of potential exposure to residual contamination before and after implementation. To a lesser degree, each alternative was evaluated to determine the level of exposure to contaminants and the reduction over time. The alternative comparison is weighted heavily toward the alternative that achieves the fast and most complete removal of all COCs in each media of concern. As expected, those alternatives that could achieve CAOs the quickest were ranked higher.

The comparative analysis for human health benefits is presented in Table 3-4. Alternative 3 is ranked first because of its ability to remove all COCs and it is achieved in the shortest timeframe. All potential pathways have been permanently removed. Alternative 2 is second only because it uses institutional controls to address arsenic in soil at the site. Alternative 5 is third because the alternative uses a proprietary method to reduce PSH at the site, which has some question to efficacy. Additionally, Alternative 5 address arsenic in soil through institutional controls. Alternative 4 and 1 were ranked forth and last respectively because of the length of time to achieve CAOs and the arsenic in soil is addressed through institutional controls.

3.1.3 Comparison of Alternatives for Environmental Benefits

The environmental benefits of the alternatives were ranked and are also shown in Table 3-4. Alternative 3 was ranked first in this category because of the removal of all COCs from the environment, thus eliminating any potential pathway to sensitive receptors. Equally as effective at removing COCs was Alternative 2 which was ranked second, however Alternative 2 would leave arsenic in the surface soil. The first two ranked alternatives will be treating groundwater prior to discharge. The potential exists to negatively impact the environment in the event of a system failure, however the likelihood is remote. Alternative 1 was ranked third in this category, even though MNA was used to address all COCs except arsenic. Alternative 4 and 5 were ranked at the bottom. Alternative 4 had potential concerns associated with migration of the dissolved plume via the air sparging system prior to complete reduction of COCs. Alternative 5 has the likelihood of an upset during CleanOX application and the unknown geochemical side effects of the CleanOX system.

3.1.4 Comparison of Alternatives by Cost

Table 3-4 summarizes the costs associated with each alternative. Alternative 1 is ranked first because it requires the least funds to implement, operate, and maintain. Alternative 2 was ranked second. Alternative 4 and 3 were ranked third and fourth. Alternative 5 was last. The cost differential between the alternatives is significant except for last two alternatives, alternatives 3 and 5.

3.2 Recommendation of the Preferred Corrective Measure

When all factors are weighed, it is apparent that given enough time, Alternative 1 is effective at addressing all contaminants within the groundwater and the PSH media. Alternative 1 is the quickest to implement, the easiest to maintain, and offers a high level of protection to human health and the environment for those media. It is recommended that the contamination in the soil media will be addressed through excavation of the PAH and arsenic contaminated areas to a depth of 2 feet bgs, with subsequent disposal of the soil to an approved landfill facility. This modification to Alternative 1 for the preferred corrective measure will eliminate the exposure pathway for soils. However, land use controls will be implemented while remediation is ongoing.

Impacted groundwater has been limited to the 470-well area. If the PSH could be removed from this area, the naturally occurring parameters should mitigate this plume. Previous sampling has shown that the dissolved plume has not moved and has favorable natural attenuation parameters. In addition, an MNA evaluation will be performed prior to the implementation of this remedy. Active remediation of the groundwater plume does not necessarily speed up the remediation time. This is evident in the need to discharge treated groundwater. Either option, permitted NPDES or UIC discharge, delays the implementation of any recovered groundwater treatment system. In the case of the NPDES discharge, it is apparent that treatment levels will be extremely stringent and would require additional post-treatment technologies in order to meet discharge limits.

Soils are also addressed adequately under the proposed modification. Approximately 1,919 cubic yards of PAH contaminated soil will be excavated, as well as 5,852 cubic yards of arsenic contaminated soil, reflecting excavation of all soils with contamination above CAOs to a depth of 2 feet bgs. The excavated soil will be ultimately disposed of at an approved landfill facility. Figure 2-8 depicts the areas of excavation for the PAH and arsenic contaminated soils. As shown, a small portion of these areas overlap, but the quantities will remain as stated for the purposes of this CMS and cost estimates.

The PSH must be reduced to 0.01 feet or less. Alternative 1 uses a simple, proven technology to capture the maximum PSH recoverable. Some alternatives use a total groundwater/PSH collection/treatment system. As previously stated, this becomes an issue when dealing with discharge options available for the treated groundwater. These options become less effective as a result of available discharge options. CleanOX® could be used at this site as a “polishing” option to remove PSH that becomes difficult to capture (e.g. between 0.1 and 0.01 feet). CleanOX® is not recommended to remove large amounts of PSH.

Another positive aspect of the PSH skimming system is its flexibility. The design calls for at least two self-contained portable skimming systems to be used. These systems would be trailer mounted with small tanks for PSH recovery located on the trailer. Solar cells that charge on-board batteries would be used to operate the pumps and controls. These systems would allow the Navy to respond to newly identified wells with measurable PSH in them.

The areas where the interim skimming system was used, still has PSH available for recovery. Alternative 1 would use the existing interim skimming system to the maximum extent practicable. A permanent skimming system would be placed in these wells to capture PSH. Sanitary well seals will be placed on these wells to prevent storm water runoff from entering the well. Previous operations of the interim skimming system have resulted in the capture of large volumes of water. Proper operation and maintenance will reduce the production of groundwater and greatly increase recoverable PSH.

In order to demonstrate the effectiveness of the passive skimming system, the Navy proposes that the passive skimming alternative be fully implemented. Two years of data from a fully implemented passive skimming alternative will be collected and will be reported in an Engineering Evaluation Report (EER). The EER may also evaluate other technologies that may be more effective in the event that the passive skimming system is not removing the PSH in a timely manner. The effectiveness of MNA will also be evaluated in the EER after the first two years of operation. The evaluation will include an update of the expected timeframe to achieve CAOs. Any potential pilot tests to evaluate enhancement of MNA will be described in the EER. Additionally, any polishing techniques such as CleanOx will also be evaluated in the EER to enhance cleanup times at this point. The EER may also include a discussion on hydrogeology and hydraulic characteristics of the PSH-impacted area if the skimming system proves to be ineffective.

The cost for this combination of alternatives is estimated to be $6,204,079, obtained by simply adding the excavation and disposal cost from Alternative 3 to the total of Alternative 1. This adjustment of alternatives would result in approximately a rank of 3 for costs, as shown in Table 3-4.

3.3 Schedule

Figure 3-1 shows the anticipated schedule milestones associated with Alternative 1. Three major areas are illustrated. Pending the approval of the Final CMS, the corrective measure implementation (CMI) would occur. The CMI consists of the design portion of the remedial activity and the implementation of the corrective measure. Pending approval of the CMI Design, the corrective action would be implemented. The corrective action would be the actual construction and startup of the remedial system. The final portion of the schedule includes the actual operation of the remedial system.

4.0 REFERENCES

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TABLES

TABLE 1-1

Revised: November 8, 2004

FINAL COCs AND CAOs
CORRECTIVE MEASURES STUDY - FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Media	COC	CAO	Maximum Observed	Most Recently Observed Maximum
Surface Soil (mg/kg)	*Metals* [1]			
	Arsenic	2.7E+00	3.4	NA
	Semivolatiles			
	Benzo(a)anthracene	2.9E+00	6J	NA
	Benzo(a)pyrene	2.9E+00	23J	NA
	Benzo(b)fluoranthene	2.9E+00	5.9J	NA
	Indeno(1,2,3-cd)pyrene	2.9E+00	5.3J	NA
Combined Surface and Subsurface Soil (mg/kg)	*Semivolatiles*			
	Benzo(a)pyrene	7.30E+00	23J	NA
Groundwater (ug/L)	*Volatiles*			
	1,2,4-Trimethylbenzene	3.3E+03	4,600	4,600
	Benzene	5.5E+02	26,000 [6]	19,000D [6]
	Ethylbenzene	1.0E+03	95,702 [4]	18,000 [5]
	Trichloroethene [2]	2.2E+01	28,000J	28,000J
PSH (feet of product above water table) [3]	*PSH*	1.0E-02	13.2	3.31

COC--Contaminant of Concern
CAO--Corrective Action Objective
mg/kg--milligrams/kilogram
ug/L--micrograms/Liter
PSH--Phase-separated hydrocarbon
NA--Not applicable
J--quantified as estimated
Notes:
(1)--Zinc is a Chemical of Potential Concern with a CAO to be determined
(2)--Trichlorethene is not addressed in this CMS Report, see text
(3)--PSH is not a COC. However, it will be assigned a regulatory CAO and is considered a source for remedial purposes.
(4)--located at UGW1, 3/1991
(5)--located at 470MW3, 1/2002
(6)--located at 470MW1, 4/1998 and 1/2002

TABLE 1-2

Revised: August 29, 2005

ALTERNATIVES MATRIX
CORRECTIVE MEASURES STUDY - FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

	Process Options				
Media	*Alternative 1*	*Alternative 2*	*Alternative 3*	*Alternative 4*	*Alternative 5*
Soil	Institutional Controls (Land Use Restrictions)	Institutional Controls (Land Use Restrictions), In-Situ Biological Treatment (Bioventing)	Institutional Controls (Land Use Restrictions), Excavation/Disposal (Off Site)	Institutional Controls (Land Use Restrictions), Excavation/Ex-situ Thermal Treatment (HTTD), In-Situ Physical Chemical Treatment (Soil Vapor Extraction)	Institutional Controls (Land Use Restrictions), Excavation/Ex-situ Biological Treatment (Land Farming), In-situ Biological Treatment (Biodegradation)
Groundwater	Institutional Controls (Restrict Water Usage) Monitored Natural Attenuation	Institutional Controls (Restrict Water Usage), Monitored Natural Attenuation, Containment/Collection (Dual Phase Extraction and Steam Flushing), Ex-Situ Physical Treatment (Air Stripping), Discharge (NPDES)	Institutional Controls (Restrict Water Usage), Monitored Natural Attenuation, Containment/Collection (Extraction Wells & Oil/Water Separator), In-Situ Physical/Chemical Treatment (Vacuum Vapor Extraction), Ex-Situ Biological Treatment (Bioreactor), Discharge (Re-Injection)	Institutional Controls (Restrict Water Usage), Monitored Natural Attenuation, In-Situ Physical/Chemical Treatment (Air Sparging)	Institutional Controls (Restrict Water Usage), Monitored Natural Attenuation, In-Situ Physical/Chemical Treatment (ECGO)
PSH	Containment/Collection--PSH skimming	Containment/Collection--Dual Phase Extraction	Containment/Collection (Extraction Wells and Oil/Water Separator)	Containment/Collection--PSH skimming	In-situ Biological Treatment (CleanOx)

PSH--Phase separated hydrocarbon
HTTD--High temperature thermal desorption
ECGO--Electro-chemical Geo-oxidation
NPDES--National Pollutant Discharge Elimination System

TABLE 3-1

Revised: August 29, 2005

CORRECTIVE MEASURE ALTERNATIVE SUMMARY TABLE
SOIL MEDIA
CORRECTIVE MEASURES STUDY -- FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Alternative	EVALUATION CRITERIA									
	TECHNICAL								HUMAN HEALTH	ENVIRONMENTAL
	PERFORMANCE		RELIABILITY		IMPLEMENTABLITY			SAFETY		
	Effectiveness	Useful Life	O&M Req	Demons./Expect	Constructability	Time				
						Implementation	*Results*			
1	Moderate to Low institutional controls and physical barriers prevent access; all COCs remain on site	Long access restricted indefinitely	Low minor maintenance to fence otherwise no equipment necessary	High fencing is expected to obstruct unwanted access to the site	High fence already exists no other construction needed	Low initiated immediately	Low >10 years COC left in place with institution/physical controls	Low Risk minimal worker safety issues no exposure to contaminants no safety issues to nearby residents	Moderate Risk land use restrictions remove potential exposure pathways all contamination left in place	Low to Moderate Risk no short and long term adverse effects on sensitive areas COCs left in place
2	Moderate institutional controls and physical barriers prevent access, some COCs may not achieve CAO; arsenic remains on site	Long to Moderate access restricted indefinitely 3 to 5 years for bioventing	Moderate to Low bioventing has some minor periodic maintenance required	Moderate to High simplicity of injection process	Moderate to High simple skid mounted equipment	Moderate to Low 6 to 12 months	Moderate 3-5 years arsenic left in place with institution/physical controls	Low Risk minimal risk during remediation no safety issues to nearby residents	Moderate to Low Risk reduction of PAHs by bioventing exposure to arsenic reduced by controls	Low to Moderate Risk no short and long term adverse effects on sensitive areas reduction of most COCs arsenic left in place
3	High all COCs removed to CAOs	Long Removing COCs is permanent.	Low No O & M required.	High Excavation has high reliability for removal of COCs	High Excavation is easily implemented.	Low Excavation Work Plan and approval of landfill facility is required.	High 1 year estimate	Moderate to Low Risk minor risk during excavation no safety issues to nearby residents	Low Risk reduction of all COCs to CAOs	Low Risk reduction of all COCs to CAOs
4	Moderate to High institutional controls and physical barriers prevent access; most COCs meet CAOs; arsenic remains in place	Moderate variable depending on maintenance, 2 years for HTTD, 3-5 years for SVE	Moderate HTTD and SVE require periodic maintenance	Moderate to High HTTD and SVE should operate as expected with periodic maintenance	Moderate pilot SVE required HTTD requires specialized equipment	Moderate to High 1 year; specialized equipment	Moderate 3-5 years SVE; 1 year HTTD arsenic left in place with institution/physical controls	Moderate to Low Risk minor risk during excavation no safety issues to nearby residents	Moderate to Low Risk reduction of PAHs by venting exposure to arsenic reduced by controls	Moderate to Low Risk no short and long term adverse effects on sensitive areas arsenic left in place
5	Moderate to High institutional controls and physical barriers prevent access; most COCs meet CAOs; arsenic remains in place	Moderate to High equipment for land farming averag 5-7 years, heterogenity will affect in-situ schedule	Moderate to Low Land farming requires minor maintenance of equipment	Moderate to High Land farming/biodeg. are expected to operate as expected	Moderate to High commonly available equipment requires some on site construction	Moderate to Low 6-12 months	Moderate 2-3 years land farming 3-5 years biodegradation arsenic left in place with institution/physical controls	Moderate to Low Risk minor risk during excavation no safety issues to nearby residents	Moderate to Low Risk removal of PAHs by HTTD exposure to arsenic reduced by controls	Moderate to Low Risk no short and long term adverse effects on sensitive areas arsenic left in place most COCs meet CAOs

LEGEND	
Green	most favorable
Blue	more favorable
Yellow	favorable
Orange	less favorable
Red	least favorable

TABLE 3-2

Revised: November 8, 2004

CORRECTIVE MEASURE ALTERNATIVE SUMMARY TABLE
GROUNDWATER MEDIA
CORRECTIVE MEASURES STUDY -- FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Alternative	EVALUATION CRITERIA									
	TECHNICAL								HUMAN HEALTH	ENVIRONMENTAL
	PERFORMANCE		RELIABILITY		IMPLEMENTABLITY			SAFETY		
	Effectiveness	Useful Life	O&M Req	Demons./Expect	Constructability	Time				
						Implementation	*Results*			
1	**Moderate to Low** relies on MNA only	**Moderate to Long** 5+ years for MNA	**Low** no equipment to maintain	**High** no equipment to maintain	**High** no equipment	**High** sampling is only requirement	**Moderate to Low** 7-10 years depending upon effectiveness of PSH removal	**Low Risk** no equipment to install no risk to nearyby residents no worker safety issues	**Moderate Risk** institutional controls and physical barriers prevent access to COCs reduction of COC is slow	**Low to Moderate Risk** COCs are not accessible to flora and fauna; slow COC removal rate via MNA and PSH skimming
2	**Moderate to High** provided NPDES limits can be met and provided PSH mobility increased due to steam	**Moderate** 3-5 years remedial system 5+ years for MNA	**Moderate to High** frequent O&M required for complex components numerous components	**Moderate** provided O&M addressed effectively. Low flexibility. should conditions change	**Moderate to Low** restricted by inability to obtain necessary equipment quickly complex system layout NPDES permit required	**Moderate to Low** 2-3 years collection and containment still requires NPDES potential delay of several years	**Moderate** 3-5 years depending upon the PSH removal rate	**Moderate to Low Risk** minor risk associated with construction no risk to nearyby residents	**Low to Moderate Risk** institutional controls and physical barriers prevent access to COCs reduction of COC is moderate	**Low Risk** COCs are not accessible to flora and fauna; moderate COC removal rate
3	**Moderate to High** provided UIC limits can be met and provided PSH mobility increased due to steam	**Moderate** 3-5 years dependent on ability to target/extract desired quantities of groundwater 5-7 years for biological treatment system 5+ years for MNA	**High** periodic maintenenance overhaul reqd after 5 years. Bioreactor failure would cause failure in re-injection stds. vacuum vapor still in pilot stage. re-injection reqs frequent O&M	**Moderate to Low** effective unless failure of oil/water separator, causing shutdown. limited adjustability to conditions	**Moderate to low** complex, vacuum vapor reqs separator and bioreactor construction, pilot tests req'd UIC permit required	**Moderate to Low** UIC permits, shipping materials, construction, pilot studies 2-3 years implementation time many potential delays.	**Moderate** 3-5 years for PSH/groundwater depending on success of system	**Moderate to Low Risk** minor risk associated with construction no risk to nearyby residents	**Low to Moderate Risk** institutional controls and physical barriers prevent access to COCs reduction of COC is moderate	**Low to Moderate Risk** COCs are not accessible to flora and fauna; moderate COC removal rate; failure of re-injection system may impact potential receptors via groundwater quality in aquifer
4	**Moderate** volatilization hampered by overburden rely on MNA	**Moderate to Long** 5 years for air sparging system 5+ years for MNA	**Moderate to High** air sparing periodic maintenance	**Moderate to High** simple components wells require periodic redevelopment	**Moderate to High** air sparging is only component to construct	**Moderate** 6-18 months construction, pilot study longer implementation time potential delays.	**Moderate to Low** 7-10 years PSH removal rate will hamper effectiveness of air sparging system	**Moderate to Low Risk** minor risk associated with construction no risk to nearyby residents	**Moderate Risk** institutional controls and physical barriers prevent access to COCs reduction of COC is slow because of slow PSH removal	**Low to Moderate Risk** COCs are not accessible to flora and fauna; moderate COC removal rate; air sparging may spread plume
5	**Moderate** treat "hot spot" volume only rely on MNA for balance	**Moderate to Long** 5 years for ECGO system 5+ years for MNA	**Moderate** ECGO specialized maintenance by proprietary personnel	**Moderate** ECGO requires specially trained personnel to operate/maintain	**Moderate** ECGO requires specially trained personnel to construct	**Moderate** 1-2 years to implement	**Moderate** 3-5 years once PSH is removed, ECGO system treat "hot spot" in <1 year	**Moderate to Low Risk** minor risk associated with construction no risk to nearyby residents	**Low to Moderate Risk** institutional controls and physical barriers prevent access to COCs reduction of COCs is moderate	**Low to Moderate Risk** COCs are not accessible to flora and fauna; slow COC removal rate due to prior PSH skimming

LEGEND	
Green	most favorable
Blue	more favorable
Yellow	favorable
Orange	less favorable
Red	least favorable

TABLE 3-3

Revised: November 8, 2004

CORRECTIVE MEASURE ALTERNATIVE SUMMARY TABLE
PSH MEDIA
CORRECTIVE MEASURES STUDY -- FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Alternative	EVALUATION CRITERIA									
	TECHNICAL								HUMAN HEALTH	ENVIRONMENTAL
	PERFORMANCE		RELIABILITY		IMPLEMENTABLITY			SAFETY		
	Effectiveness	Useful Life	O&M Req	Demons./Expect	Constructability	Time				
						Implementation	*Results*			
1	**Moderate to Low** mobility of product in subsurface no continuing source of product present	**High** 5-10 years proper maintenance req'd	**Low** reliable and parts readily accessable	**High** proper maintenance insures results; similar systems in use for decades	**High** use existing interim system as basis minimal necessary additional equipment req'd	**High** 3-6 months, including refurbishing interim system	**Moderate to Low** 7-10 years with beneficial reduction	**Moderate to Low Risk** minor risk to workers during construction no risk to nearby residents	**Moderate Risk** low levels of PSH would remain during removal; institutional and physical barriers prevent access	**Moderate to Low Risk** PSH not accessible to flora and fauna; slow PSH removal rates
2	**Moderate to High** depending on vacuum to influence PSH smear zone	**Moderate to Low** 3 - 5 years collection limited by quantity and discharge permit requirements	**Moderate to High** components are also associated with groundwater recovery requires frequent O&M	**Moderate** dependent upon frequent O&M due to complex system	**Moderate to Low** complex components restricted by ability to obtain necessary NPDES permits	**Moderate to Low** 2-3 years; collection and containment still requires NPDES; potential delay of several years	**Moderate** 3-5 years for PSH/groundwater depending on success of system	**Moderate to Low Risk** minor risk to workers during construction no risk to nearby residents	**Moderate to Low Risk** moderate removal rate institutional and physical barriers prevent access	**Low Risk** PSH not accessible to flora and fauna; moderate removal rates
3	**Moderate to High** ability of steam to move smeared PSH from vadoze	**Moderate to Low** 3-5 years dependent upon proper O&M of complex system	**High** Frequent maintenance, full overhaul after 5 years. Failure in bioreactor would stop PSH recovery. Vacuum vapor still in pilot stage. Reinjection reqs frequent O&M	**Moderate to Low** effective unless failure of oil/water seperator, would cause complete shutdown. Limited adjustability to changing conditions, and weather bedrock aquifer	**Moderate to Low** complex, vacuum vapor reqs separator and bioreactor construction, pilot tests req'd UIC permit required.	**Moderate to Low** UIC permits, shipping materials, construction, pilot studies, 2-3 years to implement, many potential delays	**Moderate** 3-5 years for PSH/groundwater depending on success of system	**Moderate to Low Risk** minor risk to workers during construction no risk to nearby residents	**Moderate to Low Risk** moderate removal rate institutional and physical barriers prevent access	**Low Risk** PSH not accessible to flora and fauna; moderate removal rates
4	**Moderate to Low** mobility of product in subsurface no continuing source of product present	**High** 5-10 years proper maintenance req'd	**Low** reliable and parts readily accessable	**High** proper maintenance insures results; similar systems in use for decades	**High** use existing interim system as basis minimal necessary additional equipment req'd	**High** 3-6 months, including refurbishing interim system	**Moderate to Low** 7-10 years with beneficial reduction	**Moderate to Low Risk** minor risk to workers during construction no risk to nearby residents	**Moderate** low levels of PSH would remain during removal; institutional and physical barriers prevent access	**Moderate to Low Risk** PSH not accessible to flora and fauna; slow PSH removal rates
5	**Moderate** several applications required, depending on PSH levels/effectiveness	**High** 5 - 10 years dependent upon well integrity since well acts as a point source for application	**Moderate to Low** No working parts inproper application could damage well integrity	**Low** mixed results in pilot study specialized labor required treatment not flexible	**High** Batch application	**High** 3 - 6 months per application	**Moderate** 5 years depending on frequency of reapplications; results potential variable depending on PSH recharge	**Moderate Risk** risk due to CleanOX application potentially hazardous minor risk to nearby residents	**Low Risk** potentially faster removal rate institutional and physical barriers prevent access	**Moderate Risk** greater potential for environmental release from application upset

LEGEND	
Green	most favorable
Blue	more favorable
Yellow	favorable
Orange	less favorable
Red	least favorable

TABLE 3-4

Revised: August 29, 2005

COMPARISON OF ALTERNATIVES
CORRECTIVE MEASURES STUDY--FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Comparison of Alternatives on Technical Merits

Alternative	Rank	Reason
1	1	PSH will meet CAO but over a longer period of time. All other COCs rely on MNA. Skimming is mobile but slow. No groundwater removal, O & M minor.
2	5	Doesn’t treat arsenic, Requires groundwater extraction and disposal. High O&M. Follow with MNA. Bioventing only moderately effective on PAH's.
3	3	Excavation and disposal is effective. Requires groundwater extraction and discharge. Oil/water separator and vacuum extraction effective for PSH and volatiles. Pilot testing also needed for extraction rates and volumes. Discharge through reinjection needs a pilot test. Requires treatment and holding of large volumes of water. However, all COCs in each media will meet their respective CAO.
4	2	SVE not effective for PAHs and arsenic not treated. Air sparging radius of influence determined by pilot testing. Skimming effective but requires the longest time to reach CAO. Only slightly better than Alternative 1.
5	4	Landfarming does not treat arsenic in the soils. Pilot test on groundwater technology needed. CleanOX procedures need effective safety precautions, and likely more than one injection. Remediation to CAOs not likely for PSH. Pilot test not favorable.

Comparison of Alternatives for Human Health Benefits

Alternative	Rank	Reason
1	5	Low levels of PSH would remain on the aquifer over a longer period of time. Most COCs will require longer time since MNA primary option used.
2	2	Moderate removal rate, however arsenic will be left in place.
3	1	Moderate removal rate, however all medias will obtain CAOs in the shortest timeframe.
4	4	Similar approach to removing PSH as Alternative 1, except quicker results.
5	3	Longer time to achieve CAOs and arsenic left in place.

Comparison of Alternatives for Environmental Benefits

Alternative	Rank	Reason
1	3	Environmental benefits are apparent, but require a large amount of time.
2	2	Would remove COCs from all media except for arsenic.
3	1	Removes all COCs from all media. However, failure of treatment system may decrease quality of water reinjected.
4	4	Sparging wells may cause deterioration of groundwater quality by allowing impacted groundwater to migrate before beneficial results are realized. Leaves some COCs untreated.
5	5	Unknown geochemical changes due to process option implementation. Possible upsets during CleanOX application may impact environment.

Comparison of Alternatives by Cost

Alternative	Rank	Cost
1	1	$3,334,526
2	2	$4,546,705
3	4	$7,381,243
4	3	$6,370,025
5	5	$7,407,689

FIGURES

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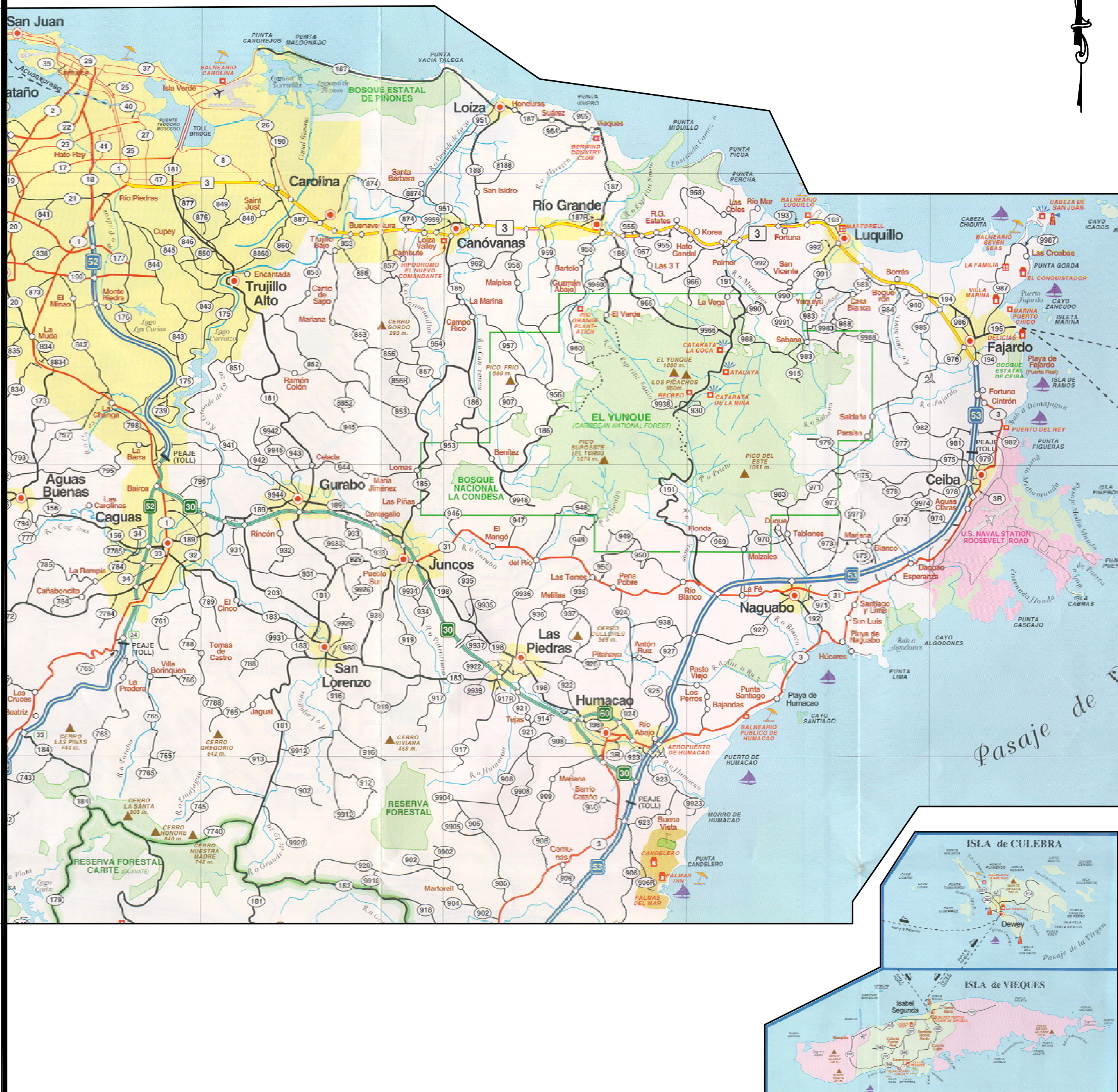

4 0 2 4 8

1 inch = 4 miles

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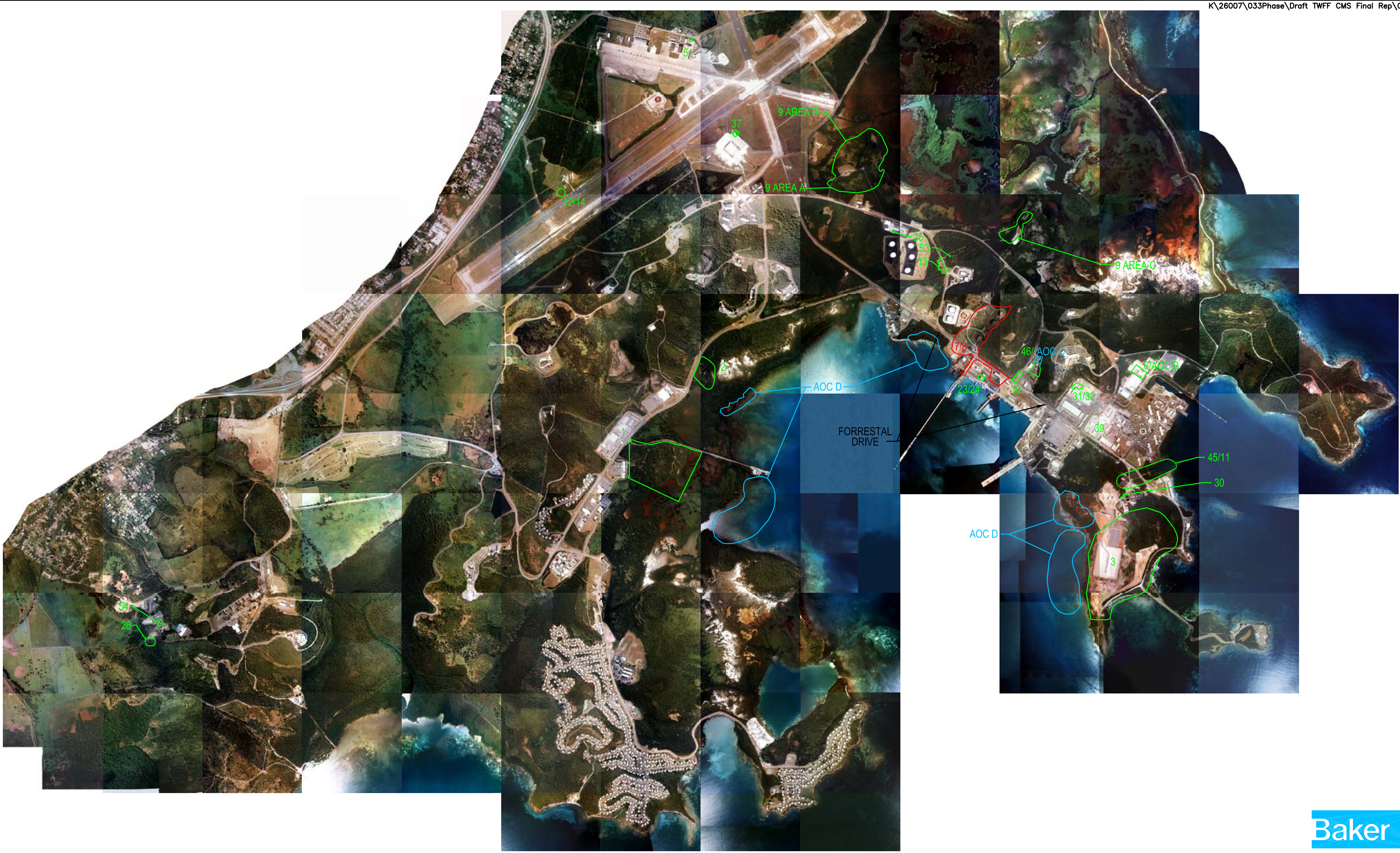
FIGURE 1-1
REGIONAL LOCATION MAP

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

SOURCE: METRODATA, INC., 1999.

K\26007\033Phase\Draft TWFF CMS Final Rep\CMS002



LEGEND

1 – SWMUs

7/8 – AREA OF WHICH THIS INVESTIGATION PERTAINS TO

AOC D – AOCs

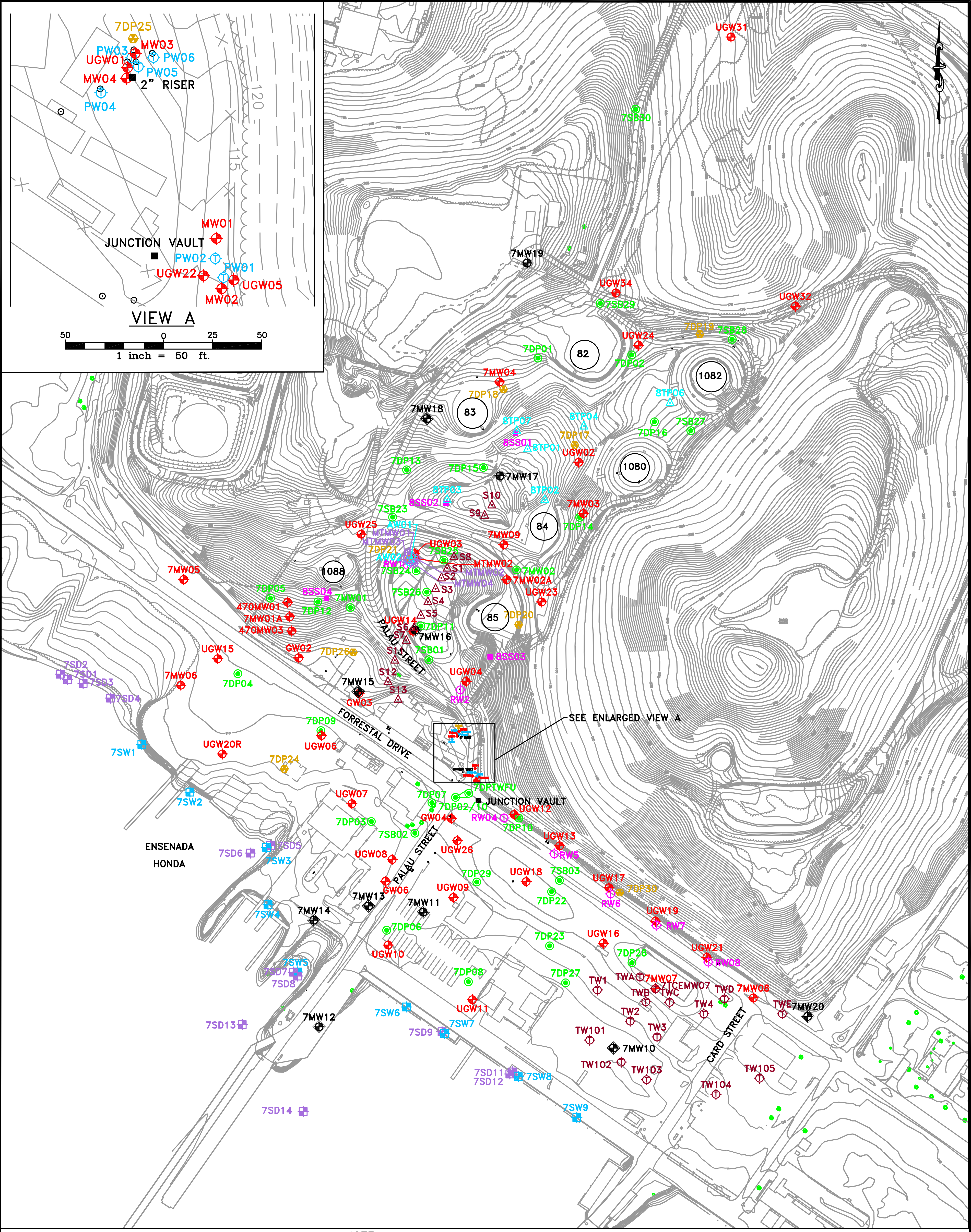
SOURCE: GEO–MARINE, INC., SEPTEMBER 6, 2000.

2500 0 1250 2500

1 inch = 2500 ft.

FIGURE 1–2
TWFF LOCATION MAP

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



250 0 125 250
1 inch = 250 ft.

K\26007\033Phase\Draft TWFF CMS Final Rep\CMS003

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

SOURCE: LANTDIV, FEB. 1992/1997

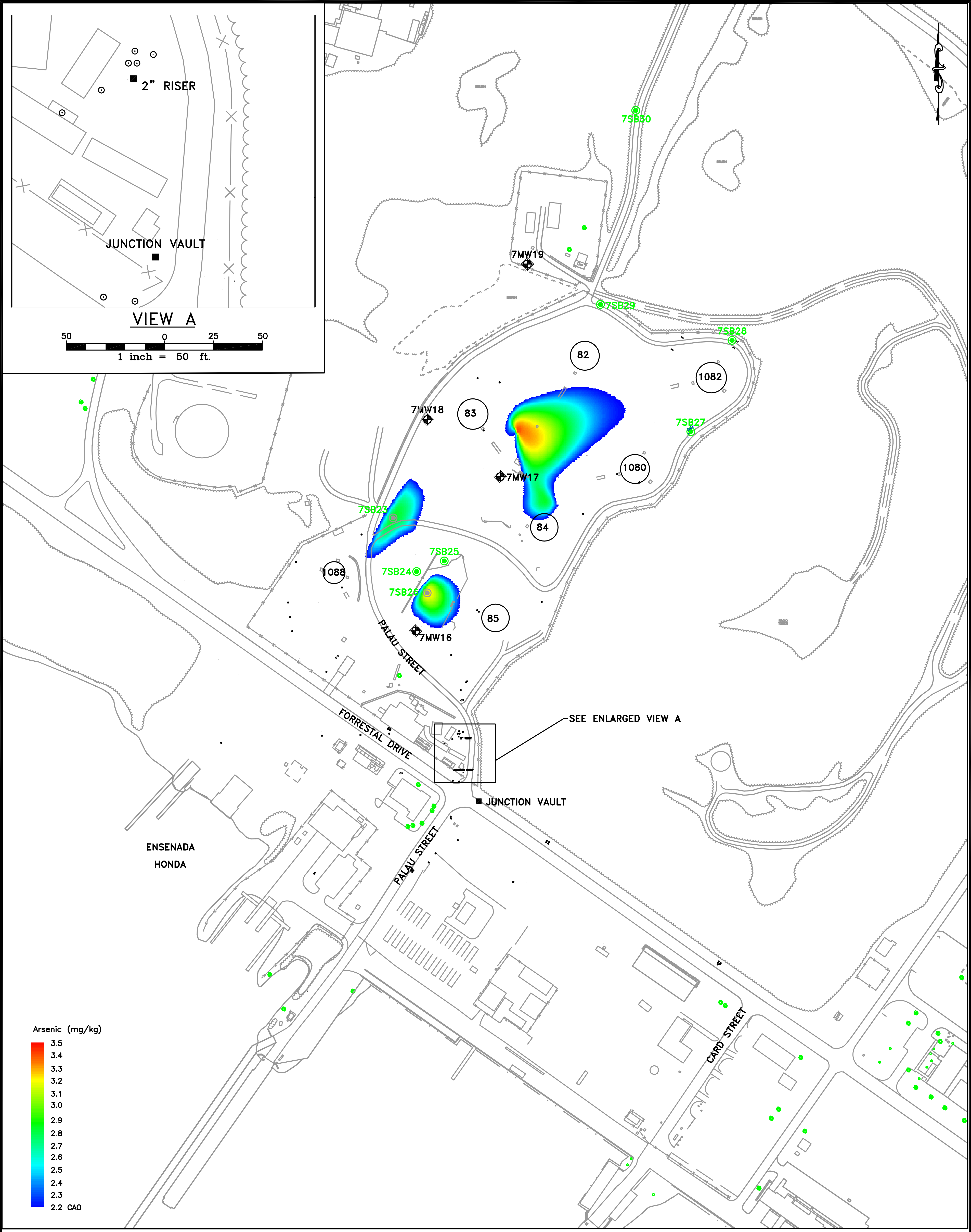
Baker

LEGEND

- NEW MONITOR WELL LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION, 2002)
- MONITOR WELL LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION (CMSI, 1998)
- SURFACE SOIL LOCATION
- TEST PIT LOCATION (RFI, 1996)
- DFM FUEL LINE REPAIR (APRIL 1997)
- SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION, 2002)
- SURFACE WATER SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION, 2002)
- TEMPORARY MONITOR WELL LOCATION (TCE INVESTIGATION, 1999)
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- MANTECH MONITOR WELL
- MANTECH CLEANOx APPLICATION WELL

FIGURE 1-3
SITE PLAN
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



250 0 125 250
1 inch = 250 ft.

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

SOURCE: LANTDIV, FEB. 1992/1997

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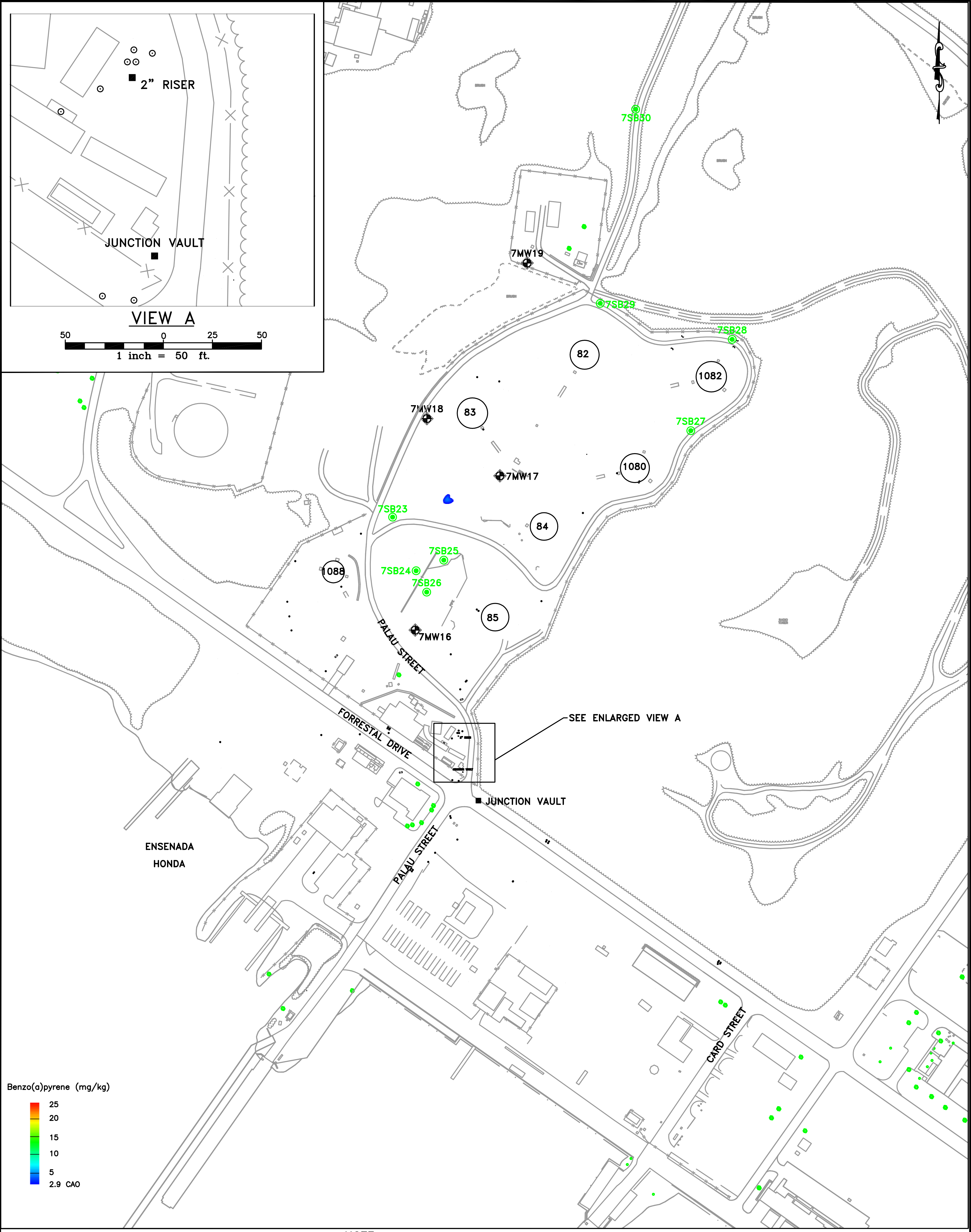
K\26007\033Phase\Draft TWFF CMS Final Rep\CMS004

LEGEND

- NEW MONITOR WELL LOCATION
- SOIL BORING LOCATION

FIGURE 1-4
SURFACE SOIL WITH ARSENIC ABOVE CAO
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



250 0 125 250

1 inch = 250 ft.

K\26007\033Phase\Draft TWFF CMS Final Rep\CMS005

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

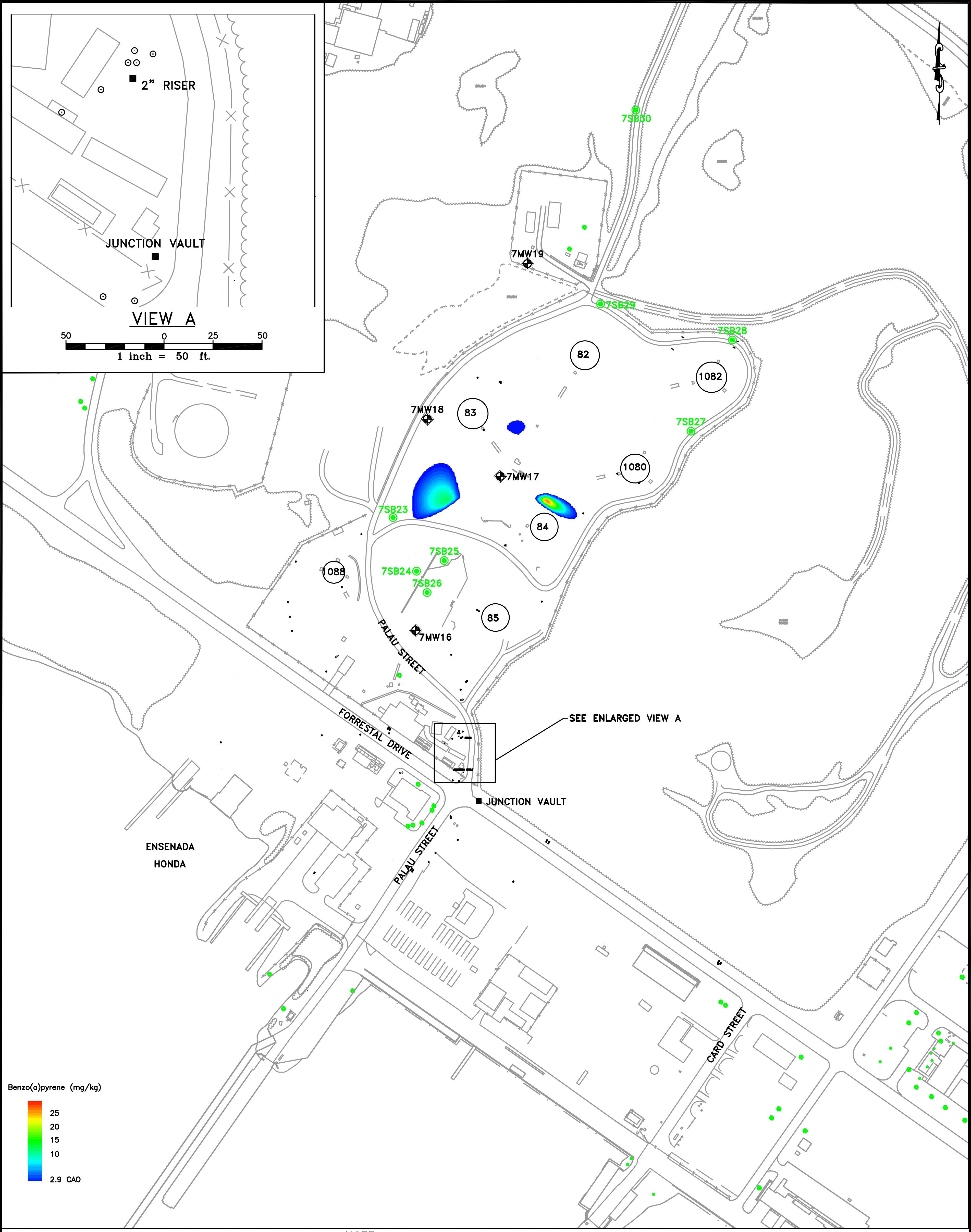
SOURCE: LANTDIV, FEB. 1992/1997

Baker

LEGEND

- NEW MONITOR WELL LOCATION
- SOIL BORING LOCATION

FIGURE 1-5
SURFACE SOIL WITH
BENZO(a)ANTHRACENE ABOVE CAO
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



250 0 125 250

1 inch = 250 ft.

K\26007\033Phase\Draft TWFF CMS Final Rep\CMS006

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

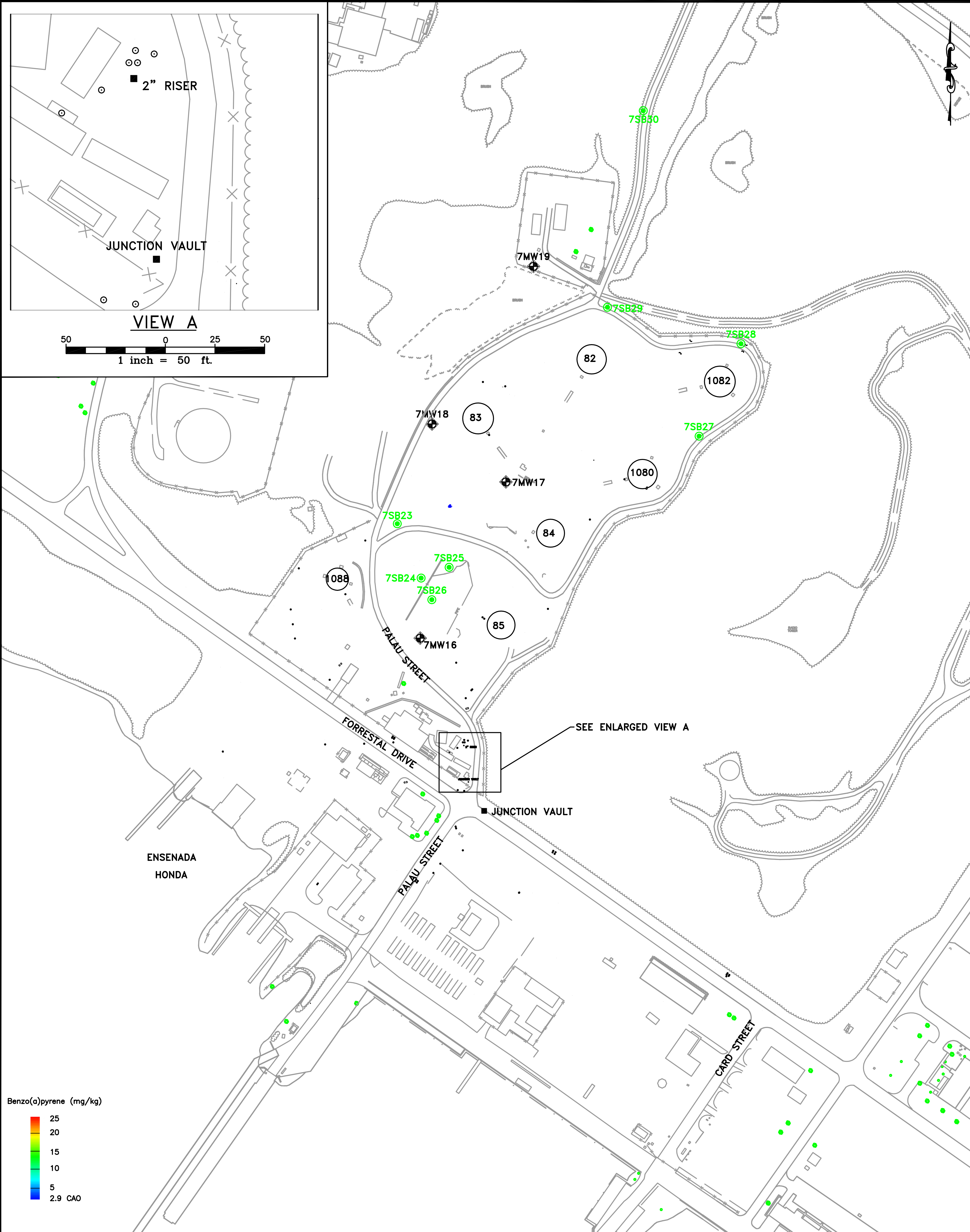
SOURCE: LANTDIV, FEB. 1992/1997

Baker

LEGEND

- NEW MONITOR WELL LOCATION
- SOIL BORING LOCATION

FIGURE 1–6
SURFACE SOIL WITH
BENZO(a)PYRENE ABOVE CAO
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



250 0 125 250
1 inch = 250 ft.

K\26007\033Phase\Draft TWFF CMS Final Rep\CMS007

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

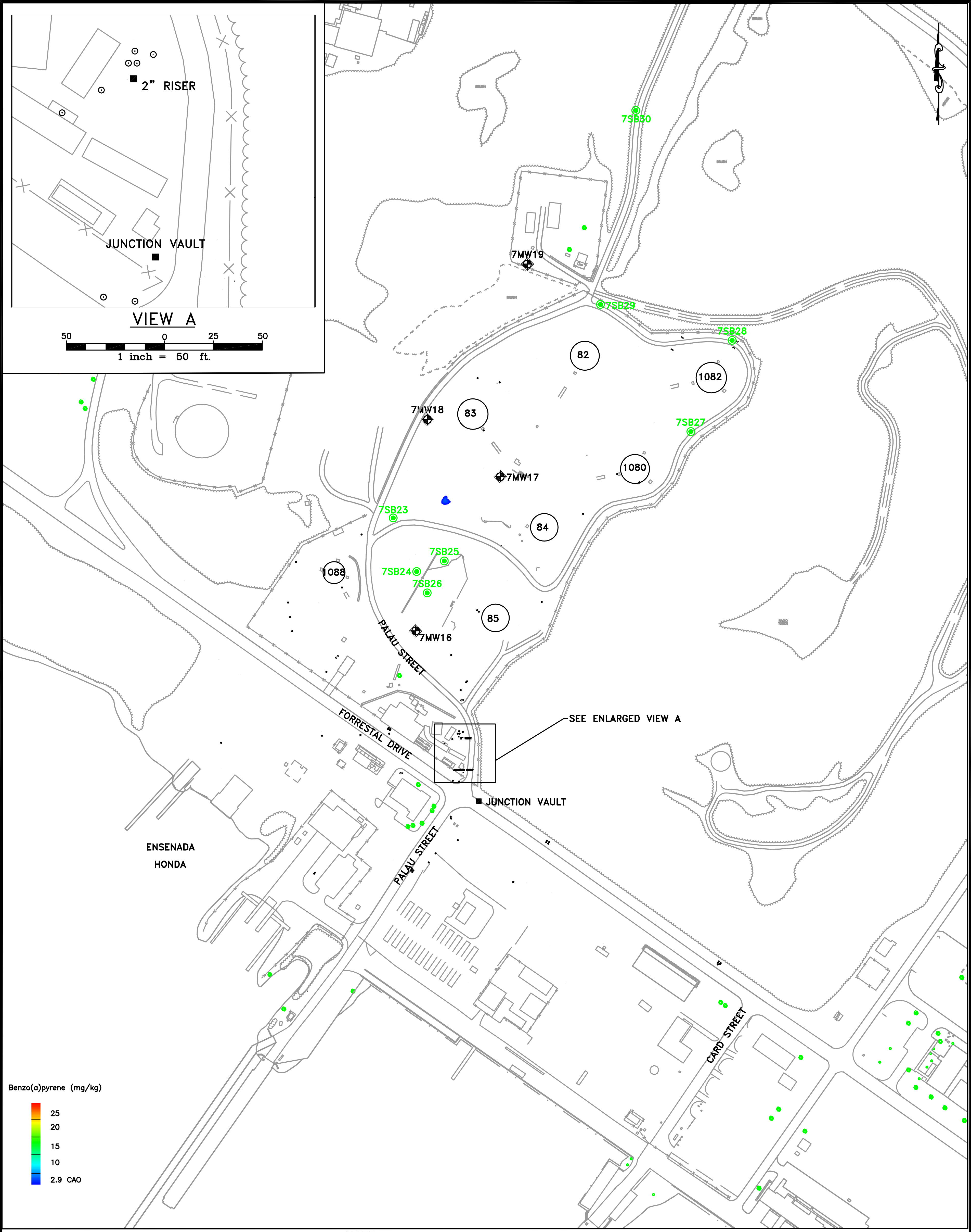
SOURCE: LANTDIV, FEB. 1992/1997

Baker

LEGEND

- NEW MONITOR WELL LOCATION
- SOIL BORING LOCATION

FIGURE 1–7
SURFACE SOIL WITH
BENZO(a)FLUORANTHENE ABOVE CAO
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



250 0 125 250
1 inch = 250 ft.

K\26007\033Phase\Draft TWFF CMS Final Rep\CMS008

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

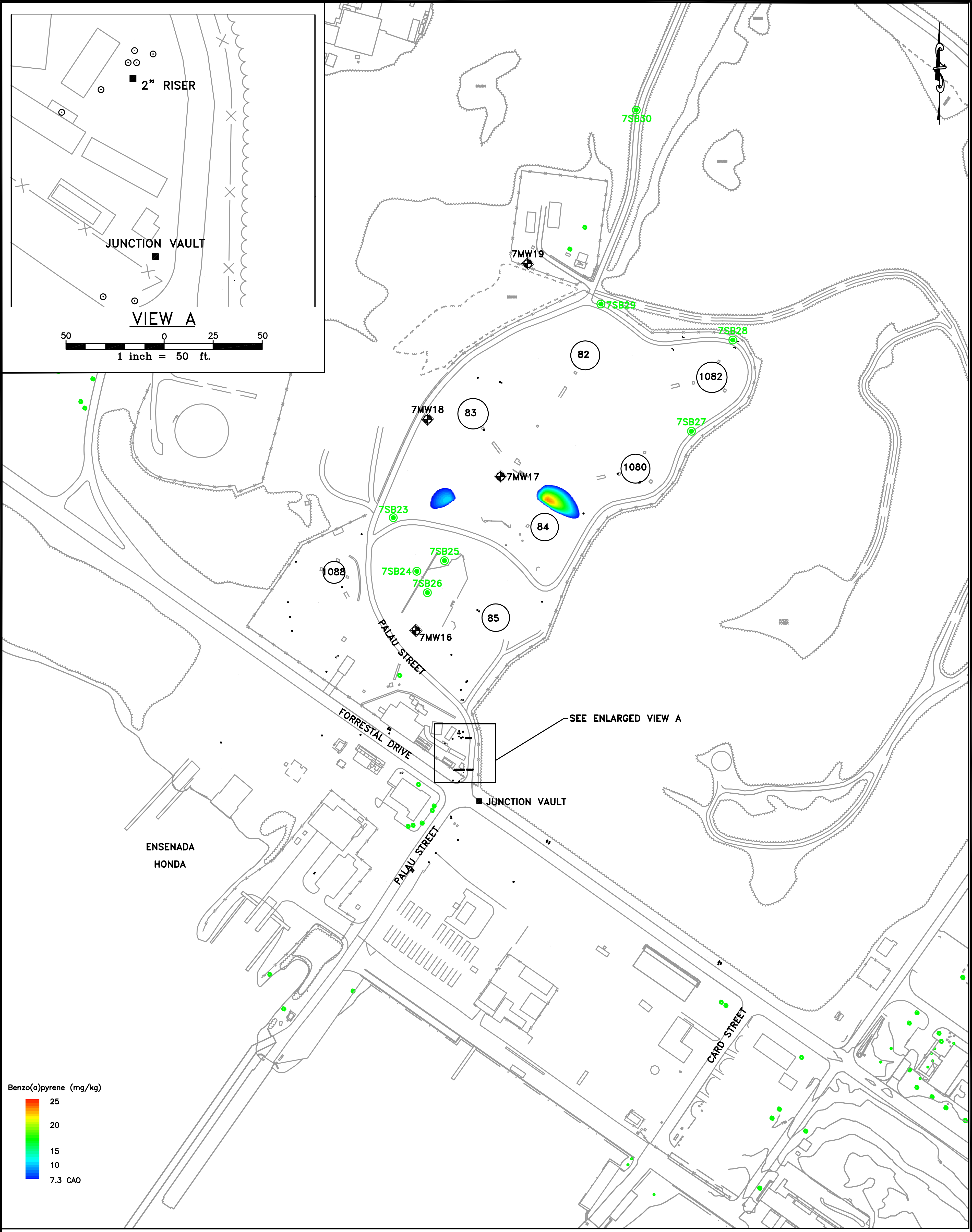
SOURCE: LANTDIV, FEB. 1992/1997

Baker

LEGEND

- NEW MONITOR WELL LOCATION
- SOIL BORING LOCATION

FIGURE 1–8
SURFACE SOIL WITH INDENO(1,2,3–cd)PYRENE ABOVE CAO
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



250 0 125 250
1 inch = 250 ft.

K\26007\033Phase\Draft TWFF CMS Final Rep\CMS009

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

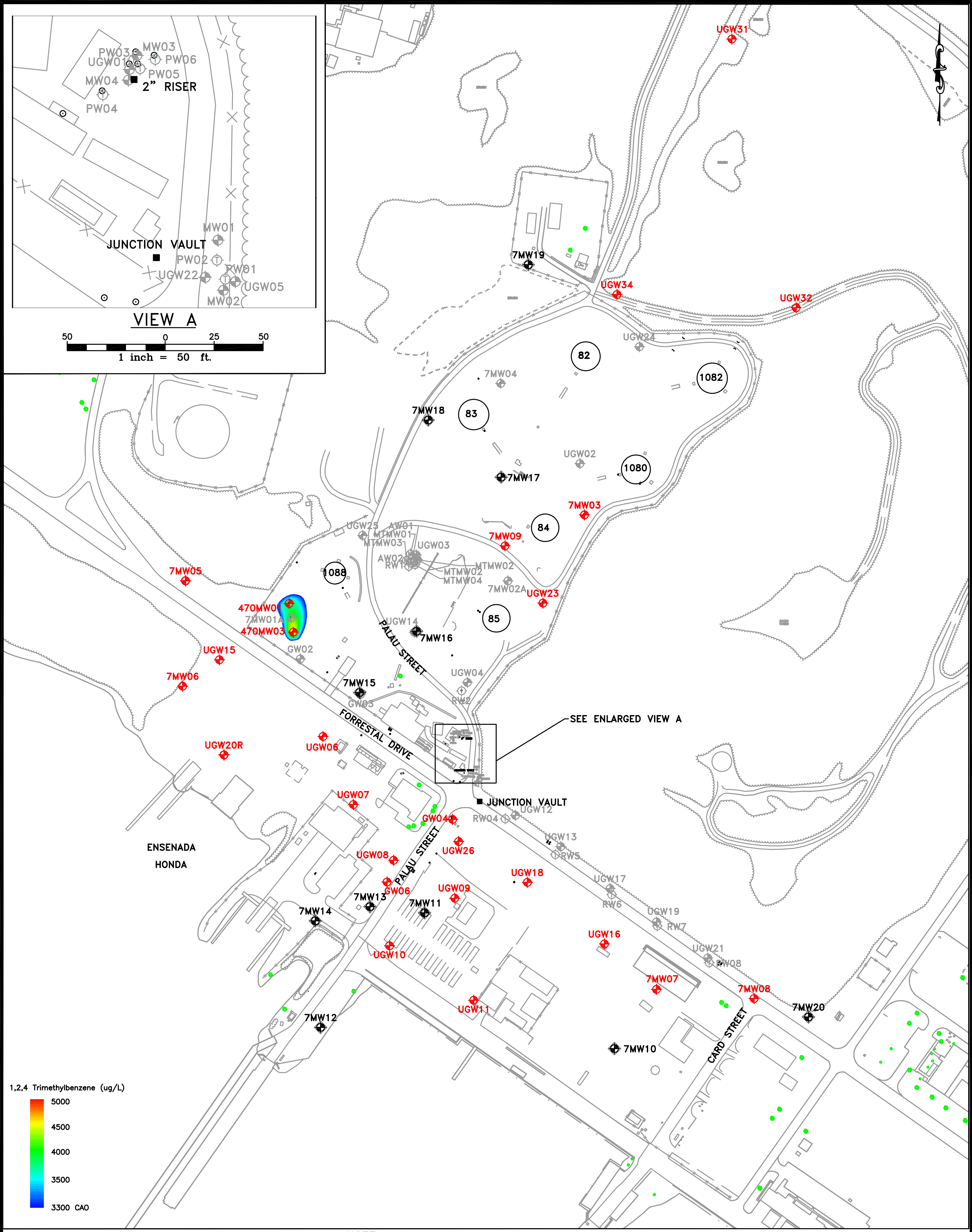
SOURCE: LANTDIV, FEB. 1992/1997

Baker

LEGEND

- NEW MONITOR WELL LOCATION
- SOIL BORING LOCATION

FIGURE 1–9
TOTAL (SURFACE AND SUBSURFACE) SOIL WITH BENZO(a)PYRENE ABOVE CAO
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



1 inch = 250 ft.

K\26007\033Phase\Draft TWFF CMS Final Rep\CMS010

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

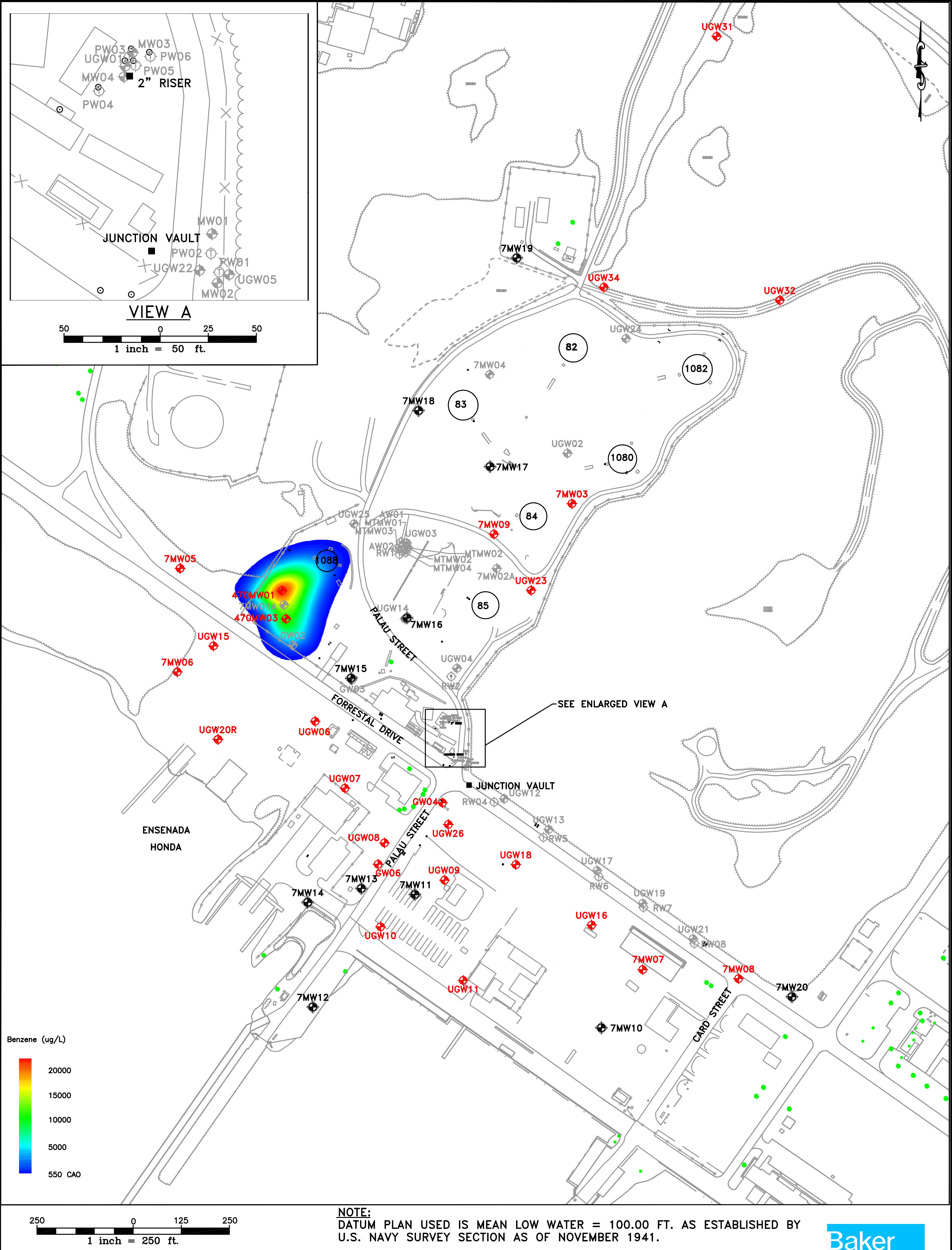
SOURCE: LANTDIV, FEB. 1992/1997

Baker

LEGEND

- NEW MONITOR WELL LOCATION
- MONITOR WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- MANTECH MONITOR WELL
- MANTECH CLEANOx APPLICATION WELL

FIGURE 1–10
1,2,4–TRIMETHYLBENZENE DISSOLVED GROUNDWATER PLUME
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

SOURCE: LANTDIV, FEB. 1992/1997

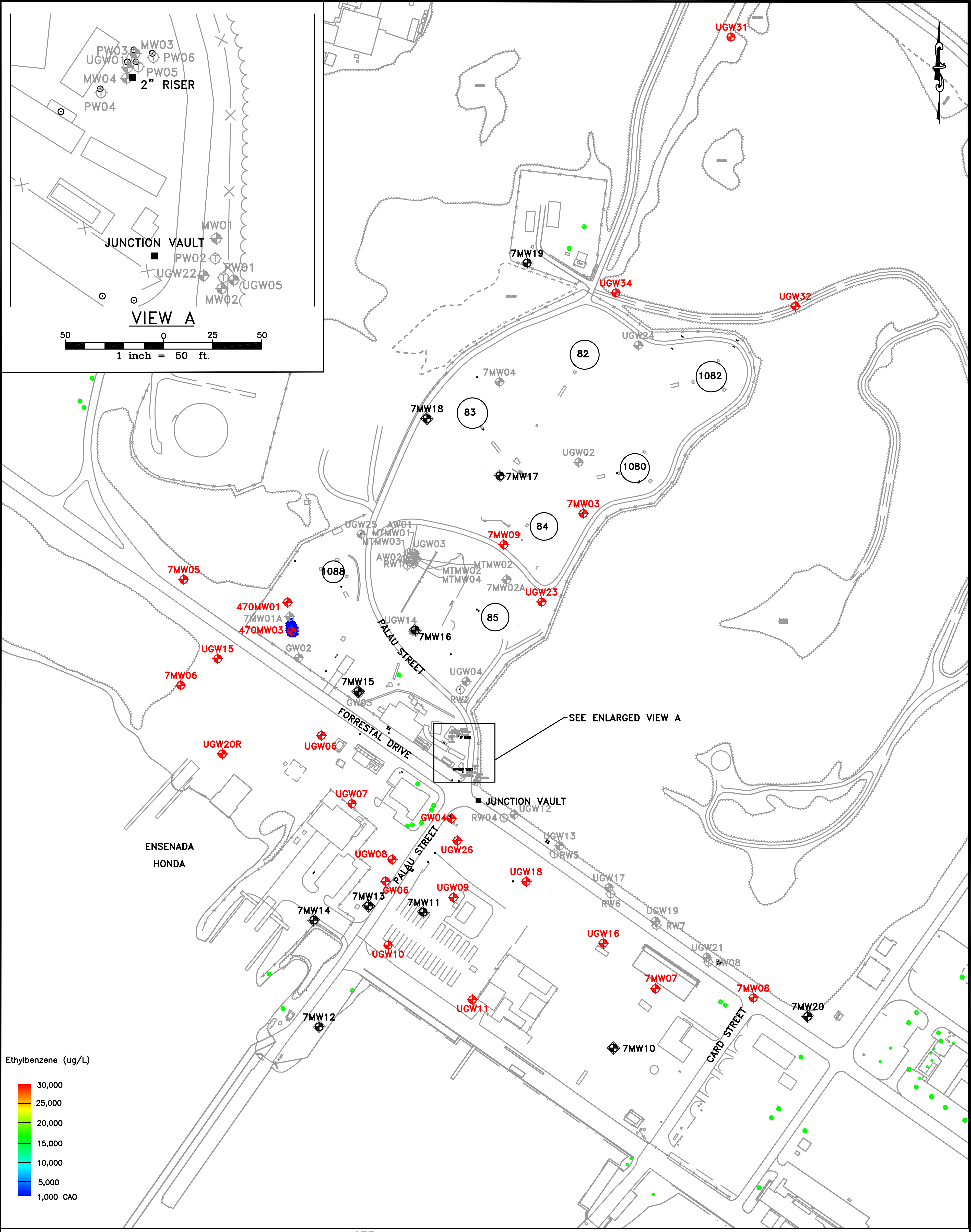
K\26007\033Phase\Draft TWFF CMS Final Rep\CMS011

Baker

LEGEND

- NEW MONITOR WELL LOCATION
- MONITOR WELL LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- MANTECH MONITOR WELL
- MANTECH CLEANOx APPLICATION WELL

FIGURE 1-11
BENZENE DISSOLVED GROUNDWATER PLUME
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



250 0 125 250
1 inch = 250 ft.

K\26007\033Phase\Draft TWFF CMS Final Rep\CMS012

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

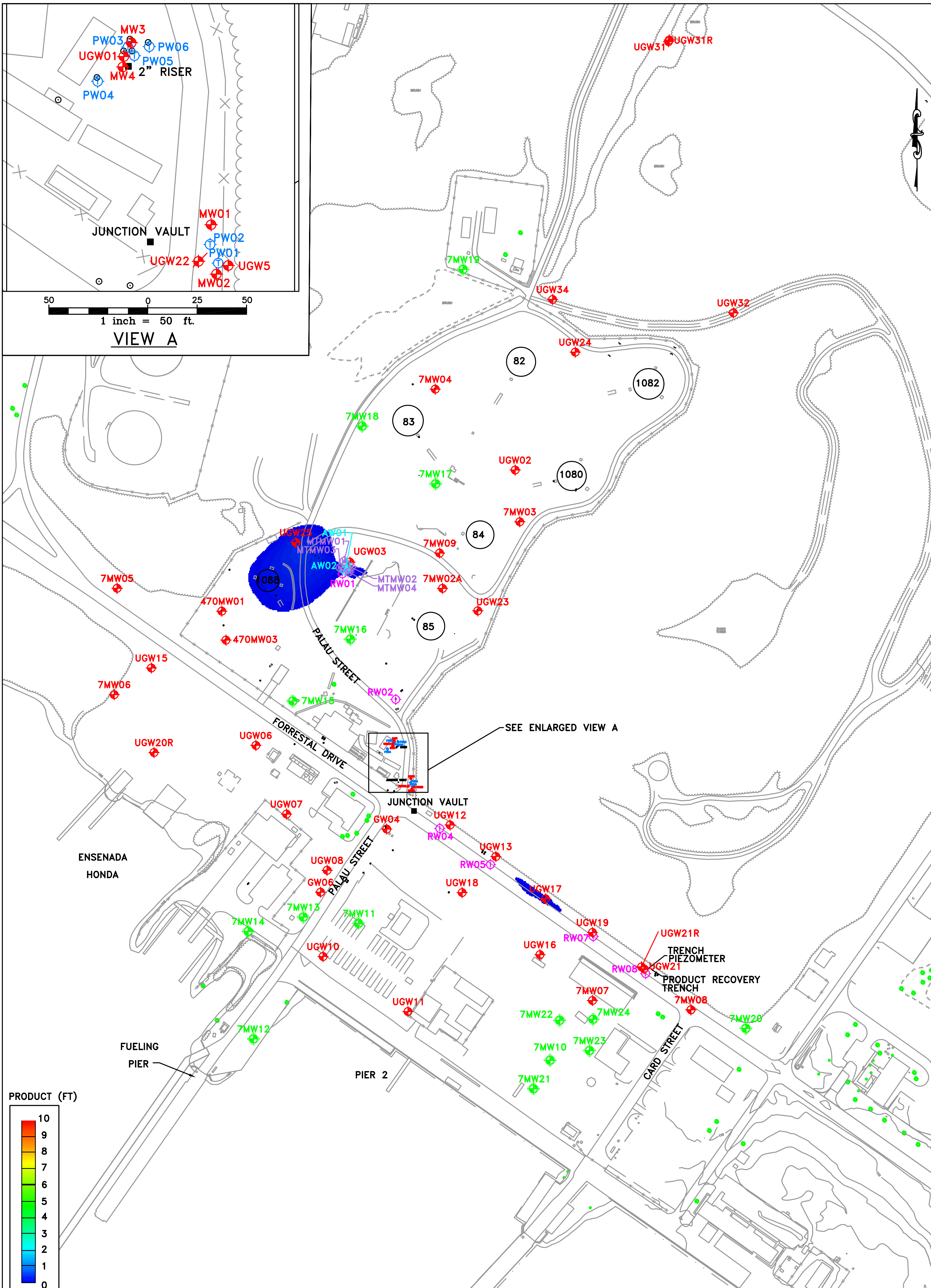
SOURCE: LANTDIV, FEB. 1992/1997

Baker

LEGEND

- NEW MONITOR WELL LOCATION
- MONITOR WELL LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- MANTECH MONITOR WELL
- MANTECH CLEANOx APPLICATION WELL

FIGURE 1-12
ETHYLBENZENE DISSOLVED GROUNDWATER PLUME
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



250 0 125 250
1 inch = 250 ft.

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

Baker

K:\26007\033 PHASE\TWF CMS FINAL REPORT\ CMS021 Fig 1-13

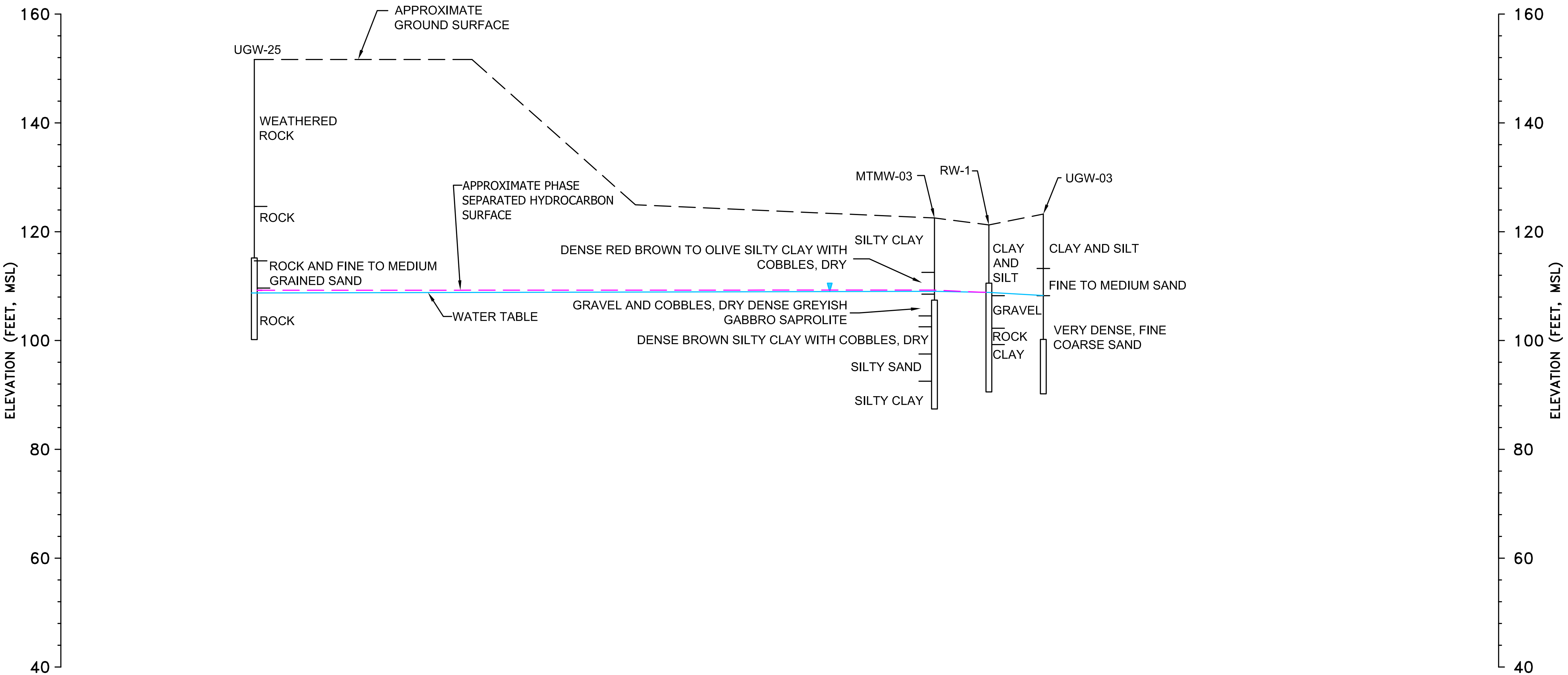
LEGEND

- MONITOR WELL LOCATION
- NEW MONITOR WELL LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- MANTECH MONITOR WELL
- MANTECH CLEANOx APPLICATION WELL

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 1-13
FREE PRODUCT THICKNESS AND EXTENT MAP (JULY 2005)
CORRECTIVE MEASURES STUDY
FINAL REPORT
TOW WAY FUEL FARM

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO



Baker

LEGEND

- APPROXIMATE PHASE SEPARATED HYDROCARBON SURFACE (JULY 20, 2005)
- WATER TABLE

Approximate Horizontal Scale: 1 inch = 20 ft.

Vertical Scale: 1 inch = 20 ft.

THE SOIL BORING INFORMATION IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED BASED ON ACCEPTED SOIL ENGINEERING PRINCIPLES AND GEOLOGIC JUDGEMENT.

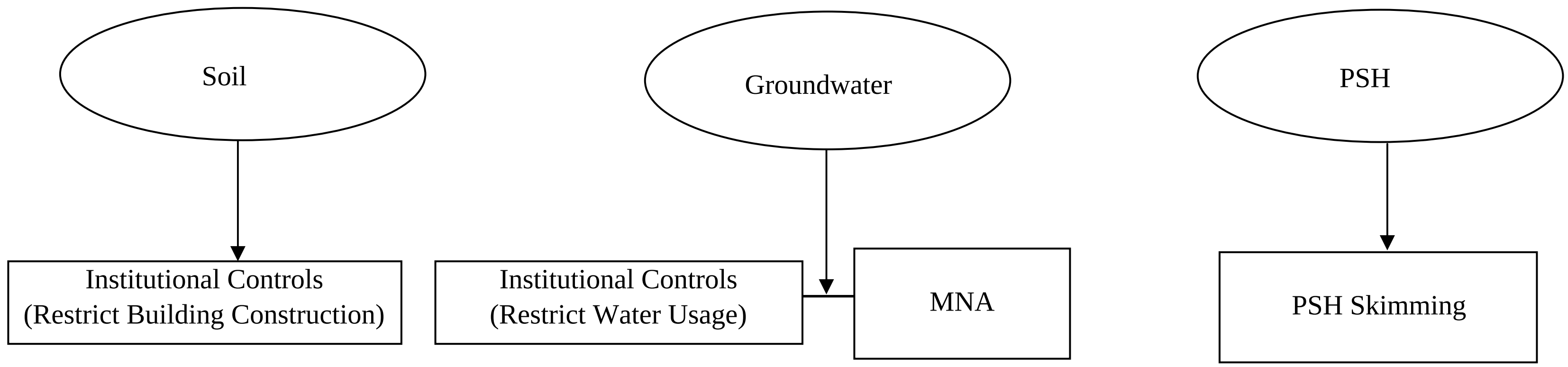
FIGURE 1-14
PHASE SEPARATED HYDROCARBON CROSS SECTION
JULY 20, 2005 CORRECTIVE MEASURES STUDY
FINAL REPORT
TOW WAY FUEL FARM

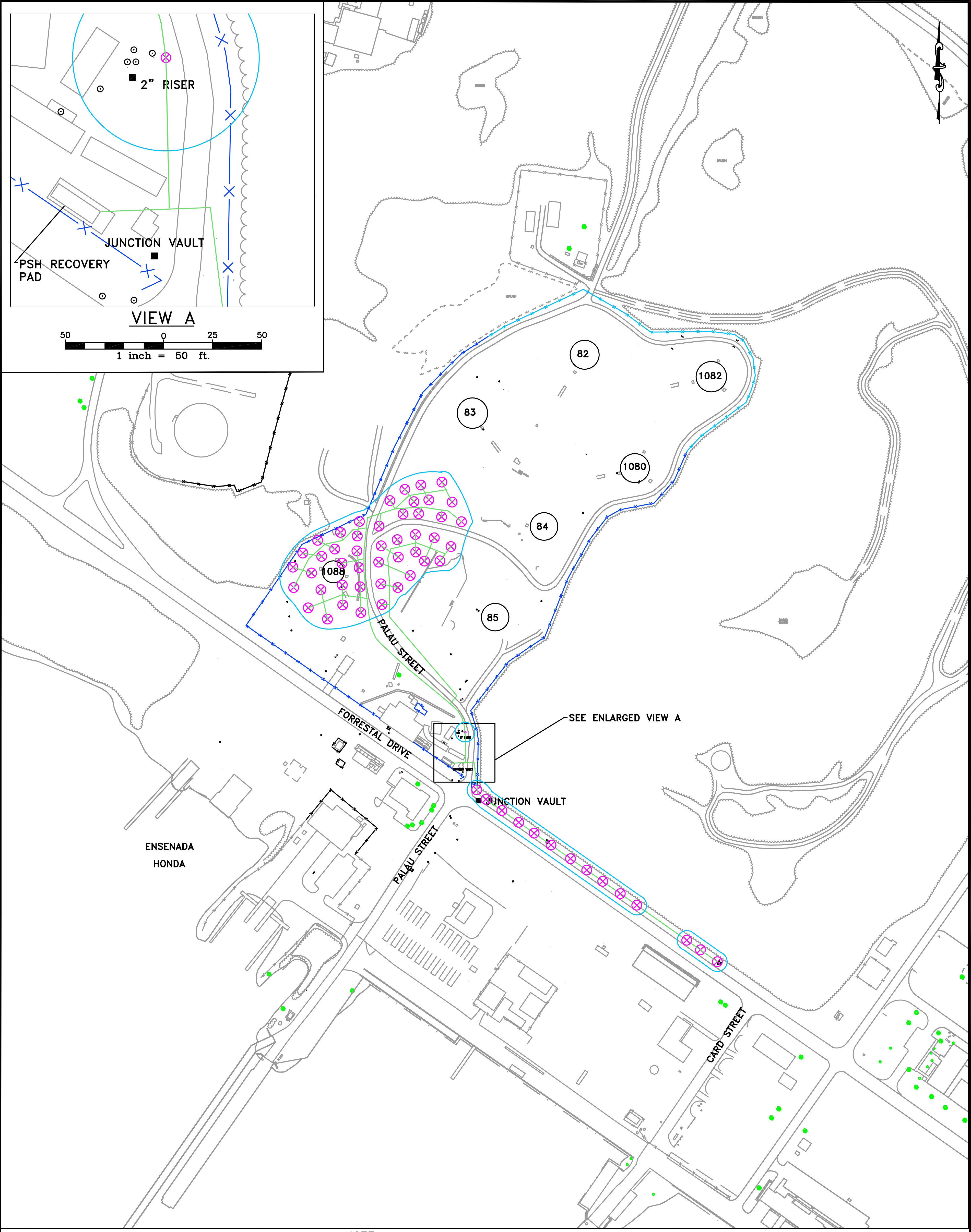
NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO.

FIGURE 2-1

Revised: November 8, 2004

ALTERNATIVE 1 PROCESS FLOW DIAGRAM
CORRECTIVE MEASURES STUDY--FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO





250 0 125 250
1 inch = 250 ft.

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

SOURCE: LANTDIV, FEB. 1992/1997

K\26007\033Phase\TWFF CMS Final Rep\CMS014 Fig 2–2

LEGEND

- PSH RECOVERY WELL
- ZONE OF INFLUENCE
- CONVEYANCE PIPING
- FENCE

FIGURE 2–2
ALTERNATIVE 1 CONCEPTUAL LAYOUT
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

FIGURE 2-3

Revised: November 8, 2004

ALTERNATIVE 1 CONCEPTUAL COMPONENT LAYOUT
CORRECTIVE MEASURES STUDY--FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTVITY PUERTO RICO, CEIBA, PUERTO RICO

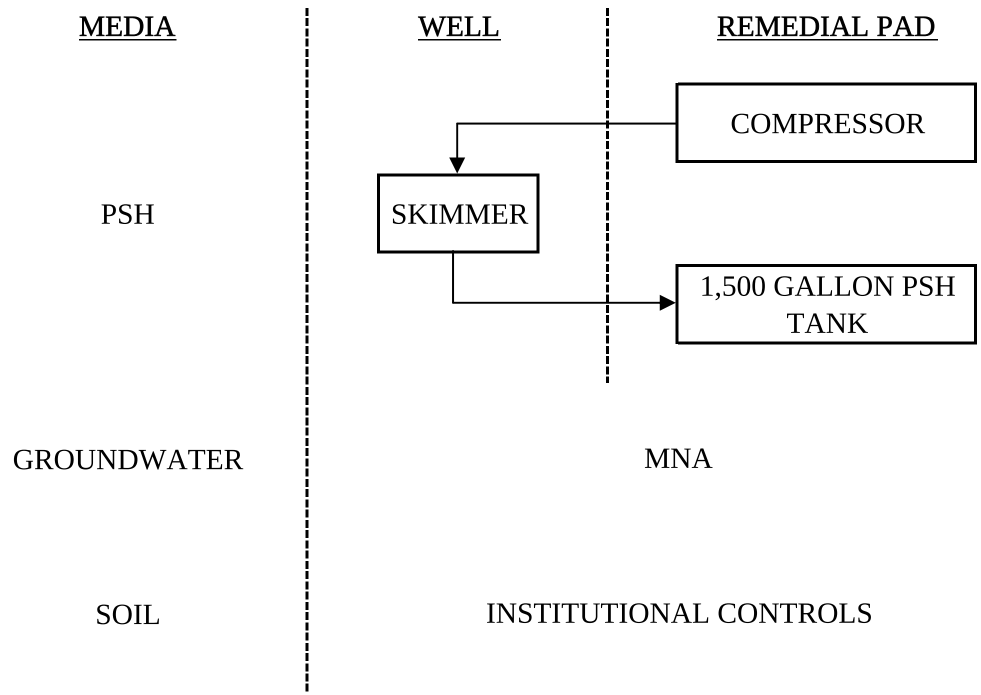
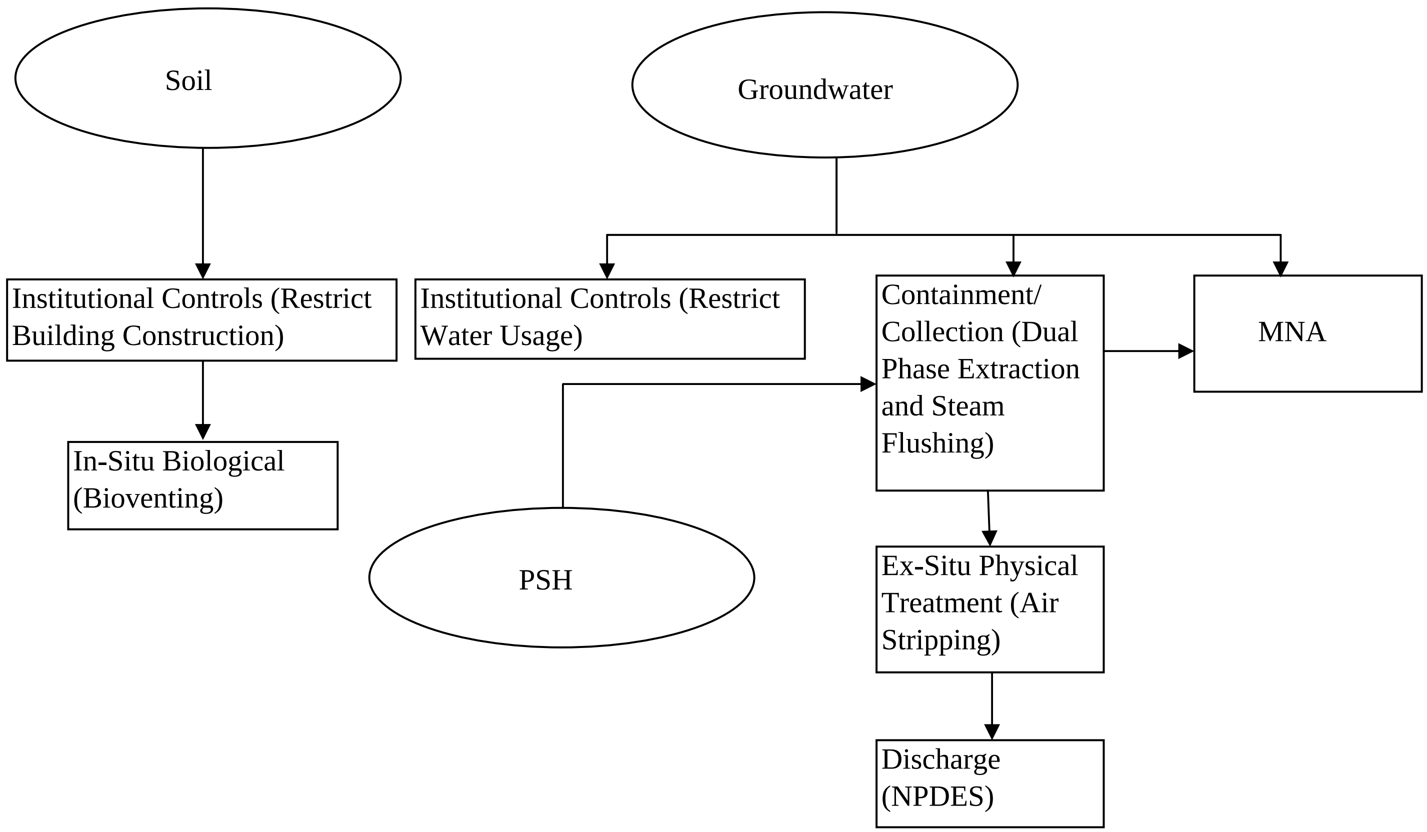


FIGURE 2-4

Revised: November 8, 2004

ALTERNATIVE 2 PROCESS FLOW DIAGRAM
CORRECTIVE MEASURES STUDY--FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO



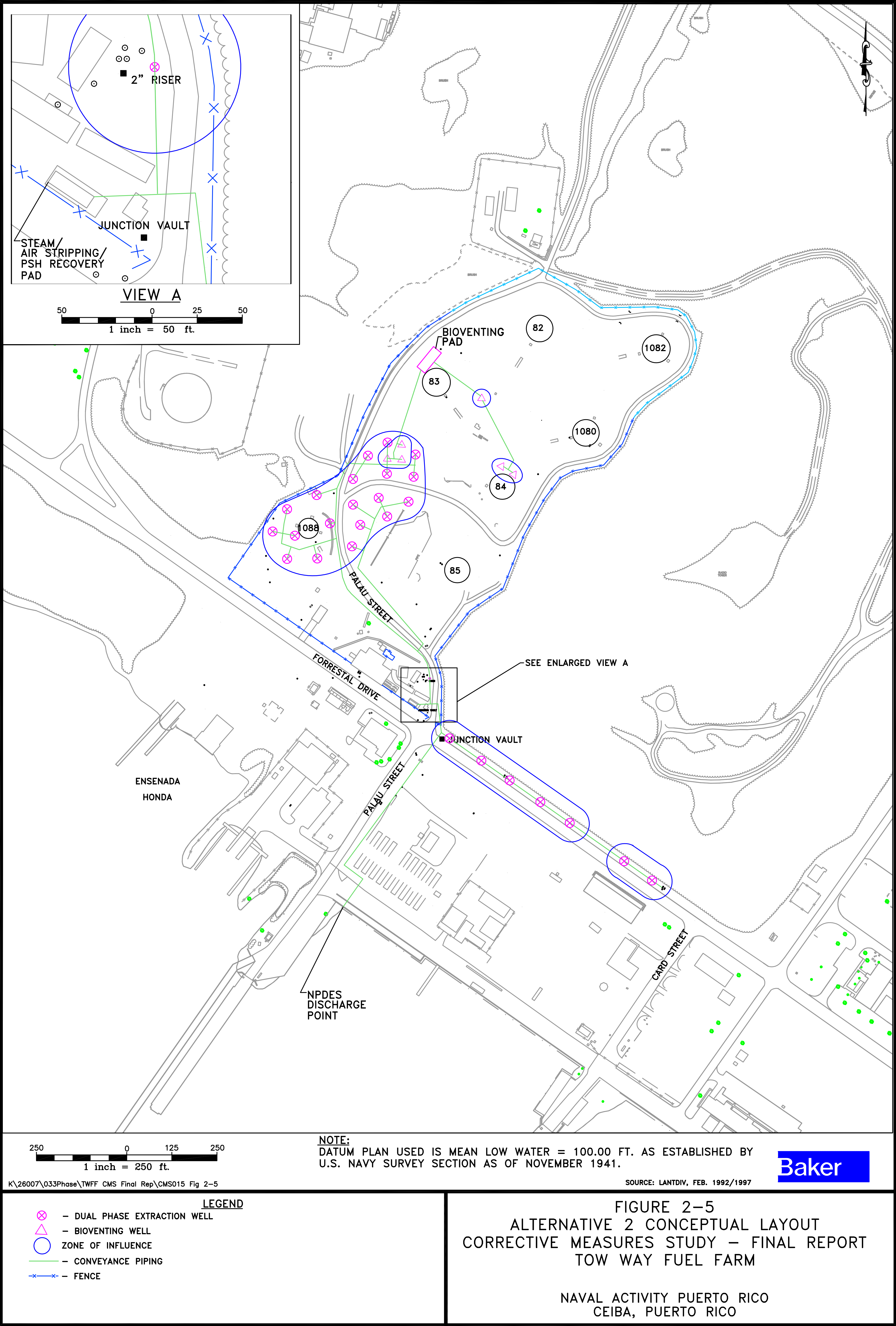


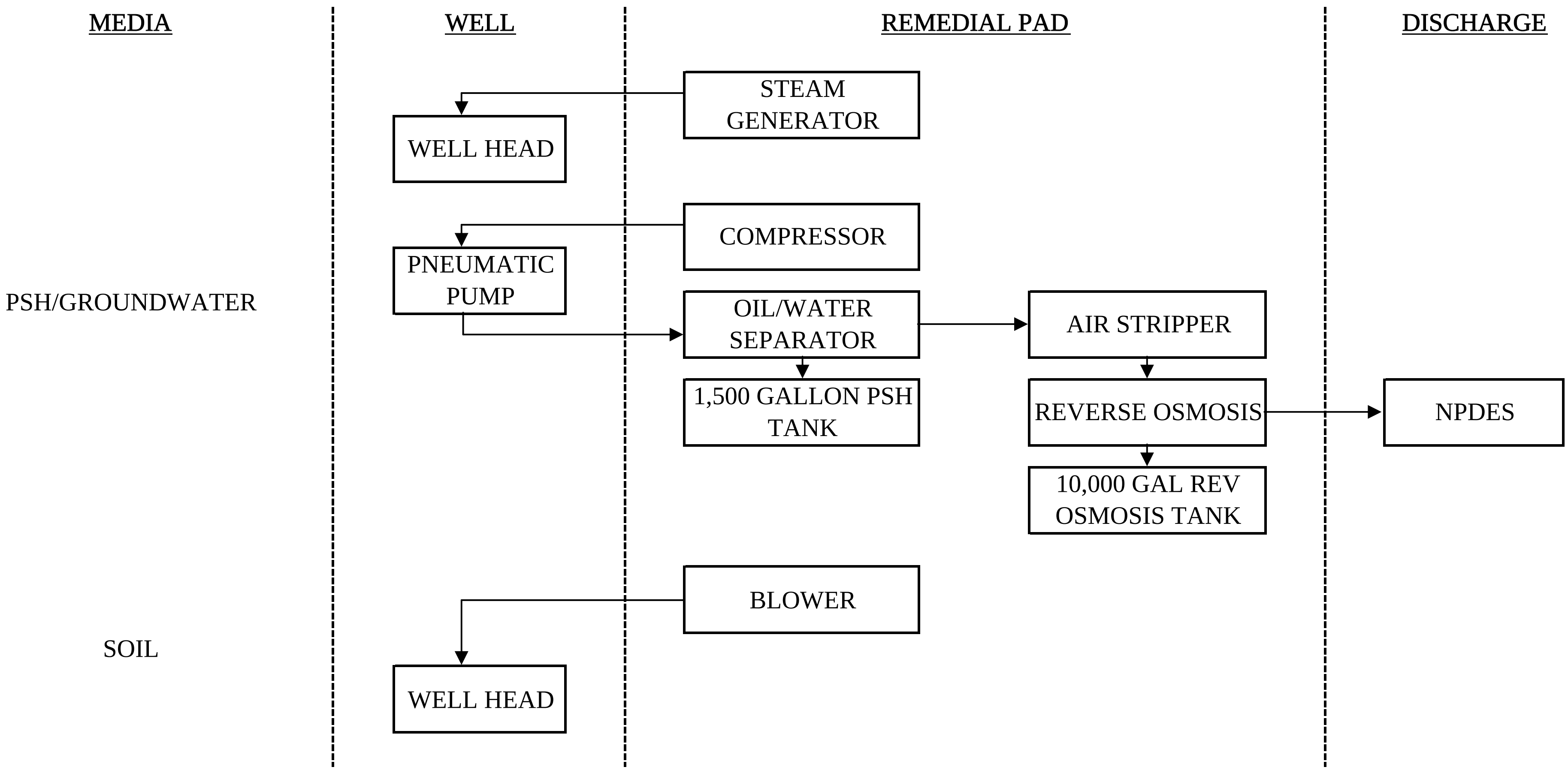
FIGURE 2-5
ALTERNATIVE 2 CONCEPTUAL LAYOUT
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

FIGURE 2-6

Revised: November 8, 2004

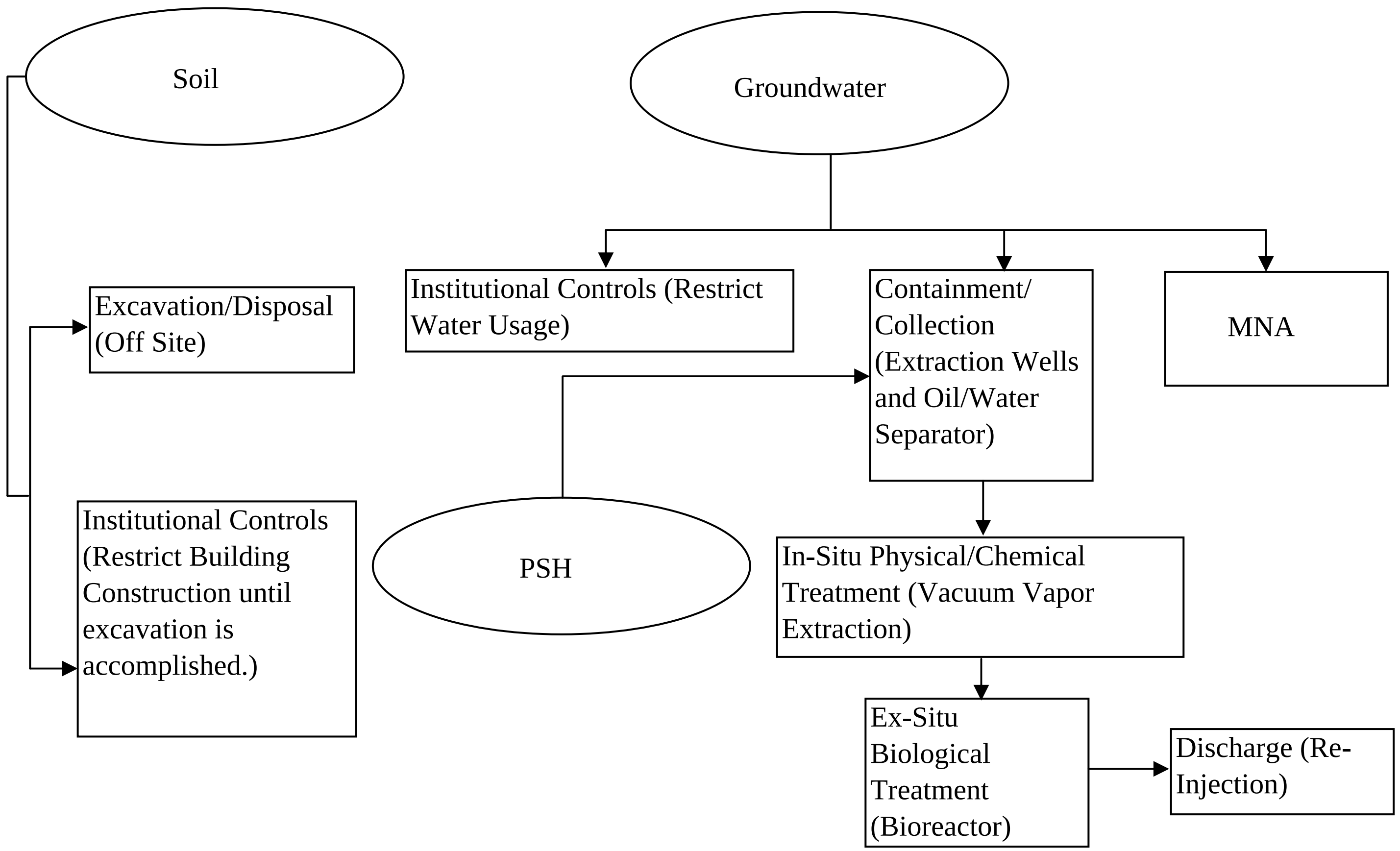
ALTERNATIVE 2 CONCEPTUAL COMPONENT LAYOUT
CORRECTIVE MEASURES STUDY--FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

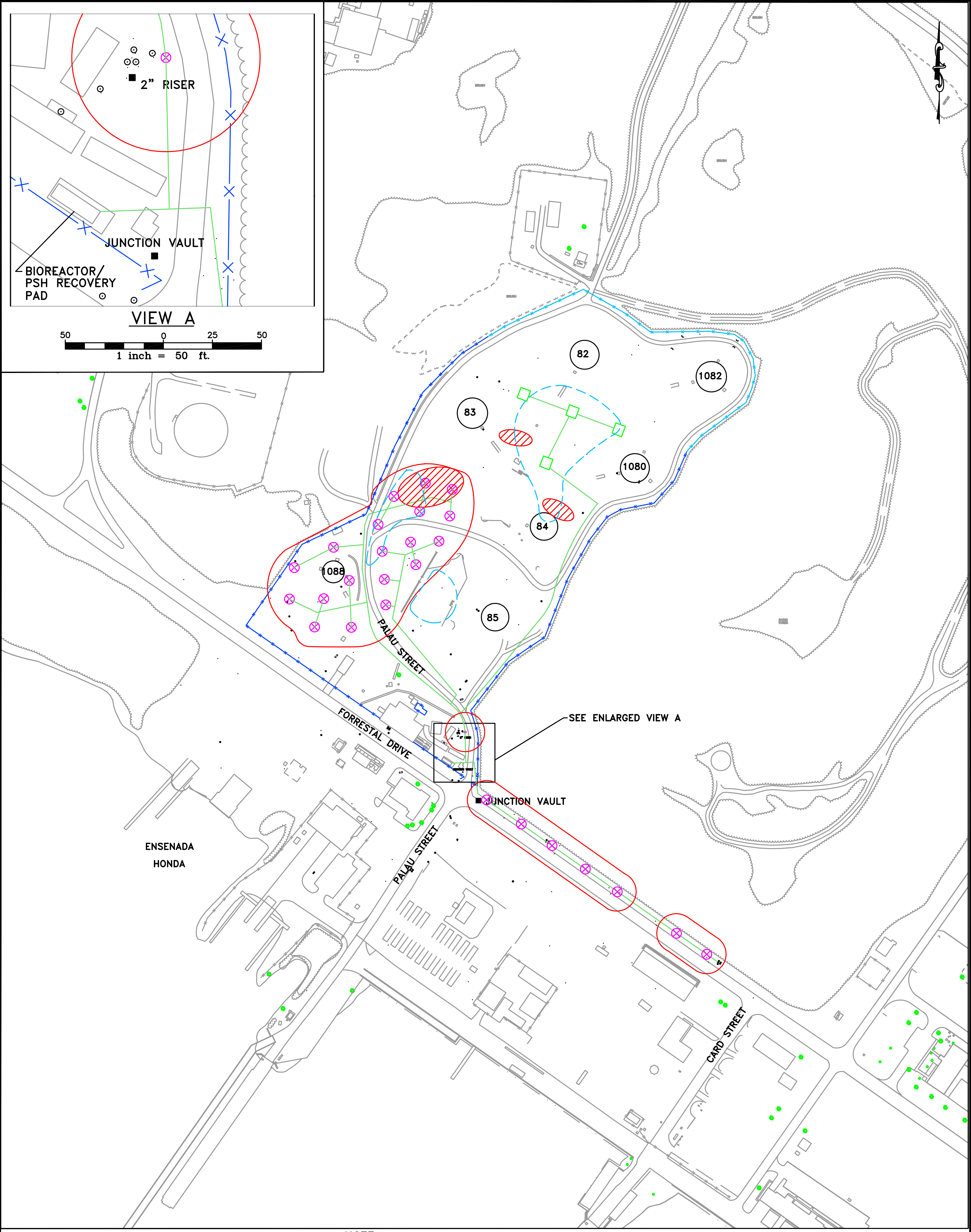


Revised: August 29, 2005

FIGURE 2-7

ALTERNATIVE 3 PROCESS FLOW DIAGRAM
CORRECTIVE MEASURES STUDY--FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO





NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

SOURCE: LANTDIV, FEB. 1992/1997

Baker

K\26007\033Phase\TWFF CMS Final Rep\CMS019 Fig 2–8

LEGEND

- PAH EXCAVATION AREA
- ARSENIC EXCAVATION AREA
- REINJECTION WELL
- VACUUM VAPOR EXTRACTION/GROUNDWATER EXTRACTION WELL
- ZONE OF INFLUENCE
- CONVEYANCE PIPING
- FENCE

FIGURE 2–8
ALTERNATIVE 3 CONCEPTUAL LAYOUT
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

Revised: August 29, 2005

FIGURE 2-9

ALTERNATIVE 3 CONCEPTUAL COMPONENT LAYOUT
CORRECTIVE MEASURES STUDY--FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

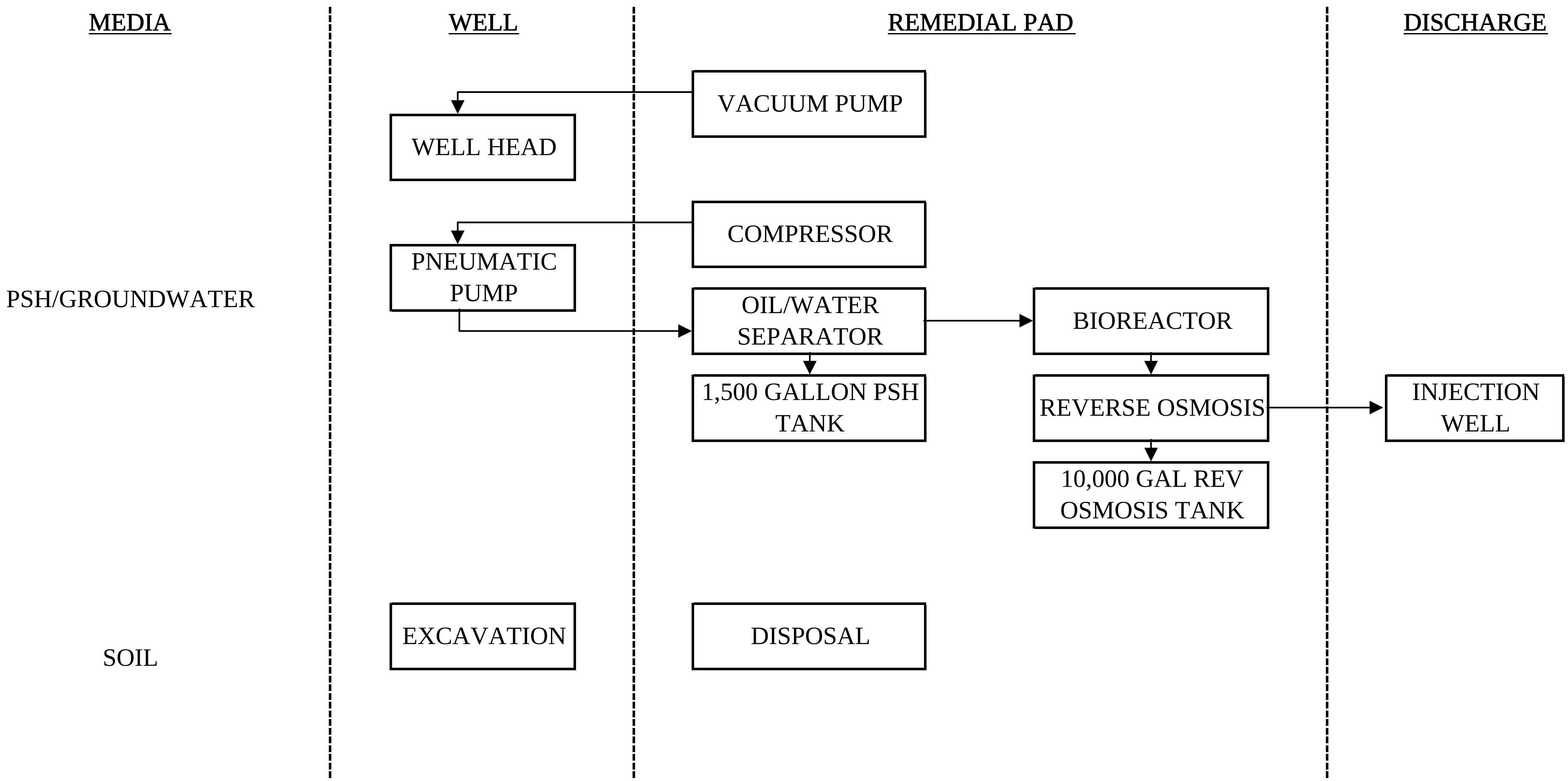
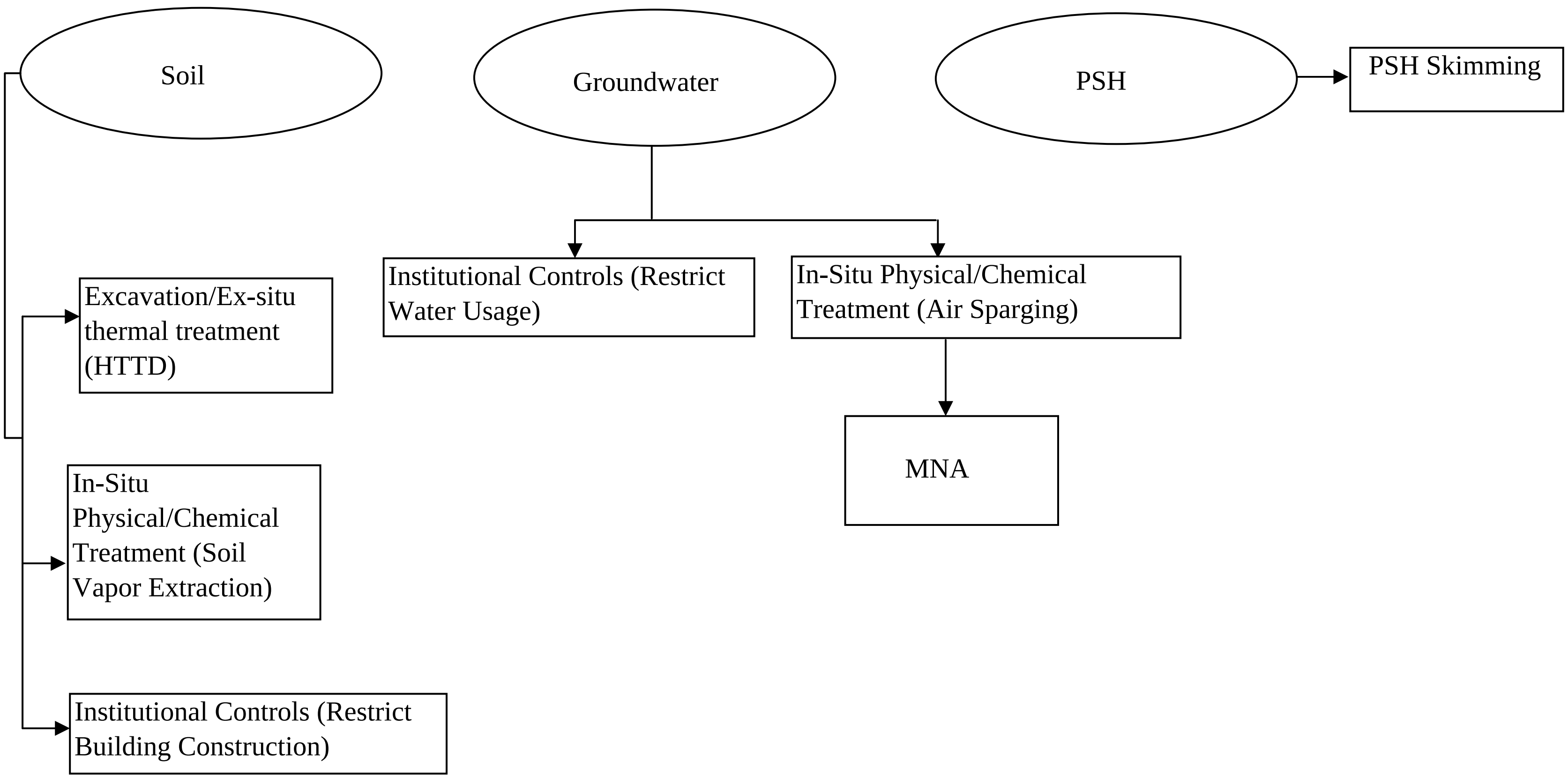
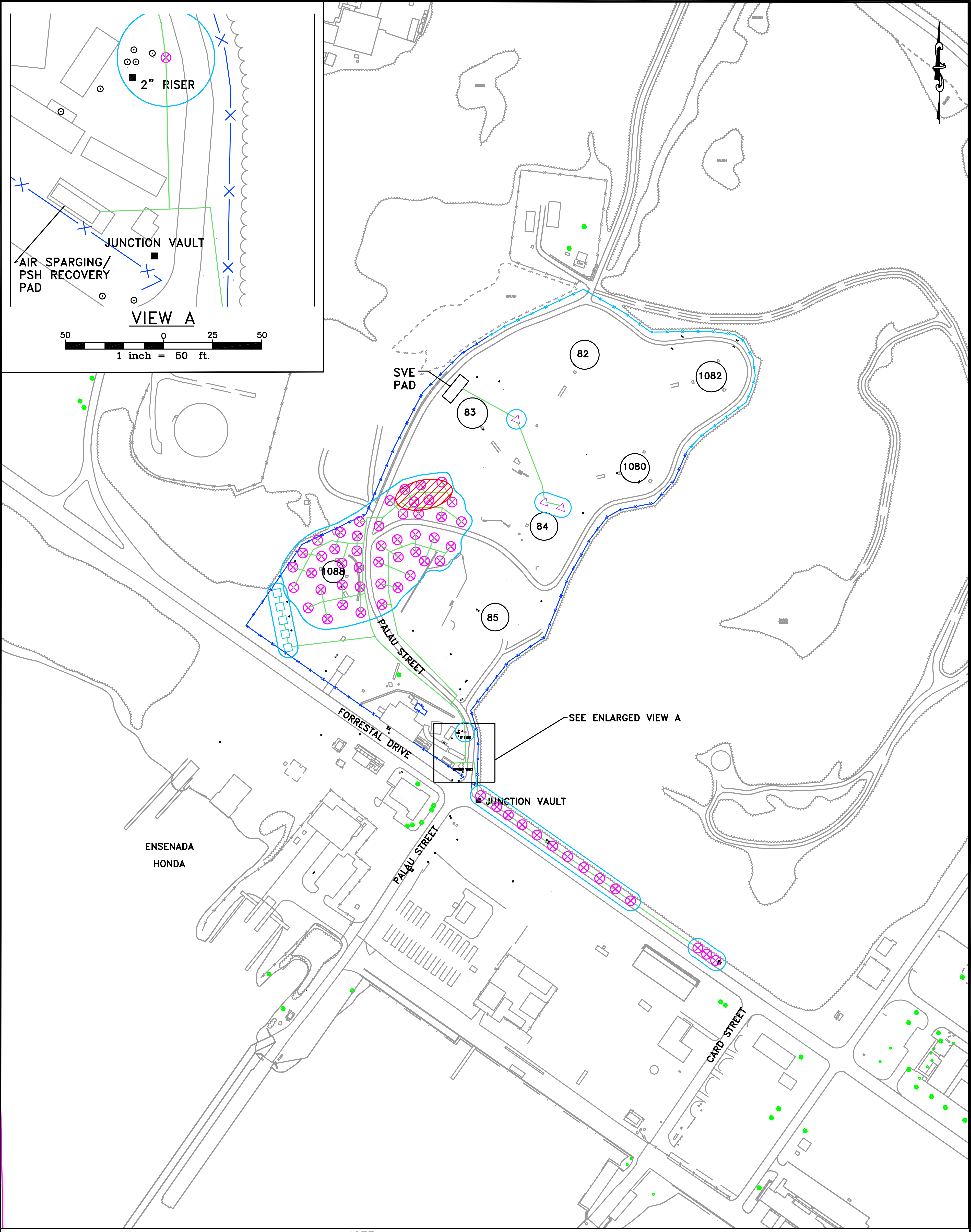


FIGURE 2-10

Revised: November 8, 2004

ALTERNATIVE 4 PROCESS FLOW DIAGRAM
CORRECTIVE MEASURES STUDY--FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO





250 0 125 250
1 inch = 250 ft.

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

SOURCE: LANTDIV, FEB. 1992/1997

Baker

K\26007\033Phase\TWFF CMS Final Rep\CMS017 Fig 2-11

LEGEND
- △ – SOIL VAPOR EXTRACTION (SVE) WELL
- □ – AIR SPARGING WELL
- ⊗ – PSH RECOVERY WELL
- ○ – ZONE OF INFLUENCE
- HTTD EXCAVATION AREA
- CONVEYANCE PIPING
- FENCE

FIGURE 2-11
ALTERNATIVE 4 CONCEPTUAL LAYOUT
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

FIGURE 2-12

Revised: November 8, 2004

ALTERNATIVE 4 CONCEPTUAL COMPONENT LAYOUT
CORRECTIVE MEASURES STUDY--FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

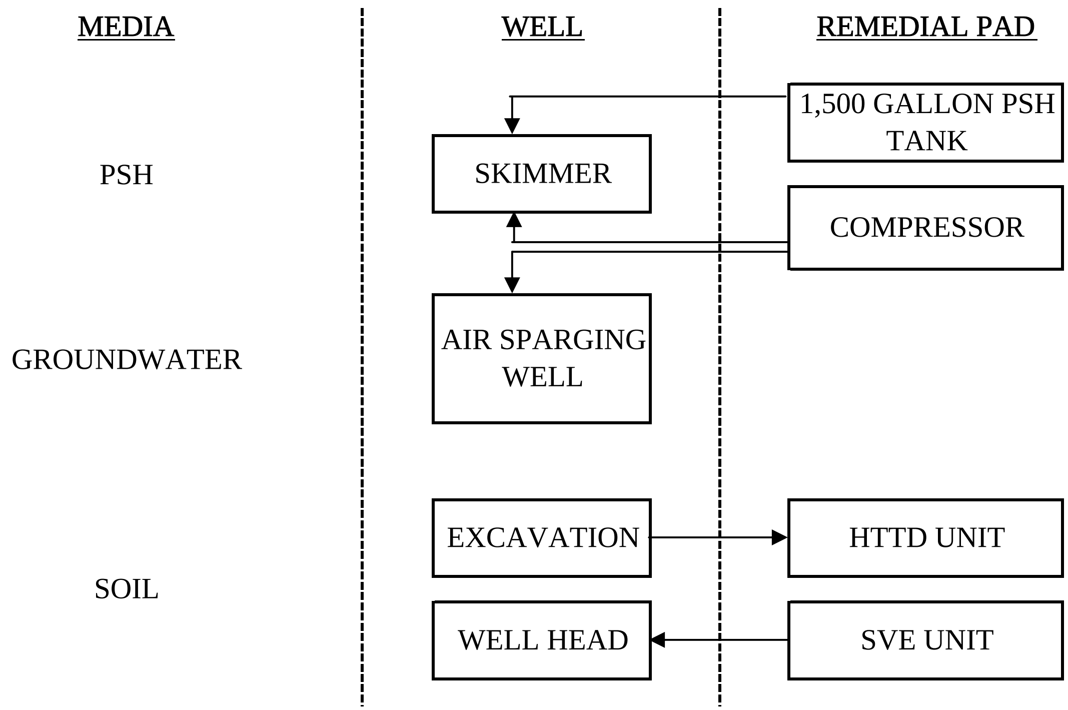
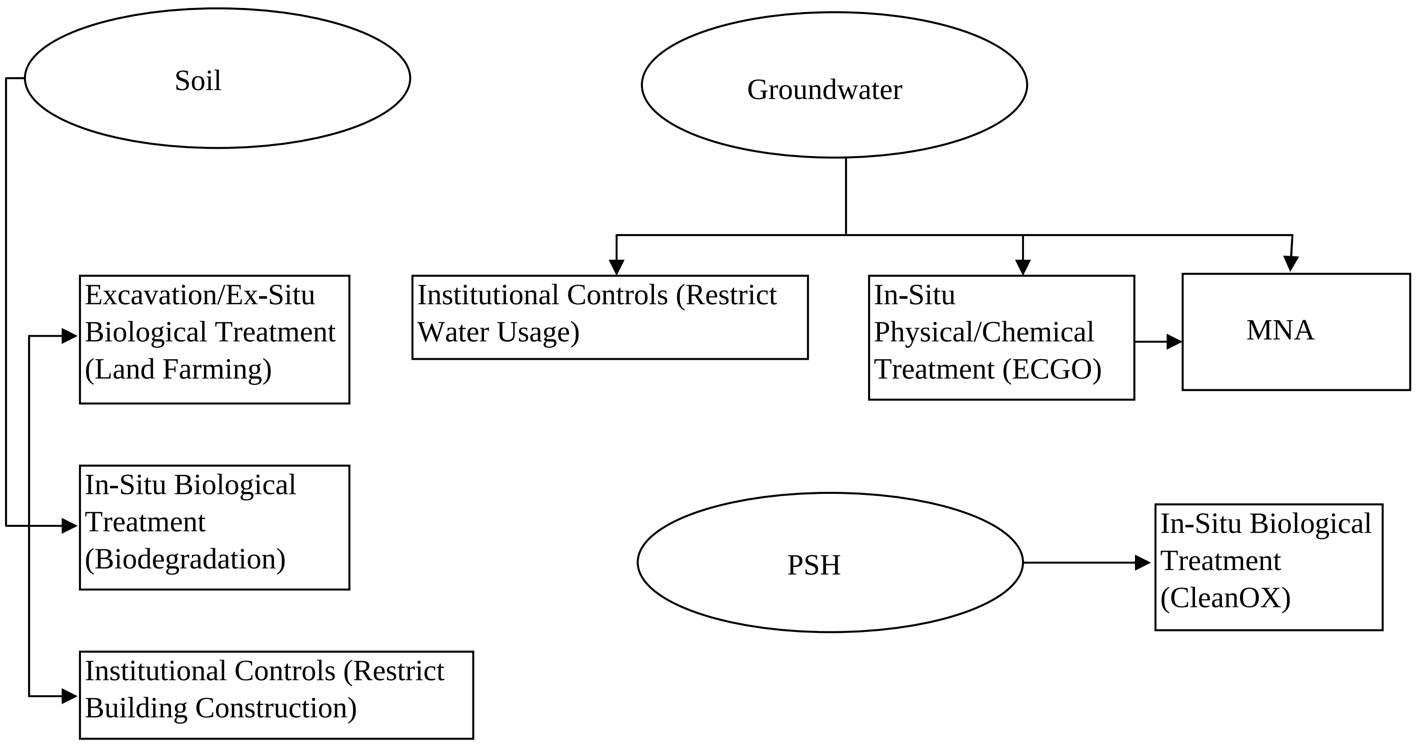
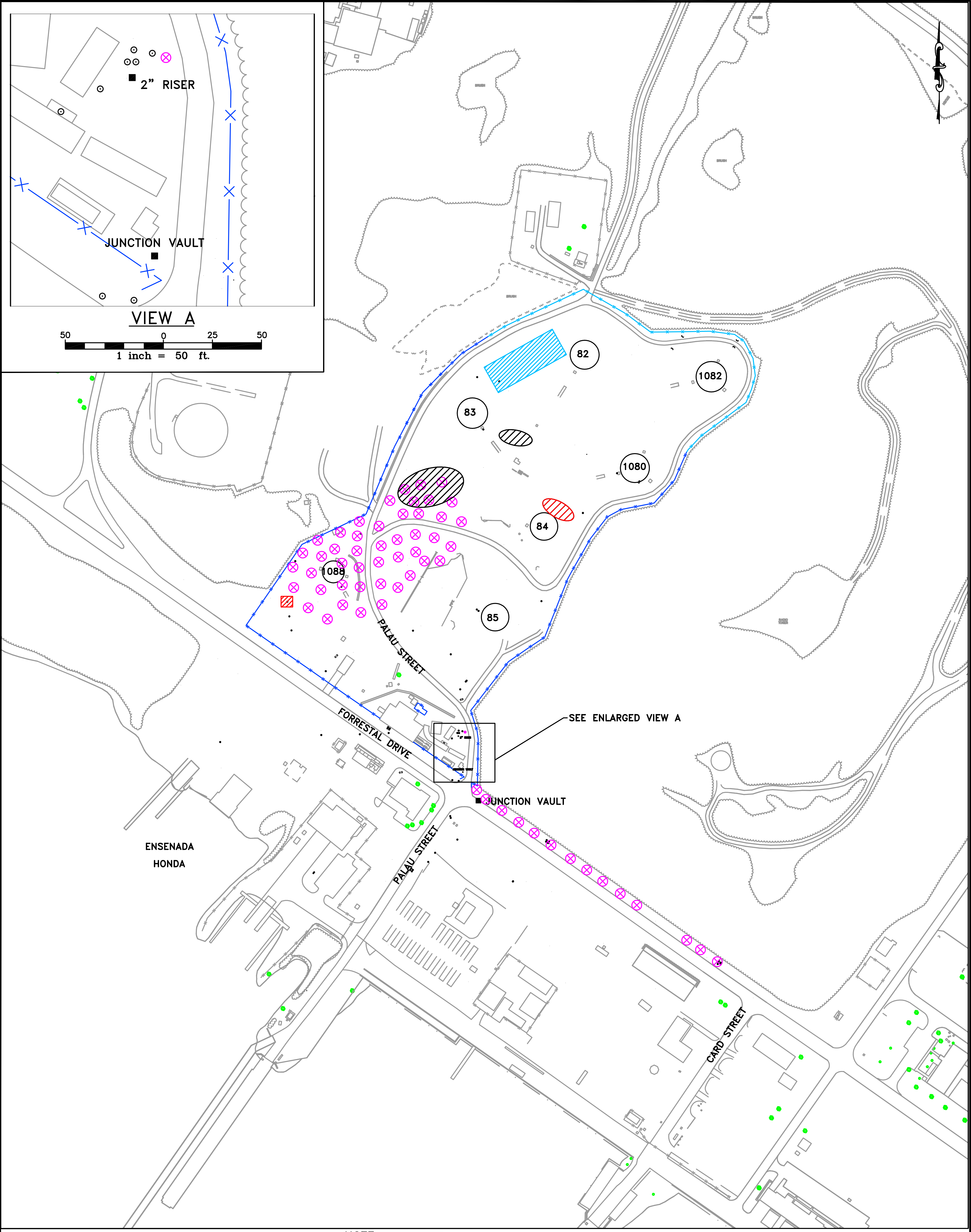


FIGURE 2-13

Revised: November 8, 2004

ALTERNATIVE 5 PROCESS FLOW DIAGRAM
CORRECTIVE MEASURES STUDY--FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO





NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

SOURCE: LANTDIV, FEB. 1992/1997

Baker

K\26007\033Phase\TWFF CMS Final Rep\CMS018 Fig 2-14

LEGEND
- ECGO GROUNDWATER TREATMENT AREA
- LAND FARMING AREA
- EXCAVATION AREAS FOR LAND FARMING
- IN-SITU BIOLOGICAL TREATMENT AREA
- CLEAN OX WELL
- FENCE

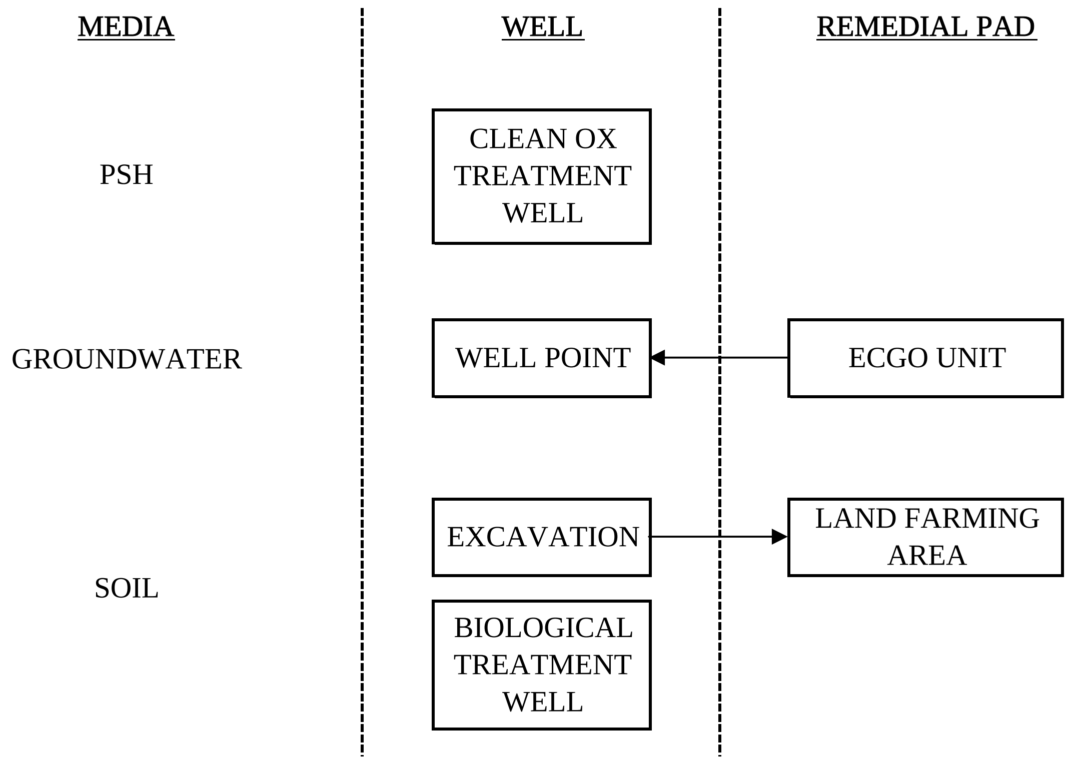
FIGURE 2-14
ALTERNATIVE 5 CONCEPTUAL LAYOUT
CORRECTIVE MEASURES STUDY – FINAL REPORT
TOW WAY FUEL FARM

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

Revised: November 8, 2004

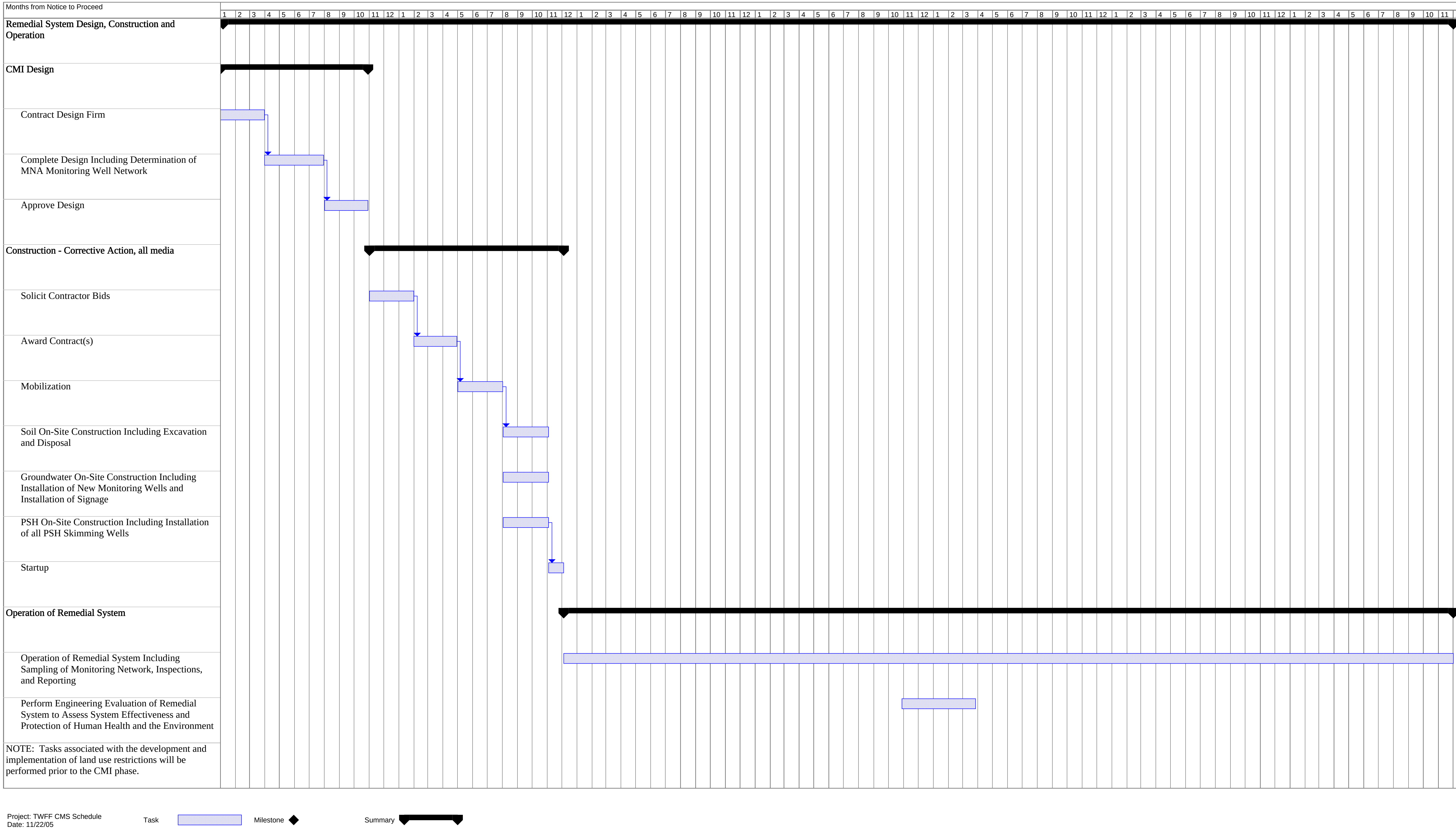
FIGURE 2-15

ALTERNATIVE 5 CONCEPTUAL COMPONENT LAYOUT
CORRECTIVE MEASURES STUDY--FINAL REPORT
TOW WAY FUEL FARM
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO



Revised: November 22, 2005

FIGURE 3-1
Corrective Measure Proposed Schedule
Corrective Measures Study - Final Report
Tow Way Fuel Farm
Naval Activity Puerto Rico, Ceiba, Puerto Rico



Project: TWFF CMS Schedule
Date: 11/22/05

APPENDICIES

APPENDIX A
ADDITIONAL ZINC DATA COLLECTION INVESTIGATION REPORT

Final

Additional Zinc Data Collection Investigation Report
Tow Way Fuel Farm
Naval Activity Puerto Rico
RCRA/HSWA Permit No. PR2170027203
Ceiba, Puerto Rico

Prepared For

Department of the Navy

Naval Facilities Engineering Command

Atlantic Division

Norfolk, Virginia

Under the

LANTDIV CLEAN Program

Contract No. N62470-95-D-6007

CTO-0033

August 29, 2005

Prepared by

CH2M HILL

Baker
Environmental, Inc.

CDM
Federal Programs Corp.

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LIST OF ACRONYMS AND ABBREVIATIONS

Baker	Baker Environmental, Inc.
bgs	below ground surface
CMS	Corrective Measures Study
COC	Chemical of Concern
COPC	Chemical of Potential Concern
CTO	Contract Task Order
EPA	Environmental Protection Agency
ERA	Ecological Risk Assessment
LANTDIV	United States Navy, Atlantic Division
mg/kg	milligrams per kilogram
NSRR	Naval Station Roosevelt Roads
NFESC	Naval Facilities Engineering Command
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SOP	Standard Operating Procedures
STL	Severn Trent Laboratories
SWMU	Solid Waste Management Unit
TWFF	Tow Way Fuel Farm
UCL	Upper Confidence Limit

1.0 INTRODUCTION

This document presents results from the Additional Zinc Data Collection Investigation performed during September 2003, for Solid Waste Management Unit (SWMU) 7/8, Naval Station Roosevelt Roads (NSRR), Ceiba, Puerto Rico. This report is prepared under the Corrective Action provisions of the NSRR's Resource Conservation and Recovery Act (RCRA) Permit No. PR 2170027203. Baker Environmental, Inc. (Baker) has prepared this report under contract to the Atlantic Division, Naval Facilities Engineering Command (LANTDIV) Contract Number N62470-95-D-6007, Contract Task Order (CTO) 033.

The Final Corrective Measures Study (CMS) Task I Report (Baker, 2003a) identified zinc in the surface soil as a chemical of potential concern (COPC) at the Tow Way Fuel Farm (TWFF). The ecological risk assessment (ERA) identified zinc in surface soil boring 7MW17-00 at 290 mg/kg, which was above the ERA plant screening value of 50 mg/kg. This surface soil sample was collected from a surface run-off depositional area (depression) south of Tank No. 83. The recommendation from the CMS called for additional samples to be collected in the swale, down gradient of 7MW17.

On September 16, 2003, Baker field personnel collected three surface soil samples and one duplicate immediately down gradient of 7MW17. The surface soil samples (7SS01, 7SS02, 7SS03, AND 7SS03D) at the TWFF were acquired following the appropriate Baker Standard Operating Procedures (SOPs) mentioned in the EPA approved 1995 RCRA Facility Investigation (RFI) Work Plan (Baker, 1995). Figure 1-1 presents these surface soil sampling locations along with locations of all samples used in the ecological risk assessment. Surface soil samples were collected using a decontaminated stainless steel spoon. Prior to sample collection, vegetation (grass and roots) was removed from the location. Samples were obtained to a depth of one foot below ground surface (bgs) as required by Environmental Protection Agency (EPA) Region II guidelines. Surface soil samples collected for inorganic analysis were placed on to a disposable tin pan and homogenized prior to placement into their respective containers. Samples were kept in coolers on ice and listed on a chain-of-custody record until delivered to the laboratory. The chain-of-custody form is provided in Appendix A. The samples were sent by overnight delivery to Severn Trent Laboratories (STL) for zinc analysis using EPA method 6010, inductively coupled plasma.

2.0 ANALYTICAL RESULTS

Results of the analyses performed on the surface soil samples collected on September 16, 2003 are presented in Table 2-1. As evidenced by the table, zinc was detected in each sample, with concentrations ranging from 79.2J milligrams per kilogram (mg/kg) in 7SS01 to a high of 216J mg/kg in 7SS03. Historical zinc data used in the CMS Report for SWMU 7/8 are presented in Table 2-2. Zinc concentrations in the historical data set ranged from 48J mg/kg in 7SB25-00 to 290 mg/kg in 7MW17-00. Figure 1-1 presents the concentration distribution of zinc across SWMU 7/8. The ecological significance of the zinc data presented in Tables 2-1 and 2-2 and Figure 1-1 is presented in Section 3.0.

3.0 CONCLUSIONS AND RECOMMENDATIONS

Inclusion of the September 2003 surface soil data with the existing surface soil data for SWMU 7/8 results in a mean surface soil concentration of 86.5 mg/kg. As evidenced by the surface soil HQ value of 1.73, the mean zinc concentration is only slightly elevated above the surface soil screening value of 50 mg/kg (toxicological threshold for plants from Efroymson et. al 1997a). The mean zinc concentrations is also only slightly elevated above the mean base background, SWMU 9 background, and combined background mean concentrations of 62.3 mg/kg, 52.6 mg/kg, and 57.0 mg/kg, respectively.

The distribution of zinc detections across the site indicates that elevated concentrations are isolated within the run-off swale downgradient from surface soil sample location 8SS01. Of the four surface soil samples collected within the run-off swale, three had zinc concentrations greater than the maximum base background concentration (106 mg/kg). Specific concentrations detected above the maximum base background concentration were 290 mg/kg in 7MW17-00, 127J mg/kg in 7SS02, and 216J mg/kg in 7SS03. A total of seven surface soil samples were previously collected downgradient from the run-off swale (7SB01, 7SB24, 7SB25, 7SB26, 7MW01, 7MW02, and 7MW16). Zinc concentrations in these seven samples ranged from 48J mg/kg in sample 7SB25-00 to 79.8 J mg/kg in 7MW02-00. All detections were below the maximum base background concentration of 106 mg/kg.

To evaluate the significance of zinc detections in surface soil, analytical data for this metal were compared statistically to available base background surface soil concentrations and a combined background database consisting of base background data and SWMU 9 background data in accordance with Navy guidance (NFESC 2002). Note that the comparability of base background data and SWMU 9 background data was previously demonstrated in the EPA approved Final CMS Investigation report for SWMU 9 (Baker 2003b). Table 3-1 presents a summary and results of the descriptive, distributional, and proportional statistics comparing the SWMU 7/8 surface soil data and background data. Figure 3-1 presents box plot diagrams illustrating the distribution of each data set in relation to the screening value used in the exposure estimate (note that the mean base background concentration [62.6 mg/kg] and mean background concentrations of the combined background data set [57.0 mg/kg] exceed the plant-based toxicological threshold). As evidenced by Table 3-1 and Figure 3-1, the distributional statistics performed on the SWMU data and base background data (mean of the distribution [Wilcoxon Rank-Sum Test] and right tail of the distribution [Slippage Test]) indicate that zinc concentrations at SWMU 7/8 are statistically equivalent to base background concentrations. However, the statistical evaluation of the SWMU 7/8 data and combined background data are inconclusive. The Wilcoxon Rank-Sum Test indicates that zinc concentrations are elevated above background at an alpha of 0.05, while the Quantile Test and Slippage Test indicate that SWMU 7/8 concentrations are statistically equivalent to the combined background data set.

It is noted that the terrestrial habitat at SWMU 7/8, including the run-off swale, consists of manicured grasses. Given the quality of habitat for terrestrial vegetation, a more appropriate screening value for media-specific screening would be an invertebrate-based toxicological threshold. Efroymson et al. 1997b reported a toxicological threshold for terrestrial invertebrates equal to 200 mg/kg. The mean SWMU 7/8 surface soil concentration (86.5 mg/kg), as well as the 95 percent upper confidence limit (UCL) of the mean (107.3 mg/kg) are well below the invertebrate-based toxicological threshold reported by Efroymson et. al (1997b). There is uncertainty related to the 7MW17-00 and 7SS03 zinc detections (290 mg/kg and 216J mg/kg). Both samples were duplicated in the field. The duplicate result for 7MW17-00 was 95J mg/kg, while the duplicate result for 7SS03 was 137J mg/kg. Both duplicate results are less than the invertebrate toxicological threshold.

Based on mean concentrations only slightly elevated above a conservative plant-based toxicological threshold, the distribution of zinc detections across the site, the statistical comparison of SWMU 7/8 zinc data to base background data and the combined background data, and the quality of habitat at SWMU 7/8 relative to terrestrial vegetation, zinc is not considered a potential risk driver for SWMU 7/8 surface soil and development of a CAO is not warranted.

4.0 REFERENCES

Baker Environmental Inc. (Baker), 1995. Final RCRA Facility Investigation, Naval Station Roosevelt Roads, Puerto Rico. September 14, 1995. Coraopolis, Pennsylvania.

Baker. 2003a. Final Corrective Measures Study Task I Report, Naval Station Roosevelt Roads, Ceiba, Puerto Rico. April 22, 2003.

Baker. 2003b. Final Corrective Measures Study Investigation Report for SWMU 9, Naval Station Roosevelt Roads, Ceiba, Puerto Rico. April 25, 2003. Coraopolis, Pennsylvania.

Efroymson, R.A., Will, M.E., and Suter II, G.W., and Wooten, A.C. (1997a). Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. (ES/ER/TM-85/R3).

Efroymson, R.A., Will, M.E., and Suter II, G.W. (1997b). Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. (ES/ER/TM-126/R2).

Naval Facilities Engineering Command (NFESC). 2002. Guidance for Environmental Background Analysis. Volumn I: Soil. NFESC User's Guide UG-209-ENV. April 2002

TABLES

TABLE 2-1

SUMMARY OF INORGANIC DETECTIONS IN SURFACE SOIL
TWFF - ADDITIONAL ZINC DATA COLLECTION INVESTIGATION
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Site ID	7SS01	7SS02	7SS03	7SS03D
Sample ID	7SS01	7SS02	7SS03	7SS03
Sample Date	09/16/03	09/16/03	09/16/03	09/16/03
Metals - Total (mg/kg)				
Zinc	72.9 J	127 J	216 J	137 J

Notes:
mg/kg - milligrams per kilogram.
J - Estimated value.
U - Not Detected.

TABLE 2-2

SUMMARY OF INORGANIC DETECTIONS IN SURFACE SOIL
TWFF - ADDITIONAL ZINC DATA COLLECTION INVESTIGATION
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Sample ID	7MW01-00	7MW02-00	7MW03-00	7MW04-00	7MW16-00	7MW17-00	7MW18-00	7MW19-00	7SB01-00	7SB02-00	7SB03-00
Site ID	7MW01	7MW02	7MW03	7MW04	7MW16	7MW17	7MW18	7MW19	7SB01	7SB02	7SB03
Sample Depth (ft.)	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0
Sample Date	3/27/1996	3/21/1996	3/21/1996	3/21/1996	1/15/2002	1/16/2002	1/29/2002	1/30/2002	3/21/1996	3/21/1996	3/21/1996
Metals - Total (mg/kg)											
Zinc	54.2 J	79.8 J	51.3 J	52.5 J	60	290	83 J	56 J	64.4 J	52.6 J	59.8 J

Notes:
mg/kg - milligrams per kilogram.
J - Estimated value.
U - Not Detected.

TABLE 2-2

SUMMARY OF INORGANIC DETECTIONS IN SURFACE SOIL
TWFF - ADDITIONAL ZINC DATA COLLECTION INVESTIGATION
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Sample ID	7SB23-00	7SB24-00	7SB25-00	7SB26-00	7SB27-00	7SB28-00	7SB29-00	7SB30-00	8SS01	8SS02	8SS03	8SS04
Site ID	7SB23	7SB24	7SB25	7SB26	7SB27	7SB28	7SB29	7SB30	8SS01	8SS02	8SS03	8SS04
Sample Depth (ft.)	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0
Sample Date	1/23/2002	1/23/2002	1/24/2002	1/24/2002	1/12/2002	1/22/2002	1/12/2002	1/12/2002	4/4/1996	4/4/1996	4/4/1996	4/4/1996
Metals - Total (mg/kg)												
Zinc	78 J	54 J	48 J	74 J	85	96 J	74	73	NA	NA	NA	NA

Notes:
mg/kg - milligrams per kilogram.
J - Estimated value.
U - Not Detected.

TABLE 3-1

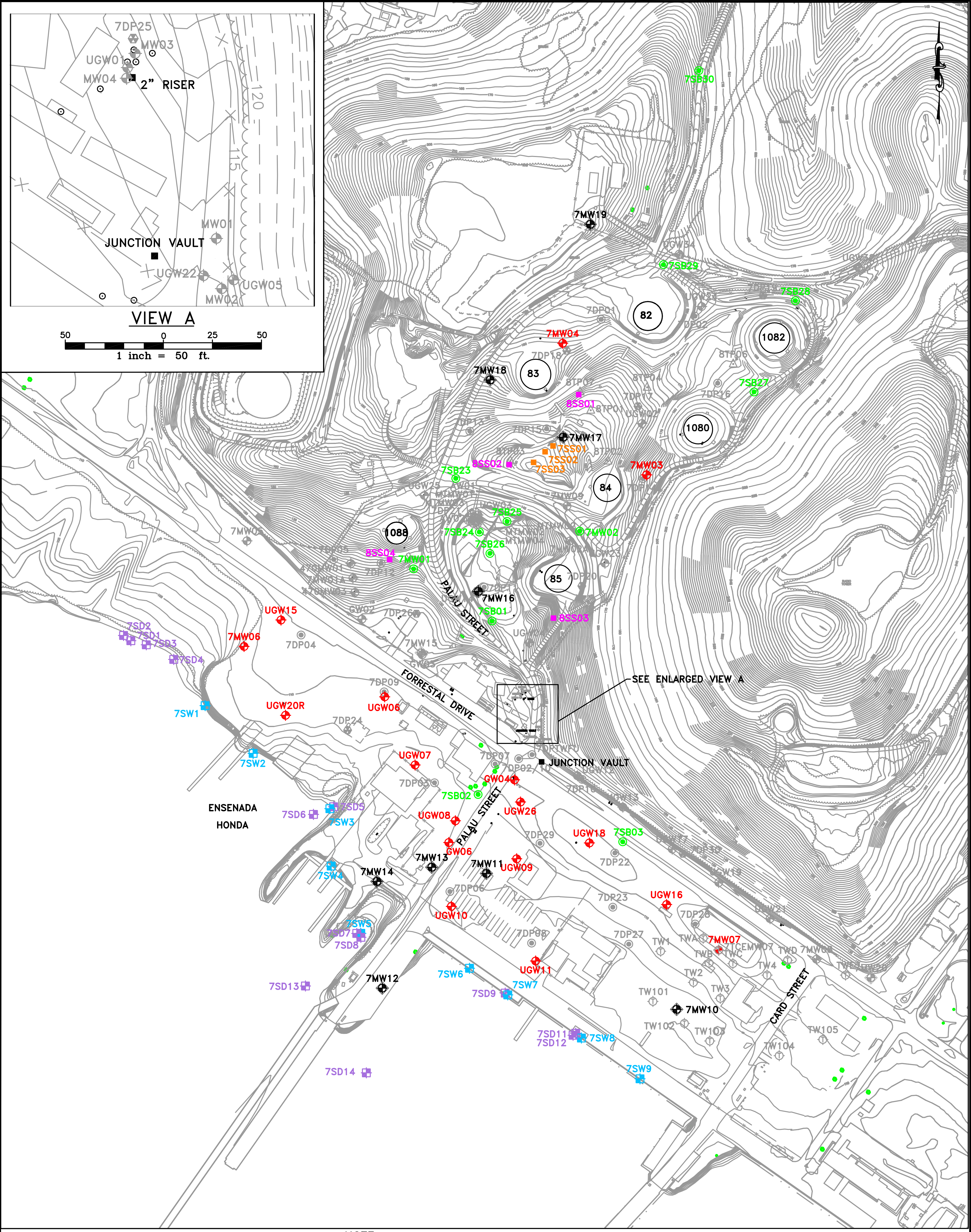
SUMMARY STATISTICS AND RESULTS - SURFACE SOIL
TWFF - ADDITIONAL ZINC DATA COLLECTION INVESTIGATION INVESTIGATION
NAVAL STATION ROOSEVELT ROADS< CEIBA< PUERTO RICO

Chemical[1]	SSSV[2]	Population	Descriptive Statistics					Distributional Statistics[4]		
								Mean of the Distribution[5]	Right Tail of the Distribution[6]	
			Frequency of Detection	Range of Detections	Mean[3]	SE	95% UCL		Quantile Test	Slippage Test
Zinc	50	SWMU 7/8	22/22	48J - 290	86.45	12.37	107.73	WRS, p=0.1432, Not a COPC	---	Not a COPC
		Base Background	4/4	34.2J - 106J	62.58	15.95	100.11			
Zinc	50	SWMU 7/8	22/22	48J - 290	86.45	12.37	107.73	WRS, p=0.0165, COPC	Not a COPC	Not a COPC
		Combined Background	9/9	34.2J - 106J	57.03	7.31	70.63			

Notes:
1 All units in mg/kg
2 Plant-based toxicological threshold.
3 Mean based on 1/2 non-detected values.
4 Unless otherwise noted, α=0.05.
5 Normality verified with Shapiro-Wilks test, Homogeneity of variance verified with F-test.
6 Quantile and Slippage tests only determines whether or not a particluar contaminant is likely a COPC.
If not likely, then there is insufficient evidence to conclude that it is a COPC.

SE = Standard Error
SSSV = Surface Soil Screening Value
WRS = Wilcoxon Rank-Sum Test
95% UCL = 95% Upper Confidence Limit of the Mean
--- = Indeterminate test due to size of data set

FIGURES



NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

SOURCE: LANTDIV, FEB. 1992/1997

Baker

K\26007\033Phase\Cad\RRoads\ Rr2033046

LEGEND

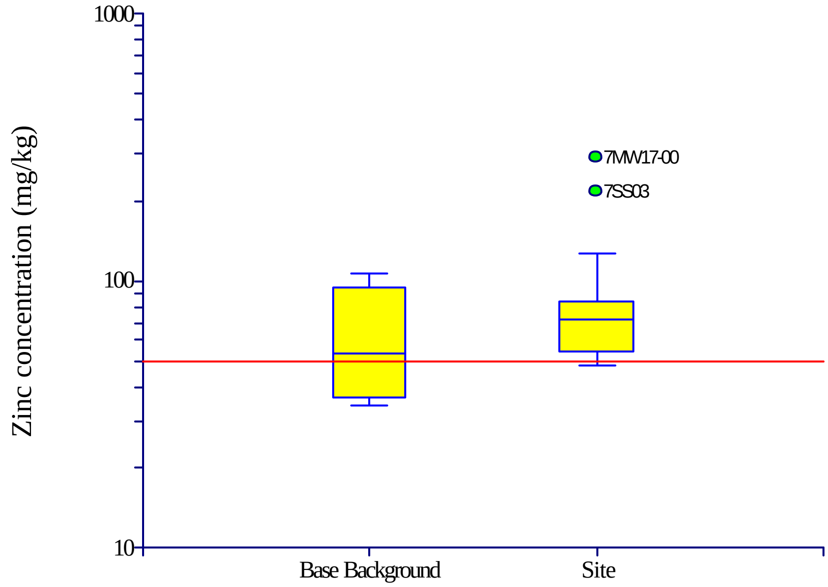
- NEW MONITOR WELL LOCATION
- MONITOR WELL LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- SURFACE SOIL LOCATION
- SURFACE SOIL LOCATION – SEPTEMBER 2003
- TEST PIT LOCATION
- SEDIMENT SAMPLE LOCATION
- SURFACE WATER SAMPLE LOCATION
- TEMPORARY MONITOR WELL LOCATION
- MANTECH MONITOR WELL
- MANTECH CLEANOx APPLICATION WELL

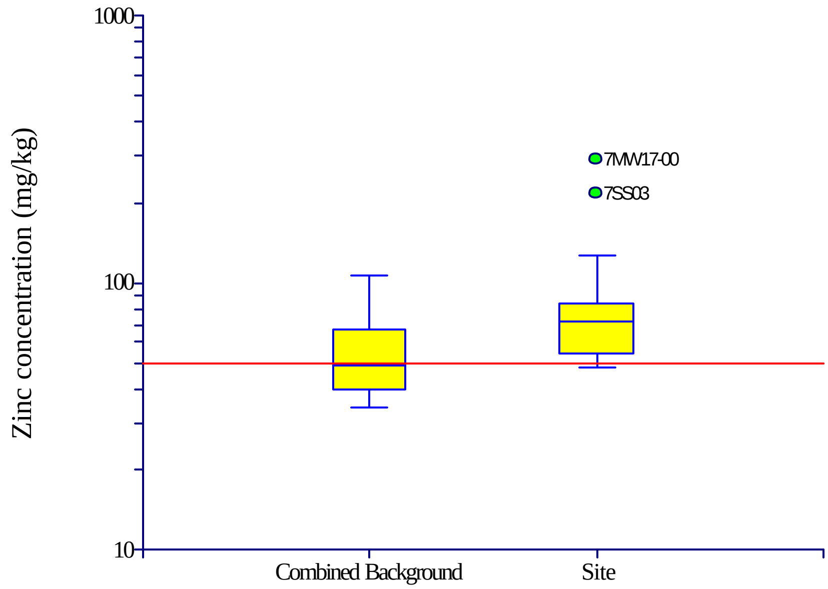
FIGURE 1–1
LOCATIONS OF SAMPLES USED IN ECOLOGICAL RISK ASSESSMENT
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

FIGURE 3-1

BOX PLOT COMPARISON OF SITE AND BACKGROUND SURFACE SOILS
TWFF – ADDITIONAL ZINC DATA COLLECTION INVESTIGATION
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO





Surface Soil Screening Value

Combined Background = Base Background and SWMU 9 Background

11/26/2003

APPENDIX A
CHAIN OF CUSTODY

Serial Number 06699

ANALYSIS REQUEST AND CHAIN OF CUSTODY RECORD

SEVERN TRENT **STL**

Mosbee Air Waybill #
8348 2976 2120

7-1

STL Savannah
5102 LaRoche Avenue
Savannah, GA 31404

Website: www.stl-inc.com
Phone: (912) 354-7858
Fax: (912) 352-0165

Alternate Laboratory Name/Location
Phone:
Fax:

PROJECT REFERENCE	SWMU 7
PROJECT NO.	CTO-268
PROJECT LOCATION (STATE)	PR
STL (LAB) PROJECT MANAGER	Angie Weimerskirk
P.O. NUMBER	
CONTRACT NO.	CLEAN II
CLIENT (SITE) PM	Jon Edel
CLIENT PHONE	(787) 485-1097
CLIENT FAX	(412) 375-3995
CLIENT NAME	Baker
CLIENT E-MAIL	mkimes@mbakercorp.com
CLIENT ADDRESS	100 Airside Drive, Moon Twp., PA 15108
COMPANY CONTRACTING THIS WORK (if applicable)	CH2M Hill
PAGE	1 OF 2
STANDARD REPORT DELIVERY	DATE DUE 28 Day TAT
EXPEDITED REPORT DELIVERY (SURCHARGE)	DATE DUE
NUMBER OF COOLERS SUBMITTED PER SHIPMENT:	

REQUIRED ANALYSIS / NUMBER OF CONTAINERS SUBMITTED

SAMPLE DATE	SAMPLE TIME	SAMPLE IDENTIFICATION	COMPOSITE (C) OR GRAB (G) INDICATE	AQUEOUS (WATER)	SOLID OR SEMISOLID	AIR	NONAQUEOUS LIQUID (OIL, SOLVENT,...)	APP. IX VOCs 5035/8260B	Solvent Screen EPA 8260	Interfacial Tension ASTM 1331A	Viscosity 50C ASTM D445	Ignitability SW846 1010/1030	Reactive Cyanide 7.3.3.2/7.3.4.2	Corrosivity 9040/9045	TCLP VOCs APP IX EPA 8260B	Zinc	Percent Moisture	REMARKS
PRESERVATIVE								Methanol NaSO4								—	—	
9-16-03	0943	7SS01	G		X											1		
9-16-03	0947	7SS02	G		X											1		
9-16-03	0955	7SS03	G		X											1		
9-16-03	0955	7SS03D	G		X											1		
9-16-03	0955	7SS03MS/MSD	G		X											1		
9-13-03	0944	7TCESB05-05	G		X			1/2									1	
9-13-03	1453	7TCESB08-05	G		X			1/2									1	
9-15-03	1543	7TCESB03-04	G		X			1/2									1	
9-13-03	0822	7TCESB08-02	G		X			1/2									1	
9-15-03	1533	7TCESB03-03	G		X			1/2									1	
9-16-03	0730	7TCETW201	G	X											3			*24 hour turn around*
9-16-03	0810	7TCETW203	G	X											3			*24 hour turn around*

RELINQUISHED BY: (SIGNATURE)	DATE	TIME	RELINQUISHED BY: (SIGNATURE)	DATE	TIME	RELINQUISHED BY: (SIGNATURE)	DATE	TIME
EMPTY CONTAINERS			Jon C. Edel Jr.	9-16-03	1423			
RECEIVED BY: (SIGNATURE)	**DATE**	**TIME**	**RECEIVED BY: (SIGNATURE)**	**DATE**	**TIME**	**RECEIVED BY: (SIGNATURE)**	**DATE**	**TIME**
EMPTY CONTAINERS Jon C. Edel Jr.	9/8/03	1000						

LABORATORY USE ONLY

RECEIVED FOR LABORATORY BY: (SIGNATURE)	DATE	TIME	CUSTODY INTACT	CUSTODY SEAL NO.	STL SAVANNAH LOG NO.	LABORATORY REMARKS
			YES / NO			

APPENDIX B
COST ESTIMATES

Revised: August 29, 2005

EVALUATION OF ALTERNATIVES SUMMARY SHEET
Tow Way Fuel Farm, Naval Activity Puerto Rico

Alternative	Cost
1	$3,334,526
2	$4,546,705
3	$7,381,243
4	$6,370,025
5	$7,407,689

Revised: August 29, 2005

ALTERNATIVE 1

ORDER OF MAGNITUDE COST ESTIMATE (1)
TOW WAY FUEL FARM, NAVAL ACTIVITY PUERTO RICO

Cost Item	Total Cost	Assumptions (Basis of Cost Estimate)
PSH Skimming	$1,923,138	Assumes PSH skimmers to be installed on 60 wells (2 portable skimmers), replacement of skimmers once each two years. Ten years of O&M.
Institutional Controls (2)	$20,000	Estimate, including legal
Monitored Natural Attenuation, Groundwater	$1,391,388	Assumes MNA evaluation, installation of 5 additional wells, sampling of 25 wells semiannually for 20 years (present value used). Includes reporting of results.
TOTAL PROJECT COST SUMMARY	$3,334,526	

Notes:

(1) Cost estimate to be used for comparison of costs relative to other corrective measure alternatives.

(2) The Institutional Control costs are fixed administrative costs associated with implementation of the Land Use Controls.
The maintenance of the institutional controls (periodic review) is covered in the O&M costs for each alternative.

Revised: August 29, 2005

ALTERNATIVE 2

ORDER OF MAGNITUDE COST ESTIMATE (1)
TOW WAY FUEL FARM, NAVAL ACTIVITY PUERTO RICO

Cost Item	Total Cost	Assumptions (Basis of Cost Estimate)
Bioventing, soil, including institutional controls	$489,014	Assumes 4796 cubic yards of soil treated for three years.
Institutional Controls (2)	$20,000	Estimate, including legal
Dual phase extraction with steam stripping, treatment of water with air stripping, discharge via NDPES, groundwater and PSH	$2,987,419	Assumes 27 dual phase extraction units, and 2 areas to be enhanced with steam. These costs are for two year of operation.
Monitored natural attenuation follow-up to groundwater treatment	$1,050,272	Assumes MNA evaluation, installation of 5 additional wells, sampling of 25 wells semiannually for 10 years (present value used). Includes reporting of results.
TOTAL PROJECT COST SUMMARY	$4,546,705	

Notes:
(1) Cost estimate to be used for comparison of costs relative to other corrective measure alternatives
(2) The Institutional Control costs are fixed administrative costs associated with implementation of the Land Use Controls.
The maintenance of the institutional controls (periodic review) is covered in the O&M costs for each alternative.

ALTERNATIVE 3

Revised: August 29, 2005

ORDER OF MAGNITUDE COST ESTIMATE (1)
TOW WAY FUEL FARM, NAVAL ACTIVITY PUERTO RICO

Cost Item	Total Cost	Assumptions (Basis of Cost Estimate)
Excavation and Disposal, soil	$2,869,553	Assumes 7771 CY of soil removed (arsenic & PAH).
Institutional Controls, Groundwater (2)	$20,000	No action will be taken for remediation of groundwater in certain locations. Periodic review of site conditions may be required by U.S. EPA and PREQB.
Extraction Wells with Vacuum Vapor Extraction, Oil/Water Separators, Bioreactor treatment and Injection, groundwater & PSH	$3,441,419	Assumes 27 extraction wells, aboveground oil/water separator, bioreactor, and four 60 foot deep injection wells, 5 years O&M
Monitored Natural Attenuation follow-up to groundwater treatment	$1,050,272	Assumes installation of 5 additional wells, sampling of 25 wells semiannually for 10 years (present value used). Includes reporting of results.
TOTAL PROJECT COST SUMMARY	$7,381,243	

Notes:

(1) Cost estimate to be used for comparison of costs relative to other corrective measure alternatives

(2) The Institutional Control costs are fixed administrative costs associated with implementation of the Land Use Controls.

The maintenance of the institutional controls (periodic review) is covered in the O&M costs for each alternative.

Revised: August 29, 2005

ALTERNATIVE 4

ORDER OF MAGNITUDE COST ESTIMATE (1)
TOW WAY FUEL FARM, NAVAL ACTIVITY PUERTO RICO

Cost Item	Total Cost	Assumptions (Basis of Cost Estimate)
Excavation and HTTD, soil	$1,827,637	Assumes 1157 CY of soil treated and replaced.
Soil Vapor Extraction, soil	$559,616	Assumes 1903 CY of soil treated in the CAO area of soil.
Institutional Controls, Groundwater (2)	$20,000	No action will be taken for remediation of groundwater in certain locations. Periodic review of site conditions may be required by U.S. EPA and PREQB.
Air sparging, groundwater	$989,363	Assumes 1 acre of treatment area in the groundwater plume "hot spot".
Monitored Natural Attenuation follow-up to groundwater treatment	$1,050,272	Assumes installation of 5 additional wells, sampling of 25 wells semiannually for 10 years (present value used). Includes reporting of results.
PSH skimming, PSH	$1,923,138	Assumes PSH skimmers to be installed on 60 wells (2 portable skimmers), replacement of skimmers once each two years. Ten years of O&M.
TOTAL PROJECT COST SUMMARY	$6,370,025	

Notes:
(1) Cost estimate to be used for comparison of costs relative to other corrective measure alternatives
(2) The Institutional Control costs are fixed administrative costs associated with implementation of the Land Use Controls.
The maintenance of the institutional controls (periodic review) is covered in the O&M costs for each alternative.

Revised: August 29, 2005

ALTERNATIVE 5

ORDER OF MAGNITUDE COST ESTIMATE (1)
TOW WAY FUEL FARM, NAVAL ACTIVITY PUERTO RICO

Cost Item	Total Cost	Assumptions (Basis of Cost Estimate)
Excavation and Land Farming, soil	$492,387	Assumes 1157 CY of soil treated.
In-Situ Biological Treatment, soil	$623,438	Assumes 1903 CY of soil treated.
Institutional Controls, Groundwater (2)	$20,000	No action will be taken for remediation of groundwater in certain locations. Periodic review of site conditions may be required by U.S. EPA and PREQB.
Monitored Natural Attenuation, groundwater	$1,050,272	Assumes installation of 5 additional wells, sampling of 25 wells semiannually for 10 years (present value used). Includes reporting of results.
ECGO, groundwater	$557,692	Assumes hot spot treatment around 470MW01, 25' x 25' area, 25' treatment zone with depth.
CleanOX, PSH	$4,663,900	From CleanOX pilot test, assumes areas A,C,D, and E. (see report)
TOTAL PROJECT COST SUMMARY	$7,407,689	

Notes:

(1) Cost estimate to be used for comparison of costs relative to other corrective measure alternatives

(2) The Institutional Control costs are fixed administrative costs associated with implementation of the Land Use Controls.

The maintenance of the institutional controls (periodic review) is covered in the O&M costs for each alternative.

Revised: August 29, 2005

PSH SKIMMING COST ESTIMATE

for

TWFF

Sheet A

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By:
Checked By:

Date: October, 2004

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$25,000	$25,000	Engineering estimate
	PSH Skimmers (1)	60	each	$1,560	$93,600	Means, 2004, 33-23-0823
	Trailers for Trailer Mounted Skimmers	2	each	$5,000	$10,000	Engineering estimate
	PSH Filters	60	each	$301	$18,032	Means, 2004, 33-23-2610
	Compressor	1	each	$14,159	$14,159	Means, 2004, 33-31-0206
	Recovery Tank (1500 gallons)	1	each	$5,000	$5,000	Engineering estimate
	Well Vaults	60	each	$3,806	$228,360	Means, 2004, 33-23-2204
	Trenching	5,000	ft	$1.03	$5,150	Means, 2003, 02315-940-0450
	Recovery Piping	5,000	ft	$5.44	$27,200	Means, 2004, 33-26-0502
	Instrumentation	1	L/S	$5,000	$5,000	Engineering estimate
	Subtotal--Direct Capital Costs				$431,501	
	Scope and Bid Contingency				$151,025	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$582,527**	
	Professional Services					
	Project Management	1	L/S	$58,253	$58,252.69	Assume 10% of total direct capital cost
	Remedial Design/Engineering Support	1	L/S	$116,505	$116,505.38	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$116,505	$116,505.38	Assume 20% of total direct capital cost
	Total, Professional Services				**$291,263.45**	
	O & M Costs (1 Year)					
	Operation Labor (4 hrs/day, 5 days/week)	1,040	hours	$75.00	$78,000.00	Engineering estimate
	Maintenance					
	Labor (5 hours/week)	260	hours	$75.00	$19,500.00	Engineering estimate
	Materials	1	L/S	$10,000.00	$10,000.00	Engineering estimate
	Utilities	1	L/S	$2,500.00	$2,500.00	Engineering estimate
	Disposal	15	K gals	$1.75	$26.25	Means, 2004, 33-19-7102
	Disposal Transportation	15,000	gallons	$0.29	$4,350.00	Means, 2004, 33-19-7103
	Administrative	80	hours	$95.00	$7,600.00	Engineering estimate
	Insurance/Licensing	1	L/S	$2,000.00	$2,000.00	
	Subtotal--O & M Costs				$123,976.25	
	Reserve/Contingency	1	L/S	$18,596.44	$18,596.44	Assume 15% contingency
	Total, O & M Costs, 1 year				**$142,572.69**	
	Present Value, assuming 6% interest and 10 years O&M				**$1,049,347.39**	
TOTAL					**$1,923,137.73**	

1-- Assumes skimmers will be placed in existing wells

Revised: August 29, 2005

BIOVENTING
COST ESTIMATE

for

TWFF

Sheet A

Baker

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By:
Checked By:

October 2004
Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$25,000	$25,000	Engineering estimate
	Installation of vent wells	6	each	$5,000	$30,000	Engineering estimate
	Blowers	6	each	$2,972	$17,832	Means, 2004, 33-31-0108
	Compressor	1	each	$14,159	$14,159	Means, 2004, 33-31-0206
	Well Vaults	6	each	$3,806	$22,836	Means, 2004, 33-23-2204
	Trenching	500	feet	$1	$515	Means, 2003, 02315-940-0450
	Instrumentation	1	L/S	$5,000	$5,000	Engineering estimate
	Subtotal--Direct Capital Costs				$115,342	
	Scope and Bid Contingency				$40,370	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$155,712**	
	Professional Services					
	Project Management	1	L/S	$15,571	$15,571.17	Assume 10% of total direct capital cost
	Remedial Design/Engineering Support	1	L/S	$31,142	$31,142.34	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$31,142	$31,142.34	Assume 20% of total direct capital cost
	Total, Professional Services				**$77,855.85**	
	O & M Costs (1 Year)					
	Operation Labor (2 hrs/day, 5 days/week)	520	hours	$75.00	$39,000.00	Engineering estimate
	Maintenance					
	Labor (5 hours/week)	260	hours	$75.00	$19,500.00	Engineering estimate
	Materials	1	L/S	$10,000.00	$10,000.00	Engineering estimate
	Utilities	1	L/S	$5,000.00	$5,000.00	Engineering estimate
	Administrative	80	hours	$95.00	$7,600.00	Engineering estimate
	Insurance/Licensing	1	L/S	$2,000.00	$2,000.00	Engineering estimate
	Subtotal--O & M Costs				$83,100.00	
	Reserve/Contingency	1	L/S	$12,465.00	$12,465.00	Assume 15% contingency
	Total, O & M Costs, 1 year				**$95,565.00**	
	Present Value, assuming 6% interest and 3 years O&M				**$255,446.39**	
TOTAL					**$489,013.94**	

Revised: August 29, 2005

EXCAVATION AND DISPOSAL COST ESTIMATE

for
TWFF
Sheet A

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By: October, 2004
Checked By: Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$25,000	$25,000	Engineering estimate
	Excavation PAH	1,919	CY	$5	$9,593	Means 2003,17-03-0202
	Backfilling with clean fill, including delivery, spreading and compaction in 6" lifts	1,919	CY	$9	$17,267	Means 2003,17-03-0423
	Excavation Arsenic	5,852	CY	$5	$29,259	Means 2003,17-03-0202
	Backfilling with clean fill, including delivery, spreading and compaction in 6" lifts	5,852	CY	$9	$52,668	Means 2003,17-03-0423
	Vegetative cover	11,656	SY	$4.10	$47,788	Means 2003,02310-460-0900
	Transportation	11,656	ton	$10.00	$116,556	
	Disposal	11,656	ton	$96.00	$1,118,933	Environmental Mgt Specialists Quote
	Subtotal--Direct Capital Costs				$1,417,063	
	Scope and Bid Contingency				$495,972	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$1,913,035**	
	Professional Services					
	Project Management	1	L/S	$191,304	$191,304	Assume 10% of total direct capital cost
	Remedial Design/Engineering Support	1	L/S	$382,607	$382,607	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$382,607	$382,607	Assume 20% of total direct capital cost
	Total, Professional Services				**$956,518**	
	TOTAL				**$2,869,553**	

Construction costs and material estimates are based on the following assumptions.
RSMeans--Environmental Remediation Cost Data, 9th annual edition, 2003
RSMeans--Site Work and Landscape Data, 22nd annual edition, 2003

Revised: August 29, 2005

SVE
COST ESTIMATE
for
TWFF
Sheet A

Baker

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By: October, 2004
Checked By: Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$25,000	$25,000	Engineering estimate
	Pilot Test	1	LS	$40,000	$40,000.00	Unit Price from RTDF web site
	Installation of vent wells	6	each	$5,000	$30,000	Engineering estimate
	Blowers	6	each	$2,972	$17,832	Means, 2004, 33-31-0108
	Compressor	1	each	$14,159	$14,159	Means, 2004, 33-31-0206
	Instrumentation	1	L/S	$5,000	$5,000	Engineering estimate
	Subtotal--Direct Capital Costs				$131,991	
	Scope and Bid Contingency				$46,197	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$178,188**	
	Professional Services					
	Project Management	1	L/S	$17,819	$17,818.79	cost
	Remedial Design/Engineering Support	1	L/S	$35,638	$35,637.57	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$35,638	$35,637.57	Assume 20% of total direct capital cost
	Total, Professional Services				**$89,093.93**	
	O & M Costs (1 Year)					
	Operation Labor (2 hrs/day, 5 days/week)	520	hours	$75.00	$39,000.00	Engineering estimate
	Maintenance					
	Labor (5 hours/week)	260	hours	$75.00	$19,500.00	Engineering estimate
	Materials	1	L/S	$15,000.00	$15,000.00	Engineering estimate
	Utilities	1	L/S	$12,000.00	$12,000.00	Engineering estimate
	Administrative	80	hours	$95.00	$7,600.00	Engineering estimate
	Insurance/Licensing	1	L/S	$2,000.00	$2,000.00	
	Subtotal--O & M Costs				$95,100.00	
	Reserve/Contingency	1	L/S	$14,265.00	$14,265.00	Assume 15% contingency
	Total, O & M Costs, 1 year				**$109,365.00**	
	Present Value, assuming 6% interest and 3 years O&M				**$292,333.95**	
TOTAL					**$559,615.73**	

Note: all soil not treated with this process. Other soil treated with HTTD.
Assumes 2000 CY of PSH soil also treated with SVE

Revised: August 29, 2005

LAND-FARMING COST ESTIMATE

for
TWFF
Sheet A

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By:
Checked By:

October, 2004
Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$25,000	$25,000	Engineering estimate
	Pilot Test	1	LS	$50,000	$50,000.00	Unit Price from RTDF web site
	Landfarming	1157	CY	$75	$86,805.56	Unit Price from RTDF web site
	Vegetative cover	1,736	SY	$4.10	7,118.06	Means 2003,02310-460-0900
	Subtotal--Direct Capital Costs				$168,924	
	Scope and Bid Contingency				$59,123	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$228,047**	
	Professional Services					
	Project Management	1	L/S	$22,805	$22,804.69	cost
	Remedial Design/Engineering Support	1	L/S	$45,609	$45,609.38	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$45,609	$45,609.38	Assume 20% of total direct capital cost
	Total, Professional Services				**$114,023.44**	
	O & M Costs (1 Year)					
	Operation Labor (5hrs/week)	260	hours	$75.00	$19,500.00	Engineering estimate
	Maintenance					
	Labor (4 hours/week)	208	hours	$75.00	$15,600.00	Engineering estimate
	Materials	1	L/S	$5,000.00	$5,000.00	Engineering estimate
	Utilities	1	L/S	$5,000.00	$5,000.00	Engineering estimate
	Administrative	40	hours	$95.00	$3,800.00	Engineering estimate
	Subtotal--O & M Costs				$48,900.00	
	Reserve/Contingency	1	L/S	$7,335.00	$7,335.00	Assume 15% contingency
	Total, O & M Costs, 1 year				**$56,235.00**	
	Present Value, assuming 6% interest and 3 years O&M				**$150,316.83**	
TOTAL					**$492,387.14**	

Note: all soil not treated with this process. Other soil treated with biological degradation

Revised: August 29, 2005

HTTD
COST ESTIMATE
for
TWFF
Sheet A

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By:
Checked By:

October, 2004
Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization, HTTD	1	lump sum	$457,000.00	457,000.00	Means, 2004, 33-14-0103
	Mobilization/Demobilization, excavators	1	lump sum	$500	500.00	Engineer's Estimate
	Erosion and Sedimentation Control	1	L.S.	$5,000	5,000.00	Engineer's Estimate
	Excavation	1,157	CY	$5	5,787.04	Means 2003,17-03-0202
	Infrared furnace, fixed cost, including O&M	1,736	ton	$345	598,958.33	Means, 2004, 33-14-0107
	Backfilling with reclaimed soil, spreading and compaction in 6" lifts	1,736	CY	$5	8,680.56	Means 2003,17-03-0423
	Vegetative cover	1,736	SY	$4.10	7,118.06	Means 2003,02310-460-0900
	Subtotal--Direct Capital Costs				$1,083,044	
	Scope and Bid Contingency				$379,065	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$1,462,109**	
	Professional Services					
	Project Management	1	L/S	$73,105	$73,105	Assume 5% of total direct capital cost
	Remedial Design/Engineering Support	1	L/S	$146,211	$146,211	Assume 10% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$146,211	$146,211	Assume 10% of total direct capital cost
	Total, Professional Services				**$365,527**	
	TOTAL				**$1,827,637**	

Assumes only part of the soil to be remediated this way.

Revised: August 29, 2005

IN-SITU BIODEGRADATION FOR SOIL COST ESTIMATE

for
TWFF
Sheet A

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By:
Checked By:

October, 2004
Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$25,000	$25,000	Engineering estimate
	Bench Scale Test	1	LS	$40,000.00	$40,000.00	Engineer's Estimate
	In-Situ Biodegradation	1,903	CY	$160	$304,444.44	$80/CY from RTDF web site, assume two treatments
	Subtotal--Direct Capital Costs				$369,444	
	Scope and Bid Contingency				$129,306	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				$498,750	
	Professional Services					
	Project Management	1	L/S	$24,938	$24,938	Assume 5% of total direct capital cost
	Remedial Design/Engineering Support	1	L/S	$49,875	$49,875	Assume 10% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$49,875	$49,875	Assume 10% of total direct capital cost
	Total, Professional Services				$124,688	
TOTAL					$623,438	

Revised: August 29, 2005

DUAL PHASE EXTRACTION/STEAM COST ESTIMATE

for
TWFF
Sheet A

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By: October, 2004
Checked By: Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$30,000	$30,000	Engineering estimate
	Dual Phase Well Installation	27	each	$5,000	$135,000	Engineering estimate
	Dual Phase Extraction Unit	27	each	$8,884	$239,868	Means, 2004, 33-23-0802
	Underground Steam System, piping	2,500	ft	$27	$66,775	Means, 2004, 19-05-0403
	150 HP Steam Boiler, monthly rental	12	month	$6,575	$78,900	Means, 2004, 33-13-2903
	Air Stripping Unit	1	each	$21,265	$21,265	Means, 2004, 33-13-0718
	Well Vaults	27	each	$3,806	$102,762	Means, 2004, 33-23-2204
	Trenching	4,000	ft	$1.03	$4,120	Means, 2003, 02315-940-0450
	Piping	4,000	ft	$9	$36,000.00	Means, 2003, 33-26-0101
	Reverse Osmosis Groundwater Treatment	1	each	$30,000	$30,000	Lifestream Water Systems Quote
	RO Recovery Tank (10,000 gallons)	1	each	$15,000	$15,000	Engineering estimate
	Recovery Tank (1500 gallons)	1	each	$5,000	$5,000	Engineering estimate
	Recovery/Discharge Piping	4,000	ft	$5.44	$21,760	Means, 2004, 33-26-0502
	Instrumentation	1	L/S	$5,000	$5,000	Engineering estimate
	Subtotal--Direct Capital Costs				$791,450	
	Scope and Bid Contingency				$277,008	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$1,068,458**	
	Professional Services					
	Project Management	1	L/S	$106,846	$106,845.75	Assume 10% of total direct capital cost
	Remedial Design/Engineering Support	1	L/S	$213,692	$213,691.50	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$213,692	$213,691.50	Assume 20% of total direct capital cost
	Total, Professional Services				**$534,228.75**	
	O & M Costs (1 Year) (1)					
	Operation Labor (4 hrs/day, 5 days/week)	1,040	hours	$75.00	$78,000.00	Engineering estimate
	Maintenance					
	Labor (5 hours/week)	260	hours	$75.00	$19,500.00	Engineering estimate
	Materials	1	L/S	$10,000.00	$10,000.00	Engineering estimate
	Utilities	1	L/S	$30,000.00	$30,000.00	Engineering estimate
	Disposal	30,000	gallons	$1.75	$52,500.00	Means, 2004, 33-19-7102
	Administrative	260	hours	$95.00	$24,700.00	Engineering estimate
	Insurance/Licensing	1	L/S	$2,000.00	$2,000.00	
	Subtotal--O & M Costs				$216,700.00	
	Reserve/Contingency	1	L/S	$32,505.00	$32,505.00	Assume 15% contingency
	Total, O & M Costs, 1 year				**$249,205.00**	
	Present Value, 5 years O & M at 6%				**$1,049,742**	
	TOTAL				**$2,652,428.37**	

(1) Operation labor costs include pump adjustments, wellhead checks, periodic discharge sampling, and conveyance piping checks.
Maintenance labor costs include removing pumps periodically and removing any biofouling, removing conveyance piping clogs, periodic maintenance on compressor, periodic maintance on product tanks, periodic maintenance on treatment system, and periodic maintenance on vacuum system.

Revised: August 29, 2005

AIR SPARGING COST ESTIMATE

for
TWFF
Sheet A

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By:
Checked By:

October 2004
Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$25,000	$25,000	Engineering estimate
	Pilot Study	1	LS	$40,000	$40,000	Engineering estimate
	Air Sparging well casings (1)	150	ft	$17	$2,550	Means, 2003, 33-23-0103
	Air Sparging well screens, 20 foot	100	ft	$31	$3,100	Means, 2003, 33-23-0203
	Installation of extraction wells	250	ft	$61	$15,250	Means, 2003, 33-23-1150
	Blowers	5	each	$2,972	$14,860	Means, 2004, 33-31-0108
	Piping	2,000	ft	$9	$18,000.00	Means, 2003, 33-26-0101
	Trenching	2,000	ft	$1.03	$2,060	Means, 2003, 02315-940-0450
	Compressor	1	each	$14,159	$14,159	Means, 2004, 33-31-0206
	Instrumentation	1	L/S	$5,000	$5,000	Engineering estimate
	Subtotal--Direct Capital Costs				$139,979	
	Scope and Bid Contingency				$48,993	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$188,972**	
	Professional Services					
	Project Management	1	L/S	$18,897	$18,897	Assume 10% of total direct capital cost
	Remedial Design/Engineering Support	1	L/S	$37,794	$37,794	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$37,794	$37,794	Assume 20% of total direct capital cost
	Total, Professional Services				**$94,486**	
	O & M Costs (1 Year)					
	Operation Labor (8 hrs/week)	416	hr	$75	$31,200	Engineers estimate
	Maintenance					
	Labor (4 hours/week)	208	hr	$75	$15,600	Engineers estimate
	Materials	1	L/S	$15,000.00	$15,000	Engineers estimate
	Utilities	1	L/S	$12,000.00	$12,000	Engineers estimate
	Administrative	80	hours	$95.00	$7,600	Engineering estimate
	Insurance/Licensing	1	L/S	$2,000.00	$2,000	
	Subtotal--O & M Costs				$83,400	
	Reserve/Contingency	1	L/S	$12,510.00	$12,510	Assume 15% contingency
	Total, O & M Costs, 1 year				**$95,910**	
	Present Value, assuming 6% interest and 10 years O&M				**$705,906**	
	TOTAL				**$989,363**	

1--Assume 5 new 6 inch air sparging wells, each at 50 foot depth

Revised: August 29, 2005

EXTRACTION WELLS COST ESTIMATE

for
TWFF
Sheet A

Baker

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By:
Checked By:

October, 2004
Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$30,000	$30,000	Engineering estimate
	Extraction well casings (1)	810	ft	$17	$13,770	Means, 2003, 33-23-0103
	Extraction well screens, 20 foot	540	ft	$31	$16,740	Means, 2003, 33-23-0203
	Installation of extraction wells	1,350	ft	$61	$82,350	Means, 2003, 33-23-1150
	Extraction pumps	27	each	$4,019	$108,513	Means, 2003, 33-23-0571
	Vapor Recovery System	27	each	$3,912	$105,624	Means, 2004, 33-13-2301
	Piping	4,000	ft	$9	$36,000.00	Means, 2003, 33-26-0101
	Trenching	4,000	ft	$1.03	$4,120	Means, 2003, 02315-940-0450
	Reverse Osmosis Groundwater Treatment	1	each	$30,000	$30,000	Lifestream Water Systems Quote
	Instrumentation	1	L/S	$5,000	$5,000	Engineering estimate
	Subtotal--Direct Capital Costs				$432,117	
	Scope and Bid Contingency				$151,241	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$583,358**	
	Professional Services					
	Project Management	1	L/S	$58,336	$58,336	Assume 10% of total direct capital cost
	Remedial Design/Engineering Support	1	L/S	$116,672	$116,672	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$116,672	$116,672	Assume 20% of total direct capital cost
	Total, Professional Services				**$291,679**	
	O & M Costs (1 Year) (2)					
	Operation Labor (16 hrs/week)	832	hr	$75	$62,400	Engineers estimate
	Maintenance					
	Labor (16 hrs/week)	832	hr	$75	$62,400	Engineers estimate
	Materials	1	L/S	$10,000.00	$10,000	Engineers estimate
	Utilities	1	L/S	$1,200.00	$1,200	Engineers estimate
	Administrative	80	hours	$95.00	$7,600	Engineering estimate
	Insurance/Licensing	1	L/S	$2,000.00	$2,000	
	Subtotal--O & M Costs				$145,600	
	Reserve/Contingency	1	L/S	$21,840.00	$21,840	Assume 15% contingency
	Total, O & M Costs, 1 year				**$167,440**	
	Present Value, assuming 6% interest and 5 years O&M				**$705,318**	
	TOTAL				**$1,580,355**	

(1) Assume 27 new 6 inch pumping wells, each at 50 foot depth
(2) Operation labor costs include pump adjustments, wellhead checks, periodic discharge sampling, and conveyance piping checks.
Maintenance labor costs include removing pumps periodically and removing any biofouling, removing conveyance piping clogs, periodic maintenance on compressor, periodic maintance on product tanks, periodic maintenance on treatment system, and periodic maintenance on vacuum system.

Revised: August 29, 2005

INJECTION WELLS COST ESTIMATE

for

TWFF

Sheet A

Baker

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By: October, 2004

Checked By: Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$25,000	$25,000	Engineering estimate
	Drilling	240	ft	$50	$12,000	Engineering estimate
	Injection well casings	80	ft	$17	$1,360	Means, 2003, 19-01-0208
	Injection well screens, 40 foot	160	ft	$56	$9,037	Means, 2003, 33-23-0113
	Installation of injection wells	240	ft	$99	$23,861	Means, 2003, 33-23-1133
	Injection pumps	4	each	$2,164	$8,656	Means, 2003, 33-29-0106
	Trenching	1,500	ft	$1.03	$1,545	Means, 2003, 02315-940-0450
	Piping from other treatment	1,500	ft	$12	$17,955	Means, 2003, 33-26-0430
	Subtotal--Direct Capital Costs				$99,414	
	Scope and Bid Contingency				$34,795	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$152,163**	
	Professional Services					
	Project Management	1	L/S	$15,216	$15,216	Assume 10% of total direct capital cost
	Remedial Design/Engineering Support	1	L/S	$30,433	$30,433	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$30,433	$30,433	Assume 20% of total direct capital cost
	Total, Professional Services				**$76,082**	
	O & M Costs (1 Year)					
	Operation Labor (5 hrs/week)	260	hr	$75	$19,500	Engineers estimate
	Maintenance					
	Labor (16 hrs/week)	208	hr	$75	$15,600	Engineers estimate
	Materials	1	L/S	$8,000.00	$8,000	Engineers estimate
	Utilities	1	L/S	$5,000.00	$5,000	Engineers estimate
	Administrative	40	hours	$95.00	$3,800	Engineering estimate
	Insurance/Licensing	1	L/S	$2,000.00	$2,000	Engineering estimate
	Subtotal--O & M Costs				$53,900	
	Reserve/Contingency	1	L/S	$8,085.00	$8,085	Assume 15% contingency
	Total, O & M Costs, 1 year				**$61,985**	
	Present Value, assuming 6% interest and 5 years O&M				**$261,103**	
	TOTAL				**$489,348**	

1--Assume 4 new 8 inch pumping wells, each at 60 foot depth

Revised: August 29, 2005

OIL WATER SEPARATOR COST ESTIMATE

for

TWFF

Sheet A

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By: October, 2004
Checked By: Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$25,000	$25,000	Engineering estimate
	200 gpm unit	1	LS	$14,098	$14,098.00	Means, 2003, 33-13-1214
	Piping	500	ft	$9	$4,500.00	Means, 2003, 33-26-0101
	Product storage unit, 550 gallon	1	each	$1,980	$1,980.00	Means, 2003, 19-04-0602
	Subtotal--Direct Capital Costs				$45,578	
	Scope and Bid Contingency				$15,952	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$61,530**	
	Professional Services					
	Project Management	1	L/S	$6,153	$6,153	cost
	Remedial Design/Engineering Support	1	L/S	$12,306	$12,306	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$12,306	$12,306	Assume 20% of total direct capital cost
	Total, Professional Services				**$30,765**	
	O & M Costs (1 Year)					
	Operation Labor (5 hrs/week)	260	hr	$75	$19,500	Engineers estimate
	Maintenance					
	Labor (16 hrs/week)	208	hr	$75	$15,600	Engineers estimate
	Materials	1	L/S	$8,000.00	$8,000	Engineers estimate
	Utilities	1	L/S	$1,200.00	$1,200	Engineers estimate
	Administrative	40	hours	$95.00	$3,800	Engineering estimate
	Insurance/Licensing	1	L/S	$2,000.00	$2,000	Engineering estimate
	Subtotal--O & M Costs				$50,100	
	Reserve/Contingency	1	L/S	$7,515.00	$7,515	Assume 15% contingency
	Total, O & M Costs, 1 year				**$57,615**	
	Present Value, assuming 6% interest and 5 years O&M				**$242,695**	
TOTAL					$334,991	

BIOREACTOR
COST ESTIMATE

for
TWFF
Sheet A

Revised: August 29, 2005

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By:
Checked By:

October, 2004
Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$25,000	$25,000	Engineering estimate
	5000 gal water tank, steel	1	each	$9,510.00	$9,510.00	Means, 2003, 19-01-0310
	Gas-fired water boiler, 275 MBH	1	each	$6,541.00	$6,541.00	Means, 2003, 33-11-9302
	Bioreactor, 5000 gallon, fixed film	1	each	$76,500	$76,500.00	Means, 2003, 33-11-9322
	Pressure filter press, 4 inch	1	each	$11,552	$11,552.00	Means, 2003, 33-13-0102
	Piping from oil/water separator	300	ft	$14	$4,281.00	Means, 2003, 33-26-0102
	Reverse Osmosis Groundwater Treatment	1	each	$30,000	$30,000	Lifestream Water Systems Quote
	RO Recovery Tank (10,000 gallons)	1	each	$15,000	$15,000	Engineering estimate
	Subtotal--Direct Capital Costs				$133,384	
	Scope and Bid Contingency				$46,684	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				$180,068	
	Professional Services					
	Project Management	1	L/S	$18,007	$18,007	Assume 10% of total direct capital cost
	Remedial Design/Engineering Support	1	L/S	$36,014	$36,014	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$36,014	$36,014	Assume 20% of total direct capital cost
	Total, Professional Services				$90,034	
	O & M Costs (1 Year)					
	Labor (10 hrs/week)	520	hr	$75	$39,000.00	Engineers estimate
	Maintenance					
	Labor (10 hrs/week)	520	hr	$75	$39,000.00	Engineers estimate
	Materials	1	L/S	$50,000.00	$50,000.00	Engineers estimate
	Utilities	1	L/S	$10,000.00	$10,000.00	Engineers estimate
	Administrative	129	hours	$95.00	$12,255	Engineering estimate
	Insurance/Licensing	1	L/S	$8,000.00	$8,000	
	Subtotal--O & M Costs				$158,255	
	Reserve/Contingency	1	L/S	$23,738.25	$23,738	Assume 15% contingency
	Total, O & M Costs, 1 year				$181,993	
	Present Value, assuming 6% interest and 5 years O&M				$766,622	
TOTAL					$1,036,724	

Revised: August 29, 2005

ECGO--GROUNDWATER
COST ESTIMATE

for
TWFF
Sheet A

Baker

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By: October, 2004
Checked By: Date:

ITEM NO.	ITEM	QTY.	UNIT	UNIT PRICE	ITEM PRICE	NOTE(S)
	Direct Capital Costs					
	Mobilization/Demobilization	1	L/S	$25,000	$25,000	Engineering estimate
	ECGO Process	1,740	CY	$120	$208,800	Unit Price from RTDF web site
	Subtotal--Direct Capital Costs				$233,800	
	Scope and Bid Contingency				$81,830	35% total contingency (25% scope and 10% bid contingencies
	Total, Direct Capital Costs				**$315,630**	
	Professional Services					
	Project Management	1	L/S	$31,563	$31,563	Assume 10% of total direct capital cost
	Remedial Design/Engineering Support	1	L/S	$63,126	$63,126	Assume 20% of total direct capital cost
	Construction Oversite and Startup	1	L/S	$63,126	$63,126	Assume 20% of total direct capital cost
	Total, Professional Services				**$157,815**	
	O & M Costs (1 Year) (2)					
	Utilities	1	L/S	$20,000	$20,000	Engineers estimate
	Total, O & M Costs, 1 year				**$20,000**	
	Present Value, assuming 6% interest and 5 years operation				**$84,247**	
	TOTAL				$557,692	

Note: groundwater volumes treated with ECGO only in the hot spot area, approximately 25' by 25' area and 25' depth
assume 10 pore volumes, porosity assumed to be 0.3

Revised: August 29, 2005

REMEDIATION VOLUME ESTIMATES

for

TWFF

Sheet A

Baker

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By: October, 2004
Checked By: Date:

Soil volumes--B(a)P above screening values--Bioventing					
Area location	Area (SF)	Volume (CF)*	Volume (CY)	Weight (tons)	Additional Considerations
1, 125' x 125' surface soil, Figure 1-6	15625	78125	2894	4340	
2, 125' x 75' subsurface soil, Figure 1-6	9375	46875	1736	2604	
3, 30' x 30' surface soil, Figure 1-6	900	4500	167	250	
Total	**25900**	**129500**	**4796**	**7194**	
*Assume 5 foot treatment depth					

Soil volumes -- Arsenic above screening values -- Excavation					
Area location	Area (SF)	Volume (CF)*	Volume (CY)	Weight (tons)	Additional Considerations
1, Upper TWFF near Tank 82,83, and 84	54000	108000	4000	6000	
2, Area between Tank 1086 and Tank 83	13000	26000	963	1444	
3, Area between Tank 1086 and Tank 85	12000	24000	889	1333	
Total	**79000**	**158000**	**5852**	**8778**	
*surface soil - 2 foot depth					

Volumes for Steam Flushing					
Area location	Area (SF)	Volume (CF)*	Volume (CY)	Weight (tons)	Additional Considerations
1, 200' x 200', representative larger PSH area	40000	800000	29630	44444	
Total	**40000**	**800000**	**29630**	**44444**	
*assume 20 foot treatment depth					

Soil volumes--B(a)P above screening values--Excavation					
Area location	Area (SF)	Volume (CF)*	Volume (CY)	Weight (tons)	Additional Considerations
1, 125' x 125' surface soil, Figure 1-6	15625	31250	1157	1736	
2, 125' x 75' subsurface soil, Figure 1-6	9375	18750	694	1042	
3, 30' x 30' surface soil, Figure 1-6	900	1800	67	100	
Total	**25900**	**51800**	**1919**	**2878**	
*Assume 2 foot excavation					

Soil volumes--B(a)P above screening values--ECGO					
Area location	Area (SF)	Volume (CF)*	Volume (CY)	Weight (tons)	Additional Considerations
2, 125' x 75' subsurface soil, Figure 1-6	9375	46875	1736	2604	
3, 30' x 30' surface soil, Figure 1-6	900	4500	167	250	
Total	**10275**	**51375**	**1903**	**2854**	
*Assume 5 foot treatment depth					

CY -- cubic yards

Assume 1.5 tons/CY

Revised: August 29, 2005

MNA
COST ESTIMATE
for
TWFF
Sheet A

MICHAEL BAKER JR., INC.
CONSULTING ENGINEERS
CORAOPOLIS, PENNSYLVANIA

Computed By:
Checked By:

October, 2004
Date:

Cost Item	Quantity	Units	Unit Cost	Total Cost	Assumptions (Basis of Cost Estimate)
DIRECT CAPITAL COSTS					
I. Full-Scale MNA Implementation					
A. Mobilization/Demobilization	2	EA	$10,000	$20,000	Estimated (1 mobilization for characterization and 1 for well installation)
B. Site Characterization for MNA	1	LS	$80,000	$80,000	Estimate, includes one report
C. Installation of 5 Monitoring Wells (25 feet deep)	5	EA	$5,000	$25,000	Engineering Estimate
Subtotal - Direct Capital Costs				$125,000	
Scope & Bid Contingency				$43,750	35% total contingency (25% scope and 10 % bid contingencies)
TOTAL - DIRECT CAPITAL COSTS				**$168,750**	
PROFESSIONAL SERVICES					
I. Project Management	1	LS	$10,125	$10,125	Assume 6% of total direct capital cost
II. Engineering Support, including MNA Plan and Contingency Plan	1	LS	$20,250	$20,250	Assume 12% of total direct capital cost
III. Construction Oversight	1	LS	$20,250	$20,250	Assume 12% of total direct capital cost
TOTAL - PROFESSIONAL SERVICES COSTS				**$50,625**	
ANNUAL OPERATION & MAINTENANCE COSTS					
I. Quarterly Monitoring-- Per year for 2 years					
A. Sampling Labor	4	events	$15,000	$60,000	25 wells, 2 technicians, 10 days, 10 hr/day @ $75/hour (includes prep/travel time)
B. Expenses	4	events	$8,000	$32,000	Travels costs, per diem, equipment costs, shipping, etc.
C. Analytical Costs	108	samples	$500	$54,000	16 samples per event for VOCs, gases, sulfate, nitrate/nitirite, chloride (25wells + 2 QA/QC)
D. Reporting	1	report	$7,500	$7,500	One annual report
TOTAL - ANNUAL QUARTERLY MONITORING				**$153,500**	
II. Semi Annual Monitoring-- Per year for 18 years					
A. Sampling Labor	2	events	$15,000	$30,000	25 wells, 2 technicians, 10 days, 10 hr/day @ $75/hour (includes prep/travel time)
B. Expenses	2	events	$8,000	$16,000	Travels costs, per diem, equipment costs, shipping, etc.
C. Analytical Costs	54	samples	$500	$27,000	27 samples per event for VOCs, gases, sulfate, nitrate/nitrite, chloride (25 wells + 2 QA/QC)
D. Reporting	1	report	$5,000	$5,000	One annual report
E. Project Management	1	LS	$5,000	$5,000	
TOTAL - SEMI ANNUAL MONITORING				**$83,000**	
TOTAL PROJECT COST SUMMARY					
DIRECT CAPITAL COSTS				$168,750	
PROFESSIONAL SERVICES COSTS				$50,625	
PRESENT WORTH OF QUARTERLY MONITORING, YEAR 1				$153,500	Initial year is year 0
PRESENT WORTH OF QUARTERLY MONITORING, YEAR 2				$144,811	2nd year of quarterly monitoring
PRESENT WORTH OF MNA, SEMI-ANNUAL				$873,702	Assume long-term monitoring for next 18 years at 6% discount rate.
PRESENT WORTH OF MNA, SEMI-ANNUAL				$532,585	Assume long-term monitoring for next 8 years at 6% discount rate.
TOTAL PROJECT COST, 20 YEARS				**$1,391,388**	
TOTAL PROJECT COST, 10 YEARS				**$1,050,272**	

Note:
(1) Estimated accuracy of cost estimate is -30% to +50%. Cost estimate is to be used primarily for comparison of costs relative to other alternatives.