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CORRECTIVE MEASURES STUDY
TASK 1 REPORT
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
RCRA/HSWA Permit No. PR2170027203
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LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	Applicable or Relevant and Appropriate Requirements
AOC	areas of concern
Baker	Baker Environmental, Inc.
BB&L	Blasloud, Bouck, and Lee, Inc.
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and total xylenes
CAP	Corrective Action Plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMS	Corrective Measure Study
CMES	Corrective Measures Screening
cm/sec	centimeters per second
COCs	Contaminants of Concern
CS	Confirmation Study
CsFs	Cancer Slope Factors
DFM	diesel fuel marine
DoN's	Department of the Navy's
DRMO	Defense Reutilization and Marketing Office
DRO	diesel range organics
ECGO®	Electro Chemical Geo Oxidation®
ESE	Environmental Science and Engineering
g/ml	grams per milliliter
GRO	gasoline range organics
HI	Hazard Index
HSWA	Hazardous and Solid Waste Amendments
IAS	Initial Assessment Study
ICM	Interim Corrective Measure
ICR	Incremental Cancer Risk
ID	inside diameter
IR	Installation Restoration
LANTDIV	Atlantic Division, Naval Facilities Engineering Command
MCLs	Maximum Contaminant Levels
mg/kg	milligrams per kilogram
NACIP	Navy Assessment and Control of Installation Pollutants
NCP	National Contingency Plan
NSRR	Naval Station Roosevelt Roads

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

ppmV	parts per million by volume
PREQB	Puerto Rico Environmental Quality Board
pvc	polyvinyl chloride
RA	Risk Assessment
RBCs	Risk Based Concentrations
RCRA	Resource Conservation and Recovery Act
RfDs	reference doses
RFI	RCRA Facility Investigations
SWMUs	solid waste management units
TCLP	Toxicity Characteristic Leaching Procedure
TOC	total organic carbon
TOX	total organic halogens
TPH	total petroleum hydrocarbons
TWFF	Tow Way Fuel Farm
USEPA	United States Environmental Protection Agency
USGS	United States Geological Society
USTs	underground storage tanks
VOCs	volatile organic compounds

1.0 INTRODUCTION

This document presents the Corrective Measure Study (CMS) Task I Report for the Tow Way Fuel Farm (TWFF) located at Naval Station Roosevelt Roads (NSRR), Ceiba, Puerto Rico under the Corrective Action provisions of the Station's Resource Conservation and Recovery Act (RCRA) permit. This report has been prepared by Baker Environmental, Inc. (Baker) under contract to the Atlantic Division, Naval Facilities Engineering Command (LANTDIV), Contract Number N62470-89-D-4814.

On October 20, 1994, a Final RCRA Part B Permit was issued by the United States Environmental Protection Agency (USEPA) Region II to NSRR. 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 NSRR, 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 NSRR, included provisions for corrective action under the Hazardous and Solid Waste Amendments (HSWA) provisions of RCRA.

1.1 Context of this Report

This report was developed to meet the requirement of Task I under Module III, Appendix B (Scope of Work for a Corrective Measure Study) as contained in the Stations RCRA Part B Permit. The Task I CMS report identifies the preliminary corrective measure technologies to address the soil and groundwater contamination present at the site from the site operations. The technologies identified are screened and developed for removal, containment, treatment and/or other remediation of the contamination based on the objectives established for the corrective action.

Numerous environmental investigations have been performed and reported on at this site including 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), Project Close-Out Report

Interim Corrective Measure Free Product Recovery System (1997), and the Corrective Measures Study Investigation (1998). A more detailed discussion of these reports is provided in Section 2.2 of this document.

1.2 Objectives of the Task 1 Effort

The objective of this Task I CMS for the TWFF is to identify, screen, and develop the corrective measure alternative or alternatives for removal, containment, treatment and/or other remediation of the contamination based on the objectives established for the corrective action. The Task I CMS includes the initial screening of the possible corrective actions for the TWFF, a description of current conditions at the site and establishes the clean-up goals. The evaluation of the corrective measure alternative or alternatives is conducted in the Task II CMS. The Task III CMS justifies and recommends a corrective measure alternative using technical, human health, and environmental criteria. The Task II and Task III CMS reports will follow the approval of the Task I CMS.

1.3 Report Format

This report is divided into five sections. Section 1.0 of this document includes this introduction and the objectives of this Task I CMS Report. The description of the current situation of the site is described in Section 2.0. Section 3.0 presents the establishment of corrective action objectives. Section 4.0 identifies the preliminary corrective measure technologies. The screening of these corrective measure technologies is conducted in Section 5.0. Section 6.0 identifies the corrective measure alternative or alternatives. The references utilized in development of this report are provided in Section 7.0.

2.0 DESCRIPTION OF CURRENT SITUATION

This section of the report provides an update to the information describing the current situation at the TWFF and the known nature and extent of the contamination as documented by the RFI Report (Baker, 1997), the Corrective Measures Study Investigation Report (Baker, 1998a), and the most recent Tow Way Fuel Farm Quarterly Summary Progress Report No. 6 (Baker 1998b). An update of the previous RCRA activities at the TWFF including previous response activities and any interim measures which have or are being implemented are also provided. The facility-specific statement of the purpose for the response, based on the results of the RFI is included in this section of the report. The statement of purpose identifies the actual or potential exposure pathways that should be addressed by the corrective measures.

2.1 General Site Description

This section contains a description of the Station, the two SWMU's located at the TWFF, and a summary of the fuel loss history through the years of operations at the TWFF.

2.1.1 Station Description

NSRR occupies part of the northern side of the east coast of Puerto Rico, along Vieques Passage with Vieques Island lying to the east about 10 miles from the harbor entrance. The northern entrance to NSRR is about 35 miles east along the coast road (Route 3) from San Juan. The closest large town is Fajardo (population approximately 37,000), which is about 10 miles north of NSRR on Route 3. Ceiba (population approximately 17,000) adjoins the west boundary of NSRR (see Figure 2-1).

NSRR occupies over 33,500 acres at the northeastern most portion of Puerto Rico. NSRR has administrative and command responsibilities for operations separated from the main base on Vieques Island.

NSRR was commissioned in 1943 as a Naval Operations Base, and finally redesignated a Naval Station in 1957. The primary mission of NSRR today is provision of full support for Atlantic Fleet weapons training and development activities.

2.1.2 SWMU 7 - Tow Way Fuel Farm

The TWFF is located on a hillside along Forrestal Road north of Ensenada Honda (Figure 2-2). Constructed prior to 1957, the fuel farm originally consisted of nine USTs containing diesel fuel marine (DFM), Bunker C fuel, and jet fuel (JP-5). That number has since been reduced to seven (Figure 2-3) by the removal of two tanks. Data obtained from previous reports indicate that the USTs have been used solely for the storage of marine fuel and jet fuel since their construction.

2.1.3 SWMU 8 - Tow Way Fuel Farm Sludge Disposal Pits

Prior to RCRA regulations, it was common industry practice to dispose of accumulated sludge material in excavated pits adjacent to the tanks during tank cleaning operations. This practice was apparently employed by TWFF personnel prior to the current practice of disposal by a licensed contractor. Previous investigations were unable to locate evidence of the pits; however, SWMU 8 was included in the permit as a full RFI site.

2.1.4 Fuel Loss History

There have been numerous spills of small and large quantities of fuels stored in the TWFF. The known fuel loss history according to O'Brien & Gere (1992) is summarized as follows:

- 1957/1958 - Approximately 420,000 gallons of Bunker C fuel leaked from UST No. 82.

- 1960s/1970s/1980s - A cumulative volume of approximately 420,000 gallons of fuel leaked from UST Nos. 56A and 56B during this time period.

- 1971/1972 - Approximately 3,900 to 7,500 cubic yards of Bunker C fuel-sludge was removed from UST Nos. 83 and 1080 and was buried in pits excavated adjacent to the USTs.

- 1978 - Approximately 65,000 gallons of diesel fuel leaked from UST No. 1080. Approximately 10,000 gallons were recovered during cleanup operations.

- 1986 - Approximately 91,000 gallons of JP-5 leaked from UST No. 85. Approximately 32,000 gallons were recovered by various methods.

Seven fuel storage tanks are located north of Tow Way Road on a hill overlooking Ensenada Honda. As referenced from the NEESA report 13-051, September 1984, spills, leaks, and sludge disposal have occurred here since 1957. The following paragraphs provide more detail for the above billeted items.

In 1957 or 1958, a fuel line to Tank 82 leaked, resulting in a spill of Bunker C fuel. It is estimated that approximately 420,000 gallons of Bunker C fuel leaked from the storage tank. The oil spill followed a path downhill toward the harbor in a southwesterly direction towards Ensenada Honda, extending to the shoreline and the Ensenada Honda mangrove swamp across the harbor.

From approximately the 1960s through the 1980s, it is also estimated that approximately 420,000 gallons of fuel spilled from Tanks 56A and 56B onto the surrounding soil over a 15- to 20-year period. The tanks were replaced in February 1984. A dark fuel-stained soil was present around the old tanks. Isolated pools of oil from the spills and leaks were evident on the groundwater that seeped into the holes where the tanks had been removed.

Between 1971 and 1972, Tanks 83 and 1080 were cleaned and the Bunker C fuel-sludge was emptied into two pits dug within a 100-foot radius of the tanks. One pit was dug approximately 100 feet in circumference and 10 to 20 feet in depth near Tank 83; the second pit was 50 feet in circumference and 10 to 20 feet in depth near Tank 1080. It is estimated that 3,900 to 7,500 cubic yards of Bunker C fuel-sludge were cleaned from the tanks and disposed of at the site in these pits.

In 1978 a leak occurred at Tank 1080, resulting in the release of approximately 65,000 gallons of diesel fuel from the tank. It is estimated that about 10,000 gallons were recovered during cleanup operations.

In November 1986, Tank 85 leaked approximately 91,000 gallons of JP-5. Approximately 12,000 gallons were recovered on land and 10,000 gallons were recovered from water. Another

10,000 gallons were trapped in sand under the tank. As a result, approximately 59,000 gallons were unaccounted for during the spill.

The seven USTs are located in the Upper TWFF, which is on an area of higher elevation than the Lower TWFF. The Upper and Lower TWFFs are separated by Forrestal Drive. Based on the TWFF topography and historic groundwater flow directions, fuel leaking from the USTs and associated piping flows to the southwest towards Ensenada Honda. However, the free-product plume at the site does not extend to Ensenada Honda, it pools at the base of the hill that separates the Lower and Upper TWFFs.

One spill event of over 100,000 gallons of fuel caused fuel to enter Ensenada Honda directly. It was known prior to the start of RFI investigations that free product was present in the subsurface floating on the groundwater surface (active remediation of this condition is underway). For this reason, the TWFF was included in the Corrective Action portion of the RCRA permit as a SWMU requiring a full RFI.

2.2 Previous RCRA Activities at the Tow Way Fuel Farm

Numerous environmental investigations have been conducted at NSRR; however, this section deals only with those associated with SMWU 7/8 which comprise the TWFF.

2.2.1 Initial Assessment Study

As part of the Navy-wide program to manage past disposal sites through the Navy Assessment and Control of Installation Pollutants (NACIP), NSRR was designated for an Initial Assessment Study (IAS) in 1982. Conducted in 1983 and 1984 by Greenleaf/Telesca Planners, Engineers, Architects (Miami, Florida) and Ecology and Environment (Buffalo, New York), the IAS consisted of a records search at various government agencies, national and regional archives, and United States Geological Society (USGS); an on-site survey; and personnel interviews. The study identified 16 sites that warranted further study under NACIP including SWMU 7/8 (formerly referred to as IR Site 12).

2.2.2 Confirmation Study

In May 1986, a Confirmation Study (CS) was performed by Environmental Science and Engineering (ESE) of Gainesville, Florida. Fifteen of the 16 sites identified in the IAS were investigated as part of this study including SMWU 7/8. This study consisted of two rounds of sample collection from the 15 sites. Completed in April 1988, the CS indicated 14 sites, including SWMU 7/8, required additional investigation.

2.2.3 Underground Fuel Investigation

Initial investigatory work at the TWFF was performed under the provisions of the RCRA Underground Storage Tank (UST) program for which PREQB had primacy over.

This investigation was a groundwater and soil assessment conducted by O'Brien and Gere Engineers, Inc. in 1991. The study included the installation of ten soil borings (B-1 through B-10) to an average depth of 15 feet below ground surface (bgs) and 18 monitoring wells (UGW-1 through UGW-18) at SWMU 7/8 to define the extent of groundwater contamination, free floating product, and soil contamination. The soil samples were analyzed for total organic halogens (TOX), toxicity metals, flash point, and total petroleum hydrocarbon (TPH).

The monitoring wells installed between February 1991 and March 1991 were constructed of 2-inch inside diameter (ID) polyvinyl chloride (PVC) and designated UGW-1 through UGW-18. One round of groundwater samples were collected and analyzed for volatile aromatic and unsaturated organic compounds (USEPA Method 503.1) and lead. In addition, in situ tests were conducted in 11 monitoring wells to determine site hydraulic conductivity, newly existing monitoring wells were surveyed with the elevations tied into the U. S. Geological Survey datum, and two rounds of groundwater and product thickness measurements were collected (March 29 and April 4, 1991).

Semi-confined aquifer conditions were encountered in nine monitoring wells (UGW-1, UGW-3, UGW-4, UGW-8, UGW-9, UGW-10, UGW-12, UGW-13, and UGW-14). At each of these locations, the monitoring well screen was placed across the top of the aquifer (first encountered saturated conditions); however, with time, the water level and/or product layer was found to occur above the well screen. The field investigation defined the extent of free floating product, but only partially defined the extent of groundwater and soil contamination.

2.2.4 Preliminary Site Assessment Underground Storage Tank Site No. 443

A limited site assessment was completed by Law Environmental-Caribe in 1992 in the area surrounding a leaking 550-gallon waste oil tank which had failed a tightness test. This tank was located approximately 100 feet west of monitoring well UGW-18 along Forrestal Drive (Figure 2-3). Three soil borings were advanced to a depth of 20 feet bgs surrounding the tank. One soil sample with highest OVA reading from each soil boring was sent to the laboratory and analyzed for benzene, toluene, ethylbenzene, and total xylenes (BTEX) and TPH. The soil samples which were sent had a strong hydrocarbon odor. Laboratory TPH analyses indicated concentrations in the soil ranging from 230 to 1,200 milligrams per kilogram (mg/kg) in excess of the Puerto Rico Environmental Quality Board (PREQB) standard of 100 mg/kg. Horizontal and vertical extent of soil contamination was not determined for the soil underlaying and surrounding the 443 UST site.

2.2.5 Draft Corrective Action Plan

A series of four soil borings were installed in November 1992 at the TWFF to support preparation of a Draft Corrective Action Plan (CAP) which was submitted by Law Environmental-Caribe in October 1993. These four borings were advanced to depths ranging from 8 feet to 19 feet. Two of the soil borings were located just north of Forrestal Drive in the vicinity of existing monitoring wells UGW-3 and UGW-14. The remaining soil borings were located south of Forrestal Drive in the vicinity of existing monitoring wells GW-4 and UGW-18. Each soil boring was sampled for subsurface soil from 5 feet above the water table to the water table and composited into one sample for laboratory analysis. Soil samples were analyzed for Toxicity Characteristic Leaching Procedure (TCLP) metals, TOX, flash point, and TPH. The report noted that soil from only one boring contained TPH concentration in excess of PREQB standards (100 mg/kg). All other soil sample results were below this standard.

Groundwater samples were collected from 11 monitoring wells and analyzed for volatile aromatic and unsaturated organic compounds (USEPA Method 502.2 and 503.1), lead, and TPH. Groundwater and product thickness measurements were conducted with a interface probe for four consecutive months (August 31, September 28, November 17, and December 12, 1992). Screened

intervals for nine monitoring wells (UGW-1, UGW-3, UGW-4, UGW-8, UGW-9, UGW-10, UGW-12, UGW-13, and UGW-14) were confirmed to be below the measured groundwater and/or free product elevations. Free product was detected in nine monitoring wells (UGW-1, UGW-2, UGW-4, UGW-5, UGW-12, UGW-13, UGW-14, UGW-17, and GW-04). Free product was detected in UGW-2 in 1992, but was not detected in 1991 measurements.

It was concluded that the horizontal extent of free product had not been adequately determined. A four phased CAP was proposed to include monthly groundwater and product measurements and quarterly groundwater collection of groundwater samples analyzed for BTEX, lead, and TPH.

2.2.6 Site Characterization and CAP

A site characterization study was completed by Blasland, Bouck, and Lee, Inc. (BB&L) in April 1994. This investigation was designed to define the extent of contamination in soil and groundwater at the TWFF through the installation of seven soil borings, eight monitoring wells, performance of wellhead tests, and preparation of a site-specific risk assessment.

The field work was conducted from November to December 1993. Seven soil borings were installed to delineate the outermost boundary of soil contamination and were completed to the water table. Select soil samples were submitted to the laboratory for BTEX and TPH confirmatory analysis based on field screening results. The results from the field screening and laboratory were below 100 mg/kg PREQB TPH contamination level. Groundwater samples were collected from the open borehole and analyzed for volatile organic compounds (VOCs) and TPH in the field. Confirmatory groundwater samples for three soil borings were sent to the laboratory. If the groundwater in the soil boring was determined to be outside of the free product area, a groundwater monitoring well was installed. Soil boring BBSB-4 was the only soil boring to be drilled within the free product area and a monitoring well was not installed in the soil boring. Soil boring BBSB-5 was installed further from the TWFF than BBSB-4 to insure the extent of groundwater effect was defined. Six monitoring wells were installed to the top of the water table (UGW-19, UGW-20, UGW-21, UGW-23, UGW-24, and UGW-25). One monitoring well was installed as a deep monitoring well (UGW-26) 40 feet below the water table. Monitoring well UGW-22 was installed in the center of the free product plume as a 6-inch monitoring well to accurately estimate the thickness of the free-floating product on top of the water table. The eight newly installed monitoring wells (UGW-19 through

UGW-26) and ten existing monitoring wells (UGW-6 through UGW-11, UGW-15, UGW-16, UGW-18, and GW-02) that did not contain free product were sampled and analyzed for VOCs and TPH.

Other field activities included collecting groundwater and product elevations in on-site monitoring wells, conducting an aquifer performance test in monitoring well UGW-22, conducting one in situ test (rising head) in four monitoring wells, performing free product bail-down tests in four monitoring wells, performing preliminary product recovery rate tests, and conducting a double-ring infiltrometer test. The in situ tests and the aquifer performance test indicates permeability of sediment in the TWFF is too low to support a conventional groundwater recovery system. The product bail down tests indicated the majority of free product was located in a relatively small area north of Forrestal Drive in the vicinity of USTs 56A/56B and monitoring wells UGW-1, UGW-5, and UGW-22.

Results of the investigation showed that contamination in the soil and groundwater is confined to the general area of the TWFF and has not migrated into Ensenada Honda. The configuration of the groundwater plume generally conforms to the location of fuel distribution lines from the tanks and is primarily diesel fuel and JP-5 fuel. Also reported in the study was the indication that site soil and bedrock are of low permeability which inhibits migration of contaminants beyond the boundaries of the fuel farm. The volume of contaminated soil at the TWFF was estimated to be 2 million feet^3, contaminated groundwater was estimated to be between 3.5 and 11.1 million gallons, and free product was estimated to be between 100,000 and 243,000 gallons based on the product thickness map and an assumed soil porosity of 0.3. The true thickness of free product ranges from a few inches in perimeter monitoring wells to less than three feet in the center of the plume. The vertical and horizontal extent of free-product and groundwater contamination plume was defined within the TWFF, except on the hill east of the Upper TWFF and north of Forestall Drive due to steep terrain and dense vegetation. The report recommended that remediation should concentrate on the free product layer on the groundwater table due to the low migration rates of the soil and groundwater contamination plumes.

Data collected during this investigation was used in the preparation of a Corrective Action Plan (BB&L, September 1994). Alternatives discussed in this CAP included passive surface skimming, hand bailing, and active skimming.

2.2.7 Multi-Stage Product Recovery Test Report

An informal report for multi-stage product recovery test was submitted by Terra Vac on March 25, 1996 to the EPA. Terra Vac conducted a single, dual, and three-phase testing of free product recovery systems. Single phase recovery is free product only pumping (i.e., free product only); two-phase recovery is vacuum enhanced free product only pumping (i.e., free product and vapors); three-phase recovery is vacuum enhanced groundwater and free product recovery (i.e., free product, vapors, and groundwater). The purpose of the tests was to determine the best available technology to enhance free product recovery without causing the product to spread further. Concerns were expressed by the USEPA that upward spreading of product might occur by wicking-up the product under vacuum extraction methods or smearing the product to lower depths by lowering the water table during simultaneous product and groundwater pumping. To address USEPA concerns, low level pumping techniques were used to maintain minor groundwater elevation reduction. The scope of work included soil testing, measurement of water and product levels, product recovery rates, installation and testing of recovery systems and evaluation of radius of influence and capture zone.

A product-only (one-phase) recovery system was installed in seven existing monitoring wells on site. Advantages of a skimmer-type system are that the product is the predominant fluid recovered and hence the cost of treatment and/or disposal of recovered water is saved. Other advantages include low power requirements and operations may be based on intrinsically safe electrical or air operated systems. This was a passive system since it does not provide any driving force for product to move toward the well; it operates essentially in hydrostatic conditions. The system was limited by the rate at which product drains into the well from the capillary fringe. Without any additional driving force, other than gravity, product moves very slowly from the formation, especially in low permeability formations which are present at the site. In addition, the radius of influence of such a system is very limited; typically a few inches to a few feet. Product goes into a holding tank where the levels are monitored such that the pumping system will shut down at 90% of the capacity of the tank. The system was "turned on" on February 4, 1994. Monitoring well UGW-1 had the greatest thickness of free product measured.

Product thickness in monitoring well UGW-25 had increased 214 percent from January to August 1995. This report recommended that installation of a recovery system in UGW-25 should be considered at this time to control the expanding free product plume.

Pneumatic pumps (two-phase) were installed in seven monitoring wells in July until September 14, 1995. On September 14 the system was shut down in preparation for installation of seven new recovery systems (three-phase). During the installation of the seven new recovery system wells, 69 soil samples were collected. The soil samples were sent to a contract laboratory for TPH analysis. The seven new recovery systems were installed in six new 4-inch wells identified as PW-1 through PW-6 and one new 2-inch monitoring well labeled as MW-1. Three additional 2-inch wells were installed as monitoring wells and were identified as MW-2, MW-3, and MW-4. Well installation took place from September 11 to September 27, 1995. One of the reasons for installing new wells was to identify the impact of free product pumping in nearby monitoring wells over the previous three years. If the free product only pumping systems were effective, the surrounding area would contain no free product in these monitoring wells. Also, measurement of the product/water interface could be assessed under various operating conditions as requested by the USEPA. Phase 1 testing of these wells recovered 30 gallons of product. Based on the results of Phase I and the estimated spill volume of 243,000 gallons, it would take 44 years or more to recover the total volume of spilled product and would take approximately 270 wells spaced 15 feet to recover the free product at the site.

The total amount of product recovered from the project start in 1994 through 1995 was 12,630 gallons. Monitoring well UGW-4 had the largest product layer in September 1995. In this report, Terra Vac determined that the product layer across the site appeared to have reached a steady state even though there was still a substantial product level. It appeared the product recovery system had reached its capture capacity in the present configuration. Terra Vac indicated that the installation of vacuum assisted recovery system had the potential to greatly increase the recovery rate at the site.

Phase 2 testing began on October 10, 1995. The Phase 2 system used product recovery with product only pumps as in Phase 1 with the simultaneous addition of vacuum extraction (soil vapor extraction). The Phase 2 process was designed to extract a negative relative pressure within the well to enhance the flow of fluids into the recovery wells. If the system, as tested, was allowed to operate at these rates for 1 year and assuming product would freely migrate towards the capture zones, potentially 28,700 gallons of product would be recovered. This represents a 420 percent increase in product recovery over the "product only" system while reducing the recovered water to product ratio by 75 percent. Based on the estimated spill volume of 243,000 gallons, it was estimated that recovery would take 8.5 years or more to recover the total volume. With the radius of influence of

the vacuum system, spreading or smearing of the free product would be controlled as the hydrocarbons would either evaporate and be recovered in the vapor phase or migrate along the differential pressure gradient toward the extraction wells where they would be recovered at much higher rates in the liquid phase.

On October 17 and 18, 1995, Phase 3 testing began. The Phase 3 system included lowering vacuum hoses or pipes into the product and/or groundwater and connecting to the vacuum source at the wellhead. No independent product recovery pumps were required. The vacuum source provided the driving force to lift the fluids from the borehole. The vacuum further induces subsurface airflow and provides the velocity required to maintain fluid flow without flooding the intake which is below the static fluid level (i.e., some amount of airflow is required to lift the fluids to the surface). The entrainment process is used to recover groundwater, product, and vapors simultaneously. Free product recovery is optimized by adjusting the depth of the entrainment hoses so they recover as much of the product and vapor and as little of the groundwater as possible. The results of the test indicated that if the system, as tested, was allowed to operated for 1 year and assuming product would freely migrate towards the capture zones, potentially 49,100 gallons of product would be recovered. Based on the estimated spill volume of 243,000 gallons, it would take 5 years or more to recover the total volume. This represented a 70 percent increase in recovery rates over the two phase recovery test and a 800 percent increase over the product-only, total fluids recovery system. Also, for all of the tests it was determined that the shape of the capture zone is not radially symmetric around the respective test wells, but rather is eccentric, typical of the pattern associated with highly fractured rock. Formal delineation of capture zones are inconclusive due to the heterogeneities and natural fluctuations in the water table.

The previous system configuration was shut down on October 27, 1995, pending contract authorization. On December 20, 1995 the Vacuum Extraction Unit used during the Multi-Phase testing was demobilized from the site. There were no operations of the free product recovery system in November and December 1995. On January 24, 1996 the free product recovery systems were prepared and tested for operations. January 25, 1996 the seven free product recovery systems began operations in wells PW-1, PW-2, PW-3, PW-4, PW-5, PW-6, and MW-1. Well PW-6 had the largest product thickness measured.

On March 30, 1996 the system was shut down as requested by the Navy representatives. The water discharge hose from the oil/water separator developed a leak in the section that crosses the road. The damage was caused by vehicular traffic. April 18, 1996 repairs were made to the hose by cutting out the damaged section and splicing in a new section.

On August 1, 1996, the entire system was shut down by request of Navy representatives. On August 1, 1996 product samples were collected from the product holding Tank B and Tank C. The samples were sent to the laboratory for RCRA metals analysis. The product was determined to be non-hazardous. On August 23, 1996 the system was restarted with three phase vacuum recovery systems installed in monitoring wells, UGW-1, UGW-4, UGW-12, and UGW-13. On August 26 the system was found not to be running. The most likely reason was a power outage by unknown sources. The total amount of free product removed from January to August 1996 with the system was 20 gallons. Well UGW-4 had the greatest product thickness from February through August 1996. The VARS product recovery system was demonstrated to be significantly more effective by 1400 percent than the skimmer system.

2.2.8 Closure Report For Tank 56A/B

Reliable Mechanical, Inc. issued a Closure Report for Tank 56 in November 1996. The 2-10,000 gallon steel tanks were located underground in front of Building 56. These tanks were used by the U.S. Navy as storage for diesel fuel that was to be loaded into tanker trucks for use at remote locations. The tanks were filled by a remote 6-inch underground fuel line that had been replaced. New 2-inch fiberglass pipes in 3-inch containment pipes were installed. Two new, 15,000 gallon double walled USTs were installed and outfitted with electronic overfill protection, interstitial leak detection piping, sump leak detection, and electronic gauging. Four soil samples were colleted (two at the tank ends, one in the tank middle area, and one from the stockpiled soil from the excavation) from each tank excavation and three soil samples were collected along the pipeline excavation for a total of 11 soil samples which were analyzed for TPH and BTEX by a certified, on-site mobile laboratory. Contaminated soil (329 tons) was bioremediated and disposed as a non-regulated disposal.

2.2.9 Project Close-Out Report Interim Corrective Measure Free Product Recovery System

ICHOR Services, Inc. (formerly PDGES) issued the Project Close-Out Report on February 24, 1997 for J.A. Jones Environmental Services. The primary objective was to address the identified product plume at the TWFF. Secondary objectives include controlling the product plume to minimize migration of the plume to the south and collect as much free product as practical at the TWFF. The installation plan was developed in accordance with Response to Comment No. 5 contained in the "Response to USEPA's Comments dated June 20, 1996 and September 13, 1996, TWFF" prepared by BB&L dated September 26, 1996. The recovery wells were positioned within the limits of the free-floating product plume to maximize recovery. Product was to be recovered with eight pneumatic operated product recovery wells (RW-1 through RW-8). Seven of the wells were newly installed (6-inch ID installed in a 12-inch OD soil boring) and one pump was to be located in existing monitoring well UGW-22 (RW-3). The recovery pump was ultimately not installed in well UGW-22 because product did not accumulate significantly in this well. However, a well vault and piping was installed to this well so that a pump may be added in the future should product thickness increase. Mobilization of the project was delayed until an installation plan to address USEPA comments was prepared. Free product (296 gallons) was removed from the recovery wells from December 1996 through February 1997.

ICHOR Services, Inc. issued the Pre-Final Operation and Maintenance Manual on April 9, 1997 for J.A. Jones Environmental Services.

2.2.10 Operation of ICM

The commissioning phase of the ICM was completed on April 30, 1997. Free product removal from the ICM began in March 1997 and is presently still in operation. The free product recovered from March 1997 through October 1998 yielded a total 1,333 gallons of free product recovered.

2.2.11 Other Letter Reports Submitted

J. F. Martinez & Co. and Altol Environmental Services, Inc. performed emergency repair to a 12-inch DFM fuel line at TWFF area according to the Project Status Report #1 on April 29, 1997.

The project was executed in two phases. The first comprised soil and pipe integrity testing, replace 1,850 linear feet of damaged pipe at tunnel, and contamination and debris removal. The second consisted of repair by replacement of the piping as described below.

1. Remove ruptured pipe from utility tunnel.

2. Provide hydro pressure testing to the remaining underground piping.

3. If piping passes the hydro pressure testing then proceed to replace the 150 linear feet at the tunnel, hydro test the complete pipe section including the new pipe section again, perform soil and ultrasonic testing.

4. If piping does not pass the hydro pressure testing, perform ultrasonic and soil testing, according to applicable project scope items, and wait for instructions.

The program included the following tasks: test pit excavation, soil sampling, replacement of 150 linear foot DFM Pipe (12-inch diameter), and restoration of tunnel and excavated areas. Thirteen test pits were excavated to expose the main DFM pipe and assess pipe and soil conditions. Test pits were excavated to a maximum depth of 12 bgs. No groundwater was encountered. Soil screening was conducted for organic vapor concentrations. Thirteen soil samples were collected from the bottom and center of each excavation at a depth of 5-12 feet bgs at the DFM pipe area. Three soil sample results were not provided in the Project Status Report. Soil samples were collected from the backhoe's bucket and analyzed for TPH and BTEX. Two composite soil samples were collected from the excavated soil piles and analyzed for full RCRA TCLP analysis (VOCs, SVOCs, total metals, reactivity, corrosivity, and ignitability). Strong hydrocarbon odor was perceived in soil. TPH concentrations ranged from 122 to 43,400 mg/kg in soil samples (S-1 through S-10, D-1, and D-2) which exceeded USEPA and PREQB regulatory levels. The soil piles did not have hazardous characteristics. The existing fuel line was cut just upgradient and just downgradient of the tunnel. The cut section of pipe was removed from the tunnel. This section was replaced and the line was subsequently pressure tested. The removed section of pipe was noticeably corroded in areas, and a strong petroleum odor was evident in the tunnel. Furthermore, product was reportedly observed on the tunnel floor prior to the cutting of the pipe. Based on conversations with Activity personnel, the presence of product in the vadose zone and shallow groundwater is attributable to past storage/spills - not related to the main fuel line that is being repaired. Product

stored in the past includes JP-5 jet fuel, No. 6 fuel oil, and diesel fuel. Two types of fuel are currently stored at the fuel farm including JP-5 jet fuel and DFM. Another potential source of contamination is the overflowing of the valve pit which is located upgradient from the tunnel. Product was not observed seeping from the exposed fuel line, no cracks, holes, or voids were noted in the fuel line. The most severe soil staining was observed above the level of the pipe.

A site visit memorandum was prepared by Baker for the existing fuel line inspection. Baker was on site to provide environmental and health and safety services. Baker did not observe any evidence substantiating that the fuel line was leaking at the excavated pit locations. For example, product was not observed seeping from the exposed fuel line, no cracks, holes, or voids were noted in the fuel line, and the most severe soil staining was observed above the level of the pipe. The soil immediately underlying the fuel line at test pits 2 and 3 was discolored; however, this may be attributable to a spill issuing from another source or to the color of the backfill material. A very small seepage face of dark brown product was observed just below the pipe at the north end of test pit 9. Heavy staining of soil was observed in test pits 1, 8, and 10. Slight staining of soil was observed in test pits 2, 3, and 9. No staining was observed in test pits 4, 5, 6, and 7. The test pit locations are presented on Figure 2-1 at locations S-1 through S-13. Five samples were collected of product. Samples 97-DFM-01 and 97-JP5-01 were collected from the fuel farm sampling tap and contain fresh DFM and JP-5 jet fuel, respectively. One sample of unknown product (97-VP-01) was collected from the valve pit north of the tunnel. Two samples were collected from test pit numbers 1 (97-PIT01-W01) and 10 (97-PIT10-W01), which represented the two most contaminated test pits based on visual observations. The unknown samples closely matched the fingerprint of sample 97-DFM-01. The laboratory reports that it appears that some weathering has occurred to the three unknown samples based on the loss of the early portion of the fingerprint. The amount of weathering appeared to be the greatest in sample 97-PIT01-W01 and the least in sample 97-VP-01.

2.2.12 Corrective Measures Study Investigations

A CMS Investigation was performed during the Spring of 1998 to gather additional data with respect to the fuel related contamination to assist in the development of the CMS and selection of the most applicable remedial approach.

The investigation included the performance of 30 direct push soil borings with the collection of 68 subsurface soil samples. The subsurface soil samples were analyzed for BTEX, TPH diesel range

organics (DRO) and gasoline range organics (GRO), total organic carbon (TOC), bulk density, and particle size distribution. A total of ten soil gas samples were collected and analyzed for percent oxygen, percent carbon dioxide, and TPH (DRO and GRO). Three in-situ vertical permeability tests were conducted as was groundwater sampling from 41 monitoring wells across the site. The groundwater samples were analyzed for BTEX, TPH (DRO and GRO), methane, nitrate, sulfate, alkalinity, chloride, and ferrous iron.

The investigation was conducted to provide a recent update of the soil and groundwater contamination present at the site. A brief discussion of the results from this investigation are summarized in the following section of this report.

2.3 Summary of Site Conditions

A description of the most recent site conditions is provided in the following subsections of this report. The data included is summarized from the Corrective Measures Study Investigations Report (Baker, 1998a) and the Tow Way Fuel Farm Quarterly Summary Progress Report No. 6 (May 1, 1998 through July 31, 1998) (Baker, 1998b).

2.3.1 Soil Contamination

A total of 68 subsurface soil samples were submitted for laboratory analysis of BTEX and TPH (DRO and GRO) from the TWFF during the CMS investigation. BTEX was detected in 34 of the 68 samples ranging in concentrations from 0.17 J to 12,625 J micrograms per kilogram (μg/kg). TPH (DRO and GRO) was detected in 43 of the 68 samples ranging in concentrations from 3.8 J to 22,000 mg/kg (DRO) and 29 J to 1,100,000 J μg/kg (GRO).

Isopleth maps of the BTEX and TPH (DRO and GRO) concentrations were developed on five foot intervals to a total depth of 15 feet bgs. A minimum of three positive detections were required in each interval for the respective constituent to generate isopleth maps. This yielded a BTEX and TPH (DRO and GRO) isopleth from the three five foot intervals for a total of nine isopleth maps. Figures 2-4, 2-5, and 2-6 provide the BTEX, TPH GRO, and TPH DRO isopleth maps for the 0-5 ft bgs interval. Figures 2-7, 2-8, and 2-9 correspond to the 5-10 ft bgs interval while Figures 2-10, 2-11, and 2-12 provide the BTEX, TPH GRO, and TPH DRO isopleths.

Total organic carbon was detected in eight of the 68 samples submitted for analysis with concentrations ranging from 0.046 μg/kg to 0.77 μg/kg.

A total of five samples were submitted for analysis of bulk density. The density of the samples ranged from one gram per milliliter (g/ml) to 1.4 g/ml.

A total of ten soil gas samples were collected and analyzed for TPH (DRO and GRO), percent carbon dioxide, and percent oxygen. TPH GRO was detected in four samples ranging in concentration from 5.6 parts per million by volume (ppmV) to 45 ppmV. TPH DRO was not detected in any of the samples. Carbon dioxide concentrations ranged from 0.9% to 20.8% while the oxygen concentrations ranged from 7.6% to 25.4%.

2.3.2 Groundwater Contamination

A total of 41 groundwater samples were collected from the TWFF during the CMS investigation.

Twenty one different VOCs were detected in 28 of the 41 groundwater samples. Methylene chloride (one sample), benzene (five samples), trichloroethene (one sample), toluene (two samples), and ethyl benzene (three samples) exceeded both the federal MCLs and EPA Region III tap water RBCs. Nine VOCs were in excess of the EPA Region III tap water RBCs in as few as one sample or as many as 13 samples (1,2,4-trimethylbenzene). An isopleth map providing the BTEX concentrations in the groundwater at the TWFF is shown on Figure 2-13.

Methane was detected in 33 of the 41 samples with concentrations ranging from 0.05 to 55 µg/L. TPH GRO was detected in 26 out of 41 samples ranging from 29 J to 420,000 J µg/L. An isopleth map of the TPH GRO concentrations in groundwater at the TWFF is provided on Figure 2-14. TPH DRO was detected in 33 of 41 samples with concentrations from 65 J to 960,000 µg/L. An isopleth map of the TPH DRO concentrations in groundwater at the TWFF is provided on Figure 2-15.

The alkalinity of the groundwater samples ranged from 156,000 to 1,400,000 µg/L. Nitrate was detected in 17 out of 41 samples ranging in concentration from 110 to 3,200 µg/L. Sulfate detections ranged from 260 to 681,000 µg/L in 38 of the 41 groundwater samples. Chloride which was detected in all of the groundwater samples ranged from 14,100 to 8,340,000 µg/L, while ferrous iron was detected in 39 of the 41 samples ranging from 80 to 28,000 µg/L.

The specific conductivity of the groundwater samples ranged from 50 to 27,500 μmhos, the pH values were in the range of 6.31 to 7.76. The redox potential ranged from 354.5 to 164.1 mV. Dissolved oxygen concentrations were 0.68 to 4.03 mg/L.

2.3.3 Groundwater Level and Free Product Level Measurements

Groundwater level and free product thickness measurements are obtained at the TWFF on a monthly basis under the Interim Corrective Measure (ICM) being conducted at the site. The latest reported round of readings is from the TWFF Quarterly Summary Progress Report No. 6. The corrected groundwater surface contour map from July 1998 and the free product thickness and extent map from July 1998 are presented on Figures 2-16 and 2-17 respectively.

2.3.4 Interim Corrective Measure

Construction of the ICM at the Tow Way Fuel Farm (including the commissioning phase) was completed April 30, 1997. Prior to that point, product recovery efforts were undertaken on an "emergency recovery system" basis. The paragraphs which follow briefly describe the work done to date.

Product recovery testing started with product-only skimming pumps in several of the existing wells at the TWFF which constituted the "emergency recovery system". During this time, there were also small scale pilot tests run on various combination of recovery systems which included extraction of single, dual and triple phases (product skimming only, product skimming with groundwater table depression, and product skimming with groundwater table depression assisted by vacuum extraction of the vapor phase). Navy records indicate that a total of 12,630 gallons was recovered during the time interval beginning March 1994 through September 1995. The three phase recovery pilot study recovered a total of 7,544 gallons between September 1994 and February 1995. The combination of the emergency recovery system and the pilot study were effective in removing a total of 13,773 gallons in the period March 1994 through September 1996.

The ICM was commissioned on April 30, 1997. The ICM was initially to be comprised of eight wells equipped with product skimming pumps. One well did not receive a pump since there was no free product in the well at the time of installation. Since the original system was installed wells have been added and deleted from the system based on the presence or absence of free product in the various wells. It is very common to pump a well for a month or two whereupon there is no more free product in the well. When this occurs, the pump is moved to another well. It is equally common to see free product return to a well that was previously pumped.

The ICM continues in operation with mixed success. The original purpose of the system was to stabilize the plume and to stop its further migration. In this area it has been reasonably effective (with the exception of the area along Forrestal Drive where additional migration did occur until more wells were installed that finally stopped the plume). The second purpose was to begin recovering product from the subsurface.

2.3.5 CleanOX Pilot Study

There is presently a pilot study underway (in the early stages) using the patented CleanOX technology of ManTech Environmental, Inc. Bench scale testing of the technology was performed and it was determined that the site conditions and contaminants are amenable to treatment using the process. Proposals have been received from the technology vendor and reviewed by the Navy, EPA and EQB. A determination has been made by the EQB that no underground injection permit is necessary for a full pilot study to be performed on the site. Recently, in conjunction with this determination by EQB, the Navy and EQB have agreed to a groundwater and soil monitoring program for implementation as part of the pilot study.

ManTech and Baker have entered into contract for the pilot study and a "notice-to-proceed" has been issued to ManTech to begin the work. Presently, injection and monitoring well installation is scheduled for December 1998. At the time of installation, the baseline sampling will be performed. Injection of the reagents will begin in mid-January 1999.

Results of the pilot study for the CleanOX process will be contained and evaluated in the CMS Task II report.

2.4 Statement of Purpose

The overall purpose of the corrective measure(s) at the Tow Way is to address contamination in the exposure pathways present at the site. The pathways that have been identified are:

- Groundwater for beneficial but not potable use (e.g. the groundwater could be used to water the lawn at the facility but not as a drinking water source without treatment) and,

- Surface and subsurface soils.

Treatment of the soils and the groundwater will remove any sources of contamination from the site.

FIGURES

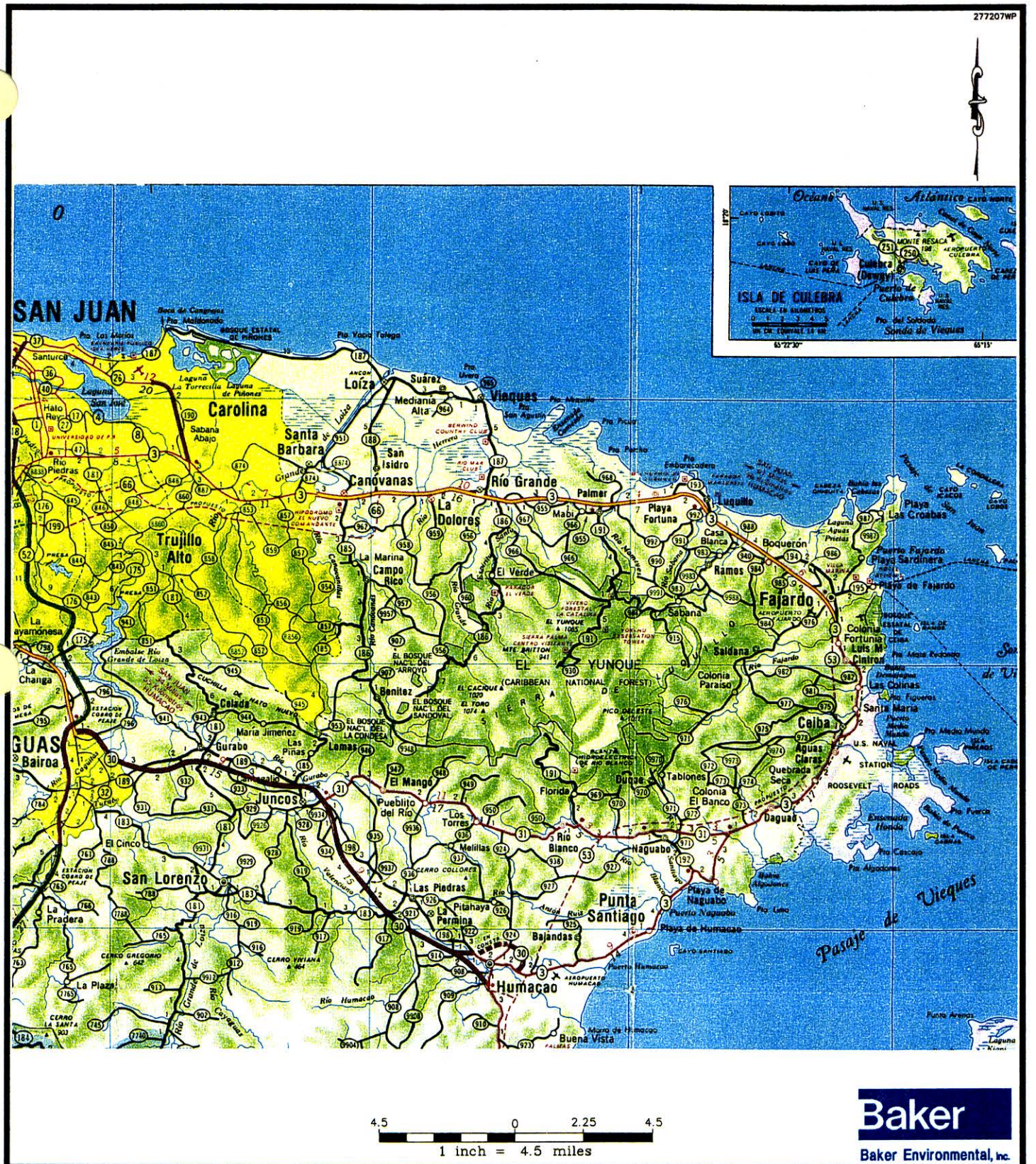


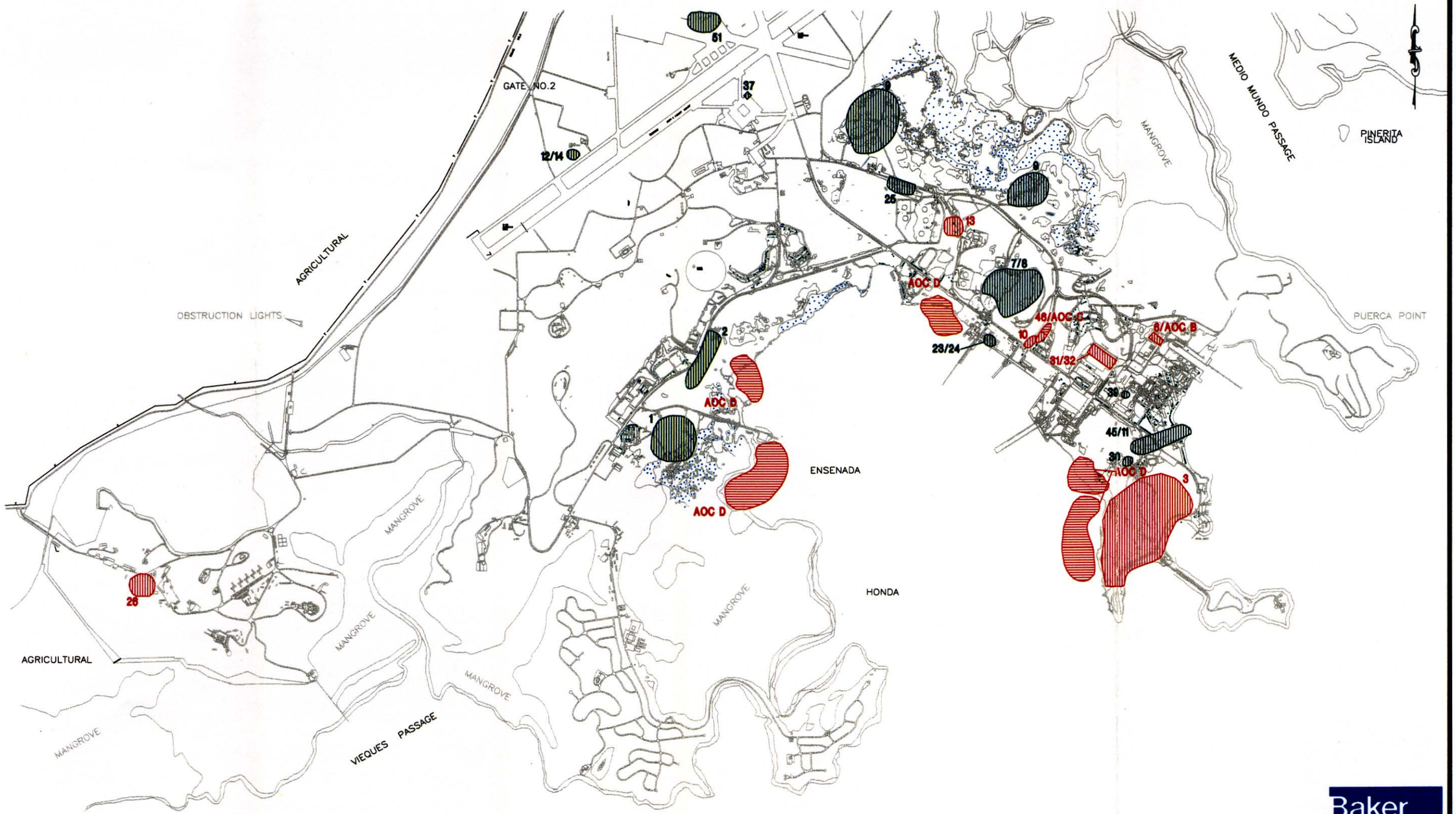
FIGURE 2-1
REGIONAL LOCATION MAP

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

SOURCE: H.M. GOUSHA, 1988.

00758CB14

277186WP



Baker
Baker Environmental, Inc.

LEGEND

1 – SWMUs

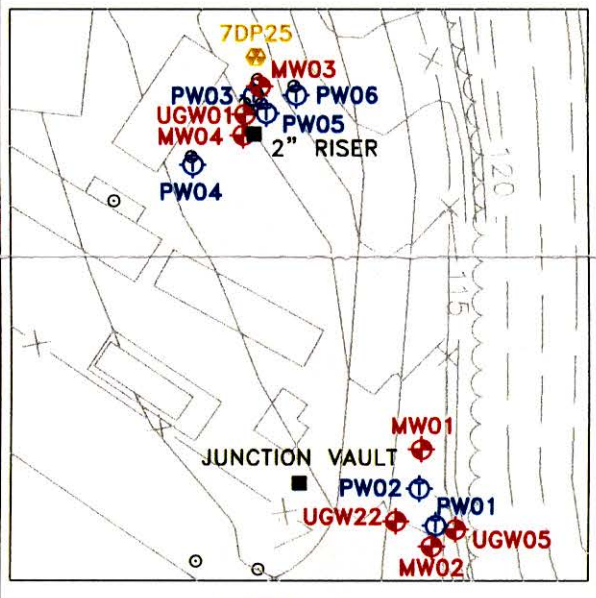
AOC D – AOCs

3 – AREA WHICH THIS INVESTIGATION PERTAINS TO

SOURCE: LANTDIV, FEB. 1992/1997

2500 0 1250 2500
1 inch = 2500 ft.

FIGURE 2–2
SWMU/AOC LOCATION MAP
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



VIEW A

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

Baker

277501CM

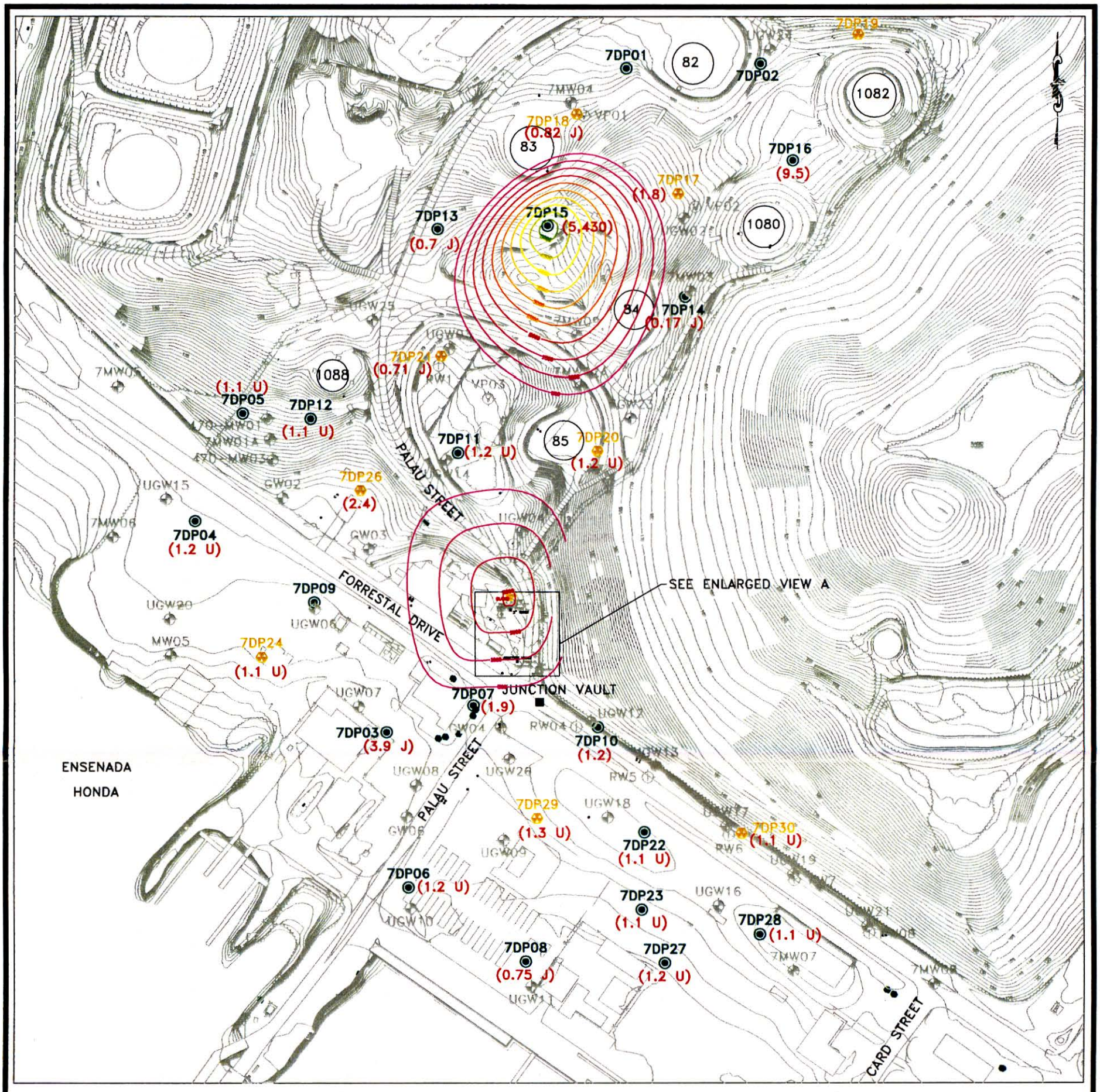
LEGEND

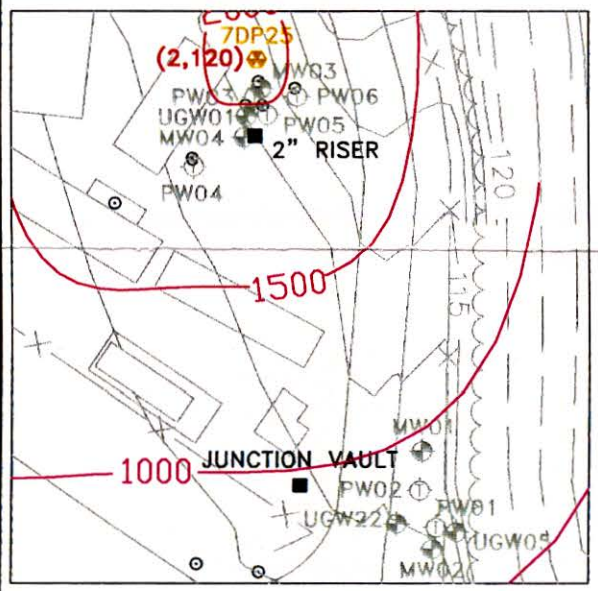
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-3
SITE PLAN
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

200 0 100 200
1 inch = 200 ft.

50 0 25 50
1 inch = 50 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

277513CM

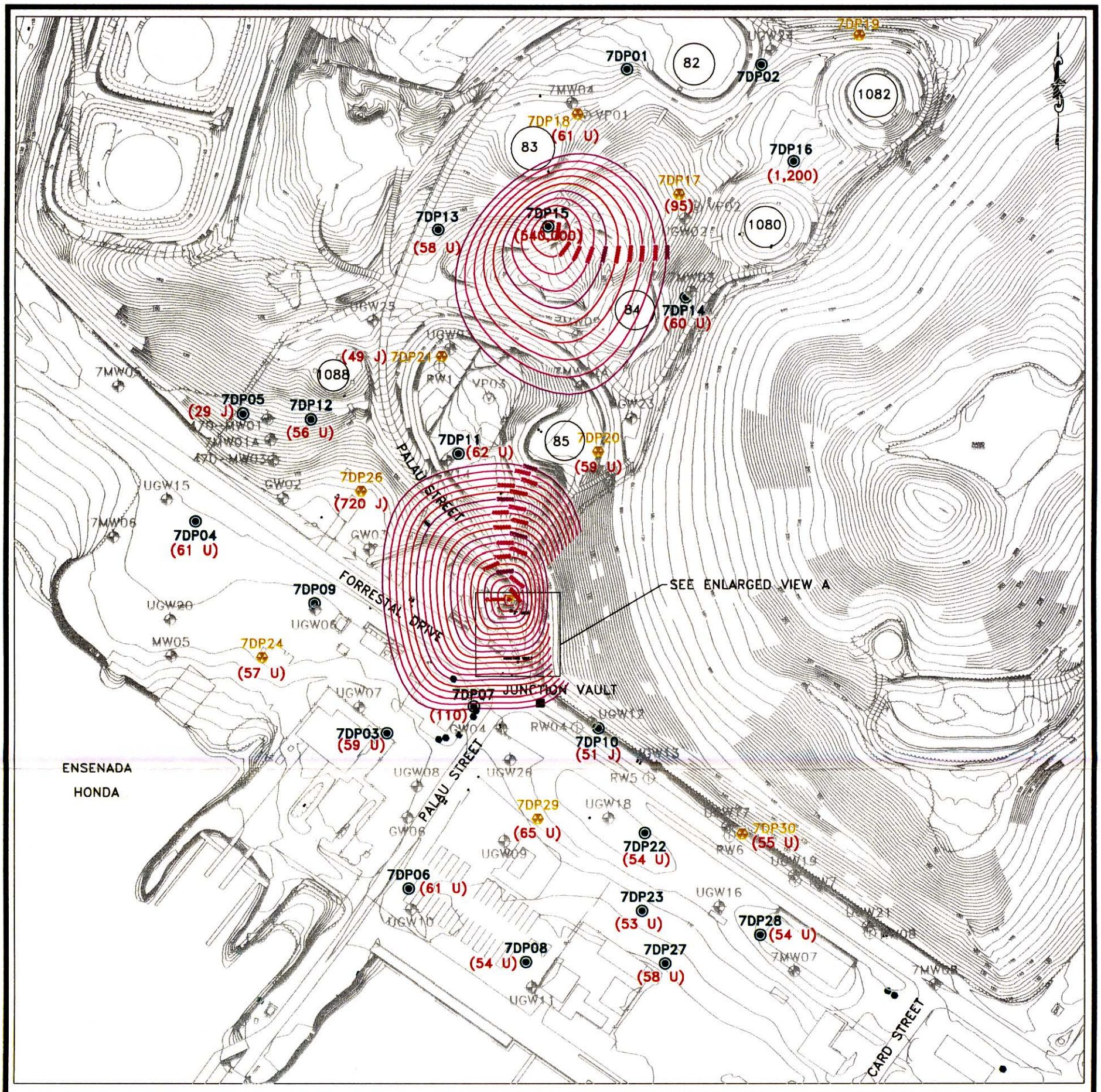
LEGEND

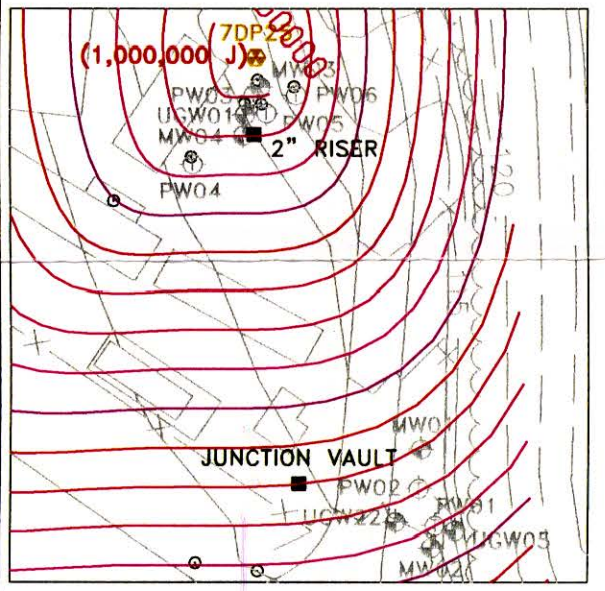
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (2.120) – BTEX CONCENTRATION (ug/kg) IN SOILS
- —1.5— – ISOCONCENTRATION LINE (ug/kg)

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-4
BTEX IN SOIL ISOPLETH MAP 0-5' BGS
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

200 0 100 200
1 inch = 200 ft.

50 0 25 50
1 inch = 50 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

277508CM

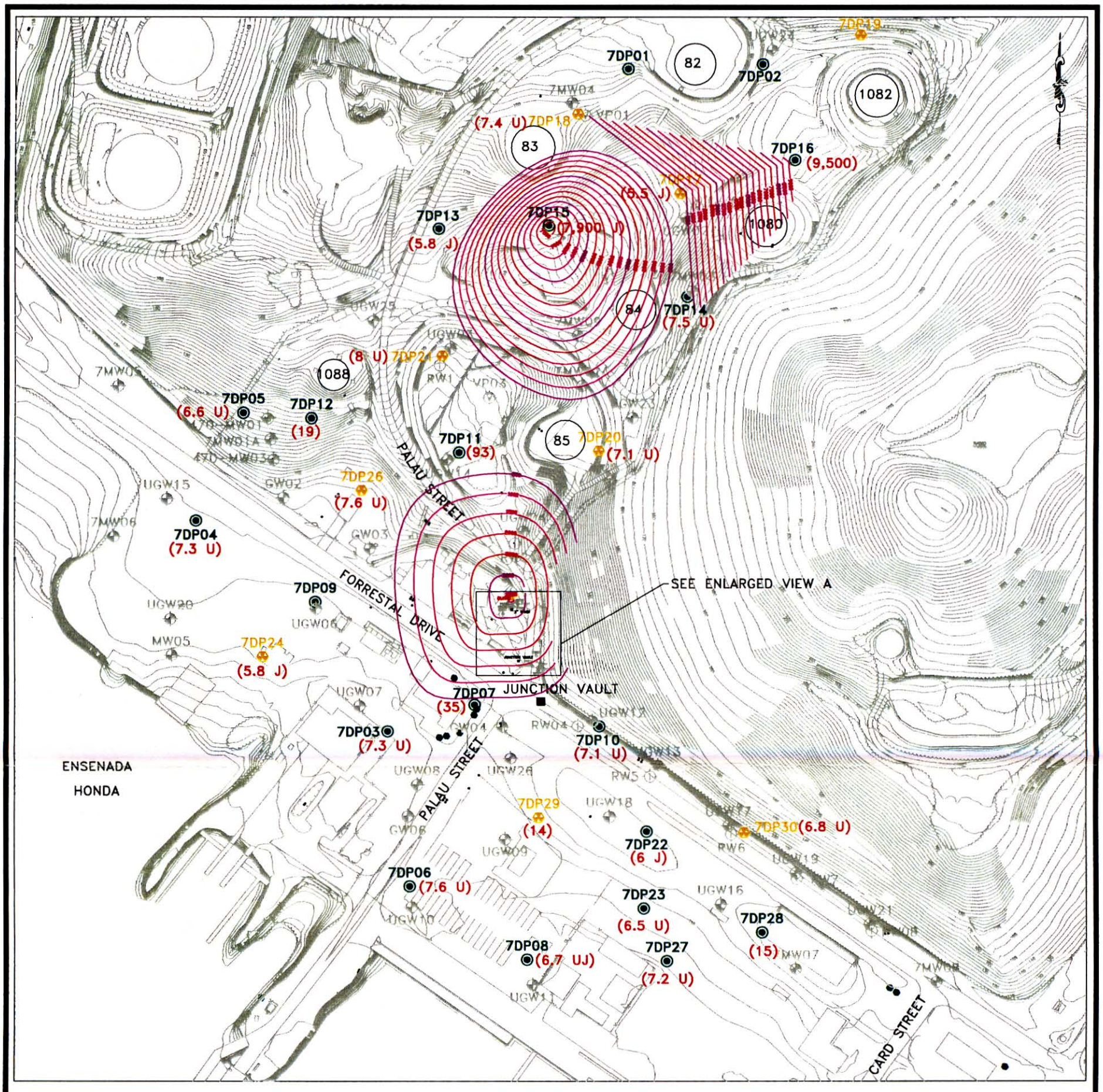
LEGEND

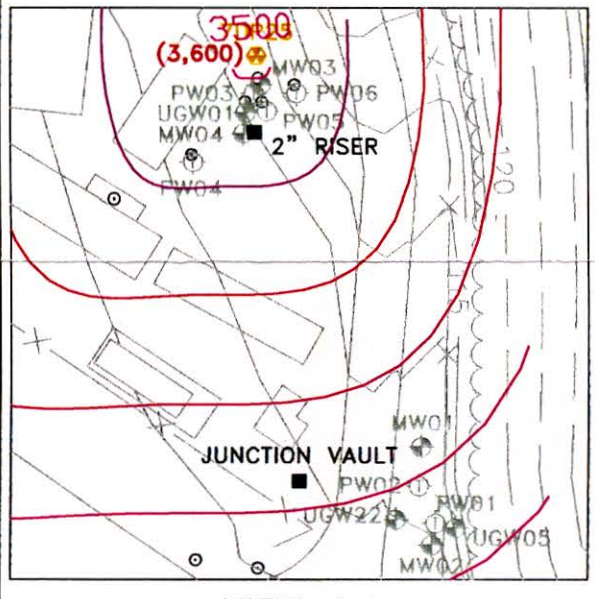
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (29 J) – TPH GRO CONCENTRATION (ug/kg) IN SOILS
- 50000 – ISOCONCENTRATION LINE (ug/kg)

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2–5
TPH GRO IN SOIL ISOPLETH MAP 0–5' BGS
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

200 0 100 200
1 inch = 200 ft.

50 0 25 50
1 inch = 50 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

277511CM

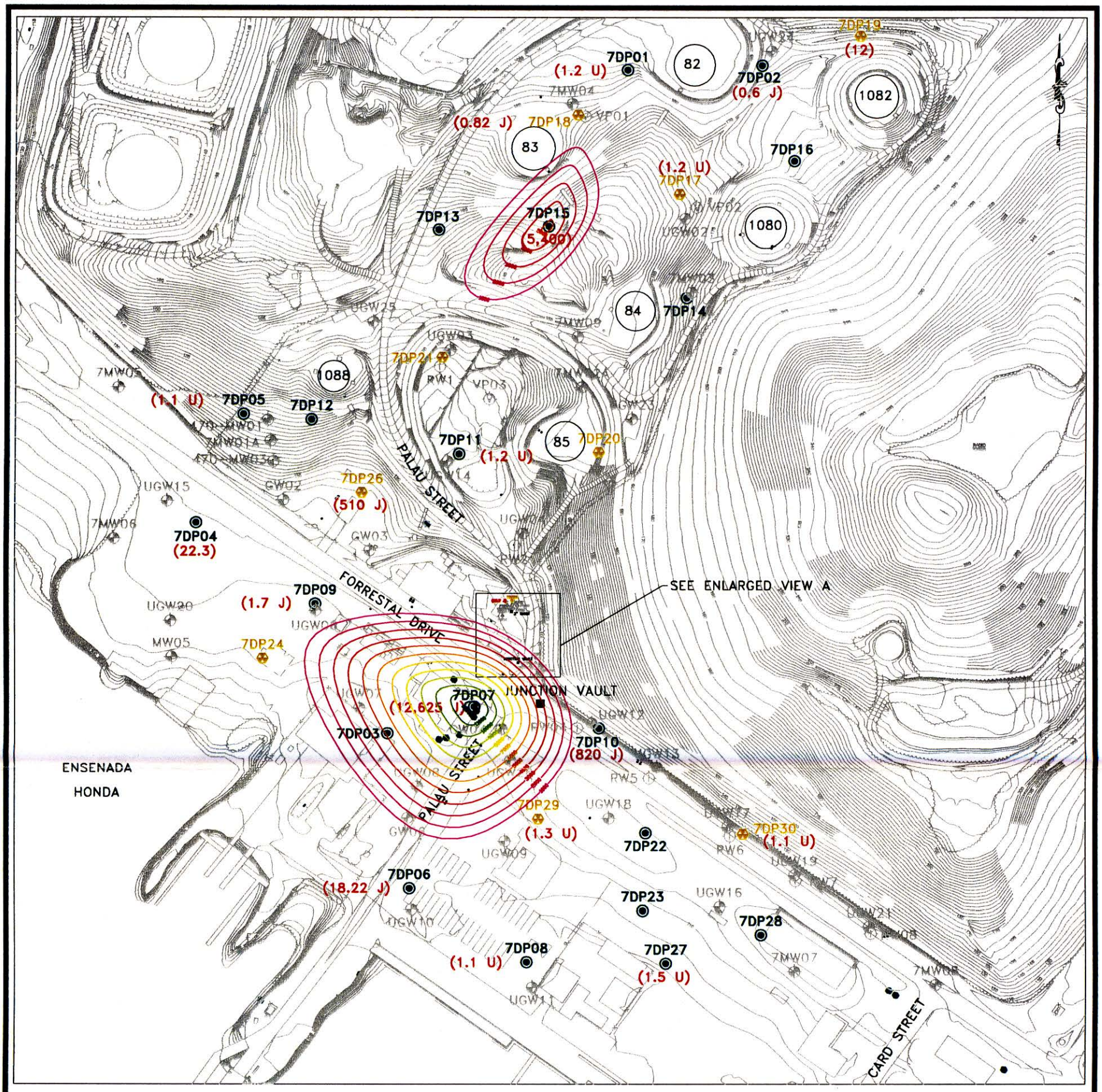
LEGEND

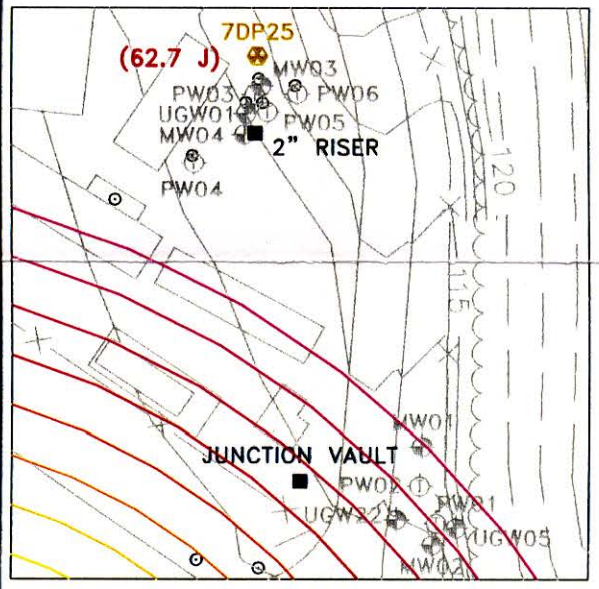
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (3,600) – TPH DRO CONCENTRATION (mg/kg) IN SOILS
- 500 – ISOCONCENTRATION LINE (mg/kg)

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-6
TPH DRO IN SOIL ISOPLETH MAP 0-5' BGS
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

200 0 100 200
1 inch = 200 ft.

50 0 25 50
1 inch = 50 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

277512CM

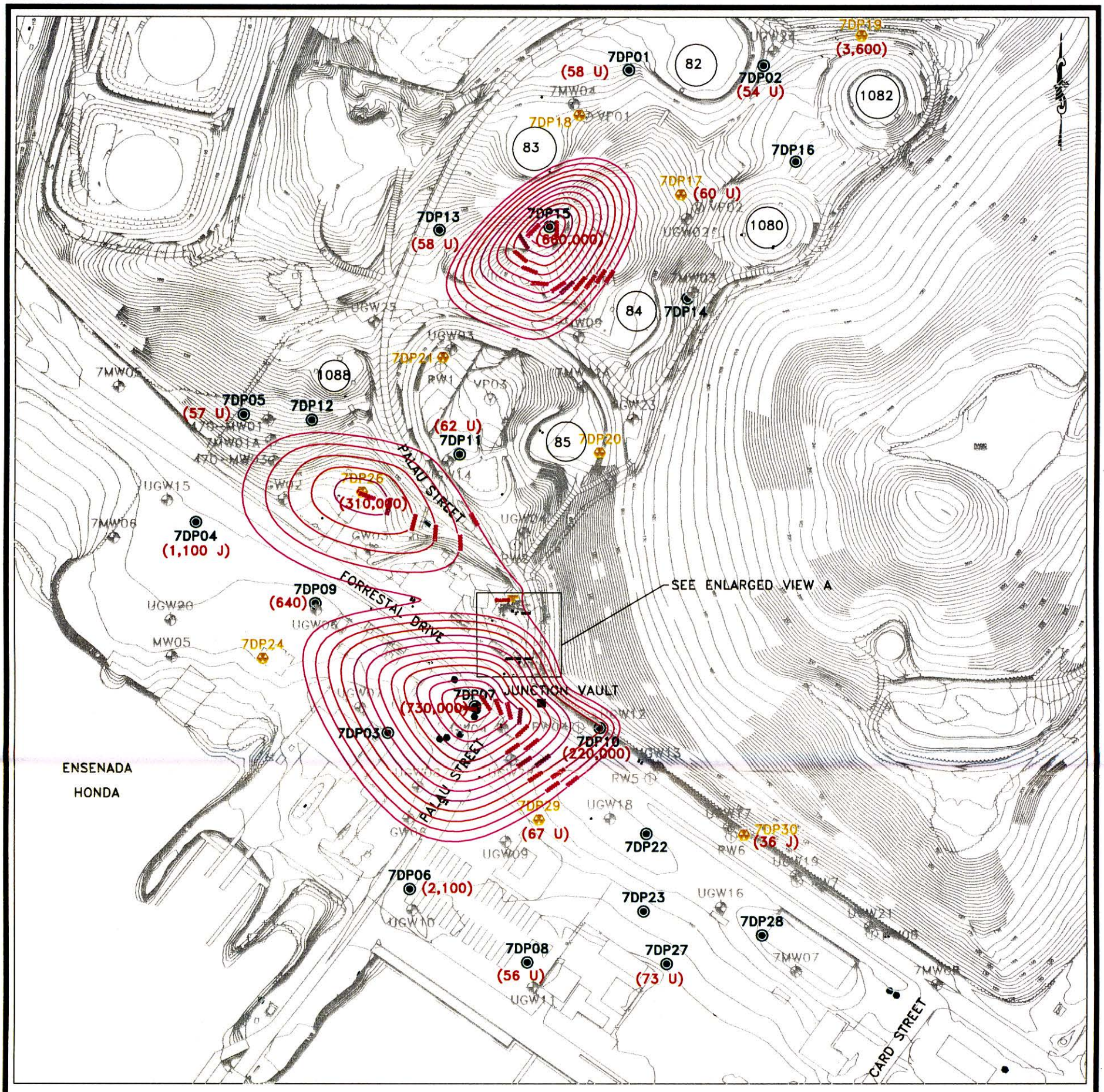
LEGEND

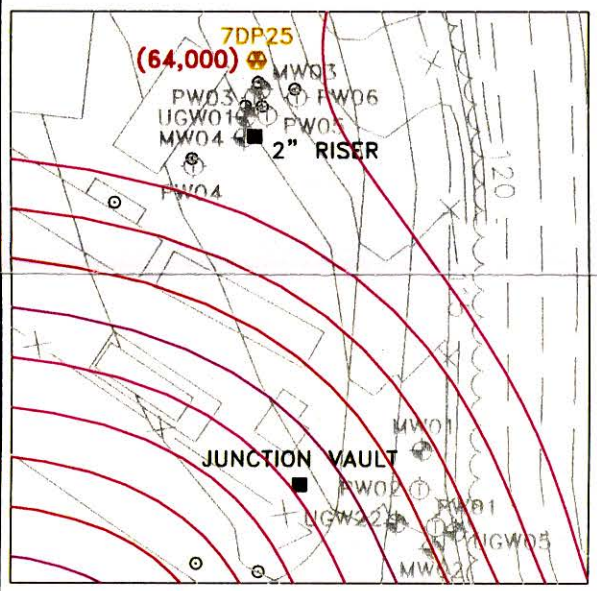
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (0.012) – BTEX CONCENTRATION (ug/kg) IN SOILS
- —10— – ISOCONCENTRATION LINE (ug/kg)

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-7
BTEX IN SOIL ISOPLETH MAP 5-10' BGS
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

200 0 100 200
1 inch = 200 ft.

50 0 25 50
1 inch = 50 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

277505CM

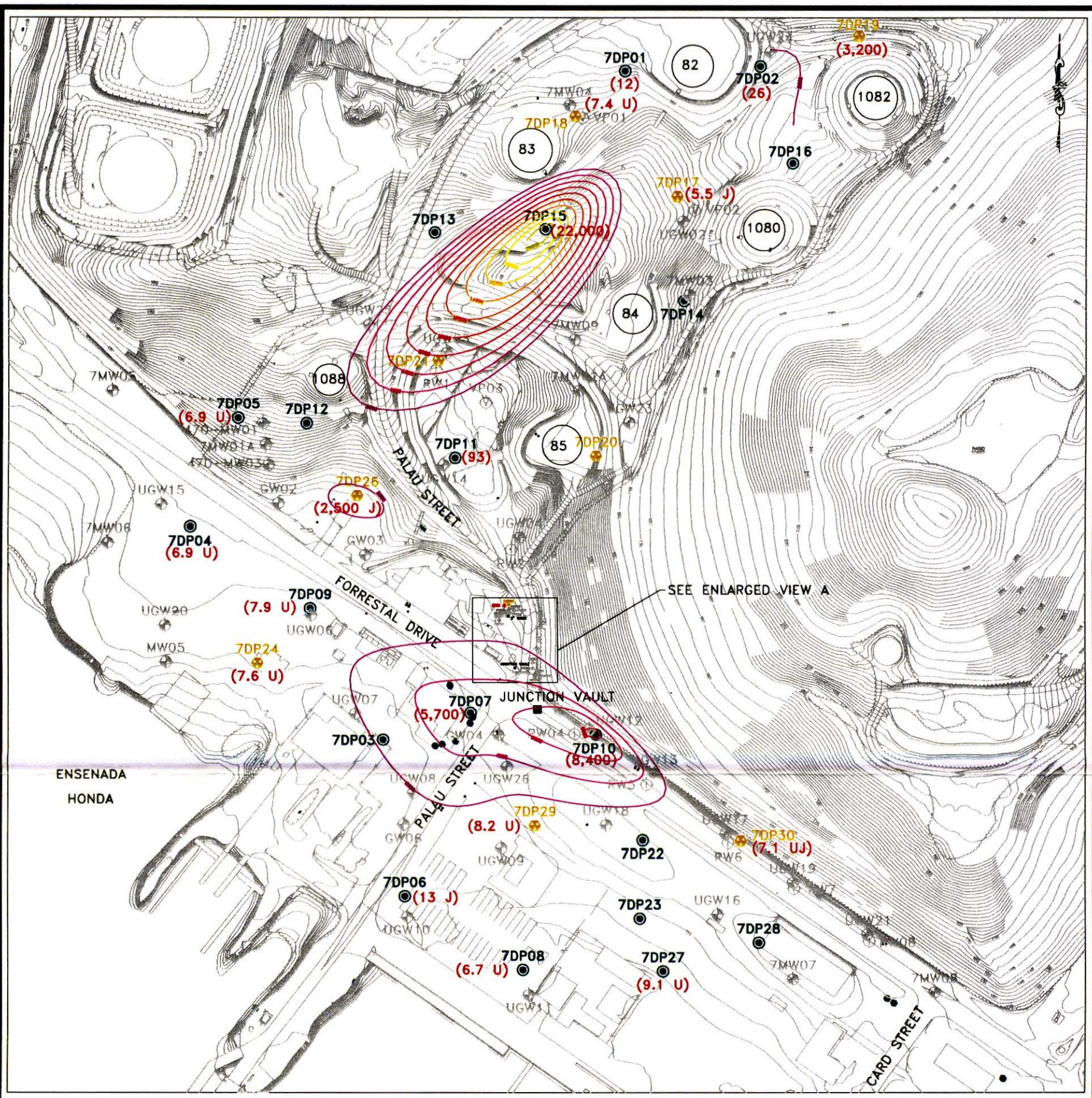
LEGEND

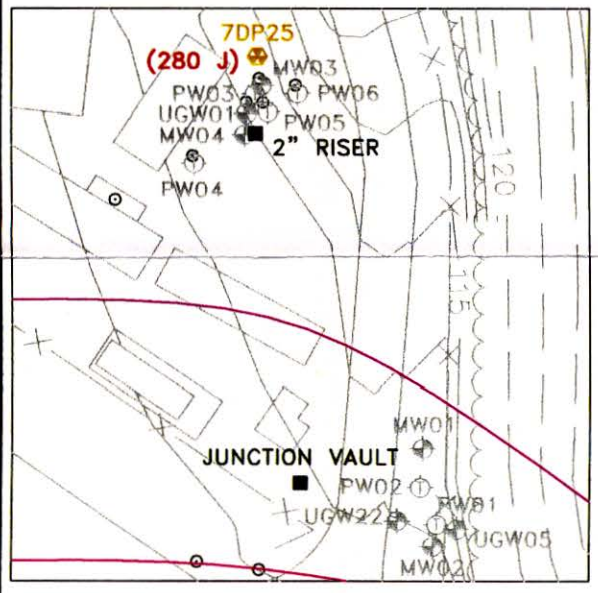
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (64,000) – TPH GRO CONCENTRATION (ug/kg) IN SOILS
- 550 – ISOCONCENTRATION LINE (ug/kg)

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-8
TPH GRO IN SOIL ISOPLETH MAP 5-10' BGS
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

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

Baker

277507CM

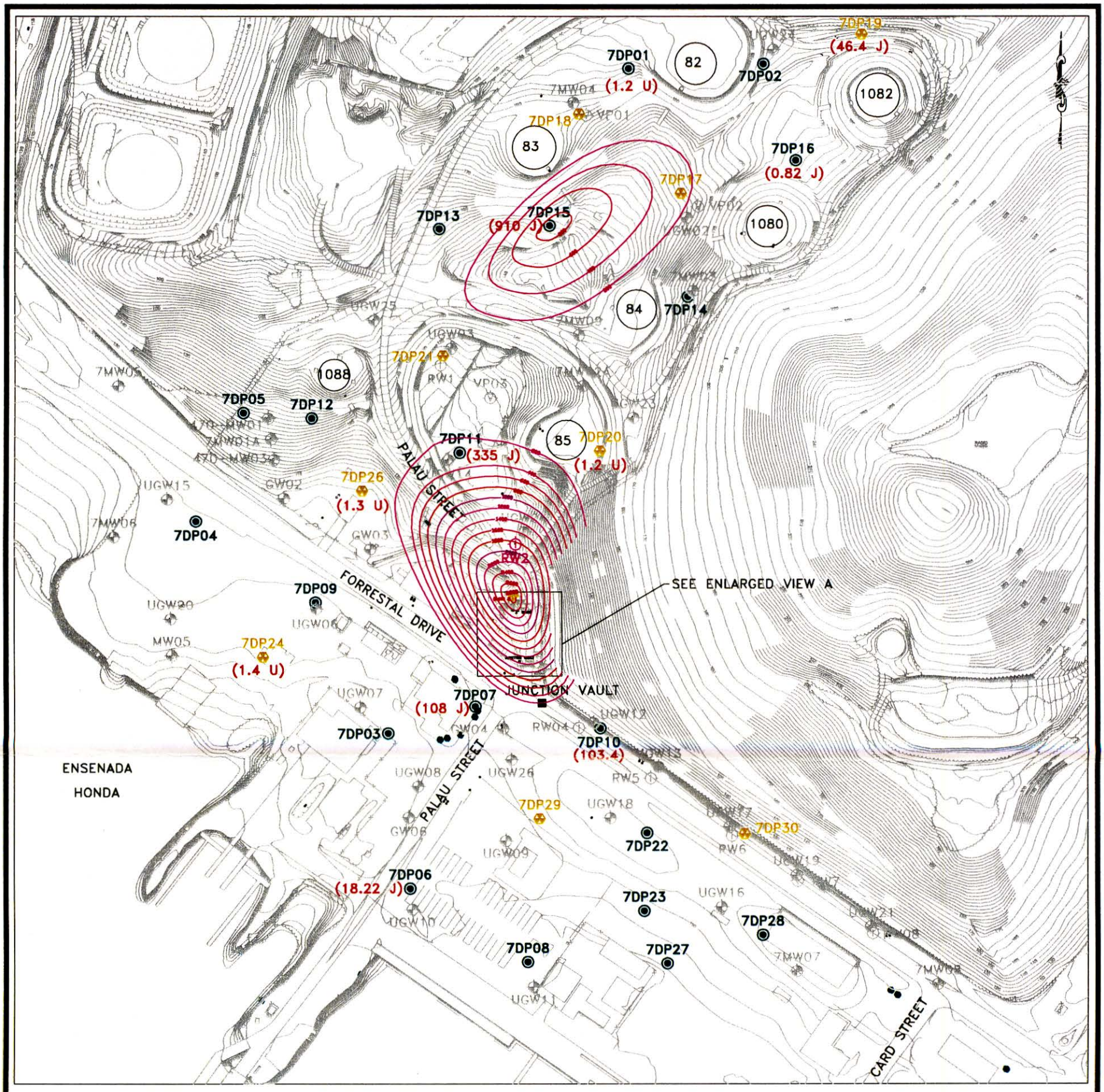
LEGEND

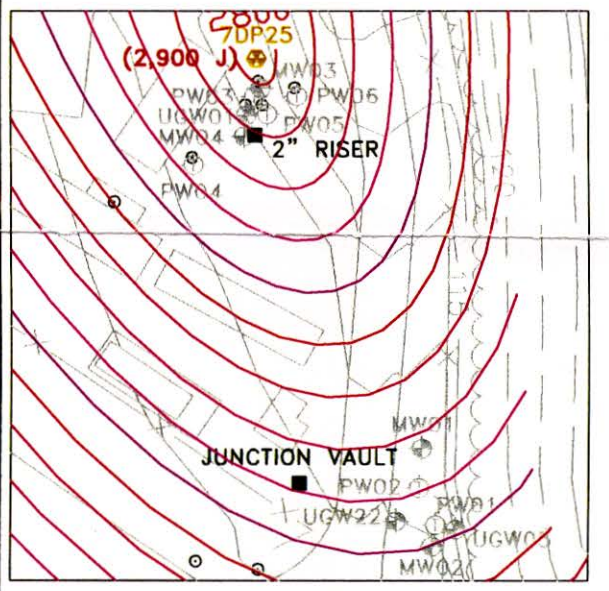
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (12) – TPH DRO CONCENTRATION (mg/kg) IN SOILS
- 4000 – ISOCONCENTRATION LINE (mg/kg)

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-9
TPH DRO IN SOIL ISOPLETH MAP 5-10' BGS
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

200 0 100 200
1 inch = 200 ft.

50 0 25 50
1 inch = 50 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

277506CM

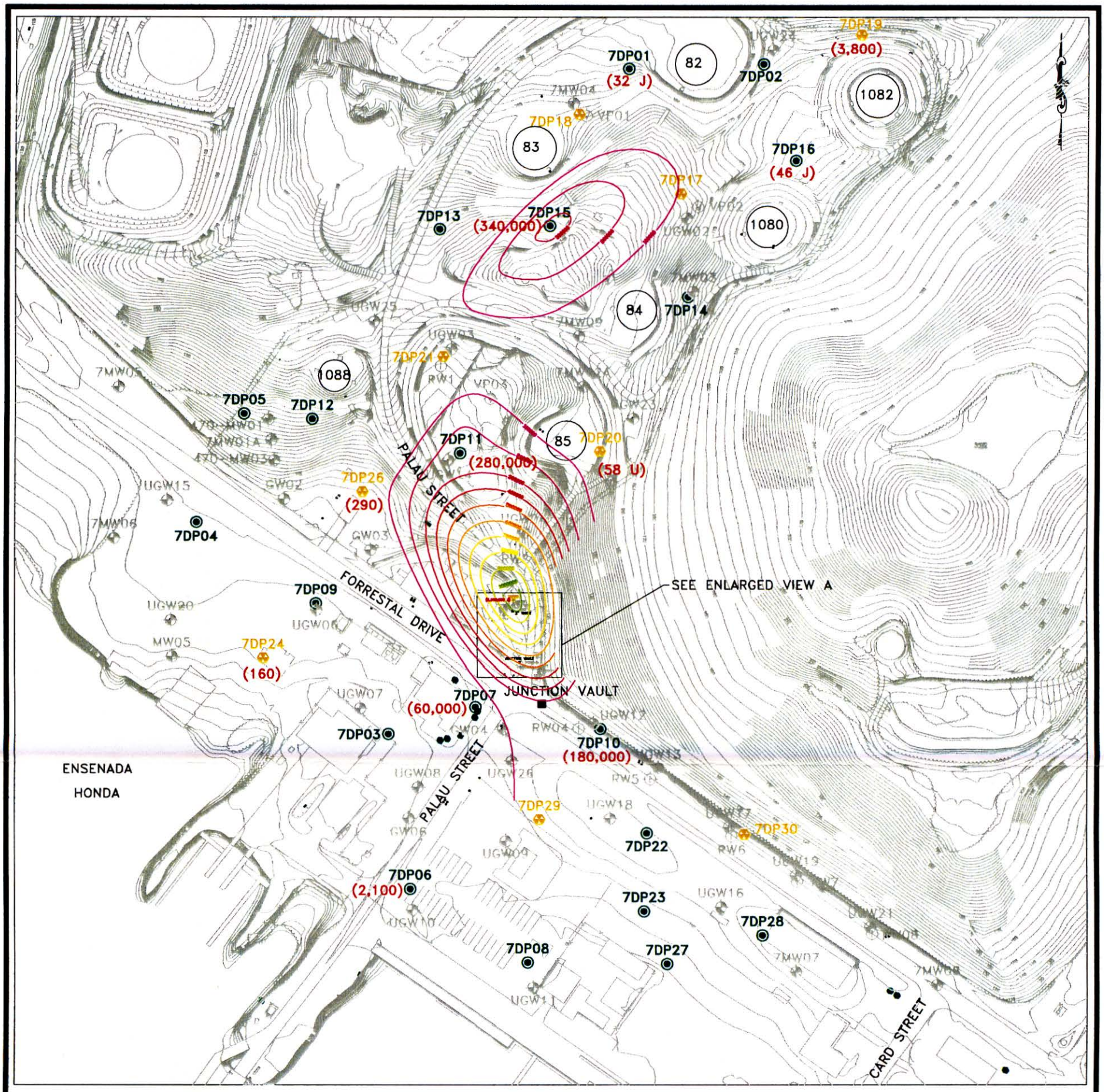
LEGEND

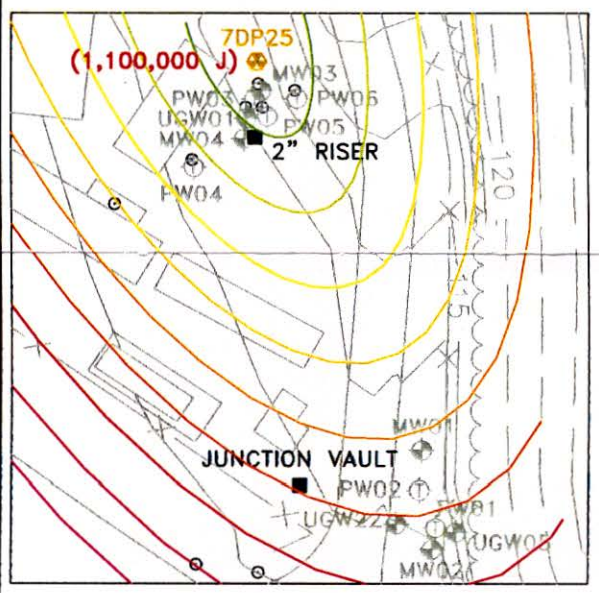
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (910) – BTEX CONCENTRATION (ug/kg) IN SOILS
- 2400 – ISOCONCENTRATION LINE (ug/kg)

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2–10
BTEX IN SOIL ISOPLETH MAP 10–15' BGS
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

200 0 100 200
1 inch = 200 ft.

50 0 25 50
1 inch = 50 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

277509CM

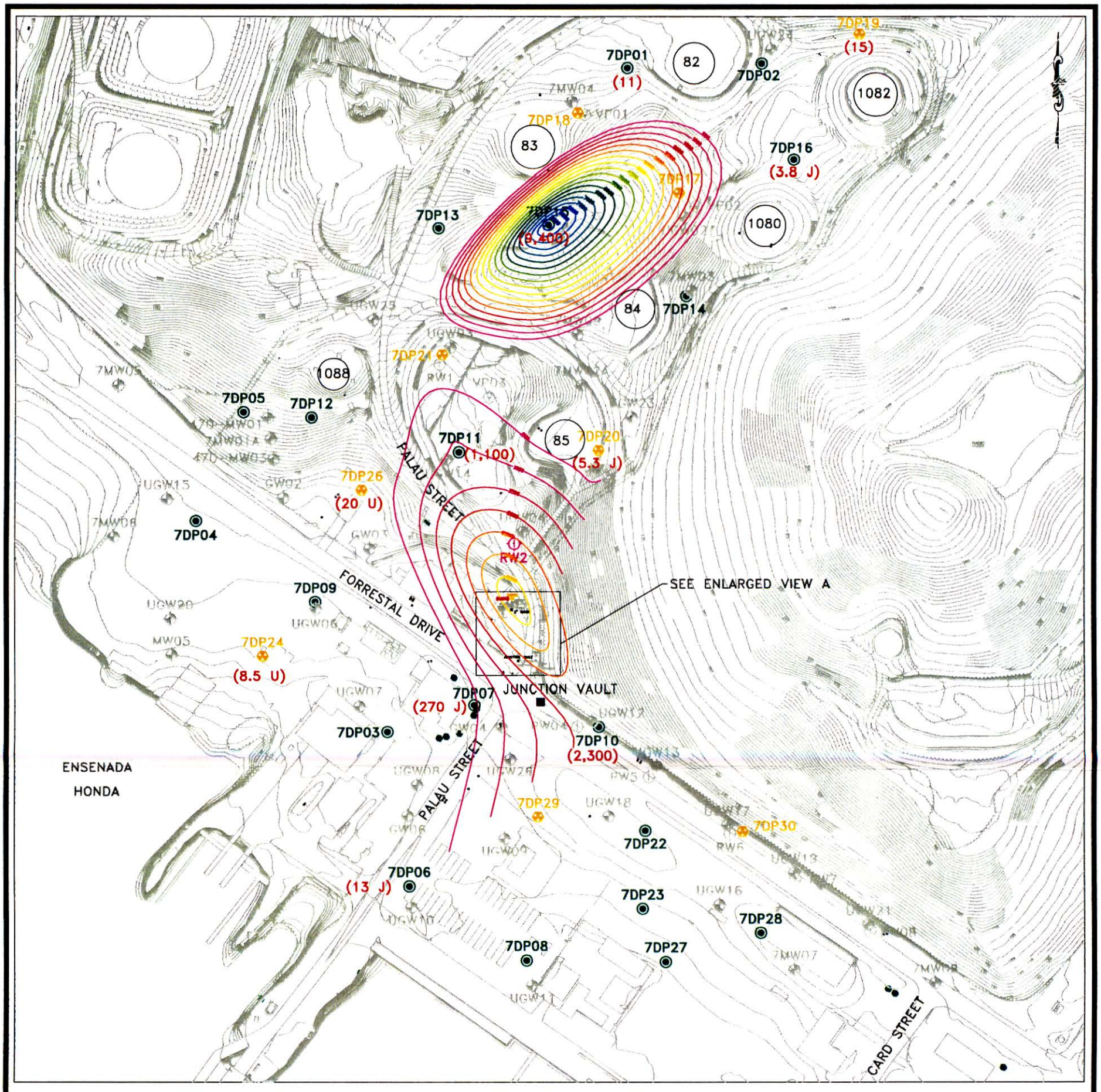
LEGEND

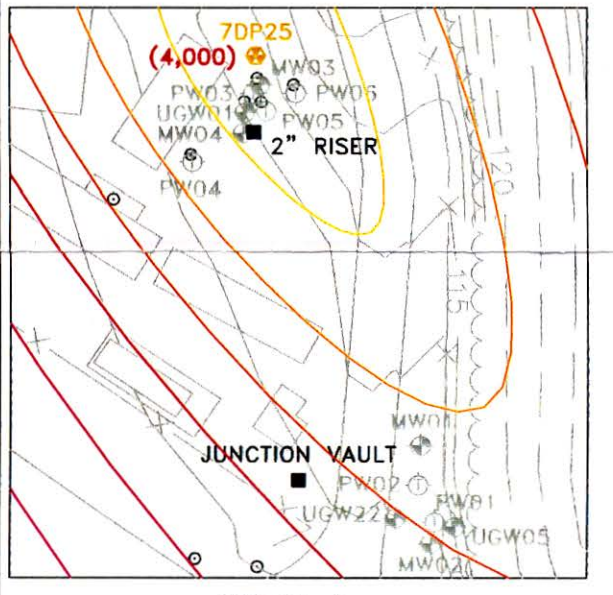
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (1,100,000 J) – BTEX CONCENTRATION (ug/kg) IN SOILS
- 1000000 – ISOCONCENTRATION LINE (ug/kg)

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2–11
TPH GRO IN SOIL ISOPLETH MAP 10–15' BGS
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

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

Baker

277510CM

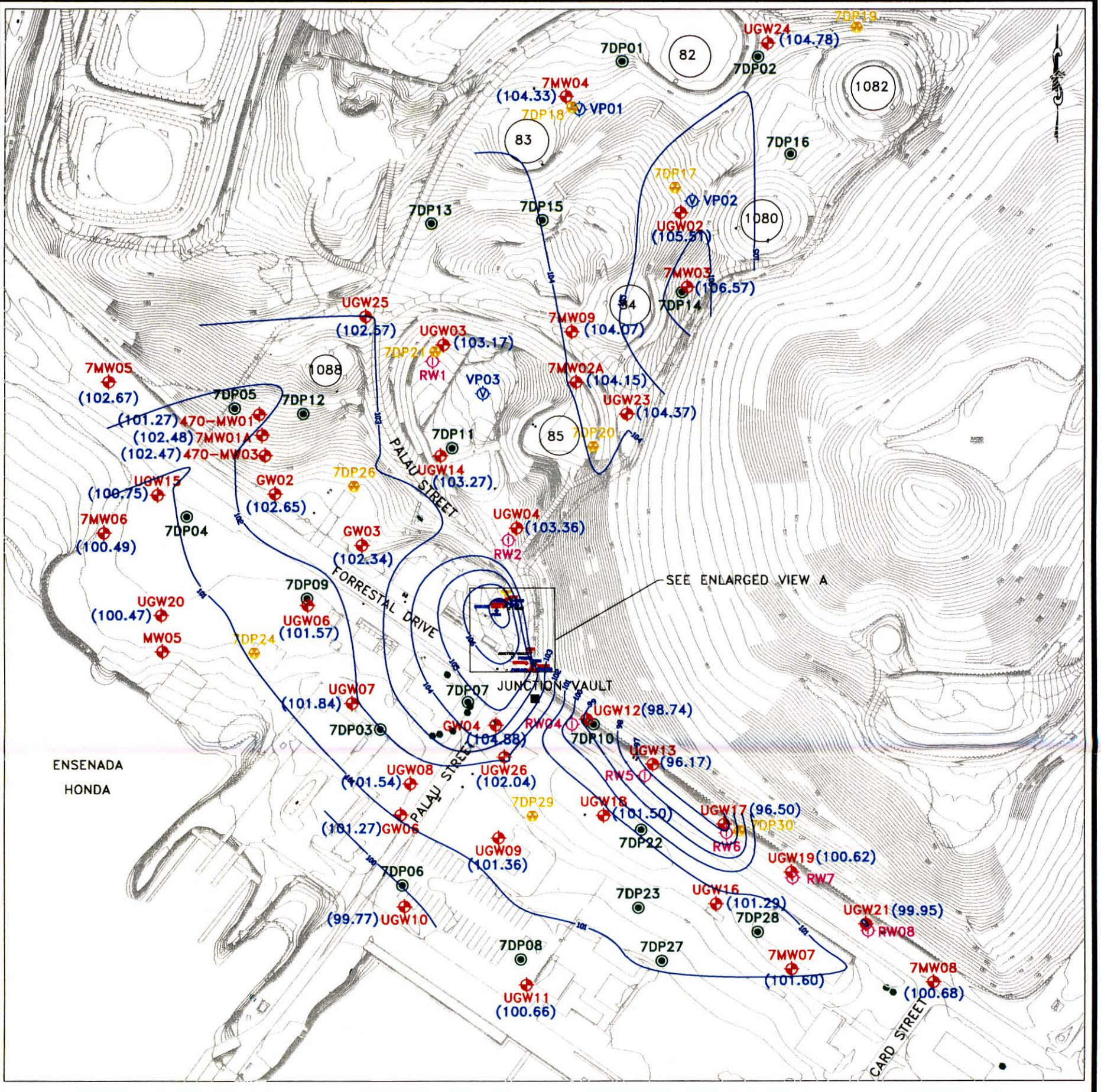
LEGEND

- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (4,000) – TPH DRO CONCENTRATION (mg/kg) IN SOILS
- 1500 – ISOCONCENTRATION LINE (mg/kg)

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2–12
TPH DRO IN SOIL ISOPLETH MAP 10–15' BGS
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.

Baker

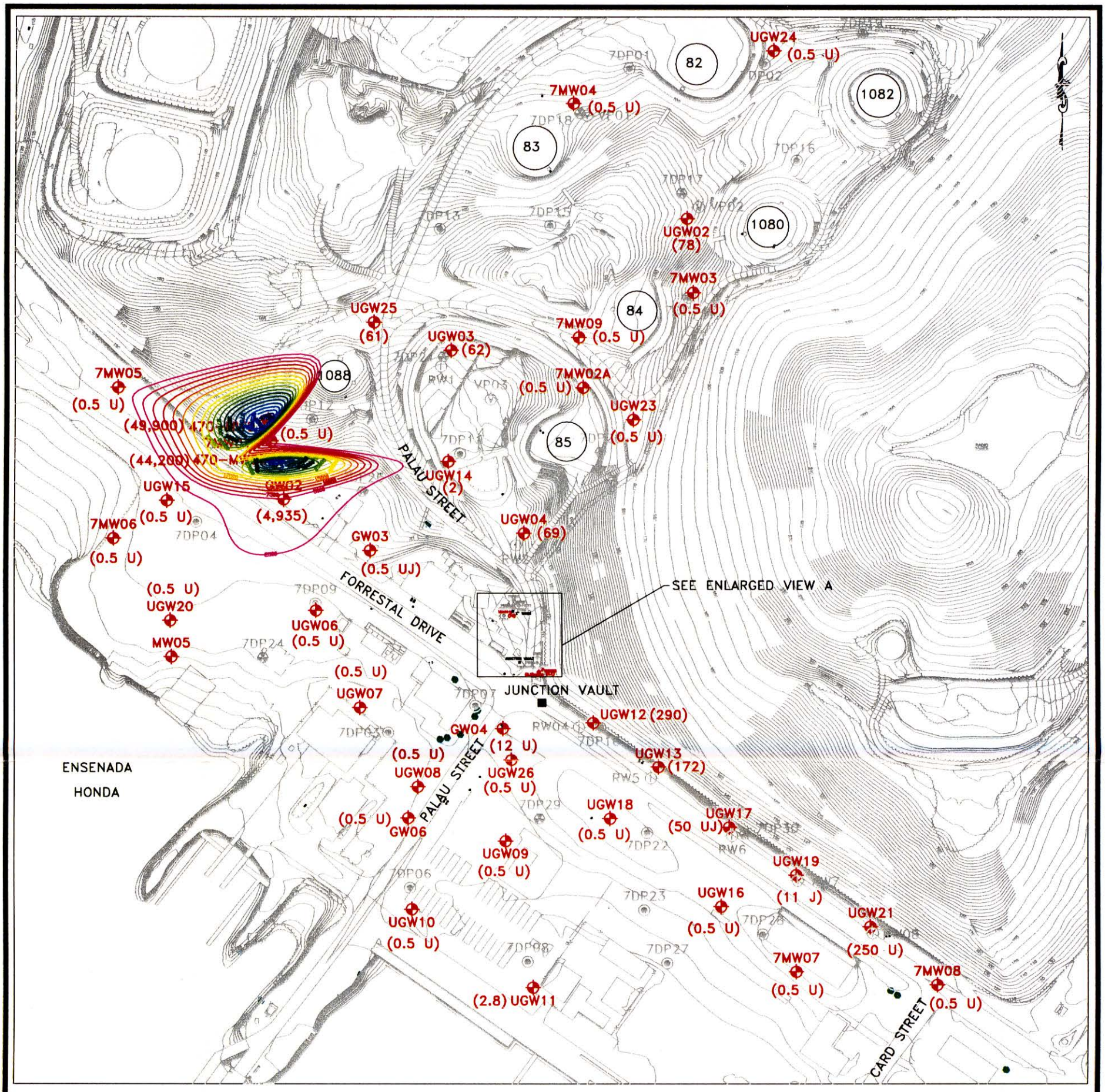
LEGEND

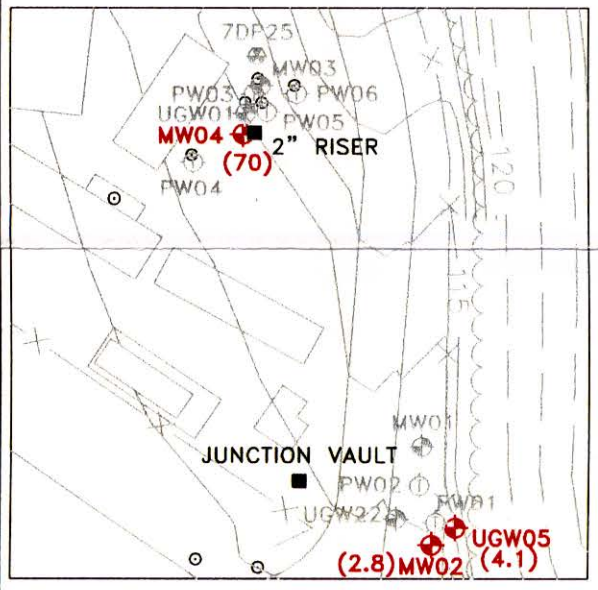
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- —103— CORRECTED GROUNDWATER SURFACE CONTOUR

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-13
CORRECTED GROUNDWATER SURFACE CONTOUR MAP
APRIL 21, 1998
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

200 0 100 200
1 inch = 200 ft.

50 0 25 50
1 inch = 50 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

277504CM

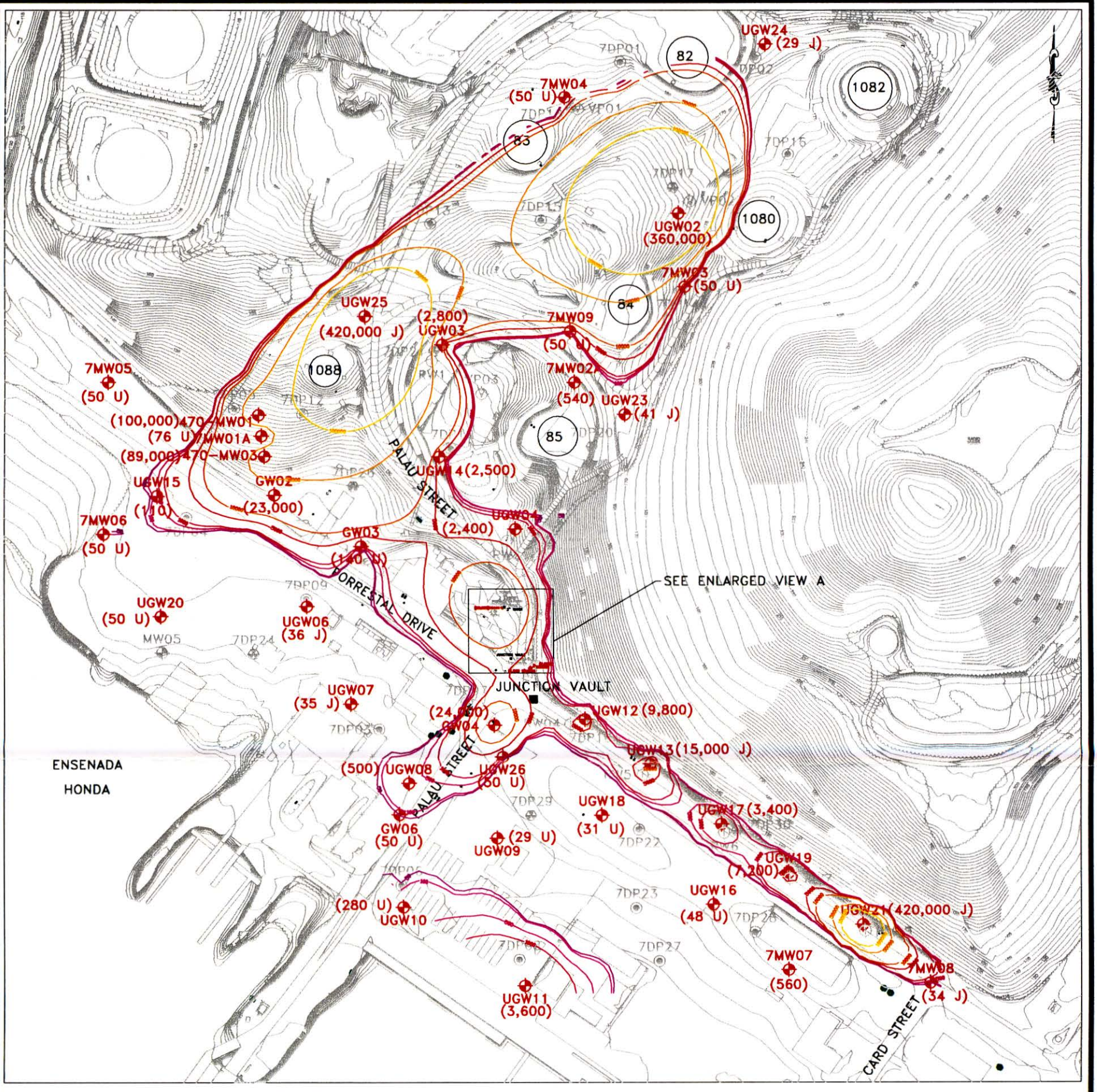
LEGEND

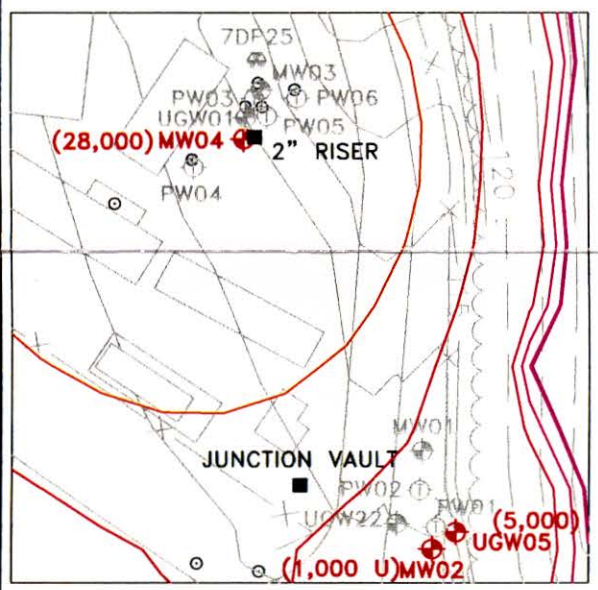
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (2.8) – BTEX CONCENTRATION (ug/L) IN GROUNDWATER
- 2500 – ISOCONCENTRATION LINE (ug/L)

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-14
BTEX IN GROUNDWATER ISOPLETH MAP
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

200 0 100 200
1 inch = 200 ft.

50 0 25 50
1 inch = 50 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

277514CM

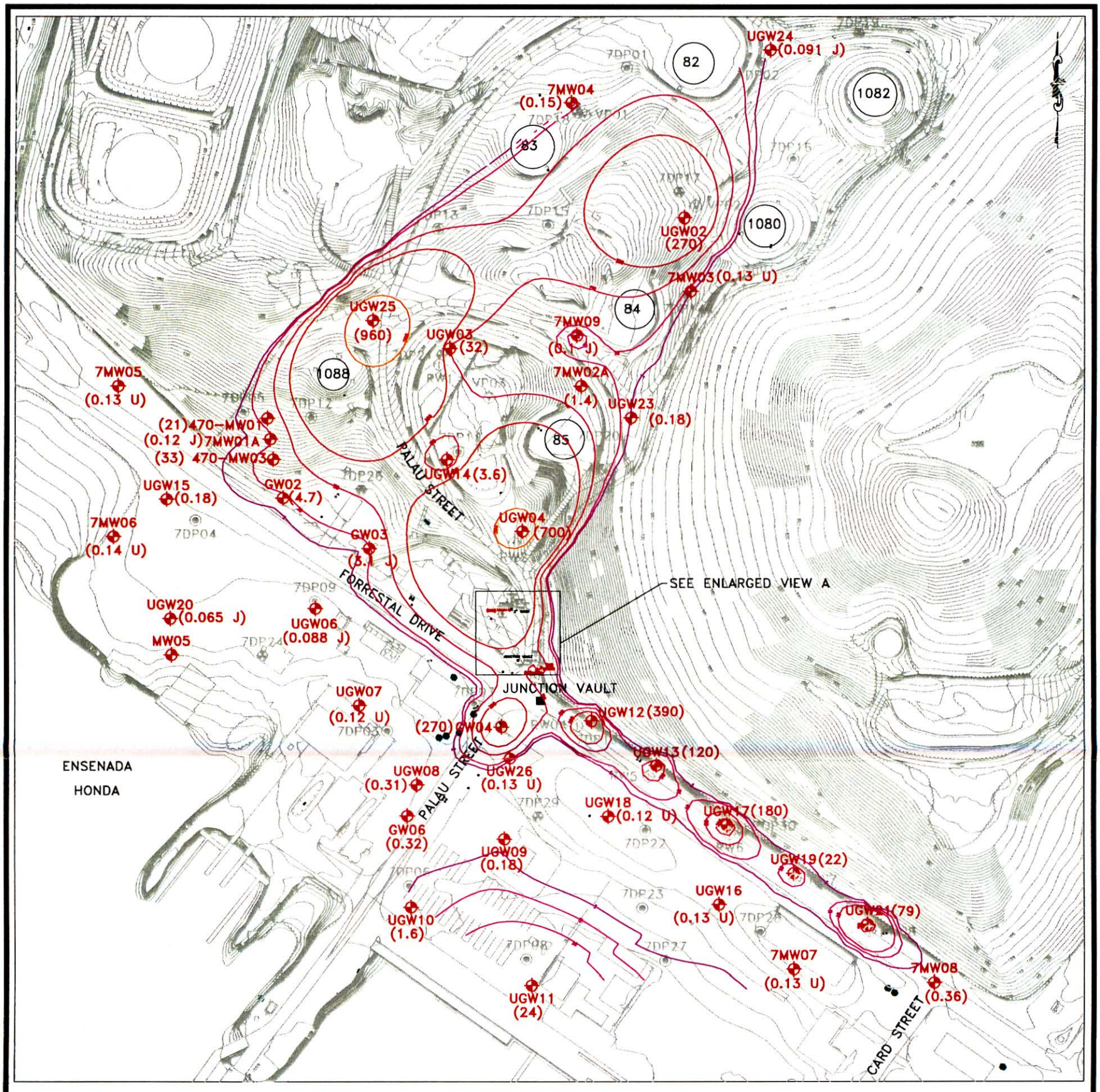
LEGEND

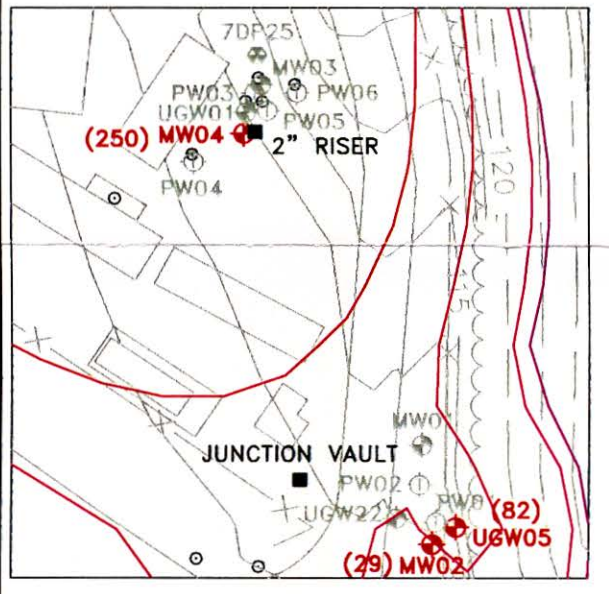
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (28,000) – TPH GRO CONCENTRATION (ug/L) IN GROUNDWATER
- 50 – ISOCONCENTRATION LINE (ug/L)

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-15
TPH GRO IN GROUNDWATER ISOPLETH MAP
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO





VIEW A

200 0 100 200
1 inch = 200 ft.

50 0 25 50
1 inch = 50 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

277515CM

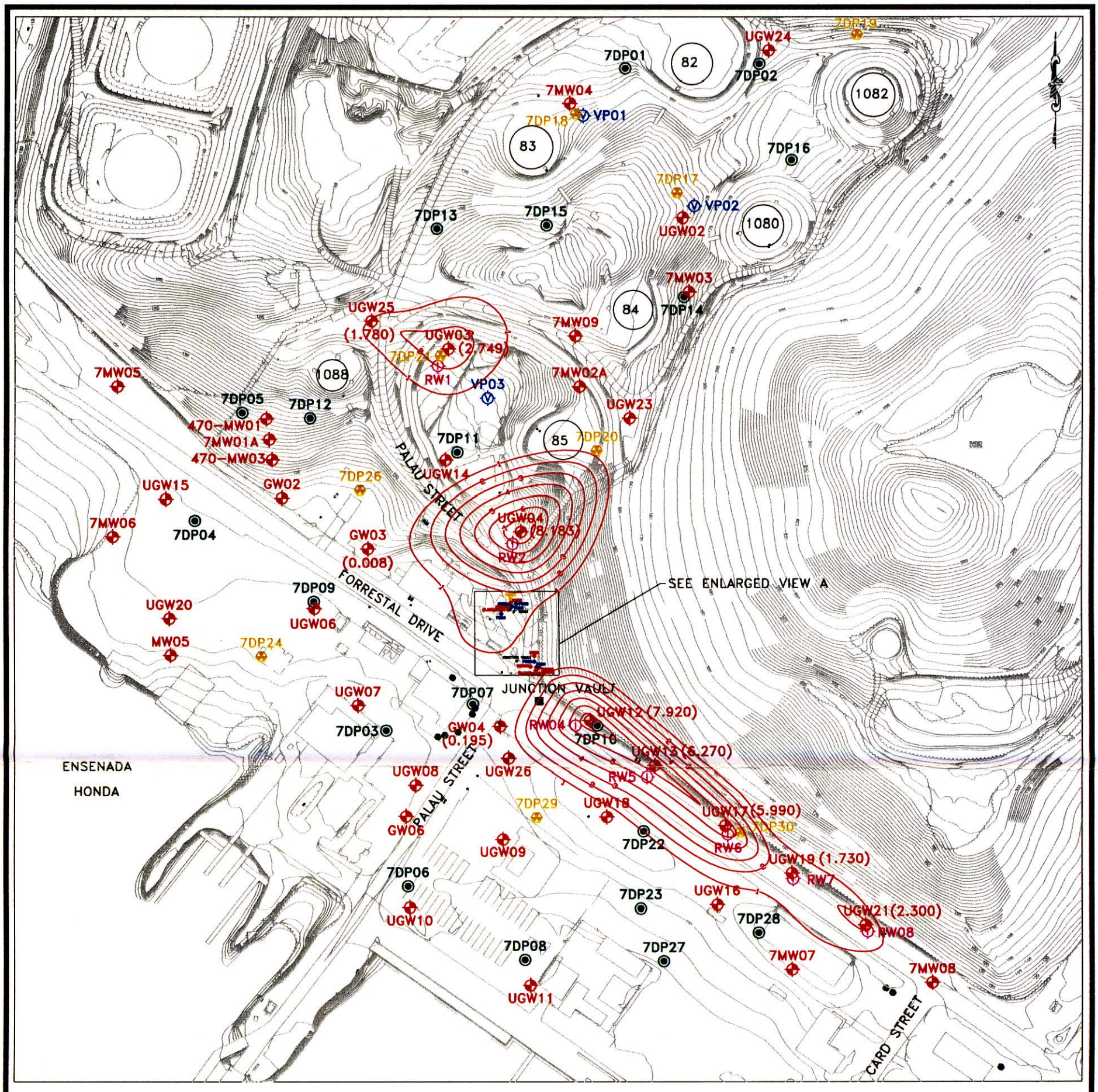
LEGEND

- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- (29) – TPH DRO CONCENTRATION (mg/L) IN GROUNDWATER
- —10— – ISOCONCENTRATION LINE (mg/L)

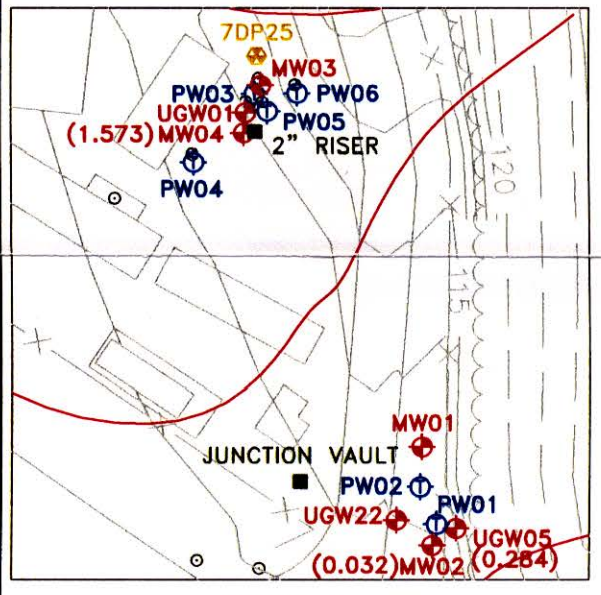
SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-16
TPH DRO IN GROUNDWATER ISOPLETH MAP
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



200 0 100 200
1 inch = 200 ft.



VIEW A

50 0 25 50
1 inch = 50 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

277503CM

LEGEND
- MONITORING WELL LOCATION
- VERTICAL PERMEABILITY SAMPLE LOCATION
- SOIL BORING LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- —4— FREE PRODUCT THICKNESS

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-17
FREE PRODUCT THICKNESS AND EXTENT MAP
APRIL 1998
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

3.0 ESTABLISHMENT OF CORRECTIVE ACTION OBJECTIVES

This section of the document establishes the site specific objectives for the corrective action. The objectives are based on public health and environmental criteria, information gathered during the RFI, EPA guidance, and the requirements of any applicable federal statutes. This is accomplished by describing the process, the proposed clean-up goals, and the corrective action objectives for this project as discussed in the following subsections.

3.1 The Process

The corrective action objectives consist of specific goals developed for protecting human health and the environment. The objectives should be as specific as possible, but not so specific that the corrective actions to be developed are limited. Important components in the development of the corrective action objectives include the identification of contaminants of concern (COCs), the identification of applicable federal statutes, and the development of clean-up goals. These components along with the resulting corrective action objectives are presented below.

3.2 Clean-up Goals

The clean up goals established for the TWFF are for the soil and groundwater media and are presented below. The TWFF clean-up goals were developed considering the USEPA Region III Risk Based Concentrations (RBCs) for residential soil and tap water, the development of the risk based cleanup levels for soil and groundwater, and the Federal and Puerto Rico maximum contaminant levels (MCLs) for groundwater. The following subsections provide a discussion on each of these items and how they went into the development of the TWFF clean-up goals.

TWFF Groundwater and Soil Risk-Based Cleanup Levels

Contaminant of Concern	Groundwater Cleanup Level (μg/L)	Soil Cleanup Level (μg/kg)
Benzene	340	25,157
Toluene	13,315	12,506,782
Ethylbenzene	4,475	6,253,391
Total Xylenes	862,295	125,067,816

3.2.1 USEPA Region III Risk Based Concentrations

USEPA Region III (Risk Based Concentrations) RBCs - RBC values are derived using conservative USEPA promulgated default values and the most recent toxicological criteria available. The RBCs for potentially carcinogenic chemicals are based on a target Incremental Cancer Risk (ICR) of $1x10^{-6}$. The RBCs for noncarcinogens are based on a target hazard quotient of 1.0. For potential carcinogens, the toxicity criteria applicable to the derivation of RBC values are oral and inhalation cancer slope factors (CSFs); for noncarcinogens, they are chronic oral and inhalation reference doses (RfDs). These toxicity criteria are subject to change as more updated information and results from the most recent toxicological/epidemiological studies become available. Therefore, the use of toxicity criteria in the derivation of RBC values requires that the screening concentrations be updated periodically to reflect changes in the toxicity criteria. The RBC table is issued on a semi-annual basis. It should be noted that the most recent update was published in October of 1998.

3.2.2 Maximum Contaminant Levels - Federal Groundwater Standards - 40 CFR 161

MCLs are enforceable standards for public water supplies promulgated under the Safe Drinking Water Act and are designed for the protection of human health. MCLs are based on laboratory or epidemiological studies and apply to drinking water supplies consumed by a minimum of 25 persons. They are designed for prevention of human health effects associated with a lifetime exposure (70-year lifetime) of an average adult (70 kg) consuming 2 liters of water per day. MCLs also consider the technical feasibility of removing the contaminant from the public water supply. Since the uppermost aquifer at the site will not be used for potable purposes, the MCLs do not necessarily apply.

3.2.3 Risk Based Cleanup Levels

In conjunction with the cleanup levels based on Federal and Commonwealth criteria (e.g., MCLs) and/or health-based levels (e.g., USEPA Region III RBCs), site specific risk-based cleanup levels were developed for the groundwater and soil COCs. The methodology used to derive the risk-based cleanup levels was in accordance with USEPA Risk Assessment Guidance for Superfund, Parts A and B (USEPA, 1989 and USEPA, 1991). For noncarcinogenic effects, risk-based cleanup levels

were calculated for significant human exposure pathways that target a Hazard Index (HI) of 1.0, or unity. COC concentrations in a given medium that are less than a corresponding risk-based cleanup level indicate that systemic health effects will not occur subsequent to exposure for even sensitive populations. For carcinogenic effects, risk-based cleanup levels were calculated that target an ICR range of 1×10^{-6} (one in a million) to 1×10^{-4} (one in ten thousand) that would be expected to result from exposure to a potential carcinogen over a lifetime, from all significant exposure pathways for a given medium. Based on the National Contingency Plan (NCP) (40 CFR 300.430), acceptable exposure levels, for known or suspected carcinogens, are generally concentrations that represent an ICR between 1×10^{-4} and 1×10^{-6}, with the latter ICR representing USEPA's point of departure.

Three steps were involved in estimating the risk-based cleanup levels for the TWFF. These steps are generally conducted for an environmental medium and land-use combination and involve the identification of: (1) the most significant exposure pathways and routes, (2) the most significant exposure parameters, and (3) equations. The equations included calculations of total intake from a given medium and were based on identified exposure pathways and associated parameters. Potential exposure pathways and receptors used to determine cleanup levels are site-specific and consider the future land use of this site. The following exposure scenarios were considered in determining total site cleanup levels associated with groundwater and soil at the TWFF:

- Accidental ingestion of soil (future adult and child residents)
- Dermal contact with soil (future adult and child residents)
- Accidental ingestion of groundwater using a beneficial use scenario (future adult and child residents)
- Dermal contact with groundwater using a beneficial use scenario (future adult and child residents)

The most conservative exposure pathways were used in the development of cleanup levels.

It is extremely unlikely that the TWFF would ever be developed into a residential area given the topography of the area and the fact that the presence of the TWFF is critical to the mission of the station. Groundwater is not currently used for potable purposes since a dedicated source of water is available from El Yunque which has redundant capacity to supply all of NSRR present and projected needs. Also, it is known based on investigations performed at the site to date that the yield

of the uppermost aquifer is insufficient to be used as a potable source. Based on these considerations, cleanup levels were calculated for groundwater using a beneficial (or nonpotable) use scenario for the future adult and child resident. [A beneficial use scenario includes activities such as watering lawns and washing cars.] An evaluation of the residential, nonpotable, uses of groundwater provides a conservative approach.

In accordance with USEPA guidance, noncarcinogenic health effects were estimated as hazard indices for human populations (including sensitive subgroups, that may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety). The cleanup level incorporated the exposure time (hours/day) and/or frequency (days/year) that represented the occurrence of exposure along with averaging time, which was the period over which exposure was averaged. Carcinogenic health effects were calculated as an incremental lifetime cancer risk in the baseline Risk Assessment (RA), expected over the course of a potentially exposed individual's lifetime (70 years).

The risk-based cleanup levels are the most applicable cleanup levels at the TWFF. The risk-based cleanup levels are site-specific, while the RBCs and MCLs are designed to cover a broad range of sites and may be too conservative for the TWFF scenario. In particular, the groundwater MCLs and tap water RBCs are calculated based on a drinking water scenario in which a 70 kg adult drinks two liters of water per day. As previously mentioned, it is unlikely that the TWFF will be developed into a residential area or the uppermost aquifer be used for potable water since the yield is insufficient to be used as a potable source. Additionally, there is currently a dedicated source of water at the TWFF. The use of site-specific cleanup goals is consistent with NCP guidance (40 CFR 300.430).

The estimation methods and models used in this section were consistent with current USEPA risk assessment guidance (USEPA, 1989 and 1991). This evaluation was conducted to assure that media and contamination at the site would be addressed on a site-specific basis. Cleanup levels were developed, with site-specific inputs, for the groundwater and soil COCs. These cleanup levels are presented in Tables 3-1 and 3-2, respectively. Calculations of risk-based cleanup levels are presented along with exposure inputs in Appendix A.

3.3 Corrective Action Objective

Corrective action objectives are specific goals for protecting human health and the environment. The corrective action objective identified for the TWFF is to establish a remedial action which protects human health and the environment by meeting or exceeding the clean-up goals described in the previous section of this report in a cost effective, economical manner.

TABLES

TABLE 3-1

GROUNDWATER CLEANUP LEVELS
CORRECTIVE MEASURES STUDY TASK 1 REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS

Contaminant of Concern	Risk-Based Carcinogenic Cleanup Levels (10^{-6})		Risk-Based Noncarcinogenic Cleanup Levels [1]		USEPA Region III Tap Water RBCs (μg/L)	MCLs (μg/L)
	Adult (μg/L)	Child (μg/L)	Adult (μg/L)	Child (μg/L)		
Benzene	340	536	10,132	4,457	0.36	5
Toluene	--	--	19,139	13,315	750	1,000
Ethylbenzene	--	--	7,984	4,475	1,300	700
Total Xylenes	--	--	2,202,586	862,295	12,000	10,000

[1] Assumes an HQ of 1.0.
-- = No cleanup level established.
Note: Groundwater risk-based cleanup levels calculated using a beneficial (nonpotable) use scenario.

TABLE 3-2

SOIL CLEANUP LEVELS
CORRECTIVE MEASURES STUDY TASK I REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS

Contaminant of Concern	Risk-Based Carcinogenic Cleanup Levels (10^{-6})		Risk-Based Noncarcinogenic Cleanup Levels [1]		USEPA Region III Residential Soil RBCs (μg/kg)
	Adult (μg/kg)	Child (μg/kg)	Adult (μg/kg)	Child (μg/kg)	
Benzene	31,578	25,157	941,935	187,602	22,000
Toluene	--	--	62,795,699	12,506,782	16,000,000
Ethylbenzene	--	--	31,397,849	6,253,391	7,800,000
Total Xylenes	--	--	627,956,989	125,067,816	160,000,000

[1] Assumes an HQ of 1.0.
-- = No cleanup level established.

4.0 PRELIMINARY CORRECTIVE MEASURE TECHNOLOGIES

This section of the CMS Task I Report provides a preliminary listing of the corrective measure technologies potentially applicable for use at the TWFF. This step of the RFI process was not conducted during the Pre-Investigation Corrective Measures Screening (CMES) Report dated April 29, 1994, since the TWFF was under the Stations UST program at the time the CMES was prepared.

4.1 Soil Remedial Technologies

Several corrective measure technologies are potentially applicable to minimize health and environmental impacts due to contamination in the soil medium. Literature sources have been reviewed to identify and characterize potential corrective measure technologies. The following general technologies were examined for potential suitability to remediate soils at the TWFF.

- No Action
- Institutional Controls
- Containment
- Excavation and Disposal
- In-situ Biological Treatment
- In-situ Physical/Chemical Treatment
- Ex-situ Biological Treatment
- Ex-situ Physical/Chemical Treatment
- Thermal
- Natural Attenuation
- Asphalt Incorporation
- Electro Chemical Geo Oxidation (ECGO®)

Table 4-1 provides a listing of more detailed technologies that are generally addressed under the broad categories bulleted above. A brief description of the treatment technologies is presented in Table 4-2. A detailed description of these technologies can be found in the Pre-Investigation Corrective Measures Screening Report (Baker, 1994).

4.2 Groundwater Remedial Technologies

Several corrective measure technologies are potentially applicable to minimize health and environmental impacts due to contamination in the groundwater medium. Literature sources have been reviewed to identify and characterize potential corrective measure technologies. The following general technologies were examined for potential suitability to remediate groundwater at the TWFF.

- No Action
- Institutional Controls
- Containment/Collection
- In-situ Biological Treatment
- In-situ Physical/Chemical Treatment
- Ex-situ Biological Treatment Chemical Processes
- Ex-situ Physical/Chemical Treatment Biotreatment
- Natural Attenuation
- Electro Chemical Geo Oxidation (ECGO®)
- CleanOx®

Table 4-3 provides a listing of more detailed technologies that are generally addressed under the broad categories bulleted above. A brief description of the treatment technologies is presented in Table 4-4. A detailed description of these technologies can be found in the Pre-Investigation Corrective Measures Screening Report (Baker, 1994).

4.3 Free Product Remedial Technologies

Several corrective measure technologies are potentially applicable to minimize health and environmental impacts due to the free product present in the subsurface. Literature sources have been reviewed to identify and characterize potential corrective measure technologies. The following general technologies were examined for potential suitability for free product recovery at the TWFF.

- No Action
- Institutional Controls
- Containment/Collection (Free product Pumps, Skimmers, etc...)
- Electro Chemical Geo Oxidation (ECGO®)
- CleanOx®

Table 4-5 provides a listing of more detailed technologies that are generally addressed under the broad categories bulleted above. A detailed description of these technologies can be found in the Pre-Investigation Corrective Measures Screening Report (Baker, 1994).

TABLES

TABLE 4-1

POTENTIALLY APPLICABLE CORRECTIVE MEASURE TECHNOLOGIES
SOIL MATRIX
CORRECTIVE MEASURES STUDY TASK I REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS

Technology	Tow Way Fuel Farm
No Action	X
Institutional Controls	X
Containment:	
Capping	X
Excavation and Disposal:	
Excavation	X
On-Site Disposal	X
Off-Site Disposal	X
Treatment Technologies:	
In-situ Biological Treatment	
Biodegradation	X
Bioventing	X
In-situ Physical/Chemical Treatment	
Soil Vapor Extraction	X
Ex-situ Biological Treatment (assuming excavation)	
Composting	X
Controlled Solid Phase Biological Treatment	X
Land Farming	X
Slurry Phase Biological Treatment	X
Ex-situ Physical/Chemical Treatment (assuming excavation)	
Soil Washing	X
Ex-situ Thermal Treatment (assuming excavation)	
Incineration	X
Low Temperature Thermal Desorption	X
Vitrification	X
Natural Attenuation	X
Asphalt Incorporation	X
Electro Chemical Geo Oxidation (ECGO®)	X

TABLE 4-2

CORRECTIVE MEASURES TREATMENT TECHNOLOGY DESCRIPTIONS
CORRECTIVE MEASURES STUDY TASK I REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS

Technology	Description
SOIL	
In Situ Biological Treatment	
Biodegradation	The activity of naturally occurring microbes is 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.
Bioventing	Oxygen is delivered to contaminated unsaturated soils by forced air movement (either extraction or injection of air) to increase oxygen concentrations and stimulate biodegradation.
In Situ Physical/Chemical Treatment	
Soil Vapor Extraction	Vacuum is applied through 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 also is known as in situ soil venting, in situ volatilization, enhanced volatilization, or soil vacuum extraction.
Ex Situ Biological Treatment (assuming excavation)	
Composting	Contaminated soil is excavated and mixed with bulking agents and organic amendments such as wood chips, animal and vegetative wastes, which are added to enhance the porosity and organic content of the mixture to be decomposed.
Controlled Solid Phase Biological Treatment	Excavated soils are mixed with soil amendments and placed in aboveground enclosures. Processes include prepared treatment beds, biotreatment cells, soil piles, and composting.
Land farming	Contaminated soils are applied onto the soil surface and periodically turned over or tilled into the soil to aerate the waste.
Slurry Phase Biological Treatment	An aqueous slurry is created by combining soil or sludge with water and other additives. The slurry is mixed to keep solids suspended and microorganisms in contact with the soil contaminants. Upon completion of the process, the slurry is dewatered and the treated soil is disposed of.
Ex Situ Physical/Chemical Treatment (assuming excavation)	
Soil Washing	Contaminants sorbed onto fine soil particles are separated from bulk soil in an aqueous-based system on the basis of particle size. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals.
Ex Situ Thermal Treatment (assuming excavation)	
Incineration	High temperatures, 817 - 1,204 °C (1,600 2,200 °F), are used to combust (in the presence of oxygen) organic constituents in hazardous wastes.
Low-Temperature Thermal Desorption	Wastes are heated to 93 - 315 °C (200 - 600 °F) to volatize water and organic contaminants. A carrier gas or vacuum system transports volatized water and organics to the gas treatment system.
Vitrification	Contaminated soils and sludges are melted at high temperatures to form a glass and crystalline structure with very low leaching characteristics.
Other Treatment	
Natural Attenuation	Natural subsurface processes - such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials - are allowed to reduce contaminant concentrations to acceptable levels.
ECGO®	In Situ process that uses induced electric current to create oxidation-reduction (Redox) reactions leading to complete mineralization of organic constituents (or mobilization of inorganic constituents) present in a volume of soil and groundwater between the electrode locations.

TABLE 4-3

POTENTIALLY APPLICABLE CORRECTIVE MEASURE TECHNOLOGIES
GROUNDWATER MATRIX
CORRECTIVE MEASURES STUDY TASK I REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS

Technology	Tow Way Fuel Farm
No Action	X
Institutional Controls:	
Alternate Water	Already Available
Relocation	X
Containment/Collection:	
Capping	X
Barriers	X
Trenches	X
Extraction Wells	X
Subsurface Drains	X
Treatment Technologies:	
In-situ Biological Treatment	
Nitrate Enhancement	X
Oxygen Enhancement with Air Sparging	X
Oxygen Enhancement with Hydrogen Peroxide (CleanOx®)	X
In-situ Physical/Chemical Treatment	
Air Sparging	X
Dual Phase Extraction	X
Steam Stripping/Flushing	X
Vacuum Vapor Extraction	X
Ex-situ Biological Treatment (Assuming Pumping)	
Bioreactors	X
Ex-situ Physical/Chemical Treatment (Assuming Pumping)	
Ultraviolet Oxidation	X
Natural Attenuation	X
Electro Chemical Geo Oxidation (ECGO®)	X

TABLE 4-4

CORRECTIVE MEASURES TREATMENT TECHNOLOGY DESCRIPTIONS
CORRECTIVE MEASURES STUDY TASK I REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS

Technology	Description
GROUNDWATER	
In Situ Biological Treatment	
Nitrate Enhancement	Nitrate is circulated throughout groundwater contamination zones as an alternative electron acceptor for biological oxidation of organic contaminants by microbes.
Oxygen Enhancement with Air Sparging	Air is injected under pressure below the water table to increase groundwater oxygen concentrations and enhance the rate of biological degradation of organic contaminants by naturally occurring microbes.
Oxygen Enhancement with Hydrogen Peroxide	A dilute solution of hydrogen peroxide is circulated throughout a contaminated groundwater zone to increase the oxygen content of groundwater and enhance the rate of aerobic biodegradation of organic contaminants by microbes.
In Situ Physical/Chemical Treatment	
Air Sparging	Air is injected into saturated matrices to remove contaminants through volatilization.
Dual Phase Extraction	A high vacuum system is applied to simultaneously remove liquid and gas from low permeability or heterogeneous formations.
Hot Water or Steam Flushing/Stripping	Steam is forced into an 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.
Vacuum Vapor Extraction	Air is injected into a 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.
Ex Situ Biological Treatment (assuming pumping)	
Bioreactors	Contaminants in extracted groundwater 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 systems, such as rotating biological contractors and trickling filters, microorganisms are established on an inert support matrix.
Ex Situ Physical/Chemical Treatment (assuming pumping)	
UV Oxidation	Ultraviolet (UV) radiation, ozone, and/or hydrogen peroxide are used to destroy organic contaminants as water flows into a treatment tank. An ozone destruction unit is used to treat off-gases from the treatment tank.
Other Treatment	
Natural Attenuation	Natural subsurface processes - such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials - are allowed to reduce contaminant concentrations to acceptable levels.
ECGO®	In Situ process that uses induced electric current to create oxidation-reduction (Redox) reactions leading to complete mineralization of organic constituents (or mobilization of inorganic constituents) present in a volume of soil and groundwater between the electrode locations.

TABLE 4-5

POTENTIALLY APPLICABLE CORRECTIVE MEASURE TECHNOLOGIES
FREE PRODUCT
CORRECTIVE MEASURES STUDY TASK I REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS

Technology	Tow Way Fuel Farm
No Action	X
Institutional Controls	X
Containment/Collection:	
Barriers	X
Interceptor Trenches	X
Extraction Wells *	X
Dual Phase Extraction	X
Three Phase Extraction	X
Floating Filter Pumps	X
Surface Oil/Water Separators	X
CleanOx®	X
Electro Chemical Geo Oxidation (ECGO®)	X

Note:
*Includes the various combinations of skimming, groundwater table depression and reinjection of water upgradient to enhance head differentials

5.0 SCREENING OF CORRECTIVE MEASURE TECHNOLOGIES

This section of the report reviews the results of the RFI and the CMS Investigation and assesses the technologies which are applicable to the facility. The identified corrective measure technologies are screened to eliminate those that may prove infeasible to implement, that rely on technologies unlikely to perform satisfactorily or reliably, or that do not achieve the corrective measure objective within a reasonable time period. This screening process focusses on eliminating those technologies which have severe limitations for a given set of waste and site-specific conditions. The screening step may also eliminate technologies based on inherent technology limitations. The site and waste characteristics and technology limitations for the TWFF are discussed in the following subsections.

5.1 Site Characteristics

This section provides a review of the site data during the CMS Investigation to identify conditions that may limit or promote the use of certain technologies. Technologies whose use is clearly precluded by the site characteristics described in this section of the report will be eliminated from further consideration.

5.1.1 Soils

The in-situ vertical permeability of the soils was calculated during the CMS Investigation from three different locations on the TWFF hillside. The results from this test yielded a range of 4.4×10^{-4} centimeters per second (cm/sec) to 8.5×10^{-4} cm/sec. This information is pertinent to the screening of the technologies which utilize groundwater reinjection through surface application.

The bulk density of the soils collected from the TWFF ranged from 1.0 to 1.4 grams per milliliter (g/ml). The bulk density of the soil is utilized when estimating quantities for technologies such as excavation, transportation, and disposal.

5.1.2 Groundwater

Slug tests were conducted during the CMS Investigation which yielded an average hydraulic conductivity of 9.91×10^{-4} cm/sec from the monitoring wells screened in the bedrock. The hydraulic

conductivity of the unconsolidated aquifer (very loose fine to coarse sand) was estimated at 4.89 x 10^{-2} cm/sec. Limited pump tests were conducted from two monitoring wells screened in the fractured bedrock during the RFI for the TWFF (Baker, 1997). The results of the two pump tests yielded hydraulic conductivity results ranging from 1.65 x 10^{-5} cm/sec to 4.13 x 10^{-6} cm/sec, transmissivity values of 288 ft^2/day, and storativity values of approximately 310. This information is valuable when screening those technologies which require groundwater pumping.

5.1.3 Free Product

Two baildown tests were performed on two of the monitoring wells during the CMS Investigation. The results of the baildown test indicated that the recharge of free product into the monitoring wells is very slow over time. For example, the original free product thickness in groundwater monitoring well UGW-19 was estimated to be 1.24 feet thick. After a period of 16 hours the free product only recovered 0.08 feet. Monitoring well UGW-21 had a little better response to product recovery then UGW-19. The initial free product thickness was measured at 1.63 feet, 14.5 hours later the free product recovered 0.16 feet.

The ICM which is currently in operation at the TWFF yielded an average free product recovery rate of only 1.6 gallons per day (January 1998 through October 1998). This information is pertinent to the screening of those technologies which include free product recovery.

5.2 Waste Characteristics

Identification of the waste characteristics that limit the effectiveness or feasibility of technologies is an important part of the screening process. These waste characteristics are detailed in this subsection. Technologies which are clearly limited by the waste characteristics will be eliminated from consideration.

5.2.1 Soils

A summary of the contaminants detected in the soil matrix during the CMS Investigation indicate BTEX, TPH (DRO and GRO) contamination in the subsurface soils. The following table identifies the minimum and maximum concentrations of the referenced constituents.

SUBSURFACE SOIL WASTE CHARACTERISTICS

Constituent	Minimum Detected Concentration (μg/kg)	Maximum Detected Concentration (μg/kg)
BTEX		
Benzene	1.20 J	150 J
Toluene	0.79 J	12,000
Ethylbenzene	0.68 J	680
Xylene	0.60 J	2,300
Total Petroleum Hydrocarbons		
Diesel Range Organics	3,800 J	22,000,000
Gasoline Range Organics	29 J	1,100,000 J

5.2.2 Groundwater

A summary of the contaminants detected in the groundwater matrix during the CMS Investigation indicate BTEX, trimethylbenzene isomers, TPH (DRO and GRO) contamination in the groundwater. The following table identifies the minimum and maximum concentrations of the referenced constituents.

GROUNDWATER WASTE CHARACTERISTICS

Constituent	Minimum Detected Concentration (μg/l)	Maximum Detected Concentration (μg/l)
BTEX		
Benzene	0.80 J	26,000
Toluene	0.50	7,800
Ethylbenzene	2.00 J	2,900
Xylene	0.60 J	18,900
Total Petroleum Hydrocarbons		
Diesel Range Organics	65 J	960,000
Gasoline Range Organics	29 J	420,000 J

5.3 Technology Limitations

The level of technology development, performance record, and inherent construction, operation, and maintenance problems are identified for each technology being considered in this subsection. Technologies that are unreliable, perform poorly, or are not fully demonstrated may be eliminated in the screening process. Table 5-1 provides a screening matrix on the treatment technologies being discussed for the TWFF. This table rates the various topics better, average, and worse. This information is being considered for the initial screening of the corrective measure technology for the TWFF.

5.4 Technology Screening

The technologies listed in Section 4.0 are screened in this subsection. This screening looks at all the limitations discussed in the previous subsections along with inherent technology limitations. Tables 5-2 through 5-4 list the technologies being evaluated, whether or not they are applicable to the site, and the reason for exclusion. It should be kept in mind that some of the technologies passing the screening may be combined for the corrective measure alternative for the TWFF.

TABLE 5-1

TREATMENT TECHNOLOGIES SCREENING MATRIX
CORRECTIVE MEASURES STUDY TASK I REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS

	Development Status	Availability	Residuals Produced	Treatment Train (excludes off-gas treatment)	Contaminants Treated					System Reliability/ Maintainability	Cleanup Time	Overall Cost	O&M or Capital Intensive
					VOCs	SVOCs	Fuels	Inorganic	Explosives				
SOIL													
In Situ Biological Treatment													
Biodegradation	Full	■	None	No	■	■	■	△	■	△	△	◍	O&M
Bioventing	Full	■	None	No	■	■	■	△	I	■	◍	■	Neither
In Situ Physical/Chemical Treatment													
Soil Vapor Extraction (in Situ)	Full	■	Liquid	No	■	◍	■	△	△	■	◍	■	O&M
Ex Situ Biological Treatment													
Composting	Full	■	None	No	■	◍	■	△	■	■	◍	■	Neither
Controlled Solid Phase Bio. Treatment	Full	■	None	No	■	◍	■	△	■	■	◍	■	Neither
Land Farming	Full	■	None	No	■	◍	■	△	◍	■	△	■	Neither
Slurry Phase Bio. Treatment	Full	◍	None	No	■	◍	■	△	■	◍	◍	◍	Both
Ex Situ Physical/Chemical Treatment (assuming excavation)													
Soil Washing	Full	◍	Solid. Liquid	Yes	◍	■	■	■	■	◍	■	◍	Both
Ex Situ Thermal Treatment (assuming excavation)													
Incineration	Full	■	Liquid, Solid	No	◍	■	■	△	■	◍	■	△	Both
Low Temperature Thermal Desorption	Full	■	Liquid	Yes	■	◍	■	△	■	◍	■	■	Both
Vitrification	Full	◍	Liquid	No	◍	◍	◍	■	△	◍	◍	△	Both
Other Treatment													
Natural Attenuation	NA	■	None	No	■	■	■	△	△	■	△	■	Neither
GROUNDWATER													
In Situ Biological Treatment													
Nitrate Enhancement	Pilot	△	None	No	■	■	■	△	◍	◍	◍	■	Neither
Oxygen Enhancement with Air Sparging	Full	■	None	No	■	■	■	△	◍	■	◍	■	Neither
Oxygen Enhancement with H2O2	Full	■	None	No	■	■	■	△	◍	△	◍	◍	O&M
In Situ Physical/Chemical Treatment													
Air Sparging	Full	■	Vapor	Yes	■	△	■	△	△	■	■	■	Neither
Dual Phase Extraction	Full	■	Liquid, Vapor	Yes	■	△	■	△	△	◍	◍	◍	O&M
Hot Water or Steam Flushing/Stripping	Pilot	◍	Liquid, Vapor	Yes	◍	■	■	△	△	△	■	◍	CAP
Vacuum Vapor Extraction	Pilot	△	Liquid, Vapor	No	■	◍	■	I	△	■	◍	◍	CAP
Ex Situ Biological Treatment (assuming pumping)													
Bioreactors	Full	■	Solid	No	■	■	■	△	◍	◍	NA	■	CAP
Ex Situ Physical/Chemical Treatment (assuming pumping)													
UV Oxidation	Full	■	None	No	■	■	■	△	■	△	NA	◍	Both
Other Treatment													
Natural Attenuation	NA	■	None	No	■	■	■	△	△	■	△	■	Neither

Rating Codes

■ Better
◍ Average
△ Worse
I Inadequate Information
NA Not Applicable

Source: Remediation Technologies Screening Matrix and Reference Guide, EPA/542/B-94/013NTIS PB95-104782

TABLE 5-2

APPLICABLE CORRECTIVE MEASURE TECHNOLOGIES
SOIL MATRIX
CORRECTIVE MEASURES STUDY TASK I REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS

Technology	Applicable	Reason for Exclusion
No Action	X	
Institutional Controls	X	
Containment:		
Capping		Surface soils not significantly impacted
Excavation and Disposal:		
Excavation		Unfeasible to excavate soils in an active fuel farm
On-Site Disposal		Unfeasible to excavate soils in an active fuel farm
Off-Site Disposal		Unfeasible to excavate soils in an active fuel farm
Treatment Technologies:		
In-situ Biological Treatment		
Biodegradation		Soil heterogeneity may impede O_2 transfer limitations
Bioventing	X	
In-situ Physical/Chemical Treatment		
Soil Vapor Extraction	X	
Ex-situ Biological Treatment (assuming excavation)		
Composting		Unfeasible to excavate soils in an active fuel farm
Controlled Solid Phase Bio Treatment		Unfeasible to excavate soils in an active fuel farm
Land Farming		Unfeasible to excavate soils in an active fuel farm
Slurry Phase Bio Treatment		Unfeasible to excavate soils in an active fuel farm
Ex-situ Physical/Chemical Treatment (assuming excavation)		
Soil Washing		Unfeasible to excavate soils in an active fuel farm
Ex Situ Thermal Treatment (assuming excavation)		
Incineration		Unfeasible to excavate soils in an active fuel farm
Low Temperature Thermal Desorption		Unfeasible to excavate soils in an active fuel farm
Vitrification		Unfeasible to excavate soils in an active fuel farm
Natural Attenuation	X	
Asphalt Incorporation		Unfeasible to excavate soils in an active fuel farm
Electro Chemical Geo Oxidation (ECGO®)	X	

TABLE 5-3

APPLICABLE CORRECTIVE MEASURE TECHNOLOGIES
GROUNDWATER MATRIX
CORRECTIVE MEASURES STUDY TASK I REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS

Technology	Applicable	Reason for Exclusion
No Action	X	
Institutional Controls:		
Alternate Water	X	
Relocation		Unfeasible
Containment/Collection:		
Capping		Surface soils not significantly impacted
Barriers	X	
Trenches	X	
Extraction Wells	X	
Subsurface Drains		Unacceptable to Regulators
Treatment Technologies:		
In-situ Biological Treatment		
Nitrate Enhancement		Nitrate injection into groundwater is prohibited
O_2 Enhancement with Air Sparging	X	
O_2 Enhancement with H_2O_2	X	
In-situ Physical/Chemical Treatment		
Air Sparging	X	
Dual Phase Extraction	X	
Hot Water or Steam Flushing/Stripping	X	
Vacuum Vapor Extraction	X	
Ex-situ Biological Treatment (Assuming Pumping)		
Bioreactors	X	
Ex-situ Physical/Chemical Treatment (Assuming Pumping)		
Ultraviolet Oxidation		Aqueous stream should be from oil and grease
Natural Attenuation	X	
Electro Chemical Geo Oxidation (ECGO®)	X	
CleanOx®	X	

TABLE 5-4

APPLICABLE CORRECTIVE MEASURE TECHNOLOGIES
FREE PRODUCT
CORRECTIVE MEASURES STUDY TASK I REPORT
TOW WAY FUEL FARM
NAVAL STATION ROOSEVELT ROADS

Technology	Applicable	Reason for Exclusion
No Action	X	
Institutional Controls	X	
Containment/Collection:		
Barriers	X	
Interceptor Trenches	X	
Extraction Wells *	X	
Dual Phase Extraction	X	
Three Phase Extraction	X	
Floating Filter Pumps	X	
Surface Oil/Water Separators	X	
CleanOx®	X	
Electro Chemical Geo Oxidation (ECGO®)	X	

Note:
*Includes the various combinations of skimming, groundwater table depression and reinjection of water upgradient to enhance head differentials

6.0 IDENTIFICATION OF THE CORRECTIVE MEASURE ALTERNATIVE

This section of the CMS Task I Report is designed to develop the corrective measure alternative or alternatives based on the corrective measure objectives and analysis of the preliminary corrective measure technologies. The development should include sound engineering to determine which of the previously identified technologies appear most suitable for the TWFF. Technologies can be combined to form the overall corrective action alternative or alternatives. The selected alternative or alternatives represents a workable number of options that each appear to adequately address all site problems and corrective action objectives.

It is premature at this time to select the most appropriate corrective measure alternative for the TWFF site due to factors such as the CleanOx® pilot study that is just getting underway and modifications that are being made to the ICM at the TWFF. It should be noted that the screening of applicable technologies was performed for the TWFF in this Task I Report. It would be more feasible to select the corrective measure alternative following the completion of the CleanOx® pilot study and evaluating the modifications to the ICM. This will enable a better evaluation of the technologies to be performed which will assist in providing the best alternative to be selected for the site. The identification of the most applicable technology initially screened in this Task I Report will be performed in the CMS Task II Report. The technologies at a minimum which will be screened further in the Task II Report are presented below.

The following technologies will be screened further for suitability to remediate soils at the TWFF.

- No Action
- Institutional Controls
- In-situ Biological Treatment (Bioventing)
- In-situ Physical/Chemical Treatment (Soil vapor extraction)
- Natural Attenuation
- Electro Chemical Geo Oxidation (ECGO®)

The following technologies will be screened further for suitability to remediate groundwater at the TWFF.

- No Action
- Institutional Controls (alternate water)
- Containment/Collection (Barriers, trenches, extraction wells)
- In-situ Biological Treatment (O_2 enhancement)
- In-situ Physical/Chemical Treatment (Air sparging, dual phase extraction, hot water or steam flushing/stripping)
- Ex-situ Biological Treatment Chemical Processes (Bioreactors)
- Natural Attenuation
- Electro Chemical Geo Oxidation (ECGO®)
- CleanOx®

The following technologies will be screened further for suitability for free product recovery at the TWFF.

- No Action
- Institutional Controls
- Containment/Collection (Free product Pumps, Skimmers, etc...)
- Electro Chemical Geo Oxidation (ECGO®)
- CleanOx®

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APPENDIX A
RISK ASSESSMENT CALCULATIONS

FUTURE ON-S HILD RESIDENT
FUTURE BENEFICIAL USE SCENARIO
GROUNDWATER EXPOSURE ASSESSMENT- PRELIMINARY REMEDIATION GOALS (PRGs)
COMBINING INGESTION AND DERMAL ROUTES OF EXPOSURE

RGOs from ingestion and dermal contact with groundwater are calculated as follows:

RGOc (mg/L) = ICR/([Ing + Derm][CSF])
RGOnc (mg/L) = HQ*RfD/(Ing + Derm)

Ing = IR*EF*ED/(ATc or ATnc*BW)
Derm = SA*EF*ET*PC*ED*CF/(ATc or ATnc*BW)

Where:	INPUTS
ICR = incremental cancer risk (unitless)	1.00E-06
HQ = hazard quotient (unitless)	1
RGOc = carcinogenic contaminant concentration in water (ug/L)	calculated
RGOnc = noncarcinogenic contaminant concentration in water (ug/L)	calculated
ATc = averaging time for carcinogen (days)	25550
ATnc = averaging time for noncarcinogen (days)	2190
CF = conversion factor (0.001 L/cm3)	0.001
CSF = cancer slope factor (mg/kg-day)-1	specific
RfD = reference dose (mg/kg-day)	specific
EF = exposure frequency (days/year)	40
IR = water ingestion rate (L/hour)	0.05
SA = skin surface area available for contact (cm2)	2006
ED = exposure duration (years)	6
BW = body weight (kg)	15
ET = exposure time (hours/day)	1
PC = permeability constant (cm/hr)	specific

Note: Inputs are scenario and site specific

Contaminant	ICR	HQ	Permeability Constant (cm/hr)	Slope Factor (mg/kg-day)-1	Dermally Adj. Slope Factor (mg/kg-day)-1	Reference Dose (mg/kg-day)	Dermally Adj. Ref. Dose (mg/kg-day)	Ingestion Dose Carc	Dermal Dose Carc	Ingestion Dose Noncarc	Dermal Dose Noncarc	**RGO Carc (ug/L)**	**RGO Noncarc (ug/L)**
Benzene	1.00E-06	1.00E+00	2.10E-02	2.90E-02	3.63E-02	3.00E-03	3.00E-03	3.13E-05	2.64E-05	3.65E-04	3.08E-04	**536**	**4,457**
Toluene	1.00E-06	1.00E+00	1.00E+00	0.00E+00	0.00E+00	2.00E-01	2.00E-01	3.13E-05	1.26E-03	3.65E-04	1.47E-02	**NA**	**13,315**
Ethylbenzene	1.00E-06	1.00E+00	1.20E+00	0.00E+00	0.00E+00	1.00E-01	8.00E-02	3.13E-05	1.51E-03	3.65E-04	1.76E-02	**NA**	**4,475**
Total Xylenes	1.00E-06	1.00E+00	8.00E-02	0.00E+00	0.00E+00	2.00E+00	1.20E+00	3.13E-05	1.00E-04	3.65E-04	1.17E-03	**NA**	**862,295**

FUTURE RESI[illegible]L CHILD
SOIL EXPOSURE ASSESSMENT-PRELIMINARY REMEDIATION GOALS (PRGs)
COMBINED INGESTION AND DERMAL ROUTES OF EXPOSURE

RGOs from accidental ingestion and dermal contact with soil are calculated as follows:

RGOc (mg/kg) = ICR/[(Ing *CSFo)+ (Derm*CSFd)]
RGOnc (mg/kg) = HQ/[(Ing/RfDo) + (Derm/RfDd)]

Ing = IR*ED*EF*CF/ATc or ATnc*BW
Derm = SA*ED*EF*AF*ABS*CF/ATc or ATnc*BW

Where:

	INPUTS	
ICR = apportioned target incremental cancer risk, unitless	1E-06	
HQ = target hazard quotient, unitless	1.0	
RGOc = carcinogenic contaminant concentration in surface soil, mg/kg	calculated	
RGOnc = noncarcinogenic contaminant concentration in surface soil, mg/kg	calculated	
ATc = averaging time for carcinogen, days	25550	
ATnc = averaging time for noncarcinogen, days	2190	
CF = conversion factor, kg/mg	1E-06	
CSFo = oral cancer slope factor, (mg/kg-day)-1	CS	(chemical specific value)
CSFd = dermally adjusted cancer slope factor, (mg/kg-day)-1	CS	
RfDo = oral reference dose, mg/kg-day	CS	
RfDd = dermally adjusted reference dose, mg/kg-day	CS	
ED = exposure duration, years	6	
EF = exposure frequency, days/year	350	
IR = ingestion rate, mg/day	200	
BW = body weight, kg	15	
SA = skin surface area available for contact, cm2	2006	
AF = soil to skin adherence factor, mg/cm2	0.2	
ABS = Absorption Factor, unitless	CS	

Note: Inputs are scenario and site specific

Contaminant	Target ICR	Target HQ	Absorption Factor (unitless)	Slope Factor (mg/kg-day)-1	Reference Dose (mg/kg-day)	Dermally Adj. Slope Factor (mg/kg-day)-1	Derm. Adj. Ref. Dose (mg/kg-day)	Ingestion Dose Carc	Dermal Dose Carc	Ingestion Dose Noncarc	Dermal Dose Noncarc	RGO Carc (ug/kg)	RGO Noncarc (ug/kg)
Benzene	1.0E-06	1.0	0.100	2.90E-02	3.00E-03	3.63E-02	2.40E-03	1.10E-06	2.20E-07	1.28E-05	2.56E-06	**25,157**	**187,602**
Toluene	--	1.0	0.100	--	2.00E-01	--	1.60E-01	1.10E-06	2.20E-07	1.28E-05	2.56E-06	--	**12,506,782**
Ethylbenzene	--	1.0	0.100	--	1.00E-01	--	8.00E-02	1.10E-06	2.20E-07	1.28E-05	2.56E-06	--	**6,253,391**
Total Xylenes	--	1.0	0.100	--	2.00E+00	--	1.60E+00	1.10E-06	2.20E-07	1.28E-05	2.56E-06	--	**125,067,816**

FUTURE ON-. DULT RESIDENT
FUTURE BENEFICIAL USE SCENARIO
GROUNDWATER EXPOSURE ASSESSMENT- PRELIMINARY REMEDIATION GOALS (PRGs)
COMBINING INGESTION AND DERMAL ROUTES OF EXPOSURE

RGOs from ingestion and dermal contact with groundwater are calculated as follows:

RGOc (mg/L) = ICR/([Ing + Derm][CSF])
RGOnc (mg/L) = HQ*RfD/(Ing + Derm)

Ing = IR*EF*ED/(ATc or ATnc*BW)
Derm = SA*EF*ET*PC*ED*CF/(ATc or ATnc*BW)

Where:	INPUTS
ICR = incremental cancer risk (unitless)	1.00E-06
HQ = hazard quotient (unitless)	1
RGOc = carcinogenic contaminant concentration in water (ug/L)	calculated
RGOnc = noncarcinogenic contaminant concentration in water (ug/L)	calculated
ATc = averaging time for carcinogen (days)	25550
ATnc = averaging time for noncarcinogen (days)	8760
CF = conversion factor (0.001 L/cm3)	0.001
CSF = cancer slope factor (mg/kg-day)-1	specific
RfD = reference dose (mg/kg-day)	specific
EF = exposure frequency (days/year)	40
IR = water ingestion rate (L/hour)	0.05
SA = skin surface area available for contact (cm2)	5300
ED = exposure duration (years)	24
BW = body weight (kg)	70
ET = exposure time (hours/day)	1
PC = permeability constant (cm/hr)	specific

Note: Inputs are scenario and site specific

Contaminant	ICR	HQ	Permeability Constant (cm/hr)	Slope Factor (mg/kg-day)-1	Dermally Adj. Slope Factor (mg/kg-day)-1	Reference Dose (mg/kg-day)	Dermally Adj. Ref. Dose (mg/kg-day)	Ingestion Dose Carc	Dermal Dose Carc	Ingestion Dose Noncarc	Dermal Dose Noncarc	**RGO Carc (ug/L)**	**RGO Noncarc (ug/L)**
Benzene	1.00E-06	1.00E+00	2.10E-02	2.90E-02	3.63E-02	3.00E-03	2.40E-03	2.68E-05	5.97E-05	7.83E-05	1.74E-04	**340**	**10,132**
Toluene	1.00E-06	1.00E+00	1.00E+00	0.00E+00	0.00E+00	2.00E-01	1.60E-01	2.68E-05	2.84E-03	7.83E-05	8.30E-03	**NA**	**19,139**
Ethylbenzene	1.00E-06	1.00E+00	1.20E+00	0.00E+00	0.00E+00	1.00E-01	8.00E-02	2.68E-05	3.41E-03	7.83E-05	9.96E-03	**NA**	**7,984**
Total Xylenes	1.00E-06	1.00E+00	8.00E-02	0.00E+00	0.00E+00	2.00E+00	1.60E+00	2.68E-05	2.28E-04	7.83E-05	6.64E-04	**NA**	**2,202,586**

FUTURE RES. AL ADULT
SOIL EXPOSURE ASSESSMENT-PRELIMINARY REMEDIATION GOALS (PRGs)
COMBINED INGESTION AND DERMAL ROUTES OF EXPOSURE

RGOs from accidental ingestion and dermal contact with soil are calculated as follows:

RGOc (mg/kg) = ICR/[(Ing *CSFo)+ (Derm*CSFd)]
RGOnc (mg/kg) = HQ/[(Ing/RfDo) + (Derm/RfDd)]

Ing = IR*ED*EF*CF/ATc or ATnc*BW
Derm = SA*ED*EF*AF*ABS*CF/ATc or ATnc*BW

Where:

	INPUTS	
ICR = apportioned target incremental cancer risk, unitless	1E-06	
HQ = target hazard quotient, unitless	1.0	
RGOc = carcinogenic contaminant concentration in surface soil, mg/kg	calculated	
RGOnc = noncarcinogenic contaminant concentration in surface soil, mg/kg	calculated	
ATc = averaging time for carcinogen, days	25550	
ATnc = averaging time for noncarcinogen, days	8760	
CF = conversion factor, kg/mg	1E-06	
CSFo = oral cancer slope factor, (mg/kg-day)-1	CS	(chemical specific value)
CSFd = dermally adjusted cancer slope factor, (mg/kg-day)-1	CS	
RfDo = oral reference dose, mg/kg-day	CS	
RfDd = dermally adjusted reference dose, mg/kg-day	CS	
ED = exposure duration, years	24	
EF = exposure frequency, days/year	350	
IR = ingestion rate, mg/day	100	
BW = body weight, kg	70	
SA = skin surface area available for contact, cm2	5300	
AF = soil to skin adherence factor, mg/cm2	0.2	
ABS = Absorption Factor, unitless	CS	

Note: Inputs are scenario and site specific

Contaminant	Target ICR	Target HQ	Absorption Factor (unitless)	Slope Factor (mg/kg-day)-1	Reference Dose (mg/kg-day)	Dermally Adj. Slope Factor (mg/kg-day)-1	Derm. Adj. Ref. Dose (mg/kg-day)	Ingestion Dose Carc	Dermal Dose Carc	Ingestion Dose Noncarc	Dermal Dose Noncarc	**RGO Carc (ug/kg)**	**RGO Noncarc (ug/kg)**
Benzene	1.0E-06	1.0	0.100	2.90E-02	3.00E-03	3.63E-02	2.40E-03	4.70E-07	4.98E-07	1.37E-06	1.45E-06	**31,578**	**941,935**
Toluene	--	1.0	0.100	--	2.00E-01	--	1.60E-01	4.70E-07	4.98E-07	1.37E-06	1.45E-06	--	**62,795,699**
Ethylbenzene	--	1.0	0.100	--	1.00E-01	--	8.00E-02	4.70E-07	4.98E-07	1.37E-06	1.45E-06	--	**31,397,849**
Total Xylenes	--	1.0	0.100	--	2.00E+00	--	1.60E+00	4.70E-07	4.98E-07	1.37E-06	1.45E-06	--	**627,956,989**