03.01-09/27/96-00505

Baker

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(412) 269-6000
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September 27, 1996

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

Attn: Mr. Raymond Basso
Chief, RCRA Programs

Re: Contract N62470-89-D-4814
Navy CLEAN, District III
U.S. Naval Station Roosevelt Roads (NSRR)
Tow Way Fuel Farm (SWMU 7)
RCRA/HSWA Permit No. Pr 2170027203
Response to Comments

Dear Mr. Basso:

Baker Environmental, Inc. (Baker), on behalf of the Navy, is pleased to submit two sets of responses to EPA comments regarding the Draft Workplans for the Tow Way Fuel Farm at NSRR. It should be noted that the responses address comments received in EPA letters of June 20, 1996 and September 13, 1996 and those discussed in conference calls with Mr. Gordon of your staff held on September 10, 1996, and September 17, 1996.

There are two separate documents submitted with this letter. The first document outlines the Navy's proposed strategy for a phased approach to remedial activities at the Tow Way. The second provides detailed responses to EPA's written comments. Included as an attachment to the second document are detailed results of modeling used to estimate the volume of LNAPL present in the subsurface and to predict remediation duration. As indicated in the text, the model will be periodically updated as new data becomes available. Please note that EPA granted an extension for the submission of the modeling results until October 15, 1996. During the development of our responses it was found necessary to rely on modeling results to adequately address some comments. For this reason, the modeling results have been provided ahead of the revised schedule date.

bcc: A.Robb/CF, J.Mentz/R.Wattras/PRGM F; T.Fuller/PJT F; ~~C.Boes~~; Daily File
S.O.# 62470-277-SRN
Subfile #8
Initials RR

Baker

Please feel free to call me at 412-269-2065 or Mr. Christopher T. Penny (Navy-LANTDIV) at 804-322-4815 if you have any questions.

Sincerely,

BAKER ENVIRONMENTAL, INC.

Thomas C. Fuller
Activity Coordinator

TCF/lq

Attachment

cc: Mr. Christopher T. Penny-LANTDIV, Code 1822
Ms. Madeline Rivera-NSRR
Ms. Kathy Luke - Blasland, Bourk & Lee

Navy's Proposed Strategy for
Phased Approach to Remedial Activities
Tow Way Fuel Farm
Ceiba, Puerto Rico

Permit No. Pr2170027203

(Pursuant to teleconferences held

September 10, 1996 and September 17, 1996)

September 27, 1996

Navy's Proposed Strategy for Phased Approach to Remedial Activities
Tow Way Fuel Farm

It is the Navy's intent to address all of the USEPA's concerns regarding the presence of light, non-aqueous phase liquids (LNAPLs) in the subsurface beneath the Tow Way Fuel Farm (TWFF) site. To accomplish this, the Navy has developed a strategy for implementing additional LNAPL investigative and remediation activities at the site. The additional activities will be performed in four phases of work as summarized below:

Phase I Activities

Expected Completion Date - April 1997

Activities to be conducted or already completed under Phase I include:

A. Evaluation of current site conditions based on fluid level measurements conducted during August 1996.

B. Installation of the proposed Interim Corrective Measure (ICM), pending USEPA's review of this document and tentative approval of the proposed ICM.

C. Initial development of ARMOS™ model and preliminary estimate of the LNAPL volume and recovery rate.

D. Completion of an Operations & Maintenance Manual for the ICM.

E. Ongoing review of site hydrogeologic data and identification of data gaps associated with the extent, volume, and recoverability of the LNAPL.

F. Ongoing evaluation of conceptual hydrogeologic model.

Navy's Proposed Strategy for Phased Approach to Remedial Activities
Tow Way Fuel Farm

Phase II Activities

Expected Completion Date - January 1998

Activities to be conducted under Phase II include:

A. Address the data gaps identified in Phase I through the completion of additional monitoring wells (outpost locations necessary to define the LNAPL extent), borings, and hydrogeologic testing as necessary.

B. Refine the conceptual hydrogeologic model based on the data collected in item A and evaluation of ICM operational data collected during Phase I Activities.

C. Refine the preliminary estimates of the LNAPL volume and recovery rate using additional site hydrogeologic data collected under item A and based on an evaluation of ICM operational data collected during Phase I activities.

D. Perform an initial focused corrective measures analysis to evaluate applicable LNAPL recovery technologies and potential enhancements to the ICM (e.g., interceptor trench, large diameter recovery wells, vacuum enhanced recovery, and, if applicable, a quantitative ground water/LNAPL model). During the focused corrective measures analysis, emphasis will be placed on limiting conditions such as requirements of the existing NPDES permit, infiltration gallery capacity, and wastewater treatment plant capacity.

Navy's Proposed Strategy for Phased Approach to Remedial Activities
Tow Way Fuel Farm

Phase III Activities

Expected Completion Date - February 1999

Activities to be conducted under Phase III include:

A. Install additional LNAPL recovery wells if needed for LNAPL plume coverage.

B. Complete additional monitoring wells, as required to assess the ICM effectiveness.

C. Perform pilot testing of alternative LNAPL recovery technologies and enhancements to the ICM.

D. Full-scale implementation of the best alternative LNAPL recovery technologies and enhancements to the ICM based on results of the pilot tests.

Phase IV Activities

Expected to Commence February 1999

Activities to be conducted under Phase IV include:

A. Monitoring and maintenance of the ICM and best alternative technologies installed under Phase III (this activity will be ongoing).

Response to USEPA's Comments

Dated June 20, 1996 and September 13, 1996

for Free Product Recovery

Interim Corrective Measures Program

Tow Way Fuel Farm

Ceiba, Puerto Rico

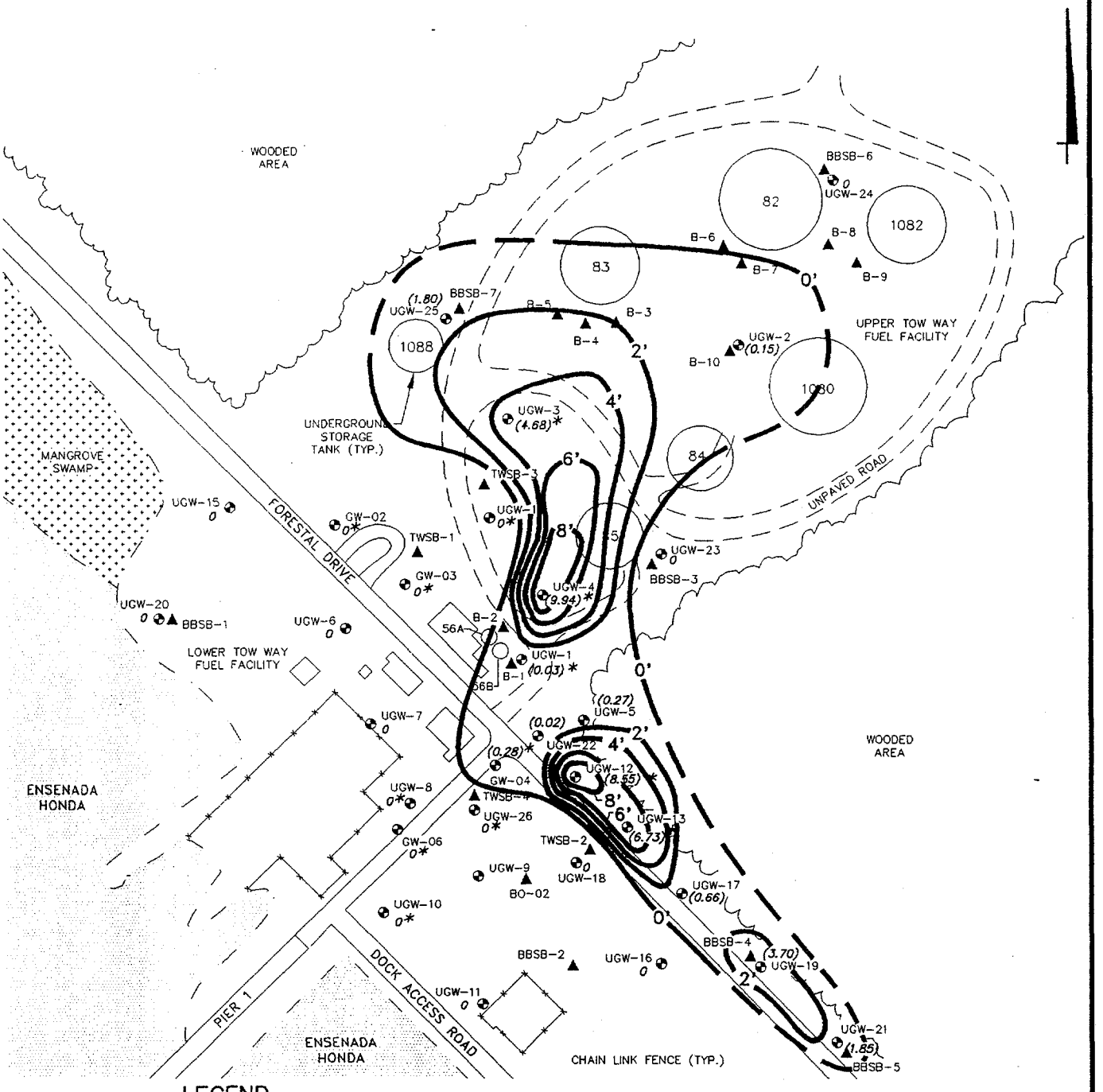
September 27, 1996

Response to USEPA's Comments Dated June 20, 1996 and September 13, 1996
Tow Way Fuel Farm

Response to Comment No. 1

Per the EPA's request, attached is an Apparent Light, Non-Aqueous Phase Liquid (LNAPL) Isopach Map (Figure 1) for the entire Tow Way Fuel Farm (TWFF), based on data collected August 13, 1996. The data used to construct Figure 1 are presented in Table 1. We have referred to LNAPL thickness measured at monitoring wells as "apparent LNAPL thickness" because it is recognized that the apparent thickness of LNAPL measured at monitoring wells is generally larger than the actual thickness of mobile LNAPL in porous media, and use of apparent LNAPL thicknesses may lead to erroneous estimates of LNAPL volume (e.g., Abdul, et al., 1989). Data used to generate Figure 1 consist of the apparent LNAPL thickness measurements obtained at site monitoring wells with an oil/water interface probe accurate to 0.01 feet. The apparent LNAPL thickness measurements have not been corrected or altered in any way from the measurements collected in the field. The Navy acknowledges that the extent of the LNAPL has not been delineated and the contours shown on Figure 1 have been dashed at areas where no data are available. Specifically, data gaps are present east of the Upper TWFF near tank 1080, northeast along Forestal Drive near monitoring wells UGW-12, UGW-13, UGW-17, UGW-19, and UGW-21, and west of UGW-25. These data gaps will be addressed during the proposed Phase II activities of site work through the installation of additional monitoring wells. Additionally, monitoring well GW-04 will be replaced as a monitoring well since the screened interval is unknown. An appropriate workplan will be submitted to the EPA for comment prior to the initiation of the work.

In response to the EPA comment regarding the phenomenon of how a 0.21 foot free product layer in the aquifer could be responsible for a 14.83 foot free product layer in the well bore of well UGW-4, attempts have been made to evaluate the relationship between apparent LNAPL thickness and actual LNAPL thickness at the site using baildown test results as described in Testa and Paczkowski (1989). In porous media, this phenomenon is related to the presence and distribution of soil capillary



LEGEND

- MONITORING WELL
- SOIL BORING
- (0.07) APPARENT LNAPL THICKNESS IN FEET (8/13/96)
- * WELL SCREENED INTERVAL BELOW POTENTIOMETRIC SURFACE OR UNKNOWN
- 8' APPARENT LNAPL THICKNESS CONTOUR IN FEET (DASHED WHERE INFERRED) C.I. = 2-FEET

APPROXIMATE SCALE IN FEET

150 0 150

NOTE: ALL LOCATIONS ARE APPROXIMATE.

ROOSEVELT ROADS U.S.NAVAL STATION
TOW WAY FUEL FACILITY
CEIBA, PUERTO RICO

APPARENT LNAPL ISOPACH MAP AUGUST 13, 1996

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

FIGURE 1

L: LNAPL
P: APX
9/26/96 SYR-54-PGL
39928002/39928SM1.DWG

TABLE 1
FLUID LEVEL MEASUREMENTS - AUGUST 13, 1996

ROOSEVELT ROADS U.S. NAVAL STATION
TOW WAY FUEL FARM
CEIBA, PUERTO RICO

Well	TOC Elevation (ft NGVD)	Screened Interval (ft NGVD)	LNAPL Density (g/cc)	LNAPL Elevation (ft NGVD)	Groundwater Elevation (ft NGVD)	LNAPL Thickness (feet)	Potentiometric Elevation (ft NGVD)	Status
GW-02	13.57	unknown	0.811	-	2.18	0.00	2.18	u
GW-03	13.18	unknown	0.811	-	1.47	0.00	1.47	u
GW-04	12.83	unknown	0.833	5.15	4.87	0.28	5.10	u
GW-06	10.70	unknown	0.811	-	1.30	0.00	1.30	u
UGW-1	16.34	-9.5 to 0.5	0.811	2.12	2.09	0.03	2.11	s
UGW-2	61.93	2.3 to 12.3	0.811	5.54	5.39	0.15	5.51	p
UGW-3	24.76	-12.1 to -2.1	0.810	3.28	-1.40	4.68	2.39	s
UGW-4	20.21	-15.9 to -5.9	0.804	4.23	-5.71	9.94	2.28	s
UGW-5	16.04	-14.0 to 6.0	0.811	2.17	1.90	0.27	2.12	p
UGW-6	11.24	-8.4 to 1.6	0.811	-	0.75	0.00	0.75	p
UGW-7	9.81	-7.6 to 2.4	0.811	-	1.23	0.00	1.23	p
UGW-8	10.03	-8.6 to 1.4	0.811	-	1.76	0.00	1.76	s
UGW-10	10.50	-9.5 to 0.5	0.811	-	0.84	0.00	0.84	s
UGW-11	9.45	-9.1 to 0.9	0.811	-	0.49	0.00	0.49	p
UGW-12	13.97	-10.4 to -0.4	0.801	3.40	-5.15	8.55	1.70	s
UGW-13	13.34	-13.8 to -3.8	0.811	2.00	-4.73	6.73	0.73	s
UGW-14	19.23	-20.5 to -10.5	0.811	-	2.31	0.00	2.31	s
UGW-15	12.33	-7.1 to 2.9	0.811	-	0.32	0.00	0.32	p
UGW-16	13.63	-8.0 to 2.0	0.811	-	0.81	0.00	0.81	p
UGW-17	12.28	-13.0 to 2.0	0.806	0.78	0.12	0.66	0.65	p
UGW-18	14.28	-7.4 to 2.6	0.811	-	1.01	0.00	1.01	p
UGW-19	12.27	-6.2 to 3.8	0.811	1.19	-2.53	3.72	0.49	p
UGW-20	11.92	-5.1 to 4.9	0.811	-	0.07	0.00	0.07	p
UGW-21	13.28	0.8 to 5.8	0.811	0.89	-0.96	1.85	0.54	p
UGW-22	15.18	-9.8 to 10.2	0.814	1.94	1.92	0.02	1.94	p
UGW-23	69.20	3.2 to 18.2	0.811	-	3.23	0.00	3.23	p
UGW-24	78.94	0.9 to 15.9	0.811	-	3.05	0.00	3.05	p
UGW-25	53.92	-0.1 to 14.9	0.810	2.89	1.09	1.80	2.55	p
UGW-26	14.51	-31.5 to -26.5	0.811	-	5.64	0.00	5.64	s

Notes:

TOC = top of well casing.

ft NGVD = feet above mean sea level relative to National Geodetic Vertical Datum (NGVD).

LNAPL = light, non-aqueous phase liquid.

g/cc = grams per cubic centimeter at 25-degrees Celsius.

* LNAPL density reported by laboratory.

All other LNAPL densities taken as average of laboratory measured LNAPL densities.

A dash (-) indicates no measurable LNAPL present.

All data collected August 13, 1996.

Status: u = unknown; s = well screen below potentiometric surface; p = well screened across potentiometric surface.

Potentiometric Elevation (POT) computed using formula:

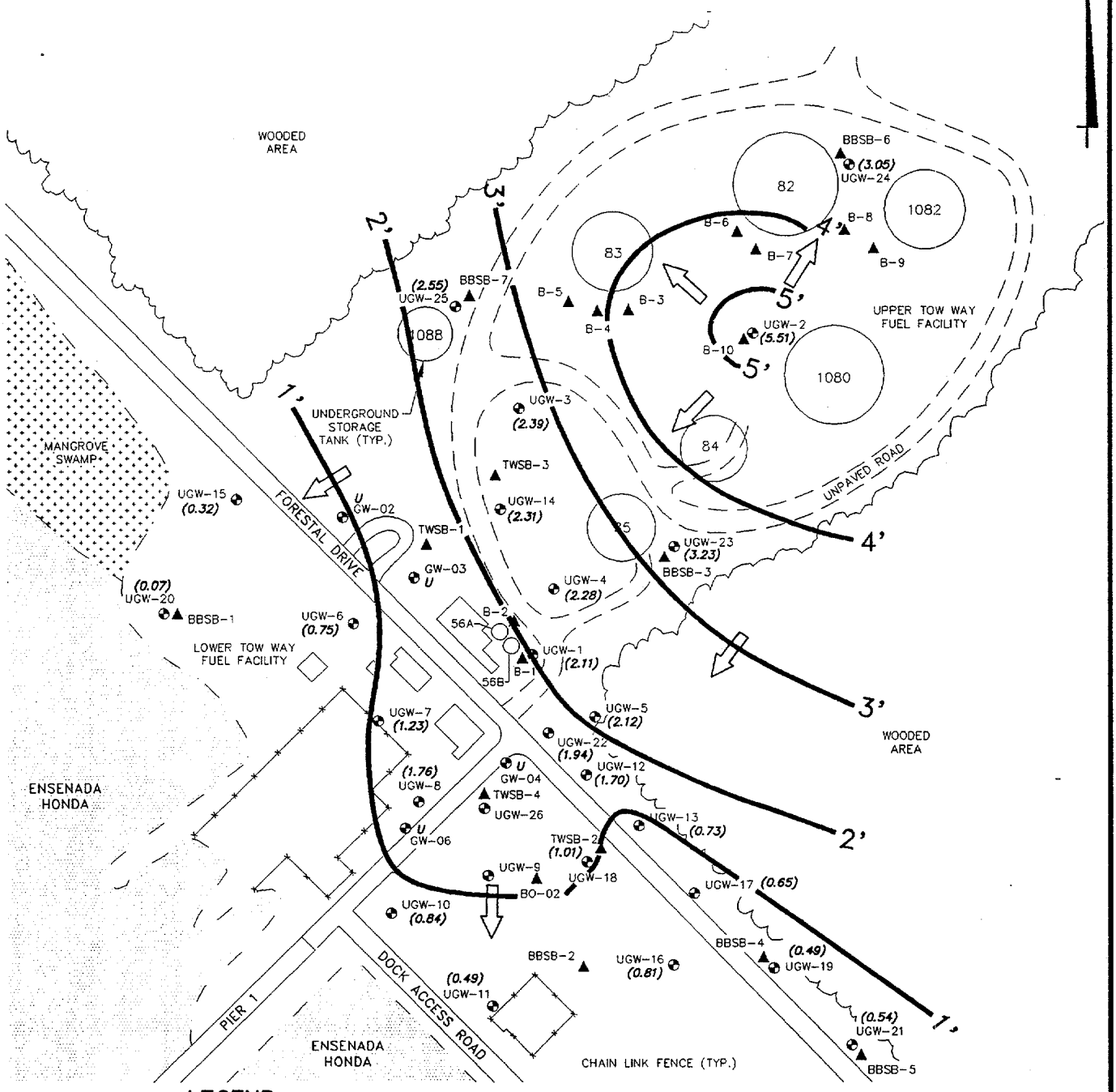
POT = Ground-water elevation + (LNAPL Thickness x LNAPL Density)

migration are governed not only by capillary forces but more importantly by structural controls imposed by the fractured bedrock. Thus, a 2 inch wide fracture zone containing LNAPL, where the actual LNAPL thickness is limited 2 inches, may contribute to 14 feet of LNAPL at a monitoring well. Based on this line of reasoning, the Navy recognizes the limitations of baildown analyses in a fractured rock medium and has used an alternative method to estimate the volume of LNAPL beneath the site. However, the baildown test results can be useful in assessing the LNAPL migration rate and will be further evaluated during refinement of the conceptual hydrogeologic model, as part of Phase II activities.

In an effort to provide a preliminary estimate of the volume of LNAPL beneath the TWFF, the numerical model ARMOS™ version 5.21 (ES&T, 1996) was used to simulate storage capacities and hydrogeologic conditions at the site relevant to the distribution and migration of LNAPL. Because LNAPL is present in competent and weathered fractured bedrock at the site, an equivalent porous medium (EPM) was assumed by adjusting the porosity and specific yield terms within the model to reflect the expected bedrock storage conditions. The modeling approach, assumptions, and input parameters are provided as an attachment to this letter (Attachment A). Based on the results of preliminary ARMOS modeling, it is estimated that approximately 33,000 gallons of LNAPL may be present in the subsurface beneath the site, subject to the assumptions stated in Attachment A. As additional site data become available, the ARMOS model will be updated on a semi-annual basis to provide more accurate estimates of the LNAPL volume.

Response to Comment No. 2

Per the EPA's request, attached is a potentiometric ground-water contour map (Figure 2) for the entire TWFF, based on data collected August 13, 1996 (Table 1). The potentiometric ground-water elevations shown on Figure 2 were computed using the method of Lenhard and Parker (1990), which takes into account apparent LNAPL thickness and LNAPL density at each monitoring well. Table 1 presents data used to construct Figure 2.



LEGEND

- ⊕ MONITORING WELL
- ▲ SOIL BORING
- (0.07) GROUNDWATER POTENTIOMETRIC ELEVATION CORRECTED FOR LNAPL THICKNESS AND DENSITY IN FEET RELATIVE TO NATIONAL GEODETIC VERTICAL DATUM (NGVD)
- 2' —— POTENTIOMETRIC CONTOUR LINE IN FEET RELATIVE TO NGVD
- ⇦ POTENTIOMETRIC GRADIENT
- u UNKNOWN WELL SCREEN INTERVAL

APPROXIMATE SCALE IN FEET

150 0 150

NOTE: ALL LOCATIONS ARE APPROXIMATE.

ROOSEVELT ROADS U.S.NAVAL STATION
TOW WAY FUEL FACILITY
CEIBA, PUERTO RICO

POTENTIOMETRIC CONTOUR MAP
AUGUST 13, 1996

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

FIGURE
2

L: GW1
P: APX
9/26/96 SYR-54-PGL
39928002/39928SM1.DWG

elevations shown on Figure 2 were computed using the method of Lenhard and Parker (1990), which takes into account apparent LNAPL thickness and LNAPL density at each monitoring well. Table 1 presents data used to construct Figure 2.

Response to Comment No. 3

Per the EPA's request, the proposed free product recovery system has been expanded in the southeastern portion of the LNAPL plume to address LNAPL detected at monitoring wells UGW-19 and UGW-21. Figure 3 presents locations of additional proposed LNAPL recovery wells to address the EPA's concerns regarding LNAPL migration near the southeast flank of the plume.

Response to Comment No. 4

Per the EPA's request, the attached Table 2 presents proposed recovery well details including recommended recovery well depth, screened interval, pump position, and average LNAPL/water and LNAPL/air depths.

Response to Comment No. 5

A total of seven additional recovery wells will be installed at the approximate locations indicated on Figure 3 during Phase I of the site activities. Recovery well construction details are presented in Table 2. Additional recovery wells will be installed during Phase II activities based on performance monitoring data collected during start-up and monitoring of the proposed ICM. Phase II activities will include, at a minimum, the installation of two LNAPL recovery wells at locations near monitoring wells UGW-25 and GW-04, as depicted on Figure 3. Additional recovery wells may be installed at other locations, as required for plume coverage.

TABLE 2
PROPOSED LNAPL RECOVERY WELL CONSTRUCTION DETAILS

ROOSEVELT ROADS U.S. NAVAL STATION
TOW WAY FUEL FARM
CEIBA, PUERTO RICO

For the Proposed RW Near	LNAPL / Ground-water Elevation (ft NGVD)	Approximate Ground Surface Elevation (ft NGVD)	Depth to LNAPL / Ground-water (ft bgs)	Proposed RW Total Depth (ft bgs)	Proposed RW Screen Length (feet)	Proposed RW Screened Interval (ft bgs)	Proposed Pump Intake Elevation (ft bgs)
GW-04	5.15 / 4.87	12	6.9 / 7.1	12	10	2 to 12	7.1
UGW-3	3.28 / -1.40	23	19.7 / 24.4	30	20	10 to 30	21.2
UGW-4	4.23 / -5.71	19	14.8 / 24.7	30	20	10 to 30	16.3
UGW-12	3.40 / -5.15	13	9.6 / 18.2	25	20	5 to 25	11.1
UGW-13	2.00 / -4.73	12	10.0 / 16.7	25	20	5 to 25	11.5
UGW-17	0.78 / 0.12	11	10.2 / 10.9	20	15	5 to 20	10.9
UGW-19	1.19 / -2.53	10	8.8 / 12.5	20	15	5 to 20	10.3
UGW-21	0.89 / -0.96	10	9.1 / 11.0	20	15	5 to 20	10.6
UGW-25	2.89 / 1.09	50	47.1 / 48.9	60	20	40 to 60	48.6

Notes:

RW = recovery well.

ft NGVD = feet above mean sea level relative to National Geodetic Vertical Datum (NGVD).

ft bgs = feet below ground surface.

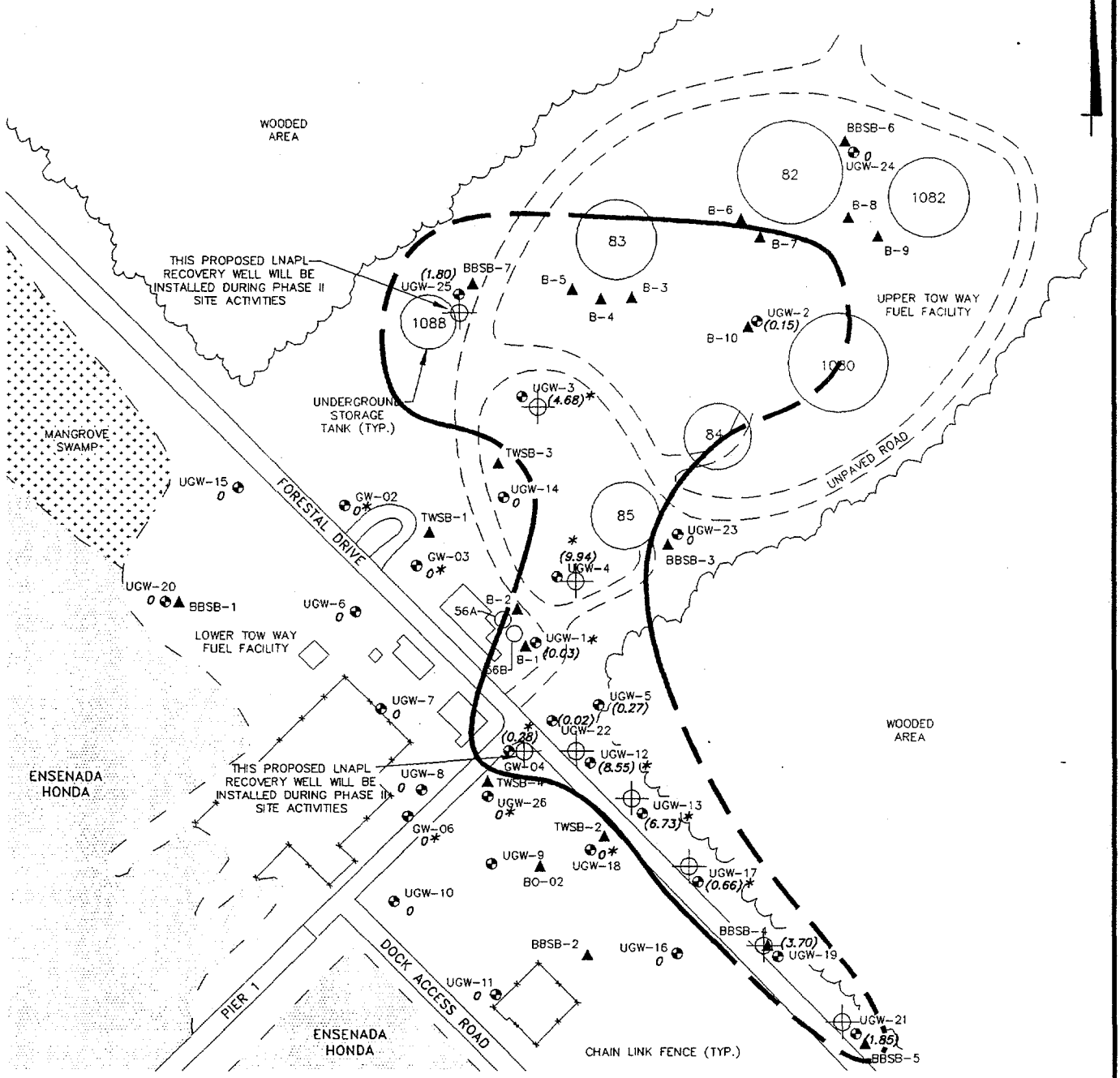
LNAPL = light non-aqueous phase liquid.

Proposed LNAPL RW locations shown on Figure 3.

LNAPL and ground-water elevations from 8/13/96 (Table 1).

Approximate ground surface elevation from well construction logs.

Proposed pump intake interval taken as depth to LNAPL plus 1.5 feet.



LEGEND

- MONITORING WELL
- SOIL BORING
- (0.07) APPARENT LNAPL THICKNESS IN FEET (8/13/96)
- * WELL SCREENED INTERVAL BELOW POTENTIOMETRIC SURFACE OR UNKNOWN
- LNAPL EXTENT (APPROX.) DASHED WHERE INFERRED
- PROPOSED LNAPL RECOVERY WELL LOCATIONS

APPROXIMATE SCALE IN FEET

150 0 150

NOTE: ALL LOCATIONS ARE APPROXIMATE.

ROOSEVELT ROADS U.S.NAVAL STATION
TOW WAY FUEL FACILITY
CEIBA, PUERTO RICO

PROPOSED LNAPL RECOVERY WELL LOCATIONS

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

FIGURE 3

L: P-LNAPL, P-WELLS
P: APX
9/26/96 SYR-54-PGL
39928002/39928SM1.DWG

the total LNAPL recovery rate for the proposed ICM is estimated to range from approximately 0.2 gph to 7.5 gph. Assuming residual LNAPL volume comprises approximately 5% of the preliminary estimate of the total LNAPL volume (Attachment A), and based on the preliminary estimated recovery rates, it would require approximately one to 18 years to recover the estimated volume of mobile LNAPL. This range for cleanup time will be refined once initial product recovery rates are established and the ARMOS model is updated with field data.

Because LNAPL beneath the TWFF is present within competent and weathered fractured bedrock, the estimated potential LNAPL volume and recovery rates should be used with caution due to inherent uncertainties associated with bedrock hydraulics. Specifically, the wide range in potential LNAPL recovery rates is due to:

- The uncertain volume of LNAPL that may have infiltrated site soils during spill events; and
- Uncertainties associated with the fact that LNAPL migration at the site is controlled by structural and hydraulic characteristics of the bedrock, which have not been investigated.

The estimated LNAPL recovery rates will be re-evaluated semi-annually (every other quarter) based on ICM performance monitoring data and actual LNAPL recovery rates observed in the field.

Response to Comment No. 7

Per the EPA's request, the Navy will prepare an Operations and Maintenance (O&M) Manual for the proposed ICM as a stand alone document. The O&M Manual will be submitted to the EPA for comment prior to start up of the ICM. This will be accomplished during Phase I activities and is expected to be completed by April 1997.

Response to Comment No. 8

Response to USEPA's Comments Dated June 20, 1996 and September 13, 1996
Tow Way Fuel Farm

Response to Comment No. 7

Per the EPA's request, the Navy will prepare an Operations and Maintenance (O&M) Manual for the proposed ICM as a stand alone document. The O&M Manual will be submitted to the EPA for comment prior to start up of the ICM. This will be accomplished during Phase I activities and is expected to be completed by April 1997.

Response to Comment No. 8

The LNAPL recovery pumps specified for the ICM will be equipped with a specific gravity skimmer float attached to the pump intake that floats above ground water at the ground-water/LNAPL interface. The float/intake assembly has a 2 foot vertical range to accommodate fluctuations in the ground-water/LNAPL level. This configuration permits the float/intake to selectively collect LNAPL and minimizes collection of ground water. Additionally, a high water indicator will be installed in the LNAPL recovery tank to indicate the presence of water. Ground water that is incidentally collected will be tested pursuant to 40 CFR 261. Storage and disposal of collected ground water will be based on analytical results and will conform to all applicable regulations.

Response to Comment No. 9

Soils excavated during installation of the proposed ICM will be tested pursuant to 40 CFR 261. Storage and disposal of excavated soils will be based on analytical results and will conform to all applicable regulations.

Response to Comment No. 10

Per the EPA's request, an Apparent LNAPL Isopach Map has been prepared (Figure 1) that

accurately portrays the extent of LNAPL at the TWFF based on fluid level measurements collected August 13, 1996. The line representing the approximate extent of LNAPL (zero foot contour line) has been dashed where no data are available. Data gaps will be addressed during Phase II activities and the extent of the LNAPL will be more accurately defined.

Response to Comment No. 11

Due to the presence of subsurface utilities, the LNAPL recovery trench proposed in the Draft Workplan will not be installed during Phase I activities. Instead, additional recovery wells will be installed at the locations depicted on Figure 3. The possibility of installing the LNAPL recovery trench at an alternate location will be evaluated during Phase II activities.

Response to Comment No. 12

Per the EPA's request, the proposed ICM includes an LNAPL recovery well located adjacent to monitoring well UGW-25 (Figure 3). The proposed recovery well will be installed during Phase II activities.

References

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Attachment A

ARMOS™ Modeling

ATTACHMENT A

The numerical model ARMOS™ version 5.21 (Areal Multiphase Organic Simulator; ES&T, 1996) was selected to provide a preliminary estimate of the LNAPL volume beneath the Tow Way Fuel Farm (TWFF). In addition to calculating total LNAPL volume, this model may also be used to simulate LNAPL migration and aid in optimizing LNAPL recovery during future phases of work. The model is based on theories presented by Lenhard and Parker (1990) and advanced by Parker et al., (1990), which assume vertical equilibrium pressure distributions and three-phase saturation-pressure relations using soil and fluid properties. Input to the model included LNAPL fluid properties (density, viscosity, and interfacial tension with water), site soil properties (hydraulic conductivity, porosity, anisotropy, storage coefficient), and a scaled site map.

The model domain completely encompasses the TWFF and is presented on Figure A-1. As shown on Figure A-1, the domain has been divided into two regions based on whether the LNAPL is present in fractured bedrock or overburden materials. This determination was based on the fluid level measurements of August 13, 1996 and boring logs compiled for the site. In an effort to simulate the storage capacity of the fractured bedrock zone, an equivalent porous medium (EPM) approach was used where the hydrogeologic aspects of fractured rock were represented by a porous medium with estimated equivalent hydraulic properties. The volume of LNAPL in the subsurface was computed using fluid level measurements from August 13, 1996, which are presented in Table 1 of the Response to USEPA's Comments.

The model was set up to run for 25 days and the LNAPL volume was taken at the end of the run time. Ground-water flow was not simulated and was assumed to remain static (initial elevations) for the duration of the modeling run. No stresses (pumping, recharge, or boundary fluxes) were placed on the system. Sensitivity analyses indicated that LNAPL volume calculations were sensitive to changes in the porosity and specific yield of the soils but not sensitive to changes in the hydraulic conductivity.

ATTACHMENT A

It should be noted that results of this modeling effort are to be considered a preliminary estimate only of the LNAPL volume. Several variables associated with the bedrock structure and hydraulic properties provide significant uncertainties which yield all results from this modeling effort to be considered preliminary. Only through a detailed characterization of the bedrock structure and hydraulic properties can a more accurate estimate of the LNAPL volume be made.

Assumptions

Fractured Bedrock

- Consisted of crystalline lava (probably andesite) of the Daguao Formation based on the USGS Geologic Map for the area (1979) and field descriptions from soil borings and monitoring wells;

- Hydraulic conductivity was 3.9×10^{-5} cm/sec based on geometric mean of slug test results reported by O'Brien and Gere (1992);

- Porosity was 0.101 (Walton, 1991);

- Specific yield was 0.0082 (Baker Environmental, 1996);

- Anisotropy angle of the maximum hydraulic conductivity was 136 degrees clockwise from north; and

- Anisotropy ratio was 2 (quotient of maximum principle conductivity by minimum principle conductivity).

ATTACHMENT A

Overburden (fill materials)

- Consisted of fine to medium grained sand with some silt and clay, based on field descriptions from soil borings and monitoring wells;

- Hydraulic conductivity was 1.4×10^{-4} cm/sec based on a geometric mean of slug test results reported by O'Brien and Gere (1992);

- Porosity was 0.3 (Walton, 1991);

- Specific yield was 0.1 (Walton, 1991);

- Anisotropy angle of the maximum hydraulic conductivity was 136 degrees clockwise from north; and

- Anisotropy ratio was 2 (quotient of maximum principle conductivity by minimum principle conductivity).

LNAPL Fluid Properties

- Described generally as Bunker C (O'Brien and Gere, 1992);

- Average viscosity was 44 millipascal seconds (average of ASTM D-2196 analyses performed on 7 LNAPL samples); and

- Average density was 0.811 grams-per-cubic-centimeter (average of analyses performed on

7 LNAPL samples).

Model Boundaries

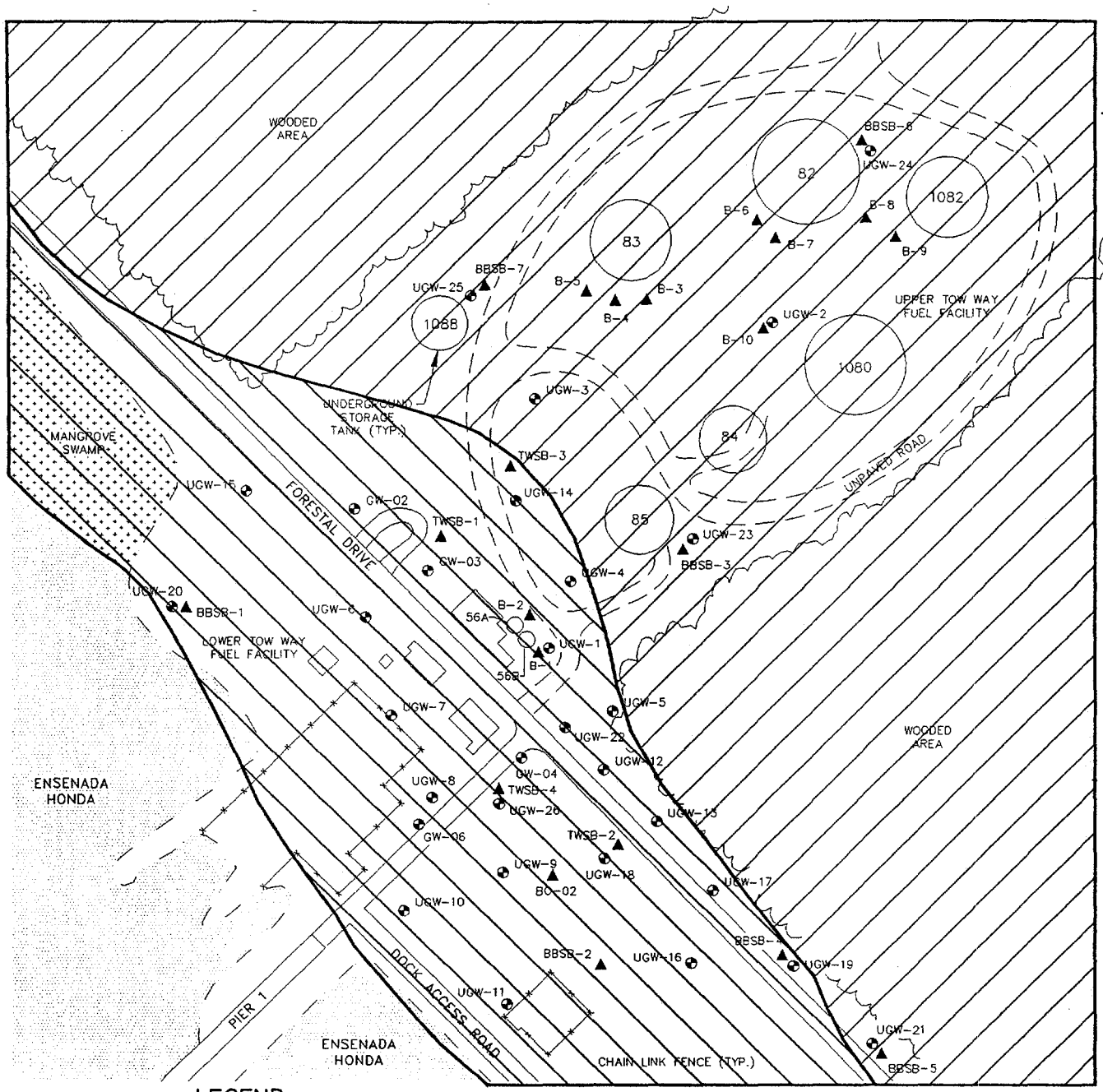
- Nodes along Ensenada Honda were assigned specified head values of 0.00 feet above mean sea level relative to the National Geodetic Vertical Datum (NGVD).

Model Initial Conditions

- Fluid level measurements recorded August 13, 1996 at wells containing measurable thicknesses of LNAPL were used as initial conditions. All fluid level measurements were converted to feet above mean sea level relative to the NGVD.

Model Output

- Total volume of LNAPL: 4,412 cubic feet (approximately 33,090 gallons);
- Total Residual volume of LNAPL: 239 cubic feet (approximately 1,793 gallons); and
- Mass balance error: 0.0002%



LEGEND

- MONITORING WELL
- SOIL BORING
- POTENTIOMETRIC SURFACE IN FRACTURED BEDROCK
- POTENTIOMETRIC SURFACE IN OVERBURDEN

APPROXIMATE SCALE IN FEET

150 0 150

NOTE: ALL LOCATIONS ARE APPROXIMATE.

ROOSEVELT ROADS U.S.NAVAL STATION
TOW WAY FUEL FACILITY
CEIBA, PUERTO RICO

LNAPL MODEL DOMAIN

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

FIGURE
A-1

L: A-1
P: APX
9/26/96 SYR-54-PGL
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