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LEAK CHARACTERIZATION STUDY
NAVAL AIR STATION NORFOLK
NORFOLK, VIRGINIA

HLA Job No. 02176,088.12

by

for Henry B. Peters, III
Senior Hydrogeologist

James W. Tremblay, P.E.
Principal Engineer

Harding Lawson Associates
6220 Westpark Drive, Suite 100
Houston, Texas 77057
Telephone: (713) 789-8050

STATE OF TEXAS
J.W.A. TREMBLAY
34873
REGISTERED
PROFESSIONAL ENGINEER

August 24, 1987

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I EXECUTIVE SUMMARY

Harding Lawson Associates (HLA) has performed Phases I and II of a jet fuel (JP-5) leak investigation at the Naval Air Station (NAS), Norfolk, Virginia. The purpose of this investigation was to delineate those areas where phase separated and dissolved hydrocarbon (JP-5) exists in the soil and groundwater, to investigate the amount and move- ment of the hydrocarbon, and to discuss these findings in terms of remediation of the problem. Initial remediation should include JP-5 fuel line integrity testing, interim recovery of fuel, and additional borings/monitoring wells to delineate the eastern extent of the hydrocarbon plume.

NAS Norfolk is a large Naval air facility and support complex which provides the fleet with runway, hangar, training and maintenance facilities, as well as a home base for speciality support units. The facility was constructed during the 1920's and 1930's. During the construction of the air station, the subgrade Boush Creek Culvert was constructed generally along the historical creek drainage pattern and is now the main storm water drainage system at NAS Norfolk.

In late 1984, NAS Norfolk personnel discovered a jet fuel leak in Boush Creek Culvert near Building LP-78. The results of preliminary studies indicated that jet fuel was entering Boush Creek Culvert at points extending from the bulk storage fuel farm and extending to the

north-northeast of the new jet engine test cells, Building LP-78. JP-5 fuel supply lines were suspected leakage sources. The Commonwealth of Virginia, State Water Control Board reviewed the plan of action, and approved the scope of this investigation prior to the commencement of the field activities.

The field investigation commenced with mobilization of the HLA field crew to NAS Norfolk in September, 1986. All prospective boring locations were surveyed for underground obstructions using surface geophysical techniques. Once a location was cleared, a boring was drilled to approximately 20 feet in depth. Monitoring wells were constructed in each boring using 4-inch diameter PVC pipe and screen. Soil and fluid samples from each well were obtained and shipped to an analytical laboratory for gas chromatograph and fingerprint analysis of JP-5. Aquifer tests were performed on selected wells to characterize local hydrogeologic conditions. Water level and hydrocarbon thickness measurements were obtained at each of the monitoring wells concurrently with the sampling and testing program.

The laboratory results indicate hydrocarbon presence in soil samples from 11 borings. In addition, 18 wells contained measurable hydroarbon in the fluid samples, 10 samples of which were "pure" JP-5 (petroleum hydrocarbon blend similar to JP-5). Groundwater level data show a general hydraulic gradient toward the northeast. The groundwater levels in the wells were apparently not significantly influenced

by local tidal action; however, they were influenced by precipitation (or lack thereof). Analytical analyses of aquifer test data show that the strata in the area have moderate (average) permeability and transmissivity. In-situ testing indicates that the aquifer is disrupted and modified by local construction at the NAS, including deep building foundations and Boush Creek Culvert, to the extent that data at any one well may not characterize the aquifer as a whole.

Primary recommendations focus on three distinct areas:

1. The need to eliminate the sources of the fuel in the subsurface as quickly as possible. This will include integrity testing to determine which JP-5 pipelines leak and the immediate repair/replacement of defective lines. All future work on site should be predicated on the elimination of the leak source(s). Installation of leak monitoring equipment could be very effective in minimizing future problems.

2. The timely implementation of a fluid recovery system which would pump phase separated hydrocarbons and hydrocarbon-contaminated groundwater into an above-ground recovery and treatment system. This system would separate the hydrocarbon from the pumped groundwater and, depending upon local regulatory requirements, treat the groundwater for discharge. Size and cost of the final system will depend upon the extent and volume of phase separated hydrocarbon on the groundwater surface.

3. The continuation of the subsurface investigations in the area east of the present site area. Additional borings/monitoring wells, along with supplemental aquifer test data, will further define the extent of the hydrocarbon body and dissolved concentrations of hydrocarbon in the groundwater. This information will permit improved technical and cost evaluation of the final remedial techniques.

II INTRODUCTION

The U. S. Navy engaged Harding Lawson Associates (HLA) to perform a site characterization study of a jet fuel leak at Naval Air Station (NAS) Norfolk, Virginia. The study was performed under existing contract with Southern Division, Naval Facilities Engineering Command (SOUTHDIV) supporting Atlantic Division, Naval Facilities Engineering Command (LANTDIV) and NAS Norfolk. This report presents the results of the HLA field investigation which was conducted to delineate the extent of phase separated and dissolved hydrocarbon migration in the subsurface, to possibly estimate volumes of hydrocarbon present at select locations, and to propose appropriate alternative remedial action, and/or make recommendations for additional study.

NAS Norfolk is a large naval air facility and support complex which provides the fleet with runway, hangar training and maintenance facilities, as well as a home base for specialty support units. The facility was constructed during the 1920's and 1930's. Prior to this, much of the site was a marshy environment. Surface water entered the site via Boush Creek which apparently followed a northeasterly drainage. During the construction of the air station, the subgrade Boush Creek Culvert was constructed generally along the historical creek drainage pattern and is now the main storm water drainage system at NAS Norfolk (refer to Plates 1 and 2).

In late 1984, NAS Norfolk personnel discovered a jet fuel leak in Boush Creek Culvert near Building LP-78. Preliminary investigations of this leak were performed in September 1984 by LANTDIV and Naval Air Rework Facility (NARF) engineers who established the general area of interest for the current study. The results of the preliminary studies indicated that jet fuel was entering Boush Creek Culvert at points extending from the bulk storage fuel farm and extending to the north-northeast of the new jet engine test cells, Building LP-78. JP-5 fuel supply lines were suspected leakage sources. HLA conducted a preliminary site investigation on April 24, 1986, to formulate a plan of action for the field investigation. Interviews with Navy personnel and a review of available drawings, borings, and literature served as a basis for defining the initial area of interest and selecting the field and laboratory methodology to be utilized. The Commonwealth of Virginia, State Water Control Board reviewed the plan of action, and approved the scope of investigation prior to the commencement of the field activities.

The field investigation was begun on September 2, 1986 and completed on November 7, 1986. Due to the apparent magnitude and duration of the fuel leakage problem, the HLA investigation was subdivided into two phases. Phase I was conducted to estimate the approximate extent of phase separated and dissolved hydrocarbon in the subsurface and to investigate the geologic and hydrologic conditions in the area. The Phase II field work was developed from the site

specific data obtained during Phase I. Phase II, which included additional monitoring well installation and aquifer testing, was conducted to further define the extent of hydrocarbon migration, the associated hydrologic and geologic conditions, and to attempt to identify the source(s) of leakage. Both Phase I and II drilling and monitoring well installation were conducted without interruption.

Phases I and II of this program were designed to characterize the extent and nature of subsurface hydrocarbon along with the geologic/ hydrogeologic environment, within the physical boundaries set out in the HLA Work Plan. The results of Phases I and II have focused on these physical boundaries to the east, in the apparent direction of migration of the plume.

III SETTING

Norfolk lies in the southeastern portion of the State of Virginia in the Atlantic Coastal Plain Physiographic Province. The locality is characterized by low relief, and abundant estuaries. The following sections discuss the regional geologic and hydrogeologic setting at NAS Norfolk.

A. Regional Geology

Norfolk is underlain by gently eastward dipping unconsolidated sediments ranging from Cretaceous to Holocene Age. The Tertiary Yorktown Formation, and the Quaternary Columbia Group are the uppermost stratigraphic units in the region, and the rocks of interest for this study (refer to Table 1). The Columbia Group outcrops over most of Norfolk.

TABLE 1

Geologic Units in the Norfolk Area

Age	Series	Name	Character	Thickness (feet)
Quaternary	Pliocene-Holocene	Columbia Group	Light-colored oxidized deposits; mainly clays, silts, sands, and gravels; some peat.	0-120
Tertiary	Miocene	Yorktown Formation	Gray to bluish-gray silts, sands, shell beds; clay beds uncommon. Bioclastic sands and quartz-glauconite sands in southeastern part.	0-400

B. Regional Hydrogeology

The Atlantic Coastal Plain Region is underlain by a system of sand and gravel aquifers separated by silt and clay confining layers. These aquifers are divided into the upper unconfined aquifer known as the Columbia Aquifer and five lower confined aquifers. The confined aquifers from youngest to oldest are the Yorktown-Eastover, Chickahominy-Piney Point, Aquia, Brightseat, and Potomac Aquifers. The highest water yields are derived from the confined aquifers. Precipitation is the primary source of recharge to the aquifers.

In the eastern portion of the Coastal Plain groundwater is supplied by the Columbia and Yorktown-Eastover Aquifers. The Yorktown-Eastover and Columbia Aquifers have typical well yields of 5-500 and 5-250 gallons per minute (gpm), respectively.

Groundwater withdrawals for public and industrial supply in Virginia began about 50 years ago. Since that time, groundwater levels in aquifers have steadily declined, and cones of depression have grown around major withdrawal centers. This effect has not been as noticeable in the Yorktown-Eastover Aquifer. Greater groundwater production from the underlying aquifer has caused the confining layers separating the overlying Columbia from the Yorktown-Eastover to leak. Consequently, groundwater from the Columbia is recharging the Yorktown-Eastover, and the depressed water table in the Columbia is the result of both production and leakage.

IV FIELD INVESTIGATION

This section presents both a summary of field activities carried out by HLA at NAS Norfolk, and discussion and interpretation of the field data. A more detailed explanation of field equipment and procedures is presented in Appendix A. Prior to mobilization to NAS Norfolk, HLA developed a site specific Health and Safety Plan (refer to Appendix B) in accordance with the project Scope of Work . This plan addressed the safety of those involved with the planned field investigation of the JP-5 fuel leak at NAS Norfolk. The plan was approved by the Navy and provided by HLA to all subcontractors and field personnel.

A. Methods and Procedures

On September 3, 1986, HLA mobilized a field crew to NAS Norfolk to begin the two-phase field investigation. Following meetings with LANTDIV personnel, HLA conducted a survey, using an HNu Systems, Inc., Photoionization Detector (HNu), for volatile organic vapors. The instrument is calibrated to benzene. The HNu survey was conducted on open storm sewer drains located in the general site area to investigate the presence of hydrocarbon vapors (refer to Appendix A-1 and Plate 2). This information, to the extent possible, was used in the initial location of the Phase I borings/monitoring wells.

Prior to drilling a location, a surface geophysical technique, Ground Penetrating Radar (GPR) was used to investigate subsurface pipes and utilities so that these obstructions could be avoided during drilling (refer to Appendix A-2).

Borings were advanced by an all-terrain vehicle mounted drilling rig using hollow-stem augers and rotary wash drilling techniques; samples were taken with a split-spoon sampler (refer to Appendix A-3). Boring depths ranged from approximately 18 feet to 26 feet below ground surface. Upon completion of each boring, 4-inch diameter PVC wells were installed with sand pack and sealed with bentonite (refer to Appendix A-4). Christy boxes were installed for protection of the well casing and cemented in-place. In addition to boring location clearance, surface geophysical methods were used to trace the routes of the JP-5 pipes into the tank farm and between the tank farm and the test cells.

There was no time break between Phase I and Phase II as boring location, geophysical clearance, drilling and well installation progressed simultaneously. Phase II borings were located using information which HLA assimilated and developed during the Phase I drilling operations. By September 23, 1986, twenty-three (23) wells had been installed. Soil samples were shipped to the analytical laboratory for testing and the HLA crew demobilized.

On October 31, 1986 HLA remobilized to NAS Norfolk to perform aquifer testing and groundwater sampling. Wells were developed by pumping and both slug and constant discharge aquifer tests were performed (refer to Appendix A-5). Well fluid samples were obtained and shipped to the analytical laboratory for testing. Concurrent with the other activities, groundwater level and hydrocarbon thickness measurements were taken periodically in each well. HLA demobilized from the site at the completion of Phase II on November 7, 1986.

B. Data Analysis and Interpretation

The following section presents the results of the analysis and interpretation of data collected during the Phase I and II field work at NAS Norfolk. All field methodology, laboratory analysis, and data are presented in Appendices A through H.

1. HNu Survey

The initial step in the Phase I field effort was to perform a survey of water, stormwater, and sanitary sewer system manholes with the HNu (refer to Appendix A-1 for field techniques and methodology). The data obtained from this survey were utilized in selecting the tentative Phase I and II boring locations, based upon the theory that in areas where high vapor concentrations were detected, fuel in the subsurface would probably be entering the system in the immediate vicinity. Relatively high readings were recorded north and south of LP-176, east and northeast of LP-78, and east and southeast of LP-179.

Twelve borehole locations were tentatively located on either side of Boush Creek Culvert based upon these data.

2. Geophysics

Following the HNu survey and tentative location of borehole sites, a surface geophysical survey was performed. The geophysical data obtained were interpreted in the field to clear borehole locations of subsurface obstructions, and to locate the JP-5 fuel lines in the study area (refer to Appendix A-2 for methodology).

Twenty-three boring locations were successfully drilled, although monitoring wells MW-6 and MW-23 were relocated to permit the drilling equipment to be more easily operated (overhead clearance, subsurface obstructions, freedom of movement, etc.). Boring MW-19 was not drilled to total depth, due to the presence of subsurface obstructions, which were encountered during drilling. It was not completed as a monitoring well. It was not relocated for safety considerations, since the geophysical equipment used to clear the borehole locations had been demobilized prior to drilling.

A search of available files and records did not accurately define the locations of subsurface fuel lines. Geophysics techniques were selected to better locate these fuel lines. Two sets of JP-5 fuel lines were located and traced through the study area using GPR and Electromagnetic (EM) techniques. The lines were marked on the

pavement using yellow surveyor's paint, and measurements were taken from adjacent or nearby building corners.

These data were used to illustrate the fuel lines (refer to Plate 2). The exact location of the subsurface JP-5 lines is uncertain in three areas at this time:

- Between Building LP-176 and LP-177, where the pipes run north-south;
- Between Buildings LP-176 and LP-78, where the pipes run east-west; and
- Between Building LP-176 and Value Pit (VP)-15, where the pipes run north-south.

However, taking known data points on either side of the above areas, the lines can be tentatively linked together.

During HLA's field investigation, two jet fuel line valve pits were observed - VP Pit 15 and VP Pit 80. Using surface geophysical methods, the JP-5 pipelines from Willoughby Bay were identified to be entering VP Pit 15. Although JP-5 lines were not tracked by HLA via geophysical methods to VP Pit 80, NAS Norfolk personnel indicated that the pipelines entered this valve pit. The JP-5 pipeline system pump house (LP-44) is located on the southern boundary of the site. HLA followed the JP-5 pipelines via geophysical methods from this building, across the site. Access to the pipelines

can likely be achieved at this building. A pipeline access manhole ws observed by HLA north of LP-176 (refer to Plate 2A).

In addition to the JP-5 pipeline access points observed by HLA, NAS Norfolk personnel reported three additional valve pits, VP Pit 14, VP Pit 13, and VP Pit 12. Each of these valve pits is located along the JP-5 line from Willoughby Bay (refer to Figure 1). VP Pit 12 is located near building SP-312, the pump house for the fuel lines from Willoughby Bay.

Groundwater levels, as measured in the completed monitoring wells, varied between 4 to 7 feet below ground surface. The maximum penetration obtained by the GPR system is also within this range depending on location. Attempts were made to correlate groundwater elevations to the GPR records; however, no clearly defined level of groundwater saturation is apparent on the GPR records.

3. Monitoring Well Drilling and Installation

The following section presents the geologic and hydrogeologic data obtained from the drilling and installation of the 23 monitoring wells during the Phase I and II field investigation. Each of the boreholes was logged, and soil samples were collected from selected subsurface intervals. Table 2 summarizes the complete data on boring/monitoring well installations.

TABLE 2

Boring/Monitoring Well Summary

Boring/ Well No.	Depth of Boring Below Ground Level (feet)	Depth of Well Below Ground Level (feet)	Screened Interval Below Ground Level (feet)	Thickness** of Major Aquifer (feet)	Elevation*** of Top of Casing (feet)
MW-1	26.5	24.0	2.3-23.5	15.3	12.81
MW-2	23.0	19.5	1.5-19.0	22.0	11.70
MW-3	23.0	22.0	2.0-21.5	18.5	12.85
MW-4	22.0	22.0	2.0-21.5	13.0	10.00
MW-5	23.0	22.0	2.0-21.5	13.0	10.85
MW-6	23.5	22.7	2.7-22.2	>22.0	10.80
MW-7	23.0	22.0	2.0-21.5	17.0	12.70
MW-8	23.0	22.0	2.0-21.5	17.0	12.82
MW-9	23.0	22.0	2.0-21.5	16.0	12.69
MW-10	23.0	22.0	2.0-21.5	>23.0	12.45
MW-11	25.0	22.0	2.0-21.5	15.0	12.34
MW-12	23.0	22.0	2.0-21.5	16.6	11.25
MW-13	25.0	22.3	2.3-21.8	>19.0	12.57
MW-14	23.5	21.1	1.1-20.6	10.5	12.22
MW-15	20.5	20.3	5.3-19.8	14.1	12.16
MW-16	23.5	23.3	3.3-22.8	>19.0	11.87
MW-17	23.0	22.8	2.8-22.3	16.7	11.92
MW-18	24.0	23.0	3.0-22.5	15.5	13.06
MW-19*					
MW-20	25.5	25.0	5.2-24.7	>25.0	12.12
MW-21	23.0	22.0	2.0-21.5	18.2	12.25
MW-22	23.5	22.3	2.3-21.8	>20.0	12.85
MW-23	23.5	22.3	3.3-22.8	14.6	10.67
MW-24	23.5	22.3	2.3-21.8	>22.0	12.40

* MW-19 was not drilled, or relocated, refer to text.
** Total aquifer sand thickness in each specific boring.
*** Elevations tied to U.S. Geological Survey benchmark referenced to Mean Sea Level (MSL).

Following the installation of screen, casing, filter pack and bentonite seals in each borehole, groundwater level and hydrocarbon thickness measurements were taken at selected intervals during periods of high and low tide. Refer to Appendices A-3 and A-4 for drilling techniques and monitoring well completion methodology, respectively.

4. Site Specific Geology

Strata encountered during the drilling program were primarily unconsolidated sediments composed of sands, silts, sands with clay, silty clay, and clay. Sediments logged at monitoring wells MW-15 and MW-16 were interpreted to be hydraulic fill from channel dredgings, based on the presence of a much larger volume of organic debris, shell fragments, etc., and the lack of correlative soils with the other 21 borings. The boring logs indicate that sand with varying amounts of silt and clay occurs from immediately beneath the cover material and topsoil to depths ranging from 10.5 feet in boring No. 14 to greater than 25 feet in boring No. 20 (refer to Appendix C). This unit represents the uppermost water-bearing strata, and the zone to which the phase separated and dissolved hydrocarbon is apparently confined. The unit is traceable throughout the area of investigation; however, inclusions of silt and clay with thicknesses up to 1.0 foot occur sporadically and can not be correlated between the borings.

In monitoring wells MW-1 through MW-6, MW-9, MW-11, MW-12,

MW-14, MW-15, MW-17, MW-18, MW-21, and MW-23, an underlying soft, gray clay unit was encountered. The clay layer ranged in depth from 14 feet to greater than 25 feet below land surface. Monitoring well MW-16 was completed in a sandy silt encountered at 18 feet below ground surface. Monitoring wells MW-7, MW-8, MW-10, MW-13, MW-20, and MW-22 were completed in loose, saturated sand.

In each instance where the monitoring well completions were set in the underlying clay zone, drilling and installation was accomplished using the hollow-stem auger technique. In those borings where loose sand was encountered at total well depth, the drilling technique had to be converted to rotary wash with drilling mud to prevent the caving of the hole, and the consequent refusal of the screen, casing and filter pack.

Three stratigraphic cross-sections were prepared using the boring logs for the purposes of determining the relative dip of the strata, and the configuration of the potentiometric surface relative to the subsurface materials (refer to Plates 3 through 5). Cross-sections A-A' and B-B' trend northwest to southeast across the study area. Cross-section C-C' trends northeast to southwest and roughly parallels Boush Creek Culvert (refer to Plate 2).

The cross-sections indicate that the subsurface strata are relatively flat (little or no dipping of the beds). The underlying

clay zone was encountered in all wells south of MW-21, and in wells MW-14 and MW-15 to the northeast. Wells between these areas terminated in a medium to coarse-grained sand. The potentiometric surface as shown on the cross-sections is relatively flat and follows the general land surface topography.

5. Soil Sampling

Subsurface soil samples were collected during the drilling program for the purpose of visual inspection and screening by use of the HNu meter. Based on the results of these qualitative screening processes, soil samples which were believed to contain the highest concentration of volatile hydrocarbons from each boring were selected for laboratory analysis. A gas chromatograph/fingerprint analysis was used to quantify JP-5 present in each soil sample.

Forty-three soil samples were analyzed from boring/monitoring wells MW-3 through MW-24, with the exception of MW-19. A minimum of two samples were submitted from each boring/monitoring well. The results of the laboratory analyses of soil samples with the highest indication of JP-5 for each boring/monitoring well are summarized in Table 3 below. Fifteen soils samples from 10 wells demonstrated positive comparative properties with the raw JP-5 fingerprint. Complete laboratory analytical results for the soil samples are included in Appendix D.

TABLE 3

Soil Sample Laboratory Analysis

Indication of JP-5, in mg/kg	Number of Wells	Well Numbers
No Hydrocarbon Blend Present	11	3, 4, 5, 13, 14, 15, 16, 18, 20, 22, 24
< 100	2	8, 21
100 - 10,000	4	6, 9, 10, 17
10,000 - 50,000	2	7, 12
> 50,000	2	11, 23

Note: Summarized results are for samples with the highest concentration of JP-5 detected from multiple samples submitted for each boring/well.

6. Groundwater Levels and Phase Separated Hydrocarbon Thicknesses

Groundwater and hydrocarbon levels were measured in each monitoring well throughout the course of the Phase I and II field investigations, using an electric water level probe and a steel tape coated with water and hydrocarbon sensitive pastes. These measurements were made daily during approximate high and low tides to determine the influence of tidal fluctuations. Table 4 lists the most recent (November 7, 1986) groundwater and hydrocarbon levels for each of the 23 monitoring wells. A complete listing of groundwater and hydrocarbon measurements is presented in Appendix E.

TABLE 4

Groundwater Levels and Hydrocarbon Thicknesses

Well No.	Date	TOC* Elevation (Feet MSL**)	Depth to Water (Feet)	Hydrocarbon Thickness (Feet)	Elevation of Water (Feet MSL)	Corrected Water Elevation (Feet MSL)
MW-1	11/07/86	12.81	6.03	0.00	6.78	6.78
MW-2	11/07/86	11.70	5.93	0.00	5.77	5.77
MW-3	11/07/86	12.85	8.15	0.00	4.70	4.70
MW-4	11/07/86	10.00	4.57	0.00	5.43	5.43
MW-5	11/07/86	10.85	7.24	1.47	3.61	4.82
MW-6	11/07/86	10.80	5.79	2.02	5.01	6.67
MW-7	11/07/86	12.70	6.66	0.00	6.04	6.04
MW-8	11/07/86	12.82	6.83	0.00	5.99	5.99
MW-9	11/07/86	12.69	6.91	0.87	5.78	6.49
MW-10	11/07/86	12.45	8.31	2.78	4.14	6.42
MW-11	11/07/86	12.34	9.32	4.65	3.02	6.83
MW-12	11/07/86	11.25	7.70	1.58	3.55	4.85
MW-13	11/07/86	12.57	6.68	0.00	5.89	5.89
MW-14	11/07/86	12.22	5.72	0.00	6.50	6.50
MW-15	11/07/86	12.16	7.74	0.00	4.42	4.42
MW-16	11/07/86	11.87	5.65	0.00	6.22	6.22
MW-17	11/07/86	11.92	6.05	0.00	5.87	5.87
MW-18	11/07/86	13.06	7.18	0.00	5.88	5.88
MW-19***						
MW-20	11/07/86	12.12	6.15	0.00	5.97	5.97
MW-21	11/03/86	12.25	9.33	3.82	2.92	6.05
MW-22	11/07/86	12.85	7.01	0.12	5.84	5.94
MW-23	11/01/86	10.67	7.65	4.13	2.02	6.41
MW-24	11/07/86	12.40	6.57	0.00	5.83	5.83

* TOC = Top of Casing
** MSL = Datum - Mean Sea Level
*** MW-19 was not drilled, or relocated. Refer to text.

When present, phase separated hydrocarbon depresses the water surface in monitoring wells, therefore measured hydrocarbon thicknesses were multiplied by 0.82 (an average specific gravity for JP-5) and the resulting water equivalent head was added to the measured static groundwater levels to obtain the corrected groundwater elevation.

Phase separated hydrocarbon was detected in monitoring wells MW-5, MW-6, MW-9, MW-10, MW-11, MW-12, MW-17, MW-21, MW-22, and MW-23. From September 15 to 21, 1986, the hydrocarbon thicknesses in MW-12 and MW-17 increased from 0 to 0.73 feet and 0.56 to 1.69 feet, respectively. Between September 21, 1986 and November 1, 1986, the hydrocarbon thickness decreased from 1.69 feet to 0.00 feet in MW-17, and increased from 0.00 feet to 0.80 feet in MW-9. In the other wells, the hydrocarbon thicknesses remained relatively constant. The fluctuations in hydrocarbon thicknesses may represent either a movement of the hydrocarbon body across the site, or a variance in the volume of hydrocarbon entering the subsurface. A hydrocarbon isopach map was developed from data obtained on November 7, 1986, which approximately defines lateral extent of the subsurface hydrocarbon body (refer to Plate 6). Hydrocarbon thicknesses observed in wells do not necessarily represent the thickness of hydrocarbon in subsurface materials.

Water level measurements were collected on November 7, 1986 for the purpose of generating a potentiometric map for the area of investigation. The measurements were made in a very short time interval (approximately one hour), which should have eliminated influences on the static water table, such as precipitation, baro- metric pressure changes, tides, etc. A site potentiometric surface map was developed from the November 7, 1986, groundwater levels measured in the 23 monitoring wells (refer to Plate 7).

7. Site Hydrogeology

Unconfined (water table) groundwater conditions prevail in all of the materials penetrated during the Phase I and II investigations. Groundwater elevations range from 4.42 to 6.78 feet above mean sea level. The data do not appear to reflect any significant tidal effect on the water table within the vicinity of the monitoring wells (refer to Appendix G). Corrected water elevations remained fairly constant throughout the field investigation although a slight rise in elevations was noted during periods of precipitation.

Analysis of the water level data and Plate 7 indicates that the water table is highest in the southwest corner of the site. The hydraulic gradient is inconsistent over the site but generally slopes to the northeast, and is estimated from Plate 7 to be approximately 6 feet/mile (.0011 ft/ft).

8. Fluid Samples

Fluid samples were collected from each monitoring well during Phase II of the field effort, and screened in the field by visual inspection. The samples ranged from phase separated hydrocarbon to groundwater with dissolved hydrocarbon to groundwater with no phase separated or dissolved hydrocarbon. A fluid sample from each monitoring well was analyzed. Table 5 summarizes the laboratory results and shows that 18 of the 23 monitoring wells contain detectable levels of hydrocarbon. Ten of the 18 samples were found to be

"pure" JP-5 (phase separated). Two of the samples (MW-7 and MW-20) containing dissolved hydrocarbon were described as thermally degraded hydrocarbon blend similar to JP-5. With the exception of monitoring well MW-22, all of the wells whose samples were determined to be "pure" JP-5 are located on the east side of Boush Creek Culvert and the jet fuel supply lines. This suggests that subsurface hydrocarbon movement is in an easterly direction. Complete laboratory analytical results for the fluid samples are included in Appendix F.

TABLE 5

Fluid Sample Laboratory Analysis

Indication of JP-5, in ug/L	Number of Wells	Well Numbers
<25*	5	1, 2, 13, 14, 16
26 - 1,000	6	3, 4, 8, 15, 20, 24
>1,000	2	7, 18
Pure**	10	5, 6, 9, 10, 11, 12, 17, 21, 22, 23

* Detection limit for analytical method.
** Samples were determined to be essentially pure hydrocarbon blend similar to JP-5.

9. Aquifer Tests

Aquifer testing consisted of slug tests and constant rate pumping tests on the shallow water-bearing strata encountered in this hydrogeological investigation.

Aquifer testing was performed to estimate the hydraulic conductivity and transmissivity of the water-bearing strata. These parameters provide insight into shallow groundwater flow and the migration of phase separated and dissolved hydrocarbon migration. These parameters also assist in the evaluation of various remediation techniques based on the strata's fluid-flow characteristics, which are discussed later in this report.

a. Slug Tests

Slug tests were performed on several monitoring wells during the period November 6 to 7, 1986, A 5-gallon slug of water was injected into each well tested. Water levels were measured with pressure transducers, and the data points were used in the calculations.

The slug test data were analyzed in accordance with methods presented in "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells" (Bouwer and Rice, 1976). The results of the slug tests are summarized in Table 6 (refer to Appendix G for all field data and computations). An average hydraulic conductivity of 111 gpd/ft^2 and an average transmissivity of 3.5 x 10^{-3} ft^2/sec were estimated from the slug test results. These values represent mid-range (average) hydraulic conductivities which are typical of fine to coarse gravel sand aquifers.

TABLE 6

Slug Test Results

Well No.	Date	Hydraulic Conductivity (gpd/ft^2)	Transmissivity (ft^2/sec)
MW-1	11/06/86	60	1.5×10^{-3}
MW-2	11/06 86	105	2.7×10^{-3}
MW-3	11/06/86	368	6.5×10^{-3}
MW-4	11/06/86	117	1.7×10^{-3}
MW-7	11/06/86	40	9.8×10^{-4}
MW-13	11/07/86	50	1.3×10^{-3}
MW-14	11/07/86	60	1.2×10^{-3}
MW-16	11/06/86	94	1.9×10^{-3}
MW-20	11/06/86	130	3.4×10^{-3}
MW-24	11/06/86	85	2.1×10^{-3}
MEAN VALUES		111	3.5×10^{-3}

b. Pump Tests

HLA performed pump tests on the shallow water-bearing strata during the period November 3 through November 5, 1986. Tests were performed in monitoring wells MW-10 and MW-17.

Monitoring well MW-10 was pumped on November 5, 1986 for 230 minutes at an average discharge rate of 2.0 gpm. An artificial recharge boundary was encountered in MW-10 after less than one minute of groundwater discharge. According to Walton, an artificial recharge boundary condition may be recognized as follows: (1) initially, water levels will decline as anticipated (for a given discharge); (2) when the artificial recharge boundary is encountered there will be a gradual decline in drawdown until the inflow from the recharge source is equal to the discharge rate of the pumped well; and, (3) at the moment of equilibrium and from that time on, no additional drawdown will be observed. The recharge source may have been a leak through a crack in one of the storm or sewer lines in the vicinity of the well. Once inflow from the source was equal to the discharge rate of the pump (approximately 2.0 gpm), a constant water level in MW-10 was established and maintained. After 230 minutes of pumping MW-10, the water level had not changed and the test was aborted. No drawdown was observed in MW-9, the nearby observation well. Recovery water levels were monitored for 74 minutes after cessation of pumping. The rapid recovery in MW-10 indicates a hydraulic conductivity generally in agreement with with the results of the slug test analyses.

Monitoring well MW-17 was pumped November 3 and 4, 1986 for 1,860 minutes at an average discharge rate of 2.2 gpm without reaching equilibrium. This test was terminated after pumping water levels in the well began approaching the level of the intake of the pump.

Should the water level drop below the pump intake, the pump will break suction reducing the discharge rate, and jeopardizing the accuracy of the final pumping data and all recovery data . The pumping test was terminated to obtain valid pumping recovery data for analysis.

Drawdown data from the pumping well frequently does not yield accurate estimates of hydraulic conductivity and transmissivity, due to the turbulent flow of groundwater as it enters the well bore and pump. Accurate, representative water level measurements are typically not possible under these conditions. No drawdown was observed in the observation wells during pumpage. The average discharge rate of 2.2 gpm was evidently too low to develop a cone of depression sufficient to affect Well MW-5, the nearest observation well which is approximately 150 feet away from MW-17. Other pumping rates were tested during earlier step-drawdown aquifer tests but resulted in drawdowns below the pump intake in a very short time. In addition, building foundations and disturbed water-bearing strata probably obstructed natural groundwater flow patterns, which may have prevented a response in the observation wells. Since the borings/ monitoring wells were installed primarily to delineate the hydrocarbon contamination, ideal spacing of wells for pump test observations was not available.

Recovery water levels from pumping well MW-17 were monitored for 120 minutes. These data were analyzed in accordance with methods

presented in Ground Water and Wells (Driscoll, Fletcher G., 1986). Graphs, curves, and calculations for the hydrogeologic parameters using recovery data are presented in Plates 8 through 11. All field measurements made during the tests are presented in Appendix G.

The recovery data were reduced and analyzed using the Jacob Modified Theis Equation. This analytical method, although generally applicable for confined aquifer conditions, can be used in certain cases for unconfined aquifer conditions, as is this case (refer to Appendix A-5). This method, as shown in the Appendix A-5, may be applied to two types of graphical analysis:

1. Residual drawdown (s') plotted against the ratio of time, (t/t'); and
2. Water level recovery data plotted against time after pumping stopped.

In each case the data are plotted on semi-logarithmic paper. Results are as follows:

Method 1

Transmissivity (T) = 1.56×10^{-3} ft^2/sec

Hydraulic Conductivity (K) = 91.7 gpd/ft^2

Method 2

Transmissivity (T) = 1.52×10^{-3} ft^2/sec

Hydraulic Conductivity (K) = 89.3 gpd/ft^2

The values obtained from these calculations demonstrate the anticipated consistency for T and K, and are mid-range for a water table aquifer. According to Driscoll, aquifers composed of fine to coarse grained sand have hydraulic conductivities which range from 10^{-1} to 10^{4} gpd/ft^2. These parameters (T, K) are reflective of the strata's relative ability to transmit fluids through a portion of the subject aquifer.

Utilizing the average hydraulic conductivity of 90.5 gpd/ft^2, as determined from pumping test data, and an average porosity of 35 percent (representative of the type of soils encountered during drilling), the groundwater velocity (particle) was estimated to be approximately 14 feet/year. Utilizing the average hydraulic conductivity of 111 gpd/ft^2, as determined from the slug test data, and the porosity value of 35 percent, the groundwater velocity (particle) was estimated to be approximately 16 feet/year (refer to Appendix A-5).

Particle velocity values represent the distance a "particle" of water will travel between any two points in the aquifer in a specified time. The velocity range of 14 to 16 feet/year determined for this shallow aquifer system at NAS Norfolk is low to moderate. Refer to Appendix A-5 for the analytical methods used in determining the particle velocity.

10. Phase Separated and Dissolved Hydrocarbon

Measurable amounts of phase separated hydrocarbon were consistently observed in monitoring wells MW-5, MW-6, MW-9, MW-10, MW-11, MW-12, MW-17, MW-21, MW-22, and MW-23 during the field investigation. Laboratory analysis of fluid samples collected from the monitoring wells shows that MW-3, MW-4, MW-7, MW-8, MW-15, MW-18, MW-20, and MW-24 contained dissolved hydrocarbon varying from trace amounts to greater than 1,000 micrograms (ug/l) per liter (refer to Table 6). Only monitoring wells MW-1, MW-2, MW-13, MW-14, and MW-16 failed to exhibit some indication of JP-5 (refer to Table 6).

Plates 6, 12 and 13 were developed from the field hydrocarbon thickness measurements, and results laboratory analyses of the fluid and soils samples, respectively. Each of these maps represents phase separated or dissolved hydrocarbon in the subsurface. All of the maps (Plates 6, 12 and 13) indicate significant hydrocarbon concentrations immediately opposite and east of Boush Creek Culvert, and the set of fuel lines supplying Building LP-176 (new test cells) and LP-78 (old test cells). This suggests that the fuel lines may be the source of hydrocarbon and that the general flow trend of the hydrocarbon body may be toward the east. Also, each map shows elevated hydrocarbon levels in the soil and groundwater samples taken to the northwest of the major fuel concentration area. This may indicate an earlier leak in the fuel lines at a more northerly point (possibly within the Willoughby Bay fuel farm supply lines), a change

in direction of the hydraulic gradient, and/or the advent of the cracks in the culvert walls, which would result in the interception of northerly moving hydrocarbon.

Additionally, Plate 7 indicates that the hydraulic gradient is relatively small and generally toward the northeast across the site, presumably along Boush Creek Culvert. However, there is a "mounding" effect, or rise in fluid elevations, in the area of maximum hydrocarbon thickness (between and east of Buildings LP-176 and LP-78). This mounding is possibly due to "over-accummulation" of phase separated hydrocarbon in these monitoring wells, resulting in slightly elevated, corrected groundwater elevations.

Plates 12 and 13 indicate the presence of hydrocarbon in soils and groundwater west of Boush Creek Culvert. This may be the result of hydrocarbon migration to the north and northwest at rates greater than the interception of migrating fluids by the culvert.

The absence of hydrocarbon in monitoring wells MW-13, MW-14 and MW-16, which are also downgradient from the identified hydrocarbon body, suggests that Boush Creek Culvert is effectively intercepting hydrocarbons migrating to the north and east or that hydrocarbon has not migrated to that extent as yet. Apparently no significant current leaks are located in the JP-5 supply pipelines north of their intersection with Boush Creek Culvert. No phase separated hydrocarbon

has been observed in monitoring wells MW-8, MW-13, and MW-16 which are adjacent or downgradient from these pipelines. The absence of phase separated hydrocarbon in well MW-18 suggests no significant current leakage in the east-west trending portion of the pipelines in the section west of the Boush Creek Culvert (refer to Plate 6). The absence of hydrocarbon in well MW-17 in November is most likely a result of hydrocarbon being pumped from the well during the pump test rather than migration of hydrocarbon out of the immediate well vicinity. Presumably, the hydrocarbon body still exists in the general vicinity of MW-17. No phase separated hydrocarbon has been detected in the remaining wells MW-1, MW-2, MW-3 and MW-4 which are located upgradient from fuel lines.

Monitoring wells MW-5 and MW-17, which have consistently contained phase separated hydrocarbon are located to the east of Boush Creek Culvert and to the west of pipelines to the jet engine test cells (refer to Plate 6). This suggests that a leak exists in the pipelines extending from the Willoughby Bay to the tank farm.

Results of this investigation suggest that two distinct pipeline leaks may be present in the JP-5 delivery system at NAS Norfolk. The Willoughby Bay pipelines may be leaking between the tank farm and Building LP-179; and, as previously mentioned, the fuel lines supplying the test cells may be leaking between Building LP-176 and LP-78.

Plates 6, 12, and 13 illustrate the need to develop additional data on the east side of the area of investigation. Wells MW-9, MW-10, and MW-12, which are the most eastern wells from the fuel lines, contain significant amounts of phase separated hydrocarbon, therefore, additional delineation of the extent of hydrocarbon migration is required east of the existing wells.

V REMEDIATION TECHNIQUES

Remediation techniques are biological, chemical and physical methods which may be used individually or in combination to mitigate contamination. The appropriate combination and timing of techniques should result in a remedial action that effectively satisfies all site objectives. A brief description of each of the remediation alternatives available for phase separated and dissolved hydrocarbon contamination and presented in the NAS Norfolk Final Work Plan, is discussed below.

None of these remediation techniques can recover one hundred percent of the subsurface hydrocarbon. However, they can be used independently or in combination to maximize hydrocarbon recovery potential. Migrating phase separated and dissolved hydrocarbon can be recovered or removed and residual hydrocarbon can be reduced to safe levels. With time, indigenous bacteria should reduce the residual hydrocarbon.

A. Recovery Wells

Recovery wells may be designed to utilize the natural hydrodynamic forces which cause hydrocarbon to migrate into the wells, or to create a hydrodynamic environment (i.e., cone of depression) which will cause hydrocarbon to migrate into wells. If the hydraulic gradient on-site is adequate to provide significant hydrocarbon

accumulation in wells, a skimming type system may be installed in each well to recover hydrocarbon only. In most cases and in particular, in areas with very low hydraulic gradients such as at NAS Norfolk, a hydrocarbon/groundwater pumping system is necessary to create a cone of depression sufficient to enhance hydrocarbon recovery and stop hydrocarbon migration. With this type of system, groundwater must be continually withdrawn to maintain the cone of depression, while hydrocarbon is recovered either by skimming or with the pumped water. This approach will generally result in large volumes of water relative to hydrocarbon recovered. The water will need to be treated on- or off-site for removal of phase separated or dissolved hydrocarbon. Recovered hydrocarbon may be stored in an above or below ground storage tank or other structure, pending reprocessing or disposal. The use of recovery wells is considered a viable remediation technique for application at NAS Norfolk.

B. Interceptor Trenches

Interceptor trenches are often both an excellent immediate and long term remedial technique for shallow, unconfined groundwater conditions. The approach consists primarily of construction of a gently sloping trench downgradient from the spill or leak, of sufficient length to intercept the entire lateral extent of the migrating contaminant plume. The trench must be of sufficient depth to intercept the vertical extent of the migrating plume. For hydrocarbon, the trench should extend several feet below the ground-

water surface. The bottom of the trench is filled with a porous and permeable material such as gravel and the down-gradient side of the trench is lined with an impermeable fabric or low permeability clay or silt. The phase separated hydrocarbon is recovered by skimming methods in either a recovery well(s) or sumps located at one or more down slope locations in the trench. This system is not considered practicable for NAS Norfolk because of the large lateral extent of the hydrocarbon body which may extend across numerous hangar areas and beneath buildings. Construction of a trench in these areas would be very disruptive to normal base activities and therefore would probably not be feasible.

C. Slurry System

A slurry system is an effective way to prevent further migration of contaminant plumes. The system consists primarily of construction of a trench downgradient from the plume. The trench must be of sufficient length and depth to intercept the entire lateral and vertical extent of the migrating contaminant plume. During excavation, the trench is progressively backfilled with a bentonite slurry, which is heavy enough to prevent caving of the trenched material. After the trench is completed, the bentonite slurry is replaced with a cement slurry or another impermeable material such as clay, thus forming a barrier to hydrocarbon migration. This technique only immobilizes the hydrocarbon. It must be used on conjunction with another remediation technique for removal of the contaminants. This

system is not considered feasible for NAS Norfolk for the same reasons as previously stated for an interceptor trench, particularly, the potential interruption of ongoing NARF operations.

D. Flushing Systems

Flushing systems are effective, long-term remediation techniques. For this method, both recovery and injection wells are used in combination to develop cyclic flow of hydrocarbon and contaminated groundwater. Water is pumped into the designated injection wells and displaces the existing hydrocarbon and contaminated water, which is pumped by the recovery wells. The contaminated water and hydrocarbon is then recovered in a central recovery well(s). Recovered water should be treated on-site and injected into wells on the perimeter of the contaminant plume. Recovered hydrocarbon should be stored pending reprocessing or disposal. A flushing system generally requires at least twice as many injection wells as recovery wells. It also requires available unsaturated materials to receive the injected water. At NAS Norfolk, the shallow groundwater levels probably result in insufficient unsaturated materials to allow effective reinjection. Under prevailing conditions, this system is likely not feasible at NAS Norfolk.

E. Microbial Degradation

In situ microbial degradation can be used alone or as a final step with other remediation methods. Phase separated and dissolved

hydrocarbon in groundwater as well as vapors in the unsaturated zone can be completely degraded by indigenous microbial organisms. Aerobic bacteria are able to most efficiently decompose refined petroleum products. Natural environmental conditions generally result in relatively slow degradation. However, the potential for degradation can be greatly increased by creating optimal environmental conditions for microbial growth.

Enhancement of environmental conditions usually requires injection of large volumes of oxygen rich air into the contaminated area through designated air injection wells. In addition to oxygen, microbial degradation also requires additional nutrients which must be present to maintain or enhance microbial activity.

Pumping wells are used to effectively control groundwater movement and to evenly distribute the active bacteria. An existing monitoring well network often may be used as pumping wells for this remediation technique. Microbial degradation, when incorporated into a complete remediation system is considered feasible at NAS Norfolk. Generally, this technique is required only to attain very stringent restoration levels.

F. Waste Removal/Disposal

Waste removal/disposal is an effective, direct method of site remediation. After definition of the contaminant plume is complete,

the affected area and volume of contaminated subsurface material (soil and fluids) is estimated. This material is then excavated and transported to the appropriate disposal facility. Disposal of the contaminated subsurface material at NAS Norfolk is not considered feasible. The volume of contaminated subsurface material at NAS Norfolk is probably large and the contaminated areas extend beneath buildings, parking areas, and other base facilities, with limited access for excavation.

G. Waste Treatment

Waste treatment systems for phase separated or dissolved hydrocarbons are generally designed to treat waste on-site. Gravity separators may or may not be used at sites where phase separated hydrocarbon is the predominant recovered fluid. Typically, the recovered hydrocarbon is separated from incidental groundwater withdrawal. When the recovered fluid is predominantly water (i.e., cone of depression), the recovered hydrocarbon is separated from substantially larger volumes of potentially contaminated groundwater. The separator allows the two liquids (hydrocarbon and water) to dissimilate. Recovered hydrocarbon, withdrawn from the separator or a storage tank, may be reprocessed for future use or disposed of at an on- or off-site facility. Groundwater pumped from the separator may require treatment prior to discharge. Any remediation technique generating significant volumes of groundwater should include some form

of waste water treatment and disposal. This system is considered feasible for remediation at NAS Norfolk.

H. Reinjection

Reinjection is an effective long-term remediation technique. Water recovered by a flushing or recovery well system is generally treated on-site using a separator and other treatment methods. After the water has been treated and meets necessary water quality standards, it is reinjected into the subsurface. Reinjection can be used as part of the flushing system or as a means for disposal of treated groundwater from other techniques. Under most circumstances, this system is not considered feasible for NAS Norfolk for the same reasons as stated earlier in the discussion of flushing systems.

VI RECOMMENDATIONS AND SUMMARY

A. Recommendations

HLA has conducted an investigation to determine the presence and migration of jet fuel in the subsurface at NAS Norfolk. As a result of the findings of this investigation, three recommendations for immediate action are proposed:

1. Isolation and elimination of the source(s) of JP-5 fuel contamination in the subsurface including fuel pipeline testing, repair/replacement of damaged pipeline sections, and installation of subsurface leak detection equipment.

2. Interim (initial) recovery of phase separated hydrocarbon from the subsurface utilizing existing and additional proposed wells.

3. Installation of additional borings/monitoring wells, beyond the area of investigation of this study, to further delineate the extent and nature of subsurface hydrocarbon contamination.

1. Isolation and Elimination of Sources. A fuel leak(s) appears to be the source of the jet fuel (phase separated and dissolved hydrocarbon) in the subsurface. Immediate isolation and

repair/replacement of the facility equipment is imperative. HLA recommends line integrity testing for the two sets of fuel pipelines from the tank farm to the jet engine test cells, and the two sets of fuel pipelines from Willoughby Bay to the tank farm. During the course of integrity testing, it may become evident that the most cost effective approach would be to abandon the existing delivery system and install new piping rather than try to isolate and repair the numerous leaks suspected in the existing piping. The results of the line integrity testing will provide information to aid in the assessment of repair/replacement.

In the event major repair/replacement efforts must be undertaken, the installation of subsurface leak detection equipment is strongly recommended in conjunction with the pipeline construction.

2. Additional Borings/Monitoring Wells. The results of the Phase I and II investigation indicate that the subsurface hydrocarbon contamination extends to the east of the present area of investigation. HLA recommends up to an additional 20 borings/ monitoring wells be located as shown on Plate 14. These additional borings/wells will provide delineation of the eastern extent of the hydrocarbon and provide data necessary to develop the final site remediation system. The borings/monitoring wells will be installed in phases, as indicated on Plate 14, with each subsequent group dependent upon the previous drilling results.

3. Hydrocarbon Recovery. With due consideration to the factors existing at NAS Norfolk as characterized in this report, the recommended approach for remediation of the Norfolk facility is generally to remove subsurface hydrocarbon from the groundwater surface via a system of recovery wells, separate the hydrocarbon from entrained contaminated groundwater by oil/water separators, dispose of the hydrocarbon via recycling or off-site disposal, dispose of the groundwater in accordance with regulatory requirements and allow natural biodegradation of residual hydrocarbon in the subsurface.

Conceptual design, equipment and estimated capital costs for the recommended interim recovery system were reviewed and discussed along with available manufacturer's literature (refer to Appendix H). Table 7 below summarizes the estimated capital and annual operating costs. This estimate does not include any costs for engineering design, preparation of plans and specifications, construction management and long term monitoring of the recovery effort.

We recommend design, installation, start-up and long-term monitoring of two recovery modules for interim recovery of subsurface hydrocarbons. The location and approximate radius of influence of these modules are shown on Plate 15. The highly variable shallow subsurface conditions observed during our field investigations (i.e., building foundations, subsurface facilities, utility corridors, etc.) can have a significant impact on the effectiveness of any single,

Table 7

ESTIMATED HYDROCARBON RECOVERY COSTS

Capital and Operating Costs: Per Module

	Capital Cost	Annual Operating Cost
Basic Module	$73,500	$3,700

Capital and Operating Costs of Total Recovery System*

	Capital Cost	Cumulative Capital Cost	Annual Operating Costs	Cumulative Annual Operating Costs
Basic Module	$661,500	$661,500	$ 33,300	$ 33,300

* Nine Recovery Modules

shallow recovery system. Since proposed Module 1 does not require any additional wells to be installed, we recommend that it be constructed first and considered a pilot system for recovery of shallow subsurface hydrocarbons. The performance of Module 1 should be monitoringed, and the results of this monitoring used to suggest possible modification to proposed Module 2. Descriptions of the rationale and characteristics of the hydrocarbon recovery system are included in Appendix H. The proposed monitoring well network shown on Plate 14 for additional

investigation is designed to provide subsurface information as well as serve as the basis for additional recovery system modules as described in Appendix H.

B. Summary

HLA has performed a characterization study of the presence of jet fuel in the subsurface at NAS Norfolk, Virginia. The field investigation included locating and drilling 23 borings, installing monitoring wells in each boring, taking groundwater level and hydrocarbon thickness measurements, collecting and analyzing soil and groundwater samples for hydrocarbon contamination, and conducting aquifer testing. Data and information have been reduced, analyzed and presented in this report. As a result of this characterization, three specific recommendations are presented:

1. Isolate and stop the source of fuel into the subsurface

2. Drill additional borings and install monitoring wells to the east of the present area of investigation to complete the delineation of size, volume and movement of the fuel plume.

3. Initiate interim recovery efforts to pump fuel out of the subsurface.

It is of the utmost importance that the leakage of fuel into the subsurface be corrected prior to implementation of recovery and treatment methodologies. All future efforts at remediation and further study are essentially dependent upon successful accomplishment of this initial step.

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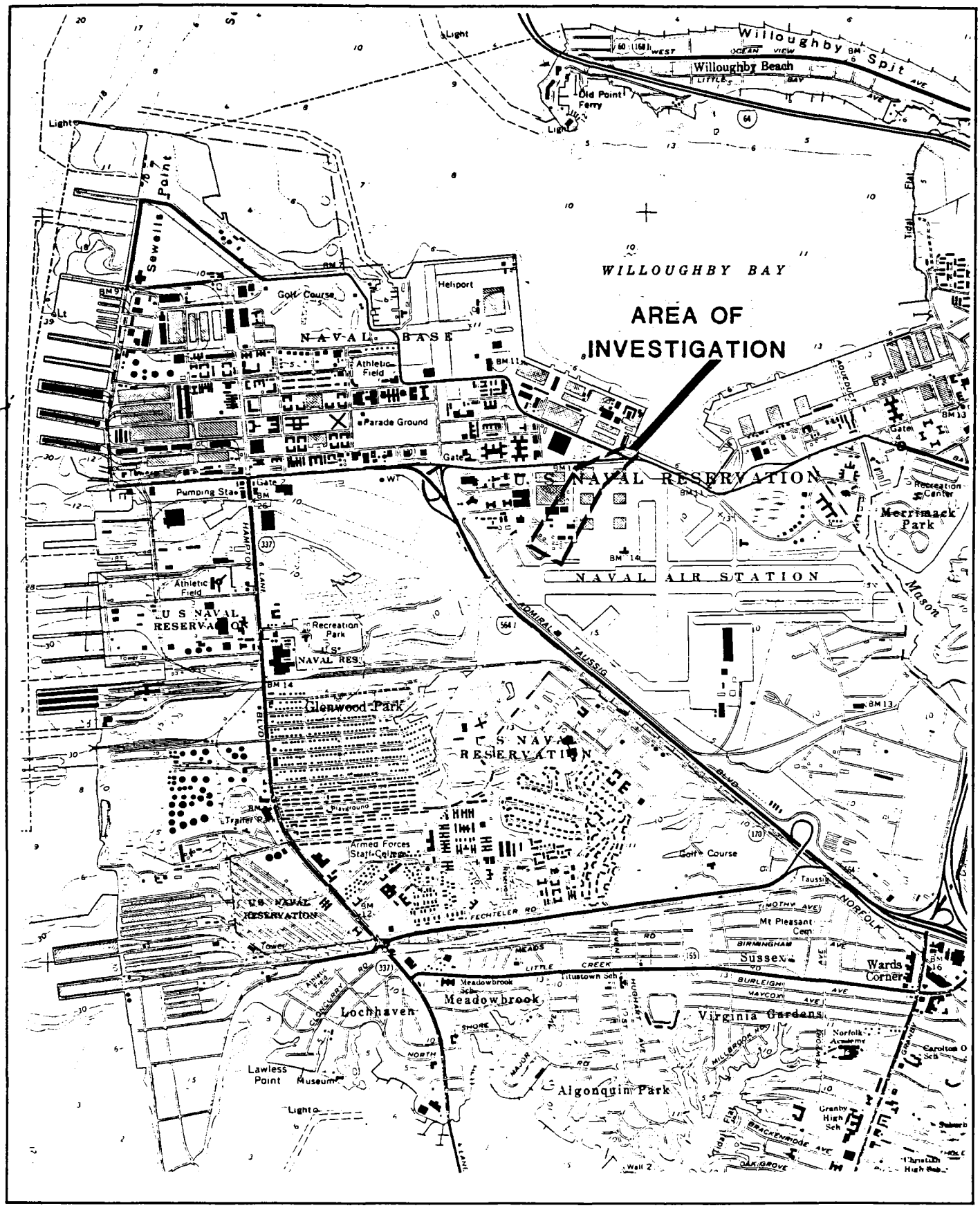

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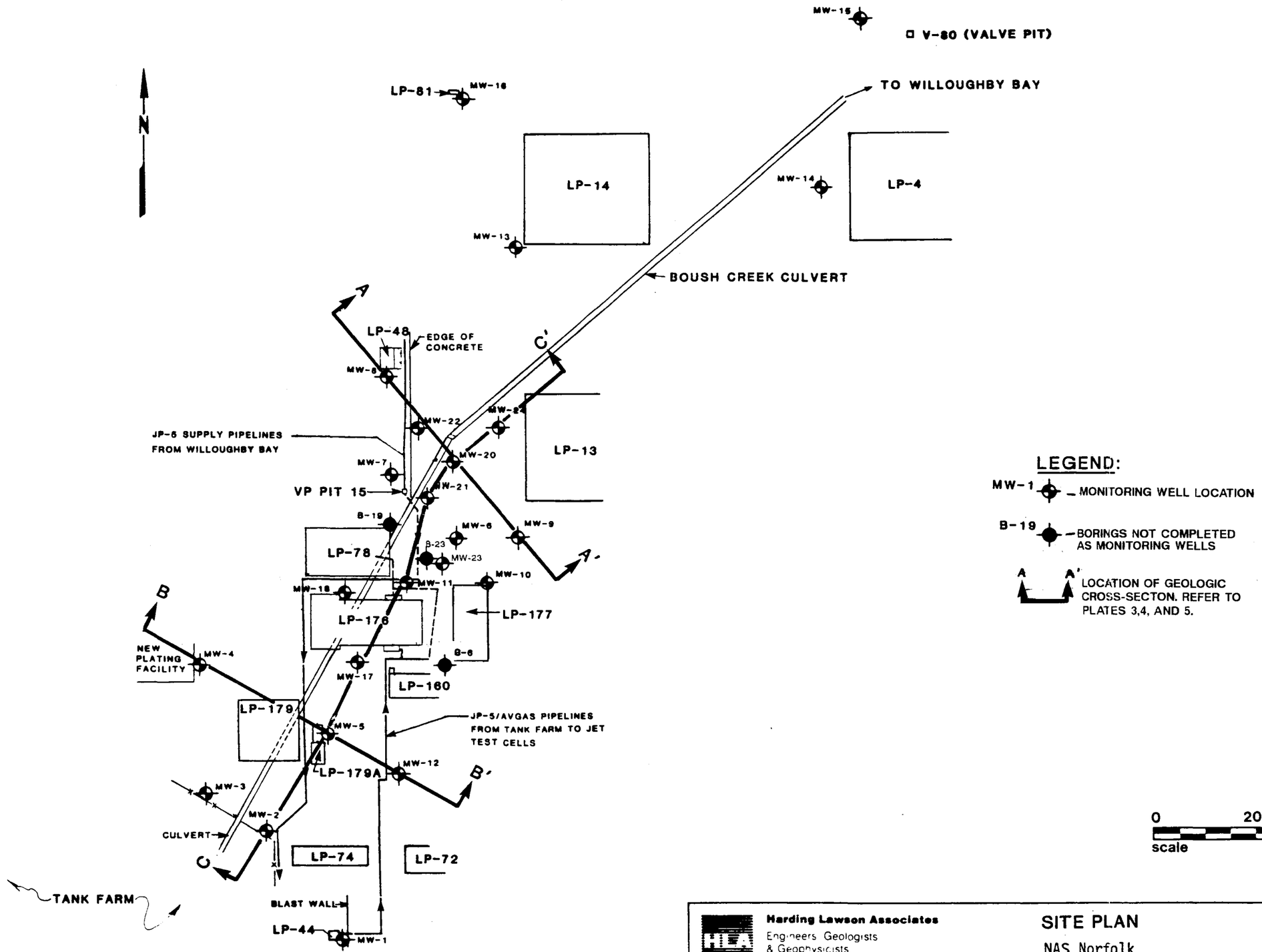
Engineers, Geologists
& Geophysicists

VICINITY MAP
NAS Norfolk
Norfolk, Virginia

PLATE
1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
RC	2176,085.12				



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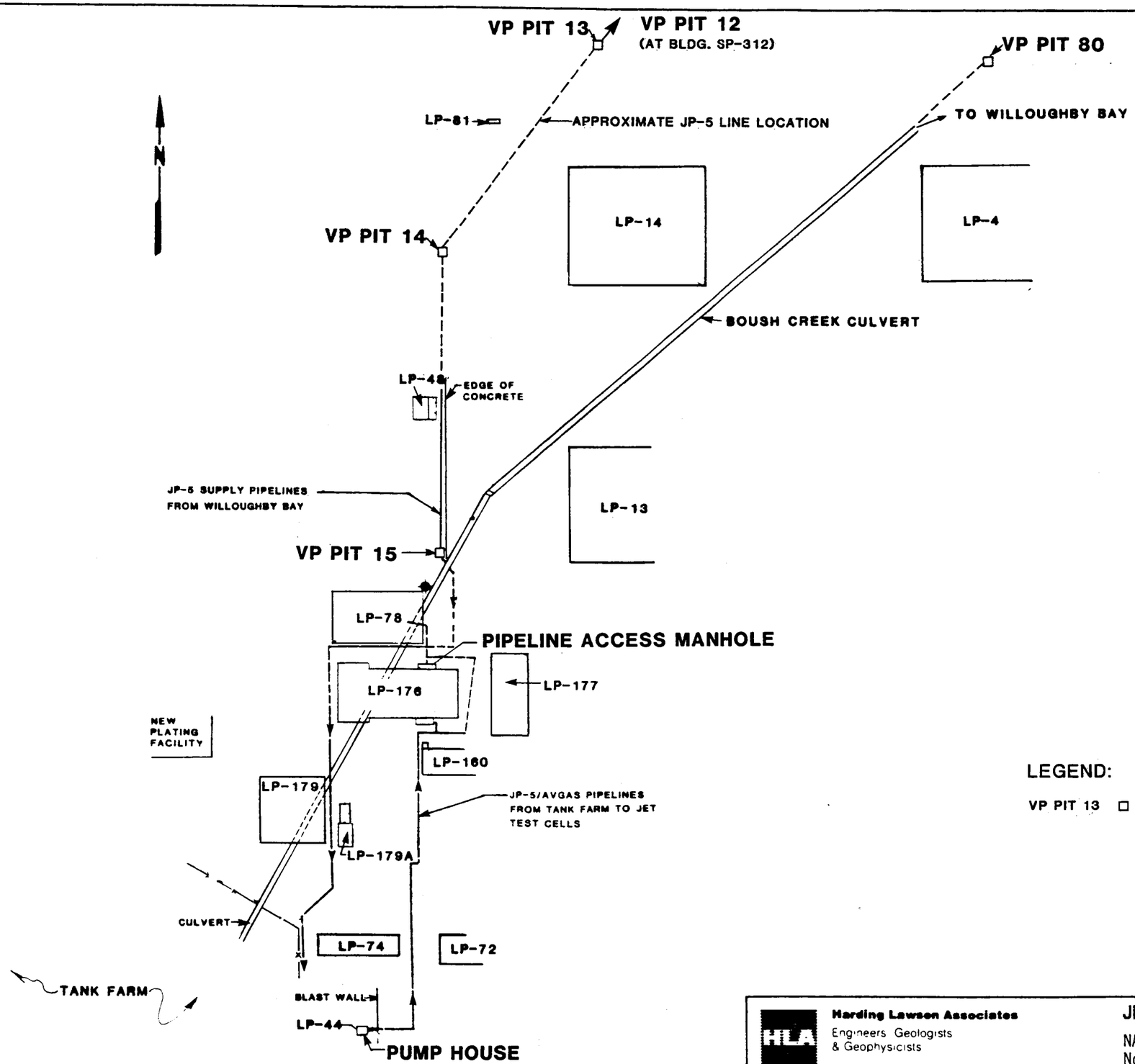
SITE PLAN

NAS Norfolk
Norfolk, Virginia

PLATE 2

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12		8/24/87		



LEGEND:

VP PIT 13 □ VALVE PIT LOCATION AND NUMBER DESIGNATION

0 200 400
scale feet

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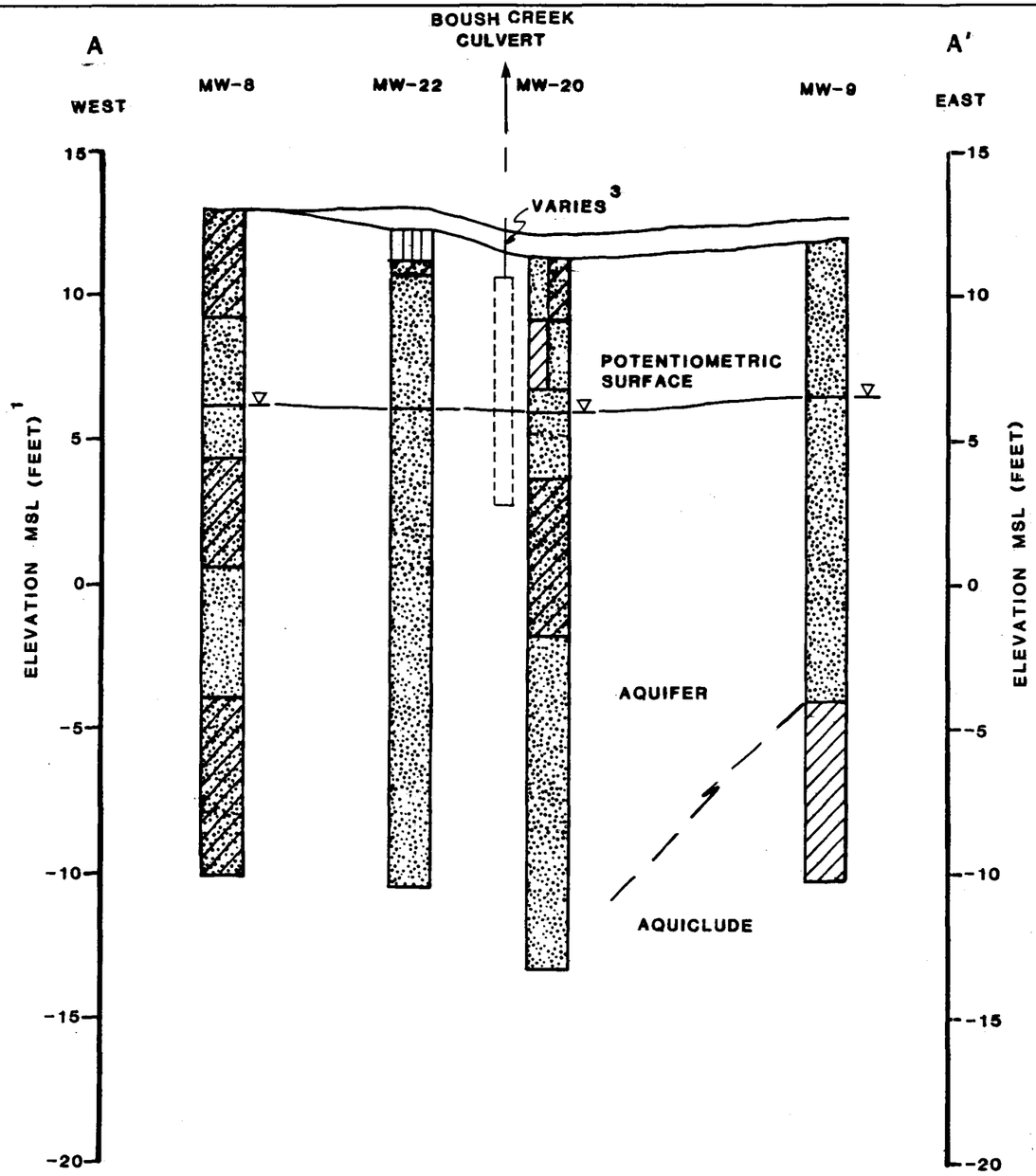
JP-5 LINE ACCESS LOCATIONS

NAS Norfolk
Norfolk, Virginia

PLATE 2A

DRAWN ES. | JOB NUMBER | APPROVED | DATE 9/24/87 | REVISED | DATE



LEGEND:

- CONCRETE, ASPHALT, OR GRAVEL PAVEMENT
- AQUIFER, CLAYEY SAND, SAND, AND SILTY SAND
- AQUICLUDE, CLAY
- GROUNDWATER LEVELS MEASURED ON 11/7/86. GROUNDWATER LEVELS IN WELLS MW-9 and MW-22 ADJUSTED FOR PHASE SEPARATED HYDROCARBON.

NOTES

1. Elevations based on USGS Benchmark.
2. Location of section on Plate 2, Site Plan.
3. Dimensions and depth of Boush Creek Culvert varies.

0 100 200
scale feet

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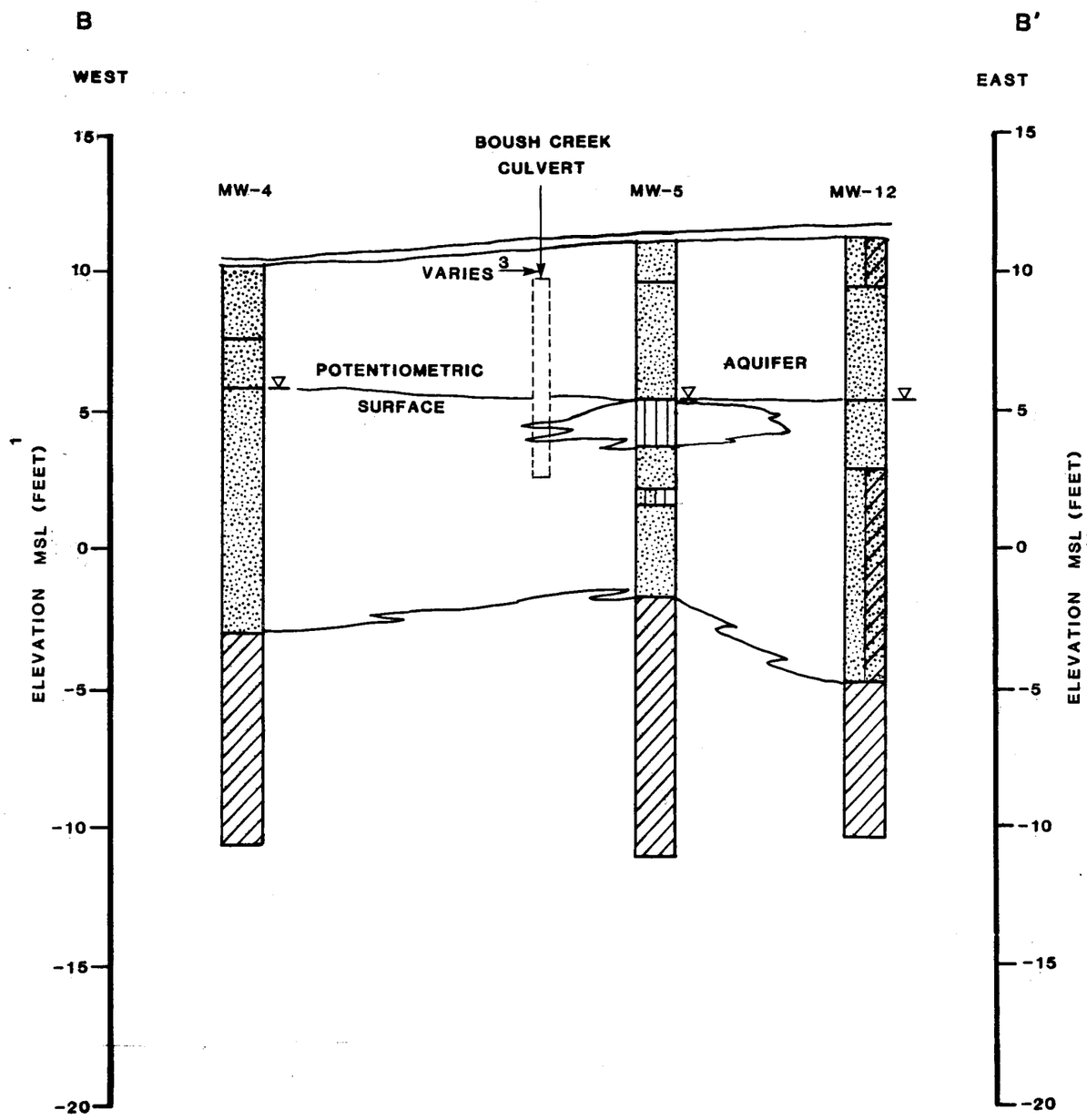
HYDROGEOLOGIC SECTION A-A' 2

NAS Norfolk
Norfolk, Virginia

PLATE 3

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES.	2176,085.12		8/28/87		



LEGEND:

- CONCRETE, ASPHALT, OR GRAVEL PAVEMENT
- AQUIFER, CLAYEY SAND, SAND, AND SILTY SAND
- AQUICLUDE, CLAY
- GROUNDWATER LEVELS MEASURED ON 11/7/86. GROUNDWATER LEVEL IN WELL MW-5 ADJUSTED FOR PHASE SEPARATED HYDROCARBON.

NOTES

1. Elevations based on USGS Benchmark.
2. Location of section on Plate 2, Site Plan.
3. Dimensions and depth of Boush Creek Culvert varies.

0 100 200
scale feet

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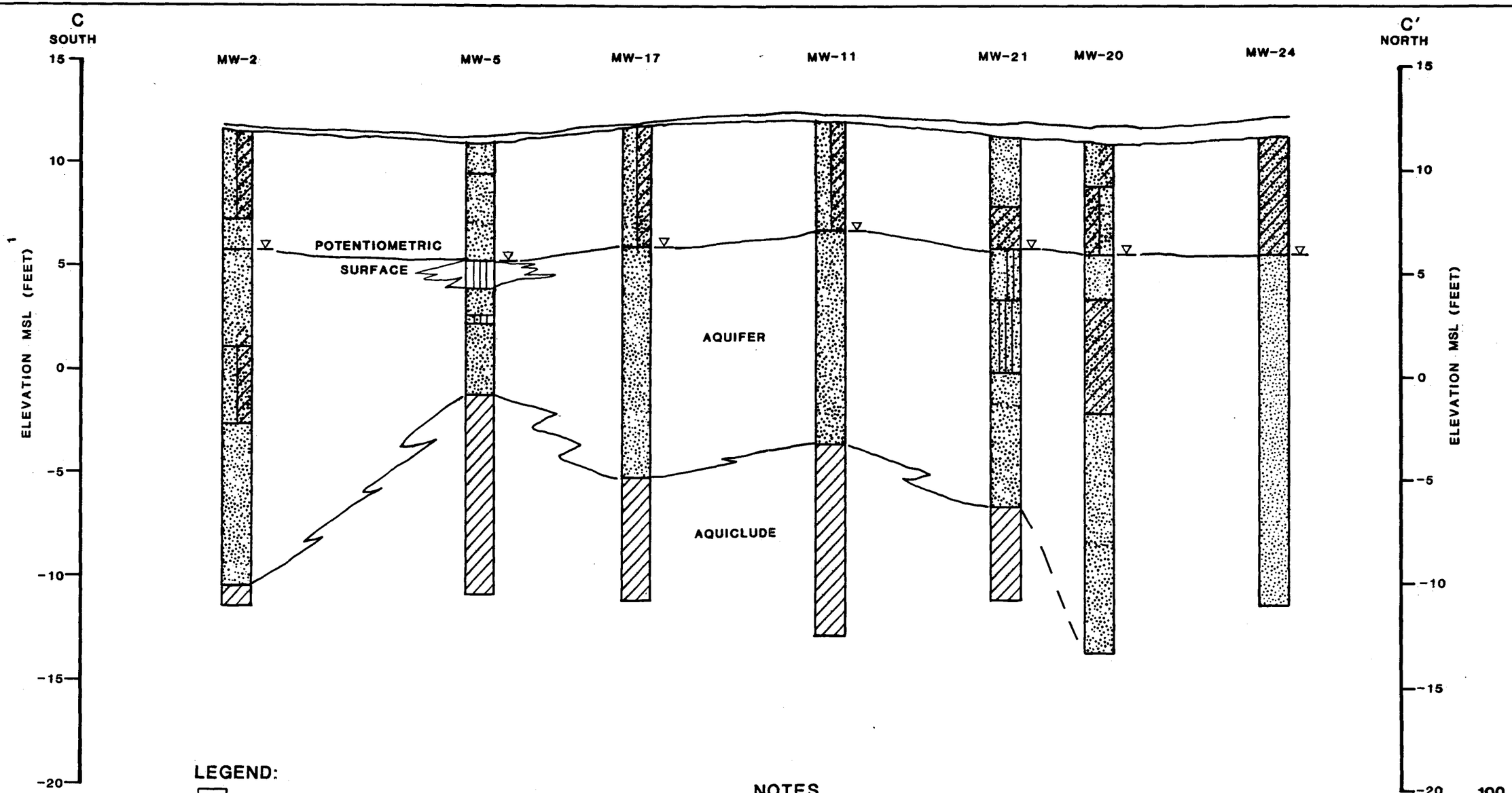
Engineers, Geologists & Geophysicists

HYDROGEOLOGIC SECTION B - B' 2

NAS Norfolk
Norfolk, Virginia

PLATE 4

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
EB	2176,085.12	[illegible]	9/24/87		



LEGEND:

- CONCRETE, ASPHALT, OR GRAVEL PAVEMENT
- AQUIFER; CLAYEY SAND, SAND AND SILTY SAND
- AQUICLUDE; CLAY
- GROUNDWATER LEVELS MEASURED ON 11/7/86 (11/3/86 FOR MW- 21). GROUNDWATER LEVELS IN WELLS MW-5, MW-11, AND MW-21 ADJUSTED FOR PHASE SEPARATED HYDROCARBON.

NOTES

1. Elevations based on USGS Benchmark.
2. Location of section on Plate 2, Site Plan.

0 100 200
scale feet

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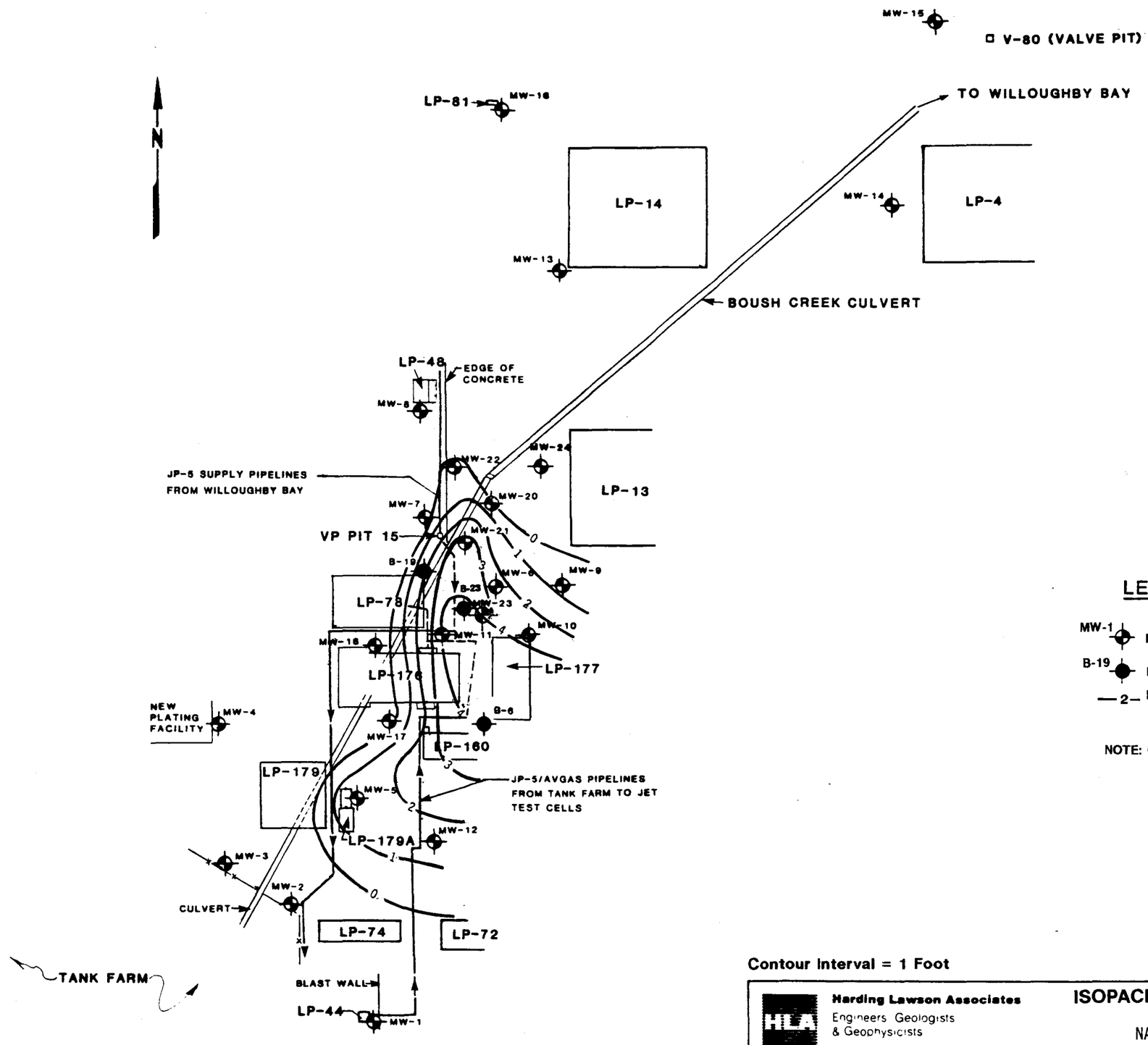
HYDROGEOLOGIC SECTION C - C' 2

NAS Norfolk
Norfolk, Virginia

PLATE 5

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,085.12		8/24/87		



Monitoring Well No.	November 7, 1986 Thickness of Phase Separated Hydrocarbon
MW-1	0.00
MW-2	0.00
MW-3	0.00
MW-4	0.00
MW-5	1.47
MW-6	2.02
MW-7	0.00
MW-8	0.00
MW-9	0.87
MW-10	2.78
MW-11	4.65
MW-12	1.58
MW-13	0.00
MW-14	0.00
MW-15	0.00
MW-16	0.00
MW-17	0.00
MW-18	0.00
MW-20	0.00
MW-21	3.82
MW-22	0.12
MW-23	4.13
MW-24	0.00

LEGEND:

MW-1 — MONITORING WELL LOCATION AND NUMBER

B-19 — BORINGS NOT COMPLETED AS MONITORING WELLS

—2— HYDROCARBON THICKNESS (FEET)

NOTE: Observed hydrocarbon thicknesses in wells do not necessarily represent the actual hydrocarbon thickness in subsurface materials.

0 200 400
scale feet

Contour Interval = 1 Foot

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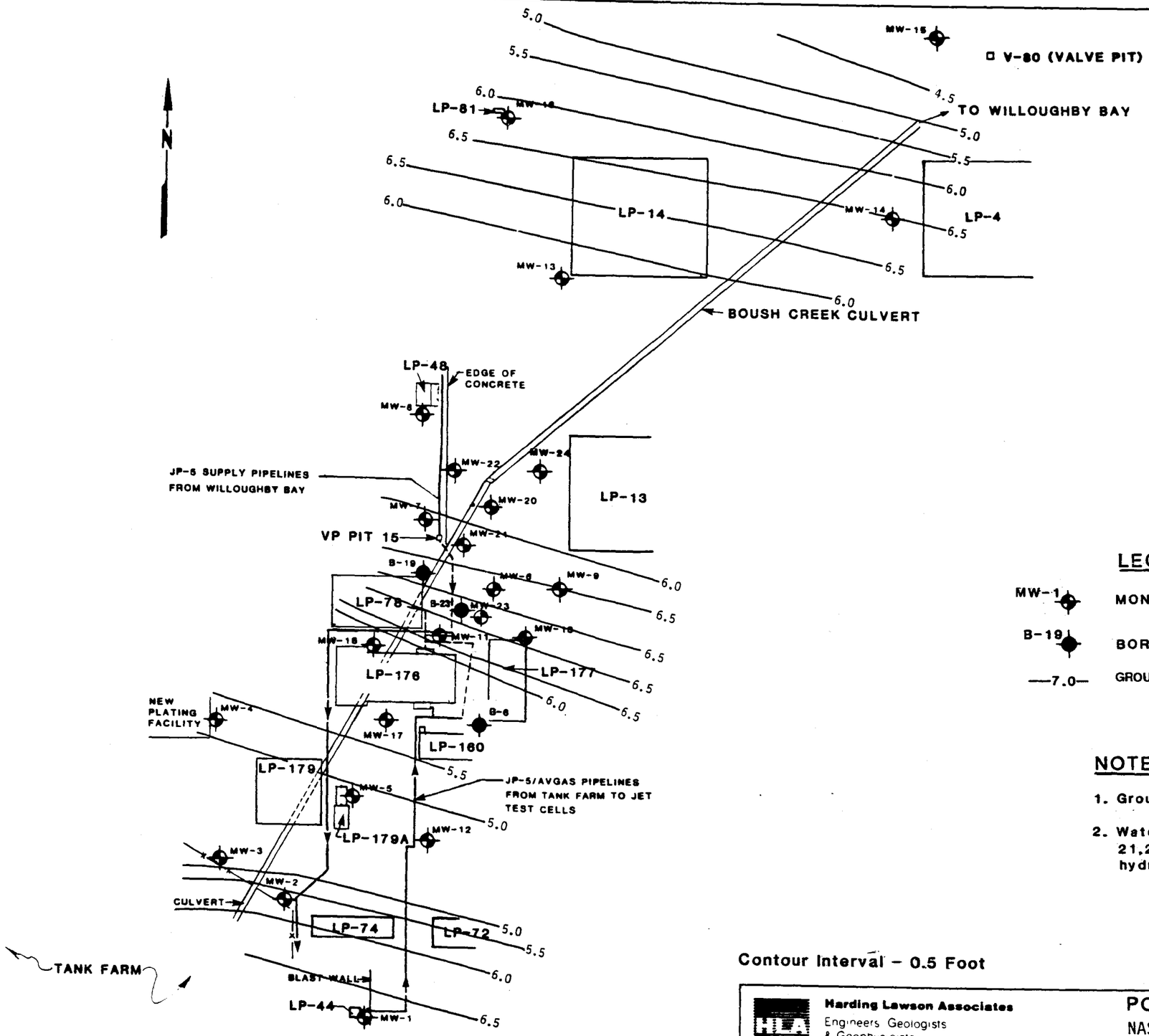
ISOPACH MAP - HYDROCARBON THICKNESS

NAS Norfolk
Norfolk, Virginia

PLATE 6

DRAWN: EB. | JOB NUMBER 2176,088.12 | APPROVED: | DATE 8/28/87 | REVISED: | DATE



Monitoring Well No.	Potentiometric Level 1&2 (ft. MSL)
MW-1	6.78
MW-2	5.77
MW-3	4.70
MW-4	5.43
MW-5	4.82
MW-6	6.67
MW-7	6.04
MW-8	5.99
MW-9	6.49
MW-10	6.42
MW-11	6.83
MW-12	4.85
MW-13	5.89
MW-14	6.50
MW-15	4.42
MW-16	6.22
MW-17	5.87
MW-18	5.88
MW-20	5.97
MW-21	6.05
MW-22	5.94
MW-23	6.41
MW-24	5.83

LEGEND:

MW-1 — MONITORING WELL LOCATION

B-19 — BORINGS NOT COMPLETED AS MONITORING WELLS

—7.0— GROUNDWATER ELEVATION CONTOUR

NOTE:

1. Groundwater elevation based on USGS benchmark.
2. Water levels in monitoring wells MW-5, 6, 9, 10, 11, 12, 21, 22 and 23 adjusted for phase separated hydrocarbon.

0 200 400
scale feet

Contour Interval – 0.5 Foot

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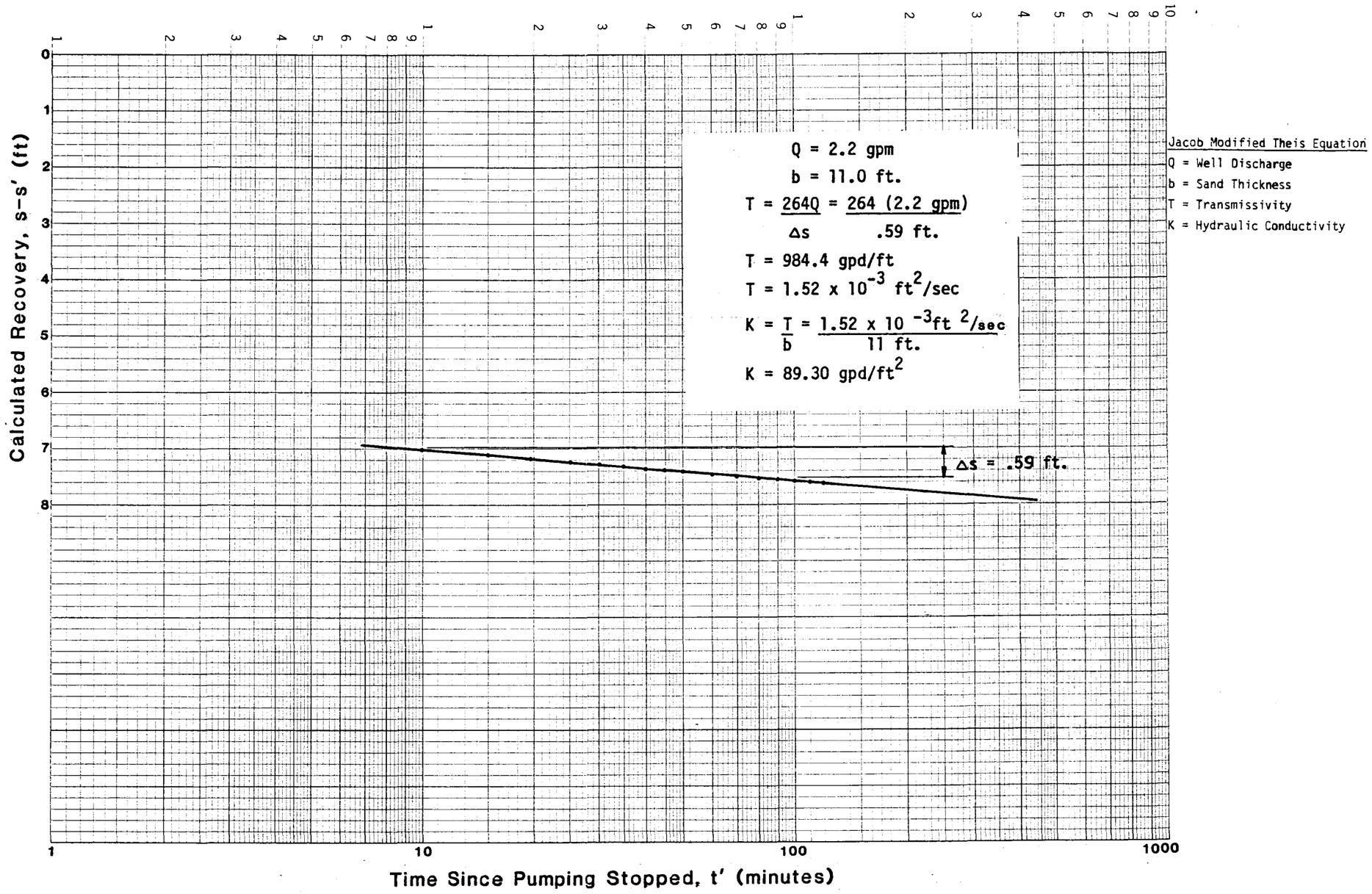
POTENTIOMETRIC SURFACE MAP

NAS Norfolk
Norfolk, Virginia

PLATE 7

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES.	2176,085.12	[illegible]	8/26/87		



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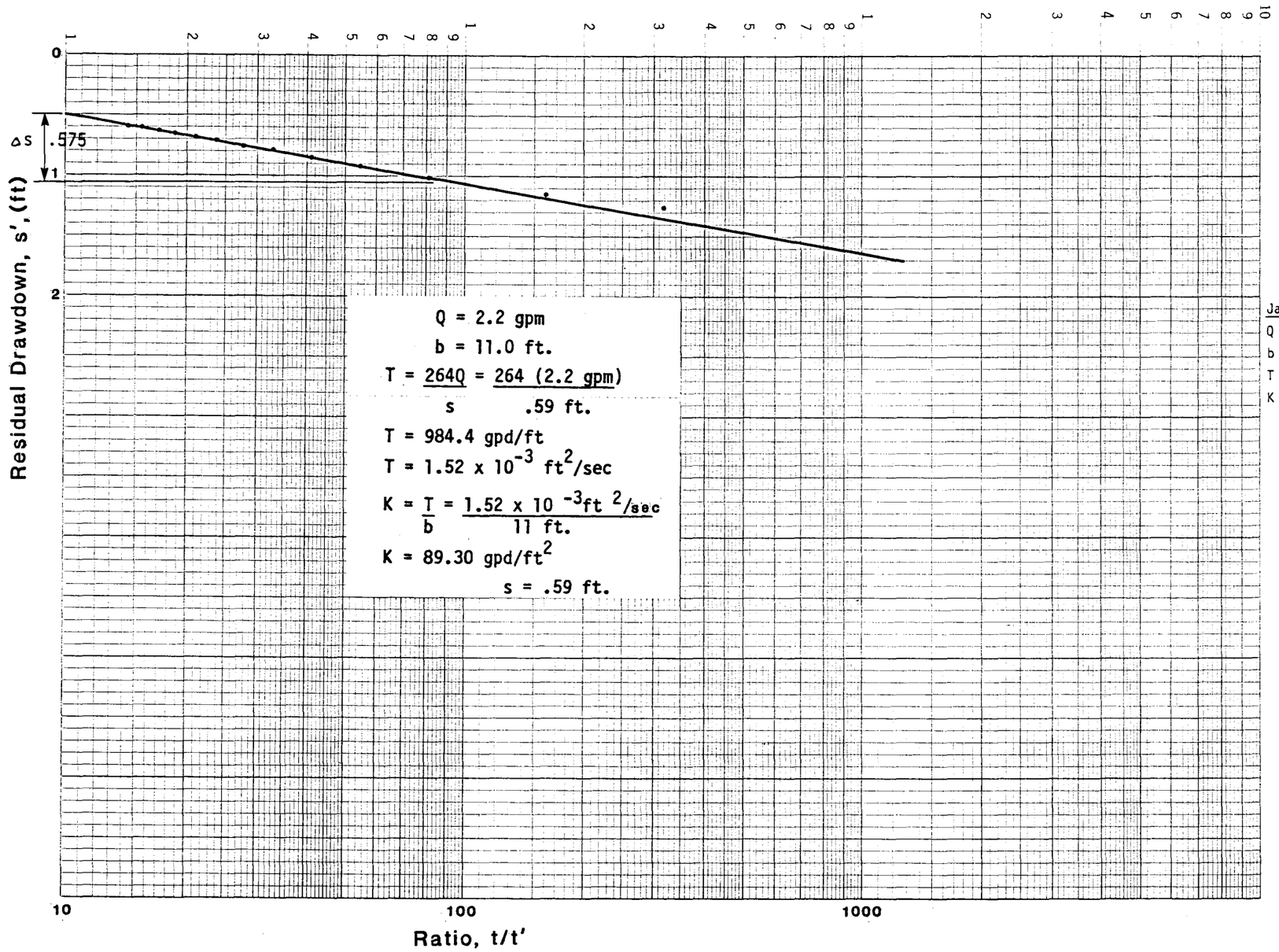
MONITORING WELL MW-17 PUMP TEST
CALCULATED RECOVERY CURVE
NAS Norfolk
Norfolk, Virginia

PLATE **8**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES.	2176,085.12		8/24/87		



Jacob Modified Theis Equation

Q = Well Discharge

b = Sand Thickness

T = Transmissivity

K = Hydraulic Conductivity

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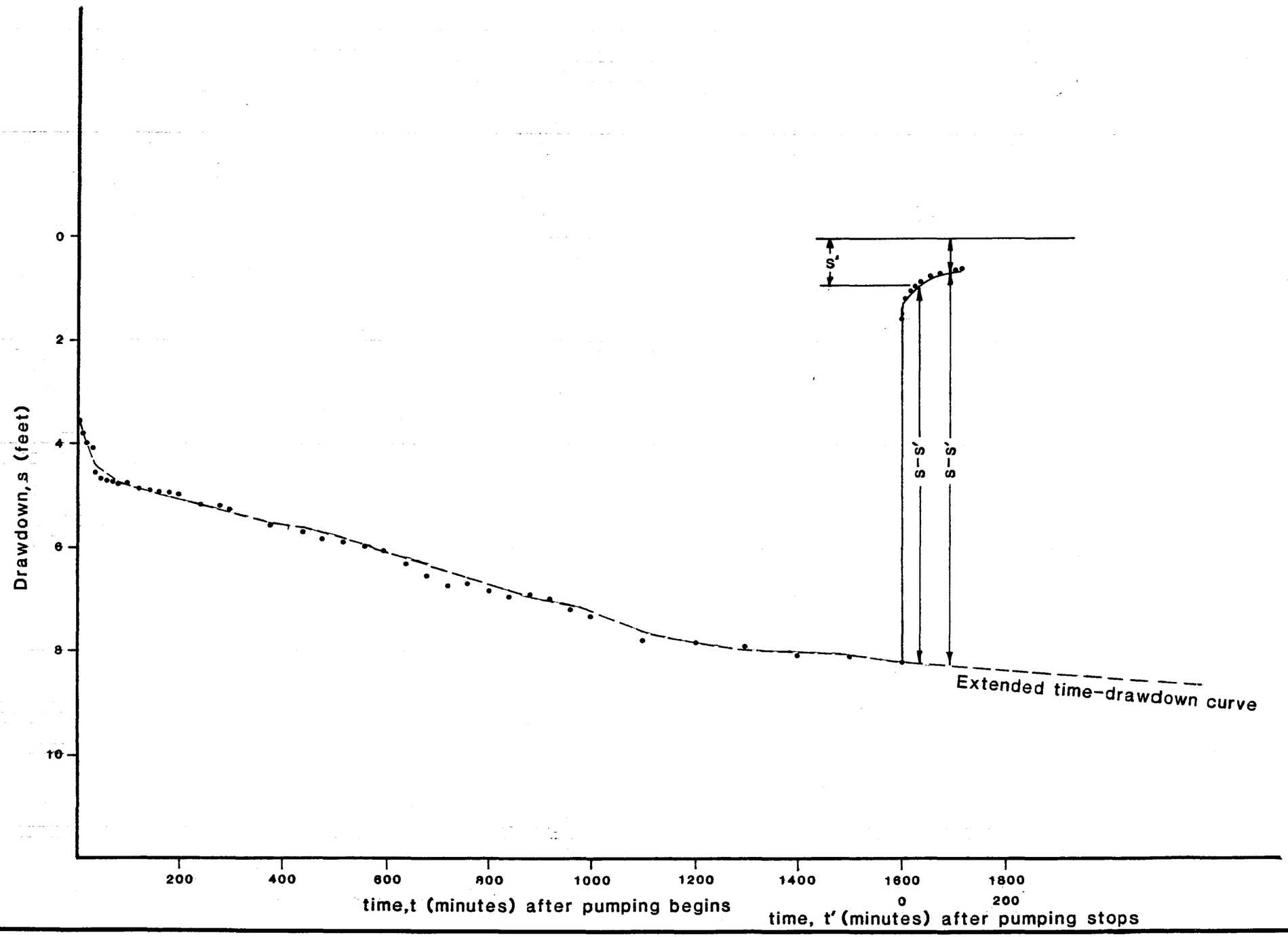
MONITORING WELL MW-17 PUMP TEST
RESIDUAL DRAWDOWN CURVE

NAS Norfolk
Norfolk, Virginia

PLATE 9

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
CS.	2176,085.12		8/24/87		



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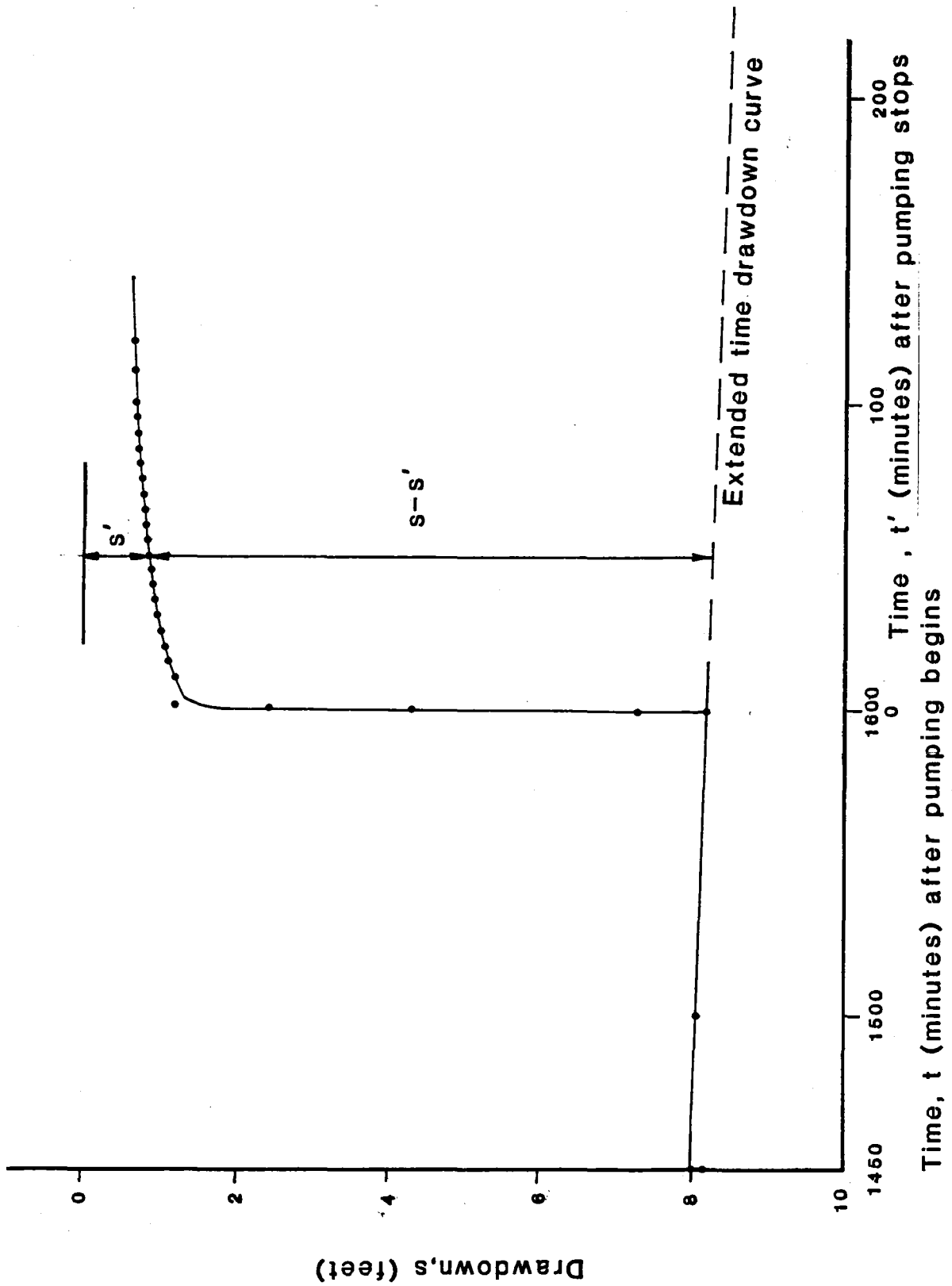
MONITORING WELL MW-17 PUMP TEST
DRAWDOWN & RECOVERY CURVES
NAS Norfolk
Norfolk, Virginia

PLATE **10**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,085.12		8/24/87		



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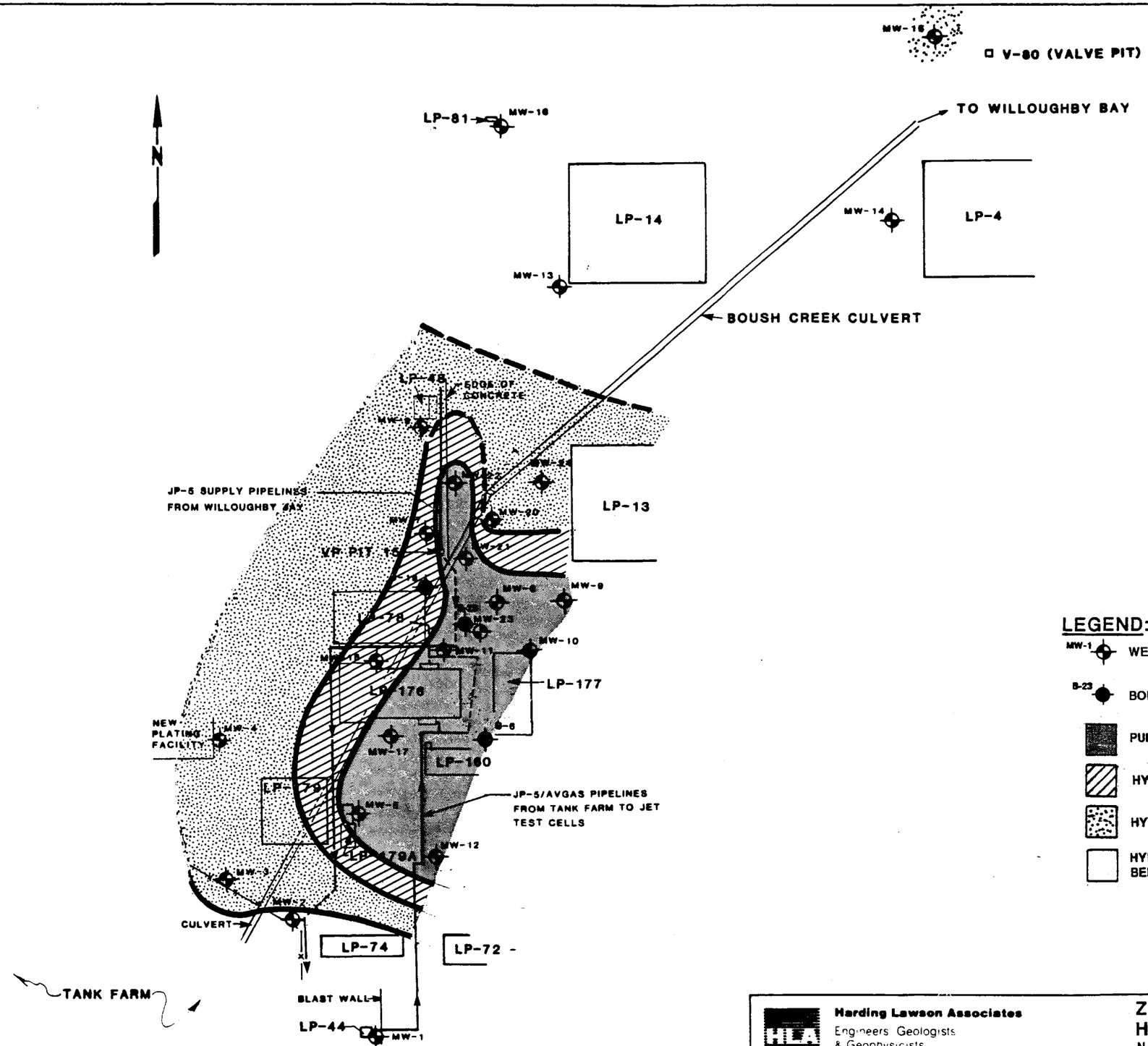
MONITORING WELL MW-17 PUMP TEST RECOVERY CURVE
NAS Norfolk
Norfold, Virginia

PLATE **11**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12		8/24/87		



Monitoring Well No.	Hydrocarbon[1] in Fluid Samples (ug/l)
MW-1	< 25 [2]
MW-2	<25
MW-3	120
MW-4	550
MW-5	Pure [3]
MW-6	Pure
MW-7	26,000
MW-8	250
MW-9	Pure
MW-10	Pure
MW-11	Pure
MW-12	Pure
MW-13	<25
MW-14	<25
MW-15	39
MW-16	<25
MW-17	Pure
MW-18	1,400
MW-20	48
MW-21	Pure
MW-22	Pure
MW-23	Pure
MW-24	130

NOTES:

1. The hydrocarbon present is a blend similar to JP-5.
2. Below detection limit.
3. Sample essentially pure hydrcocarbon blend.

LEGEND:

- MW-1 — WELL LOCATION AND NUMBER
- B-23 — BORING NOT COMPLETED AS MONITORING WELL
- PURE HYDROCARBON IN FLUID SAMPLE
- HYDROCARBON IN FLUID SAMPLE (> 1000 ug/l)
- HYDROCARBON IN FLUID SAMPLE (25 -1000 ug/l)
- HYDROCARBON IN FLUID SAMPLE BELOW DETECTION LIMITS (<25 ug/l)

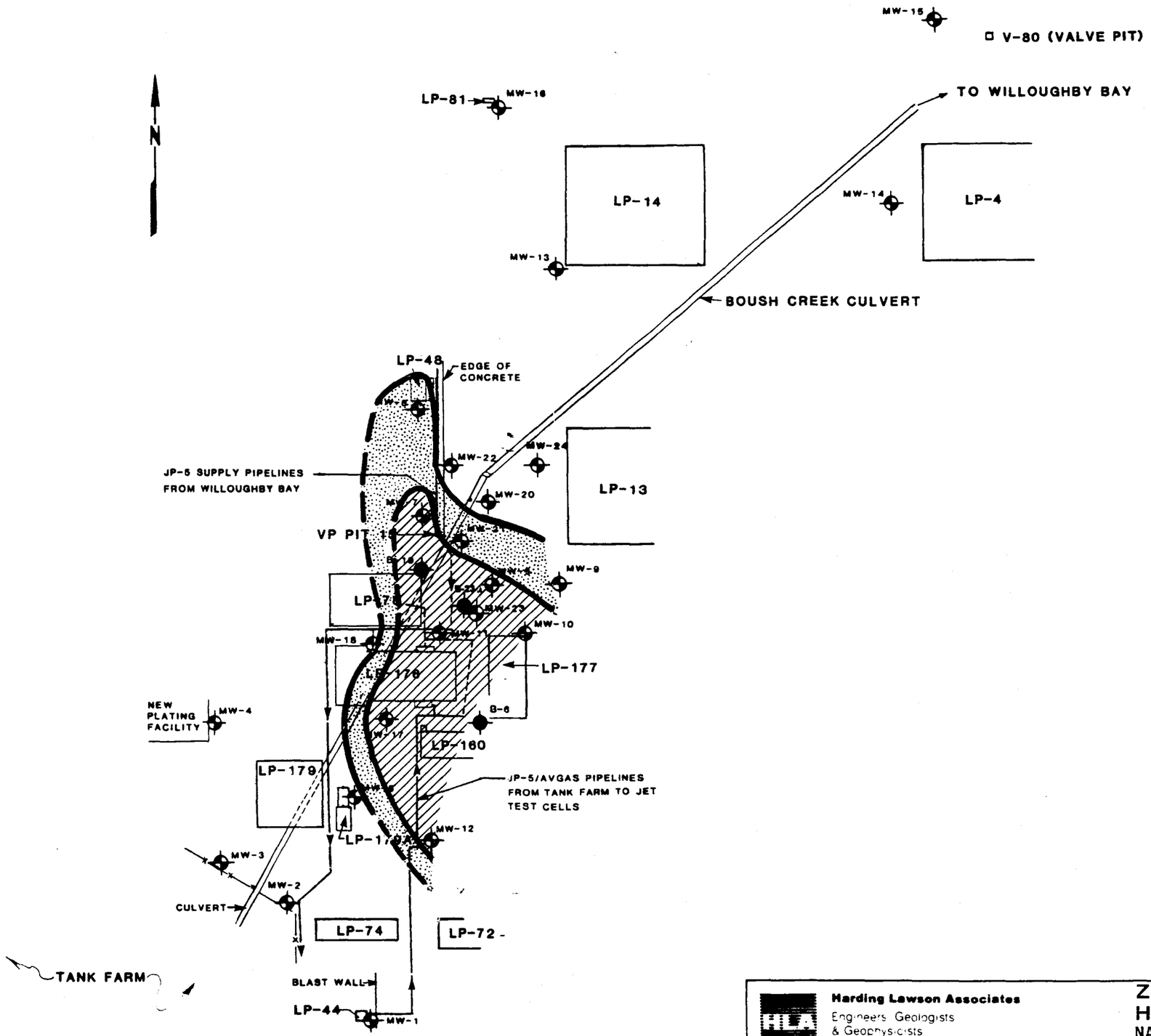
0 200 400
scale feet

Harding Lawson Associates
Engineers Geologists & Geophysicists

ZONES OF OCCURRENCE – HYDROCARBON IN FLUID SAMPLES
NAS Norfolk
Norfolk, Virginia

PLATE 12

DRAWN ES. | JOB NUMBER 2176,085.12 | APPROVED | DATE 8/24/87 | REVISED | DATE



Monitor Well No.	Sample Designation	Hydrocarbon[1] in Soil Sample (mg/kg)
MW-1	-[2]	-
MW-2	-[2]	-
MW-3	All	BDL[3]
MW-4	All	BDL
MW-5	All	BDL
MW-6	MW-6 2.5 - 3.5	5,320
MW-7	MW-7 8.0 - 8.5	14,600
MW-8	MW-8 6.5 - 7.5	34
MW-9	MW-9 6.0 - 7.5	551
MW-10	MW-10 6.0 - 7.5	6,560
MW-11	MW-11 6.0 - 7.5	95,100
MW-12	MW-12 6.0 - 7.5	46,000
MW-13	All	BDL
MW-14	All	BDL
MW-15	All	BDL
MW-16	All	BDL
MW-17	MW-17 7.0 - 8.0	2,390
MW-18	All	BDL
MW-20	All	BDL
MW-21	MW-21 7.0 - 7.5	32
MW-22	All	BDL
B-23	B-23 2.5 - 4.0	5,250
MW-23	MW-23 4.5 - 5.5	83,300
MW-24	All	BDL

NOTES:

1. The hydrocarbon present is a blend similiar to JP-5.
2. Results from monitor wells MW-1 and MW-2 are not available.
3. Below detection limit.
4. Zones are based on the MAXIMUM hydrocarbon measurement within a given boring.

LEGEND

MW-1 WELL LOCATION AND NUMBER

B-23 BORING NOT COMPLETED AS MONITORING WELL

HYDROCARBON IN SOIL SAMPLE (>1,000 mg/kg)

HYDROCARBON IN SOIL SAMPLE (DETECTION LIMIT-1,000mg/kg)

HYDROCARBON IN SOIL SAMPLE BELOW DETECTION LIMIT

0 200 400
scale feet

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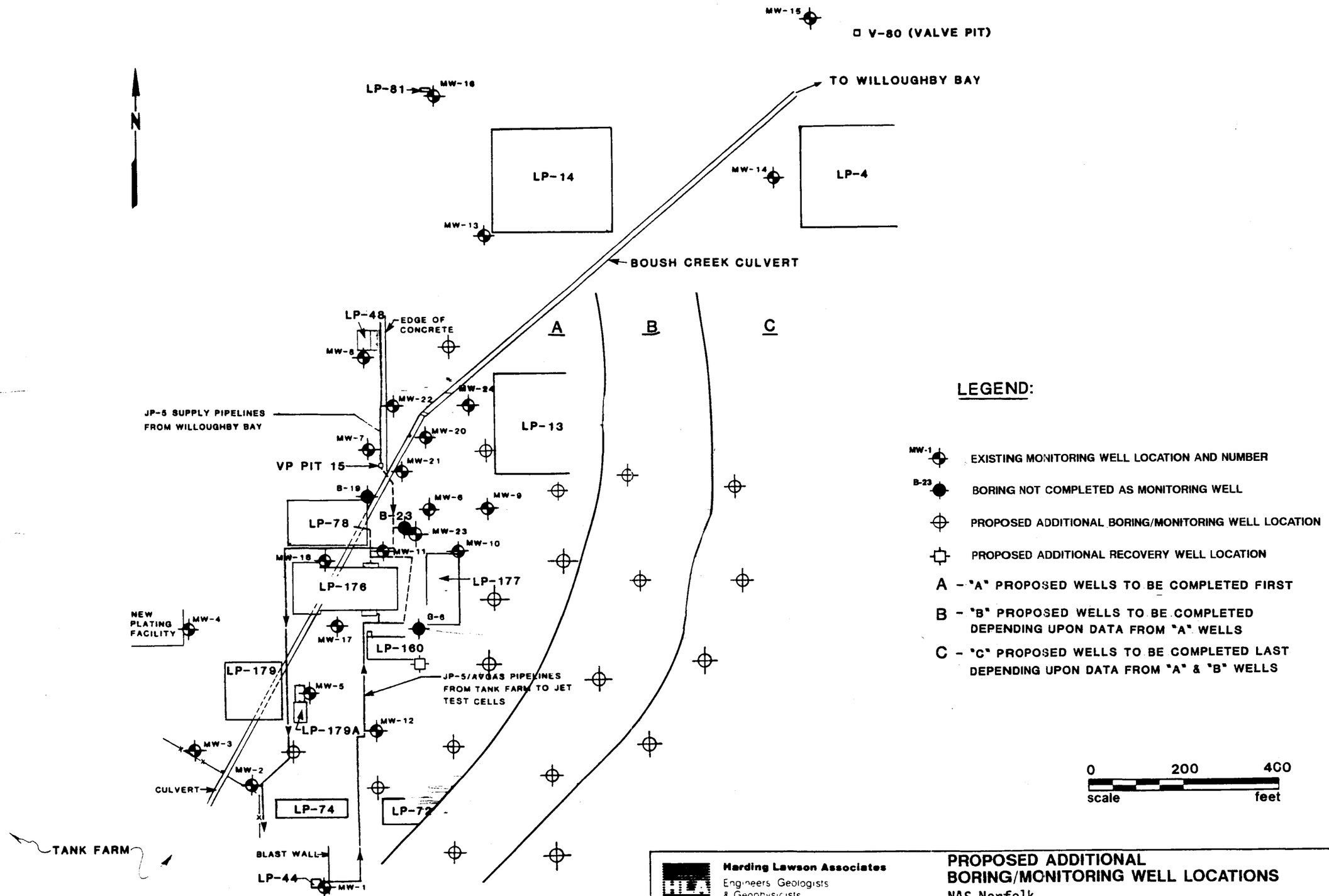
ZONES OF OCCURRENCE - HYDROCARBON IN SOIL SAMPLES

NAS Norfolk
Norfolk, Virginia

PLATE 13

DRAWN: EB. | JOB NUMBER: 2176,085.12 | APPROVED: | DATE: 8/28/87 | REVISED: | DATE



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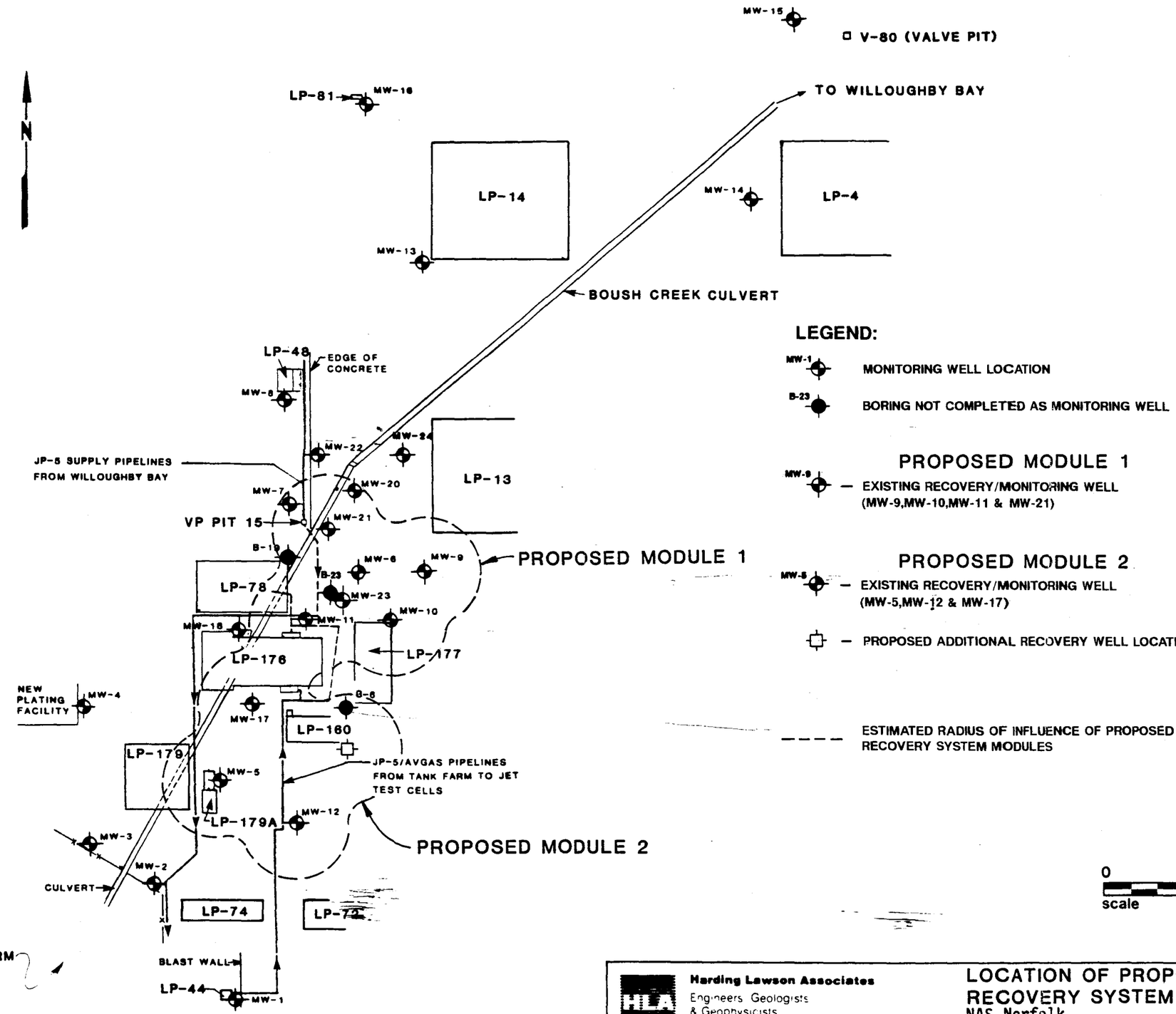
PROPOSED ADDITIONAL BORING/MONITORING WELL LOCATIONS

NAS Norfolk
Norfolk, Virginia

PLATE 14

DRAWN: E.S. | JOB NUMBER: 2176,085.12 | APPROVED | DATE 8/24/87 | REVISED | DATE



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LOCATION OF PROPOSED RECOVERY SYSTEM MODULES

NAS Norfolk
Norfolk, Virginia

PLATE 15

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12		8/4/87		

APPENDIX A

FIELD METHODOLOGY AND EQUIPMENT

A-1	HNu Survey
A-2	Geophysicical Survey
A-3	Soil Borings
A-4	Monitoring Well Installation
A-5	Aquifer Tests

A-1

HNu Survey

A survey was conducted to determine the presence and relative concentration of JP-5 vapor in the site area using a portable photo-ionization detector (HNu Model PI 101) and a 10.2 ev lamp probe. The equipment was calibrated to measure benzene, a major constituent of petroleum products which include JP-5. Relative concentrations of benzene should correlate with relative concentrations of JP-5 vapor, and thus be a general indicator as to the presence or absence of the JP-5.

The HNu survey was conducted as follows:

- Survey manholes or open drains which previously exhibited product vapors;
- Survey surrounding manholes or open drains, if product concentration is detectable on the meter;
- Survey manholes or open drains along Boush Creek Culvert, and;
- Survey surrounding manholes or open drains if product concentration is detectable on the meter.

A-2

Geophysical Survey

Ground Penetrating Radar (GPR) was used to determine the possible presence of underground obstructions. In addition to the GPR, an Electromagnetic Terrain Conductivity Meter (EM) was used to locate and follow the two sets of active JP-5 lines from the fuel farm to the jet engine test cells and beyond toward Willoughby Bay.

The GPR equipment used specifically on this project was the Geophysical Survey Systems Inc. (GSSI) Model SIR-8. The GPR system uses radar technology to obtain continuous high-resolution electromagnetic profiles of the subsurface. The depth of penetration is a function of the electrical properties of subsurface materials and the frequency of the radar antenna. When the subsurface signal encounters a boundary between media with the different electrical properties, such as soil and a buried pipe, some of the wave energy is reflected back to the surface, picked up by the antenna, amplified and printed on a graphic recorder. A traverse along a radar line results in a continuous graphic record of the subsurface.

The ability of the instrument to differentiate surfaces or materials at depth is dependent on the frequency of the pulse. Low frequency pulses generate a greater penetration downward but with lower resolution, whereas high frequency pulses affords much less

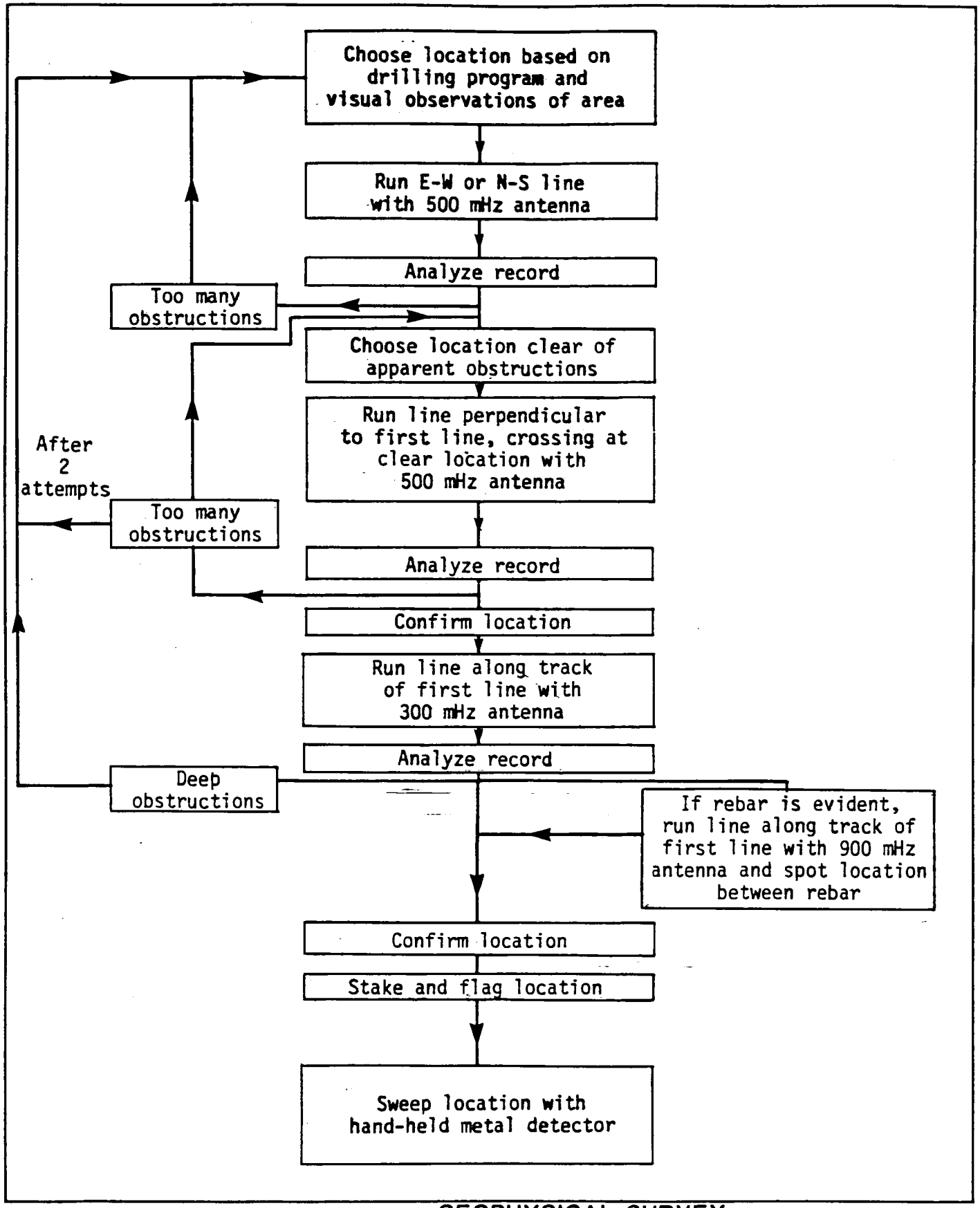
penetration but with higher resolution. Three GPR antennae, having different frequencies, were utilized at NAS Norfolk: a 300 megaHertz (mHz) for deeper penetration, a 500 mHz for better resolution, and a high resolution 900 mHz to determine rebar spacing in areas of concrete pavement.

Geophysical field operations for the subsurface investigation at prospective boring/well locations were conducted as follows: (Plate A-2-1).

- Determine approximate boring/well location based on HNu survey, drilling plan, rig access and hydraulic data.
- Run either an east-west or north-south line approximately 30 to 40 feet long through the area of interest with the 500 mHz antenna (Plate A-2-2).
- Analyze the GPR record for evidence of pipes, utility trenches, or anomalous conditions.
- Select a location free of apparent obstructions (if there is no clear area, move location and start again).
- Run a line perpendicular to the original line, with the designated location as a center point, approximately 10 feet long using the 500 mHz antenna (Plate A-2-3).
- Analyze the GPR record again for evidence of pipes, utility trenches or anomalous conditions.
- Confirm location if free of subsurface obstructions. If obstructions are present move to another clear location on the original line and repeat the perpendicular line. If no clear position can be found, move to a nearby location and start again.
- Run a GPR line, along the same track as the first line, using the 300 mHz antenna (Plate A-2-4).

- Analyze the GPR record for location.
- If prospective boring/well location is on concrete reinforced with rebar, run one or more GPR lines using the 900 mHz antenna to position the final location between the rebar (Plate A-2-5).
- Stake, label and flag final boring/well location.
- Sweep location with hand-held metal detector.

A Geonics Model EM-310 electromagnetic (EM) Terrain Conductivity Meter was used to verify the locations of the JP-5 pipes identified by the GPR, as well as trace the pipe locations in areas where the GPR had been inconclusive in identifying the JP-5 pipes. The EM technique involves setting up an electromagnetic field with a transmitter coil. Through inductive coupling, the magnetic field causes very small currents to flow in the earth and they, in turn, induce their own, small secondary magnetic field. Both primary and secondary fields are sensed by the unit's receiver coil. Gradual changes in these fields can be due to changes in the conductive nature of the soil, while abrupt changes occur due to passing over metallic objects such as pipes or utilities. The survey technique employed with the GPR was also followed during the EM Survey.



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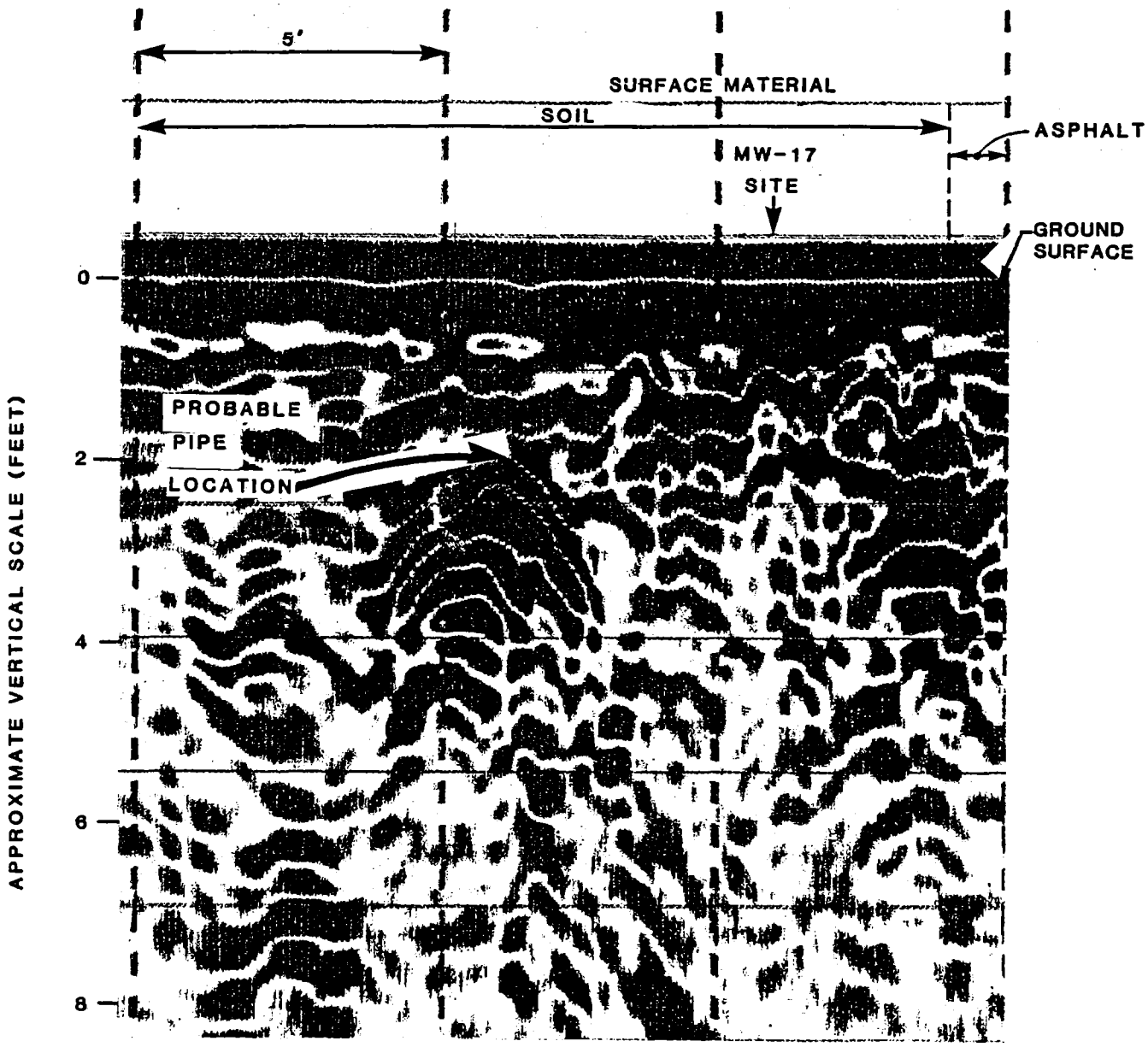
GEOPHYSICAL SURVEY
BORING/WELL LOCATION CLEARANCE
NAS Norfolk
Norfolk, Virginia

PLATE **A-2-1**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,088.12		8/26/87		



GPR RECORD
500 MHZ ANTENNA
LINE T
BORING MW-17

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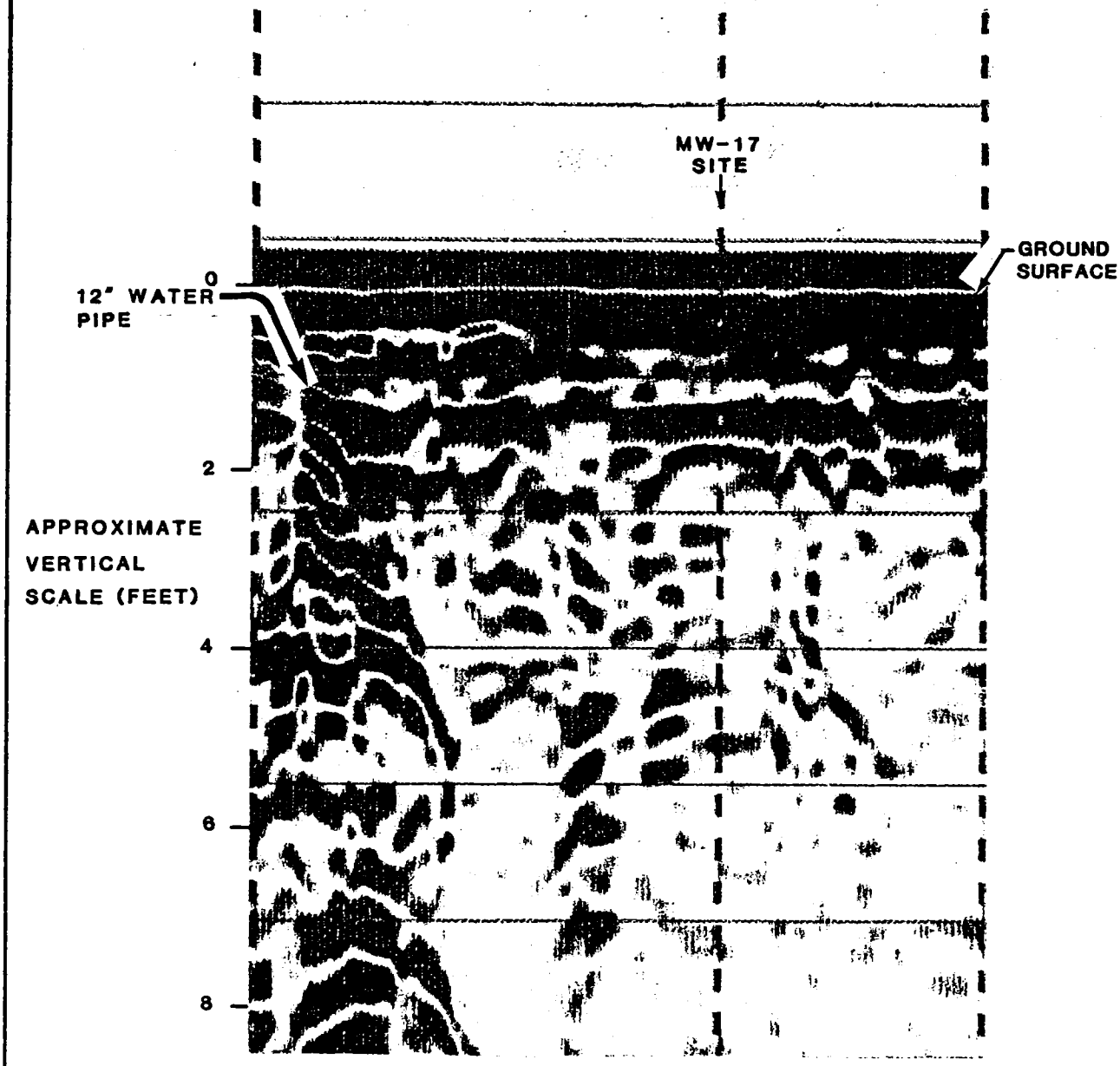
GEOPHYSICAL SURVEY

NAS Norfolk
Norfolk, Virginia

PLATE
A-2-2

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES.	2176,088.12		8/24/87		



GPR RECORD
500 MHZ ANTENNA
LINE T PERPENDICULAR
BORING MW-17

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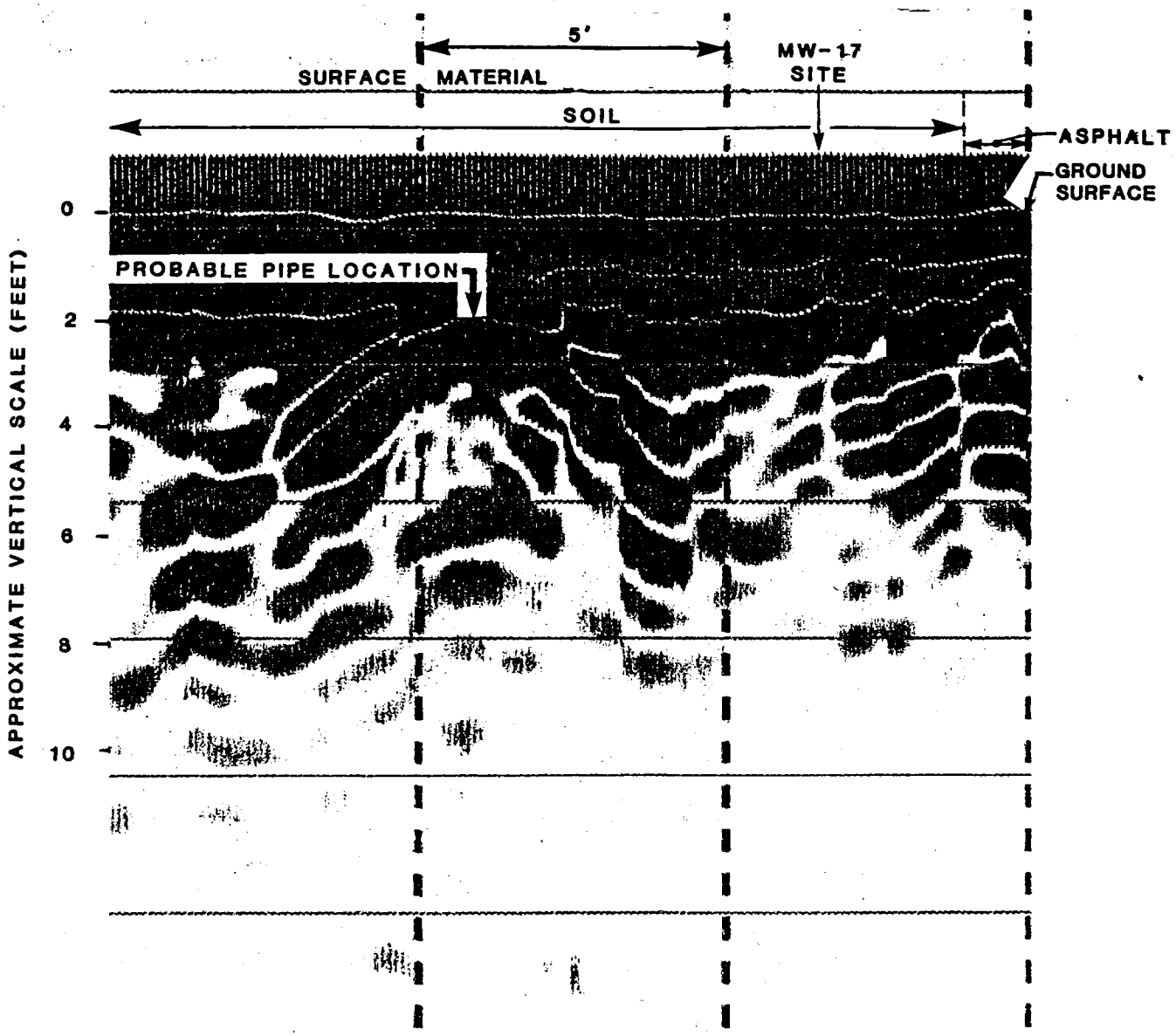
GEOPHYSICAL SURVEY

NAS Norfolk
Norfolk, Virginia

PLATE
A-2-3

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
EB	2176,088.12		8/24/87		



GPR RECORD
300 MHZ ANTENNA
LINE T
BORING MW-17

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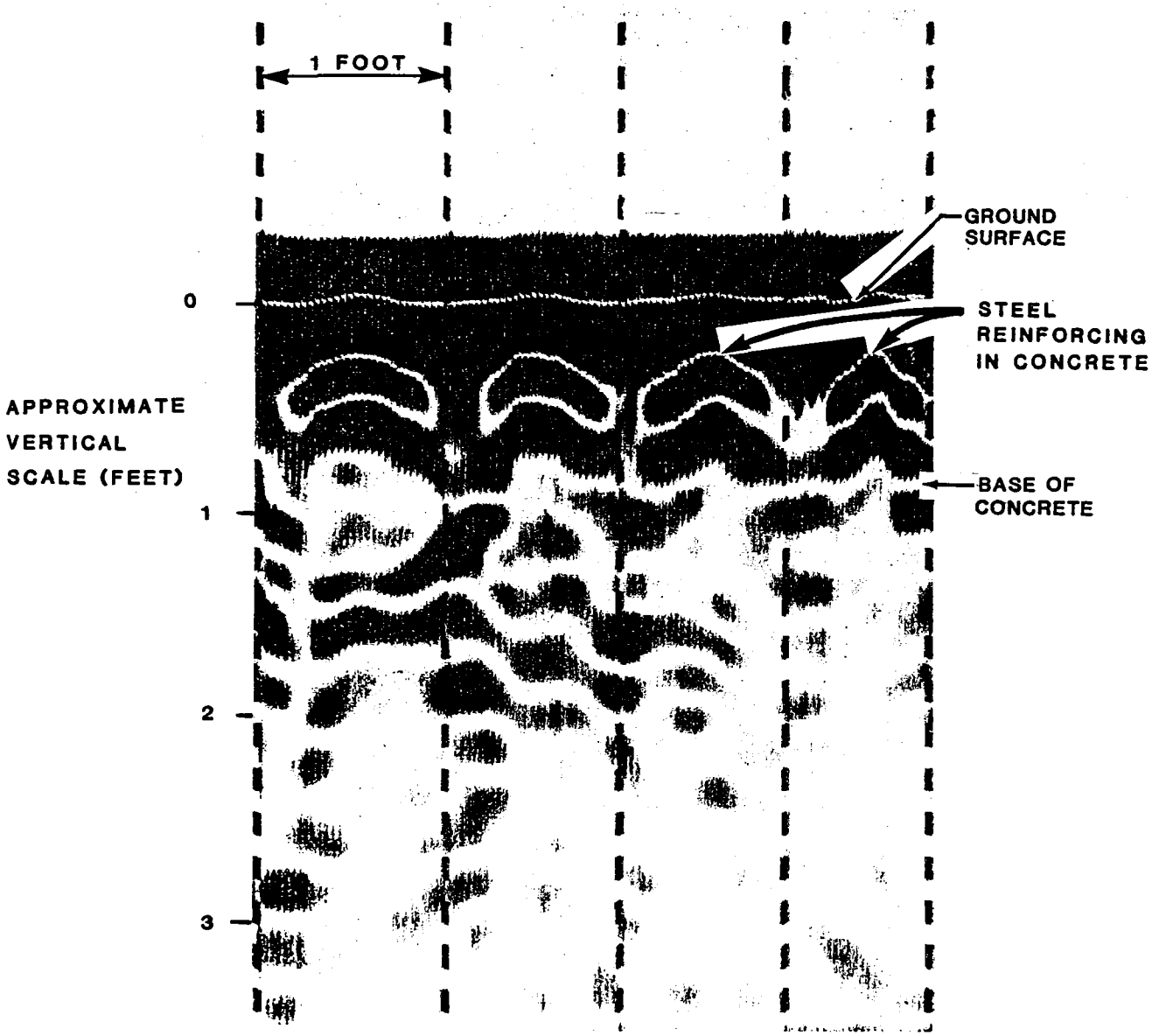
GEOPHYSICAL SURVEY

NAS Norfolk
Norfolk, Virginia

PLATE
A-2-4

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
Es.	2176,088.12	JM	8/24/87		



GPR RECORD
900 MHZ ANTENNA
LINE V

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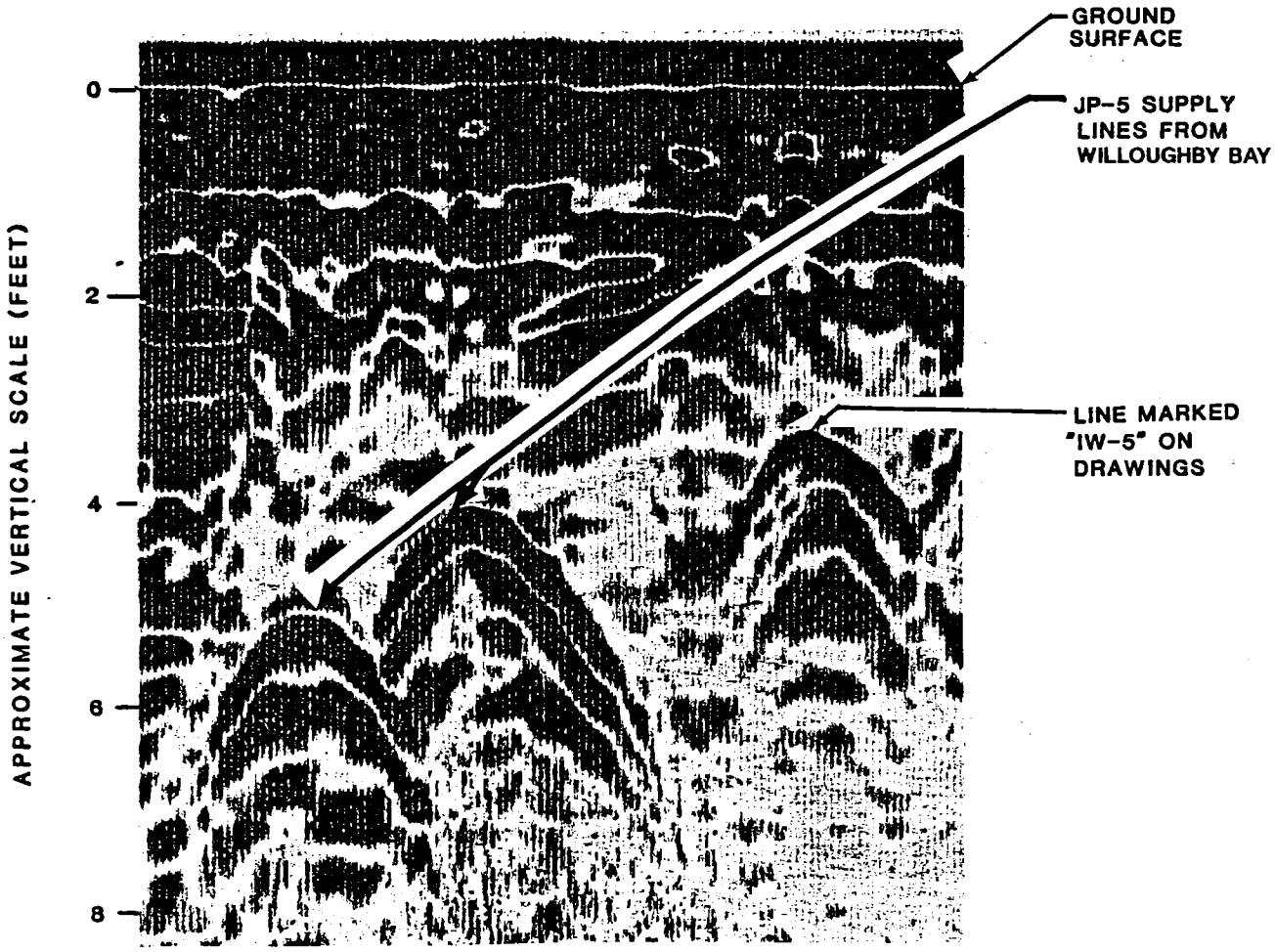
GEOPHYSICAL SURVEY

NAS Norfolk
Norfolk, Virginia

PLATE A-2-5

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,088.12	[illegible]	8/24/87		



GPR RECORD
500 MHZ ANTENNA
JP-5 LINE TRACKING
NORTH OF VP-15

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GEOPHYSICAL SURVEY
NAS Norfolk
Norfolk, Virginia

PLATE
A-2-6

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
CS	2176,088.12		8/24/87		

A-3

Soil Borings

The Phase I and II borings were drilled by Froehling & Robinson, Inc. (F&R) under subcontract to HLA. F&R utilized an all-terrain vehicle with a CME 55 drilling rig. Borings were advanced with a 10-inch diameter hollow stem auger. In some instances during the course of drilling, flowing sands were encountered and wet rotary drilling with mud was required to wash out the borehole and prevent caving. Soil samples were obtained with a split-spoon sampler driven by a 140-pound hammer. All samples were logged on-site by an HLA geologist/engineer. Boring logs are presented in Appendix C. Those samples chosen for analytical laboratory analysis were sealed in clean glass jars with teflon-lined lids. Each jar was labeled with date, boring number and depth of sample, and stored in chilled containers for shipment to the laboratory (IEA, Inc.) Drill cuttings from each well were placed in drums on-site for disposal by the Navy.

In accordance with the site safety plan, the HNu meter was used during drilling operations to monitoring the relative concentration of hydrocarbon vapors in the immediate vicinity of drilling and sampling operations. In addition, a combustible gas indicator/explosimeter (MSA Model 100) was used to monitoring the level of potentially explosive vapors at the open borehole.

Refer to Table 2 and Appendix C for complete data on the 23 borings.

A-4

Monitoring Well Installation

Based on site conditions, it was determined that the monitoring wells should be screened from 2 to 20 feet below ground surface to assure proper coverage of the water-bearing strata. The monitoring wells were constructed by placing a 20-foot section of 4-inch I.D. Schedule 40 PVC pipe with 0.02-inch slots into the borehole. Approximately 2 feet of blank PVC riser pipe were attached to the top of the screened interval. The annular space was then backfilled with No. 2 clean filter sand to just above the top of the screen section. A one-foot-thick bentonite seal was placed on top of the filter sand and the remainder of the annulus was grouted with cement/sand grout and capped to preclude any surface water from entering the well. All of the wells (with the exception of MW-3) were protected with 12-inch Christy Boxes cemented in-place, at-grade over the riser pipe. Monitoring well MW-3 was completed above-grade with a 10-inch diameter protective steel pipe and locking cap cemented in place. Prior to any sampling or testing, each well was developed by hand bailing and/or pumping to assure response of the well to local groundwater conditions.

Following well development, one fluid sample was collected from each of the monitoring wells for chemical analysis to determine the presence and amount of hydrocarbon. After each sample was collected, the sampling bailer was washed in detergent and water, and then rinsed

with distilled water. The contaminated section of rope used to lower the bailer into the well was cut off and the remainder was retied to the bailer. The fluid samples were sealed in clean glass jars with teflon-lined lids, and labeled. These samples were stored and shipped in chilled containers for analysis to HLA's subcontract analytical laboratory (IEA, Inc.).

IEA utilized a gas chromatography/fingerprint analysis for petroleum hydrocarbons to quantify the total petroleum hydrocarbons present in each sample. The fingerprint was made from a "raw" JP-5 sample. This method generates a chromatogram which is used to determine, in general terms, the amount of hydrocarbon contaminants present and if the sample resembles the "raw" JP-5 samples.

A-5

Aquifer Tests

Following development of the monitoring wells, two types of aquifer tests were performed: slug tests and pump tests.

Slug Tests

To obtain rapid water level readings, a pressure transducer was set in the test well attached at the surface to a data logger which stored the water level readings. The data logger used on this project was the HERMIT environmental data logger Model SE 1000B, In-Situ Inc.

The slug tests were conducted as follows:

- Measure initial water and hydrocarbon levels.
- Set transducer in well below water level.
- Pour 5 gallons of water down well.
- Record the corresponding water/hydrocarbon levels with respect to time until the water level recovers to 80 percent of its initial level.

The slug test data were analyzed in accordance with methods presented in "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells" (Bouwer and Rice, 1976).

The results of the slug tests are included in Appendix G, including all field data and computations.

Pump Tests

For the pump test, a hydrocarbon-resistant, explosion-proof submersible pump was operated to maintain a constant discharge rate. To obtain accurate and rapid water level readings, pressure transducers were set up in the pumped well and in the closest observation well. The transducers were attached to the data logger, which stored the water level readings for each well.

The pumping test procedure was as follows:

- Perform step-drawdown test to establish the optimal pumping test rate. Step-drawdown tests are performed by varying the discharge rates from the pumping well and observing the associated drawdown. The desired discharge may then be selected.
- Begin pump test at established pumping rate as determined in the step-drawdown test, and measure water levels in observation wells.
- Stop pump when drawdown data is sufficient in observation wells or water level approaches the pump intake in the pumping well. Begin recording recovery water level measurements in pumping and observation wells.
- Stop water level measurements when wells are nearly recovered.

Pump tests were initiated in monitoring wells MW-10, MW-17 and

MW-23. Before the tests were begun, each well was pumped at an approximate rate of 2 gallons per minute (gpm) until the discharged water was clean and free of fine sediments. An optimal pumping rate could not be established at MW-23; therefore, the pump test was relocated to well MW-17. Based on field observations during well development, a pumping rate of 2.0 gpm was chosen in MW-10 which would create an initial drawdown in the well. Various pumping rates were run in MW-17, and depth to water versus time was recorded. A final pumping rate of 2.2 gpm was established for the pump test in MW-17.

Pump tests were conducted after the water levels had recovered from development and the step-drawdown test. Water levels were recorded on a logarithmic schedule. During pumping, measurements were taken rapidly at the beginning of the pumpage phase and gradually decreased as testing progressed. Pumping was terminated in MW-10 after the water levels had stabilized. Pumping was terminated in MW-17 as the water level was approaching the pump intake. After the pumps were turned off, recovery data were taken in the observation and pumped wells and recorded on a logarithmic schedule similar to that during pumping. The initial water levels during pumping and recovery are most critical to proper aquifer test data analysis.

The recovery data from MW-17 were reduced and analyzed using the Jacob Modified Theis equation. Calculations are presented on the graphs (refer to Plates 8 through 11). The transmissivity (T) was

estimated using the recovery data. A representative hydraulic conductivity (K) was calculated from the value for transmissivity. Although the Theis equation was developed for non-leaky, confined aquifer conditions, in this case it can be applied to unconfined aquifer conditions such as those observed at NAS Norfolk. With long periods of pumping, the effects of gravity drainage under unconfined conditions became small, therefore the Theis equation provides a reliable approximation of drawdown in a well under unconfined conditions. Refer to references 4 and 9 in the Bibliography for complete theoretical applicability of the equations and data utilization in this analysis.

Two types of graphical analysis were used:

1. Residual drawdown plotted against the ratio t/t'; transmissivity is calculated from the pumping rate and the slope of the graph, using the equation:

$$T = \frac{264\ Q}{s'}, \text{ and } K = \frac{T}{b}$$

Where:

Q	=	Pumping rate, in gpm
s'	=	Slope of the graph, expressed as the change in residual drawdown between any two times on the log scale whose ratio is 10 (one log cycle)
t	=	Time since pumping began
t'	=	Time since pumping stopped
b	=	Aquifer thickness

2. Calculated recovery plotted against time after pumping stopped; transmissivity is calculated from the pumping rate and the slope of the graph, using the equation:

$$T = \frac{264\ Q}{s}\ ,\ \text{and}\ K = \frac{T}{b}$$

Where: Q = Pumping rate in gpm

s = Slope of the graph expressed as the change in the difference between projected drawdown and residual drawdown, and any two times on the log scale whose ratio is 10 (one log cycle)

b = Aquifer thickness

Based on the November 7, 1986 water level measurements, the hydraulic gradient of the groundwater surface is estimated to be .0011 feet/foot. Using data from the recovery test in monitoring well MW-17 the average hydraulic conductivity is estimated to be 90.5 gpd/ft^2 (1.4×10^{-4} ft/sec). Using data from the slug tests, the average hydraulic conductivity is estimated to be 111 gpd/ft^2 (1.7×10^{-4} ft/sec). The effective porosity was estimated to be 35 percent. Using these figures, particle velocity was estimated as follows:

<u>Recovery Test Data</u>

$$\text{Estimated Velocity} = \frac{(\text{Hydraulic Conductivity})\ (\text{Hydraulic Gradient})}{\text{Effective Porosity}}$$

$$\text{Estimated Velocity} = \frac{(1.4 \times 10^{-4}\ \text{ft/sec})\ (.0011\ \text{ft/ft})}{.35}$$

Estimated Velocity = 4.4×10^{-7} ft/sec

Estimated Velocity = 14 ft/yr

Slug Test Data

$$\text{Estimated Velocity} = \frac{(\text{Hydraulic Conductivity})\ (\text{Hydraulic Gradient})}{\text{Effective Porosity}}$$

$$\text{Estimated Velocity} = \frac{(1.7 \times 10^{-4}\ \text{ft/sec})\ (.0011\ \text{ft/ft})}{.35}$$

Estimated Velocity = 5.0×10^{-7} ft/sec

Estimated Velocity = 16 ft/yr

The particle velocity estimated above is for groundwater flow in the shallow aquifer at NAS Norfolk. The velocity of flow for phase separated hydrocarbon in the shallow aquifer at NAS Norfolk is probably of the same order of magnitude. The velocity of hydrocarbon flow can be significantly different (increased/decreased) from the velocity of groundwater flow in certain subsurface materials. Hydrocarbon flow is significantly affected by the chemical and physical characteristics of the subsurface materials.

β

APPENDIX B
SITE SPECIFIC SAFETY PLAN

HARDING LAWSON ASSOCIATES

SITE SPECIFIC
JOB HEALTH AND SAFETY PLAN

SITE INVESTIGATION
NAS NORFOLK,VIRGINIA

PREPARED FOR:

DEPARTMENT OF THE NAVY
SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
CHARLESTON, SOUTH CAROLINA

Engineers
Geologists &
Geophysicists

6220 Westpark Dr
Suite 100
Houston, TX 77057

Telephone
713/789-8050

Alaska
Arizona
California

Colorado
Hawaii
Nevada

Texas

HEALTH AND SAFETY PLAN
CERTIFICATION

I certify that I _____ have read this site-specific Job Health and Safety Plan (JHASP) and applicable sections of the HLA Generic Health and Safety Plan (GHASP) and am familiar with the provisions therein.

	(name)	(signature)
Site Safety Officer	Richard Cunningham	Richard Cunningham
Project Manager	[illegible]	[illegible]
Other Site Personnel		

Harding Lawson Associates

JOB SAFETY PLAN

Part 1 - Site Information

1. Site: *NAS Norfolk* 2. Job No.: *02176,078.12*
3. Location: *Norfolk Naval Air Station Norfolk, Virginia*
4. Plan Prepared By: *Richard C. Cunningham* Date: *5/21/86*
5. Plan Approved By: _____ Date: _____
6. Plan Revised: _____ 7. Approved: _____
8. Facility Description: *Active Naval Air Station*
9. Status (active, inactive, unknown): *Active*
10. Unusual Features (dike integrity, powerlines, etc.): *Pipe Leak, unknown pipe Location*
11. History (injuries, exposures, complaints): *Seepage into Boush Creek Culvert*
12. Surroundings (location with respect to residences, businesses, natural features): *75% Pavement, Buildings, Tank Farm, Taxiways*
13. Site Sketch (attach sketch showing salient features)
14. Climate: *Mid-Atlantic Coastal*

    a) average wind speed and direction: *5 KTS from East*

    b) *Estimated*

	July	October	January	April
mean high temperature	87	72	50	70
mean low temperature	65	55	35	50

15. Hazardous Material Type: __Liquid __Solid __Sludge __Gas/Vapor __Other _____
16. Hazardous Material Characteristics: __Corrosive __Ignitable __Toxic __Volatile __Reactive __Radioactive __Carcinogenic __Other _____

17. Chemical Information Summary

Material Name	*JP-4* *JP-5*
Chemical Constituent	
Information Reference/Page	

Likely Encounter

Source (1)	*S/GW* *S/GW*
Physical State (2)	*L/V* *L/V*

Concentrations

Measured or Estimated	*E*
Media	*Soil*
Maximum Value	*Free Prod.*
Minimum Value	

Pure Chemical Characteristics *(See Attached Hazardline)*

Water Solubility	
Vapor Density	
Flash Point	
Vapor Pressure	
LEL	
UEL	

Hazard Specifics of Pure Chemical

STEL	
TLV	
LD50/LC50	
IDLH Level	
Odor Threshold	
Hazard Property (3)	
Exposure Route (4)	
Toxic Effects (5)	
Respirator Level	

(1) Tank, drum, soil, groundwater, surface impoundment, etc.
(2) Liquid, solid, gas, vapor, dust, fume, mist, sludge
(3) Corrosive, ignitable, toxic, volatile, reactive, radioactive, carcinogenic, infections, etc., Fill in all that apply.
(4) Inhalation, skin absorption, ingestion, skin and eye contact
(5) Exposure symptoms and effects

Task Description: Drilling Boreholes and Installing Monitor Wells

Task Name: Borehole Drilling

18. ANALYSIS OF KNOWN OR SUSPECTED UNMITIGATED HAZARDS		19. RISK ANALYSIS		
Hazard Type	How Does Hazard Exist?	Expos	Prob	Conseq
Mechanical	Drilling	Cont	Unk	Min to Fatal
Electrical	Underground Lines	OCC	Unk	Min to Fatal
Chemical	Underground Lines	OCC	Unk	Min to Fatal
Temperature	Stress	Cont	Unk	Min
Acoustical				
Radioactive				
O2 Deficiency				
Biohazard				

Expos: Frequency of exposure to the hazard event
- cont - many times per day
- freq - once or twice per day
- occ - once a week or month
- seld - once a month or year

Prob: Liklihood that an injury will occur upon exposure
- cert - certain
- like - 50/50 chance
- unu - unusual
- imp - improbable

Conseq: Degree of injury if one occurs
- fatal - fatality
- ser - serious, requires hospitalization
- mod - moderate, requires out-patient care
- min - requires on-site first aid
- chron - chronic, no acute affects

20. MITIGATION MEASURES	REQUIRED PERSONAL PROTECTIVE EQUIPMENT	
Observe safe drilling standards	LEVEL _A _B _C x D	
Research Location of all underground/overhead	Head: Hard Hat	Eye/Face: Glasses Available
Run a geophysical survey to locate underground lines at each drilling location	Hand: Neoprene	Body: Coated Tyvek Available
	Lung:	Ear:
	Foot: Steel Toe	Rubber Available
	Special Equipment Required: Combustible Gas Indicator, No. 10 Fire Extinguisher	

Special Procedures Required:

Monitor Borehole with combustible Gas Indicator

Provide a No. 10 Fire Extinguisher

Provide dry ice to be placed in Borehole should CBl reading exceed 25% LEL

Avoid high RPM Drilling at all times

No Smoking

Advise against contact lenses

21. Required Personal Protective Equipment

Task: *Drilling Boreholes and Installing Monitor Wells*

Level: ___A ___B ___C x D

Head

/ Hardhat

Eye/Face *(If Necessary)*

/ Safety Glasses ___ Face Shield
___ Goggles

Hand *(If Necessary)*

/ Neoprene ___ Nitrile ___ PVC
___ Viton ___ Underglove ___ Other: ___

Body

___ Full Encapsulating Suit: ___

___ Two Piece Rainsuit, Material = ___

___ One Piece Splash Suite, Material = ___

___ Tyvek Suit ___Tyvek/Saranax Suit / Tyvek/Polyethylene Suit *(If Necessary)*

___ Cloth Coveralls ___ Other: ___

Lung

___ SCBA (open circuit, pressure demand): ___

___ Full Face Respirator, cartridge = ___

___ Half Mask Respirator, cartridge = ___

___ Other: ___

Ear

___ Earplug, type = ___

___ Earmuff, type = ___

Foot

/ Boots, type = *Steel Toe Rubber if necessary*

___ Disposable Overboots, type = ___

22. Special Equipment, Facilities, or Procedures: ___

Combustible Gas Indicator

No. 10 Fire Extinguisher

Dry Ice

Safety Glasses, Polyethylene Coated Tyvek, Neophene Gloves and Rubber Boots will be available should conditions warrant

23. **Decontamination Procedures:** *Steam Clean Drilling and Sampling Equipment after each boring in which Jet Fuel is found*

24. **Investigation-Derived Material Disposal:** *Cuttings remain on site, if contaminated, handle as hazardous waste, Contaminated cuttings should be drummed or in other containers as soon as possible.*

25. **Site Resources**
Water Supply: *Local Buildings*
Telephone: *Local Buildings*
Radio:
Other:

26.

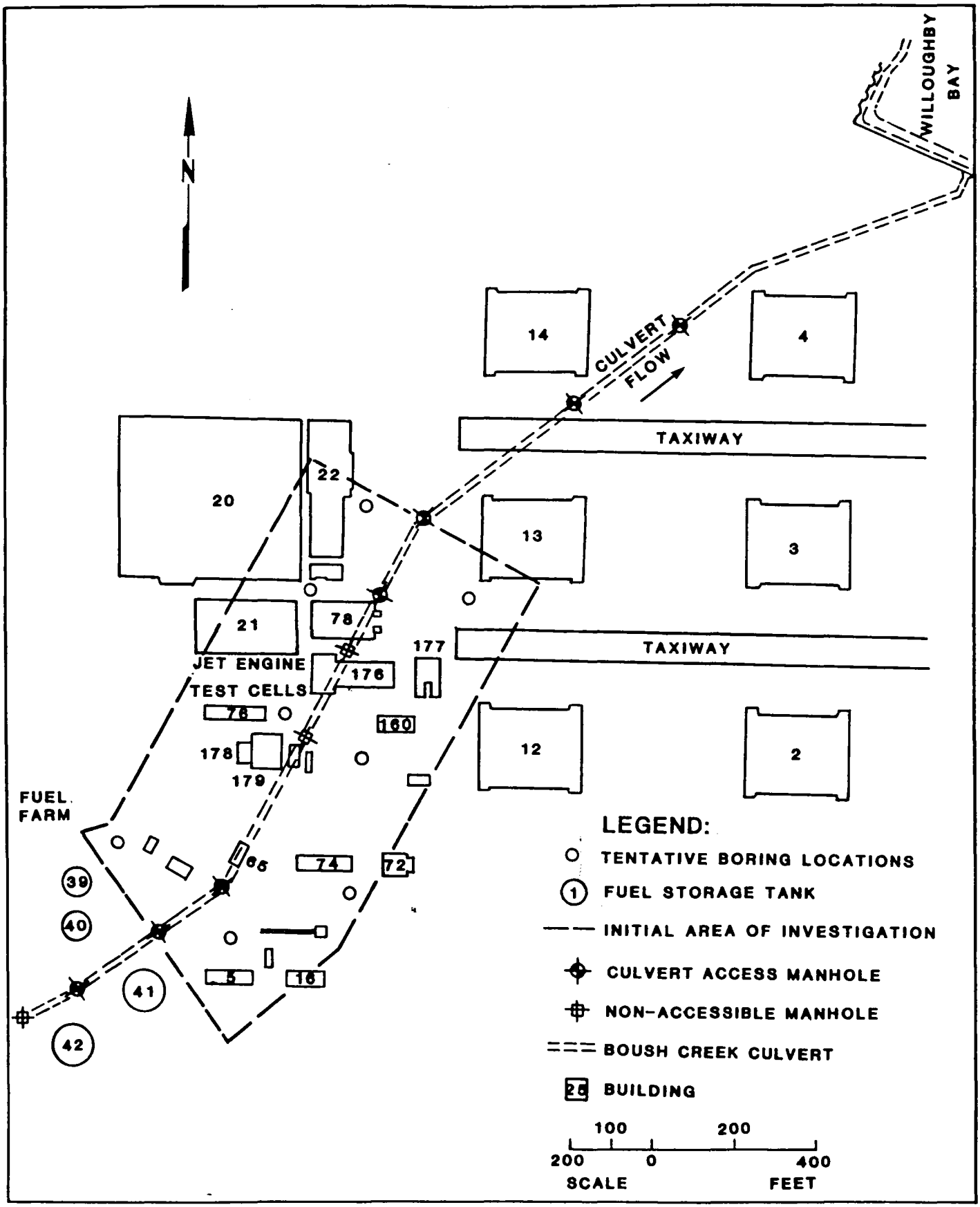
Team Member	Responsibility	Date of Safety Training	Date of Physical Exam
Jim Tremblay	*Project Consultant*	*5/85*	*2/85*
Hank Peters	*Project Manager*	*3/86*	*4/86*
Steve Neely	*Engineering*	*10/85*	*8/86*
Richard Cunningham	*Geophysics*	*10/85*	*5/86*
David Gibbs	*Geophysics*	*12/83*	*8/85*
Barry Harrison	*Drilling Supervisor*	*7/86*	*6/86*
Clara Mizenko	*Hydrogeology*	*3/86*	*3/86*

27. **Emergency Telephone Numbers**
Phone/Radio Location: *All emergency facilities are on the base. Will coordinate with base personnel.*
Ambulance: *444-2676*
Hospital Emergency Room: *444-1532*
Poison Control Center: *Portsmouth Naval Hospital 398-5898*
Police: *444-3333*
Fire Department: *444-2361*
Airport: *-*
Explosives Unit: *422-7191*
EPA Contact: *-*
State Contact:
Client: *Paul Parker (804) 445-2932*

28. **Emergency Equipment Location**
a. Safety Shower/Eyewash
b. First Aid Kit
c. Fire Extinguishers *at rig*
d. Other

29. **Emergency Routes (give road or other directions; attach map)**
Hospital

Other



Harding Lawson Associates
Engineers, Geologists
& Geophysicists

SITE PLAN

NAS - NORFOLK, VIRGINIA

PLATE 1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
EL	2176,078.12	RC	6/26		

CHEMICAL NAME
JET FUEL JP-5

FORMULA
MIXTURE

SYNONYMS
KEROSENE, HEAVY
JP-5 JET FUEL
UN 1863
OHS12320

PERMISSIBLE EXPOSURE LIMIT
NONE ESTABLISHED
AQUATIC TOXICITY RATING 1 (TLM96 100 - 1000 PPM)
NO DATA LOCATED - A (1) RATING WAS ASSIGNED, AS IT IS PROBABLY LESS TOXIC THAN GASOLINE (2), AND MORE TOXIC THAN KEROSENE (0).
CERCLA HAZARD RATINGS - TOXICITY U - IGNITABILITY 2 - REACTIVITY 0 - PERSISTENCE 1

IMMEDIATELY DANGEROUS TO LIFE OR HEALTH CONCENTRATION
NONE SPECIFIED

PHYSICAL DESCRIPTION
COLORLESS TO LIGHT BROWN LIQUID
MILD PETROLEUM ODOR

CHEMICAL AND PHYSICAL PROPERTIES
MOLECULAR WEIGHT: VARIES
BOILING POINT AT 1 ATM, F: 349 TO 549 F
SOLUBILITY IN WATER, G/100 G WATER AT 20C: INSOLUBLE
FLASH POINT, CLOSED CUP, F (OR OPEN CUP IF OC): 95 TO 145 F
VAPOR PRESSURE @ 20 C, MMHG: NA
MELTING POINT, F: <-54 F
UPPER EXPLOSIVE LIMIT IN AIR, % BY VOLUME: 4.6
LOWER EXPLOSIVE LIMIT IN AIR, % BY VOLUME: 0.6
AUTOIGNITION TEMPERATURE: 475 F (EST.)
SPECIFIC GRAVITY: 0.82

INCOMPATIBILITIES
STRONG OXIDIZERS
HEAT
THERMAL DECOMPOSITION PRODUCTS ARE HAZARDOUS AND/OR TOXIC

PERSONAL PROTECTIVE EQUIPMENT
NO NIOSH/OSHA DATA; RECOMMEND
PREVENT REPEATED OR PROLONGED SKIN CONTACT
WEAR IMPERVIOUS CLOTHING
WEAR GLOVES
WEAR FACESHIELD (8 INCH MINIMUM)

PLACE CONTAMINATED CLOTHING IN CLOSED CONTAINERS FOR STORAGE UNTIL LAUNDERED OR DISCARDED
IF CLOTHING IS TO BE LAUNDERED, INFORM PERSON PERFORMING OPERATION OF CONTAMINANT'S HAZARDOUS PROPERTIES

GOGGLES
NO STANDARD REQUIREMENT, BUT ADVISE EYE PROTECTION TO
PREVENT REASONABLE PROBABILITY OF EYE CONTACT
WEAR FACE SHIELD OR VENTED GOGGLES

WASHING CHEMICALS FROM THE SKIN
NO STANDARD REQUIREMENT, BUT ADVISE WASHING
PROMPTLY WHEN SKIN BECOMES CONTAMINATED AND AT END OF EACH WORK SHIFT

ROUTINE CHANGING OF WORK CLOTHING
NO STANDARD REQUIREMENT, BUT ADVISE CHANGING
IF IT IS REASONABLY PROBABLE THAT CLOTHING IS CONTAMINATED
LEAVE CLOTHING & EQUIPMENT FOR DECONTAMINATION & DISPOSAL

CLOTHING REMOVAL FOLLOWING ACCIDENTAL CONTAMINATION
NO STANDARD REQUIREMENT, BUT ADVISE REMOVING
PROMPTLY IF IT IS NON-IMPERVIOUS AND CONTAMINATED

SPECIFIC EMERGENCY PROVISIONS
NO NIOSH/OSHA DATA, ADVISE:
EYE-WASH FOUNTAIN WITHIN IMMEDIATE WORK AREA WHERE EMPLOYEES' EYES MAY BE EXPOSED TO SUBSTANCE
QUICK DRENCHING FACILITIES WITHIN IMMEDIATE WORK AREA WHERE EMPLOYEES MAY BE EXPOSED TO SUBSTANCE

RESPIRATOR SELECTION (UPPER LIMIT DEVICES PERMITTED)

NO SPEC: ADVISE
- CHEMICAL CARTRIDGE RESPIRATOR
  WITH AN ORGANIC VAPOR CARTRIDGE
  WITH A DUST, MIST, AND FUME FILTER

HIGH LEVELS
- SELF-CONTAINED BREATHING APPARATUS
  WITH A FULL FACE-PIECE, HELMENT, OR HOOD

FIREFIGHTING
- SELF-CONTAINED BREATHING APPARATUS
  WITH A FULL FACE-PIECE
  OPERATED IN PRESSURE-DEMAND OR POSITIVE-PRESSURE MODE

ROUTE OF ENTRY INTO BODY
INHALATION
SKIN OR EYE CONTACT
INGESTION

SYMPTOMS
RESPIRATORY IRRITATION
MUCOUS MEMBRANE IRRITATION
DYSPNEA
EYE IRRITATION
SKIN IRRITATION
DERMATITIS
ECZEMA
HEADACHE
ABDOMINAL PAIN
CENTRAL NERVOUS SYSTEM DEPRESSION
NAUSEA
VOMITING
STUPOR
CONVULSIONS

UNCONSCIOUSNESS
PNEUMONITIS
COUGHING
INCOORDINATION
RESPIRATORY EDEMA
DIZZINESS
HEMATOPOIETIC BLOOD CHANGES IF BENZENE IN SUBSTANCE

FIRST AID PROCEDURES FOLLOWING EXPOSURE

IF THIS CHEMICAL GETS INTO THE EYES, IMMEDIATELY WASH THE EYES WITH LARGE AMOUNTS OF WATER, OCCASIONALLY LIFTING THE LOWER AND UPPER LIDS. GET MEDICAL ATTENTION IMMEDIATELY. CONTACT LENSES SHOULD NOT BE WORN WHEN WORKING WITH THIS CHEMICAL.

IF THIS CHEMICAL GETS ON THE SKIN, IMMEDIATELY WASH CONTAMINATED SKIN WITH SOAP OR MILD DETERGENT & WATER. IF THIS CHEMICAL SOAKS CLOTHING, IMMEDIATELY REMOVE CLOTHING & WASH SKIN WITH SOAP OR MILD DETERGENT & WATER. GET MEDICAL ATTENTION PROMPTLY.

IF A PERSON BREATHES IN LARGE AMOUNTS OF THIS CHEMICAL, MOVE THE EXPOSED PERSON TO FRESH AIR AT ONCE. IF BREATHING HAS STOPPED PERFORM ARTIFICIAL RESPIRATION. KEEP THE AFFECTED PERSON WARM AND AT REST. GET MEDICAL ATTENTION AS SOON AS POSSIBLE.

WHEN THIS CHEMICAL HAS BEEN SWALLOWED, DO NOT INDUCE VOMITING. REMOVE BY GASTRIC LAVAGE AND CATHARSIS.

INGESTION OF PETROLEUM DISTILLATES/HYDROCARBONS:
EMERGENCY TREATMENT - PREVENT ASPIRATION. IF AMOUNT INGESTED EXCEES 1 ML/KG, OR IF TOXIC INGREDIENT PRESENT, SUBSTANCE MUST BE REMOVED. GASTRIC LAVAGE WITH ACTIVATED CHARCOAL AND CUFFED ENDOTRACHEAL TUBE TO PREVENT ASPIRATION SHOULD BE PERFORMED WITHIN 15 MINUTES. IN ABSENCE OF DEPRESSION OR CONVULSIONS OR GAG REFLEX, IPECAC EMESIS CAN ALSO BE DONE WITHOUT INCREASING ASPIRATION HAZARD. WHEN VOMITING OCCURS, HOLD PATIENT WITH HEAD LOWER THAN HIPS TO PREVENT ASPIRATION. AFTER VOMITING CEASES, GIVE 30-60 ML OF FLEET'S PHOSPHO-SODA DILUTED 1:4 IN WATER.
FURTHER TREATMENT - GIVE ARTIFICIAL RESPIRATION WITH OXYGEN IF NECESSARY.
SPECIAL TREATMENT - TREAT BACTERIAL ASPIRATION PNEUMONIA BY ORGANISM-SPECIFIC CHEMOTHERAPY. TREAT PULMONARY EDEMA. (DREISBACH, HANDBOOK OF POISONING, 11TH ED.)

GASTRIC LAVAGE - GIVE PATIENT GLASS OF WATER PRIOR TO PASSING OF STOMACH TUBE. LAY PATIENT ON ONE SIDE, WITH HEAD LOWER THAN WAIST. IMMOBILIZE A STRUGGLING PATIENT WITH A SHEET OR BLANKET. MEASURE DISTANCE ON TUBE FROM MOUTH TO EPIGASTRIUM, MARK TUBE WITH INDELIBLE MARKING OR TAPE. REMOVE DENTURES AND OTHER FOREIGN OBJECTS FROM MOUTH. OPEN MOUTH, USE GAG IF NECESSARY. EXTEND HEAD BY LIFTING THE CHIN. PASS TUBE OVER TONGUE AND TOWARD BACK OF THROAT WITHOUT EXTENDING HEAD OR NECK. IF OBSTRUCTION IS MET BEFORE THE MARK ON TUBE REACHES LEVELS OF TEETH, DO NOT FORCE, BUT REMOVE TUBE AND REPEAT PROCEDURE UNTIL TUBE PASSES TO MARK. PLACE END OF TUBE IN GLASS OF WATER. IF TUBE IS OBSTRUCTED WHEN INTRODUCED ABOUT HALFWAY TO THE MARK, IT MAY HAVE ENTERED TRACHEA.

AFTER TUBE IS PLACED IN STOMACH, ASPIRATE FIRST TO REMOVE STOMACH CONTENTS BY IRRIGATION SYRINGE. SAVE STOMACH CONTENTS FOR EXAMINATION, AND REPEAT INTRODUCTION AND WITHDRAWAL OF 100-200 ML WARM WATER UNTIL AT LEAST 3 LITERS OF CLEAR RETURN ARE OBTAINED. USE ACTIVATED CHARCOAL AT BEGINNING OF LAVAGE TO AID IN POISON INACTIVATION. LEAVE

IF INTRODUCTION AND REMOVAL OF LAVAGE FLUID BY GRAVITY REQUIRES MORE THAN FIVE MINUTES, ASSIST WITH ASEPTO SYRINGE. PREVENT ASPIRATION WITH CUFFED ENDOTRACHEAL TUBE. AVOID GIVING LARGE QUANTITIES OF WATER.

MASSAGE OF EPIGASTRIUM WHILE STOMACH TUBE IS BEING ASPIRATED MAY AID IN POISON REMOVAL.

IF PATIENT COMATOSE, INTUBATE TRACHEA WITH CUFFED ENDOTRACHEAL TUBE. SUCCINYLCHLORINE MAY BE ADMINISTERED BY QUALIFIED MEDICAL PERSONNEL TO EASE INSERTION OF TRACHEAL CATHETER PRIOR TO PASSAGE OF STOMACH TUBE.
(DREISBACH, HANDBOOK OF POISONING, 11TH ED.)

ACTIVATED CHARCOAL - GIVE ACTIVATED CHARCOAL WITHIN FIRST MINUTES OF POISONING. GIVE PORTION EQUIVALENT TO ABOUT 5 ML/KG, ORALLY OR BY GASTRIC LAVAGE. REMOVE BY SUCTION OR EMESIS AND REPEAT UNTIL A TOTAL OF 100 GRAMS OF CHARCOAL HAS BEEN INTRODUCED AND RECOVERED. ONE GRAM OF CHARCOAL ADSORBS 100-1000 MG OF POISON. DO NOT MIX CHARCOAL WITH OTHER AGENTS TO INCREASE PALATABILITY.
(DREISBACH, HANDBOOK OF POISONING, 11TH ED.)

SYRUP OF IPECAC - GIVE 15 ML (ONE TABLESPOON) OF SYRUP OF IPECAC FOLLOWED BY ONE-HALF GLASS OF WATER. IF EMESIS DOES NOT OCCUR IN THIRTY MINUTES, REPEAT WITH SAME DOSE. IF PATIENT MUST BE MOVED, KEEP IN HEAD-DOWN POSITION TO FACILITATE EMESIS AND PREVENT ASPIRATION OF VOMITUS. IF EMESIS DOES NOT OCCUR AFTER SYRUP OF IPECAC IS GIVEN, PERFORM GASTRIC LAVAGE TO PREVENT EMETINE POISONING. SAVE SPECIMENS OF EMESIS FOR ANALYSIS.
(DREISBACH, HANDBOOK OF POISONING, 11TH ED.)

PULMONARY EDEMA - RELIEVE ANXIETY. GIVE MORPHINE SULFATE, 10 MG, TO DECREASE RATE OF RAPID, INEFFICIENT RESPIRATION. GIVE 40% OXYGEN BY FACE MASK. USE INTERMITTENT POSITIVE-PRESSURE OXYGEN RESUSCITATOR FOR SHORT PERIODS. GIVE AMINOPHYLLINE, 0.5 G, INTRAVENOUSLY, TO RELIEVE ASSOCIATED BRONCHIAL CONSTRICTION. TREAT EDEMA CAUSED BY MORPHINE OR MORPHINE ANALOGS BY GIVING NALOXONE AND OXYGEN.
(MEDICATION MUST BE GIVEN BY QUALIFIED MEDICAL PERSONNEL)
(DREISBACH, HANDBOOK OF POISONING, 11TH ED.)

ORGANS
LUNGS
RESPIRATORY SYSTEM
MUCOUS MEMBRANES
SKIN
CENTRAL NERVOUS SYSTEM
EYES

STATUS OF REGULATORY ENFORCEMENT
OSHA STANDARD 29CFR1910.1200 HAZARD COMMUNICATION
REQUIRES CHEMICAL MANUFACTURERS AND IMPORTERS TO ASSESS THE HAZARDS OF CHEMICALS WHICH THEY PRODUCE OR IMPORT, AND ALL EMPLOYERS HAVING WORKPLACES IN THE MANUFACTURING DIVISION, STANDARD INDUSTRIAL CLASSIFICATION CODES 20 THROUGH 39, TO PROVIDE INFORMATION TO THEIR EMPLOYEES CONCERNING HAZARDOUS CHEMICALS BY MEANS OF HAZARD COMMUNICATION PROGRAMS INCLUDING LABELS, MATERIAL SAFETY DATA SHEETS, TRAINING, AND ACCESS TO WRITTEN RECORDS
49FR59250 11/25/83

FOLLOWING OSHA STANDARDS APPLICABLE TO SUBSTANCES LISTED 29CFR1910, OTHERWISE ADVISE:

OSHA STANDARD 29CFR1910.94 VENTILATION

OSHA STANDARD 29CFR1910.134 RESPIRATORY PROTECTION

OSHA STANDARD 29CFR1910.20 ACCESS TO EMPLOYEE EXPOSURE AND MEDICAL RECORDS

OSHA STANDARD 29CFR1910.132 PERSONAL PROTECTIVE EQUIPMENT

OSHA STANDARD 29CFR1910.141 SANITATION

OSHA STANDARD 29CFR1910.151 MEDICAL SERVICES AND FIRST AID

OSHA STANDARD 29CFR1910.133 EYE AND FACE PROTECTION

40CFR717 RECORDS AND REPORTS OF ALLEGATIONS THAT CHEMICAL SUBSTANCES CAUSE SIGNIFICANT ADVERSE REACTIONS TO HEALTH OR THE ENVIRONMENT
REQUIRES MANUFACTURERS AND CERTAIN PROCESSORS OF CHEMICAL SUBSTANCES AND MIXTURES TO KEEP RECORDS OF SIGNIFICANT ADVERSE REACTIONS TO HEALTH OR THE ENVIRONMENT ALLEGED TO HAVE BEEN CAUSED BY A SUBSTANCE OR MIXTURE. EPA MAY INSPECT AND REQUIRE REPORTING OF SUCH RECORDS.
48FR38178 08/22/83

49CFR172.101 TABLES OF HAZARDOUS MATERIALS, THEIR DESCRIPTION, PROPER SHIPPING NAME, CLASS, LABEL, PACKAGING, AND OTHER REQUIREMENTS
DESIGNATED IN HAZARDOUS MATERIALS TABLE AS HAZARDOUS MATERIAL FOR THE PURPOSE OF TRANSPORTATION.
41FR15996 04/15/76
45FR34588 05/22/80 (AMENDMENT)
45FR46420 07/10/80 (AMENDMENT)
45FR62080 09/18/80 (AMENDMENT)
45FR74649 11/10/80 (AMENDMENT)
46FR17739 03/19/81 (AMENDMENT)
46FR19235 03/30/81 (AMENDMENT)

49CFR172.102 TABLES OF HAZARDOUS MATERIALS, THEIR DESCRIPTION, PROPER SHIPPING NAME, CLASS, LABEL, PACKAGING, AND OTHER REQUIREMENTS
DESIGNATED IN OPTIONAL HAZARDOUS MATERIALS TABLE (UNDER N.O.S. CATEGORY) WITH ALTERNATIVES TO CORRESPONDING REQUIREMENTS IN 49CFR172.101 FOR INTERNATIONAL SHIPMENTS.
41FR15996 04/15/81
46FR29393 06/01/81 (AMENDMENT)
46FR32250 06/22/81 (AMENDMENT)

TECHNICAL ASSISTANCE DATA COMPLETED/PUBLISHED CLEAN WATER ACT (CWA) SECTION 311

SUBSTANCE AND MIXTURES CONTAINING 10% OR MORE BY WEIGHT OF THIS SUBSTANCE REQUIRE SPECIAL LABELING UNDER FEDERAL HAZARDOUS SUBSTANCES ACT SECTION 3(B). 16CFR1500.14

MEDICAL SURVEILLANCE REQUIRED
NO NIOSH/OSHA DATA; ADVISE:
EBG RECOMMENDED IF EMPLOYEE TO WEAR FULL-FACE RESPIRATOR
GENERAL MEDICAL HISTORY
40CFR717 RECORDS AND REPORTS OF ALLEGATIONS THAT CHEMICAL SUBSTANCES CAUSE SIGNIFICANT ADVERSE REACTIONS TO HEALTH OR THE ENVIRONMENT
TOXIC SUBSTANCES CONTROL ACT (TSCA) SECTION 8(C) RULE REQUIRES

MANUFACTURERS AND CERTAIN PROCESSORS OF CHEMICAL SUBSTANCES AND MIXTURES TO KEEP RECORDS OF SIGNIFICANT ADVERSE REACTIONS TO EMPLOYEE HEALTH FOR 30 YEARS
48FR38187 08/22/83
48FR39225 08/30/83 (EFFECTIVE DATE CORRECTION)
PHYSICIAN EXAMINATION
INDUSTRIAL EXPOSURE HISTORY
PRE-PLACEMENT AND ANNUAL EXAMS
MEDICAL WARNING FOR REFUSAL OF MEDICAL EXAMINATION
CENTRAL NERVOUS SYSTEM EXAMINATION
BLOOD CHEMISTRY
WHEN BENZENE PRESENT

CERTIFICATIONS

NO FEDERAL AGENCY REQUIREMENT, BUT DUE TO HAZARDOUS NATURE OF SUBSTANCE, ADVISE FOLLOWING:

HEALTH STATUS CLASSIFICATION

OSHA RESPIRATOR CERTIFICATION 29CFR1910.134

DEPARTMENT OF TRANSPORTATION IF OPERATES HEAVY EQUIPMENT

EMPLOYEE HAZARDOUS MATERIALS EDUCATION RECEIPT

EMPLOYEE MEDICAL RECORDS RECEIPT

TOXIC SUBSTANCES CONTROL ACT (TSCA) SECTION 8(C) RULE REQUIRES MANUFACTURERS AND CERTAIN PROCESSORS OF CHEMICAL SUBSTANCES AND MIXTURES TO KEEP RECORDS OF SIGNIFICANT ADVERSE REACTIONS TO EMPLOYEE HEALTH FOR 30 YEARS. CONTACT: JACK P. MCCARTHY, OFFICE OF TOXIC SUBSTANCES, EPA (800)424-1404. 48FR38178 8/22/83

MEDICAL WARNING REQUIRED FOR MEDICAL EXAM REFUSAL SIGNED BY EMPLOYEE

SPECIAL DIAGNOSTIC TESTS

IF SYMPTOMS OF CENTRAL NERVOUS SYSTEM OCCUR, OBTAIN BLOOD GLUCOSE AND RECTAL TEMPERATURE. PERFORM COMPLETE NEUROLOGIC EXAMINATION AND ANY OTHER SPECIFIC NEUROLOGIC TESTS AS APPLICABLE

CONVULSIONS - BLOOD ANALYSIS FOR GLUCOSE, CALCIUM, UREA NITROGEN AND CARBON DIOXIDE

LEAKS AND SPILL PROCEDURES

****

DEPARTMENT OF TRANSPORTATION HAZARD CLASS
49CFR172.101 HAZARDOUS MATERIALS TABLE

FLAMMABLE LIQUID

DEPARTMENT OF TRANSPORTATION LABELING REQUIREMENTS
49CFR172.101 (SUBJECT TO ADDITIONAL LABELING REQUIREMENTS OF 49CFR172.402)

FLAMMABLE LIQUID

WASTE

THIS MATERIAL NOT LISTED AS HAZARDOUS SUBSTANCE, AS DEFINED IN SECTION 101(14) OF THE COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA) OF 1980, PURSUANT TO ONE OR MORE OF THE FOLLOWING:

* FEDERAL WATER POLLUTION CONTROL ACT (FWPCA) SECTION 311(B)(2)(A)
* SOLID WASTE DISPOSAL ACT SECTION 3001
* CLEAN WATER ACT (CWA) SECTION 307(A)
* CLEAN AIR ACT (CAA) SECTION 112
* TOXIC SUBSTANCES CONTROL ACT (TSCA) SECTION 7
* COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA) SECTION 102

CAS NUMBER

UNKNOWN

REGISTRY TOXIC CHEMICALS NUMBER

NONE

BULLETINS

SPECIAL INFORMATION

MIXTURE OF PARAFFINIC, OLEFINIC, NAPHTHENIC, AND AROMATIC HYDROCARBONS.

TYPE WHAT INFORMATION YOU REQUIRE

/ALL/, SPECIFIC INFORMATION (BY 4-LETTER COMMAND, /HELP/, OR /NONE/.

APPENDIX C

BORING LOGS

TABLE C-1

BORING/WELL NUMBERING

HLA Report Boring/Well No.	USN Number
MW-1	NFK-LP-44-MW-1
MW-2	NFK-LP-44-MW-2
MW-3	NFK-LP-44-MW-3
MW-4	NFK-LP-44-MW-4
MW-5	NFK-LP-44-MW-5
MW-6	NFK-LP-44-MW-6
MW-7	NFK-LP-44-MW-7
MW-8	NFK-LP-44-MW-8
MW-9	NFK-LP-44-MW-9
MW-10	NFK-LP-44-MW-10
MW-11	NFK-LP-44-MW-11
MW-12	NFK-LP-44-MW-12
MW-13	NFK-LP-44-MW-13
MW-14	NFK-LP-44-MW-14
MW-15	NFK-LP-44-MW-15
MW-16	NFK-LP-44-MW-16
MW-17	NFK-LP-44-MW-17
MW-18	NFK-LP-44-MW-18
MW-19	NFK-LP-44-MW-19
MW-20	NFK-LP-44-MW-20
MW-21	NFK-LP-44-MW-21
MW-22	NFK-LP-44-MW-22
MW-23	NFK-LP-44-MW-23
MW-24	NFK-LP-44-MW-24

MAJOR DIVISIONS				TYPICAL NAMES
COARSE-GRAINED SOILS MORE THAN HALF IS LARGER THAN NO. 200 SIEVE	GRAVELS MORE THAN HALF COARSE FRACTION IS LARGER THAN No. 4 SIEVE SIZE	CLEAN GRAVELS WITH LITTLE OR NO FINES	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES
			GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES
		GRAVELS WITH OVER 12% FINES	GM	SILTY GRAVELS, POORLY GRADED GRAVEL-SAND-SILT MIXTURES
			GC	CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES
	SANDS MORE THAN HALF COARSE FRACTION IS SMALLER THAN NO. 4 SIEVE SIZE	CLEAN SANDS WITH LITTLE OR NO FINES	SW	WELL-GRADED SANDS, GRAVELLY SANDS
			SP	POORLY GRADED SANDS, GRAVELLY SANDS
		SANDS WITH OVER 12% FINES	SM	SILTY SANDS, POORLY GRADED SAND-SILT MIXTURES
			SC	CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES
FINE-GRAINED SOILS MORE THAN HALF IS SMALLER THAN NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT 50% OR LESS		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS, OR CLAYEY SILTS WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL	ORGANIC CLAYS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50%		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS

UNIFIED SOIL CLASSIFICATION SYSTEM

Bentonite Seal

Concrete/Bentonite Grout

Grout

KEY TO WELL CONSTRUCTIONS

Filter Sand

Well Screen

Pea Gravel

Solid Casing

KEY TO WELL CONSTRUCTION

Harding Lawson Associates
Engineers, Geologists
& Geophysicists

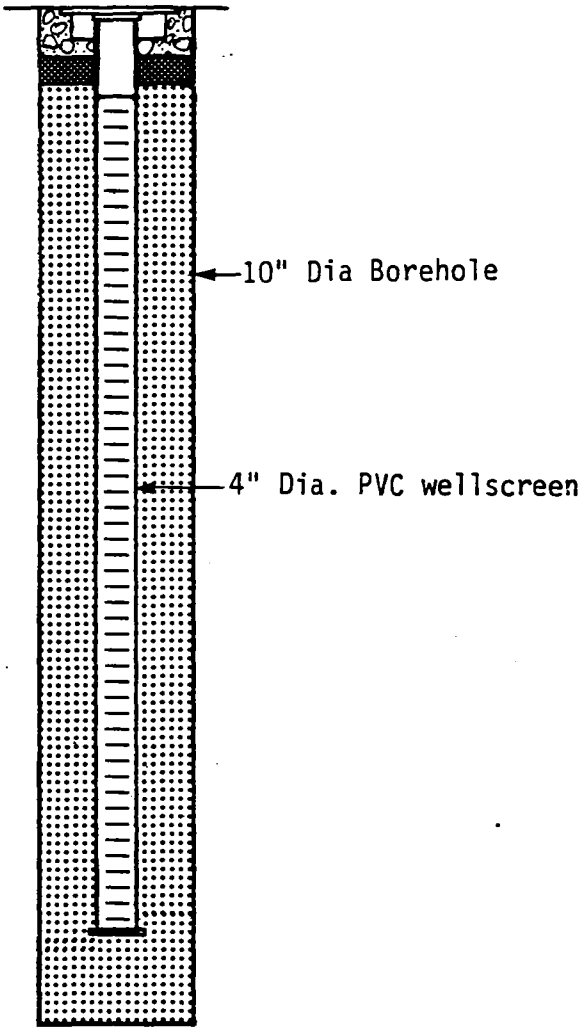
SOIL CLASSIFICATION CHART AND KEY TO WELL CONSTRUCTION

NAS Norfolk
Norfolk, Virginia

PLATE
C-1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
S.K.	2176,085.12	[illegible]	8/24/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 12.81* Date 9/4/86 to 9/5/86

Depth (ft) | Sample

0 — 2-inches Brown Topsoil

BROWN TO TAN WELL-GRADED SAND WITH SILT (SW-SM)
medium dense, moist, fine- to medium-grained

5 — TAN WELL-GRADED SAND (SW)
loose, moist, medium-grained, with occasional shell fragments
medium- to coarse-grained below 3.5 feet
hydrocarbon streaming from sample at 5.5 to 6.0 feet

10 — LIGHT BROWN & TAN WELL-GRADED SAND WITH CLAY (SW-SC)
loose, wet, medium- to coarse-grained

15 — LIGHT BROWN & TAN WELL-GRADED SAND WITH SILT (SW-SM)
loose, wet, medium- to coarse-grained

20 — ORANGE CLAY WITH SAND (CL)
soft

25 — gray clay below 25.0 feet

End of Boring - 26.5 feet

30

35

40

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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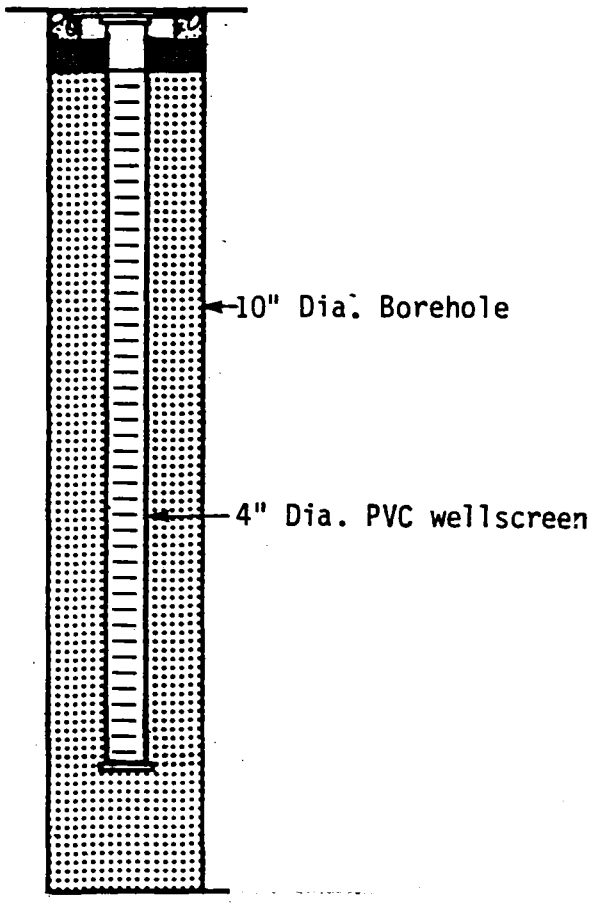
LOG OF BORING/MONITORING WELL MW-1

NAS Norfolk
Norfolk, Virginia

PLATE **C-2**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12		8/24/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 11.70* Date 9/6/86

Depth (ft)	Sample	Description
0		2-inches Black Topsoil LIGHT BROWN WELL-GRADED CLAYEY SAND (SC) moist, fine- to medium-grained GRAY WELL-GRADED SAND (SW) medium dense, moist, medium-grained, possible black hydrocarbon remnants in sample slight hydrocarbon odor 6.0 to 6.5 feet wet below 6.5 feet
5		
10		TAN WELL-GRADED CLAYEY SAND (SC) loose, wet, medium-grained, with bands of black organic material
15		TAN WELL-GRADED SAND (SW) loose, wet, medium- to coarse-grained
20		GRAY CLAY (CL) soft End of Boring - 23 feet
25		
30		
35		
40		

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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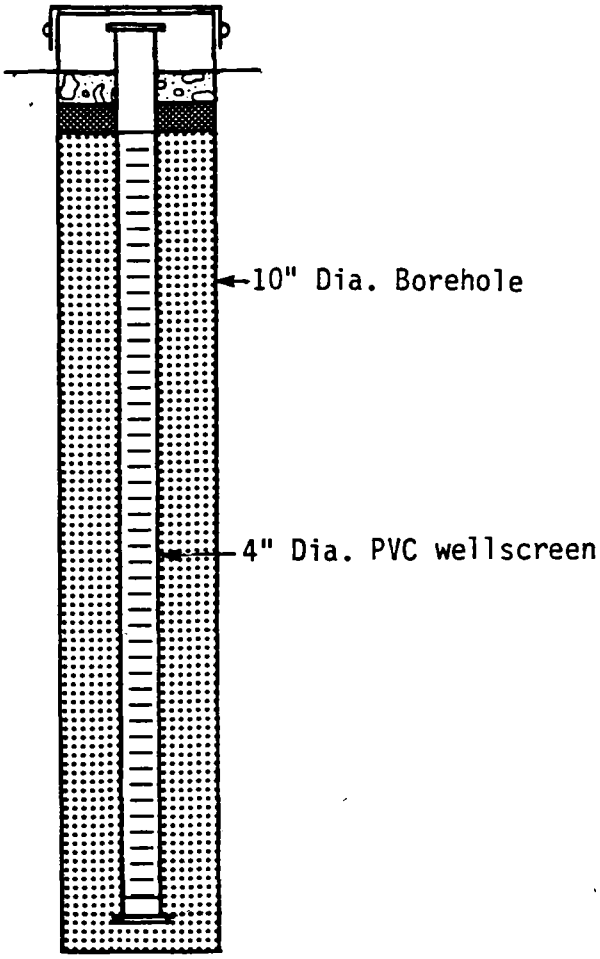
LOG OF BORING/MONITORING WELL MW-2

NAS Norfolk
Norfolk, Virginia

PLATE C-3

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12		8/24/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 12.85* Date 9/9/86

Depth (ft)	Sample	Description
0		8-inch Paving (Concrete)
		TAN WELL-GRADED CLAYEY SAND (SC) slight hydrocarbon odor
		GRAY TO BLACK WELL-GRADED SAND (SW) medium dense, moist, coarse-grained
5		loose below 5.5 feet
		slight hydrocarbon odor 5 to 6 feet
10		
15		orange below 15 feet
		gray below 18 feet
		GRAY CLAY (CL) soft, moist
20		
		End of Boring - 23 feet
25		
30		
35		
40		

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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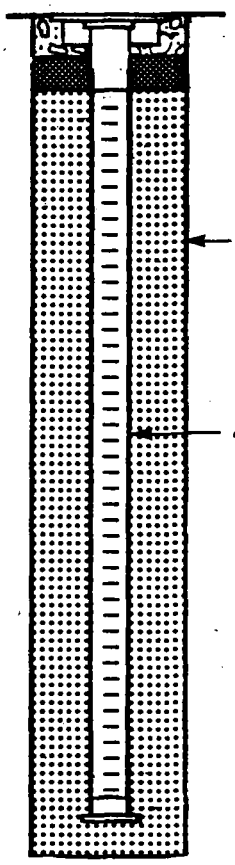
LOG OF BORING/MONITORING WELL MW-3

NAS Norfolk
Norfolk, Virginia

PLATE C-4

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12		8/24/87		

MONITORING WELL DETAIL



Depth (ft) | Sample

Equipment Hollow-Stem Auger

Elevation 10.00* Date 9/8/86

0

TAN WELL-GRADED SAND WITH SILT (SW-SM)
medium dense, moist, fine- to medium-grained

TAN WELL-GRADED SAND (SW)
loose, wet, medium-grained, occasional gravel

5

coarse-grained below 7.5 feet
slight hydrocarbon odor
gray to dark gray below 9 feet

10

GRAY ORGANIC CLAY (OH)
soft, wet, with organic root material

15

20

End of Boring - 22 feet

25

30

35

40

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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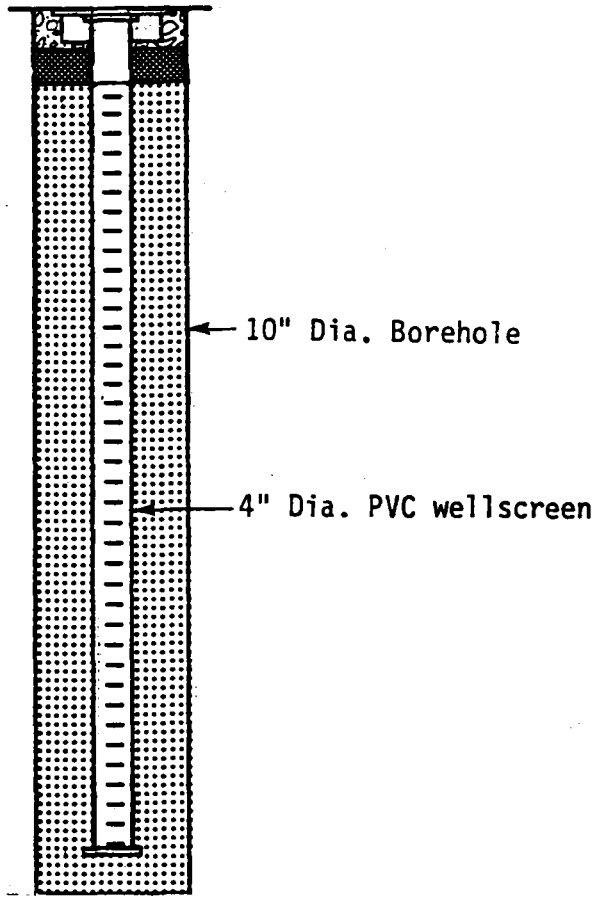
LOG OF BORING/MONITORING WELL MW-4

NAS Norfolk
Norfolk, Virginia

PLATE **C-5**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,085.12	[illegible]	8/24/87		

MONITORING WELL DETAIL



*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

Equipment Hollow-Stem Auger

Elevation 10.85* Date 9/8/86

Depth (ft)	Sample	
0		3-inches Gravel Paving
		TAN TO DARK GRAY POORLY-GRADED SILTY SAND WITH GRAVEL (SM) slight hydrocarbon odor from cuttings
5		GRAY TO BLACK WELL-GRADED SAND (SW) medium dense, moist, medium- to coarse-grained, with shell fragments, moderate to strong hydrocarbon odor
		GRAY-GREEN-BLACK SILT (ML) moderate hydrocarbon odor
10		GRAY WELL-GRADED SAND (SW) loose, wet, coarse-grained, with shell fragments, no odor below 7.5 feet
		ALTERNATING SILTY SAND (SM) & SILT (ML) very strong hydrocarbon odor
15		GRAY WELL-GRADED SAND (SW) medium dense, wet, coarse-grained very strong hydrocarbon odor
		GRAY CLAY (CL) soft, moist
20		
		End of Boring - 23 feet
25		
30		
35		
40		

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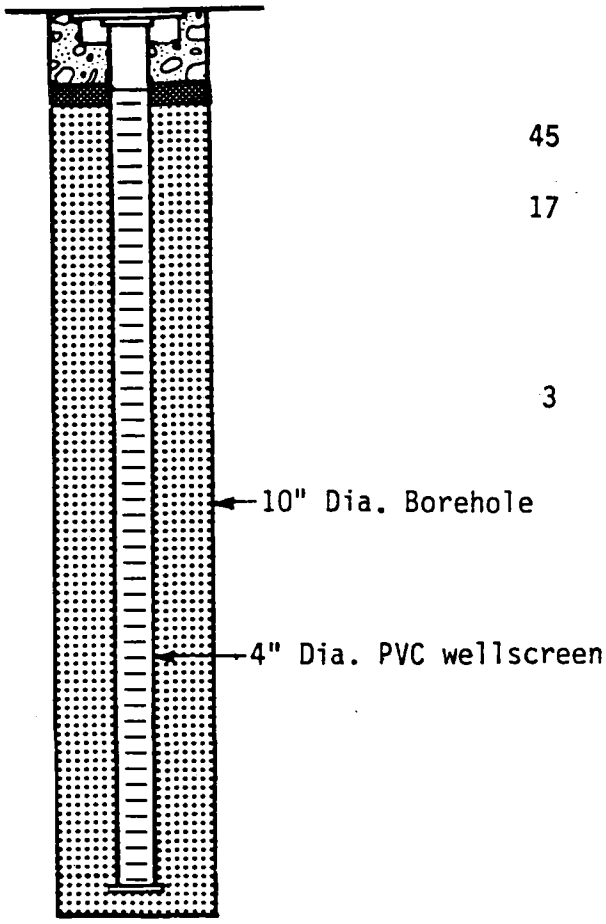
LOG OF BORING/MONITORING WELL MW-5
NAS Norfolk
Norfolk, Virginia

PLATE C-6

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12		8/04/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 10.80* Date 9/21/86

Blows/foot	Depth (ft)	Sample	
	0		8-inches Concrete BROWN SILT (ML) Soil TAN & GRAY SAND WITH SOME CLAY (SP-SC) medium- to coarse-grained, moist, few shell fragments, black streaks, hydrocarbon odor, saturated with hydrocarbon at approximately 4.5 feet saturated with water at 7 feet
45			
17	5		
3	10		GRAY CLAYEY SAND (SC) medium- to coarse-grained sand, loose, wet increased clay content at 13 feet
	15		GRAY LEAN CLAY (CL) medium stiff, saturated, some sand, few shell fragments
	20		End of Boring - 23.5 feet
	25		
	30		
	35		
	40		

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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LOG OF BORING/MONITORING WELL MW-6

NAS-Norfolk
Norfolk, Virginia

PLATE **C-7**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
EL	2176,085.12	[illegible]	8/28/87		

Depth (ft) | Sample

Equipment Hollow-Stem Auger

Elevation - Date 9/13/86

0

BROWN CLAYEY SAND (SC)
moist, with up to 3-inch pebbles
Concrete
End of Boring - 3 feet

5

Auger refused on concrete slab, drilled 5-inches into concrete.

10

15

20

25

30

35

40

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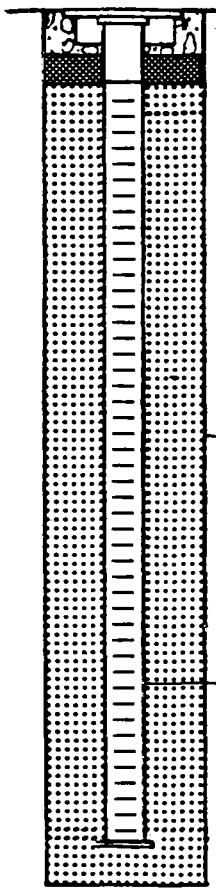
LOG OF BORING B-6

NAS-Norfolk
Norfolk, Virginia

PLATE **C-8**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES.	2176,085.12		8/24/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 12.70* Date 9/9/86 to 9/11/86

Blows/foot	Depth (ft)	Sample	Description
7	0		BROWN CLAYEY SAND (SC)- loose, moist, with rock and shell fragments
			GRAY WELL-GRADED SAND (SW) loose, moist, fine- to medium-grained, with occasional shell fragments, moderate hydrocarbon odor
10	5		
18			building debris at 3 feet
16			GRAY & BROWN CLAYEY SAND (SC) medium dense, moist, moderate hydrocarbon odor
6	10		TAN WELL-GRADED SAND (SW) medium dense, moist, coarse-grained, strong hydrocarbon odor loose below 9 feet, saturated with hydrocarbon at 9.5 feet
5	15		TAN WELL-GRADED SAND WITH CLAY (SW-SC) loose, wet, coarse-grained, slight hydrocarbon odor
15	20		TAN WELL-GRADED SAND (SW) medium dense, wet, coarse-grained
			End of Boring - 23 feet
	25		
	30		
	35		
	40		

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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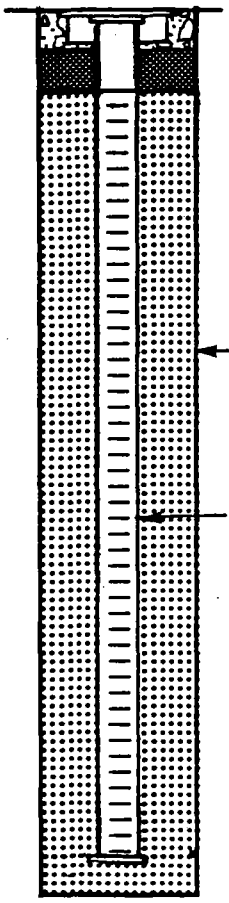
LOG OF BORING/MONITORING WELL MW-7
NAS Norfolk
Norfolk, Virginia

PLATE C-9

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
EJ	2176,085.12	[illegible]	8/24/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 12.82* Date 9/12/86

Blows/foot	Depth (ft)	Sample	
	0		2-inches Sand & Gravel Pavement
6			TAN POORLY-GRADED CLAYEY SAND (SC) loose, moist
			DARK GRAY WELL-GRADED SAND (SW) loose, moist, medium- to coarse-grained, with black bands, very strong hydrocarbon odor saturated with hydrocarbon from 6.5 to 8.5 feet
4	5		
5			
			TAN CLAYEY SAND (SC) loose, wet, strong hydrocarbon odor
5	10		
			TAN WELL-SORTED SAND (SW) loose, wet, coarse-grained, strong hydrocarbon odor
6	15		
			CLAYEY SAND (SC) soft, wet
	20		
			End of Boring - 23 feet
	25		
	30		
	35		
	40		

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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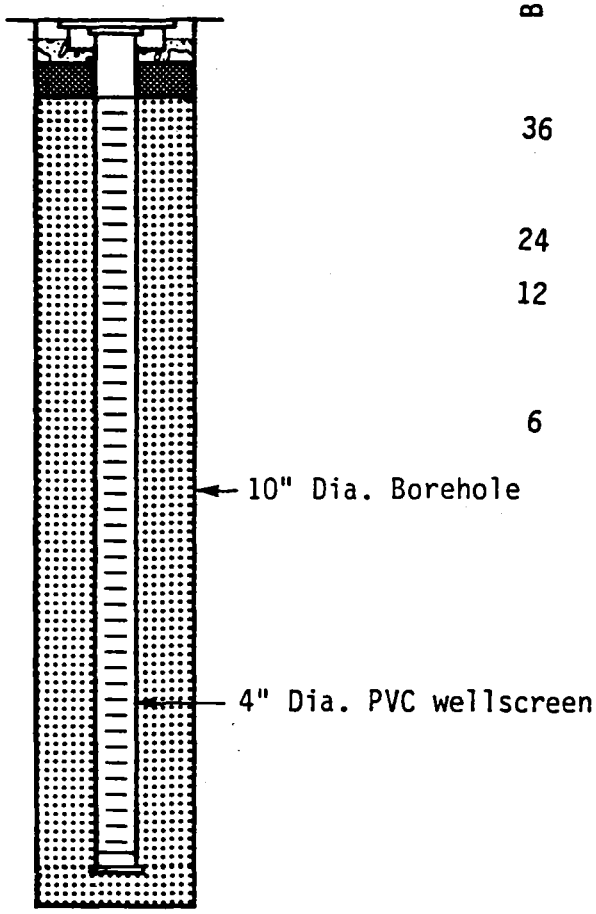
LOG OF BORING/MONITORING WELL MW-8

NAS Norfolk
Norfolk, Virginia

PLATE C-10

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
Es.	2176,085.12				

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 12.69* Date 9/13/86

Blows/foot	Depth (ft)	Sample	Description
	0		10-inches Concrete
			TAN WELL-GRADED SAND (SW) dense, moist, coarse-grained, with shell fragments
36			
	5		gray to dark gray, abundant shell fragments, saturated with hydrocarbon 4.5 to 11 feet
24			
12			
6	10		
	15		GRAY CLAY (CL) soft, wet
	20		
			End of Boring - 23 feet
	25		
	30		
	35		
	40		

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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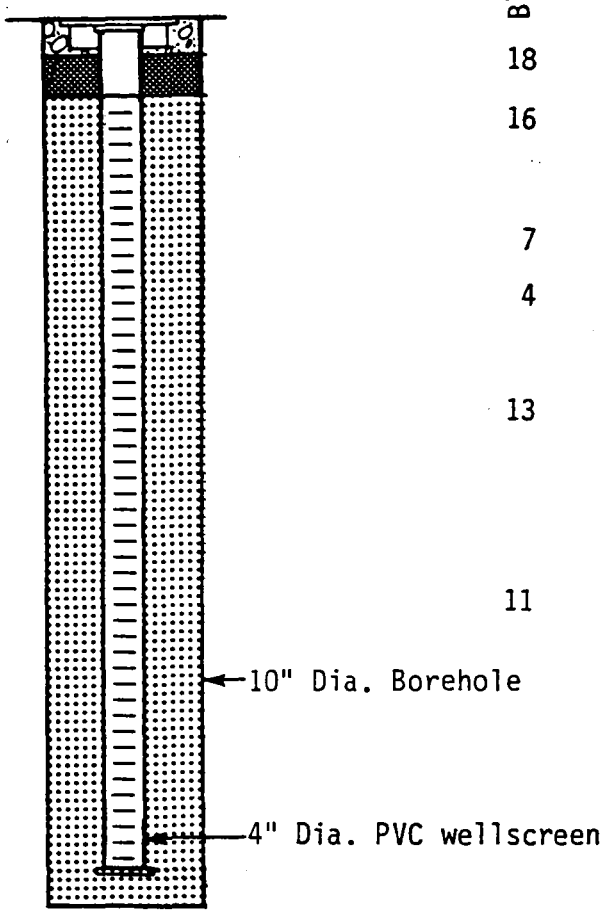
LOG OF BORING/MONITORING WELL MW-9

NAS Norfolk
Norfolk, Virginia

PLATE C-11

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12				

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 12.45* Date 9/13/86

Blows/foot	Depth (ft)	Sample	Description
	0		3-inches Asphalt
18			TAN WELL-GRADED SAND WITH GRAVEL (SW)
16			medium dense, moist, medium- to coarse-grained
	5		gravel decreasing below 2 feet, slight hydrocarbon odor
7			dark gray to black sand saturated with hydrocarbon from 5 to 11 feet
4			wood and shell fragments at 7 feet
13	10		
			GRAY WELL-GRADED SAND WITH CLAY (SW-SC)
11	15		medium dense, wet, moderate hydrocarbon odor
	20		ORANGE WELL-GRADED SAND WITH CLAY (SW-SC)
			wet, coarse-grained
			End of Boring - 23 feet
	25		
	30		
	35		
	40		

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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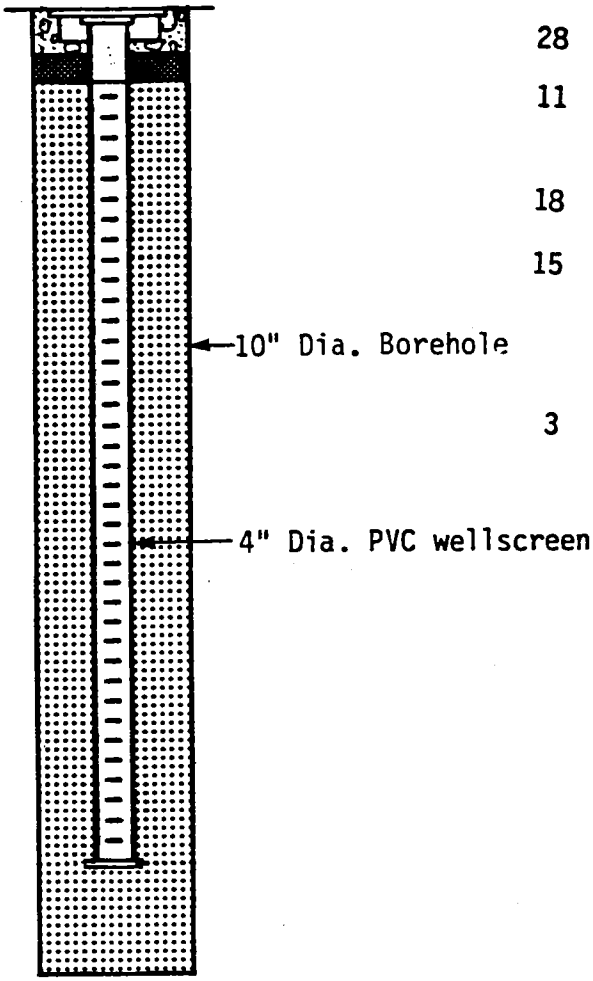
LOG OF BORING/MONITORING WELL MW-10

NAS Norfolk
Norfolk, Virginia

PLATE C-12

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12		8/24/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 12.34* Date 9/12/86

Depth (ft)	Sample	Description
0		2-inches Asphalt
	28	GRAY POORLY-SORTED SAND WITH CLAY (SP-SC) medium dense, moist, medium-grained, with shell and concrete fragments, slight hydrocarbon odor
	11	
5	18	DARK GRAY WELL-SORTED SAND (SW) medium dense, coarse-grained, saturated with hydrocarbon wet below 7 feet
	15	
10	3	loose sand below 10 feet, very strong hydrocarbon odor
15		GRAY CLAY (CL) soft, moist
20		
25		End of Boring - 25 feet
30		
35		
40		

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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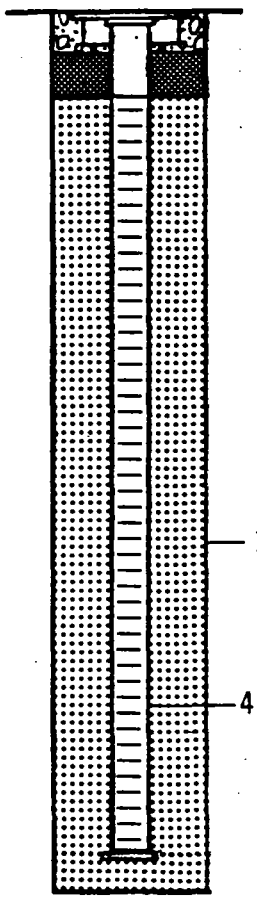
LOG OF BORING/MONITORING WELL MW-11

NAS Norfolk
Norfolk, Virginia

PLATE C-13

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES.	2176,085.12		12/6/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 11.25* Date 9/15/86

Blows/foot	Depth (ft)	Sample	Description
	0		6-inches Paving (1-inch Asphalt, 5-inches Concrete)
15			TAN POORLY-GRADED CLAYEY SAND (SP-SC) medium dense, moist, medium-grained, with abundant sea shells, slight hydrocarbon odor
36			
12	5		GRAY TO BLACK WELL-GRADED SAND (SW) dense, moist, coarse-grained, with sea shells, slight hydrocarbon odor
20			medium dense below 4.5 feet saturated with hydrocarbon at 6 feet
2	10		GRAY WELL-GRADED SAND WITH CLAY (SW-SC) loose, wet, coarse-grained, abundant sea shells, slight hydrocarbon odor
	15		GRAY CLAY (CL) soft, moist
	20		End of Boring - 25 feet
	25		
	30		
	35		
	40		

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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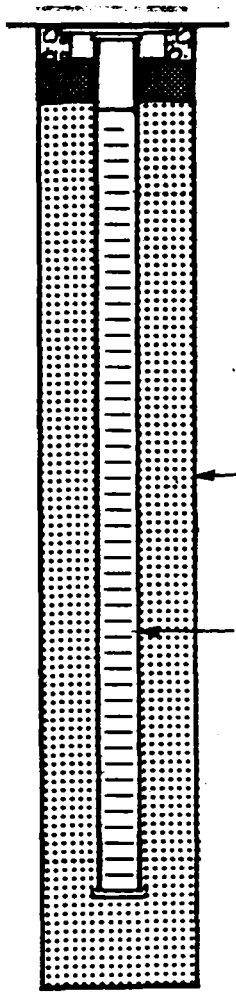
LOG OF BORING/MONITORING WELL MW-12

NAS Norfolk
Norfolk, Virginia

PLATE C-14

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
CS.	2176,085.12		8/28/87		

MONITORING WELL DETAIL



Equipment: Hollow-Stem Auger/ Rotary Wash

Elevation: 12.57* Date: 9/20/86

Depth (ft)	Blows/foot	Sample	Description
0			8- to 10-inches Concrete Clay Sand and Concrete Rubble Fill moist
	14		
	11		
5			DARK GRAY SAND & LEAN CLAY (SP-CL) medium- to coarse-grained, wet
	10		
	4		saturated with water at 7.5 feet
10			
15			
20			GRAY SILT & SAND (ML-SP) coarse-grained, saturated
25			End of Boring - 25 feet
			Product sheen on cuttings.
30			
35			
40			

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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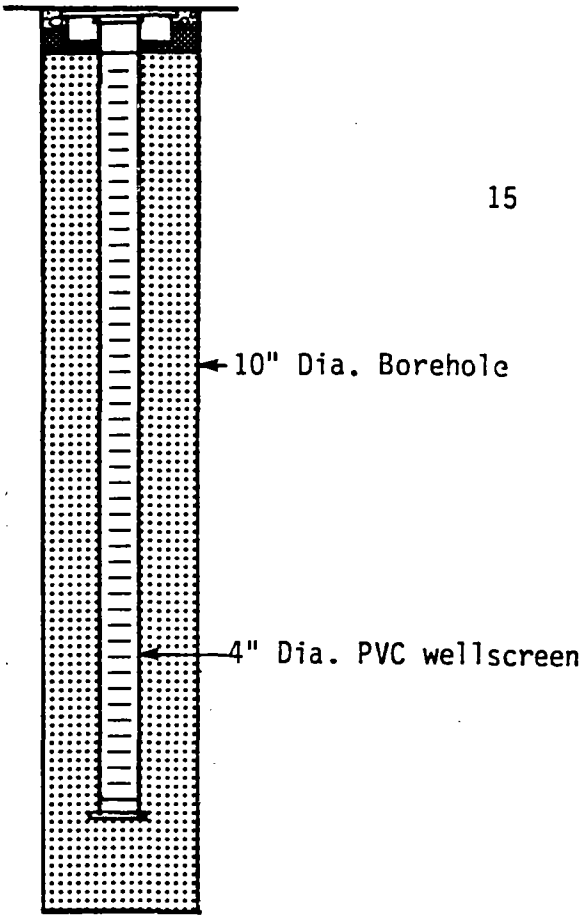
LOG OF BORING/MONITORING WELL MW-13

NAS-Norfolk
Norfolk, Virginia

PLATE **C-15**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
EJ	2176,085.12	[illegible]	9/26/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 12.22* Date 9/21/86

Depth (ft)	Blows/foot	Sample	Description
0			8-inches Concrete
			4-inches Silt, Clay & Sand Fill
			3-inches Concrete
			BROWN LEAN CLAY WITH SOME SAND (CL) moist, little gravel, detritus
	15		sand lens at 5 feet Fill
5			sand lens at 5 feet
			TAN & GRAY CLAYEY SAND (SC) saturated with water at 7 feet
10			TAN & GRAY SAND (SW) saturated, loose
15			clay lens 16 to 17 feet
			TAN & GRAY SAND (SW) saturated, loose
			GRAY LEAN CLAY (CL) medium stiff, saturated, few shell fragments
20			End of Boring - 23.5 feet
25			
30			
35			
40			

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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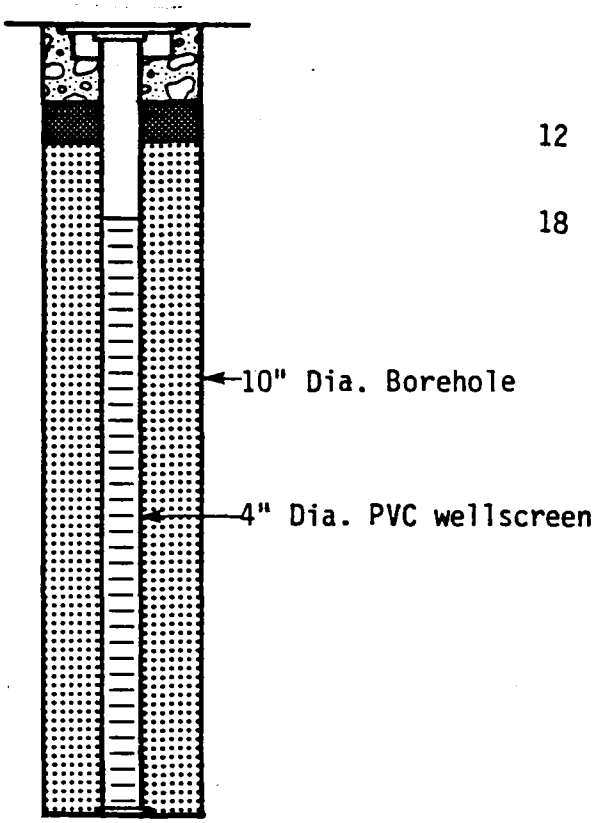
LOG OF BORING/MONITORING WELL MW-14

NAS-Norfolk
Norfolk, Virginia

PLATE C-16

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
EG	2176,085.12		8/26/87		

MONITORING WELL DETAIL



*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

Equipment Rotary Wash

Elevation 12.16* Date 9/20/86 to 9/21/86

Depth (ft)	Sample	Description
0		BROWN SILT (ML) with some Gravel and Sand
		TAN SAND & LEAN CLAY (SP-CL) medium- to coarse-grained, moist, soft gravel at 3.5 feet
5		TAN SAND (SC) medium- to coarse-grained, moist
10		ORANGE-YELLOW CLAYEY SAND (SC) medium-grained, soft, wet
15		GRAY CLAY (CL) WITH SOME SAND medium stiff, saturated
20		End of Boring - 20.5 feet
25		
30		
35		
40		

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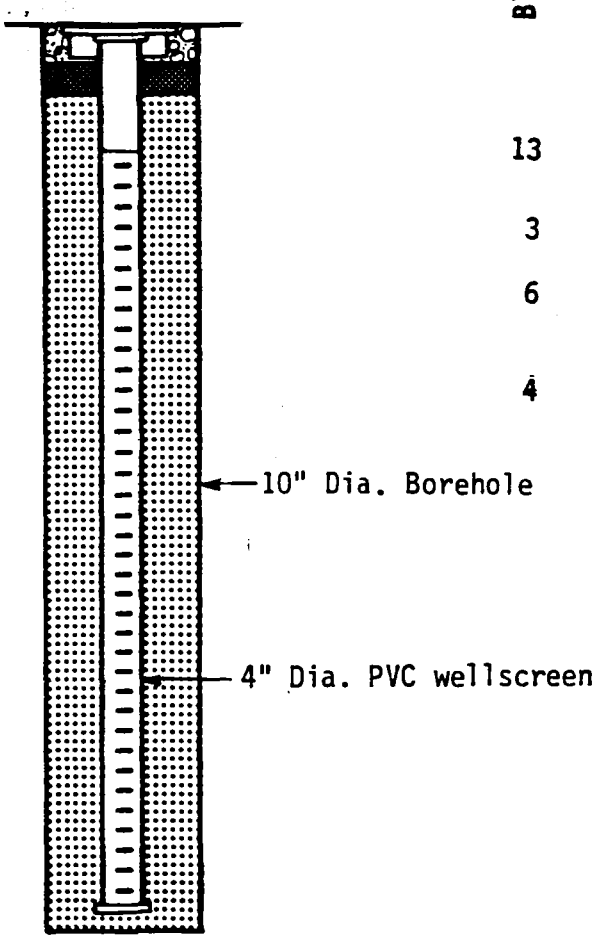
LOG OF BORING/MONITORING WELL MW-15
NAS-Norfolk
Norfolk, Virginia

PLATE C-17

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,085.12		8/20/87		

MONITORING WELL DETAIL



Equipment: Hollow-Stem Auger/ Rotary Wash

Elevation: 11.87* Date: 9/19/86

Depth (ft)	Sample	Blows/foot	Description
0			Clay & Sand Fill fine- to medium-grained, some gravel
		13	TAN SAND (SP) medium- to coarse-grained, moist
5		3	DARK GRAY CLAYEY SAND (SC) medium- to coarse-grained, moist
		6	TAN & GRAY SAND (SW) medium- to coarse-grained, some clay saturated with water at 8 feet
		4	
10			decreased clay content at 11 feet
15			
			DARK GRAY & BROWN SANDY SILT (ML) saturated
20			
			End of Boring - 23.5 feet
25			
30			
35			
40			

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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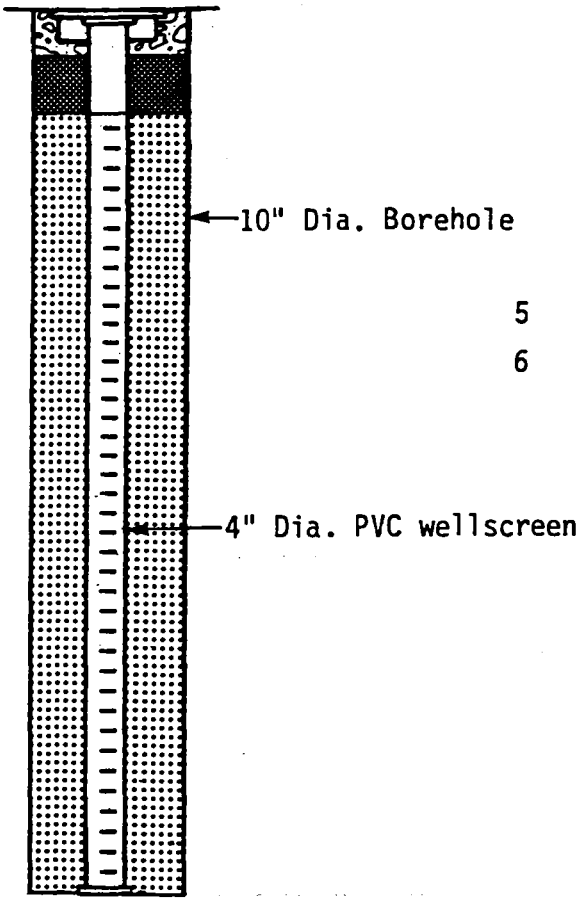
LOG OF BORING/MONITORING WELL MW-16

NAS Norfolk
Norfolk, Virginia

PLATE C-18

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.L.	2176,085.12		8/28/87		

MONITORING WELL DETAIL



*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

Equipment Hollow-Stem Auger

Elevation 11.92* Date 9/15/86

Depth (ft)	Sample	
0		2-inches Gravel & Sand Paving
		TAN WELL-GRADED SAND WITH CLAY (SW-SC) moist, coarse-grained
5		slight hydrocarbon odor at 5 feet
		GRAY WELL-GRADED SAND (SW) loose, wet, coarse-grained, abundant shell fragments, strong hydrocarbon odor
		slight hydrocarbon odor at 8 feet
10		
15		GRAY CLAY (CL) soft, moist
20		
		End of Boring - 23 feet
25		
30		
35		
40		

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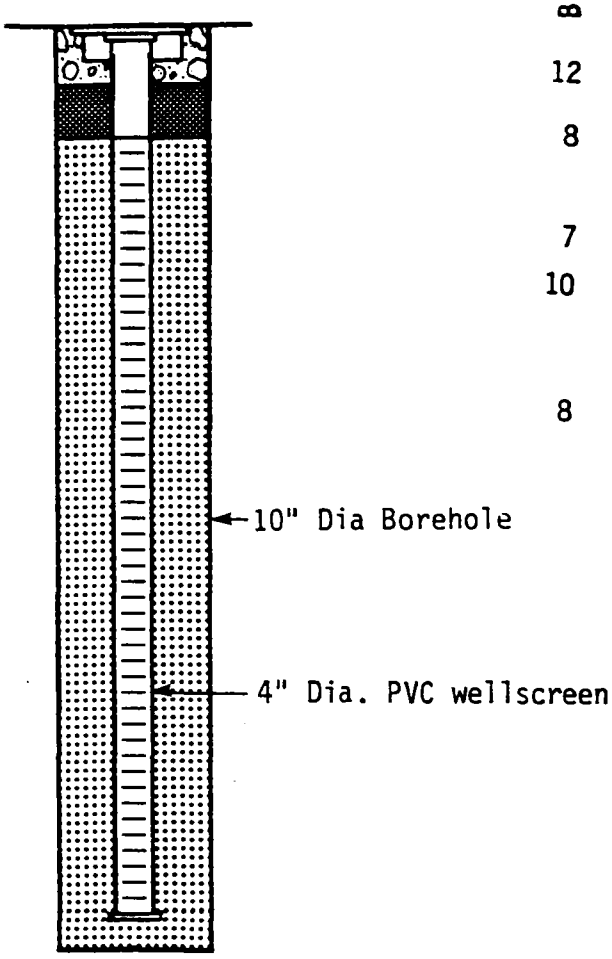
LOG OF BORING/MONITORING WELL MW-17

NAS Norfolk
Norfolk, Virginia

PLATE C-19

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
CS	2176,085.12		8/24/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 13.06* Date 9/13/86

Depth (ft)	Blows/foot	Description
0		2-inches Asphalt
	12	TAN CLAYEY SAND (SC) medium dense, moist, with 2-
	8	medium dense, moist, slight hydrocarbon odor
5	7	TAN WELL-GRADED SAND WITH CLAY (SW-SC) loose, moist, with occasional cobbles moderate hydrocarbon odor
	10	
10	8	TAN WELL-GRADED SAND (SW) medium dense, moist, coarse-grained gray below 9 feet
		GRAY CLAYEY SAND (SC)
15		GRAY CLAY (CL) soft, moist
20		
		End of Boring - 24 feet
25		
30		
35		
40		

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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LOG OF BORING/MONITORING WELL MW-18

NAS Norfolk
Norfolk, Virginia

PLATE C-20

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,085.12		8/24/87		

Equipment Hollow-Stem Auger

Elevation - Date 9/17/86

Blows/foot	Depth (ft)	Sample	
17	0		4-inches Concrete TAN SAND WITH CLAY (SP-SC) medium- to coarse-grained, moist Refusal on concrete at 3 feet (Backfilled with cuttings, capped with concrete)
	5		
	10		
	15		
	20		
	25		
	30		
	35		
	40		

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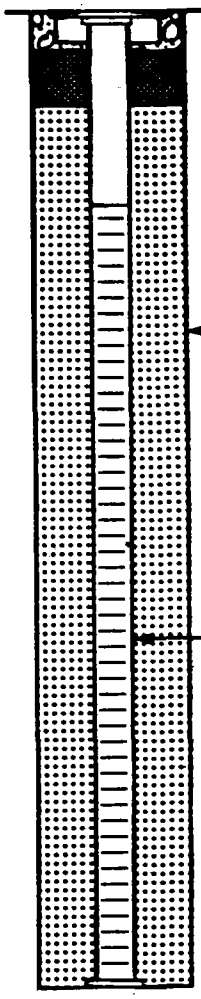
LOG OF BORING B-19

NAS-Norfolk
Norfolk, Virginia

PLATE **C-21**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	2176,085.12		8/24/87		

MONITORING WELL DETAIL



Equipment: Hollow-Stem Auger/ Rotary Wash

Elevation: 12.12* Date: 9/16/86

Depth (ft)	Blows/foot	Sample	Description
0			10-inches Concrete
	31		TAN SAND WITH CLAY (SP-SC) medium- to coarse-grained, moist, with shell fragments
	8		ORANGE LEAN CLAY WITH SAND (CL-SP) soft, moist
5	5		TAN SAND (SP) coarse-grained, moist wet at 6 feet
	7		GREEN-GRAY CLAYEY SAND (SC) wet
10	5		
			TAN SAND (SW) loose, wet
15			
20			
25			End of Boring - 25.5 feet
30			
35			
40			

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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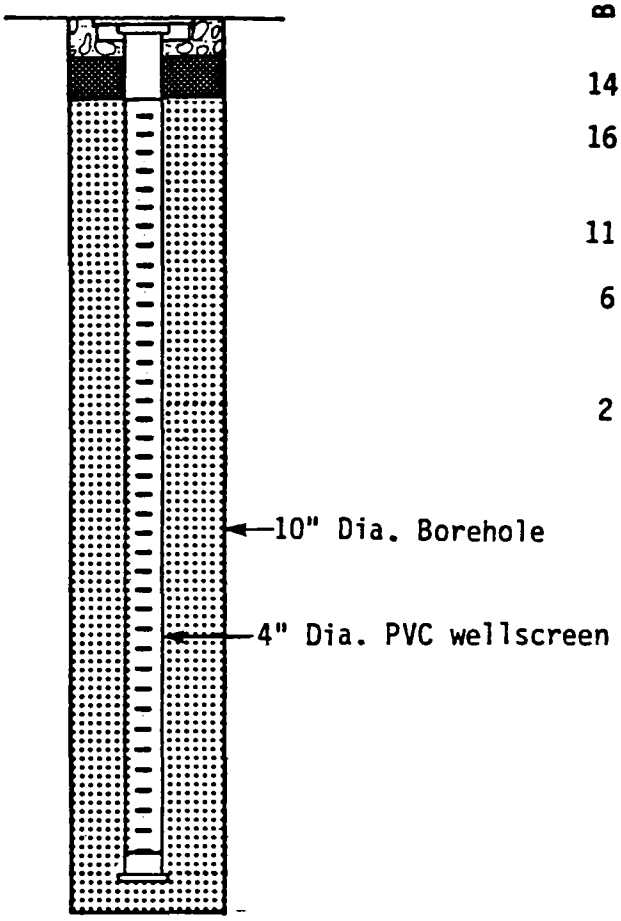
LOG OF BORING/MONITORING WELL MW-20
NAS-Norfolk
Norfolk, Virginia

PLATE C-22

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
CS.	2176,085.12		8/24/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 12.25* Date 9/17/86

Blows/foot	Depth (ft)	Sample	Description
	0		10-inches Concrete, No Rebar
14			TAN WELL-GRADED SAND (SW) medium dense, moist, coarse-grained, with trace sea shells slight hydrocarbon odor below 2.5 feet
16			
11	5		TAN CLAYEY SAND (SC) medium dense, moist
6			
2	10		DARK GRAY & TAN WELL-GRADED SAND WITH SILT (SW-SM) medium dense, moist, strong hydrocarbon odor
			BLACK SILTY SAND (SM) loose, moist, with abundant organic debris, very strong hydrocarbon odor
	15		GRAY WELL-GRADED SAND (SW)
			GRAY CLAY (CL) soft
	20		End of Boring - 23 feet
	25		
	30		
	35		
	40		

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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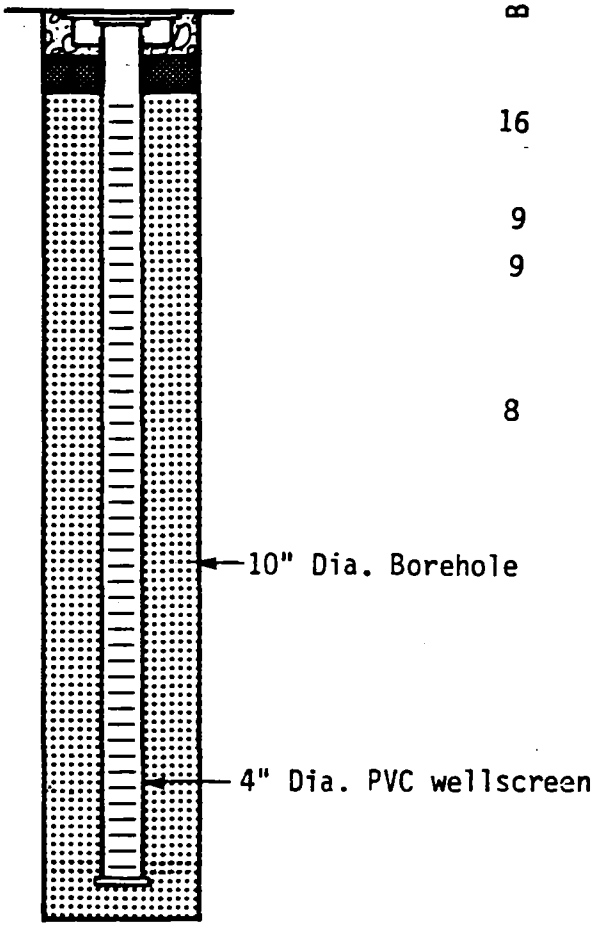
LOG OF BORING/MONITORING WELL MW-21

NAS Norfolk
Norfolk, Virginia

PLATE C-23

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES.	2176,085.12		8/24/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 12.85* Date 9/17/86

Depth (ft)	Blows/foot	Sample	Description
0			8-inches Concrete
			DARK BROWN & GRAY CLAYEY SILT (ML) moist
	16		LIGHT TAN & BROWN CLAYEY SAND (SC) medium stiff, medium- to coarse-grained, moist
5	9		LIGHT TAN & BROWN SAND (SW) medium- to coarse-grained, some silt, odd chemical odor
	9		strong hydrocarbon odor at 9.5 feet
10	8		saturated with hydrocarbon at 10 feet
			saturated with water at approximately 11 feet
			decreased silt content at 12 feet
15			some clay in cuttings at 16 feet
20			
			End of Boring - 23.5 feet
25			
30			
35			
40			

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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LOG OF BORING/MONITORING WELL MW-22

NAS-Norfolk
Norfolk, Virginia

PLATE **C-24**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12	[illegible]	8/24/87		

Equipment Dry Auger

Elevation - Date 9/15/86

Depth (ft)	Sample	
0		10-inches Concrete
	21	GRAY SAND WITH CLAY (SP-SC) medium- to coarse-grained, moist, with sea shells and organic debris, strong hydrocarbon odor
	30	
5		GRAY TO DARK GRAY SAND (SW) coarse-grained, saturated with hydrocarbon
		End of Boring - 4.5 feet
10		Pipe at 4.5 feet
15		
20		
25		
30		
35		
40		

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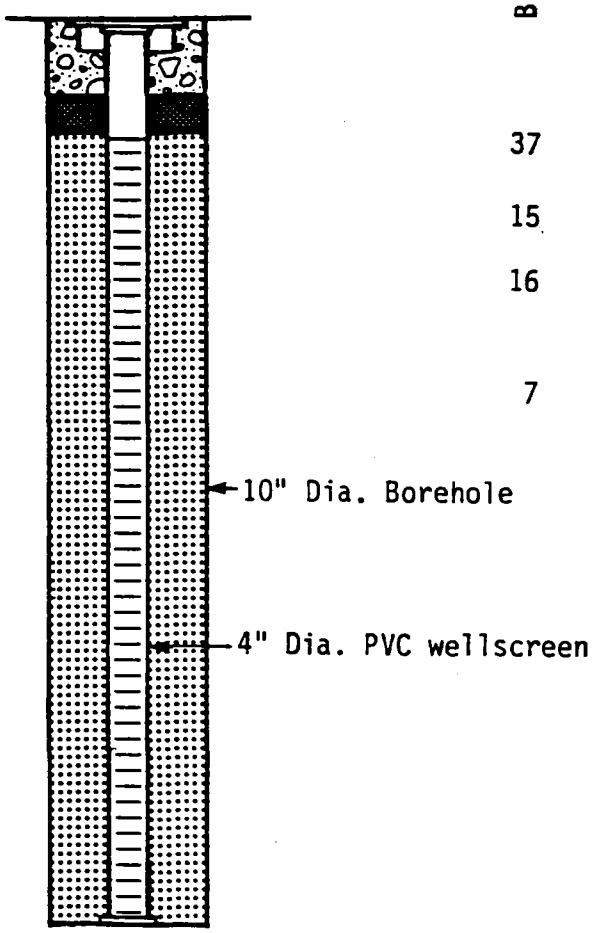
LOG OF BORING B-23

NAS-Norfolk
Norfolk, Virginia

PLATE **C-25**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
EB	2176,085.12		8/26/87		

MONITORING WELL DETAIL



Equipment Hollow-Stem Auger

Elevation 9.67* Date 9/19/86

Depth (ft)	Blows/foot	Sample	Description
0			2-inches Asphalt + 26-inches Base (southside) and 8-inches Concrete (northside)
	37		BROWN SILT (ML) Fill
	15		TAN SAND & SILTY SAND (SP-SM) medium- to coarse-grained, moist, some silt and clay, few pebbles
5	16		shell fragments, strong hydrocarbon odor at 4.5 feet
	7		saturated with hydrocarbon at 6 feet
10			
15			DARK GRAY LEAN CLAY (CL) soft, saturated, few sand grains
20			
			End of Boring - 23.5 feet
25			
30			
35			
40			

*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

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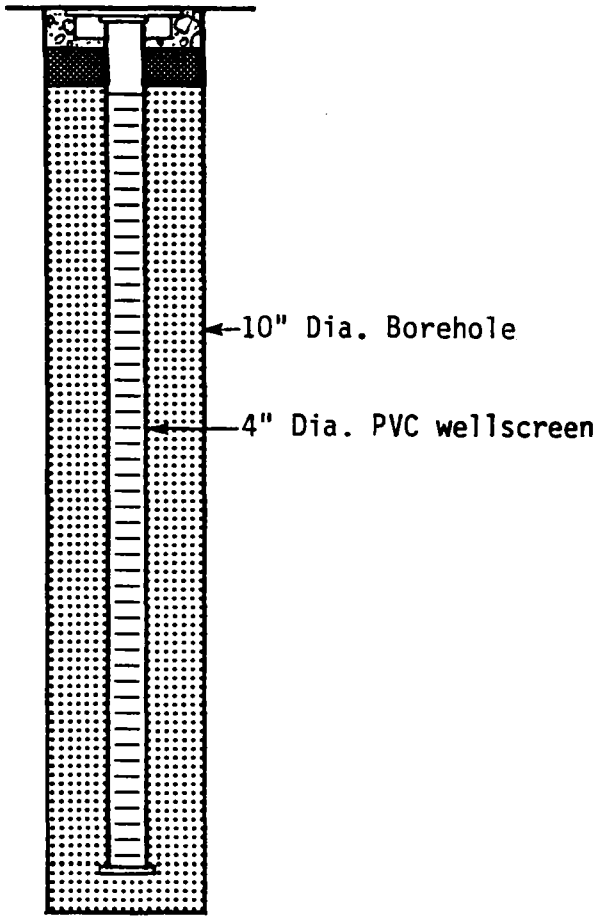
LOG OF BORING/MONITORING WELL MW-23

NAS-Norfolk
Norfolk, Virginia

PLATE C-26

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,085.12		8/24/87		

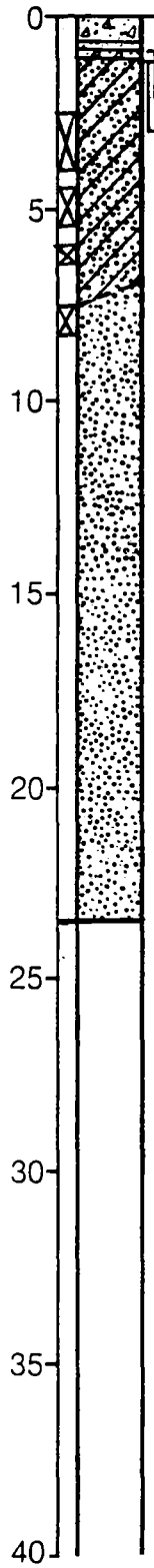
MONITORING WELL DETAIL



*Note: Elevation is referenced to Mean Sea Level (MSL) and is taken on top of PVC well casing.

Equipment: Hollow-Stem Auger/ Rotary Wash

Elevation: 12.40* Date: 9/18/86



8-inches Concrete
Brown Silty Sand Fill
3-inches Concrete
TAN CLAYEY SAND (SC)
medium- to coarse-grained, moist, few shell fragments, some gravel
gravel at 6 feet
TAN SAND (SW)
coarse-grained, wet
saturated with water at 8 feet

3-inches clayey sand at 11 feet

shell fragments at 17.5 feet

End of Boring - 23.5 feet

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LOG OF BORING/MONITORING WELL MW-24

NAS-Norfolk
Norfolk, Virginia

PLATE **C-27**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,085.12		8/24/87		

APPENDIX D

IEA LABORATORY RESULTS

SOIL SAMPLES

Industrial & Environmental Analysts, Inc.
P.O. Box 12846 • Research Triangle Park, NC 27709 • 919-467-9919

NOV 5 1986
RECEIVED

October 28, 1986
IEA Project No. 08606 **Revision #Two**

Harding Lawson Associates
6300 Westpark Drive
Suite 100
Houston, TX 77057

Attention: Mr. Jim Tremblay, P.E.

Reference: HLA Project No. 02176, 074.12
Norfolk NAS, VA - Soil & Ground Water Analysis

The GC fingerprint analysis for indication of JP-5 in 43 soil samples submitted by Harding Lawson has been completed. Enclosed are analytical results on our report numbers 525-1 through 525-4.

In accordance with verbal instructions given to us by Hank Peters, we did not run fingerprint analysis on the diesel fuel sample.

In order to ensure that adequate sample is received to allow us to perform fingerprint analysis on water samples, we ask that you provide a one liter of each water sample collected.

We appreciate the opportunity to provide this information, and look forward to receipt of water samples. If we can be of futher assistance in the interim, please do not hesitate to call on us.

Very truly yours,

INDUSTRIAL & ENVIRONMENTAL ANALYSTS, INC.

Bob Marschalk
Project Manager

BM/sbm

Enclosures

IEA REPORT NO. 525-1
Samples Received 9/12/86

GC Fingerprint Analysis for Indication of JP-5 In Soil Samples

IEA I.D.	Client I.D.	Results
1	9-9 - MW3 - 0.5-2	No hydrocarbon blend present
2	9-9 - MW3 - 4.5-6	No hydrocarbon blend present
3	9-9 - MW4 - 5-6.5	No hydrocarbon blend present
4	9-8 - MW4 - 7-8.5	No hydrocarbon blend present
5	9-8 - MW5 - 3-4.5	No hydrocarbon blend present
6	9-8 - MW5 - 4.5-6	No hydrocarbon blend present
7	9-9 - MW7 - 7-8.5	14,600 mg/kg JP5 present
8	9-9 - MW7 - 9-10.5	23 mg/kg JP5 present

IEA REPORT NO. 525-2
Samples Received 9/17/86

GC Fingerprint Analysis for Indication of JP-5 In Soil Samples

IEA I.D.	Client I.D.	Results
1	9-12 - MW8 - 4.5-6	Narrow cut of a petroleum blend
2	9-12 - MW8 - 6-7.5	34 mg/kg JP5 present
3	9-12 - MW8 - 9.5-11	No hydrocarbon blend present
4	9-13 - MW9 - 1.5-3.0	No hydrocarbon blend present
5	9-13 - MW9 - 6-7.5	551 mg/kg JP5 present
6	9-13 - MW10 - 1.5-3	No hydrocarbon blend present
7	9-13 - MW10 - 6-7.5	6,560 mg/kg JP5 present
8	9-12 - MW11 - 4.5-6	Narrow cut of a petroleum blend
9	9-12 - MW11 - 6-7.5	95,100 mg/kg JP5 present
10	9-13 - MW18 - 0-1.5	No hydrocarbon blend present
11	9-13 - MW18 - 9-10.5	No hydrocarbon blend present

IEA REPORT NO. 525-3
Samples Received 9/19/86

GC Fingerprint Analysis for Indication of JP-5 In Soil Samples

IEA I.D.	Client I.D.	Results
1	9-15 - .75-2.25 - ~~MW~~B-23	918 mg/kg JP5 present
2	9-15 - 2.25-3.75 - ~~MW~~B-23	5,250 mg/kg JP5 present
3	9-15 - 4.5-6 - MW-12	No hydrocarbon blend present
4	9-15 - 6-7.5 - MW-12	46,000 mg/kg JP5 present
5	9-15 - 7-8.5 - MW-17	2,390 mg/kg JP5 present
6	9-15 - 8.5-10 - MW-17	No hydrocarbon blend present
7	9-16 - ~~5~~4.5-6 - MW-20	No hydrocarbon blend present
8	9-16 - 6-7.5 - MW-20	No hydrocarbon blend present
9	9-17 - 2-3.5 - MW-21	No hydrocarbon blend present
10	9-17 - 4.5-6 - MW-21	No hydrocarbon blend present
11	9-17 - 4.5-6 - MW-22	No hydrocarbon blend present
12	9-17 - 6-7.5 - MW-21	32 mg/kg JP5 present
13	9-17 - 10-11.5 - MW-22	No hydrocarbon blend present
14	9-18 - 2.5-4 - MW-24	No hydrocarbon blend present
15	9-18 - 4.5-6 - MW-24	No hydrocarbon blend present

IEA REPORT NO. 525-4
Samples Received 9/23/86

GC Fingerprint Analysis for Indication of JP-5 In Soil Samples

IEA I.D.	Client I.D.	Results
1	9-19 - MW-23 - 4.5-6	No hydrocarbon blend present
2	9-19 - MW-23 - 4.5-6	83,300 mg/kg JP5 present
3	9-19 - MW-23 - 6-7.5	24,500 mg/kg JP5 present
4	9-19 - MW-13 - 6-7.5	No hydrocarbon blend present
5	9-20 - MW-6 - 2.5-4	5,320 mg/kg JP5 present
6	9-20 - MW-13 - 2.5-4	No hydrocarbon blend present
7	9-20 - MW-15 - 4.5-6	No hydrocarbon blend present
8	9-21 - MW-14 - 4.5-6	No hydrocarbon blend present
9	9-21 - MW-6 - 6-7.5	11 mg/kg JP5 present

APPENDIX E

COMPLETE GROUND WATER

AND

HYDROCARBON MEASUREMENTS

NAS - NORFOLK
FREE PRODUCT THICKNESSES AND WATER LEVELS

WELL NUMBER	DATE	(1) DEPTH TO WATER (feet)	(1) DEPTH TO FIRST FLUID (feet)	PRODUCT THICKNESS (feet)	(2) TOC ELEVATION (feet)	(2) CORRECTED WATER ELEVATION (feet)	(3) HIGH (H) OR LOW (L) TIDES
MW-1	9/6/86	5.33	5.33	0.00	12.81	7.48	*
	9/9/86	5.66	5.66	0.00	12.81	7.15	L
	9/10/86	5.62	5.62	0.00	12.81	7.19	L
	9/11/86	5.34	5.34	0.00	12.81	7.47	L
	9/11/86	5.35	5.35	0.00	12.81	7.46	H
	9/12/86	5.34	5.34	0.00	12.81	7.47	H
	9/12/86	5.35	5.35	0.00	12.81	7.46	L
	9/12/86	5.39	5.39	0.00	12.81	7.42	H
	9/13/86	5.49	5.49	0.00	12.81	7.32	L
	9/15/86	5.48	5.48	0.00	12.81	7.33	L
	9/16/86	5.47	5.47	0.00	12.81	7.34	H
	9/17/86	5.54	5.54	0.00	12.81	7.27	L
	9/19/86	5.53	5.53	0.00	12.81	7.28	H
	9/20/86	5.59	5.59	0.00	12.81	7.22	H
	9/21/86	5.57	5.57	0.00	12.81	7.24	L
	11/2/86	5.85	5.85	0.00	12.81	6.96	*
	11/7/86	6.03	6.03	0.00	12.81	6.78	*
MW-2	9/9/86	5.49	5.49	0.00	11.70	6.21	L
	9/10/86	5.49	5.49	0.00	11.70	6.21	L
	9/11/86	5.42	5.42	0.00	11.70	6.28	L
	9/11/86	5.38	5.38	0.00	11.70	6.32	H
	9/12/86	5.36	5.36	0.00	11.70	6.34	H
	9/12/86	5.36	5.36	0.00	11.70	6.34	L
	9/12/86	5.37	5.37	0.00	11.70	6.33	H
	9/13/86	5.55	5.55	0.00	11.70	6.15	L
	9/15/86	5.60	5.60	0.00	11.70	6.10	L
	9/16/86	5.50	5.50	0.00	11.70	6.20	H
	9/17/86	5.65	5.65	0.00	11.70	6.05	L
	9/19/86	5.57	5.57	0.00	11.70	6.13	H
	9/20/86	5.62	5.62	0.00	11.70	6.08	H
	9/21/86	5.60	5.60	0.00	11.70	6.10	L
	11/2/86	5.87	5.87	0.00	11.70	5.83	*
	11/6/86	5.91	5.91	0.00	11.70	5.79	*
	11/7/86	5.93	5.93	0.00	11.70	5.77	*
MW-3	9/10/86	10.60	10.60	0.00	15.85	5.25	L
	9/11/86	7.71	7.71	0.00	12.85	5.14	L
	9/11/86	7.68	7.68	0.00	12.85	5.17	H
	9/12/86	7.60	7.60	0.00	12.85	5.25	H
	9/12/86	7.63	7.63	0.00	12.85	5.22	L
	9/12/86	7.63	7.63	0.00	12.85	5.22	H
	9/13/86	7.75	7.75	0.00	12.85	5.10	L
	9/15/86	7.76	7.76	0.00	12.85	5.09	L
	9/16/86	7.65	7.65	0.00	12.85	5.20	H
	9/17/86	7.80	7.80	0.00	12.85	5.05	L
	9/19/86	7.34	7.34	0.00	12.85	5.51	H
	9/20/86	7.79	7.79	0.00	12.85	5.06	H

FREE PRODUCT THICKNESSES AND WATER LEVELS cont'

WELL NUMBER	DATE	(1) DEPTH TO WATER (feet)	(1) DEPTH TO FIRST FLUID (feet)	PRODUCT THICKNESS (feet)	(2) TOC ELEVATION (feet)	(2) CORRECTED WATER ELEVATION (feet)	(3) HIGH (H) OR LOW (L) TIDES
MW-3	9/21/86	7.84	7.84	0.00	12.85	5.01	L
cont'	11/2/86	7.90	7.90	0.00	12.85	4.95	*
	11/6/86	8.05	8.05	0.00	12.85	4.80	*
	11/7/86	8.15	8.15	0.00	12.85	4.70	*
MW-4	9/9/86	4.45	4.45	0.00	10.00	5.55	L
	9/10/86	4.42	4.42	0.00	10.00	5.58	L
	9/11/86	4.38	4.38	0.00	10.00	5.62	L
	9/11/86	4.36	4.36	0.00	10.00	5.64	H
	9/12/86	4.34	4.34	0.00	10.00	5.66	H
	9/12/86	4.35	4.35	0.00	10.00	5.65	L
	9/12/86	4.37	4.37	0.00	10.00	5.63	H
	9/13/86	4.49	4.49	0.00	10.00	5.51	L
	9/15/86	4.46	4.46	0.00	10.00	5.54	L
	9/16/86	4.44	4.44	0.00	10.00	5.56	H
	9/17/86	4.52	4.52	0.00	10.00	5.48	L
	11/2/86	4.43	4.43	0.00	10.00	5.57	*
	11/6/86	4.53	4.53	0.00	10.00	5.47	*
	11/7/86	4.57	4.57	0.00	10.00	5.43	*
MW-5	9/9/86	6.40	5.54	.86	10.85	5.16	L
	9/10/86	6.52	5.46	1.06	10.85	5.20	L
	9/11/86	6.54	5.43	1.11	10.85	5.22	L
	9/11/86	6.32	5.48	.84	10.85	5.22	H
	9/12/86	6.52	5.44	1.08	10.85	5.22	H
	9/12/86	6.52	5.42	1.10	10.85	5.23	L
	9/12/86	6.42	5.40	1.02	10.85	5.27	H
	9/13/86	6.55	5.43	1.12	10.85	5.22	L
	9/15/86	6.60	5.45	1.15	10.85	5.19	L
	9/16/86	6.63	5.46	1.17	10.85	5.18	H
	9/17/86	6.69	5.44	1.25	10.85	5.19	L
	9/18/86	6.75	5.47	1.28	10.85	5.15	L
	9/19/86	6.79	5.47	1.32	10.85	5.14	H
	9/20/86	6.86	5.51	1.35	10.85	5.10	H
	9/21/86	6.83	5.52	1.31	10.85	5.09	L
	11/2/86	7.30	5.73	1.57	10.85	4.84	*
	11/3/86	7.35	5.77	1.58	10.85	4.80	*
	11/7/86	7.24	5.77	1.47	10.85	4.82	*
MW-6	9/21/86	5.39	3.65	1.74	10.80	6.84	L
	11/1/86	5.73	3.72	2.01	10.80	6.72	*
	11/7/86	5.79	3.77	2.02	10.80	6.67	*
MW-7	9/12/86	6.09	6.09	0.00	12.70	6.61	H
	9/12/86	6.09	6.09	0.00	12.70	6.61	L
	9/12/86	6.11	6.11	0.00	12.70	6.59	H
	9/13/86	6.19	6.19	0.00	12.70	6.51	H
	9/13/86	6.21	6.21	0.00	12.70	6.49	L
	9/15/86	6.26	6.26	0.00	12.70	6.44	L
	9/16/86	6.27	6.27	0.00	12.70	6.43	H
	9/17/86	6.33	6.33	0.00	12.70	6.37	L
	9/19/86	6.31	6.31	0.00	12.70	6.39	H
	9/20/86	6.33	6.33	0.00	12.70	6.37	H

FREE PRODUCT THICKNESSES AND WATER LEVELS cont'

WELL NUMBER	DATE	(1) DEPTH TO WATER (feet)	(1) DEPTH TO FIRST FLUID (feet)	PRODUCT THICKNESS (feet)	(2) TOC ELEVATION (feet)	(2) CORRECTED WATER ELEVATION (feet)	(3) HIGH (H) OR LOW (L) TIDES
MW-7	9/21/86	6.32	6.32	0.00	12.70	6.38	L
cont'	11/1/86	6.61	6.61	0.00	12.70	6.09	*
	11/6/86	6.65	6.65	0.00	12.70	6.05	*
	11/7/86	6.66	6.66	0.00	12.70	6.04	*
MW-8	9/12/86	6.02	6.02	0.00	12.82	6.80	L
	9/12/86	5.78	5.78	0.00	12.82	7.04	H
	9/13/86	6.36	6.36	0.00	12.82	6.46	H
	9/13/86	6.34	6.34	0.00	12.82	6.48	L
	9/15/86	6.43	6.43	0.00	12.82	6.39	L
	9/16/86	6.43	6.43	0.00	12.82	6.39	H
	9/17/86	6.46	6.46	0.00	12.82	6.36	L
	9/19/86	6.45	6.45	0.00	12.82	6.37	H
	9/20/86	6.48	6.48	0.00	12.82	6.34	H
	9/21/86	6.48	6.48	0.00	12.82	6.34	L
	11/3/86	6.80	6.80	0.00	12.82	6.02	*
	11/7/86	6.83	6.83	0.00	12.82	5.99	*
MW-9	9/15/86	5.87	5.87	0.00	12.69	6.82	H
	9/16/86	5.87	5.87	0.00	12.69	6.82	H
	9/17/86	5.93	5.93	0.00	12.69	6.76	L
	9/19/86	5.93	5.93	0.00	12.69	6.76	H
	9/20/86	5.97	5.97	0.00	12.69	6.72	H
	9/21/86	5.95	5.95	0.00	12.69	6.74	L
	11/1/86	6.82	6.09	.73	12.69	6.47	*
	11/5/86	6.89	6.11	.78	12.69	6.44	*
	11/7/86	6.91	6.04	.87	12.69	6.49	*
MW-10	9/15/86	7.73	5.24	2.49	12.45	6.76	L
	9/16/86	7.68	5.23	2.45	12.45	6.78	H
	9/17/86	7.74	5.25	2.49	12.45	6.75	L
	9/18/86	7.81	5.25	2.56	12.45	6.74	L
	9/19/86	7.63	5.26	2.37	12.45	6.76	H
	9/20/86	7.79	5.30	2.49	12.45	6.70	H
	9/21/86	7.65	5.28	2.37	12.45	6.74	L
	11/1/86	8.28	5.46	2.82	12.45	6.48	*
	11/7/86	8.31	5.53	2.78	12.45	6.42	*
MW-11	9/13/86	8.24	4.89	3.35	12.34	6.85	H
	9/13/86	8.22	4.87	3.35	12.34	6.87	L
	9/15/86	8.21	4.86	3.35	12.34	6.88	L
	9/16/86	8.25	5.88	2.37	12.34	6.03	H
	9/17/86	8.30	4.91	3.39	12.34	6.82	L
	9/18/86	8.44	4.90	3.54	12.34	6.80	L
	9/19/86	8.48	4.89	3.59	12.34	6.80	H
	9/20/86	8.39	4.89	3.50	12.34	6.82	H
	9/21/86	8.36	4.87	3.49	12.34	6.84	L
	11/1/86	9.11	5.10	4.01	12.34	6.52	*
	11/2/86	9.16	5.09	4.07	12.34	6.52	*
	11/7/86	9.32	4.67	4.65	12.34	6.83	*
MW-12	9/16/86	6.04	6.04	0.00	11.25	5.21	H
	9/17/86	6.10	6.02	.08	11.25	5.22	L
	9/20/86	6.53	6.00	.53	11.25	5.15	H

FREE PRODUCT THICKNESSES AND WATER LEVELS cont'

WELL NUMBER	DATE	(1) DEPTH TO WATER (feet)	(1) DEPTH TO FIRST FLUID (feet)	PRODUCT THICKNESS (feet)	(2) TOC ELEVATION (feet)	(2) CORRECTED WATER ELEVATION (feet)	(3) HIGH (H) OR LOW (L) TIDES
MW-12	9/21/86	6.69	5.96	.73	11.25	5.16	L
cont'	11/2/86	7.62	6.06	1.56	11.25	4.91	*
	11/7/86	7.70	6.12	1.58	11.25	4.85	*
MW-13	9/21/86	6.43	6.43	0.00	12.57	6.14	L
	11/3/86	6.58	6.58	0.00	12.57	5.99	*
	11/7/86	6.68	6.68	0.00	12.57	5.89	*
MW-14	11/3/86	5.63	5.63	0.00	12.22	6.59	*
	11/6/86	5.69	5.69	0.00	12.22	6.53	*
	11/7/86	5.72	5.72	0.00	12.22	6.50	*
MW-15	11/3/86	7.72	7.72	0.00	12.16	4.44	*
	11/7/86	7.74	7.74	0.00	12.16	4.42	*
MW-16	9/20/86	4.85	4.85	0.00	11.87	7.02	H
	9/21/86	5.07	5.07	0.00	11.87	6.80	L
	11/3/86	5.44	5.44	0.00	11.87	6.43	*
	11/6/86	5.45	5.45	0.00	11.87	6.42	*
	11/7/86	5.65	5.65	0.00	11.87	6.22	*
MW-17	9/15/86	6.21	5.65	.56	11.92	6.17	H
	9/16/86	6.80	5.39	1.41	11.92	6.28	H
	9/17/86	6.99	5.49	1.50	11.92	6.16	L
	9/18/86	7.10	5.46	1.64	11.92	6.16	L
	9/19/86	7.14	5.38	1.76	11.92	6.22	H
	9/20/86	7.27	5.45	1.82	11.92	6.14	H
	9/21/86	7.15	5.46	1.69	11.92	6.16	L
	11/2/86	6.14	6.14	0.00	11.92	5.78	*
	11/7/86	6.05	6.05	0.00	11.92	5.87	*
MW-18	9/15/86	7.09	7.09	0.00	13.06	5.97	L
	9/16/86	7.08	7.08	0.00	13.06	5.98	H
	9/17/86	7.13	7.13	0.00	13.06	5.93	L
	9/19/86	7.16	7.16	0.00	13.06	5.90	H
	9/20/86	7.19	7.19	0.00	13.06	5.87	H
	9/21/86	7.23	7.23	0.00	13.06	5.83	L
	11/2/86	7.29	7.29	0.00	13.06	5.77	*
	11/7/86	7.18	7.18	0.00	13.06	5.88	*
MW-19							
MW-20	9/18/86	5.81	5.81	0.00	12.12	6.31	H
	9/20/86	5.82	5.82	0.00	12.12	6.30	H
	9/21/86	5.79	5.79	0.00	12.12	6.33	L
	11/3/86	6.12	6.12	0.00	12.12	6.00	*
	11/6/86	6.14	6.14	0.00	12.12	5.98	*
	11/7/86	6.15	6.15	0.00	12.12	5.97	*
MW-21	9/17/86	6.09	5.51	.58	12.25	6.64	L
	9/21/86	8.05	5.34	2.71	12.25	6.42	L
	11/3/86	9.33	5.51	3.82	12.25	6.05	*
MW-22	9/18/86	6.80	6.63	.17	12.85	6.19	L
	9/20/86	6.73	6.56	.17	12.85	6.26	H
	9/21/86	6.80	6.57	.23	12.85	6.24	L
	11/3/86	6.90	6.83	.07	12.85	6.01	*
	11/7/86	7.01	6.89	.12	12.85	5.94	*
MW-23	9/20/86	6.73	3.30	3.43	10.67	6.75	H

FREE PRODUCT THICKNESSES AND WATER LEVELS cont'

WELL NUMBER	DATE	(1) DEPTH TO WATER (feet)	(1) DEPTH TO FIRST FLUID (feet)	PRODUCT THICKNESS (feet)	(2) TOC ELEVATION (feet)	(2) CORRECTED WATER ELEVATION (feet)	(3) HIGH (H) OR LOW (L) TIDES
MW-23	9/21/86	6.73	3.28	3.45	10.67	6.77	L
cont'	11/1/86	7.65	3.52	4.13	10.67	6.41	*
MW-24	9/19/86	6.19	6.19	0.00	12.40	6.21	H
	9/20/86	5.76	5.76	0.00	12.40	6.64	H
	9/21/86	6.25	6.25	0.00	12.40	6.15	L
	11/3/86	6.53	6.53	0.00	12.40	5.87	*
	11/6/86	6.58	6.58	0.00	12.40	5.82	*
	11/7/86	6.57	6.57	0.00	12.40	5.83	*

(1) Measured from TOC (Top of Casing)
(2) Elevation is referenced to a TBM using an assumed elevation of 100 feet.
(3) Tide table predictions at Sewells Point

NOTE:
CORRECTED DEPTH TO WATER =
DEPTH TO WATER - (PRODUCT THICKNESS * 0.82)
where 0.82 is specific gravity of JP-5

MW-19 was not drilled or relocated. Refer to text.

(*) no tidal information available

APPENDIX F

IEA LABORATORY RESULTS

FLUID SAMPLES

Industrial & Environmental Analysts, Inc.
P.O. Box 12846 • Research Triangle Park, NC 27709 • 919-467-9919

DEC 12 1986

December 9, 1986
IEA Report No. 08606B-R1

Harding Lawson Associates
6300 Westpark Drive, Suite 100
Houston, Texas 77057

Attention: Mr. Jim Tremblay, P.E.

Reference: HLA Project No. 02176, 074.12
Norfolk NAS, VA - Soil & Ground Water Analysis - IEA Lab No. 525-5

The GC fingerprint analysis for indication of JP-5 in 23 water samples submitted by Harding Lawson has been completed. Following are the analytical results.

We appreciate the opportunity to provide this information, and look forward to working with you in South Carolina. If we can be of further assistance in the interim, please do not hesitate to call on us.

Very truly yours,

INDUSTRIAL & ENVIRONMENTAL ANALYSTS, INC.

Bob Marschalk

Bob Marschalk
Project Manager

BM/sbm

Enclosure

Well ID, date, and time given below are as appeared on sample bottle labels. Due to some being torn, and/or ink smearing, the information provided is accurate to the best of our knowledge.

IEA ID	Well ID	Date	Time	Results
1 *	M.Well #7	11/01/86	15:34	26,000 µg/L - a thermally degraded petroleum hydrocarbon blend similar to JP5
2	M.Well #10	11/01/86	15:25	Is a petroleum hydrocarbon blend similar to JP5
3	M.Well #9	11/01/86	15:59	Is a petroleum hydrocarbon blend similar to JP5
4	M.Well #11	11/01/86	14:59	Is a petroleum hydrocarbon blend similar to JP5
5	M.Well #23	11/01/86	14:55	Is a petroleum hydrocarbon blend similar to JP5
6	M.Well #6	11/01/86	14:35	Is a petroleum hydrocarbon blend similar to JP5
7	M.Well #17	11/04/86	13:34	Is a petroleum hydrocarbon blend similar to JP5
8 *	M.Well #8	11/03/86	12:05	250 µg/L - a petroleum hydrocarbon blend in the same distillation range as JP5
9 *	M.Well #14	11/03/86	11:15	< 25 µg/L
10	M.Well #22	11/03/86	16:50	Is a petroleum hydrocarbon blend similar to JP5
11 *	M.Well #24	11/03/86	16:00	130 µg/L - a petroleum hydrocarbon blend similar to JP5
12	M.Well #21	11/03/86	17:10	Is a petroleum hydrocarbon blend similar to JP5

IEA ID	Well ID	Date	Time	Result
13 *	M.Well #13	11/03/86	11:55	< 25 µg/L
14 *	M.Well #20	11/03/86	16:10	48 µg/L - a thermally degraded petroleum hydrocarbon blend similar to JP5
15 *	M.Well #16	11/03/86	11:50	< 25 µg/L
16 *	M.Well #1	11/02/86	12:55	< 25 µg/L
17 *	M.Well #2	11/02/86	12:45	< 25 µg/L
18	M.Well #12	11/02/86	13:10	Is a petroleum hydrocarbon blend similar to JP5
19 *	M.Well #3	11/02/86	12:29	120 µg/L - a petroleum hydrocarbon blend similar to JP5
20 *	M.Well #18	11/02/86	03:48	1400 µg/L - a petroleum hydrocarbon blend similar to JP5
21 *	M.Well #15	11/03/86	11:00	39 µg/L - a petroleum hydrocarbon blend similar to JP5
22 *	M.Well #4	11/02/86	11:19	550 µg/L - a petroleum hydrocarbon blend similar to JP5
23	M.Well #5	11/02/86	13:20	Is a petroleum hydrocarbon blend similar to JP5

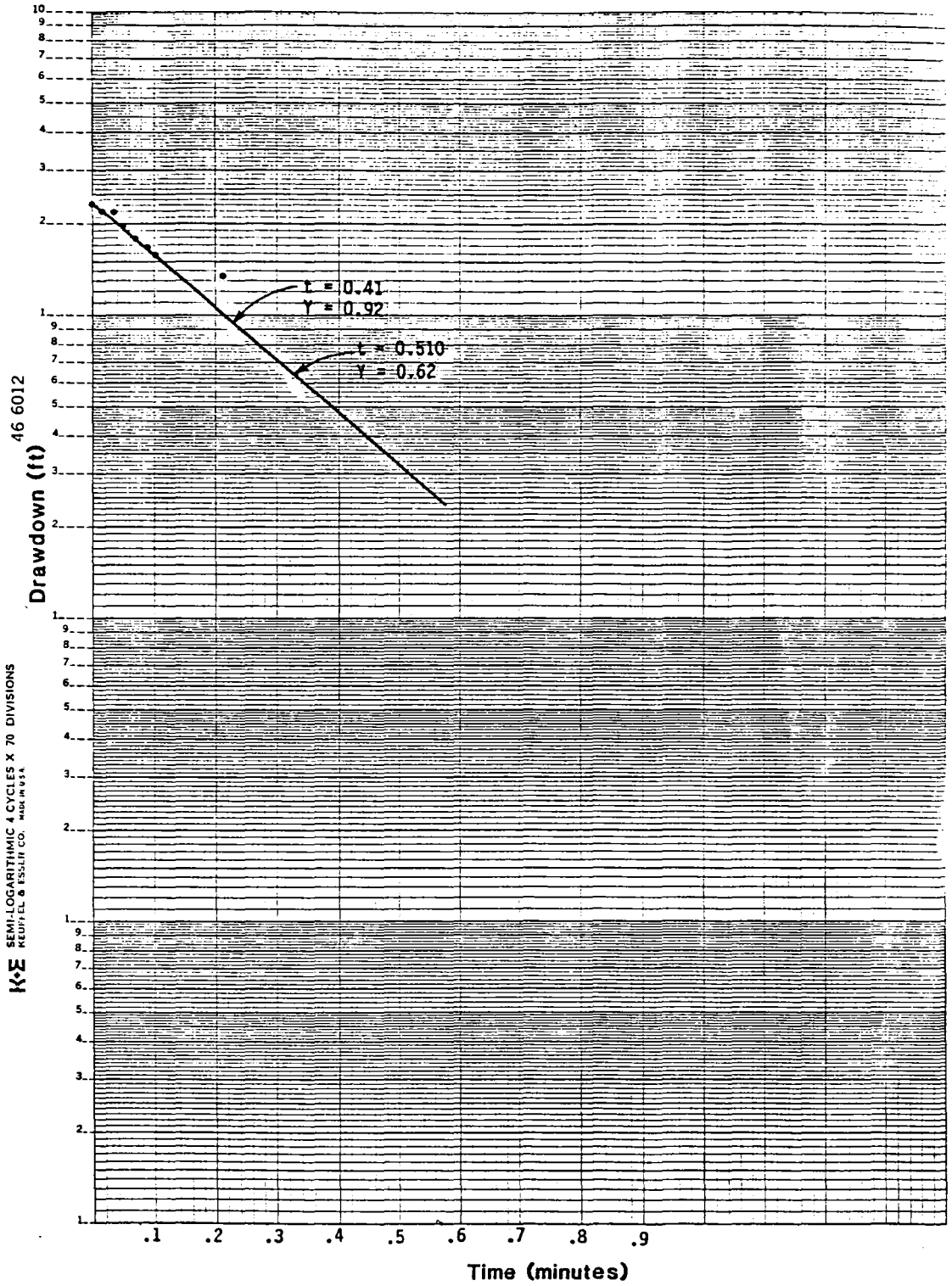
Note: **Asterisked samples were extracted and GC analysis performed on the extract.**
Non-asterisked samples were determined to be essentially pure hydrocarbo blend, and were therefore diluted as the JP5 fingerprint reference sample was prior to analysis.

APPENDIX G
COMPLETE AQUIFER TEST DATA

SLUG TEST MW-1
NOVEMBER 6, 1986

Elapsed Time (min)	Depth to Water (ft)	Drawdown (ft)
0.00	3.50	2.26
0.02	3.65	2.11
0.03	3.63	2.13
0.05	3.87	1.89
0.07	4.02	1.74
0.08	4.14	1.62
0.10	4.22	1.54
0.12	4.28	1.48
0.22	4.46	1.30
0.30	4.50	1.26
0.55	4.54	1.22
1.0	4.62	1.14
1.5	4.65	1.11
3.0	4.96	0.80
5.0	5.25	0.51
10.0	5.63	0.13

Note: Drawdown is the difference in the water level at time, "t" from the original water level.



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SLUG TEST - MW-1
NOVEMBER 6, 1986
NAS Norfolk
Norfolk, Virginia

PLATE
G-1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
EB	2176,085.12	JWR	8/24/87		

SLUG TEST (Injection)

for Unconfined Aquifers with completely of partially penetrating wells.

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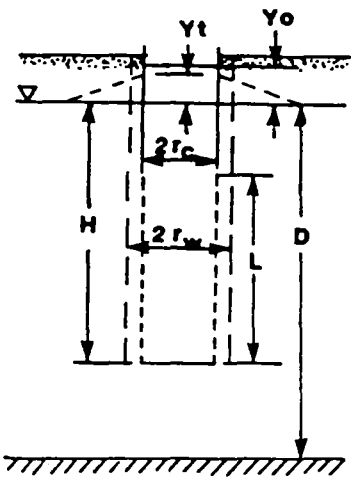
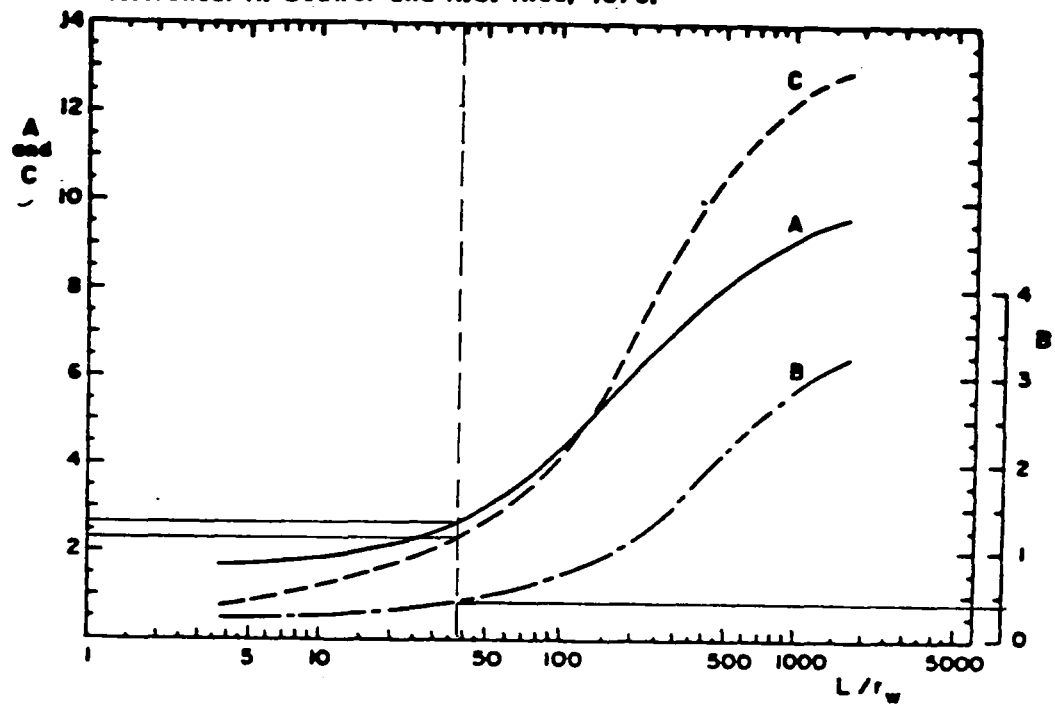
SHEET 1 OF 3
JOB NO. 2176,086.12
DATE 11/14/86
COMPUTED BY WLD
CHECKED BY CIPM

PROJECT NAS Norfolk
SUBJECT Slug Test MW-1 11/6/86

Reference: H. Bouwer and R.C. Rice, 1976.



Partially penetrating, partially perforated well in unconfined aquifer.



Curves relating coefficients *A*, *B*, and *C* to L/r_w

D = 16.25
L = 16.25
H = 16.25
r_w = .417
r_c = .167
Yo = 2.26

L/rw = 38.97; A = 2.70; B = .42; C = 2.30

$\ln\{(D-H)/r_w\}$ = _____ (max 6.0); if D=H, see*

$$\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{A+B \times \ln\{(D-H)/r_w\}}{L/r_w}\right\}^{-1} = _____$$

$$*\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right\}^{-1} = 2.78$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} * \frac{1}{t} \ln(Y_o/Y_t) = \frac{2.38\times10^{-3}}{} * \frac{1}{t} \ln(Yo/Yt)$$

Assumptions:

t	Y_t	$\frac{1}{t}\ln(Yo/Yt)$	Hydraulic Conductivity (1) ft/sec	ft/yr	gpd/ft²	Transmissivity ft²/sec
24.6	.92	3.65×10^{-2}	8.68×10^{-5}	2740	56.14	1.41×10^{-3}
30.6	.62	4.23×10^{-2}	1.01×10^{-4}	3175	65.06	1.64×10^{-3}

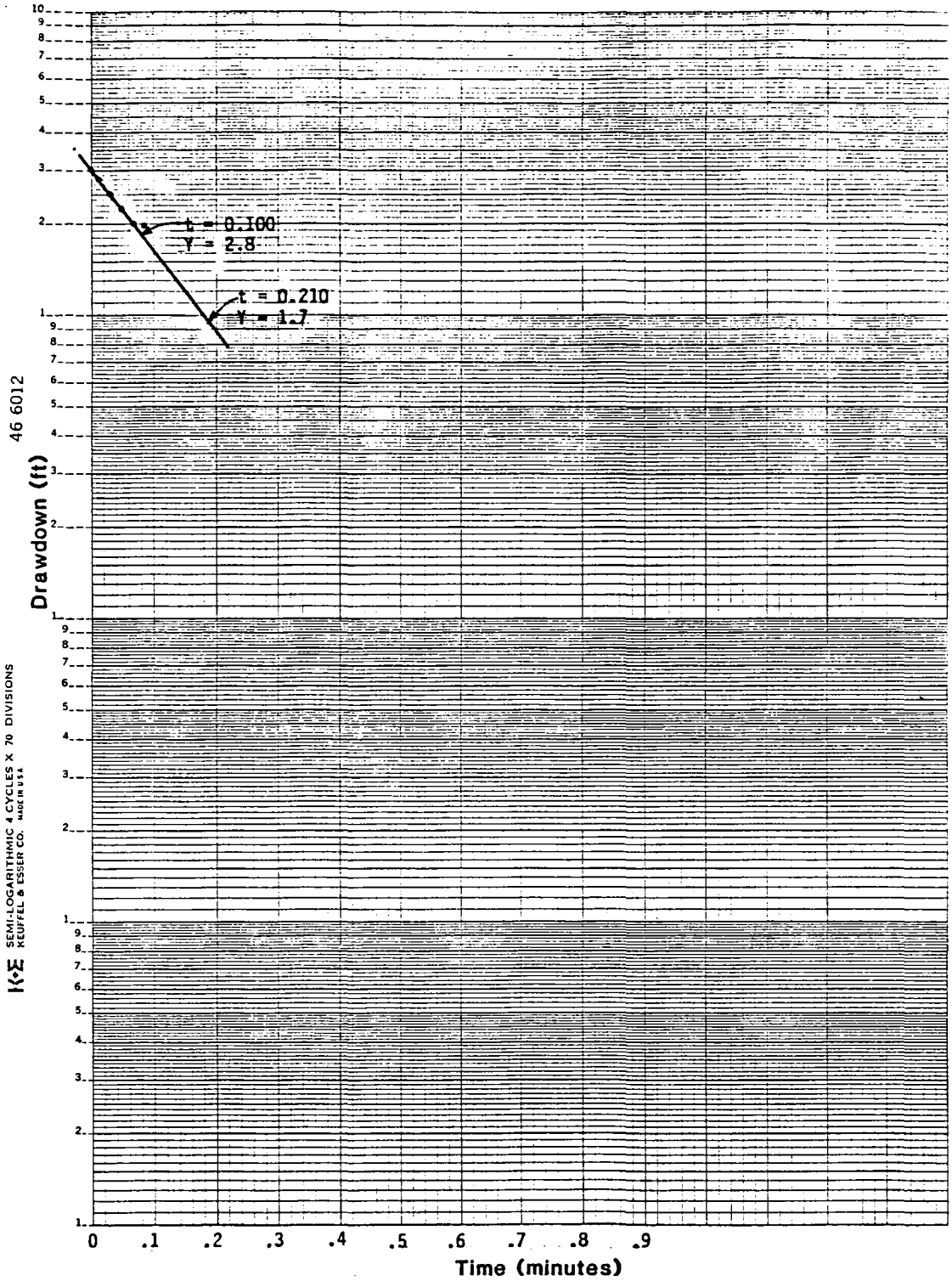
(1) Multiply ft/sec by 646.272 for gpd/ft²

see graph for t and Yt.

SLUG TEST MW-2
NOVEMBER 6, 1986

Elapsed Time (min)	Depth to Water (ft)	Drawdown (ft)
0.00	1.54	4.16
0.02	1.65	4.05
0.03	1.91	3.79
0.05	2.19	3.51
0.07	2.47	3.23
0.08	2.71	2.99
0.10	2.90	2.80
0.12	3.06	2.64
0.15	3.30	2.40
0.40	3.91	1.79
0.50	3.95	1.75
1.0	4.05	1.65
1.5	4.07	1.63
3.0	4.08	1.62
5.0	4.09	1.61
10.0	4.14	1.56

Note: Drawdown is the difference in the water level at time, "t" from the original water level.



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SLUG TEST MW-2
NOVEMBER 6, 1986
NAS Norfolk
Norfolk, Virginia

PLATE
G-2

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
CS	2176,085.12		8/24/87		

SLUG TEST (Injection)

for Unconfined Aquifers with completely of partially penetrating wells.

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SHEET 1 OF 3
JOB NO. 2176,086.12
DATE 11/14/86
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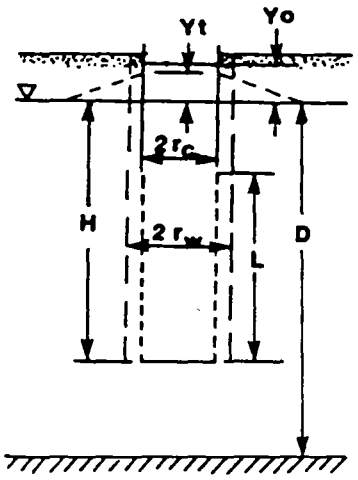
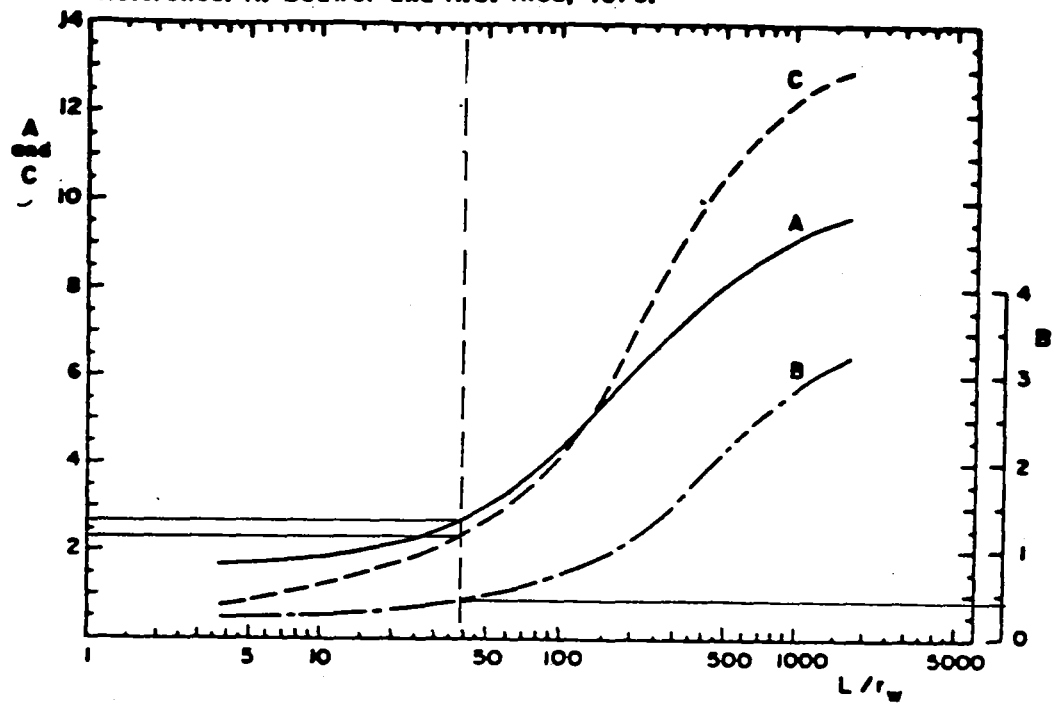
PROJECT NAS Norfolk
SUBJECT Slug Test MW-2 11/6/86

Reference: H. Bouwer and R.C. Rice, 1976.



Partially penetrating, partially perforated well in unconfined aquifer.



Curves relating coefficients *A*, *B*, and *C* to *L/rw*

D = 16.50
L = 16.50
H = 16.50
r_w = .417
r_c = .167
Yo = 4.16

L/rw = 39.57; A = 2.72 ; B = .43 ; C = 2.25

ln{(D-H)/rw} = _____ (max 6.0); if D=H, see*

$$\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{A+B \times \ln\{(D-H)/r_w\}}{L/r_w}\right\}^{-1} = _____$$

$$*\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right\}^{-1} = 2.81$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} * \frac{1}{t} \ln(Y_o/Y_t) = 2.37\times10^{-3} * \frac{1}{t} \ln(Yo/Yt)$$

Assumptions:

t	Y_t	$\frac{1}{t}\ln(Yo/Yt)$	Hydraulic Conductivity (1) ft/sec	ft/yr	gpd/ft²	Transmissivity ft²/sec
6.0	2.8	6.60×10^{-2}	1.56×10^{-4}	4930	101.0	2.58×10^{-3}
12.6	1.7	7.10×10^{-2}	1.68×10^{-4}	5307	108.7	2.78×10^{-3}

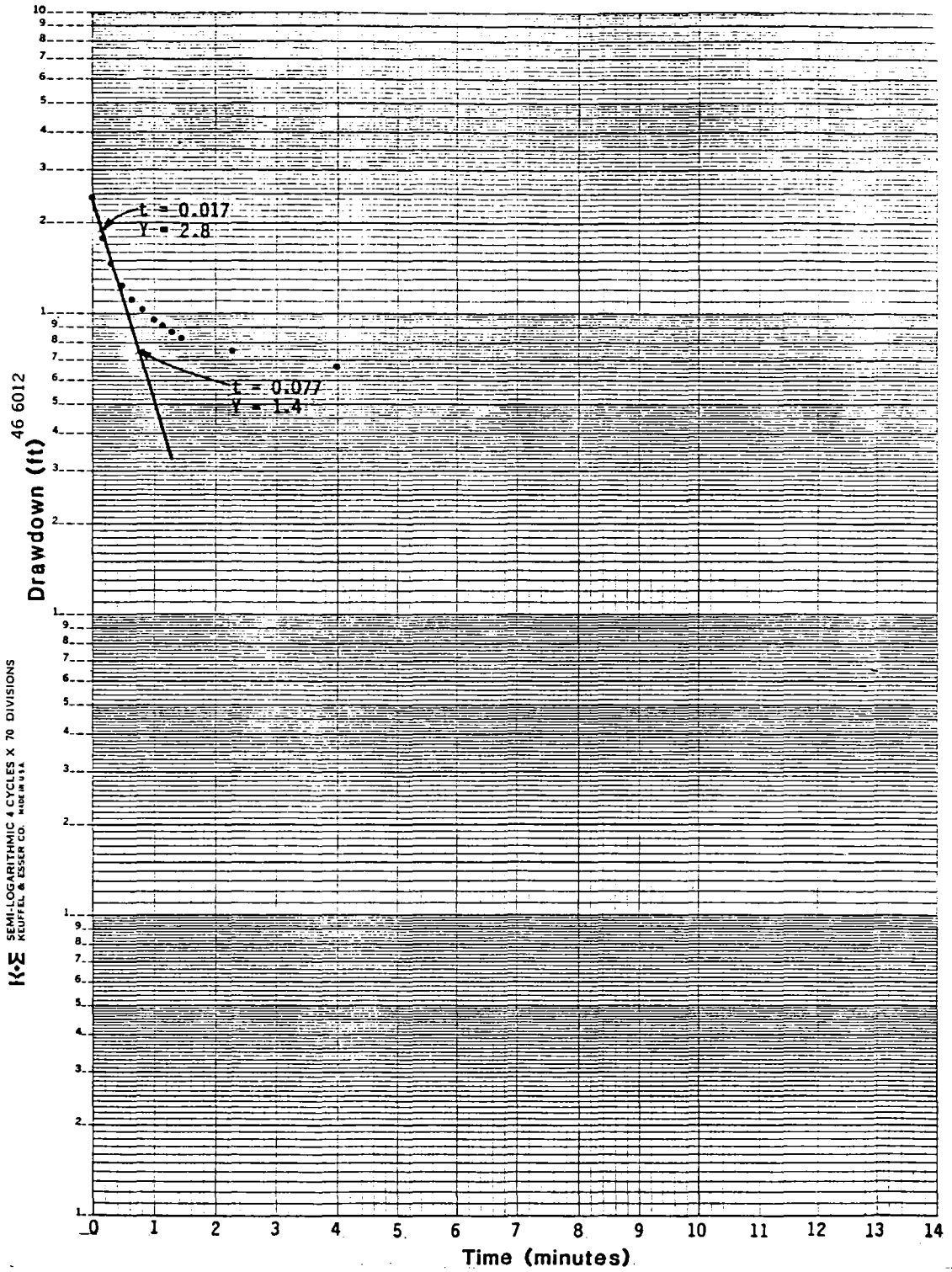
(1) Multiply ft/sec by 646.272 for gpd/ft²

see graph for t and Yt.

SLUG TEST MW-3
NOVEMBER 6, 1986

Elapsed Time (min)	Depth to Water (ft)	Drawdown (ft)
0.00	4.09	3.39
0.02	4.80	2.68
0.03	5.16	2.32
0.05	5.41	2.07
0.07	5.57	1.91
0.08	5.69	1.79
0.10	5.78	1.70
0.12	5.85	1.63
0.13	5.90	1.58
0.15	5.94	1.54
0.23	6.06	1.42
0.32	6.12	1.36
0.50	6.23	1.25
0.75	6.35	1.13
1.0	6.46	1.02
3.0	7.00	0.48
5.0	7.26	0.22
10.0	7.40	0.08

Note: Drawdown is the difference in the water level at time, "t" from the original water level.



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SLUG TEST - MW-3
NOVEMBER 6, 1986
NAS Norfolk
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PLATE
G-3

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,085.12		8/28/87		

SLUG TEST (Injection)

for Unconfined Aquifers with completely of partially penetrating wells.

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SHEET 1 OF 3
JOB NO. 2176,088.12
DATE 11/25/86
COMPUTED BY WLD
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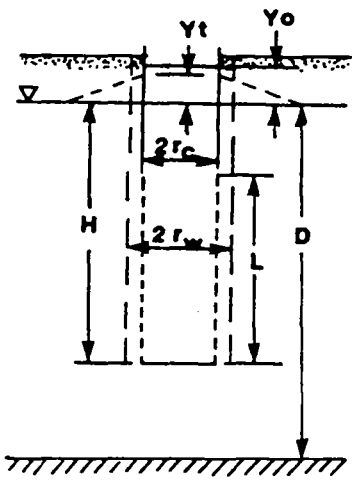
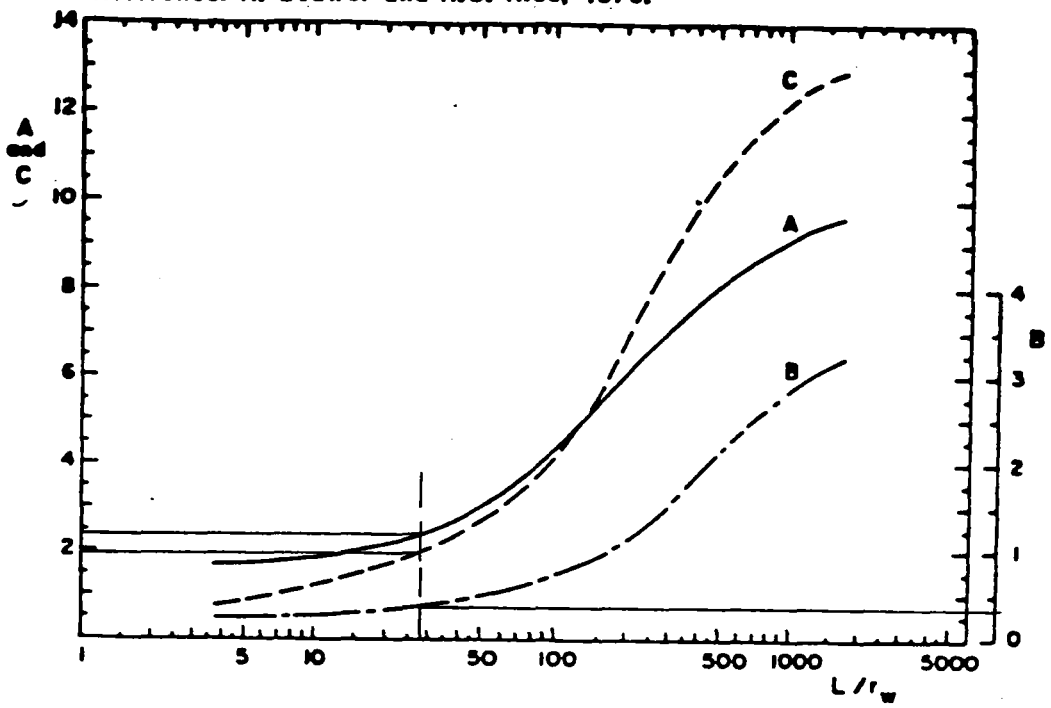
PROJECT NAS Norfolk
SUBJECT Slug Test MW-3 11/6/86

Reference: H. Bouwer and R.C. Rice, 1976.



Partially penetrating, partially perforated well in unconfined aquifer.



Curves relating coefficients A, B, and C to L/rw

D = 11.5
L = 11.5
H = 11.5
r_w = .417
r_c = .167
Yo = 3.39

L/rw = 27.58; A = 2.40 ; B = .35 ; C = 1.99

ln {(D-H)/rw} = _____ (max 6.0); if D=H, see*

$$\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{A+B \times \ln\{(D-H)/r_w\}}{L/r_w}\right\}^{-1} = _____$$

$$*\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right\}^{-1} = 2.48$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} * \frac{1}{t} \ln(Y_o/Y_t) = 3.00 \times 10^{-3} * \frac{1}{t} \ln(Yo/Yt)$$

Assumptions:

t	Yt	$\frac{1}{t}\ln(Yo/Yt)$	Hydraulic Conductivity (1) ft/sec	ft/yr	gpd/ft²	Transmissivity ft²/sec
1.02	2.8	.188	5.63×10^{-4}	17760	364	6.48×10^{-3}
4.62	1.4	.191	5.75×10^{-4}	18130	372	6.61×10^{-3}

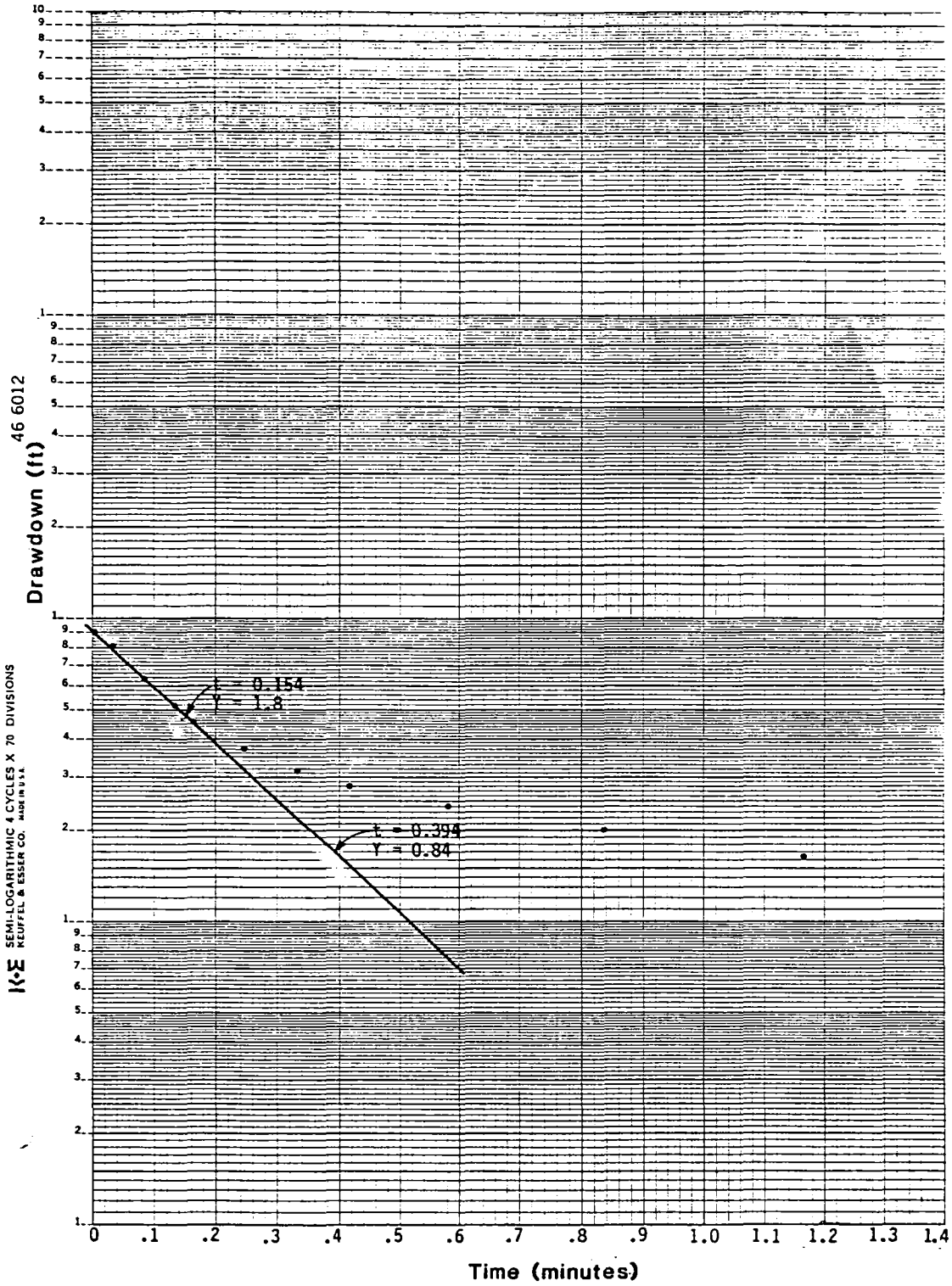
(1) Multiply ft/sec by 646.272 for gpd/ft²

see graph for t and Yt.

SLUG TEST MW-4
NOVEMBER 6, 1986

Elapsed Time (min)	Depth to Water (ft)	Drawdown (ft)
0.00	1.47	2.86
0.02	1.48	2.85
0.03	1.61	2.72
0.05	1.79	2.54
0.08	2.09	2.24
0.10	2.21	2.12
0.12	2.31	2.02
0.13	2.40	1.93
0.15	2.49	1.84
0.17	2.56	0.77
0.25	2.83	1.50
0.33	3.00	1.33
0.58	3.25	1.08
0.83	3.38	0.95
1.00	3.44	0.89
1.50	3.60	0.73
3.0	3.90	0.43
5.0	4.09	0.24
10.0	4.27	0.06

Note: Drawdown is the difference in the water level at time, "t" from the original water level.



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SLUG TEST - MW-4
NOVEMBER 6, 1986
NAS Norfolk
Norfolk, Virginia

PLATE
G-4

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
CS	2176,085.12		8/24/87		

SLUG TEST (Injection)

for Unconfined Aquifers with completely of partially penetrating wells.

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SHEET 1 OF 3
JOB NO. 2176,088.12
DATE 11/19/86
COMPUTED BY CIPM
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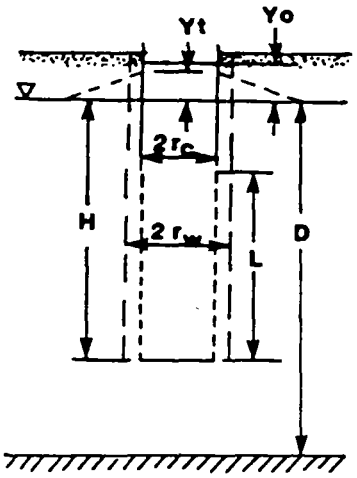
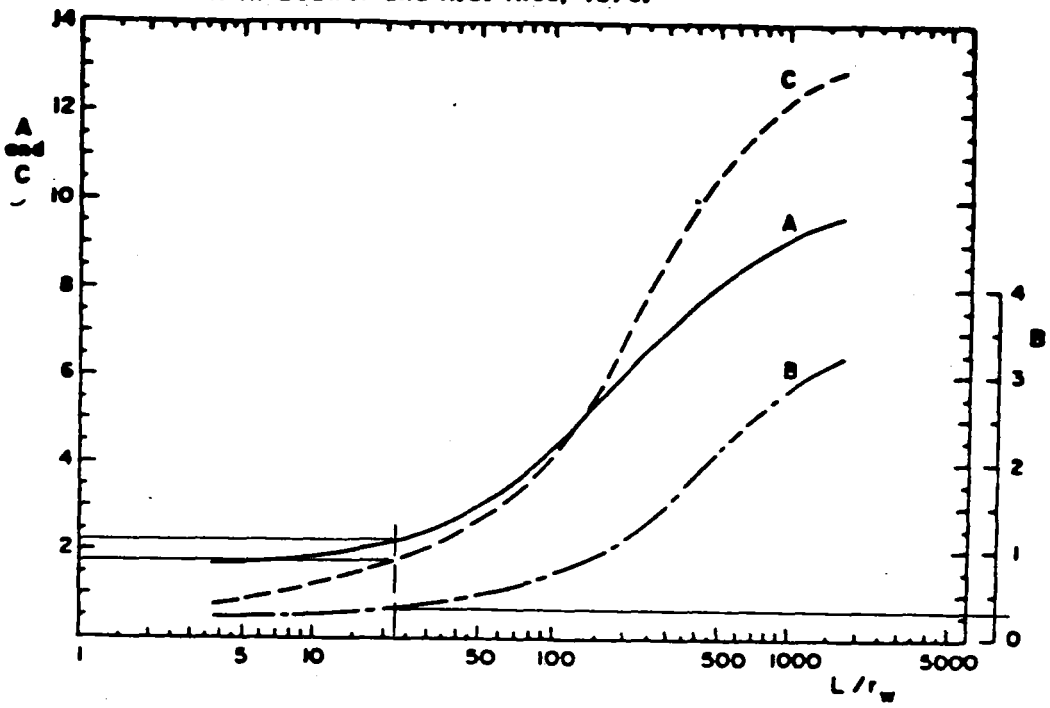
PROJECT NAS Norfolk
SUBJECT Slug Test MW-4 11/06/86

Reference: H. Bouwer and R.C. Rice, 1976.



Partially penetrating, partially perforated well in unconfined aquifer.



Curves relating coefficients A, B, and C to L/rw

D = 9.17
L = 9.17
H = 9.17
r_w = .417
r_c = .167
Yo = 2.86

L/rw = 21.99; A = 2.20; B = 0.30; C = 1.70

ln{(D-H)/rw} = _____ (max 6.0); if D=H, see*

$$\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{A+B \times \ln\{(D-H)/r_w\}}{L/r_w}\right\}^{-1} = _____$$

$$*\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right\}^{-1} = 2.308$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} * \frac{1}{t} \ln(Y_o/Y_t) = \frac{3.51\times10^{-3}}{} * \frac{1}{t} \ln(Yo/Yt)$$

Assumptions:

t	Yt	$\frac{1}{t}\ln(Yo/Yt)$	Hydraulic Conductivity (1) ft/sec	ft/yr	gpd/ft²	Transmissivity ft²/sec
9.00	1.82	5.14×10^{-2}	4.80×10^{-4}	5690	116.6	1.65×10^{-3}
23.4	0.84	5.24×10^{-2}	1.84×10^{-4}	5800	118.9	1.69×10^{-3}

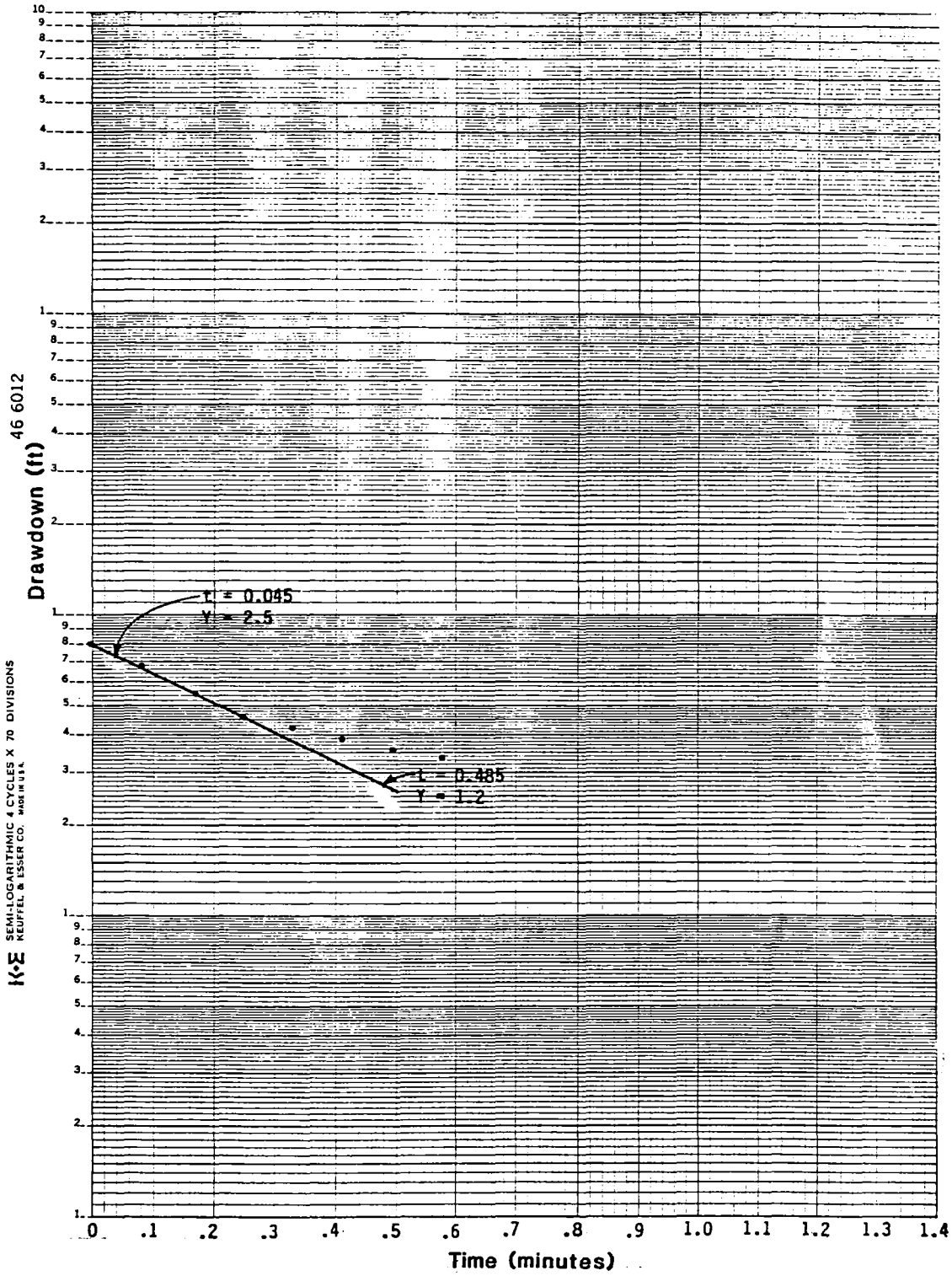
(1) Multiply ft/sec by 646.272 for gpd/ft²

see graph for t and Yt.

SLUG TEST MW-7
NOVEMBER 6, 1986

Elapsed Time (min)	Depth to Water (ft)	Drawdown (ft)
0.00	3.82	2.67
0.08	4.11	2.38
0.17	4.49	2.00
0.25	4.70	1.79
0.33	4.83	1.66
0.42	4.92	1.57
0.50	5.00	1.49
0.58	5.07	1.42
0.67	5.12	1.37
1.0	5.29	1.20
1.5	5.44	1.05
3.0	5.73	0.76
5.0	5.87	0.62
7.5	6.00	0.49
10.0	6.11	0.38

Note: Drawdown is the difference in the water level at time, "t" from the original water level.



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SLUG TEST - MW-7
NOVEMBER 6, 1986
NAS Norfolk
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PLATE
G-5

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,085.12		8/28/87		

for Unconfined Aquifers with completely of partially penetrating wells.

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SHEET 1 OF 3
JOB NO. 2176,088.12
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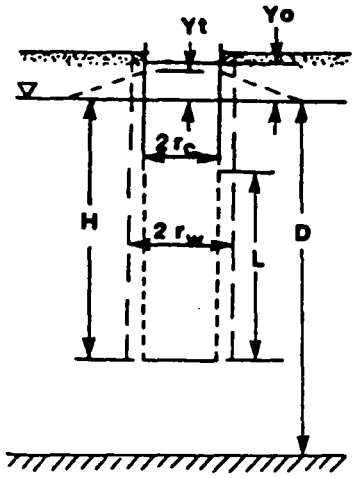
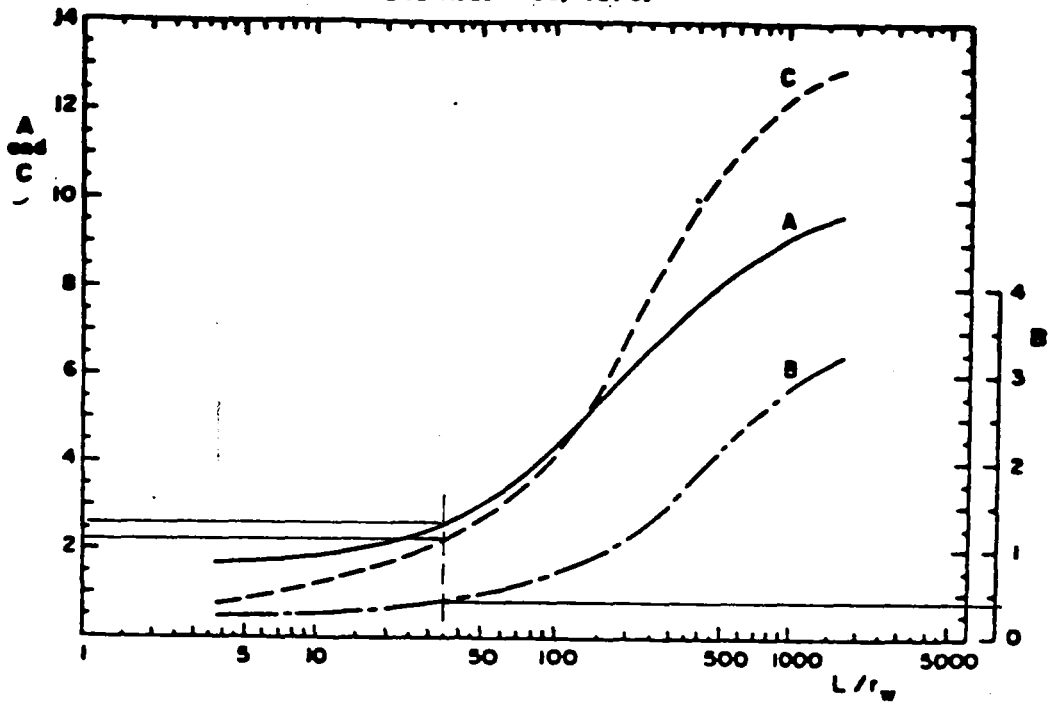
SUBJECT Slug Test MW-7 11/06/86

Reference: H. Bouwer and R.C. Rice, 1976.



Partially penetrating, partially perforated well in unconfined aquifer.



Curves relating coefficients A, B, and C to L/rw.

D = >16.25
L = 15.0
H = 15.0
r_w = 0.417
r_c = 0.167
Yo = 2.67

L/rw = 35.97 ; A = 2.58; B = 0.41 ; C = 2.25

ln{(D-H)/rw} = 6 (max 6.0); if D=H, see*

$$\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{A+B \times \ln\{(D-H)/r_w\}}{L/r_w}\right\}^{-1} = 2.236$$

$$*\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right\}^{-1} = 2.706$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} * \frac{1}{t}\ln(Y_o/Y_t) = _____ * \frac{1}{t}\ln(Y_o/Y_t)$$

Assumptions:
if D > H = 2.08×10^{-3}
if D = H = 2.52×10^{-3}

t	Yt	$\frac{1}{t}\ln(Yo/Yt)$	Hydraulic Conductivity (1) ft/sec	ft/yr	gpd/ft²	Transmissivity ft²/sec	
2.7	2.5	2.44×10^{-2}	5.07×10^{-5}	1600	32.78	9.22×10^{-4}	D > H
			6.15×10^{-5}	1939	39.74		D = H
29.1	1.2	2.75×10^{-2}	5.72×10^{-5}	1803	36.97	1.04×10^{-3}	D > H
			6.93×10^{-5}	2185	44.79		D = H

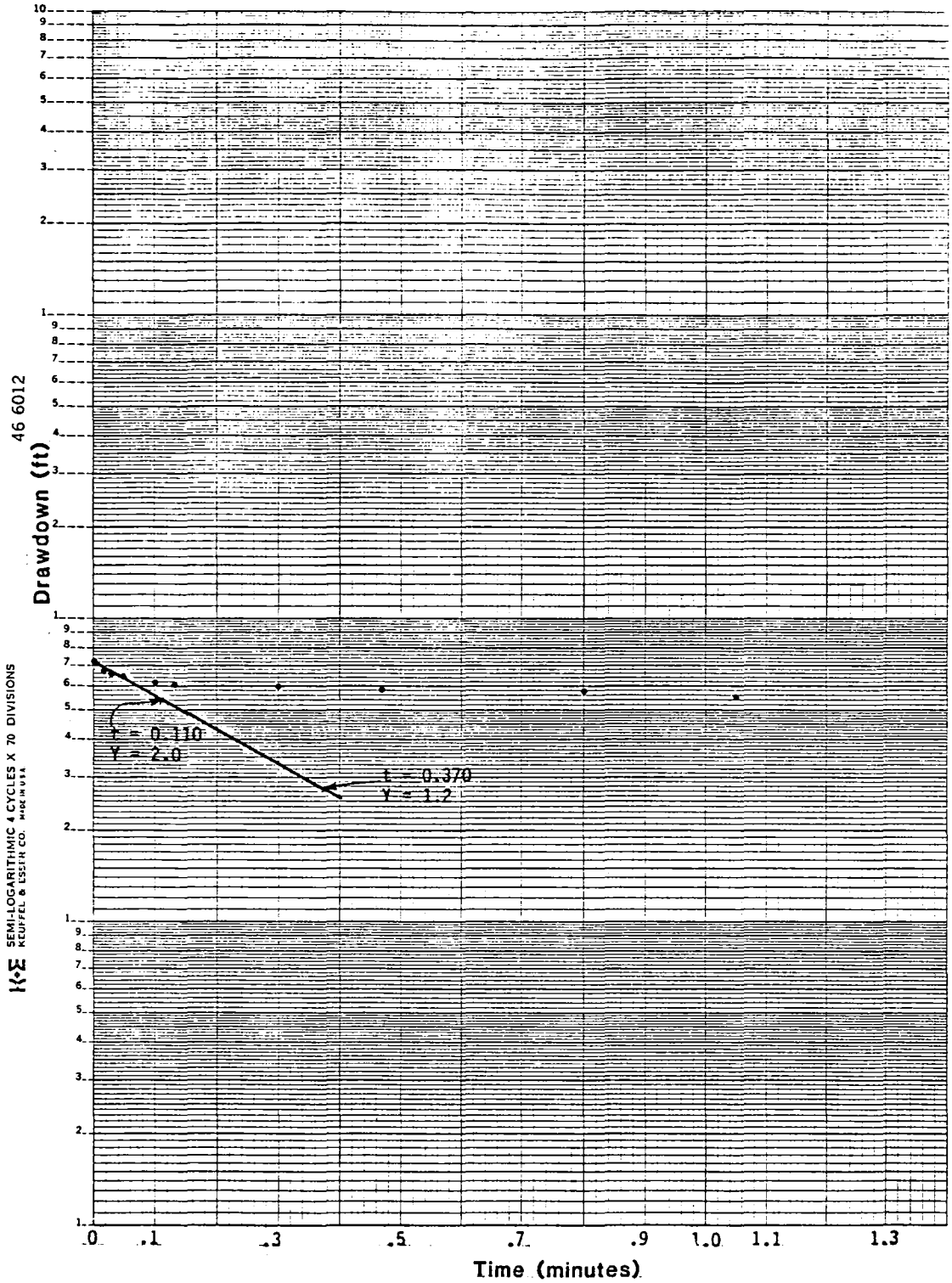
(1) Multiply ft/sec by 646.272 for gpd/ft²

see graph for t and Yt.

SLUG TEST MW-13
NOVEMBER 7, 1986

Elapsed Time (min)	Depth to Water (ft)	Drawdown (ft)
0.00	3.86	2.49
0.02	4.00	2.35
0.03	4.04	2.31
0.05	4.06	2.29
0.07	4.10	2.25
0.08	4.12	2.23
0.10	4.14	2.21
0.12	4.16	2.19
0.13	4.17	2.18
0.22	4.19	2.16
0.30	4.20	2.15
0.50	4.22	2.13
1.0	4.27	2.08
1.5	4.33	2.02
2.0	4.39	1.96
5.0	4.65	1.70
10.0	4.95	1.40

Note: Drawdown is the difference in the water level at time, "t" from the original water level.



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SLUG TEST - MW-13
NOVEMBER 6, 1986
NAS Norfolk
Norfolk, Virginia

PLATE
G-6

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	2176,085.12		8/28/87		

SLUG TEST (Injection)

for Unconfined Aquifers with completely of partially penetrating wells.

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SHEET 1 OF 3
JOB NO. 2176,088.12
DATE 11/19/86
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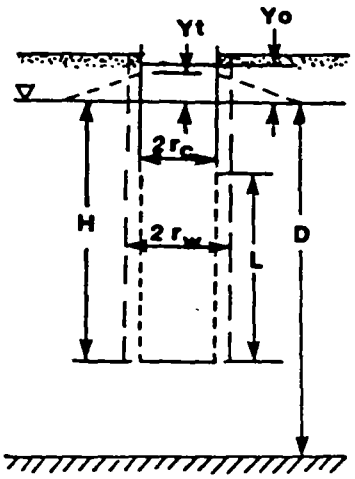
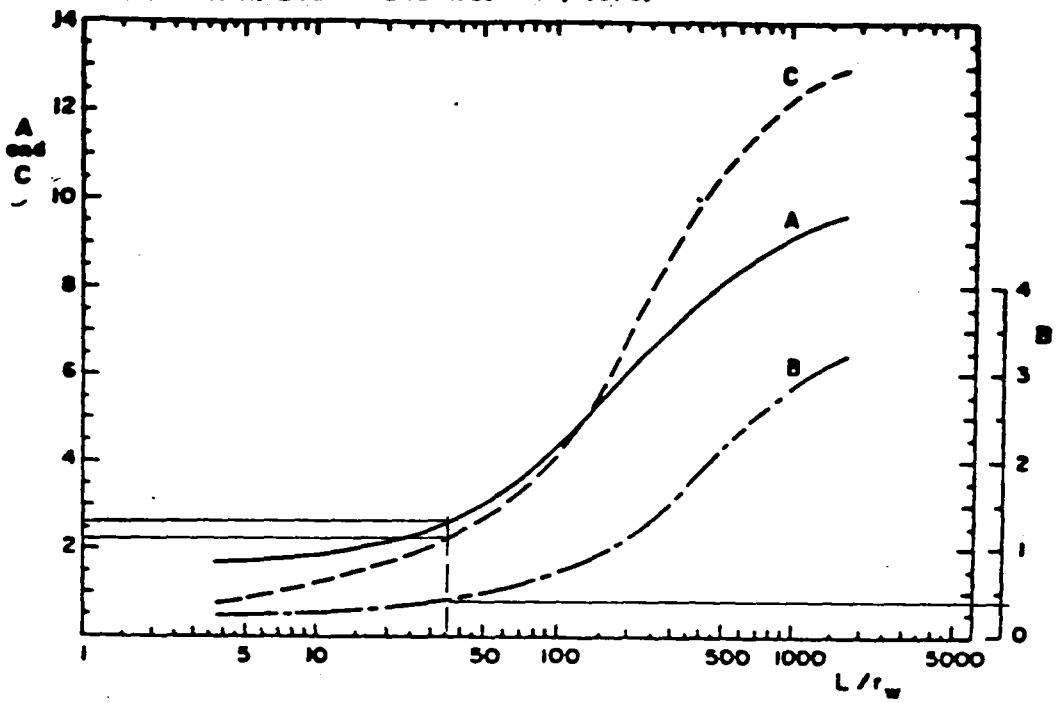
PROJECT NAS Norfolk
SUBJECT Slug Test MW-13 11/07/86

Reference: H. Bouwer and R.C. Rice, 1976.



Partially penetrating, partially perforated well in unconfined aquifer.



Curves relating coefficients A, B, and C to L/rw

D = 17.50
L = 15.0
H = 15.0
r_w = .417
r_c = .167
Yo = 2.50

L/rw = 35.97; A = 2.58 ; B = .40 ; C = 2.25

ln{(D-H)/rw} = 6 (max 6.0); if D=H, see*

$$\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{A+B \times \ln\{(D-H)/r_w\}}{L/r_w}\right\}^{-1} = 2.245$$

$$*\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right\}^{-1} = 2.706$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} * \frac{1}{t}\ln(Y_o/Y_t) = _____ * \frac{1}{t}\ln(Y_o/Y_t)$$

Assumptions:

if D > H = 2.08×10^{-3}

if D = H = 2.52×10^{-3}

t	Yt	$\frac{1}{t}\ln(Yo/Yt)$	Hydraulic Conductivity (1) ft/sec	ft/yr	gpd/ft²	Transmissivity ft²/sec	
6.6	2.0	3.38×10^{-2}	7.05×10^{-5}	2225	45.59	1.27×10^{-3}	D > H
			8.52×10^{-5}	2686	55.05		D = H
22.2	1.2	3.31×10^{-2}	6.90×10^{-5}	2176	44.59	1.25×10^{-3}	D > H
			8.33×10^{-5}	2627	53.84		D = H

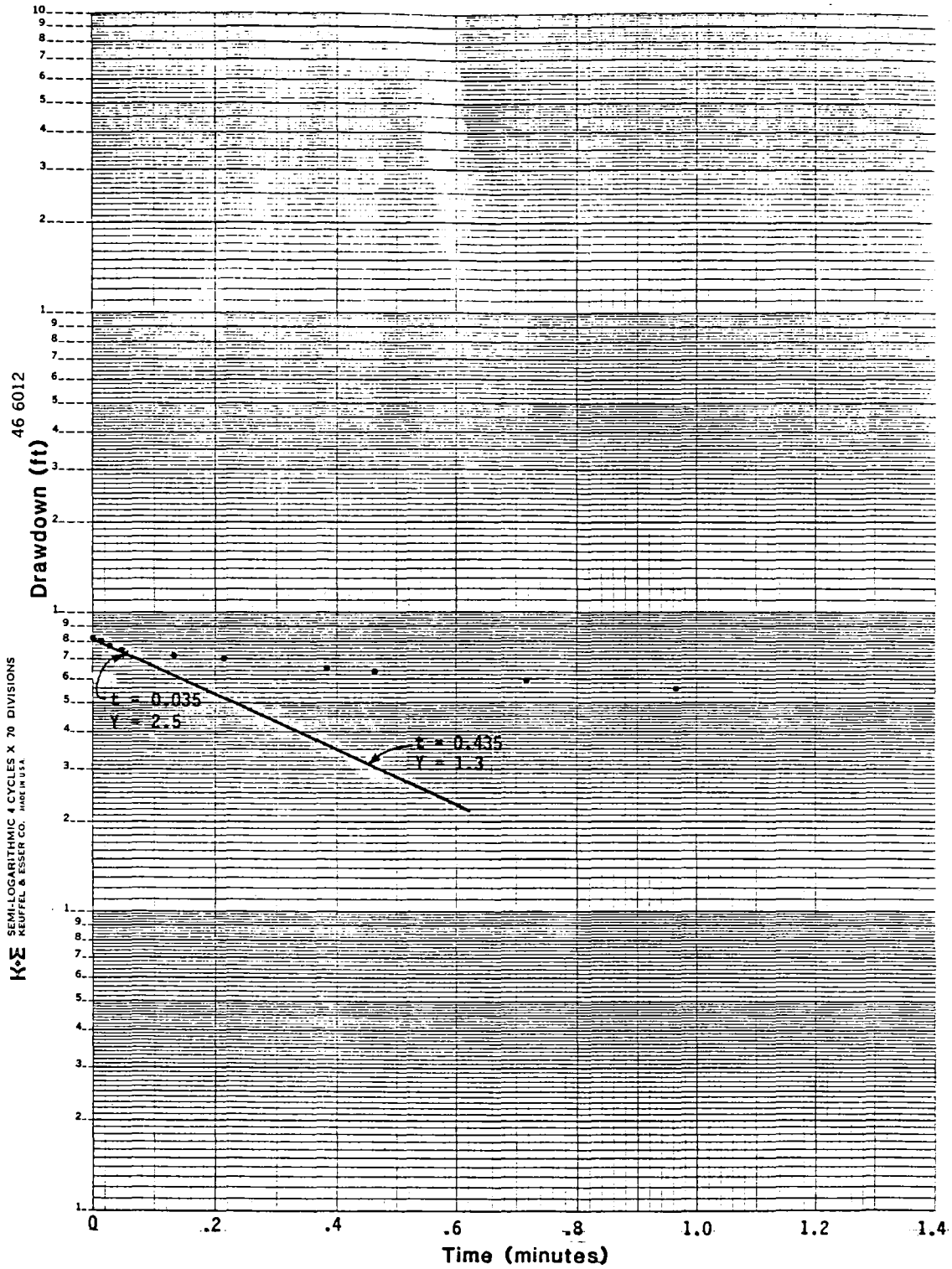
(1) Multiply ft/sec by 646.272 for gpd/ft²

see graph for t and Yt.

SLUG TEST MW-14
NOVEMBER 7, 1986

Elapsed Time (min)	Depth to Water (ft)	Drawdown (ft)
0.00	2.58	2.72
0.02	2.62	2.68
0.03	2.68	2.62
0.05	2.72	2.58
0.13	2.81	2.49
0.22	2.88	2.42
0.30	2.95	2.35
0.38	3.00	2.30
0.47	3.05	2.25
0.72	3.16	2.14
1.0	3.28	2.02
1.5	3.41	1.89
3.0	3.77	1.53
5.0	4.16	1.14
10.0	4.85	0.45

Note: Drawdown is the difference in the water level at time, "t" from the original water level.



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SLUG TEST - MW-14
NOVEMBER 6, 1986
NAS Norfolk
Norfolk, Virginia

PLATE
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
EL	2176,085.12		5/04/87		

SLUG TEST (Injection)

for Unconfined Aquifers with completely of partially penetrating wells.

Harding Lawson Associates
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SHEET 1 OF 3
JOB NO. 2176,088.12
DATE 11/19/86
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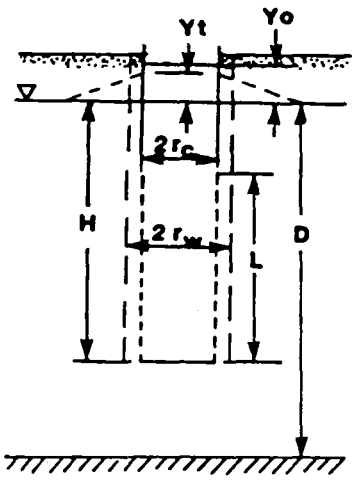
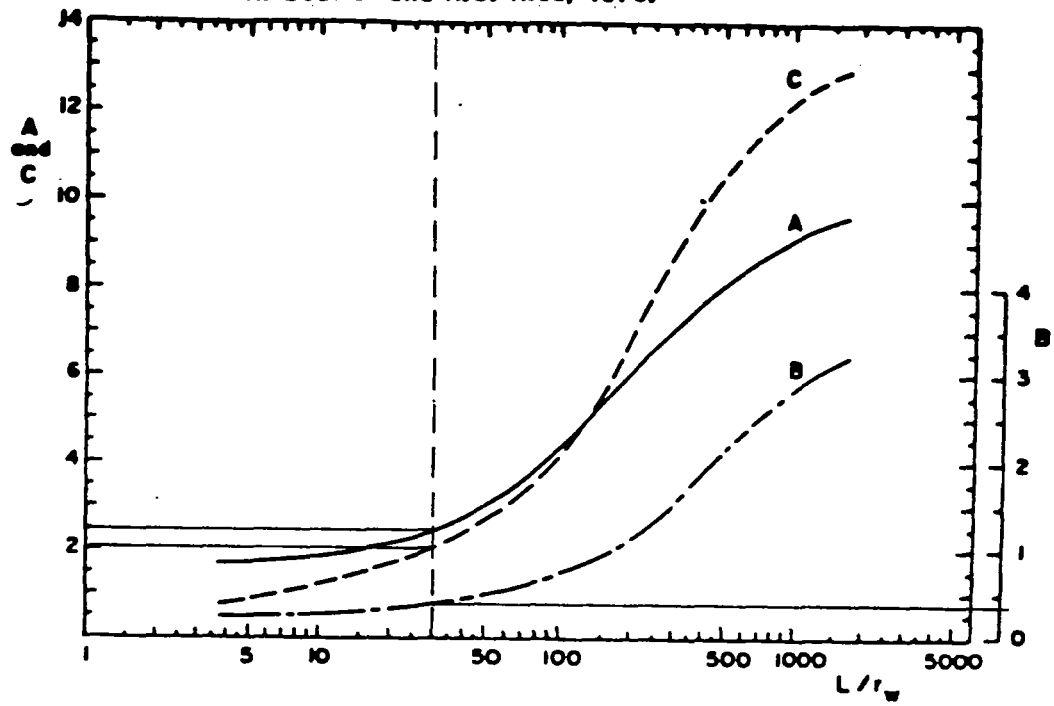
PROJECT NAS Norfolk
SUBJECT Slug Test MW-14 11/07/86

Reference: H. Bouwer and R.C. Rice, 1976.



Partially penetrating, partially perforated well in unconfined aquifer.



Curves relating coefficients *A*, *B*, and *C* to *L/rw*

D = 12.5
L = 12.5
H = 12.5
r_w = .417
r_c = .167
Yo = 2.72

L/rw = 29.98; A = 2.49; B = .38; C = 2.00

ln{(D-H)/rw} = _____ (max 6.0); if D=H, see*

$$\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{A+B \times \ln\{(D-H)/r_w\}}{L/r_w}\right\}^{-1} = _____$$

$$*\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right\}^{-1} = 2.49$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} * \frac{1}{t} \ln(Y_o/Y_t) = 2.79 \times 10^{-3} * \frac{1}{t} \ln(Yo/Yt)$$

Assumptions:

t	Yt	$\frac{1}{t}\ln(Yo/Yt)$	Hydraulic Conductivity (1) ft/sec	ft/yr	gpd/ft²	Transmissivity ft²/sec
2.1	2.5	4.02×10^{-2}	1.12×10^{-4}	3535	72.43	1.40×10^{-3}
28.2	1.3	2.62×10^{-2}	7.30×10^{-5}	2304	47.21	9.13×10^{-4}

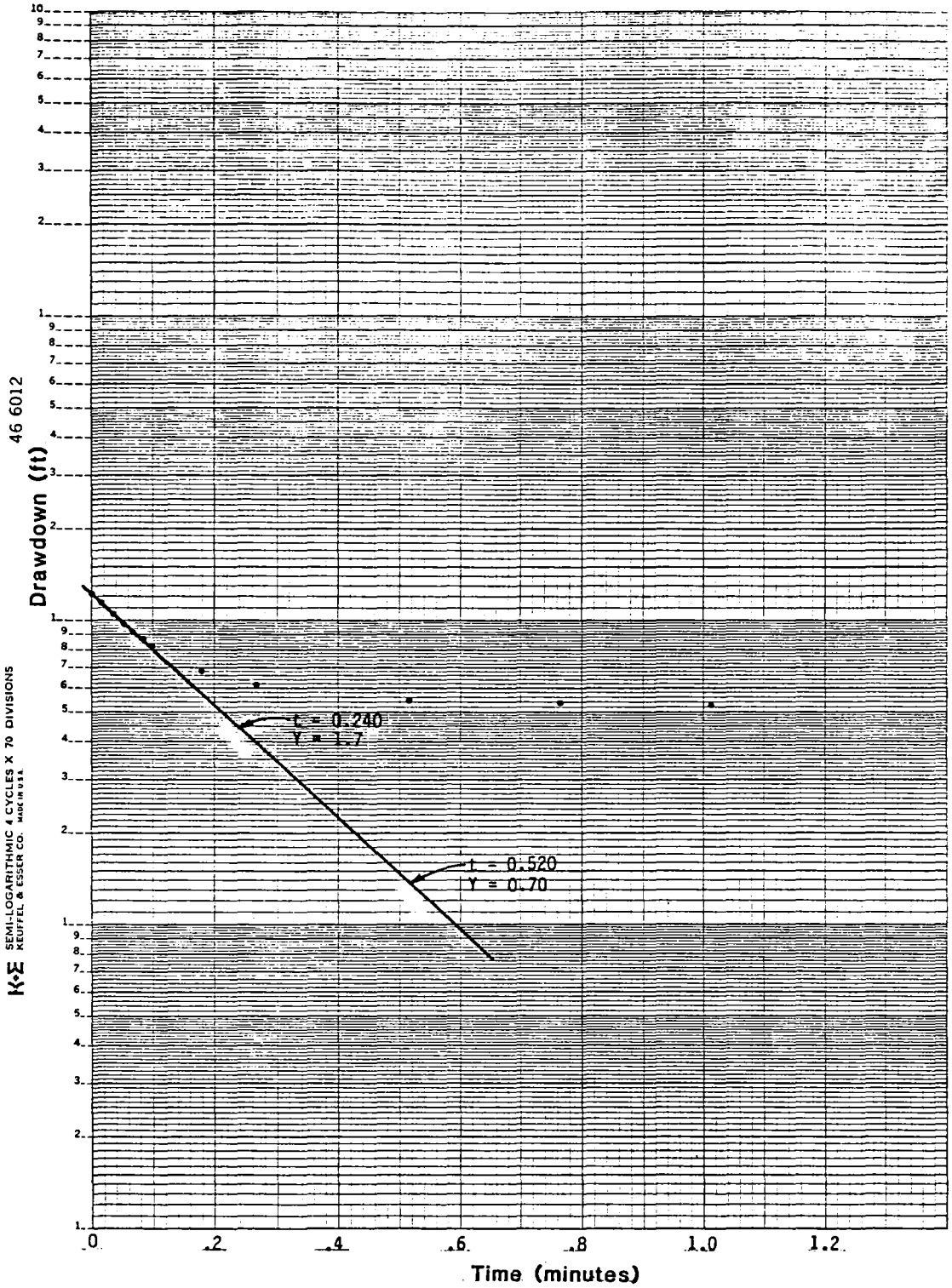
(1) Multiply ft/sec by 646.272 for gpd/ft²

see graph for t and Yt.

SLUG TEST MW-16
NOVEMBER 6, 1986

Elapsed Time (min)	Depth to Water (ft)	Drawdown (ft)
0.00	1.31	3.61
0.02	1.49	3.43
0.03	1.68	3.24
0.05	1.84	3.08
0.07	1.98	2.94
0.08	2.10	2.82
0.10	2.21	2.71
0.18	2.57	2.35
0.27	2.74	2.18
0.50	2.93	1.99
1.0	2.96	1.96
1.5	2.99	1.93
3.0	3.06	1.86
5.0	3.08	1.84
10.0	3.26	1.66

Note: Drawdown is the difference in the water level at time, "t" from the original water level.



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SLUG TEST - MW-16
NOVEMBER 6, 1986
NAS Norfolk
Norfolk, Virginia

PLATE
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12				

SLUG TEST (Injection)

for Unconfined Aquifers with completely of partially penetrating wells.

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SHEET 1 OF 3
JOB NO. 2176,088.12
DATE 11/19/86
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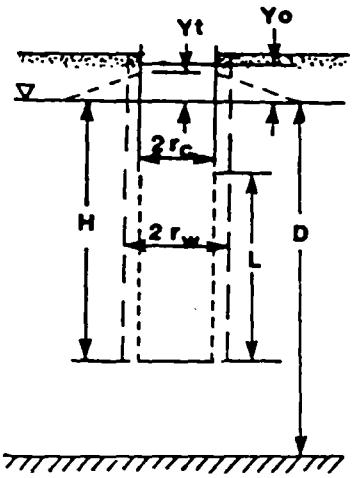
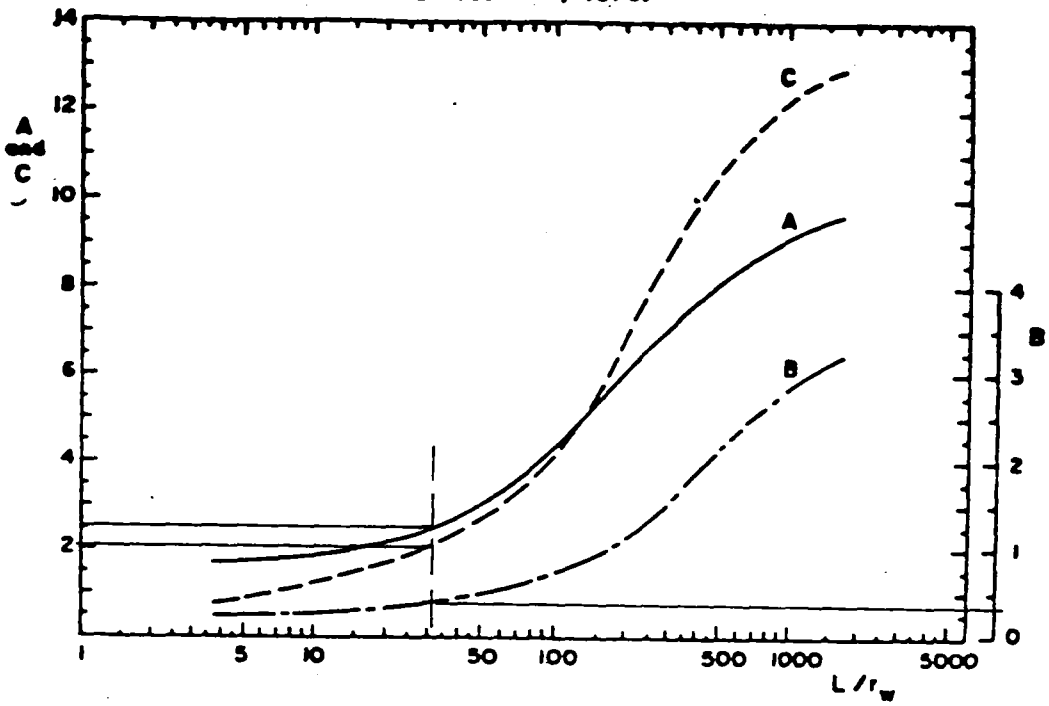
SUBJECT Slug Test MW-16 11/06/86

Reference: H. Bouwer and R.C. Rice, 1976.



Partially penetrating, partially perforated well in unconfined aquifer.



Curves relating coefficients A, B, and C to L/rw.

D = 13.0
L = 13.0
H = 13.0
r_w = .417
r_c = .167
Yo = 3.61

L/rw = 31.18; A = 2.49; B = .35; C = 2.05

ln{(D-H)/rw} = _____ (max 6.0); if D=H, see*

$$\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{A+B \times \ln\{(D-H)/r_w\}}{L/r_w}\right\}^{-1} = _____$$

$$*\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right\}^{-1} = 2.59$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} * \frac{1}{t}\ln(Y_o/Y_t) = _____ * \frac{1}{t}\ln(Yo/Yt)$$

Assumptions:

t	Yt	$\frac{1}{t}\ln(Yo/Yt)$	Hydraulic Conductivity (1) ft/sec	ft/yr	gpd/ft²	Transmissivity ft²/sec
14.4	1.7	5.23×10^{-2}	1.45×10^{-4}	4585	93.96	1.89×10^{-3}
31.2	.7	5.26×10^{-2}	1.46×10^{-4}	4611	94.50	1.90×10^{-3}

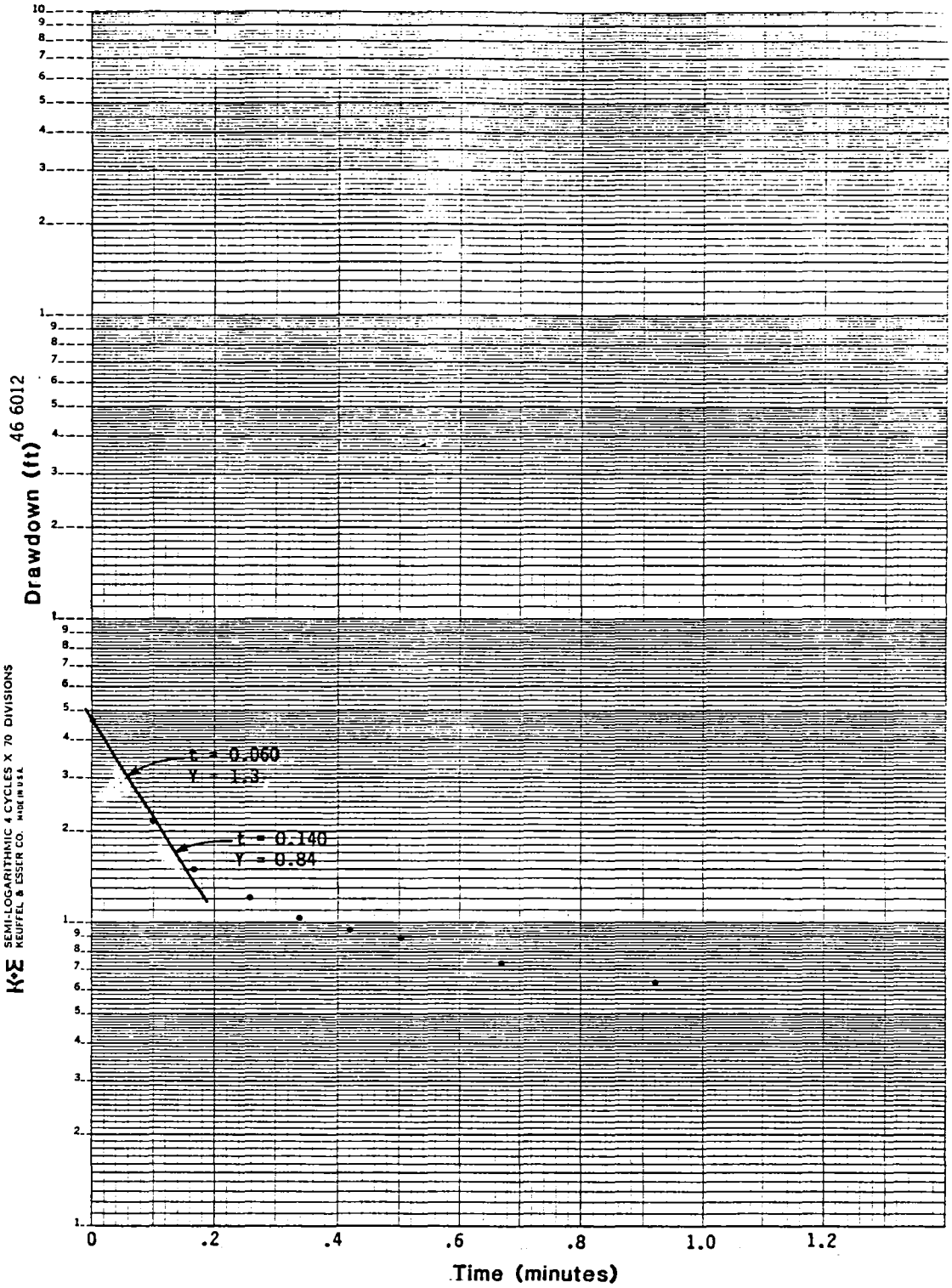
(1) Multiply ft/sec by 646.272 for gpd/ft²

see graph for t and Yt.

SLUG TEST MW-20
NOVEMBER 6, 1986

Elapsed Time (min)	Depth to Water (ft)	Drawdown (ft)
0.00	4.29	1.78
0.08	5.06	1.01
0.17	5.30	0.77
0.25	5.41	0.66
0.33	5.48	0.59
0.42	5.52	0.55
0.50	5.54	0.53
0.67	5.61	0.46
1.00	5.66	0.41
1.25	5.70	0.37
1.5	5.73	0.34
3.0	5.85	0.22
5.0	5.92	0.15
10.0	6.01	0.06

Note: Drawdown is the difference in the water level at time, "t" from the original water level.



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SLUG TEST - MW-20
NOVEMBER 6, 1986

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Norfolk, Virginia

PLATE
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ES	2176,085.12	[illegible]	8/24/87		

SLUG TEST (Injection)

for Unconfined Aquifers with completely of partially penetrating wells.

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SHEET 1 OF 3
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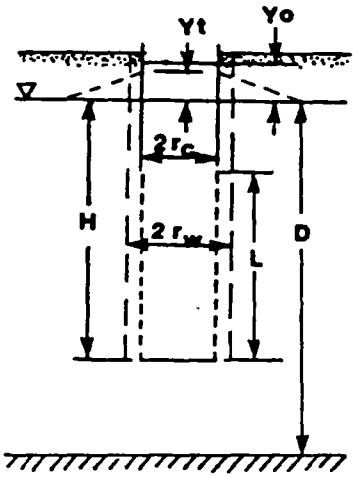
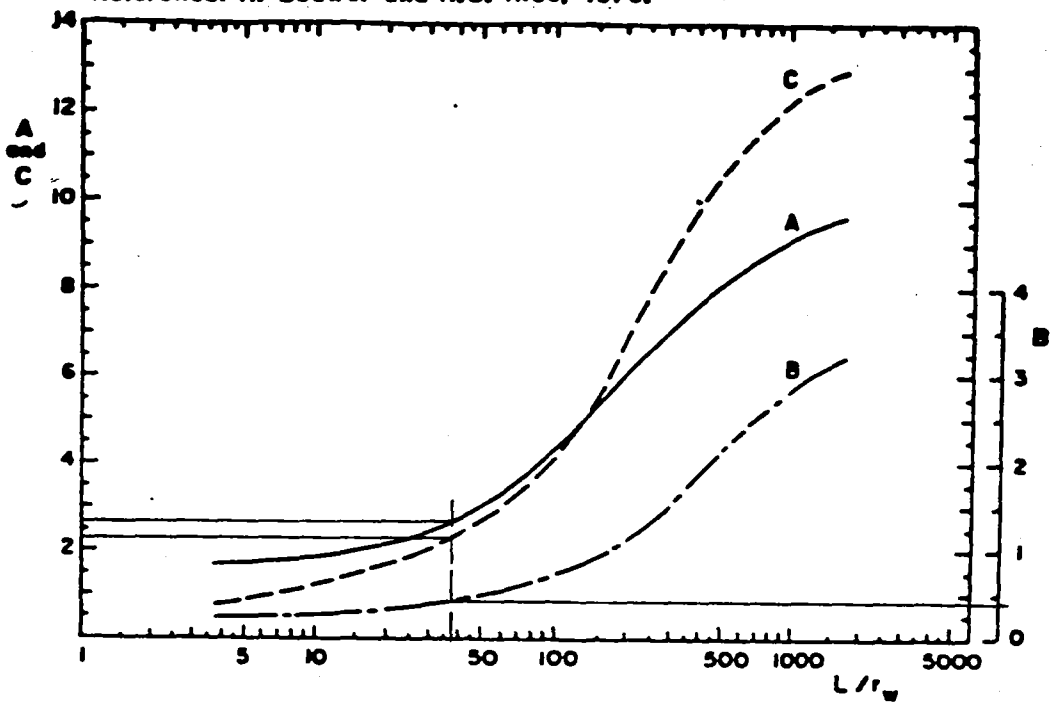
SUBJECT Slug Test MW-20 11/06/86

Reference: H. Bouwer and R.C. Rice, 1976.



Partially penetrating, partially perforated well in unconfined aquifer.



Curves relating coefficients A, B, and C to L/rw

D = >16.0
L = 16.0
H = 16.0
r_w = .417
r_c = .167
Yo = 1.78

L/rw = 38.37; A = 2.62; B = .43; C = 2.25

ln{(D-H)/rw} = 6 (max 6.0); if D=H, see*

$$\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{A+B \times \ln\{(D-H)/r_w\}}{L/r_w}\right\}^{-1} = 2.29$$

$$*\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right\}^{-1} = 2.78$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} \cdot \frac{1}{t} \ln(Y_o/Y_t) = _____ * \frac{1}{t} \ln(Y_o/Y_t)$$

Assumptions:

if D > H = 1.99×10^{-3}

if D = H = 2.42×10^{-3}

t	Y_t	$\frac{1}{t}\ln(Y_o/Y_t)$	Hydraulic Conductivity (1) ft/sec	ft/yr	gpd/ft²	Transmissivity ft²/sec	
3.6	1.3	8.73×10^{-2}	1.73×10^{-4}	5487	112.5	3.38×10^{-3}	D > H
			2.11×10^{-4}	6654	136.4		D = H
8.4	.84	8.94×10^{-2}	1.78×10^{-4}	5610	115.0	3.46×10^{-3}	D > H
			2.16×10^{-4}	6823	139.8		D = H

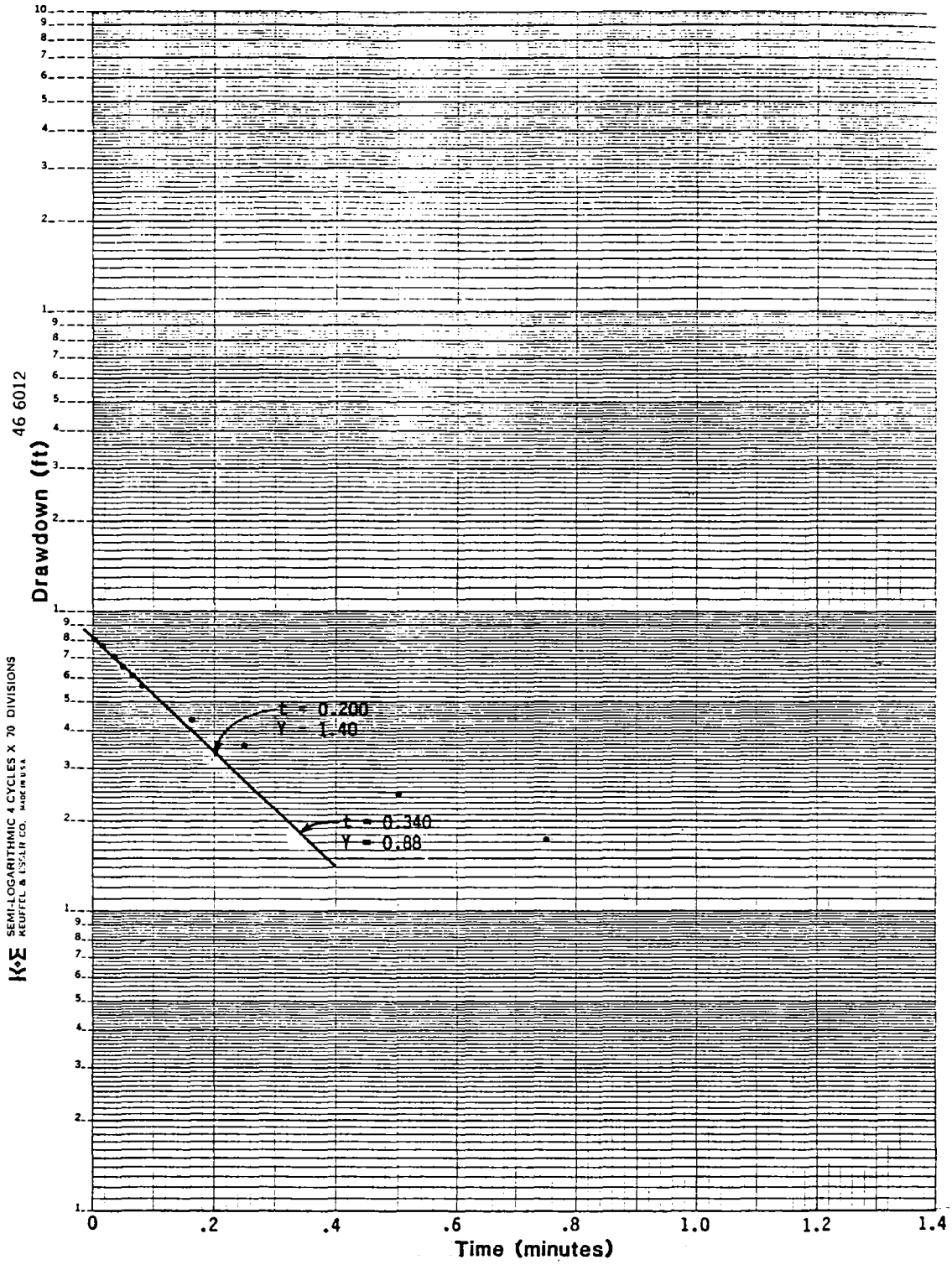
(1) Multiply ft/sec by 646.272 for gpd/ft²

see graph for t and Yt.

SLUG TEST MW-24
NOVEMBER 6, 1986

Elapsed Time (min)	Depth to Water (ft)	Drawdown (ft)
0.00	3.81	2.64
0.02	3.85	2.60
0.03	4.00	2.45
0.05	4.16	2.29
0.07	4.29	2.16
0.08	4.40	2.05
0.17	4.76	1.69
0.25	4.97	1.48
0.50	5.34	1.11
0.75	5.59	0.86
1.0	5.78	0.67
1.5	6.01	0.44
3.0	6.29	0.16
5.0	6.40	0.05
10.0	6.45	0.00

Note: Drawdown is the difference in the water level at time, "t" from the original water level.



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SLUG TEST - MW-24
NOVEMBER 6, 1986
NAS Norfolk
Norfolk, Virginia

PLATE
G-10

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,085.12		8/24/87		

SLUG TEST (Injection)

for Unconfined Aquifers with completely of partially penetrating wells.

Harding Lawson Associates
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SHEET 1 OF 3
JOB NO. 2176,088.12
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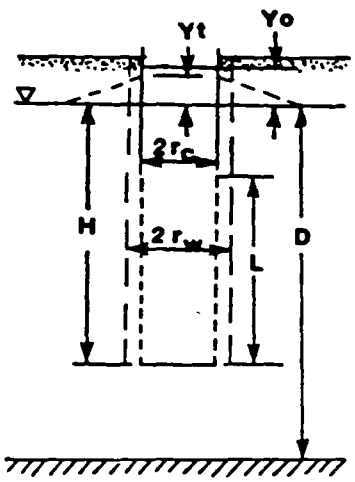
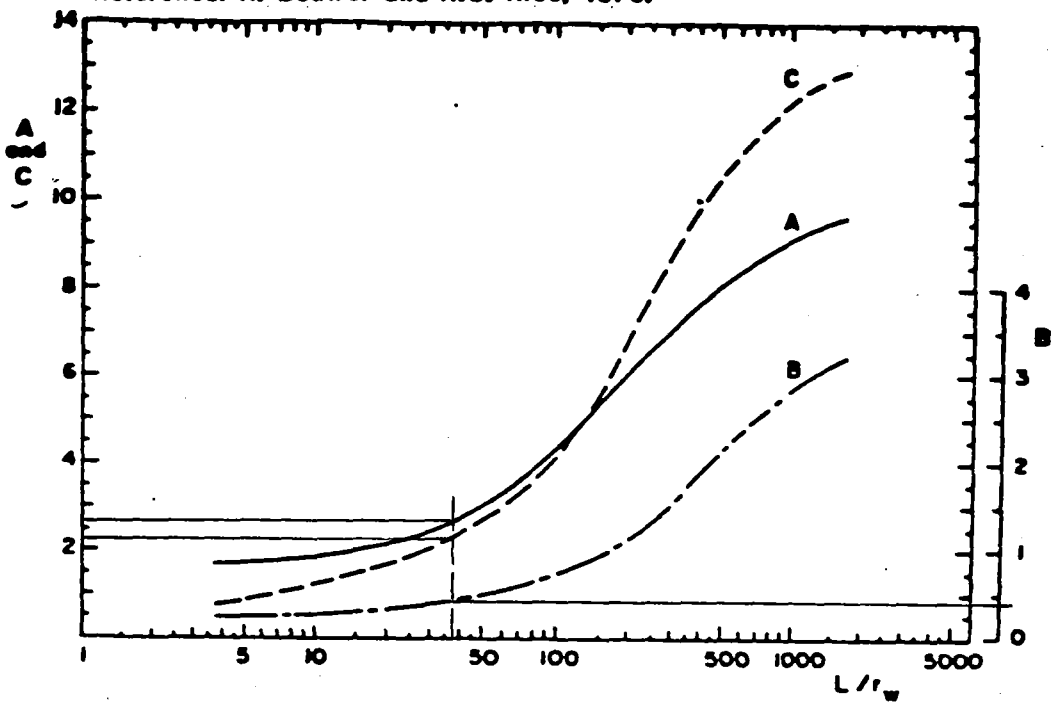
SUBJECT Slug Test MW-24 11/06/86

Reference: H. Bouwer and R.C. Rice, 1976.



Partially penetrating, partially perforated well in unconfined aquifer.



Curves relating coefficients A, B, and C to L/rw

D = >17.0
L = 16,0
H = 16.0
r_w = .417
r_c = .167
Yo = 2.70

L/rw = 38.37; A = 2.70; B = .45 ; C = 2.30

ln{(D-H)/rw} = .6 (max 6.0); if D=H, see*

$$\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{A+B \times \ln\{(D-H)/r_w\}}{L/r_w}\right\}^{-1} = 2.261$$

$$*\ln(R_e/r_w) = \left\{\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right\}^{-1} = 2.766$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} \cdot \frac{1}{t} \ln(Y_o/Y_t) = _____ * \frac{1}{t}\ln(Y_o/Y_t)$$

if D > H = 1.97×10^{-3}

Assumptions:

if D = H = 2.41×10^{-3}

t	Yt	$\frac{1}{t}\ln(Yo/Yt)$	Hydraulic Conductivity (1) ft/sec	ft/yr	gpd/ft²	Transmissivity ft²/sec	
12.0	1.4	5.47×10^{-2}	1.89×10^{-4}	3400	69.72	2.11×10^{-3}	D > H
			1.32×10^{-4}	4160	85.28		D = H
20.4	0.88	5.49×10^{-2}	1.08×10^{-4}	3415	70.00	2.12×10^{-3}	D > H
			1.32×10^{-4}	4175	85.60		D = H

(1) Multiply ft/sec by 646.272 for gpd/ft²

see graph for t and Yt.

PUMP TEST MW-17
November 3 and 4, 1986

Elapsed Time (min)	MW-17 Depth to Water (ft)	MW-17 Drawdown (ft)	MW-5 Depth to Water (ft)	MW-5 Drawdown (ft)
0.0	6.77	0.00	7.03	0.00
0.1	7.34	0.57	7.08	0.05
0.5	8.69	1.92	7.04	0.01
1.0	9.45	2.68	7.04	0.01
1.5	9.95	3.18	6.98	-0.05
2.0	10.17	3.40	7.01	-0.02
2.5	10.23	3.46	6.96	-0.07
3.0	10.29	3.52	7.03	0.00
3.5	10.35	3.58	7.02	-0.01
4.0	10.41	3.64	7.06	0.03
4.5	10.43	3.66	6.76	-0.27
5.0	10.45	3.68	6.98	-0.05
6.0	10.49	3.72	7.03	0.00
7.0	10.53	3.76	7.03	0.00
8.0	10.57	3.80	6.95	-0.08
10	10.62	3.85	7.03	0.00
12	10.66	3.89	7.01	-0.02
14	10.69	3.92	6.91	-0.12
16	10.72	3.95	7.03	0.00
18	10.74	3.97	7.03	0.00
20	10.76	3.99	7.00	-0.03
30	10.86	4.09	6.97	-0.06
40	11.37	4.60	7.04	0.01
50	11.43	4.66	6.84	-0.19
60	11.45	4.68	7.06	0.03
70	11.48	4.71	6.93	-0.10

Note: Drawdown is the drop in the water level at time, "t" from the original water level.

PUMP TEST MW-17
November 3 and 4, 1986
(Continued)

Elapsed Time (min)	MW-17 Depth to Water (ft)	MW-17 Drawdown (ft)	MW-5 Depth to Water (ft)	MW-5 Drawdown (ft)
80	11.48	4.71	7.03	0.00
90	11.52	4.75	7.00	-0.03
110	11.49	4.72	7.01	-0.02
150	11.70	4.93	7.05	0.02
200	11.74	4.97	6.88	-0.15
250	11.91	5.14	6.97	-0.06
300	12.01	5.24	6.98	-0.05
350	12.15	5.38	6.91	-0.12
400	12.41	5.64	7.02	-0.01
450	12.52	5.75	7.03	0.00
500	12.63	5.86	7.08	0.05
548	12.73	5.96	6.96	-0.07
598	12.83	6.06	6.97	0.06
648	13.16	6.39	7.03	0.00
698	13.38	6.61	7.09	0.06
748	13.43	6.66	6.99	-0.04
798	13.57	6.80	7.02	-0.01
848	13.69	6.92	7.03	0.00
898	13.72	6.89	7.00	-0.03
948	13.90	7.13	7.07	0.04
998	14.07	7.30	7.12	0.09
1098	14.56	7.79	7.06	0.03
1198	14.58	7.81	7.06	0.03
1298	14.65	7.88	7.12	0.09
1398	14.86	8.09	7.09	0.06
1498	14.89	8.06	7.11	0.08
1598	14.95	8.18	7.10	0.07

Note: Drawdown is the drop in the water level at time, "t" from the original water level.

RECOVERY TEST MW-17
November 3 and 4, 1986

Elapsed Time (min)	MW-17 Depth to Water (ft)	MW-17 Drawdown (ft)	MW-5 Depth to Water (ft)	MW-5 Drawdown (ft)
.00	14.01	7.24	6.79	-0.24
.01	14.15	7.38	6.81	-0.22
.02	14.06	7.29	6.76	-0.27
.03	14.07	7.30	6.72	-0.21
.05	13.89	7.12	6.76	-0.27
.10	13.67	6.90	6.93	-0.10
.20	13.21	6.44	6.82	-0.21
.30	12.72	5.95	6.84	-0.19
.50	11.75	4.98	6.89	-0.14
.75	10.69	3.92	6.81	-0.22
1.00	9.81	3.04	6.85	-0.18
1.25	9.09	2.32	6.80	-0.23
1.50	8.42	1.65	6.79	-0.24
1.75	7.80	1.03	6.83	-0.20
2.0	7.76	0.99	6.85	-0.18
2.5	7.88	1.11	6.82	-0.21
3.0	7.95	1.18	6.79	-0.24
3.5	7.99	1.22	6.79	-0.24
4.0	8.01	1.24	6.61	0.42
4.5	8.03	1.26	6.88	0.15
5.0	8.03	1.26	6.78	-0.25
5.5	8.02	1.25	6.83	-0.20
6.0	8.01	1.24	6.76	-0.27
6.5	8.00	1.23	6.80	-0.23
7.0	7.99	1.22	6.86	-0.17
7.5	7.98	1.21	6.84	-0.19
8.0	7.96	1.19	6.89	-0.14

Note: Drawdown is the drop in the water level at time, "t" from the original water level.

RECOVERY TEST MW-17
November 3 and 4, 1986
(Continued)

Elapsed Time (min)	MW-17 Depth to Water (ft)	MW-17 Drawdown (ft)	MW-5 Depth to Water (ft)	MW-5 Drawdown (ft)
8.5	7.95	1.18	6.84	-0.19
9.0	7.94	1.17	6.85	-0.18
9.5	7.93	1.16	6.90	-0.13
10	7.92	1.15	6.77	-0.26
20	7.78	1.01	6.93	-0.10
30	7.69	0.92	6.89	-0.14
40	7.62	0.85	6.93	-0.10
50	7.57	0.80	6.92	-0.11
60	7.52	0.75	6.79	-0.24
70	7.48	0.71	6.90	-0.13
80	7.45	0.68	6.88	-0.15
90	7.42	0.65	6.94	-0.09
100	7.40	0.63	6.96	-0.07
110	7.37	0.60	6.88	-0.15
120	7.36	0.59	6.91	-0.12

Note: Drawdown is the drop in the water level at time, "t" from the original water level.

PUMP TEST MW-10
November 5, 1986

Elapsed Time (min)	MW-10 Depth to Water (ft)	MW-10 Drawdown (ft)	MW-9 Depth to Water (ft)	MW-9 Drawdown (ft)
0.00	4.05	0.00	11.57	0.00
0.01	4.11	0.06	11.57	0.00
0.03	4.45	0.40	11.57	0.00
0.05	4.90	0.85	11.57	0.00
0.10	5.92	1.87	11.57	0.00
0.20	9.41	5.36	11.57	0.00
0.30	10.95	6.90	11.57	0.00
0.50	12.04	7.99	11.57	0.00
0.75	12.80	8.75	11.57	0.00
10.0	12.80	8.75	11.57	0.00
20.0	12.81	8.76	11.57	0.00
230.0	12.81	8.76	11.57	0.00

Note: (1) From 0.75 minutes to 20 minutes the depth to water in MW-10 fluctuated between 12.80 and 12.81 ft and remained at 11.57 ft in MW-9.

(2) From 20 to 230 minutes the depth to water in MW-10 was 12.81 ft and remained at 11.57 ft. in MW-9

RECOVERY TEST MW-10*
November 5, 1986

Elapsed Time (min)	Depth to Water (ft)	Drawdown (ft)
0.00	12.81	8.76
0.25	11.93	7.88
0.5	10.85	6.80
0.75	9.92	5.87
1.0	9.10	5.05
1.25	8.36	4.31
1.58	7.69	3.64
1.75	7.12	3.07
2.0	6.69	2.64
3.0	5.82	1.77
4.0	5.38	1.33
5.0	5.05	1.00
6.0	4.81	0.76
7.0	4.66	0.61
8.0	4.55	0.50
9.0	4.48	0.43
10.0	4.46	0.41
20	4.17	0.12
30	4.06	0.01
40	4.01	-0.04
50	3.98	-0.07
60	3.96	-0.09
70	3.94	-0.11

*No recovery data was taken for MW-9, because no drawdown was effected during pumpage

APPENDIX H
SUBSURFACE HYDROCARBON RECOVERY SYSTEM

APPENDIX H

The following section describes the remediation technique recommended for hydrocarbon recovery at NAS Norfolk. The basic remediation system will consist of a series of recovery modules, each of which will contain approximately 4 pumping wells (refer to Plate 15). The wells will be interconnected by a pipeline system, and the well-grouping will be connected to a main control panel. Hydrocarbon, which is recovered in the module, will be discharged to an above-ground storage tank. Initially, the recovery modules may be installed using existing monitoring wells. Following repair/replacement of leaking lines, and clear delineation of the hydrocarbon migration to the east, installation of additional recovery modules should be considered.

Existing monitoring wells should be used as recovery wells whenever possible (refer to Plate 15). A low volume pneumatic pumping system is recommended for hydrocarbon and groundwater pumping. Examples of pneumatic pumping systems are the Well Ejector by Ejector Systems, Inc. (ESI) and the Pulse Pump by QED Environmental Systems, Inc. (QED) (see attached vendor data). Such a pneumatically driven system provides a sharper separation of hydrocarbon and groundwater than that normally encountered with centrifugal or turbine pumps, thereby reducing the potential quantity of groundwater requiring management. This system also provides a lower capital cost per well

when used in multiple well systems, because several recovery wells can be served by a single main control board and air compressor. The use of multiple shallow wells also minimizes the total quantity of water pumped and treated.

The proposed initial recovery system at NAS Norfolk groups four (4) recovery wells and any associated groundwater treatment equipment into a module. The basic module consists of the four (4) recovery wells (with pumps, valves, piping and wellhead controls) with associated compressor and main control panel, a hydrocarbon/water separator to separate the hydrocarbon and water phases, a storage tank to accumulate the recovered hydrocarbon for off-site recycling or disposal, and wastewater treatment units if required, for disposal of the water. A schematic of the proposed recovery system module is shown on Plate H-1.

Based on vendor data and on our field experience, we anticipate that the aqueous effluent flow from the separator will contain no more than approximately 50-100 ppm of dissolved volatile organic carbon (VOC) from the recovered hydrocarbon. If the effluent quality is sufficient to meet the criteria imposed for discharge, no further treatment is required.

The preliminary estimated capital and annual operating costs for each module are summarized in Table H-1. The costs presented in Table

H-2 are estimates of capital and annual operating costs for equipment and installation of nine recovery modules. This is a preliminary estimate of the total number of modules considered necessary to clean-up the subsurface at NAS Norfolk. The number of modules may increase or decrease significantly after the full extent of hydrocarbon contamination is delineated and the effectiveness of hydrocarbon recovery has been observed in the field. These tables do not include design, engineering and construction management services required for implementation of the recovery system module.

TABLE H-1

CAPITAL AND OPERATING COST: PER MODULE

1. Basic Module

a) Capital Costs

• 4 recovery wells x 20 ft/well x $50/ft	=	$ 4,000*
• Pumps, valves and main control panel @ $7,000/well	=	28,000
• Compressor	=	5,000
• Separator, slant rib, coalescing (50 gpm)	=	9,000
• Recovered hydrocarbon storage tank; above ground, steel, 4,000 gal	=	$ 3,000
• Installation, piping, elec, etc.	=	24,500
Total Estimated Capital Cost	=	$73,500

b) Operating Costs = $3,700/yr

* Some existing monitoring wells may be converted to recovery wells which would reduce this cost.

TABLE H-2

CAPITAL AND OPERATING COSTS OF
TOTAL RECOVERY SYSTEM*

	Capital Cost	Cumulative Capital Cost	Annual Operating Costs	Cumulative Annual Op Costs
Basic Module	$661,500	$661,500	$ 33,300	$ 33,300

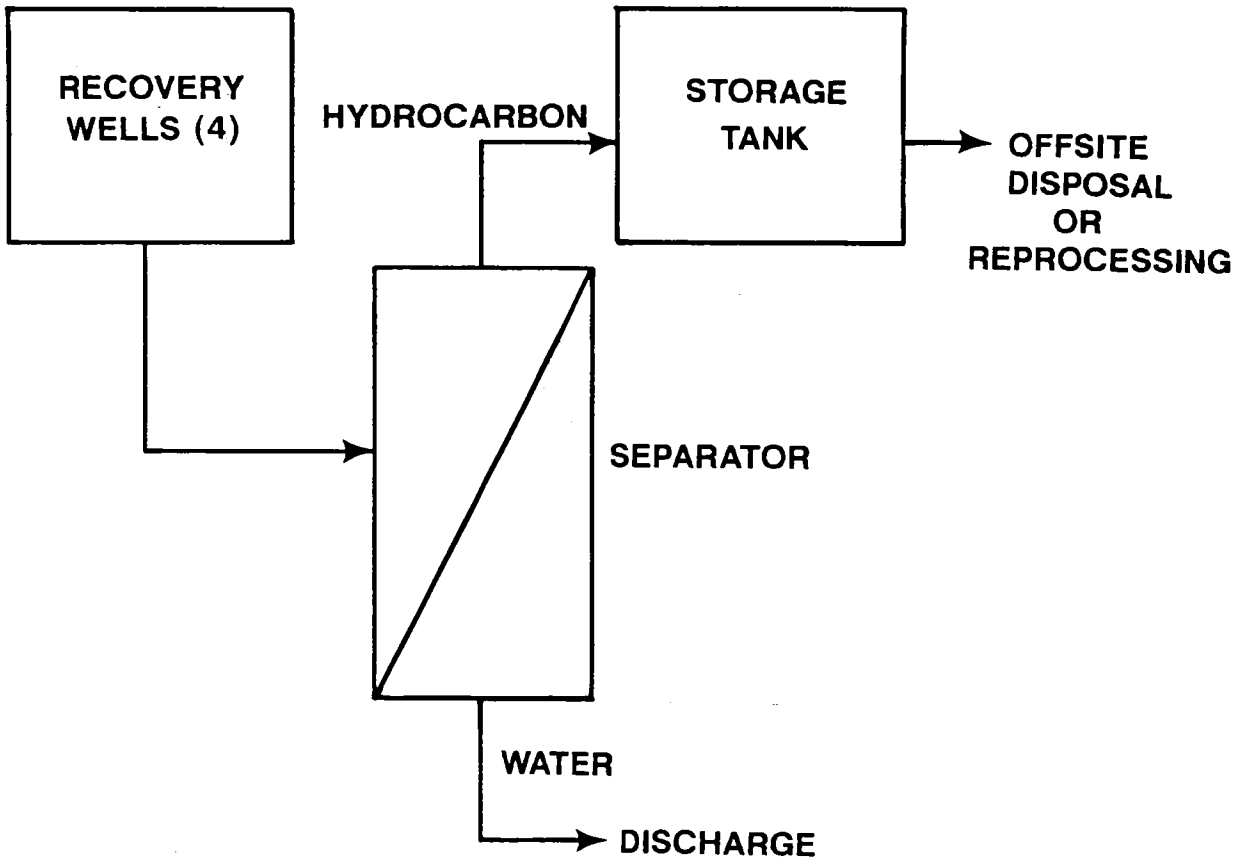
* Nine Recovery Modules

The time required for remediation is dependent on many indeterminate variables, the most significant of which is the rate of movement of the hydrocarbon through the subsurface soil matrix.

Based on the hydrogeologic conditions at the site, the estimated effectiveness of recovery pumping, and the approximate volume of hydrocarbon in the subsurface within Module 1, it is estimated that 90 percent hydrocarbon recovery will take approximately 3.7 years. This estimate is based on:

1. An average per well yield of 1.5 gallons per minute,
2. Four pumping wells within the module,
3. A surficial area of 250,000 ft^2,
4. A mean hydrocarbon thickness of 2 feet in the subsurface,
5. Effective porosity of subsurface materials of 0.35, and
6. Ten percent recovery rate of hydrocarbon from total fluids pumped.

The above mentioned estimate of time for recovery should be viewed only as an "order of magnitude" estimate. This estimate assumes recovery of existing hydrocarbon in the subsurface with no additional accumulation or migration of hydrocarbon within the area of influence of the module. Recovery rates generally decrease rapidly as the recovery effort proceeds, and long-term recovery rates could be significantly lower than assumed for this time estimate. In many cases, the volume of hydrocarbon recoverable from the subsurface is significantly lower than assumed for this estimate.



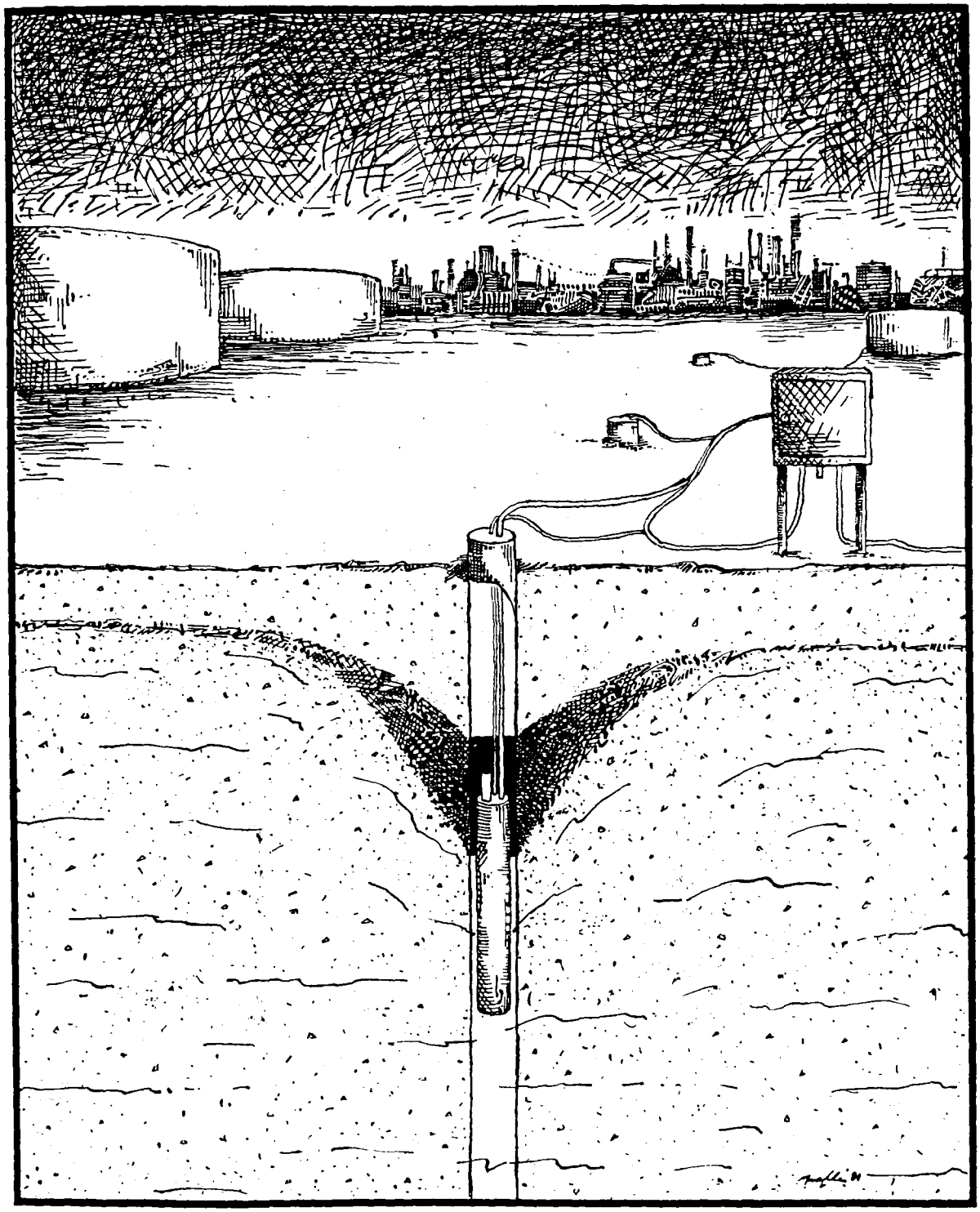
Harding Lawson Associates
Engineers, Geologists & Geophysicists

HYDROCARBON RECOVERY MODULE
NAS Norfolk
Norfolk, Virginia

PLATE
H-1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E.S.	2176,085.12	[illegible]	8/24/87		

EJECTOR SYSTEMS, INC.



Into every industry there comes a time when a new solution is found to an age-old problem. A solution so simple it redefines not just the practical aspects of the problem, but the economic ones as well.

Introducing the ESI Well Ejector System. It represents a new level of both performance and dependability in the recovery of liquid hydrocarbon contaminates from groundwater.

THE FIRST LAW OF MAINTENANCE: SIMPLE IS ALWAYS BETTER.

In the search for a superior pumping system, it became necessary to abandon the conventional. Applying technology for the sake of performance instead of gimmickry, ESI perfected the all-pneumatic ejector pump. The result is a dramatic-improvement in both performance and reliability over conventional pumping methods.

The ejector's all-pneumatic design is the ultimate in simplicity. There are no impellers or high-speed moving parts to break down. In fact, except for the pair of check valves, there are no moving parts in the ejector at all. With none of the inherent maintenance problems of a centrifugal pump, the ESI ejector can easily handle silted conditions or even highly corrosive materials. The ejector can operate at conditions far below designed flow rates without compromising performance. Also, there are no electric motors, controls or friction-causing moving parts in the well; fire and explosion risks have been all but eliminated. For installations calling for explosion proof equipment, air operated controls can be supplied, making the entire system intrinsically safe.

The bottom line is a stronger, safer, more dependable pumping system that's easy to install, easy to operate, and easy to maintain.

FINALLY, A PUMPING SYSTEM THAT RESPECTS THE FACT THAT OIL AND WATER DON'T MIX.

Keeping the hydrocarbon and groundwater layers separate is a basic goal of contaminant recovery. Yet the inherent design of centrifugal pumps, spinning at 3450 RPM, does exactly the opposite. Whenever product and water enter a centrifugal pump the two are invariably mixed, whipping them into an emulsion and making topside separation extremely difficult.

Not so with the ESI ejector. Its steady, gentle air pressure does not mix hydrocarbon and groundwater layers. Topside separation is fast and efficient. Thus a single ejector can be used to pump both layers, making the simplicity and savings of total fluids recovery a reality.

ESI EJECTORS: EVOLVED IN THE FIELD, NOT ON THE DRAWING TABLE.

ESI ejectors are more than just a good idea, they're a proven one. The ejector's unique design allows for a high degree of flexibility, and all systems are custom designed to fit the specific job and its needs. Ejectors can be top or bottom fill. They can be used in single or dual configuration, and can operate separately or stacked in combination. Flexibility also means well size, as ejectors can easily operate in 4 inch or smaller diameter "observation" wells. Remote control panels offer a high degree of flexibility, too, with precision, even simultaneous control of multiple ejectors, each up to 200 feet away.

PERFORMANCE BACKED BY PERFORMANCE

With a growing client list that includes many major oil companies, ESI is rapidly becoming the experts' choice for groundwater contamination problems. ESI offers a proven, superior product, custom engineering, turn-key installation and maintenance, even an exclusive one year, unconditional warranty on products and service. And all at prices that are very competitive.

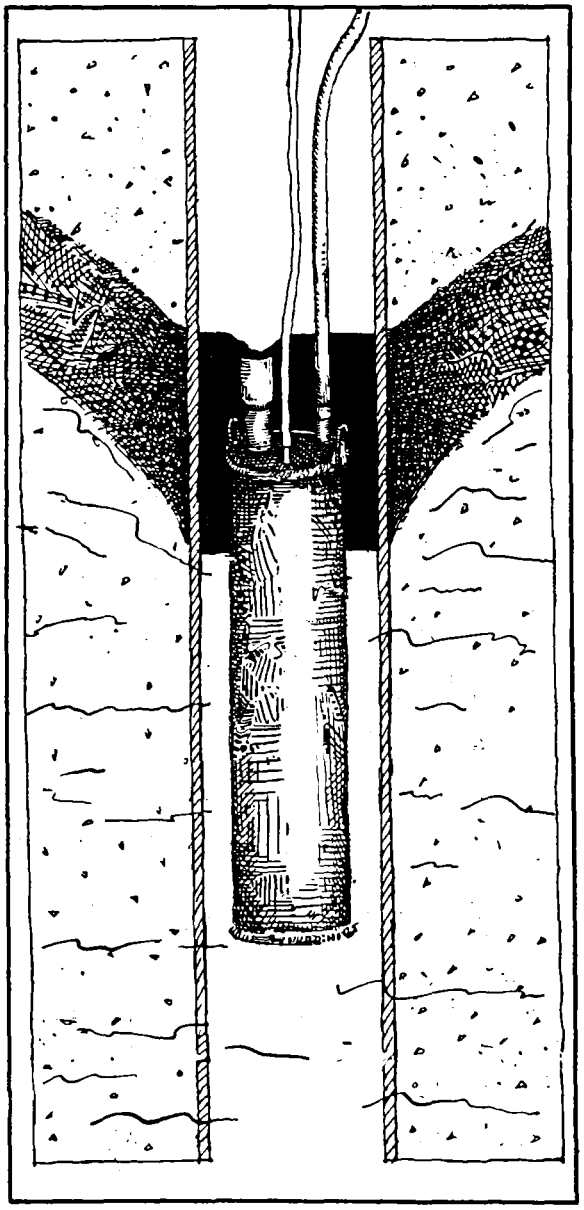
For further information or references, please call ESI at 312/543-2214 today. We'll be proud to show you how ESI has become the industry's innovator.

TOTAL FLUIDS

In the search for a more efficient, more reliable way of recovering contaminates from groundwater, ESI has taken its "simpler is better" philosophy yet another step. Introducing total fluids pumping. Depending on the specifics of your job site, total fluids pumping could be the simplest, most efficient and least expensive recovery method available.

ESI DISMISSES THE NOTION THAT GOOD ENOUGH IS GOOD ENOUGH.

The ESI ejector pumps' unique features have allowed us to go beyond the traditional drawdown and product pump design to a very simple, efficient concept: pump both product and groundwater together. The ESI ejectors' gentle air pressure does not mix product and water, as would conventional centrifugal pumps, so topside separation is fast and efficient. Maintenance is minimal, because the only moving parts in the well are two rugged check valves. All controls are conveniently located in a remote box which can be up to 200 feet away. Multiple well pumps can efficiently be controlled from a single panel. Plus, the control panel can be built for all-pneumatic operation, for an intrinsically safe system. ESI total fluids ejector pump systems also mean you can drill smaller diameter, less expensive wells for recovery. For example: an ESI total fluids pump in a 4 inch well can easily deliver 15 GPM. ESI pumps can even operate in wells as small as 2 inches in diameter. ESI ejector pumps are available with top, bottom, or top and bottom intakes. An optional extension allows for water intake from deeper in the well. And ESI pumps, like all ESI products, are covered by an exclusive one year, unconditional warranty.



PATENT PENDING

EJECTOR CYCLE

PATENT PENDING

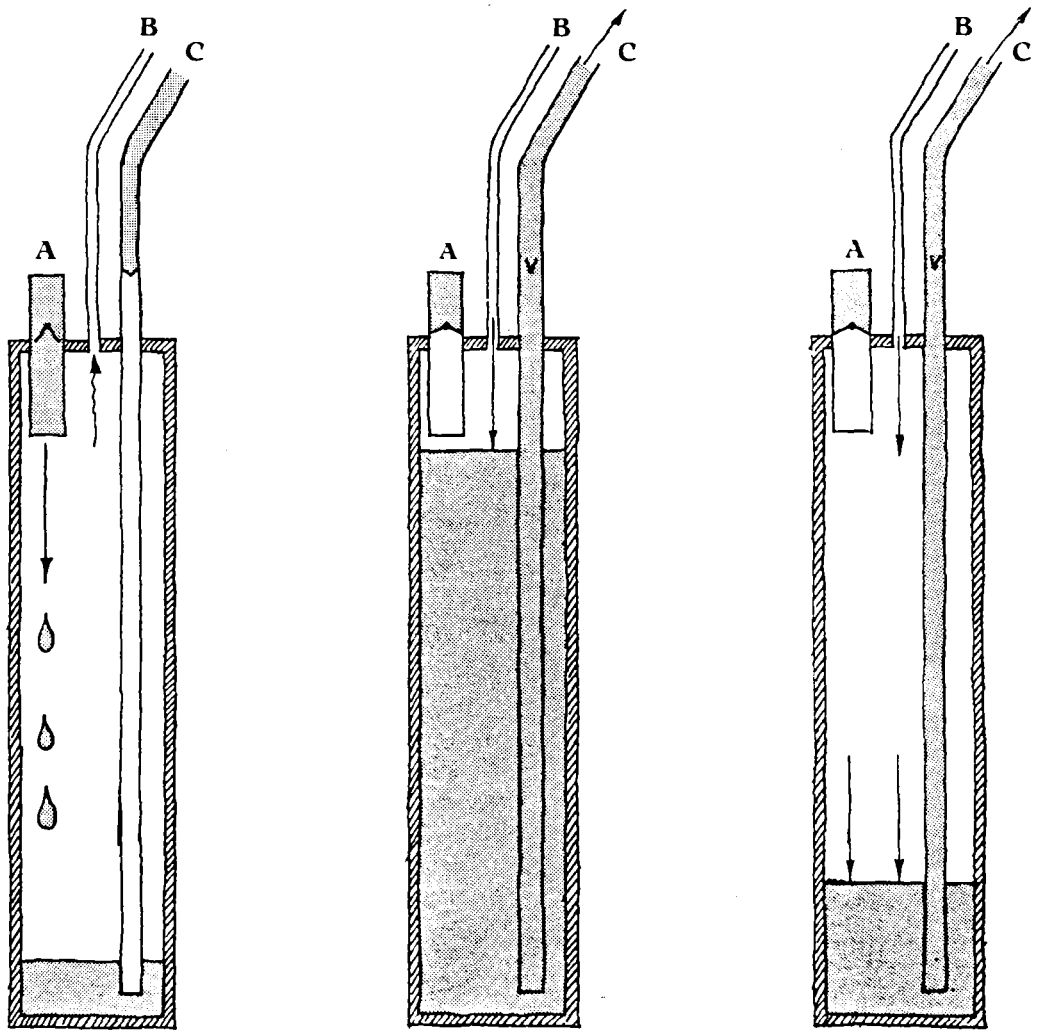


Figure 1 Figure 2 Figure 3

The ESI ejector is as efficient as it is simple. The ejector is alternately pressurized by a timer controlled solenoid valve, and can be controlled up to 200 feet away without significant loss of efficiency.

In figure 1., solenoid valve is "off," allowing the vessel to vent air and fill through valve A. Valve C. is kept closed by back pressure from discharge line.

As the solenoid valve switches in figure 2., the vessel is pressurized. Valve A. is forced closed as C. opens and the vessel quickly empties.

As vessel is emptied in figure 3., the solenoid once again turns "off," and vents the vessel. Back pressure immediately closes C., and A. opens to fill as the cycle repeats.

CONTROL PANEL

A pumping system is only as good as what controls it. That's why at Ejector Systems, Inc. our control panels are designed and built to the same exacting standards as our ejector pumps. The result is a *TOTAL* pumping system that offers more dependability and flexibility than has ever before been available for the removal of hydrocarbon contaminates from groundwater.

AT LAST A PUMPING SYSTEM WITH ALL ITS CONTROLS IN ONE PLACE

The ESI control panel is as simple as it is ingenious. Based on a hassle-free, time controlled air valve, the ESI control panel is a reliable system that's easy to operate, and easy to maintain. The durable air valves themselves have cycle lives on the tens of millions of lubricated cycles. All controls are sensibly located in one remote box, so unlike other systems, there are no controls at all down the well. Even well levels are accurately read back at the control panel.

TECHNOLOGY FOR THE SAFE PERFORMANCE, NOT GIMMICKRY.

In the pursuit of a rugged, reliable control panel, ESI rejected fancy, overly-complicated electronics. Instead, all our controls are hardwired for dependability and easy trouble-shooting. Even if something does malfunction, all ESI controls are modular for fast, simple replacment. In fact, ESI control panels are so simple, no special skills are required for operation or repair. And ESI control panels, like all ESI products, are covered by an exclusive one year, unconditional warranty.

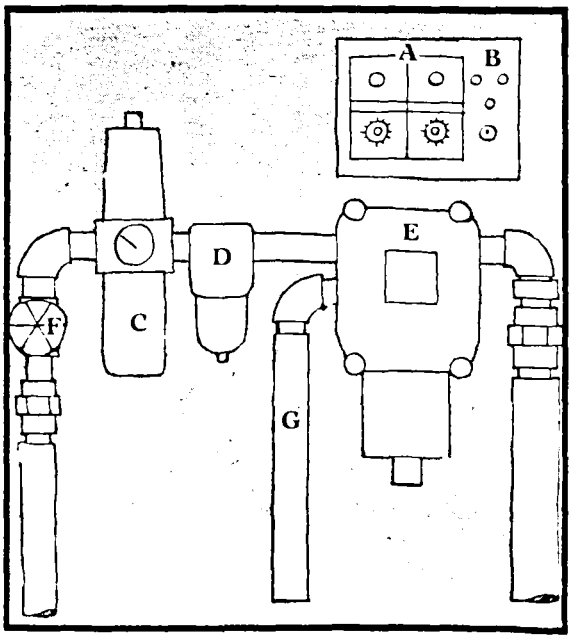
FLEXIBILITY. BECAUSE NO TWO JOB SITES ARE ALIKE.

ESI disdains the rigidity of many systems by offering a wide selection of control panel configurations and options. And with whatever type of single or dual pump system you choose, the ESI control panel can easily control multiple pump systems, up to 200 feet away.

Control panels are available for the traditional two pump configuration, with separate drawdown and product pumps. Also available are single panels for total fluid systems utilizing one or more pumps. And, of course, single product pump controls, for single or multiple pump systems.

TOTAL FLUIDS PANEL

A. Timer
B. Fuses
C. Filter regulator
D. Lubricator
E. Solenoid valve
F. Shut off valve
G. Vent tube



PATENT PENDING

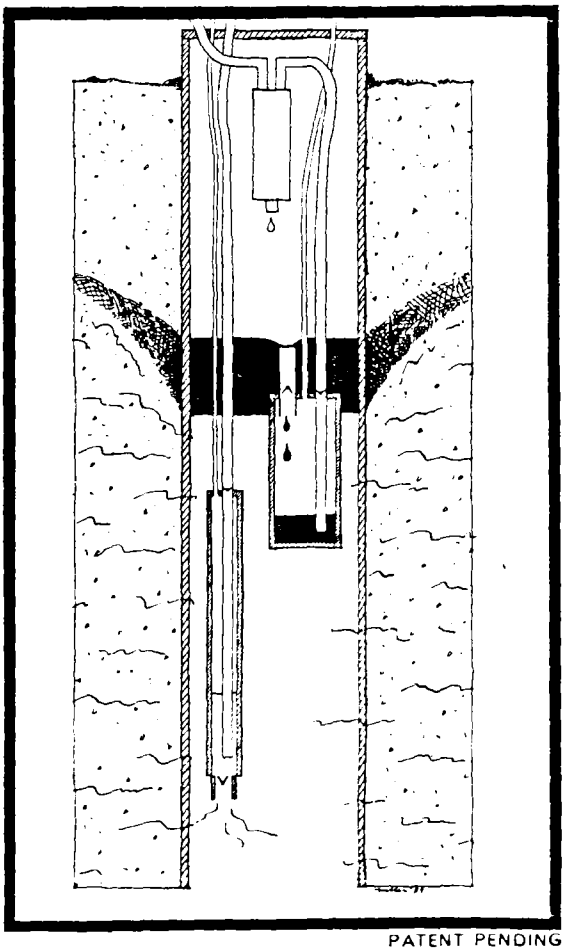
TWO PUMP SYSTEM

Ejector Systems Inc. brings a new level of dependability and flexibility to the industry accepted contaminate recovery method of separate drawdown and product pumps. Utilizing ESI's unique ejector pumps, significant flow rates can dependably be achieved even from well sites as small as 4 inches in diameter.

PERFORMANCE YOU CAN DEPEND UPON.

Just how much can ESI ejector pumps deliver? Example: An ESI 2-pump operating in a 4 inch diameter well can consistently deliver 15 GPM of groundwater and .75 GPM of product *at the same time*. In a 6 inch well, ESI pumps deliver 50 GPM of groundwater and 1 or more GPM of product. And, of course, the larger the well, the higher the flow rate.

But flow rates are only part of the story. ESI's unique ejector design offers significant advantages over conventional centrifugal pumps. The ejector's gentle air pressure does not mix product and water, so topside separation is fast and efficient. There are a minimum of moving parts; only 2 rugged check valves per vessel. There are no filter devices to malfunction or clog. ESI ejectors have no electrical components or control functions down the well. In fact, all controls can be conveniently located up to 200 feet away from the well site, even in multiple pump set-ups. And ESI pumps, like all ESI products, are covered by an exclusive one year, unconditional warranty.



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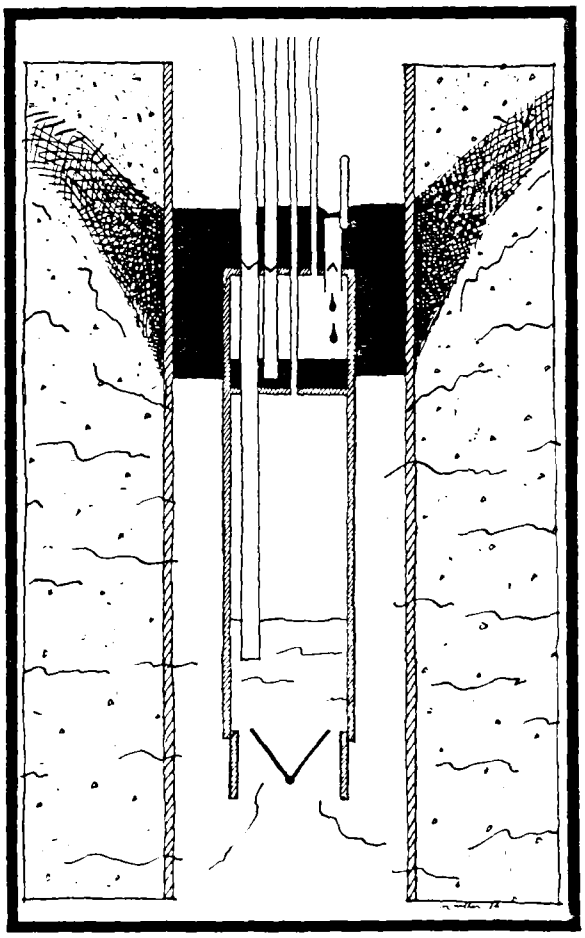
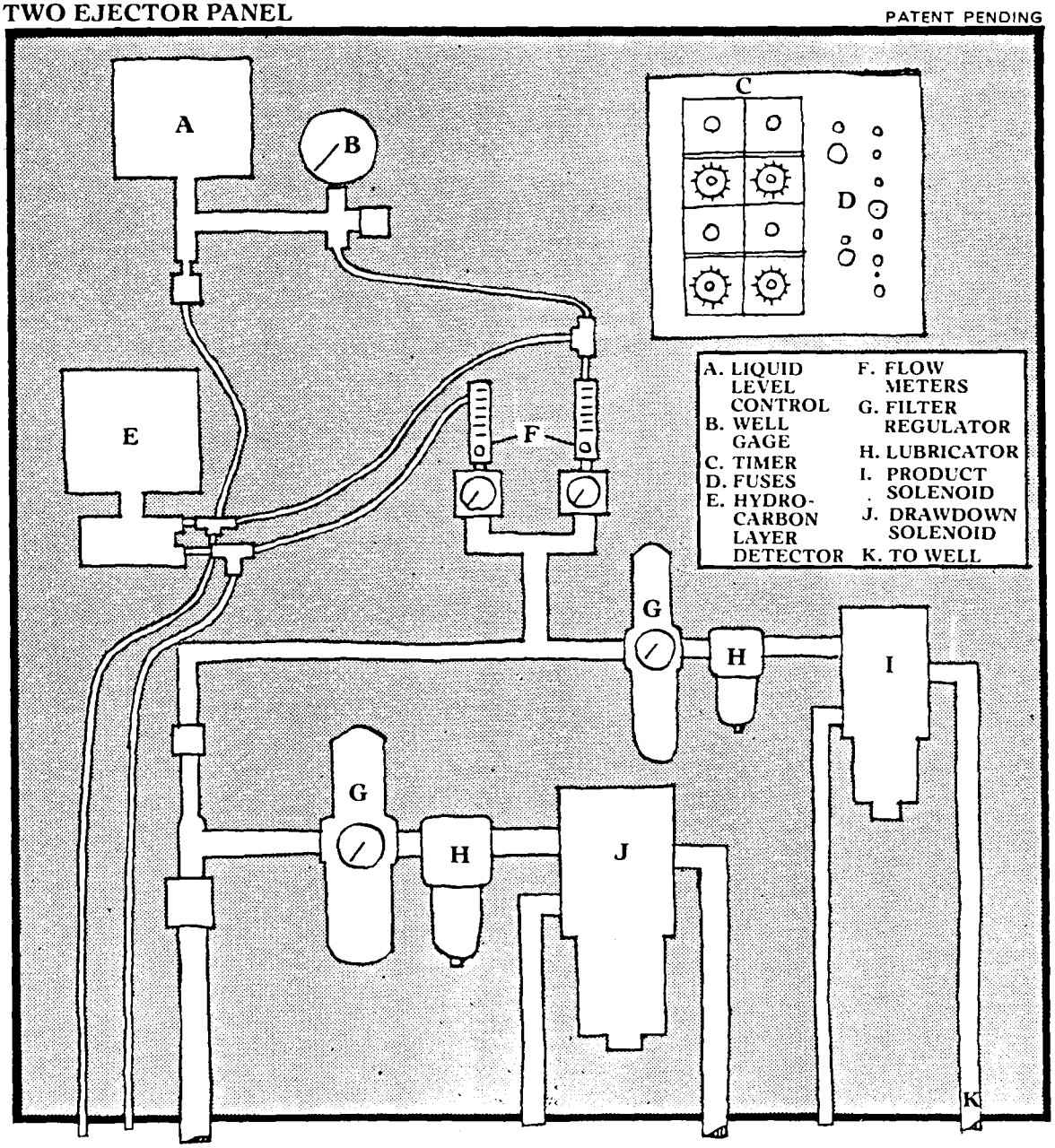


PATENT PENDING

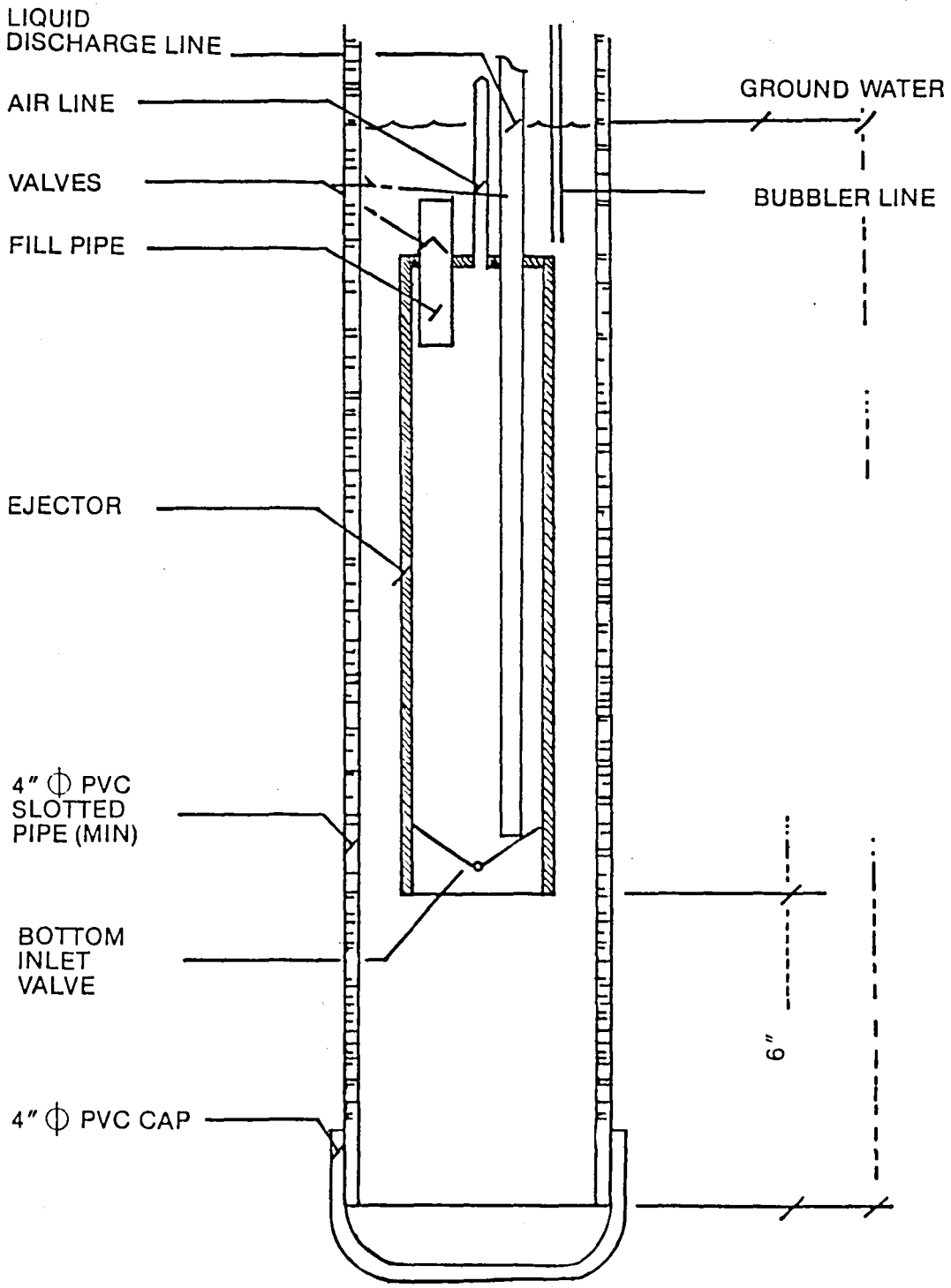
TWO EJECTOR PANEL

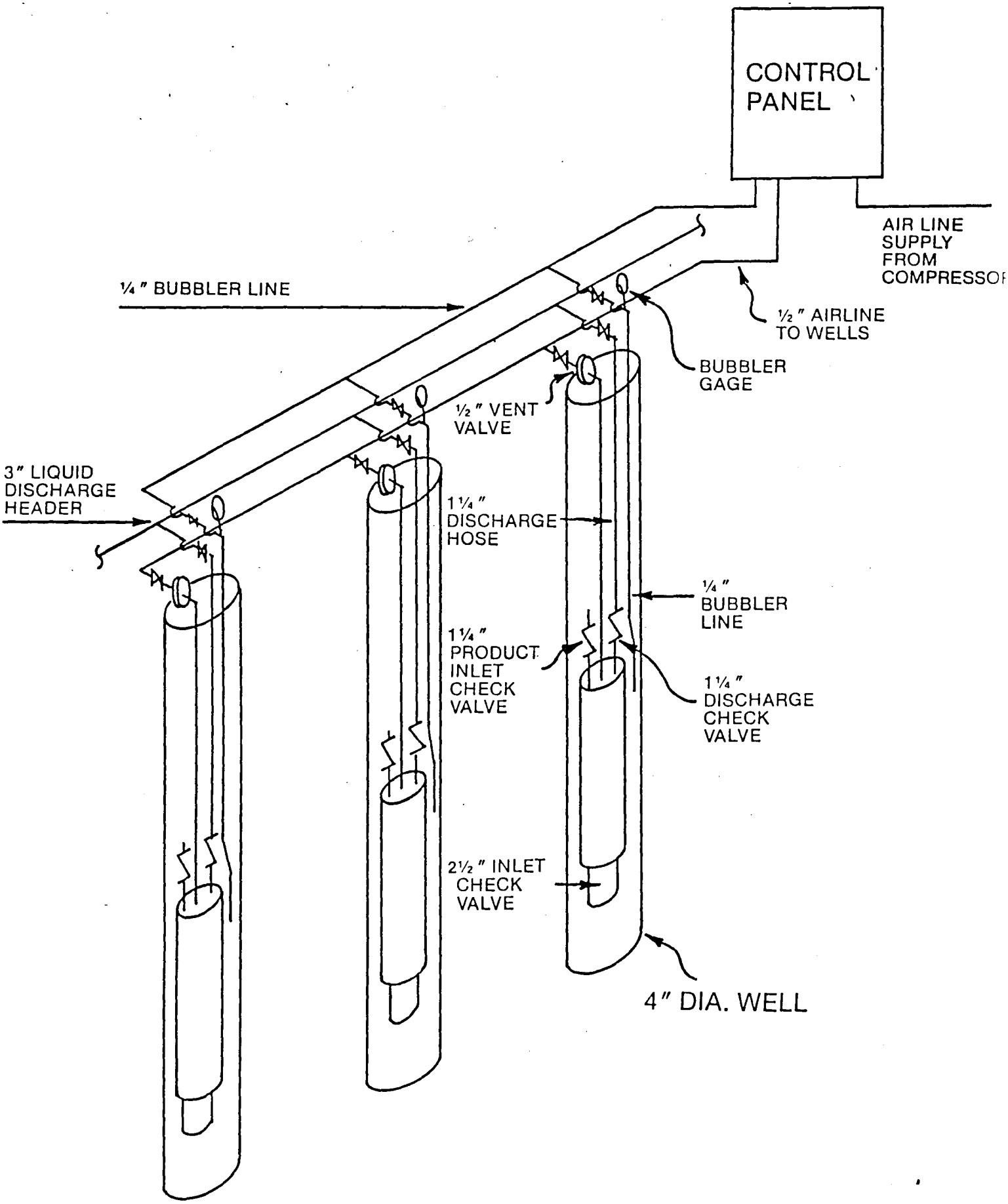
PATENT PENDING



To further customize the pumping system to fit the specific needs of your job site, ESI offers a variety of important control panel options:

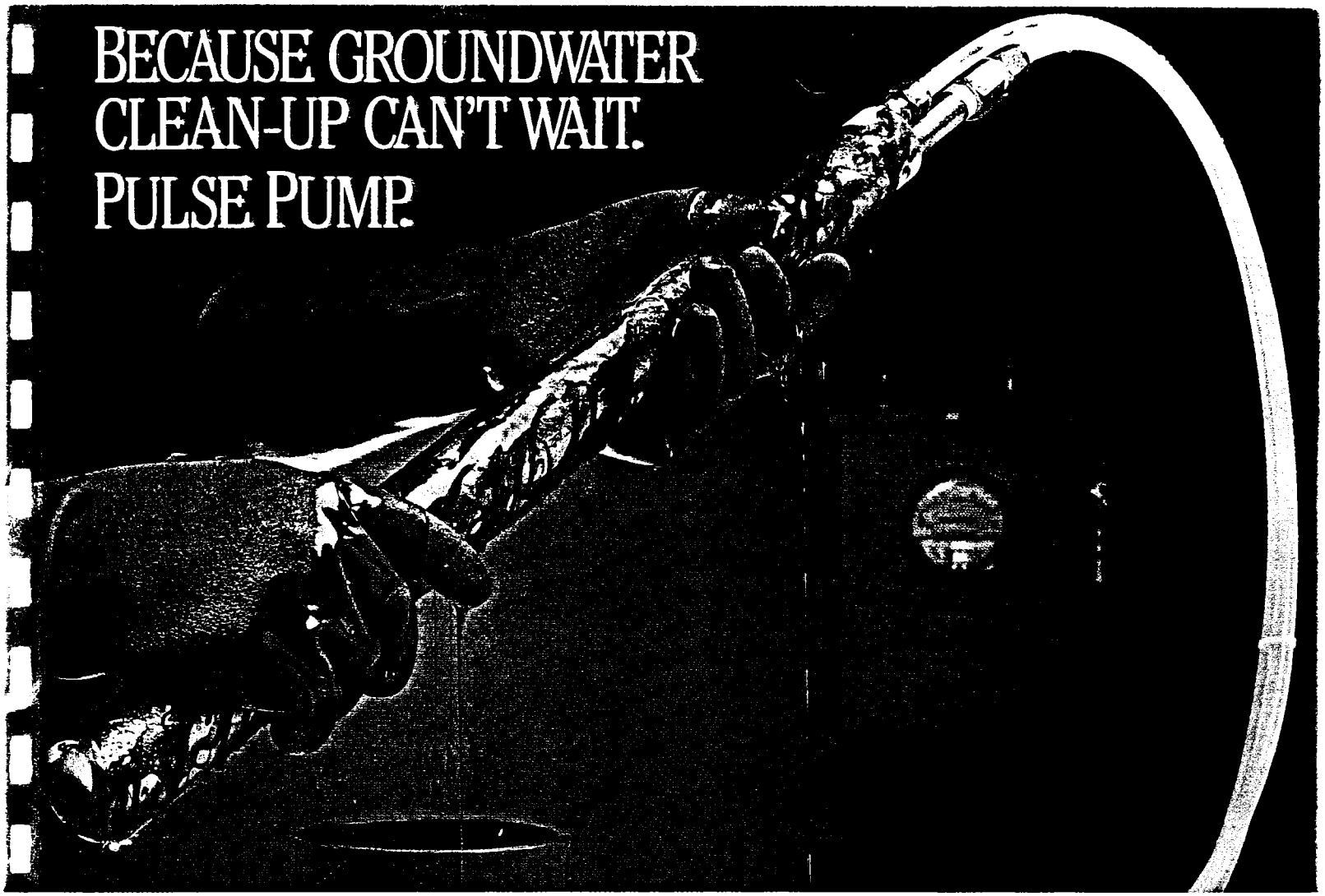
1. An automatic control that maintains liquid level in the well.
2. A simple hydrocarbon sensor that prevents product from accidentally getting into the drawdown pump.
3. A high-tank shut off that automatically shuts off product pump when its tank is full, preventing product tank overflow.
4. The ultimate intrinsically safe system: an all pneumatic control panel. Every function is all-air logic, all-air control.


LIQUID
DISCHARGE LINE
AIR LINE
VALVES
FILL PIPE
EJECTOR
4″ ⌀ PVC
SLOTTED
PIPE (MIN)
BOTTOM
INLET
VALVE
4″ ⌀ PVC CAP
GROUND WATER
BUBBLER LINE
6″



THREE PUMP

EJECTOR SCHEMATIC



Get into action with Pulse Pump™ in as little as one week.

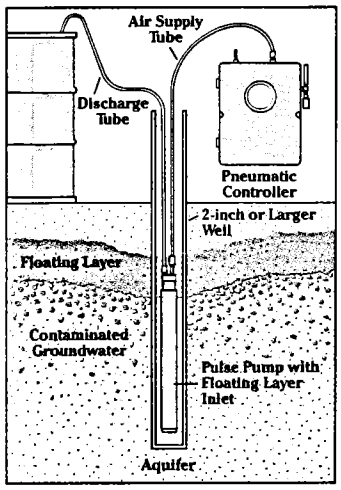
Groundwater contamination is a complex problem that demands your immediate attention. And action. When you go into action, you have to be prepared to deal effectively with floating layers, sinking layers, anything in-between, and leachate. Serious problems that demand a serious solution.

When you're faced with the problem of contaminated groundwater, you can start clean-up quickly with Pulse Pump at a fraction of the cost of other systems. The all-pneumatic Pulse Pump system's simplicity, ruggedness and versatility make it the value leader.

Ask the experts. People like Frank Ferraro, President of Advantech, Hydrocarbon Recovery Specialists:

"Pulse Pump goes to work right off the shelf... it's the best looking system I've seen out of the box. It fills a need for a cost effective recovery system."

Pulse Pump goes right to work for you because it's a modular system of pneumatic pumps and controllers that we can deliver promptly from our complete stock. One person can install the pumps in minutes with a few quick tubing connections.



The modular design of the Pulse Pump system lowers your cost and gives you maximum flexibility in matching your needs. Any pump you choose for size and function will work with any of our controllers. And you get the versatility of being able to expand or change the system later. You can even change Pulse Pump from floating layer pumping to general purpose pumping simply by threading on a different inlet adapter.

Pulse Pump's pneumatic design eliminates the installation costs, operating hazards and break-downs of electrical systems. With Pulse Pump, you can even use existing 2-inch wells. This means savings and value from purchase to installation to maintenance.

When the challenge is groundwater clean-up, get into action with Pulse Pump.

Call now for your free Pulse Pump Application Guide or immediate help from an Application Engineer at 1-800-624-2026.

PULSE PUMP™

Solving groundwater clean-up, leachate and product recovery problems.

QED Environmental Systems, Inc.

6095 Jackson Rd., P.O. Box 3726, Ann Arbor, MI 48106
800/624-2026 In Michigan, 313/995-2547 In Canada, 519/485-0290

Call 1-800-624-2026

PULSEPUMP™

PNEUMATIC PUMPING SYSTEM

PulsePump, the automatic pumping system from QED Environmental Systems, Inc., is designed to provide continuous pumping of explosive, contaminated and hazardous liquids. Its simple design allows easy installation and economical maintenance, and the pump, controller, and level sensor all operate pneumatically for greater safety and reliability.

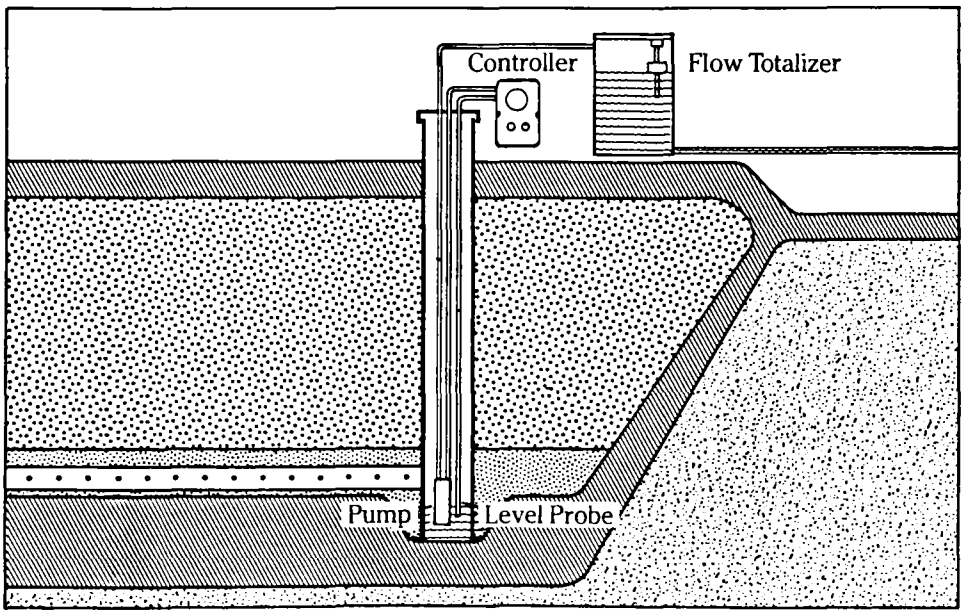
PulsePump Systems feature:

- **Small Diameter.** PulsePump's ability to fit casings down to 2″ diameter allows cost savings in pumping system design and installation.
- **An All-Pneumatic Pumping Mechanism.** Reduces costly downtime while providing high reliability and low maintenance.
- **All-Pneumatic On/Off Level Controls and Logic.** Intrinsically Safe. No electrical power or batteries are required.
- **Inert Materials of Construction.** Provides longer system life when the *entire* system is constructed of inert materials.
- **Flow Totalization.** Simplifies the determination of pumped volumes with an accurate, yet rugged design.

Each riser or recovery well may be equipped with a pump, cap, tubing, controller and exhaust valve. In this configuration, when the liquid depth over the level probe exceeds several inches, pump operation begins. It ceases when the liquid level drops.

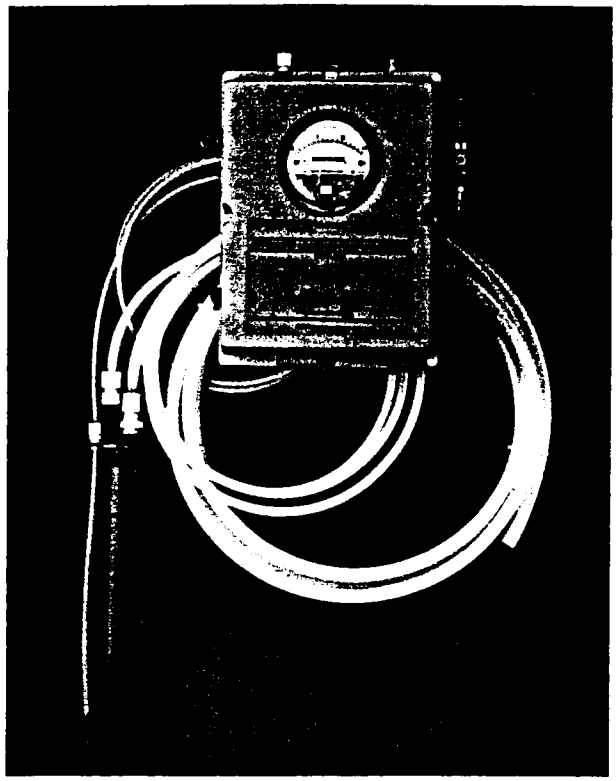
Up to six risers may be pumped from one controller continuously. In this configuration each riser is equipped with a remote well operator which the single, central controller operates. This system can pump at 0.25 to 1.5 GPM up to 150 feet vertically and several thousand feet horizontally and to the almost dry condition of only several inches of water over the pump's bottom intake.

The flow totalizer measures flow by an accumulation tank FILL/DISCHARGE action that gives reliable measurement of low flows and contaminated liquids without electric power.



PULSEPUMP™

PNEUMATIC PUMPING SYSTEM



PUMPS

- Gas displacement design, with intake screen and level control bracket.
- All PVC, Polypropylene, and Teflon* construction.
- Liquid flow rates range from 0.25 to 1.5 GPM (depending on pump submergence and discharge pipe configuration).
- Dimensions: 2.88″ O.D. × 15″ L (4″ models)
  1.66″ O.D. × 20″ L (2″ models)

CAPS

- Available to fit 2″ and larger pipe and provide terminal fittings for both operating air and liquid discharge.

TUBING

- Polyethylene, cross linked Polyethylene, Teflon and UV Protected tubing available.
  0.75″ O.D. discharge tube
  0.50″ O.D. air supply tube
  0.25″ O.D. level probe tube

CONTROLLERS

- Three models to meet your system needs: Continuous pumping or with on/off level control.
- Liquid level is detected by the bubbler tube principle with the response point adjusted by positioning the level probe height, in on/off level control models.
- Pump refill and discharge cycles and operating pressures are adjustable to attain desired pumping performance.
- All pneumatic operation gives intrinsically safe performance.
- Requires 3.0 SCFM at 100 PSI air supply for maximum pump performance.
- Mounting bracket allows easy clamping to vertical pipe or casing.
- Dimensions: 14″L × 10.5″W × 7.5″D

REMOTE WELL OPERATOR

- Used to operate remote pumps from one controller, inexpensively.

EXHAUST VALVES

- Quick exhaust valve, positioned on the air line beneath the cap in the 4″ model and above the cap in the 2″ model, vents compressed air during the pump refill cycle.

FLOW TOTALIZER

- High density, polyethylene accumulator tank measures total flow volume by counting FILL/DISCHARGE cycles.
- 2″ inlet spigot; 3″ outlet spigot.
- Requires gravity discharge condition.
- Dimensions: 22″ dia., 3.5′H

Call 1-800-624-2026 to speak with our applications engineers about your recovery pumping needs and to receive our detailed PulsePump Application Guide.

*Teflon is a registered trademark of Dupont

QED Environmental Systems, Inc.
P.O. Box 3726, Ann Arbor, MI 48106
800/624-2026 In Michigan, 313/995-2547

Form No. 66 Lith 1/87 5M

Pulse Pump®

Pnuematic Pumping System

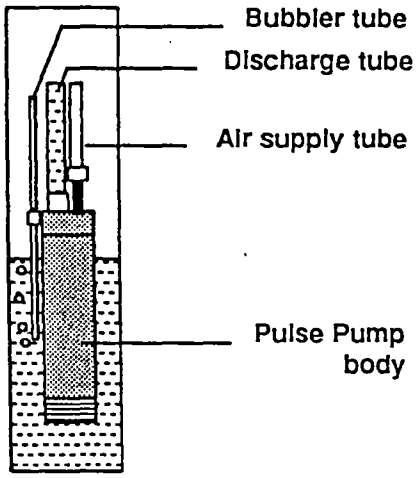
Applications

The following diagrams illustrate some of the many uses of the Pulse Pump Pneumatic Pumping System .

Contaminated Liquid Pumping:

In the diagram, *Pulse Pump* is partially submerged in a column of contaminated liquid. An optional bubbler tube and on/off level control are to the left of the pump. On/off level control is useful in risers that recover more slowly than the pump's flow rate. It insures that the pump operates only when liquid is available to pump.

Since all liquid contacting parts can be constructed of Teflon*, polypropylene or PVC, *Pulse Pump* can be used with a wide range of corrosive and/or organically aggressive liquids.

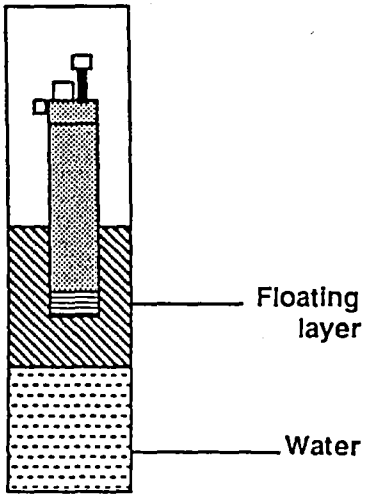


Thick Floating Layer Pumping:

Pulse Pump is shown here partially submerged in a floating layer. *Pulse Pump* can pump liquid down to within 4 inches of the pump bottom, allowing recovery of floating layers thicker than 6 inches. A bubbler tube and on/off level control are available if the floating layer recovers more slowly than the pump's flow rate.

As above, availability of the pump in a wide range of materials allows *Pulse Pump* to be used with most aggressive organic solvents.

Also, since the *Pulse Pump* operates pneumatically, it is safe for explosive liquid pumping.



**Teflon is a registered trademark of the E.I. DuPont Corporation*

QED Environmental Systems, Inc.

P.O. Box 3726, Ann Arbor, MI 48106
800/624-2026 In Michigan, 313/995-2547

Pulse Pump®

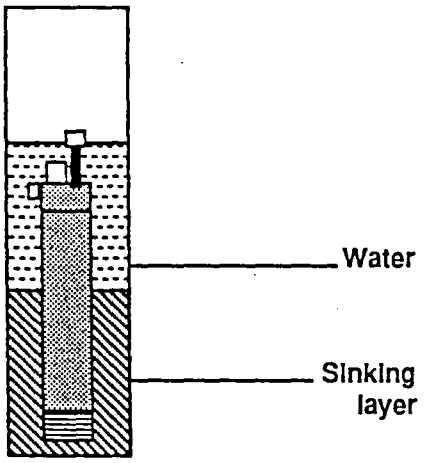
Pnuematic Pumping System

Applications

Sinking Layer Pumping:

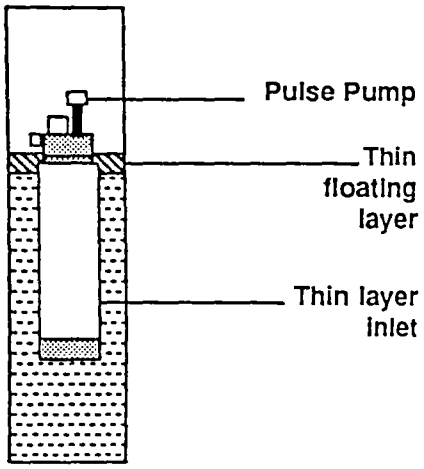
To pump a sinking layer, *Pulse Pump* fills from the bottom through a 2 inch screen, so that the sinking liquids fill the pump. The wide selection of materials available for the liquid contacting parts allows *Pulse Pump* to be used with most types of sinking layer organics.

Soon to be available: an automatic level control which will turn the *Pulse Pump* on and off in response to the thickness of the sinking layer.



Thin Floating Layer Recovery:

An optional thin layer recovery inlet is available for *Pulse Pump*. This attachment allows *Pulse Pump* to recover thin floating layers by moving the effective pump inlet from the bottom of the pump to the very top. The floating layer flows over the top edge of the inlet and fills *Pulse Pump*. By adjusting the number of pump cycles and the pumping duration, an economical and reliable floating layer recovery system can be configured.



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Pulse Pump®

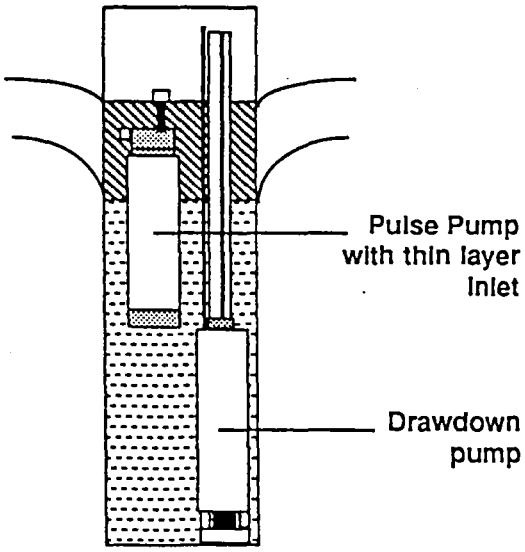
Pnuematic Pumping System

Applications

Floating Layer Recovery with Drawdown Pump:

Pulse Pump, teamed with an electric submersible drawdown pump, will recover a floating layer from a high recovery well. *Pulse Pump* is moved up or down in the recovery well as needed to maximize recovery effectiveness.

Pulse Pump operates pneumatically, making it ideal for the recovery of explosive liquids.



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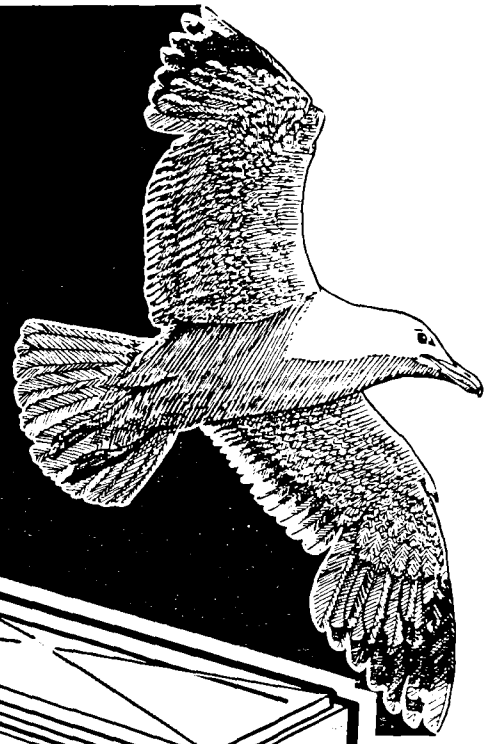
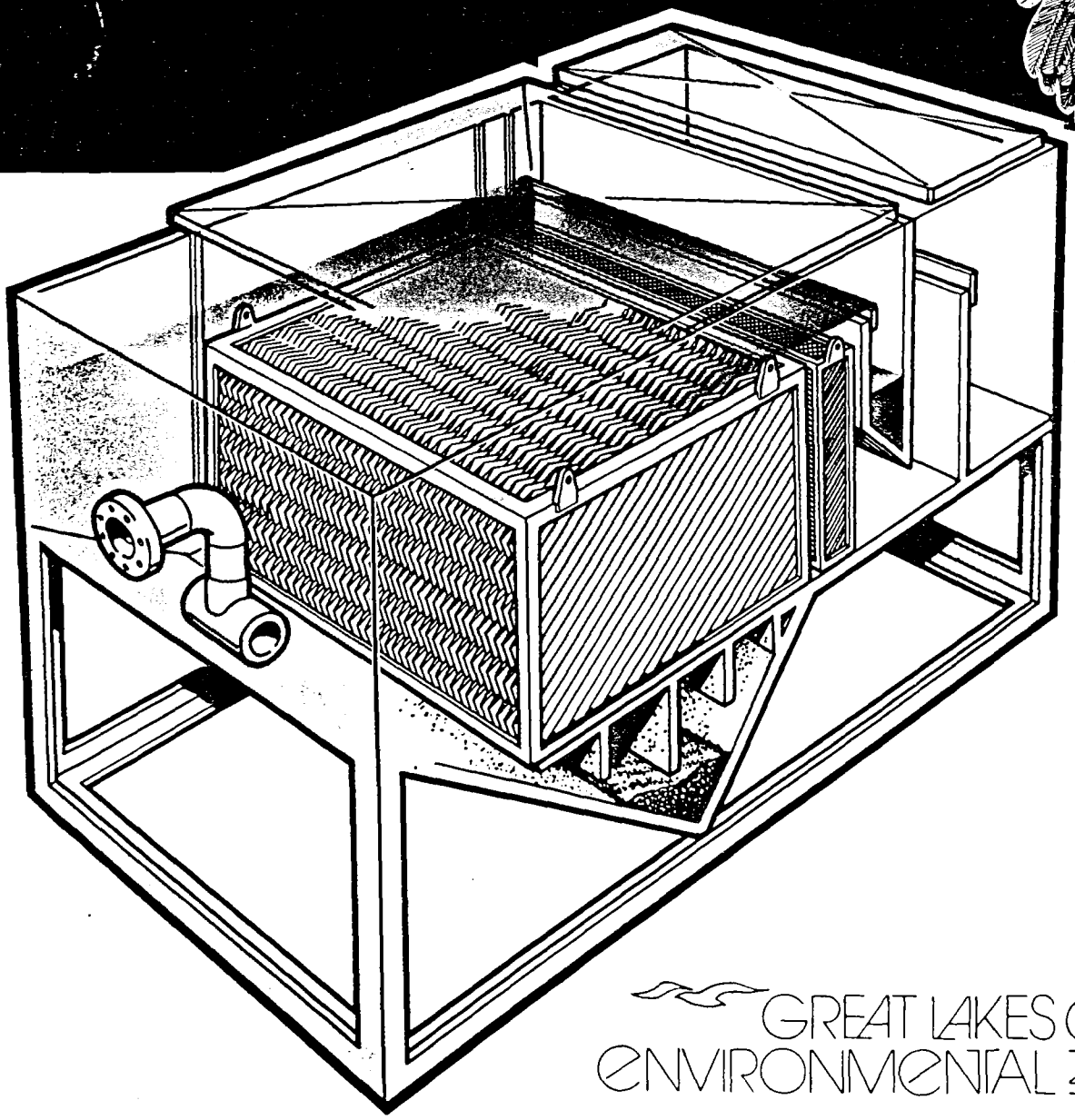
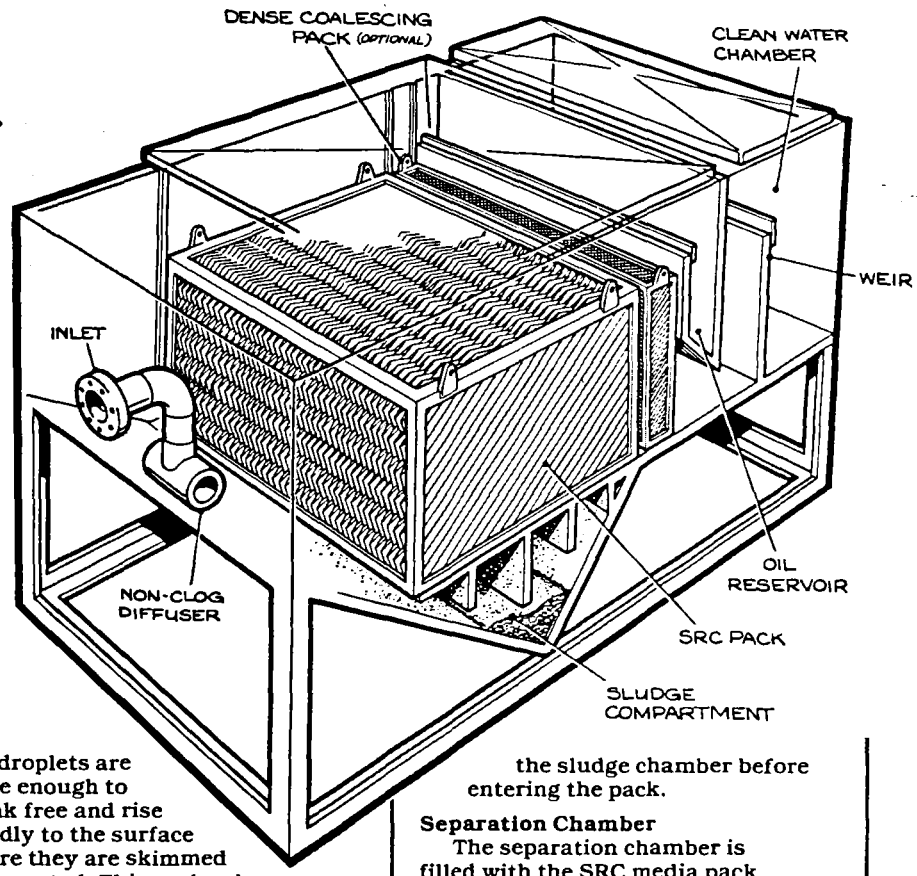
SLANT RIB COALESCING OIL/WATER SEPARATOR





GREAT LAKES ENVIRONMENTAL

The Slant Rib Coalescing Separator is a highly effective gravity separator for the removal of dispersed oil and solids from water.



GENERAL INFORMATION

The Great Lakes Slant Rib Coalescing (SRC) Separators are capable of effectively separating oils and solids from water where the oil and solids have a specific gravity different than that of water. The SRC performance is superior to other gravity coalescing units for the separation of dispersed oil and settleable solids. Effluent concentrations of dispersed oil are less than 10 mg/L. The SRC Separators are ½ the volume and as little as ⅓ the length of straight gravity separators.

The Slant Rib Coalescers are installed in rectangular tanks containing special baffles and weirs designed to direct flow, skim oil and control the liquid levels in the separator. Pitched sludge compartments are provided below the separation chamber for easy sludge removal.

The separators are available in standard models with capacities from 5 GPM to 2000 GPM. They can be installed above grade, flush with grade, or below grade as required. The separators can operate entirely by gravity or pumps can be supplied for product or effluent transfer when required.

DESIGN

When certain materials are placed in the waste water flow, removal efficiencies of oil increase due to impingement on their surfaces. Plastic media is particularly effective because of its oleophilic (oil attracting) characteristics. As fine oil droplets impinge upon or pass close to the plastic surface, they are attracted to it and adhere. Additional droplets continue to be attracted and coalesce or merge with previous droplets to produce much larger droplets. At a point, the droplets are large enough to break free and rise rapidly to the surface where they are skimmed or decanted. This coalescing action allows removal of smaller droplets than is possible with a straight gravity separator.

The effectiveness of any particular coalescing media is governed by several variables; density, available surface area, velocity and direction of flow and shape of the media. All of these variables influence the potential contact area, so it becomes of particular importance to form the media properly to maximize contact while minimizing blinding. The Slant Rib Coalescing (SRC) media pack was designed with consideration of all these factors. The SRC media provides greater coalescing and solids separation area than any other media currently available. The patented shape and specific spacing of the plates provides maximum protection from blinding, while providing a series of inclines that enhance solids separation and a tortuous path through which the water must pass. This continuous change of direction insures a high degree of oil droplet contact on the plate surface with resultant coalescence and oil removal. The ribs are slanted toward the surface in the direction of flow, encouraging separated oil to float to the surface along the plates before breaking free.

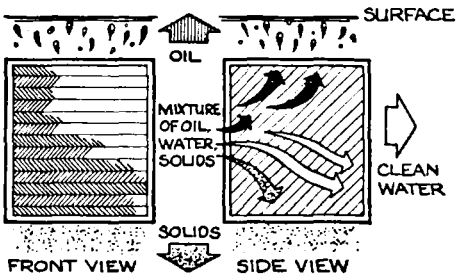
OPERATION

Inlet and Diffusion Chamber

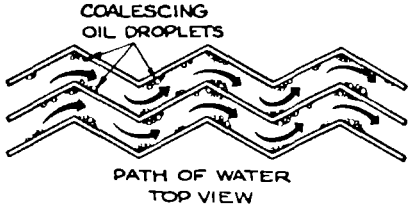
Flow enters the inlet chamber where it is dispersed through a non-clog diffuser across the width and depth of the media pack. Larger solids drop out here into the sludge chamber before entering the pack.

Separation Chamber

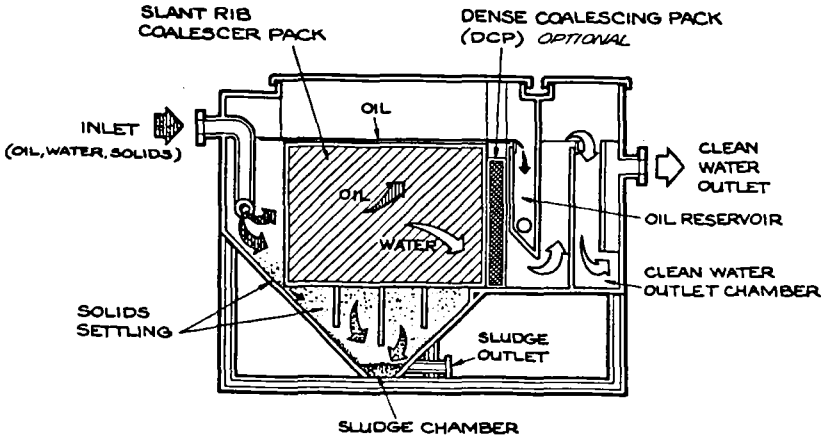
The separation chamber is filled with the SRC media pack. The ribbed plates are arranged vertically in the direction of flow,



spaced ¾" apart. When looking at the side of the media pack the ribs run from the bottom of the inlet side to the top of the outlet side on a 45° angle. The depth of the ribs is more than twice the distance of the spacing creating an overlap condition. This causes the flow to zig-zag around 90° corners throughout the pack, causing resistance to flow, collisions of the droplets 20 microns and larger with the plates and coalescence. The coalesced oil has the least restricted path to exit the waste stream, and slides to the surface on the underside of the rib.

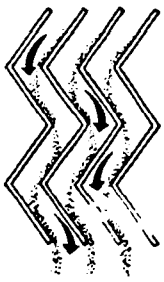


An optional Dense Coalescer Pack (DCP) is available when additional polishing is desired.



SLANT RIB COALESCING SEPARATOR

Solids entering the pack encounter a 55° angle of inclination created by the ribs which is optimum for solids settling. The solids slide down the top of the rib and fall to the next rib, gathering mass and velocity as they near the bottom of the pack and drop into the sludge chamber. The horizontal projected area of the top side of the ribs provides a conservative 0.20 GPM per square foot separation rate at design loadings.



SOLIDS SETTLING
FRONT VIEW

Sludge Chamber

The sludge chamber is located directly beneath the separation chamber and provides adequate volume for the settled sludge. The sides of the sludge chamber are sloped 45° to insure easy and complete removal of the sludge.

Oil Removal

The separated oil accumulates at the surface of the separation chamber where it displaces the water. As the oil layer increases, oil spills over a weir into an oil reservoir where it can flow by gravity or be pumped automatically to remote storage tanks.

Clean Water Chamber

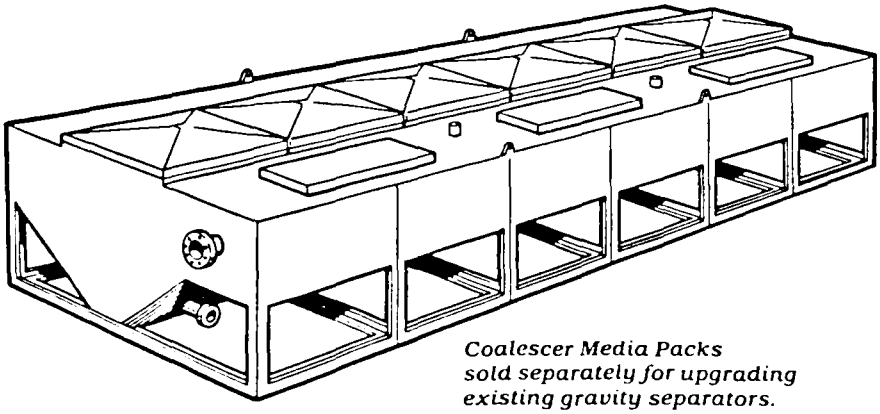
The clean water leaving the SRC media pack passes under an oil retention baffle and into the effluent or clean water chamber. From there, the clean water passes over a weir which maintains the liquid level in the separator. The clean water flows by gravity through a "T" pipe outlet or effluent pumps can be provided. The "T" pipe provides an excellent spot for sampling.

Covers

Hatches are provided for easy access into the separator. Sealed, vapor tight hatches are available. Lifting lugs are provided on the media packs and on the separator.

MATERIALS OF CONSTRUCTION

Materials of construction include ¼" thick Class A carbon steel, stainless steel and fiberglass. The standard Slant Rib Coalescing media is fiberglass reinforced plastic (FRP) with special additives to make the plates highly oleophilic. The plates can also be supplied in stainless steel. Fiberglass separators are constructed with an exterior welded steel frame encased in fiberglass for corrosion protection. All steel tank welds are Magnaflux tested in accordance with military specifications.



Coalescer Media Packs sold separately for upgrading existing gravity separators.

COATINGS

Above grade carbon steel tanks are coated on the exterior with coal tar epoxy. Flush with grade and below grade carbon steel tanks have asphaltum exterior coatings. Steel separators are supplied with a standard interior coating of zinc primer. Special interior and exterior coatings are available.

AVAILABLE OPTIONS

- Flow control package
- Water Pump out system
- Recovered Oil Pump Out System
- Effluent Oil Monitor
- Heaters for freeze protection
- Dense Coalescing Pack
- Sludge Pump Out System
- Design Flexibility to Satisfy Your Application

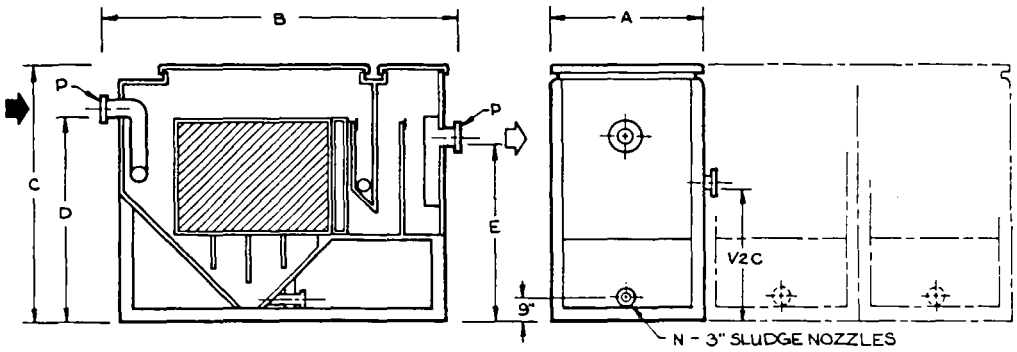
APPLICATIONS

- Automotive
- Airports
- Bus Terminals
- Bulk Plants
- Chemical Plants
- Fabricated Metal Plants
- Glass Factories
- Military Bases
- Oil Fields
- Petroleum Plants
- Pulp and Paper Mills
- Parking Lots
- Railroad Yards
- Textile Mills
- Tramp Oil
- Truck Terminals
- Utility Companies
- Wash Racks

For further information contact Great Lakes Environmental, Inc., or our local representative. We will be glad to assist you in selecting a properly sized unit for your application.

GREAT LAKES ENVIRONMENTAL

Slant Rib Coalescing Oil/Water Separator



DIMENSIONS, WEIGHTS & CAPACITIES

MODEL	A	B	C	D	E	P	N	No. Packs	Coalescing Area Sq. Ft.	Settling Area Sq. Ft.	Empty Weight	Operating Weight
SRC-15	2.7′	8.0′	5.0′	3.5′	3.0′	3″	1	1	360	90	1260	2700
SRC-30	2.7′	8.0′	6.0′	4.5′	4.0′	3″	1	1	720	180	1720	4120
SRC-50	2.7′	8.0′	7.0′	5.5′	5.0′	4″	1	1	1080	270	1840	5190
SRC-75	3.7′	8.0′	7.0′	5.5′	4.9′	4″	1	1	1620	405	2130	7160
SRC-100	3.7′	9.5′	7.9′	6.5′	5.7′	6″	1	1	2160	540	3380	10650
SRC-150	5.7′	9.5′	7.9′	6.5′	5.7′	6″	1	1	3600	900	4800	16920
SRC-200	6.7′	9.5′	7.9′	6.5′	5.5′	8″	2	1	4320	1080	5380	19920
SRC-250	8.7′	9.5′	7.9′	6.5′	5.5′	8″	2	1	5760	1440	6540	25930
SRC-300	9.7′	9.5′	7.9′	6.5′	5.3′	10″	2	2	6480	1620	7251	29060
SRC-400	12.7′	9.5′	7.9′	6.5′	5.3′	10″	3	2	8640	2160	9120	38200
SRC-500	15.7′	9.5′	7.9′	6.5′	5.3′	10″	3	2	10800	2700	10990	47340
SRC-600	18.7′	9.5′	7.9′	6.5′	5.3′	10″	4	3	12960	3240	12860	56680
SRC-700	21.7′	9.5′	7.9′	6.5′	5.3′	(2) 10″	5	3	15120	3780	14730	65630
SRC-800	24.7′	9.5′	7.9′	6.5′	5.3′	(2) 10″	5	3	17280	4320	16600	72760
SRC-900	27.7′	9.5′	7.9′	6.5′	5.3′	(2) 10″	6	4	19440	4860	18470	83910
SRC-1000	30.7′	9.5′	7.9′	6.5′	5.3′	(2) 10″	6	4	21600	5400	20340	93050
SRC-1100	33.7′	9.5′	7.9′	6.5′	5.3′	(2) 10″	7	5	23760	5940	22210	102190
SRC-1200	36.7′	9.5′	7.9′	6.5′	5.3′	(2) 10″	8	5	25920	6480	24080	111330
SRC-1300	39.7′	9.5′	7.9′	6.5′	5.3′	(3) 10″	8	5	28080	7020	25950	120470
SRC-1400	42.7′	9.5′	7.9′	6.5′	5.3′	(3) 10″	9	6	30240	7560	27820	129610
SRC-1500	45.7′	9.5′	7.9′	6.5′	5.3′	(3) 10″	9	6	32400	8100	29690	138750
SRC-1600	48.7′	9.5′	7.9′	6.5′	5.3′	(3) 10″	10	6	34560	8640	31560	147890
SRC-1700	51.7′	9.5′	7.9′	6.5′	5.3′	(3) 10″	11	7	36720	9180	33430	157030
SRC-1800	54.7′	9.5′	7.9′	6.5′	5.3′	(3) 10″	11	7	38880	9720	35300	166170
SRC-1900	57.7′	9.5′	7.9′	6.5′	5.3′	(4) 10″	12	8	41040	10260	37170	175310
SRC-2000	60.7′	9.5′	7.9′	6.5′	5.3′	(4) 10″	12	8	43200	10800	39040	184450

Dimensions and capacities are for reference only and are not to be used for construction. Model No. represent nominal flow rates in GPM.

GREAT LAKES ENVIRONMENTAL
463 Vista • Addison, IL 60101 • (312) 543-9444

CALGON

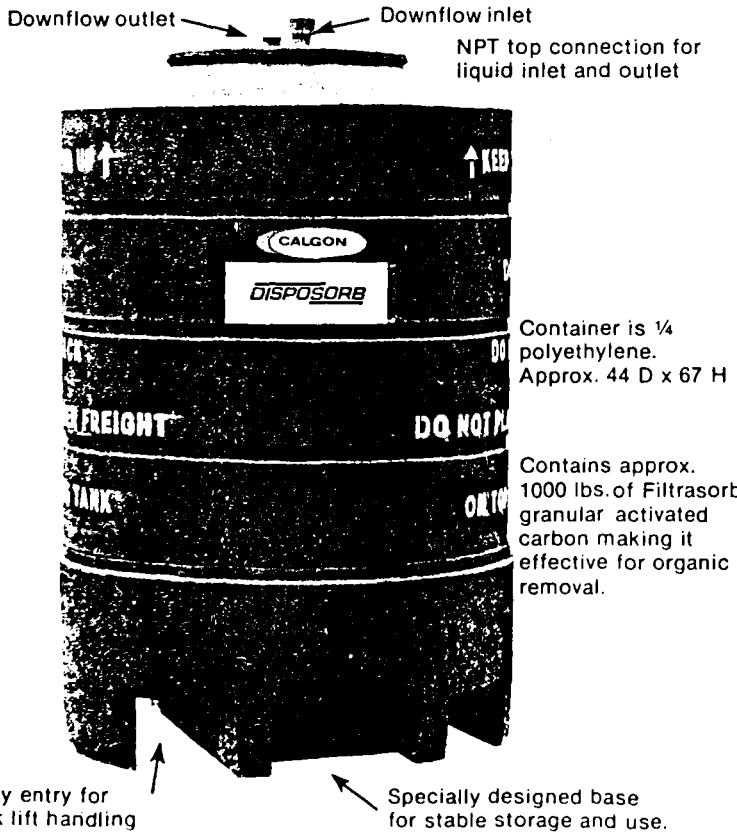
DISPOSORB™

ACTIVATED CARBON PRODUCT BULLETIN

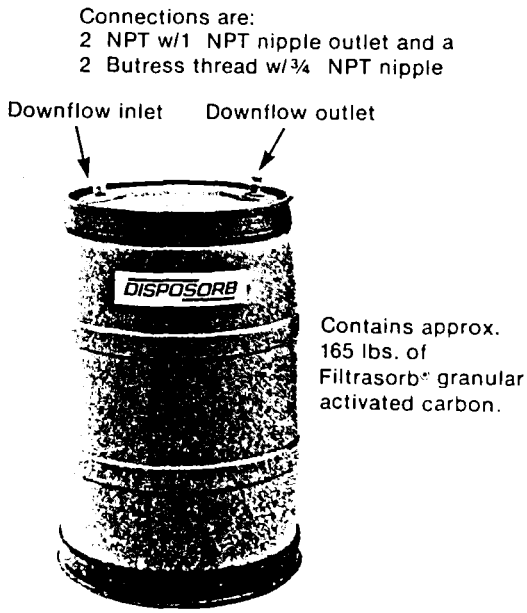
DISPOSORB has been developed by Calgon Carbon Corporation for cleanup of off-spec product batches, accidental spills, contaminated rainwater in tank-farm containment dikes, and many other uses. It is the first disposable, compact, granular activated carbon adsorber providing all the essentials of a full-scale system. Available in two sizes, 350 gallon capacity and 55 gallon capacity.

DISPOSORB applications

- Hazardous/Toxic Dissolved Organic Removal
  - ☐ Process Stream Purification
  - ☐ In-Plant Spill Treatment
  - ☐ Laboratory Bench Drains
  - ☐ Storage Tank Washdown
  - ☐ Monitoring Well Discharges
  - ☐ Dechlorination
  - ☐ Decolorization of Liquids
  - ☐ Small Wastewater Streams
- Evaluation of Adsorption for Liquid Processes
  - ☐ Feasibility Studies
  - ☐ Laboratory Investigation
  - ☐ Pilot Plant Studies
- Tandem KLENSORB 100/Granular Activated Carbon Operation
  - ☐ Multicomponent Treatment
  - ☐ Gasoline From Groundwater
  - ☐ Hazardous Waste Lagoons



350 gal and 55 gal DISPOSORBS—The unique, low-cost approach for on-the-spot liquid phase uses. Pollution Control, Process Purification.



Container is HMWPE approximately 23 D x 36 H

how DISPOSORB works

DISPOSORB contains granular activated carbon which removes dissolved organic pollutants from water by a process called adsorption. As water passes through the porous granules of activated carbon, molecules of the organic pollutants are attracted to the surface of the pores and are held there by weak physical forces. The phenomenon is somewhat similar to iron filings being held by a magnet.

The ability of granular activated carbon to remove large quantities of organic impurities is a function of its highly developed internal pore structure. This unique pore structure is created during the manufacturing process, which involves the crushing and thermal "activation" of select grades of bituminous coal under carefully controlled conditions. As a result of this processing, an extensive network of pores is created inside each carbon granule, providing an enormous internal surface area.

Granular activated carbon's great porosity is responsible for its high capacity for trapping and holding organic molecules. For example, just one pound of carbon granules has an effective total (external and internal) surface area equal to that of a 100-acre farm.

In general, the adsorption capacity for non-polar organic compounds increases with concentration, molecular weight and decreased solubility. Compounds which adsorb well are aromatic and unsaturated aliphatic compounds and halogenated solvents.

Low-molecular-weight (less than 50) and/or high-polar compounds, highly soluble in water—such as formaldehyde, alcohols, glycols— will not be readily adsorbed.

When the concentration of organic wastes in the effluent equals the concentration in the influent, the DISPOSORB unit is saturated with the maximum organic loading possible.

the inside story

Each 350 gallon DISPOSORB is filled with approximately 1000 pounds of either Filtrasorb 300 or Filtrasorb 400 products. These carbons are manufactured from select grades of bituminous coal to produce a high density, high surface area, durable granular product suitable for use in either potable or wastewater applications. The 55 gallon DISPOSORB is filled with approximately 165 pounds of either of these carbons. The DISPOSORB may be ordered with other types of carbons for use in unique applications. In addition, DISPOSORB units can be provided with Klensorb 100. Klensorb 100 is a granular absorbent media which removes insoluble oil (both free and emulsified) and similar heavy organic compounds from water. Klensorb 100 units can be used for treatment independently or in tandem with carbon units.

The internals of the DISPOSORB are a combination of PVC and stainless steel. In applications involving contaminants which attack these materials, alternative internal construction materials can be ordered.

DISPOSORB units are constructed of polyethylene. They are not suitable for applications where solvents of high-density polyethylene are present in large concentrations or at temperatures above 100°F.

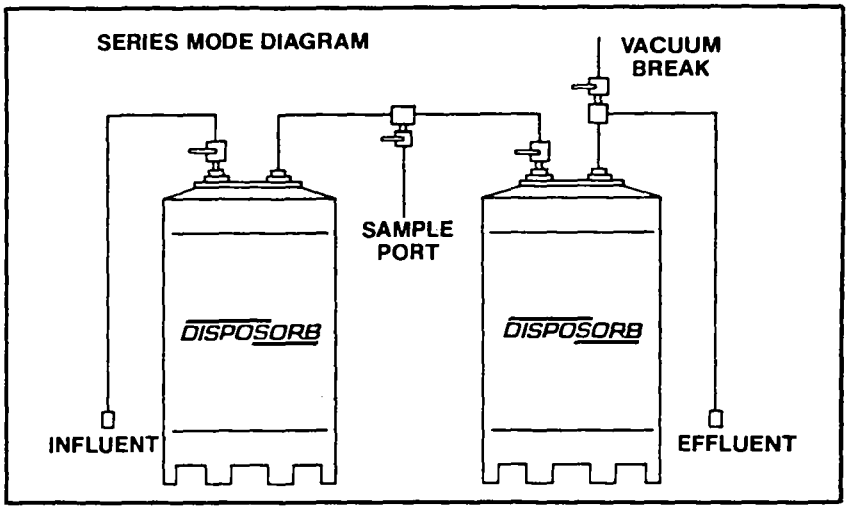
how to ensure efficient utilization of DISPOSORB

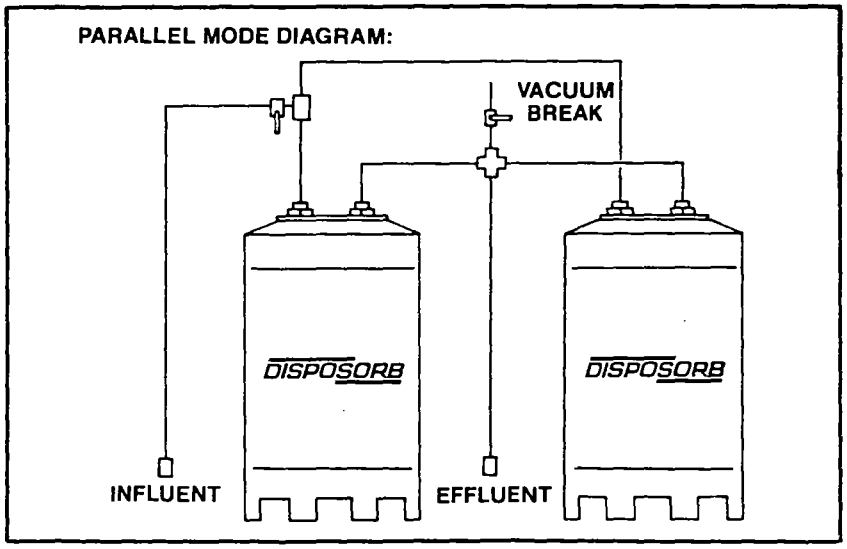
The stream entering the DISPOSORB unit should have less than 50 ppm suspended solids or prefiltration may be necessary. A flow of 30 gpm will provide 10 minutes contact time per 350 gallon DISPOSORB unit. Flow in the 350 gallon DISPOSORB unit should not exceed 30 gpm. A flow of 10 gpm will provide 5 minutes contact time per 55 gallon DISPOSORB unit. Flow in the 55 gallon DISPOSORB unit should not exceed 10 gpm.

Contact time and organic removal efficiency will be enhanced by using multiple DISPOSORB units in parallel or series mode operation. Depending upon the specific application, consideration should be given to using a vacuum-break or anti-siphon loop to ensure the DISPOSORB is flooded.

Monitoring the influent to the final DISPOSORB in series mode is a good precaution against effluent breakthrough.

DISPOSORB units can be moved easily to treatment site.





350 gallon DISPOSORB units 44"diameter by 67" high may be prepared for operation using hose connections of hard pipe. Connections are male 1½"NPT inlet and outlet. Calgon Carbon has available hose harnesses for this purpose as optional equipment. The *white* connection is the *inlet* for *downflow* operation. The outlet is grey. The DISPOSORB is not recommended for upflow operation.

55 gallon DISPOSORB units 23" diameter by 36" high may be prepared for operation using hose connections or hard pipe. Connections are ¾" NPT inlet and 1" NPT outlet.

DISPOSORB units are not designed for operation under pressure. The units have been tested under pressure and are recommended for operation under 7.5 psig.

Granular activated carbon must be thoroughly wetted before use to dispel air and to assure proper contact with the influent stream. To facilitate use in the field Calgon Carbon has performed the wetting procedure prior to shipment. Before placing the DISPOSORB unit into service, fill the unit through the effluent line. The DISPOSORB is now ready for use in the normal operating mode.

disposal

Depending upon what materials are adsorbed on the carbon, the storage, transportaion and disposal of the spent carbon may be subject to Federal, State and local regulations as a hazardous material.

transporting adsorber units

DISPOSORB adsorber units may be easily moved by sling or forklift.

Shipping weight for the 350 gallon DISPOSORB units containing granular activated carbon is approximately 2500 pounds. Spent units can be expected to weigh about 2500 pounds after water is drained via siphon on the effluent line or 1 psi air pressure connected to the influent line.

For 350 gallon DISPOSORB units which contain Klensorb 100, shipping weight is approximately 2800 pounds.

Shipping weight for the 55 gallon DISPOSORB units containing granular activated carbon is approximately 350 pounds. Spent units can be expected to weigh approximately 350 pounds after water drain.

For 55 gallon DISPOSORB units which contain Klensorb 100, shipping weight is approximately 400 pounds

precautions

Wet activated carbon preferentially removes oxygen from air. In closed or partially closed containers and vessels, oxygen depletion may reach hazardous levels. If workers are to enter a vessel containing carbon, appropriate sampling and work procedures for potentially low-oxygen spaces should be followed, including all applicable Federal and State requirements.

warranty

There are no warranties either expressed or implied or any warranty of merchantability or fitness for a particular purpose associated with the sale of this product.

For information regarding incidents involving human and environmental exposure, call (412) 787-6700 and ask for the Regulatory and Trade Affairs Department.

For further information, phone (412) 787-6700, or contact:
Calgon Carbon Corporation, P.O. Box 717, Pittsburgh, PA 15230-0717

CALGON

CALGON CARBON CORPORATION

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